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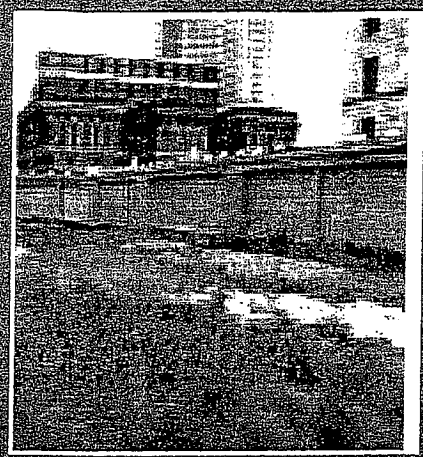
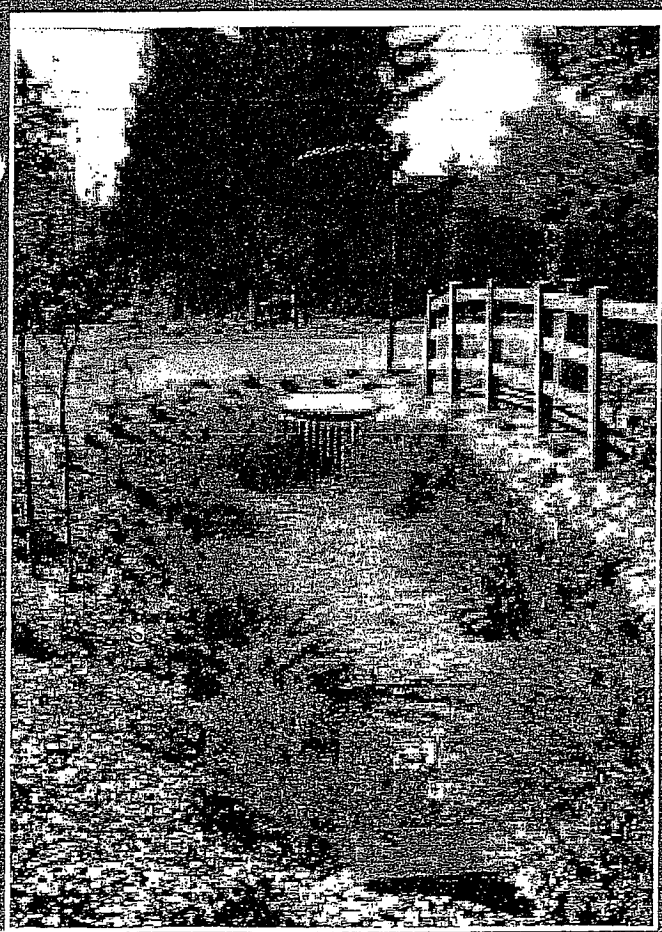
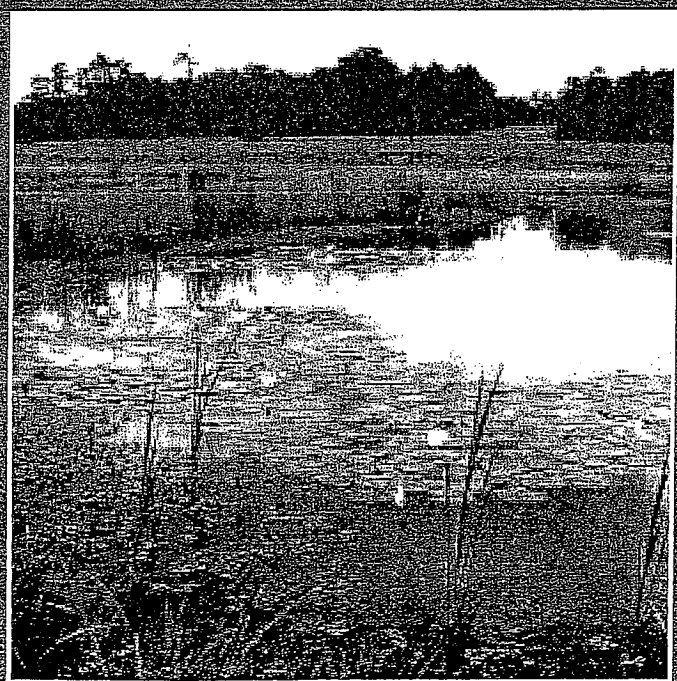


Building Better II

A Guide to America's Best New Development Projects

CLEAN WATER EDITION





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Cover photos (clockwise from top left): Alberici Constructors headquarters, Overland, Missouri; Heinz 57 Center's green roof, Pittsburgh, Pennsylvania; Brays Bayou restored wetland, Mason Park, Houston, Texas; Street Edge Alternatives natural drainage system, Seattle, Washington.

Thank you to all who contributed to this report.

Building Better II: A Guide to America's Best New Development Projects can be found on the Sierra Club's website at: *www.sierraclub.org/buildingbetter*

The Sierra Club's members are 750,000 of your friends and neighbors. Inspired by nature, we work together to protect our communities and the planet. The Sierra Club is America's oldest, largest and most influential grassroots environmental organization.

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Building Better II

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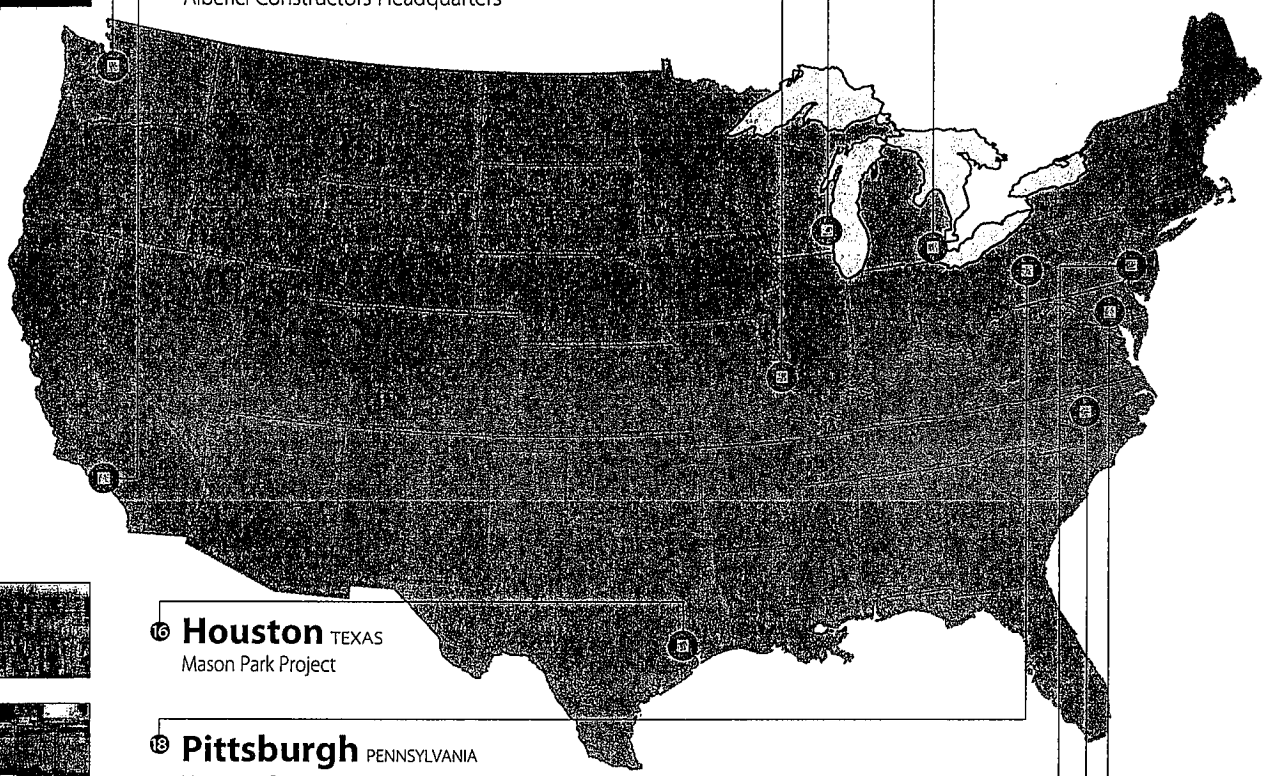

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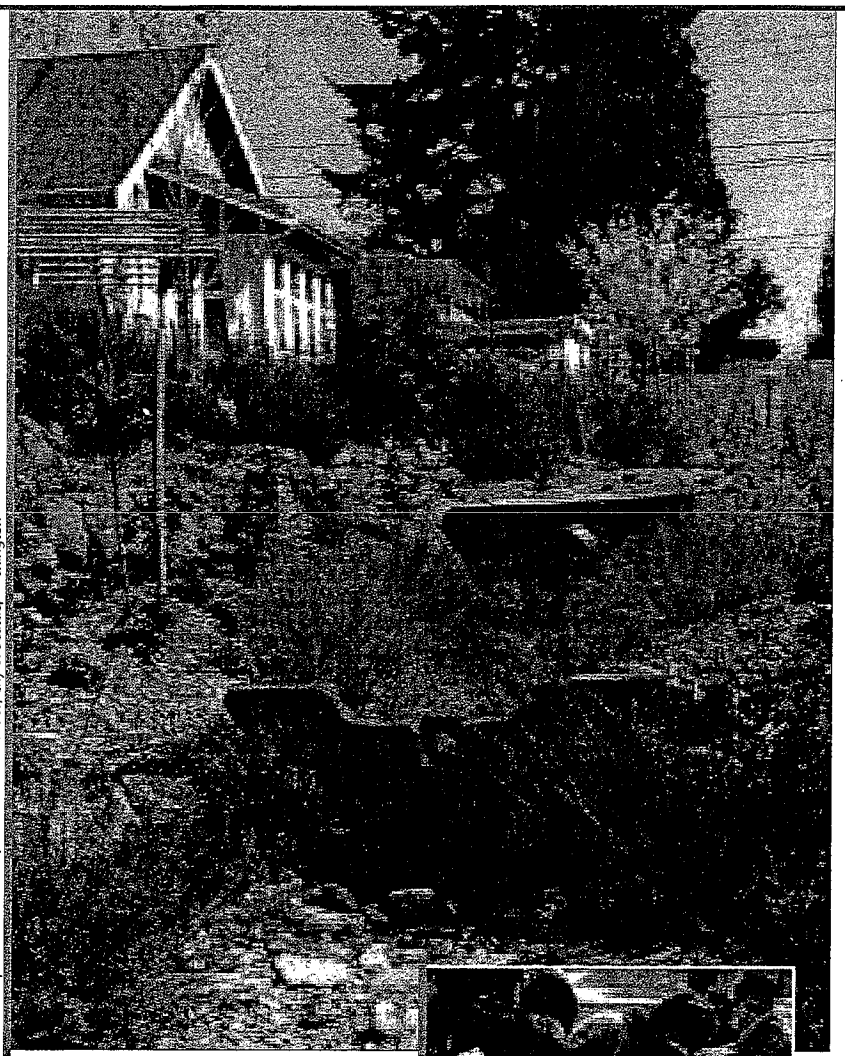
Building Better II

A Guide to America's Best New Development Projects CLEAN WATER EDITION



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Melinda Kelley, TreePeople

Above: Seattle SEA Streets' natural drainage system. See page 6.

Right: Children look into cistern at Open Charter Magnet Elementary School Westchester, California. See page 8.

Stormwater runoff and sewage overflows are growing threats to the health of our water. Across the country sprawling developments are generating huge amounts of sewage and stormwater runoff. Land that used to absorb rain is being paved over, creating more runoff than treatment systems can handle. The end result is that more untreated or poorly treated sewage and urban runoff is polluting the sources of our drinking water.

Fortunately, there are simple solutions that can make a big difference. The key is to think of stormwater as a resource, not a waste product. By changing this perspective, we can reap a host of benefits from recycling stormwater. This report highlights ten outstanding projects using innovative design to protect clean water and recognizes developers, institutions and communities who are leading the way toward combining a respect for nature with development and redevelopment.

Stormwater's Toll on the Environment

Almost 35 years after passage of the Clean Water Act, many of our nation's waterways are still polluted. When Congress enacted the law, industrial dumping and other "point source" contamination was the major cause of polluted rivers, streams, lakes and bays. Today the largest source of water pollution comes from two areas: (1) stormwater runoff washing contaminants into the water from parking lots and roads; and (2) combined sewer overflows, which occur when stormwater overwhelms the sanitary sewer system. An explanation of both methods of contamination follows.

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Pollutant Runoff

The pollutants that wash into our waterways during storms are an ugly toxic soup. They range from auto-related fluids from roads and parking lots—including oil, grease, gasoline and hydrocarbons—to metals and other contaminants like copper, zinc, lead, cadmium, chloride, and nitrate. Runoff can also contain bacteria and other pathogens, pesticides, fertilizers, nutrients, sediment, debris, and much more. Each of these pollutants and toxins threatens water quality and aquatic life in their own way. Sediment clouds the water, killing plants and destroying habitat,[1] while nutrients contribute to algae blooms that can deplete oxygen, creating "dead zones" in water.[2] Bacteria can cause human illness, and heavy metals and chemicals can be harmful or deadly to both animals and humans.[3]

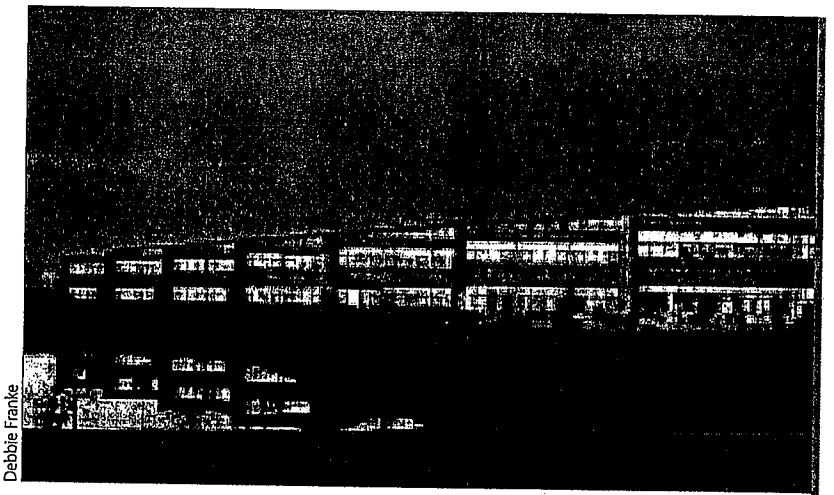
Sewer Overflows

In many of our older urban areas, the storm drain system and the sewer system are connected. This normally poses little problem during dry weather, but when rainstorms occur, runoff can overwhelm the sewers, causing both stormwater and raw sewage to overflow into streams and rivers without ever receiving treatment at a sewage treatment facility. The EPA estimates that an astounding 1.2 trillion gallons of untreated sewage combined with stormwater and industrial waste are dumped into our waterways each year due to combined sewer overflows, contaminating our waters.[4] According to the EPA, sewer overflows "pose major health concerns to the general public, and are responsible for gastrointestinal diseases, many beach closings, shellfishing restrictions, and limitations on other recreational activities."[5]

Development's Role in Stormwater Runoff

Runoff is produced largely through conventional development which creates swaths of impermeable surfaces—roofs, roads, and parking lots that rain falls on and drains off into waterways, picking up trash and toxins along the way.

The volume of stormwater runoff from developed sites is staggering. Twenty-five thousand gallons of water run off a single acre of impermeable surface, as opposed to only 2,700 gallons that run off an undeveloped acre during a one-inch storm.[6] With development occurring at a rapid rate across our nation, the runoff of harmful pollutants entering our waterways has far surpassed acceptable levels. According to the EPA, over 10 trillion gallons of urban stormwater runoff flows into the nation's rivers, streams and other waterways each year.[7]



Debbie Franke

Alberici Constructors Headquarters in Overland, Missouri keeps 100 percent of runoff on site. See page 14

Historically, as is noted by an engineer in one of our stories in the following pages, stormwater has been treated as a waste product—to be disposed of as quickly and efficiently as possible. This approach has led to expensive projects involving large volumes of concrete, elaborate piping, and other mechanisms to channel runoff —and its pollutants—from streets, parking lots and rooftops out to our natural waterways.

However, by viewing stormwater as a resource, not a waste product, we can create a host of benefits. Retaining natural features and vegetation slows and filters stormwater before it reaches waterways. Capturing and re-using stormwater from our roofs and other surfaces will not only help prevent pollutants from entering waterways, but will also conserve water, replenish groundwater and reduce flooding. These methods of managing stormwater are better for our environment, and in many cases they are less expensive than conventional approaches.

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Redevelopment and Revitalization Help Water Quality

In addition to the particular stormwater management practices outlined in these stories, communities can continue to advocate for redevelopment of existing urbanized areas, which reduces the amount of sprawl and creates more opportunities for people to live, work and shop within walking distance. It can help reduce both impermeable surfaces like parking lots and roads, and the need to drive—which helps cut down on the pollutants that get washed into streams during wet weather. The Sierra Club has long advocated for these approaches to development, since they disturb less land, use less energy, promote more walking and less driving, and produce less polluted runoff.

Charting a Course for the Future

While vast acres of poorly planned development continue to contribute to sprawl and polluted stormwater runoff, many developers, institutions and communities, are recognizing the environmental benefits and long-term savings of easily implemented, more natural stormwater management practices. In the following pages, we offer ten outstanding examples of environmentally responsible stormwater runoff management projects, with the hope that the leadership shown by the proponents of these projects will become

Charriss York

Restored wetland at Houston's Mason Park. See page 16

Innovative Stormwater Solutions

Re-creating wetlands: Over 120 million wetland acres have been destroyed in the nation's history to make way for development and other uses.[8] Creating new and restored wetlands that hold and filter stormwater runoff is a key to controlling flooding and cleansing the water.

Rain gardens and swales: These are depressed, landscaped areas that catch and hold rain water and runoff, allowing it to slowly seep into the ground. Plants in these rain gardens and swales also absorb the stormwater.

Stormwater parks, bio-retention ponds: Like rain gardens and swales, these depressed areas hold excess stormwater so that it does not simply run off into waterways. These areas help prevent flooding, while also helping filter the stormwater. Stormwater parks and bioretention ponds are generally larger areas, and temporarily hold water only during wet weather.

Green roofs: Unlike conventional roofs, these have a thin layer of soil with native plantings which absorb rainfall. They also provide good insulation, which saves energy, and they have twice the lifetime of a conventional roof.

Cisterns and rain barrels: These storage tanks hold stormwater runoff for re-use. The runoff can be used to water plants and athletic fields, and for non-potable indoor uses like toilets.

Cascades: In steeper areas, these "mini-waterfalls" and pools help to slow the flow of water. This prevents erosion and sedimentation, while also holding water in pools and helping filter the water through vegetation.

Urban "greening" and natural plantings: Planting trees, native vegetation, and breaking up impervious surfaces all help absorb stormwater and prevent it from running off into streams and rivers.

commonplace in communities throughout the country in the years to come. Carried out on a watershed-wide basis, these relatively easy-to-implement types of projects could make a large-scale, lasting improvement in cleaning up our polluted rivers and bays. Government agencies—from the local and state level up to federal government—should provide incentives for more of these low impact development projects rather than throwing money into ineffective methods of stormwater management.

When citizens and local officials demand better development projects and more environmentally sound stormwater management practices, we help protect our drinking water sources and make our rivers, lakes and beaches safe for recreation and wildlife.

Nancy Aten

Milwaukee's new Menomonee Valley Park after a two-inch rainstorm, holding stormwater. See page 12.

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1. U.S. Environmental Protection Agency, "After the Storm." *http://www.epa.gov/weatherchannel/stormwater.html*
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4. U.S. Environmental Protection Agency, "Combined Sewer Overflows." *http://www.epa.gov/reg3wapd/cso/*
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Seattle WASHINGTON

SEA Streets Project

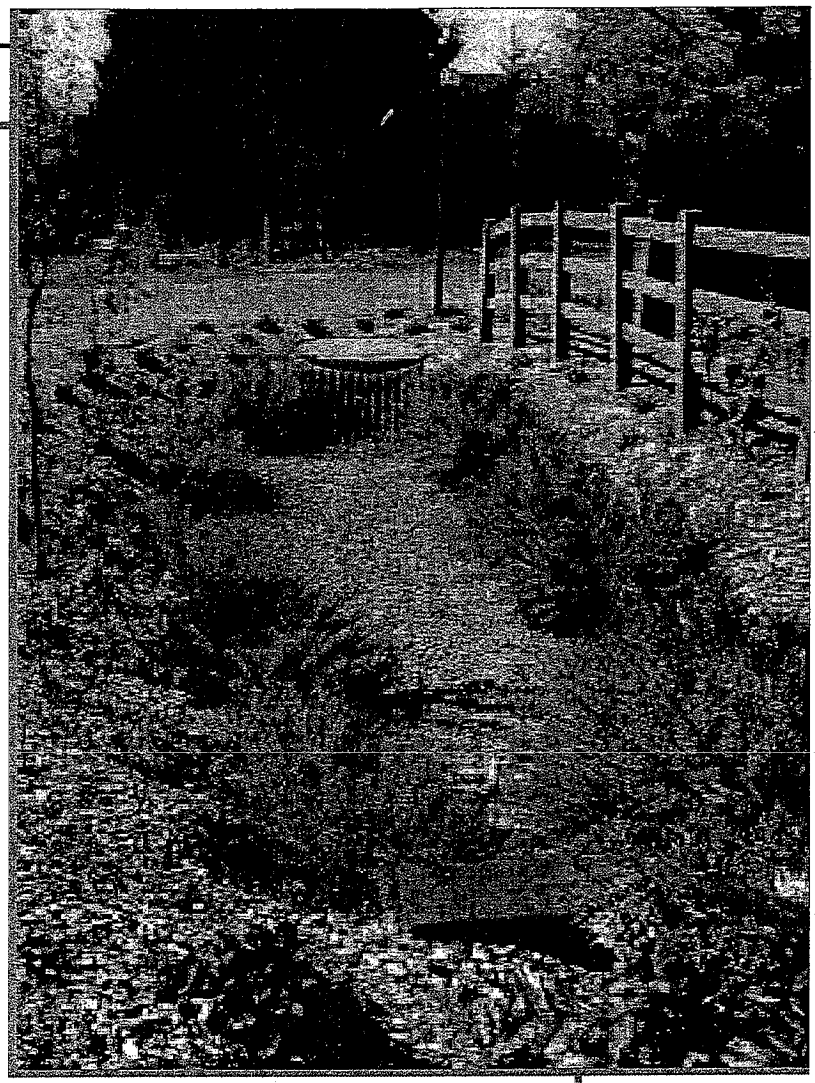
In response to the high mortality of the endangered Coho salmon in Puget Sound estuaries, likely caused by toxic stormwater runoff, Seattle and Seattle Public Utilities (SPU) have developed an innovative plan requiring any new development or street to incorporate better stormwater management when redevelopment occurs. Consideration must be given to expansion of basic drainage systems, flood protection, protecting ditch drainage systems, coordination of landslide mitigation and expanding water quality monitoring.

Street Edge Alternatives (SEA Streets) Project

SPU initiated Street Edge Alternative (SEA Streets), its first Natural Drainage System project, with the goal of catching, detaining and filtering runoff from a 2.3-acre area near Pipers Creek.

Instead of installing a "traditional" stormwater system exclusively involving culverts, drains and pipes, SPU created a drainage system along streets and sidewalks which incorporated native plantings and swales with soils that catch, hold and filter water. In the process of creating more natural drainage systems, SEA Streets reduced the impervious surface area of city streets by 11 percent, helping to rein in the pavement that contributes to high velocity, toxic rainwater runoff.[1]

The impressive results of the SEA Streets project – a decrease in the volume of stormwater runoff by 98 percent for a 2-year storm event—have led the way for other Natural Drainage System projects, such as the 110th Street Cascade project.[2]



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110th Street Cascade Project

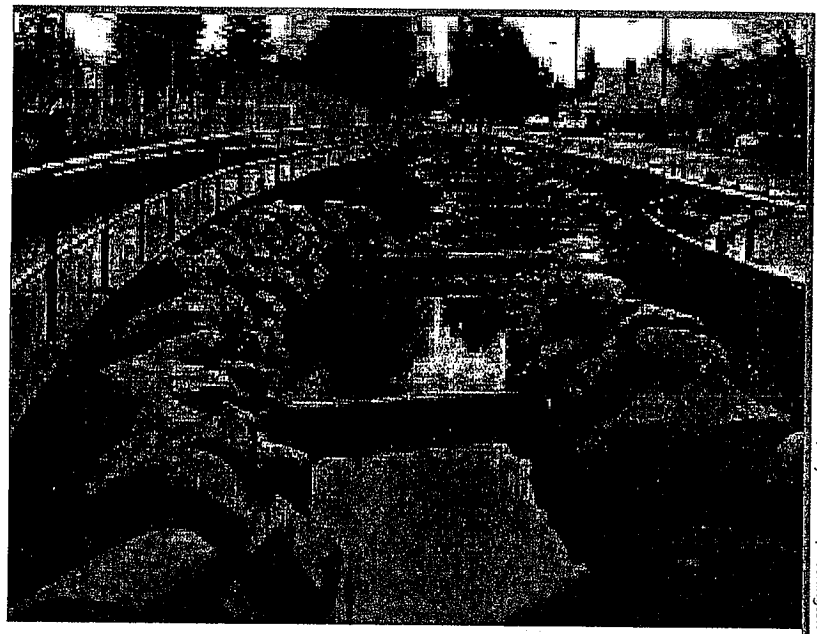
The Cascade project contains and filters runoff from a steeply sloped, 21-acre area by employing a system of pools that step down through a series of mini-waterfalls that mimic nature,[3] slowing the velocity of the water. Vegetation and swales that form part of the system help to filter out and break down polluted runoff, before the water reaches Pipers Creek.

An example of one of Seattle's Street Edge Alternative projects—a natural drainage system.

Seattle's Green Future

As the Natural Drainage System project continues to grow, areas like the Broadview Green Grid, a 32-acre, 15 square block area are incorporating techniques from both the SEA Streets and Cascade projects, using vegetated swales and tiered water pools to control stormwater. Ambitious projects are planned for the Thornton Creek watershed and are underway for the 129-acre High Point Housing project, where SPU is partnering with the Seattle Public Housing Authority to improve stormwater management in this project that comprises 10 percent of the Longfellow Creek watershed.[4]

Working in conjunction with the Seattle Department of Transportation, Seattle Public Utilities has started a path toward a cleaner, better way of building residential streets. Already, university researchers and other local government officials have made Seattle's streets a destination to learn about these good models of stormwater stewardship.



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A cascade helps slow the downhill flow of runoff protecting land from erosion while helping filter stormwater.

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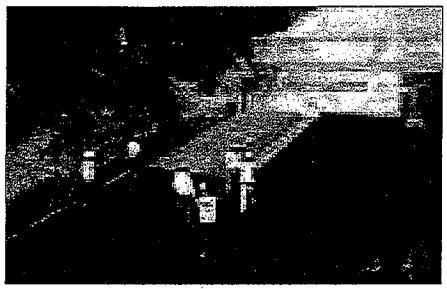
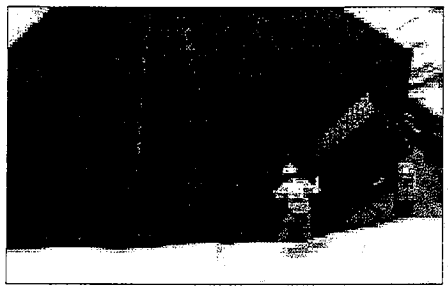
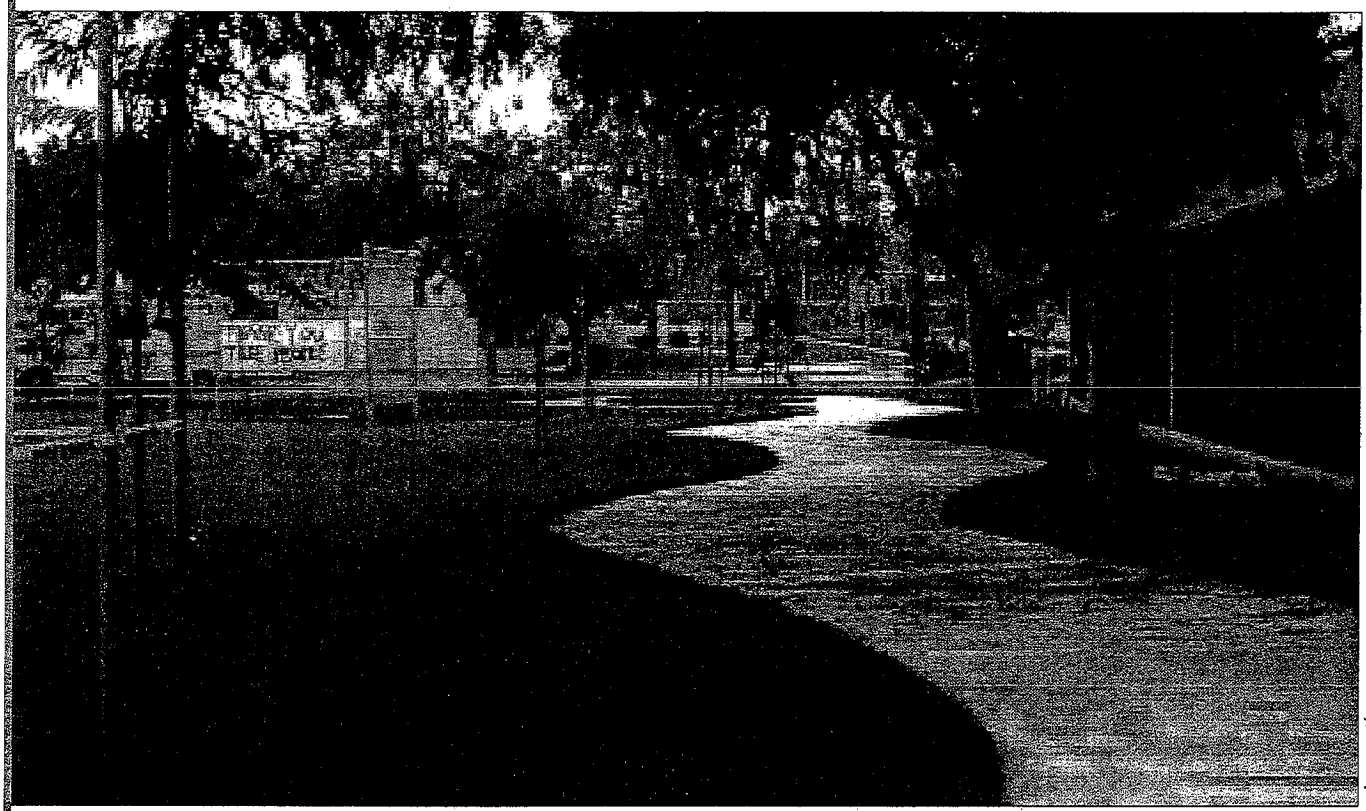
Westchester

CALIFORNIA





Small photos by Rebecca Drayse, TreePeople



Melinda Kelley, TreePeople

Open Charter Magnet Elementary School

Photos at top show before and during construction of the cistern project, which is now beneath the grassy field in the larger picture.

Los Angeles and Santa Monica Bay have faced their share of water quality problems. The loss of 98 percent of L.A.'s wetlands has jeopardized the health of its waterways. The health of the Bay has improved from horribly poor water quality several decades ago, but challenges still remain. Following the heavy rains of 2004-2005, Heal the Bay wrote, "Wet weather water quality trends look fairly dismal...exceedingly heavy rainfall magnifies a continuing problem in Los Angeles, the lack of significant progress on wet weather water quality and lack of appropriate funding to clean up wet weather water quality. In the near future, wet weather water quality, it appears, will only improve with less rain."[1]

Parents, Teachers and Children Working Together

In a watershed that can empty more than 80 billion gallons of runoff into the Santa Monica Bay in a year, one school is leading the way toward a more innovative future.[2] The Open Charter Magnet Elementary School in Westchester, California made a

number of improvements to its grounds to capture and re-use stormwater under the leadership of Andy Lipkis, an Open Charter parent and founder of Tree People, an environmental nonprofit best known for its work planting over two million trees in the Los Angeles area.

Starting in 1999, Tree People worked with the school's staff, students, and parents to create a more environmentally friendly site, by planting trees and other vegetation on school grounds and breaking up impervious parking lot surfaces to help prevent polluted stormwater runoff. However, the largest, most significant stormwater improvement to the school grounds was a 110,000 gallon cistern buried beneath the campus's playing fields. This underground tank collects, holds, and cleans runoff from the property, enabling the school to use the recycled water for watering the vegetation on the site instead of letting wasted water gather pollution and flow into the Bay.

Melinda Kelley, TreePeople

Children get an education in stormwater pollution as they look into the school's cistern.

Stormwater: A Resource, Not a Waste Product

The system created for the Open Charter cistern project varies from the traditional engineering approach, which is to treat stormwater as a waste product to be disposed of as quickly as possible. One of the engineers for the project, Michael Drennan, P.E. explains, "As we look at how the system evolved over time we realize that the way we designed the (stormwater) system was reactionary and single purpose in its approach ... if you think about multiple objectives like flooding, pollution reduction, and water supply, then you might design a system like we did at Open Charter, which manages stormwater as a resource rather than a waste."[3]

Los Angeles: A Look Ahead

The Open Charter project is helping lead the way for more positive stormwater solutions in Los Angeles. Los Angeles voters recently passed a $500 million bond to underwrite projects to meet the goals of the new Integrated Resources Plan (IRP) which seeks to capture, clean and reuse water, while also creating open space and wildlife habitat where possible. The State's Regional Water Quality Control Board has come to recognize the value of natural treatment systems for cleaning polluted stormwater, including swales, treatment wetlands and vegetated buffers. Sierra Club activists have proposed a treatment wetland just down the hill from Open Charter Elementary on more than 100 acres in the Ballona Valley floodplain where the Los Angeles River historically converged with Centinela Creek. These treatment wetlands will not only capture stormwater, but also cleanse pollutants before the waters empty into the Santa Monica Bay. Bringing back more of the natural landscape throughout the watershed, rather than pouring more concrete, can best help L.A. improve its water quality.

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1. Heal the Bay's 15th Annual Beach Report Card. *www.healthebay.org/brc/annual/2005/counties/la/analysis.asp*
2. The Daily Breeze, March 4, 2005, on Tree People Web site, it says in a season of 30 inches of rainfall, 82 billion gallons of runoff emptied into the Bay. The average rainfall in a year is 15 inches. *http://home.att.net/~station_climo/LACVPRCP.GIF*
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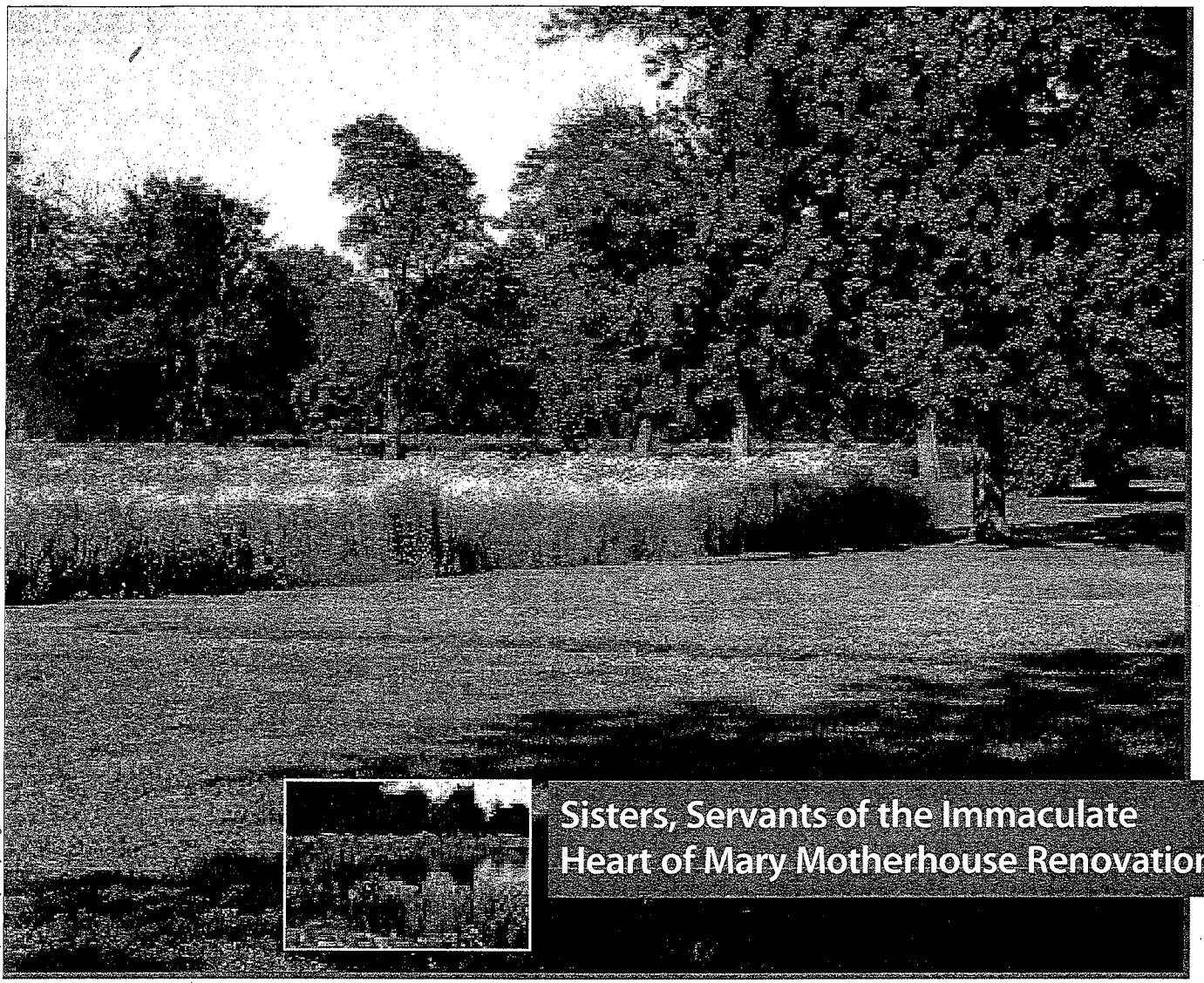
MICHIGAN
Monroe



Sisters, Servants of the Immaculate Heart of Mary Motherhouse Renovation

Both photos by Holly Knight

Dedicated to the Earth

For the Sisters, Servants of the Immaculate Heart of Mary (IHM), good stewardship of their corner of the environment is part of their larger social and economic justice mission. So when their Motherhouse began showing its age after 70 years of wear, the home's 250 Sisters set about the updates with an eye toward preserving the natural environment, creating a building and grounds that tread lightly on the earth.

The Sisters preserved much of the landscaping during construction, including all of the trees on the 280-acre site, while also restoring portions of the campus grounds to wetlands and meadows which help hold and filter water. The creation of these natural sponges keeps and cleans water, preventing polluted runoff from flowing into the River Raisin where *E. coli* and pollution levels are already elevated.

The wetlands also collect greywater from the facility's sinks and showers, recycling it to be treated and re-used in the building's toilets instead of going into the sewer system. Recycling reduces the Sisters' water usage by 55 percent, diverting 7,000 gallons per day to wetlands and recycling 4,500 per day to flush toilets.[1]

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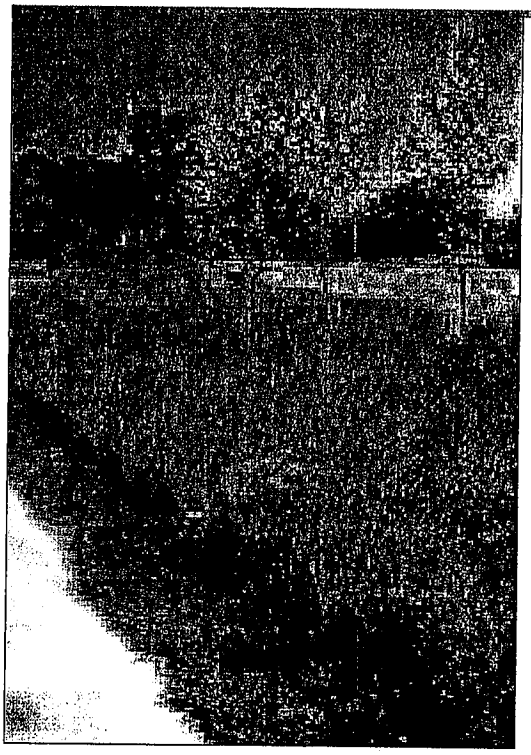
To further reduce stormwater runoff, the parking lots have been retrofitted with vegetated swales that break up the large impervious surface and create natural drainage systems.

Building Renovation

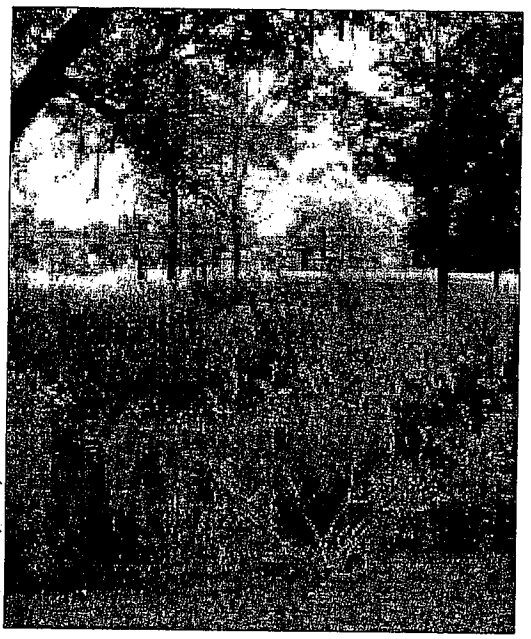
In addition to recycling wastewater, there are hosts of energy, resource, and water conservation features built into the project, which has received the bronze level Leadership in Energy and Environmental Design (LEED) certification. The renovation maximizes the use of natural daylight, uses low-flow shower spigots and uses environmentally sustainable products like fast-growing cork in the flooring. It also employs an innovative geothermal heating and cooling system, as well as a heat recovery system to reclaim heat from ductwork exhaust. The geothermal system sends water deep into the ground where it taps into the earth's natural temperature instead of relying on other energy sources to heat and cool the building.

People Making the Difference

The Sisters, who studied and became experts in ecological design, were aided in their renovation endeavor by architect William McDonough, a national leader in ecological design and sustainability. The Christman Company managed construction, the H.F. Lenz Company handled engineering and design, while the Middleton Corporation and Jackson & Sons Drilling Company were responsible for the geothermal drilling.



A swale of native plantings helps absorb parking lot runoff.



Both photos by Shirley Mathus

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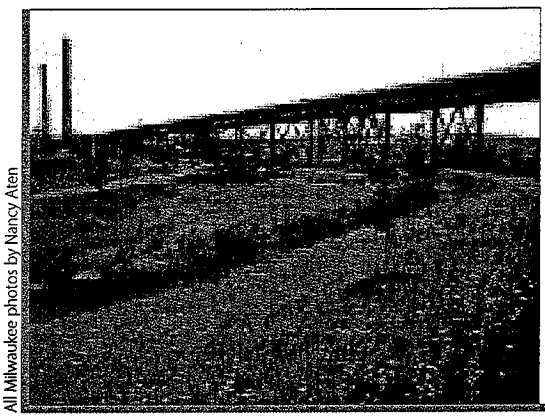
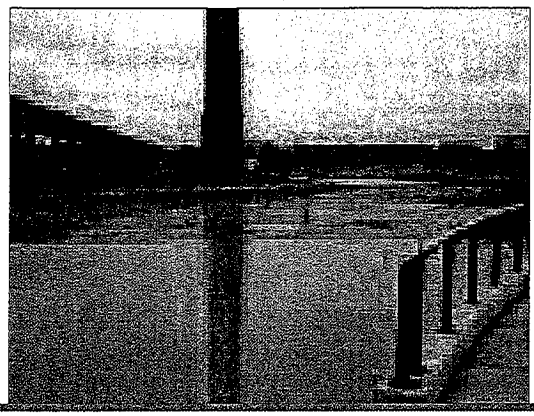
WISCONSIN

Milwaukee





All Milwaukee photos by Nancy Aten

Menomonee Valley Industrial Site

Menomonee Valley's stormwater park

A Wasteland Made Green

The former rail yard and manufacturing center in the Menomonee Valley had long been an environmental wasteland until a $20 million cleanup project of this Brownfield site was completed in 2004.[1] It took nearly two dozen state and federal Brownfield grants to address the environmental hazards—from free petroleum to arsenic, asbestos and other contaminants on the site. Now that the site is clean, portions of the 1,200-acre space in the heart of Milwaukee, are slated for light industrial redevelopment and a business park.

Already on the site, Harley-Davidson, Inc. is building a $95 million motorcycle museum, and Palermo Villa, Inc., a frozen pizza company, is currently developing a 14-acre site.[2] Caleffi North America, a division of an Italian company manufacturing hydronic systems, plans to build a 35,000-square-foot plant, while Badger Railing, which makes ornamental iron products, is planning an 18,400-square-foot building to house 41 employees.[3]

Water Woes

Worries over stormwater management heavily influenced the Menomonee Valley development after heavy rains overwhelmed the Milwaukee sewer system in 2004, dumping 1.7 billion gallons of raw sewage into Lake Michigan.[4] During the same period, surrounding communities released another 5.1 million gallons of sewage into the lake, which is a drinking water source for more than 10 million people.[5,6] The relatively small drainage area of the lower Menomonee and Milwaukee Rivers contributes disproportionately large amounts of pollutants associated with urban runoff and are designated as "areas of concern," meaning that the water quality impairments affect recreation, fish consumption and drinking water.[7]

Stormwater Park

In an effort to better stormwater management practices, a stormwater park has been created on 70 acres of the Menomonee Valley site, which runs along the Menomonee River. The park which will feature natural areas, open space, playing fields, and the Hank Aaron State Trail, is expected to capture every drop of rain that falls on the business park.[8] The native plants, woodlands and new topography will serve to detain flood water and will clean water contaminants from the new commercial and industrial area that would otherwise drain into the river. Two large smokestacks from the original rail yard on the site have been left standing, and serve as a visual contrast to link Milwaukee's future to its industrial past. The site plan for the park has been recognized for excellence by the American Society of Landscape Architects.

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City Leadership Combating Stormwater Runoff

The city is answering the wake up call of tragic floods which overwhelmed Milwaukee in 1997 and 1998, costing several lives and $35 million in damages. The stormwater park is only one part of Milwaukee's Mayor Tom Barrett's initiative to control flooding and implement better stormwater management practices. Among other strategies, he plans to reduce stormwater runoff from city properties through the use of green roofs, rain gardens, and native plantings along roadways and public green spaces.

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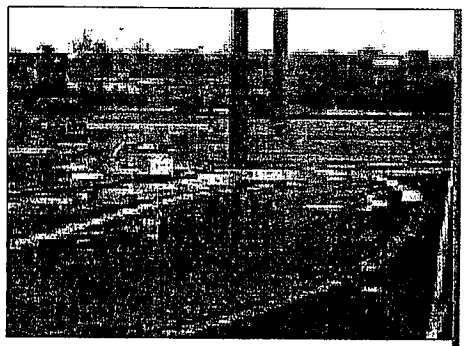
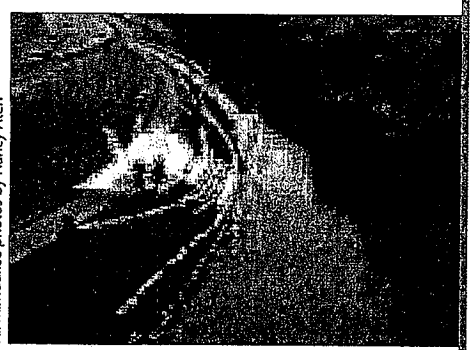
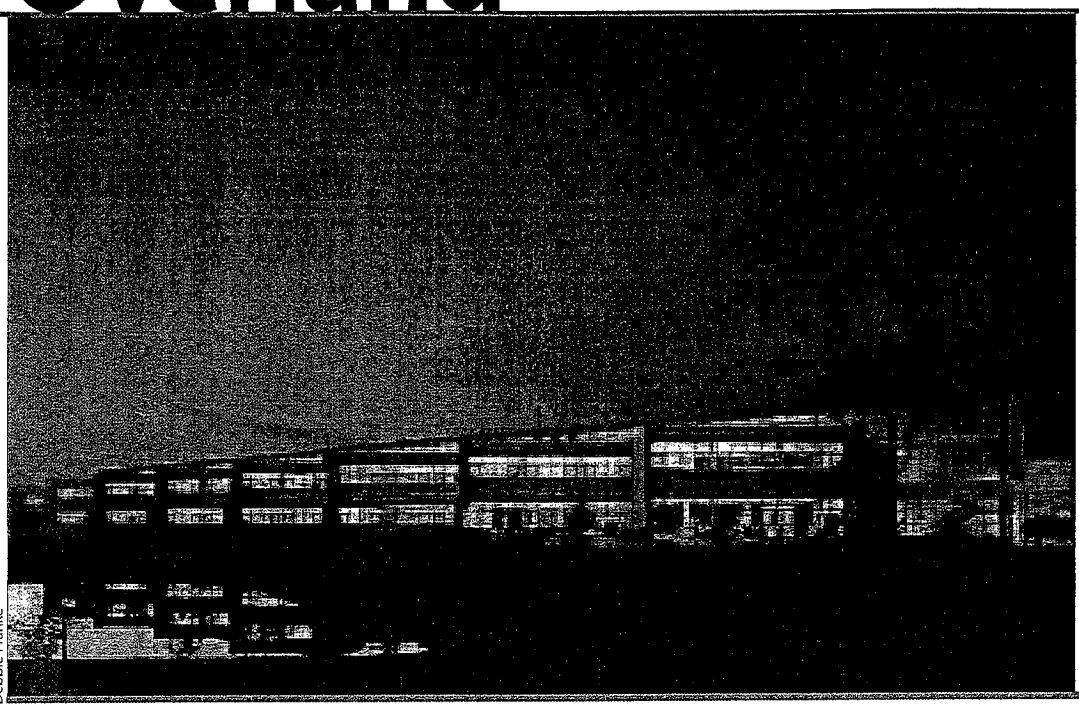




All Milwaukee photos by Nancy Aten

Milwaukee's stormwater park and the Menomonee River

MISSOURI Overland



Debbie Franke

Alberici Constructors Headquarters

Alberici's headquarters keeps 100 percent of runoff on site

Building Greener

As one of the largest general contracting construction companies in the nation, Alberici Constructors has been building large-scale projects since 1918.[1] Yet, their experience building green began much later, in 2003, when the company decided to build a new headquarters in Overland, Missouri. The goal was to construct an example of the very best in environmental design and construction and receive a platinum-rated Leadership in Energy and Environmental Design (LEED) building. Alberici was successful and their headquarters is one of only six buildings worldwide to achieve this top rating of environmental excellence.

Protecting Water Quality—Zero Runoff

While the building has many remarkable energy saving and environmental features, perhaps the most notable is that the building and surrounding property produce zero stormwater runoff.

Rainwater from the one-acre roof is captured by a 38,000 gallon, underground cistern.[2] The captured water is then used in the building's urinals and toilets, saving an estimated 300,000 gallons of water annually and saving it from running off the site.[3] According to Thomas Taylor, Alberici Constructors' Vice President of Special Projects, water-saving measures like using recycled water and low-flow faucets result in a 67 percent reduction in water use over a comparable, conventional building.

Alberici removed an unneeded 60,000 square foot building from the site and reduced the impermeable surface by removing large surface parking and replacing both the building and the parking lot with landscaping made up exclusively of native plants. Six acres of prairie and wetlands were constructed to filter out pollutants and help keep 100 percent of the water on site as it runs slowly into the vegetation where it is absorbed.

A Better Building for People and Nature

The platinum-rated LEED building has a number of other environmentally-friendly features. A significant portion of the building was constructed using recycled materials. Alberici saved 93 percent of potential construction waste

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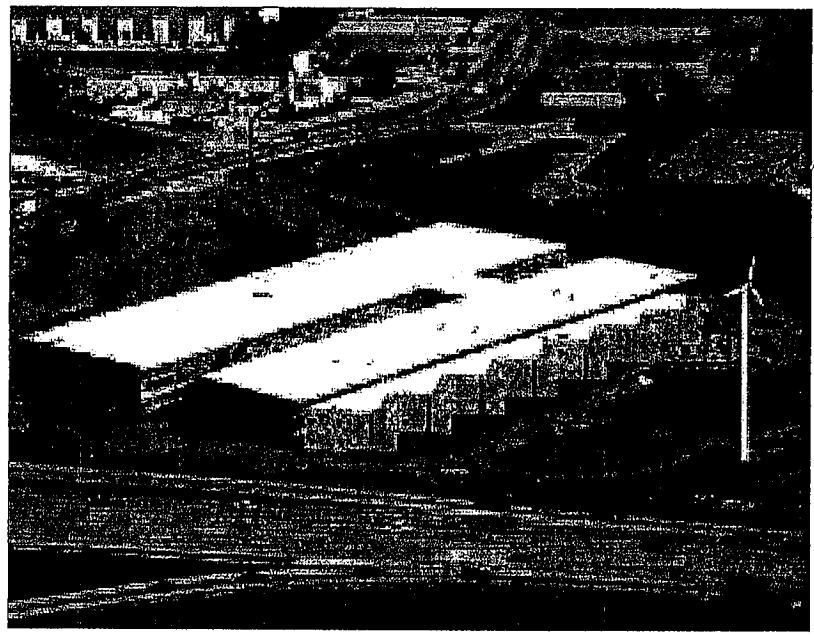
from going to the landfill[4] and approximately 30 percent of the new building materials were recycled.

Through the use of energy recovery—which extracts heat from the air without the need to recirculate stale air—and a number of other features like operable windows, under-floor air distribution, a passive solar preheat system for heating the building's water, and a 65kW refurbished wind turbine, which supplies 20 percent of the energy for the building,[5] the building is "60 percent more energy efficient than a conventional building."[6] The building is designed to take advantage of natural daylight, which minimizes the need for indoor lighting and reduces the stress of employees.

Alberici encourages employees to carpool by giving parking preference to carpoolers, and they provide bike racks inside the parking garage protected from the elements. They also provide showers and locker rooms for employees who bike to work. While it is a suburban location, with limited public transportation options, there is a bus stop a short distance from the building.[7]

Industry Inspiration

Alberici Constructors has used their headquarters to create a real-life example of innovative, cost-effective green building. Through their attention to environmental excellence Alberici is leading the construction industry in green building and stormwater management. Alberici hosts tours of the facility, and encourages others to learn from their work.



Alberici Constructors

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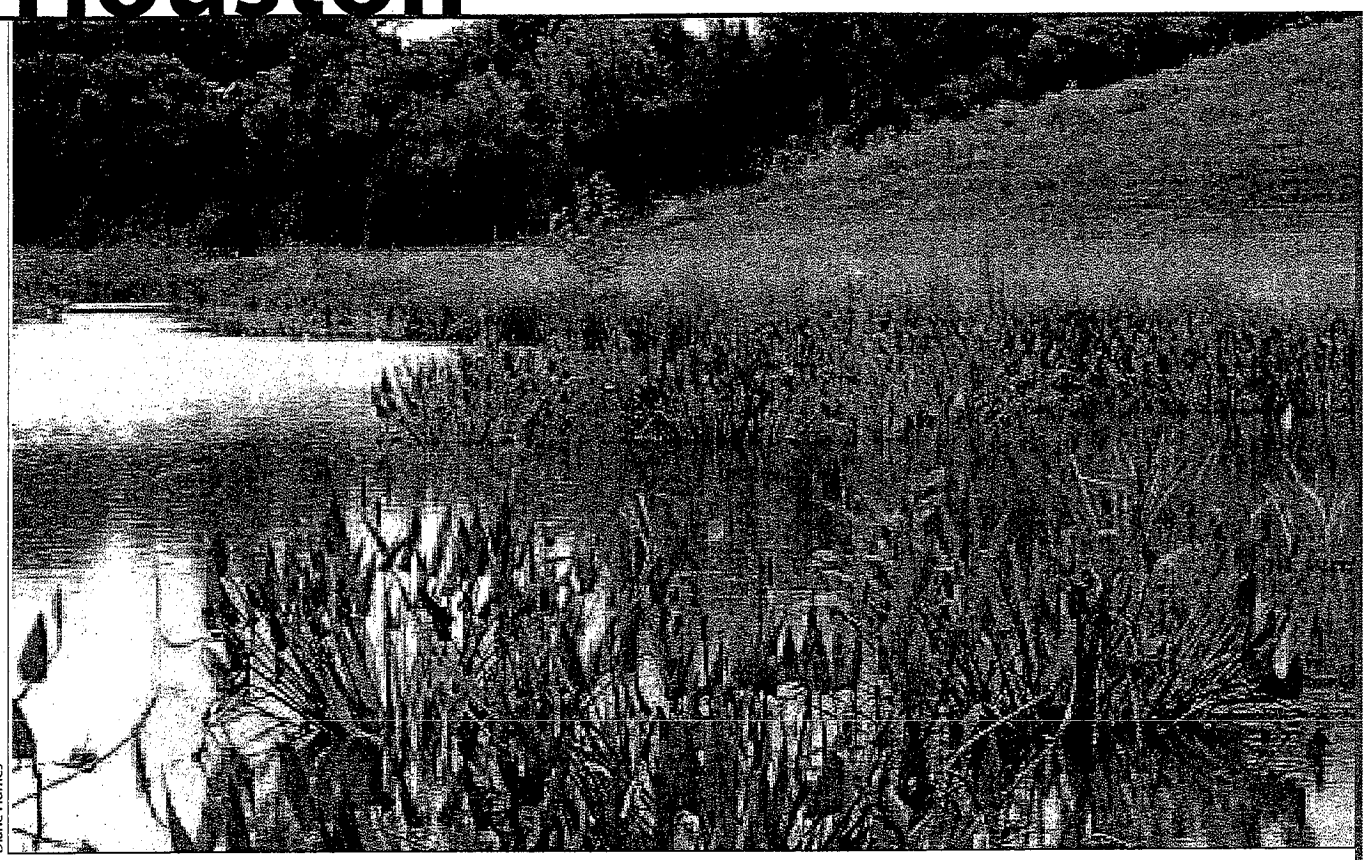
TEXAS
Houston



Diane Hunter

Mason Park Project and Better Bayou Protection

Correcting Mistakes of the Past

In the race for urbanization, Houston's Harris County lost many of its estimated 800 miles of bayous to artificial, concrete gulches that moved water—and the pollution in it—quickly to Galveston Bay, destroying water quality. High concentrations of fecal coliform and increased nitrate nitrogen levels have forced the closing of about one-half of the Bay's shellfish harvesting areas.[1] However, an array of local partners including the City of Houston and Harris County are now taking action to address polluted stormwater runoff, the top water quality problem facing the Bay, by creating new wetlands at Mason Park in southeast Houston and in other locations.

Mason Park Project

Constructed through a partnership between the Harris County Flood Control District, the Army Corps of Engineers, the Houston Parks Department, and the Texas Parks and Wildlife Department, a new 3.5-acre wetland area at Houston's Mason Park serves as a filter for runoff from a 30-acre urban residential watershed. Where a stormwater culvert once dumped polluted runoff directly into the bayou, now three terraced ponds with native plantings seek to re-create a freshwater marsh that existed in the area nearly 50 years ago.[2] This marsh, which helps hold and cleanse water before it makes its way on to the Bay, is part of a pilot project that will eventually lead to the creation of a series of wetlands along the length of Brays Bayou. The Mason Park project is one of several efforts that began after recent severe floods to address flooding along Brays Bayou by using re-created wetlands as an effective means of slowing and cleaning large volumes of stormwater.

Improving Habitat

Not only will the project help control stormwater pollution, it will also provide habitat for fish and wildlife. Birds such as ibis, white pelicans, osprey, heron and egrets that are found in the area will flock to

Diane Humes

The re-created wetland at Mason Park controls stormwater and provides wildlife habitat.

the restored marsh and fish will use the natural freshwater marsh as a nursery.[3]

Community Involvement and Partnerships

Students from Chavez and Austin High Schools spent months planting natural vegetation on the Mason Park site,[4] which will serve as a laboratory they will use to see natural science in action. Eventually the project will even include an outdoor education area for classes.[5] In 2006, the Harris County Flood Control District was honored for a Brave Bayou Tidal Marsh Project by the nonprofit Park People. Park People is "dedicated to promoting the importance of park and green space" in Houston.[6]

Innovative Work in Harris County

In addition to the 3.5-acre wetland at Mason Park, significant work in and around Houston to protect its bayous is being done by the Harris County Flood Control District. These significant projects include a multiple use detention basin called the Hill at Sims Greenway, where existing dirt has been sculpted into hills, and where a trail system and recreational facility is being established.[7] This project—and the overall 19-mile work on the Sims Bayou Main Channel—is a tremendous move away from the typical "concrete ditch" system. The Main Channel work, which was started in 1992, includes no concrete and instead has a gentler, more natural and sloping channel. Thousands of trees were planted along the bayou and the work preserved existing trees. Other innovative detention facilities have been constructed in the White Oak Bayou watershed and on the northwest side of Houston.

Promise for a Cleaner Watershed

The pioneering work that occurred in Harris County to advocate for, and construct, the Mason Park wetland, the Hill at Sims Greenway, and other projects, is a step toward reducing the threat of flooding as well as cleaning up polluted runoff into Galveston Bay's tributaries. With more marshland restoration planned in the regional watershed, there is positive movement toward reversing some of the past environmental damage that was done to the waterways. Managing urban watersheds and creating more natural stormwater filters is a key to improving overall water quality in Houston.

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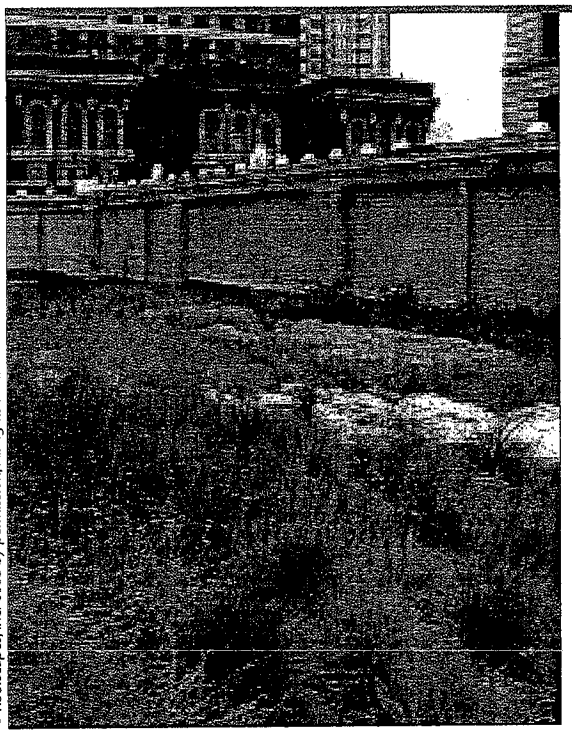
PENNSYLVANIA

Pittsburgh

Pittsburgh's Sewer Problems

Pittsburgh, which sits at the juncture of the Monongohela, Allegheny, and Ohio Rivers, has serious problems with combined sewer overflows in the Three Rivers. "I would not go swimming in the Three Rivers after it rains," said Noel Hefele, who has worked on a Carnegie Mellon University project studying pollution in Allegheny County's rivers and streams over the last five years. "One-tenth of an inch of rainfall can lead to a sewage overflow."[1] However, the average rainfall in Pittsburgh is one-quarter of an inch.[2] Each year an estimated 16 billion gallons of raw sewage are discharged from hundreds of outfalls in the region's sewage collection system to local waterways in the Pittsburgh area.[3]

Capturing rainwater before it makes its way into the storm system, however, can be an affordable key to preventing an overload of the system that contributes to these sewer overflows.



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Heinz 57 Center

Heinz 57 center's green roof and plantings absorb rainfall.

An Environmental Renovation: Saving Runoff, Energy, Reducing Heat

In 2001, the Heinz Corporation moved its North American headquarters into a renovated, 14-story, historic Gimbels Department Store building in downtown Pittsburgh. Heinz worked with McKnight Development Partners to add an atrium to the top seven floors of the building, which lets in light, reducing energy use and creating a more comfortable environment.

The most impressive environmental feature of the building is its 12,000-square-foot green roof, completed in 2001. No outside irrigation is needed for the plants in the five inch thick roof, which absorb rainfall that would otherwise make its way into the stormwater system and contribute to sewage overflows. The roof is estimated to have a 55 percent annual rainfall retention rate and since green roofs last twice as long as traditional roofs, the Heinz building will continue to reduce stormwater for years to come.

As an added bonus the green roof helps bring down energy costs by providing insulation, and reducing the rooftop heat generated in the summer. By absorbing the sun's warmth, the roof will

help mitigate the "heat island effect," caused by a lack of vegetation and the presence of dark roofs and pavement in cities. Summer heat is about eight degrees hotter in cities due to the heat island effect.[4]

The Heinz 57 Center's roof was constructed by Philadelphia's Roofscapes, Incorporated, in cooperation with the architects Burt, Hill, Kozar, Rittlemann Associates.

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A closeup of the Heinz 57 Center's green roof

Pittsburgh's Past Becomes its Future

Thanks to the environmentally sound decision to renovate a historical and until recently vacant building, the Heinz 57 Center reflects a strong sense of Pittsburgh's history and architecture. Originally constructed in 1914, the Heinz building has now become an example of using revitalization and green construction to minimize the environmental footprint of growth.

Conveniently located in a pedestrian friendly mixed-use area, with shops, restaurants and businesses, the Heinz Center is worker friendly as well as eco-friendly. The location and the transportation options it provides help the more than 800 employees who work in the building avoid having to drive. The building that once stood during Pittsburgh's industrial past now helps point to a cleaner future.

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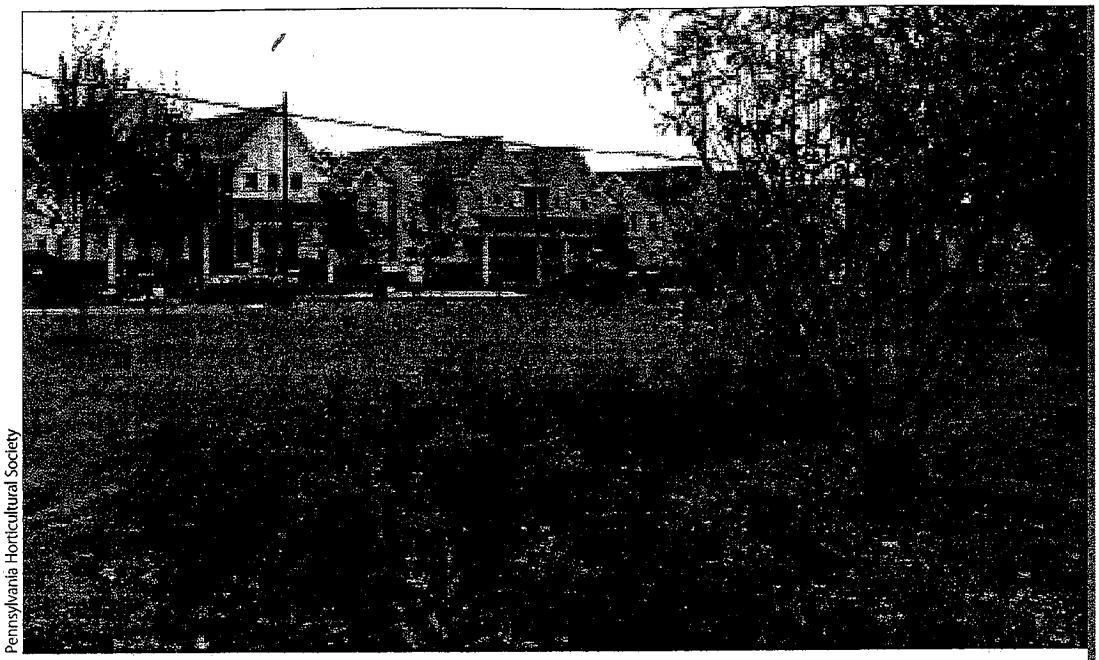
PENNSYLVANIA

Philadelphia



Pennsylvania Horticultural Society

'Philadelphia Green' Urban Greening and Stormwater Projects

One of many re-created "natural" drainage areas in Philadelphia that absorb stormwater.

Philadelphia has a significant problem with sewage overflows, which means that the local sewer systems are overwhelmed during periods of heavy rain and untreated sewage overflows into the surrounding rivers and streams. At 165 locations around the city sewage routinely overflows into the Delaware and Schuylkill Rivers and other waterways during rainstorms.[1] The Schulkill supplies drinking water to 1.5 million people in Philadelphia[2] and both are important centers of commerce and recreation in the region. Experts agree that the main contributor to the poor water quality of these rivers is stormwater runoff.

Philadelphia Green: Cleaning Philadelphia's Stormwater

Philadelphia Green—a program of the Pennsylvania Horticultural Society and the City of Philadelphia—has initiated projects across the city to clean up vacant lots, green the city, and improve stormwater management.

Teaming up with the Philadelphia Water Department in 2003, and with grant support from the Pennsylvania Department of Environmental Protection's Growing Greener Program, Philadelphia Green has transformed five plots of land into models of good stormwater management by installing shallow trenches and berms that harness the rainfall and allow it to seep slowly into the ground over a 24- to 36-hour period.[3] "We hope to create a whole series of 'natural sponges' in the city that reconnect the urban land to the natural water cycle," said Gerry Abrams, an urban watershed planner at the Philadelphia Water Department.[4] These natural sponges help reduce the volume of water contributing to sewer overflows and purify the water before it reaches the rivers.

Greening Schools, Reducing Impervious Surface

In 2005, Philadelphia Green, in conjunction with the Philadelphia Water Department (PWD), started work on a project with seven

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Philadelphia schools to address stormwater runoff, while promoting environmental education.[5] At S. Weir Mitchell Elementary School, one of the seven schools participating in the project, children created a raised bed vegetable garden in a paved parking lot, which will help to reduce the "heat island effect" and absorb stormwater instead of contributing to runoff.

Mitchell Elementary is also slated for a stormwater retrofit project by Philadelphia Green and the PWD in the near future, which calls for the addition of vegetation, infiltration trenches, bio-swales and a rain garden on the 3-acre impervious site.[6] According to the designers of the plan, "the stormwater management and planting plan at the Mitchell School is designed to capture a significant portion of this [stormwater] volume by mitigating runoff generated by all storms less than or equal to the 1 inch rainfall."[7]

A Greener Future

Philadelphia, like many older American cities, faces severe stormwater challenges due to its massive combined sewer system and the large, paved surface area of the metropolitan area. But Philadelphia is making strides toward a greener city and cleaner water since the city and the Philadelphia Horticultural Society have teamed up to take on the problem. With more projects on the horizon to green vacant lots and school grounds, Philadelphia Green continues to make strides to improve water quality in and around Philadelphia.

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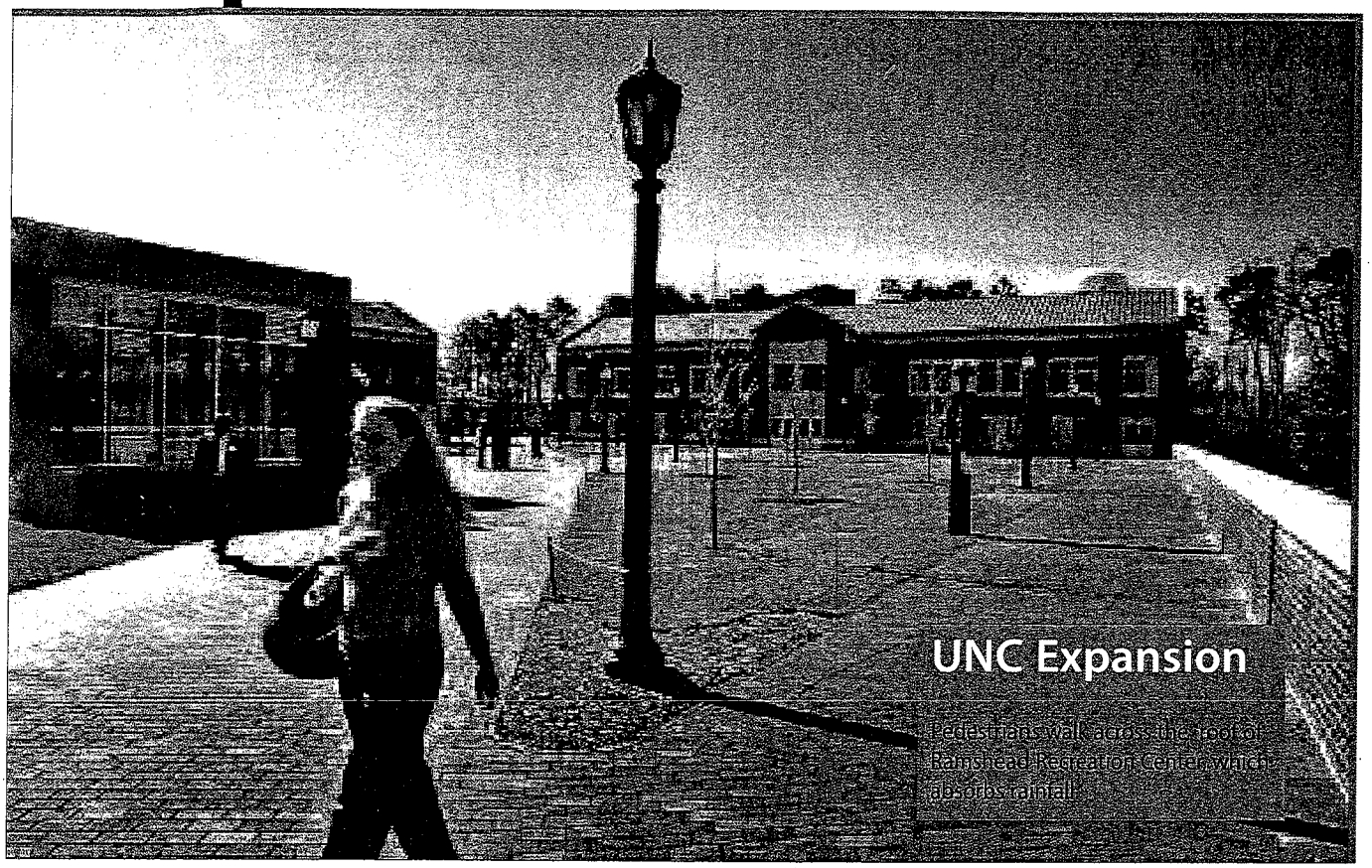
Chapel Hill NORTH CAROLINA



UNC Expansion

Pedestrians walk across the roof of Ramshead Recreation Center, which absorbs rainfall.

Dan Sears

UNC Environmental Sustainability

Impaired biological integrity for aquatic life, including several endangered species, in "Meeting of the Waters Creek," shellfish harvesting closures in the Cape Fear River, and impaired water quality in Jordan Lake – a major source of drinking water – emphasized the need for water quality improvement in North Carolina. "There is no doubt [the Cape Fear River] is impaired, and no doubt stormwater has a large part to do with it," says Bill Murray of Cape Fear River Watch, Inc.[1] To address water quality problems such as these North Carolina established "Project Green" in 1998 to promote environmental sustainability in state government.

As part of this project, the University of North Carolina, Chapel Hill is pursuing a billion-dollar construction plan to meet the needs of its growing programs. The 5.9 million square feet of new buildings on campus will be constructed using methods that accommodate new development without adding to stormwater runoff, something conventional development could never accomplish.[2,3]

The UNC Plan

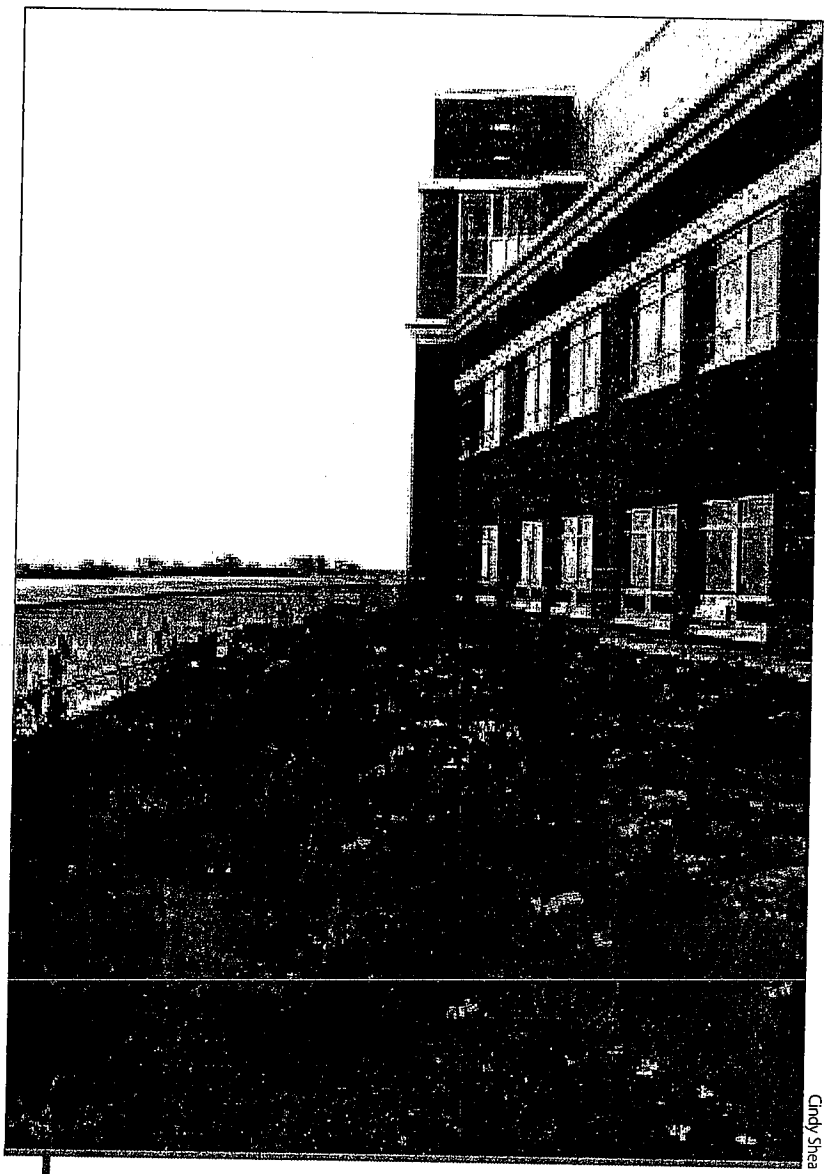
While the development plan for the University will take a decade, much of it is being implemented now and several projects are already complete. The newly finished Ram's Head recreation center and 750-space parking garage, and the Carrington Hall addition both feature green roofs that catch and clean stormwater to prevent polluted water from entering the waters nearby. The reduction of 20 acres of impermeable surface, and replacement of traditional parking lots with porous pavement and 10 acres of green space also aids in controlling stormwater pollution by reducing the amount of oil, grease and other auto-related pollutants running into waterways.

One of the most enterprising of UNC's stormwater management improvements is the installation of a 70,000 gallon underground cis-

tern beneath Carmichael athletic field. Rainwater gathered from the roofs of nearby buildings, including the School of Government and the Ram's Head recreation center, is stored in the cistern and then used to irrigate the playing fields and landscaping.

Making the Grade

As development continues, UNC has plans to replace lawn areas with mulch beds, which will improve the infiltration of stormwater, and create additional rain gardens on the campus to absorb runoff from paved surfaces. Both during and after construction, streams will be monitored to ensure that water quality is upheld and two streams that were piped through campus will be opened up to restore oxygen and sunlight to the water. With more stormwater solutions in the works UNC is on the leading edge of sustainable development among universities and other large institutions.



Cindy Shea

Carrington Hall's roof captures rainwater.

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Mt. Rainier MARYLAND

The small community of Mt. Rainier, Maryland is taking action to help protect the Chesapeake Bay. About 5 percent of the Bay has been classified as a dead zone because of excessive nutrients from sewage discharges, urban stormwater and fertilizer runoff, and other pollution sources.[1] Gutter filters and bioinlets installed along Route 1 as part of Mt. Rainier's pilot program are making real improvements in preventing polluted stormwater runoff that contributes to poor water quality of the Bay.

What are Bioinlets and Gutter Filters?

These methods of addressing stormwater runoff are uniquely suited to urban areas where there is little land available for other methods of filtering runoff.

"Gutter filters are similar to sand filters which work on the principle of sedimentation and filtration," says Ameya Ulhas Pradhan, who studied these stormwater management methods in a Master's Thesis at the University of Maryland. "They are constructed below grade .... [and] the filtered runoff is discharged to a storm drain or natural channel."[2] In other words, the stormwater runoff flows into the gutter filter where the water is filtered through sand, which catches many of the chemicals, metals and other pollutants before the water flows into the Bay. In Mt. Rainier, these are constructed along the roadside, in the place of a traditional storm drain.

Bioinlets include vegetation to help break down pollutants and provide sedimentation, filtration, soil absorption, microbial decay processes and uptake of pollutants by plants.[3] These act like bio-retention areas, which collect and hold water while it is filtered through soil and into plants. Like the gutter filter, bioinlets fit into the small area of a traditional storm drain.

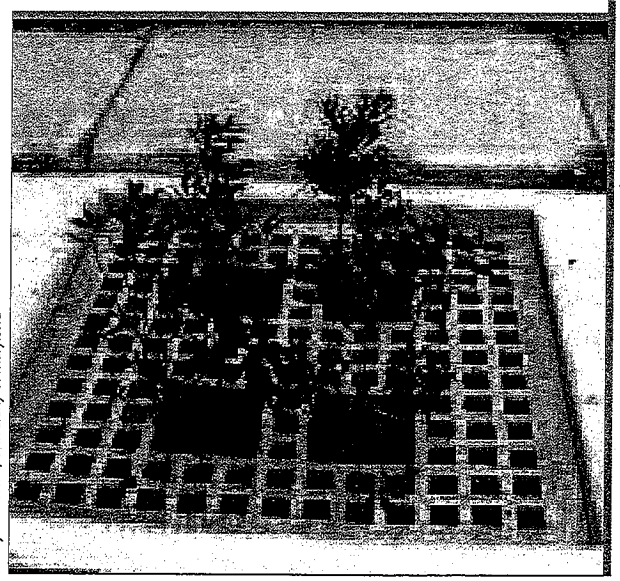
Results for a Cleaner Watershed

A variety of tests and studies conducted confirm the effectiveness of bioinlets and gutter filters. Gutter filters were found to eliminate Total Suspended Solids by 75 percent, Total Kjeldahl Nitrogen by 50 percent, zinc by 71 percent, copper by 40 percent, lead by 69 percent, and cadmium by 43 percent. However, there was no effect on nitrate or total phosphorus.[4]

With the installation of both the bioinlets and gutter filters, there was generally an even greater reduction in these pollutants. Total Suspended Solids were reduced by 83 percent, cadmium by 86-89 percent, lead by 84 percent, and zinc by 58 percent. Nitrogen was reduced by 42 percent, Total Kjeldahl Nitrogen by 12 percent, and copper by 29 percent. Nitrogen and phosphorus contribute to the growth of algae, which can deplete water of life-sustaining oxygen when it decomposes, and metals can be harmful or toxic to human health and aquatic life.

Urban Roadside Project

A bioinlet absorbs water and its vegetation helps break down pollutants.



Ameya Pradhan, University of Maryland

An Effective Stormwater Management Practice

These small steps have an effect, and they can make a big difference in water quality if done on a large scale. They can be replicated across the region efficiently, without a lot of retrofitting, and without a huge price tag.

Ameya Pradhan, University of Maryland

A curb filter cleanses runoff before sending water to the stormdrain.

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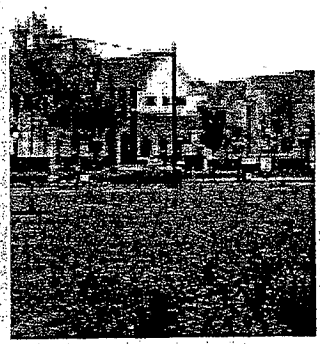

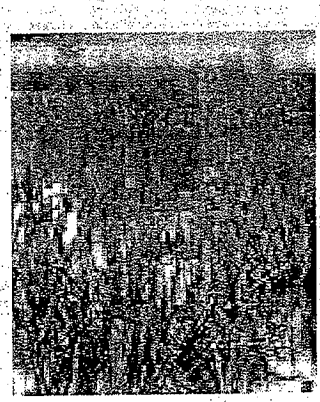

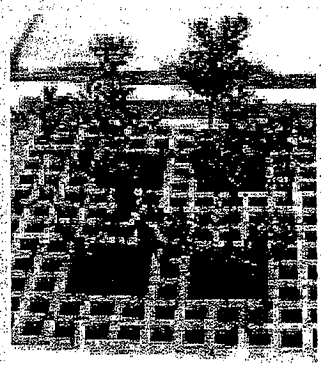

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CONTRA COSTA CLEAN WATER PROGRAM

Stormwater Quality Requirements for Development Applications

Stormwater C.3 Guidebook

SECOND EDITION—MARCH 2005

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Best Management Practice (BMP)	Any procedure or device designed to minimize the quantity of pollutants that enter the storm drain system. See Chapter Two for a discussion of the various types of BMPs.
C.3	Provision, added in February 2003, of the San Francisco Bay **Regional Water Quality Control Board**'s (see) **stormwater NPDES permit** (see). Requires each **Discharger** (see) to change its development review process to control the flow of stormwater and stormwater pollutants from new development sites. Order R2-2003-0022.
California Association of Stormwater Quality Agencies (CASQA)	Publisher of the California Stormwater Best Management Practices Handbooks, available at www.cabmphandbooks.com. Successor to the Storm Water Quality Task Force (SWQTF).
California BMP Method	A method for determining the volume of treatment BMPs. Described in Section 5.5.1 of the California Stormwater Best Management Practice Manual (New Development) (CASQA, 2003).
Compensatory Mitigation	Treatment of an equivalent pollutant loading or quantity of stormwater runoff or other equivalent water quality benefit, created where no other requirement for treatment exists, in lieu of on-site treatment BMPs.
Conditions of Approval (COAs)	Requirements a municipality may adopt for a project in connection with a discretionary action (e.g., adoption of an EIR or negative declaration or issuance of a use permit). COAs may include features to be incorporated into the final plans for the project and may also specify uses, activities, and operational measures that must be observed over the life of the project.
Contra Costa Clean Water Program (CCCWP)	CCCWP is established by an agreement among 19 Contra Costa cities and towns, Contra Costa County, and the Contra Costa County Flood and Water Conservation District. See **Dischargers**. CCCWP implements common tasks and assists the member agencies to implement their local stormwater pollution prevention programs.
Design Storm	A synthetic rainstorm defined by rainfall intensities and durations. See Chapter Two.
Detention	The practice of holding stormwater runoff in ponds, vaults, within berms, or in depressed areas and letting it discharge slowly to the storm drain system. See **infiltration** and **retention**.
Directly Connected Impervious Area	Any impervious surface which drains into a catch basin, area drain, or other conveyance structure without first allowing flow across pervious areas (e.g. lawns).

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Direct Infiltration Infiltration via methods or devices, such as dry wells or infiltration trenches, designed to bypass unsaturated surface soils and transmit runoff directly to groundwater.

Dischargers The agencies named in the **stormwater NPDES permit** (see): Contra Costa County, Contra Costa County Flood Control and Water Conservation District, City of Clayton, City of Concord, Town of Danville, City of El Cerrito, City of Hercules, City of Lafayette, City of Martinez, Town of Moraga, City of Orinda, City of Pinole, City of Pittsburg, City of Pleasant Hill, City of Richmond, City of San Pablo, City of San Ramon, and City of Walnut Creek. In addition, three Contra Costa cities within the jurisdiction of the Central Valley Regional Water Quality Control Board have agreed to implement C.3 provisions under the same schedule: City of Antioch, City of Brentwood, and City of Oakley.

Drawdown time The time required for a stormwater detention or infiltration BMP to drain and return to the dry-weather condition. For detention BMPs, drawdown time is a function of basin volume and outlet orifice size. For infiltration BMPs, drawdown time is a function of basin volume and infiltration rate.

Exemption Exemption from the requirement to provide **compensatory mitigation** may be allowed for projects that meet certain criteria set by the RWQCB. These projects must, however, show impracticability (see **impracticable**) of on-site treatment BMPs and also show that the costs of compensatory mitigation would place an "undue burden" on the project.

Flow-based BMPs **Stormwater Treatment BMPs** that remove pollutants from a moving stream of water through filtration, infiltration, adsorption, or biological processes.

Head In hydraulics, energy represented as a difference in elevation. In slow-flowing open systems, the difference in water surface elevation, e.g., between an inlet and outlet.

Hydrograph Runoff flow rate plotted as a function of time.

Hydrograph Modification Management Plan (HMP) As required by Provision **C.3** provisions of the **Stormwater NPDES permit**, a draft HMP must be submitted by November 15, 2004 and an HMP must be submitted by May 15, 2005. The HMP, once approved by the RWQCB, will be implemented so that post-project runoff shall not exceed estimated pre-project rates and/or durations, where the exceedance would result in increased potential for erosion or other adverse impacts to beneficial uses.

Hydrologic Soil Group Classification of soils by the Natural Resources Conservation Service (NRCS) into A, B, C, and D groups according to infiltration capacity. See Appendix C.

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Impervious surface	Any material that prevents or substantially reduces infiltration of water into the soil. See discussion of imperviousness in Chapter Two.
Impracticable	As applied to on-site treatment BMPs, technically **infeasible** (see) or excessively costly, as demonstrated by set criteria.
Infeasible	As applied to on-site treatment BMPs, impossible to implement because of technical constraints specific to the site.
Indirect Infiltration	Infiltration via facilities, such as swales and bioretention areas, that are expressly designed to hold runoff and allow it to percolate into surface soils. Runoff may reach groundwater indirectly or may be underdrained through subsurface pipes.
Infiltration	Seepage of runoff through the soil to mix with groundwater. See **retention.**
Infiltration Device	Any structure that is designed to infiltrate stormwater into the subsurface and, as designed, bypasses the natural groundwater protection afforded by surface or near-surface soil.
Integrated Management Practice (IMP)	A **BMP** that provides small-scale treatment, retention, or detention and is integrated into site layout, landscaping and drainage design. See **Low Impact Development.**
Integrated Pest Management (IPM)	An approach to pest management that relies on information about the life cycles of pests and their interaction with the environment. Pest control methods are applied with the most economical means and with the least possible hazard to people, property, and the environment.
Intensity-duration-frequency (IDF)	An adjunct to the **rational method** (see), IDF allows calculation of the governing rainfall intensity based on the estimated time required for runoff flows from the farthest point of a drainage area to reach the point where peak flows are to be determined.
Lead Agency	The public agency that has the principal responsibility for carrying out or approving a project. (CEQA Guidelines §15367).
Low Impact Development	An integrated site design methodology that uses small-scale detention and retention (Integrated Management Practices, or **IMPs**) to replicate pre-existing site hydrological conditions.
Maximum Extent Practicable (MEP)	Standard, established by the 1987 amendments to the Clean Water Act, for the implementation of municipal **stormwater pollution prevention programs** (also see). See Chapter Two.
National Pollutant Discharge Elimination System (NPDES)	As part of the 1972 Clean Water Act, Congress established the NPDES permitting system to regulate the discharge of pollutants from municipal sanitary sewers and industries. The NPDES was expanded in 1987 to incorporate permits for stormwater discharges as well.

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Nomograph	A chart that aids engineering calculations by representing the relationship among three variables. Nomographs in the California BMP Handbooks represent the relationship among percent annual capture, watershed imperviousness, and unit water quality volume.
Numeric Criteria	Sizing requirements for stormwater treatment BMPs established in Provision C.3.d. of the RWQCB's stormwater NPDES permit.
Operation and Maintenance (O&M)	Refers to requirements in the **Stormwater NPDES Permit** to inspect treatment BMPs and implement preventative and corrective maintenance in perpetuity. See Chapter Six.
Permeable Pavements	Pavements for roadways, sidewalks, or plazas that are designed to infiltrate runoff, including pervious concrete, pervious asphalt, unit-pavers-on-sand, and crushed gravel.
Percentile Rainfall Intensity	A method of determining design rainfall intensity. Storms occurring over a long period are ranked by rainfall intensity. The storm corresponding to a given percentile yields the design rainfall intensity.
Planned Unit Development (PUD)	Allows land to be developed in a manner that does not conform to existing zoning requirements. Allows greater flexibility and innovation because the PUD is regulated as one unit rather than each component lot being regulated separately.
Rational Method	A method of calculating runoff flows based on rainfall intensity, and tributary area, and a factor representating the proportion of rainfall that runs off.
Regional (or Watershed) Stormwater Treatment Facility	A facility that treats runoff from more than one project or parcel. Participation in a regional facility may be in lieu of on-site treatment controls, subject to the requirements of NPDES permit provision C.3.g.
Regional Water Quality Control Board (RWQCB)	California RWQCBs are responsible for implementing pollution control provisions of the Clean Water Act and California Water Code within their jurisdiction. There are nine California RWQCBs. Western and central Contra Costa County are under the jurisdiction of the RWQCB for the San Francisco Bay Region; eastern Contra Costa County is under the jurisdiction of the RWQCB for the Central Valley Region.
Retention	The practice of holding stormwater in ponds or basins and allowing it to slowly infiltrate to groundwater. Some portion will evaporate. See **infiltration** and **detention**.
Self-retaining area	An area designed to retain runoff from the **design storm.** Self-retaining areas may include graded depressions with landscaping or pervious pavements and may also include tributary impervious areas up to a 2:1 impervious-to-pervious ratio.

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Stormwater Control Plan	A plan specifying and documenting permanent site features and BMPs that are designed to control pollutants for the life of the project.
Stormwater Control Operation & Maintenance Plan	A plan detailing operation and maintenance requirements for stormwater treatment BMPs incorporated into a project. An acceptable Stormwater Control Operation and Maintenance Plan must be submitted before the building permit is made final and a Certificate of Occupancy is issued.
Stormwater NPDES Permit	A permit issued by a **Regional Water Quality Control Board** (see) to local government agencies (**Dischargers**) placing provisions on allowable discharges of municipal stormwater to waters of the state.
Storm Water Pollution Prevention Plan (SWPPP)	A plan providing for temporary measures to control sediment and other pollutants during construction.
Stormwater Pollution Prevention Program	A comprehensive program of activities designed to minimize the quantity of pollutants entering storm drains. See Chapter One.
Storm Water Quality Task Force (SWQTF)	Publisher of the 1993 California Storm Water BMP Handbooks. See California Association of Stormwater Quality Agencies (CASQA).
Volume-based BMPs	**Stormwater Treatment BMPs** that detain runoff and treat it primarily through settling or infiltration.
WEF Method	A method for determining the minimum design volume of treatment BMPs, recommended by the Water Environment Federation and American Society of Civil Engineers. Described in *Urban Runoff Quality Management* (WEF/ASCE, 1998).
Water Board	See **Regional Water Quality Control Board.**
Water Quality Volume (WQV)	For stormwater treatment BMPs that depend on detention to work, the volume of water that must be detained to achieve maximum extent practicable pollutant removal. This volume of water must be detained for a specified **drawdown time**.

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Start

How to Use this Guidebook

Read the Overview to get a general understanding of the requirements. Then follow the step-by-step instructions to prepare your Stormwater Control Plan.

THIS *Guidebook* will help you ensure that your project complies with the California Regional Water Quality Control Boards' C.3 requirements. The requirements are complex and technical, and most applicants will require the assistance of a qualified civil engineer, architect, or landscape architect. Because every project is different, you should begin by scheduling a **pre-application meeting** with municipal planning staff. At this meeting, you can ask how the C.3 requirements, and other planning and zoning requirements, apply to your project.

ICON KEY
Helpful Tip
Submittal Requirement
Terms to Look Up
References & Resources

To use the *Guidebook*, start by reviewing **Chapter One**, which provides a brief overview and explanation of the new requirements to control runoff from new development projects. The overview covers regulations, the plan review process, design issues, and the environmental benefits the regulations are intended to achieve.

If there are terms and issues you find puzzling, try finding answers in the glossary or in **Chapter Two**. Chapter Two consists of one-page summaries of key concepts like "maximum extent practicable," "imperviousness," and "design storm."

Then proceed to **Chapter Three** and follow the step-by-step guidance to prepare a Stormwater Control Plan for your site.

If your project requires CEQA review, **Chapter Four** will tell you how to integrate analysis of stormwater impacts and mitigations into your documentation.

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Design requirements are provided in **Chapter Five**, along with references that will aid you in designing the features you've identified in your Stormwater Control Plan. Chapter Five also includes schematic designs and a simplified procedure for sizing stormwater treatment and hydrograph modification BMPs.

Chapter Six describes the agreements—dedication of fee or easement, a maintenance agreement that "runs with the land," or other long-term commitment—to provide for operation and maintenance of stormwater treatment facilities in perpetuity. Chapter Six also outlines maintenance requirements for some recommended treatment and hydrograph modification management devices.

Chapter Seven discusses some options you may have for alternative (off-site) compliance with the Regional Water Quality Control Boards' C.3 requirements.

Local Requirements
Cities, towns, or the County may have requirements that differ from, or are in addition to, this county-wide Guidebook. See Appendix A for local requirements.

Throughout each Chapter, you'll find references and resources to help you understand the regulations, complete your Stormwater Control Plan, and design stormwater control measures into your project. Your local planning and community development department will have copies of most of these references and resources.

The most recent, updated version of the *Guidebook* is on the Contra Costa Clean Water Program website at www.cccleanwater.org/construction/nd.php. The on-line *Guidebook* is in Adobe Acrobat format. If you are reading the Acrobat version on a computer with an internet connection, you can use hyperlinks to navigate the document and to access various references. The hyperlinks are throughout the document, as well as in "References and Resources" sections (marked by the 🕮 icon) and in the **bibliography**. Some of these links (URLs) may become outdated. In that case, you might try entering portions of the title or other relevant keywords into an internet search engine.

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For a broad-based understanding, look at the Stormwater C.3 requirements from four different perspectives: as water-quality regulations, as planning requirements, as a design challenge, and as a way to obtain environmental benefits for the community.

The California Regional Water Quality Control Boards for the San Francisco Bay Region and Central Valley Region (RWQCBs) have mandated that Contra Costa municipalities impose new, more stringent requirements to control runoff from development projects.

The RWQCBs added **Provision C.3** to the municipalities' stormwater NPDES permit in February 2003. The municipalities are phasing in the requirements from 2004 through 2006.

The RWQCBs have determined that the new Provision C.3 requirements are needed to implement Federal Clean Water Act provisions governing discharges to municipal storm drains.

Clean Water Act
Regulations on stormwater discharges have grown progressively more stringent since the Clean Water Act was amended in 1987.

Congress adopted amendments to the Clean Water Act in 1987, and the United States Environmental Protection Agency (USEPA) issued implementing regulations in 1990. The San Francisco Bay RWQCB began issuing stormwater discharge permits to municipalities that same year.

Since the early 1990s, Contra Costa municipalities have required contractors to implement **temporary Best Management Practices (BMPs)** to minimize the amount of sediment and other pollutants that enter site runoff during construction. For several years, the municipalities have also encouraged applicants to design their projects to minimize new impervious area and to incorporate into

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their plans **permanent treatment BMPs** – features and devices that detain, retain, or treat runoff for the life of the project.

"Maximum Extent Practicable"
For more on this and other stormwater terms, see the Glossary and discussions in Chapter Two.

As before, the standard for these BMPs is **"maximum extent practicable,"** or MEP. However, the new permit requirements define MEP more specifically and include design criteria.

The new development provisions are one part of a **comprehensive stormwater pollution prevention program** implemented by each Contra Costa municipality. Those programs also require:

- Controls on runoff from existing commercial and industrial sites.
- Temporary measures to control sediment and other pollutants in runoff from construction sites.
- Changes in the way the municipalities maintain streets, parks and public infrastructure.
- Prevention of illegal dumping in storm drains.
- Public outreach and education.

Under the RWQCBs' stormwater discharge permits, cities, towns, and the County implement some activities individually. Other activities are done jointly through the Contra Costa Clean Water Program (CCCWP).

RWQCB staff monitors each municipality's implementation of permit requirements. Each municipality must report on its development review process, number and type of projects reviewed, and what runoff control measures were included in the projects.

ICON KEY

- Helpful Tip
- Submittal Requirement
- Terms to Look Up
- References & Resources

As required by Permit Provision C.3.f., the CCCWP is preparing a **Hydrograph Modification Management Plan (HMP)**. The purpose of the HMP is to manage post-project runoff so that it does not exceed pre-project rates or durations if such an increase could contribute to downstream erosion. The HMP will provide instructions on how to determine whether a project might increase the amount and duration of runoff and provide guidance on how to design a site and incorporate BMPs so that post-project runoff flow and volume will not exceed pre-project rates or durations. As an alternative, project proponents may demonstrate that the risk of erosion due to increased runoff is minimal or may propose in-stream measures to control erosion.

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While the HMP is being completed, project applicants are encouraged to use "dual-purpose" designs. These designs control pollutants and reduce runoff quantities by minimizing imperviousness and by slowing, retaining, and detaining runoff flows. The design approach recommended in Chapter Five achieves dual purposes by distributing small detention areas throughout the site, reducing overall runoff and increasing the time it takes for runoff to reach storm drains.

References and Resources

- San Francisco Bay RWQCB Order No. R2-2003-0022 (Stormwater NPDES Permit C.3 Amendment)
- San Francisco Bay RWQCB Order 99-058 (Stormwater NPDES Permit)
- Central Valley RWQCB Order 5-00-120 (Stormwater NPDES Permit covering Antioch, Brentwood, and Oakley and eastern portions of unincorporated Contra Costa County)
- RWQCB Fact Sheet on New Development Provisions
- RWQCB Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan)
- RWQCB Water Quality Control Plan for the Central Valley Region (Basin Plan)
- Clean Water Act Section 402(p)
- 40 CFR 122.26(d)(2)(iv)(A)(2) – Stormwater Regulations for New Development
- CCCWP – Stormwater Management Plan (1999-2004)
- CCCWP Hydrograph Modification Management Plan Literature Review and Work Plan

Local Development Review Perspective

The Contra Costa Clean Water Program created this Guidebook to help project applicants implement the stormwater C.3 requirements. The C.3 requirements are the same in all Contra Costa municipalities; however, specific procedures and application requirements may differ somewhat from one municipality to the next. The staff of each municipality aims to make the complex C.3 requirements clear and easy to follow. Municipal staff will work with project applicants to facilitate timely and complete review of their projects.

Local Requirements
Review Appendix A for information on local planning procedures and application requirements.

► THRESHOLDS

For previously undeveloped sites, and for project applications "deemed complete" after **February 15, 2005**, the C.3 requirements apply if a project creates one acre or more impervious area. On **August 15, 2006,** this threshold is reduced to 10,000 square feet of impervious area.*

Threshold
A Stormwater Control Plan will be required for projects that create more than one acre of new impervious area.

For sites that have been previously developed, the threshold is more complex.

- If the new project results in an increase of, or replacement of, 50% or more of the previously existing impervious surface, and the existing

* Water Board staff has stated that projects creating less than one acre impervious area will not be subject to Provision C.3.f (Hydrograph Modification Management Plan) requirements.

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development was not subject to stormwater treatment measures, then the entire project must be included in the treatment measure design.

- If less than 50% of the previously impervious surface is to be affected, only that portion must be included in the treatment measure design.

Interior remodels, routine maintenance or repair, roof or exterior surface replacement, and repaving are not subject to C.3 requirements.†

► DEVELOPMENT REVIEW PROCESS

The process for reviewing stormwater controls is integrated with the municipalities' development review process. A simplified diagram of a typical development review process is shown in Figure 1-1.

If the C.3 requirements apply, planning staff will require that a Stormwater Control Plan be submitted along with the Planning and Zoning application. This should be discussed at the pre-application meeting.

CEQA
See Chapter Four for a discussion of how to document stormwater impacts and mitigations in Initial Studies and Environmental Impact Reports.

If the project requires review under the California Environmental Quality Act (CEQA), planning staff will require submittal of an **Environmental Information Form.** This submittal should document potential impacts of the project's changes to stormwater runoff. Typically, staff will use an initial study checklist to determine whether the project may still have significant effects on the environment after proposed mitigation measures are included. Stormwater impacts can be mitigated by minimizing site imperviousness, controlling pollutant sources, and incorporating **treatment BMPs** that retain, detain, or treat runoff.

This *C.3 Guidebook* will assist you to prepare a stormwater control plan for your project. Staff will use the checklist in Chapter 3 to determine if the stormwater control plan portion of your application is complete. Once the application is deemed complete, staff will use the *Guidebook* to determine whether the stormwater control plan complies with the RWQCBs' C.3 requirements.

Planning staff or the Planning Commission (or in some cases, a City Council or the County Board of Supervisors) will approve or deny the application. If the application is approved, staff, the commission, or the Council or Board will attach conditions of approval, including a requirement that you implement your stormwater control plan. A typical standard condition of approval mandating stormwater control plan implementation is in Appendix B.

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† This summary is for information only. For application to a specific project, consult the RWQCB Order and discuss with City staff.

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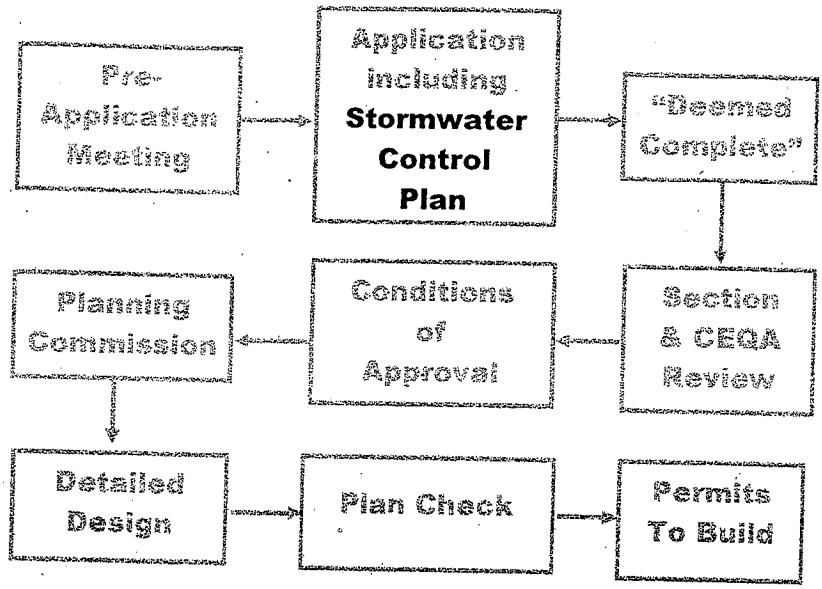

FIGURE 1-1. REVIEW OF THE STORMWATER CONTROL PLAN is integrated with the municipal development review process.

Following approval of your planning and zoning application, you may submit your application for building permits. City staff will check that the features and devices specified in the Stormwater Control Plan are incorporated into the construction plans, that the stormwater controls meet specified design criteria, and that their construction will comply with applicable building codes. A stormwater treatment control operation and maintenance plan (described in Chapter 6) must be submitted and approved before the building permit can be made final and a certificate of occupancy issued.

Prepare the stormwater control plan simultaneously with the preliminary site plan and landscaping plan.

Doing so will:

- Maximize multiple benefits of site landscaping.
- Reduce overall project costs.
- Improve site aesthetics and produce a better quality project.
- Be more likely to achieve "maximum extent practicable."
- Speed project review.
- Avoid unnecessary redesign.

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A Stormwater Control Plan is a separate document from the Storm Water Pollution Prevention Plan (SWPPP). The SWPPP provides for temporary measures to control sediment and other pollutants during construction at sites that disturb one acre or more. The Stormwater Control Plan specifies permanent controls that should last for the life of the project. In some cases, the two plans need to be coordinated. For example, at the end of the construction phase, a basin used for temporary sediment control could be converted to a permanent swale, basin, or bioretention area. The basin would be shown in both plans.

Preparing a Stormwater Control Plan involves the following steps:

1. Assemble needed information.
2. Identify constraints and opportunities.
3. Design to minimize imperviousness.
4. Compare pre- and post-project runoff hydrographs.
5. Locate and select treatment and hydrograph modification management BMPs.
6. Perform preliminary design of BMPs.
7. Specify source controls.
8. Integrate with other preliminary drawings.
9. Identify permitting and code compliance issues.
10. Identify BMP maintenance requirements.
11. Complete a Stormwater Control Plan & Report.

Chapter Three helps guide you through each step. **Chapter Four** includes information on how to document stormwater potential impacts and mitigations in CEQA documentation.

References and Resources:

- RWQCB Order No. R2-2003-0022 (Stormwater NPDES Permit Amendments) Provisions C.3.(b) and C.3.(j)
- California Planning and Zoning Law
- California Environmental Quality Act
- *CEQA Deskbook 1999 [Second] Edition* (Bass, Herson, and Bogdan, Solano Press Books, 2001)
- California Building Code
- *California Stormwater Best Management Practice Handbook (Construction)*
- *Manual of Standards for Erosion and Sediment Control Measures* (Association of Bay Area Governments, 1986)

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TABLE 1-1. A SWPPP and a Stormwater Control Plan are two separate documents.

	Storm Water Pollution Prevention Plan (SWPPP)	*Stormwater Control Plan*
Primary objective	Minimize potential runoff pollution during construction.	Minimize potential runoff pollution for the life of the project.
Pollutants targeted	Sediment from erosion and site disturbance, maintenance of construction equipment, construction activities (e.g. painting).	Pollutants deposited in airborne dust, liquids and dust from automobiles, cleaning solutions (e.g. from food service), litter and trash.
Coordination with review process	Submitted with application for building permit.	Submitted with application for planning and zoning review.
Coordination with project planning	Coordinated with grading plans and construction scheduling and phasing.	Integrated with site plan, drainage plan, and landscaping.

In most cases, stormwater controls will add to the overall cost of a project. Stormwater controls may also constrain use of the site.

However, if executed well, and if integrated with landscaping and site amenities, stormwater controls can **add to your project's quality and value**.

From a site design perspective, the aim of stormwater controls is to **make site drainage mimic, as much as possible, the way a natural landscape drains.**

Much of the rain falling on a natural landscape is held by vegetation, soaks into the soil, or seeps slowly downhill. Pollutants washed out from the atmosphere are absorbed through contact with soils and vegetation.

Roofs and paving prevent rain from reaching the soil. Pollutants wash off the impervious surfaces, and drain pipes transport the runoff rapidly and efficiently to creeks or the Bay. Higher peak flows and runoff volumes may promote channel erosion—unless streambanks are hardened.

Because small storms make up most of total rainfall—and because small storms have cumulative and profound effects on stream channel stability—it makes sense

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Because small storms make up most of total rainfall—and because small storms have cumulative and profound effects on stream channel stability—it makes sense to **design stormwater treatment controls to detain, retain, and treat runoff from small storms**. Consistently throughout the U.S., 80% or more of average annual total rainfall comes in storms of less than one inch rainfall depth.

An obvious, and effective, way to limit site runoff is to **minimize the amount of pavement and roofs**. Some paved areas can be designed with unit pavers, gravel, or other pervious surfaces. Runoff from small paved areas, like sidewalk or driveway strips, can be sloped to drain to concave lawns or landscaping.

Runoff collected from larger impervious areas, like roofs or parking lots, can be channeled through features located in depressions and integrated into the landscape. These features include swales, infiltration/detention basins, and bioretention areas.

These **treatment BMPs** can help infiltrate runoff into the soil. If soils are impermeable or groundwater is too close to the surface—as in parts of Contra Costa County—the features can detain and treat runoff before it is allowed to slowly drain away.

Where space and site layout do not allow swales, basins, or bioretention areas, it is still possible to use vaults for storage and sand filters for treatment. These devices work, but are more expensive, require more maintenance, do not contribute to site aesthetics, and (if not carefully maintained) can provide breeding habitat for mosquitoes.

Projects in the Bay Area, throughout the U.S., and in other countries have successfully implemented these techniques. Design manuals are available to guide architects and engineers through the design process, including the selection of options, sizing, and specifications.

Chapter Five provides guidance on design requirements.

References and Resources

- *Start at the Source* (BASMAA, 1999)
- California Best Management Practice Handbooks (CASQA, 2003).
- Urban Runoff Quality Management (WEF/ASCE, 1998)
- Low Impact Development Design Strategies: An Integrated Approach (Maryland, 2001)
- Site Planning for Urban Stream Protection (Scheuler, 1995)
- *Urban Small Sites Best Management Practice Manual* Barr Engineering for Metropolitan Council of Governments (Minneapolis/St. Paul)

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The diverse natural geography of Contra Costa County includes tidal and freshwater wetlands, alluvial plains, and mountain slopes. Annual rainfall varies from 12.5 inches in Brentwood to 30 inches in Orinda.

The climate, soils, slope, and vegetation give each Contra Costa stream a characteristic structure of riffles, pools, terraces, floodplains, and wetlands. In relatively undisturbed stream reaches, this geomorphic structure supports trees and other riparian vegetation. Trees provide shade (cooling stream temperatures), create root wads and undercut banks (refuge for fish) and produce falling leaves and detritus (the bottom of a food web). Fish, frogs, and other animals have evolved to thrive in riparian habitats. Because Contra Costa habitats are diverse and complex, some species are specialized, have limited ranges, and may be rare.

Contra Costa's landscape, like that of all the San Francisco Bay Area, has been repeatedly transformed since the Spanish arrived in the 1770s. Even before the area was developed, European grasses, weeds, and other plants replaced much of the native vegetation. Creek flows were diverted to irrigate farms and wetlands were diked or filled for farmland.

Suburbs and former farm towns developed rapidly during and after the Second World War. In many places, to make flood-prone land suitable for development, creeks were channelized or confined within levees. Buildings, streets, and pavement now cover much of the land, and storm drains pipe runoff from urban neighborhoods directly into the creeks. Urbanization has changed the timing and intensity of stream flows and has set off a chain of unanticipated consequences. These consequences include more frequent flooding, destabilized stream banks, armoring of streambanks with riprap and concrete, loss of streamside trees and vegetation, and the destruction of stream habitat.

The remaining habitat, even where it has been disturbed and reduced to remnants, is an important refuge for various species. The U.S. and California have listed some of these species, including steelhead (*Oncorhyncus mykiss),* as endangered. Other species are listed as threatened, rare, or having other special status.

Once altered, natural streams and their ecosystems cannot be fully restored. However, **it is possible to stop, and partially reverse, the trend of declining habitat** and preserve some ecosystem values for the benefit of future generations.

This is an enormous, long-term effort. Managing runoff from a single development site may seem inconsequential, but by changing the way most sites are developed (and redeveloped), we may be able to preserve and enhance existing stream ecosystems in urban and urbanizing areas.

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References and Resources

- *Restoring Streams in Cities* (Riley, 1998)
- *Stream Restoration: Principles, Processes, and Practices* (Federal Interagency Stream Restoration Working Group, 1998)
- *Contra Costa County Watershed Atlas* (Contra Costa County, 2003)

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All about BMPs, MEP, imperviousness, etc.

Like practitioners in any other specialized field, planners and engineers working on stormwater control have created their own lingo. Within the array of acronyms and shorthand, there are several key concepts—some of them based on water-quality regulations, others on evolved design practice—that are indispensable to communication between project proponents, designers, and reviewers.

The glossary at the front of this Guidebook lists words and concepts that can be explained adequately in a sentence or two. Other concepts require elaboration, including an explanation of how they apply to designing and permitting development projects.

This chapter explains the following key concepts:

- Maximum Extent Practicable
- Best Management Practices
- Imperviousness
- Design Storm

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As required by the Clean Water Act, the RWQCB limits the allowable concentration (and sometimes the allowable load) of pollutants in municipal and industrial sewage discharged to State waters.

When it amended the Clean Water Act in 1987, Congress recognized that it was not technically feasible to establish similar limits on pollutants in stormwater discharged from municipal storm drains. Instead, Clean Water Act Section 402(p)(3)(iii) says that each state:

> ...shall require controls to reduce the discharge of pollutants to the **maximum extent practicable**, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

"Maximum extent practicable" is not defined in Federal law or regulation.

CCCWP's Stormwater Management Plan incorporates **continuous improvement** to ensure that the pollution-prevention efforts consistently achieve "maximum extent practicable." Under the stormwater discharge permit, CCCWP updates **performance standards** that establish, for various elements of the stormwater pollution prevention program, the level of effort that currently corresponds to "maximum extent practicable."

When reviewing proposed development projects, municipal staff uses current performance standards and best professional judgment to determine whether proposed stormwater controls meet the "maximum extent practicable."

As knowledge of stormwater control develops, it is becoming more common for "maximum extent practicable" to be expressed as numeric criteria. For example, the 2003 amendments to the stormwater permit established numeric standards for sizing stormwater treatment BMPs. Municipal staff must apply these standards when reviewing proposed development projects.

For other aspects of site design and treatment BMP design, municipal staff may consult available design manuals and apply their engineering or other professional judgment.

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Clean Water Act Section 402(p) and USEPA regulations (40 CFR 122.26) specify a municipal program of "management practices" to control stormwater pollutants. **Best Management Practice (BMP)** refers to any kind of procedure or device designed to minimize the quantity of pollutants that enter the storm drain system.

Since the adoption of the regulations in 1990, a rough taxonomy of BMPs has emerged. As shown in Table 2-1, BMPs can be classified three ways:

A. *Manifestation.* **Structural BMPs** are built devices or site features (e.g., a constructed wetland). **Operational BMPs** are practices or procedures (e.g., dumping washwater in an indoor sink rather than the gutter, or sweeping outside work areas daily).

B. *Longevity.* **Permanent BMPs** are structural BMPs intended to last the life of the project (e.g. a constructed wetland). **Temporary BMPs** (e.g. silt fences) are removed when construction is finished.

C. *Mode.* **Source control BMPs** (or source control measures) aim to stop pollutants from entering stormwater. All operational BMPs are for source control, but source control BMPs can also be permanent structural BMPs (e.g., a berm around a dumpster area). **Treatment BMPs** are features or devices that remove pollutants that have already become suspended or dissolved in stormwater.

TABLE 2-1. BMPs classified three ways.

A. Manifestation	*B. Longevity*	*C. Mode*
Structural	Permanent	Source Control
Operational	Temporary	Treatment

As described in Chapter Three and Chapter Five, there are two approaches to incorporating treatment BMPs into new development sites. Treatment BMPs can be integrated into the landscape design and distributed throughout the site **(Integrated Management Practices, or IMPs)**, or site drainage can be piped to a larger, engineered **conventional** treatment BMP. Many IMPs are **flow-based BMPs**—they treat runoff by filtering it continuously through soil. Detention basins, the most common type of conventional treatment BMP, are an example of a **volume-based BMP**. Volume-based BMPs treat stormwater primarily through settling or infiltration.

Commercial and industrial facilities must implement operational BMPs to the maximum extent practicable, and residents are expected to avoid allowing anything other than stormwater (e.g., soapy water, paint, litter) from entering storm drains. These requirements are implemented and enforced by other parts of municipal comprehensive stormwater pollution prevention programs.

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Schueler (1995) proposed **imperviousness** as a "unifying theme" for the efforts of planners, engineers, landscape architects, scientists, and local officials concerned with urban watershed protection. Schueler argued (1) that imperviousness is a useful indicator linking urban land development to the degradation of aquatic ecosystems, and (2) imperviousness can be quantified, managed, and controlled during land development.

Imperviousness has long been understood as the key variable in **urban hydrology.** Peak runoff flow and total runoff volume from small urban catchments is usually calculated as a function of the ratio of impervious area to total area **(rational method).** The ratio correlates to the runoff factor, usually designated "C". Increased flows resulting from urban development tend to increase the frequency of small-scale flooding downstream.

Imperviousness links urban land development to degradation of aquatic ecosystems in two principal ways.

First, the combination of paved surfaces and piped runoff efficiently collects urban **pollutants** and transports them, in suspended or dissolved form, to surface waters. These pollutants may originate as airborne dust, be washed from the atmosphere during rains, or may be generated by automobiles and outdoor work activities.

Second, increased peak flows and runoff durations typically cause **erosion of stream banks and beds**, transport of fine sediments, and disruption of aquatic habitat. Measures taken to control stream erosion, such as hardening banks with riprap or concrete, may permanently eliminate habitat. By reducing groundwater infiltration, imperviousness may also reduce dry-weather stream flows.

Imperviousness has two major components: rooftops and transportation (including streets, highways, and parking areas). The transportation component is usually larger and is more likely to be **directly connected** to the storm drain system.

The effects of imperviousness can be mitigated by disconnecting impervious areas from the drainage system and by making drainage less efficient—i.e., by encouraging detention and retention of runoff near the point where it is generated. Detention and retention reduce peak flows and volumes and allow pollutants to settle out or adhere to soils before they can be transported downstream.

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No two rainstorms are exactly alike. Hydrologists sort and analyze rain gauge records to find long-term patterns of rainfall **intensity** and **duration**. Then they predict runoff flows and volumes based on these patterns and on the size, slopes, soils, land uses, and drainage patterns of a particular watershed.

Engineers select a **design storm** to calculate the required size of facilities that convey, store, or treat runoff. Because small storms occur many times a year, and larger storms come once in many years, the design storm is selected based on probability (e.g., the allowable likelihood that a channel will overflow in any given year). Often, applicable regulations specify the rainfall intensity and duration that must be used in design.

Different design storms apply to different purposes. Selection of a design storm balances costs and benefits. Roof leaders and flood control channels are typically designed to convey runoff from a storm with a one-in-one-hundred (1%) probability of occurring in any particular year (commonly called the "one-hundred-year storm"). Flood control detention basins may be designed to hold a storm predicted to occur, on average, in 4% or 10% of the coming years (a 25-year or 10-year storm, respectively).

NPDES permit Provision C.3.d includes criteria for designing treatment BMPs. These criteria target treatment of 80% of **average annual** runoff. (See the discussion of maximum extent practicable on page 14.) Because a large portion of average annual runoff is produced by small storms that occur many times a year, treatment BMPs can be designed to bypass larger storms. The 80% criterion means that BMPs will be bypassed, on average, every 1-2 years.

Because treatment BMPs are designed to treat only small storms, they can be considerably smaller than detention basins designed to protect property during flood-generating storms that may recur in 10%, 4%, or 1% of coming years. However, treatment BMPs must be designed as part of an overall drainage system that can accommodate larger storms.

Development sites subject to NPDES permit Provision C.3.f will be required to maintain runoff peak flows and durations that existed prior to development, if increased flows or durations could cause downstream erosion. CCCWP's **Hydrograph Modification Management Plan** (HMP) will identify the method that must be used to compute pre- and post-development peak flows and durations. It is possible to design "dual-purpose" BMPs that infiltrate or detain stormwater flows and also remove stormwater pollutants.

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Preparing Your Stormwater Control Plan

Step-by-step assistance for site design and BMP selection.

Begin by scheduling a pre-application meeting with municipal planning staff to identify and discuss specific requirements that may apply to your project. Prepare your Stormwater Control Plan for submittal along with the other items specified by planning staff.

► OBJECTIVES.

Your Stormwater Control Plan must demonstrate that your project will incorporate site design characteristics, landscape features, and BMPs that will minimize imperviousness, retain or detain stormwater, slow runoff rates, and reduce pollutants in post-development runoff to the **maximum extent practicable**. Additional requirements may apply if runoff from your site discharges directly to creeks or wetlands. (See Order R2-2003-0022, Provision C.3.b.ii).

A complete and thorough Stormwater Control Plan will enable planning staff to verify that your project complies with these requirements. Every Contra Costa municipality requires a Stormwater Control Plan for every applicable project so that municipal staff can document their compliance with the RWQCB permits.

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Submittal Requirement
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► CONTENTS.

Your Stormwater Control Plan will consist of a plan and a report. **Staff will use the following checklist** to evaluate the completeness of your Plan.

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STORMWATER CONTROL PLAN CHECKLIST

Required	Adequate	CONTENTS OF PLAN
		Show on drawings:
☐	☐	Existing natural hydrologic features (depressions, watercourses, relatively undisturbed areas) and significant natural resources. (Step 1 in the following step-by-step instructions)
☐	☐	Soil types and depth to groundwater (if infiltration is proposed). See Appendix C. (Step 1)
☐	☐	Existing and proposed site drainage network and connections to drainage off-site. (Step 3)
☐	☐	Proposed design features and surface treatments used to minimize imperviousness. (Steps 3 and 4)
☐	☐	Separate drainage areas, depending on complexity of drainage network. (Steps 3, 4, and 5)
☐	☐	Existing condition of each drainage area, including pervious and impervious areas. (Steps 3, 4, and 5)
☐	☐	For each drainage area, types of impervious area (roof, plaza/sidewalk, and streets/parking) and area of each. (Steps 3, 4, and 5)
☐	☐	Proposed locations and approximate sizes of infiltration, treatment, or hydrograph modification BMPs. (Steps 4 and 5)
☐	☐	Pollutant source areas, including loading docks, food service areas, refuse areas, outdoor processes and storage, vehicle cleaning, repair or maintenance, fuel dispensing, equipment washing, etc., and corresponding required source controls from Appendix E. (Step 6)

Required	Adequate	CONTENTS OF REPORT
		A report accompanying the drawings should include:
☐	☐	Narrative analysis or description of site features and conditions that constrain, or provide opportunities for, stormwater control. (Step 2)
☐	☐	Narrative description of site design characteristics that protect natural resources. (Step 3)
☐	☐	Narrative description and/or tabulation of site design characteristics, building features, and pavement selections that reduce imperviousness of the site. (Step 3)
☐	☐	Tabulation of pervious and impervious area, showing self-retaining areas and areas tributary to each infiltration, treatment, or hydrograph modification BMP. (Steps 3, 4, and 5)
☐	☐	Preliminary designs, including calculations, for each treatment or hydrograph modification management BMP. Elevations should show sufficient hydraulic head for each. (Step 5)
☐	☐	A table of identified pollutant source areas and for each, the source control measure(s) used to reduce pollutants to the maximum extent practicable. See worksheet in Appendix E. (Step 6)
☐	☐	Identification of any conflicts with codes or requirements or other anticipated obstacles to implementing the Stormwater Control Plan (Step 8).
☐	☐	General description of maintenance needs for treatment/hydrograph modification BMPs (Step 9)
☐	☐	Means by which BMP maintenance will be financed and implemented in perpetuity. (Step 9)
☐	☐	Statement accepting responsibility for interim operation & maintenance of treatment BMPs (Step 9).
☐	☐	Construction Plan C.3 Checklist (Step 10).
☐	☐	Certification by a civil engineer, architect, and landscape architect (Step 10).

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The Clean Water Program recommends that you plan and design your stormwater controls integrally with the site planning and landscaping for your project. It's best to start with general project requirements and preliminary site design concepts; then **prepare the detailed site design, landscape design, and stormwater control plan simultaneously.**

Even if a site design has already been prepared, you can still incorporate adequate stormwater controls. However, because you'll be working within the constraints of the design, you may be limited to selecting more expensive, higher-maintenance, and less aesthetically pleasing stormwater treatment options.

Suggested coordination with site and landscape design

The following step-by-step procedure should optimize your design by identifying the best opportunities for stormwater controls **early in the design process. Regardless of which design procedure you use**, you should still review this chapter for explanation of expectations and requirements for your Stormwater Control Plan.

Begin with general project requirements and program.

The recommended steps are:

1. Assemble needed information.
2. Identify site opportunities and constraints.
3. Design to minimize imperviousness.
4. Locate and select treatment/hydrograph modification BMPs.
5. Perform preliminary design of treatment/hydrograph modification BMPs.
6. Specify source controls.
7. Integrate the Stormwater Control Plan with site and landscape plans.
8. Identify permitting and code compliance issues.
9. Identify BMP maintenance requirements.
10. Complete the Stormwater Control Plan.

Sketch conceptual site layout, building locations, and circulation.

Complete the landscape design.

Complete the detailed site design.

Submit Site Plan, Landscape Plan, and Stormwater Control Plan

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Step 1: Assemble Needed Information

To select types and locations of BMPs, the designer needs to know the following site characteristics:

- **Existing natural hydrologic features** and natural resources, including any contiguous natural areas, wetlands, watercourses, seeps, or springs.
- **Existing site topography**, including contours of any slopes of 4% or steeper, general direction of surface drainage, local high or low points or depressions, any outcrops or other significant geologic features.
- **Zoning**, including requirements for **setbacks** and **open space**.
- Soil types (including **hydrologic soil groups**) and depth to groundwater, which may determine whether infiltration is a feasible option for managing site runoff. A preliminary determination of infiltration feasibility may be made using maps and criteria in Appendix C. As discussed there, depending on site location and characteristics, site-specific information (e.g. from boring logs or geotechnical studies) may be required.
- **Existing site drainage.** For undeveloped sites, this should be obtained by inspecting the site and examining topographic maps and survey data. For previously developed sites, site drainage and connection to the municipal storm drain system can be located from site inspection, municipal storm drain maps, and plans for previous development.
- Existing **vegetative cover** and **impervious areas**, if any.

References and Resources

- Appendix C, Stormwater Infiltration Guidelines
- *Start at the Source* (BASMAA 1999), p. 36
- USDA NRCS Technical Release TR55 Documentation—Appendix A: Soil Types

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Review the information collected in Step 1. Identify the principal constraints on site design and BMP selection as well as opportunities to reduce imperviousness and incorporate BMPs into the site and landscape design. For example, **constraints** might include impermeable soils, high groundwater, groundwater pollution or contaminated soils, steep slopes, geotechnical instability, high-intensity land use, heavy pedestrian or vehicular traffic, or safety concerns. **Opportunities** might include existing natural areas, low areas, oddly configured or otherwise unbuildable parcels, easements and landscape amenities including open space and buffers (which can double as locations for BMPs), and differences in elevation (which can provide hydraulic head for BMPs).

Prepare a brief **narrative** describing site opportunities and constraints. In the review process, this narrative may help establish the **maximum extent practicable** degree of stormwater control required for your site.

► OPTIMIZE THE SITE LAYOUT

To minimize stormwater-related impacts, apply the following design principles to the layout of newly developed and redeveloped sites:

- Define development envelope and protected areas, identifying areas that are most suitable for development and areas that should be left undisturbed.
- Set back development from creeks, wetlands, and riparian habitats.
- Preserve significant trees.
- Avoid erodible soils and steep slopes.

Where possible, conform the site layout along natural landforms, avoid excessive grading and disturbance of vegetation and soils, and replicate the site's natural drainage patterns. Concentrate development on portions of the site with less permeable soils, and preserve areas that can promote infiltration.

► LIMIT PAVING AND ROOFS

For all types of development, **limit overall coverage** of paving and roofs. This can be accomplished by designing compact, taller structures, narrower and shorter streets and sidewalks, smaller parking lots (fewer stalls, smaller stalls, and more efficient lanes), and indoor or underground parking. Examine site layout and

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circulation patterns and identify areas where landscaping or planter boxes can be substituted for pavement.

► MINIMIZE DIRECTLY CONNECTED IMPERVIOUS AREA

With the built and landscaped areas defined on a site drawing, look for opportunities to minimize directly connected impervious area:

- **Direct runoff from impervious areas to adjacent pervious areas** or depressed landscaped areas. A 2:1 ratio of impervious to pervious area is generally acceptable where soils permit (except in hillside areas). As discussed in Chapter 5, much higher ratios (up to 25:1) can be used with an appropriately designed landscape infiltration/bioretention BMP, which may require a subsurface liner and/or drainage.

- **Select permeable pavements and surface treatments.** Inventory paved areas on the preliminary site plan and identify locations where permeable pavements, such as crushed aggregate, turf block, or unit pavers can be substituted for impervious concrete or asphalt paving.

► DETAIN AND RETAIN RUNOFF THROUGHOUT THE SITE

- **Use drainage as a design element.** Use drainage swales, depressed landscape areas, vegetated buffers, and bioretention areas as amenities and focal points within the site and landscape design. In some cases, swales can be placed alongside roadways to convey and treat stormwater runoff.

- **Minimize peak flow and volume of runoff.** Design landscaped areas and incorporate Integrated Management Practices (IMPs, Steps 4 and 5) to detain or retain runoff to the maximum extent practicable.

► DOCUMENT YOUR DESIGN DECISIONS

Chapter Five describes how to document pervious and impervious areas within your project and how to **quantify the benefits** achieved by your design decisions to reduce paved and roofed areas, to create self-retaining landscaped areas and pervious pavements, and to direct runoff from impervious to pervious areas.

Chapter Five also includes instructions for using the provided spreadsheet to create a table of pervious areas within your site.

To accompany the table, prepare a brief **narrative** that documents the site layout and site design decisions you made that minimize imperviousness, retain or detain stormwater, slow runoff rates, and reduce pollutants in post-development runoff to the maximum extent practicable.

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References and Resources

- *Start at the Source* (BASMAA, 1999).
- Your municipality's *General Plan*
- Your municipality's Zoning Ordinance and Development Codes
- *Low Impact Development Manual* (Maryland, 1999).
- *Site Planning for Urban Stream Protection* (Schueler, 1995b).

Step 4: Select Treatment BMPs

In Step 3, you minimized the total quantity of runoff by reducing impervious area and directing some runoff to pervious areas. You also sketched the site's drainage system, divided the site into drainage areas, and tabulated pervious areas.

In this step, inventory and tabulate impervious areas and identify appropriate locations for facilities **(BMPs)** that will retain, or detain and treat, runoff before it flows offsite. Then select the appropriate BMPs. The opportunities and constraints identified earlier (in Step 2) will help guide this process.

There is no hard-and-fast procedure or set of rules for selecting treatment and hydrograph modification management BMPs. Selection is ultimately by the designer's professional judgment and preference, but the suite of BMPs selected must meet the criteria set in the RWQCB permit.

A first consideration in identifying a drainage and treatment strategy is to decide whether **infiltration** to groundwater is a practical option for the site. In general, the cheapest and most effective treatment BMPs are adequately sized areas, designed into site landscaping, that will infiltrate design flows to groundwater. In sites with space constraints, infiltration can be promoted by using surface infiltration basins, subsurface trenches or dry wells.

Infiltration to groundwater may not be used where:

- The infiltration BMP would receive drainage from areas where chemicals are used or stored, where vehicles or equipment are washed, or where refuse or wastes are handled.
- Surface soils are polluted.
- The BMP could receive sediment-laden runoff from disturbed areas or unstable slopes.
- Soils are insufficiently permeable to allow the BMP to drain within 72 hours.

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Infiltration BMPs may also be infeasible because of steep slopes, geotechnical instability, high groundwater, low-permeability soils, or a combination of these factors.

Special restrictions apply to the following **infiltration devices** that, as designed, may bypass filtration through surface soils before reaching groundwater:

- Infiltration basins.
- Infiltration trenches (includes french drains).
- Unlined retention basins (i.e., basins with no outlets.
- Unlined or open-bottomed vaults or boxes installed below grade (includes bubble ups and permeable pavement with underground storage).

These restrictions are detailed in **Appendix C**.

On sites where infiltration is not feasible, BMPs will use **detention and treatment**, rather than infiltration to groundwater, to manage runoff.

Treatment is accomplished by either detaining runoff long enough for pollutants to settle out or by filtering runoff through sand or soil. Typically, the limiting design factors will be available **space** and available **head** (difference in water surface elevation between inflow and outflow). In some cases, a small adjustment of elevations within the site plan can make a treatment option feasible and cost-effective.

ICON KEY
Helpful Tip
Submittal Requirement
Terms to Look Up
References & Resources

A second consideration in developing a drainage and treatment strategy is whether to route most or all drainage through a single detention and treatment BMP or to disperse smaller BMPs (IMPs) throughout the site. Piping runoff to a single treatment area may be simpler and easier to design, but designs that integrate IMPs such as swales, small landscaped areas, and planter boxes throughout the site are typically more cost-effective, easier to maintain, and more aesthetically pleasing.

► GUIDANCE FOR SELECTING BMPS

Appendix C includes fact sheets for widely applicable IMPs that can be integrated into site landscaping and distributed throughout the site.

Low Impact Development Strategies: An Integrated Design Approach (Prince George's County, Maryland, Department of Environmental Resources, 1999) guides the designer through the **Low Impact Development** (LID) approach to stormwater

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control, which emphasizes small, cost-effective, widely distributed landscape features (**Integrated Management Practices, or IMPs**) rather than larger facilities located at the bottom of drainage areas.

Urban Runoff Quality Management (Water Environment Federation Manual of Practice No. 23; American Society of Civil Engineers Manual and Report on Engineering Practice No. 87) focuses on larger, **conventional BMPs**. For areas with less permeable soils (Hydrologic Soil Groups C & D), and where nutrients are not a major concern, the WEF/ASCE manual recommends extended detention, ponds with permanent pools, constructed wetlands, or media filtration.

One approach or the other may be best for a particular site, or elements of both approaches may be combined. In addition to the WEF/ASCE Manual and Low Impact Development manual, the City of Portland's *Stormwater Manual* (revised 2002) includes many design details for treatment BMPs.

Links to additional manuals and design resources can be found on the Contra Costa Clean Water Program's website. Local agencies may also have available manuals and other design guides for your reference. These manuals and guides should be used as a starting point for selection and design of treatment BMPs that meet the RWQCB requirements and local codes. Keep in mind that the criteria and recommendations in these manuals may be different, or inapplicable, to projects in specific municipalities or locations.

The overall design for the site must meet RWQCB requirements, local planning and zoning requirements, and applicable building codes.

The designs must also be maintainable. Maintenance requirements for BMPs must be identified in the Stormwater Control Plan. (See Step 10 and Chapter 6.) A detailed **Stormwater BMP Maintenance Plan** will be required at the time of application for a Certificate of Occupancy.

► LOCATING TREATMENT BMPS ON YOUR SITE

Finding the right location for treatment and hydrograph modification management BMPs on your site involves a careful and creative integration of several factors:

- For effective, low-maintenance operation, **locate BMPs so drainage into and out of the device is by gravity flow.** Pumped systems can be feasible, but are expensive, require more maintenance, are prone to untimely failure, and can cause mosquito control problems. Most stormwater BMPs require a minimum 2-3 feet of head.

- **Consider final ownership and maintenance responsibility.** If the BMP will serve only one site owner, make sure it is located for ready

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access by inspectors from the local municipality and the Contra Costa Mosquito and Vector Control District. If the property is being subdivided now or in the future, the BMP should be in a **common, accessible area.** Dedication of title or easement providing ownership and/or access to your local agency may be required at the time of subdivision. In particular, avoid locating BMPs on private residential lots.

- The BMP must be accessible to equipment needed for its maintenance. **Access requirements for maintenance** will vary with the type of BMP selected. For example, planter boxes or biofiltration swales will typically need access for the same types of equipment used for landscape maintenance. Wet or dry detention ponds typically require maintenance roads that can be used by heavy vehicles for dredging and control of emergent vegetation. Vaults and underground filters may require special equipment for periodic clean out and media replacement. See Chapter Six for typical maintenance requirements for various types of BMPs.

- To make the most efficient use of the site and to maximize aesthetic value, **integrate BMPs with site landscaping**. Many local zoning codes may require landscape setbacks or buffers, or may specify that a minimum portion of the site be landscaped. It may be possible to locate some or all of your site's treatment and hydrograph modification BMPs within this same area.

References and Resources

- RWQCB R2-2003-0022, Provision C.3.d
- *Urban Runoff Quality Management* (WEF/ASCE, 1998).
- Low Impact Development Design Strategies: An Integrated Approach (Maryland, 1999)
- Site Planning for Urban Stream Protection (Scheuler, 1995)
- *Stormwater Manual* (City of Portland, 2002).
- *California Stormwater BMP Handbooks*
- *Minnesota Urban Small Sites BMP Manual* (Barr Engineering, 2001)

Step 5: Perform Preliminary Design of BMPs

Demonstrate the feasibility and effectiveness of the treatment BMPs you selected by showing that they meet the design criteria in Chapter Five. Detailed construction drawings are not required at this stage, but drawings or sketches should be included as needed to illustrate the proposed design and to support calculations.

Chapter Five also provides a method of accounting for pervious and impervious areas and for demonstrating that the suite of BMPs you choose is sufficient to

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meet the RWQCB permit requirements. The procedure includes the design of BMPs for stormwater treatment, followed by assessment and redesign, if necessary, to control the peaks and durations of stormwater flows. See page 50. The Contra Costa Clean Water Program recommends that you use this procedure in preparing your Stormwater Control Plan.

Some everyday activities – such as trash recycling/disposal and washing vehicles and equipment – generate pollutants that tend to find their way into storm drains. These pollutants can be minimized by applying **source control BMPs**.

Source control BMPs include **permanent**, structural features that must be incorporated into your project plans and **operational** BMPs, such as regular sweeping and "housekeeping," that must be implemented by the site's occupant or user. The maximum extent practicable standard typically requires both types of BMPs. In general, operational BMPs cannot be substituted for a feasible and effective permanent BMP.

Use the following procedure to specify source control BMPs for your site:

► IDENTIFY POLLUTANT SOURCES

Review your preliminary site plan. Then review the first column in the **Pollutant Sources/Source Control Checklist** (Appendix E). Check off the potential sources of pollutants that apply to your site.

► NOTE LOCATIONS ON SITE PLAN

Note the corresponding requirements listed in Column 2 of the Pollutant Sources/Source Control Checklist (Appendix E). Incorporate these items into your Stormwater Control Plan drawings.

► PREPARE A TABLE AND NARRATIVE

Check off the corresponding requirements listed in Column 3 in the Pollutant Sources/Source Control Checklist (Appendix E). Now, create a table using the format in Table 3-1. In the left column, list each potential source on your site (from Appendix E, Column 1). In the middle column, list the corresponding **permanent, structural BMPs** (from Columns 2 and 3, Appendix E) used to prevent pollutants from entering runoff. Accompany this table with a narrative that explains any special features, materials, or methods of construction that will be used to implement these permanent, structural BMPs.

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TABLE 3-1. Format for table of permanent and operational source control measures.

Potential source of runoff pollutants	*Permanent source control BMPs*	*Operational source control BMPs*

► IDENTIFY OPERATIONAL SOURCE CONTROL BMPS

To complete your table, refer once again to the Pollutant Sources/Source Control Checklist (Appendix E, Column 4). List in the right column of your table the operational BMPs that should be implemented as long as the anticipated activities continue at the site. The local stormwater ordinance requires that these BMPs be implemented; the same BMPs may also be required as a condition of a use permit or other revocable discretionary approval for use of the site.

References and Resources

- Appendix E, Stormwater Pollutant Sources/Source Control Checklist
- RWQCB Order R2-2003-0022, Provision C.3.k
- *Start at the Source*, Section 6.7: Details, Outdoor Work Areas
- *California Stormwater Industrial/Commercial Best Management Practice Handbook*
- *Urban Runoff Quality Management* (WEF/ASCE, 1998) Chapter 4: Source Controls

Step 7: Integrate With Other Preliminary Drawings

Depending on the complexity of the project, the Stormwater Control Plan drawing may be combined with the site plan, landscape plan, or drainage plan. In any case, the Stormwater Control Plan should be carefully coordinated with these plans, with site grading and drainage, and with construction-phase erosion and sediment control plans.

Local Requirements

Cities, towns, or the County may have requirements that differ from, or are in addition to, this countywide Guidebook. See Appendix A and check with local planning and community development staff.

Here are some typical considerations that may arise in coordinating stormwater control plans with other construction plans:

Excess fill. Excavation for landscape detention areas, swales, and other BMPs—and overexcavation/replacement of clay soils with more permeable soils—can alter the cut-and-fill balance for site grading and preparation. By considering this issue early in site design, it may be possible to avoid excessive export of soil from the site.

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Compaction of soils during construction. Compaction from construction traffic can radically reduce the infiltration capacity of site soils. Construction staging plans should set aside and protect areas that will be used for self-retaining areas, infiltration, or IMPs.

Building Drainage. Building codes require that drainage from roofs and impervious areas be drained away from the building. The codes also specify minimum sizes and slopes for roof leaders and drain piping. Detailed designs of BMPs located in or on the building, or that may affect building foundations, must accommodate these codes while also meeting the minimum requirements for detention or flow stated in Provision C.3.

Control of elevations. Distribution of overland flow to landscaped areas may require that grading and landscape plans be executed with greater attention to slopes and elevations. Here are two typical problems to avoid:

- **Inadequate reveal** between pavement and vegetated areas. Provide adequate reveal (drop) at the edge of pavement to accommodate the growth of turf or other vegetation in an adjacent filter strip, swale, or landscape retention area. Otherwise, runoff will tend to pond on the edge of the paved surface.

- **Differential settlement.** The soil in filter strips, swales, and landscape retention areas must be left loose and uncompacted. However, concrete structures (e.g. inlets and outlets) must be supported on a firm foundation. Otherwise, they will tend to settle more than the surrounding ground, creating depressions which may harbor mosquito larvae.

Drainage Plans. The local building or engineering department may require a drainage plan when the project final design is submitted for plan check. In most cases, the drainage plan is designed to prevent street flooding during a 10-year storm and successfully route flows from a 100-year storm. To meet the requirements for both the Stormwater Control Plan design storm and the Drainage Plan design storm, BMP designs must incorporate bypasses or overflows to route excess flows to the storm drain system. It may be necessary to complete a preliminary drainage plan at the planning and zoning review stage.

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Plant selection. Depressed landscaped areas, bioretention areas, vegetated swales, and many other BMPs require appropriate plant selection to work properly. Plant selection should be coordinated with or incorporated into the landscape plan. Local codes require landscaping to be designed for water

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conservation and may also encourage the use of native or other drought-tolerant plants. Some also require potable water not be used for irrigation where recycled water is available.

Access for periodic maintenance. All BMPs will require access for periodic inspection in accordance with an approved maintenance plan. Many BMPs (e.g., bioretention basins and swales) require relatively little maintenance, but others (e.g., sand filters or proprietary devices) may require regular replacement of surface sand or replacement of cartridges or inserts. Site plans should provide for the necessary access for personnel and equipment. If BMPs are to be maintained by a public agency, then a deeded access easement may be required. See Step 9.

Organizing traffic and parking. Your stormwater control plan may call for depressing landscaped areas below paved areas rather than setting them above paved areas and surrounding them with curbs. Striping or bollards may be needed to guide traffic. Parking lots with crushed aggregate, unit-paver, and other permeable pavements may also require bollards or signs to organize parking.

References and Resources

- Your Municipality's Municipal Code (See Appendix A)
- Your Municipality's Standard Engineering Drawings

Step 8: Permitting & Code Compliance Issues

To meet the RWQCB's "maximum extent practicable" standard, Stormwater Control Plans will typically need to incorporate innovative site design features, pavements, drainage design practices, and BMPs. Because these practices are new, there may be inconsistencies with existing building codes, engineering requirements, and standard conditions of approval.

The Clean Water Program makes no representation that the design practices or recommendations in this Guidebook (or in the publications listed as references and in the bibliography) meet existing applicable codes or standards.

Where conflicts occur between recommended stormwater control practices and existing codes and standards, municipal staff will work with the applicant to identify one or more regulatory or design solutions that can satisfy all applicable requirements.

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Discuss potential conflicts with municipal planning staff you note in the Stormwater Control Plan. By doing so, it may be possible to resolve the issue prior to final design. This will help avoid the need for redesign and resubmittal of final plans and associated project delays.

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As required by NPDES Permit Provision C.3.e, your local municipality will periodically verify that treatment BMPs on your site are maintained and continue to operate as designed.

To make this possible, your municipality will require:

1. That you specify, in your Stormwater Control Plan, a means to finance and implement BMP maintenance in perpetuity.

2. That you specify, in your Stormwater Control Plan, general maintenance requirements for the treatment and hydrograph modification BMPs you have selected.

3. That you prepare and submit, before applying for building permit final and Certificate of Occupancy, a detailed Stormwater BMP Operation and Maintenance Plan that sets forth a maintenance schedule for each of the treatment and hydrograph modification BMPs built on your site.

A summary of these requirements follows. See Chapter Six for additional detail.

► SPECIFY A MEANS TO FINANCE AND IMPLEMENT BMP MAINTENANCE

Your Stormwater Control Plan must specify a means to **finance and implement maintenance** of treatment and hydrograph modification BMPs **in perpetuity.**

Depending on the intended use of your site and the policies of your municipality, this may require one of the following:

- Dedication of fee title or easement transferring ownership of the BMP to the municipality.
- Execution of a maintenance agreement that "runs with the land."
- Application for a permit for the site owner to operate the BMP.
- Compliance with the conditions of a municipal ordinance.

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Your municipal planner or other representative will help you determine which of these apply to your project and will specify what must be included in your Stormwater Control Plan.

► MAINTENANCE NEEDS AND YOUR STORMWATER CONTROL PLAN

Your Stormwater Control Plan should include a general description of anticipated BMP maintenance requirements. This will help ensure that:

- Ongoing costs of maintenance have been considered in your BMP selection and design.
- Site and landscaping plans provide for access for inspections and by maintenance equipment.
- Landscaping plans incorporate irrigation requirements for BMP plantings.
- Initial maintenance and replacement of BMP plantings is incorporated into landscaping contracts and guarantees.

Chapter Six includes a discussion of **typical maintenance requirements** for some commonly used BMPs.

Local Requirements
Cities, towns, or the County may have requirements that differ from, or are in addition to, this countywide Guidebook. See Appendix A and check with local planning and community development staff.

In your Stormwater Control Plan, you should also note issues or concerns, specific to your site or to a specific BMP installation, to be followed up during the detailed design and construction phases of your project. For example, it may be necessary to verify that weirs and flow spreaders remain level and that sediment and debris accumulated during construction does not fill depressions or clog inlets and outlets. These items to be verified post-construction should be included in the Stormwater Control Plan.

► STORMWATER CONTROL OPERATION AND MAINTENANCE PLAN

Your local municipality will require submittal of a draft **Stormwater Control Operation and Maintenance Plan** (O&M Plan) for the site with your building permit application. A final O&M Plan must be submitted prior to issuance of a certificate of occupancy. Instructions for preparing an O&M Plan are in Appendix F. Your O&M plan will list all treatment and hydrograph modification management BMPs on the site along with the required periodic maintenance.

Except for BMPs that are transferred to the public, the municipality will typically require an annual report to verify that maintenance has been done. The municipality will also require that the O&M Plan be kept on site. Municipal inspectors will refer to the O&M Plan during site visits.

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Your O&M Plan must also include the project developer's signed statement accepting responsibility for maintenance from the time the BMPs are constructed until responsibility for operation and maintenance is legally transferred.

Your Stormwater Control Plan Report should document the information gathered and decisions made in Steps 1-10. A clear, complete, well-organized report will make it possible to confirm that the "maximum extent practicable" standard has been applied in each aspect of the project design.

► SAMPLE OUTLINE AND CONTENTS

I. Project Setting

- A. Project Name, Location, Description
- B. Existing site features and conditions
- C. Opportunities and constraints for stormwater control

II. Measures to Limit Imperviousness

- A. Measures to cluster development and protect natural resources
- B. Measures used to limit directly connected impervious area
  - (1) Site design features
  - (2) Pervious pavements
  - (3) Detention and drainage design
- C. Table summarizing pervious and self-retaining areas.

III. Selection and Preliminary Design of Treatment and Hydrograph Modification BMPs

- A. Locations and elevations
- B. Sizing calculations
- C. Table summarizing impervious areas and BMPs

IV. Source Control Measures

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A. Description of site activities and potential sources of pollutants

B. Table showing sources and permanent controls

C. List of operational source control BMPs

V. Summary of Permitting and Code Compliance Issues

VI. BMP Maintenance Requirements

A. Ownership and responsibility for maintenance in perpetuity.

(1) Commitment to execute any necessary agreements.

(2) Statement accepting responsibility for operation and maintenance of BMPs until that responsibility is formally transferred.

B. Summary of maintenance requirements for each BMP.

VII. Construction Plan C.3 Checklist

VIII. Certification

► CONSTRUCTION PLAN C.3 CHECKLIST

When you submit construction plans for City review and approval, the plan checker will compare that submittal with your Stormwater Control Plan. By creating a Construction Plan C.3 Checklist for your project, you will facilitate the plan checker's comparison and speed review of your project.

TABLE 3-2. Format for Construction Plan C.3 Checklist

Stormwater Control Plan Page #	*BMP Description*	*See Plan Sheet #s*

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Here's how:

1. Create a table similar to Table 3-2. Number and list each measure or BMP you have specified in your Stormwater Control Plan in Columns 1 and 2 of the table. Leave Column 3 blank. Incorporate the table into your Stormwater Control Plan.

2. When you submit construction plans, **duplicate the table** (by photocopy or electronically). Now fill in Column 3, identifying the plan sheets where the BMPs are shown. List all plan sheets on which the BMP appears. Submit the updated table with your construction plans.

Note that the updated table—or Construction Plan C.3 Checklist—is **only a reference tool** to facilitate comparison of the construction plans to your Stormwater Control Plan. Planning Department staff can advise you regarding the process required to propose changes to the approved Stormwater Control Plan.

▶ CERTIFICATION

Your local municipality may require that your Stormwater Control Plan be certified by an architect, landscape architect, or civil engineer. See Appendix A. Certification should state: "The selection, sizing, and preliminary design of treatment BMPs and other control measures in this plan meet the requirements of Regional Water Quality Control Board Order R2-2003-0022."

▶ EXAMPLE STORMWATER CONTROL PLAN

Example Stormwater Control Plans are in Appendix G. Your Stormwater Control Plan will reflect the unique character of your own project and should meet the requirements identified in this *Guidebook*. Municipal staff can assist you to determine how specific requirements apply to your project.

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Incorporating stormwater impacts and control measures into Initial Studies and Environmental Impact Reports

CEQA—the California Environmental Quality Act – requires local jurisdictions to identify and evaluate the environmental impacts of their actions, including zoning decisions and discretionary land-use approvals. The CEQA process makes decision makers and the public aware of potential adverse environmental impacts and prevents environmental damage by requiring implementation of feasible alternatives or mitigation measures.

Further guidance on the CEQA process is available from your local Planning or Community Development department and from the references and resources listed on page 44. This chapter clarifies how information in your Stormwater Control Plan may be used in the CEQA process.

The CEQA process is typically conducted in three phases:

1. Preliminary review to determine if the project is subject to CEQA.
2. Preparation of an Initial Study to determine the environmental effects of the project.*
3. Preparation of an Environmental Impact Report (EIR), Negative Declaration, or Mitigated Negative Declaration.

Your Stormwater Control Plan contains information to be reviewed during one or more of these phases of the CEQA process.

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* The lead agency may choose to skip the Initial Study and proceed directly to an EIR.

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CEQA review begins with a pre-application consultation at your local municipality's planning or community development department. At this meeting, a planner will help you identify specific issues that must be addressed in your application for planning and zoning approval.

If your project is subject to the C.3 Provisions—i.e., creates or replaces impervious area in excess of the applicable threshold—a complete Stormwater Control Plan should be part of this application.

By submitting a complete and adequate Stormwater Control Plan with your application for planning and zoning approval, you may be able to avoid further CEQA review for long-term (post-construction) stormwater impacts.

To determine if your project is also subject to CEQA, municipal planning staff will typically require that you complete an **Environmental Information Form** as part of your application for planning and zoning review. Depending on your project's scope, your municipality may require additional information and documentation.

Local Requirements
Check Appendix A now to see if your local municipality has specified procedures for CEQA review, and talk to a local planner before commencing work on CEQA or C.3 documentation.

If your project is not subject to CEQA—e.g., because of a statutory or categorical exemption—your local agency may choose to file a Notice of Exemption. Filing a notice reduces the length of time that the agency's decision is subject to challenge. **Any C.3 requirements for your project will still apply.**

If your project is not exempt from CEQA, planning or community development staff will complete an **Environmental Checklist** and **Initial Study**. Depending on the results of the Initial Study, the planner may recommend a Negative Declaration or Mitigated Negative Declaration be issued for the project, or recommend that an Environmental Impact Report be prepared.

NPDES permit provision C.3.m requires local municipalities to evaluate water quality effects and identify appropriate mitigation measures when they conduct environmental review of proposed projects.

The Governor's Office of Planning and Research (OPR) recommends that CEQA lead agencies should integrate CEQA review "to the fullest extent possible" with review for compliance with Federal, state, or local laws, regulations, or policies (*CEQA Guidelines* §15124(d)(1)(C)). In 1998, OPR revised the example Environmental Checklist Form (CEQA Guidelines Appendix G) to more closely

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align with Federal and state laws and requirements, including those of the state's Fish and Game Code, the Federal Clean Water Act, and the California Water Code. Most municipalities use the OPR Environmental Checklist Form or a variation thereof.

Questions on the Environmental Checklist Form connect potentially significant project impacts with water-quality regulations. For example:

- Question VIII.a asks: **"Would the project violate any water quality standards or waste discharge requirements?"**
- The potential effects of increased runoff peak flows and durations are addressed in question VIII.c: **"Would the project substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation off-site?**
- Potential impacts of runoff pollutants are targeted in Question VIII.e, which asks: **"Would the project create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?"**
- Finally, Question VIII.f. asks: **"Would the project otherwise substantially degrade water quality?"**

The C.3 provisions include suitable criteria for determining that a project could not contribute "substantial additional sources" of runoff or pollutants.

► THRESHOLDS OF SIGNIFICANCE

A threshold of significance is "a quantitative or qualitative standard, or set of criteria, pursuant to which the significance of an environmental effect may be determined." (OPR 1994). Thresholds are not rigid or absolute—the significance of an activity depends on its specific location—but they do help Lead Agencies make consistent and well-supported determinations.

In most cases, your local municipality will regard projects that exceed the threshold in NPDES permit provision C.3.c., defined therein as a "Group 1 project," to have potentially significant impacts (unless mitigated) due to increases in runoff pollutants over the life of the project.*

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* Construction-phase impacts should be addressed in a Storm Water Pollution Prevention Plan, which is required for projects that disturb an acre or more. See page 8.

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This threshold is one acre of new impervious area for projects with applications deemed complete on February 15, 2005 or later, and 10,000 square feet of new impervious area for projects with applications deemed complete on August 15, 2006 or later. The threshold does not apply to projects for which the municipality has issued a waiver of the requirements for treatment BMPs as provided in NPDES permit Provision C.3.g. The CEQA threshold and C.3 requirements are intended to address both cumulative and site-specific increases in runoff pollutants due to imperviousness.

A project may also have potentially significant impacts due to increases in runoff pollutants if the facility includes outdoor storage of materials or wastes or if it accommodates outdoor activities such as automotive or equipment repair. Examples include car washes, grocery stores, some restaurants, and corporation yards. The threshold of significance in this case is qualitative and requires project-specific assessment of the potential for pollutants generated on-site to reach storm drains.

Increased site imperviousness may, by increasing the peaks and durations of runoff, potentially increase erosion of the beds and banks of downstream watercourses. In most cases, the threshold of significance for this impact is **no increase** in runoff peaks and durations, although there may be exceptions. The Contra Costa Clean Water Program's **Hydrograph Modification Management Plan** (HMP, Appendix D, to be completed in May 2005) specifies the methods for determining whether a project will increase runoff peaks and durations when compared against the existing condition of the site. In some cases, it may be possible to increase runoff peaks and durations without having a significant impact on erosion of downstream watercourses. The HMP specifies methods for determining whether this is the case for a particular site.

► FORMS AND CHECKLISTS

If a project is required to implement stormwater BMPs, the potential for significant stormwater impacts should be noted on the **Environmental Information Form**. If OPR's form (*CEQA Guidelines* Appendix H) is used, this is **Question 26** (Change in ocean, bay, lake, stream, or ground water quality or quantity or alteration of existing drainage patterns). **Reference the Stormwater Control Plan** for the project when completing the Environmental Information Form.

If the Stormwater Control Plan for the project meets the criteria in NPDES permit C.3.d and incorporates recommended source control measures for each potential source of pollutants identified, then the relevant questions regarding stormwater quality in the **Initial Study Checklist** can, in most cases, be answered "less than significant with mitigation incorporation." The initial study should note the specific source control and treatment BMPs incorporated and reference the Stormwater Control Plan.

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If the Initial Study finds that your project could have a significant environmental impact, a mitigated Negative Declaration or Environmental Impact Report must be prepared.

In general, the implementation of treatment BMPs that meet the numeric criteria in Provision C.3.d, as described in Chapter 5, will mitigate the effects of increased imperviousness on water quality to a level that is less than significant. Similarly, implementation of recommended source control BMPs for each identified source of potential pollutants will effectively mitigate the creation of these additional sources.

Methods for demonstrating that hydrograph modification BMPs mitigate potential increases in runoff peaks and durations are in the HMP (Appendix D).

The preparer of the EIR or other CEQA document may decide where and how to include detailed information from the Stormwater Control Plan—in the body of the CEQA document, as an appendix, or by reference.

In summary, municipalities may use the criteria in the C.3 provisions to specify thresholds of significance for stormwater impacts and also to identify and evaluate measures required to mitigate those impacts.

If the amount of impervious area created by a project is less than the threshold identified in NPDES permit provision C.3.c, and there are no significant new sources of runoff pollutants created by the project, then the relevant questions on the Initial Study Checklist can be answered "less than significant impact."

If the amount of impervious area created by a project exceeds the C.3.c threshold, and the project's Stormwater Control Plan incorporates the appropriate BMPs, a municipality may find that the project could not have a significant impact on stormwater quality.

Note that in some cases, a project may be below the impervious-area threshold in Provision C.3.c but could still create a significant new source of potential runoff pollutants. This might occur, for example, with an application for a use permit for a new business (say, a car wash) on an already fully developed (and impervious) site. In these cases, potential impacts can be mitigated through incorporation of appropriate permanent and operational source control BMPs.

Source control or treatment BMPs must be maintained for the life of the project to effectively mitigate the potential environmental effect. Similarly, operational

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BMPs must be implemented thoroughly and consistently to be effective mitigations. Monitoring of permanent BMPs will be accomplished through the municipal **BMP verification program** (Chapter Six). The municipality also inspects industrial and commercial sites to verify consistent use of operational BMPs.

References and Resources

- California Environmental Quality Act Statutes (Public Resources Code §21000 *et seq.*)
- Governor's Office of Planning and Research—*CEQA Guidelines* (14 Cal. Code Regs.) and other resources.
- Environmental Information Form (*CEQA Guidelines* Appendix H)
- Environmental Impact Assessment Form (Initial Study Checklist—*CEQA Guidelines* Appendix G)
- CEQA Deskbook (Bass, et. al., 2001)

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Technical Requirements

Technical guidance for designing self-detaining areas and sizing treatment and hydrograph modification BMPs

Your Stormwater Control Plan (Chapter 3), to be submitted with your planning and zoning application, must show the locations, sizes, and types of treatment and hydrograph modification BMPs. Your Stormwater Control Plan must also include calculations showing:

- Your treatment BMPs meet the minimum sizing criteria in the stormwater NPDES permit.
- Your hydrograph modification BMPs meet the criteria in the Program's Hydrograph Modification Management Plan (HMP).

Your construction plans must be consistent with your approved Stormwater Control Plan. During plan check, local agency staff will also review the details of how your drainage and BMPs are constructed and will verify that they meet the requirements of the stormwater NPDES permit.

The Program has developed the following resources to help you design treatment and hydrograph modification BMPs for your project:

- "Fact sheets" for a gallery of practical and widely applicable BMPs. The fact sheets are in **Appendix C** and include illustrations, design checklists, and (for some BMPs) standard details.
- Simplified design methods. Some BMPs can be sized by simply multiplying the amount of impervious area draining to the BMP times a specified factor. The methods are described in this chapter.
- A procedure, described in this chapter, for tabulating pervious areas, impervious areas, and BMPs. The resulting tables make it easy to demonstrate compliance with the NPDES permit criteria.

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This chapter has three parts.

The **first part** explains applicable **technical criteria** for sizing treatment BMPs, interprets the RWQCB's aims in establishing the criteria, and refers to the documents, studies, and rationales on which the criteria are based. This first part also provides some recommendations for selecting among the alternative sizing criteria allowed by the RWQCB. Finally, the first part summarizes the rationale for the HMP requirements.

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The **second part** of this chapter provides guidance for design and documentation of **self-retaining areas** and treatment and hydrograph-modification BMPs. A recommended design process maximizes the use of self-retaining areas and **Integrated Management Practices (IMPs)** while allowing choice and flexibility. The design process includes step-by-step completion of a table that can be submitted as part of your Stormwater Control Plan.

The **third part** of Chapter Five includes design tips and references to available design manuals.

The NPDES C.3. provisions require a complex, multifaceted approach to on-site stormwater control. In effect, project applicants must implement several different, independent measures to control stormwater pollutants, and each of these measures must independently meet a "maximum extent practicable" standard.

Specifically, applicants must:

- Control pollutant sources to the maximum extent practicable.
- Implement site design and landscape features which reduce runoff pollutants to the maximum extent practicable.
- Control increases in peak flows and durations to the maximum extent practicable.

Most measures of "maximum extent practicable" are qualitative and are based on professional judgment and current practices. However, the permit includes **numeric criteria** for the design of treatment BMPs. These numeric criteria are intended to ensure that the BMPs are adequately sized to remove a significant proportion of pollutants in runoff.

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Permit Provision C.3.f requires limits on runoff peak flows, volumes, and durations. The Program's **Hydrograph Modification Management Plan** (HMP, to be completed in May 2005) will detail methods for demonstrating that the project design adequately manages runoff flows where increases in flows could accelerate erosion or otherwise affect beneficial uses of creeks.

Criteria for stormwater treatment and criteria for peak flow and volume of runoff are separate and independently applicable.

Your design of site drainage and BMPs must demonstrate that both sets of criteria are met.*

Note, in particular, that requirements for peak flow and volume control are dependent on the pre-development condition of your site. In contrast, the stormwater treatment criteria will be the same regardless of how or whether the site was previously developed.

► LIMITS ON THE USE OF DIRECT INFILTRATION

RWQCB permit Provision C.3.i. requires "treatment BMPs that function primarily as **infiltration devices**"—structures that are designed to infiltrate stormwater into the subsurface and, as designed, bypass the natural groundwater protection afforded by surface or near-surface soil—to have a 10-foot vertical separation from the "seasonal high groundwater mark." In addition, these BMPs should not serve work areas, including automotive shops, car washes, fleet storage, nurseries, or other areas that may be significant sources of pollutants.

In many areas of Contra Costa, high groundwater or impermeable soils preclude the use of infiltration. In other areas, steep slopes and geological instability make infiltration inadvisable. See **Appendix C** for guidance that will help you determine whether infiltration can be used for stormwater treatment or disposal on your site.

If infiltration is feasible, the design criteria and procedures in Appendix C will help you design infiltration devices that are appropriate for your site.

► NUMERIC CRITERIA FOR STORMWATER TREATMENT BMPS

The RWQCB permit assumes that treatment BMPs can be classified as relying either on detention and infiltration (e.g. detention basins, dry wells, or constructed wetlands) or on filtration (e.g., sand filters). The permit specifies **volume-based criteria** for those BMPs relying on infiltration and detention and **flow-based criteria** for BMPs relying on filtration.

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* Treatment control requirements apply to projects deemed complete on or after February 15, 2005. HMP requirements will take effect following RWQCB approval of the final plan, which is to be submitted by May 15, 2005.

A013818

► COMPARISON OF VOLUME-BASED NUMERIC CRITERIA

The RWQCB permit specifies two alternative methods for calculating **water quality volume**, the volume of water that must be detained for a BMP to meet the "maximum extent practicable" criterion. The first method is stated in the book *Urban Runoff Quality Management* (Water Environment Federation Manual of Practice No. 23; ASCE Manual and Report on Engineering Practice No. 87, 1998) and is referred to as the **WEF Method**. The second method is in Appendix D of the *California Storm Water Best Management Practice Handbook (Municipal)* (SWQTF, 1993) and is referred to as the **California BMP Method.***

The two methods are based on the same rainfall data and hydrological methodology, and they tend to yield similar results. The methods differ in some aspects of their practical application.

Both methods use long-term rainfall records to identify a **design storm** for stormwater treatment. Approximately eighty percent of total annual runoff is produced by storms this size and smaller. The design storm for stormwater treatment varies from (roughly) 0.45 to 0.85 inches in Contra Costa County.

The WEF method requires that the designer specify a **drawdown time** of 12, 24, or 48 hours. Longer drawdown times require larger BMP volumes (because of the potential for back-to-back storms). Although the permit does not specify a drawdown time, the longer time (48 hours) has been recommended because sediments from the Bay Area's fine-grained soils require a relatively long time to settle out. The California BMP method uses a fixed drawdown time of 40 hours.†

The WEF method is based on 80% capture of average annual runoff. The California BMP Method allows the designer to select a capture ratio; however, the RWQCB permit specifies that an 80% capture ratio be used.

The WEF method requires estimation of a mean storm precipitation volume. This can be based on local rainfall data. The analysis is conducted by taking periodic (e.g. hourly) rain gauge data, identifying distinct storms, calculating the total rainfall depth of each, and taking an average. The California BMP method incorporates this analysis into a **nomograph** for the specific locality.

The WEF method requires calculation of a composite (weighted) runoff coefficient for the area that is tributary to the BMP being designed. The method provides a formula for calculating the runoff coefficient from the "watershed imperviousness ratio," or the percent total imperviousness.

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* The 2003 edition of the *California Storm Water Best Management Practices Handbook* (CASQA, 2003, available at www.cabmphandbooks.org) also describes this method, with some minor revisions.

† The 2003 revision to the California BMP Handbooks uses a drawdown time of 48 hours. A 48-hour drawdown time has been used in preparing the nomograph and sizing equations in Appendix H.

A013819

Similarly, the California BMP Method requires estimation of Directly Connected Impervious Area (DCIA), "the percentage of impervious area directly connected to the storm drain system. DCIA is defined as the area covered by pavement, building, and other impervious surfaces which drain directly into a storm drain without first flowing across pervious areas (e.g. lawns)." Conceptually, the tributary drainage is divided into areas that are either wholly pervious or wholly impervious.

▶ FLOW-BASED CRITERIA FOR TREATMENT BMPS

The RWQCB permit allows three alternatives for calculating the **peak flow rate** that a continuous-flow BMP (e.g., a sand filter without an upstream detention area) must be able to accommodate.

All three use the **rational method** to calculate peak flows:

$$Q = C i A$$

where

Q = Peak flow rate

C = Runoff coefficient (related to percent imperviousness)

i = Rainfall intensity

A = Tributary area

The difference between the three methods is in the calculation of the rainfall intensity, *i*.

The three alternatives are **intensity-duration-frequency (IDF)**, **percentile rainfall intensity**, and **0.2 inches/hour**.

The **intensity-duration-frequency** alternative requires that a time of concentration (T_c) be calculated for the tributary area. Calculation of a time of concentration is based on analysis of the time required for a hypothetical drop of water to flow from the furthest point of the watershed, overland and/or through pipes, to the BMP. Once T_c is determined, a corresponding *i* can be found from graphs of rainfall intensity vs. time from start of storm. The RWQCB permit specifies use of the rainfall intensity corresponding to a 50-year storm.

The **percentile rainfall intensity** alternative is based on ranking the hourly depth of rainfall from storms over a relatively long record. The RWQCB permit specifies that the design rainfall intensity be equal or greater than the 85th percentile hourly depth multiplied by two.

A013820

The **0.2 inches/hour** alternative simply specifies the required i : 0.2 inches per hour. **This is the recommended option.**

In summary, if the designer uses either the percentile rainfall intensity alternative or the 0.2 inches/hour alternative to size a flow-based BMP, he or she need only specify the tributary area and its percent imperviousness.

If the intensity-duration-frequency method is used, the designer must calculate T_c. Because calculation of T_c is complex and uncertain, and because the peak flow rate can be sensitive to T_c, the Program discourages applicants from using this method. This method is most applicable to larger sites with overland drainage and relatively little impervious cover; however, the use of flow-based BMPs (such as sand filters) in such sites is not recommended because of the potential for clogging the filter with fine sediments.

▶ HYDROGRAPH MODIFICATION MANAGEMENT TECHNICAL CRITERIA

The objective of the HMP is that post-project runoff peaks and durations should not exceed pre-project runoff peaks and durations. In some cases, an increase may be allowed if it can be demonstrated that there is minimal risk of downstream erosion as a result of the increased runoff.

The Program's forthcoming HMP Guidance (Appendix D) will detail methods and criteria for:

- Characterizing and comparing pre- and post-project site hydrology.
- Predicting the effectiveness of hydrograph modification management BMPs.

References and Resources

- RWQCB Order R2-2003-0022, Provision C.3.d
- *California Stormwater Best Management Practice Handbooks* (SWQTF, 1993).
- *California Stormwater Best Management Practice Handbooks* (CASQA, 2003).
- *Urban Runoff Quality Management* (WEF/ASCE, 1998)
- *Hydrology Handbook, Second Edition* (ASCE, 1996)
- *Low Impact Development Design Strategies: An Integrated Approach* Chapter 3. (Maryland, 2001)

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There are two general approaches to managing site runoff.

The **Low Impact Development** approach emphasizes "disconnection" of impervious areas from the drainage system and detention, infiltration, and treatment of runoff throughout the site. Detention areas, infiltration areas, and Integrated Management Practices (IMPs), such as planter boxes, swales, and bioretention areas, are sized and shaped to fit the available space. Maintenance requirements may be little more than what is required for normal landscaping.

The **conventional BMP** approach emphasizes the design of fewer, larger facilities that can retain, detain, and treat runoff from large portions of the site or from the whole site. These BMPs typically serve a mix of impervious, pervious, and partially pervious areas and generally are more dependent on precise engineering and frequent maintenance. The WEF/ASCE Manual of Practice, *Urban Runoff Quality Management*, exemplifies the conventional BMP approach.

The two approaches are not exclusive and can be combined within a site.

In general, IMPs distributed throughout the site look better and can require less area. In addition, IMPs are less likely to fail and are less likely to harbor mosquitoes or other vectors. However, the Low Impact Development approach typically requires a more complex documentation of site drainage. Demonstrating compliance with C.3 requirements for stormwater treatment is somewhat more difficult with IMPs than with conventional BMPs. It is necessary to account for the impervious area treated by each IMP and show that each IMP has been appropriately sized.

Designs using IMPs are able to distribute runoff storage throughout the site. By incorporating small detention areas and IMPs into the flow path, these designs tend to increase the time of concentration of flow, reducing peak discharges and "flattening" the site hydrograph. However, the design and analysis of site drainage, and the preparation of site hydrographs, becomes more complicated.

The Program recommends the Low Impact Development approach. The following procedure has been developed to simplify (and make consistent) selection, sizing, and documentation of IMPs for stormwater treatment and hydrograph modification management.

A013822

➤ RECOMMENDED PROCEDURE FOR DESIGN AND DOCUMENTATION

The Program has developed the following **recommended procedure** for selecting and documenting self-retaining areas, IMPs, and conventional BMPs to achieve the mandated stormwater treatment criteria and to meet the requirements of the Program's hydrograph modification management plan.

The procedure maximizes the use of self-retaining areas and IMPs. It anticipates that, in many cases, conventional BMPs such as detention basins and media filters may not be necessary to achieve compliance with the C.3 provisions. Where conventional BMPs are required, the procedure minimizes their size.*

ICON KEY
Helpful Tip
Submittal Requirement
Terms to Look Up
References & Resources

The procedure requires careful delineation of pervious areas and impervious areas (including roofs) throughout the site. The procedure accounts for the runoff produced by each delineated area during the design storm. This simplifies design and arranges documentation of IMP sizing in a consistent format for presentation and review.

The recommended design procedure is intended to facilitate, not substitute for, creative interplay among site design, landscape design, and drainage design. **Several iterations may be needed** to find the combination of self-retaining areas, IMPs, and conventional BMPs that provides the optimal aesthetics, circulation, and use of available area for your site.

A **spreadsheet template**, in Microsoft Excel format, is provided for making calculations and presenting your submittal. See **Appendix I**. The spreadsheet can be copied into your Stormwater Control Plan.

To begin using the spreadsheet, first enter the project name, location, and Assessor's Parcel Number (APN). Then enter the total project area. Exclude areas of the site which will not be disturbed or developed.

Locate your project site on Figure B-166 (isohyetal map), which is in **Appendix H**. Interpolate as necessary to estimate the mean annual precipitation at your site and enter this number where indicated on the spreadsheet (at the top of Table 3). Note: this step is not required if all drainage from the site will be managed with self-retaining areas and indirect infiltration IMPs.

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* The publication *Using Site Design Techniques to Meet Development Standards for Stormwater Quality, A Companion Document to Start at the Source* (BASMAA, May 2003, 14 pp. available at www.scvurppp.org) suggests using self-retaining areas to reduce the size of detention basins and other conventional BMPs. The approach described here maximizes self retaining areas first, then maximizes the use of IMPs, and incorporates conventional BMPs only as a last resort.

A013823

water over its surface before overflowing. Prolonged ponding is a potential problem at higher impervious/ pervious ratios. In your design, ensure that the pervious area is designed to handle the additional run-on and is sufficiently well-drained. In flat areas with clayey soils, an underdrain system (perforated pipe embedded in an 8-to-12-inch layer of crushed rock and daylighted or connected to a storm drain) may be needed.

Areas covered with pervious pavement (e.g., crushed stone, pervious asphalt, or pervious concrete) can sometimes be handled similarly. Note that care must be taken to ensure that sediment from landscaped or undeveloped areas does not wash on to the pervious pavement and cause clogging.

Use Table 1 in the spreadsheet to document turf, landscape, pervious pavement, and other areas that are not completely impervious. Also use this table to list combined pervious/impervious **self-retaining** areas.

For **non-self-retaining areas only**, select the appropriate runoff factor "C" and enter it on the spreadsheet. (This factor will later be used to size conventional flow-based BMPs should they be proposed for your site.)

TABLE 5-1. ILLUSTRATION OF SPREADSHEET TABLE 1, for documenting pervious areas.

Area ID (as indicated on site drawing)	*Surfaces*	*Size (in SF) – Self-retaining areas*	*Size (in SF) – Non-self retaining areas*	*If non self-retaining, estimate runoff factor "C"*	*Size × C*
Total					

"C" factors (from BASMAA, 2003)

Turf	0.10	Pervious concrete	0.60
Landscape	0.10	Pervious asphalt	0.55
Crushed aggregate	0.10		

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▶ DIVIDE THE SITE INTO DISCRETE DRAINAGE AREAS

While referring to preliminary roof plans and grading plans, divide the **entire project area** into discrete drainage areas. Minimize the concentration of runoff and amount of piping by distributing drainage from opposite sides of driveways, opposite sides of buildings, and from different sections of parking lots.

Assign each discrete area an identification number and determine its size (in square feet). Each area will be entered into Tables 1, 2, or 3 on the spreadsheet.

▶ IDENTIFY AND LIST PERVIOUS AND SELF-RETAINING AREAS

The required size of each treatment and hydrograph modification IMPs is proportional to the total amount of area draining to the IMP. The best way to reduce the number and size of treatment and hydrograph modification management IMPs is to **disconnect portions of the tributary area** and remove these disconnected areas from the sizing calculation.

Pervious areas, including turf, landscaped areas, and pervious pavements, may be disconnected by designing them to **retain the design storm**. In effect, this means that they must be designed to absorb the depth of the design storm before overflowing to the drainage system. Where possible, **make all landscaped areas self-retaining**, so that only impervious roofs and pavement drain to IMPs. This yields a simpler, more efficient design and also helps protects IMPs from becoming clogged by sediment.

Equivalence
Retaining the first inch of rainfall effectively disconnects an area from the drainage system for the purposes of the water-quality design storm.

To create self-retaining turf and landscape areas in flat areas or on terraced slopes, berm the area or depress the grade so that these areas will retain the required rainfall depth. Specify slopes, if any, toward the center of the pervious area. Drain inlets should be set above the low point to allow ponding. (Note: Landscape areas may also be appropriate locations for treatment and hydrograph modification BMPs.)

Self-retaining areas may include up to 2 parts **impervious area** for every 1 part pervious area. The drainage from the impervious area must be directed to and dispersed within the pervious area, and the pervious area must be designed to retain the design storm depth over the entire area. For example, for a 1-inch-deep design storm, and a ratio of 2 parts impervious and 1 part pervious, the pervious area must absorb 3 inches of

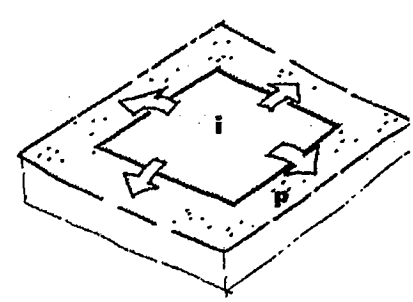

FIGURE 5-1. Relationship of impervious to pervious area for self-retaining areas: $p \geq \frac{1}{2} i$
From: Start at the Source.

A013825

TABLE 5-2. ILLUSTRATION OF SPREADSHEET TABLE 2,
for documenting impervious areas and sizing planters, swales, and bioretention areas

Area ID (as indicated on site drawing)	*Description (e.g., roof, parking lot, driveway)*	*Size (in SF)*	*BMP ID# and type*	*Area Served by BMP*	*Sizing Factor*	*Minimum required BMP Surface Area*	*Surface Area as Designed*
Total							

Sizing Factors

Vegetated or Grassy Swale	0.04	Bioretention	0.04
Flow-through Planter	0.04	Infiltration Planter	0.04

▶ SIZING PLANTERS, SWALES, AND BIORETENTION AREAS

Runoff from **impervious areas** (roofs and impervious pavements) can be routed to planter boxes, swales, or bioretention areas, which use **indirect infiltration** and are integrated into the landscaping. Simple sizing factors may be used to size these IMPs.

Equivalence
The 0.04 sizing factor is applicable to BMPs that infiltrate runoff from rainfall of 0.2 inches per hour on 100% impervious area through soil or sand with a minimum infiltration rate of 5 inches per hour. (0.2/5 = 0.04).

To size swales, planters, and bioretention areas, follow this procedure:

1. Determine the impervious surface area that will drain to the IMP. (Only one IMP must be associated with each area listed. Two or more delineated areas may drain to the same IMP.)

2. Select an IMP type and apply the corresponding sizing factor to determine the required surface are of the IMP. (Currently, the sizing factor for all three of these IMPs is 0.04.)

3. Check that the required surface area can be accommodated within your site design, and redesign if necessary.

Enter the area of the IMP as designed. Design requirements and details for planters, swales, and bioretention areas are in Appendix C.

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TABLE 5-3. ILLUSTRATION OF SPREADSHEET TABLE 3,
for documenting impervious areas and sizing infiltration basins, infiltration trenches, and dry wells

Area ID (as indicated on site drawing)	*Percent directly connected impervious area*	*Amount of Area (SF)*	*BMP ID# and type*	*Area Served by BMP*	*Required Water Quality Volume*	*Infiltration Rate (inches per hour)*	*Porosity of fill (Basin= 100%)*	*BMP Depth (feet)*	*Minimum required BMP Surface Area*	*Surface Area as Designed*
Total										

► SIZING INFILTRATION BASINS, INFILTRATION TRENCHES, AND DRY WELLS

Where native soils are in **hydrologic soil groups** "A" or "B" it may be possible to use **direct infiltration** IMPs such as infiltration basins, infiltration trenches, and dry wells. See Appendix C for help determining if direct infiltration is appropriate for your site.

Direct infiltration IMPs must meet two sizing criteria:

1. The detention volume must be equal to or greater than the required **water quality volume.**

2. The required bottom **surface area** depends on the infiltration rate and must be sufficient to ensure the IMP drains completely within 72 hours.

The spreadsheet calculates the required water quality volume using the California BMP method and local rainfall data (presented in Appendix H). Follow these steps:

1. First calculate the **percent directly connected impervious area**. The percent directly connected impervious area is simply the impervious area tributary to the IMP divided by the remaining total area tributary to the IMP. (Self-retaining areas are not included.) To avoid clogging, it is strongly preferred to drain only 100% impervious areas to direct-infiltration IMPs.

   The spreadsheet calculates the **unit water quality volume** using the formulae on the nomograph in **Appendix H,** performing any required interpolation for you.

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The spreadsheet also multiplies the unit water quality volume times the area tributary to the IMP and displays the required water quality volume.

2. To determine the required surface area required for this water quality volume, begin by specifying a proposed working depth (i.e., from the bottom of storage to the height of overflow) of the basin or rock fill. For dry wells and infiltration trenches, the water quality volume must be divided by the porosity of the rock fill (normally 35%) to obtain the fill volume. For basins, enter 100%.

   The spreadsheet calculates the minimum required surface area based on the specified depth.

3. Next, enter the infiltration rate and confirm it is sufficient to drain the completely full IMP within 72 hours. Procedures for estimating or measuring the infiltration rate are in **Appendix C** and attachments.

► SIZING VOLUME-BASED CONVENTIONAL BMPS

If drainage from all impervious areas can be routed to adequately sized self-retaining areas or IMPs, then **no conventional BMPs are required**. However, if IMPs do not sufficiently retain, detain, and treat runoff flows, then conventional BMPs are necessary. (The self-retaining areas and IMPs will help minimize the required size of the conventional BMPs.)

The runoff from the remaining area in each catchment —pervious areas that are not self-retaining, plus impervious areas that are not completely served by IMPs— must be routed to a conventional BMP.

As described in the RWQCB permit, conventional BMPs are either **volume-based** or **flow-based**. For some volume-based conventional BMPs (e.g., detention basins and constructed wetlands) discharge is controlled by the size of the outlet orifice. Note that suitable outlet orifices cannot be designed for small flows; for this reason, these BMPs should only be used to treat large areas. Extended (dry) detention basins seem to work best and are least prone to problems when designed to serve areas of 20 acres or more.

The spreadsheet shows the remaining impervious area and total area not draining to IMPs, the percent DCIA of that area, and the resulting water quality volume for a conventional volume-based BMP such as an extended detention basin or wetland.

Note that if Tables 1, 2, and 3 are left blank (except for entering mean annual precipitation in Table 3), the spreadsheet shows the required water quality volume for a conventional extended detention basin or wetland.

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► SIZING CONVENTIONAL FLOW-BASED BMPS

The spreadsheet calculates a composite "C" factor for areas not draining to IMPs, using information for "non-self-retaining" pervious areas in Table 1 and assuming a factor of 1.0 for impervious areas. The composite "C" factor is multiplied times the total area in square feet and a rainfall intensity of 0.2 inches/hour to obtain the design flow for a conventional flow-based BMP serving the entire site. The result is divided by 43,200 in-sec/ft-hr (converts the flow rate to cubic feet per second).

► HYDROGRAPH MODIFICATION MANAGEMENT IMPS

For projects subject to Provision C.3.f*, the next step is to check to determine if the project design—now including self-retaining areas and IMPs designed for stormwater treatment—will increase flow peaks and durations.

The Program's forthcoming Hydrograph Modification Management Plan (HMP, in Appendix D) will include step-by-step instructions (and spreadsheets or other tools) for comparing the site's hydrology in the pre-project and proposed project condition. An iterative procedure will make it possible to adjust the planned size of IMPs and to recheck results until an adequate design is obtained.

► CONVENTIONAL HYDROGRAPH MODIFICATION MANAGEMENT FACILITIES

Design of conventional detention facilities to control hydrograph modification typically involves:

1. Simulating pre- and post-project runoff from the project using continuous rainfall records.
2. Generating peak-recurrence and flow-duration curves from the results.
3. Designing a basin or other facility that generates a flow-duration curve that matches the pre-project flow-duration curve.

An iterative process is used to adjust storage and orifice sizes in the outlet structure. The outlet structure typically consists of a series of orifices at different elevations.

The HMP will include guidance for using a continuous runoff simulation model to evaluate site hydrology and design hydrograph modification management facilities.

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* Provision C.3.f will go into effect some time after May 15, 2005, and will apply to projects that create one acre or more impervious area.

A013829

References and Resources

- RWQCB Order R2-2003-0022, Provision C.3.d
- *Hydrology Handbook, Second Edition* (ASCE 1996)
- *Highway Design Manual* (California Department of Transportation, 2001). Chapter 8.
- *Portland Stormwater Management Manual* (City of Portland, 2002).
- *USDA SCS Technical Release TR55*, Appendix A: Soil Types

Part 3: Design Help

► SITE DESIGN AND SELF-RETAINING AREAS

Start at the Source: Design Guidance Manual for Stormwater Quality Protection, published in 1999 by the Bay Area Stormwater Management Agencies Association (BASMAA), is an updated version of a manual first published in 1997. The 1999 edition covers planning and zoning, site design, and drainage systems. The manual also includes some details for site design, pervious pavements and landscaping, and BMPs.

Start at the Source is an excellent general design guide and is best consulted at the **beginning of the site design process**.

► SELECTING AND DESIGNING IMPS

Attachment C-1 to Appendix C contains ten Infiltration Feasibility Fact Sheets covering site design practices, indirect infiltration practices, and direct infiltration practices.

The fact sheets include general information, illustrations, and design checklists as well as design details for some IMPs.

The fact sheets cover a wide range of options suitable for different site conditions and types of development in Contra Costa County. Consult Table 5-4 for an initial selection of options which may be suitable to your site.

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TABLE 5-4. IDEAS FOR APPLYING IMPs
included in the Infiltration Feasibility Fact Sheets in Appendix C

Site Features and Design Objectives	*Green Roofs*	*Downspouts & Cisterns*	*Grading, Paving, & Land-scaping*	*Flow-through Planter*	*Infiltration Planter*	*Bio-retention Area*	*Vegetated or Grassy Swale*	*Infiltration Basin*	*Dry Well*	*Infiltration Trench*
Clayey native soils	✓	✓	✓	✓	✓	✓	✓			
Permeable native soils	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Very steep slopes	✓			✓						
Shallow groundwater	✓	✓	✓	✓	✓	✓	✓			
Avoid saturating subsurface soils	✓		✓	✓						
Connect to roof downspouts		✓		✓	✓				✓	
Parking lots/islands and medians			✓		✓	✓	✓			
Sites with extensive landscaping		✓	✓			✓	✓	✓		
Densely developed sites with limited space/landscape	✓		✓	✓	✓				✓	✓
Fit BMPs into landscape and setback areas		✓			✓	✓	✓			✓
Make drainage a design feature		✓	✓			✓	✓			
Convey as well as treat stormwater							✓			

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The fact sheets are provided to assist you with developing a Stormwater Control Plan. Additional drawings and specifications, showing construction materials and methods to be used, plumbing connections, etc., may be required with your application for a building permit. Check with the local Building Department for requirements that apply to your project.

► DESIGN OF CONVENTIONAL BMPS

For guidance on designing constructed wetlands or detention basins, see *Urban Runoff Quality Management* (WEF/ASCE, 1998) and the *California Stormwater BMP Handbooks* (CASQA, 2003).

► MISCELLANEOUS CONSIDERATIONS FOR ENGINEERING BMPS

The following notes and design advice have been compiled from observations and experience with the design of BMPs for development sites and from the Program's Vector Control Plan. Review these notes and incorporate applicable items into your Stormwater Control Plan. This will help ensure that these concerns are addressed in the final design and construction permit review process.

Local Requirements

Cities, towns, or the County may have requirements that differ from, or are in addition to, this countywide Guidebook. See Appendix A and check with local planning and community development staff.

BMPs will require 1 to 4 feet or more **head** (difference in elevation between the inlet and outlet). Note that in some cases BMP outlets can be piped to underground storm drain systems. Wherever possible, locate and design the BMP along the hydraulic grade line of the site drainage. Vaults, pumps, and sumps are strongly discouraged because they reduce reliability, increase maintenance, and create potential vector problems.

To avoid **mosquito** problems, the California Department of Health Services recommends that dry basins (extended detention basins) should be designed to drain completely within **72 hours** of a rainfall. In many cases, it is acceptable in Contra Costa County to allow a maximum of five days for complete drainage.

Large, shallow basins with **gentle side slopes** are easiest to maintain and may be designed as multi-use facilities (e.g. playing fields or landscape). Design extended detention basins with a sloped bottom channel to promote complete drainage. Consider over-excavating and replacing the detention-basin bottom with permeable soil. Consider an underdrain to promote healthy turf and drainage.

Design and construct inlets and outlets to **avoid differential settlement** that can cause shallow, persistent puddles. Riprap or rock may be required to dissipate energy at inlets and outlets, but can collect standing water and create mosquito problems. Use cemented rock or ensure that any areas where water may temporarily pool are well-drained.

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Underground vaults, deflection separators, oil/water separators, and drain inlet inserts are **discouraged**. Underground vaults typically lack the detention time required for removal of pollutants associated with fine particles. They also require frequent maintenance. Because vaults may be "out of sight, out of mind," experience shows that the required maintenance may not occur. If vaults are allowed they must be sealed against mosquito access and must also include suitable access doors and hatches to allow for frequent inspections and maintenance. The Water Board has stated that inlet inserts and oil/water separators are inadequate to meet the "maximum extent practicable" standard for stormwater treatment.

► OTHER DESIGN RESOURCES

Links to additional BMP design resources are on the Program's C.3 web page at www.cccleanwater.org/construction/nd.php.

References and Resources

- Contra Costa Clean Water Program *Vector Control Plan*.
- RWQCB Order R2-2003-0022, Provision C.3.d
- *Urban Runoff Quality Management* (WEF/ASCE, 1998).
- *Start at the Source* (BASMAA, 1999).
- *Low Impact Development Manual* (Prince Georges County, 1999).
- *Stormwater Manual* (City of Portland, 2002).
- *California Stormwater BMP Handbooks*
- *Storm Water Technology Fact Sheet: Bioretention* (EPA 832-F-99-012, 1999)
- *Minnesota Urban Small Sites BMP Manual* (Barr Engineering, 2001)
- *Stormwater Manual for Western Washington, Volume V* (Washington Dept. of Ecology, 2001)
- Bruce Wolfe, RWQCB, letter to Geoff Brosseau, BASMAA (August 5, 2004), "Use of Storm Drain Inlet Filters and Oil/Water Separators to Meet the Requirements of NPDES Municipal Stormwater Permits."
- "Application of Water-Quality Engineering Fundamentals to the Assessment of Stormwater Treatment Devices" (Salvia, 2000).

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Identify the maintenance needs for the treatment BMPs on your site.

Treatment BMPs must be regularly maintained to ensure that they continue to be effective and that they do not cause flooding, harbor vectors, or otherwise cause a nuisance.

NPDES Permit Provision C.3.e requires Contra Costa municipalities to periodically verify operation and maintenance (O&M) of the treatment BMPs installed in their jurisdiction. Each year, they must report to the Water Board the treatment BMPs they have inspected that year and the status of each.

The treatment BMPs you install as part of your project will be incorporated into your municipality's operation and maintenance verification program. This is a six-stage process:

1. Determine **who will own** the BMP and be responsible for its maintenance in perpetuity.

2. Identify typical maintenance requirements, integrate these requirements into project planning and preliminary design, and document them in the **Stormwater Control Plan**. The Stormwater Control Plan must also identify any title transfers or maintenance agreements that will be executed before construction is complete.

3. Develop an **Operation and Maintenance Plan** for the site incorporating detailed requirements for **each treatment BMP**. This operation and maintenance plan must be submitted before the building permit is final and a certificate of occupancy is issued. With submittal of the operation and maintenance plan, execute any required agreements.

4. **Maintain** the treatment BMPs from completion of construction until ownership and maintenance responsibility is formally transferred.

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5. **Formally transfer** operation and maintenance **responsibility** to the site owner or occupant.

6. Maintain the treatment BMPs in perpetuity and comply with your municipality's self-inspection, reporting, and **verification** requirements.

TABLE 6-1. SCHEDULE for planning operation and maintenance of stormwater treatment BMPs.

Step	*Description*	*Where documented*	*Schedule*
1	Determine BMP ownership and maintenance responsibility	Stormwater Control Plan	Discuss with planning staff at pre-application meeting
2	Identify general maintenance requirements	Stormwater Control Plan	Submit with planning & zoning application
3	Develop detailed operation and maintenance plan	BMP O&M Plan	Submit draft with Building Permit application; final due before applying for a Certificate of Occupancy
4	Interim operation and maintenance of BMPs	As required by municipal O&M verification program	During and following construction
5	Formal transfer of operation & maintenance responsibility	As required by municipal O&M verification program	On sale and transfer of property or permanent occupancy
6	Ongoing maintenance and compliance with inspection & reporting requirements	As required by municipal O&M verification program	In perpetuity

Ownership and maintenance responsibility for treatment BMPs should be discussed at the **initial stages of project planning**, typically at the pre-application meeting for planning and zoning review.

► PRIVATE OWNERSHIP AND MAINTENANCE

Typically, treatment (and hydrograph modification management) BMPs that serve a single commercial, industrial, multi-family residential, or multi-use parcel will be built on that parcel and will be maintained in perpetuity by the property owner.

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The municipality may require a maintenance agreement to be executed, or a permit to operate the treatment BMP obtained, as a condition of project approval. In either case, the municipality may require an annual fee to offset the cost of inspecting the site to verify that the BMP is being maintained. Alternatively, the municipality may rely on its existing authorities (including its stormwater pollution prevention ordinance) to require ongoing maintenance of privately owned treatment BMPs.

The Program recommends that applicants and municipalities consider carefully the potential consequences of locating treatment BMPs on new private residential lots. This arrangement would require a municipality to verify that homeowners were maintaining their BMPs in perpetuity (and to take enforcement action if they have not been adequately maintained). The Program also recommends against maintenance of BMPs by homeowners associations or other private associations, because the private association may cease to exist at some point, while the municipality will always retain regulatory liability to ensure that the BMP is maintained. However, individual municipalities may find specific circumstances where private ownership and maintenance of BMPs in single-family residential areas is acceptable. On some lots it may be possible to use self-retaining areas (see page 53) instead of BMPs.

▶ TRANSFER TO PUBLIC OWNERSHIP

In subdivisions, municipalities may sometimes choose to have a treatment BMP deeded to the public in fee or as an easement. In that case, the municipality maintains the treatment BMP as part of the municipal storm drain system. The municipality may recoup the costs of maintenance through a special tax, assessment district, or similar mechanism.

Locating a treatment BMP in a public right-of-way or easement creates an additional constraint—along with hydraulic grade, aesthetics, landscaping, and circulation—to the location and design of BMPs. However, because sites typically drain toward the street, it may be possible to locate a swale or similar BMP parallel with the edge of the parcel. The swale may complement, or substitute for, an underground storm drain system.

Even if the treatment BMP is to be conveyed to the municipality after construction is complete, it is still the responsibility of the builder to identify general operation and maintenance requirements, prepare a detailed operation and maintenance plan, and to maintain the BMP until that responsibility is formally transferred.

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Following are general maintenance requirements for typical treatment BMPs, including those featured in the fact sheets in Appendix C.

You can use this information to prepare your Stormwater Control Plan.

► SWALES AND BIORETENTION AREAS

These BMPs remove pollutants primarily by filtering runoff slowly through an active layer of soil. Routine maintenance is needed to ensure that flow is unobstructed, that erosion is prevented, and that soils are held together by plant roots and are biologically active. Typical maintenance consists of the following:

- Inspect **inlets** for channels, exposure of soils, or other evidence of erosion. Clear any obstructions and remove any accumulation of sediment. Examine rock or other material used as a splash pad and replenish if necessary.
- Inspect **outlets** for erosion or plugging.
- Inspect **side slopes** for evidence of instability or erosion and correct as necessary.
- Observe soil at the bottom of the swale or filter for uniform **percolation** throughout. If portions of the swale or filter do not drain within 48 hours after the end of a storm, the soil should be tilled and replanted. Remove any debris or accumulations of sediment.
- Confirm that **check dams** and **flow spreaders** are in place and level and that channelization within the swale or filter is effectively prevented.
- Examine the **vegetation** to ensure that it is healthy and dense enough to provide filtering and to protect soils from erosion. Replenish mulch as necessary, remove fallen leaves and debris, prune large shrubs or trees, and mow turf areas. When mowing, remove no more than 1/3 height of grasses. Confirm that irrigation is adequate and not excessive. Replace dead plants and remove noxious and invasive vegetation.
- Abate any potential **vectors** by filling holes in the ground in and around the swale and by insuring that there are no areas where water stands longer than 48 hours following a storm. If mosquito larvae are present and persistent, contact the Contra Costa Mosquito and Vector Control District for information and advice. Mosquito larvicides should

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be applied only when absolutely necessary and then only by a licensed individual or contractor.

► PLANTER BOXES

Planter boxes capture runoff from downspouts or sheet flow from plazas and paved areas. The runoff briefly floods the surface of the box and then percolates through an active soil layer to drain rock below. Typical maintenance consists of the following:

- Examine **downspouts** from rooftops or sheet flow from paving to ensure that flow to the planter is unimpeded. Remove any debris and repair any damaged pipes. Check splash blocks or rocks and repair, replace, or replenish as necessary.
- Examine the **overflow** pipe to make sure that it can safely convey excess flows to a storm drain. Repair or replace any damaged or disconnected piping.
- Check the **underdrain** piping to make sure it is intact and unobstructed.
- Observe the **structure** of the box and fix any holes, cracks, rotting, or failure.
- Check that the **soil** is at the appropriate depth to allow a reservoir above the soil surface and is sufficient to effectively filter stormwater. Remove any accumulations of sediment, litter, and debris. Till or replace soil as necessary. Confirm that soil is not clogging and that the planter will drain within 3-4 hours after a storm event.
- Determine whether the **vegetation** is dense and healthy. Replace dead plants. Prune or remove any overgrown plants or shrubs that may interfere with planter operation. Clean up fallen leaves or debris and replenish mulch. Remove any nuisance or invasive vegetation.

► INFILTRATION TRENCHES AND DRY WELLS

Infiltration trenches and dry wells store runoff and allow it to infiltrate into native soil. The primary objective of maintenance is to **avoid entry of fine sediments** which may clog the soil interface. Typical inspection and maintenance tasks include the following:

- Inspect periodically and following **major storms**. Remove any accumulated trash or sediment.
- Clean out **sediment traps** and pre-filters.

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- Check **observation wells** 2-3 days after storms to confirm drainage.
- Repair any **erosion** at inflow or overflow structures.
- Mow and trim **vegetation** around the trench or dry well.

Upon failure (when the device fails to drain within 72 hours) the trench or dry well must be renovated. Typically this requires removal of rock fill and accumulated sediment, scarification of the bottom, replacement of filter fabric, and refilling the trench or dry well with clean rock fill.

► WET, EXTENDED WET DETENTION, DRY DETENTION, & INFILTRATION BASINS

These larger-scale BMPs remove pollutants by detaining runoff in a quiescent pool long enough for some of the particulates to settle to the bottom. They require both routine (preventative) maintenance and non-routine maintenance.

For any basin, vault or other device that is designed to hold, or does hold water for longer than 72 hours, the following will typically be required:

- A copy of the O&M plan must be provided to the Contra Costa Mosquito and Vector Control District (CCMVCD).
- Access to all potential vector-producing areas will be given to CCMVCD personnel.
- Copies of O&M reports will be supplied to CCMVCD.
- The CCMVCD will be given advance notice of O&M activities such as silt management, vegetation management, and water management.
- A schedule of routine O&M activities will be given to the CCMVCD.
- O&M personnel will cooperate with CCMVCD and adjust activities as necessary to facilitate control of mosquitoes and vectors.

Typical routine maintenance consists of the following:

- Examine **inlets** to ensure that piping is intact and not plugged. Remove accumulated sediment or debris near the inlet.
- Examine **outlets** and **overflow structures** and remove any debris or sediment that could plug the outlets. Identify and correct any sources of sediment and debris. Check rocks or other armoring and replace as necessary.

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- Inspect **embankments**, dikes, berms, and side slopes for signs of erosion or structural deficiencies.
- Confirm that any **fences** around the facility are secure.
- Control **vectors** by filling any holes in or around the pond and examine the pond for evidence of mosquito larvae.

Typical non-routine maintenance includes the following:

- **Dredge** accumulated sediment. This may be required every five to 15 years, and more frequently if there are excess sources of sediment (as may occur on newly constructed sites where soils are not yet stabilized). Dredging is usually a major project requiring mechanized equipment. The work will include an initial survey of depths and elevations; sediment sampling and testing; removal, transport, and disposal of accumulated sediment, and reestablishment of original design grades and sections.
- Remove **invasive plants**. Depending on the success of the design and the rate of sedimentation, ponds may be subject to excessive growth of rooted macrophytes, which reduce the effective area of the pond and create quiescent surface water that supports mosquito larvae. Removal may require a level of effort similar to dredging.

[illegible]

After the construction drawings and specifications for your stormwater treatment and hydrograph modification BMPs have been completed, prepare a Stormwater Control Operation and Maintenance (O&M) plan.

The O&M plan may be simple or complex depending on the type of BMPs selected and implemented for your project. For example, scheduled maintenance for landscape detention areas may require little more explanation than irrigation cycles, plant care, and observation of any drainage problems. In contrast, a system with pumps and sumps should incorporate manufacturer's maintenance recommendations, warranty information, detailed operating plans, and a seasonal schedule for inspections. **Wet ponds** or **constructed wetlands** will require detailed O&M plans to monitor and, if necessary, abate problems with mosquitoes or excessive macrophyte growth. In addition, it may be advisable to manage wet ponds or wetlands to avoid designation as **critical habitat** for endangered species.

Appendix F provides instructions for the preparation of O&M plans. Example Stormwater Control Operation and Maintenance Plans are in Appendix J.

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Step 4: Interim Operation & Maintenance

In accordance with Provision C.3.e.ii. of the Stormwater NPDES permit, the project proponent must provide a signed statement "accepting responsibility for maintenance [of stormwater treatment BMPs] until the responsibility is transferred to another entity..."

Include a statement to this effect in your Stormwater Control Plan.

The detailed O&M plan should incorporate solutions to any problems noted or changes that occurred during construction. For this reason, the detailed O&M plan may be submitted at the end of the construction period, before the application for final building permit and Certificate of Occupancy.

Step 5: Transfer Responsibility

As part of the detailed O&M plan, note the expected date when responsibility for operation and maintenance will be transferred. Notify your municipality when this transfer of responsibility takes place.

Step 6: Operation & Maintenance Verification

Each Contra Costa municipality will implement a Stormwater Treatment Measures Operation and Maintenance Verification Program, including periodic site inspections. The local verification program is described in Appendix K.

References and Resources

- *Start at the Source* (BASMAA, 1999) pp. 139-145.
- *Urban Runoff Quality Management* (WEF/ASCE, 1998). pp 186-189.
- *Stormwater Management Manual* (Portland, 2002). Chapter 6.0.
- *California Storm Water Best Management Practice Handbooks* (CASQA, 2003).
- *Best Management Practices Guide* (Public Telecommunications Center for Hampton Roads, 2002).
- Contra Costa Clean Water Program *Vector Control Plan*
- *Operation, Maintenance, and Management of Stormwater Management Systems* (Watershed Management Institute, 1997)

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Alternatives for meeting stormwater control requirements for your site by participating in a regional stormwater facility, by implementing compensatory mitigation, or obtaining an exemption.

Contra Costa municipalities may establish an **alternative compliance** program or, in the absence of such a program, allow a particular project to implement "alternative compliance" in lieu of incorporating stormwater treatment BMPs into their project.

Under certain conditions, a project applicant may choose to reduce or omit treatment BMPs from their project design. Instead, applicants may create an equivalent water-quality benefit at a different site. Where feasible, this site should be in the same drainage basin.

Local Requirements

Cities, towns, or the County may have requirements that differ from, or are in addition to, this countywide Guidebook. See Appendix A and check with local planning and community development staff.

Other C.3 requirements—including site designs to minimize imperviousness and structural and operational source control BMPs—will still apply.

The Program recommends that you follow the steps in Chapter 3 to prepare a Stormwater Control Plan for your project before considering options for alternative (off-site) compliance.

Should an alternative compliance option be necessary, the Stormwater Control Plan for your project site is still needed to detail how site design measures, source control BMPs and other remaining on-site requirements will be met and will also help establish that on-site treatment measures are **infeasible** or **impracticable**, if that is the case.

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"Alternative compliance" may be implemented by pursuing any of the following three options:

1. Participate in a **regional stormwater treatment facility**.

2. Demonstrate the **impracticability** of incorporating treatment BMPs on your development site **and** also demonstrate how you will provide **compensatory mitigation** (equivalent treatment or equivalent water-quality benefit) at another site.

3. Obtain an **exemption** from the requirements if impracticability of incorporating treatment BMPs on your site can be established, the costs of participating in a regional facility or implementing compensatory mitigation at another site would "unduly burden" the project, and the project is a redevelopment project that also meets certain categorical criteria established by the Water Board.

Provision C.3.g of the stormwater NPDES permit details the Water Board's requirements for "alternative compliance."

Local planning and engineering staff can provide up-to-date information on your municipality's proposed "alternative compliance" program or requirements and how they might apply to your project.

References and Resources

- San Francisco Bay RWQCB Order No. R2-2003-0022 (Stormwater NPDES Permit C.3 Amendment), Provision C.3.g

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BASMAA. 1999. Bay Area Stormwater Management Agencies Association. *Start at the Source: Design Guidance Manual for Stormwater Quality.* Tom Richman and Associates. 154 pp. plus appendix. http://www.cccleanwater.org/construction/nd.php#SATS

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Resource List for Stormwater Management Programs

May 2004
EPA 833-F-04-003

This is a list of helpful resources for stormwater program managers. It is by no means a comprehensive list as there are too many helpful materials produced by too many organizations. This list is meant to highlight EPA's tools and resources to get stormwater programs managers started on developing or improving their programs.

This list is divided into six sections—general stormwater information, public education and outreach, illicit discharge detection and elimination, construction site runoff control, post-construction site runoff control, and pollution prevention/good housekeeping.

General Stormwater Information

- **EPA Stormwater Website** - This EPA website contains technical and regulatory information about the NPDES stormwater program. It is organized according to the three types of regulated stormwater discharges—construction activities, industrial activities, municipal separate storm sewer systems.
  www.epa.gov/npdes/stormwater

- **2003 Construction General Permit** - This 59-page document is EPA's new Construction General Permit (CGP). http://www.epa.gov/npdes/pubs/cgp2003_entirepermit.pdf

- **Construction General Permit** - The website describes EPA's construction general permit and provides links to fact sheets and the new electronic notice of intent web site.
  www.epa.gov/npdes/stormwater/cgp

- **Construction Industry Compliance Assistance Center** - This website, developed by the National Center for Manufacturing Sciences, provides explanations of environmental rules for the construction industry. Also provided are links to detailed information, including state regulations and other resources.
  http://www.cicacenter.com/

- **EnviroFacts Data Warehouse** - EPA's one-stop resource for environmental topics. Includes advanced search capabilities for maps, reports and queries.
  http://www.epa.gov/enviro/index_java.html

- **EPA's Electronic Stormwater Notice of Intent (eNOI) Homepage** - This online resource allows construction sites and Industrial facilities to apply for EPA's General Construction Permit (GCP) or Multi-Sector General Permit (MSGP-2000) electronically.
  http://cfpub.epa.gov/npdes/stormwater/enoi.cfm

- **Fact Sheet on EPA's 2003 CGP** - This 38-page document describes EPA's CGP.
  http://www.epa.gov/npdes/pubs/cgp2003_fs.pdf

- **Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation.** This book by The Watershed Management Institute

contains a comprehensive review of the institutional frameworks behind successful urban runoff management programs. Includes summaries of 32 successful programs.

- **Menu of Best Management Practices (BMPs) for Phase II** - This EPA website contains more than 100 fact sheets detailing BMPs for each minimum control measures. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm

- **Measurable Goals Guidance** - EPA developed this website to help small MS4 communities select measurable goals to evaluate their program. www.epa.gov/npdes/stormwater/measureablegoals

- **Nonpoint Source News Notes** - A periodic report on the condition of water-related environment, the control of nonpoint water pollution and ecological management and restoration of wetlands. http://www.epa.gov/newsnotes/

- **NPDES News** - Use this website to sign up for EPA's NPDES News listserver to receive updates on the EPA's NPDES program. http://cfpub.epa.gov/npdes/newsregister.cfm

- **NPSINFO** - Nonpoint Source Pollution Information listserve is a forum for open discussion of nonpoint source pollution issues. Participants exchange information on urban runoff, hydrologic modification, technology and more. Sponsored by the EPA's Office of Wetlands, Oceans and Watersheds. http://www.epa.gov/OWOW/info/NewsNotes/listsrv.htm

- **Operation, Maintenance and Management of Stormwater Management Systems** - Developed in cooperation with the EPA's Office of Water, this manual contains a comprehensive review of the technical, educational and institutional elements needed to build, maintain and operate a stormwater management system. http://www.epa.gov/owow/nps/wmi/

- **Stormwater: The Journal for Surface Water Quality Professionals** - This online publication features articles, interviews and news about water quality improvement and protection. http://stormh2o.com/sw.html

- **Stormwater Authority** - A comprehensive online source for relevant information, news, events and education on stormwater. http://www.stormwaterauthority.org/

- **Stormwater Case Study: Monroe County, New York** - Monroe County enlists the aid of volunteers to help monitor streams and large water bodies. http://cfpub.epa.gov/npdes/stormwater/casestudies_specific.cfm?case_id=16

- **Stormwater Control Operation and Maintenance Model Ordinance** - EPA developed this web site to assist managers in developing their own ordinances. http://www.epa.gov/owow/nps/ordinance/stormwater.htm

- **Stormwater Phase II Final Rule Fact Sheet Series** - EPA developed these fact sheets to explain the Phase II rule, minimum control measures and permitting. http://cfpub.epa.gov/npdes/stormwater/swfinal.cfm

- **Storm Water Management for Construction Activities**: Developing Pollution Prevention Plans and Best Management Practices - This manual provides detailed guidance on the development of storm water pollution prevention plans (SWPPP) and identification of best

management practices (BMPs) for construction activities. It provides technical assistance and support for all construction activities subject to pollution prevention requirements established under NPDES permits for storm water point source discharges. It includes a set of worksheets, a checklist, and a sample SWPPP (EPA 832-R-92-005).
http://www.epa.gov/npdes/pubs/owm0307.pdf

- **Stormwater Management** - Center for Watershed Protection developed this website to provide managers with links to helpful manuals and other web sites.
http://www.cwp.org/stormwater_mgt.htm

- **Stormwater Manager's Resource Center** - This website has many resources for stormwater managers, including guidance documents, slide shows, model ordinances, and fact sheets.
http://www.stormwatercenter.net/

- **Stormwater Phase II Fact Sheet Series** - EPA developed this website to provide links to 15 helpful fact sheets.
http://cfpub.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6

- **Stormwater Practices for Cold Climates** - The document, developed by the Center for Watershed Protection can be downloaded for free.
http://www.cwp.org/cold-climates.htm

- **International Stormwater Best Management Practices (BMP) Database**- This database, developed under a cooperative agreement between EPA and ASCE, provides access to BMP performance data for 200 BMP studies conducted over the past 15 years.
http://www.bmpdatabase.org/

- **Catching the Rain: a Great Lakes Resource Guide for Natural Stormwater Management**- This report by American Rivers outlines natural stormwater management approaches appropriate for the great lakes region. It demonstrates alternative stormwater management techniques.
http://www.americanrivers.org/newreportonstormwatermanagement.html

- **UNH Stormwater Research Center** - The University of New Hampshire's online stormwater database contains factsheets, research materials, articles and links to other stormwater sites.
http://www.unh.edu/erg/cstev/index.htm

- **Watershed Academy Web: Online Training in Watershed Management** - This online distance learning program offers self-paced training modules for a basic introduction to the watershed management field.
http://www.epa.gov/watertrain/

Public Education and Outreach

- **After the Storm Video** (EPA 840-V-04-001) - New ½ hour television program about watersheds co-produced by EPA and The Weather Channel premiered on Feb. 4, 2004.
http://www.epa.gov/weatherchannel/

- **American Oceans Campaign** - This website has helpful materials for educating the public, such as a video narrated by Ted Danson, links to stormwater resources in California, and a special report developed by AOC.
http://www.americanoceans.org/runoff/main.htm

- **City of Los Angeles Stormwater Program** - This expansive site includes links to public outreach resources, industry BMPs, teacher workshops and educational programs, and

much more.
http://www.lastormwater.org/WPD/program/pubedpage.htm

- **Communicator's Guide for Federal, State, Regional, and Local Communicators** - The Federal Communicator's Network developed this guide to offer some general guidance to improve the trust between government and the public by helping officials communicate clearly to the public and by making government's message relevant.
http://govinfo.library.unt.edu/npr/library/papers/bkgrd/communicators.html

- **Community Culture and the Environment: A Guide to Understanding a Sense of Place, Nov. 2002** (EPA 842-B-01-003)
The Guide was developed by EPA and explores the concepts of community and culture and provides tools for identifying, assessing, and working cooperatively within the social dynamics and local values connected to environmental protection.
http://www.epa.gov/ecocommunity/tools/community.pdf

- **Earthwater Stencils** - This site provides ideas for public involvement activities for stormwater programs.
http://www.earthwater-stencils.com/

- **Enviroscapes** - Website for manufacturer of realistic, three-dimensional models of watersheds, landfills, wetlands and more. An effective demonstration tool for students interested in learning about point sources and non point sources of water pollution.
http://www.enviroscapes.com

- **Getting In Step: A Guide for Conducting Watershed Outreach Campaigns**, (EPA 841-B-03-002) - The Getting in Step watershed outreach guidebook provides some of the tools you will need to develop and implement an effective watershed outreach plan. If you're a watershed practitioner trained in the sciences, this manual will help you address public perceptions, promote management activities, and inform or motivate stakeholders.
http://www.epa.gov/nps/outreach.html

- **Getting in Step: Engaging and Involving Stakeholders in Your Watershed** - This document, developed by EPA, provides the tools needed to effectively identify, engage, and involve stakeholders throughout a watershed to restore and maintain healthy environmental conditions.
http://www.epa.gov/nps/outreach.html

- **Kids, Students, Teachers** - This EPA website provides information and curricula on educating a variety of age groups on the environment and water pollution.
http://www.epa.gov/epahome/students.htm

- **Know Your Watershed** - This website, developed by the Conservation Technology Information Center, has a good list of helpful resources (including guidebooks) for watershed groups.
http://www.ctic.purdue.edu/KYW/

- **Polluted Runoff (Non Point Source Pollution): Outreach** - This EPA website contains information and links to a variety of non point source pollution documents, factsheets, testimonials, videos and more.
http://www.epa.gov/owow/nps/outreach.html

- **Public Education and Outreach Menu of BMPs** - This website has links to 14 facts sheets on different BMPs for educating the public.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/pub_ed.cfm

- **Public Involvement and Participation Menu of BMPs-** This EPA website has links to 10 fact sheets detailing ideas and activities n how to get the public involved.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/pub_inv.cfm

- **Stormwater Month Outreach Materials and Reference Documents** - EPA has developed a set of materials that state or local governments can customize and use in their own stormwater outreach campaigns.
www.epa.gov/npdes/stormwatermonth

- **Think Blue San Diego** - This site provides an overview of San Diego's stormwater pollution prevention program Think Blue San Diego. Includes program objectives and organization.
http://www.thinkbluesd.org/why.htm

- **Volunteer Monitoring** - Check out this EPA website to download helpful fact sheets and methods manuals, learn about upcoming events, and link to other helpful resources.
http://www.epa.gov/owow/monitoring/volunteer/

- **Water Environment Federation for Students** - Check out ths web page to download WEF's materials and curricula for educating various age groups. Also provides information in Spanish.
http://www.wef.org/WefStudents/index.jhtml

Illicit Discharge Detection and Elimination

- **Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments** - This comprehensive manual outlines practical, low-cost and effective illicit discharge detection and identification techniques.
http://www.cwp.org/idde_verify.htm

- **Illicit Discharge Detection and Elimination Manual** - The New England Interstate Water Pollution Control Commission developed this manual to provide an overview of the IDDE component of the Phase II regulations and practical information on various approaches municipalities can use to carry out the requirements of the regulations.
http://www.neiwpcc.org

- **Illicit Discharge Detection and Elimination (IDDE) Menu of BMPs-** This EPA web site links to 8 fact sheets outlining various IDDE best management practices.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/illicit.cfm

- **Illicit Discharges Model Ordinances** - EPA developed this website to assist managers in developing their own ordinances.
http://www.epa.gov/owow/nps/ordinance/discharges.htm

- **Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems: A User's Guide** Information to allow the design and conduct of local investigations to identify the types and to estimate the magnitudes of non-stormwater entries into storm drainage systems (EPA-600-R-92-238).
http://www.epa.gov/npdes/pubs/investigating_inappropriate_pesds.pdf

- **Sanitary Sewer Overflows (SSOs)** - EPA developed this website to provide more information on SSOs, including fact sheets and an SSO toolbox.
www.epa.gov/npdes/sso

Construction Site Runoff Control

- **Best Management Practices for South Florida Urban Stormwater Management Systems** - The South Florida Water Management District has prepared this document to

increase public awareness about the management of urban stormwater runoff and how best management practices (BMPs) can be used to improve water quality.
http://www.sfwmd.gov/org/reg/evg/bmp_manual.pdf

- **Construction Site Runoff Control Menu of BMPs** - This EPA website links to 39 fact sheets outlining various IDDE best management practices.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/con_site.cfm

- **Erosion and Sediment Control Model Ordinances** - EPA developed this website to assist managers in developing their own ordinances.
http://www.epa.gov/owow/nps/ordinance/erosion.htm

- **International Erosion Control Association** - The International Erosion Control Association is a non-profit, member organization that provides education and resource information for professionals in the erosion and sediment control industry.
http://www.ieca.org/

- **International Stormwater Best Management Practices Database** - This database provides access to BMP performance data for about 200 BMP studies conducted over the past 15 years.
http://www.bmpdatabase.org

- **Kentucky Erosion Prevention and Sediment Control Field Guide** - Comprehensive guide to Kentucky's BMPs for erosion and sediment control for highway construction projects.
http://www.tetratech-ffx.com/wstraining/pdf/esc_guide.pdf

- **Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices** - This manual provides detailed guidance on the development of storm water pollution prevention plans (SWPPP) and identification of best management practices (BMPs) for construction activities. It provides technical assistance and support for all construction activities subject to pollution prevention requirements established under NPDES permits for storm water point source discharges. It includes a set of worksheets, a checklist, and a sample SWPPP (EPA 832-R-92-005).
http://www.epa.gov/npdes/pubs/owm0307.pdf

Post-Construction Site Runoff Control

- **Bioretention Applications. EPA Fact Sheet** - Two case studies (in Largo, Maryland, and Tampa, Florida) demonstrate the potential to use low impact development practices in the design of new parking facilities and as retrofits for existing parking facilities to reduce runoff volume and remove pollutants. Includes monitoring data.
http://www.epa.gov/owow/nps/lid/lidlit.html

- **Green Roofs for Healthy Cities** - This non-profit industry association's website collects and publishes technical information on green roof products and services.
http://www.greenroofs.org/index.php?page=index

- **Low Impact Development Center** - The Low Impact Development Center strives to help communities use proper site design techniques to protect their water resources.
http://www.lowimpactdevelopment.org/

- **Low Impact Development Practices for Stormwater Management** - This technical information resource sponsored by the housing industry discusses building products, materials, new technologies, business management and housing systems.
http://www.toolbase.org/tertiaryT.asp?TrackID=&CategoryID=1232&DocumentID=2007

- **Low-Impact Development Page** - This page, developed by EPA, provides links to EPA

documents and other helpful organization's web sites.
http://www.epa.gov/owow/nps/lid/

- **Low Impact Development Integrated Management Practices Guide** - Prince George's County Maryland developed this manual to push the site design envelope to show how stormwater controls can be integrated into a site in innovative ways. The practices are pure concepts which are presented to provide the user with examples of what could be done to control stormwater.
http://www.goprincegeorgescounty.com/Government/AgencyIndex/DER/PPD/LID/principles.asp?h=20&s=&n=50&n1=160

- **Low Impact Development: Urban Design Tools** - This site provides watershed managers with tools and techniques for meeting regulatory and receiving water protection program goals for urban retrofits, redevelopment projects and new development sites.
http://www.lid-stormwater.net/

- **Natural Approaches to Stormwater Management** - This book, produced by the Puget Sound Action Team, showcases early examples of the efforts of planners, developers and engineers to transition to low impact development.
http://www.psat.wa.gov/Publications/LID_studies/LID_approaches.htm

- **Post Construction Controls Model Ordinance** - EPA developed this website to assist managers in developing their own ordinances.
http://www.epa.gov/owow/nps/ordinance/postcons.htm

- **Post-Construction Site Runoff Control Menu of BMPs** - This EPA website links to 39 fact sheets outlining various structural and non-structural best management practices for post-construction runoff control.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm

- **Puget Sound Online: Low Impact Development** - Sponsored by the Puget Sound Action Team Partnership, this web page addresses issues and innovations in low impact development.
http://www.psat.wa.gov/Programs/LID.htm

- **Smart Growth** - This EPA site provides information on various smart growth topics and EPA funding sources, and links to other helpful web sites.
http://www.epa.gov/livability/

- **Smart Growth Online** - Sponsored by the Smart Growth Network, this site is a forum for discussing smart growth BMPs, innovative policies, tools and ideas.
http://www.smartgrowth.org/sgn/default.asp?res=800

- **Smart Growth for Clean Water: Helping Communities Address the Water Quality Impacts of Sprawl** - This report from the National Association of Local Government Environmental Professionals identifies five smart growth approaches, and profiles several local partnerships that have reaped the economic and environmental benefits of these approaches.
http://www.nalgep.org/publications/PublicationsDetail.cfm?LinkAdvID=42157

- **Street Storage for Combined Sewer Surcharge Control**: reducing the rate of runoff entering combined sewer systems using street storage and catch basin modifications - Two case studies in Illinois. October 2000. EPA-841-B-00-005C.
http://epa.gov/ednnrmrl/repository/epa-600-r-00-065/index.html

- **Street Storage System for Control of Combined Sewer Surcharge:** Retrofitting

Stormwater Storage into Combined Sewer Systems. EPA Report: EPA/600/R-00/065 available in PDF. Also available through NTIS: NTIS NO: PB2000-107451.
http://www.epa.gov/ednnrmrl/repository/epa-600-r-00-065/index.html

- **Vegetated Roof Cover:** EPA Fact Sheet, EPA-841-B-00-005D. Case study in Philadelphia, Pennsylvania on vegetated roofs. The study demonstrates the use of a vegetated roof to reduce runoff, conserve energy and improve community aesthetics. Includes design information and monitoring data.
http://www.epa.gov/owow/nps/lid/lidlit.html

Pollution Prevention/Good Housekeeping

- **National Management Measures to Control Nonpoint Source Pollution from Urban Areas**
This draft document contains information on the best available methods to economically reduce urban-generated surface and ground water pollution .
http://www.epa.gov/owow/nps/urbanmm/index.html

  Pollution Prevention and Good Housekeeping Menu of BMPs - This EPA web site links to 31 fact sheets outlining various best management practices for pollution prevention and good housekeeping.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/poll.cfm

- **Techniques for Tracking, Evaluating and Reporting the Implementation of Non Point Source Control Measures** - This EPA guidance helps federal, state, regional and local environmental professionals track the implementation of BMPs used to control urban non point source pollution.
http://www.epa.gov/owow/nps/urban2.html

Funding Sources

- **An Internet Guide to Financing Stormwater Management** - This site was designed to help communities find ways to fund stormwater management projects.
http://stormwaterfinance.urbancenter.iupui.edu/

- **Catalog of Federal Funding Sources for Watershed Protection** - The Catalog of Federal Funding Sources for Watershed Protection Web site is a searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects.
http://cfpub.epa.gov/fedfund/

- **State Revolving Fund** - State Revolving Fund programs in each state and Puerto Rico are funded by EPA and operated like banks. Assets are used to make low- or no-interest loans.
http://www.epa.gov/owm/cwfinance/cwsrf/index.htm

STORMWATER MANAGEMENT SYSTEM INSPECTION FORMS

FROM:
OPERATION, MAINTENANCE, AND MANAGEMENT OF STORMWATER MANAGEMENT SYSTEMS

PUBLISHED BY:
WATERSHED MANAGEMENT INSTITUTE, INC.

In cooperation with:
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STORMWATER MANAGEMENT SYSTEM INSPECTION FORMS

From CHAPTER 6: CONSTRUCTION INSPECTION of *Operation, Maintenance, and Management of Stormwater Management Systems*

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The handbook *Operation, Maintenance, and Management of Stormwater Management Systems* was produced by the Watershed Management Institute, Inc. in cooperation with the United States Environmental Protection Agency, Office of Water, through Cooperative Agreement CX823621-01-0. The contents do not necessarily reflect the views or policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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APPENDICES FROM CHAPTER 6

Construction Inspection Forms for Stormwater Management Practices

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APPENDIX 6-1

Preconstruction Inspection Meeting Topics Form

A013857

State of New Jersey
Department of Environmental Protection
Stormwater Management Facility Maintenance Manual

Example Preconstruction Meeting Topics

A. GENERAL INFORMATION

1. Attendance
2. Purpose of project and background information
3. Emergency telephone numbers
4. Construction photograph requirements
5. Project sign requirements
6. Starting date
7. Review of contract documents, including insurance certifications, bonds and subcontractors documents
8. Field office requirements
9. Responsibility for notification of affected property owners and residents
10. Chain of command for communications and correspondence
11. Construction schedules
12. Key personnel and their degree of involvement in the project (inspector, owner, engineer, agencies, etc.)

B. POLICE AND FIRE DEPARTMENT CONCERNS

1. Traffic control
2. Barricades and signs conforming to the uniform manual
3. Noise ordinance considerations
4. Working hours, including weekend and holidays
5. Vandalism and preventative measures
6. Flagmen and traffic control officers
7. Equipment storage and vehicle parking
8. Emergency vehicle access
9. Underground tank locations and precautionary construction procedures
10. Storage and use of hazardous materials

C. UTILITIES

1. Utility locations and mark-outs
2. Coordination of utility relocations
3. Emergency phone numbers of utility companies

D. FUNDING AND PAYMENTS

1. Funding sources and availability
2. Procedures and dates for payment estimates
3. Dates for payments to contractor
4. Breakdown of lump sum items for partial payment
5. Policy for payment for materials on site at the close of a payment period
6. Retained monies during and after construction

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7. Requirements of funding agencies

E. CHANGE ORDERS AND EXTRA CLAIMS

1. Requirements for additional work and submittal of change orders
2. Procedures and schedule for review and recommendations of change orders
3. Procedures for negotiating extra claims and change orders

F. CONSTRUCTION ACCESS AND EASEMENTS

1. Easement locations and maps
2. Responsibility for locating and staking easements
3. Available survey data for the site
4. Access requirements and staging areas
5. Easement restrictions and restoration requirements

G. CONSTRUCTION DETAILS

1. Unique or complex aspects of the project
2. Testing laboratories and sampling procedures
3. Cold and hot weather protection measures
4. Blasting requirements
5. Dump site location for construction related materials
6. Shop drawing requirements and review procedures
7. Specific construction techniques and procedures
8. Review of technical section of the specifications

H. PERMITS

1. Status of all required federal, state, and local permits
2. Permit restrictions and conditions
3. Start-of-work notifications

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APPENDIX 6-2

General Site Inspection and Notice to Comply Forms

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Construction Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Weather Conditions _____

Site Status _____ (active, inactive, completed)

Site Conditions:

acceptable _____
Unacceptable _____
In compliance with approved plan _____
Approved plan is adequate for the site _____

Written Comments:

_____
_____
_____
_____
_____
_____
_____

Action to be taken:

No action necessary. Continue routine inspections _____
Correct noted site deficiencies by _____
1st notice _____
2nd notice _____
Submit plan modifications as noted in written comments by _____
Notice to Comply issued _____
Final inspection, project completed _____
Other _____

_____
Received by

_____
Inspector

I acknowledge receipt of this inspection report. My signature does not imply agreement or disagreement with its content

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency the appropriate address and phone number.

white: developer/contractor yellow: file pink: legal/enforcement

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Notice to Comply Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date _____

To: _____

Address: _____

_____

Project/Site/Contract Name _____

An inspection of the above referenced project on _____(Date) revealed that the site is not in compliance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations, and the following violations exist:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Notice is hereby given that the above violations shall be corrected in accordance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations on or before _____ (Date). The site will be reinspected at that time to determine if the site has been brought into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

Failure to comply with this notice will result in the initiation of legal action by the Department in order to bring the site into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

_____ _____

Received by Inspector

I hereby acknowledge receipt of this notice to comply. My signature does not imply agreement or disagreement with its content

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number

white: developer/contractor yellow: file pink: legal/enforcement

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APPENDIX 6-3

Sediment/Stormwater Management Basin Construction Inspection Checklist

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Sediment/Stormwater Management Basin Construction Checklist

For Permanent structures per Delaware NRCS Pond Code 378 and Delaware Sediment and Stormwater Regulations
(Developed by Randy Greer, Environmental Engineer)

KEY

_4_ Item meets standard
_6_ Item not acceptable
_N/A_ Item not applicable
_C_ Item requires engineer's certification

PROJECT INFORMATION

Project ID: _____
Contractor: _____
Inspector: _____
Date(s): _____

I. Materials and Equipment

_____ Pipe and appurtenances on-site prior to construction and dimensions checked.
- _____ 1. Material (including protective coating, if specified)
- _____ 2. Diameter
- _____ 3. Dimensions of metal riser or pre-cast concrete outlet structure
- _____ 4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans
- _____ 5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope
- _____ 6. Number and dimensions of prefabricated anti-seep collars
- _____ 7. Watertight connectors and gaskets
- _____ 8. Outlet drain valve

_____ Appropriate compaction equipment available, including hand and small power tamps
_____ Project benchmark near pond site
_____ Equipment for temporary de-watering

II. Subgrade Preparation

_____ Area beneath embankment stripped of all vegetation, topsoil, and organic matter
_____ Cut-off trench excavated a minimum of 4 feet below subgrade and minimum 4 feet below proposed pipe invert, with side slopes no steeper than 1:1
_____ Impervious material used to backfill cut-off trench

III. Pipe Spillway Installation

_____ Method of installation detailed on plans

A. Bed preparation
- _____ Installation trench excavated with 1:1 side slopes
- _____ Stable, uniform, dry subgrade of relatively impervious material *(If subgrade is wet, contractor shall have defined steps before proceeding with installation)*
- _____ Invert at proper elevation and grade

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B. Pipe placement

_____ Metal/Plastic pipe

_____ 1. Watertight connectors and gaskets properly installed

_____ 2. Anti-seep collars properly spaced and having watertight connections to pipe

_____ 3. Backfill placed and tamped by hand under "haunches" of pipe

_____ 4. Remaining backfill placed in max. 8" lifts using small power tamping equipment until 2 feet cover over pipe is reached

_____ Concrete pipe

_____ 1. Pipe set on blocks or concrete slab for pouring of low cradle

_____ 2. Pipe installed with rubber gasket joints with no spalling in gasket interface area

_____ 3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set

_____ 4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant

_____ 5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix

_____ 6. Upper half of anti-seep collar(s) formed with reinforcing steel set

_____ 7. Concrete for collar of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ 8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary

C. Backfilling

_____ Fill placed in maximum 8" lifts

_____ Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment

IV. Riser/Outlet Structure Installation

A. Metal riser

_____ Riser base excavated or formed on stable subgrade to design dimensions

_____ Embedded section of aluminum or aluminized pipe to be painted with zinc chromate or equivalent on **inside and outside** surfaces

_____ Set on blocks to design elevations and plumbed

_____ Reinforcing bars placed at right angles and projecting into sides of riser

_____ Concrete poured so as to fill inside of riser to invert of barrel

B. Pre-cast concrete structure

_____ Dry and stable subgrade

_____ Riser base set to design elevation

_____ If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely

_____ Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway

C. Poured concrete structure

_____ Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set

_____ Structure formed to design dimensions, with reinforcing steel set as per plan

_____ Concrete of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

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V. Embankment Construction

A. Fill material
- _____ Soil engineer's test
- _____ Visual test by inspector

B. Compaction
- _____ Soil engineer's test
- _____ Visual test by inspector

C. Embankment
- _____ Fill placed in maximum 8" lifts and compacted with appropriate equipment
- _____ Constructed to design cross-section, side slopes and top width
- _____ Constructed to design elevation plus allowance for settlement

VI. Impounded Area Construction

- _____ Excavated/graded to design contours and side slopes
- _____ Inlet pipes have adequate outfall protection
- _____ Forebay(s)
- _____ Wet pond requirements
  - _____ 1. 10 feet reverse slope bench one foot above normal pool elevation
  - _____ 2. 10 feet wide level bench one foot below normal pool elevation

VII. Earth Emergency Spillway Construction

- _____ Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.
- _____ Excavated to proper cross-section, side slopes and bottom width
- _____ Entrance channel, crest, and exit channel constructed to design grades and elevations

VIII. Outlet Protection

A. End section
- _____ Securely in place and properly backfilled

B. Endwall
- _____ Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified
- _____ Endwall formed to design dimensions with reinforcing steel set as per plan
- _____ Concrete of an approved mix and vibrated into place. (Protected from freezing, if necessary
- _____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

C. Riprap apron/channel
- _____ Apron/channel excavated to design cross-section with proper transition to existing ground
- _____ Filter fabric in place
- _____ Stone sized as per plan and uniformly placed at the thickness specified

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IX. Vegetative Stabilization

_____ Approved seed mixture or sod
_____ Proper surface preparation and required soil amendments
_____ Excelsior mat or other stabilization materials, as per plan

X. Miscellaneous

_____ Toe drain
_____ Temporary dewatering device installed as per plan with appropriate fabric, stone size and perforations if included
_____ Drain for ponds having a permanent pool
_____ Trash rack/anti-vortex device secured to outlet structure
_____ Trash protection for low flow pipes, orifices, etc.
_____ Fencing (when required)
_____ Access road
_____ Set aside area for clean-out maintenance

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APPENDIX 6-4

Sediment/Stormwater Pond Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

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Stormwater/Sediment Pond
Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

(Developed by Randy Greer, Environmental Engineer
Delaware Department of Natural Resources and Environmental Control
Sediment and Stormwater Program)

1. NOTIFY PLAN REVIEW/CONSTRUCTION REVIEW AGENCY AS REQUIRED

    a. Arrange the preconstruction meeting
    b. Clear up any questions regarding the approved plan

2. PRE-CONSTRUCTION MEETING WITH CONSTRUCTION REVIEW AGENCY

    a. Review the site plan and layout and discuss any problems or changes needed to the plan
    b. Obtain approvals for the plan changes from the appropriate inspection or plan review agency
    c. Discuss the stages of construction which notification to the construction review agency is needed

3. SITE LAYOUT

    a. Make sure site layout agrees with the plan
    b. Check elevation of the proposed outfall structure
    c. Physically mark any areas not to be disturbed, such as limit of disturbance, wetlands, property lines, etc.

4. INSTALL PERIMETER EROSION AND SEDIMENT CONTROLS

    a. Sediment controls will be needed at the downstream perimeter during the clearing and grubbing for the pond wherever sediment may leave the site.

5. INSTALL TEMPORARY CHANNEL DIVERSION

    a. Divert clean water flow away from pond area
    b. Stabilize the diversion

6. CLEAR AND GRUB THE POND AREA

7. REMOVE TOPSOIL FROM THE POND AREA

    a. Stockpile the soil in an approved location
    b. Stabilize the stockpile area

8. FACILITY STAKEOUT

    a. Stakeout centerline of embankment, outside and inside toe of slopes

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9. CORE TRENCH/EMBANKMENT AREA

   a. Arrange to meet the site reviewer to discuss location of core trench
   b. If core trench is needed, determine where material will come from before trench is opened.
   c. Make arrangements for de-watering of the core trench if necessary
   d. Excavate for core trench
   e. Fill core trench with suitable material assuring proper compaction to existing ground elevation

10. CONSTRUCT OUTFALL CHANNEL

   a. Rock outlet protection with filter cloth
   b. Remaining channel constructed and stabilized

11. INSTALL BARREL WITH ANTI-SEEP COLLARS

   a. This should be done BEFORE any embankment work
   b. Prepare the bedding for the barrel
   c. Place barrel and anti-seep collars checking pipe grade
   d. Watertight pipe connections to be checked
   e. Backfill of barrel with particular attention to the compaction requirements. All structural backfill shall be completely free of rocks and other objectionable material

12. RISER PLACEMENT

   a. Check riser structure for conformance to specifications
   b. Check elevation of structure
   c. Set riser and pour concrete riser base

13. INSTALL ANY EROSION CONTROL STRUCTURES REQUIRED

14. CONSTRUCT REMAINING CORE AND EMBANKMENT

   a. Most impervious material placed in core of embankment
   b. Material should be checked and approved for suitability
   c. Compact the embankment according to specifications
   d. Check UNSETTLED elevation and top width of embankment
   e. Stabilize embankment

15. DIVERT FLOWS INTO PIPE SYSTEM

16. CONSTRUCT EMERGENCY SPILLWAY

   a. If earth spillway, construct in undisturbed ground
   b. Check elevation of control section and exit channel

17. INSTALL INFLOW CHANNELS

   a. Stabilize according to plan including pipe outfalls into pond

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18. COMPLETE EXCAVATION OF POND TO FINAL GRADE

19. VEGETATIVELY STABILIZE ALL DISTURBED AREAS

20. COMPLETE POND CONVERSION

    a. Requires approval of inspector to convert from sediment to stormwater control
    b. Properly de-water the pond in an approved manner
    c. Remove accumulated sediment and restore pond to design grade. Complete final stabilization
    d. Make any structural modifications to the riser for permanent function

A013871

APPENDIX 6-5

Construction Checklists for Infiltration Practices

Basins (Appendix 6-5A)
Trenches (Appendix 6-5B)
Dry Wells (Appendix 6-5C)
Paving (Appendix 6-5D)
Swales (Appendix 6-5E)

A013872

Infiltration Basin Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

1. Pre-construction

	Satisfactory	Unsatisfactory
Runoff diverted	_____	_____
Area stabilized	_____	_____

2. Excavation

Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____

3. Embankment

Cut-off trench	_____	_____
Fill material	_____	_____

4. Final Excavation

Drainage area stabilized	_____	_____
Sediment removed from facility	_____	_____
Basin floor tilled	_____	_____
Facility stabilized	_____	_____

5. Final Inspection

Pretreatment facility in place	_____	_____
Inlets/outlets	_____	_____
Site stabilization	_____	_____
Access to facility provided	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____
Correct noted site deficiencies by _____
1st notice _____
2nd notice _____
Submit plan modifications as noted in written comments by _____
Notice to Comply issued _____
Final inspection, project completed _____

A013873

Infiltration Trench Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Material		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Observation Well		
Pipe size	_____	_____
Removable cap/footplate	_____	_____
Initial depth = _____ ft.	_____	_____
6. Final Inspection		
Pretreatment facility in place	_____	_____
Stabilization	_____	_____
Outlet	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A013874

Infiltration Drywell Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Material		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Observation Well/roof leader		
Pipe size	_____	_____
Removable cap/footplate	_____	_____
Initial depth = _____ ft.	_____	_____
6. Final Inspection		
Pretreatment facility in place	_____	_____
Debris/gutter screens	_____	_____
Stabilization	_____	_____
Outlet	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

A013875

Infiltration Paving Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Base Course		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Aggregate Filter Course		
Size	_____	_____
Clean/washed material	_____	_____
Placed Properly	_____	_____
6. Porous Surface Course		
Proper temperature/compaction	_____	_____
7. Final Inspection		
Smooth Surface & Transition	_____	_____
Test section	_____	_____
Final stabilization	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____ Final inspection, project completed _____

A013876

Infiltration Swale Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

1. Pre-construction

	Satisfactory	Unsatisfactory
Runoff diverted		
Area stabilized		

2. Excavation

Size and location		
Side slope stable		
Soil Permeability		
Groundwater/Bedrock		

3. Check dams

Dimensions		
Compaction		

4. Final Inspection

Dimensions		
Check dams		
Proper outlet		
Effective stabilization		

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A013877

APPENDIX 6-6

Construction Checklist for Filtration Practices

A013878

Filtration Facility Construction Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Facility area cleared	_____	_____
Facility location staked out	_____	_____
2. Excavation		
Size and location	_____	_____
Side slopes stable	_____	_____
Foundation cleared of debris	_____	_____
Foundation area compacted	_____	_____
3. Structural Components		
Dimensions and materials	_____	_____
Forms adequately sized	_____	_____
Concrete meets standards	_____	_____
Prefabricated joints sealed	_____	_____
Underdrains (size, materials)	_____	_____
4. Completed Facility Components		
24 hour water filled test	_____	_____
Contributing area stabilized	_____	_____
Filter material per specification	_____	_____
Underdrains installed to grade	_____	_____
5. Final Inspection		
Dimensions	_____	_____
Structural Components	_____	_____
Proper outlet	_____	_____
Effective site stabilization	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A013879

APPENDIX 6-7

Construction Checklist for Biofiltration Practices

A013880

Biofiltration Construction Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Facility area cleared	_____	_____
Facility location staked out	_____	_____
Facility not in heavily shaded area	_____	_____
2. Excavation		
Size and location	_____	_____
Lateral slopes completely level	_____	_____
Longitudinal slopes within design range	_____	_____
3. Check dams and Level Spreaders		
Dimensions, spacing, and materials	_____	_____
Compaction	_____	_____
Level spreaders are completely level	_____	_____
4. Structural Components		
Inlets and outlets installed correctly	_____	_____
Flow bypasses installed correctly	_____	_____
Pretreatment devices installed	_____	_____
Curb cuts installed per plans	_____	_____
5. Vegetation		
Complies with planting specs.	_____	_____
Topsoil adequate in composition and placement	_____	_____
Adequate erosion control measures in place	_____	_____
4. Final Inspection		
Dimensions	_____	_____
Check dams and level spreaders	_____	_____
Proper outlet	_____	_____
Effective stand of vegetation and stabilization	_____	_____
Construction generated sediments removed	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A013881

APPENDICES FROM CHAPTER 7

Operation, Maintenance, and Management Inspection Forms for Stormwater Management Practices

A013882

APPENDIX 7-1

Operation, Maintenance, and Management Inspection Checklist for Ponds

A013883

Operation and Maintenance Inspection Report for Stormwater Management Ponds

(Adapted from Anne Arundel County, Maryland)

Inspector Name _____ Community _____
Inspection Date _____ Address _____
Stormwater Pond _____
Normal Pool _____ _____
Normally Dry _____ Watershed _____

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
I, Pond components						
A. Embankment and Emergency spillway					A,S	
1. Vegetation and ground Cover adequate						
2. Embankment erosion						
3. Animal burrows						
4. Unauthorized plantings						
5. Cracking, bulging, or sliding of dam a. Upstream face						
b. Downstream face						
c. At or beyond toe Upstream						
Downstream						
d. Emergency spillway						
6. Pond, toe & chimney drains clear and functioning						
7. Seeps/leaks on downstream face						
8. Slope protection or riprap failures						
9. Vertical and horizontal alignment of top of dam as per "As-Built" plans						
10. Emergency spillway clear of obstructions and debris						
11. Other (specify)						
B. Riser and principal spillway					A	
Type: Reinforced concrete ___ Corrugated pipe ___ Masonry ___						
1. Low flow orifice obstructed						
2. Low flow trash rack a. Debris removal necessary						
b. Corrosion control						
3. Weir trash rack maintenance a. Debris removal necessary						
b. Corrosion control						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

A013884

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
4. Excessive sediment accumulation inside riser						
5. Concrete/Masonry condition Riser and barrels a. Cracks or displacement						
b. Minor spalling (<1")						
c. Major spalling (rebars exposed)						
d. Joint failures						
e. Water tightness						
6. Metal pipe condition						
7. Control valve a. Operational/exercised						
b. Chained and locked						
8. Pond drain valve a. Operational/exercised						
b. Chained and locked						
9. Outfall channels functioning						
10. Other (specify)						
C. Permanent pool (wet ponds)					M	
1. Undesirable vegetative growth						
2. Floating or floatable debris removal required						
3. Visible pollution						
4. Shoreline problems						
5. Other (specify)						
D. Sediment forebays						
1. Sedimentation noted						
2. Sediment cleanout when depth < 50% design depth						
E. Dry pond areas					M	
1. Vegetation adequate						
2. Undesirable vegetative growth						
3. Undesirable woody vegetation						
4. Low flow channels clear of obstructions						
5. Standing water or wet spots						
6. Sediment and/or trash accumulation						
7. Other (specify)						
F. Condition of outfalls into pond					A,S	
1. Riprap failures						
2. Slope erosion						
3. Storm drain pipes						
4. Endwalls/headwalls						
5. Other (specify)						
G. Other					M	
1. Encroachments on pond or easement area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

A013885

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
2. Complaints from residents (describe on back)						
3. Aesthetics a. grass mowing required						
b. graffiti removal needed						
c. Other (specify)						
4. Any public hazards (specify)						
5. Maintenance access						
H. Constructed wetland areas					A	
1. Vegetation healthy and growing						
2. Evidence of invasive species						
3. Excessive sedimentation in wetland area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

II. Summary

1. Inspectors Remarks: _____

2. Overall condition of Facility (Check one)

_____ Acceptable

_____ Unacceptable

3. Dates any maintenance must be completed by:

_____

A013886

APPENDIX 7-2

Operation, Maintenance, and Management Inspection Checklists for Infiltration Practices:

Basins (Appendix 7-2A)
Trenches (Appendix 7-2B)
Dry Wells (Appendix 7-2C)
Paving (Appendix 7-2D)
Swales (Appendix 7-2E)

A013887

Infiltration Basin Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Basin bottom clear of debris		_____	_____
Inlet clear of debris		_____	_____
Outlet clear of debris		_____	_____
Emergency spillway clear of debris		_____	_____
2. Sediment traps or forebays	(Annual)		
Obviously trapping sediment		_____	_____
greater than 50% of storage volume remaining		_____	_____
3. Vegetation	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion			
4. Dewatering	(Monthly)		
Basin dewaters between storms		_____	_____
5. Sediment cleanout of basin	(Annual)		
No evidence of sedimentation in basin		_____	_____
Sediment accumulation does not yet require cleanout		_____	_____
6. Inlets	(Annual)		
Good condition		_____	_____
No evidence of erosion		_____	_____
7. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____
8. Structural repairs	(Annual, After Major Storm)		
Embankment in good repair		_____	_____
Side slopes are stable		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A013888

	Satisfactory	Unsatisfactory
9. Fences/access repairs (Annual)		
Fences in good condition	_____	_____
No damage which would allow undesired entry	_____	_____
Access point in good condition	_____	_____
Locks and gate function adequate	_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____

Signature of Inspector

A013889

Infiltration Trench Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Trench surface clear of debris		_____	_____
Inlet areas clear of debris		_____	_____
Inflow pipes clear of debris		_____	_____
Overflow spillway clear of debris		_____	_____
2. Sediment traps, forebays, or pretreatment swales	(Annual)		
Obviously trapping sediment		_____	_____
greater than 50% of storage volume remaining		_____	_____
3. Vegetation	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion			
4. Dewatering	(Monthly)		
Trench dewaters between storms		_____	_____
5. Sediment cleanout of trench	(Annual)		
No evidence of sedimentation in trench		_____	_____
Sediment accumulation does not yet require cleanout		_____	_____
6. Inlets	(Annual)		
Good condition		_____	_____
No evidence of erosion		_____	_____
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A013890

	Satisfactory	Unsatisfactory
8. Aggregate repairs (Annual)		
Surface of aggregate clean	_____	_____
Top layer of stone does not need replacement	_____	_____
Trench does not need rehabilitation	_____	_____
9. Vegetated surface (Monthly)		
No evidence of erosion	_____	_____
Perforated inlet functioning adequately	_____	_____
Water does not stand on vegetative surface	_____	_____
Good vegetative cover exists	_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____

Signature of Inspector

A013891

Infiltration Dry Well Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Roof drains and downspouts clean		_____	_____
2. Vegetation on top of dry well	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
3. Dewatering	(Monthly)		
Dry well dewaters between storms		_____	_____
4. Inlets	(Annual)		
Good condition of down spouts		_____	_____
No evidence of deterioration		_____	_____
Roof gutters drain correctly into dry well		_____	_____
5. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____

Signature of Inspector

A013892

Infiltration Paving Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris on infiltration paving parking area (Monthly)			
Paving area clean of debris		_____	_____
2. Vegetation (any buffer areas or pervious areas in drainage area)	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
3. Dewatering	(Monthly)		
Infiltration paving dewaters between storms		_____	_____
4. Sediments	(Monthly)		
Area clean of sediments		_____	_____
Area vacuum swept on a periodic basis		_____	_____
5. Structural condition	(Annual)		
No evidence of surface deterioration		_____	_____
No evidence of rutting or spalling		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____

Signature of Inspector

A013893

Infiltration Swale Well Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Swales and contributing areas clean of debris		_____	_____
2. Vegetation	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
Minimum mowing depth not exceeded		_____	_____
3. Dewatering	(Monthly)		
Swale dewaters between storms		_____	_____
4. Check dams or energy dissipators	(Annual, After Major Storm)		
No evidence of flow going around structures		_____	_____
No evidence of erosion at downstream toe		_____	_____
5. Sediment deposition	(Annual)		
Swale clean of sediments		_____	_____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____

Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____

Signature of Inspector

A013894

APPENDIX 7-3

Operation, Maintenance and Management Inspection Checklist for Filtration Practices

A013895

Filtration Facility Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Warning: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Contributing areas clean of debris		_____	_____
Filtration facility clean of debris		_____	_____
Inlets and outlets clear of debris		_____	_____
2. Vegetation	(Monthly)		
Contributing drainage area stabilized		_____	_____
No evidence of erosion		_____	_____
Area mowed and clippings removed			
3. Oil and grease	(Monthly)		
No evidence of filter surface clogging		_____	_____
Activities in drainage area minimize oil & grease entry		_____	_____
4. Water retention where required	(Monthly)		
Water holding chambers at normal pool		_____	_____
No evidence of leakage		_____	_____
5. Sediment deposition	(Annual)		
Filtration chamber clean of sediments		_____	_____
Water chambers not more than 1/2 full of sediments		_____	_____
6. Structural components	(Annual)		
No evidence of structural deterioration		_____	_____
Any grates are in good condition		_____	_____
No evidence of spalling or cracking of structural parts		_____	_____
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		_____	_____
No evidence of erosion (if draining into a natural channel)		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A013896

		Satisfactory	Unsatisfactory
8. Overall function of facility	(Annual)		
No evidence of flow bypassing facility		_____	_____
No noticeable odors outside of facility		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

A013897

APPENDIX 7-4

Operation, Maintenance and Management Inspection Checklist for Biofiltration Practices

A013898

Biofiltration Facility Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Biofilters and contributing areas clean of debris		_____	_____
No dumping of yard wastes into biofilter		_____	_____
Litter (branches, etc.) have been removed		_____	_____
2. Vegetation	(Monthly)		
Plant height not less than design water depth		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
Grass height not greater than 6 inches		_____	_____
Is plant composition according to approved plans		_____	_____
No placement of inappropriate plants		_____	_____
3. Dewatering	(Monthly)		
Biofilter dewaters between storms		_____	_____
No evidence of standing water		_____	_____
4. Check dams/energy dissipators/sumps	(Annual, After Major Storm)		
No evidence of sediment buildup		_____	_____
Sumps should not be more than 50% full of sediment		_____	_____
No evidence of erosion at downstream toe of drop structures		_____	_____
5. Sediment deposition	(Annual)		
Swale clean of sediments		_____	_____
Sediments should not be > than 20% of swale design depth		_____	_____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____
No evidence of any blockages		_____	_____
7. Integrity of biofilter	(Annual)		
Biofilter has not been blocked or filled inappropriately		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A013899

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

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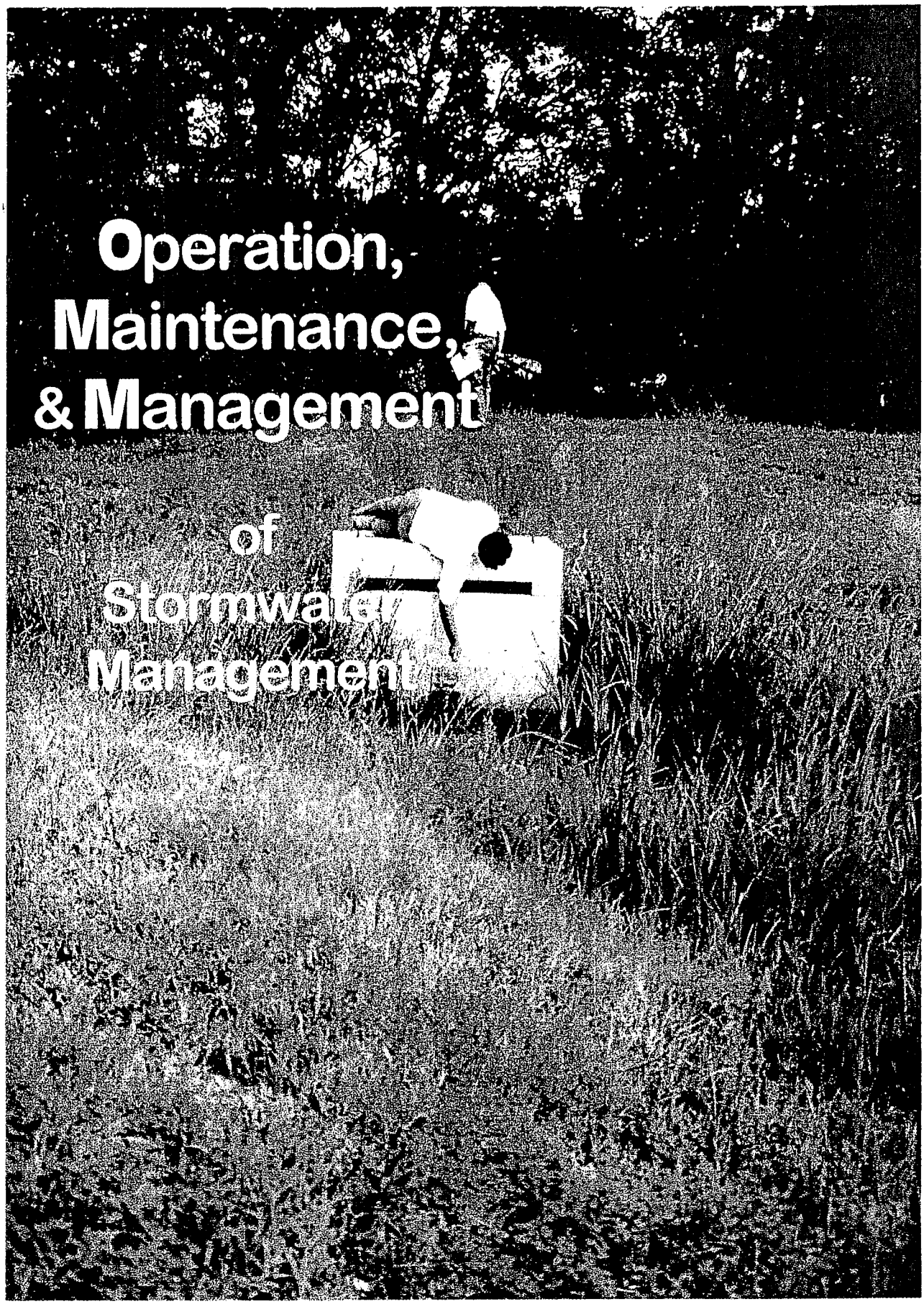
Operation, Maintenance, & Management of Stormwater Management



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Operation, Maintenance, and Management of Stormwater Management Systems

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Produced by the Watershed Management Institute, Inc.

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Chapter 1
Introduction

1. WHY IS STORMWATER SYSTEM OPERATION, MAINTENANCE, AND MANAGEMENT IMPORTANT?

Over the last two decades, stormwater management systems have evolved considerably from their traditional roles as conveyance devices that are only intended to transport stormwater runoff safely and efficiently from one location to another. Such conveyance systems have included bridges, culverts, ditches, and the ubiquitous piped storm drain (sewer). However, in response to growing concerns over nonpoint source (NPS) pollution, flooding, and erosion, a new type of stormwater system has been created. This type not only conveys runoff, but also manages it by deliberately modifying its flow rate, volume, and/or water quality. These stormwater management systems rely upon practices such as infiltration or retention areas, extended dry or wet detention, sand filters, vegetated swales, and constructed wetlands.

Whether designed for conveyance or management, all stormwater systems require proper design, construction, and maintenance to perform successfully. However, due to their more demanding duties and objectives, today's multipurpose stormwater practices have proven themselves to be inherently more complex than their more traditional conveyance counterparts. Accordingly, they require a much greater level of effort by those who design, construct, maintain, and operate them.

This is particularly true for stormwater management system maintenance and management. Maintenance has always been recognized as vital to the proper and prolonged performance of all stormwater systems. However, ***thorough and consistent maintenance is particularly crucial to the successful performance of stormwater treatment practices***, an importance that carries over to the entire stormwater management program they support. Reasons for this increased importance include:

- As noted above, stormwater management systems are inherently more complex than traditional runoff conveyances. Not only in their function or operation, but also in the number and types of materials used to construct them. This may even include natural materials such as aquatic vegetation and microorganisms. This increased complexity and variety demands a greater level of maintenance and management to assure safe and effective operation.

- Unlike drainage systems, many stormwater practices achieve their management goals through impoundment or storage of runoff instead of conveyance. This is accomplished through the use of dams, berms, tanks, or chambers. To successfully impound water, either temporarily (for example, in a dry detention or infiltration basin) or permanently (in a wet detention pond or constructed wetland), requires a greater degree of structural strength. Safely impounding stormwater requires more safeguards to avoid the possibly catastrophic downstream damage caused by structural failure and sudden release of the impounded water. These increased levels of strength and safety, which must be provided continually throughout the life of the stormwater management facility, demand a similarly higher level of maintenance.

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- Stormwater conveyances and flood control systems typically are designed to transport or impound the runoff from a relatively rare storm event, with a recurrence interval of 25 to 100-years. As such, they may experience maximum design conditions only a few times during their lifetime. However, ***stormwater management systems***, particularly those ***intended to treat runoff*** and reduce pollutants, typically are designed to capture smaller, more frequent rainfall/runoff events (e.g., half inch storm; 2-yr, 1-hr storm). Therefore, they **may experience maximum design conditions several times each year.** This more frequent and repetitive operation at their design limit creates more stress, which again demands greater attention and commitment to proper maintenance and management.

- ***Failure to perform adequate maintenance of stormwater management systems*** not only leads to reductions in expected or desired performance levels, but ***may even create conditions that are worse than if the facility had not been constructed*** at all. For example, a neglected dam may fail and release impounded water onto downstream properties, an eroding swale may be the source of excessive sediment, or a poorly managed constructed wetland may create harmful levels of nutrients or temperature.

Stormwater management has become an important part of our efforts to achieve clean water and a safe environment. However, as seen above, neglect of stormwater management systems not only poses a threat to those living downstream, but it can also undermine the entire stormwater management program that led to their creation. The importance of regular inspection and thorough stormwater system maintenance can not be understated. In fact, ***stormwater systems should not even be constructed if the stormwater program is not willing to make the necessary commitments to assure that the systems are properly maintained, managed, and operated.***

The objective of this handbook is to help assure that necessary maintenance and management of stormwater systems is performed. The handbook is aimed at a diverse audience - all of those individuals and groups which have been shown by both experience and research to play an important role in a successful stormwater management system maintenance program. This includes persons involved in developing and implementing stormwater management programs, stormwater system designers and builders, land developers and their consultants, stormwater system plan reviewers and inspectors, stormwater system owners and operators, public officials, and all citizens.

2. CHAPTER CONTENTS

The handbook is divided into eight additional chapters, each addressing an important aspect of stormwater system operation and maintenance:

Chapter 2 - Stormwater Management Practices ***presents an overview of several different types of commonly used stormwater management practices.*** These include infiltration or retention systems, wet and dry detention systems, constructed wetlands, vegetated swales, and filtration systems such as sand filters and biofiltration systems. For each type of practice, information is presented on its basic runoff quantity and quality control mechanisms, pollutant removal potentials, site and operating limitations, and operation and maintenance obligations. This presentation of ***basic information is intended to improve the understanding of the needs and limitations of each practice by those who design, regulate, construct, own, operate, or maintain them.*** All of these individuals pla

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a vital role in assuring proper maintenance and operation of the practice.

Chapter 3 - Planning and Design Considerations ***is addressed directly to stormwater management system planners and designers. Information is presented which demonstrates how proper planning and design can help to both minimize and facilitate system maintenance.*** The maintenance problems that can result from inadequate or inattentive planning or design are also highlighted. Additionally, planning and design guidelines to help achieve minimum maintenance goals are presented for each type of stormwater management practice described in Chapter 2. This information ***stresses the importance of simplicity, accessibility, and durability in designing stormwater management systems.***

Chapter 4 - Programmatic and Regulatory Aspects ***highlights the key role that program implementers play in achieving proper levels of stormwater management system maintenance and how their ignorance or indifference can lead to maintenance neglect and facility failure.*** Proper planning, design, and construction all contribute to a successful maintenance program. However, the key to success is ensuring that each of these activities gets done, a role for which program implementation staff are uniquely suited. To achieve this goal, ***implementation staff must become as involved in the maintenance of stormwater management systems as they are with the planning, design, and construction.*** Maintenance of stormwater systems can not simply be left for others to resolve. ***Guidance for establishing the proper institutional framework and standards is provided***, including essential program aspects such as mandatory operation and maintenance plans, designating responsible entities, operating permits, enforcement options, and maintenance default contingency plans.

Chapter 5 - Owner, Operator, and User Considerations ***provides each of these individuals and groups with important information regarding how their system works, why it is needed, and what maintenance it will require.*** It also explains in clear terms why it is in their best interest to provide thorough and consistent levels of system maintenance and how maintenance neglect on their part can lead to serious environmental, safety, and legal problems. The Chapter also provides suggestions for establishing a successful maintenance program and will discuss the environmental, financial, aesthetic, and civic rewards for doing so.

Chapter 6 - Construction Inspection ***highlights a vital but often overlooked aspect of successful stormwater management system maintenance.*** It is the inspectors who must complete the job started by the administrators, planners, and designers, and who must provide the owners, operators, and maintainers with a sound, durable facility that is worthy of their maintenance investment. ***The Chapter assists construction inspectors*** **by** ***providing detailed checklists of important inspection items during each stage of construction.*** It also emphasizes the importance of system construction scheduling, phasing, and coordination with other site activities and promotes close coordination and communication between inspectors, contractors, owners, designers, and reviewers. Finally, recommendations for establishing training and certification programs for inspectors are also provided, including a model program curriculum.

Chapter 7 - Post-Construction Inspection and Maintenance ***presents pertinent information to the final members of the overall maintenance team - those responsible for inspecting, scheduling, and performing the actual maintenance and management of stormwater management systems.*** This Chapter seeks to address a deficiency in many

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state and local stormwater management programs. It provides detailed information to both inspectors and owner/operators and emphasizes the importance of both groups to the success of the overall stormwater management program. ***Inspectors are provided with checklists détailing a comprehensive system inspection program***, including recommended inspection frequencies and a breakdown of inspection practices by system component. ***Owner/operators are presented with descriptions of typical maintenance tasks, including recommended equipment, techniques, materials, and frequencies.*** Finally, information on developing a training and certification program for those who perform system maintenance is also presented.

Chapter 8 - Maintenance Costs and Financing discusses an aspect of stormwater management system maintenance that is of interest to everyone from administrators to owners, and which is vital to the success of any stormwater management program. ***Summaries of expected or typical costs for various maintenance tasks, both regular and episodic, are presented.*** Estimated costs of materials and equipment also are provided. In addition, various means of financing these costs are discussed, with examples of various institutional programs highlighted.

Chapter 9 - Disposal of Sediments ***presents information on a new issue of concern*** that emphasizes both the complex nature of stormwater management systems and the need for a comprehensive maintenance program. Sedimentation is one of the primary mechanisms for pollutant removal in many stormwater management systems. As a result, the sediment collected in the facility may contain heavy metals, hydrocarbons, greases, nutrients, and other pollutants depending upon the character and use of the land draining to the system. ***Depending upon their concentrations and quantities, these pollutants may pose disposal problems for facility owners, operators, and maintainers.*** General recommendations for analyzing and properly disposing of these sediments are presented along with a discussion of potent' regulatory constraints.

As can be seen from the above review, stormwater management system maintenance is a broad and complex topic. It is hoped that this handbook attracts an equally broad and diverse group of readers. ***To assist readers find the information they seek quickly, each chapter in the handbook begins with a brief summary of its contents, including the goals of the Chapter and a list of its intended readers.*** This should allow the reader to quickly assess the contents of each Chapter and determine its applicability to his or her interests or needs. To further guide the reader, major topics within each chapter are presented under their own descriptive headings.

3. HANDBOOK BMP TERMINOLOGY

The field of stormwater management has grown considerably in the past two decades. This growth has produced, among many accomplishments, a long and sometimes conflicting list of names for various stormwater management practices. Unfortunately, these names can vary by state or region. This can confuse or mislead the experienced practitioner, not to mention the new reader. Therefore, in order to minimize such confusion and maximize the handbook's effectiveness, the following general definitions have been adopted for use in the handbook:

3.1. Detention Practice:

A stormwater management practice which temporarily impounds runoff and discharges it through an outlet structure. Any additional outflow through infiltration or evaporation is negligible and, therefore, not ordinarily cor

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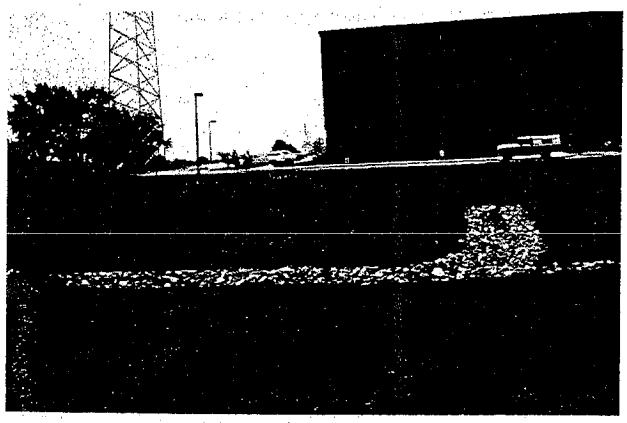
sidered in the facility's design. Detention practices may be either wet or dry. They often are divided into three categories:

A. Dry detention practices which detain runoff for a relatively short time (1 to 24 hours) and release it at a controlled rate until the system is once again dry.

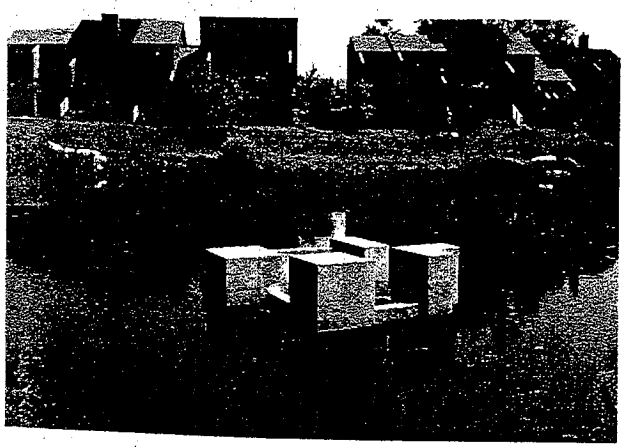
B. Extended dry detention practices which detain runoff for a longer time (24 to 48 hours), thereby increasing sedimentation and pollutant removal before the runoff is released at a controlled rate and the system is once again dry.

Extended Dry Detention System



C. Wet detention practices, or wet ponds, which have a permanent pool of water, detain and release runoff over five days or even longer, and allow sedimentation, flocculation, and chemical and biological processes to occur, reducing stormwater pollutants. During and immediately after storms, runoff is temporarily stored above the permanent water pool.

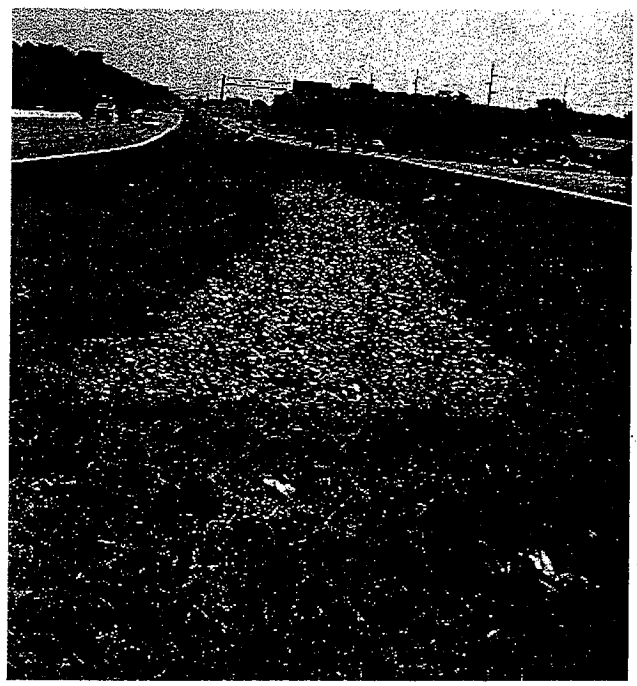
Wet Detention System (Pond)



3.2. Infiltration (Retention) Practices:

A stormwater management practice which temporarily impounds a specified amount of runoff (treatment volume), retains it on-site, and discharges it through percolation into the underlying soil and by evapotranspiration. On-line practices typically will have outlet structures to safely convey the flood control volume, and emergency overflows from extreme storm events. Infiltration practices are expected to be dry during non-rainfall periods. The retention practice tool box includes infiltration basins and trenches, swales, pervious pavements, dry wells, and seepage pits.

Infiltration Trench



3.3 Filtration Practices:

A stormwater management system which filters the runoff through a medium to remove pollutants, especially particulate pollutants.

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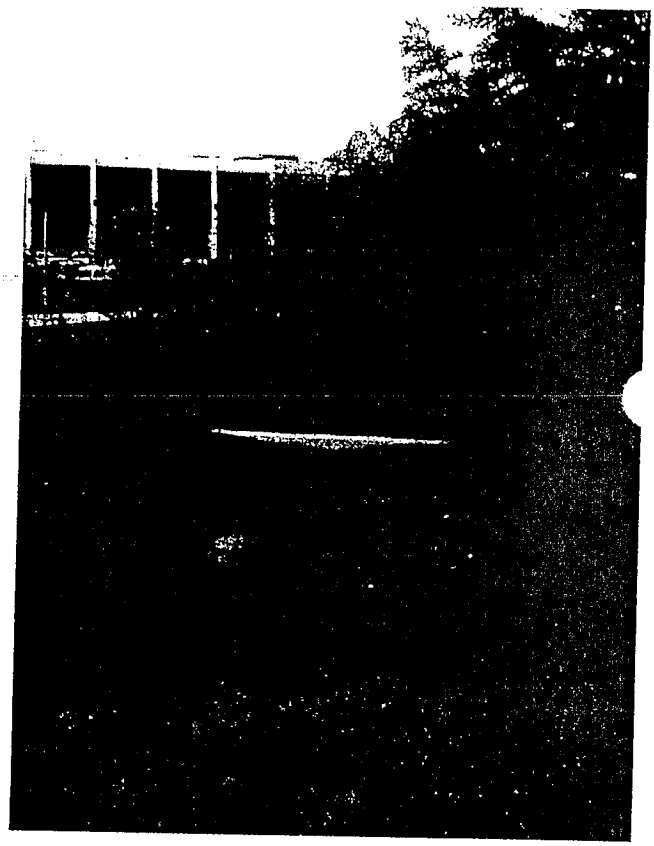
Sand Filtration Facility

Filter systems usually are used in combination with detention systems. Filter media include mixtures of sand, peat, and compost. Filters can be either confined (in boxes, bags, etc.) or unconfined. They can be designed as sidebank or vertical systems, meaning that the water flow is sideways or downward, respectively.

3.4 Biofiltration Practices:

A stormwater management system which incorporates vegetative filtration, allowing runoff to slowly pass through the vegetation ' reduce pollutants. In addition to vegetati. filtering, these systems may also promote the infiltration of runoff, depending on soil conditions. The organic nature of the soils and supporting vegetation helps reduce the potential for ground water contamination. Biofiltration practices include swales, buffer strips, and bioretention areas.

Swale with a swale block.



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Chapter 2
Stormwater Management Practices

1. OVERVIEW

State and local governments have implemented a wide variety of programs to address the stormwater problems resulting from changes to land use. Traditionally, these programs have focused on the prevention or minimization of flooding to protect the homes, buildings, property and lives of their citizens. "Drainage" ordinances and programs have been established in most communities. Today, however, existing ***stormwater programs must evolve and become more comprehensive to address stormwater management objectives which extend beyond the traditional drainage focus. Expanded program objectives now include: erosion and sediment control during construction, water quality protection, stormwater reuse, and open space and recreation.***

The tools or management practices that are used to prevent and mitigate these stormwater impacts also need to evolve. ***This chapter will review the stormwater management practices that are most commonly used for stormwater treatment. For each practice the pollutant removal mechanisms, expected performance, limitations on use, and operation, maintenance and management needs will be discussed and summarized.*** Additionally, for each practice, specific operation, maintenance, and management recommendations will be made.

1.1. Intended Readers

This chapter is intended for all readers of this publication. It's information will be useful to:

- **Persons involved in developing and implementing stormwater management programs.**
- **Stormwater system designers and builders.**
- **Land developers and their consultants.**
- **Stormwater system plan reviewers and inspectors.**
- **Stormwater system owners or operators.**
- **Public officials and citizens.**

2. STORMWATER MANAGEMENT PROGRAM CONSIDERATIONS

Before discussing stormwater practices, stormwater management program considerations will be briefly reviewed. ***Successful stormwater management requires more than simply the use of runoff control techniques. It also requires a strong institutional foundation.*** A key component of this foundation is establishing effective mechanisms to assure that stormwater systems not only are designed and constructed correctly, but that they also are inspected, maintained and operated properly.

2.1 Stormwater Program Components

This section briefly discusses the many components of a successful stormwater management program. No single framework for a stormwater management program can be recommended. Flexibility is needed to

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establish or refine programs, based on an area's existing legal authorities and institutional framework.

Experience has shown that no single entity can do everything. ***Program implementation typically will be shared by a partnership involving all appropriate levels of government, together with the public sector and all citizens. Cooperation and coordination among all of the partners involved in program implementation are cornerstones of successful programs.*** It is especially important that the roles of each partner involved in program implementation be clearly stated. This will help to avoid duplication and distribute program activities to the entity most suited for the role. This is especially true for assuring the long term performance of stormwater management practices.

Experience also has shown that successful stormwater management programs share several common building blocks (WMI, 1997). These involve the program's institutional framework, its technical foundations, and the many activities that are undertaken by the stormwater program (Figure 2-1).

2.2. Stormwater Program Evolution to Address Existing Development

Stormwater quality management programs typically must be phased in. They usually must be integrated with existing "drainage" programs to provide coordinated management of stormwater quantity and quality. ***Initial program efforts are aimed at preventing and mitigating stormwater problems from new development, both during and after construction.*** Generally, these programs rely upon on-site planning and BMP implementation. Once all aspects, including inspections and operation/maintenance, of this new development program are running smoothly, the program can be expanded to correct stormwater problems caused by existing development and land uses (retrofitting). Section 2.3 discuss important components of programs aimed at stormwater from new development.

Establishing a program to retrofit existing stormwater systems, however, presents many technical, institutional, financial, and cultural dilemmas. In many instances, the unavailability or high cost of land in urban areas makes the use of conventional BMPs infeasible. State laws and institutional arrangements promote piecemeal, crisis-solving approaches aimed at managing stormwater within political boundaries — yet stormwater follows watershed boundaries. Retrofitting often is prohibitively expensive. With many local governments already short of funds, the need for innovative, dedicated stormwater funding sources, such as stormwater utility fees, cannot be overemphasized. Finally, cultural change is needed to get citizens and businesses to embrace nonstructural BMPs and to support the stormwater program.

Solving existing stormwater problems will require comprehensive, coordinated, creative approaches and technology. Essential elements of a comprehensive, long-term effort to reduce pollutant loadings from existing land uses and older stormwater systems include:

A. Watershed Management

A watershed approach which integrates land use planning with the development of stormwater infrastructure is essential. After all, ***it is the intensification of land use and the increase in impervious surfaces within a watershed that creates the stormwater and water resources management problems.*** Consequently, a "watershed management team" effort is necessary which involves state, regional and local

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PROGRAM ACTIVITIES

Inspections
- Erosion/sediment controls
- Stormwater system construction
- Stormwater system operation

Stormwater system operation/maintenance
- Public facilities
- Private facilities
- Adopt a pond program

Plan review and approval
- Site plans
- Erosion control plans
- Stormwater plans

Education programs
- School curriculum
- General public
- Elected officials
- Designers
- Developers
- Builders
- Inspectors
- Practitioners

Structural BMPs
- Design criteria
- Research/performance
- Proper construction
- Proper operation
- Maintenance

Administration
- Lead agency?
- Separate agency?

Staffing
- Engineers
- Inspectors
- Planners
- Scientists
- Maintenance
- Clerical

Performance standards
- Peak discharge rate
- Volume
- Treatment

Compliance/enforcement
- Stop work orders
- Fines
- Civil or criminal

Nonstructural BMPs
- Site planning
- Source controls
- Street sweeping

Program evaluation
- Citizen surveys
- Bldg. community surveys
- BMP monitoring
- Water body monitoring

Stormwater retrofitting
- Watershed goal
- Targeting/prioritization
- Capital improvements
- Regional BMPs

Local land use plan **Stormwater master planning** **Watershed planning**

Integration with other federal, state and local programs

Adopt program laws/regulations **Adopt stormwater utility ordinance/fees**

Legal Authority | **Funding** | **Staffing** | **Public Support** | **Govt. Roles Responsibilities**

Cumulative Impacts | **Comprehensive** | **Continuity** | **Cooperation** | **Communication** | **Coordination** | **Creativity** | **Common Sense** | **Commitment**

Figure 2 -1. Cornerstones (the Big Cs), Building Blocks, and Activities of a Stormwater Management Program

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governments, together with the private sector and all citizens within a watershed.

B. Treatment Requirements for Older Systems (Retrofitting)

Numerous problems inherent to a highly urbanized area make it nearly impossible to apply the same stormwater design and performance standards that are applied to new developments. Instead, a "watershed loading" concept should be considered. This "big picture" approach considers the beneficial uses of the receiving waters, assesses the loadings from all pollution sources, and establishes the maximum loadings of pollutants that can be assimilated by those waters. A key element is setting a "stormwater pollutant load reduction goal" for existing untreated stormwater discharges. An ecologically based goal should be established, such as increasing the area of sea grasses or restoring habitat for desired aquatic species. It is important that the ecologically-based goal is understood by the public and determined with broad community participation.

Success in meeting the load reduction goal will depend not only on the treatment benefits from retrofitting projects, but also by assuring that the on-site systems serving new development are constructed, operated, and maintained properly. Even with BMPs, post-development stormwater pollution loadings are still greater than pre-development levels. Minimizing stormwater pollutant loadings from new developments is essential in assuring the success of stormwater retrofitting programs. Otherwise, the desired watershed pollutant loadings will be exceeded and the community's desired ecological goals will not be achieved.

C. Selective Targeting

The extremely high cost of retrofitting older urban stormwater systems makes it essential to carefully evaluate pollutant reduction goals, allocation strategies, and BMP implementation. ***States should establis priority watershed program which leaus to development and implementation of watershed management plans.*** Implementation of these long term (15-30 years) plans will be designed to protect or restore the beneficial uses of priority, targeted water bodies.

Within priority watersheds, sub-basins can be targeted based on pollution sources, flooding, and water quality problems. Regional and local stormwater master plans are an essential component of the watershed plan. In these local plans, existing stormwater systems can be targeted for modification to assure that citizens receive the greatest benefit (pollutant load reduction, flood protection) for the dollar. The upgrading of older systems also needs to be coordinated with other planned infrastructure improvements, such as road widenings, and with park, recreation, and urban redevelopme projects .

D. Alternative Controls

Nonstructural BMPs and source controls need to be used extensively to reduce stormwater pollution from already developed areas. For example, street sweepers remove lots of litter, debris, and sediments from paved surfaces even if they can't collect the smaller particles (<60 microns) which contain high concentrations of metals and other pollutants. Prohibiting and eliminating the discharge of wastewaters other than stormwater into storm sewers and other conveyances can also greatly reduce pollutant loadings. These types of controls are especially appropriate in downtown business districts, where other BMPs usually are infeasible, and in certain industrial situations.

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Storm drain stenciling.

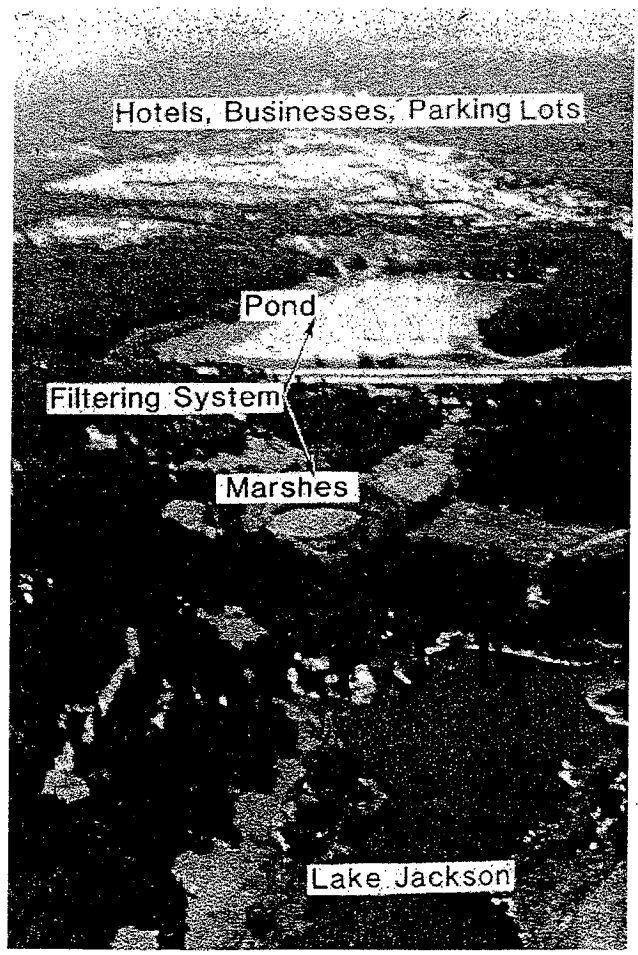
Education programs for the public and for stormwater management professionals also are vital. Citizens, businesses, and practitioners need to understand how their everyday activities contribute to stormwater pollution. For example, citizens should not discard leaves, grass clippings, used motor oil or other material into swales or storm sewers. Yet ***many people believe that storm "sewers" go to the wastewater treatment plant and not to the nearest water body.*** Getting youth and citizen groups involved in storm sewer stenciling projects (Dump No Wastes, Drains to Lake) is an excellent way of reducing dumping of potential pollutants into these conveyances. Equally important are comprehensive training and certification programs for those in the private and public sectors who design, review, construct, inspect, operate, or maintain stormwater management systems.

E. Funding

Even just to solve existing flooding problems, the national cost of improving stormwater infrastructure is gigantic. Yet, local governments already are struggling financially. ***Traditional revenue sources such as property taxes cannot be relied upon to pay for stormwater management.*** Alternative funding sources are needed. An excellent example is the stormwater utility - a dedicated source of revenue with fees based on a site's contribution to the stormwater problem.

F. Innovative BMPs

The infeasibility of using traditional BMPs to reduce stormwater pollutant loads in urban areas requires creative and innovative BMPs. ***Regional stormwater systems, which manage stormwater from several developments or an entire drainage basin, offer many advantages over the piecemeal approach that relies upon small, individual on-site systems.*** Regional systems can use natural processes, such as extended detention and constructed wetlands, or mechanical processes, such as alum injection,



Lake Jackson regional stormwater system, Tallahassee, Florida.

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to reduce stormwater pollutants. They provide economies of scale in construction, operation and maintenance. Regional systems are especially useful in managing stormwater from existing land uses. They need to be a central part of any retrofitting program. They can also be used to provide stormwater management for new development, but this requires excellent planning and an expenditure of funds by the local government or a developer to build the regional system and then get repaid by those who use it. Regional systems are most successful when a watershed approach is used that fully integrates land use, stormwater management, wetlands protection, parks, and recreation/open space.

Innovative practices which are not land intensive are urgently needed. Injecting chemical coagulating agents into storm sewers to enhance flocculation and sedimentation of stormwater pollutants is an example. This often may be a better BMP where land for traditional detention basins is unavailable or expensive. Several alum injection systems have been installed in urban areas in Florida to help restore receiving lakes. Concerns over potential aluminum toxicity, however, must still be addressed before this innovative BMP can be fully endorsed.

2.3. Stormwater BMPs and New Development

This section will briefly discuss some key issues of using BMPs to reduce the stormwater impacts associated with new development. These issues include the stormwater program's goals, the setting of performance standards, and the establishment of design criteria for specific BMPs.

2.3.1. Program Goals

The goals of a stormwater management program must be clearly established in front. Until recently, this was a relatively easy task since programs typically were established only to control stormwater peak discharge rates. This is why stormwater management frequently is referred to as "drainage" -- the traditional focus is on draining runoff away from developed property as quickly as possible.

A. Stormwater Quantity Goals

Today, even the goals of stormwater quantity management are changing and broadening. Control of stormwater volume, not just peak discharge rate, is being required in closed basins and for discharges to estuaries. Peak discharge rate control also is evolving - from control of a single frequency storm to multiple frequency storms. ***It is becoming common to control the peak discharge from a 1 or 2-year storm to minimize the erosion of stream channels, in addition to controlling the peak discharges for 10-, 25- and/or 100-year storms for flood control.*** Some stormwater management entities such as the Suwannee River Water Management District and the Florida Department of Transportation are requiring control of the "critical storm". This storm creates the biggest difference between pre-development and post-development peak discharge rate and/or volume.

B. Stormwater Quality Goals

The increasing awareness of stormwater quality problems by citizens and elected officials, along with Federal Clean Water Act requirements, is stimulating state and local governments to broaden the objectives of their stormwater programs. ***Today, stormwater management program goals include consideration of stormwater***

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quantity, stormwater quality, erosion prevention and sediment control, aesthetic values, stormwater reuse, and even open space and recreational benefits.

Stormwater quality programs need to be implemented within the framework of the federal Clean Water Act. It establishes two types of regulatory approaches to control pollutant discharges. ***Technology-based effluent limitations*** reflect the best controls available, considering their technical and economic achievability. ***Water quality-based effluent limitations*** reflect the water quality standards and allowable pollutant loadings set up by permit (U.S. EPA, 1994).

With respect to stormwater discharges, the latter approach possibly can be developed and implemented through a comprehensive monitoring approach. This not only involves traditional water chemistry monitoring, but also needs to includes sediment chemistry, and an assessment of physical habitat, stream bank erosion, biological community structure, and possibly even whole-effluent toxicity. These techniques are more appropriate than water column chemistry in assessing cumulative, intermittent stormwater impacts.

However, implementing a water quality-based effluent limit permit program for stormwater discharges is nearly impossible because of staffing and technical limitations. The many land use changes occurring in this country create tens of thousands of new stormwater discharges each year. Site-specific analyses to establish water quality-based effluent limitations for so many new discharges simply can't be done. Additionally, there is a sparsity of data on stormwater toxicity and ecological impacts. Therefore, ***nearly all stormwater quality permitting programs are technology-based.***

In 1987, the EPA issued guidance on the development of technology-based stormwater programs and the role of water quality criteria. The guidance recognizes that **Best Management Practices (BMPs)** are the primary mechanism for achieving water quality standards. ***BMPs are control techniques used for a given set of site conditions to achieve stormwater quality and quantity enhancement at a minimum cost*** (Wanielista and Yousef, 1986). The guidance also recommends that state programs should include the following iterative process:

1. Design of BMPs based on site-specific conditions, technical, institutional and economic feasibility, and the water quality standards of the receiving waters.
2. Monitoring to ensure that practices are correctly designed and applied.
3. Monitoring to determine the effectiveness of BMPs in meeting water quality standards and the appropriateness of water quality criteria in reasonably assuring protection of beneficial uses.
4. Adjustment of BMPs when water quality standards are not being protected to a designed level, or evaluation and possible adjustment of water quality standards.

The ultimate water quality goal of stormwater management programs is to protect or restore the beneficial uses of the receiving waters through the proper installation and operation of program-approved BMPs. If beneficial uses are not maintained or restored, additional BMPs need to be implemented and/or the design criteria for current BMPs should be modified to improve their performance.

2.3.2. Program Performance Standards

Whether for BMPs serving new development or for retrofitting, a performance standard must be established so that specific BMP

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design criteria can be developed. ***The performance standard establishes a technology-based effluent limitation for stormwater treatment systems.***

A. Stormwater Management Goals

Ideally, the basic goal for stormwater systems serving new development is to assure that the post-development peak discharge rate, volume, timing and pollutant load does not exceed pre-development levels. However, this goal usually is unattainable because our current BMPs, either alone or in combination, can not achieve this level of treatment and/or volume control, and because of the limitations imposed by variations in site conditions. This necessitates the establishment of performance standards that can be achieved through the implementation of BMPs.

B. Stormwater Treatment Performance Standards

The stormwater treatment programs in Florida, Delaware, and Maryland have established similar performance standards for stormwater systems serving new development. ***They require stormwater systems to achieve at least an 80% reduction in the annual average post-development pollutant loading of Total Suspended Solids (TSS) discharged to fishable/swimmable waters.*** This performance standard corresponds to secondary treatment levels, thereby helping to create greater equity between intermittent stormwater discharges and the treatment requirements for traditional point sources such as domestic and industrial wastewater discharges. Florida's program also sets a 95% removal level for stormwater discharges to sensitive waters such as potable supply waters, shellfish harvesting waters, and Outstanding Florida Waters.

2.3.3. BMP Design Criteria Factors

Once the performance standard is established, design criteria then need to be set for each of the various BMPs that are going to be used for stormwater management. ***This section will briefly review some of the factors that must be considered when setting BMP design criteria.*** The primary factors influencing BMP removal efficiency include rainfall characteristics; the volume of stormwater that is detained, infiltrated, or reused ("treatment volume"); the time needed to recover the treatment volume; the processes used to capture, filter, or assimilate stormwater pollutants; whether the system is on-line or off-line; and site conditions. By analyzing the factors below, an average annual pollutant removal efficiency can be calculated based on the annual mass of pollutants introduced and the annual mass removed.

A. Rainfall Characteristics

An analysis of long-term rainfall records needs to be undertaken to determine the statistical distribution of various rainfall characteristics such as storm intensity and duration, precipitation volume, number of storms, time between storms, etc. ***Unlike flood control, which focuses on large, infrequent storms, effective stormwater treatment generally relies on capturing and treating runoff from small, frequent events that carry the majority of pollutants.*** For example, in Florida, nearly 90% of a year's storm events produce one inch of rainfall or less, and 75% of the total annual volume of rain falls in storms of one inch or less (Wanielista, 1977). Also, the average time between storms is an important consideration in designing stormwater management practices (Wanielista et. al., 1991).

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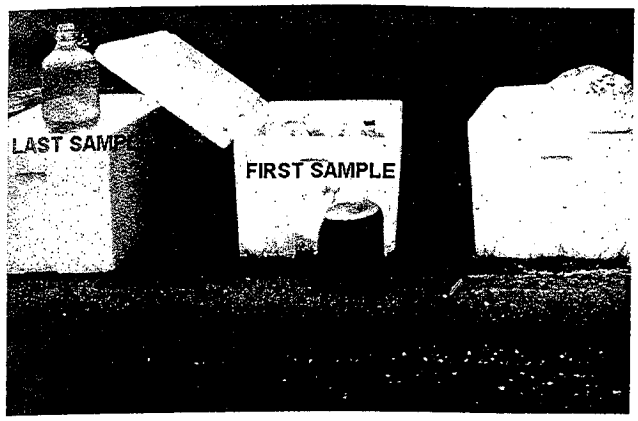


Example of first flush runoff from a parking lot.

B. "First Flush" Phenomenon

"First flush" describes the washing action that runoff may have on accumulated pollutants in the watershed. In the early stages of runoff, the land surfaces, especially impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This can result in higher concentrations of some stormwater pollutants, especially particulates, during the early part of the storm (Miller, 1985). However, ***the occurrence of "first flush" depends on many factors, including the pollutant, conveyance system, drainage area, percent imperviousness, rainfall patterns, and location.*** For example, in the Pacific northwest, which has frequent, long duration, low volume storms, first flush is much less pronounced. Where a target pollutant is associated with the first flush phenomenon, only this early fraction of the total storm runoff volume must be captured and treated to reach the desired treatment level.

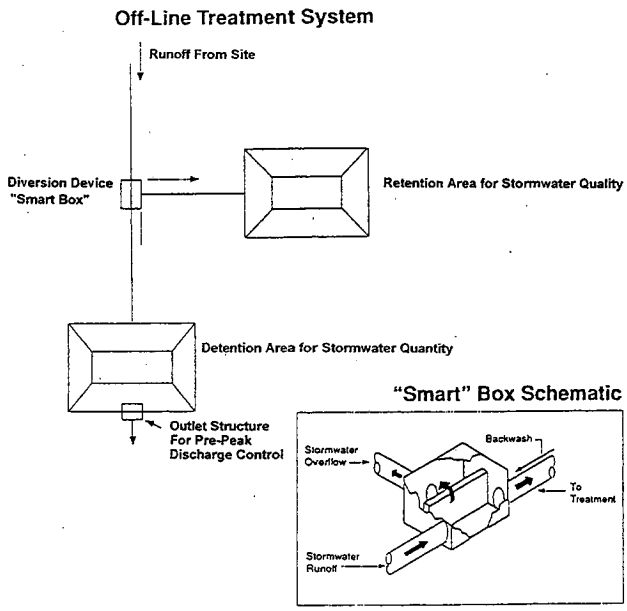
C. Land Use Pollutant Loadings

Stormwater pollutant sources, concentration peaks, and decay functions vary from site to site. Accordingly, ***the typical stormwater pollutant loading from any particular type of land use can vary greatly.*** Runoff from residential lands have lower concentrations and loadings of most pollutants when compared to stormwater from commercial land uses or highways. Runoff from streets and parking lots will have higher concentrations of heavy metals and other petroleum associated pollutants. Consequently, setting design criteria for stormwater BMPs must include evaluation of factors such as land use, the pollutants on site, and the characteristics of the drainage basin, such as the soil type, amount of imperviousness, type of stormwater conveyance system, and the length and time of travel.

D. On-line vs. off-line BMPs

On-line BMPs capture all of the runoff from a design storm, temporarily storing it before discharge. They primarily provide flood control benefits, with water quality benefits secondary. However, some on-line BMPs, such as wet detention systems, can do an excellent job of achieving both objectives.

Off-line BMPs divert the runoff "treatment volume" for treatment and isolate it from the remaining fraction of runoff, which must still be managed for flood control. This



SCHEMATIC OF AN OFF-LINE TREATMENT SYSTEM

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helps to improve treatment efficiency, reduce BMP maintenance, and make maintenance easier.

E. BMP Efficiency and Cost Data

During the past 15 years, many investigations of BMP effectiveness have been performed. Typical information generated often includes the pollutant removal effectiveness of various BMPs, and the costs of BMP construction and operation. A review of Florida BMP investigations (Wanielista and Shannon, 1977) revealed that ***the cost of treatment increases exponentially beyond "secondary treatment" (i.e., removal of 80% of the annual load).*** Therefore, higher levels of treatment are required in Florida only for stormwater discharges to the state's most sensitive water bodies.

F. Site evaluation

The soil types, slopes, geology, water table and other features of a site will greatly influence which BMPs will be most effective. Sandy soils imply using infiltration practices while natural low areas and high water tables offer opportunities for wet detention ponds or constructed wetlands.

3. STORMWATER POLLUTANTS AND REDUCTION MECHANISMS

The key to properly specifying, designing, and operating treatment practices is an awareness of the pollutants in stormwater and an understanding of the biological, chemical, and physical mechanisms that can be used to prevent them from proceeding into receiving waters. Table 2-1 lists the principal mechanisms that have potential to capture, hold, and transform the various classes of pollutants in urban runoff. The most common stormwater pollutants and amelioration mechanisms are summarized below:

1. **Sediment** is solid material that originates mostly from disintegrated rocks, eroded soil, or accumulated organic materials deposited on the land surface. The quantity, characteristics, and causes of the sediment are influenced by many factors including slope, slope length, soil characteristics, and land use, and traffic volume. Sediment particles vary greatly in size and density. ***The settleability of a particular sediment particle depends directly on it's size and density.*** Sediment size and density must be determined to know which BMPs are most appropriate to remove the particles and to build into the stormwater management system appropriate mechanisms to promote the settling of these particles. Some soils, because of their silty, colloidal nature, can almost never be settled once they get into suspension. These soils may require the use of coagulating agents, such as alum or ferric compounds, to remove them from the water. ***Of course, the most effective control method for sedimentation is erosion control—prevent the production of sediment as much as possible.***

2. **Oxygen-demanding substances** include numerous organic materials that are decomposed by microorganisms thereby creating a need for oxygen. Consequently, a stormwater system such as a detention pond must include mechanisms to maintain high oxygen levels and prevent the formation of anaerobic conditions. Oxygenation mechanisms can be natural (such as shallow depths, sufficient length and width to induce wind mixing, and orientation to maximize the opportunities for wind mixing) or mechanical (such as aerators).

3. **Heavy metals** in highway runoff originate from the operation of motor vehicles, atmospheric deposition, and the degradation of highway materials. The most abundant heavy metals in stormwater are lead, zinc and copper, which together account for about 90

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TABLE 2-1. Summary of Stormwater Pollutant Removal Mechanisms

MECHANISM	POLLUTANTS AFFECTED	REMOVAL PROMOTED BY
Physical sedimentation	Solids, BOD, pathogens, particulate COD, P, N, synthetic organics	Low turbulence, increased residence time
Filtration	Same as sedimentation	Fine dense herbaceous plants, constructed filters
Soil incorporation	All	Medium-fine texture
Chemical precipitation	Dissolved P, metals	High alkalinity
Adsorption	Dissolved P, metals, synthetic organics	High soil Al, Fe, organics, circumneutral pH (around 7)
Ion exchange	Dissolved metals	High soil cation exchange capacity
Oxidation	COD, petroleum hydrocarbons, synthetic organics	Aerobic conditions
Photolysis	Same as oxidation	High light
Volatilization	Volatile petroleum hydrocarbons, synthetic organics	High temperature and air movement
Biological microbial decomposition	BOD, COD, petroleum hydrocarbons, synthetic organics	High plant surface area and soil organics
Plant uptake and metabolism	P, N, metals	High plant surface area and activity
Natural die-off	Pathogens	Plant excretions, saline water
Nitrification	NH-3	Dissolved oxygen < 2 mg/l, low toxicants, temperature > 5-7 C, circumneutral pH
Denitrification	NO3 + NO2	Anaerobic, low toxicants, temperature > 15 C

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percent of the dissolved heavy metals and 90-98 percent of the total metal concentrations (Harper, 1985). ***Except for copper, zinc, and cadmium, the majority of metals are present in particulate form.*** Consequently, very good removal efficiencies (60-95%) can be obtained in properly designed stormwater management practices.

To maximize heavy metal removal in detention designs, designers should provide physical configurations which encourage a gradual reduction in flow velocity to promote particle sedimentation; maximize the flow length from inlets to the discharge point; prevent short circuiting of flows and hydraulically dead zones; and include suitable aquatic plants to promote uptake and removal of dissolved metal species. ***To keep metals bound to sediment, it is important that the sediment pH be kept near 7 and that the sediments be aerobic.*** A decrease in pH and, to lesser extent, a reduction in redox potential, will cause metals to become soluble and release from the sediment (Harper, 1985). For this reason, it is important to monitor the accumulation of sediment and decaying organic matter within detention ponds since this can result in lowered pH and possible anaerobic conditions. Failure to properly remove sediments could cause release of accumulated metals into the underlying ground water or into surface waters.

4. **Nutrients**, such as nitrogen and phosphorus, are common constituents of stormwater. They stimulate the growth of algae and other aquatic plants, and contribute to oxygen depletion as these plants decompose. Excessive nutrients accelerate the natural process of eutrophication in lakes and streams. ***Nutrients in stormwater may be either dissolved or particulate, with particulate forms slightly dominating (about 60%).*** Consequently, a stormwater management system, especially a wet detention system, must incorporate provisions for settling to remove particulate forms of nutrients and include nutrient assimilation for dissolved forms. A litto zone planted with suitable aquatic plants should be concentrated near the discharge point to provide nutrient assimilation. Biofiltration, swale conveyance, sediment sumps, or a perimeter swale and berm system can be used to reduce particulate nutrients.

5. **Increased temperature of stormwater** occurs because urban lands, especially impervious surfaces, are heated on warm days. Runoff stored in BMPs, especially shallow ponds, is also heated by the sun between storms. Proper selection of BMPs is the best way to minimize adverse thermal impacts from stormwater BMP discharges. Galli (1991) ranks the potential of BMPs to raise receiving water temperatures, from least to most serious, as: infiltration basins < extended detention wetlands < extended dry detention ponds < wet detention ponds. Other methods to lessen thermal impact include using wetland plants, or trees to help shade BMPs, especially pilot channels and outfall channels for extended dry detention ponds. The use of exposed riprap or concrete surfaces for these channels also can be minimized. BMPs also can be oriented to take advantage of prevailing winds, promoting water circulation and cooling.

6. **Increased stormwater volume** associated with the increased imperviousness which accompanies urbanization is now being recognized as a major cause of water body degradation. The increased volume of runoff causes channels and streams to flow at bank full levels more frequently resulting in streambank and bed erosion, and loss of habitat. Additionally, the discharge of greater volumes of runoff to estuaries has led to decreases in their salinity and shifts in biological communities. Reducing stormwater volume is not easy. Nonstructural BMPs to

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minimize imperviousness and reduce directly connected impervious area are the most effective. Structural BMPs which help to reduce stormwater volume include infiltration systems, many biofiltration systems, and wet detention stormwater reuse systems.

Although not specifically listed in Table 2-1, ***treatment time is an important factor in the functioning of all mechanisms.*** The effectiveness of settling a solid particle is directly related to the time provided to complete sedimentation at the characteristic settling velocity of the particle. Time is also a crucial variable in determining the degree to which chemical and biological mechanisms operate. Chemical reactions and biologically mediated processes all proceed at characteristic rates, which must be implicitly recognized to obtain their benefits in treatment. ***For all of these reasons, water residence time is the most basic variable for applying treatment practice technology effectively.***

An alternative way of looking at the information presented in Table 2-1 is to group features that promote certain specific pollutant control objectives. The following list extracts those features for the most common objectives:

Features That Help Achieve All Objectives

Increasing hydraulic residence time
Low turbulence
Fine, dense herbaceous plants
Medium-fine texture soil

Features That Help Achieve Specific Objectives

Phosphorus control:
- High soil exchangeable aluminum and/or iron content
- Addition of precipitating agents

Nitrogen control:
- Alternating aerobic and anaerobic conditions
- Low levels of toxicants
- Circumneutral pH (around 7)

Metals control:
- High soil organic content
- High soil cation exchange capacity
- Circumneutral pH

Organics control:
- Aerobic conditions
- High light
- High soil organic content
- Low levels of toxicants
- Circumneutral pH

The degree of control that the treatment system designer and operator can exert to influence the operation of these various features differs. Fortunately, at least three of the four features that promote all favorable mechanisms (possibly excluding the soil) are under a high degree of control. The additional features that promote the more specific objectives require more intervention (e.g., developing some desired soil condition).

4. STORMWATER MANAGEMENT PRACTICES (BMPs)

The stormwater management tool box contains many tools that can help prevent or correct stormwater problems. The broadening objectives of stormwater management is leading to the development of new tools and the refinement of some of our existing tools. The goals of a stormwater program usually will play a major role in deciding which tools will be selected and used.

Generally, the ***stormwater tool box can be separated into two main drawers: nonstructural controls and structural controls.***

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Generally, nonstructural controls are those that can help to prevent stormwater problems, while structural controls are used to mitigate stormwater problems. Until recently, most stormwater programs, because of their focus on flood control, have relied upon structural controls.

Nonstructural controls often are somewhat difficult to implement. Several of them require consideration and control of changes in property (i.e., growth management, land use planning, zoning) - often very controversial topics. ***Nonstructural controls also include "source controls", which are used to limit the types and amounts of potential pollutants that get into runoff.*** Many source controls involve modifying or controlling certain aspects of human behavior such as the use of fertilizers, pesticides or household cleaners. Doing so may be very difficult or highly controversial. However, source controls can be very effective, especially in highly urbanized areas, and less costly than structural controls. ***The dilemma for stormwater managers is the effectiveness of nonstructural controls is not well understood yet.***

With respect to structural controls, broadening of stormwater management goals often requires reconsideration of the usual BMP design, less emphasis and use of certain practices, changes in preferred alternatives, and greater emphasis on regular maintenance. For example:

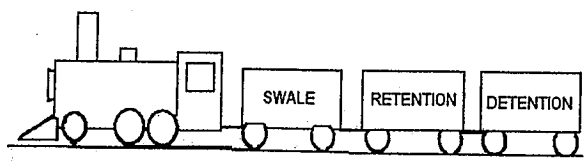
- To improve pollutant removal, detention pond design typically must be changed to increase residence time, maximize length of flow through the pond, and include shallow littoral zones planted with appropriate native wetland plants to help remove dissolved nutrients and metals.

- Less emphasis is placed on use of dry detention, which is used widely for flood control. However, dry detention systems provide very low pollutant removal benefits because of very short detention times, bottom discharge controls, a paved channels.

- In many locations, local codes require the use of street curbs and gutters with storm sewers to eliminate ponding of runoff, even for short periods of time. To promote infiltration, thereby decreasing runoff volume and improving pollutant removal, many localities are eliminating this requirement and promoting the use of roadside vegetated swales, especially in low or medium density residential areas.

- ***There is increasing emphasis on the "BMP treatment train" concept, wherein several types of stormwater controls are used together and integrated into a comprehensive stormwater management system.*** This is especially true where wet detention ponds are the primary control but are being promoted as a visual and recreational amenity on project. To help prevent the wet pond from turning into an algae-covered eyesore, swales can be used for conveyance instead of storm sewers, and vegetated littoral zones are added to assimilate nutrients. Increasingly, the use of small, off-line depressional storage areas is being integrated into site plans, usually as part of the site's required open space and landscaping. These can not only reduce pollutants but decrease the overall size

BMP TREATMENT TRAIN



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and cost of downstream stormwater system components.

4.1. BMP Selection

Effective operation and minimum maintenance of a stormwater system begins with selection of the most appropriate BMP(s) for the site. Factors which need to be evaluated include:

A. Watershed Area

Infiltration, biofiltration, and filter BMPs generally are more suitable for smaller areas. Pond BMPs typically require a larger drainage area to assure proper operation.

B. Area Required

Adequate area must be available at the site. Many BMPs are land intensive but some can be installed underground, although this increases maintenance difficulties and costs.

C. Stormwater pollutants

Most BMPs are more effective at removing particulate related pollutants. Some BMPs, primarily those with vegetative components, can also reduce dissolved constituents.

D. High Sediment Loading

Many BMPs are highly susceptible to clogging. Pretreatment (BMP Treatment Train) helps to increase effectiveness, reduce maintenance, and extend the life of BMPs.

E. Soil type

Soil permeability has a profound influence on BMP effectiveness, especially for infiltration practices. Also, silty and clayey soils that get into stormwater are much harder to settle than sandy ones.

F. Slope

Steep slopes can restrict the use of several BMPs, especially when water ponding or flow velocity may cause instability or erosion.

G. Water Table Elevation

A crucial factor in the design of all BMPs is water table elevation. Incorrectly estimating the seasonal high water table so it is too close to the bottom can cause BMP failure, decrease effectiveness, and increase maintenance. This is especially true for infiltration or dry detention systems. Wet ponds need high water tables to maintain their permanent pools.

H. Bedrock or Hardpan

Restrictive soil layers or rock can impede downward infiltration of runoff or make excavation for ponds impossible or expensive.

Solution pipe sinkhole in the bottom of an infiltration system.

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I. Karst Geology

Fractured limerock geology provides channels for stormwater pollutants to migrate into the ground water. Excavation or the hydraulic head of stored runoff may create sinkholes in the bottom of BMPs creating a direct discharge to ground water.

J. Proximity to Foundations, Septic Tanks, and Wells

BMPs should not be located close to building foundations, septic tanks, or drinking wells. Seepage problems or ground water pollution can result, especially from infiltration practices.

K. Receiving Water

If the stormwater discharge will be to an estuary or other saline habitat, BMPs which reduce stormwater volume need to be considered first. If the discharge is to a water body which supports a cold water fishery or biological community, the potential thermal impacts must be considered in the selection of the most appropriate stormwater BMPs.

L. Water Availability

Water may be needed during the dry season to keep grass or other vegetation alive and continuing to function as a filtering media.

M. Side Effects and Ancillary Benefits

Potential for mosquito breeding or ground water contamination need to be considered, as do opportunities for wildlife use and passive recreation.

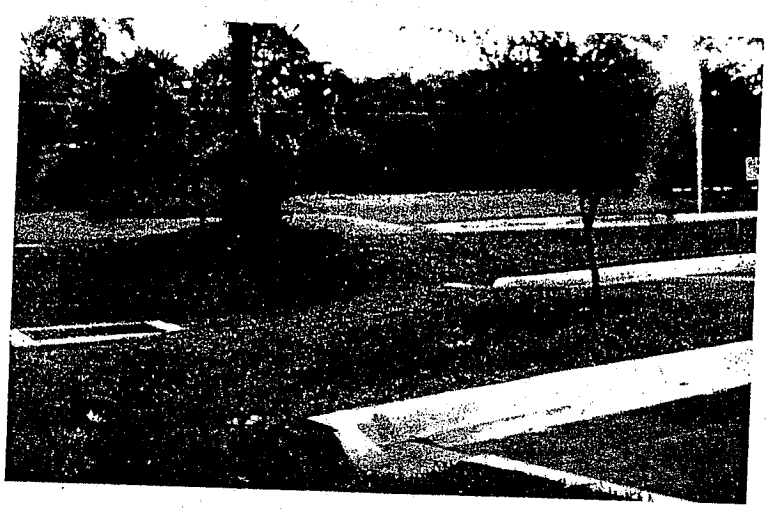
N. Public Acceptance

No stormwater system will be maintained if the property owner does not like or approve of its design or the types of BMP used.

4.2. BMP Fact Sheets

The remainder of this chapter consists of a series of fact sheets on each of the major types of stormwater management practices used to treat runoff. They are presented in the following order:

- Infiltration Practices
  - Infiltration Basin
  - Infiltration Trench
  - Exfiltration Trench
  - Pervious Pavement
  - Modular Pavement
- Detention Practices
  - Dry Detention Basin
  - Extended Dry Detention Basin
  - Wet Detention Basin
- Biofiltration Practices
- Constructed Wetlands
- Filtration Practices



BMP Treatment Train. Runoff is routed off the parking lot through curb cuts, into a swale which conveys stormwater to a raised inlet. A storm sewer transports the runoff to a wet detention pond, all in a landscaped setting. Remember "BMP" does not stand for Big Muddy Pond!

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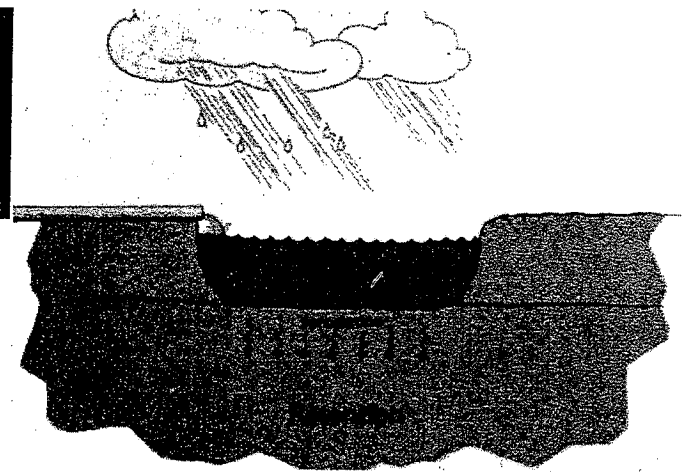
Infiltration Practices



Description

A family of practices in which the "treatment volume" is infiltrated into the soil rather than discharged off-site. Infiltration practices include basins, trenches, dry wells, pervious pavement, and, to a certain extent, swales, which will be considered a biofiltration practice in this handbook.

Purpose

Infiltration practices are used for two primary purposes: reducing the total volume of stormwater runoff, and reducing the stormwater pollutant loading discharged off-site.

Pollutant Removal Mechanisms

The primary "treatment" mechanism is the infiltration and evaporation of runoff. This reduces the total volume of stormwater leaving the site, thereby reducing the total pollutant loading. Ancillary benefits of reducing stormwater volume include a decrease in stream channel erosion and loss of stream habitat.

Pollutant removal occurs as runoff passes through the soil profile and/or the vegetation root mass. Pollutants are trapped, bound, or decomposed in the vegetation, its roots, and in the pore spaces between the soil particles, while runoff passes into the ground. Soils must have an appropriate infiltration rate, contain sufficient organic matter, and maintain aerobic conditions to minimize migration of pollutants into the ground water.

Expected Stormwater Quantity and Quality Performance

Infiltration BMPs are highly effective in reducing total stormwater volume. This helps to reduce peak discharge rates, downstream channel erosion, and downstream water elevations. The infiltrated water also help to preserve stream base flow.

Stormwater treatment effectiveness depends primarily on whether the infiltration practice is on-line or off-line, and on the sizing criteria used to design the facility. When designed as off-line BMPs, infiltration practices remove 100% of the stormwater pollutant loading for all of the runoff which is infiltrated. Total annual pollutant load reduction depends on the volume of annual runoff which is diverted into the BMP and infiltrated into the ground.

On-line infiltration systems will have lower treatment efficiencies than off-line systems.

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Expected annual average pollutant removal efficiencies of on-line systems are :

Total Suspended Solids	75%	Total lead	50%
Total Phosphorus	50%	Total zinc	65%
Total Nitrogen	40%, but highly variable	Total copper	25%
COD	40%		

Limitations on Use

- Require porous soils, such as sands and gravels, to allow infiltration of runoff within desired time.
- Not suitable if soils have 30 percent or greater clay content or 40 percent or greater silt/clay content.
- Not suitable in areas with high water tables, shallow depth to highly impervious strata such as bedrock or clay soils.
- Not suitable on fill sites or steep slopes.
- Risk of ground water contamination, especially in coarse sandy soils and karst geology.
- May not be appropriate at sites where spills of hazardous materials may occur.

Operation, Maintenance, and Management Needs and Obligations

Retention basin with soggy bottom because it doesn't infiltrate the runoff within the design time.

■ Operation

Infiltration practices all depend on the ability of stormwater to pass through the vegetation and soil into the groun Therefore, long term operation of the practice depends on maintaining its permeability.

The primary causes of infiltration system failure include:

- inadequate soil investigation,resulting in poorly designed systems that do not percolate.
- inaccurate estimation of the soil infiltration rate at the bottom of the proposed facility.
- premature use of facility before contributing area is stabilized.
- improper construction, resulting in soil compaction or sedimentation.
- high sediment loadings or a lack of maintenance, leading to clogging.

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■ Maintenance

The frequency and need for maintenance will depend primarily on the loading of particulates and whether pretreatment practices have been used. Maintenance activities will include:

- Removal of accumulated solids.
- Mowing and removal of vegetation.
- Vegetative stabilization of eroding sides or bottom.
- Rototilling, disking, or aerating the bottom or bottom vegetation.
- Clearing materials that have accumulated in the discharge structure.
- Cleaning pretreatment BMPs (i.e., swales, sediment sumps) so they can continue to protect the infiltration practice.

■ Management Needs and Obligations

- Inspect the facility semiannually (just before the wet season and at the end of it) and after large storms. If there is still water in the BMP after 72 hours (or after 24-36 hours for vegetated systems), it is time to clean it and restore its percolation capacity. Cleanout frequency will depend on whether the practice is on-line or off-line, vegetated or not vegetated, its design storage capacity, sediment loading, and use of pretreatment BMPs.
- Eroding sides or bottoms need to be revegetated as soon as possible.
- Revegetate the contributing area where needed to stabilize and reduce generation of particulates.

Recommendations to Assure Proper Operation, Maintenance and Performance

1. One of the most difficult aspects of designing infiltration practices, and the key to proper operation, is obtaining reliable information about the actual infiltration rate of the soil where the BMP will be constructed. To determine the infiltration rate, recommendations include:
   - Use a conservative estimate and a safety factor.
   - Measure infiltration rates at the actual location where the BMP is to be sited.
   - Since soil characteristics, including infiltration rate, change with depth, it is crucial that the measurements be made at the depth of the design elevation of the bottom of the practice.
   - Infiltration rates should be determined by mass balance field tests, if possible. If field tests are not possible, then infiltrometer tests should be used. Lab permeability tests are a third option. In either of these latter two tests, the design infiltration rate should be half of the lowest measured rate.

2. To minimize the potential for ground water contamination, be sure that the bottom of the infiltration practice is at least four feet above the seasonal high ground water elevation. Be sure to include consideration of ground water mounding.

3. Do not use infiltration practices for erosion and sediment control during construction.

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4. Do not place infiltration systems into operation until their contributing drainage area is completely stabilized.

5. Use pretreatment practices such as swale conveyances and sediment sumps to reduce sediment loading and potential clogging.

6. Underground systems must include pretreatment BMPs and an observation well to allow easy determination of whether runoff is percolating within the design time.

7. Include a maintenance access that lets O&M activities get done without moving heavy equipment onto the infiltration area.

8. Bedrock should be at least four feet beneath the bottom of the practice. In those parts of the country with fractured bedrock or where limestone is at or near the land surface, special precautions must be taken to prevent ground water contamination. This is especially true in "Karst Sensitive Areas" where sinkhole formation is prevalent. In these types of areas, a site specific hydrogeological investigation needs to be undertaken including geologic borings wherever infiltration practices are proposed. Infiltration practices in these areas should include several small off-site areas, swale conveyance for pretreatment, be as shallow as possible, be vegetated with permanent cover such as sodded grasses, and have flat bottoms to keep the runoff spread out across the entire infiltration area.

Retention basin built in area of Karst geology.

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8. Construction Recommendations: To protect the natural infiltration rate and minimize potential clogging, special precautions need to be taken during construction including:

- If possible, schedule construction so it does not occur during the rainy season and does occur during the vegetative growing season.
- Infiltration areas should be well marked in the field and heavy equipment and sediment kept away from them.
- Construction should be overseen by someone who is trained and experienced in the installation of infiltration practices and who is knowledgeable about their purpose and operation.
- The design team should inspect the exposed soil after excavation to confirm that soil conditions are as expected and are suitable. If they are not, work should stop and the situation should be analyzed to determine whether or not design or construction changes are necessary to ensure success.
- If possible, build the facility without driving heavy equipment over the infiltration surface as this will compact the soil and reduce the infiltration rate. Any equipment driven on the surface should have extra wide, low pressure tires.
- During construction, place excavated material at least 10-15 feet away from the infiltration area.

Sediment from construction activities can quickly clog an infiltration basin.

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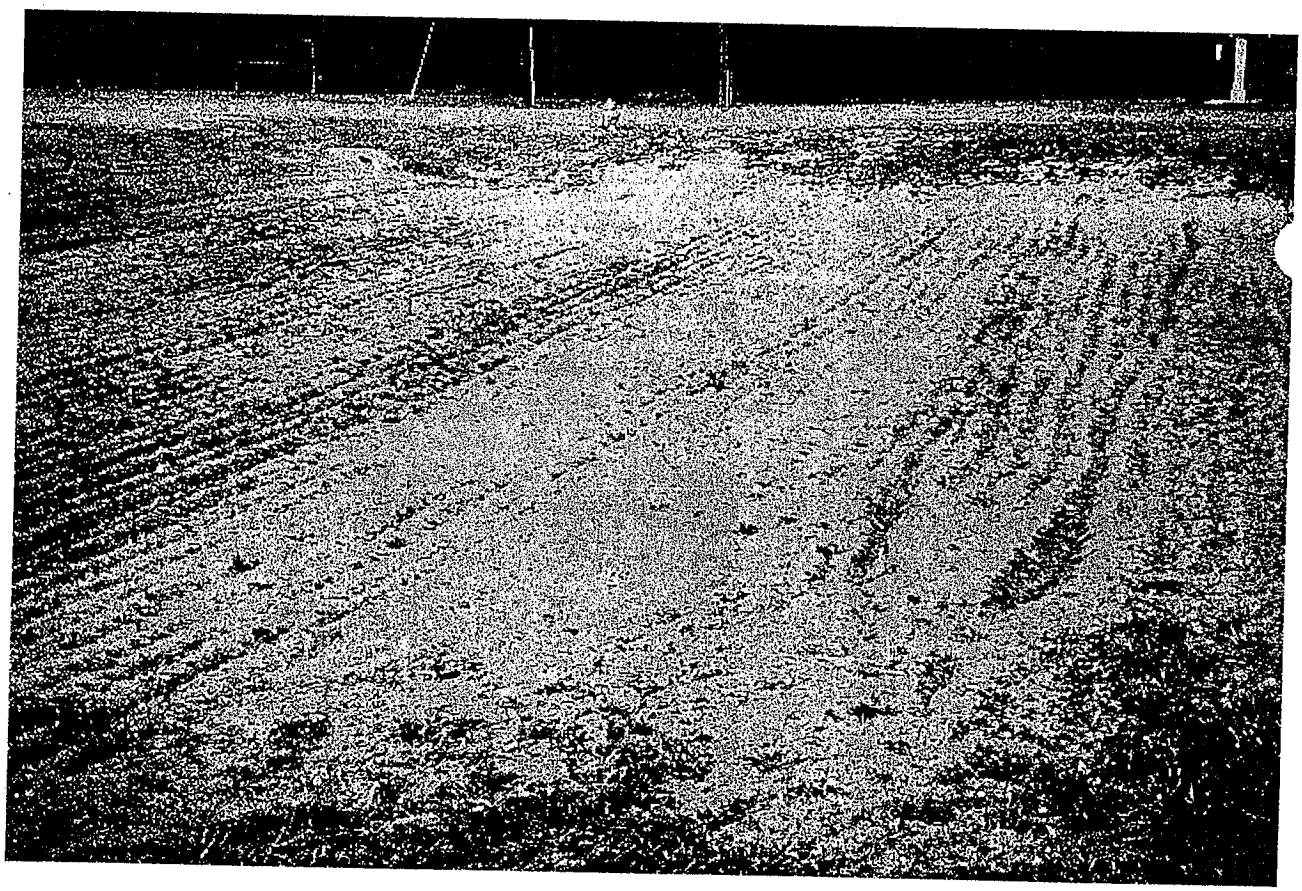
- Construction of the infiltration practice should not begin until after the site has been completely stabilized. If this is not possible, then:
  - Diversion berms should be placed around the perimeter of infiltration areas to divert runoff and sediment away from them during the construction phase of a project.
  - The facility should not be excavated to final grade until after the contributing drainage area is stabilized. Leave one foot of native soil which can be removed in layers as it clogs while construction is occurring.
  - Excavate infiltration areas using light equipment and construction procedures which minimize compaction.
- After final grading, the infiltration surface area should be deeply tilled to provide a well aerated, highly porous surface texture.



A retention basin which has been recently tilled to help restore its infiltration capabilities.

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Infiltration Basin

Description

A surface area used to temporarily store runoff for a selected design storm or specified treatment volume. Storage volume is recovered when the runoff percolates into the soil or evapotranspires. Infiltration basins may be made by either excavating soil or by building an embankment.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the vegetation, roots, and soil profile.

Advantages

- Can be integrated into a site's open space and landscaping helping to increase aesthetics.
- Area can be used for ancillary purpose, such as recreation, between storms.
- Surface systems are more easily inspected and maintained.

Disadvantages

Land needed for the basin can be expensive and prevents this area from being used for other development related purposes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the basin's floor and side slopes. To minimize the potential for ground water contamination, and to naturally help maintain percolation rates, vegetation such as grasses should be planted and maintained on the basin floor and side slopes.

■ Maintenance

Activities necessary to maintain the basin's function include:

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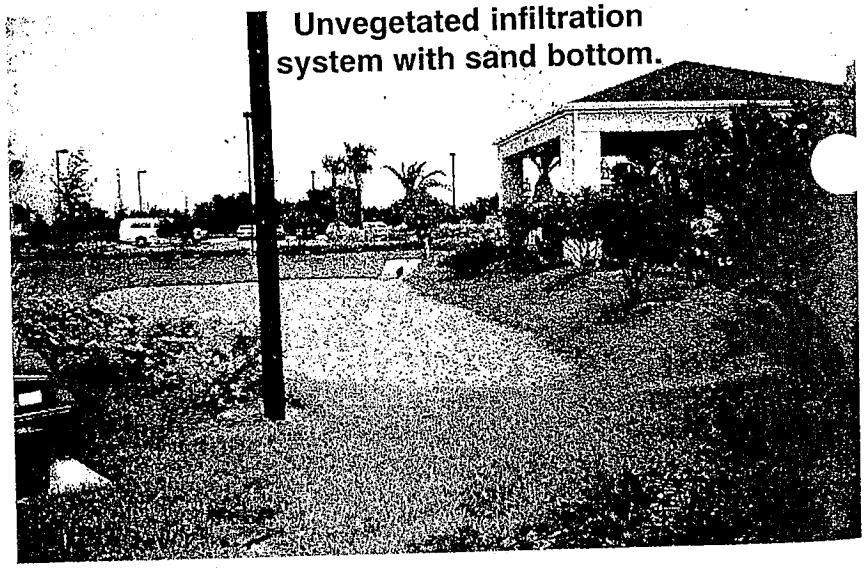
- Removal of accumulated solids. Ideally, these are trapped in a pretreatment settling forebay to minimize the need to disturb the basin's vegetation. In non-vegetated basins, sediments should be removed from the basin when its floor is dry and after the accumulated sediments have cracked and separated from the bottom. Hand raking and removal is recommended, if possible, to minimize compaction. In vegetated basins, the grass often will grow up through sediment deposits unless they are extremely heavy.

Infiltration system vegetated with grass.

- Mowing and removal of vegetation. The use of low growing grasses is recommended to minimize mowing frequency.

- Fertilizers should only be used if absolutely necessary.



Unvegetated infiltration system with sand bottom.

- Vegetative stabilization of eroding sides or bottom.

- In vegetated basins, the grassed floor should be aerated annually.

- Rototilling or disking the bottom in non-vegetated basins. Tilling is required periodically (at least once annually and perhaps more often) to help restore the natural infiltration capacity. All accumulated sediment must be removed first. Light tractors with rotary tillers or disc harrows can be used, followed by use of a levelling drag. After tilling, the basin floor should be level, smooth, and free of ridges and furrows to ease future removal of sediments. In northern climates, the basin surface may be very porous in the spring due to the effects of freeze and thaw. Infiltration capacity will diminish rapidly afterwards so tilling should be scheduled for late spring or early summer to help restore percolation.

- Clearing materials that have accumulated in the discharge structure.

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- Management Needs and Obligations

Inspect semiannually and after large storms to assure proper percolation, prevent erosion, measure sediment accumulations, and assure proper vegetation growth. Signs that the basin is not infiltrating as designed include a "soggy" bottom, death of grass cover, or invasion by cattails or other wetland type vegetation. A simple "staff gage" made from a one inch pipe driven into the ground can be used to measure sediment depths.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. See recommendations for "Infiltration Practices".

2. Use energy dissipation at inlet to minimize erosion.

3. Side slopes of at least 3:1 for safety, and for ease of mowing, although 4:1 is optimal.

4. Provide dedicated access to the basin bottom for maintenance vehicles.

5. <u>Construction recommendations:</u>

   - Follow all of the construction recommendations under "Infiltration Practices".

   - To maximize opportunities for infiltration, it is crucial that the basin's floor be evenly graded with a zero slope. If the bottom is uneven, these low spots will remain under water too long and may become chronically wet.

   - Since some compaction will occur during excavation and construction, deeply till the bottom of the infiltration surface after final grading or excavation.

   - Stabilize with vegetation within one week after construction. Vegetation not only helps to prevent erosion, provide filtration and uptake stormwater pollutants, but the roots help to naturally maintain the soil's infiltration rate. The condition of the newly established vegetation should be checked several times during the first few months. Remedial actions such as reseeding, sodding, fertilization, or irrigation should be taken whenever necessary.

Clogged infiltration basin. Standing water creates an aesthetic and mosquito problem.

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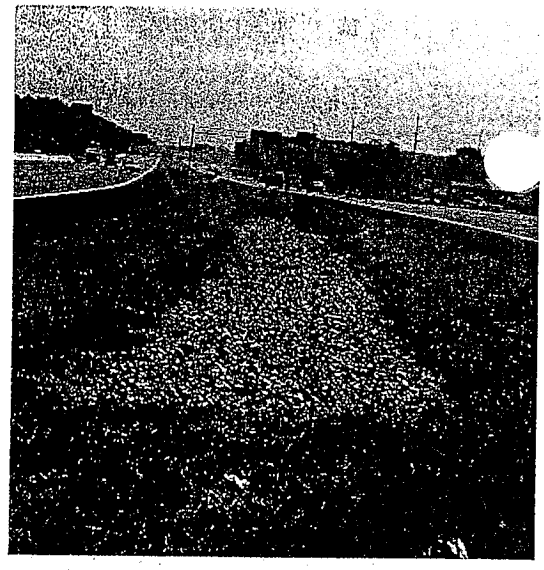
Infiltration Trench



Description

A shallow excavated trench, usually two to ten feet deep, backfilled with a coarse stone aggregate, allowing for temporary storage of runoff in the voids between the aggregate material. Trenches can be located on the surface or below the ground. Surface trenches receive sheet flow runoff directly from adjacent area, usually after the runoff flows over a grass buffer. Underground trenches receive runoff from storm sewers and must have pretreatment inlets.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the soil profile.

Advantages

- Require less land area than do surface basins.
- One of the few BMPs that can be used when land area is limited and can be fit into highway medians, site perimeters, and other unused areas of a site.

Disadvantages

- Difficult to monitor their continued performance, especially if observation wells are not included.
- Can become clogged fairly easily and very difficult to unclog, especially underground trenches.

Operation, Maintenance, and Management Needs and Obligations

- Operation

Successful operation depends on maintaining the percolation rate of the trench's sides and bottom. The keys to assuring successful long term performance are accurate estimation of the percolation rate, proper construction, pretreatment, off-line design, and maintenance accessibility.

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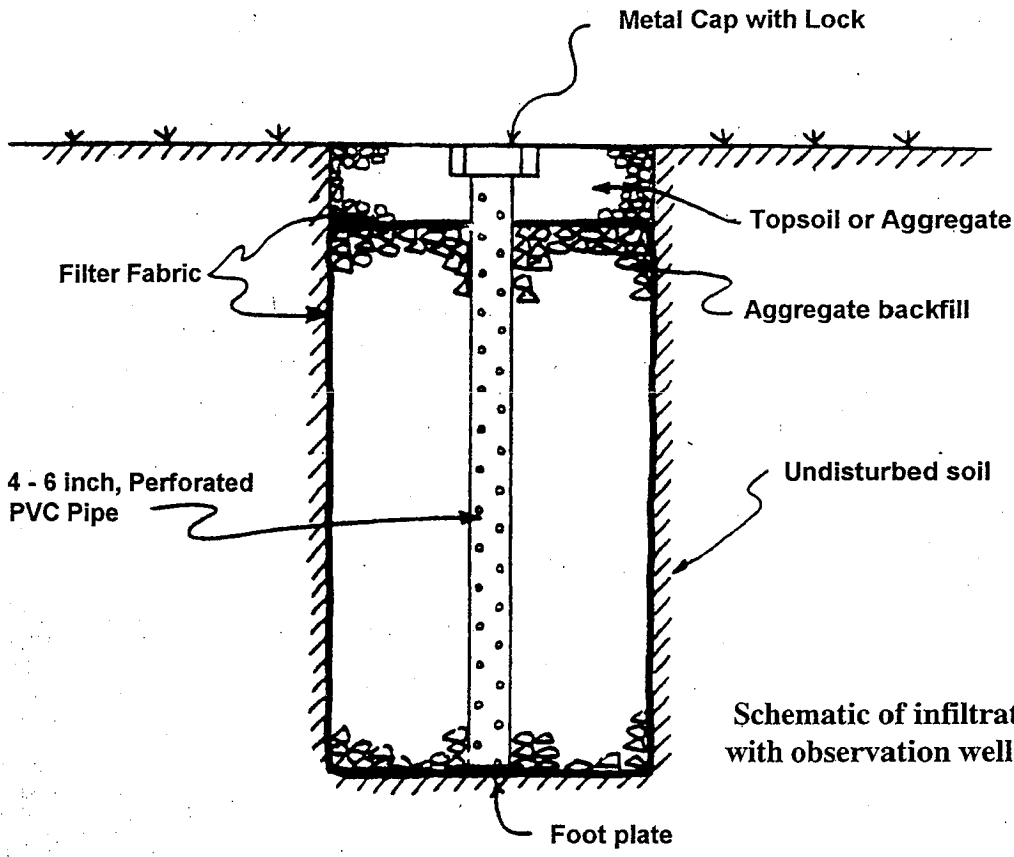
■ Maintenance

Activities necessary to maintain the trench's function include:

- Regular removal of accumulated solids from the pretreatment BMPs to prevent them from moving into the trench.
- Removing sediment buildup in the stone aggregate. This can involve monitoring and removal of sediments within the top foot of aggregate or allowing sediments to penetrate deeper into the trench necessitating removal and replacement of much of the stone aggregate. The former option is preferred.



Schematic of infiltration trench with observation well.

■ Management Needs and Obligations

The observation well needs to be monitored periodically. For the first year after construction, the well and pretreatment BMP should be monitored monthly after a storm during the rainy season and quarterly in the dry season. A log book should be maintained by the responsible maintenance entity and include information such as the date, water level, date of last rainfall, and calculation of the drawdown time. Once the trench's performance characteristics have been documented, the monitoring schedule can be reduced until the performance data indicates a reduction in percolation rate.

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Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Accurately estimating the trench's infiltration rate is crucial to successful operation. Whether infiltration primarily occurs through the trench bottom or sides will depend on the elevation of the water table and soil properties.

2. To minimize the potential for ground water contamination, the bottom of the trench should be at least four feet above the seasonal high ground water elevation. Don't forget to include consideration of ground water mounding when setting the elevation of the trench bottom.

3. Pretreatment is essential to minimize sediment and organic matter loading thereby reducing the potential for the stone filled trench to become clogged.

4. A 4 or 6 inch diameter observation well with locking cap must be included to allow evaluation of performance and the infiltration rate over time.

5. <u>Construction recommendations:</u>

   - Follow all of the recommendations under "Infiltration Practices".

   - Timing - The trench should not be constructed or placed into service until all of the contributing drainage area is completely stabilized. If the trench is constructed prior to drainage area stabilization, then the trench should be covered with heavy plastic to prevent any inflow until stabilization is completed.

   - Erosion and sediment control - Special care must be taken to prevent soil from getting into the trench between the aggregate and the geotextile fabric.

   - Excavation - The trench should be excavated using a backhoe or trencher equipped with tracks or oversized tires. Normal rubber tires should be avoided since they compact the subsoil and reduce infiltration capability. For the same reason, bulldozers or front-end loaders should not be used unless they are equipped with extra-wide treads ("low pressure treads"). Excavated materials should be kept at least 15 feet away from the trench to avoid backsliding and cave-ins.

   - Geotextile fabric - Once the trench is excavated, the bottom and sides should be lined with an appropriate geotextile fabric to prevent upward piping of underlying soils. Before installing the fabric, inspect the bottom and side walls of the facility for any protruding objects, like tree roots, that may puncture the filter fabric. Care should be taken in selecting the proper kind of fabric as available brands differ significantly in their permeability and strength. When cutting the fabric, be sure the length and width are sufficient to conform to the trench's dimensions and allow a 12 inch minimum top overlap. If more than one roll of fabric is needed, the upstream roll should overlap at least 2 feet over the downstream roll to provide a shingled effect.

   - Unstable excavation sites - Vertically excavated walls may be difficult to maintain in

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areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions may require laying back the side slopes or using trench safety procedures. Trapezoidal excavation may result when laying back the side slopes creating a need to carefully back fill the space between the filter fabric and the excavation sides. Natural soils should be placed in these spaces at the most convenient time during construction to assure fabric conformity to the final side dimensions. Trenches over four feet deep require shoring pursuant to OSHA regulations.

- Stone aggregate - Clean, washed stone aggregate should be placed in lifts and compacted with plate compactors. Soft stones such as limestone or bluestone aggregates should be avoided. A maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing potential for soil piping, fabric clogging, and settling problems.

- Covering - Once the stone aggregate is placed, the filter fabric needs to be folded over it to form a minimum 12 inch longitudinal overlap. The desired fill soil or stone aggregate should be carefully placed atop the fabric so as to maintain the overlap.

- Operation - The trench should remain covered until all of the contributing drainage area is completely stabilized.

Infiltration trench covered with plastic, upon which sediment has accumulated, to prevent sediment entry during construction.

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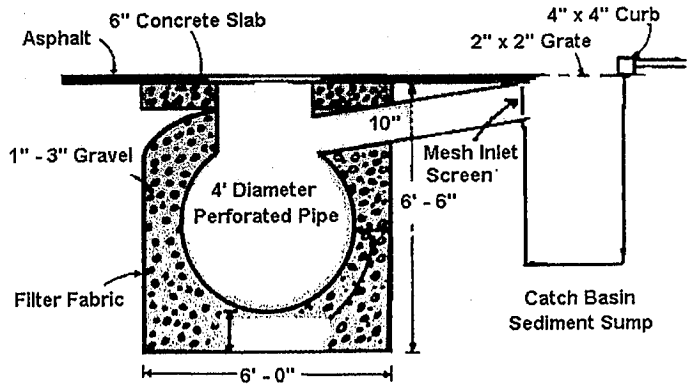
Exfiltration Trench



Description

An infiltration trench in which the runoff (treatment volume) is stored in a perforated or slotted pipe, and percolates out through the surrounding gravel envelope and filter fabric into the soil.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the soil profile.

Advantages

Similar to infiltration trenches, except they can also be placed beneath paved surfaces such as parking lots and streets.

Disadvantages

- Difficult to monitor their continued performance, requiring regular visual inspection of the inside of the pipe to determine accumulation of sediments and other materials. Observation wells may not be as useful as for infiltration trenches.
- Can become clogged fairly easily, and they are very difficult and expensive to unclog.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the trench's sides and bottom. The keys to assuring successful long term performance are accurate estimation of percolation rate, proper construction, pretreatment, off-line design, and maintenance accessibility.

■ Maintenance

Activities necessary to maintain the trench's function include:

- Regular removal of accumulated solids from the pretreatment BMPs to prevent them from moving into the trench.

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- Implementation of source controls, such as street sweeping, landscaping practices, and other good housekeeping practices, which reduce the generation of sediments.
- Removing sediments and other organic matter that accumulates within the exfiltration pipe.
- Pipes should be inspected quarterly for the first year to determine how quickly materials accumulate in them. Accumulated materials can be vacuumed out with a vactor. High pressure cleaning of the holes or slots in the pipes can help to reduce clogging.
- Removing sediments which accumulate within the aggregate envelope, with possible replacement of aggregate necessary if sediments aren't removed from the pipe.

■ Management Needs and Obligations

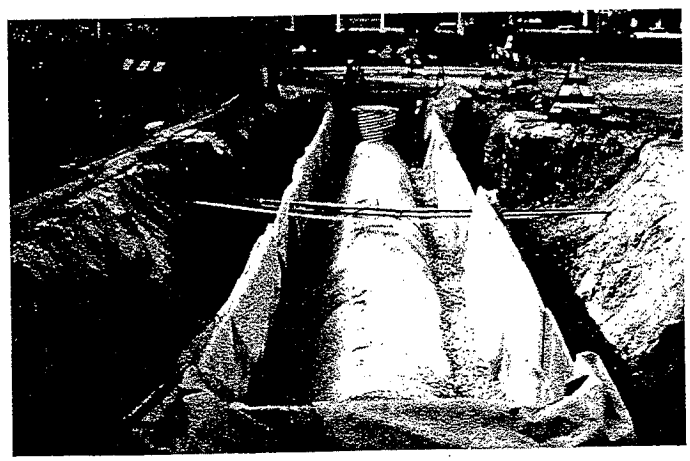
The exfiltration system needs to be monitored periodically. For the first year after construction, the pipe should be monitored quarterly. The pretreatment BMP should be checked monthly during the rainy season and quarterly in the dry season. The observation well, included to monitor water levels in the surrounding gravel envelope, should be monitored after storms monthly during the rainy season and quarterly in the dry season. A log book should be maintained by the responsible maintenance entity and include information such as the inspection date, date and amount of last rainfall, visual observations of the pretreatment BMP and pipe, water level, and calculation of the drawdown time. Once the trench's performance characteristics have been documented, the monitoring schedule can be reduced until the performance data indicates a reduction in percolation rate.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Follow all of the recommendations for "Infiltration Trenches".

2. When estimating the design exfiltration rate, Wanielista *et. al.* (1991) concluded:

   - Permeability of the parent soil is not the limiting exfiltration rate.
   - The limiting exfiltration rate is set by the geotextile filter fabric not the soil.
   - A maximum rate of 0.5 inch/hour should be used if infiltration is assumed to occur through both the sides and bottom of the trench.
   - A maximum rate of 1.0 inch/hour should be used if infiltration is assumed to occur only through the trench's sides.



3. <u>Construction recommendations:</u>

   - Follow all of the recommendations for "Infiltration Trenches".

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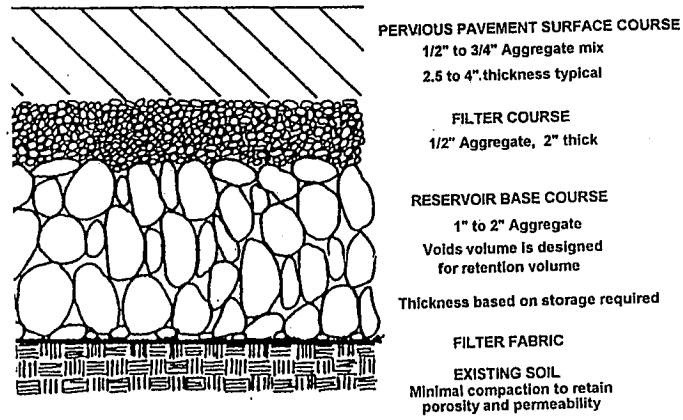
Pervious Pavement



Description

A pavement with traditional strength characteristics but which allows rainfall and runoff to percolate through it rather than running off.

There are two types of pervious pavements - porous asphalt and pervious concrete. Porous asphalt consists of an open graded coarse aggregate held together by asphalt with sufficient interconnected voids to provide a high rate of permeability. Pervious concrete is a discontinuous mixture of Portland cement, coarse aggregate, admixtures, and water which allow for passage of runoff and air. Both types of pervious pavements omit most or all of the fine aggregate typically used in conventional pavements.

Pollutant Removal Mechanisms

- Percolation of rainfall and runoff through the pavement into the underlying aggregate storage reservoir and ultimately into the soil.

Advantages

- Reduces site imperviousness thereby reducing stormwater volume and peak discharge rate.
- Generally, ground water recharge rates are slightly higher under pervious pavement than under natural conditions because vegetation is absent thereby reducing transpiration of soil water.
- Overall construction costs may be reduced because of the reduction or elimination of storm sewers, inlets, and traditional stormwater practices such as detention or retention areas.
- Pervious pavements reduce hydroplaning and skidding by up to 15%.
- Water puddles less on pervious pavement since it moves rapidly into the underlying aggregate reservoir. Besides allowing people to walk through parking lots without getting their feet wet, this also reduces headlight reflection off the surface and makes pavement markings more visible.

Disadvantages

- The major disadvantage is the tendency for pervious pavement to clog. This can occur as a result of improper batching, placement, finishing, and, most commonly, lack of maintenance. Once clogged, it is very difficult and expensive to rehabilitate, often requiring complete replacement.

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- Another concern related to failure of pervious pavements is the lack of experience many pavement engineers and contractors have with these pavements. Proper design, batching, pouring, and finishing are essential to the successful use of pervious pavements. Both porous asphalt and pervious concrete require a very high level of workmanship and special procedures to assure that they retain their porous qualities.
- Spills of gasoline or other potentially hazardous materials can lead to soil or ground water contamination and may break down the asphalt binder to greater depths than in conventional pavements. Spills must be immediately vacuumed, followed by a jet washing.
- In areas with long duration rainfalls, such as the Pacific Northwest, anaerobic conditions may develop in the underlying soils since the soils are unable to dry out between storms. This can prevent aerobic bacteria from reducing organic pollutants. Additionally, the wet subgrade soils may not support the design load.

Improper batching at Florida Dept. of Environmental Protection parking lot necessitated replacement of pervious concrete section.

Operation, Maintenance, and Management Needs and Obligations

- Operation

Successful operation depends on maintaining the permeability of the pavement surface. This begins with proper design and construction and is assured over time by proper maintenance.

A013950

- Maintenance

Activities necessary to maintain the performance of pervious pavements include:

- "Good housekeeping" practices by the users to minimize the production and transport of particulates onto the pervious pavement. This includes vegetative stabilization of adjacent areas which may erode and become a source of sediments.

- Routine maintenance to remove debris that is too coarse to be washed through the pavement.

- Regular vacuuming with a vacuum street sweeper to remove particulates that are fine enough to be carried into the pavement but too large to pass through, thereby causing clogging of the void spaces. The frequency of vacuuming will depend on factors such as the amount and type of traffic, and the sources and loadings of particulates.

- High pressure jet hosing on an annual basis to "deep clean" the voids and help restore permeability.

Pressure cleaning the FDEP pervious parking lot.

- Management

- All pervious pavements should be inspected several times in the first few months after construction to assure that they are working correctly and to make sure that they were installed properly. Inspections should be conducted after storms to check for surface ponding that may indicate local or widespread clogging. Additionally, the pavement should be checked for the first six months for raveling (dislodging of surface aggregate) or severe rutting.

- The surface should be visually inspected on a routine basis, especially after a prolonged storm event, for evidence of debris, ponding of water, oil dripping accumulations, clogging of pores, and other damage. Debris should be removed periodically to minimize accumulations. If ponding or clogging is noticed, then a main

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tenance program needs to be implemented. First, a vacuum street sweeper should be used. If ponding continues to persist, steam cleaning with a biodegradable cleaner should be performed, followed by vacuum sweeping.

- If pervious pavement continues to clog after vacuuming and steam cleaning, rehabilitation or replacement of a section or all of the pavement may be needed. Clogged pervious concrete pavements have been successfully restored by drilling holes, 0.25 inch in diameter on one foot centers. Clogged porous asphalt sections have been similarly restored. If clogging continues, sections of pervious concrete can be saw cut and removed. Six to twelve inches of subbase should be replaced with clean, coarse sand or crushed stone, then proof-rolled, followed by a new layer of pervious concrete.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Only designers, engineers, and contractors experienced in the placement of pervious pavements should be used. Otherwise, the services of an experienced consultant should be obtained.

2. Proper design is essential. The following steps should be taken to ensure proper design:

   - Determine the suitability of the site for the use of pervious pavement. Examine the soils, slopes, and projected use of the site including the expected traffic intensity.

   - Sample and test the site's soils to determine their permeability and load carrying capacity. If permeability is marginal, ways to augment percolation (such as perforated underdrains) should be evaluated. Since pervious pavements distribute the loads over a large area, uniformity of subgrade support, rather than strength, is the major criteria of a suitable subgrade. The presence of silts and clays that are highly compressible, lack cohesion, or expand when wet can create problems. These soil conditions must be analyzed individually for their support values and modified or replaced when necessary.

   - In frost penetrates deeper than the thickness of the pavement and reservoir courses, and the subgrade soil has the potential for frost heaving, additional thickness must be added to the reservoir base course to extend it below the frost line to allow for adequate drainage.

   - Use specifications such as those of the Franklin Asphalt Research Laboratories or found in the Portland Cement Pervious Pavement Manual to determine the appropriate thickness of the pervious pavement system, including its pavement course, filter course, and reservoir course. The thickness of the reservoir course will also depend on the desired storage volume.

   - Prepare specifications for materials, product installation, testing, and maintenance. Consult literature from the Franklin Asphalt Research Laboratories or the Portland Cement Pervious Pavement Manual for example specifications.

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3. Construction recommendations:

- To preclude premature clogging and/or failure of pervious pavements, they should not be placed into service until the entire contributing surface drainage area has been completely stabilized.

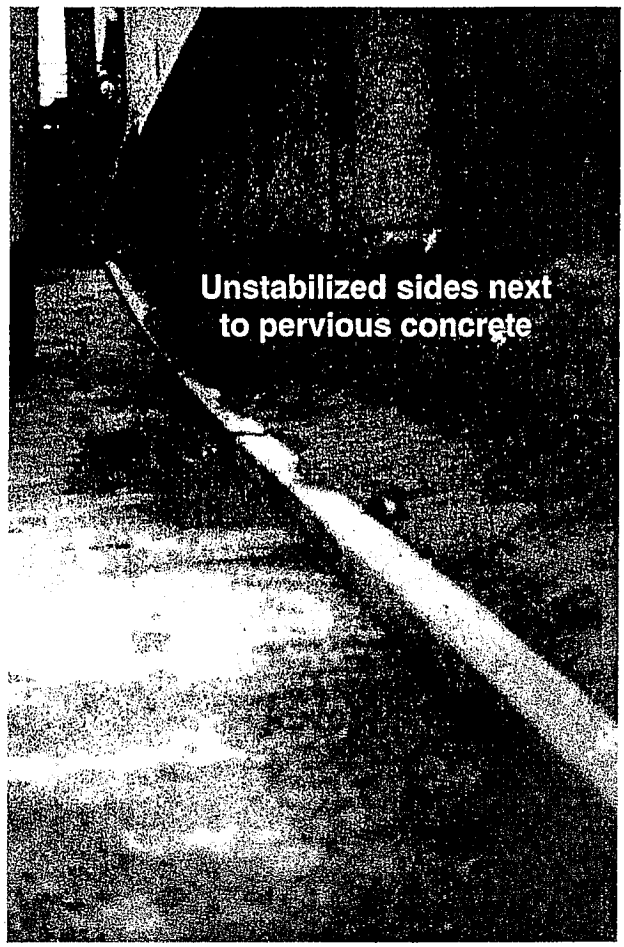
- Clearly mark the planned area for pervious pavement to prevent heavy equipment from compacting the underlying soils.

- Install diversions to keep runoff off the area until the pervious pavement is in place.

- Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

- Once excavation is complete, the bottom and sides of the stone reservoir should be lined with an appropriate geotextile filter fabric to prevent upward piping of underlying soils. Be sure the fabric is placed flush with at least a 2 feet overlap between rolls. Note that the filter fabric is not used for pervious concrete pavements.

- Clean, washed stone aggregate should be placed in lifts and lightly compacted with plate compactors.



- Porous Asphalt Surface Course - Before placement, be sure that the asphalt mix meets the desired specifications. Lay the asphalt in one lift directly over the aggregate base course but only when the air temperature is above 50° F and the laying temperature is between 230° and 260° F. Roll the asphalt when it is cool enough to withstand a ten-ton roller. One or two passes by the roller normally provides proper compaction. More rolling could cause reduction in the surface course porosity. After final rolling, all traffic should be kept off the porous asphalt area for at least one day to allow proper hardening.

- Pervious Portland Cement - Carefully follow the specifications and guidance set forth in the Portland Cement Pervious Pavement Manual. Before accepting the load, be sure that it meets the desired specifications. To assure proper operation, it is crucial that (1) the total water content in the mixture be within the desired narrow range; (2) the mixture is held within the truck for no more than 45 to 60 minutes depending on air

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temperature; (3) the mixture is visually inspected before placement to assure that the proper water-cement paste is uniform in consistency and adequately coating the aggregate surface; (4) the mixture should be discharged from the truck as rapidly and continuously as possible, and distributed on the prepared moist subgrade as evenly as possible; (5) spreading, strike-off, and compaction should be performed as quickly as possible; (6) a vibrating screed should be used to strike-off the mixture, with an inch of material along the base of the screed to provide uniform compaction; (7) compaction, using a small plate vibrating or roller compactor on top of 3/4" plywood, should be done within 20 minutes after strike-off to minimize the potential for raveling; (8) moist curing is started within 20 minutes after placement. The concrete should be sprayed with a light mist of water so as not to wash the cement paste off the aggregate. It is then covered with plastic sheets for 3 to 7 days.

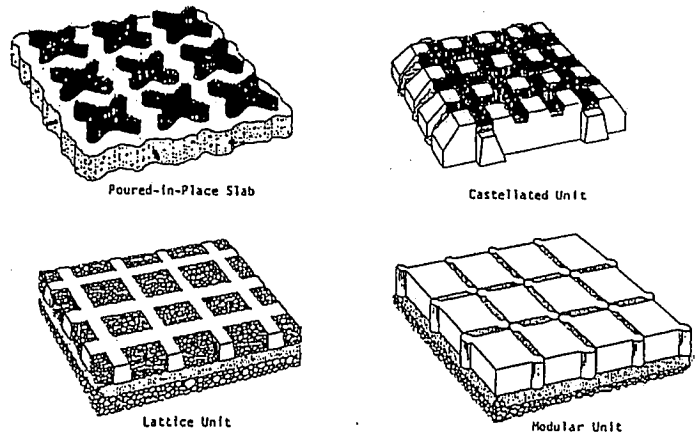
- Be sure that the adjacent areas and all of the contributing drainage area is completely stabilized to minimize the generation of sediments that can enter the pervious pavement.

- Post signs to alert users that the area has pervious pavement and that vehicles with muddy tires should not enter.

- Although snow and ice tends to melt more quickly on pervious pavement, it may still be necessary to apply deicing compounds. Do not use sand or ash because they may cause clogging of the pavement. Remember the potential for ground water pollution.

A013954

Modular Pavement



Description

Pavement consisting of strong structural materials having regularly interspersed void areas which are filled with pervious materials such as sand, gravel, or sod. Generally used in low-volume traffic areas such as the outer parts of a parking lots or in parking lots serving parks or recreational areas. Modular pavement systems vary considerably in configuration. Categories include:

1. Poured-in-place Concrete Slabs - Steel reinforced concrete slabs covering large areas are poured in place with void areas in between. Suitable for heavy loads and has maximum resistance to movement caused by frost heave or settling.
2. Precast Concrete Grids - Concrete paving units incorporating void areas. Types include *lattice pavers*, which generally are flat and grid-like in surface configurations, and *castellated pavers*, which show a higher percentage of grass surface and have a more complex surface configuration characterized by crenels and merlons that are exposed when pervious materials are added.
3. Modular Unit Pavers - Small pavers in various shapes which may be clay bricks, granite sets, cast concrete, or even pervious concrete. These pavers are monolithic units which do not have void areas but provide pervious void spaces in the gaps between them.
4. GeoWeb - A geotextile material which is installed as a framework to provide structural strength, then filled with sand, and sodded to provide a completely grassed parking area.

Pollutant Removal Mechanisms

- Percolation of rainfall and runoff through the voids into the underlying permeable base and then into the soil.
- Filtration of rainfall and runoff by the vegetation that can grow in the voids.

Advantages

- Reduces site imperviousness thereby reducing stormwater volume and peak discharge rate.
- Modular pavements reduce hydroplaning and skidding by up to 15%.
- Water puddles less on modular pavement since it moves rapidly into the underlying permeable base and soils.

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Disadvantages

- The major disadvantage is the tendency for modular pavement void spaces to clog, especially if not vegetated. Proper maintenance is essential to ensure long term performance.
- Modular pavement may cost up to twice as much as conventional pavements. Some of the additional cost can be recovered by the decreased need for stormwater pipes, etc.
- Spills of gasoline or other potentially hazardous materials can lead to soil or ground water contamination. Spills must be immediately vacuumed up with possible removal and replacement of underlying soils.
- In areas with long duration rainfalls, such as the Pacific Northwest, anaerobic conditions may develop in the underlying soils since the soils are unable to dry out between storms. This can prevent aerobic bacteria from reducing organic pollutants. Additionally, the wet subgrade soils may not support the design load.
- Can present a safety hazard to some users (i.e. women in high heeled shoes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the void spaces and the underlying base and soils. Keys to assuring long term performance are accurate estimation of the soil's percolation rate, proper construction, and regular maintenance.

■ Maintenance

Activities necessary to maintain the performance of modular pavements include:

- "Good housekeeping" practices by the users to minimize the production and transport of particulates onto the modular pavement. This includes vegetative stabilization of adjacent areas which may erode and become a source of sediments.

- Replacement of base and underlying soils if they become clogged and water ponding persists.

- When turf is incorporated into the installation, normal turf maintenance, will be necessary. However, mowing is seldom required in areas of frequent traffic and fertilizers and pesticides should be used sparingly since they may adversely affect concrete products and ground water.

■ Management

All modular pavements should be inspected several times in the first few months after construction to assure that they are working correctly and were installed properly. Inspections should be conducted after storms to check for long duration surface ponding that may indicate local or widespread clogging.

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Recommendations to Assure Proper Operation, Maintenance, and Performance

1. As with all infiltration practices, accurate estimation of the soil's percolation rate is essential.

2. Be sure turf block parking is appropriate for the setting and the primary users.

3. Construction recommendations:

- Install all modular pavements following manufacturer's specifications. The requirement for skilled labor for laying modular pavement may be reduced if mechanical vibrators are used for levelling uneven surfaces.

- To preclude premature clogging and/or failure, modular pavements should not be placed into service until the entire contributing surface drainage area has been completely stabilized.

- Clearly mark the planned area for modular pavement to prevent heavy equipment from compacting the underlying soils.

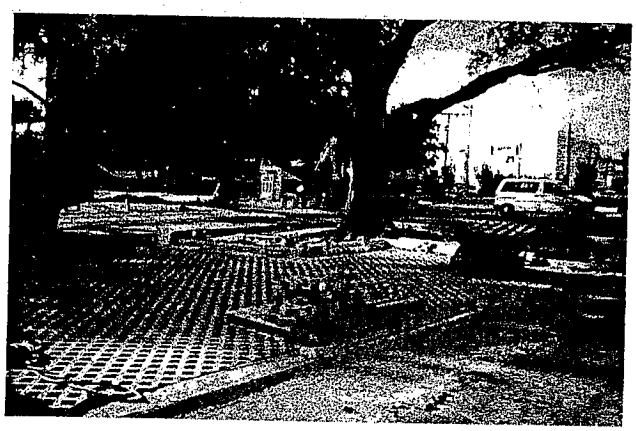
- Install diversions to keep runoff off the area until the modular pavement is in place.

- Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

- Be sure that the adjacent areas and all of the contributing drainage area is completely stabilized to minimize the generation of sediments that can enter the modular pavement

- Although snow and ice tends to melt more quickly on modular pavement, it may still be necessary to apply deicing compounds. Do not use sand or ash because they may cause clogging of the pavement. Remember the potential for ground water pollution.

Turf block parking lot under construction.



Geoweb fabric being installed and filled with sand before sod is added to create grass parking.

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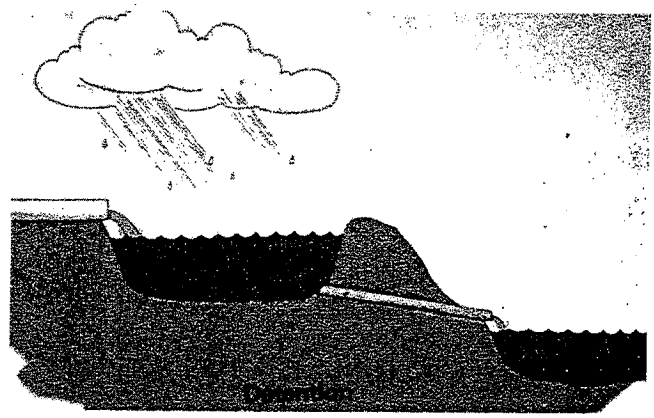
Detention Practices



Description

A family of practices which "detain" runoff, typically from a design storm, and then discharge it, usually at the pre-development peak discharge rate. Detention practices can be classified as dry detention, extended dry detention, or wet detention systems.

Purpose

Traditionally, detention practices, especially dry detention, have been used only for flood protection. They detain runoff and then discharge it at a specified rate supposedly reducing the potential for downstream flooding by delaying the arrival of runoff from upper parts of a watershed. More recently, detention system designs have been modified to also reduce stormwater pollutants. For example, dry detention systems have been modified to extend the detention time of runoff thereby increasing pollutant settling. Wet detention systems have been modified to increase residence time and flow path, and to include shallow littoral zones in which wetland plants grow.

Pollutant Removal Mechanisms

The primary "treatment" mechanism of all detention systems is settling or sedimentation. However, the pollutant removal mechanisms vary depending on the type of detention system. They will be discussed in the following BMP Fact sheets on dry detention, extended dry detention, and wet detention systems.

Expected Stormwater Quantity and Quality Performance

All detention systems are highly effective in reducing peak discharge rates. Depending on their design and their location within a watershed, they also may be effective in reducing downstream channel erosion and downstream water elevations and flooding.

Stormwater treatment effectiveness depends on the type of detention system. In general, they can be ranked, from least to most effective, in their ability to remove stormwater pollutants: dry detention, extended dry detention, wet detention. Unlike dry detention systems, wet detention provides mechanisms that promote the removal of dissolved stormwater pollutants, not just particulate pollutants.

Since each type of detention system is so different, aspects of their use, operation, maintenance, and management will be discussed separately in the following sections on dry detention, extended dry detention, and wet detention.

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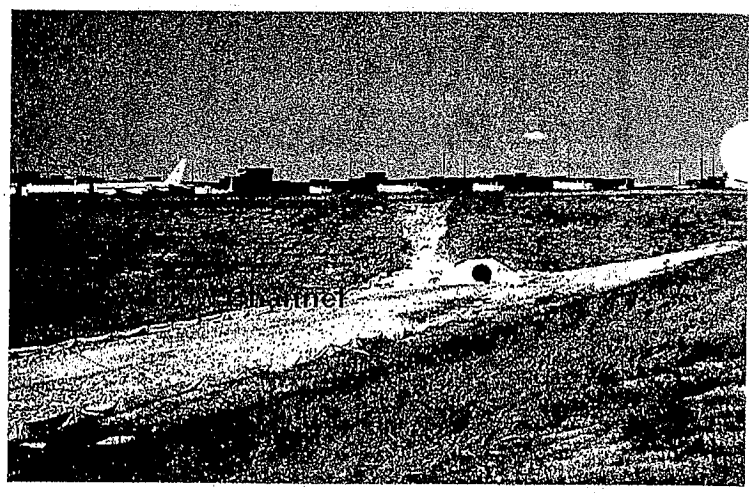
Dry Detention Basin



Description

An area used to detain stormwater for a relatively short period of time to reduce downstream peak discharge rates. The area should go dry between storms. This is the traditional type of detention system used in "drainage" programs for many years to help provide flood protection.

Pollutant Removal Mechanisms

Settling or sedimentation of larger, heavier particles is the primary mechanism. In some systems, limited infiltration may occur.

Advantages

Since these systems are dry between storms, the land area can be used for low intensity secondary uses such as recreation or sports.

Disadvantages

- Very poor stormwater treatment effectiveness.
- Often considered unattractive nuisances by residents.
- Poorly designed or maintained systems which do not go dry may become breeding areas for mosquitoes.

Expected Stormwater Quantity and Quality Performance

Dry detention systems generally provide good attenuation of peak discharge rates. However, their pollutant removal effectiveness generally is very low, depending on detention time, flow path, and frequency of sediment removal. Sedimentation of larger particles is the primary treatment in dry detention systems. Therefore, the small particles, to which the majority of stormwater pollutants such as metals adhere, are discharged downstream. The ranges of expected pollutant removal in dry detention systems are:

• Total Suspended Solids	20 to 60 percent	• Total lead	20 to 60 percent
• Total Phosphorus	10 to 30 percent	• Total Zinc	10 to 50 percent
• Total Nitrogen	10 to 20 percent	• Total copper	10 to 40 percent
• COD	20 to 40 percent	• Bacteria	20 to 40 percent

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Limitations on Use

- Need fairly porous soils to assure that the bottom stays dry between storms.
- Not suitable in areas with high water tables or shallow depth to bedrock.
- Not suitable on fill sites or steep slopes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system's infiltration capability.

■ Maintenance

Activities necessary to maintain the functioning of a dry detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially from the low flow channel. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.
- Removal of debris from the control device, especially if it has a small orifice.
- Mowing and removal of vegetation. The use of low growing, native grasses is recommended to minimize mowing frequency and the need for irrigation and fertilizers, which should only be used when absolutely necessary.
- Vegetative stabilization of eroding sides or bottom.

■ Management Needs and Obligations

Inspect monthly and after large storms to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Provide a system to allow stormwater to bypass the facility. This will allow maintenance to be done faster, and during the rainy season if needed.
2. Design the dry detention system as an "off-line" facility.
3. The seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom is dry.
4. Use a sediment forebay at all inflow points to trap sediments and allow for easy removal.

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5. The length of the basin should be at least three times the width (preferably five times), with the basin narrow at the inlet and wide at the outlet.

6. Side slopes should be at least 3:1 for safety and ease of mowing, although 4:1 slopes are optimal.

6. The basin floor should be flat with a 2% slope toward the outlet.

7. Have an area on-site to hold sediments that are removed from the dry detention system. The area should be capable of holding the sediments removed during a two year period. Sizing of the disposal area should be based on the estimated annual sediment load trapped.

8. Provide dedicated access to the forebay and to all parts of the dry detention system for maintenance equipment and vehicles.

9. Construction Recommendations:

- If the system will rely on infiltration to some extent, then follow the recommendations for construction of infiltration practices.

- Make sure the embankment and discharge structure are installed properly, at the correct elevations, and with proper compaction.

- Make sure that anti-seep collars are installed properly.

South Florida dry detention system integrated into the site's landscaping.

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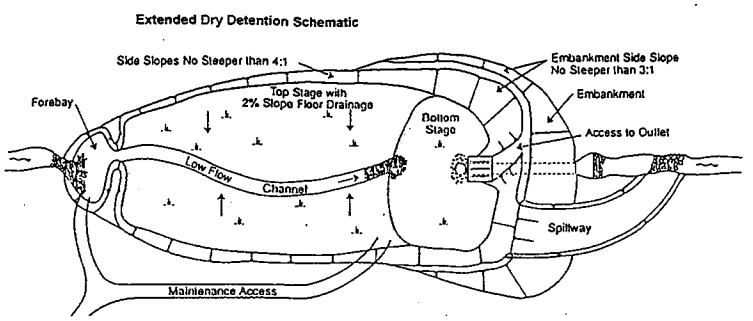
Extended Dry Detention Basin



Description

A dry detention system with a discharge structure which is modified to extend the detention time of runoff, typically up to 24 to 48 hours. The modified discharge may also include some type of filtering device (i.e., gravel or sand envelope) to improve the removal of particulate pollutants.

Extended dry detention systems may be designed as either on-line or off-line facilities. They also may be designed as either a single-stage or two-stage basin. Single-stage basins normally are used only for flood control and are not recommended for stormwater treatment. A two-stage basin detains runoff from small, frequent storms and the "first flush" from larger storms in a lower second stage, with a normally dry upper stage for detention of larger storms for flood control. To improve stormwater treatment the second stage can be designed and managed as a shallow marsh.

Pollutant Removal Mechanisms

- Settling or sedimentation, especially of larger, heavier particles, is the primary mechanism.
- Plant uptake and bacterial activity in two-stage systems with a shallow marsh.
- In some systems, limited infiltration may occur.

Advantages

Since many of these systems are dry between storms, the land area can be used for low intensity secondary uses such as recreation or sports.

Disadvantages

- Relatively low stormwater treatment effectiveness
- May be less reliable in treating stormwater pollutants than other BMPs
- Primarily remove particulate pollutants with little removal of dissolved pollutants.
- Shallow depth can significantly warm the detained water, making use inappropriate when discharge is to temperature sensitive receiving waters, such as a trout stream.
- Often considered unattractive nuisances by residents.
- Poorly designed or maintained systems which do not go dry may become breeding areas for mosquitoes.
- Discharge structure may clog easily, especially if a filtration system is used.
- Relatively frequent removal of accumulated sediments is needed to prevent resuspension and discharge and to maximize treatment effectiveness.

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Expected Stormwater Quantity and Quality Performance

Extended dry detention systems generally provide good attenuation of peak discharge rates but do not reduce runoff volume. Pollutant removal effectiveness generally is low but can b improved by design considerations such as making the system off-line, increasing the "treatment volume", and increasing the detention time. The ranges of expected pollutant removal in extended dry detention systems are:

• Total Suspended Solids	30 to 80 percent	• Total lead	20 to 70 percent
• Total Phosphorus	15 to 40 percent	• Total Zinc	10 to 60 percent
• Total Nitrogen	10 to 40 percent	• Total copper	10 to 50 percent
• COD	20 to 50 percent	• Bacteria	20 to 60 percent

Limitations on Use

- Require fairly porous soils to assure that the bottom stays dry between storms.
- Not suitable in areas with high water tables or shallow depth to bedrock.
- Not suitable on fill sites or steep slopes.
- Requires elevation differential between inlet and outlet.
- May not be suitable if receiving water is temperature sensitive, such as a trout stream.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system's infiltration capability.

■ Maintenance

Activities necessary to maintain the functioning of an extended dry detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially the low flow channel if included. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.

- Removal of debris from the control device since it typically will have a small orifice.

- Mowing and removal of vegetation. The use of low growing, native grasses is recommended to minimize mowing frequency and the need for irrigation and fertilizers, which should only be used when absolutely necessary.

- Vegetative stabilization of eroding sides or bottom.

- Management of aquatic plants if portions of the basin have been designed as a constructed wetland.

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- Management Needs and Obligations

Inspect monthly and after large storms to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Include a system to allow stormwater to bypass the facility. This will allow maintenance to be done faster, and during the rainy season if needed.

2. Design the extended dry detention system as an "off-line" facility.

3. The seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom stays dry.

4. Use a sediment forebay at all inflow points to trap sediments and allow for easy removal.

5. The length of the basin should be at least three times the width (preferably five times), with the basin narrow at the inlet and wide at the outlet.

6. Side slopes should be at least 3:1 for safety and ease of mowing, although 4:1 slopes are optimal.

7. The basin floor should be flat with a 2% slope toward the outlet.

8. The discharge structure should incorporate mechanisms to promote filtering of stormwater pollutants but minimize the potential for clogging. Experience in Austin (TX), Denver (CO), Washington, and Florida has found that a perforated riser pipe, wrapped in filter fabric and surrounded by gravel (1" to 3" stone), can greatly reduce the potential for orifice clogging. This design also increases the treatment effectiveness.

9. Have an area on-site to hold sediments that are removed. The area should be capable of holding the sediments removed during a two year period. Sizing of the disposal area should be based on the estimated annual sediment load trapped.

10. Provide dedicated access to the forebay and to all parts of the extended dry detention system for maintenance equipment and vehicles.

11. <u>Construction Recommendations:</u>

    - If the system will rely on infiltration to some extent, then follow the recommendations for construction of infiltration practices.
    - Make sure the embankment and discharge structure are installed properly, at the correct elevations, and with proper compaction.
    - Make sure that anti-seep collars are installed properly.

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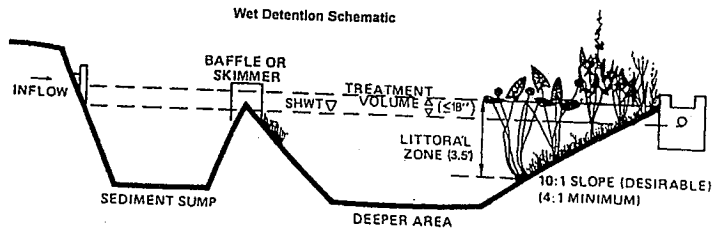
Wet Detention Pond



Description

A detention system with a permanent pool of water which is completely or partially displaced by stormwater from the contributing drainage area. Water is temporarily stored before gradually discharging it, typically at the predevelopment peak discharge rate. A wet detention system is essentially a small lake with rooted wetland vegetation in the littoral zone.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Chemical flocculation which occurs when heavier sediment particles overtake and coalesce with smaller, lighter particles to form still larger particles.
- Dissolved stormwater pollutants are reduced by a variety of biological processes including filtering, adsorption onto bottom sediments, uptake by aquatic plants including algae, and metabolism by microorganisms inhabiting bottom sediments and aquatic plants.
- ***Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storms.***

Advantages

- Relatively high level of flood control and stormwater treatment.
- Can be used in areas with a high water table or poorly drained or percolating soils.
- Excellent multiuse BMP which can provide ancillary benefits such as habitat, recreational opportunities, high value aesthetics associated with "lake front" property, and serving as a source of fill dirt often needed in areas with high water tables or flat topography.
- Relatively low maintenance requirements.
- Can be used as sediment trap or basin during construction phase of a project.

Disadvantages

- May provide limited flood storage in areas with high water tables.
- Safety and aesthetic problems if the pond, especially the littoral zone and discharge structure, is not maintained properly.
- Fairly land intensive, often two to five percent of contributing area.
- Wet season may not be coincident with plant growing season.
- May be regulated as a "wetland".
- May be an attractant for children creating potential safety and liability issues.
- May become fecal and nutrient source because of attracted waterfowl.

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Expected Stormwater Quantity and Quality Performance

Wet detention systems provide very good flood control and stormwater treatment benefits. Only infiltration practices provide better management of stormwater quantity and quality. The permanent pool and wetland vegetation provide for a variety of pollutant removal mechanisms which are highly effective in removing both particulate and dissolved stormwater constituents. Treatment effectiveness of wet detention systems depends on a number of design factors including the storage volume, detention time, permanent pool volume, volume ratio, depth of permanent pool, elevation of control structure in relation to seasonal high water table elevation, pond geometry, size and location of littoral zone, type and density of littoral zone plants, and use of the "BMP Treatment Train" to incorporate pretreatment devices such as sediment forebays and swale conveyances. The ranges of expected pollutant removal in wet detention systems are:

• Total Suspended Solids	50 to 90 percent	• Total lead	30 to 90 percent
• Total Phosphorus	30 to 80 percent	• Total Zinc	30 to 90 percent
• Total Nitrogen	30 to 60 percent	• Total copper	20 to 80 percent
• COD	30 to 70 percent	• Bacteria	20 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- May need supplemental water supply to maintain permanent pool if not dug into the ground water.
- Minimum contributing drainage area of 8 to 10 acres is needed to maintain the permanent pool.
- Infeasible in very dense urban areas or areas with high land costs.
- May not be suitable if receiving water is temperature sensitive, such as a trout stream.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on good design, construction, and maintenance, especially of the discharge structure and littoral zone vegetation.

■ Maintenance

Activities necessary to maintain the functioning of wet detention system can be broken down into two categories: Routine and Corrective.

Specific routine maintenance activities include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.

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- Monitoring and periodic removal of nuisance species in the littoral zone.
- Thinning and transplanting of thriving littoral zone plants as needed to maintain good growth throughout the littoral zone.
- Monitoring for mosquitoes and introduction of *Gambusia* or other natural predators as needed.
- Monitoring of sediment accumulations in forebays or in the pond bottom.
- Monitoring of channel erosion in downstream conveyances.

Specific corrective maintenance activities include:

- Pond dewatering and removal of accumulated sediments. The frequency will depend on a variety of factors including use of pretreatment BMPs or forebays, contributing drainage area, land use, sediment loading, etc. Yousef et. al. (1992) determined that the typical wet detention system in Florida needed sediment removal every 10 to 15 years. A good rule of thumb is to remove sediments when 10 to 20% of the system's storage volume has been lost.
- Structural repairs to inlets, outlets, or discharge structure, including the emergency spillway.
- Repairs to the dam, embankment, or slopes to prevent erosion or piping.
- Repairs to fences, if applicable.

■ Management Needs and Obligations

- Inspect monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine health of littoral zone vegetation.

- Monitor pond sediment accumulations annually. This can be done by coring, installation of a permanent measuring device such as a "yardstick", or even by mapping the pond bathymetry in larger ponds.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. The design should include a bottom bleeddown device, and preferably a system that allows stormwater to bypass the facility. This will allow easy pond dewatering and facilitate maintenance.

2. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays, especially if the wet pond is going to be promoted as an aesthetic amenity for the development.

3. To maximize removal of dissolved pollutants, pool storage hydraulic residence time should be at least 2-3 weeks. This generally means that the pond will consume 3-7 percent of the contribution drainage area depending on factors such as impervious area, rainfall characteristics, water table elevation, etc.

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4. The system should include shallow areas (less than 3 feet deep) and deep areas (more than 8 feet). The shallow areas should be used for the littoral zone which provide habitat for aquatic wetland vegetation and serves as a shallow bench along the shore, helping to minimize the potential for drowning. Deep areas should make up 25-50 percent of the pond and be located near inflow points. The maximum depth should be limited to a level that minimizes the risk of thermal stratification. This helps to reduce short circuiting, maintain aerobic bottom waters and sediments, and minimize the potential for ground water contamination.

5. The littoral zone should cover at least 30% of the pond's surface area and slope gently (6:1 or flatter) to a depth two feet below the control elevation. Ideally, the littoral zone and its emergent wetland vegetation should extend around the entire perimeter of the pond with an expanded littoral zone at the outlet area. A wide variety of native plants, especially those with attractive flowers, should be used as part of the "aquascaping" of the system, helping to increase aesthetics. Unfortunately, experience has shown that many residents will remove the beneficial aquatic plants adjacent to their lots because of concerns about snakes and other "swamp critters". This has led to the practice of concentrating the littoral zone near inflows and at the outlet. A better alternative is to educate residents about the values - environmental, safety, and aesthetics - of the littoral zone plants.

6. Pond geometry has a very strong influence on the effectiveness of wet detention systems. Little or no pollutant removal occurs in dead storage areas where the inflow is bypassed without mixing. To avoid this problem, the effective length to width ratio should be at least 3:1 and preferably 5:1. Additionally, the locations of inflows and the discharge structure should minimize short circuiting and maximize the flow path.

7. Better performance can be expected by enlarging the surface area to gain volume as opposed to deepening the pond.

8. Proper design, construction, and maintenance of the discharge structure and the dam or embankment is critical, especially to minimize potential downstream damage from structural failure. In particular, the designer should:

   - Avoid potential piping of water along the outside of the outlet conduits by using drainage seepage diaphragms, or by careful material selection and good compaction around the conduit.
   - Minimize the number of conduits through the embankment.
   - Ensure against leaky joints within the embankment.
   - Not use thin-walled conduit through the embankment without a protective exterior encasement.
   - Provide a safety factor in outlet structure openings to account for debris collection. Spillway and discharge structure entrances are natural locations for debris buildup.

9. Provide access to all parts of the system for equipment needed to conduct maintenance. The maintenance right-of-way should be at least 20 feet wide, as should any fence gates.

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10. Construction recommendations:

Failure to properly construct the wet detention system, especially the embankment (dam) and discharge structure, can lead to failure possibly resulting in downstream flooding, [illegible] erty damage, and even personal injury. Experience has shown that problems in constru[illegible]ig wet detention systems primarily are associated with the following:

A. Contractor error

- Construction sequence or plans are not followed.
- Concrete placement doesn't seal riser bottom.
- Pipes are improperly placed or damaged while installed.
- Separation of joints due to uneven settlement.
- Connections are not water tight.

B. Improper use of soil materials.

- Overly pervious materials are used around pipes or in the dam resulting in piping or failure.
- Top soil not spread or spread too thinly resulting in poor vegetative cover and erosion.

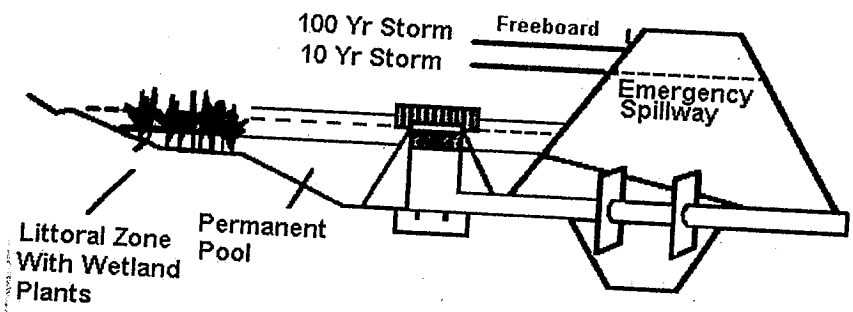
C. Principal spillway materials are not water tight.

- Connecting bands and gaskets are from different manufacturers or are too narrow.
- Improper pipe placement - uneven grades, settlement, or poor alignment.
- Water movement through connections from saturated zone.

D. Availability of specified materials.

- Rip rap sizes are unavailable.
- Materials not present when needed to insure timely construction during critical periods.

Wet Detention Schematic



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To avoid the problems described above it is important to follow the construction sequence, especially if the wet detention system is used as a sediment basin during construction. A potential construction sequence is:

1. Pre-construction meeting
   - Stress importance of proper construction sequencing and implementation.
   - Determine project phasing, especially of structures.
2. Install erosion and sediment controls.
3. Clear and grub site.
4. Strip and stock pile top soil
5. Excavate and backfill the core trench.
6. Install the principal spillway - pay special attention to compaction and installation of anti-seep devices.
7. Construct the dam and emergency spillway.
8. Excavate pond.
9. Spread top soil.
10. Vegetatively stabilize all areas.
11. If the wet detention system was used as a sediment basin, remove accumulated sediments to restore required storage volume.
12. Plant the littoral zone.

Wet detention pond at the Fl. Dept. of Environmental Protection office in Tallahassee.

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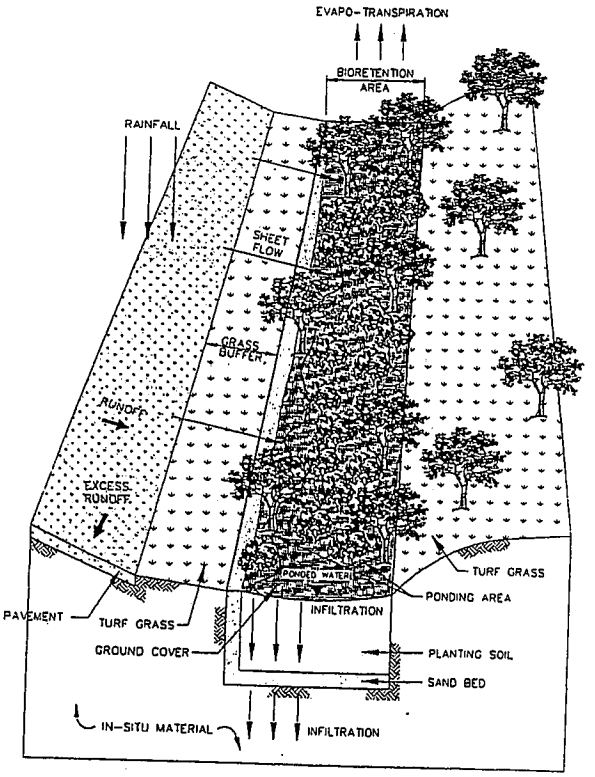
Biofiltration Practices



Description

Biofiltration is a term used to describe the generally simultaneous processes of filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants from runoff as it flows through a vegetated stormwater management system. Biofiltration practices include vegetated swales, filter strips, and bioretention areas. Swales are conveyances where the flow passes through vegetation at some specified depth. Filter strips are broad surfaces which receive flow as a well distributed thin sheet. Bioretention practices capture sheet flow from impervious surfaces and treats it by infiltration, filtration, plant uptake, and microbial processes as the runoff flows through native forest or landscaped areas.

Purpose

Biofiltration practices are used primarily to reduce stormwater pollutants through natural vegetative processes, but they can also reduce stormwater volume if infiltration occurs.

Pollutant Removal Mechanisms

- Infiltration, ion exchange, and adsorption
- Settling
- Vegetative filtration and uptake
- Microbial action
- The degree to which the various pollutant removal mechanisms operate depends on soil properties, condition and types of plants, depth, water velocity, slope, and residence time.

Advantages

- Can be incorporated into a site's landscaping and open space areas.
- Very effective at reducing oil, grease, and petroleum hydrocarbons.
- Excellent use as part of the "BMP Treatment Train".
- Can be aesthetically pleasing and enhance parking areas.

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Disadvantages

- Not useful by themselves for reducing stormwater quantity.
- Successful operation depends mainly on proper construction and maintenance, which requires effective inspection and enforcement efforts.
- Except for swales, the treatment effectiveness of biofiltration practices is still largely unknown.
- Too little is known about the treatment benefits of various plant species to make sound recommendations on the types of plants to use in biofiltration practices. Still, since filtering is the main function performed by the plants, the most important factor is a uniform, dense growth of fine grasses or herbaceous wetland plants.

Expected Stormwater Quantity and Quality Performance

Biofiltration practices, especially swales and filter strips, and bioretention practices generally provide minimum stormwater quantity benefits such as attenuation of peak discharge rates or runoff volume. The extent of these benefits will depend largely on how much infiltration of runoff occurs.

Stormwater pollutant removal by biofiltration systems will vary depending on a wide variety of design factors, especially the amount of infiltration and the hydraulic residence time. In general, biofiltration swales are very good at reducing particulate runoff pollutants such as total suspended solids, turbidity, and the least soluble metals such as lead, iron, and zinc. Materials which adhere to grass surfaces, such as oil and grease and total petroleum hydrocarbons are also effectively removed. Removal of nutrients, especially nitrogen, and coliforms are often inconsistent, with best removals seen for bioavailable phosphorus. Some authorities believe that biofilters can achieve better nutrient reductions if vegetation is carefully mowed and removed before it dies and releases assimilated nutrients but this hypothesis is unproven. There is little information on the pollutant removal effectiveness of filter strips or bioretention areas.

The ranges of expected pollutant removal in biofiltration swales are:

• Total Suspended Solids	50 to 85 percent	• Total lead	40 to 80 percent
• Total Phosphorus	20 to 40 percent	• Total Zinc	30 to 80 percent
• Total Nitrogen	0 to 40 percent	• Total copper	30 to 60 percent
• COD	10 to 40 percent	• Bacteria	10 to 60 percent

Limitations on Use

- Can not be used where the contributing drainage area exceeds a few acres because of the excessive surface area needed to produce sufficient residence time. The maximum drainage area depends on its specific characteristics (i.e., land use, % imperviousness, etc.).
- Should not be used for erosion and sediment control during construction nor where the post-development sediment loading will be high.
- Need fairly porous soils to promote infiltration.

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- Not suitable on steep slopes or where there is shallow depth to bedrock.
- May be limited to areas where summer irrigation is feasible.
- Generally not suitable in areas with high water tables, although "wet swales" with wetland plants have worked well in Florida.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on proper design, especially estimation of hydraulic residence times and infiltration rates, proper construction and regular maintenance.

■ Maintenance

Activities necessary to maintain the functioning of biofiltration practices include:

- A key O&M need of biofilters is vegetation removal to maintain adequate hydraulic functioning. Biofilter turf grass height should not exceed 6 inches nor be less than 2 inches. Excessively long grass can flatten when water flows over it, preventing sedimentation. Additionally, if not removed, decaying vegetation could release captured nutrients and other pollutants.

- Frequent removal of accumulated solids, debris, and litter. Sediments should be removed when they reach 20% of the design depth in any spot, cover or hinder the growth of vegetation, or otherwise interfere with operation. Maintenance workers should give special attention to sediment accumulation in the upper portion of swales after major storm events. Sediment and large debris should be removed from biofilters at least twice annually and more frequently, if needed.

- Vegetative stabilization of eroding sides or bottom, or of bare areas created when removing sediments. Fertilizer use should be minimized. Vegetation should be maintained and replanted early enough in the growing season so that it is well established before the rainy season or before the prime growing period ends.

- If swale blocks are used to promote infiltration or sedimentation, special attention needs to be paid to their maintenance. Sediments need to be carefully removed without damaging the swale block or its associated vegetation.

- If curb cuts are used as inflows to biofilters, sediments and vegetation growths should be removed from the curb cut when they begin to interfere with inflow.

- Roadside shoulder scraping and ditch cleaning should be based on hydraulic necessity, not simply a timed schedule. When these operations are performed, only the amount of sediment to restore hydraulic capacity should be removed. More importantly, the shoulder and swale should be revegetated immediately to minimize erosion and restore treatment effectiveness. Operations should be done in the dry season.

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- Implement education programs for residents near biofiltration practices, such as residents within subdivisions with swales, to teach them about their purpose, solicit their help in maintenance, and minimize use of swales as debris or trash depositories.

■ Management Needs and Obligations

- Inspect semiannually and, when possible, after large storms to assure proper flow, vegetative growth, and to monitor accumulation of sediments, trash, and debris.

- Institutionally, a stormwater program which allows the use of biofiltration practices must have an inspection and enforcement program to assure that maintenance occurs. Public education programs also are highly recommended.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. For dry systems, the seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom is dry.

2. To provide proper flood control, biofilters must be combined with more traditional practices such as detention. Biofilters can either be designed as on-line components of a BMP Treatment Train or as an off-line stormwater treatment component of the overall stormwater management system. Off-line systems are preferable because the detention element can meter flow into the biofilter up to the design storm intended to receive treatment and protect the biofilter from high flows.

3. The design of biofilters, especially swales and filter strips, will depend largely on the rainfall, topographic, and land cover characteristics of the site. These will determine the "treatment volume" and greatly influence the location and use of biofilters, along with other design considerations such as their residence time. The specific length of a biofilter will depend largely on the residence time and the associated length and width.

4. It is essential that flow through biofilter systems be uniform sheet flow (filter strips) or flow of minimal depth below the vegetation height (swales). This will maximize contact with the vegetation and microbes which promote treatment. This requires a flat bottom to minimize any potential for channelized flow.

5. Use a flow-spreading device and/or energy dissipation device at the inlet to minimize erosion and maximize uniform distribution of flow.

6. Maximum design velocity should not exceed 1.5 to 3.0 feet per second to prevent erosion and maximize treatment capability.

7. Slopes of biofilters should be between 2 and 4 percent. Underdrains may be needed if slopes are less than 2 percent and a dry system is desired. Swale blocks should be used when slopes exceed 4 percent.

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8. Water depth should be no greater than one half the height of the vegetation up to a maximum of 5 inches. Ideally, the water depth should not exceed 2 inches.

9. Biofilters should be situated along natural drainage routes and contours whenever feasible. Designers can reduce the risk of channelized flow and erosion by not forcing runoff to flow in unnatural directions.

10. Biofilter designers must investigate the climate and microclimate of the site in order to choose optimal varieties of vegetation. Grasses are the superior choice of vegetation because they are resilient, provide abundant surface area, and can sprout through thin deposits of sand and sediment. Grasses that are stiffer, denser, and have greater leaf surface areas are preferable. If water tables are high, a "wet swale" should be designed using appropriate wetland plants.

11. In regions that experience extended dry periods, selecting drought-tolerant plant species or constructing biofilters in locations where soils remain moist during dry periods can reduce irrigation needs.

12. Avoid heavy and prolonged shading of biofilters by adjusting placement relative to buildings and trees.

13. Construction recommendations.

- Since most biofilters rely upon infiltration, follow construction recommendations for "Infiltration practices". The key is to minimize compaction of the soil and the resulting reduction of the infiltration rate of the soil.

- Do not place biofilters into operation until the contributing drainage area is completely stabilized.

- If possible, divert runoff during the period of vegetation establishment. If this is not possible, sodding should be used whenever possible, especially if significant runoff could occur before vegetation establishment. Other methods of minimizing erosion in flowing channels includes the use of "erosion mats" combined with seed.

Erosion matting is used to prevent erosion of biofiltration swale during establishment of its vegetative cover.

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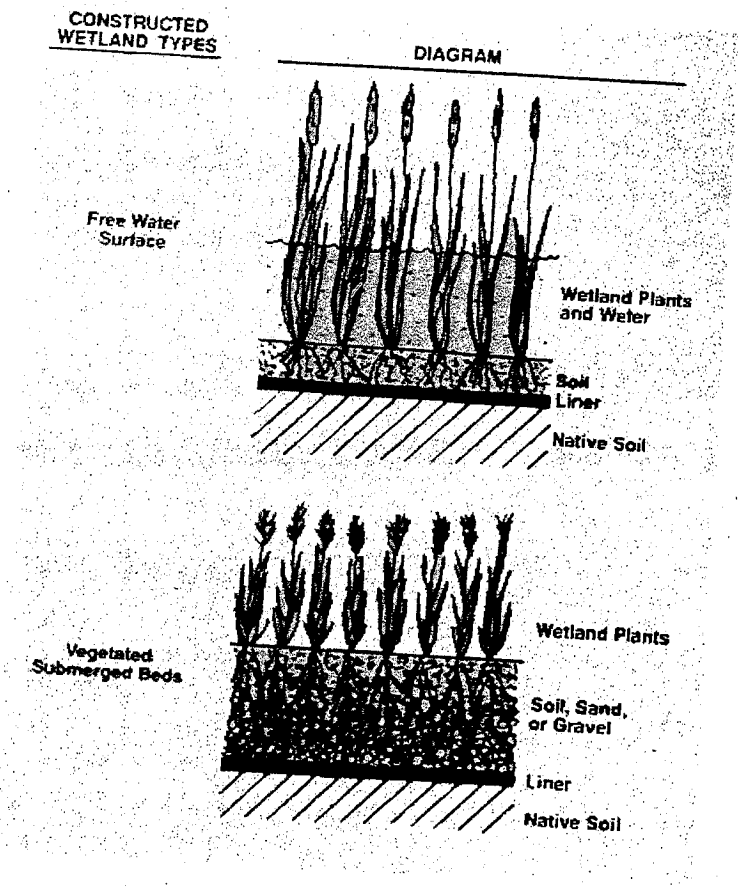
Constructed Wetlands



Description

A runoff storage and treatment area constructed in uplands which is vegetated with aquatic macrophyte plants native to the area. These systems attempt to incorporate properties of natural wetlands such as shallow, sheet flow through dense, diverse assemblage of wetland plants which also serve as habitat for microorganisms. There are numerous configurations for constructed wetlands. They range from shallow marshes, to the littoral zones of wet detention systems, to a combination extended detention and marsh system.

Purpose

Constructed wetlands are being used to remove stormwater pollutants through the natural processes that occur within these ecosystems.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Adsorption to sediments, vegetation, or detritus
- Filtration by plants.
- Microbial uptake and/or transformations.
- Uptake by wetland plants or algae.
- Extended detention.
- ***Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storms.***

Advantages

- Can be used in areas with high water table or poorly drained or percolating soils.
- Can be used in areas with highly pervious soils if a liner is used to minimize infiltration.
- Can remove dissolved pollutants.
- Can be aesthetically pleasing and provide wildlife habitat.

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Disadvantages

- In many parts of the country, especially in the western states, wetland vegetation is dormant during the rainy season. However, since plant uptake is only a minor mechanism in removal of most pollutants, a standing crop of vegetation can still provide filtration and an area for surface removal processes.
- Provide limited flood storage and attenuation.
- Shallow depth may significantly warm the detained water, making use inappropriate when discharge is to temperature sensitive receiving waters, such as a trout stream. However, monitoring in Delaware shows that shallow, well vegetated systems have water temperatures much lower than unvegetated systems.
- Fairly land intensive.
- Possible mosquito problems associated with dense, emergent wetland vegetation.
- May be regulated as a "wetland" unless continuously operated and maintained as a treatment system.
- Can become either a nutrient or fecal "source", depending on wildlife use and populations and vegetation management.

Expected Stormwater Quantity and Quality Performance

Constructed wetlands are used primarily to remove pollutants from runoff and typically are not used by themselves to attenuate stormwater peak discharge rates or volumes. Constructed wetlands should still be considered an experimental stormwater treatment BMP as too little is known about their long-term treatment effectiveness or maintenance requirements. They have been used in numerous locations around the country with varying success. Treatment effectiveness will depend on a number of design considerations including the treatment volume, surface area to volume ratio, length and type of flow path, plant types and densities, plant growing season in relation to rainy season, deep water pools, and use of the BMP Treatment Train by incorporating pretreatment devices such as sediment forebays and swale conveyances. The ranges of expected pollutant removal of constructed wetland systems are (median values for the relatively soluble pollutants like phosphorus, nitrogen, copper, and zinc are likely to be in the lower part of these ranges) :

•Total Suspended Solids	60 to 90 percent	•Total lead	50 to 90 percent
•Total Phosphorus	30 to 85 percent	•Total Zinc	30 to 90 percent
•Total Nitrogen	30 to 80 percent	•Total copper	20 to 80 percent
•COD	10 to 50 percent	•Bacteria	20 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- May need supplemental water supply to maintain base flow if not dug into the ground water.
- Unless excavated into the water table, the minimum contributing drainage area needed to maintain base flow will need to be determined. This will vary depending on rainfall and watershed characteristics.
- Overgrowth of aquatic plants can lead to reduced hydraulic capacity.
- Infeasible in very dense urban areas or areas with high land costs.

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- Operation

Successful operation depends on good design, construction, and maintenance, especially of the sediment forebays, wetland vegetation, and the discharge structure.

- Maintenance

Activities necessary to maintain the long term functioning of a constructed wetland system are still relatively unknown. As a minimum, the following actions will be needed:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Monitoring and periodic removal of nuisance plant and animal species as specified in a written procedure prepared by a wetland scientist.
- Thinning and transplanting of thriving wetland plants as needed to maintain good growth throughout the constructed wetland. Again, this should be done in accordance with a written procedure prepared by a wetland plant scientist.
- Monitoring for mosquitoes and introduction of *Gambusia* or other natural predators as needed.
- Monitoring and removal of sediment accumulations in forebays or within the constructed wetland.

- Management Needs and Obligations

- Inspect quarterly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine health of wetland vegetation.
- Closely monitor the wetland plant community, both during the growing season and, if needed, during the dry season, to assure healthy growth of desired plants. Remove exotic or nuisance species as soon as they appear to limit their establishment and areal extent. Thin or transplant plants from areas where they are growing densely and use them to further establishment or growth in areas with less vigorous plant growth.

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- Monitor sediment accumulations in forebays semiannually. Sediments should be removed when 25% of the storage volume of the forebay has been lost.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. The design should include a bottom bleeddown device, and preferably a system that allows stormwater to bypass the facility. This will allow easy dewatering of the wetland and facilitate maintenance.

2. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays to minimize sedimentation in the wetland. There are several rules of thumb for sizing and designing the sediment forebay. These should be reviewed and those which are relevant to the conditions at the site should be followed. For example, Delaware's stormwater program requires the forebay to be sized to hold 10% of the total basin volume with a maximum depth of four feet.

3. Follow locally applicable design guidelines which take into account local rainfall conditions, hydrology, and plant characteristics. Specific design guidelines for constructed stormwater wetlands have been developed by several state stormwater management programs including Maryland, Delaware, Florida, California, and Puget Sound. These design guidelines can be used as a starting point for the development of state, regional, or locally specific guidelines. It is important to keep the design simple and buildable without extensive supervision. Since the highest level of functioning for stormwater management requires some degree of structural complexity, however, designers and botanists should plan to be in the field to interpret the plans for construction staff.

4. Minimize short circuiting by maximizing the distance from the inlet to the outlet with a minimum length to width ratio of 3:1, preferably 5:1. Baffles, islands, and peninsulas can be used to increase the flow path.

5. The designer needs a good understanding of the local hydrology at the site proposed for a constructed wetland. The ground water table should be at or near the surface, or soil of low permeability should underlay the site. If excessive seepage is a concern, impervious liners can be used. Liners can be geotextiles or 4 to 6 inches of silt loam, clay loam, or organic muck. Experience has shown that most soils in Hydrologic Soil Groups B, C, and D will eventually seal themselves.

6. Soils must be suitable for wetland plant growth and for adsorption, especially if high removal levels of phosphorus or many metals are desired. Neutral soil pH (6 to 8) is best for supporting microorganisms, insects, and other aquatic animals, and is also best for sequestering pollutants in the sediments. Soils with fairly high levels of aluminum or iron are best for adsorption. Medium to fine textured soils, such as loams and silt loams, are optimal for establishing plants and capturing pollutants. A relatively high content of highly decomposed organics ("muck") is favorable for plant and microorganism growth and the adsorption of metals and other organic pollutants.

7. Selection of the plants needs to be done by a wetland scientist. The selection will be

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based on climate, hydroperiod of the wetland, sensitivity to pollution, and aesthetic appeal. A well planned wetland will include a diverse mixture of floating, emergent, and submergent plants. The following guidelines for selection of wetland plants are offered:

- Base selections more on the prospects for successful establishment than on specific pollutant uptake capabilities. Plant uptake is a significant mechanism only for nutrients, which may be released upon the plants' death. Chemical and microbial processes remove more nutrients than plant uptake.

- Match the environmental requirements of plant selections to the conditions to be offered by the site. Consider especially the hydroperiod, light requirements, climate, sensitivity to probable pollutants, and aesthetic appeal. Also consider effects from wind, waves, and water currents.

- Select species that are adapted to the broadest possible ranges of depth, frequency, and duration of inundation (hydroperiod). Careful selection is especially important when runoff quantity control is an objective because water depths will be periodically greater than those that normally occur in natural wetlands.

- Select native species to ease establishment and minimize maintenance. Include some plants that are strong colonizers but avoid exotic species and those native species that are aggressive invaders which crowd out more desirable species.

- Use a minimal number of species for each depth zone. Diversification will occur naturally. One planting recommendations is to use three species per depth zone.

- Select mostly perennial species.

- The establishment of herbaceous plants should precede that of woody species.

- Give priority to species that have been used successfully in constructed wetlands in the past and to species that are commercially available. Use of plants propagated at wetland plant nurseries will minimize pressure to remove plants from natural wetlands.

8. Experience has shown that wetland plants typically will establish themselves naturally in shallow wet ponds, regardless of soil conditions. However, it has become increasingly clear that plant communities develop best when soils harbor substantial vegetative roots, rhizomes, and seed banks. Hydric soils containing vegetative plant material are known as "wetland mulch." Use of this mulch greatly enhances plant community diversity and speeds establishment. However, the content of the mulch is unpredictable and donor sites are limited. A risk of using wetland mulch is the possible presence of exotic, opportunistic species that will displace more desirable natives. Therefore, use of mulch likely to harbor such species should be avoided. Potential sources of wetland soils include (a) spoils from maintenance of highway ditches, swales, and stormwater ponds; (b) spoils from dredging; and, (c) soils removed from natural wetlands that are going to be filled under permit (although these soils are best used for mitigating the loss). It is recommended that the upper 6 inches of donor soils be obtained at the end of the growing season, if possible.

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9. While wetland plants will establish themselves naturally in shallow wet ponds, experience has shown that constructed wetlands are best established by planting. This helps to minimize colonization by undesirable invader species. It is recommended that at least half of the marsh area be planted at a constant density. The design guidelines for constructed wetlands prepared by the state stormwater programs listed above can provide a general introduction to planting densities and strategies. Planting of wetland vegetation in stormwater systems, whether a constructed wetland or the littoral zone of a wet detention system, can provide an excellent public education opportunity, especially for school children.

10. Construction recommendations

- Involve a wetland plant specialist in the system's design and construction.
- Implement good erosion and sediment controls to minimize sediment loading delivered to the constructed wetland. If necessary, divert flows to a sediment basin or other stormwater system during the construction phase until the contributing drainage area is stabilized.
- Schedule construction so that wetland plants can be planted during the growing season, preferably the beginning of it.
- The landscaping plan should be finalized after the wetland has been constructed to confirm soil, moisture, and inundation conditions.
- Order wetland plants from the nursery three to six months before the time planned for installation to ensure they will be available.
- Install control structures and embankment following wet detention guidelines.
- Grade the wetland to an interim elevation slightly deeper than desired final elevation.
- Add a 3 to 6 inch layer of soil amendments or wetland mulch, and spread out over the entire wetland area.
- Stabilize side slopes and allow the wetland to fill until the desired planting time.
- Once wetland plants are delivered to the site, be sure that they are frequently watered and well-shaded to minimize plant loss.
- If necessary, drain the wetland to a depth that facilitates planting (3 to 12 inches).
- Remove plants from their containers and loosen up their root/soil ball before planting.
- A supplemental planting should be scheduled, typically at the beginning of the second growing season, to reinforce plant establishment and obtain the desired plant coverage and density.

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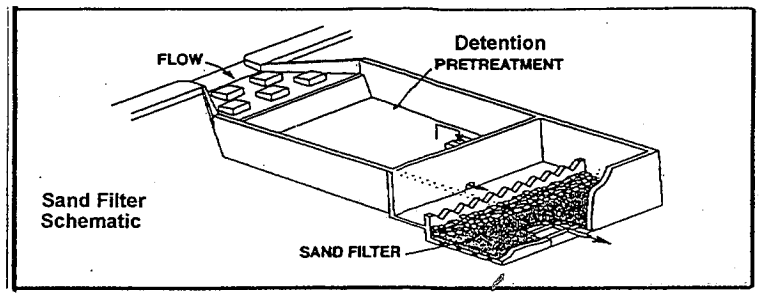
Stormwater Filters



Sand Filter Schematic

Description

A family of stormwater treatment practices which typically consist of a storage BMP in conjunction with a filtering device. The most common filter media is sand, but filters have been made of peat/sand mixtures and even from leaf compost. Filters can be categorized as either "unconfined" or "confined" systems. A side bank underdrain filter within a wet detention system is an example of an unconfined filter - the sand/gravel filter media and underdrain pipes are built into the side banks of the wet pond. Alternatively, the filter media in a confined filter is contained within some type of structure, often a concrete vault. Examples include vertical volume recovery filters, the Austin sand filter, and the Delaware sand filter.

Purpose

Stormwater filters are used solely to remove certain pollutants, primarily particulates, from runoff. They must be used in combination with other BMPs to provide flood protection.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Filtration by sand or other filter media.
- Microbial uptake and/or transformations.

Advantages

- Can be used in urban areas and on highly impervious sites.
- Can be used at sites with high water tables but which have too small of a contributing drainage area for use of wet detention systems.
- May be very cost effective, especially the Delaware sand filter design where the concrete boxes are now being prefabricated in sections.

Disadvantages

- Very maintenance intensive. Filter media may need cleaning or even replacement several times a year, although this depends on a number of factors. However, this level of maintenance can be reduced by controlling erosion and otherwise restricting sediment loadings.
- Provide limited flood storage and attenuation.

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Expected Stormwater Quantity and Quality Performance

Stormwater filter systems are used primarily to remove particulate pollutants from runoff and typically are not used by themselves to attenuate stormwater peak discharge rates or volumes. Treatment effectiveness will depend on a number of design considerations including the treatment volume, whether the system is on-line or off-line, whether it is a confined or unconfined filter, the type of land use, and whether pretreatment is provided by use of the BMP Treatment Train. Studies of the effectiveness of stormwater filter systems have varied greatly. In a study of a wet detention pond with an unconfined side bank filter, Harper and Herr (1993) concluded that most of the treatment occurred in the wet pond, with the filter enhancing removal of only total nitrogen, TSS, and total zinc. Field research in Austin, Texas (Chang et.al., 1990) indicates that their sedimentation/filtration systems remove 70 to 90% of the suspended solids, but only 20 to 85% of the metals, 20 to 40% of the nitrogen, and 50 to 65% of the phosphorus. Two recent studies of the Delaware sand filter design (Horner, 1995 and Bell, 1996) found these designs to be effective and fairly easy to maintain, at least for filter systems. These filters removed 80 to 90% of the total suspended solids, 40 to 60% of the total nitrogen, 40 to 75% of the total phosphorus, and 30 to 90% of the total zinc. The ranges of expected pollutant removal of stormwater filter systems are:

• Total Suspended Solids	60 to 85 percent	• Total lead	50 to 80 percent
• Total Phosphorus	30 to 75 percent	• Total Zinc	30 to 80 percent
• Total Nitrogen	30 to 60 percent	• Total copper	30 to 60 percent
• COD	30 to 75 percent	• Bacteria	40 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- Only use at sites with a full time maintenance entity.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on good design, construction, and most importantly, on regular maintenance, especially of the filter media. With stormwater filters, the question is not whether the filter will clog, but when.

■ Maintenance

Activities necessary to maintain the long term functioning of stormwater filtrations systems include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.

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- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Removal of sediments and other materials that accumulate in pretreatment practices, such as sediment traps or forebays.
- Periodic scraping and aeration of the filter media, with partial removal.
- Complete replacement of the filter media.

■ Management Needs and Obligations

- Inspect monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine whether the filter media is clogging.
- Closely monitor clogging of the filter media to determine when maintenance is needed. There are two approaches to filter media maintenance. Most of the stormwater programs which have created design criteria for filters require eighteen inches to two feet of filter media. This allows the filter to be periodically scraped to remove an inch or two of filter media until only one foot is left. The coloration of the sand will provide a good indication of what depth of removal is required. Then additional filter media is added to restore the original two feet of filter material. Alternatively, especially for unconfined filters, the filter media is completely replaced when the time required to recover the stormwater treatment volume decreases to one-half of the design time.
- Monitor sediment accumulations in sediment traps or forebays semiannually. Sediments should be removed when 25% of the storage volume has been lost.
- Since filters often are used on highly impervious sites with potentially high loading of heavy metals and petroleum hydrocarbons, it is recommended that the filter media be analyzed periodically. This can help to prevent the accumulation of these materials in concentrations that may cause the filter media to be considered a hazardous waste. For example, Horner and Horner (1995) reported that within seven months of use, the levels of total petroleum hydrocarbons in a Delaware Sand Filter at a Seattle barge terminal exceeded Washington's Model Toxics Control Act hazardous waste threshold of 200 mg/kg by two orders of magnitude.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays to minimize sedimentation loadings and reduce oils, greases, and other petroleum hydrocarbons. There are several rules of thumb for sizing and designing the sediment forebay or the presettling basin/chamber for the Delaware Sand Filter (DSF). These should be reviewed and those which are relevant to the conditions at the site should be followed. For example, Alexandria's (VA) program recommends that the presettling basin/

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chamber for the DSF on highly impervious sites contain a minimum of 20% of the stormwater treatment volume but that the entire volume be contained by this chamber on sites with pervious surfaces.

2. Use confined filters which are constructed as "off-line" stormwater treatment systems and which are designed to let stormwater bypass the filter during maintenance.

3. Carefully select the filter media to assure that it meets the specifications established by the stormwater program. Neutral soil pH (6 to 8) is best for supporting microorganisms and is also best for sequestering pollutants in the sediments. Soils with fairly high levels of aluminum or iron are best for adsorption and will help to increase removal of phosphorus and some metals.

4. Balance the hydrologic efficiency of the filter media with its pollutant removal effectiveness. While coarse sands will pass stormwater quickly, few pollutants are removed.

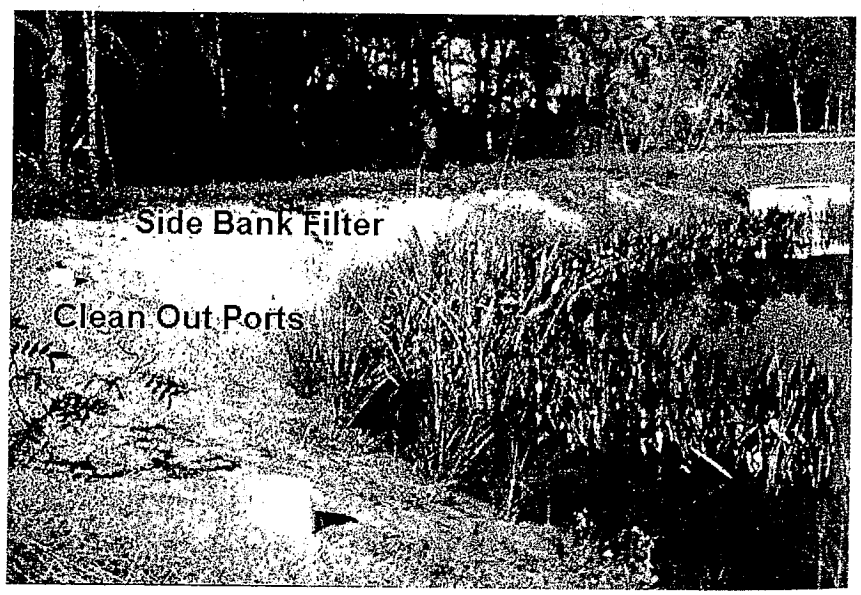
5. Unconfined, mound filters which are sodded provide a relatively low maintenance filter system and provide higher levels of treatment than do sand filters without vegetation.

6. <u>Construction recommendations:</u>

- For confined filters, do not allow inflow of runoff until construction on site is completed and all soil surfaces in the contributing drainage area are completely stabilized with vegetation.

- If detention ponds with unconfined sidebank filters are used for erosion and sediment control, the filter media should be completely replaced once construction is completed and all soil surfaces in the contributing drainage area are completely stabilized with vegetation.

- Side bank filters should contain clean out ports, spaced every 50 feet, to allow underdrain pipes to be cleaned.



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- Filter media should be checked to assure that it meets all specifications, especially grain size and uniformity coefficient.

- Filter underdrain pipes should be carefully placed on a bed of gravel which has been compacted properly, thereby reducing the potential for soil piping and settling problems. Pipes must have proper slope as specified in the design plans.

- For the Delaware Sand Filter design, it is essential that:

  - The top of the sand filter is completely level.
  - The inverts of the notches, orifices, or weirs dividing the sedimentation chamber from the filter chamber are completely level.
  - If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment which must be readily available to maintenance crews.
  - Where underdrains are used, the minimum slope of the pipe needs to be 0.5%.

Delaware sand filter being installed in Alexandria, Virginia.

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Chapter 3

Planning and Design Considerations

> **design** \di-zine\ vb 1: to conceive and plan out in the mind 2: to devise for a specific function or end 3: to conceive and draw the plans for
> - Merriam-Webster Dictionary

1. OVERVIEW

The above definition of the word "design" succinctly describes both the scope and sequence of activities typically undertaken by the designer of a stormwater management facility. Having identified a stormwater problem or need that can best be solved through the construction of a facility, the designer will then select the most appropriate type, conceptualize its function and operation, and determine the specific characteristics necessary for the facility or practice to achieve its desired performance. Having completed this, the designer must then transform these characteristics into a physical entity. This is done through the development of detailed construction plans and specifications, which are used to construct the facility in the field.

Throughout the entire endeavor, the stormwater system designer must, of course, fulfill certain technical responsibilities if the system is to comply with the standards and requirements of the community's overall stormwater management program. To do so, the designer must be familiar with these program requirements as well as the technical data, equations, and analytic techniques commonly used to meet them. However, if stormwater management is to grow beyond its traditional concerns for stormwater quantity to also address stormwater quality and nonpoint source (NPS) pollution, such technical compliance is not enough.

Instead, ***the designer must also recognize his or her unique responsibilities to the people who will inspect and maintain the facility once construction is completed.*** For it is through such recognition that the designer can help ensure both the overall success of the community's stormwater management program and the quality of life of the people that will live, work, or travel past the facility they are creating. It is only by fulfilling these larger design responsibilities that stormwater management will be able to achieve and sustain the public support and participation it needs to effectively address the complex problems demanded of it. ***A description of each of these design responsibilities is presented below, with particular emphasis on minimizing and facilitating stormwater management facility maintenance.*** Suggestions for meeting these responsibilities are also presented, including specific recommendations and design guidelines for various types of stormwater management practices.

1.1. Objectives

To advance the handbook's overall goal of effective and efficient stormwater management system operation, maintenance, and management, the objectives of this Chapter will be:

- To describe maintenance needs and common maintenance problems of various types of stormwater management practices, facilities, and systems.

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- To demonstrate the direct link between many of these needs and problems and the decisions and actions of facility planners and designers.

- To emphasize the ability of comprehensive and enlightened planning, design, and review practices to minimize and facilitate stormwater management facility maintenance.

- To illustrate the long-term cost-effectiveness of such practices during a facility's planning, design, and review stages.

- To encourage facility planners, designers, and reviewers to regard facility maintenance as equal in importance to a proposed facility's hydrologic, hydraulic, structural, biologic, and aesthetic aspects.

- To present planning and design guidelines for specific types of stormwater management facilities and practices that minimize and facilitate post-construction maintenance.

1.2. Intended Readers

This chapter is intended primarily for the following readers:

- **Stormwater management facility planners and designers.**

- **Project design and permit application reviewers and supervisors.**

In addition, stormwater management facility owners (both present and future) can gain valuable insight into the planning and design process. This can help in the selection of a competent designer of a proposed facility and in the development of an adequate project design budget. Finally, construction managers, inspectors, and contractors can develop a greater appreciation of the overall planning and design effort and the need to follow the resulting design plans and specifications as closely as possible. Such understanding can also promote a greater exchange of information and ideas between designers and constructors, thereby enhancing the activities of both.

2. STORMWATER MANAGEMENT PRACTICES AND COMPONENTS

As noted in Chapter 2, the field of stormwater management has grown considerably in the last two decades. One of the less fortunate products of this growth has been a long and sometimes conflicting list of names for the facilities (systems) and practices produced by planners and designers. Therefore, to minimize confusion, increase effectiveness, and illustrate their different maintenance problems and needs, the following definitions have been adopted for use in this Chapter and throughout the entire handbook:

2.1. Detention Practice:

A stormwater management facility that temporarily impounds runoff and discharges it through an outlet structure. Any additional outflow through infiltration or evaporation is negligible and, therefore, not ordinarily considered in the detention system's design. Detention facilities may vary by the duration of time that they store runoff and, therefore, are further subdivided into the following three subcategories:

A. **Dry Detention Facilities** detain runoff for a relatively short time (e.g., 2 to 6 hours) and, as such, are normally used for erosion and/or flood control purposes. In addition, all detained runoff is released following the storm event and the facility is normally dry during inter-storm periods.

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B. Extended Dry Detention Facilities detain runoff for much longer time periods (e.g., 18 to 48 hours) than dry detention facilities and, as such, also provide runoff quality benefits. Similar to dry detention facilities, they release all detained runoff through an outlet structure and are expected to be dry during inter-storm periods.

C. Wet Detention Facilities also release runoff through an outlet structure. However, some runoff is retained permanently in a pool, pond, or lake during inter-storm periods. This permanent pool provides greater water quality benefits through increased sedimentation, flocculation, and biological activity.

2.2. Infiltration Practice:

A stormwater management system that temporarily impounds runoff and discharges it through infiltration through the surrounding soil. Additional discharge may occur through evapotranspiration. Similar to dry and extended dry detention facilities, an infiltration facility is expected to completely drain and be dry during inter-storm periods. Typical infiltration practices includes infiltration basins, swales, drywells, and seepage pits.

2.3. Filtration Practice:

A stormwater management system that filters runoff through selected inorganic or relatively inert media to remove pollutants. Since filtration practices do not normally provide runoff quantity benefits, they are often used in combination with detention systems as pretreatment facilities. Typical filter media include sand, compost, gravel and other materials.

2.4. Biofiltration Practice:

A stormwater management practice that filters runoff through dense vegetation or other organic, biologically active media to remove pollutants. The organic nature of the underlying soils also promotes further pollutant removal as well as infiltration of runoff. Typical biofiltration practices include vegetated swales, filter strips, and buffer areas.

To further organize the presentation and provide thorough coverage of all facility types, each facility or practice has been broken into one or more of the components described in Table 3-1. Due to their different physical or operating characteristics, it is important to note that some practices will not have all of the components listed in the table. Additional information and photographs of the various types of stormwater management practices are presented in Chapter 2.

3. THE RESPONSIBILITIES OF THE FACILITY DESIGNER

As noted above, there are several levels of responsibility that the designer of a stormwater management facility must fulfill. ***First and foremost, the designer is responsible for complying with the technical requirements and standards of the overall stormwater management program*** of which the facility will be a part. This will typically include achieving the required level and range of peak outflow control necessary to prevent or reduce downstream flooding, as well as the detention times and pollutant load reductions necessary for stormwater quality enhancement. Additional technical requirements of the stormwater management program may include emergency discharge capacity to insure dam or embankment safety and structural and geotechnical standards to achieve stability and strength. Therefore, ***the facility designer must be familiar with the specific technical requirements of the stormwater management program as well as the theoretical basis for and use of the various hydrologic, hydraulic, structural, chemical, bio-***

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TABLE 3 - 1.

Major Components of Stormwater Management Practices

COMPONENT	DESCRIPTION
PRINCIPAL OUTLET	Hydraulic structure that controls and conveys the facility's outflow to the downstream conveyance or receiving water.
EMERGENCY OUTLET	Hydraulic structure or spillway that safely conveys emergency overflows from the facility. Includes approach and exit channels.
DAM/EMBANKMENT	Wall or structural fill that impounds runoff in the facility above the adjacent ground surface.
BOTTOM	The lowest or deepest surface within the facility.
SIDE SLOPES	Slopes at dams, embankments, spillways, and facility perimeters constructed through excavation or filling.
TRASH RACK	Device placed upstream of the principal outlet or drain to intercept trash and debris that would otherwise block it.
LOW FLOW SYSTEM	Surface and/or subsurface measures that convey low and dry weather inflows to the principal outlet without storage.
INLETS	Upstream surface and/or subsurface conveyance measures that discharge runoff into the facility.
OUTFLOW SYSTEMS	Downstream surface and/or subsurface conveyances or water bodies which receive facility outflows from the principal outlet.
PERIMETER	Area immediately adjacent to the facility.
ACCESS SYSTEMS	Measures and devices that provide maintenance personnel and equipment access to various facility components.
VEGETATIVE COVER	Vegetation planted on various facility components to stabilize their surfaces and/or provide stormwater treatment.
BYPASS SYSTEM	A system which allows a facility owner to temporarily bypass the stormwater facility to allow a maintenance activity to occur in the "city."

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logical, and geotechnical analyses typically used to comply with them.

However, the responsible facility designer (and the government reviewer approving the design) should not only be familiar with the stormwater management program's technical requirements, but also understand it's overall intent or goals. ***The responsible designer and reviewer must recognize that the program's technical requirements are only the means by which the program's goals are achieved.*** As such, a stormwater management facility will contribute more towards those goals if its designer understands, for example, not just what detention time an extended detention basin should have, but why it should even have one, why it should be a certain duration, and what will happen if it doesn't. Such understanding by designers and reviewers also produces facility designs that are better able to achieve satisfactory results over a much wider range of real world conditions than the limited few used in most design processes.

In addition, due to the inherent complexities of stormwater quality and NPS pollution, the technical requirements of many stormwater management programs are not defined as precisely as the program's goals. For example, it is much easier to specify a program goal of 80 percent removal of suspended solids from stormwater runoff than it is to specify the exact technical measures required to achieve it. However, this disparity between a stormwater program's means and ends can be overcome to a great degree by the responsible designer who, aware of the disparity, is willing and able to look behind and beyond the program's somewhat more limited technical requirements and produce designs that do a better job of achieving the program's goals.

Another design responsibility is based upon the realization that the designer's efforts will ultimately result in an actual physical facility that must first be constructed and then maintained. As such, ***it is vital that the facility be both simple and practical to build and maintain.*** With regards to maintenance, a study of 51 stormwater management facilities in New Jersey by the state's Department of Environmental Protection found that ***more than half of the problems encountered by maintenance personnel at the facilities could be linked to shortcomings in the planning, design, and review process.*** These included:

- a lack of adequate planning and design standards,
- inadequate investigation and analysis of site conditions,
- poor understanding of facility function and operational needs,
- inattentive review, and,
- at times, simply a failure by the designer and reviewer to recognize or remember the facility's post-construction maintenance needs.

According to the study, these shortcomings and failures sometimes resulted in facility maintenance problems that "were virtually unsolvable without massive infusions of time, money, and hard work".

Flat bottom in dry detention basin prevents complete emptying and complicates basin maintenance.

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Typical stormwater system operation, maintenance, and management problems that can be directly linked to poor planning and design or to inattentive review include:

MAINTENANCE PROBLEM: Soggy, unstable bottom in dry detention basin which is difficult to mow.
CAUSE: Bottom will not drain and dry completely between rain events.
SOURCE OF PROBLEM: Flat basin bottom specified by designer.

MAINTENANCE PROBLEM: Mosquito breeding in an infiltration basin.
CAUSE: Persistent standing water in bottom.
SOURCE OF PROBLEM: Basin bottom set below groundwater table due to designer oversight.

MAINTENANCE PROBLEM: Inability to drain and desilt wet detention basin.
CAUSE: Lack of low level drain.
SOURCE OF PROBLEM: Low level drain not provided due to designer oversight.

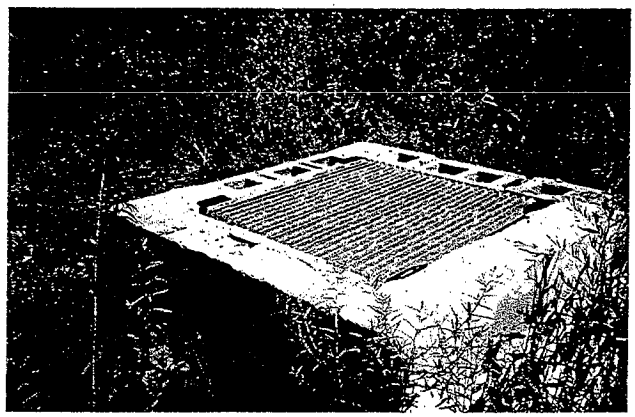
MAINTENANCE PROBLEM: Grass mowing along basin side slopes is time consuming and dangerous.
CAUSE: Excessively steep basin side slopes.
SOURCE OF PROBLEM: Excessive side slope specified by designer.

Highly visible and accessible facilities can be quickly inspected for mosquitoes and other maintenance problems.

MAINTENANCE PROBLEM: Sediment and debris removal from sand filter is time consuming and difficult.
CAUSE: Lack of access manhole from ground surface to sediment chamber.
SOURCE OF PROBLEM: Access manhole not provided due to designer oversight.

MAINTENANCE PROBLEM: Check for standing water in dry detention basin by mosquito control inspector is time consuming.
CAUSE: Basin cannot be viewed from roadway or parking lot. Inspector must stop and exit vehicle and walk to basin to view.
SOURCE OF PROBLEM: Basin located in remote part of site by designer. Access road not provided due to designer oversight.

Less durable outlet structure materials, such as cinder blocks, may save one-time construction costs but will increase long-term maintenance costs.



MAINTENANCE PROBLEM: Continuing repairs of outlet structure and trash racks required at detention basin.
CAUSE: Structural failures due to debris loadings and weather conditions.
SOURCE OF PROBLEM: Inferior, nondurable materials specified by designer.

As described above, ***poor facility design and/or inattentive review can adversely effect facility maintenance in several ways. These include hindering inspection and maintenance activities through lack of***

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adequate access, increasing maintenance efforts through adverse site conditions, and creating additional maintenance needs through the use of inadequate materials. The result of any of these causes is increased maintenance time, effort, and expense and the increased potential for maintenance neglect and facility malfunction or even failure. These points have even greater impact when it is remembered that, unlike facility design or construction, which are normally completed in a matter of weeks, maintenance must be performed for the life of the facility. In addition, the increased potential for maintenance neglect and failure, which the designer or reviewer could have prevented with a few extra hours of effort in the office, may remain a threat for years to come.

It must also be noted that maintenance personnel are not the only people who will suffer the long term effects of poor facility planning, design, and/or review. As noted above, a facility design that first exists only on paper will ultimately exist in or on the ground. Since virtually all stormwater management systems are constructed as part of land development activities, other structures such as homes, offices, stores, factories, warehouses and/or roads will normally be close by, along with the people that will live, work, or travel them. ***While the facility will only be required, on average, to function a few days a month or year, these people must coexist with it every day. If the system is poorly maintained, these people may then be subjected to health threats from mosquitoes, rodents, and other vermin as well as adverse quality-of-life effects from odors or unsightly appearance.*** If these conditions are due, even in part, to deficiencies in the system's design (as demonstrated above), then the planner, designer, and reviewer must share the blame for their creation.

Finally, in the design of any stormwater management facility or practice, cost must also be an important factor. The responsible designer will not only appreciate this fact, but will also be able to accurately determine and compare the costs of the system and the benefits it provides in order to measure the its true cost effectiveness. To do so, ***the designer has a responsibility to fully understand both the combined cost of system operation and maintenance and the relative benefits or cost savings that can be gained from various design alternatives.*** For example, while the use aluminum trash racks or reinforced concrete structures (in place of less durable materials) may increase the client's initial design and construction costs, these increases may be quickly offset by reduced (and recurring) maintenance costs. To accurately perform such analyses requires, among other traits, a high degree of objectivity in order to ensure that the costs and benefits determined by the designer are based upon reality and not the interests or desires of his or her client, supervisor, or government regulator.

4. BMP DESIGN CONSIDERATIONS: POINTS TO PONDER

From the above, it can be seen that ***the responsible stormwater management system designer must not merely be concerned with the technical requirements of a stormwater management program, but must also strive to produce facilities with reasonable and affordable maintenance needs.*** The system must also be practical, safe, aesthetically pleasing, and relatively easy and inexpensive to build. The stormwater facilities that result from such an effort will become assets to the community which they serve and will promote the public interest and involvement necessary for overall stormwater program success.

Faced with such a formidable list of requirements, it can be seen that the responsible de-

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signer and reviewer must not only bring competent technical ability to the design process, but also an informed, open attitude and even a sense of mission or purpose. To help promote such an attitude and more fully prepare them for the job ahead, the following points regarding stormwater management system design, construction, and operation are offered:

4.1. Interested Parties

To produce a stormwater management facility design good enough to earn an "Approved" stamp from a program reviewer (who is presumably interested in assuring compliance with the program's regulations), a facility designer must identify with those interests and make sure they are reflected on the construction drawings. However, to further ensure that the facility will truly be an asset to the community and will make a positive statement about the value of stormwater management, the system designer must expand this list of interested parties to include the following:

The Client: Including the Client on a list of parties having an interest in a facility's design should not come as a surprise. However, a review of what those interests actually are can be enlightening. Therefore, the responsible designer will not automatically assume to know their client's interests (however obvious they may appear), but will instead fully discuss them with the client.

The prospect of having such a discussion should then lead the responsible designer to ask the following questions:

- What should the client's interests be?
- Does the client fully understand the long term operation and maintenance costs which sometimes are the owners responsibility?
- Does the client have a misinformed or misguided attitude towards the goals of stormwater management?
- Is this attitude based upon a lack of understanding or information?

In such cases, ***the responsible designer can, through education (and a touch of diplomacy), both expand the client's understanding and improve their attitude towards stormwater management, thereby enhancing the designer's own chances of producing a positive facility design.*** This will also provide the designer with an excellent opportunity to educate the client about long term system maintenance requirements and costs which the client may not be aware of or fully appreciate.

The Reviewer: Similar to the Client, this individual is also an obvious choice for an "Interested Party" list. However, once again, the following questions may be raised: What are the reviewer's interests and what should they be? Since a reviewer's check of a BMP design can sometimes stray from the program's technical standards into more subjective areas (due, at times, to a lack of such standards), it is often helpful to know what interests the reviewer has in those areas. Are those interests both in keeping with the goals of the stormwater management program and within the program's (and, therefore, the reviewer's) jurisdiction?

Similar to the client, a facility designer may encounter a reviewer who, through a lack of knowledge or an abundance of incorrect information, either misunderstands the importance of system maintenance, or fails to appreciate the costs and effort required to do it properly, or the consequences of neglecting it. Once again, ***the responsible facility designer can, through education and a competent, comprehensive design, expand the regulator's knowledge, interests, and abil-***

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ity, particularly in regard to BMP operation, maintenance, and management.

The Constructor: As noted earlier, one of the key responsibilities of a stormwater management system designer is to transform the system from concept to reality by preparing detailed plans and specifications of how it should be built. It is then up to the constructor to finish the project by actually building the facility from these plans and specifications. Therefore, ***the responsible designer appreciates the efforts of the constructor and does not see their own efforts as an independent exercise, but rather as an integral part of a much larger process***; a process which requires the participation of the constructor and then, ultimately, the operator/maintainer.

As such, the responsible system designer will recognize and respond to the constructor's interests by producing a well-thought out design that can be constructed as easily and simply as possible. Since this may not always be possible, particularly when faced with complex structures, precise dimensions, or difficult site conditions, ***the responsible designer will also take extra care to bring any difficult or unusual aspects of the design to the constructor's attention prior to the start of construction and will even consult with the constructor during the design phase to mutually devise the best construction technique, material, or sequence.***

Under ideal circumstances, the facility designer will also continue their involvement in the project throughout the construction phase. When contracts are agreed upon by the developer and the designer, the contract should include input from the designer throughout the construction phase of project implementation. The designer should work with the constructor to correct mistakes, address oversights, and develop revised designs as necessary to overcome construction problems that were encountered in the field or that may become maintenance problems in the future. It is usually very advantageous to the project for the designer(s) to be in the field to interpret the design at all critical points in the construction. This need is especially acute when the contractor does not have substantial experience building the precise type of project, or when there are any complex elements at all in the design.

The Maintainer: Once construction of the stormwater system has been completed, the designer's involvement with the process (assuming it lasted through construction) normally ends. However, as described above, there are interested parties whose involvement with the facility is just about to start and whose interests the designer must also consider. These are the maintenance personnel who will be responsible for mowing the grass, removing the sediment, clearing the debris, managing the habitats, and performing the necessary repairs at the facility for the rest of its serviceable life. Similar to the constructor, the maintainer's actions will be governed by what the designer creates on paper. However, since construction has been completed and the designer has moved on to other projects, it will be considerably more difficult for the maintainer to have deficiencies or oversights in the design corrected.

As such, ***it is vital that the designer understand and address the interests of the maintainer before it is too late.*** As described in greater detail throughout this chapter, this can be accomplished by designing a facility that, optimally, requires a minimum amount of maintenance that can be performed as easily as possible.

The Resident: As described above, this interested party may also be the worker, commuter, shopper, student, or local government official who will interact with the stormwater management system on a regular basis once

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construction is completed and maintenance begun. This interaction may be physical (through the sense of touch, sight, hearing, or smell) or psychological (as anyone who has worried about their children's safety or the value of their property will know).

In any case, these are the people who most likely have the strongest interest in seeing that a positive facility design is achieved. These are also the people who may soon be asked to participate in the community's nonstructural stormwater management programs by changing some of their aesthetic values and life styles, and who will be paying for the facility's maintenance through their drainage fees, owner association fees, rents, leases, or purchases. Therefore, the facility designer must be aware of their interests and incorporate them into the design plans and specifications.

4.2. Operating Conditions

Just as there are a wide range of people with an interest, either direct or indirect, in the design of a stormwater management system, there is also a wide range of conditions under which it must operate. However, just as the designer may fail to recognize all of the design's interested parties, he or she may also fail to consider all of the real world conditions under which the facility must operate. Instead, ***many designers focus solely on the design conditions necessary for official program approval.***

This is unfortunate, since these design conditions, which may receive all of the designer's attention, will in reality only occur during a small fraction of the system's serviceable life. However, its performance during the remainder of its existence, while ignored by some designers, can largely determine both the amount and frequency of required maintenance and the conditions under which it must be performed. How the system "performs" under these non-design conditions may also largely determine the community's opinion of it and the stormwater program it represents.

Therefore, it is important that the stormwater management system designer be aware of all the weather and other site conditions that the facility will be subject to, including:

Design Conditions: These are obviously the designer's first concern and, as noted above, are normally established by the community's stormwater management program. ***In the case of runoff quantity control, these conditions usually include either a single or range of relatively extreme storm events, the runoff from which must be stored and released at a predetermined rate.*** For example, New Jersey's Stormwater Management Regulations require that the runoff from a proposed land development site for the 2, 10, and 100-year storm events be controlled so that the peak rate of runoff after development for each storm does not exceed the peak rate that existed prior to development. The Somerset County, New Jersey standards are more strict, requiring a peak rate after development that is actually <u>less</u> than existing to account for development induced changes in runoff volume and overall hydrograph shape as well.

In the case of stormwater quality control, typical design conditions may include the temporary storage and slow release of the runoff from a much smaller, more frequent storm event in order to promote pollutant removal through sedimentation. For example, New Jersey's Stormwater Management Regulations require the temporary storage of runoff from a 1-year storm event, with release occurring over 18 to 36 hours depending upon the character and intensity of the proposed development. Delaware's stormwater program requires extended stor-

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age of the first inch of runoff from a proposed site, with release occurring over 24 hours. Stormwater quality BMPs in Florida are designed to treat up to the first two inches of runoff, with release occurring between 24 and 120 hours. In the Puget Sound Basin, the runoff volume or rate, depending on BMP type, from the 6-month, 24-hour "water quality design storm" is the basis for sizing treatment practices.

Whatever exact design conditions the stormwater management program may specify, it is vital that the structural BMP function properly under them or the goals of the program cannot be met.

Extreme Conditions: In addition to the program's design conditions, which have been selected with the goal of runoff quantity and/or quality in mind, the responsible system designer must also recognize that more extreme storms will also eventually occur. Therefore, ***due to the inherent dangers of storing runoff and the exceptionally large quantities of runoff that can be produced by these extreme events, it is vital that the designer also address the goal of safety by ensuring that the facility will also function properly under such extreme conditions.*** Extreme conditions may be defined as either extreme weather or storm conditions where rainfall exceeds normal design values or where equipment or components fail structurally or operationally.

Addressing extreme conditions at a stormwater management system will typically include the provision of an emergency spillway or other auxiliary outflow device that will safely convey the extreme event runoff that exceeds the capacity of the facility's normal outflow structure. It will also include protection of critical portions of any embankment, dam, or discharge points that may be subject to scour or erosion from the high flow velocities generated by this storm event. Protection of such critical areas from damage will not only increase safety but reduce and even eliminate the need for post-storm maintenance and repairs.

Consideration of extreme conditions is also important when reviewing the accessibility of system components to maintenance personnel. For example, if a trash rack is blocked or damaged during a storm event and is causing dangerous water levels in a facility, will maintenance personnel be able to reach it safely? Will inspectors be able to reach the system itself during an extreme storm event to evaluate the potential for overtopping and failure? These questions can only be answered satisfactorily if the facility's performance under such extreme conditions is thoroughly analyzed by the designer.

Dry Weather Conditions: While extreme storm conditions can be expected to occur periodically, a common operating condition at a stormwater management system will be dry weather with various seasonal temperatures, winds, humidities, and periods of daylight. However, while dry weather may be the most prevalent operating condition and the one during which most maintenance will be performed, it is also the one that is most frequently overlooked by the system designer. As a result, how the facility will look, smell, and even sound during the majority of its operating life is then left to chance. This can be particularly unfortunate for the system maintainer and, perhaps more critically, the resident, worker, or commuter who, knowing when to come in out of the rain, will interact most often with the BMP during dry weather conditions. This is especially true if the stormwater system is a multipurpose dry practice. As a result, ***the responsible BMP designer will not only address design and extreme storm conditions, but will also make sure that the facility also performs satisfactorily when it isn't raining at all.***

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4.3. Design Methodologies

Prior to starting the actual design, the responsible stormwater management facility designer will have an adequate understanding of the design methodologies that have been selected or required. These methodologies can cover such aspects as rainfall-runoff computations, hydrograph routings, infiltration and ground water movement, structural design, and geotechnical issues. In doing so, the designer's understanding should include each methodology's theoretical basis, assumptions, limitations, and applicability.

In addition, the responsible designer will also have an understanding of both the accuracy needed to perform the design and the accuracy of the method selected to do it. From this information, the responsible designer will not waste time producing unneeded accuracy nor attempt to achieve a level of accuracy beyond the limits of the method. In addition, the responsible designer will understand the sensitivity of each of the method's input variables and will appropriately allocate his or her efforts, time, and resources in developing each one.

Finally, the responsible designer will understand the applicability of each methodology to the design of such maintenance-related items as bottom and side slopes, trash racks, erosion protection measures, low flow channels, forebays, and outlet works.

4.4. Facility Type

The final point for a stormwater management facility designer to consider before or during the design process is the exact type of practice to be used. There are typically a wide range of stormwater management practices available for consideration, ranging from relatively simple vegetated filter strips and swales to large wet ponds and constructed wetlands. However, ***selection of the most appropriate type of facility may have a greater impact on maintenance effort than all other factors combined.***

Selection of the most appropriate stormwater BMP will depend upon a number of factors, including program requirements, facility location, site conditions, maintenance needs, safety, cost, and performance characteristics. Similar to that of selecting/determining facility operating conditions, however, the facility designer may often consider only a few of these factors, most notably program requirements (keep the reviewer happy and get the approval) and cost (keep the client happy, too). The ***responsible designer, however, will recognize the performance, construction and maintenance needs, uncertainties, and risks inherent in each facility type and will then select (or help influence the selection of) the most appropriate type of system for the site or project.*** This process typically begins with the identification of the fundamental characteristics of each type of stormwater management practice, along with the project's physical, economic, social, and regulatory constraints. The process then becomes one of comparison and analysis, with the best match of site and facility found by eliminating those options least suitable.

For example, a site with porous soils, low ground water table, and close proximity to residences may not be best suited for a wet pond or constructed wetland, while the active recreational needs of the residents may benefit from an infiltration basin or dry, extended detention basin that can also serve as an athletic field. In addition, the maintenance needs of these two practices should be well within the homeowners' abilities, while a constructed wetland may require expensive maintenance expertise far beyond both the homeowners' ability or budget. ***Recognizing that there are rarely perfect matches, comparisons and analyzes such as this will help reduce the***

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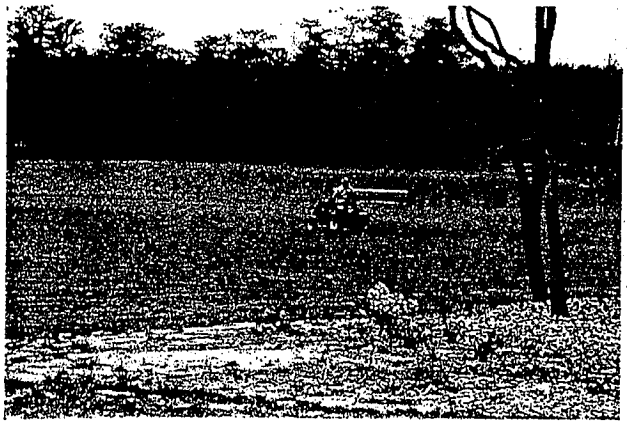

Minimum maintenance performed at maximum efficiency should be a goal of every stormwater facility planner, designer, and reviewer.

number of potential facility types, improve the thoroughness and objectivity of the overall selection process, and ideally produce the optimum stormwater system, not only from a performance or regulatory viewpoint, but from a maintenance viewpoint as well. This process can even help identify inherent weaknesses in or problems with the selected BMP or exceptional maintenance demands. This will enable the responsible facility designer to devote additional time and effort towards correcting or minimizing them during the design phase.

To undertake such a selection process obviously requires a stormwater designer who understands the fundamental characteristics and needs of each facility type and who can objectively assess all of the pertinent site constraints. Such a designer must also be willing and able to address the differing opinions of other, less objective or informed parties (including the reviewer, client, or member of the public) in order to assure that the best practice is ultimately selected. As noted throughout this chapter, ***achieving an optimum stormwater management facility design is a complex and demanding process which must incorporate numerous interests and requirements. Starting the process with the wrong facility type, however, transforms a complex and demanding process into an impossible one.***

5. BMP DESIGN CONSIDERATIONS: A CHECKLIST

Having completed the BMP practice selection process with idealism, and design contract still intact, and armed with the necessary technical and regulatory knowledge and economic, social, and maintenance sensitivity, the responsible stormwater system designer is ready to begin the actual design process. ***Presented below is a checklist of six key design considerations to help guide this effort, with particular emphasis placed upon long term facility maintenance. Ideally, these six items have or will become an integral part of the designer's thought process and will automatically be included in each design effort.*** These items can also serve as guidelines for reviewers responsible for the review and approval of specific system designs and can even serve as goals for those developing new stormwater management programs.

5.1. Safety

For many reasons, the safety of the stormwater management system must be the primary concern of the designer. Due to its structural nature and, in many instances, the fact that it will impound water either permanently or temporarily, a stormwater facility will inherently pose some degree of safety threat.

Those at risk will include people living, working, or travelling downstream of the system and whose safety and/or property will be jeopardized if the facility were to fail and release stored runoff. Since this is a risk that has been created solely by the system, the designer must assure that the probability of such a failure is acceptably small.

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However, also at risk at the facility are maintenance personnel, inspectors, mosquito control personnel, and equipment operators, who must work in and around it. Typical hazards include deep water, excessively steep slopes, slippery or unstable footing, limited or unsafe access, and threats posed by insects and animals. As noted above, ***the responsible stormwater designer understands the importance of minimizing and facilitating facility maintenance. Providing a safe working environment for the system maintainer is one important way to do it.***

Finally, those living, working, traveling, attending school, or playing in the vicinity of a facility may also be at risk, particularly if the system serves both as a stormwater management and recreational facility. Once again, such things as standing water, steep slopes, unstable footings, and insect and animal bites must be addressed by the designer in order to avoid creating a system that is a detriment to the community it is intended to serve. Failure to do so will only alienate those members of the community that are being asked to play a vital role in the community's stormwater management efforts.

5.2. Performance

Having made a strong commitment to safety, the designer must then consider facility performance. This will normally include achieving the necessary stormwater detention times, flow velocities, settling rates, peak flow attenuation, and/or ground water recharge for the range of storm events to be managed. In addition, again with a commitment to safety, the designer must also ensure that the system performs adequately under emergency conditions, most notably when the peak rate and/or volume of runoff flowing into the basin exceeds the discharge capacity of the facility's principal outlet. This will require the inclusion of emergency or auxiliary outlets in the facility to safely convey this excessive inflow through the BMP without jeopardizing its structural integrity.

In most instances, the performance standards that the system's design must meet will be specified in the stormwater management program's regulations. However, experience has shown that these performance standards may, at times, be vague, contradictory, or even impossible to meet. For example, many stormwater system designers have been confronted with a requirement to reduce both the peak rate <u>and</u> total runoff volume from a developed (or developing) watershed to predeveloped levels. This has often led to much head scratching, for the solution will normally require the use of an infiltration or recharge basin which, due to site constraints, may either be impossible to construct or impractical to operate and maintain. Or the regulations may require high sediment removal rates but preclude the use of low flow channels that can greatly facilitate the sediment's removal by maintenance personnel. ***Faced with such circumstances, the responsible designer will look beyond the written regulations and investigate their origins and true intent with regulatory personnel. Direct inclusion of these individuals in the design process will also help ensure more positive overall results.***

5.3. Constructability

Up until now, the designer's efforts to achieve adequate facility safety and performance levels will be achieved only on paper or computer disk. However, ***since the ultimate goal of the design process is to actually create a stormwater management system, the designer must also give careful consideration to how it is to be constructed.*** Achieving exceptional safety and performance characteristics in a system that cannot actually be built solves nothing and wastes much. Achiev-

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ing required levels of safety and performance in a facility that can be constructed with relative ease, using readily available materials, equipment, and skills is commendable. It not only solves a specific stormwater management problem, but also helps to advance the community's overall stormwater management program.

"Constructability" can be defined as a measure of the effort required to construct a stormwater management system. A facility that is highly "constructible" will use materials that are readily available, relatively inexpensive, and do not require special shipping or handling measures. They will be both durable and easily modified in the field to meet specific site conditions. Similarly, the construction techniques and equipment required to construct the system will also be relatively simple, straight forward, and familiar to the people who will be performing and operating them.

In addition, construction plans and specifications should be complete, clear, and concise. They should be well organized - with all of the necessary information regarding a specific facility component or construction stage provided on a single or adjoining sheets. All new or more difficult techniques, stages, or components should be given extra attention, with ample instructions, notes, and details.

It is important to note that the above description is <u>not</u> intended to discourage the use of new or innovative materials or construction techniques, nor to inhibit creativity in the stormwater system design process. In fact, ***innovation in design and construction is vital to the future growth of stormwater management.*** Instead, the above description of "constructability" is intended to remind designers that they must consider the construction aspects of the BMP in the design process and strike an optimum balance between performance and safety requirements, constructability, and innovation for each design they undertake. In addition, ***the more well-constructed a stormwater management facility is, the less overall maintenance and repair it will require.***

5.4. Maintenance

Obviously, in a handbook on stormwater management system operation and maintenance, the same recommendation, given above for constructability, must be repeated for facility maintenance. Similar to construction, the degree of effort and expense required to adequately maintain a stormwater management system will help determine the overall success of its design. A system with manageable maintenance needs can be expected to remain in reasonably good condition and will have a stronger chance to become and remain an asset to the surrounding community. On the other hand, a facility with excessive maintenance needs is more likely to be neglected and will quickly become a community liability. As such, ***BMP operation and maintenance can directly effect the overall success of the community's stormwater management program.***

The stormwater designer can help determine a facility's maintenance needs by considering several aspects of that maintenance in the design process. First, it is important that the system design include the ***use of durable materials*** that are able to withstand the many and varied physical conditions the facility will experience over its lifetime. Secondly, ***suitable access to key facility components and areas is vital*** if required maintenance levels are to be achieved. This will include provisions for walkways, staging and disposal areas, access hatches and gates, and safe, stable working areas. The frequency of maintenance will have a large impact on both maintenance cost and quality, and it is the designer's responsibility to achieve an appro-

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priate level. Finally, the ***system designer should always strive to minimize the overall amount of maintenance at the facility and to make that amount as easy as practicable to perform.*** A more detailed discussion of maintenance considerations during system design is presented in the following section.

5.5. Cost

Inclusion of a stormwater management system's cost in a list of design considerations should not be surprising. However, once again, a review of the full costs associated with a facility may yield a few surprises that may increase designers' understanding and encourage them to give system costs the full consideration they deserve. ***Where costs are surprising, the designer should communicate with the local regulatory agency to ensure that the costs are "real" and to make the regulatory agency aware of the economic impacts of pertinent program requirements.***

The cost that will be most obvious to the designer will be the systems's construction cost. This can be readily estimated with reasonable accuracy and will be the one most directly borne by the designer's client. As such, this cost is the one that the designer will most often focus on during the design process to the exclusion of all others.

In doing so, what other costs will be overlooked? One may be the designer's own fee, which is part of the overall system cost but which has probably been excluded because it has already been determined. However, the amount of the designer's fee will have a direct impact on the facility design, since it will determine the amount of effort and resources the designer can/will use to produce it. The level of effort expended during the system's design can have a similarly direct effect on the effort and cost of both construction and maintenance. As such, it can be seen that ***paying a higher cost for a more comprehensive facility design may ultimately result in even greater cost savings to the client during subsequent project stages.***

Therefore, while this is <u>not</u> a signal to facility designers to raise their fees, it is meant to remind designers that their fee <u>is</u> part of the overall system cost. It is their responsibility to determine what level of design effort and cost represents the best investment for both the client and the community.

Another portion of a system's total cost that is frequently overlooked is the cost associated with its operation, maintenance, and management. ***While the annual cost is usually a small percentage of the construction or even the design cost, it must be remembered that, unlike construction or design, OMM costs are recurring and must be paid throughout the life of the system.*** Therefore, while a maintenance cost savings may appear to be insignificant on a per operation basis and not worth the extra design or construction costs required to achieve it, value may be viewed quite differently when multiplied by the numerous times the savings will be realized. For example, an added investment in design to produce a trash rack that will require less frequent cleaning or an added investment during construction to reduce the frequency of outlet structure repairs may quickly yield a positive return in the form of reduced maintenance costs. Similar conclusions can be reached for many other design and construction efforts, such as providing better access, using more durable materials, and selecting a BMP type that best suits site conditions.

5.6. Community Acceptance

The final recommended design consideration

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once again involves those people who may have the greatest interest in the stormwater management system: the community. Not coincidentally, these same people will have the greatest role in funding the facility's maintenance and will ultimately have the greatest role in the various nonstructural programs intended to augment stormwater management systems in the future. To protect these interests and encourage assumption of that role, ***it is up to the designer to help create a facility that will be viewed as a community asset rather than a liability.***

As discussed above, this can be achieved only by considering the system's aesthetic value, preventing the creation of nuisances and safety threats, minimizing and facilitating facility maintenance, as well as achieving required performance levels. It is only through all of these factors that stormwater management will gain the understanding and credibility it requires within the community.

6. SPECIFIC MAINTENANCE CONSIDERATIONS

To further help stormwater management planners, designers, and reviewers include system maintenance in their everyday thinking, three specific maintenance considerations have been developed. These considerations, which were originally developed for the New Jersey Department of Environmental Protection's Stormwater Management Facility Maintenance Manual, should ideally come to mind whenever a stormwater management practice is pondered, planned, designed, or reviewed. The facility designer should pretend that they must do the maintenance to see if access and maintainability are provided.

6.1. Maintainability

Maintainability can be expressed in three ways, all of which should be given equal importance by facility designers and reviewers:

- Every effort should be made to minimize the amount and frequency of regular maintenance at a stormwater management system.
- Performance of the remaining maintenance tasks should be as easy to perform as possible.
- All efforts should be made to eliminate the need for emergency or extraordinary maintenance at the facility.

Recommended techniques for accomplishing these goals, which can be used to both select the most appropriate type of BMP, as well as design and review it, are presented below.

6.2. Accessibility

According to many maintenance personnel, the biggest problem they encounter is not the amount or frequency of maintenance they must perform, but the difficulties they have in simply reaching the location of the required maintenance work. In order for proper maintenance to be performed, the various components of the stormwater system and, indeed, the facility itself, must be accessible to both maintenance personnel and their equipment and materials. Physical barriers such as fences, curbs, steep slopes, and lack of adequate and stable walking, standing, climbing, and staging areas can seriously hinder maintenance efforts and drastically increase maintenance difficulty, cost, time, and safety hazards. Amenities such as depressed curbs, hand and safety rails, gates, access roads, hatches, and manholes will expedite both inspection and maintenance efforts and help hold down costs and improve efficiency.

Important design considerations for components such as gates, hatches, manholes, trash

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racks, and other components that must be lifted or moved during inspection or maintenance operations, include both the item's weight and a secure place to put it when it's not in its normal location. When weight becomes excessive, mechanical aids such as hoists, lifts, and lifting hooks should be provided. When fastening removable items like trash racks, orifice and weir plates, and gratings, the use of noncorroding, removable, and readily accessible fasteners will also help greatly.

Sometimes design considerations may conflict. For example, in designing access roads, they must have the proper turning radius, slope, and wheel loading to allow cleaning of a pond by heavy construction equipment. The road's storm drain covers, designed for the desired wheel loading, may be too heavy to move easily. Perhaps a different access way may need to be provided.

Finally, ***legal barriers such as lack of access rights or inadequate maintenance easements can stop the best maintenance efforts before they can even get started.*** This is especially pertinent to project reviewers, who normally have the authority to require such legal aspects of the project.

6.3. Durability

The use of strong, durable, and noncorroding materials, components, and fasteners can greatly expedite facility maintenance efforts. These include strong, lightweight metals such as aluminum for trash racks, orifice and weir plates, and access hatches; reinforced concrete for outlet structures and inlet headwalls; hardy, disease-resistant vegetation for bottoms, side slopes, and perimeters; and durable rock for gabions and riprap linings. ***In most instances, the extra investment normally required for more durable materials will pay off over time.***

7. SUGGESTED DESIGN REVIEW TECHNIQUES

Throughout this chapter, the stormwater system designer has been encouraged to consider a wide range of interests, operating conditions, costs, and other responsibilities throughout the design process. Presented below are two recommended techniques to help accomplish it. They can either be used as review techniques following completion of a facility design or, ideally, be incorporated into the overall design process and used continually during it.

7.1. Spend a Mental Year at the Facility

To use this technique, ***the stormwater designer or reviewer simply imagines conditions at the completed facility throughout a full year.*** This should not only include rainy and sunny weather, but also light rain showers (with little or nor runoff) and, where appropriate, both light and heavy snowfalls and frozen ground conditions. Other site conditions may include late autumn, when trees have lost their leaves and they have collected at the facility bottom, and hot, dry weather or drought, when the turf or other vegetation is stressed or killed. Finally, for safety purposes, the designer should also imagine what the system will be like at night.

As these conditions are visualized, ***the designer should also imagine how they may affect not only the operation of the system itself, but also the people that will maintain it or otherwise interact with it.*** Will the outlet structure's trash rack be particularly prone to clogging by fallen leaves, especially from the trees the designer just specified for the facility's bottom? Can falling and/or blowing snow completely fill the facility, leading the unsuspecting snow plower or pedestrian to think that the grade is level? What about the ice that will form on the surface of a pond or

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constructed wetland? Can someone fall through? Could that someone be a child taking a shortcut home or out looking for a place to skate? How will they be warned not to? How will they be rescued if they do anyway?

What about night conditions? Will the constructed wetland next to the office parking lot that's so attractive during summer lunch hours become a safety hazard to workers walking to their cars in the winter's darkness? Or will that same summer sun and a lack of rainfall produce some of the wonderful aromas of anaerobic decomposition?

At first, it may be exasperating to realize that the number of possible site conditions and circumstances can be as numerous and varied as the number of possible facilities types. But then again, that is the point of this exercise. It is intended to help the designer consider and design for all possible conditions at the facility, not just the 1 or 100-year storm event required by the regulations. In doing so, the facility designer will not only meet the letter of the regulations, but will raise the spirit of the entire stormwater management program.

7.2. Who, What, When, Where, and How?

The second recommended review technique a system designer may employ is to simply focus on one or more characteristic or function of the facility and then ask (and attempt to answer) the above question. For example, let's consider stormwater system operation and maintenance and then ask:

- **Who will perform it?** Does the stormwater system's design require specialists or will someone with general maintenance equipment and training be able to do the job?

- **What needs to be maintained?** Preparing a list of all facility components included in a design that will need attention sooner or later may prompt a revised design with a shorter list.

- **When will maintenance need to be performed?** Once a day? A week? A year? Remember, the recurring costs of system maintenance can be substantial. In addition, can maintenance only be performed during dry weather? If so, what happens during two or three weeks of wet, rainy weather? What happens when repairs need to be made or debris removed during a major storm event? In terms of effort and possible consequences, it is easier for the designer to find answers to these questions now, than for maintenance or emergency personnel to scramble for them later.

- **Where will maintenance have to be performed?** Will the maintainer be able to get there? Once there, will they have a stable, safe place to stand and work? In addition, where will such material as sediment, debris, and trash removed from the facility be disposed of? Before answering that question, do you know how much there might be and what it might contain? Are there toxic or hazardous materials in the sediment or debris? If so, is the place you originally intended to use for disposal still suitable? Once again, it is easier to address these questions now then when the dump truck is loaded and the engine's running.

- **How will maintenance be performed?** The simple instruction to remove the sediment or harvest the vegetation can become rather complicated if there hasn't been any provisions made to allow equipment to get to the bottom of the facility or even into the site. "Mowing the grass" can become "risking your limbs" on long, steep slopes. How will you explain to your client why the stormwater management facility they have invested in has become a liability to themselves and their community?

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Similar exercises can be performed with constructors, inspectors, and residents as the object of inquiry. For example, where will the nearest residence be? How will the constructor build the emergency spillway? When will an inspector need to visit to check for mosquitoes?

Similar to the "mental year" review technique, the questions raised in this technique are intended to make the designer more aware of all the possible impacts the facility may have and, further, to encourage the designer to address those impacts now, during the design phase, rather than leave them for others, particularly maintenance personnel, to cope with later. Even if the designer cannot completely answer all of the questions, he or she will be able to advise the others of any unavoidable needs or problems that will be inherent in the facility and allow them time to adequately prepare.

8. DESIGN GUIDELINES

Presented on the following pages are technical design guidelines that are intended to minimize and facilitate maintenance at detention, infiltration, filtration, and biofiltration practices. Separate guidelines are presented for each BMP type. In addition, the guidelines are further divided into each facility's major components for easier reading and reference use. Descriptions of typical maintenance problems at various facility components have also been included to further stimulate the reader's efforts to produce BMP designs that require minimum levels of maintenance effort. The technical guidelines have been based upon similar guidelines presented in the Stormwater Management Facilities Maintenance Manual prepared by the N.J. Department of Environmental Protection.

It is important to note that the guidelines should be used with all other hydrologic, hydraulic, structural, geotechnical, biological, aesthetic, and legal requirements of the stormwater management program governing the design of a particular facility or practice. As such, they are not meant to conflict or replace these requirements but, instead, to complement and expand them. Finally, a responsible designer understands that each project and facility site is unique and may require special, additional, or more strict measures.

9. SUMMARY

Stormwater management must still be considered a relatively new endeavor, particularly on a nationwide basis. However, despite that status, it has been charged with the responsibility of addressing some very complex environmental problems. In order for stormwater management to grow to the level demanded by this charge, the designers of stormwater management facilities must be willing to assume a degree of responsibility for that growth. ***BMP designers can fulfill that responsibility by producing facility designs that do not merely meet official regulations and standards, but help inspire new, better, and more comprehensive ones***.

Facility designers must also incorporate a wide range of interests into the facility design, including those held by stormwater program regulators, contractors, maintainers, and those members of the community interacting with the facility and paying for its long term maintenance. During the design process, the facility designer must not only consider the facility's performance, but also the extent, frequency, difficulty, and cost of facility maintenance. Finally, the BMP designer must always recognize the facility's impacts both on the community around it and the stormwater management program the community has entrusted them with.

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10. DESIGN GUIDELINES FOR DETENTION PRACTICES

10.1. INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater detention systems that require minimum levels of maintenance. Typical detention practices include:

- **Dry Detention Basins**
- **Extended Dry Detention Basins**
- **Wet Detention Basins or Ponds**
- **Subsurface Detention Facilities**

To help accomplish this minimum maintenance goal, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that ***these design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce stormwater detention systems that require optimum levels of maintenance performed with the least practical effort, time, and expens***e. Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibilities for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of detention BMP are presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

10.2. BOTTOMS

A. Dry and Extended Detention Dry Facilities

In a study performed by the N.J. Department of Environmental Protection, facility bottoms were the most likely location of chronic maintenance problems at dry and extended dry detention facilities. Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Standing Water**
- **Soggy Surfaces**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. To promote complete emptying and prevent standing water or soggy surfaces, vegetated bottoms should have a minimum slope

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of 2 percent and be graded to the outlet structure or low flow channel.

2. To promote complete emptying and prevent standing water or soggy surfaces, the lowest point in the bottom should be at least 4 feet above the seasonally high ground water level or bedrock unless adequate subsurface drains are provided.

3. To provide adequate drying time, to avoid delaying scheduled maintenance efforts, and to prevent mosquito breeding, the maximum storage or ponding duration should not exceed 24-48 hours, depending on the vegetation's tolerance to wetness.

4. To avoid delaying scheduled maintenance efforts, topsoils and subsurface soils should be sufficiently permeable to allow rapid infiltration, evaporation, and evapotranspiration.

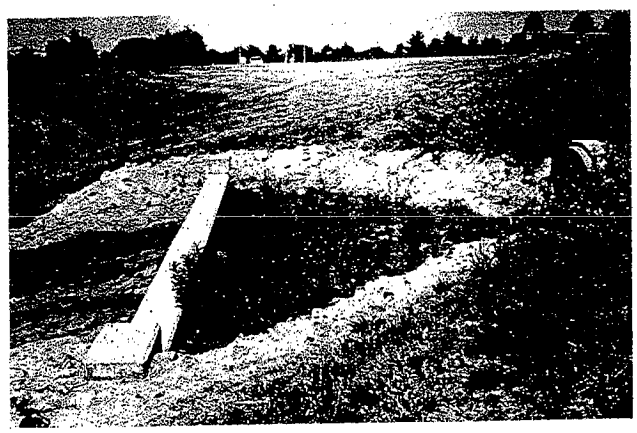
5. Subsurface drains connected to the principal outlet structure, low flow channel, or other discharge point are encouraged to promote quick and thorough drying of the facility bottom. In doing so, care should be taken to prevent stormwater inflow from inadvertently bypassing the basin's outlet controls. (See **G. LOW FLOW MEASURES** for additional details.)

6. To minimize routine grass maintenance such as mowing and fertilizing, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on native grass varieties and mixtures are available from agencies such as the local Cooperative Extension Service or Soil Conservation District. (See **H. VEGETATIVE COVER** for additional details.)

7. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. (See **H. VEGETATIVE COVER** for additional details.)

8. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Sediment traps or forebays at inflow and outflow points should always be used. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.



9. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain removed sediment, on a long-term basis.

10. Suitable access for maintenance personnel and equipment needs to be provided to the facility bottom. (See **J. ACCESS** for details.)

11. Construction plans and specifications should include provisions that minimize the potential for localized settlement and subsequent ponding. These provisions include

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Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.

proper surface and subsurface soil characteristics, compaction requirements, grading equipment, and erosion control prior to the establishment of permanent vegetative cover.

12. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

13. At subsurface detention facilities, suitable access, observation points and/or monitoring wells should be provided to facilitate inspection and cleaning. (See **J. ACCESS** for additional details.)

B. Wet Detention Facilities

While unseen, wet detention system bottoms collect sediment and other material at a much faster rate than their dry counterparts. Removal of this material can be difficult and expensive. Other problems may arise in the aquatic ecosystem as well. Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Poor Water Quality**
- **Limited Access and Staging Areas**
- **Non-Permanent Pool**
- **Excessive Sedimentation**

1. In order to promote a healthy aquatic ecosystem, the minimum permanent pool depth should be 4 feet or greater. On the other hand, it should not be so deep as to allow thermal stratification to develop in the summer, with the resultant likelihood of anaerobic conditions developing in the bottom stratum. Depth should be limited to that at which small lakes in the vicinity stratify; 8 feet maximum is probably a widely applicable limit.

2. Design of a wet detention system should include the determination of the proposed site's ability to adequately support a viable permanent pool with an equally viable ecosystem. The design should account for such factors as the required rate and quality of dry weather inflow, the quality of stormwater inflow, seasonal and longer term variations in the ground water table, and the effects of expected sediment and other pollutant loadings. In the highly seasonal climates of the West Coast, it may be appropriate to design for a semipermanent wet pool, which gradually dries in the summer.

3. The establishment of predacious native (if possible) fish species in the permanent pool will help control mosquito breeding, but introduction of nonnatives or fish not already established in the area should be avoided.

4. Provisions to drain the permanent pool are necessary for maintenance and safety. A gravity drain is the preferred method. If this is not feasible, suitable pumps and both primary and backup power sources should be provided. To ensure that they are available when needed, all pumps and backup power sources should be reserved for facility use only. In residential communities, pumps may only be allowed to run during daytime hours due to noise. This needs to be considered when determining times for the drainage to occur.

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5. To promote complete emptying of the permanent pool when necessary, the bottom should have a minimum slope of 2 percent and be graded to the outlet drain or pump intake.

6. Water quality, including suitable oxygen levels, should be maintained through continuous recharge with fresh water from natural surface or subsurface sources. Alternatively, orienting the detention system to take advantage of prevailing winds can help to promote aeration and circulation. Mechanical aeration should be relied upon only when absolutely necessary.

7. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas upstream of the permanent pool. The BMP Treatment Train is strongly recommended for wet detention systems, especially if they are to be promoted as "lakes" and serve as an aesthetic and recreational amenity for the development. Swale conveyances and sediment traps or forebays at inflows are encouraged. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

8. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 5 years or more of removed sediment.

9. Suitable access for maintenance personnel and equipment should be provided to the facility bottom to allow proper use of equipment that is used by the maintainer. (See **J. ACCESS** for details.)

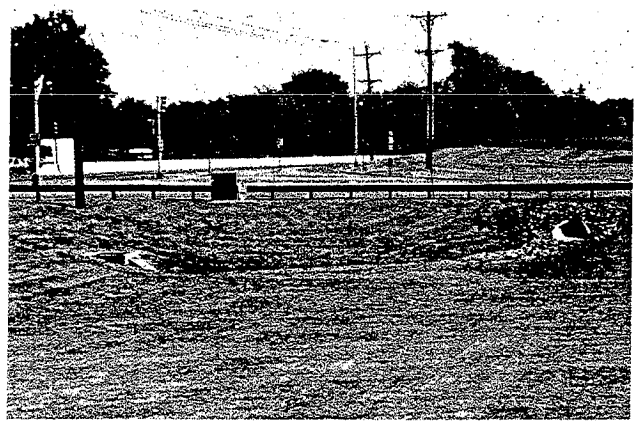
10.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long, Continuous Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater that 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side slopes less that 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

Mild side slopes allow maintenance personnel to perform their jobs quickly and safely.



2. For safe movement of maintenance personnel and safe operation of equipment, side slopes steeper than 5 to 1 and higher than 15 feet should be terraced at their midpoints. The terrace should have a minimum width of 3 feet and should be graded at 2 percent or flatter towards the lower half of the slope.

3. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **J. ACCESS** for details.)

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4. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a safety hazard to maintenance personnel walking along or up the slope.

5. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

6. The effects of rapid pool drawdown should be checked to prevent side slope sloughing.

7. For safe movement of maintenance personnel and safe operation of equipment, fences should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, or roadways.

8. Below the permanent pool level at wet detention facilities, a 4-foot to 10-foot wide level area or safety ledge should be provided to prevent people or objects from sliding or falling into deeper water. This area can be used to create a vegetated littoral zone along the shoreline. The vegetated littoral zone provides biological processing of dissolved pollutants, requires less regular maintenance than a grass shoreline, and provides habitat for predacious insects, fish, and birds which control mosquito breeding.

9. Durable linings such as gabions or riprap need to be considered along wet detention system shorelines prone to erosion due to excessive wave action or ice movement. Such linings should extend sufficiently above and below the permanent water level to account for wave and ice run-up.

Good shoreline erosion protection is vital for facility maintenance and safety.

10.4. PRINCIPAL OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Structural Deterioration**
- **Limited Access**
- **Corroded Appurtenances**
- **Vandalism**
- **Excessive Debris Accumulation**

1. For durability, principal outlet structures should be constructed of reinforced concrete containing Type II cement and having a minimum specified 28-day compressive strength

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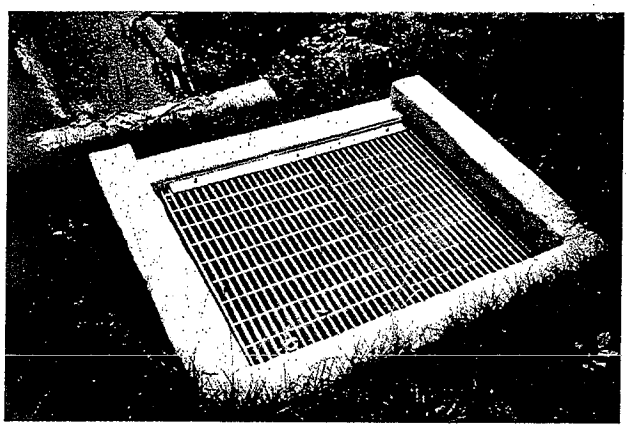
of 3,000 PSI. Concrete shall be designed in accordance with all applicable codes and requirements.

2. For durability, all appurtenances, including access hatches, trash racks, gratings, railings, orifice and weir plates, and fasteners should be constructed of lightweight, noncorroding materials. Material strengths should be sufficient to withstand design loads without damage or failure.

Outlet structure gratings, trash racks, and other appurtenances should be lightweight, durable, and removable.



3. Outlet orifice and weir plates should be constructed from aluminum or other lightweight, noncorroding material. The plates should be fastened to the structure with noncorroding, removable fasteners. A gasket of neoprene or similar material should be placed between the plate and the structure wall. The opening in the structure wall over which the plate is bolted should have at least twice the area of the outlet orifice or weir to facilitate field adjustments and future expansion. See Figure 3-A at the rear of this chapter for details.

4. To facilitate access and movement by maintenance personnel, principal outlet structures should have a minimum horizontal interior dimension of 4 feet. (See **J. ACCESS** for additional details.)

5. Vital parts of the principal outlet structure should be readily and safely accessible to maintenance personnel during both normal and emergency conditions. Gate valves should be able to be operated in the dry when the maximum design water level occurs. Temporary measures such as ladders are only acceptable for emergency conditions as part of an approved emergency action plan. (See **J. ACCESS** for additional details.)

6. To minimize both required maintenance and the consequences of inadequate maintenance, principal outlets should avoid using moving or mechanized parts for outflow control whenever possible.

7. To facilitate cleaning, outlet pipes should have a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete. To minimize potential leakage problems, the number of outlet pipes should be kept to an absolute minimum. More than one outlet pipe should be used only where unavoidable. All outlet pipes must be watertight under the maximum expected head or pressure.

8. Grading and landscaping around principal outlet structures should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

9. Stable areas that provide maintenance personnel with firm footing should be provided at the upstream face of principal outlet structures at dry and extended dry facilities. Linings such as reinforced concrete, gabions, and grouted riprap should be considered.

10. All nonvegetative linings which are bordered by grass should be designed to permit

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complete mowing along all edges.

11. Dry weather flow through a principal outlet structure should not interfere with routine interior maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be used to convey low flow into and through the structure.

12. Principal outlet structures should be designed to discourage vandalism and graffiti. The use of aesthetic type vegetation to cover walls is encouraged.

10.5. OUTFLOW SYSTEMS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The outflow conveyance system downstream of a detention system should have adequate capacity to accommodate its outflows. This will not only allow design outflows and water surfaces to be attained, but will also help achieve required drawdown and emptying times.

2. Outflow velocities should be high enough to prevent sedimentation and low enough to prevent erosion and scour.

3. Manholes, grates and other suitable access points should be provided for cleaning and inspection. (See **J. ACCESS** for additional details.)

10.6. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The number of inlets to a detention system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlet pipes or channels should be placed on a minimum slope to prevent high entrance velocities. If high velocities can not be avoided, the designer should consider riprap inlet protection to prevent erosion and baffling to slow flow and guard against short circuiting to the outlet.

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.

Inlets should be located to prevent or minimize flow short-circuiting. If inlets and outlets cannot be spaced so that the flow path length is at least three, and preferably, five times the average width (dimension perpendicular to length), the designer should attempt to lengthen the flow path by moving the inlet and/or outlet or using baffles to divert flow. Another excellent impediment to short circuiting is dividing the system into two cells with flow restricting to passing through a single point between them.

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2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.)

4. The BMP Treatment Train approach should be used to minimize sediment entering the facility. Street sweeping, offsite soil stabilization measures, and upstream sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment and trash removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete, ductile iron, or PVC. Inlet pipes should not have trash racks placed on them at their outlets into the pond to prevent plugging of the inlet and water backing up into the site drainage system.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by native grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

10.7. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

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10.8. LOW FLOW MEASURES - DRY AND EXTENDED DRY FACILITIES

Since low flow measures are typically one of the first facility components to receive sediment, trash, and debris from incoming runoff, they usually require a high degree of maintenance Typical problems that impede or unnecessarily increase proper maintenance include:

- **Erosion and Scour**
- **Difficult to Clean or Mow**
- **Settlement**
- **Excessive Sedimentation**

However, while attempting to minimize low flow channel maintenance, care should be taken to avoid reducing the system's pollutant removal capabilities.

1. To ensure thorough drying of the facility bottom, low flow channels should have sufficient capacity to convey the normal, dry weather discharges from the facility inlets to the principal outlet structure without overtopping. The resultant channel size should also consider the use of readily available lining materials or construction equipment.

2. Design velocities in low flow channels should be low enough to prevent erosion of linings.

3. To simplify mowing and minimize trimming, grass-lined low flow channels are recommended whenever non-erosive velocities, smooth alignment, and thorough drying between storm events can be achieved.

4. Where low flow channels with non-vegetative lining are required, the use of gabions, concrete, grouted riprap, or other durable material with a relatively smooth surface is recommended to facilitate trash and debris removal and simplify mowing and trimming of adjacent grassed areas. Avoid the use of loose stone, riprap, and other materials with irregular surfaces which require hand removal of trash, debris, and undesirable vegetation.

In addition, use of low flow channels must be balanced with the need for pollutant removal in the facility. Therefore, low flow channels lined with nonvegetated lining should be used in conjunction with pretreatment BMPs such as inlet forebays and/or outlet structure wetlands, or the channel's should include portions with vegetated linings.

5. Low flow channel underdrains connected to the principal outlet structure or other stable downstream discharge point are recom-

Sediment and debris can be removed more easily from low flow channels lined with concrete or other smooth, durable material.

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mended to promote quick, thorough drying of both the low flow channel and facility bottom.

6. To prevent erosion and scour, bank full velocities in low flow channels lined with nonvegetative lining should not exceed the maximum permissible velocity in adjacent grassed or vegetated areas. If non-erosive velocities cannot be achieved, the lining should be extended into the adjacent areas. When checking the bank-full velocities, the effects of submergence by the principal outlet structure during passage of the bank-full flow must be considered.

7. To ensure thorough drying of adjacent grassed areas, low flow channels lined with concrete, grouted riprap, and other rigid, impervious material should be designed with the top of the lining at or below the elevation of adjacent grassed areas. This will also assist mowing and trimming. To achieve this, consideration should be given to the potential for settlement of both the impervious lining and adjacent areas and the effects of frost action on the lining. Broken stone foundations and weep holes should be provided for all impervious lining. (See No. 8 below) In addition, the required depth and width of the low flow channel must be remembered when preparing the bottom grading plan.

8. Four inch diameter weep holes should be provided in all rigid, impervious linings to reduce hydrostatic pressure resulting from fluctuating groundwater levels. These weep holes should be spaced a maximum of 12 feet on center or one for every 100 square feet of lining, whichever is less. Weep holes must not be directly connected to any low flow channel underdrain pipe. Place geotextile filter fabric under weepholes.

9. In subsurface facilities, dry weather inflow should not interfere with routine inspection and maintenance. Benching, underdrains, drop inlets, and other measures should be utilized.

10.9. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth (traffic, compaction)**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance, preferable native, vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged.

In general and where appropriate, turf grass may be easier to establish and maintain than other types of ground cover vegetation. However, pollutant removal efficiency will generally be reduced. The use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions, crown vetch in the East, will minimize routine maintenance tasks such as mowing and fertilizing.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen-fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution effects of nutrients such as nitrogen and phosphorus in the outflow.

2. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

3. To promote lasting growth, an adequate

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depth of suitable topsoil should be provided below all vegetative covers. A minimum thickness of 4-6 inches is recommended for turf grasses.

4. Construction plans and specifications should include requirements for establishing all vegetative covers including requirements for reseeding or resodding as necessary.

5. At dry and extended dry detention systems, the effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

6. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Consultation with these agencies during facility planning, design, and review is encouraged.

10.10. TRASH RACKS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Difficult to Remove**
- **Structural Failure**
- **Excessive Debris**

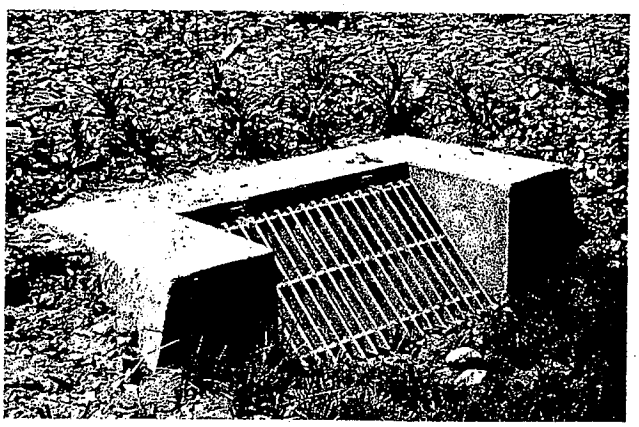
1. Trash racks are intended to prevent trash and debris from blocking a facility outlet by intercepting it at an upstream point. Therefore, the need for a trash rack should be based upon the relative sizes and shapes of both the outlet opening and the anticipated debris as well as the consequences of outlet clogging. Special consideration should be given to subsurface facilities.

2. For durability, all track rack components, including bars, hinges, fasteners, and clamps, should be constructed of lightweight, noncorroding material such as aluminum. The components should have sufficient design strength to withstand anticipated heavy loads caused by facility outflows, debris, and, where necessary, maintenance personnel.

3. To facilitate cleaning, trash racks should be comprised primarily of sloping bars, aligned longitudinally (in the direction of flow). Perpendicular bars, aligned transverse to the direction of flow, should be added for strength and rigidity. These transverse bars should be located below the top face of the longitudinal bars and, if possible, should be round in section. See Figure 3-B at the rear of the chapter for details.

4. To minimize the frequency of cleaning, trash rack bars should be spaced close enough to collect debris which may block the outlet orifice or weir but allow passage of smaller debris which will not. In general, longitudinal bars should be spaced a distance equal to 1/3 to 1/2 the diameter of the outlet orifice or 1/3 or 1/2 the width or height (whichever is less) of the outlet weir. Minimum and maximum spacings of 1 inch and 6 inches on center, respectively, are recommended. Transverse bars should be spaced as necessary for strength and rigidity. See Figure 3-B for details.

Sloping trash rack bars aligned in the direction of flow are more easily cleaned. Add transverse bars as needed for stability.



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5. Trash racks should be sloped and hinged or attached with noncorroding, removable fasteners to allow access to the outlet orifice or weir by maintenance personnel. Lightweight trash racks are easier to lift, repair, and clean behind. See Figure 3-B for details.

Hinged, lightweight trash racks can be quickly lifted for cleaning and inspection. Also note outlet orifice plate mounted to outlet structure wall with removable anchor bolts.

6. Trash racks should be accessible for cleaning when the system is dry (at dry and extended dry facilities) or at normal or permanent pool levels (at wet facilities). In addition, access should also be provided when the water level is at the facility's maximum design water surface elevation. Stable areas of adequate size should be provided around a trash rack to provide firm footing for maintenance personnel and equipment. Concrete pads of other firm surfaces are recommended.

7. At wet detention systems, stable areas of adequate size should be provided at all trash racks which protect permanent pool drains. Concrete pads or other firm surface is recommended.

10.11. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The stormwater facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents.

2. Field evaluations indicate that readily visible detention systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a minimum right-of-way width of 15 feet and a minimum roadway width of 12 feet is recommended. Access gates should be sited to allow vehicles to park off road for gate opening.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all detention systems greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

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6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility component. In doing so, avoid remote component locations, steep slopes, unstable surfaces and linings, and narrow walkways.

11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. Safe, suitable access for maintenance personnel and equipment should be provided to the interior of the principal outlet. In doing so, avoid heavy hatches, gratings, and other covers. Railings, grab rails, slip-resistant steps, low flow channels, benchings, and hinged, lightweight access covers greatly facilitate interior maintenance. Sufficient interior space should also be provided. A minimum horizontal dimension of 4 feet is recommended.

Successful facility maintenance demands adequate access for personnel and equipment. Note both wide access gate and concrete curbing that keeps it accessible.

13. At subsurface detention systems, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and the principal and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barricaded, and clearly identified.

Confined space entry considerations must be considered including:

- **proper ventilation**
- **adequate opening for full protection devices, etc.**

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10.12. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible detention systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel; and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

6. Grassed areas beyond the tops of detention systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

Lack of access prevents maintenance.

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11. DESIGN GUIDELINES FOR INFILTRATION PRACTICES

11.1. INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater infiltration facilities that require minimum levels of maintenance. Typical infiltration practices include:

- **Infiltration Basins**
- **Infiltration Swales**
- **Infiltration Trench**
- **Drywells**
- **Seepage Pits**

To help accomplish this minimum maintenance goal, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that ***these design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce stormwater infiltration facilities that require optimum levels of maintenance performed with the least practical effort, time, and expense.*** Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibility for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of infiltration practice is presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

11.2. BOTTOMS

In a study performed by the N.J. Department of Environmental Protection, the bottoms of infiltration basins and swales were the most likely location of chronic maintenance problems. Typical problems that impede or unnecessarily increase proper maintenance include:

- **Standing Water**
- **Soggy Surfaces**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. The infiltration rate of the soil will determine a site's suitability as an infiltration system. In general, infiltration practices should only be constructed in areas of Hydrologic Soil

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Group A or B as defined by the Natural Resource Conservation Service. Borings, test pits, and other appropriate field tests should be taken of the system's surface and subsurface soils. In subsurface facilities (e.g., dry wells, seepage pits, infiltration trenches) which are enveloped by geotextile or filter fabric, the limiting infiltration rate of the facility may be dictated by the fabric instead of the surrounding soil. See **Chapter 2** for additional recommendations regarding the selection of appropriate design infiltration rates for different types of infiltration practices.

2. To provide adequate drying time, to avoid delaying scheduled maintenance efforts, to avoid anaerobic conditions, and to prevent mosquito breeding, the maximum storage or ponding duration should not exceed 24-48 hours, depending on the tolerance of the system's vegetation to wetness.

3. To promote complete infiltration and prevent standing water or soggy surfaces, the lowest point in the bottom of the facility should be at least 4 feet above the seasonally high ground water level or bedrock. Subsurface drains may be used to lower ground water levels and/or promote complete infiltration. (See No. 4 below.) In determining the seasonally high ground water level, the extent of potential local ground water mounding due to the infiltration of stormwater from the facility must be evaluated.

4. To promote complete infiltration and prevent standing water or soggy surfaces, bottoms should have a minimum slope of 1 percent directed towards the center or other area of the facility bottom. It is recommended that bottoms be vegetated as the roots help to maintain soil permeability and the vegetation helps to minimize the potential for ground water contamination. A gabion-lined or stone-filled trench can be used to help promote infiltration. This trench should be located at the lowest point in the bottom and extend to all inlet points in order to direct small or dry weather inflows to the basin bottom. The elevation of the trench bottom should be at least 4 feet above the seasonally high ground water level or bedrock. See Figure 3-C at the rear of the chapter for details.

5. To avoid delaying scheduled maintenance efforts, topsoils should be sufficiently permeable to allow thorough drying through evaporation and moisture uptake by vegetative covers.

6. In order to prevent sloughing caused by outflow seepage of infiltrated water, an infiltration system should not be located on or near a steep slope. In general, a facility should not be constructed where nearby slopes exceed 15 percent. Appropriate geotechnical analyses should be conducted when necessary.

7. Sediment from construction operations can quickly clog soil pores of an infiltration system, often necessitating expensive maintenance work even before the facility is placed into normal operation. Therefore, an infiltration system should not be used for sediment control purposes during construction and, consequently, should not be constructed until the upstream drainage area is fully developed and adequately stabilized. If that is not feasible, the facility should not be excavated to it's full depth until all disturbed areas have been stabilized or protected. Thereafter, final excavation to finished grade should also include removal of all deposited sediment. Under no circumstances should a subsurface infiltration facility (e.g., drywell, seepage pit, infiltration trench, etc.) be used for sediment control during construction.

8. During construction, heavy equipment should not be allowed on the facility bottom. Compaction of the natural subgrade can seriously impair the infiltration rate.

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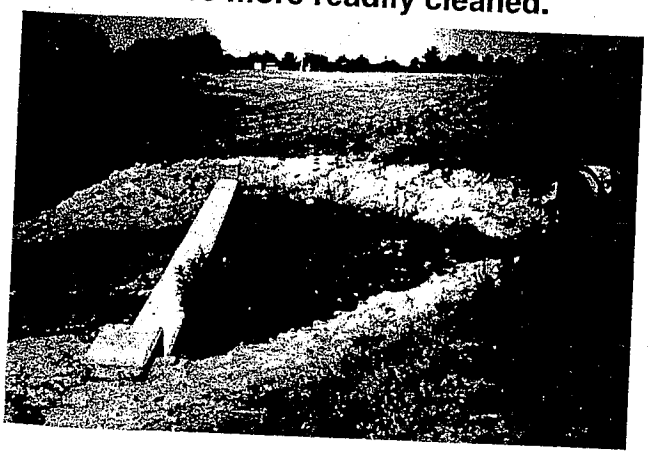
9. As an alternative cover, a 12 inch layer of filter material, such as coarse sand, may be considered in the facility bottom. This layer of material can be cleaned of sediment or replaced as necessary. Prior to the selection of this alternative material, such factors as aesthetics, weed growth, and movement of maintenance personnel and equipment about the bottom must be considered. See Figure 3-D at the rear of the chapter for details.

10. To minimize routine grass maintenance such as mowing and fertilizing, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on these and other grass varieties and mixtures are available from the local Cooperative Extension Service or Soil Conservation District. (See **E. VEGETATIVE COVER** for additional details.)

11. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and harmful runoff pollutants. (See **E. VEGETATIVE COVER** for additional details.)

12. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Swale conveyances and sediment traps or forebays at inflow and outflow points should be used. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.



13. Suitable access for maintenance personnel and equipment should be provided to the facility bottom. (See **F. ACCESS** for details.)

Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.

14. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

15. Temporary emergency measures such as pumps should be provided to drain standing water from malfunctioning infiltration practices.

16. If feasible, alternative outlet measures should be designed to permanently convert an infiltration system to a detention facility if necessary due to loss of infiltration capacity. If practical, these alternative outlet measures should be included in the facility's original construction.

17. At subsurface infiltration facilities, suitable access, observation points, and/or monitoring

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wells, should be provided to facilitate inspection and cleaning. (See **F. ACCESS** for additional details.)

18. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 2 years or more of removed sediment.

11.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater than 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side slopes less than 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

2. For safe movement of maintenance personnel and safe operation of equipment, side slopes steeper than 5 to 1 and higher than 15 feet should be terraced at their midpoints. The terrace should have a minimum width of 3 feet and should be graded at 2 percent towards the lower half of the slope.

3. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **F. ACCESS** for details.)

4. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a hazard to maintenance personnel walking on the slope.

5. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges. The use of herbicides is discouraged unless done by trained applicators.

6. The effects of rapid pool drawdown should be checked to prevent side slope sloughing.

7. For safe movement of maintenance personnel and safe operation of equipment, fences should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, or roadways.

11.4. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

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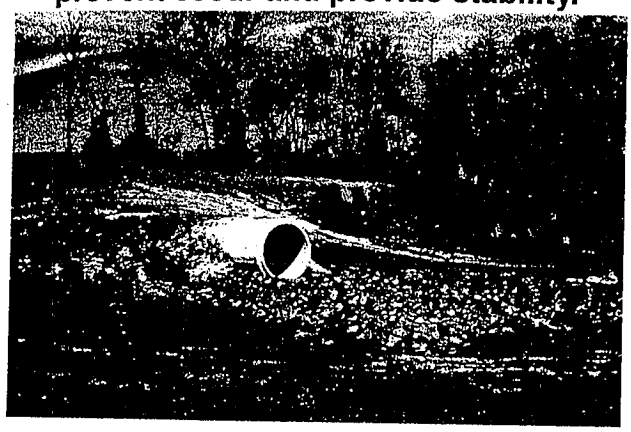
1. The number of inlets to an infiltration system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlets should be located to prevent or minimize flow short-circuiting. However, short circuiting is not an issue if the device is fully retentive. It is an issue if it is a retention/detention situation.

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.



2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.)

4. The BMP Treatment Train approach should be used to minimize sediment entering the facility should be considered. Street sweeping, offsite soil stabilization measures, and upsteam sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment and trash removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

11.5. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

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1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

11.6. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance, preferably native, vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged. In general and where appropriate, turf grass may be easier to establish and maintain than other types of ground cover vegetation. The use of grass varieties that are relatively slow growing and tolerant of poor soil conditions will minimize routine maintenance tasks such as mowing and fertilizing.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen-fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution effects of nutrients such as nitrogen and phosphorus in the outflow.

2. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

3. To promote lasting growth, an adequate depth of suitable topsoil should be provided below all vegetative covers. A minimum thickness of 6 inches is recommended for turf grasses.

4. Construction plans and specifications should include requirements for establishing all vegetative covers.

5. The effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

6. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Consultation with these agencies during facility planning, design, and review is encouraged.

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11.7. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents and be of sufficient size to handle maintenance equipment.

2. Field evaluations indicate that readily visible infiltration practices receive more and better maintenance than those in less visible, more remote locations. This is especially true for infiltration systems that are integrated into a site's overall landscaping plan or where they are used for recreation. These findings should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a minimum right-of-way width of 15 feet and a minimum roadway width of 12 week is recommended.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all infiltration facilities greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

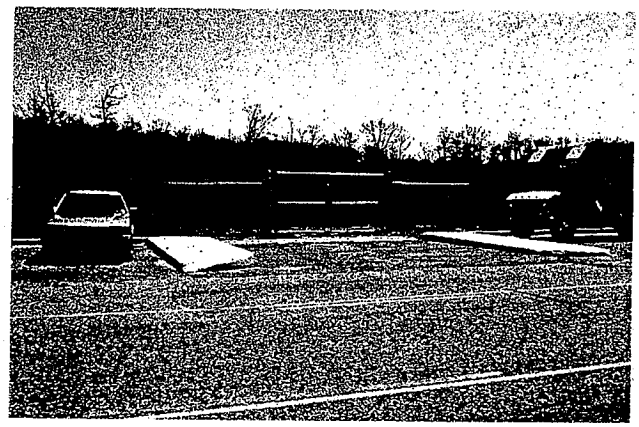
6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by

Successful facility maintenance demands adequate access for personnel and equipment. Note wide access gate and concrete curbing that keeps it accessible.



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more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility components. In doing so, avoid remote component locations, steep slopes, unstable surfaces and linings, and narrow walkways.

11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. At subsurface infiltration facilities, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barricaded, and clearly identified.

11.8. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible and multipurpose infiltration practices receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

6. Grassed areas beyond the tops of infiltration systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

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12. DESIGN GUIDELINES FOR FILTRATION AND BIOFILTRATION PRACTICES

12.1 INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater filtration and biofiltration facilities that require minimum levels of maintenance. Typical practices include:

- **Sand Filters**
- **Peat Filters**
- **Constructed Wetlands**
- **Wet and Dry Swales**
- **Vegetated Buffer Strips**

In should be noted that, in many instances, filtration and biofiltration practices are often used in combination with or as an integral part of other types of stormwater management facilities. For example, an extended dry detention basin may include a constructed wetland over all or portions of its bottom. In such cases, the reader should also refer to the design recommendations for those facilities presented in this chapter.

To help accomplish the minimum maintenance goal described above, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that the design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce filtration and biofiltration systems that require optimum levels of maintenance performed with the least practical effort, time, and expense. Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibility for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of facility or practice is presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

12.2. BOTTOMS

Due to their wide variability, the bottoms of filtration and biofiltration practices may range from the reinforced concrete bottom of a subsurface sand filter to a wetland to the grass in a filter or buffer strip. Therefore, the direct applicability of the design guidelines presented below will depend upon the type of filtration or biofiltration BMP under design. To

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assist in their use, the following design guidelines for bottoms will address both dry (e.g., filter strip) and wet (e.g., constructed wetlands) practices.

Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Standing Water (in Dry Systems)**
- **Soggy Surfaces (in Dry Systems)**
- **Lack of Permanent Pool (in Wet Systems)**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. To promote complete emptying and prevent standing water or soggy surfaces in dry systems, vegetated bottoms should have adequate bottom slope and be graded to the outlet. In selecting a bottom, care must also be taken not to exceed the slopes required for adequate pollutant removal. If a reasonable compromise cannot be achieved, another type of stormwater management practice should be considered.

2. To promote complete emptying and prevent standing water or soggy surfaces in dry-type facilities, the lowest point in the bottom should be at least 4 feet above the seasonally high groundwater level or bedrock unless adequate subsurface drains are provided.

3. To provide adequate drying time in dry practices, to avoid anaerobic conditions, to avoid delaying scheduled maintenance efforts, and to prevent mosquito breeding, the maximum wet or ponding duration should not exceed 24-48 hours, depending on the tolerance of the vegetation to wetness.

4. To avoid delaying scheduled maintenance efforts in dry facilities, topsoils and subsurface soils should be sufficiently permeable to allow both rapid infiltration and evaporation.

5. In dry systems, subsurface drains connected to the principal outlet structure or other discharge point are encouraged to promote quick and thorough drying of the facility bottom. In doing so, care should be taken to prevent stormwater inflow from inadvertently bypassing the basin's outlet controls.

6. To minimize routine grass maintenance such as mowing and fertilizing in dry systems such as filter and buffer strips, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on grass varieties and mixtures are available from agencies such as the local Cooperative Extension Service or Soil Conservation District. (See **I. VEGETATIVE COVER** for additional details.)

7. To promote lasting growth in dry systems, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. (See **I. VEGETATIVE COVER** for additional details.)

8. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Sediment traps or forebays at inflow and outflow points should always be used. Those lined completely or partially with smooth materials such as reinforced concrete

Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.

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can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

9. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 2 years or more of removed sediment.

10. Suitable access for maintenance personnel and equipment should be provided to the facility bottom. (See **I. ACCESS** for details.)

Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.

11. Construction plans and specifications should include provisions that minimize the potential for localized settlement and subsequent ponding. These provisions include proper surface and subsurface soil characteristics, compaction requirements, grading equipment, and erosion control prior to the establishment or permanent vegetative cover.

12. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

13. At subsurface filtration facilities such as sand filters, suitable access, observation points, clean out ports, and/or monitoring wells should be provided to facilities inspection and cleaning. (See **I. ACCESS** for additional details.)

14. Design of a biofiltration facility such as a constructed wetland should include the determination of the proposed site's ability to adequately support a viable and desired ecosystem. The design should account for such factors as the required rate and quality of dry weather inflow, the quality of stormwater inflow, seasonal and longer term variations in the ground water table, and the effects of expected sediment and other pollutant loadings.

15. Provisions to drain the permanent pool of wet systems (or the standing water chambers of a subsurface sand filter) are necessary for maintenance and safety. A gravity drain is the preferred method. If this is not feasible, suitable pumps and both primary and backup power sources should be provided. All pumps and backup power sources should be reserved for facility use only.

16. To promote complete emptying of the permanent pool when necessary, the bottom should have an adequate slope graded to the outlet drain or pump intake.

12.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long, Continuous Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater that 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side

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slopes less that 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

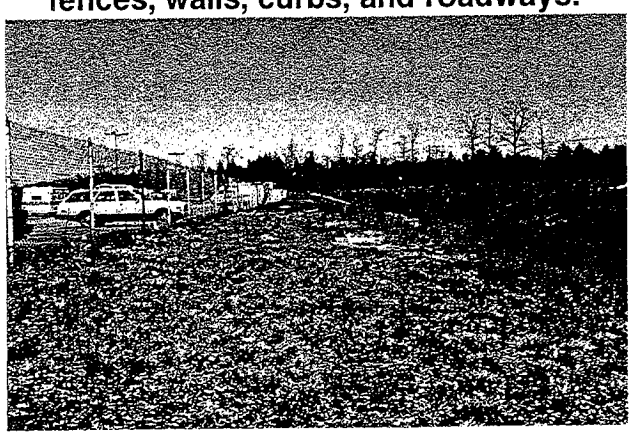
2. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **I. ACCESS** for details.)

3. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a safety hazard to maintenance personnel walking along or up the slope.

4. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

5. For safe movement of maintenance personnel and safe operation of equipment, fenced should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, and roadways.



12.4. PRINCIPAL OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Structural Deterioration**
- **Limited Access**
- **Corroded Appurtenances**
- **Vandalism**
- **Excessive Debris Accumulation**

1. For durability, principal outlet structures should be constructed of reinforced concrete containing Type II cement and having a minimum specified 28-day compressive strength of 3,000 PSI. Concrete shall be designed in accordance with all applicable codes and requirements.

2. For durability, all appurtenances, including access hatches, trash racks, gratings, railings, orifice and weir plates, and fasteners should be constructed of lightweight, noncorroding materials. Material strengths should be sufficient to withstand design loads without damage or failure.

3. Outlet orifice and weir plates should be constructed from aluminum or other lightweight, noncorroding material. The plates should be fastened to the structure with noncorroding, removable fasteners. A gasket of neoprene or similar material should be placed between the plate and the structure wall. The opening in the structure wall over which the plate is bolted should have at least twice the area of the outlet orifice or weir to facilitate field adjustments and future expansion. See Figure 3-A at the rear of the chapter for details.

4. To facilitate access and movement by maintenance personnel, principal outlet structures should have a minimum horizontal interior dimension of 4 feet. (See **I. ACCESS** for additional details.)

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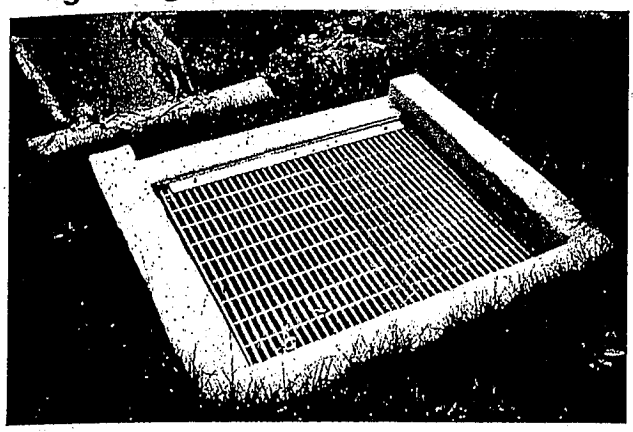
Outlet structure gratings, trash racks, and other appurtenances should be lightweight, durable, and removable.



5. Vital parts of the principal outlet structure should be readily and safely accessible to maintenance personnel during both normal and emergency conditions. Temporary measures such as ladders are only acceptable for emergency conditions such as part of an approved emergency action plan. (See **I. ACCESS** for additional details.)

6. To minimize both required maintenance and the consequences of inadequate maintenance, principal outlets should avoid using moving or mechanized parts for outflow control whenever possible.

7. To facilitate cleaning, outlet pipes should have a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete. To minimize potential leakage problems, the number of outlet pipe should be kept to an absolute minimum. More than one outlet pipe should be used only where unavoidable. All outlet pipes must be watertight under the maximum expected head or pressure.

8. Constructed wetlands and some filter systems often have a small orifices or a series of small orifices as part of the outlet structure. These are used to slowly bleed down the stormwater treatment volume. Innovative designs are needed to minimize their potential for clogging. Successful designs have included inverted siphons and half of a corrugated metal pipe, filled with large gravel, and placed in front of the orifices.

9. Grading and landscaping around principal outlet structures should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

10. Stable areas that provide maintenance personnel with firm footing should be provided at the upstream face of principal outlet structures at dry and extended dry facilities. Linings such as reinforced concrete, gabions, and grouted riprap should be considered.

11. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

12. Dry weather flow through a principal outlet structure should not interfere with routine interior maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow into and through the structure.

13. Principal outlet structures should be designed to discourage vandalism and graffiti.

12.5. OUTFLOW SYSTEMS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

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1. The outflow conveyance system downstream of a filtration or biofiltration system should have adequate capacity to accommodate its outflows. This will not only allow design outflows and water surfaces to be attained, but will also help achieve required drawdown and emptying times.

2. Outflow velocities should be high enough to prevent sedimentation and low enough to prevent erosion and scour.

3. Manholes, grates and other suitable access points should be provided for cleaning and inspection. (See **I. ACCESS** for additional details.)

12.6. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

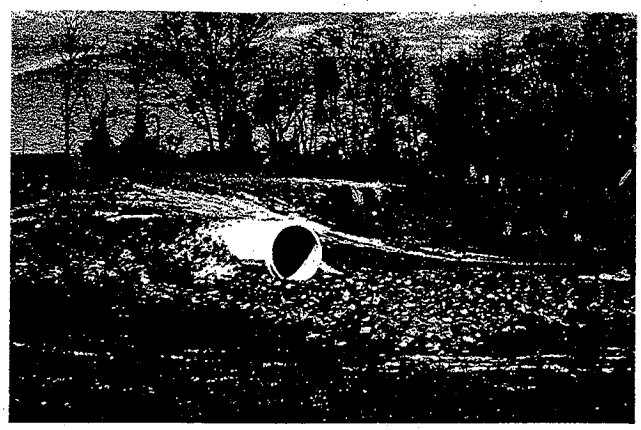
- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The number of inlets to a filtration or biofiltration system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlets should be located to prevent or minimize flow short-circuiting.

2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. Flow spreaders will help distribute flow at a shallow depth more uniformly over the facility bottom. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.



downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.) Forebay outlets can also be used to distribute inflows more uniformly over the facility bottom.

4. The BMP Treatment Train approach should be used to minimize sediment, trash, and other debris from entering the system. Street sweeping, offsite soil stabilization measures, and upsteam sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment or debris removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

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7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

12.7. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

12.8. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth (traffic, compaction)**
- **Invasion by undesirable species**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged.

For dry swales and vegetated buffers, turf grass may be easier to establish and maintain than other types of ground cover vegetation. The use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions will minimize routine maintenance tasks such as mowing and fertilizing. For constructed wetlands and wet swales, wetland aquatic plants are most appropriate. Specific recommendations regarding vegetation is presented in Chapter 2.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution

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effects of nutrients such as nitrogen and phosphorus in the outflow.

2. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

3. To promote lasting growth, an adequate depth of suitable topsoil or wetland muck soil should be provided below all vegetative covers. A minimum thickness of 6 inches is recommended for turf grasses.

4. Construction plans and specifications should include requirements for establishing all vegetative covers.

5. At both dry and wet systems, the effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

6. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Aquatic botanists should be consulted with respect to selecting and planting vegetation in constructed wetlands and wet swales. Consultation with these agencies or professionals during facility planning, design, and review is strongly encouraged.

12.9. TRASH RACKS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Difficult to Remove**
- **Structural Failure**
- **Excessive Debris**

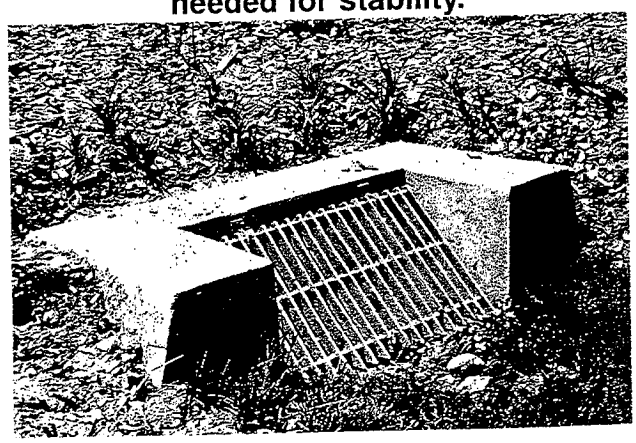
1. Trash racks are intended to prevent trash and debris from blocking a facility outlet by intercepting it at an upstream point. Therefore, the need for a trash rack should be based upon the relative sizes and shapes of both the outlet opening and the anticipated debris as well as the consequences of outlet clogging. Special consideration should be given to subsurface facilities.

2. For durability, all trash rack components, including bars, hinges, fasteners, and clamps, should be constructed of lightweight, noncorroding material such as aluminum. The components should have sufficient design strength to withstand anticipated heavy loads caused by facility outflows, debris, and, where necessary, maintenance personnel.

3. To facilitate cleaning, trash racks should be comprised primarily of sloping bars, aligned longitudinally (in the direction of flow). Perpendicular bars, aligned transverse to the direction of flow, should be added for strength and rigidity. These transverse bars should be located below the tope face of the longitudinal bars and, if possible, should be round in section. See Figure 3-B at the rear of the Chapter for details.

4. To minimize the frequency of cleaning, trash rack bars should be spaced close

Sloping trash rack bars aligned in the direction of flow are more easily cleaned. Add transverse bars as needed for stability.



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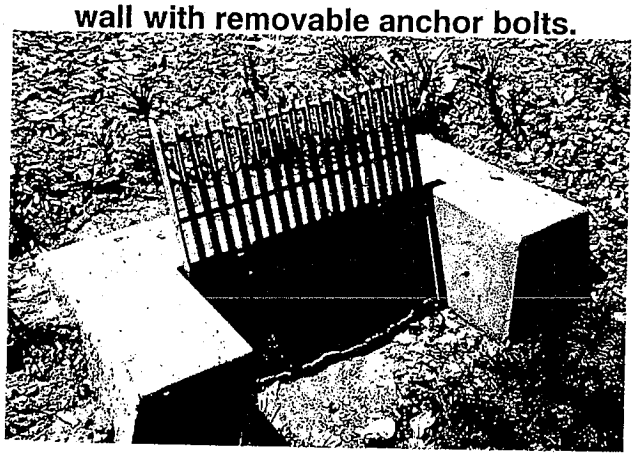
enough to collect debris which may block the outlet orifice or weir but allow passage of smaller debris which will not. In general, longitudinal bars should be spaced a distance equal to 1/3 to 1/2 the diameter of the outlet orifice or 1/3 or 1/2 the width or height (whichever is less) of the outlet weir. Minimum and maximum spacings of 1 inch and 6 inches on center, respectively, are recommended. Transverse bars should be spaced as necessary for strength and rigidity. See Figure 3-B for details.

5. Trash racks should be hinged or attached with noncorroding, removable fasteners to allow access to the outlet orifice or weir by maintenance personnel. Lightweight track racks are easier to lift, repair, and clean behind. See Figure 3-B at the rear of the chapter for details.

Hinged, lightweight trash racks can be quickly lifted for cleaning and inspection. Also note outlet orifice plate mounted to outlet structure wall with removable anchor bolts.



6. Trash racks should be accessible for cleaning when the facility is dry (at dry facilities) or at normal or permanent pool levels (at wet facilities). In addition, access should also be provided when the water level is at the system's maximum design water surface elevation. Stable areas of adequate size should be provided around a trash rack to provide firm footing for maintenance personnel and equipment. Concrete pads of other firm surfaces are recommended.

7. At wet systems, stable areas of adequate size should be provided at all trash racks which protect permanent pool drains. Concrete pads or other firm surface is recommended.

12.10. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents.

2. Field evaluations indicate that readily visible or multipurpose systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a mini-

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mum right-of-way width of 15 feet and a minimum roadway width of 12 week is recommended.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all surface facilities greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

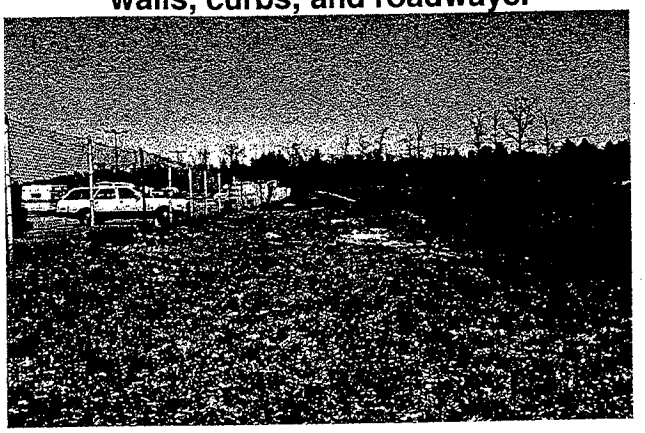
7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility component. In doing so, avoid remote component locations, steep slopes, unstable surfaces and linings, and narrow walkways.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, and roadways.



11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. Safe, suitable access for maintenance personnel and equipment should be provided to the interior of the principal outlet. In doing so, avoid heavy hatches, gratings, and other covers. Railings, grab rails, slip-resistant steps, low flow channels, benchings, and hinged, lightweight access covers greatly facilitate interior maintenance. Sufficient interior space should also be provided. A minimum horizontal dimension of 4 feet is recommended.

13. At subsurface facilities, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and the principal and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barri-

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caded, and clearly identified.

12.11. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible or multipurpose systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel; and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

6. Grassed areas beyond the tops of filtration and biofiltration systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

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APPENDIX 3-1

DRAWINGS OF TYPICAL DETAILS OF SOME IMPORTANT STORMWATER SYSTEM COMPONENTS

Figure 3A	Detention Basin Orifice and Weir Plates
Figure 3B	Detention Basin Trash Rack
Figure 3C	Infiltration Basin Underdrain
Figure 3D	Nonvegetated Infiltration Basin Bottom

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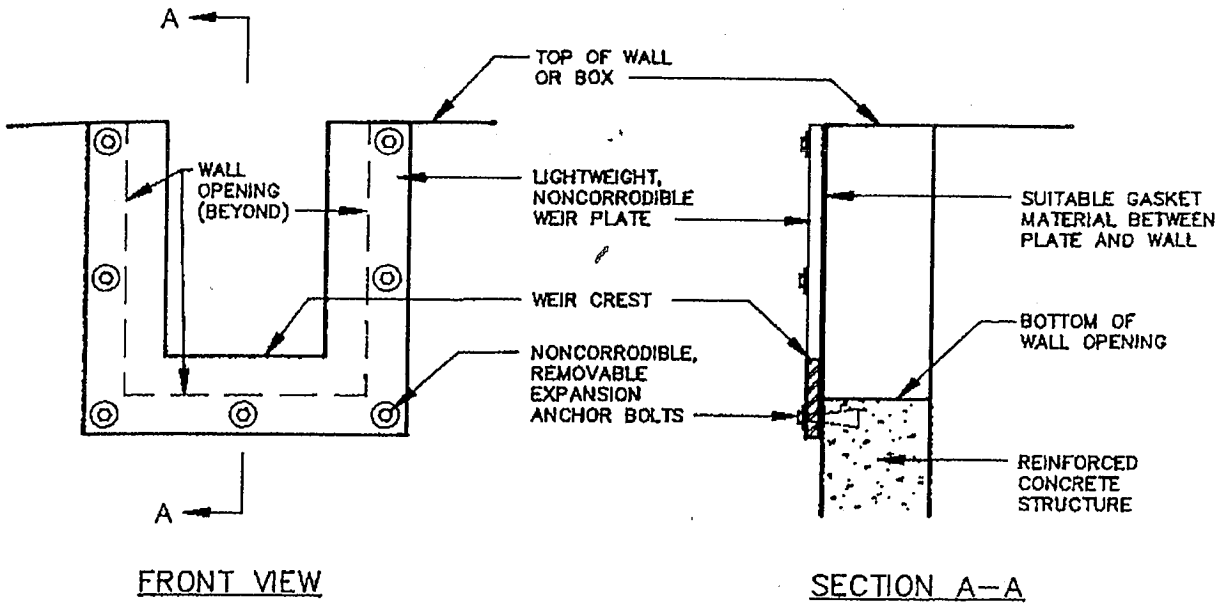
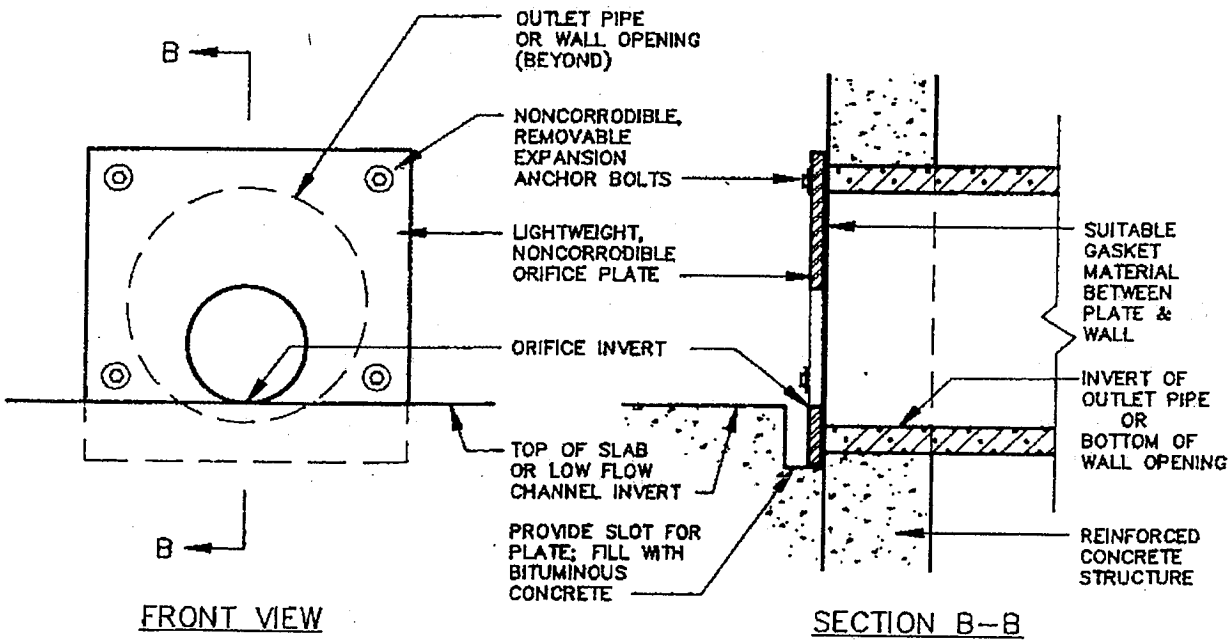


WEIR PLATE DETAILS
(NO SCALE)



ORIFICE PLATE DETAILS
(NO SCALE)

DETENTION BASIN
ORIFICE AND WEIR PLATES
TYPICAL DETAILS

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL

FIGURE 3-A

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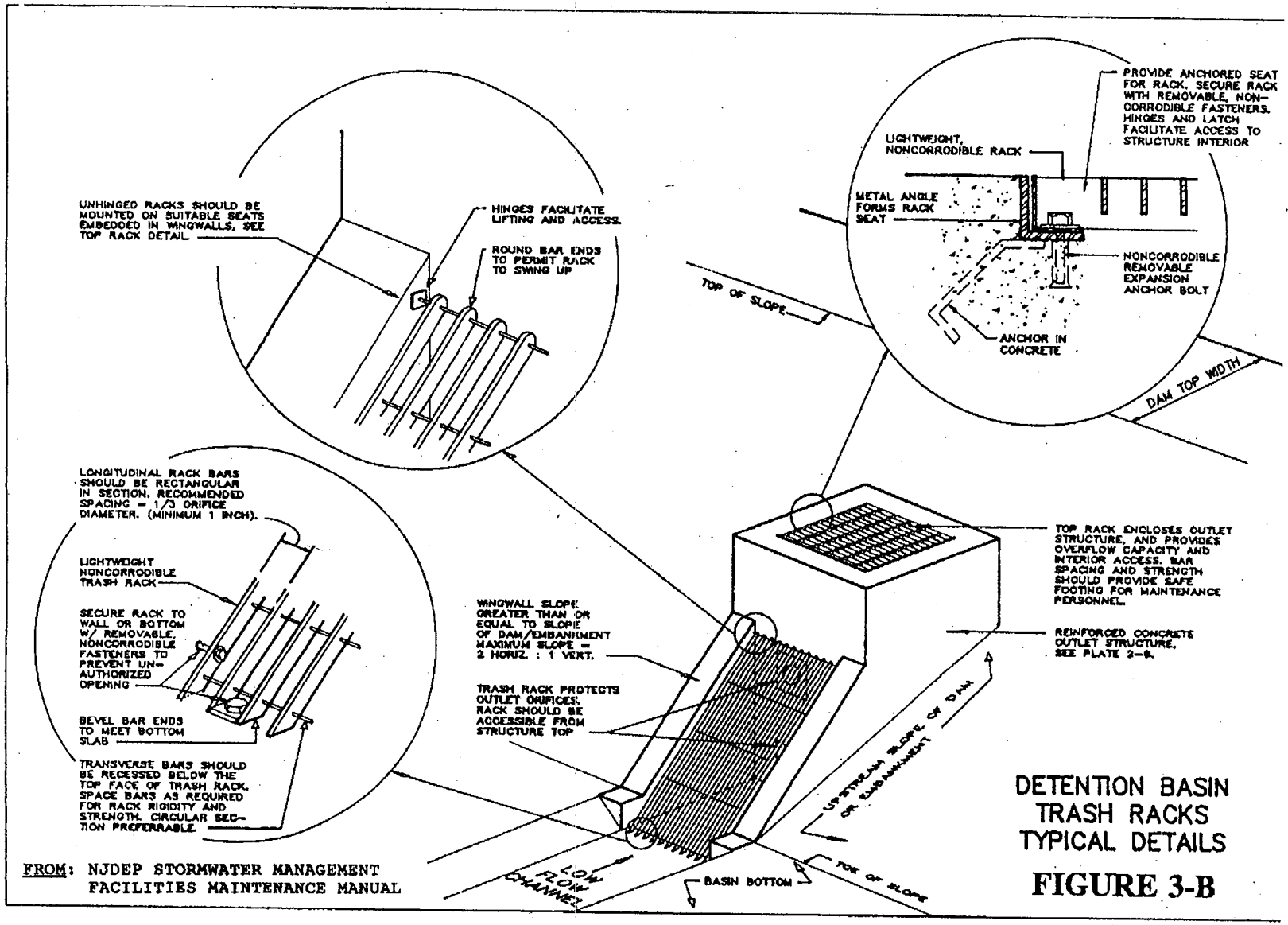

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL

DETENTION BASIN TRASH RACKS TYPICAL DETAILS

FIGURE 3-B

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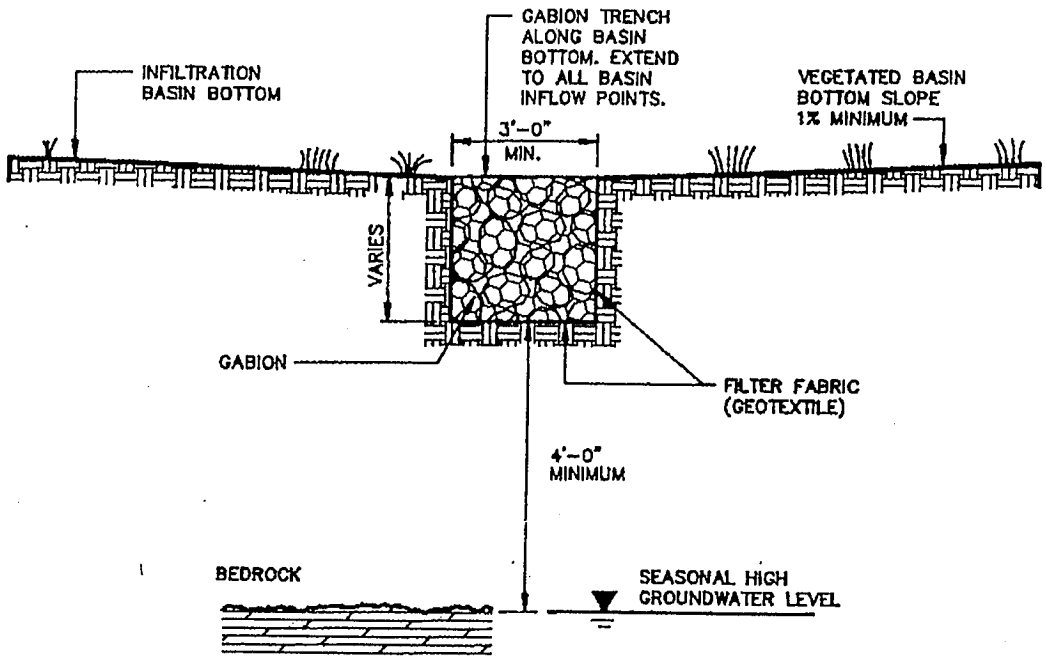


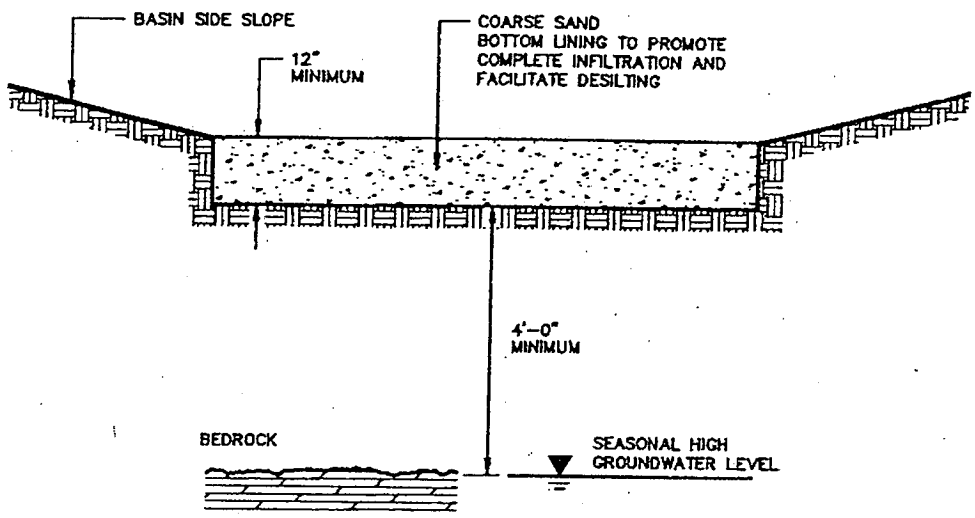
NO SCALE

NOTE: GABION BASKETS ARE RECOMMENDED OVER LOOSE STONE TO PROVIDE SMOOTH TOP SURFACE WHICH WILL FACILITATE MOWING OF BASIN BOTTOM AND TO PREVENT UNAUTHORIZED REMOVAL AND OTHER VANDALISM.

INFILTRATION BASIN UNDERDRAINS TYPICAL DETAILS

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL

FIGURE 3-C



NO SCALE

NONVEGETATED INFILTRATION
BASIN BOTTOMS
TYPICAL DETAILS

FROM: NJDEP STORMWATER MANAGEMENT
FACILITIES MAINTENANCE MANUAL

FIGURE 3-D

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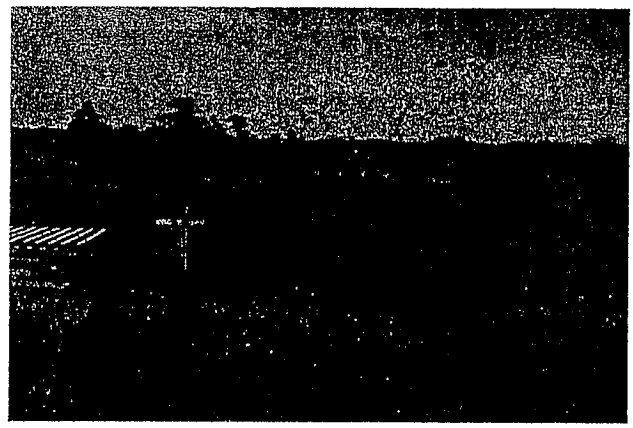
Chapter 4
Programmatic and Regulatory Aspects

1. OVERVIEW

There are many important aspects of stormwater management system maintenance. These include planning and design considerations, proper construction, inspection, compliance, and funding. Equally important, though, are institutional or programmatic considerations. The institutional framework must establish a legal basis to assure program maintenance requirements are met. This must include criteria establishing minimum standards for stormwater system inspection and maintenance - requirements that all owners must comply with to ensure the long term performance of their systems.

There are several program components which must operate cooperatively if maintenance efforts are to be effective. Initial requirements must include proper planning and design to assure that the stormwater management system, including each of its components, can be effectively maintained and properly operated. Stormwater program funding, which is beyond the scope of this handbook, is essential to assure proper design review, inspection during construction, and regular inspections of completed facilities. Funding also must be available for development of design, construction, and maintenance guidelines, and to actually perform needed maintenance activities. Educational programs are also important. The importance of proper operation, maintenance, and management of stormwater systems must be understood by designers, developers, contractors, the public, and owners of urban runoff controls. The stormwater program's institutional framework must not only create these important components, but assure that they are fully coordinated.



Constructed wetland serving a residential community showing good site stabilization.

Programmatic aspects of stormwater system operation and maintenance must include recognition of the roles of the various levels of government involved in program implementation (WMI, 1997). It is important that requirements made at the various levels of government (federal, state, regional, local) be complementary and not duplicative or conflicting. ***Stormwater system operation, maintenance, and management must be addressed by the urban runoff control program whenever it requires the use of BMPs. How explicitly or detailed stormwater system maintenance is addressed varies, depending on the degree of regulatory control exerted by each level of program implementation.***

This chapter will provide recommendations on how stormwater programs can assure that BMPs actually are maintained and operated properly. It will review the role of EPA, state government, and local governments in stormwater system operation and maintenance. Examples of successful institutional

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approaches will be presented as will specific regulatory language on stormwater system operation and maintenance. The final subsection of this chapter contains recommendations relating to public versus private maintenance of completed stormwater management facilities.

The recommendations are based on the most effective approach to ensure the future maintenance of completed stormwater management systems. The recommendations may appear idealistic, but they are based on experiences by several successful state and local urban runoff control programs around the country. They reflect the most optimal approach to stormwater management system operation, maintenance, and management which appears to be available at this time.

1.1. Intended Readers

Intended readers of this Chapter include:

- **Persons involved in developing and implementing stormwater management programs and their associated regulations.**

- **Elected and public officials** who are responsible for developing, promulgating, and/or interpreting stormwater management programs and regulations.

- **Stormwater system designers and builders** who must assure that their systems comply with relevant regulations.

- **Land developers, consultants, and stormwater facility owners** who must receive regulatory approval for their stormwater systems.

2. ROLES OF GOVERNMENT

Experience has shown that successful stormwater management programs are built upon a partnership among the different levels of government involved in program implementation (WMI, 1997). Until recently, stormwater programs were implemented by state and local governments using legal authorities established in state or local laws. However, in 1990, the EPA established federal stormwater permitting requirements under the NPDES program. These federal requirements have stimulated greater awareness of stormwater problems, the need for stormwater treatment, and the implementation of stormwater BMPs.

Whenever BMP implementation is required, stormwater system operation and maintenance requirements must be explicitly stated and enforced. With at least three levels of government often involved in program implementation, it is very important that program requirements be complementary, not conflict, and not create duplication. Stormwater maintenance considerations should be somewhat general at the federal level, with state, regional, or local programs having progressively more detailed program requirements. These requirements must then be implemented by individual property owners or public entities, with some type of compliance mechanism to assure that maintenance is actually performed.

This hierarchical approach begins with general language that requires entities implementing urban runoff control programs to adopt more specific requirements for the long term operation, maintenance, and management of stormwater management facilities. Importantly, this allows the individual jurisdictions to determine, through their existing program framework, how the requirements should be implemented. ***Having minimum standards is important, but the key to successful***

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implementation is providing flexibility to attain the standards within the institutional framework of the stormwater program, whether at the state, regional, or local level. Since stormwater systems are an essential part of the local infrastructure, local governments are the most appropriate level of government to assure proper construction, inspection, and maintenance of stormwater management facilities. At times, regional or watershed-based entities may be involved in the day to day implementation of stormwater management programs, including operation and maintenance of stormwater systems. Except for highway departments, state agencies usually will not be directly involved in stormwater system operation, maintenance, and management. Instead, they often will be responsible for establishing performance standards and BMP design criteria, reviewing plans or permitting BMPs, and they will have more of an oversight and technical guidance role. Similarly, except in those few states which are not delegated NPDES stormwater permitting, EPA's role will be to set basic program goals and requirements, and oversee implementation by states.

3. FEDERAL STORMWATER PROGRAMS

Various federal programs (i.e., Sections 319 and 402 of the Federal Clean Water Act, Section 6217 of the CZARA of 1990) may require the implementation of stormwater management programs by states, regional, or local governments, or stormwater BMPs by property owners. Consistent with the hierarchical approach discussed above, these programs have fairly general requirements for stormwater system operation and maintenance. For example, the NPDES stormwater permitting requirements for municipal separate storm sewer systems (MS4s) states "the applicant must include a description of maintenance activities and a maintenance schedule for structural controls to reduce pollution..." Since the implementation of BMPs to treat stormwater is still a new concept, experience has shown that additional guidance on BMP operation and maintenance is needed. ***More specific guidance and program requirements should be adopted by state, regional, or local governments.*** For example, the stormwater staff at the Florida Department of Environmental Protection developed a table of recommended BMP inspection frequencies and maintenance activities (Appendix 4-5). EPA Region 4 is including this table in MS4 permits issued to Florida local governments. The table is only guidance and is intended to serve as a starting point for local governments to develop and implement effective BMP inspection and maintenance programs. The recommendations in the table are not enforceable permit conditions, simply guidance. Additional, more detailed BMP inspection, operation, and management language that could be included in state, regional, or local program requirements is discussed in the next section.

4. STATE STORMWATER MANAGEMENT PROGRAMS

This section will discuss institutional aspects of stormwater system maintenance in those states which have aggressively implemented a comprehensive statewide stormwater management program. This is not the rule but the exception. ***Only five states currently have statewide programs which require implementation of stormwater BMPs by new developments.*** In those states without a comprehensive program, or where state requirements are permissive, or where state legislation enables but does not require local implementation, many of the requirements for long term performance of stormwater systems will be of interest to or implemented by local governments.

States may have a similar role to EPA in terms of overall program guidance, but they also

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have a greater capability to establish additional legislative and regulatory requirements for maintaining stormwater systems than are possible at the federal level. In some programs, the state is the permit issuing authority requiring the implementation of stormwater management facilities. In other programs, implementation responsibilities are shared by the state with regional or local governments.

This section will highlight several innovative approaches used around the country which could be adopted as stormwater management program components to significantly improve the long term performance of stormwater management systems. It will also provide recommended language that should be included in state law and in stormwater regulations, whether they are implemented at the state, regional, or local level.

4.1. Program Guidance and Requirements

Several states have implemented stormwater management programs to minimize flooding and the water quality impacts resulting from stormwater discharges associated with new development. ***However, there is general recognition by states that they alone cannot effectively implement stormwater management programs at the state level. Most of these comprehensive statewide programs have, as their foundation, a "watershed management team" approach. Implementation involves a lead state agency along with some combination of regional, local, or watershed-based entities.*** Often the lead state agency permits projects undertaken by federal or state government and by the regional or local entities involved in program implementation. Permitting of other projects is done by the regional, local, or watershed-based entity to which the state has delegated program implementation.

In these stormwater management programs, ***the roles of the various implementing entities must be explicitly stated to avoid conflicts and duplication.*** Accordingly, states, generally through legislation and regulation, establish the program's minimum goals and performance standards, its administrative procedures, and specify the minimum program components that regional, local, or watershed entities must implement to be delegated the program's administration. The actual structure of the implementing agency program depends on considerations such as the entity's organization, funding mechanism, and the priority of the stormwater program.

States can, and should, be more specific than federal agencies when establishing minimum stormwater management program standards. These standards must be developed with the recognition of impacts that they will have on the resource needs of the regional, local, or watershed agency. If the standards are absolutely necessary (as most are), the state agency must provide assistance - financial, technical, and in securing political acceptance for the program at the local level. Program requirements must be directly related to effectiveness but also be realistic and include some flexibility. Implementing agencies must be allowed to prioritize program components to fit their situation.

The stormwater program's institutional framework, goals, and procedures need to be established legislatively. General program requirements for stormwater system maintenance needs to be included in this legislation. More explicit and detailed requirements should be provided in the program's implementing regulations and guidance materials, such as its BMP manual.

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4.2. State Stormwater Legislation

State legislation provides the legal authority for the stormwater program. If program implementation can be delegated to regional or local governments, state law also provides the legal backbone for these programs. In such cases, the law also needs to establish criteria for delegation to assure that the program is implemented consistently statewide.

In general, the state stormwater legislation should be relatively simple without lots of details, especially with respect to the design, construction, and maintenance of stormwater systems. More explicit details can be established in the program's implementing regulations. The maintenance component of state legislation should provide a basic framework to assure that stormwater systems are operated and maintained properly. It must include compliance and enforcement mechanisms and procedures, including penalties. A section of the legislation should allow for regulations, and specify the program areas in which requirements can be set by the rules.

Example legislative language might include:

> The Department (the program's lead agency) shall develop regulations to specifically guide program implementation. The regulations may include, but not be limited to, the following:
>
> 1. Criteria for local program implementation or delegation.
> 2. Types of activities that require an urban runoff control approval.
> 3. Waivers, exemptions, and variances.
> 4. ***Plan approval and inspection fees including construction or maintenance performance bonds.***
> 5. Authority for a local stormwater utility.
> 6. Specific design criteria.
> 7. Permit application and approval process.
> 8. ***Operation permit requirements and time frames.***
> 9. ***Development and implementation of mandated educational programs relating to site inspection of active and completed stormwater management systems.***
> 10. Requirements for any other educational programs.
> 11. ***Inspection requirements, including certification of inspectors.***
> 12. ***Maintenance requirements once construction has been completed.***
> 13. ***Penalty provisions in the event of noncompliance with either design, construction, or operation of stormwater management systems.***

As can be seen from the italicized and bolded text, maintenance aspects of program implementation overlap with many other design and construction requirements.

Incorporating in the law the ability to adopt rules to establish maintenance requirements allows for greater flexibility and for program evolution. It is important to remember that the design, maintenance, and operation of stormwater BMPs is a relatively young field. When changes need to be made to enhance program or BMP effectiveness, it is much easier to amend rules than legislation.

There are a several state laws and regulations which should be reviewed before developing legislative language for a statewide stormwater management program. These include:

1. Delaware:
   - Chapter 40, title 7, Delaware Code, Erosion and Sediment Control and Stormwater Management Act;
   - Sediment and Stormwater Regulations

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Contact:
Delaware Department of Natural Resources and Environmental Control
Division of Water Resources
89 Kings Highway
Dover, Delaware 19903

2. Florida:
   - Section 403.0891, Florida Statutes, State, Regional, and Local Stormwater Management Plans and Programs. Also, Section 403.0893 - Stormwater Utilities and Section 403.0896 - Training and assistance for stormwater personnel.
   - Section 62-40.432 (State Water Policy) Stormwater treatment performance standards;
   - Chapters 62-25 (FDEP stormwater regulations) or 40C-42 (SJRWMD rules), Florida Administrative Code.

Contact:
Florida Dept. of Environmental Protection
Nonpoint Source Mgmt. Section (MS3570)
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

3. Maryland
   - Environmental Article, Title 4, Subtitle 1 - Sediment Control and Subtitle 2 - Stormwater Management.
   - Code of Maryland Regulations 26

Contact:
Maryland Department of the Environment
Stormwater Management Program
2500 Broening Highway
Baltimore, Maryland 21224

4. New Jersey
   - N.J.S.A. 40:55D-1, Stormwater Management Act.
   - N.J.A.C. 7:8 Stormwater Management regulations.

Woody vegetation growing on a pond embankment because of a lack of mowing.

Contact:
N. J. Dept. of Environmental Protection
Stormwater Management Program
401 East State Street
Trenton, New Jersey 08625

5. Washington
   - Chapter 90.70 Puget Sound Water Quality Authority
   - Chapter 173-275, Washington Administrative Code (W.A.C.), Stormwater Management in the Puget Sound Watershed.
   - Chapter 400-20, W.A.C. Puget Sound Water Quality Authority.

Contact:
Washington Dept. of Ecology
Stormwater Management Program
P.O. Box 47600
Olympia, Washington 98504-7600

Recognize that the ideal program will contain a mixture of ideas and language from other programs, in addition to original language necessary to address state specific considerations. No program is perfect.

Penalty provisions (Item 13 above) are critical to ensuring the continued operation of stormwater management facilities. A review of 32 stormwater management programs

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around the country indicates the need for penalty provisions (WMI, 1997). Generally, penalty provisions will not be used very often. Clear statutory authority for them, however, helps to assure maintenance activities are accomplished, especially when needed at sites with reluctant owners.

There is a question of whether penalties should be civil and/or criminal. T***here is a great reluctance to use criminal penalties due to the severity of the impact in the event of a conviction. Consequently, the most commonly used penalty to ensure compliance is a civil action.*** This generally results in some form of monetary penalty. Example statutory penalty language might be the following:

> "Any person who violates any rule, regulation, order, or condition imposed on an approved plan or other provision of the Law shall be fined not less than $_____ or more than $_____ for each offense. Each day that the violation continues shall constitute a separate offense."

The dollar amounts of penalties vary widely around the country. Representative levels range from $100 to $5,000.

Existing stormwater programs have found that the most effective compliance tool is a "stop work order." This administrative mechanism is particularly useful during the construction phase of development as it prevents any further work until the site's controls are in compliance with the site plans or permit requirements. Example statutory language follows:

> "The Department shall have the power to issue a cease and desist order to any person violating any provision of this Chapter by ordering such person to stop any site work activity other than those actions necessary to achieve compliance with this law or its implementing regulations."

Another widely used alternative to fines to assure maintenance and management of stormwater systems is authority for the government (state, regional, local) to perform the maintenance and bill the owner. Example statutory language for this concept is:

> "If the owner or responsible maintenance entity fail to maintain the stormwater management system to acceptable standards, the (unit of government) shall issue a written notice specifying actions to be taken in order to bring the system into compliance with its approved design and performance. If these actions are not completed by the time specified in the written notice, the (unit of government) shall perform or contract for this maintenance and bill the owner or maintenance entity for all costs. If the owner of maintenance entity fails to pay the bill within 60 days, a tax lien for the amount of the bill plus ten percent shall be placed upon the property."

It is recommended that the operation and maintenance violations be considered a civil offense, but that a criminal provision also be included for obvious deliberate violations. Penalties are applied most commonly for poor erosion and sediment control at construction sites. They are less commonly imposed for improper construction, maintenance, or operation of permanent stormwater management facilities.

Where there is a significant maintenance requirement that may be controversial, it should be stated in law. The following three examples are provided for consideration by other stormwater management programs.

1. Florida Stormwater Operating Permit

Florida's stormwater program recom-

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mends that regional water management districts and local governments issue renewable operating permits for completed stormwater systems. ***These require an annual inspection and certification that the stormwater system is being maintained and is performing as permitted.*** This is an excellent approach to ensure that systems are regularly inspected and properly maintained. The approach has general applicability to other stormwater programs and implementation can be tailored to a program's institutional framework.

The legislative framework for Florida's stormwater program includes Section 403.0891, Florida Statutes, which sets forth the stormwater responsibilities of the Department of Environmental Protection, the five regional water management districts, and local governments. The specific criteria and implementation procedures for the Operating Permit System are detailed in stormwater regulations, especially those of regional water management districts or local governments. For example, the City of Tallahassee's Environmental Management Ordinance includes Section 46, entitled Stormwater Management Facility Operating Permit.

One reason this approach has strong merit is because eventual property owners (residential owners especially) are seldom aware of their obligations to maintain stormwater management facilities. ***Requiring owners of stormwater systems to have an Operating Permit helps make system owners aware that they have legal operation and maintenance obligations.*** When the responsible legal maintenance entity is a Property Owners Association, the Operating Permit System helps assure that the Association assesses the individual property owners for their portion of the costs incurred when contracting for stormwater system maintenance. The submittal by the responsible maintenance entity of the annual certification and of the information periodically required to renew the Operating Permit also helps to reinforce continued awareness of maintenance obligations.

2. *State of Washington Maintenance Bonds*

Another option to assure maintenance of completed stormwater management facilities, which may require specific legislative authority, is the posting of maintenance bonds. This is required by the State of Washington as part of its Puget Sound program. ***This law requires land developers to obtain a performance bond for stormwater management facility maintenance.*** This helps assure that the stormwater management facility is constructed satisfactorily and that there are no outstanding maintenance needs which would create an immediate hardship on the eventual property owners.

The legal foundation for requiring performance bonds is set forth in Washington's Stormwater Management Regulations for New Development which are imposed within the Puget Sound watershed. Section WAC173-275-060(2)(g) states that "Performance bonding or other appropriate financial instruments shall be required for all projects to ensure compliance with these standards". Another section of the regulations requires a maintenance and operation schedule be provided for all proposed stormwater management facilities and BMPs, along with the identification of the party responsible for maintenance and operation.

3. *Delaware'Certified Site InspectorProgram*

Delaware's stormwater program includes a unique approach to site inspection that

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Partially clogged outlet at a detention basin due to not inspecting or maintaining the facility.

requires site inspectors to be certified through a formal training program sponsored by the State. Section 4013 of the state's stormwater legislation (Chapter 40, Title 7) requires individual developers to supply their own "certified" inspectors during construction to improve site implementation of temporary erosion and sediment control and permanent stormwater management facilities. The law also authorizes the state stormwater agency to adopt regulations specifying when certified inspectors are required and establishing the training course that they must attend and pass.

Section 12 of Delaware's Sediment and Stormwater Regulations requires a certified inspector on all projects disturbing over 50 acres and also allows the permitting agency to require one on a case by case basis. Certified inspectors are only required during the construction phase of a project. This section of the regulations also set forth the curriculum for the training course and specifies the inspector's responsibilities. The certified inspector documents site conditions, especially of erosion and sediment controls, on a weekly basis and submits site evaluation forms to the contractor, developer, and appropriate permitting agency.

Although established in Delaware for improving construction practices, the concept could be modified to have a certification program for those individuals, both public and private, who are responsible for inspecting permanent stormwater management systems such as would be required by an Operating Permit System. Similar education and certification programs also can be established for individuals who are actually responsible for conducting maintenance activities. Florida's stormwater program is implementing education programs and voluntary certification in both of the above areas.

4.3. Stormwater Regulations

Regulations are an integral component of urban runoff control programs. Their development and implementation are subject to public review and comment, but they are not subject to formal approval by the state legislative body. As such, it is easier to enact and modify technical requirements that are needed for program implementation and evolution. This is very important in the relatively new field of stormwater treatment where technologies and institutional approaches are rapidly changing.

With respect to stormwater facility maintenance, requirements within the regulations will be significantly more detailed than those specified in the stormwater program's enabling legislation. At the local level, regulations usually are adopted as a local ordinance or law. However, they must still include more detailed program requirements such as those to assure long term maintenance and operation of BMPs. ***Adoption as a local law may make it more difficult to amend program requirements, especially technical ones such as BMP design criteria. A better approach may be to include them in a BMP Manual that is adopted in law by reference.***

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A very important aspect of state program implementation is the development of design criteria and guidance. These are needed for program implementation and for individual strategies and practices. When state programs require local implementation or allow for delegation to local governments, it is imperative that guidance be provided on how to achieve state program goals and objectives. ***Typically, this detailed guidance is provided in a BMP Design Manual.***

The state program BMP Manual needs to provide detailed design guidance, including specifics on maintenance requirements and responsibilities, for each practice endorsed or required. ***To assure use of, and compliance with, the BMP Manual's requirements, state stormwater regulations (or local regulations, if applicable) should adopt it by reference. The rules also need to include specific statements requiring all stormwater systems to be designed, constructed, maintained and operated in compliance with the BMP Manual's requirements.*** Explicit reference to a formally adopted BMP Manual within state (or local) regulations establishes a legal basis for implementation of complex, technical information. It also allows for relatively easy revision of BMP design guidance as more information is gained about the design and performance of BMPs.

Standing water in a dry detention basin caused by a blocked outlet or bottom slopes which are too flat.

Nearly all of the states that have implemented stormwater management programs have developed a BMP Manual to provide the regulated public with explicit guidance. An example of a state required design manual used to implement stormwater programs at the local level is the "Stormwater Management Design Manual for the Puget Sound Basin (The Technical Manual)", developed by the Washington State Department of Ecology. Others are referenced in Chapter 10.

Beside the traditional design considerations typically contained in a BMP Manual, it or the program's regulations also need to include other important needs related to the successful maintenance and operation of stormwater facilities. ***An example is the need to set aside areas where sediments removed from a stormwater management facility can be placed. The single most expensive part of BMP maintenance is transportation of removed sediments to an appropriate disposal area. By setting aside an area on-site for sediment storage, maintenance costs can be significantly reduced thereby increasing the likelihood that the facility will actually be cleaned out when needed.***

A detailed discussion of concerns associated with disposal of sediments removed from stormwater management facilities, along with general recommendations, can be found in Chapter 9. The issue of sediment disposal must be addressed in program implementation, and needs to be considered during the initial review of a proposed development or stormwater management facility. The rule language recommended in Appendix 4.2, establishing the size of a set aside area, is applicable to facilities receiving expected pollutant loadings from residential lands or light commercial uses. Requirements for land uses with higher pollutant loadings would need to be considered individually.

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4.4 Example Language That Should Be Contained in State (or Local) Stormwater Management Regulations

Example language which should be considered for inclusion in stormwater regulations is presented in Appendix 4-1. Also included is a brief discussion of key issues, for four major BMP implementation areas, which need to be addressed when developing a stormwater regulation or law. Whether these requirements are established in statewide regulations, or within regional or local government regulations, will depend on the stormwater program's implementation framework.

5. LOCAL STORMWATER MANAGEMENT PROGRAMS

Most local governments have some type of stormwater management program, such as flood protection, and provide stormwater infrastructure. ***In those states without a comprehensive stormwater management program, the local stormwater law or regulations should include all of the recommendations included in the previous section of this chapter.***

Even in those states with statewide stormwater management programs, local governments usually have an important implementation role. Depending on the state program's framework, the local role may include design review and permitting, inspections during or after construction, compliance, maintenance, or master planning. ***Since local governments typically provide infrastructure such as the community's master stormwater system, they have a more vested and direct interest than state or regional agencies in assuring that all of the stormwater systems within the community are being maintained and operating properly.*** This is not only to minimize potential flooding but also to limit the local government's liability under Federal or state environmental laws since the master stormwater system almost always discharges ultimately to a water body. Additionally, if the local government has implemented a stormwater utility, especially one with credits for on-site stormwater management, assuring periodic inspections and proper maintenance of privately owned stormwater systems is especially important.

For the above reasons, along with the difficulty that state stormwater agencies have in obtaining sufficient staff to conduct regular inspections of completed stormwater systems, ***it is strongly recommended that local governments implement a Stormwater Operating Permit System.*** Possible language for inclusion in a local government stormwater ordinance or regulation is:

Stormwater Operating Permits

1. Subsequent to the final inspection and submittal of the As-built Certification and Record Drawings, no stormwater management systems shall be used until a Stormwater Operating Permit application has been submitted, the required application fee paid, and the application has been approved.

2. All permittees shall operate and maintain the stormwater management system in a manner consistent with the authorized Operating Permit and any other state or local requirements.

3. The following information shall be required in the Operating Permit application:

A. A property parcel map showing the locations and tax parcel numbers of each parcel for which an owner is required to either obtain an operating permit or maintain membership in a Stormwater Facility Property Owners Association.

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B. If the permit is to be issued to a Stormwater Management Facility Property Owners Association, a copy of the articles of incorporation and pertinent bylaws must be submitted, along with a list of the names, addresses, and telephone numbers of all Association members and officers.

C. A narrative description of the stormwater management facilities to be maintained and operated.

D. A general location map which indicates the relative location in the watershed, the property tax parcel numbers, and the names and addresses of the current owners of all parcels on which the facilities are located, the limits of the drainage basin contributing to the facilities, and the number of acres contributing runoff to each of the facilities.

E. Information regarding the operating capacities of the facilities, demonstrating that the capacities are not greater than those specified in the applicable permit for the facilities.

F. An operation and maintenance plan, including identification of an individual (including address and telephone number) who shall be designated as the responsible contact individual and who shall be responsible for the day-to-day operation, maintenance, and management of the facility. The plan shall specify operating procedures, possible routine intermittent and annual maintenance, and all other activities required to ensure that the facility performs as designed and permitted. The plan must also include estimates of equipment required, person hours and crew size, schedules, and an estimate of annual costs. Most importantly, the plan must clearly detail how funding and supervision is to be provided.

4. Stormwater operating permits shall expire three years after issuance or renewal. The permittee shall apply for a permit renewal at least three months prior to permit expiration.

5. The stormwater operating permit shall be renewed when each of the following conditions has been met:

A. Inspection by a local government or a state certified inspector that confirms that all components of the facility are in good working order, that the facility is free of debris or excessive sediment deposits and is well stabilized, and that the facility is meeting or exceeding its design performance criteria.

B. If the stormwater operating permit is being renewed by an individual, the applicant must submit updated records providing the names and addresses of current property owners with cross-referencing to the property parcel map filed with the original operating permit application.

C. If the stormwater operating permit is being renewed by a Stormwater Management Facility Property Owners' Association, the applicant shall provide a current list of the names, addresses, and telephone numbers of all Association members and officers, and submit any changes to the Association's bylaws (if any) along with a certification of good standing from the (state agency responsible for corporations).

D. The applicant provides the name, address, and telephone number of the individual responsible for day-to-day operation, maintenance, and management of the facility.

E. The applicant makes any repairs or maintenance activities noted in the inspection report.

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6. RECOMMENDATIONS ON PUBLIC VERSUS PRIVATE MAINTENANCE OF COMPLETED STORMWATER MANAGEMENT FACILITIES

Surveys conducted by several stormwater management programs around the country indicate that stormwater systems often are not maintained and operated properly. Maryland's stormwater program has conducted a series of surveys on the maintenance of stormwater practices. The report "Maintenance of Stormwater Management Structures, A Departmental Summary" (Md WRA, 1986) included the following conclusions:

1. Stormwater management facilities in Maryland, especially dry detention facilities, are not particularly well maintained. In fact, a majority of facilities have failed due to lack of routine maintenance.

2. Public facilities are better maintained than private facilities.

3. Commercial/industrial facilities are less likely to be aesthetically unsatisfactory.

4. 45% of commercial/industrial facilities were completely satisfactory, compared to 24% of residential facilities. While there may be several reasons for these results, an important one is that a very clear ownership exists for commercial/industrial facilities. The owner feels more responsibility for the facility and is more likely to maintain it. This is not the case for residential developments, where a Homeowner's Association or the developer is responsible.

5. Commercial/industrial facility owners are more concerned about their image, including the appearance of their grounds, than residential facility owners, especially if the residential facility owner is the developer.

The Maryland survey indicates that relying on commercial and industrial property owners to properly maintain their stormwater systems is probably appropriate. They generally either have staff dedicated to maintenance and landscaping activities at their site who can be responsible for stormwater system maintenance, or they contract for such services. However, even these owners need to be periodically checked by public inspectors or through submission of certifications such as required by Operating Permits.

Assuring proper maintenance and operation of residential stormwater systems is much more difficult. Typically, the maintenance of these systems is the responsibility of a Property Owners Association. These entities seldom have the technical expertise to inspect or maintain their stormwater system, and they often lack the commitment to assess their members to raise the funds needed to contract for maintenance. The ***implementation of a Maintenance Agreement or an Operating Permit System can greatly increase compliance by Property Owners Associations. Implementation of education programs, such as Hillsborough County's (FL) "Adopt - a - Pond" program, have also proven successful in getting maintenance done.***

Public ownership and responsibility appear to be the best solution for assuring the long term maintenance and operation of stormwater systems serving residential developments. However, local governments traditionally have been reluctant to accept ownership and responsibility for maintenance of residential systems. Reasons for this include the cost of providing maintenance, potential legal liabilities, and the fact that many stormwater systems are part of a residential development's open space or landscaping areas with asso-

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ciated aesthetic concerns.

Overcoming these obstacles requires sound program administrative requirements for operation and maintenance and, most importantly, an adequate program funding mechanism, such as a stormwater utility. Additionally, ***some local governments have required Maintenance Agreements between the residential development and the local government. A key aspect of these Agreements is the clear delineation of responsibilities. The local government accepts responsibility for inspecting and maintaining the stormwater system's structural components, including the periodic removal of debris and accumulated sediments. However, aesthetic maintenance and pollution prevention still rests with the Property Owners Association.***

7. EXAMPLES OF MAINTENANCE AGREEMENTS

There are several Maintenance Agreements which can be used as examples for other jurisdictions initiating stormwater management programs. ***Three examples of Maintenance Agreements worthy of consideration because of their unique features are presented in Appendices 4-2, 4-3 and 4-4.***

The first two examples are from the City of Olympia, Washington. ***"Residential Agreement to Maintain Stormwater Management Facilities and to Implement a Pollution Prevention Plan" is the first example (Appendix 4-2).*** This agreement is of interest for the following reasons:

1. Maintenance responsibility for sediment removal, managing vegetation in wet ponds, resetting orifice sizes and elevations on residential properties rests with the City.
2. The City clearly defines maintenance responsibilities of the residential property owners.
3. A pollution prevention plan that includes source control of pollutants is formally included in the maintenance agreement.
4. Authority for the City to be reimbursed for maintenance activities undertaken by the City that are the responsibility of the Homeowners Association but are not performed.
5. Requires the submission to the City of an annual report by the Homeowners Association. This helps the Association's members understand and demonstrate their commitment to undertake maintenance obligations.
6. The City obligates itself to an annual inspection of all stormwater facilities.

The second Maintenance Agreement example from the City of Olympia, Washington program is a "Commercial, Industrial Agreement to Maintain Urban Stormwater Management Facilities and to Implement a Pollution Prevention Plan" (Appendix 4-3). This Agreement is more typical and has more universal applicability in other jurisdictions. Maintenance responsibility clearly rests with the property owner, with technical assistance provided by the City. This Agreement contains the following provisions:

1. A pollution prevention plan, including source control of pollutants, is formally included in the maintenance agreement.
2. Authority for the City to be reimbursed for maintenance activities undertaken by the City that are the responsibility

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of the property owner but are not performed.

3. Requires submission to the City of an annual report by the property owner again helping the owner demonstrate an awareness and commitment to complete maintenance obligations.

4. The City obligates itself to an annual inspection of all stormwater management facilities.

5. The City has implemented a stormwater utility. One enforcement mechanism in this Agreement allows the City to revoke stormwater utility rate credits for stormwater treatment if required maintenance is not performed.

The third example Maintenance Agreement is entitled "Standard Maintenance and Monitoring Agreement for the City of Alexandria, Virginia" (Appendix 4-4). This Agreement is especially interesting because of a component dealing with "unconventional" stormwater management facilities. The City stresses new technologies for stormwater management in "ultra urban" areas. This agreement obligates the landowner to contribute the entire cost of a water quality monitoring program to assess the performance of the unconventional stormwater management practice before release of the Final Site Plan. This requirement helps the evolution of stormwater management facilities in situations where innovative practices are necessary due to site constraints. The Agreement contains the following provisions:

1. Grants permission to the City to enter the property for inspection purposes.

2. Allows the City to do needed maintenance and assess the landowner for the maintenance costs.

3. Allows the City to assess a monitoring fee for evaluating the performance of innovative stormwater management facilities.

Good access and legal authority help assure that needed maintenance gets performed.

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APPENDIX 4-1

Example Language That Should Be Contained in State, Regional, or Local Stormwater Management Regulations

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This appendix contains a discussion of essential concepts needed in stormwater regulations to effectively assure the proper design, construction, inspection, and operation and maintenance of stormwater management systems.

Several of the recommended sections might be more appropriately included in a BMP Manual if the program has one. In this case, the regulations need to adopt the Manual by reference and require compliance with the Manual's criteria. These sections are designated by (BMP Manual) at the end of the recommendation.

The recommendations are divided into four major issue areas:

- Design and review requirements
- Construction requirements
- Legal operation and maintenance requirements
- Maintenance inspection requirements

A. Design and Review Requirements for Stormwater Facilities and Plans

Design review requirements need to be considered from several different perspectives:

- Proper design and construction of the stormwater management system to ensure proper performance. Unfortunately, experience has shown that systems often are inappropriately designed for site conditions or are not constructed properly;

- Inclusion of long term maintenance and operation considerations in the design of the stormwater system. This helps assure that maintenance can be done relatively easily. This helps assure that systems will perform for a maximum time frame given their expected design flows and pollutant loadings; and

- Institutional issues such as warranty requirements or review and approval of the legal operation and maintenance entity along with its accompanying legal documents. This provides the legal framework for subsequent inspection and maintenance by a specific entity, either public or private.

Recommended language includes:

1. Stormwater system design will include careful consideration of maintenance as an essential design element. All stormwater management systems and plans shall be designed in accordance with the _____ BMP Design Manual dated _____,with approved supplements.

2. The applicant shall provide a legally dedicated easement with an access road to retention, detention, and filtration facilities from a public right of way. The access road shall be a minimum of 15 feet wide and suitable to allow heavy maintenance vehicles access to all points needed to maintain the facility.

3. Stormwater management facilities serving residential developments and the access roads serving these facilities shall be placed in separate tracts, owned in common by the property owners served by the facility or by the development's Property Owners Association.

4. Projects reviewed and approved for sediment control and permanent stormwater management shall have a certified site inspector (may want to limit type of activity, e.g., projects over 5 acres, etc.). The certified site inspector shall be responsible for the following items:

   A. Inspection of active construction sites on at least a weekly basis.
   B. Submitting a completed inspection form which documents site conditions to the contractor, developer, and permitting agency within five calendar days.

5. It shall be the responsibility of the permittee to maintain all erosion and sediment control and permanent stormwater management facilities in good operating condition during the lifetime of the permit. The permittee shall clean and repair or replace all erosion control practices as often as necessary to maintain their effectiveness and level of performance, or as directed by a certified inspector or by the permit authority. In addition, the permittee shall be responsible for assuring that any practices damaged during floods, storms, or other adverse weather conditions are returned to normal operating conditions within a defined time frame as determined by the certified inspector or permitting agency.

6. Land area adjacent to the stormwater management facility must be set aside for disposal of sediments removed from the facility when maintenance is performed. The land set aside for facility maintenance shall be sized as follows: (only suggested sizing)

A. The set aside area shall accommodate at least 2% of the stormwater management facility volume to the elevation of the 2 year storm storage volume elevation,
B. The maximum depth of the set aside volume shall be one foot,
C. The slope of the set aside area shall not exceed 5%, and
D. The area and slope of the set aside area may be modified if an alternative area or method of disposal is approved by the appropriate plan approval agency. (BMP Manual)

7. A clear statement of defined maintenance responsibility, an operation and maintenance schedule, and the specific parties responsible for maintenance shall be established during the plan review and approval process.

8. Prior to the issuance of any building or grading permit for which stormwater management is required, the responsible plan approval agency shall require the applicant or

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owner to execute an inspection and maintenance agreement binding on all subsequent owners of land served by the private stormwater management facility. Such agreement shall provide for access to the facility at reasonable times for regular inspection by an inspection agency.

B. Construction Requirements for Stormwater Management Systems

Construction activities can have a significant negative impact on the short or long term performance of stormwater management facilities. ***Improper control of pollutants, especially sediments, during site construction, or improper construction of the stormwater management facility itself, can significantly reduce the expected performance and lifespan of the facility. Criteria and recommendations to address both of these situations are needed to ensure long term performance.***

1. Protection of Permanent Stormwater Management Facilities From Premature Failure Caused By Pollutant Entry During Site Construction.

To a large extent, the treatment performance of stormwater management facilities depends on the available storage volume. In addition, several treatment practices rely upon the permeability of surrounding soils or filter media. Consequently, excess sedimentation can significantly reduce treatment performance or prevent proper functioning of the facility.

The practical aspects of site control during construction are discussed in Chapter 6. However, ensuring effective site control during construction and protecting stormwater management facilities from entry of construction site pollutants, especially sediments, also requires a strong legal foundation. Typically, the program's regulations adopt by reference its BMP Manual, and requires all plans and stormwater systems to be designed, constructed, operated, and maintained in accordance with the Manual's requirements. The program's BMP Manual needs to include specific recommendations for each of the different practices, along with general statements meant to cover all stormwater management facilities.

The following recommendations are directed towards structural stormwater management practices. However, it is extremely important to implement nonstructural, pollution prevention practices on all projects with structural stormwater management practices. These nonstructural controls serve as an overlay applicable to all types of structural stormwater management practices.

Recommended language includes:

Stormwater Detention Practices

Detention practices are often used for sediment trapping during construction. When the approved erosion and sediment control plan uses a permanent detention facility for sediment control, the following requirements should be included in the stormwater regulations or in the BMP Design Manual:

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1. The detention facility shall be installed in compliance with all approved design requirements and specifications. Special attention shall be paid to installation of the principal spillway cradle, anti-seep mechanisms (whether collars or diaphragm), core trench, compaction, and emergency spillway.

2. The principal outlet structure shall have a temporary structure attached to it which provides effective filtering of sediments prior to the release of runoff from the site. This temporary structure can either be a riser attachment surrounded by filter fabric and stone, or a horizontal pipe at the foot of the riser assembly which extends horizontally on the detention facility bottom and is covered by filter fabric and stone. Other filtering variations should be considered depending on their use, performance, and experience within the stormwater program. (BMP Manual)

3. Sediment cleanout must be accomplished before the detention facility storage to the crest of the principal spillway is reduced by 25% (may be more stringent depending on the specific jurisdiction). (BMP Manual)

4. Removal of the temporary sediment control modifications to the outlet structure shall be done only after the site has been vegetatively stabilized in accordance with the approved erosion and sediment control plan and the detention system's design bottom elevations have been met. (BMP Manual)
5. Wetland plantings, where required, shall not be performed until final site stabilization has been accomplished. (BMP Manual)

Infiltration Practices

Infiltration facilities are extremely sensitive to clogging by construction generated sediments. Therefore, stringent requirements are needed during construction to assure their long term performance once construction activities are completed. ***The following recommendations may be controversial. They need to be discussed thoroughly by the implementing agency and with the regulated community to recognize difficulties in implementation and gain support for their inclusion in the program.***

1. Infiltration facilities should not be constructed or operated prior to overall site stabilization. (BMP Manual)

2. Infiltration facilities, other than dry wells and porous pavement, shall be off-line and have pretreatment practices to reduce sediment loadings into the facility. Pretreatment can be provided by sediment sumps, biofiltration, extended detention ponding, or other means approved by the permitting agency. (BMP Manual)

3. Infiltration basin facilities shall not be used as sediment basins during construction. Sediment basins shall be constructed upstream of the infiltration basin and construction runoff shall bypass the infiltration basin until site stabilization has been completed. (BMP Manual)

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4. To prevent soil compaction, areas to be used for infiltration facilities will be clearly marked and construction equipment prevented from entering them. (BMP Manual)

Filtration Practices

Treatment in filtration practices is accomplished by passing runoff through a filter media. They often are used as a component of construction site sediment control. However, filters used for stormwater treatment need to have certain requirements placed upon them to better assure long term performance:

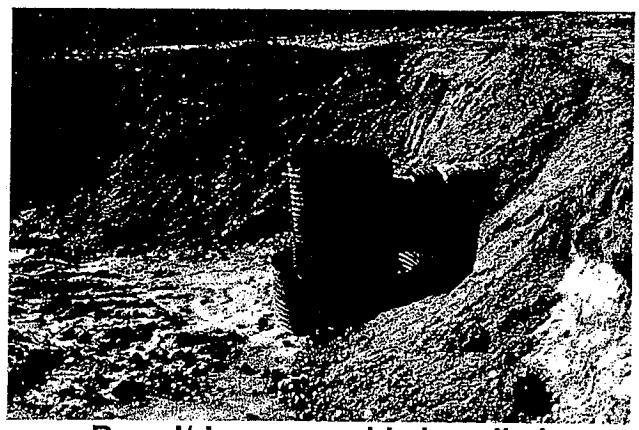
1. If used to filter sediments during construction, the filter media shall be completely replaced once the site is fully stabilized and before the filter is placed into operation for stormwater treatment. (BMP Manual)

2. If not used during construction for filtering sediments, runoff shall be diverted around the filter and filter media shall not be placed in the facility until the contributing drainage area has been stabilized. (BMP Manual)

3. Underdrain or outlet structures shall be protected from excess sediment entry. (BMP Manual)

Biofiltration Practices

Biofiltration practices rely on vegetative filtering of stormwater runoff and, in many cases, infiltration. Their effective performance depends on their length, slope, soils, vegetative stand, and flow velocity. As such, activities which may adversely impact on any of the treatment mechanisms should be addressed during construction.



Barrel/riser assembly installed upside down demonstrating a lack of understanding by the contractor and lack of inspection oversight

1. If the biofiltration practice will rely upon infiltration, then all recommendations for infiltration facilities need to be followed for biofiltration practices. (BMP Manual)

2. The facility shall be protected from excess sedimentation which could retard or smother vegetation, or impair percolation. (BMP Manual)

3. Biofiltration facilities can be used as a component of an erosion and sediment control plan, but primarily as a secondary sediment trapping facility. Examples include treatment of stormwater flows after discharge from a sediment trap, or sheet flow from a

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residential site into a biofiltration facility which, during the erosion and sediment control phase, has stone check dams to reduce flow velocities. Before being placed into service for stormwater management, biofiltration facilities will be cleared of all accumulated sediments, excavated to the design depth, and vegetatively stabilized. (BMP Manual)

4. Once the biofiltration practice has been shaped to final contours, it shall be sodded or erosion control matting or other practices shall be used to protect the soil and grades until vegetation has become established to minimum density requirements. (BMP Manual)

2. Ensuring Proper Construction of the Stormwater Management Facility

To help assure that stormwater systems are constructed properly, three essential institutional components need to be included in the stormwater program: financial assurances, periodic inspections and as-built certifications. Recommended rule language includes:

Financial assurances

1. Prior to the issuance of any building or grading permit for which stormwater management facilities are required, the plan approval agency shall require the applicant or owner to submit a financial guarantee to ensure the initial function of the completed stormwater management facility. That guarantee shall be either a surety or cash bond, or irrevocable letter of credit. The amount of the guarantee shall be established by the plan approval agency but shall not be less than 50% (actual percentage can be determined by individual state program) of the estimated construction cost of the stormwater management system.

Periodic inspections

The inspection entity, whether a public agency, state certified inspector, or site engineer, must have a visible presence during construction of stormwater management facilities. ***Inspections need to be made at specified stages of construction rather than at an assigned time frequency.*** Construction phasing may mean that a stormwater management facility may not be actively under construction for extensive time periods. Therefore, communication between contractor, consultant, and the inspection entity is critical. The following steps should be taken to assure inspections are conducted at the appropriate stages of construction:

1. The land developer shall notify the inspection entity before initiation of construction, at the construction stages specified below, and upon project completion, when a final inspection will be conducted to ensure compliance with the approved plan.

2. The land developer or contractor shall request an inspection at least 24 hours ahead of time. Inspectors will be required to approve work as it is completed at the critical

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stages of construction specified below for the different types of stormwater management facilities.

3. The approved stormwater management system plans shall be on the project site at all times during construction.

4. Site personnel shall be notified of any site inspection and receive a written report of site conditions. The report shall specify any corrections that are necessary to bring the site and the stormwater management facility into compliance with approved plans.

5. All stormwater detention systems shall be inspected at the following stages of construction:

   A. Upon completion of excavation to sub-foundation and, where required, installation of structural supports or reinforcement for structures, including, but not limited to:
      (1) Core trenches for structural embankments,
      (2) Inlet-outlet structures and anti-seep structures, watertight connectors on pipes, and
      (3) Trenches for enclosed storm drain facilities.
   B. During placement of structural fill, concrete, and installation of piping and catch basins;
   C. During backfill of foundations and trenches;
   D. During embankment construction; and
   E. Upon completion of final grading and establishment of permanent vegetation.

6. Infiltration facilities shall be inspected at the following times:

   A. When the area to be used for the infiltration facility has been staked out prior to its construction;
   B. During excavation to ensure minimal compaction and verify soil conditions;
   C. Upon completion of excavation and, if appropriate, before filling of the facility with stone or other fill material; and
   D. Upon completion of facility construction, including complete establishment of vegetation, if appropriate.

7. Filtration facilities shall be inspected at the following times:

   A. Upon completion of excavation;
   B. Upon completion of structural components, such as reinforcing bars, but prior to any concrete pouring;
   C. For prefabricated units, during joining of prefabricated sections to ensure good sealing between sections;
   D. After the facility has been filled with water to determine whether there is any leakage: and
   E. For sand filters which are part of a detention system, inspections shall occur as specified for detention facilities and before and after placement of underdrain pipes, geotextile fabrics, and filter media.

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As-built Certifications and Record Drawings

1. Completed construction of the stormwater management system shall be documented on an As-built Certification and Record Drawing, prepared and sealed by a construction professional. Normally, this is the registered professional engineer who has supervised the construction of the stormwater system. These documents certify that construction of the stormwater management system was done according to the approved plan. Any variation from the approved plan must be noted.

2. Prior to requesting a final inspection, the permittee shall have a registered professional engineer, or other qualified design professional (depending upon state or local requirements), inspect the stormwater management system, submit a complete set of drawings, and certify on the plans that:

   A. The stormwater management facilities were constructed in compliance with the approved plans. The Record Drawings will show all pertinent constructed dimensions, elevations, shapes, and materials;
   B. All variations in construction from the approved design plan shall be identified, including omissions to and additions from the approved plan;
   C. If there are modifications from the approved plan, what changes or improvements are required to bring the project into compliance with the approved plan; and
   D. Any changes which might conflict with local, state, or federal regulations.

C. Legal Operation and Maintenance Requirements for Stormwater Systems

A very important element which must be considered during the design phase is determining how to assure proper operation and maintenance of the stormwater system, both for the short and long term. ***For the short term, it is recommended that there be a warranty period during which the original developer of the site is responsible for all maintenance and operation. However, for the long term, a permanent operation and maintenance entity must be identified which has appropriate legal authority to own, operate, maintain the stormwater system, and raise funds to complete maintenance when needed.***

When there is one property owner, the maintenance responsibility is clearly defined. ***However, a major concern arises when the owner or permittee involved in development and implementation of site controls eventually sells all or part of the property.*** The new owners often will not be aware of permit requirements and will find that they have a permanent stormwater management facility on their property that they must inspect and maintain. This problem is especially compounded at residential developments, where there will be many different property owners. ***Typically, a property owners association will be responsible for stormwater system operation and maintenance. Experience in urban runoff control programs around the country shows that, even with the best intentions, maintenance of stormwater management facilities by these associations generally is not accomplished*** (WMI, 1997).

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Example wording for both situations follows :

General Assurances

1. The owner or permittee shall assure that the stormwater management system is at all times properly operated, maintained, and managed in accordance with the requirements of the permit and the approved stormwater pollution prevention plan.

2. Stormwater management facilities shall be maintained so that their performance is not diminished or impaired. Failure to maintain stormwater facilities shall be considered a permit violation and subject the responsible maintenance entity to any and all penalties established by law or these regulations.

3. Stormwater management systems shall not be modified without specific approval of the permitting agency unless such modifications are part of an approved maintenance schedule.

4. Stormwater management facilities shall be located on commonly owned property and not located on one individual's property unless that individual accepts full maintenance responsibility for the facility. There shall be dedicated easements for access to all components of the stormwater management system.

5. The owners, with a record interest in any non-public stormwater management facility, commercial, industrial, and other private practice, shall sign and record a covenant which runs with the land and binds the property on which the private stormwater management facility is located to maintain the facility.

6. An operation and maintenance plan and schedule shall be provided to the owner or the legal operation and maintenance entity.

7. The appropriate public inspection agency shall have authority to inspect private stormwater management facilities at any time to ensure compliance with maintenance schedules and requirements, and that the facilities are operating as designed and constructed.

Warranty Period

1. The permittee shall be responsible for all maintenance and proper operation of stormwater facilities for a period of two years after completion of the overall project. The permittee shall satisfactorily maintain the facility and repair any failure within this two year period. Additionally, the permittee shall post and maintain a maintenance bond or other security acceptable to the permitting agency during this two year initial maintenance period. The purpose of the maintenance bond is to cover the cost of design defects or failures in workmanship of the facilities. The amount of the maintenance bond shall be ten percent of the construction cost of the stormwater management facilities.

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2. The permittee shall be responsible for proper operation and maintenance of the stormwater system. If the permittee is going to sell or otherwise divest its interest in the permitted development or property, then a legal operation and maintenance entity, as specified below, shall be accept responsibility for the operation and maintenance of the stormwater system.

3. The permittee shall give the responsible maintenance entity copies of possible maintenance inspection forms and other appropriate documentation to educate them about their legal responsibilities of owning a stormwater management system.

4. The permittee shall provide a copy of an "as-built" plan of the stormwater management system to the responsible maintenance entity.

Legal Operation and Maintenance Entity

1. The following entities are acceptable for meeting the requirements necessary to ensure that the stormwater management system will be operated and maintained in compliance with the requirements of these regulations:

   A. Local governmental units including counties or municipalities, or special taxing districts.
   B. State or federal agencies; or
   C. Duly constituted stormwater, water, communications, sewer, electrical, or other public utilities.

2. The property owner or developer is normally not acceptable as a responsible entity when the property is intended to be subdivided. The property owner or developer shall be acceptable in any of the following circumstances:

   A. Written proof is furnished either by letter or resolution, that a governmental entity or such other acceptable entity as set forth in 1 above will accept the operation and maintenance of the stormwater management system at a specified time in the future;
   B. Proof of bonding or assurance of a similar nature is furnished in an amount sufficient to cover the cost of the operation and maintenance of the stormwater management system;
   C. The property is wholly owned by the permittee and ownership is intended to be retained. This would apply to a farm, corporate office, or single industrial facility, for example; or
   D. The ownership of the property is retained by the permittee and is either leased or rented to third parties such as in shopping centers or mobile home parks.

3. Profit or nonprofit corporations including homeowners associations, property owners associations, condominium owners associations or master associations shall be acceptable only under certain conditions that ensure the corporation has the financial, legal and administrative capability to provide for the long term operation and maintenance of the stormwater management system.

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4. Entity requirements.

A. If a multimember association such as a homeowner, property owner, condominium or master association is proposed, the owner or developer must submit Articles of Incorporation for the association, and Declaration of Covenants and Restrictions, or such other organizational and operational documents which affirmatively assign authority and responsibility for the operation or maintenance of the stormwater management system.

B. The association shall have sufficient powers reflected in its organizational or operational documents to:

1. Operate and maintain the stormwater management system as permitted or exempted by the approval authority;
2. Establish rules and regulations;
3. Assess members a fee for the cost system operation and maintenance and enforce collection of such assessments;
4. Contract for services to provide for operation and maintenance;
5. Exist in perpetuity. The Articles of Incorporation must provide that if the association is dissolved, the stormwater management system shall be transferred to and maintained by an entity acceptable to the approval authority. Transfer of maintenance responsibility shall be effectuated prior to dissolution of the association;
6. Enforce the restrictions relating to the operation and maintenance of the stormwater management system;
7. Provide that the portions of the Declarations which relate to the operation and maintenance may be enforced by the approval authority in a proceeding at law or in equity; and
8. Require that amendments to the documents which alter the stormwater management system beyond maintaining it's original condition must receive approval agency approval before taking effect.

5. Phased Projects

A. If an operation and maintenance entity is proposed for a project which will be constructed in phases, and subsequent phases will use the same stormwater management system as the initial phase or phases, the entity shall have the ability to accept responsibility for the operation and maintenance of stormwater management systems for future phases of the project.

B. If the development scheme contemplates independent operation and maintenance entities for different phases, and the stormwater system is integrated throughout the project, the entities either separately or collectively shall have the authority and responsibility to operate and maintain the stormwater system for the entire project. That authority shall include cross easements for stormwater management and the ability to enter and maintain the various facilities, should any sub-entity fail to maintain a portion of the stormwater management system within the project.

In the event the legal operation and maintenance entity fails to maintain the stormwater management system in good working condition, the permitting authority or local jurisdiction must have the legal authority to enter the property, maintain the stormwater management system,

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assess the property owners, and be able to place a lien on the property if the owners do not pay the assessment. This may be necessary for safety reasons or it may be the only way to ensure that the facility is maintained as constructed. There are several examples of legal maintenance agreements provided at the end of this Chapter which offer wording regarding this legal authority.

D. Maintenance Inspection Requirements for Stormwater Management Systems

To assure that the legal operation and maintenance entity is performing all required maintenance activities, periodic inspections and certifications are needed. ***Whether these inspections are done by a public agency, such as the permitting authority, by a state certified inspector, or by a registered professional engineer, will depend upon the stormwater program's institutional framework and staff resources. Unfortunately, due to a lack of adequate funding, most public agencies will never have enough inspectors to regularly inspect completed stormwater management systems.*** To address this problem, Florida's program is implementing a certified inspector program and recommending that local governments implement renewable Operating Permits for stormwater systems.

A question that often arises is how frequently should stormwater management systems be inspected to assure proper performance. Often this is site-specific, depending on many factors such as the types of BMPs used, the pollutant loadings, the facility's size, the contributing drainage area, and whether it is on-line or off-line. For example, while wet detention systems may only need annual inspections, BMPs such as oil/grit separators or sand filters may need monthly inspections. ***Chapter 6 provides recommendations on how often different types of BMPs need inspecting. Additionally, Appendix 4-1 includes a table prepared by the Florida Department of Environmental Protection that is included in NPDES municipal stormwater permits.***

Recommended rule inspection language follows:

General Inspection Requirements

1. The permittee or responsible maintenance entity shall conduct regular inspections of all components of the stormwater management. The person conducting the inspection shall complete and retain a stormwater management facility inspection form after each inspection.

2. At least once each year, the permittee or responsible maintenance entity shall arrange for an inspection of their stormwater management system by either a public agency inspector or a private inspector.

3. Inspection reports (detailed in **Chapter 7**) shall be maintained by the responsible inspection agency. The inspection reports shall include the following items:

   A. Date of inspection
   B. Name of the inspector

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C. The condition of:
   (1) vegetation,
   (2) fences,
   (3) spillways,
   (4) embankments,
   (5) reservoir area,
   (6) outlet channels,
   (7) underground drainage,
   (8) Filter media,
   (9) sediment load, or
   (10) other items

D. If maintenance activities are needed, the recommendations for maintenance and an expected time for completion of the needed maintenance activities will be noted on the form.

4. The permitting (or inspection) agency shall implement procedures to ensure that deficiencies indicated by inspections are rectified in a timely manner. These shall include:

   A. Notification of the responsible maintenance entity of deficiencies and needed maintenance activities, including a time frame for repairs;
   B. After the maintenance activities have been completed, the inspector will be notified so that the facilities can be reinspected. The inspector will complete a new inspection form, noting whether all recommended maintenance activities have been completed and if any other actions are needed to assure proper operation of the facility.
   C. Effective enforcement procedures or procedures to refer projects to the appropriate legal entity if repairs are not undertaken or are not done properly.

5. Copies of all stormwater management facility "As-Built" Plans shall be provided to the appropriate maintenance inspection agency and to the legal maintenance entity responsible for performing maintenance.

6. All public agency or private inspectors of permanent stormwater management facilities shall attend and pass a Departmental course on stormwater system maintenance. In addition, individuals responsible for maintenance of completed stormwater management facilities shall also be required to attend this stormwater management maintenance course. The course shall include discussion of at least the following topics:

   A. Context of the course.
   B. Aspects of law and regulation.
   C. Soils information including texture, limitations, erodibility, and classification.
   D. Stormwater management facilities and the importance of their proper function and performance.
   E. Inspection and problem documentation.
   F. Proper approach to actual maintenance including erosion and sediment control during maintenance.
   G. Disposal of materials removed from the practice.
   H. Submission of an activity completion form.

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Public Agency Inspections

1. The responsible public inspection agency shall conduct inspections of all stormwater management systems at least once per year. More frequent inspections will be conducted after an unusually high runoff event or for stormwater systems with a higher potential to fail such as filters or oil and grit separators.

Private Inspections

1. If there is no responsible public inspection agency, the legal maintenance entity shall provide for period inspections of their stormwater management system by either a registered professional engineer or a state certified inspector.

2. Inspections shall be conducted at least once per year, with more frequent inspections after an unusually high rainfall or for stormwater systems such as filters or oil and grit separators.

3. The inspector shall provide the legal maintenance entity with a copy of all inspection reports and send one to the permitting or responsible inspection agency.

4. The legal maintenance entity shall complete all maintenance activities and repairs recommended in the inspector's report within the time frame specified and request the inspector to reinspect the stormwater system following completion of all maintenance activities.

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APPENDIX 4-2

Residential Agreement to Maintain Stormwater Management Facilities and to Implement a Pollution Prevention Plan

Olympia, Washington

A014075

Drainage Design and Erosion Control Manual for Olympia, Washington

Residential Agreement to Maintain
Stormwater Management Facilities and to Implement
a Pollution Prevention Plan

The upkeep and maintenance of stormwater management facilities and the implementation of pollution prevention best management practices is essential to the protection of aquatic resources. All property owners are expected to conduct business in a manner that promotes resource protection. This Agreement contains specific provisions with respect to maintenance of stormwater management facilities and use of pollution prevention practices.

LEGAL DESCRIPTION

Whereas, the _____ have constructed improvements, including but not limited to buildings, pavement, and stormwater management facilities on the property described above. In order to further the goals of the Jurisdiction to ensure the protection and enhancement of aquatic resources, the Jurisdiction and the _____ hereby enter into this Agreement. The responsibilities of each party to this Agreement are identified below.

_____ SHALL

1. Implement the stormwater management facility maintenance program included herein as Attachment "A". (maintenance checklist similar to that developed in Chapter 7)

2. Implement the pollution prevention plan included herein as Attachment "B". (homeowner responsibilities such as disposal of household wastes, lawn care, etc.)

3. Maintain a record (in the form of a log book) of steps taken to implement the programs referenced in (1) and (2) above. The log book shall be available for inspection by appointment at _____. The log book shall catalog any action taken, who took the action, when it was taken, how it was done, and any problems encountered or follow-on actions recommended. Maintenance items ("problems") listed in Attachment "A" shall be inspected as specified in the attached instructions or more often if necessary. The _____ are encouraged to photocopy the individual checklists in Attachment "A" and use them to complete its inspections. These completed checklists would then, in combination, comprise the logbook.

4. Submit an annual report to the Jurisdiction regarding implementation of the programs referenced in (1) and (2) above. The report must be submitted on or before _____, 199_ and each calendar year and shall contain, at a minimum, the following items:

   A. Name, address, and telephone number of the businesses, the persons, or firms responsible for plan implementation, and the persons completing the report.
   B. Time period covered by the report.
   C. A chronological summary of activities conducted to implement the programs referenced in (1) and (2) above. A photocopy of the applicable sections of the logbook,

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with any additional explanations needed, shall normally suffice. For any activities conducted by paid parties, include a copy of the invoice for services.

D. An outline of planned activities for the next year.

THE JURISDICTION SHALL:

1. Execute the following periodic major maintenance on the subdivision's stormwater management facilities: sediment removal from facilities, managing vegetation in wet ponds, resetting orifice sizes and elevations, and adding baffles.

2. Maintain all stormwater management facility elements in the public rights-of-way, such as catch basins, oil-water separators, and pipes.

3. Provide technical assistance to the _____ in support of its operation and maintenance activities conducted pursuant to its maintenance and source control programs. Said assistance shall be provided upon request and as Jurisdictions time and resources permit.

4. Review the annual report and conduct a minimum of one (1) site visit per year to discuss performance and problems with the _____.

5. Review the agreement with the _____ and modify it as necessary at least once every three (3) years.

REMEDIES

1. If the Jurisdiction determines that maintenance or repair work is required to be done to the stormwater management facilities located in the subdivision, the Jurisdiction shall give the _____ notice of the specific maintenance and/or repair required. The Jurisdiction shall set a reasonable time in which such work is to be completed by the persons who were given notice. If the above required maintenance and/or repair is not completed within the time set by the Jurisdiction, written notice will be sent to the _____ stating the Jurisdiction's intention to perform such maintenance and bill the _____ for all incurred expenses.

2. If, at any time, the Jurisdiction determines that the existing facility creates any imminent threat to public health or welfare, the Jurisdiction may take immediate measures to remedy said threat. No notice to the persons listed in Remedies (1), above, shall be required under such circumstances. All other _____ responsibilities shall remain in effect.

3. The _____ grant unrestricted authority to the Jurisdiction for access to any and all stormwater management facilities for the purpose of performing maintenance or repair as may become necessary under Remedies (1) and/or (2).

4. The _____ shall assume responsibility for the cost of maintenance and repairs to the stormwater management facilities, except for those maintenance actions

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explicitly assumed by the Jurisdiction in the preceding section. Such responsibility shall include reimbursement to the Jurisdiction within 90 days of the receipt of the invoice for any such work performed. Overdue payments will require payment of interest at the current legal rate for liquidated judgements. If legal action ensues, any costs or fees incurred by the Jurisdiction will be borne by the parties responsible for said reimbursements.

This Agreement is intended to protect the value and desirability of the real property described above and to benefit all the citizens of the Jurisdiction. It shall run with the land and be binding on all parties having or acquiring any right, title, or interest, or any part thereof, of real property in the subdivision. They shall inure to the benefit of each present or future successor in interest of said property or any part thereof or interest therein, and to the benefit of all citizens of the Jurisdiction.

Agreed to and signed by:

_____

Owner Date

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, the above personally appeared before me and provided photo identification, and who executed the foregoing instrument and acknowledge that they signed the same as their free and voluntary act and deed for the uses and purposes therein mentioned.

Given under my hand and official seal this _____ day of _____, 199__

Notary Public in and for the State of
Washington, residing in _____
My commission expires _____

Dated in Olympia, Washington, this _____ day of _____, 199__

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, personally appearing before me,_____ and _____, who executed the foregoing instrument and acknowledge the said instrument to be the free and voluntary act and deed of said Municipal Corporation for the uses and purposes therein mentioned and on oath states he is authorized to execute said instrument.

Given under my hand and official seal this _____ day of _____, 199__

Notary Public in and for the State of
Washington, residing in _____
My commission expires _____

Dated in Olympia, Washington, this _____ day of _____, 199__

A014078

APPENDIX 4-3

Commercial, Industrial Agreement to Maintain Stormwater Management Facilities and to Implement A Pollution Prevention Plan

Olympia, Washington

A014079

Commercial, Industrial Agreement to Maintain Stormwater Management Facilities and to Implement A Pollution Prevention Plan

The upkeep and maintenance of stormwater management facilities and the implementation of pollution prevention plans is essential to the protection of aquatic resources. All property owners are expected to conduct business in a manner that promotes resource protection. This Agreement contains specific provisions with respect to maintenance of stormwater management facilities and use of pollution prevention practices.

LEGAL DESCRIPTION:

Whereas, Business Name, has constructed improvements, including but not limited to, buildings, pavement, and stormwater management facilities on the property described above. In order to further the goals of the Jurisdiction to ensure the protection and enhancement of Jurisdiction's aquatic resources, the Jurisdiction and Business Name hereby enter into this Agreement. The responsibilities of each party to this Agreement are identified below.

BUSINESS NAME SHALL:

1. Implement the stormwater management facility maintenance program included herein as Attachment "A". (maintenance checklist similar to that developed in Chapter 7)

2. Implement the pollution prevention plan included herein as Attachment "B". (parking lot maintenance, covering outdoor storage areas, etc.)

3. Maintain a record (in the form of a logbook) of steps taken to implement the programs referenced in (1) and (2) above. The logbook shall be available for inspection by Jurisdiction staff at _____ during normal business hours. The logbook shall catalog the action taken, who took it, when the action was done, how it was done, and any problems encountered or follow-on actions recommended. Maintenance items ("problems") listed in Attachment "A" shall be inspected on a monthly or more frequent basis as necessary. Business Name is encouraged to photocopy the individual checklists in Attachment "A" and use them to complete its monthly inspections. These completed checklists would then, in combination, comprise the monthly logbook.

4. Submit an annual report to the Jurisdiction regarding implementation of the programs referenced in (1) and (2) above. The report must be submitted on or before _____ of each calendar year and shall contain, at a minimum, the following items:

   A. Name, address, and telephone number of the business, the person, or the firm responsible for plan implementation, and the person completing the report.
   B. Time period covered by the report.
   C. A chronological summary of activities conducted to implement the program referenced in (1) and (2) above. A photocopy of the applicable sections of the logbook, with any

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additional explanation needed, shall normally suffice. For any activities conducted by paid parties not affiliated with Business Name include a copy of the invoice for services.

D. An outline of planned activities for the next year.

THE JURISDICTION SHALL:

1. Provide technical assistance to Business Name in support of its operation and maintenance activities conducted pursuant to its maintenance and pollution prevention control programs. Said assistance shall be provided upon request, and as Jurisdiction time and resources permit, at no charge to Business Name.

2. Review the annual report and conduct a minimum of one (1) site visit per year to discuss performance and problems with Business Name.

3. Review this agreement with Business Name and modify it as necessary at least once every three (3) years.

REMEDIES

1. If the jurisdiction determines that maintenance or repair work is required to be done to the stormwater management facility existing on the Business Name property, the Jurisdiction shall give the owner of the property within which the facility is located, and the person or agent in control of said property, notice of the specific maintenance and/or repair required. The Jurisdiction shall set a reasonable time in which such work is to be completed by the persons who were given notice. If the above required maintenance and/or repair is not completed within the time set by the Jurisdiction, written notice will be sent to the persons who were given notice stating the Jurisdiction's intention to perform such maintenance and bill the owner for all incurred expenses. The Jurisdiction may also revoke stormwater runoff utility rate credits for the quality component or invoke surcharges to the quantity component of the Business Name bill if required maintenance is not performed.

2. If at any time the Jurisdiction determines that the existing facility creates any imminent threat to public health or welfare, the Jurisdiction may take immediate measures to remedy said threat. No notice to the persons, listed in (1) above, shall be required under such circumstances.

3. The owner grants unrestricted authority to the Jurisdiction for access to any and all stormwater management facility features for the purpose of performing maintenance or repair as may become necessary under Remedies (1) and (2).

4. The persons, listed in (1) above, shall assume all responsibility for the cost of any maintenance and for repairs to the stormwater management facility. Such responsibility shall include reimbursement to the Jurisdiction within 30 days of the receipt of the invoice for any such work performed. Overdue payments will require payment of interest at the current legal rate for liquidated judgments. If legal action ensues, any costs or fees incurred by the Jurisdiction will be borne by the parties responsible for said reimbursements.

5. The owner hereby grants to the Jurisdiction a lien against the above-described property in an amount equal to the cost incurred by the Jurisdiction to perform the maintenance or repair work described herein.

This Agreement is intended to protect the value and desirability of the real property described above and to benefit all the citizens of the Jurisdiction. It shall run with the land and be binding on all parties having or acquiring from Business Name or their successors any right, title, or interest in the property or any part thereof, as well as their title, or interest in the property or any part thereof, as well as their heirs, successors, and assigns. They shall inure to the benefit of each present or future successor in interest of said property or any part thereof, or interest therein, and to the benefit of all citizens of the Jurisdiction.

Agreed to and signed by:

_____

Owner Date

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, the above personally appeared before me and provided photo identification, and who executed the foregoing instrument and acknowledge that they signed the same as their free and voluntary act and deed for the uses and purposes therein mentioned.

Given under my hand and official seal this _____ day of _____, 199__

Notary Public in and for the State of
Washington, residing in _____
My commission expires _____

Dated in Olympia, Washington, this _____ day of _____, 199__

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, personally appearing before me, _____ and _____, who executed the foregoing instrument and acknowledge the said instrument to be the free and voluntary act and deed of said Municipal Corporation for the uses and purposes therein mentioned and on oath states he is authorized to execute said instrument.

Given under my hand and official seal this _____ day of _____, 199__

Notary Public in and for the State of
Washington, residing in _____
My commission expires _____

Dated in Olympia, Washington, this _____ day of _____, 199__

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APPENDIX 4-4

Standard Maintenance and Monitoring Agreement

BMP Facilities Maintenance/Monitoring Agreement

City of Alexandria, Virginia

A014083

City of Alexandria, Virginia

Standard Maintenance and Monitoring Agreement
BMP Facilities Maintenance/Monitoring Agreement

THIS AGREEMENT, made and entered into this _____ day of _____, 19__, by and between _____, herein called the "Landowner" and the City of Alexandria, Virginia (the "City")

WITNESSETH

WHEREAS the Landowner is the owner of certain real property described _____ as acquired by deed in the land records of the City of Alexandria, Virginia, Deed Book _____ at Page _____, hereinafter called the "Property".

WHEREAS, the Landowner is proceeding to build on and develop the property; and

WHEREAS, Plan of Development/Site Plan/Subdivision Plan _____, hereinafter called the "Plan" which is expressly made a part hereof, as approved or to be approved by the City, provides for detention on-site treatment of stormwater runoff within the confines of the property; and

WHEREAS, the City and the Landowner, its successors and assigns agree that the health, safety, and welfare of the residents of the City of Alexandria, Virginia, require that on-site stormwater management facilities be constructed and maintained on the property; and

WHEREAS, the City requires that on-site stormwater management facilities as shown on the Plan be constructed and adequately maintained by the Landowner, its successors and assigns.

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The on-site stormwater management facilities shall be constructed by the Landowner, its successors and assigns, in accordance with the plans and specifications identified in the plans.

2. The Landowner, its successors and assigns, shall maintain the stormwater management facilities in good working condition, acceptable to the City, so that they are performing their design functions.

3. The Landowner, its successors and assigns, hereby grants permission to the City, its authorized agents and employees, to enter upon the property, and to inspect the stormwater management facilities whenever the City deems necessary. The purpose of the inspection is to assure safe and proper functioning of the facilities. The inspection shall cover the entire facilities, berms, outlet structures, pond areas, access roads, etc.

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When deficiencies are noted, the City shall give the Landowner, its successors and assigns, copies of the inspection report with findings and evaluations.

4. In the event the Landowner, its successors and assigns, fails to maintain the stormwater management facilities in good working condition acceptable to the City, the City may enter upon the Property and take whatever steps it deems necessary to maintain said stormwater management facilities and to charge the costs of the repairs to the Landowner, its successors and assigns. This provision shall not be construed to allow the City of Alexandria to erect any structure of a permanent nature on the land of the Landowner, outside of an easement belonging to the City. It is expressly understood and agreed that the City is under no obligation to maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the City.

5. The Landowner, its successors and assigns, will perform maintenance in accordance with the maintenance schedule for the stormwater management facilities including sediment removal as outlined on the approved plans and the following specific requirements:

   For extended dry detention facilities, wet ponds, or infiltration facilities, insert the following:

   Maintenance of the (Insert type of facility) shall conform to the maintenance requirements contained in the Northern Virginia BMP Handbook published by the Northern Virginia Planning District Commission.

   For unconventional BMPs for which design criteria is provided in the Design Manual, insert the following:

   Maintenance of the (insert type of facility) shall conform to the maintenance requirements contained in Chapter 2 of the Alexandria Supplement to the Northern Virginia BMP Handbook.

   For unconventional BMP's not detailed in Chapter 2 of this manual and for experimental BMP's, insert specific maintenance requirements as approved by the Director of Transportation and Environmental Services prior to release of the Final Site Plan.

6. In the event the City, pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like on account of the Landowner's or its successors' and assigns, shall reimburse the City upon demand, within _____ days of receipt thereof for all costs incurred by the City hereunder. If not paid within such _____ day period, the City shall have a lien against the property in the amount of such costs, plus interest at the Judgment Rate, and may enforce same in the same manner as a lien for real property taxes may be enforced.

7. The Landowner, its successors and assigns, shall indemnify and hold harmless the City and its agents and employees for any and all damages, accidents, casualties, occurrences or claims which might arise or be asserted against the City for the construction, presence, existence or maintenance of the stormwater management facilities by the Landowner, its successors and assigns.

   In the event a claim is asserted against the City, its agents or employees, the City shall promptly notify the Landowners, their successors and assigns, and they shall defend, at their own expense, any suit based on such claim. If any judgment or claims against the City, its agents or employees shall be allowed, the Landowner, its successors and assigns shall pay all costs and expenses in connection therewith.

   The following additional paragraph shall be added for all agreements covering non-conventional or experimental BMP's.

8. The Landowner, its successors and assigns, hereby grants permission to the City, its authorized agents and employees, and to the Northern Virginia Planning District Commission, its authorized agents, employees and consultants, to enter upon the property, and to install, operate and maintain equipment to monitor the flow rate and pollutant content of the input flow, the effluent, and at intermediate points in the BMP. The Landowner further agrees to design and construct the facility to provide access for monitoring. The Landowner further agrees to a contribution of (as established during the Site Plan approval process _____ in the case of experimental BMP's) the entire cost of the monitoring program, payable prior to the release of the Final Site Plan, towards the cost of the monitoring program.

8. or 9. This Agreement shall be recorded among the land records of the City of Alexandria, Virginia, and shall constitute a covenant running with the land and/or equitable servitude, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interests.

WITNESS the following signatures and seals:

_____

(Landowner) (Seal)

By: _____

_____

Type Name

_____

Type Name

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ATTEST:

_____

STATE OF _____

CITY OF _____

I, _____, a Notary Public in and for the City and State aforesaid, whose commission expires on the _____ day of _____, 19___, do hereby certify that _____ whose name(s) is/are signed to the foregoing Agreement bearing date of the _____ day of _____, 19___, has acknowledged the same before me in my said City and State.

GIVEN UNDER MY HAND THIS _____ day of _____, 19___.

_____
NOTARY PUBLIC

WITNESS the following signatures and seals:

_____
Director, Department of T & ES (Seal)

By: _____

_____
Type Name

_____
Type Name

ATTEST:

_____

STATE OF _____

CITY OF _____

I, _____, a Notary Public in and for the City and State aforesaid, whose commission expires on the _____ day of _____, 19___, do hereby certify that _____ whose name(s) is/are signed to the foregoing Agreement bearing date of the _____ day of _____, 19___, has acknowledged the same before me in my said City and State.

GIVEN UNDER MY HAND THIS _____ day of _____, 19___.

_____
NOTARY PUBLIC

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APPENDIX 4-5

RECOMMENDED MAINTENANCE OF STORMWATER MANAGEMENT SYSTEMS

EXAMPLE OF LANGUAGE INCLUDED IN STORMWATER NPDES MS4 PERMITS ISSUED IN FLORIDA

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TABLE II.A.1.b.
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS.

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Grass Swales (Dry)	Semi-Annual Inspection Items	• Inspect swales for signs of prolonged wetness and damage to structures including diversion devices, inflow pipes, driveway culverts, and swale blocks. • Note any critically eroded areas on banks and front or back slope and swale bottom. Schedule for stabilization. • Undercutting at the point of discharge and paved flumes or pipes and culverts should be noted and scheduled for immediate repair. • Dead or dying grass and saturation of the swale bottom are indications of potential clogging and reduced infiltration capacity. When observed the facility should be checked to insure that it percolates completely within 3 days following storms to comply with state regulations. Scraping, discing or otherwise aerating the bottom may be required to restore the infiltration capacity of the soil. For best performance swales should percolate within one day following storms. • Note any signs of excessive petroleum hydrocarbon contamination and handle appropriately (2).
	As needed. Standard Maintenance Items.	• Mowing and litter and debris removal. • Stabilization of eroded side slopes and bottom. • Repair undercut or eroded areas at culverts, flumes, or swale blocks. • Nutrient and pesticide use management (1). • Dethatch swale bottom and remove thatching. Dispose via composting and land application. As an alternative, remove grass clippings following mowing.
	Annual Maintenance	• Disc or otherwise aerate swale bottom.
	Major Maintenance Items. 5 Year Revolving Schedule	• Scrape swale bottom and remove sediment with proper sediment disposal. Restore original cross-section and infiltration rate. (2,3) • Seed or sod to restore ground cover. • Violation of water quality standards for turbidity will often result following initial construction as well as during major maintenance and restoration activities, unless water can be temporarily diverted while seeding and subsequent germination take place. In lieu of diversion it is advisable to stabilize both the swale bottom an side slopes as quickly as possible by resodding and staking all areas disturbed during swale clean out and restoration operations. Use of netting or geotextile matting in conjunction with seeding operations have also been shown to reduce the potential for erosion and subsequent turbidity problems from roadside swale maintenance.

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TABLE II.A.1.b. (continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS.

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Dry Retention	Semi-Annual Inspection Items	• Inspect facility for signs of prolonged wetness and damage to structures including diversion devices and inflow and outflow structures and pipes. • Note any critically eroded areas on banks and pond bottom. Schedule for stabilization. • Undercutting at the point of discharge and signs of piping in the vicinity of the control structure or inlets, flumes, diversion structures or pipes should be noted and scheduled for immediate repair. • Dead or dying grass on the pond bottom are indications of potential clogging and reduced infiltration capacity. When observed the facility should be checked to insure that it percolates completely within 2-3 days following storms. Scraping, discing or otherwise aerating pond bottom may be required to restore the infiltration capacity of the soil. Standing water may need to be pumped from the facility or be otherwise drained to effect restoration of the infiltration basin. The owner or owner's representative should contact FDEP or the appropriate WMD to advise the permitting authority of the need to perform the drawdown. • Note any signs of excessive petroleum hydrocarbon contamination and handle appropriately (2).
	As needed. Standard Maintenance Items.	• Mowing and litter and debris removal. • Stabilization of eroded banks. • Repair undercut or eroded areas at inflow and diversion structures or conveyances. • Nutrient and pesticide use management (1). • Dethatch pond bottom and remove thatching. Dispose via composting and land application. As an alternative, remove grass clippings following mowing.
	Annual Maintenance	• Disc or otherwise aerate pond bottom.
	Major Maintenance Items. 5 Year Revolving Schedule	• Scrape pond bottom and remove sediment with proper sediment disposal. Restore original cross-section and infiltration rate. (2,3) • Seed or sod to restore ground cover. Use netting, staked in place, in conjunction with dry organic mulch (hay or straw) or other suitable techniques to protect from erosion and promote more rapid ground cover.

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TABLE II.A.1.b. (continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS.

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Exfiltration Trench	Semi-Annual Inspection Items.	• Monitor facility for sediment accumulation in the pipe (when used) and storage volume recovery (i.e. drawdown, capacity). Observation wells and inspection ports should be checked following 3 days minimum dry weather. Failure to percolate stored runoff to the design treatment volume level within 72 hours indicates blinding of soil in the trench walls and/or clogging of geotextile liner with fine solids. Reductions in storage volume due to sediment in the distribution pipe also reduces efficiency. Minor maintenance measures can restore exfiltration rates to acceptable levels short term. Major maintenance (total rehabilitation) is required when accumulated sediment has reduced the effective treatment volume to an unacceptable level or to restore recovery rate when minor measures are no longer effective or can not be performed due to design configuration. • Inspect appurtenances such as sedimentation and oil and grit separation chambers of catch basin as well as diversion devices and over flow weirswhen used. Diversion facilities and over flow weirs should be free of debris and ready for service. Sedimentation and oil/grit separators should be scheduled for cleaning when sediment depth approaches cleanout level. Cleanout levels should be established not less than 1 foot below the control elevation of the chamber.
	As needed. Standard Maintenance Items.	• Remove sediment from sediment/oil and grease chamber of catch basin inlets and dispose of properly (2,3). • Remove debris from the outfall or "smart box" (diversion device) in the case of off-line facilities.
	Long Term Maintenance. 5 years or as needed to prolong service.	• When bypass capability is available minor maintenance measures such as extended dry periods may be used to provide short term recovery of exfiltration rate. • Remove accumulated sediment from facilities constructed with manholes or other appurtenant structures to facilitate cleanout. Sediment should be disposed of properly (2,3). This process normally involves facilities with large pipes. Cleanout may be performed by suction hose and vactor truck and/or by high pressure jet washing.
	Long Term Maintenance. 10-15 years or as needed.	• Total rehabilitation of trench to maintain storage capacity within 2/3 of the design treatment volume and 72 hour exfiltration rate limit. Excavate and remove perforated or slotted pipe, surrounding coarse aggregate envelop (bedding) and geotextile fabric (wrap). In most cases renovation will require replacement with new material of equivalent grade and quality. Trench walls should be excavated to expose clean soil. Sediment contaminated soil, coarse aggregate and filter cloth should be disposed of properly (2,3).

TABLE II.A.1.b. (continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS.

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Dry Detention Pond w/Sand Filter System	Semi-Annual Inspection Items	• Inspect facility for evidence of damage and short circuiting of the filter. Close attention should be given to the filter box, bed, trench or mound and appurtenant works. Signs of piping (erosion of filter sand) into underdrain pipes or holes next to junction box and/or discharge control structures or exposure of coarse aggregate or geotextile surrounding the underdrain pipe should be noted and scheduled for immediate repair • Note any critically eroded areas on banks, pond bottom, or filter. Schedule for stabilization. • Any undercutting at the point of discharge and erosion in the vicinity of inflow pipes, flumes and diversion structures should be noted and scheduled for immediate repair. • Dead or dying grass on the pond bottom and/or standing water following 3 days or more of dry weather are indicative of filter "blinding". When observed the facility should be scheduled for major maintenance. Standing water may need to be pumped from the facility or be otherwise drained to effect restoration of the filter. The owner or owner's representative should contact FDEP or the appropriate WMD to advise the permitting authority of the need to perform the drawdown. • Note signs of excessive petroleum contamination and handle appropriately (2). • If so equipped check "clean out" ports at the end of each underdrain and the junction box or underdrain outlet for evidence of blockage. (i.e. standing water in underdrain lateral accompanied by little or not outflow.) • Schedule cleaning of underdrain pipes via mechanical means or high pressure water jet as appropriate. Also inspect for damage to caps from mowing accidents or any breaks in seals to prevent short circuiting of the filter.
	As needed. Standard Maintenance Items.	• Mowing and removal of grass clipping. • Litter and debris removal from banks and control structure or screens. Remove sediment buildup obstructing inflows. • Stabilization of eroded banks. • Repair undercut and eroded areas in the vicinity of the discharge point or other structures such as inlet flumes, inflow pipes and energy dissipators. • Nutrient and pesticide use management (1).
	Semi-annual or As Needed Maintenance.	• Minor corrective maintenance of filtration components should be scheduled any time drawdown does not occur within 48 hours after a storm. This activity usually involves simple light disking or otherwise aerating the sod cover and/or raking the surface of the filter. • Confined unit "vault or box" type systems may be backflushed (i.e. fluidized) if these capabilities are available.
	Major Maintenance Items. 18 months or as needed to maintain 72 hr. drawdown capacity.	• Major maintenance of filtration components is required any time that nuisance conditions (standing water) persists for more than 3 days following storms. This activity involves removal and replacement of ballast gravel and geotextile covers when used. Any sod cover or the top 2-3 inches of sand must be removed in cases involving vegetated or open sand filter beds. All discolored, sediment contaminated sand must be removed and replaced with clean sand of a type equivalent to the original grade. • Sediment and contaminated sand must be disposed of properly. (2,3) • Seed or sod to restore any dead or severely damaged ground cover. Use netting, staked in place, in conjunction with dry organic mulch (hay or straw) or other suitable techniques to protect from erosion and promote more rapid ground cover. • At select locations, excavate down to and check underdrain pipe for clogging of the orifices, slots and/or fabric sock surrounding the pipe if used. Clean or otherwise replace pipe as needed to restore drainage capacity.
	Annual or as Needed Maintenance Items. To maintain 72 hour drawdown limit. **(Confined Unit or Box Type Filter).**	• Major maintenance of filtration components associated with "confined unit" type filters is usually more frequent than with other filtration devices. The activities required are facilitated however, by the unit's compact nature. Complete removal and replacement of geotextile, filter sand, and the ballast stone or gravel when used is normally required. • Restore damaged ground cover on the pond bottom and protect from erosion. • Fabric wrapped underdrain pipe should be closely inspected and replaced if clogged. Perforated or slotted pipe should be checked for damage or restricted openings. Replace or clean underdrains as needed to restore drainage capacity.

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TABLE II.A.1.b. (continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS.

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Wet Detention Pond	Semi-Annual Inspection Items	• Detention facilities that include constructed wetlands (littoral shelf) components should be monitored carefully to avoid invasive aquatic plant problems. Schedule removal of invasive species or chemical control when necessary to prevent excessive competition with beneficial or desired plants (1). • Note those areas within the littoral zone where the spread or overcrowding of beneficial plants necessitates management and harvesting.
	Annual Inspection Items	• Inspect facility for damage. Close attention should be given to the control structure and the point of discharge (POD). Undercutting at the POD and evidence of piping (erosion of soil into pipe junctions) and/or erosion in the vicinity of inflow pipes, the outlet control structure, or flumes should be noted and scheduled for immediate repair. • Note signs of excessive total petroleum hydrocarbon contamination and handle appropriately (2). • Monitor sediment accumulations and remove when _ of storage volume is filled (3). • Check for apparent signs of hypereutrophic conditions and note areas which require invasive aquatic plant control. • Bleeder devices such as orifices as well as weirs, stand pipes, box drop inlets, grates, and screens should clean, free of debris and ready for service. • All control gates should be checked for operational capacity by briefly opening and closing valve. • Forebays/sediment sumps should be monitored for sediment accumulation. The "Cleanout Level" should be calculated for each facility and the sump should be scheduled for sediment removal based on the limit established for the facility and the sediment accumulation rate.
	As needed. Standard Maintenance Items.	• Repair and stabilize undercut and eroded areas near structures and banks. • Mowing side slopes with litter and debris removal from banks. • Nutrient and pesticide use management (1).
	Monthly Maintenance	• Clean and remove debris from orifices, weirs, stand pipes, drop inlets and screens.
	Semi-annual Maintenance	• Invasive aquatic plant control (1).
	Annual or as Needed Maintenance	• Aquatic plant management and harvesting. Manage constructed wetland components to prevent overcrowding of beneficial plants and to maintain adequate open water area for aesthetics, light penetration and oxygenation. It is also important to avoid excessive cover for insect (mosquito) larvae which enhances production and inhibits predation. Not more than a 50 percent reduction in open water area is recommended prior to mechanical harvesting and reduction of macrophytes cover to its original level (i.e. 30-35 percent in most instances). • Constructed wetland management (regular selective harvesting) to encourage sites for active growth and enhanced pollutant assimilation is recommended.
	Long Term Maintenance. 5 year revolving schedule or as needed.	• Removal of sediment from forebays or sediment sumps and dispose of properly (2,3). Sediment "cleanout level" should not be higher than 1 footbelow the control elevation of the bay or sump nor should the storage volume be reduced by more than 60 percent of original design. (i.e. Cleanout Level = .2 in./acre drainage area remaining storage volume in cases where the original design calls for .5 inches of runoff volume below the control elevation in the forebay or sediment sump.).
	10-15 years or as needed to maintain adequate storage volume and treatment.	• Monitor sediment accumulations and remove when _ storage volume is filled or when hypereutrophic conditions become apparent. Sediment must be disposed of or used properly (2)(3).

TABLE II.A.1.b. (continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Wet Detention w/Sand Filtration	Annual Inspection Items	• Inspect filtration component in accordance with type of system as per "Dry Detention w/Sand Filter" guidelines. • Inspect detention pond component as described in "Wet Detention" guidelines. • Close attention should be given to the filtration component particularly evidence of short circuiting associated with piping in the vicinity of underdrain junctions and the control structure.
	As needed. Standard Maintenance Items.	• Maintain bank filter bed, trench, or box as described in Dry Detention w/Sand Filter guidelines to maintain 72 hour drawdown limit. • Flood control components (weirs, risers, drop boxes and discharge pipes) should be clean and ready for service. • Mowing banks and grass clipping removal. • Litter and debris removal from banks. • Stabilization of eroded banks and repair of undercutting or piping in the vicinity of inlets, outlet control structure and point of discharge. • Nutrient and pesticide use management (1).
	Monthly Maintenance	• Litter and debris removal from control structure and screens.
	Annual Maintenance	• Invasive plant species removal (1).
	Long Term Maintenance. 10-15 years revolving schedule or as needed.	• Sediment removal with proper sediment disposal to ensure that the depth of sediments does not exceed _ of the design cross-sectional area of the pond. (2,3).

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TABLE II.A.1.b.
(continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Pump Station	Semi-annual Inspection Items	• Inspect pump for proper operation and schedule any necessary repairs or replacement of worn parts. • Inspect sump in the vicinity of pump intake for excessive sediment, litter and debris accumulation. • A "Cleanout Level" should be established for sediment sumps and the sump should be scheduled for sediment removal based on the limit established for the facility and the sediment accumulation rate. Cleanout levels should be established not less than 1 foot below the intake elevation of the pump or as otherwise needed to prevent resuspension of particulates and excessive turbidity in discharge water.
	As Needed Standard Maintenance	• Where bar screens are used to protect the pump, remove screens and clean. Properly dispose of litter & debris collected. • Remove any accumulated sediment collected from near pump intake point and/or sediment sump and provide proper disposal. (2,3)

TABLE II.A.1.b.
(continued)
SUGGESTED MAINTENANCE SCHEDULE FOR STRUCTURAL CONTROLS

STRUCTURAL CONTROL	FREQUENCY OF INSPECTION AND MAINTENANCE	INSPECTION AND MAINTENANCE ACTIVITIES RECOMMENDED
Pollution ControlBoxes *(Catch Basins w/Oil Grease & Grit Separation Chambers)*	Semi-Annual Inspection Items.	• Monitor facility for sediment accumulation. • Inspect appurtenances such as grates, oil and grit separation chambers, over flow weirs, and discharge pipes. Over flow weirs and grated inlets should be free of debris and ready for service. Sedimentation and oil/grit separators should be scheduled for cleaning when sediment depth approaches cleanout level. Cleanout levels should be established not less than 1 foot below the control elevation of the chamber. As needed.
	Standard Maintenance Items.	• Remove leaves, litter and debris from the outfall pipe and grated inlets or screens. • Remove sediment from oil and grit chamber of catch basin and dispose of properly (2,3). Cleanout may be facilitated by suction hose and vactor truck.

Notes:

2 As a rule, pesticides should not be used in association with the maintenance of stormwater management systems. When mechanical control or other options prove to be impractical, use only pesticides approved by US EPA and FDACS for aquatic sites . Violation of water quality standards in receiving waters resulting from the use of chemicals within the treatment facility may be punishable under state law. Careful herbicide selection and application are important to avoid harm to desirable plants and animals. Applicators must be experienced and well trained in plant identification to selectively control undesirable plants while avoiding detrimental effects on desirable vegetation and possible downstream contamination. For assistance, contact the Florida Department of Environmental Protection, Bureau of Aquatic Plant Management, regional biologist, the local County Cooperative Extension Service agent, or University of Florida IFAS Center for Aquatic Plants in Gainesville.

To maintain the permitted or required treatment efficiency associated with a wet detention pond, the littoral vegetation should never be entirely removed or eradicated with chemicals. At least 30% of the surface area of the pond must remain vegetated with appropriate vegetation. A good management plan that provides for periodic removal of aquatic vegetation at select locations on a rotational basis is strongly encouraged. This practice helps to remove accumulated nutrients that otherwise promote over enrichment and reduced aesthetic value,. Regular maintenance of this nature slows the rate of accumulation of organic matter and the loss in treatment capacity from these processes. A good management program will prolong the useful life of the facility and decrease the frequency and costs incurred for major maintenance like dredging. When done regularly mechanical removal can help control unwanted aquatics such as cattails. As a secondary benefit, more active growth of desired plants such as pickerelweed and arrowhead is also encouraged. Harvesting the vegetation increases the rate of assimilation of nutrients by increasing plant growth and can balance the loss of treatment associated with the reduction in plants.

Soil amendments (fertilizer) should be used as needed to establish and maintain a healthy and vigorous cover on the banks of treatment facilities. Once ground cover is well established, normal rates of fertilization should be lowered near stormwater ponds to avoid over enrichment of the soil and adjacent waters. Following construction or reconstruction do not apply soil amendments within 15 to 20 feet of the edge of the pond unless fertility problems are evident. When mowing the grass be careful not to divert clippings into the pond. Remove them to prevent the buildup of nutrients in those areas subject to periodic or frequent inundation.

Problem areas susceptible to chronic erosion require more intense measures for protection and establishment of permanent vegetative cover. These special considerations may include the use of sod instead of seeding. Also, higher fertilization rates and provisions to provide temporary irrigation during dry

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weather conditions help insure more rapid establishment and vigorous growth in bank vegetation. Experts in soil conservation are available for assistance by contacting the local office of the Natural Resources Conservation Service with USDA.

3 Excessive petroleum hydrocarbon contamination can present severe sediment disposal problems. Evidence may include very dark oily stains particularly at inlet and outlet structures and strong odors of gasoline. The source of such inputs should be found and removed if possible. Pretreatment practices should be used whenever practical, and as necessary, to insure that influent runoff water is not contaminated so as to produce objectionable odors or a noticeable oil sheen over a significant portion of the pond surface.

4 Sediments associated with stormwater treatment devices should be regarded as contaminated well beyond the levels in runoff itself. When disposed of haphazardly, this material may become a source of pollution. Pollutants associated with stormwater sediment include high nutrients and oxygen demanding substances, heavy metals, petroleum hydrocarbons and other volatile and semi-volatile organic compounds, pesticides, and infectious organisms. However, absent circumstances which would be expected to result in the regular addition of paints, solvents, cleaning agents, pesticides and spilled fuels there is little probability that the sediment would be a hazardous waste. Usually sediment removed from basins may be land spread on-site in areas of restricted access, provided proper practices are used to limit wind and water erosion and direct discharge is minimized. Off-site disposal must be either to an approved landfill for use as landfill cover or to an approved sludge application site. Sediment from facilities serving major urban highways or industrial, commercial and fuel transfer facilities should be tested to determine the proper level of precaution for disposal. For more information regarding appropriate testing and disposal methods for stormwater sediment contact Mr. John Cox, FDEP, Bureau of Water Facilities Planning and Regulation, telephone (850) 921-9383 or Mr. Eric Livingston, Administrator, Stormwater/NPS Management Section, telephone (850) 921-9915.

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Chapter 5
Maintenance Considerations For Facility Owners

1. OVERVIEW

Of all the individuals, groups, and agencies that influence or participate in the maintenance of a stormwater management facility, the facility's owner has by far the most powerful and direct role. The owner's maintenance action (or inaction) not only affects the facility itself, but also strongly influences the actions (or reactions) of others. However, facility maintenance is only one of many activities and responsibilities vying for the owner's attention. As a result, facility maintenance is sometimes overlooked, neglected, or abused by the owner. Furthermore, as the complexity of a facility's ownership increases from a single to multiple and even corporate ownership, or ownership is conveyed over time to a series of new owners, the potential for oversight, neglect, or abuse also increases. This can lead not only to a failure to achieve expected or required facility performance levels, but can also threaten peoples' health, safety, property, and their water bodies.

Perhaps the power and influence of stormwater management facility owners can best be summarized in the following observations. ***At their best, stormwater facility owners can form the solid foundation of a successful stormwater management program, providing leadership to regulators and program managers, motivation to facility planners, designers, and maintainers, and security to fellow community members. Conversely, at their worst, facility owners, through neglect and disinterest, can mislead, discourage, and threaten these very same people, thereby undermining the stormwater management program and fostering mistrust and cynicism of its goals and importance.***

1.1. Objectives

To advance the Handbook's overall goal of effective and efficient facility maintenance and to avoid the grave consequences described above, the objectives of this Chapter will be:

- To explain the full meaning of stormwater management facility ownership.
- To educate stormwater facility owners about the purpose, goals, and operation of stormwater management systems.
- To present an overview of the mechanical, hydrologic, and biological processes by which stormwater facilities fulfill their purpose.
- To describe the potential hazards inherent in stormwater management systems by virtue of these characteristics and the potential liabilities inherent in facility ownership.
- To demonstrate to facility owners the importance of responsible maintenance in minimizing and managing these hazards and liabilities.
- To define the scope and content of a responsible facility maintenance program.

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- To assist and encourage facility owners in establishing and conducting maintenance programs.

1.2 Intended Readers

Intended readers of this Chapter include:

- **Single, multiple, and corporate owners** of both onsite and remote site facilities. This includes present facility owners as well as those who may or will become owners in the future.

- **Public officials** who are responsible for developing, promulgating, and/or operating stormwater management programs and overseeing facility performance, maintenance, and safety. These officials will find valuable insights into the duties, demands, and liabilities of facility ownership that should be useful in creating more effective and successful programs.

- **Facility planners and designers** who should also view stormwater management facilities through the eyes and budget of their owners, an experience that should motivate them to include the minimization and ease of maintenance as a primary design goal.

2. THE MEANING OF STORMWATER MANAGEMENT FACILITY OWNERSHIP

Perhaps the best way to begin a discussion of such a philosophical topic would be to describe how and why someone, some group, or some organization becomes the owner of a stormwater management facility. This can best be described by explaining how and why stormwater facilities have come to be part of an owner's property or project in the first place. Next, a discussion of basic facility operation and components will help explain why stormwater facility maintenance is both necessary and important to the owner. Finally, this discussion will also explain how these maintenance needs and priorities may vary depending the type of facility and how the owner must identify and respond to the particular needs and priories of their own facility.

The productive use of land for agriculture, industry, commercial enterprise, recreation, and governance has been a cornerstone of civilization since ancient times. As populations grew and social needs and interests expanded, the development of land for these purposes also grew. In many ways, the modern land developer, redeveloper, or owner is satisfying many of the same societal needs for housing, employment, and material goods as explorers, traders, and pioneers have done in past centuries.

Since the middle of this century, however, many of the adverse impacts of land development and land use change have come into clearer focus. Two of the most pervasive are the effects they have on the quantity and quality of stormwater runoff. As land is converted from a natural, undisturbed condition to a man-made one, a process which usually includes the elimination of indigenous vegetative cover, the regrading of the land surface, the addition of buildings, roadways, and other impervious surfaces, and the installation of more efficient stormwater drainage systems, the quantity and velocity of runoff that will flow from a parcel of land onto downstream properties and waterways can increase by several hundred percent. These increases can create new, and severely aggravate existing, flooding and erosion problems on these downstream areas. In addition, by introducing into the runoff the by-products of the new land use, including the emissions and drippings from vehicles, industrial processes, power generation and waste disposal, and the solid and liquid wastes generated by the land's inhabitants and users, the runoff's chemical and biological quality can be dramatically reduced.

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The rewards and penalties for developing and changing land use has presented society with a dilemma. While society's growth needs cannot be ignored, neither can the harm caused by our attempts to meet those needs through continued land development and redevelopment. How can this dilemma be resolved?

One possible method or technique is the creation and use of stormwater management practices, which are physical devices or facilities designed and constructed as part of the land development process to address the adverse runoff quantity and quality impacts described above. While there are several types of stormwater management facilities (see **Chapter 1 - Introduction** for definitions of the primary facility types contained in the Handbook), most facilities accomplish their stormwater management goals through a few fundamental processes. These processes were discussed briefly in **Section 3 of Chapter 2 - Stormwater Pollutants and Reduction Mechanisms** and are further described below.

2.1. Basic Stormwater Management Facility Operation

As noted above, the adverse impacts of land development or redevelopment can be an increase in the rate, volume, and speed of the runoff from the development site during a storm event. In order to prevent these increases from creating or aggravating flooding or erosion problems downstream, all or a portion of the site's runoff can be conveyed to a stormwater management facility. During periods of excessive runoff (that could cause downstream problems if it had not been constructed), the stormwater management facility will temporarily store this excess runoff within its storage area while, at the same time, discharging only a portion of the runoff through its outlet structure at a nonharmful rate.

This rate, which is sometimes established by the government agency having jurisdiction over the land development, may be equal to the rate of runoff that flowed from the site prior to its development. In other instances, particularly where there are known flooding or erosion problems downstream or where detailed engineering analyses of the downstream waterways or the entire watershed have been performed, the outflow rate considered or specified to be "nonharmful" may at times be even less than the predeveloped rate. Nevertheless, the outflow rate can be seen to be a function of both the size of the facility's storage volume and the hydraulic characteristics of its outlet structure. ***Thus, the size and characteristics of storage volume and outlet structure will, in turn, be dependent upon the amount of excessive runoff created by the development*** or, in other words, the difference in the runoff amounts from the site under predevelopment and post-development conditions. This is one reason why some development projects will require large stormwater management facilities occupying considerable amounts of land, while others will be able to accomplish the same stormwater management goals with less extensive facilities occupying much smaller areas.

In order to prevent or at least mitigate some of the harmful runoff quality impacts of the land development project, stormwater management systems may employ a variety of techniques to either remove some of the harmful pollutants from the runoff or to treat or convert them to less harmful forms. ***Many of the pollutants will settle to the bottom of the facility by gravity if the runoff is left in the facility's storage area for a long enough time. This requires careful discharge of the runoff from the storage area in order to prevent short-circuiting of the pollutants through the storage area or resuspension of the pollutants from the bottom after they have settled.*** Other removal techniques include passing the runoff through filtering me-

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dia such as sand, peat, or dense vegetation that removes certain pollutants by blocking their passage. Other practices use vegetation to actually absorb some of the runoff and pollutants into the plants through their root systems, where they are stored or converted by the plants' biological processes. Finally, some stormwater management facilities will enhance the natural removal and/or conversion processes described above through the controlled addition of chemicals or the use of mechanical treatment devices.

2.2. Stormwater Management Practices

As noted above, the characteristics of both the site and the downstream waterways can affect the required storage volume and land area of a stormwater management facility. However, facilities may vary in several other ways, including the location and nature of the storage area and the characteristics and behavior of the facility's outlet. All of these variations will create different maintenance demands that the facility owner must respond to. A review of these variations should help owners to better identify, understand, and respond to the maintenance demands of their own facilities.

For example, the storage areas of most stormwater management systems are located above the ground surface, where they can be readily inspected and accessed by maintenance personnel and equipment. However, due to site constraints, some stormwater facilities are located below ground in tanks or chambers, where access and mobility is much more restricted. In addition, some facilities may only detain incoming runoff during and immediately after a storm event, while others may retain some water permanently, creating a lake or pond that is present under both wet and dry weather conditions. As defined in **Chapter 1 - Introduction** and described in detail in **Chapter 2 - Stormwater Management Practices**, such facilities are designated as either ***dry or wet detention practices***, depending upon whether they are normally dry or wet during nonrainfall periods.

Detention practices, whether wet or dry, discharge their runoff onto downstream areas through an outflow structure, which may include orifices, weirs, pipes, and channels. However, stormwater facilities defined in Chapter 1 as ***infiltration (or retention) practices may not have formal outlet structures.*** Instead, they discharge their runoff through the soil which surrounds the bottom and/or sides of the facility's storage area.

As noted above, there are several different techniques by which runoff pollutant loadings are reduced by a stormwater management facility. These include settlement by gravity in detention practices and a combination of settling, evapotranspiration, and percolation through the ground in infiltration practices. Other facilities defined in Chapter 1 as ***filtration practices force runoff to flow through beds of sand, peat, or even compost to remove pollutants, while facilities defined as biofiltration practices use dense stands of vegetation or other organic media.*** Finally, it is important to note that many stormwater management facilities have the physical and operating characteristics of several different practices, particularly with regards to stormwater pollutant removal, and therefore cannot easily be categorized. ***Additionally, many stormwater systems may include a combination or series of facilities or practices.***

A final characterization is important. Since the runoff quantity impacts of land development or redevelopment (i.e., volume, rate, and/or velocity) have been recognized for a much longer period of time than the runoff quality impacts, many older stormwater management facilities were designed and constructed to only address these quantity impacts. In recent years, however, the runoff

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quality impacts of land development/redevelopment have gained considerable attention and, in some instances, even priority over the quantity concerns, resulting in the use of facilities for runoff quality control only. ***Therefore, it becomes necessary at times to designate whether the type of facility under consideration is intended for runoff quantity or quality control purposes. This will be done in the Handbook by adding either word to the facility type (e.g., a "quantity detention facility" or "quality infiltration facility").*** When neither word is added, the reader can assume that the facility is intended to address both stormwater management impacts. Finally, facility types such as filtration or biofiltration facilities are only intended to address runoff quality impacts and, therefore, no additional description is necessary. Detailed information regarding the various stormwater management practices included in this manual is presented in **Chapter 2**.

2.3. Stormwater Facility Components

Just as different stormwater management facilities may employ different storage, outflow, and pollutant control mechanisms, there are different functions assigned to each area or component of a facility. ***To help facility owners better understand the characteristics and operation of their own facilities, thereby enhancing their ability to identify and respond to their unique maintenance requirements, a description of the major components of most stormwater management practices is presented in Table 5-1.*** As discussed below, each of the components described in the table not only have different functions, characteristics, and locations within a stormwater management facility but, by virtue of these attributes, also have different maintenance needs and priorities.

In reviewing the table, it is important to note that not all facility types have all components. For example, since an infiltration facility discharges its outflow through the surrounding soil, it will may not have a principal outlet structure, especially if it is an off-line facility. Similarly, a vegetated swale or filter strip, which controls runoff quality by filtering runoff at shallow depths through dense vegetation, will not normally have a principal outlet structure, dam, or trash racks. In addition, since some stormwater management systems display the characteristics of many facility types, the list of components presented in the table should not be considered exhaustive. Finally, the component descriptions have been developed specifically for this Handbook. As such, different or additional descriptions may be used in other publications.

2.4. Operational Impacts on Facility Maintenance

It should be apparent by now that stormwater management facilities achieve their assigned stormwater management goals through a wide variety of means and techniques and, as such, each may consist of a similarly wide variety of components and characteristics. It is also important for facility owners to recognize that, due to these facts, ***each type of facility has its own unique maintenance demands and priorities.*** For example, an infiltration facility, which will discharge its runoff through the surrounding ground, will require more frequent removal of sediment and small debris than a dry detention facility, whose outlet structure will allow a much greater portion of the incoming sediment and small debris to pass through. This is also true of a wet detention facility, where a greater amount of sediment and debris will be captured and retained in the permanent pool than the normally dry bottom of the detention facility.

Further comparisons will also be useful. For example, while both infiltration and wet detention facilities will capture and retain a

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Table 5.1.

Major Components of Stormwater Management Practices

COMPONENT	DESCRIPTION
PRINCIPAL OUTLET	Hydraulic structure that controls and conveys the facility's outflow to the downstream conveyance or receiving water.
EMERGENCY OUTLET	Hydraulic structure or spillway that safely conveys emergency overflows from the facility. Includes approach and exit channels.
DAM/EMBANKMENT	Wall or structural fill that impounds runoff in the facility above the adjacent ground surface.
BOTTOM	The lowest or deepest surface within the facility.
SIDE SLOPES	Slopes at dams, embankments, spillways, and facility perimeters constructed through excavation or filling.
TRASH RACK	Device placed upstream of the principal outlet or drain to intercept trash and debris that would otherwise block it.
LOW FLOW SYSTEM	Surface and/or subsurface measures that convey low and dry weather inflows to the principal outlet without storage.
INLETS	Upstream surface and/or subsurface conveyance measures that discharge runoff into the facility.
OUTFLOW SYSTEMS	Downstream surface and/or subsurface conveyances or water bodies which receive facility outflows from the principal outlet.
PERIMETER	Area immediately adjacent to the facility.
ACCESS SYSTEMS	Measures and devices that provide maintenance personnel and equipment access to various facility components.
VEGETATIVE COVER	Vegetation planted on various facility components to stabilize their surfaces and/or provide stormwater treatment.
BYPASS SYSTEM	A system which allows a facility owner to temporarily bypass the stormwater facility to allow a maintenance activity to occur in the "city."

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greater portion of the inflow's sediment and debris than a dry detention facility, the presence of the wet basin's permanent pool will normally make it much more difficult, time-consuming, and expensive to remove sediments than the normally dry bottom in the infiltration facility. In addition, the removal of sediments from a properly constructed wet detention pond typically is only needed every 10 to 15 years, while an infiltration facility often requires annual removal. Finally, it can be seen that since a stormwater facility intended to address both runoff quantity and quality impacts will, by its nature and operation, capture and retain more sediment than a quantity-only facility, it will also require more frequent sediment removal efforts.

In addition to the varying maintenance needs of different stormwater management facilities, it can also be seen that ***different facility components will also impose different maintenance demands on the facility owner.*** For example, trash racks, low flow channels, and adjacent areas of the bottom will collect more sediment and debris than emergency spillways, side slopes, dams, and other components and will, therefore, require more frequent and thorough cleaning. Conversely, the structural integrity of dams, embankments, emergency spillways, and outlet structures are, relatively speaking, more vital to the safety of the facility and downstream areas and, therefore, will warrant more thorough inspection and more immediate repair than low flow channels, perimeters, or bottoms.

It is important that stormwater management facility owners understand these distinctions and comparisons, for it is through such understanding that owners can more effectively and economically allocate their maintenance resources and meet their maintenance responsibilities. This is particularly true where such resources are limited due to economic, personnel, or equipment constraints. It is also true for potential facility owners such as land developers, home buyers, and commercial or industrial leasees, who must plan and budget for facility maintenance as part of their overall operations. Failure to do so can be disastrous, as described in the following section.

2.5. The Impacts of Facility Maintenance Neglect

When the maintenance of a stormwater management facility is neglected, the immediate impacts can quickly escalate into serious health and safety problems. Immediate impacts typically include a decline in the facility's appearance, which can adversely impact the overall aesthetic character of the surrounding area. Such impacts may be severe to some owners, particularly if the area's appearance is vital to its economic or social vitality. Examples of such instances include office sites, shopping malls, and commercial buildings that need to attract and keep tenants and customers, and residential neighborhoods that want to sustain both their quality of life and high property values.

Other impacts from initial maintenance neglect can include the creation of nuisances at the facility, including odors, mosquitoes, and habitats for mice, rats, and other vermin. All of these can once again adversely impact the site's aesthetic character, and potentially adversely impact on site property values. They will also reduce the quality of life and may create health and safety threats to workers or residents in the immediate area.

If the neglect continues, the facility's ability to perform its intended functions will begin to be impaired. This can have several serious and escalating impacts. For example, if the facility is intended to provide stormwater treatment, a reduction in this treatment can result in ecological damage to downstream water bodies. If the facility has been required as part of a

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site discharge permit or land development approval, these impacts may also have serious legal consequences. If the facility is intended to prevent excess runoff from leaving the site, downstream flooding or erosion may occur. This will not only physically threaten downstream property owners but will pose serious legal and liability problems for the neglectful facility owner.

Finally, the maintenance neglect can reach such a level that dams and embankments begin to weaken and structures become unstable. At this point, the facility has become a direct threat to the health and safety of the people that live or work both at and downstream of the facility. This is particularly true if the facility impounds a significant amount of water which can suddenly be released without warning and with disastrous effects on downstream properties.

As shown above, ***many of the adverse effects of facility maintenance neglect will be felt by someone other than the facility's owner.*** This is unfortunate since, as described above, these are the people that the facility was built to protect. As such, it can be seen that any harm caused to these people or their property due to facility maintenance neglect can be the strong basis for a negligence lawsuit against the owner, particularly if it can be demonstrated that the owner willingly neglected the facility's maintenance despite the knowledge that such neglect could be harmful. Such a lawsuit may be further strengthened by the fact that the owner derives most, if not all, of the benefits provided by the facility, and not the downstream residents or owners that are threatened by the neglect or malfunction.

The exact extent of an owner's liability for damages arising from facility maintenance neglect will vary from state to state and will depend, in part, upon the exact type of facility in question. In general, however, two legal concepts may by applied, particularly if the facility impounds a body of water and is legally considered to be a dam. Under the legal concept of negligence, the degree of care exercised by the owner would be a factor in determining the owner's liability for any damages that might have occurred due to facility failure. Under the legal concept of strict liability, however, the facility owner would be held liable for any damages that occurred due to facility failure regardless of the cause of that failure. In either case, it can be easily seen that ***stormwater management facility ownership involves a significant degree of legal responsibility for regular and thorough facility maintenance and operation.***

In addition to the adverse physical and legal impacts of maintenance neglect, the neglected facility that fails to meet outflow quality or quantity requirements or safety standards may place its owner in violation of local, state, or federal discharge regulations. Such violations may subject the owner to fines, sanctions, and/or the loss of operating or occupancy permits. They will also undermine the stormwater management programs upon which the regulations are based and reduce the overall effectiveness and credibility of local, state, and federal stormwater management programs. Chronic and widespread neglect can even threaten the existence of such programs. As such, it can be seen that t***he facility owner also has a civic responsibility to conduct a regular and thorough stormwater facility maintenance program.***

Finally, neglect of a stormwater facility's maintenance can have severe economic impacts for its owner over and above any fines, legal judgements, settlements, and attorney fees. This is due to the fact that ***the cost to perform facility maintenance on a regular basis can be several times less than a one-time cost to restore a long-neglected facility to normal or required condition.*** For example, a program of grass mowing and

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sediment and debris removal performed regularly at a dry detention facility may only require a few man-hours per month using only lawnmowers, shovels, and wheelbarrows. On the other hand, if such activities where neglected for a protracted period of time, the effort to restore the facility to its normal condition can require considerably more effort, money, and equipment.

In summary, there are many legal, economic, civic, and ethical impacts that await the owner of a neglected stormwater facility. These impacts should be sufficient reason for all owners to establish and conduct a regular and thorough facility maintenance program. Details about such a program and the resources that will be required to develop one are presented below.

3. TYPES OF FACILITY OWNERS

It can be seen from the above that there are many different types of stormwater management facilities controlling the quantity and/or quality of stormwater runoff. As such, it is not surprising that there are many different types of facility owners. Since each type of owner will have somewhat different operating procedures, resources, organizational structures, and legal standing and authority, each type will have to take somewhat different steps to develop and conduct a stormwater management facility maintenance program. Therefore, it will be helpful to review the basic categories and types of facility owners.

The three basic categories of facility owners include private, public, and joint public-private ownership. Private owners include individuals, partnerships, corporations, and cooperative associations. Public owners include municipalities, counties, states, authorities, utilities, and federal agencies. Joint ownership may exist in certain instances, particularly where one party owns the facility (including the land it is located on) and the second party is responsible for its maintenance. Such arrangements are common between municipal or county governments, which are responsible for the maintenance of a facility, and residential, commercial, or industrial site owners who own the property on which the facility is located.

In the case of private ownership, it can be seen that the resources, organizational structure, and legal standing of a private individual will be considerably different from a corporation. For example, the individual can be held personally responsible for the maintenance of a facility and personally liable if damage occurs to offsite property or third parties due to maintenance neglect. A corporation may only be liable for the assets of the corporation, thereby protecting the individual shareholders. An individual owner can also be expected to be more directly involved in the actual maintenance activities, be more readily engaged in evaluating program performance, to act more quickly to remedy problems, and more flexible in addressing changes in operating procedures. However, the individual can also be expected to have fewer resources to perform facility maintenance at their disposal and less ability to raise additional capital to finance facility maintenance or repairs.

Similarly, a municipal government may be more directly involved in facility maintenance activities than its state or federal counterparts and have greater flexibility to address changes and problems. However, the municipality may once again have less overall resources at its disposal. All levels of public ownership can be expected to have less options for financing than private owners and will not be able to address changes in maintenance costs as easily or quickly. Public bidding and purchasing laws and annual budget cycles may further limit a public owner's financing and operating options.

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The overall operating experience and capabilities of the owner will also directly effect their ability to adequately perform facility maintenance. For example, a municipal or county government whose public works department regularly maintains open spaces, recreational facilities, and structures will be better prepared to develop and conduct a facility maintenance program than a homeowners association or a commercial building owner. Perhaps the owner best suited to perform facility maintenance is the stormwater utility or authority which has been established for stormwater management purposes and vested with its own financing capabilities.

Finally, studies and experience have shown that ***while all types of owners may neglect facility maintenance, the likelihood of such neglect increases with the size and complexity of the ownership organization.*** This is due, in part, to the more vague, diffuse, and even fractured designation of maintenance responsibility within the larger organization, the ability of the organization to monitor the performance of its members, and its ability to quickly respond to problems and adopt new procedures where necessary.

In summary, a successful maintenance program will require the facility's owner to have some level of organizational and management skills, legal counsel, financial resources, emergency response capabilities, maintenance equipment and personnel, and a basic understanding of facility operation and associated government regulations. In developing and then conducting a successful facility maintenance program, it is important for the owner to objectively identify and evaluate their strengths and weaknesses in these areas. This will enable the owner to realistically determine what program components they can best perform and which ones will be better performed by contractors or consultants. It will also help potential owners to evaluate the implications of facility ownership prior to assuming ownership responsibilities, so that appropriate prior arrangements can be made or ownership can either be shared with another party or avoided entirely.

4. MAINTENANCE PROGRAM DEVELOPMENT

While the details of a maintenance program for a specific stormwater management facility will be somewhat unique, there are general steps that most if not all facility owners can follow. Details of each are presented below. In many instances, additional information regarding specific aspects of each step can be found in other sections of this manual. When this is so, the specific section will be noted.

4.1. Designate a Responsible Individual

As noted above, the potential for facility maintenance neglect typically increases with the size and complexity of the organization that is responsible for the maintenance. Therefore, ***a key step in developing a successful facility maintenance program is to designate a key individual within that organization to be personally responsible for the program's overall performance.*** It is not necessary for this person to actually participate in the various maintenance tasks, although a working knowledge of these tasks based upon personal experience is certainly preferable. The responsible individual must, however, have some direct role in managing and supervising the maintenance activities. The selection of this individual should be based upon several factors. Since the individual owner is the simplest ownership organization possible, the choice of who that individual should be is obvious. However, as the size of the ownership organization increases, the choice may not be so obvious and each of the selection factors warrants careful consideration and evaluation by the owner.

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The choice of responsible individual should be a function of the person's experience, expertise, and position of responsibility within the organization. Typically, this position should be low enough to allow the person to have a significant degree of direct, personal involvement with the overall maintenance program, particularly its personnel and the various tasks they perform and equipment they use. However, the position must be high enough within the organization that the responsible individual has the authority to effectively manage the program and can command the attention of people higher up when necessary, particularly in regard to program funding.

Since the responsible individual will, indeed, be held personally responsible within the ownership organization for facility maintenance, they must be granted sufficient authority over personnel, procedures, and expenditures to achieve the success they're held accountable for. Optimally, this includes the authority to identify tasks, establish relevant policies and procedures, hire, fire, and assign personnel, delegate authority, and establish priorities.

The responsible individual should also have a basic understanding of stormwater management facility function, operation, and construction as well as an understanding and appreciation for the physical, social, regulatory, and legal implications of facility ownership and maintenance. This understanding should also extend to knowing when outside technical, physical, or legal assistance is needed to fill a gap in organization's in-house expertise or ability.

Finally, since the responsible individual will often be acting as a liaison between such diverse groups as maintenance personnel, upper management, residents, customers, government regulators, and contractors, good communication skills will also prove highly valuable.

4.2. Plan for Maintenance

A successful facility maintenance program does not happen by chance. Instead, a responsible facility owner will plan and budget for maintenance, not merely perform it. Such planning should obviously be performed as far in advance as possible of actually beginning the maintenance work, a recommendation that should not be lost on those potential or pending facility owners who are looking to develop or purchase a site with a stormwater management facility. Such planning should include several program aspects:

1. **Identify Facility Characteristics and Maintenance Needs** - As detailed above, each type of stormwater management facility has some physical, functional, and operating characteristics that are unique and, as such, each will have certain distinct maintenance needs. For example, a wet detention basin or pond intended to provide both runoff quantity and quality control will have largely different maintenance needs than a subsurface sand filter intended to provide only runoff quality control. The basic understanding of stormwater management facilities advocated earlier in this chapter will serve an owner well at this stage of the maintenance planning process.

   This ***identification process can begin with a list of all types of onsite facilities that the owner will be responsible for maintaining.*** Based upon each type, the basic operating characteristics and maintenance needs can then be determined. If possible, particularly for new facilities, the owner should consult with both the facility's designer and constructor to help identify these characteristics and needs. For new facilities, the owner should make sure that the designer will include

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maintenance as one of their primary design considerations. Further information regarding the design aspects of facility maintenance can be found in **Chapters 2 and 3** of this Handbook.

2. **Identify Regulatory and Legal Requirements** - In many instances, the stormwater management facility will have been designed and constructed to meet regulatory constraints placed upon the development and/or use of the property. These regulations may have been in the form of an approving resolution from a local or county planning board or an actual facility operating permit issued by a regional, state, or federal agency. In many jurisdictions, the owner will have been required to sign a maintenance agreement with the approving authority guaranteeing adequate facility maintenance and granting that authority certain inspection rights. ***In order to be both thorough and efficient, the maintenance planning process should identify all relevant requirements in such approvals, agreements, and permits, which should then be evaluated for their impacts on facility maintenance.*** Further information regarding the regulatory and administrative aspects of facility maintenance can be found in **Chapter 4**. While written primarily for regulators and administrators, this chapter can provide owners with valuable insight into this important aspect of facility maintenance.

   In addition to regulatory requirements, the owner should also review the legal implications of facility ownership, particularly in regard to facility maintenance and the legal impacts of its neglect. This should include both the legal impacts of violating agreements, permits, and other regulatory controls as well any physical harm caused to onsite workers, residents, customers, tenants, and/or downstream individuals and entities. In many instances, such a review not only helps to define the tasks and resources necessary for the maintenance program but also serves as a strong incentive for conducting it successfully.

3. **Define Maintenance Tasks, Personnel, and Equipment** - Once the physical, operational, and legal needs are determined, the actual maintenance tasks and their associated personnel and equipment needs can be defined. Such tasks may range from simple grass mowing and periodic debris removal, to sediment testing and removal, to aquatic plant habitat and wildlife management. Details of the various maintenance tasks required at different types of stormwater facilities can be found in **Chapter 7**.

   In addition to direct maintenance tasks, the need for periodic inspections of the facility should be included in the planning process. Since the exact success or frequency of an individual maintenance task cannot be determined prior to its execution, it will be necessary to inspect the facility periodically to assess whether the selected procedures and their frequency are adequate. Even when they are, facility operating conditions can still vary considerably over a time period and the maintenance program will be constantly subjected to dynamic forces. As a result, the inspection program must continue throughout the facility's life if the program is to remain both effective and efficient. Details of a comprehensive maintenance inspection program are also presented in **Chapter 7**.

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4. **Establish Schedules** - Since successful facility maintenance is an ongoing process, schedules must also be established. These include such obvious items as the frequency of the various maintenance tasks identified in Step 3 above. Since conditions at the facility may vary greatly over the year, the need to periodically change the type and frequency of maintenance tasks should not be overlooked. Facility inspection schedules must also be established. In addition, all regulatory reporting schedules required as part of an operating permit or other approval condition must also be determined. Some facilities may also require a formal inspection by a licensed engineer or other professional on an annual or biannual basis.

   Finally, funding availability will normally be affected by budgetary cycles or accounting periods. As such, it will be necessary to ***determine how frequently different expenditures will be required so that they can be scheduled and coordinated with their associated funding process or mechanism***. Such expenditures may range from daily or weekly expenses for fuel and material to monthly invoices from outside contractors to annual equipment upgrades. Provisions should also be made for funding emergency repairs and for such typically infrequent and/or irregular tasks as pond desilting. In addition, the frequency of any regulatory costs such as inspection fees or permit renewal fees should also determined.

5. **Establish Record Keeping Procedures** - Due to the nature of stormwater management facilities in general and the specific tasks necessary for their maintenance, ***a record of past maintenance efforts and the results of past inspections can greatly assist the continued effectiveness of the maintenance program***. For example, such records can be used to identify chronic maintenance problems that can be addressed more effectively through a new piece of equipment or change in procedure. They will also be extremely useful at budget preparation time when past costs need to be justified and new ones need to estimated and funded. Finally, comprehensive maintenance and inspection records may prove invaluable if the owner and/or the maintenance program is challenged legally by a plaintiff or regulatory agency.

4.3. Identify Costs and Allocate Resources

Prior to this step, which may be considered the most important step of any facility maintenance program, the necessary maintenance tasks and their associated equipment, personnel, and frequency should have been determined along with the facility's regulatory and legal obligations. Based upon this information, the costs of these various items and the overall cost of the maintenance program should be estimated. Once determined, the source(s) of the necessary funding must be identified and secured.

The importance of identifying costs and funding sources in a facility maintenance program cannot be overestimated. In most instances, experience has shown that the maintenance of a stormwater management facility does not, in general, require extraordinary levels of effort or expertise on the part of the maintenance personnel, nor specialized or exceptionally sophisticated equipment to assist them. As such, these are usually not the predominant factors associated with the

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failure or ineffectiveness of a facility maintenance program. Instead, such results are more likely to be simply a lack of adequate program funding, which can occur due to a lack of prior planning by the owner. ***In summary, adequate and stable funding is, in most instances, the most important key to maintenance program success.***

4.4. Create a Written Plan

Once the maintenance program and its funding have been developed, it is important that it be formalized in a written document. The exact format or level of sophistication of the document are not as important as the actual existence of the document in written form. In written form, it will be much easier to 1) understand and appreciate the overall scope of the program and all its facets, which can be particularly helpful for funding, budgeting, and regulatory purposes; 2) establish a coordinated and effective implementation plan of all those facets; 3) establish performance goals that people, especially the designated responsible individual, will be held accountable for; 4) conduct periodic program reviews (see Section 4.5 below); 5) describe and justify the scope and intent of the program in case of legal challenge.

The written plan should include:

1. The name of the current responsible individual.
2. The names and/or positions of the various maintenance staff members and, if helpful, an organization chart.
3. A list of all facilities maintained by the program along with their location, type, and other pertinent details.
4. A list and description of each of the identified maintenance and inspection tasks.
5. Lists of all required and available equipment and material.
6. All regular inspection and maintenance schedules.
7. Copies of the pertinent sections of all regulations, permits, approvals, and agreements.
8. Copies of maintenance and inspection logs.
9. An "as constructed" plan of the facility.

The written plan should also include or reference other pertinent facility information such as design computations, construction and as-built plans, emergency action plans (where required or developed). A list of off-hour telephone or pager numbers of key maintenance personnel should also be included in case of emergencies. See **Chapter 7 - Inspection and Maintenance after Construction Completion** for more information.

There should be at least two identical copies of the maintenance plan. The owner of the facility must have one of the plans while the agency responsible for stormwater program implementation or maintenance inspections should have the other. If a third entity assumes maintenance responsibility on behalf of the owner, that entity must also have a copy.

The maintenance plans should be located where they can be referred to as the need arises. The public agency should have a permanent file system where all maintenance plans reside and are available for public review. The owner's plan should be placed with other important property information, and reviewed at least on an annual basis to ensure that the plan is in good condition and accurately reflects ongoing efforts.

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4.5. Conduct Periodic Program Reviews

As noted above, both a stormwater management facility, and the program established to maintain it, will be subjected to constantly changing forces and factors. With the facility, these will include variable climatic and rainfall conditions, development and maturation of vegetation, wear and impacts on structures and linings, and even vandalism. With the program, these will include changes in personnel, cost increases due to inflation, new or revised regulatory programs and permit conditions, new equipment, material, or maintenance techniques, or internal management or ownership changes. As such, ***a successful facility maintenance program must include a regular process of review and evaluation.***

Such reviews can begin with the effectiveness and efficiency of the various maintenance tasks, including an evaluation of personnel expertise and experience and equipment performance. The program's ability to meet maintenance and reporting schedules should also be reviewed. Costs should also be tracked and evaluated to determine if rising trends can be reversed or cost savings can be realized. In this instance, such a review may best be held prior to the start of the organization's budgetary cycle.

A comprehensive program review will revisit past problems to determine what their cause was and how they might be prevented or corrected more effectively and/or efficiently. This may include an assessment of how the facility's design and/or construction may be causing the problem and how changes to these procedures may eliminate similar problems at future facilities.

In conducting the program review, it may also be productive to evaluate whether an internal maintenance program may be more effectively or efficiently performed by outside contractors. Conversely, services presently provided by such contractors should be compared with those that could be provided by in-house personnel and/or equipment. Finally, the legal environment and regulatory conditions under which the program must function should be periodically reviewed to identify necessary or helpful changes to reduce legal exposure or to comply with new regulations, laws, or permit conditions.

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Chapter 6
Construction Inspection

1. OVERVIEW

Plan design and review, construction inspection, maintenance inspections, and owner/operator understanding of obligations are essential components of successful implementation and long term performance of stormwater facilities. A breakdown in any of these areas will cause premature failure of the BMP. The best design plan has no value if the facility is not constructed according to the design. ***Construction inspection determines, to a very large extent, the frequency that subsequent maintenance is needed on a given facility.*** The use of poor quality materials for construction, and poor construction in general, can negate all of the time and effort expended during the design phase.

Stormwater facilities are constructed by individuals having a wide range of experience in their construction. Individuals with little experience constructing BMPs need assistance in knowing what to look for and what components are essential for quality control of construction. Even individuals having significant experience in BMP construction often need assistance due to changes in site conditions upon which the design was based, or where a modification to the design would improve facility construction and maintenance. The most important individual in these situations is the construction inspector.

The construction inspector interacts with the site contractor and the plan approval agency. The inspector is vital in assuring proper construction and links the overall process from design through construction. The contractor is independently retained by the site developer and generally has no input into the actual design of the stormwater facility. He is hired for construction and must review the approved plans and specifications and determine the best construction method to fit the site and approved plans. It is not his role to question design assumptions or recognize that an approved plan will not necessarily result in the best approach to site management from a stormwater management standpoint. ***The construction inspector, through his interaction with the plan approval agency and experience in stormwater management, assumes that role.***

Problems associated with poor stormwater BMP construction range from minor to major. Minor problems can include partial clogging of infiltration practices, premature maintenance needs related to sediment removal, replacement of a system component such as riprap, mosquito breeding, slope erosion, or standing water in a facility not designed to have it. Major problems could necessitate replacement of the entire facility, structural repairs, or safety concerns. ***It is easier and more cost effective to build a stormwater facility right the first time than to have to remobilize construction equipment to repair the facility on a premature basis.*** In addition, the quality of reconstruction often means that the level of expectations must be reduced from the initial design assumptions. For example, an infiltration basin, prematurely clogged with fine sediments, will probably never achieve design infiltration rates due to the presence of an increased level of fine particles in the bottom and sides, even with excavation of the finer sediments. Proper construction of stormwater facilities will have a significant beneficial impact on future maintenance costs.

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Construction inspection can be broken down into several components which together provide for effective implementation of stormwater facilities. The inspection components include:

- a clearly defined legal authority,
- preconstruction activities,
- inspection during construction,
- construction site inspection procedures, and
- short term post-construction inspection responsibility to determine stormwater facility bond release approval.

Quality of construction affects more than the long term stormwater management system performance. Facility construction can also have a direct impact on receiving systems, especially when problems are encountered during their construction. Proper inspection is needed to reduce downstream impacts of the construction process itself. The last section of this chapter is devoted to discussing ways to reduce pollutant discharge, primarily of sediments, impacts on receiving systems.

It should be recognized that the discussion provided in this chapter and elsewhere is devoted to general activities which are associated with urban runoff control. Where a specialized activity exists, such as control of industrial runoff, then individual consideration of the types and quantities of pollutants expected and their potential adverse impacts on the stormwater BMP must be done.

1.1. Intended Readers

In attempting to achieve a "minimum maintenance" stormwater system, construction inspection is often one aspect of a project that does not receive the attention it deserves from owners, project managers, and government officials. With that thought and the objectives discussed above in mind, those who will benefit most from this Chapter include:

- **Project and Construction Managers**, who should view construction inspection as a vital quality control measure that is in the best interests of all those concerned with the creation of a stormwater management system.

- **Construction Inspectors**, who should clearly understand their project responsibilities and the specific tasks that are critical to achieving the intended design.

- **Contractors**, who should realize that proper construction inspection will help avoid construction problems and delays and assure both quality workmanship and rapid completion.

- **Code officials**, who should fully understand the important role they must play in achieving a high quality, minimum maintenance stormwater facility.

Additionally, several other readers can benefit from this Chapter including:

- **Planners, Designers, and Project Reviewers**, who should be aware of the value of proper construction inspection while preparing or reviewing construction plans, specifications, and other contract documents.

- **Project Managers**, whose responsibilities include providing assurance that the project will be constructed to the best possible standards.

- **Stormwater System Owners**, who should realize that it is in their long term interest to create the highest quality facility and thereby avoid unnecessarily high OMM costs in the future.

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2. STORMWATER SYSTEM CONSTRUCTION IMPACTS AND MITIGATION

The impacts associated with construction of stormwater management systems are very similar to those occurring from general site construction activities. A major difference is that erosion and subsequent sedimentation from general construction may not result in all sediment leaving a site. Sediment may travel for a distance down a slope and then deposit itself in an area that promotes sedimentation of the suspended particles. Construction of stormwater management systems, especially ponds, generally occur in low areas of a construction site. Wet ponds often are located in a ravine or incised area adjacent to a perennial stream where the delivery of sediments is unbuffered by downstream areas of deposition. In addition, stormwater management system construction occurs where concentrated flow of runoff from upstream drainage areas accelerates the uplift and transport process of soils and sediments generated by the dam construction.

The proximity of the stormwater system construction to major stream systems and defined floodplains typically results in delivery of the sediments into environmentally sensitive areas. Also, high stream flow may inundate the facility construction area causing scour and excessive sedimentation. It is important for an inspector to realize the sensitive nature of construction impacts of stormwater facilities. They are placed on sites to reduce environmental impacts, but their construction may have a significant impact if good site control is not provided. ***During an inspection, the inspector must carefully consider the potential impact of stormwater system construction on downstream sensitive areas.***

The impacts of sedimentation off-site and downstream can be classified into two categories of impacts: Economic and Environmental.

2.1. Economic Impacts of Sedimentation During Stormwater Management Pond Construction

The displacement and transport of sediments into stream systems will create negative impacts from several perspectives. The most traditional and clearly understood economic impacts are those resulting from sedimentation to navigable waters, especially in estuaries, and to increases in the risk of flooding. Because of sedimentation, dredging of channels and boat docking areas is needed more frequently, thereby increasing the cost of maintenance dredging and sediment disposal.

Flooding and out-of-channel storm flow may increase due to sediment deposition within channels and floodplain areas. Maintenance is a significant responsibility where flood control channels have been constructed previously. In these situations, flood protection is provided through channel storage and conveyance. Sedimentation of the channel reduces its' cross-sectional area, and its ability to provide the desired level of flood protection. Another flood related impact occurs when nontidal wetlands are smothered. The wetlands vegetation, due to its dense growth, serves as a buffer during runoff events, providing flood storage and retarding flood flows. This reduces velocities of stormflow and helps provide additional flood protection to downstream areas.

Economic impacts are incurred in association with impaired function of culverts and pipes downstream from construction activities. These conveyance systems rely on the cross-sectional area of the pipe or culvert to convey the design storm flow. Sedimentation of culverts or pipes reduces their storm flow conveyance capacity. This may lead to increased road flooding, increased flooding on properties upstream of the road crossing, or increased risk of flooding downstream if the road embankment fails due to water pressure or scour.

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Another economic impact of sedimentation is related to the loss of biological resource productivity. Shellfish beds and fish eggs are smothered by sediment. Also, fish can't see food which also affects the resource. A significant commercial or sporting industry can be and has been reduced by sedimentation.

2.2. Environmental Impacts of Pollutant Discharge During Construction

In addition to strict economic impacts, stormwater system construction can cause environmental impacts. From a water quality perspective, there are a many pollutants that may be generated at a stormwater system construction site. The first and most obvious pollutant is sediment. Many other types of pollutants adhere to sediment and get transported downstream. Toxic metals are inert by nature, and many bind strongly to sediments. Control of sediment will, to some degree, control the migration of other pollutants.

Other types of construction generated pollutants are present on stormwater management facility construction sites. These pollutants are associated with motor vehicle equipment operation and commonly include the constituents listed in Table 6-1. They accumulate on construction sites and can migrate downstream causing impacts to aquatic resources. These other pollutants include organics and inorganics, nutrients, construction debris, pesticides and herbicides, and bacteria.

The health of a stream ecosystem depends largely on its benthic community. Sediment smothers aquatic organisms, upon which larger species feed. Thus, the loss of the benthic organisms reduces the stream's capability to sustain larger organisms. Experience has shown that the single largest, long term impact on a stream ecosystem results from excessive downstream sedimentation during site development. It may take years for a partial recovery of the stream system to occur.

TABLE 6-1. POLLUTANTS GENERATED BY CONSTRUCTION MOTOR VEHICLES

Pollutant	Automotive Source
Asbestos	clutch plates, brake linings
Copper	thrust bearings, bushing, and brake lining
Chromium	metal plating, rocker arms, crankshafts, rings, brake linings
Lead	leaded gasoline, motor oil, transmission babbitt metal bearings
Nickel	brake linings
Phosphorus	motor oil additive
Zinc	motor oil and tires
Grease and hydrocarbons	spills and leaks of oil and lubricants, antifreeze and hydraulic fluids
Rubber	tire wear

Beside the environmental impacts to stream ecosystems, other environmental impacts are associated with wetland loss and degradation. Wetlands provide significant water storage and pollution removal. Filling wetlands, as a result of construction sedimentation, reduces their ability to store floodwaters and remove pollutants. Wetlands also provide habitat for wildlife. As wetlands are filled by sediments, its habitat is destroyed and its wildlife value is reduced.

It is also important to note that there are other secondary, but lesser understood, impacts associated with toxics carried by stormwater. These potentially can disrupt the food chain. Uptake of toxic substances by micro- and macro-organisms can lead to bioaccumulation and biomagnification as the toxic substances are ingested by higher organisms in the food

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chain. Little is known about the actual processes and levels of impact associated with stormwater toxics, although shellfish beds have been closed to harvesting. Additional work is needed in this area to more accurately determine their impacts.

3. LEGAL AUTHORITY FOR INSPECTIONS

Stormwater management construction inspectors must have adequate legal authority, from state or local laws or regulations, to inspect and enforce the program's construction requirements. Outlined below is an example of legal authority for construction inspections adapted from the Prince George's (MD) Department of Environmental Resources Stormwater Management Design Manual:

1. Inspectors must conduct inspections and file reports for periodic inspections, as necessary, during construction of stormwater facilities to assure compliance with the approved plans.

2. Inspectors are authorized to furnish the permittee or agent the results of the inspection in a timely manner after the completion of each required inspection.

3. Inspectors are authorized to issue a Correction Order to the permittee or agent when any portion of the work does not comply with the approved plans.

4. Inspectors are authorized to issue a Notice of Violation in accordance with guidelines as a result of unsatisfactory work or progress.

5. They are authorized to issue Stop Work Orders as the result of unsafe conditions, working without a permit, unsatisfactory work, progress, or other noncompliance.

6. Inspectors are authorized to issue a Civil Citation as a result of unsafe conditions, noncompliance with a Stop Work Order, unsatisfactory work, progress or other noncompliance.

7. Inspectors are authorized to perform a final inspection upon the completion of the stormwater facility to determine if the completed work is constructed in accordance with the approved stormwater design plan, approved "as-built" plan and certified by the permittee's registered professional engineer.

8. Inspectors are authorized to inspect the stormwater facility at a specified post-construction time to determine release of the maintenance performance bond.

The authority to accomplish these functions should be provided in law, ordinance, or resolution. This provides the inspection program with the necessary "teeth" to ensure that stormwater systems are constructed in accordance with the approved plan. A variety of enforcement options should be available, as one option may be more effective than another in a particular situation. It is also important that the enforcement aspect of program implementation be progressive. The intent should be that minor enforcement actions are generally attempted first, with more serious action being reserved for those situations where there is a knowing and willful violation. There must be an ability and willingness to take aggressive action when it is required.

Having the legal authority to take enforcement actions does not necessarily mean that they will be taken. Too many programs have excellent legal authority for enforcement actions, but staff are seldom allowed to take actions necessary to improve site implementation of stormwater controls. This is especially a problem when inspections necessitate additional expenditures to correct problem areas, or where necessary site controls have not been constructed. This

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especially is a problem for erosion and sediment control practices, but is also a serious concern for the construction of permanent stormwater facilities.

The stormwater program must make a commitment to allow its staff to conduct site inspections and take necessary enforcement action when it is needed. This is not to suggest that enforcement action can be taken whenever desired - only that it is available as an option to assure compliance. Senior agency staff must be briefed when a particularly aggressive action is intended, but day-to-day enforcement actions must be endorsed by the appropriate jurisdiction to ensure continuity of program implementation and to ensure that stormwater facilities are given the best opportunity to perform to design standards for the longest possible time.

4. PRECONSTRUCTION ACTIVITIES

An approved stormwater management permit may be transferred to the responsible inspection agency for construction inspection. The inspector has two primary functions at this stage of project implementation - review of the approved plan, and a preconstruction site meeting.

4.1. Review of Approved Stormwater Management System Plan

The construction inspector should review the approved stormwater management plan to become familiar with the requirements placed upon the land developer. This review should include the following items:

A. The overall site development proposal and site conditions,

B. Location of the stormwater management facility, erosion and sediment control plan, and site grading plan,

C. Location of storm drain system,

D. Dimensions, as specified, are shown on approved plans,

E. Potential problem areas with construction that may require special attention,

F. Any special approval conditions,

G. Specifications for construction materials,

H. Shop drawings, where needed,

I. Sequence of construction (may be a requirement of plan approval or submitted by contractor prior to work initiation), and

J. Any easements or site areas having restrictions placed upon them such as wellhead protection areas or natural wetlands.

It is important that the inspector completely understand all aspects of the approved stormwater control plan, especially its structural practices and their components. If there are any questions, the inspector should contact the plan review and approval agency and receive answers to any concerns or questions. If the construction inspector is unsure of any aspect of the construction, it can almost be a certainty that the contractor will also have misunderstandings. Communication between the plan review agency and construction inspector is essential so that each can understand the perspective of the other.

One helpful approach is to have the plan review individual highlight on the plans erosion and sediment control and stormwater management BMPs or make special notes to emphasize these items to the inspector. If this cannot be done, the inspector should highlight them.

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This helps to assure they have a high visibility during future inspections. It also highlights them from other special notes that tend to be on construction drawings.

Shop drawings should be submitted for all stormwater management system components. Shop drawings should include methods of construction, as well as detailed specifications of the materials. Problems can be avoided if potential areas of ambiguity are resolved before facility construction. A situation which should be avoided is an on-site confrontation between the inspector and contractor over some material specification that was not considered before construction. Having shop drawings available for the preconstruction meeting helps reduce potential areas of disagreement. Often a contractor's bid to do work is based on the cost of materials that the contractor commonly uses. Changes to these commonly used materials may increase project costs and cause problems between the land developer and the contractor. ***By resolving potential conflict areas before construction, the quality of construction can be enhanced and potential conflicts reduced.***

4.2. Preconstruction Site Meeting

It is important to meet with the owner, contractor, project engineer, and any other site related inspectors to establish a dialogue and line of communication. Other individuals having roles in the stormwater facility construction also should be included, especially subcontractors and utility companies. Preconstruction meetings also let the owner and contractor know what aspects of the stormwater system construction are in need of the most attention. This meeting also establishes the inspection agency's importance and priority on proper construction. Items which should be discussed at the preconstruction meeting include:

A. Telephone numbers (during and after work) of the different individuals in the event of the need to communicate.

B. Recognition that the approved plans must be on site whenever there is construction.

C. The project's overall purpose and objective.

D. Specific areas where stormwater facility details need to be emphasized or which require special attention.

E. Construction sequences, schedules, and timetables.

F. A chain of command in the event that field modification or changes needs to be made.

A detailed list of recommended preconstruction meeting topics is summarized in Appendix 6-1 at the end of this chapter.

5. INSPECTION RESPONSIBILITIES DURING CONSTRUCTION

There are a number of specific responsibilities the inspector must assume during construction. These can be broken down into two areas: routine inspection responsibilities and activity-specific inspections.

5.1. Routine Inspection Responsibilities

Routine inspections are important to gauge the progress of site development and to assess the quality of construction. ***These inspections help ensure that the developer/contractor is aware of the inspector's periodic presence onsite. Routine inspections also demonstrate the importance the implementing jurisdiction places on the adequacy of stormwater system construction.***

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As stated in Chapter 4, it is important that the land developer/contractor closely coordinate and communicate with the inspection agency. This is especially true when scheduling inspections. Generally, at least 24 hours notice is needed. Inspections and inspector approval of work must be completed at the critical stages of stormwater management system construction. The actual notification of the inspection agency by the land developer at critical times may not always occur, and routine inspections are one way to assess timetables. They also provide an opportunity for the inspector to remind the contractor of the need for inspections at specific times during construction of the stormwater management system. Regardless, ***it is important for the contractor/developer to recognize the need to contact the inspector when certain stages of construction are reached.*** This is already recognized in other aspects of construction, such as electrical or plumbing inspections. The stormwater inspection agency needs to stress to the contractor the importance of scheduling inspections at important stages of construction. The agency must also convince the land developer/contractor that the inspections are in their best interest.

When routine inspections are accomplished, their results must be documented, preferably with standardized inspection forms. Examples of a Routine Inspection Form and a Notice to Comply Inspection Form are provided in Appendix 6-2. ***Inspection forms provide a consistent record of site inspections and establish a framework for inspection and enforcement activity.*** The results should then be provided to the contractor, transmitted to the developer, and also placed in the project's inspection file. This documentation of the inspection results provides feedback to the contractor and developer on the adequacy of erosion and sediment control BMPs and overall facility implementation at various stages of construction. ***Too often, inspectors visit a site, do not notify any site personnel, and leave no record of their inspection. This approach may reduce confrontation, but provides limited benefit to any individual other than the inspector.***

The inspection form details site conditions to the contractor/developer and provides a barometer of any site inadequacies which may need to be addressed. In addition, if site construction is proceeding according to the approved plan, it also notifies the contractor/developer that they are doing a good job. ***Positive feedback is as important as criticism. There are many times when the contractor/developer goes beyond the letter of the law and is extremely conscientious in their efforts. These efforts should be recognized in the inspection report.***

A program may want to use several different inspection forms. The first inspection report should be used to assess general site conditions while the second form would be used to require site correction or compliance according to an administrative order. The routine inspection form can be used when the site is generally in compliance or where minor corrections need to be made to achieve compliance. The Notice to Comply or Correction Notice establishes necessary site improvement conditions and time frames. The Notice to Comply establishes a formal paper trail of progressive enforcement. The goal is to improve site conditions and achieve compliance with approved plans.

5.2. Progress Meetings

In addition to periodic routine inspections, regular progress meetings should be held to discuss construction timetables, problems, needed changes to the approved plans, and ensure coordination between the land developer, contractor, and inspector. This inspection is primarily a meeting between the various parties

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as opposed to a site inspection to assess progress of the stormwater management system construction. The stormwater management approval engineer should attend these meetings to provide insight into the appearance, essential components, and any other aspect of the facility design which needs to be emphasized.

Extra work and needed change orders are the primary items discussed at these progress meetings. These changes will occur on all construction activities, as detailed design review and approval cannot anticipate all possible site conditions that may be encountered during construction. The inspector and, where appropriate, the design review engineer should carefully evaluate each extra work charge and change order to ensure its legitimacy. Recommendations on their acceptance must be timely. Unnecessary delays in resolving problems can result in poor relationships, poor construction quality, and unnecessary extra construction costs. Costs for the design and implementation of stormwater management systems is a great concern to everyone. Realistic costs have to be defended and expected, but unnecessary costs must be avoided. Many excessive costs can be avoided if there is effective communication during construction of stormwater management systems.

The progress meeting provides a number of benefits other than assuring proper construction. By having periodic interaction between all of the parties involved, all individuals gain a greater understanding of why these facilities are necessary, how construction needs to be accomplished, and a greater appreciation regarding the relationship between design and construction. This is very true of the plan approval engineer. Too often, these individuals become overwhelmed with the plan review function, and do not get the necessary experience in actual construction of stormwater management systems. Familiarity with construction could have a significant impact on their plan review and approval activities. The progress meetings also ensure that the developer and contractor are constantly aware of their obligations and are giving them frequent consideration.

5.3. Final Inspection

A final inspection should be required prior to the contractor being allowed to demobilize equipment from a site. This inspection should be linked with granting occupancy permits or other required final approvals. As recommended in Chapter 4, the stormwater management system bond should not be released at this time. The bond should extend for a specific time frame (warranty period typically one year) to ensure short term performance of the facility.

Any incomplete items associated with the stormwater management facility should be detailed in this inspection and provided as a specific "punch" list to the contractor and developer. A time frame for correction of the listed items should be decided upon so that a reinspection can be scheduled at the appropriate time.

This inspection is critical to the long term performance of the stormwater management system. ***Final approval of a site should not be given until all deficient items have been corrected.*** When the site receives final approval, the public and eventual site users or owners have an expectation of construction adequacy. It is important that every possible step has been taken to reduce their future expenditures for operation, maintenance, and management of the stormwater facility.

6. INSPECTION PROCEDURES

Consistent, meaningful inspection procedures are essential to effective site implementation and success of the stormwater management program.

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6.1. Have Necessary Inspection Equipment

Equipment, which should be included in an inspector's inventory, includes the following:

- A Locke level or other surveying equipment
- Local erosion and sediment control or stormwater management handbooks.
- Rain and foul weather gear.
- Copies of necessary inspection reports and forms.
- Business cards or other means of identification.
- A camera to document field conditions in the case enforcement action becomes necessary.

Other equipment may be desirable, but is not considered essential, such as a vehicle telephone that allows an office supervisor to be contacted for guidance on what to do in a given situation.

6.2. Check In At The Construction Trailer

Too often, inspectors visit a site and do not stop in at the trailer prior to conducting their inspection. Many times, a contractor will want to conduct a site inspection with the inspector. This joint inspection can provide an opportunity for the inspector to provide some educational tips to the contractor which may preclude future problems. In addition, the contractor doesn't want unauthorized people walking around the site. Recognition by the contractor that the inspector is on site will allow he or she to continue with their activities and not stop what is being done to inquire why the inspector is on the site.

6.3. Always Complete An Inspection Form and Give to the Contractor/Developer

Documentation of site conditions, both good and bad, provides a feedback loop to the contractor and developer about their efforts at construction of erosion and sediment controls and stormwater management facilities. ***An inspection report does not have to only discuss problem areas of the site. They should also be used for acknowledging good efforts, where the developer can recognize contractor activities.*** Good inspection reports can provide the contractor with positive feedback, and prove a valuable record for future inspections. If a new or different inspector visits the construction site and provides a different emphasis or evaluation, the previous positive inspection report can demonstrate the intent to comply with permit requirements.

Inspection forms also provide the basis for any necessary enforcement action. By documenting problems and corrective measures, the inspector provides the "paper trail" for legal action, should it become necessary. The forms can provide site documentation to supervisory individuals and they also provide a measure of the inspectors' work load.

6.4. Generally Speaking - Always Walk the Site in a Consistent Manner

The stormwater program should establish a specific protocol by which inspections are done. For example, always start at the site entrance and proceed in clockwise manner around the site. This allows the contractor, another inspector, or any other individual to easily follow the notation used in an inspection report. This is especially important on larger sites, where there are numerous environmental controls. Being able to follow previous inspection comments can reduce the time needed to conduct inspections, especially follow ups on a previous inspector's comments and concerns.

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6.5. Wear Safety Equipment, such as Safety Glasses, Hard Hat, and Steel Toed Shoes

All individuals at a construction site must meet minimum safety standards. The contractor is often reluctant to correct an inspector on necessary safety equipment, but is still liable for ensuring that all site personnel wear the necessary equipment. ***Wearing safety equipment, proactively, can reduce the number of adversarial issues and demonstrate the inspectors' respect for contractor obligations and site standards.***

7. INSPECTOR ATTITUDES AND TRAINING

Inspectors are often placed in a difficult confrontational position with a developer, contractor, and possibly even with their own supervisory or plan review staff. The type of individual best suited for this job would benefit by having the following attitudes. Each of these attitudes and training is important individually, but all are necessary if the individual is going to be successful in their role as an inspector.

- **Confidence**

  Inspectors are frequently confronted with reasons why a facility cannot be constructed according to the plan or why erosion and sediment control strategies cannot be implemented according to the approved plan. The inspector must have the confidence to deal with these situations and be sure of the necessary responses to each situation. At times, the correct response is to discuss the specific issue with a supervisor or the appropriate plan approval individual.

  Regardless, inspectors must feel comfortable with their experience and knowledge of the construction industry to recognize the validity of a specific issue or problem. There will be times when an inspector must insist on site modification or compliance, even if it results in a confrontational situation. The inspector cannot be the contractor's best friend. There will be situations where a hard line must be taken. Inspectors must have confidence in their actions.

- **Interest in the function**

  In too many situations, the erosion and sediment control and stormwater management inspector has been given the function for a reason other than the individual's interest in erosion and sediment control and stormwater management. In these situations, expectations for adequate construction and maintenance must be lowered. The inspector must recognize their importance to the program's overall goals and success.

  Being a regulatory program inspector requires more than experience in construction. The position is difficult when adversarial roles are established or when hearings, court cases, or meetings are held where the inspector's actions are held under a microscope. The inspector must accept these varying responsibilities and want to do the job.

- **Experience with construction**

  Inspectors must recognize the real world impact of their requirements on site. There should be an awareness of the capabilities of various types of construction equipment, and of which equipment may be inappropriate for a given function. There is a cost associated with equipment and the inspector must recognize these costs when establishing site needs and time frames.

  It is important for the contractor to recognize that the inspector does have an understanding of site work and time frames. In

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the same regard, knowledge of construction will allow the inspector to recognize when a contractor is giving an excuse for noncompliance rather than expressing a real problem. ***Contractors quickly recognize how much latitude they can get from an inspector. Their recognition of an inspector's awareness of proper construction practices will have a positive impact on site implementation of needed controls.***

Training needs

The inspector is expected to deal individually with a wide range of people in the construction industry. Often the inspector is the only individual in a group on-site that represents the program's viewpoints. That individual must be trained and given the background to enable effective communication and actions to be taken. In Maryland, it was once estimated that approximately 18 months were necessary to adequately train an inspector. The first several months were spent instructing the individual about the program's goals, and it's commonly used individual practices, strategies, and facilities.

Then the training would include traveling around with experienced inspectors to learn how to conduct site inspections, what to look for on the plans and sites, and how to interact with construction-related personnel. Interaction with construction-related personnel is extremely important, since these interactions determine whether relationships are positive or negative. ***Inspectors must learn how to control their personal emotions and act in a professional manner on construction sites or the overall program may be adversely affected.***

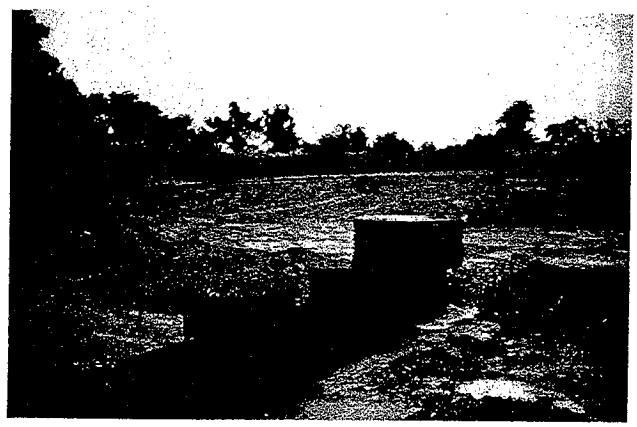
Communication

An inspector must interact with site personnel on a daily basis. Having an inspector who is a poor communicator results in misinformation or a lack of understanding by the contractor or developer on specific site concerns. Communication is an essential inspector function. The more effective the ability to communicate, the more potential exists for good site implementation of erosion and sediment control and stormwater management controls.

Commitment

Commitment means accepting limited resources, having too large a work load, periodically disagreeing with developers and contractors, and accepting that what they are doing is important. An adage located in the Sussex County Conservation District, Sediment and Stormwater Program Inspection Office (Delaware) clearly states their feelings on inspection:

"Arguing with an inspector is like wrestling with a pig in the mud, after a while you realize that the pig enjoys it"



Anti-seep collars, barrel, and riser assembly for a stormwater management detention basin.

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8. INDIVIDUAL BMP INSPECTION CONSIDERATIONS

The two site inspection forms in Appendix 6-2 are used for general site construction. They are very appropriate for erosion and sediment control inspection and can be used for stormwater management system construction inspection. However, they must be augmented by inspection checklists specific to each type of stormwater BMP. These checklists highlight critical construction details that need inspection to assure stormwater management system construction is in accordance with the approved plans. They should accompany the project file. They can assist the inspector determine when specific sites should be inspected and what components of the stormwater system may require more individual attention and consideration.

Several components of stormwater systems may not be visible if inspections are not done when these parts are being installed. Examples include core trenches for ponds, anti-seep collars or diaphragms, compaction of embankments, filter fabric for infiltration facilities, etc. It is vital that an inspector ensure that these essential parts are installed or constructed as the approved plans detail. Otherwise, there is a risk that an important component is constructed poorly or even omitted.

Routine inspections are needed to determine site progress, however, stormwater practices have unique elements which require individual attention. Specific inspection needs associated with each type of stormwater management practice will be discussed individually in this section. Detailed facility inspection forms are included in the appendices of this chapter.

The following discussions of individual practices are separated into two areas: Design Considerations and Construction Considerations. Important aspects in each category are discussed from an inspector's perspective. Communication with the plan approval agency is especially important during design discussions. If the items discussed are not detailed on the approved plans, the inspector should contact the plan approval agency to determine the reason for an item's omission. ***Communication is the cornerstone to proper stormwater system implementation.***

8.1. Detention and Retention Systems

Detention and retention systems vary in many ways. Retention and dry detention practices are normally dry, while extended dry and wet detention systems have a normal pool of water. Wet detention practices can be further subdivided into open water ponds and constructed wetlands. ***The inspection requirements for all of these practices will be summarized separately. Thereby, an individual needing specific information about a certain BMP can read only that discussion and get a comprehensive picture rather than looking in several places for pertinent information.***

Most of the information on wet systems is directed towards ponds where the normal pool of water is established by the construction of an embankment. Excavated ponds typically do not have the same safety concerns related to embankment failure. If unsure, the local Natural Resources Conservation Service can be contacted for technical assistance in determining whether a wet system is an excavated pond or an embankment pond.

8.1.1. Dry Detention Versus Wet Detention

The design and construction of these two types of detention practices is very similar. There is, however, one very big difference which is important to recognize for inspection purposes during construction. ***Detention ponds with a normal pool of water develop a zone of saturation through the embankment, which can***

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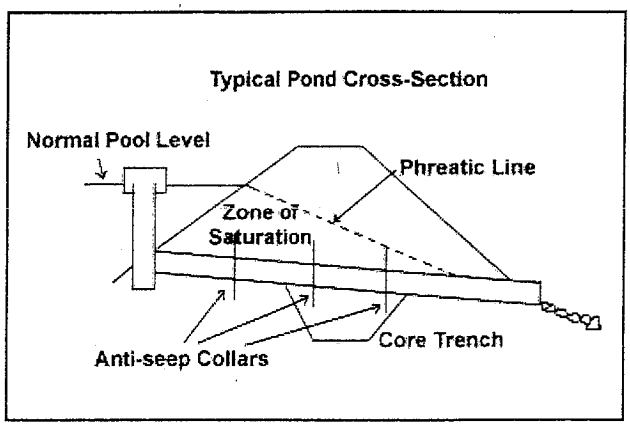
increase failure potential in the future. Concerns regarding this zone of saturation (frequently detailed on plans as the area below the phreatic line) are alleviated by good quality control during construction. The risk of a potential hazard is reduced by requiring, during design, safety features in the embankment which reduce the movement of water through the embankment. These safety features include anti-seep collars, diaphragms, core trenches, and clay cores. These features are not visible once construction is completed. Their construction and quality of construction must be verified by the inspector during their installation. Failure to inspect these features at critical times may result in embankment failure in the future.



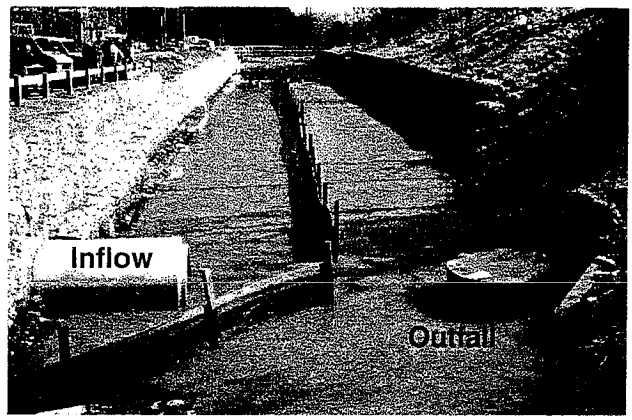
Detention or retention practices which are normally dry do not develop a zone of saturation (which results from standing water), and internal water seepage is not a critical concern. However, it is still important to have anti-seep collars or diaphragms even if embankment failure is not as important an issue.

8.1.2. Important Inspection Aspects Related to Design

When certain site conditions are encountered or where the design has an unusual aspect, it is important to communicate with the plan approval entity to ensure that a mistake wasn't overlooked. Examples of items which should be discussed include:

A. Encountering sandy soils when building a wet pond designed with a normal pool of water without a liner specified on the plans.

B. Stormwater inlets located adjacent to or near the intended outfall create a "short circuit" flow path. While this may be acceptable from a stormwater quantity perspective, the short circuiting will reduce treatment and lessen water quality benefits.



An example of a pond inflow point being close to the outfall.

C. Steep slopes into the pond with no slope breaks (benches) can increase the hazard potential and erosion of side slopes.

Steep side slopes at a dry pond. Note playground equipment at left top of slope.

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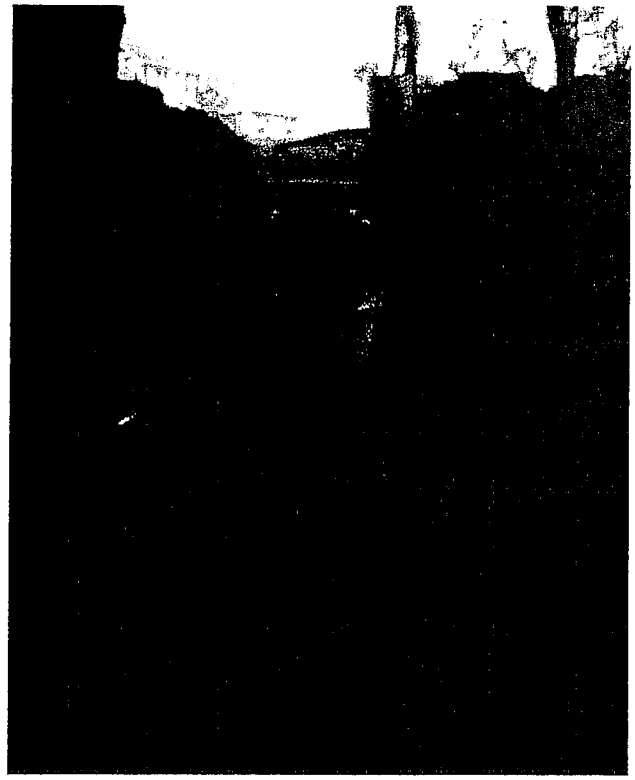
D. Essential components normally associated with ponds are not included on the plans. These parts can include anti-seep collars, trash protection for low flow pipes, principal and emergency spillways.

E. Wet detention systems should have a means to draw the water level down should draining the pond become necessary. From an inspector's viewpoint, a detention pond design without a drawdown mechanism should be brought to the attention of the plan approval agency. Where ground water provides the permanent water pool, a drawdown mechanism won't be available. The inspector should know the expected or design ground water elevations at a site, especially the seasonal high level. This information should be contained on the approved plans.



Example of a pond failure due to piping adjacent to the principal spillway.

8.1.3. Important Inspection Aspects Related to Construction

This section highlights important aspects in the construction of ponds. Appendix 6-3 is an excellent example of a Sediment/Stormwater Management Pond Construction Checklist developed for the State of Delaware. This checklist, or a similarly adapted one, should be used by inspectors during construction of stormwater management ponds.

A. ***A major cause of detention and retention system failure is water traveling along the outside of the principal spillway. This is called piping.*** It generally occurs along a corrugated metal or concrete pipe. This piping of water, which is under pressure from the depth of water in the pond, causes erosion of soil adjacent to the pipe. Erosion of this material causes the pond embankment to be weakened at that point and failure of the embankment results. ***This failure is much more likely to occur in wet detention systems than in retention systems.*** Detention ponds have a permanent pool of water next to the embankment. Water will soak into the embankment and seek a lower elevation. Failure potential can be prevented by proper installation of anti-seep collars or diaphragms, in conjunction with proper compaction of soils adjacent to the principal spillway and collars or diaphragms.

B. ***The general minimum standards for construction work also apply to the construction of stormwater systems.*** Does the construction comply with local material and equipment requirements for earthwork, concrete, other masonry, reinforcing steel, pipe, water gates, metal, and woodwork?

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C. Are interior side slopes no steeper than 3-to-1 (horizontal to vertical) and exterior side slopes no steeper than 2-to-1? The reason most stormwater embankment ponds remain stable is that the mass of earth in the embankment is heavy enough to prevent slippage of material caused by water pressure on the upstream slope. ***Steep side slopes are not only more dangerous to the general public, but they also reduce the total mass of earth material in the embankment. This can increase the potential for embankment failure.***

D. Are elevations relatively accurate and according to the approved plans? ***An inspector should carry a simple Locke level to determine whether a given location is at it's proper elevation.*** The invert elevation of a principal spillway must be lower than the elevation of the pond embankment or trouble can be expected. A Locke level provides a quick, moderately accurate, means to verify field implementation.

E. Are inlet and outlet areas stabilized to prevent erosion? Relying only on vegetative practices for stabilization is generally inadequate since it takes time for the vegetation to become well established. Some form of additional stabilization technique is generally necessary to protect soil until growth of vegetation. This can include erosion control matting, riprap, gabions, etc.

F. Are safety features provided? These may include a shallow bench surrounding the pond edge, barrier plantings to discourage approach by children, and/or fencing where required.

G. A sequence of construction must be established and followed. ***It is just as important that construction be done in the correct order as having good quality construction.*** The sequence of construction includes preconstruction meetings, temporary erosion and sediment control, core trench, etc. An example of a typical pond sequence of construction is presented in Appendix 6-4.

Pond under construction.
Reverse slope bench above waterline and shallow slope in shallow water areas.

H. Upon completion of construction, a final inspection should be performed. This inspection provides written documentation to the developer/contractor of the satisfactory completion of the facility. Depending on local requirements, this inspection augments the submission of an "As-Built" Certification or Record Drawings.

8.2 Constructed Wetlands

Many parts of the discussion in Section 8.1 above also are applicable to constructed wetlands. This BMP often is considered a subset of wet detention systems. However, they merit their own separate section because of the complexities of their design and construction. Unlike wet ponds, constructed wetlands are shallow water systems that rely, to a very large extent, on the establishment and propagation of

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emergent wetlands plants to provide water quality benefits.

8.2.1. Important Inspection Aspects Related to Design

A. Clay or geotextile liners

The shallowness of wetland stormwater treatment systems means that even a small alteration in water level can significantly impact the health of the aquatic plant community. ***It is important to ensure that water levels remain somewhat consistent.*** This may necessitate the use of a clay or geotextile liner to maintain water levels. When reviewing approved plans, the inspector must determine how water levels in the constructed wetland are to be maintained. They may be maintained by continual stream baseflow, by high ground water levels, or by installation of a liner. ***The inspector must know prior to construction how water levels will be maintained.***

Geotextile liner for a constructed wetland.

B. Organic soil conditions

Wetlands are living systems with a wide variety of organisms, each of which requires sources of essential elements for growth and propagation. The most common way to provide these elements quickly is to place organic soils on the constructed wetland floor. The approved plans should specify any special provisions for placement of organic soils.

Organic soils are not always specified, but their inclusion is highly recommended to facilitate plant growth. Not having organic soils on the constructed wetland floor results in slower growth and spread of the wetland plants. It often also leads to the invasion by nondesirable aquatic plant pioneer species which can out compete more desirable plants.

C. Shallow depth and slight grades

Unlike deeper detention systems, shallow constructed wetlands need to have exact grades in the inundated pool area. For the most part, constructed wetlands are dominated by emergent aquatic plants whose establishment and propagation typically depend on water depths under two feet. To have a diverse plant community, varying depths are needed since different plants are best suited for various water depths. The plans should detail design elevations throughout the ponded area where wetland plants will be established. They should also clearly identify where each type of plant should go.

D. Establishment of forebays

Being shallow water systems, constructed wetlands are very susceptible to filling in by sediments generated upstream. It is important that all principal inflow points be provided with forebays designed to trap the largest volume of suspended solids. ***Forebays provide a readily accessible location to allow***

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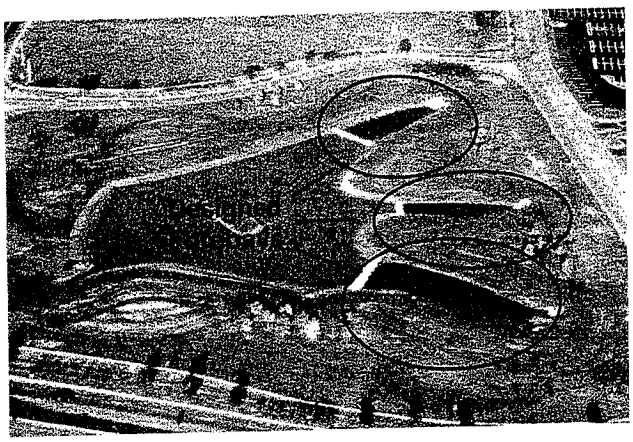
periodic removal of accumulated sediments. Plans should detail the location, size, and proposed grades of designed forebay areas, along with dedicated access for maintenance equipment.



Detail of a constructed wetland showing designed forebays.

E. Concern regarding sediment entry into the system

Because they are shallow water systems, the long term performance of constructed wetlands can be significantly reduced by sedimentation. The approved plan should be reviewed to determine if the constructed wetland will be used as a sediment basin during the construction phase of the project. ***If used as a sediment basin, the plans should detail the conversion of the sediment basin into a constructed wetland.*** If the constructed wetland is not used for sediment control, the plans should specify:

- Project phasing for overall site construction with a timetable for construction of the constructed wetland.
- How the constructed wetland will be protected from sediment entry when the drainage area is unstabilized.
- When sediment must be removed from the forebays or constructed wetland.
- That the wetland will not be planted until site stabilization is complete.

F. Reduced concern over saturated embankment problems

Most constructed wetlands have a shallow depth of water against the embankment. However, some wetland designs specify a deep water zone adjacent to the embankment. The shallow water reduces water pressure adjacent to the embankment and reduces the number of anti-seep collars needed to prevent piping along the principal spillway. The inspector should still expect to see at least one anti-seep collar on the principal spillway, but safety concerns are reduced compared to those that exist for deeper wet detention systems.

G. Reduced safety features

Deeper wet detention systems present other public safety hazards to those individuals living or working adjacent to them. ***Constructed wetlands present much less of a safety concern due to their denser vegetation, more gradual side slopes, and the shallow water depth.*** Plans, therefore, may not provide specific safety features.

H. Plant materials

Beside the water quality benefits resulting from detention time of stormwater within the wetland, water quality benefits also are provided by the wetland plant community, microbes, and the organic materials on the wetland's bottom. There are three approaches to establishing aquatic plants in constructed wetlands: plantings of aquatic plants which facilitates rapid plant growth; providing

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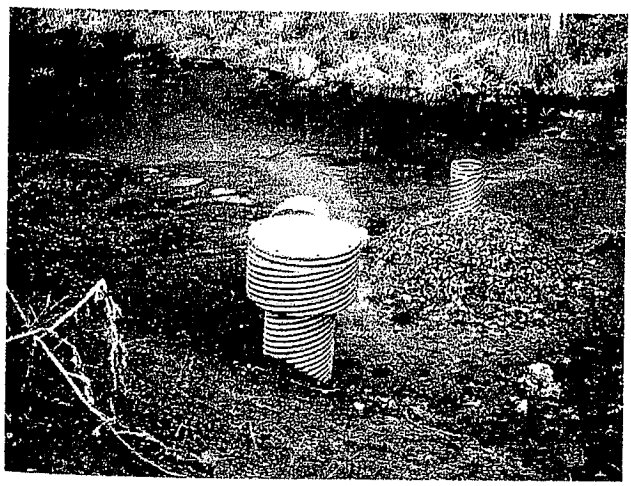
proper hydrology and soil conditions to promote colonization of the system by local vegetation; and installing soil having vegetative plant roots or rhizomes. Of course, these are not mutually exclusive, and proper conditions must be provided to sustain plantings.

The approved plan should detail which approach is used. If wetland plantings are to be used, the plan should specify:

- the plant species.
- the number of each species.
- where the plants will be located.
- if the pond water level will be lowered to facilitate planting.
- a timetable for planting to occur.

8.2.2. Important Inspection Aspects Related to Construction

A. If the constructed wetland is to be used as a sediment control basin during construction, there are a number of items which must be considered. The outlet structure must be modified by installation of a temporary dewatering device. Final grades are not important to establish at this time, but the minimum volume needed for sediment control must be provided for construction generated sediment.



Temporary sediment trapping device attached to a riser assembly.

Sediment removal will be needed to maintain the system's ability to reduce suspended solids. When sediment cleanout is required, the removed materials should be placed upstream of any sediment trapping facilities to prevent their movement downstream. ***The inspector will generally determine when sediment cleanout is needed and should specify where the removed sediments are to be placed.***

Very shallow grades on a constructed wetland.

B. ***The importance of accurate grade establishment in shallow constructed wetland systems cannot be overstated.*** During construction, survey stakes must be placed to accurately establish cuts and fills. The final grades must be accurate for successful plant establishment and propagation. Final grades should be established prior to water filling the pond, where possible. Once the bottom and side soils have become saturated, the movement of earth material becomes much more difficult and the basin may have to be dewatered and dried before final grades can be established.

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C. ***Site stabilization must be accomplished before wetland planting if site runoff passes through the facility.*** Excess sedimentation can smother the plants and change wetland elevations which would alter planting success and plant composition. Optimally, the planting should be done several months after site stabilization to allow for further reduced sedimentation into the wetland, but construction scheduling may reduce that potential.

D. The time of year that plants are placed in the wetland will influence the eventual success of the planting. Ideal times for planting are in the spring when plants are emerging from dormancy and in the late fall when plants are just entering dormancy. Other times for planting are less recommended. The inspector should discuss time frames for planting with the developer/contractor early in construction to establish a timetable for facility construction and wetland planting.

8.3. Infiltration Practices

Infiltration, or retention, practices are widely recognized as valuable stormwater management BMPs because of their multiple benefits. ***By retaining runoff onsite for percolation or evaporation, infiltration practices are the only structural stormwater BMPs which reduce the total volume of stormwater leaving an urban site.*** Infiltration practices include a wide range of BMPs including:

- trenches
- basins
- drywells
- paving (porous pavements, lattice block)
- swales

While the multiple benefits of infiltration practices make them very essential BMPs, there is a major concern, at this time, with their long term performance. Detailed evaluations of implemented infiltration facilities in Maryland (Pensyl and Clement, 1987; Lindsey, Roberts, and Page, 1991) reveal that ***infiltration systems are very sensitive to failure due to clogging of the facility's surface area.*** Many instances of premature clogging of infiltration practices were attributable to poor site control during the site construction process. Poor site control results in excess sediment loadings entering the infiltration system. Therefore, quality control during construction of infiltration practices is an essential responsibility of an inspector.

Infiltration practices can include, by some definition, buffer areas, biofiltration swales, and riparian zones. However, in this chapter, infiltration swales, filtration practices, and biofiltration practices will be discussed separately. The next two sections present general information on design and construction of infiltration practices. Section 8.3.3 will present specific information for each of the individual types of infiltration BMPs.

8.3.1. Important Inspection Aspects Related to Design

Design of stormwater infiltration systems requires a greater recognition and knowledge of specific site conditions, much more so than for detention systems. Site variables play a much greater role in infiltration facility design. The site variables listed below are important to assess and evaluate if the implementation of infiltration BMPs is to be successful. From an inspector's perspective, the approved project file should contain information on each of these parameters. Specific design recommendations, based on state or local conditions, for the parameters discussed below (i.e., maximum slope, depth to water table, minimum soil permeability rates, etc.) should be provided in state or local stormwater management design handbooks.

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A. Soils must be suitable for infiltrating runoff through the soil profile. Soils that have too much silt or clay content will tend to clog quicker than more coarse grained particles. ***Each infiltration facility should have a soils report attached to the approved plans which detail soil conditions at the site of the infiltration system.***

As an initial design consideration, the appropriate Detailed Soil Survey should be consulted to determine whether a specific site is suitable for infiltration practices. If this indicates suitable soils, ***location-specific soil borings should be taken to verify soil conditions to several feet below the bottom of the infiltration facility.*** The soils analysis will indicate the depth of various soils in the profile in addition to the depth of water table or bedrock. The inspector should become aware of the soils expected on the site at the proposed location of the infiltration BMP. This is to ensure, during construction, that those soil conditions are accurate.

The Stormwater Management Manual for the Puget Sound Basin, Volume III - Runoff Control (Washington State Department of Ecology, 1986) requires runoff to pass through at least 18 inches of soil which has a minimum cation exchange capacity of 5 milliequivalents per 100 grams of dry soil. The intent of this requirement is to ensure that pollutants do not pass through soils that are too porous creating ground water pollution. The approved plans should be checked for special conditions related to construction of the infiltration system.

Example of a soil sample being taken at an infiltration basin site.

B. The design report should contain information on the depth of soil from the proposed bottom elevation of the infiltration BMP to the water table, bedrock, or impermeable soil layer. Having limited depth of good soil above a barrier to vertical water movement may prevent long term performance of infiltration practices. As these facilities accept runoff from areas of the project site that have reduced or eliminated infiltration, the accumulation and ponding of runoff in the infiltration system increases the potential for ground water mounding. ***Mounding can cause ground water levels to rise above the design bottom elevation in the vicinity of the facility. This can prevent or significantly reduce infiltration of runoff.***

There are situations where infiltration facilities can be used despite having a high ground water table. In very permeable soils, exfiltration of runoff can occur through the sides of the facility. This process must be specifically designed for, and the plans should clearly indicate expected site conditions.

C. Site slope must be a consideration in the implementation of an infiltration BMP. Locating an infiltration system on slopes exceeding 15% could result in infiltrated

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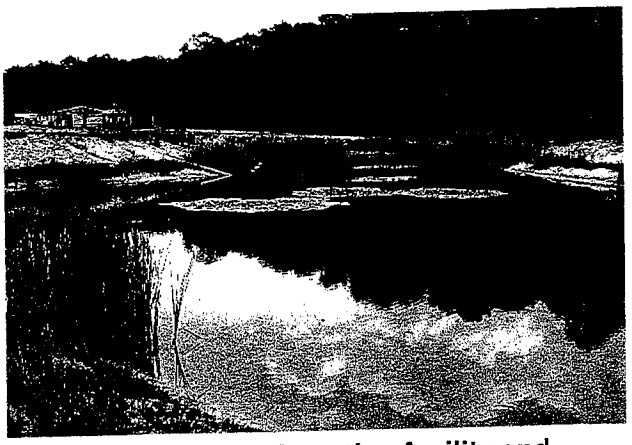

Combination detention facility and infiltration basin where exfiltration from basin occurs through the side walls.

runoff becoming surface runoff farther down the slope and increase site erosion problems. Slope can also adversely impact the performance of infiltration trenches. These are linear in nature and too steep of a slope may mean that the uphill portion of the facility never fills up with water prior to runoff overflowing the downstream end of the facility.

D. The proximity of septic fields, structure foundations, or drinking wells should be considered during the design phase to eliminate potential concerns, for obvious reasons.

E. ***Due to the sensitivity of infiltration practices to clogging, the BMP Treatment Train concept should be used to provide pretreatment.*** This can be accomplished by swale conveyances, vegetative filters or structural BMPs. Pretreatment is not practical for some infiltration BMPs such as a porous pavement or dry well. However, whenever feasible, pretreatment needs to be provided. The inspector should review the plans to see if pretreatment is provided.

F. The approved plans should detail the surface covering of the infiltration system. If vegetation is the cover material, the approval should detail the seeding specification, ground preparation, and fertilizer application. Other surface covers, such as stone riprap or apron, should also be detailed. If stone is used, the stone should be clean, washed stone to reduce potential clogging of the facility.

8.3.2. Important Inspection Aspects Related to Construction

The proper construction of infiltration facilities is very important if long term performance is to be expected. These practices are very susceptible to clogging by site generated sediments. ***It is vital that sediment laden runoff during construction not be allowed to enter the facility.*** There is also a time period after site stabilization has been accomplished that excess sediment loads still are transported downstream from areas where revegetation is done. These areas of revegetation will not have the buildup of organic material or the density of vegetation that will develop eventually. This is why pretreatment of runoff before it enters the infiltration system is needed. The following general guidelines apply to the construction phase of all infiltration practices. The guidelines are adapted from those provided in the "Control of Siltation" Section of the Stormwater Management Design Manual for the Puget Sound Basin, Volume III - Runoff Control.

A. Infiltration systems should not be constructed until permanent stabilization and permanent erosion control of areas draining to the facilities has been accomplished.

B. ***Infiltration facilities, primarily basins, should not be used for temporary sediment traps or basins during construction.*** If an infiltration system must

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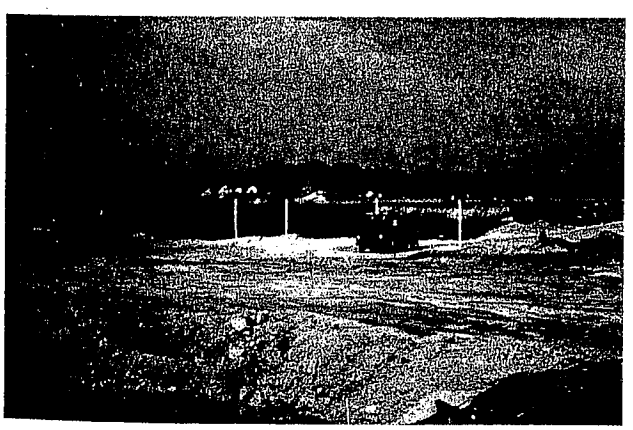
be used for sediment control, the bottom of the facility should be placed at least one foot above the design bottom elevation. If the system develops a normal pool of water due to bottom clogging by finer sediments, it should be dewatered and allowed to dry before excavation to final design bottom elevations. If the material is removed while wet, there will be the potential for the water to become turbid and for finer sediments to remain in the water column. This will reduce soil permeability at the final bottom elevation.

C. Other than infiltration dry wells and porous pavement, all infiltration practices shall be designed so that the stormwater runoff first passes through a pretreatment system to remove suspended solids before the runoff enters the infiltration system.

D. ***The location of infiltration systems should be clearly marked at the site to prevent vehicle traffic across this area.*** The traffic will compact the soils and reduce soil infiltration rates. As can be seen from the photograph, identification without education may not prevent a problem from occurring.



While the location of the infiltration basin was marked, construction workers mistakenly thought the markings identified where trucks were to enter and leave a construction site.

8.3.3. Characteristics of Individual Infiltration Practices Which Warrant Specific Attention

Although grouped together due to their common goals, infiltration BMPs also are very different in their construction and site utilization. Consequently, they will be discussed separately to provide specific guidance to the inspector. Probably the best existing source of information on construction inspection of infiltration systems is the "Inspectors Guidelines Manual for Stormwater Management Infiltration Practices" (Maryland Department of the Environment, 1985). Many of the recommendations in the following section have been adapted from it. These recommendations need to be considered in addition to those presented in the general discussion in Section 8.3.2 above. In addition, detailed construction check sheets are provided in Appendex 6-5.

A. ***Infiltration basins*** often do not have a principal spillway since runoff is infiltrated into the ground or evaporated. The primary method of construction is to construct a dam embankment or to excavate a basin into the ground. These facilities <u>temporarily</u> store (underlined for emphasis) runoff. They are generally used for larger drainage areas than are other types of infiltration BMPs. There are a number of points (See Appendix 6-5A) which must be considered by an inspector when inspecting an infiltration basin.

1. The infiltration basin dimensions and locations should be verified onsite prior to basin construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. Initial excavation should leave more than one foot of unexcavated material above the design bottom eleva-

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tion if the basin is to be used for sediment control during construction. However, ***it is recommended that infiltration basins not be used for erosion and sediment control during construction.***

Example of an infiltration basin being constructed.

3. ***During initial excavation, the excavated materials should be observed by the inspector to verify soil conditions are consistent with information in the design report.*** Significant variation of soils from the design report should be noted and the plan approval agency notified.

4. Excavation should be done by lightweight equipment to minimize the potential of soil compaction. Tracked, cleated equipment does less soil compaction than tired equipment.

5. When inspecting the basin floor at final grade establishment, the inspector should look for any material, organic or otherwise, which may reduce basin performance. Examples of such material includes tree roots, previously buried material, or areas of loose stone.

6. Where embankments are required for basin establishment, the same concerns that exist for detention ponds should be considered. This includes:

   - clear, grub, and strip topsoil
   - a cutoff trench
   - fill material for the embankment shall be taken from an approved source and be clean mineral soil free of roots or woody vegetation.
   - embankment compaction shall be the same as for detention ponds in terms of degree of compaction and depth of layers

7. ***When at final grade, the basin floor should be deeply tilled to restore the percolation rate of compacted soils and to aerate the soils.***

8. Similar to detention systems, infiltration basins should have a final inspection performed leading to preparation of written documentation on the adequacy of construction.

B. *Infiltration Trenches* tend to have a large length to width ratio and are filled with stone, gravel, or sand aggregate. Infiltration trenches are generally used in areas where space available for the BMP is limited. By being linear, and having the available area filled with stone, etc. they can be fairly deep without having a comparable width requirement. Runoff entering the facility is stored in the void areas of the aggregate material, which normally is between 30 and 40% void area. The stored runoff then exits the trench through the side and bottom walls into the soil profile. Appendix 6-5B contains an inspector check list for infiltration trenches.

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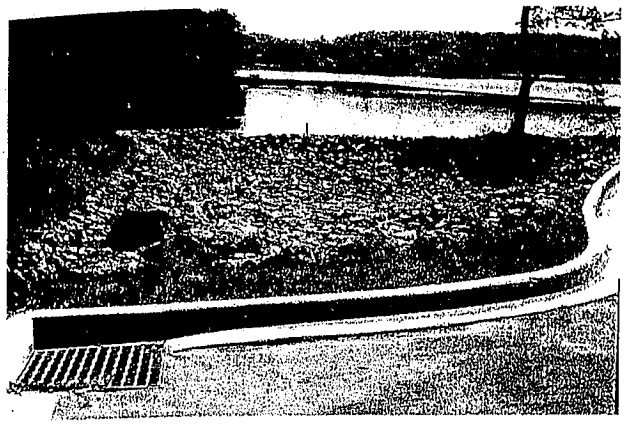

Completed infiltration basin; note the lack of pretreatment measures prior to runoff entry into the facility.

1. The infiltration trench dimensions and location should be verified onsite prior to trench construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. The trench should be excavated using a backhoe or a ladder type trencher. Front-end loaders or bulldozers should not be used as their blades can seal the infiltration soil surface. Excavated materials should be placed a sufficient distance from the sides of the excavated area to minimize the risk of sidewall cave-ins and also to prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.

3. The trench bottom and side walls should be inspected for removal of objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric.

4. The sides and bottom should be lined with filter fabric. The side fabric placement will prevent migration of soil particles from the side walls into the trench. The bottom filter fabric will prevent sealing of the aggregate soil interface.

5. The fabric should be laid with sufficient length to overlap the top of the trench. Having the trench covered after placement of the aggregate will protect the completed facility by preventing excess site sediment from entering it.

6. An observation well should be installed in the aggregate to allow future inspections to determine whether the facility is functioning as designed. The observation well should consist of a perforated PVC pipe, 4 to 8 inches in diameter and have a foot plate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.

Infiltration trench showing the observation well, foot plate, and filter fabric side walls before placement of the aggregate.

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Example of an infiltration trench treating highway runoff.

7. The aggregate material should be inspected prior to placement to ensure that it is clean material and free of debris. The size of the material should be as specified on the approved plans.

8. Upon completion of trench construction, the adjacent areas should be vegetatively stabilized. The overflow of the trench should be directed to a non-erosive outlet channel.

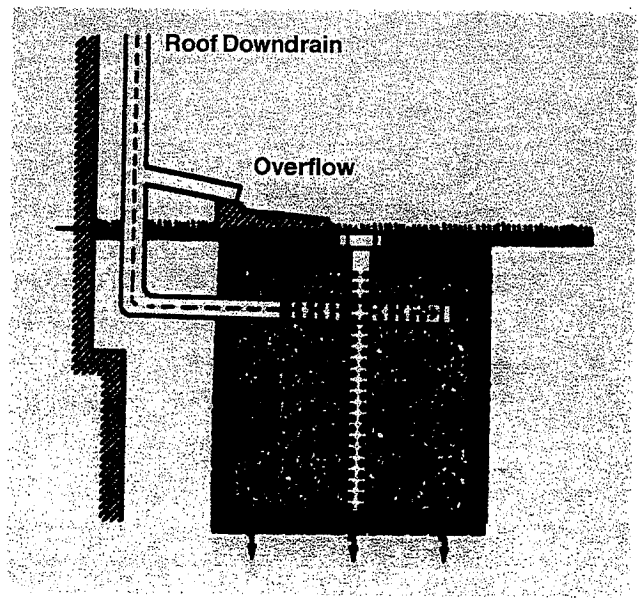
9. A pretreatment BMP should be used before the runoff enters the trench. This pretreatment should be effective at removing suspended solids and can be a biofiltration swale or other approved method.

10. The observation well should be capped and the initial depth measured and noted on the inspection checklist.

C. ***Infiltration Drywells*** are similar to infiltration trenches in that they are excavated areas that are filled with an aggregate material. The main difference is that drywells accept runoff from roofs. Therefore, they receive lower loadings of suspended solids loadings compared to that expected from ground surface runoff. The major concern with infiltration drywells is that, by serving roof areas, they must be located in the vicinity of building foundations. ***Careful consideration must be given to the correct placement of drywells so that building foundation problems do not result.*** A big advantage of a drywell over other runoff controls is that the drywell is underground and does not represent a loss of site area to the land developer. Appendix 6-5C contains an inspector check list for drywells.

1. The infiltration drywell dimensions and location should be verified onsite prior to drywell construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. The drywell should be excavated using a backhoe or ladder type trencher. Front-end loaders or bulldoz-



Schematic of an infiltration dry well.
Adapted from Schueler, 1987

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ers should not be used as the equipment blades may cause excessive compaction of the drywell bottom.

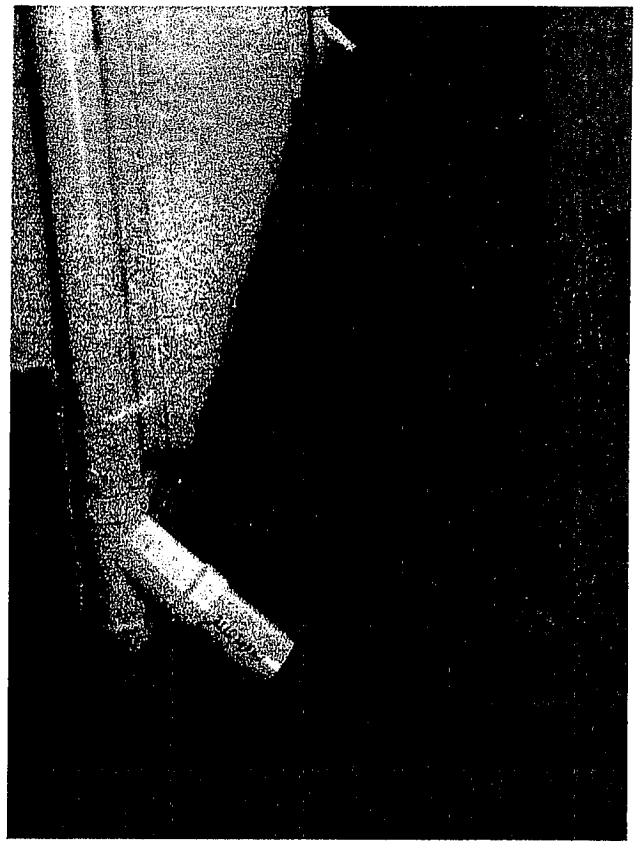
3. Excavated materials should be placed a sufficient distance from the sides of the excavated area to minimize the risk of sidewall cave-ins and also to prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.

4. The drywell bottom and side walls should be inspected for removal of objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric. Work should be scheduled so that the drywell can be covered in one day to prevent windblown or water carried suspended solids from entering the drywell.

5. The sides and bottom should be lined with filter fabric. The side fabric placement will prevent migration of soil particles from the side walls into the trench. The bottom filter fabric will prevent sealing of the aggregate soil interface.

6. Once the aggregated has been placed, filter fabric should be placed over the drywell and final grading should be done.

7. An observation well should be installed in the aggregate to allow future inspections to determine whether the facility is functioning as designed. The observation well should consist of a perforated PVC pipe, 4 to 8 inches in diameter and have a foot plate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.



Completed drywell showing overflow device: note total site utilization but also the lack of observation wells.

8. The aggregate material should be inspected prior to placement to ensure that it is clean material and free of debris. The size of the material should be as specified on the approved plans.

9. Debris and grit traps consisting of fine-mesh screen covering the downspout (roof leader) should be used with dry wells to prevent objectionable materials from entering the aggregate subbase through the inflow pipe. Roof gutter screens should also be used to protect gutters and grit traps from clogging due to wash-off of leaves, pine needles, etc. from

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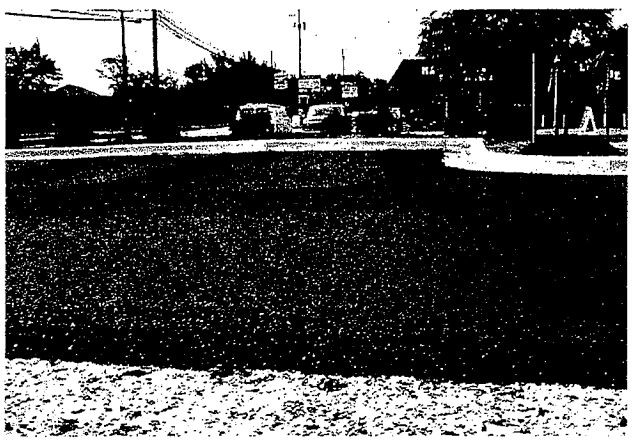
the roof area.

10. The observation well should be capped and the initial depth measured and noted on the inspection checklist.

D. ***Infiltration paving (porous pavement and lattice block) systems*** are road and parking lot surfaces whose design allows for stormwater runoff to travel through the surface into the ground. Under the porous surface, an aggregate material serves as a reservoir base for temporary storage of the runoff until the water infiltrates into the ground. ***Their best applications are in areas where there is a low volume of traffic or where overflow parking is needed on a periodic basis.*** Appendix 6-5D contains an inspection check list for pervious pavements.

Porous Asphalt

This has been the most commonly used porous paving surface. In porous asphalt the fines are left out of the mix and the asphalt content is increased slightly to increase the binding of the mixture. Leaving the fines out of the mixture increases the void spaces and allows rainfall to pass directly through the pavement. The paving consists of the porous asphalt course, a filter course, the reservoir course, filter fabric, and finally the existing soil.



Porous paving being installed showing the porous asphalt course and the filter course.

Lattice Block

Lattice block is a modular unit which is generally placed in square sections. It is concrete with large void areas which are filled with a porous material, such as sand or pea gravel. Lattice block still should have the filter course, reservoir course, and filter fabric lining, prior to entry into the soil.

Lattice block infiltration provided at a parking lot.

Pervious Concrete

Pervious portland concrete is being used widely in Florida to create porous parking areas. Like porous asphalt, the fines are left out of pervious concrete creating an open concrete pavement which allows water to pass directly through into the ground. It avoids some of the pitfalls of porous asphalt due to its strength to resist rutting and compaction. It also has greater surface openings to resist surface clogging which is such a large concern with porous paving. ***However, special expertise is required to batch, pour, and finish pervious concrete.***

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1. To help preserve the natural infiltration rate of the subgrade soils prior to excavation, the infiltration paving area should not be excessively traveled by heavy construction equipment that causes excessive compaction of soil pores. The area should be marked off and traffic kept off it to the greatest extent possible.

2. The infiltration paving dimensions and location should be verified on-site prior to construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

3. The area of the paving should be carefully excavated to prevent excessive compaction of the soils during the subgrade preparation. All grading should be carried out using wide tracked equipment.

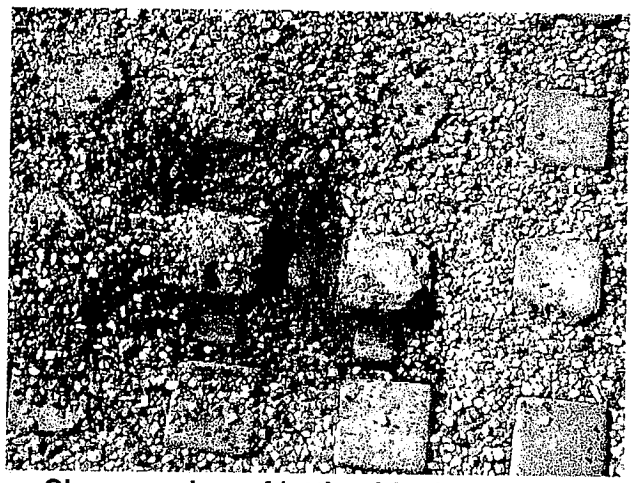
4. Once the subgrade has been reached, filter fabric should be placed on the bottom. The type of fabric should be specified on the approved plans.

5. Once the fabric has been placed, the reservoir course is placed to the design depth. This course should be clean, washed stone having a void ratio between 30 and 40%. The reservoir course should be laid in 12" lifts and lightly compacted. The aggregate should be uniformly spread.

Placement of the reservoir base at a porous pavement site.

6. The aggregate filter is placed on the reservoir course and is clean washed stone ranging in size from 3/8 to 5/8 inch. This stone provides a uniform base for the asphalt or lattice course.

7. At no time should sediments be allowed to enter the infiltration paving construction area.



Close-up view of lattice block paving with pea gravel filler in the porous areas.

8. The surface course is then laid. If porous asphalt, it should be laid directly over the aggregate filter course in one lift. The laying temperature should be done to local specifications and minimum air temperatures should be considered to ensure that cooling does not occur prior to compaction. If lattice block is used, temperature of the mix or air temperature aren't important. The void areas of the lattice block should be filled with the appropriately specified material.

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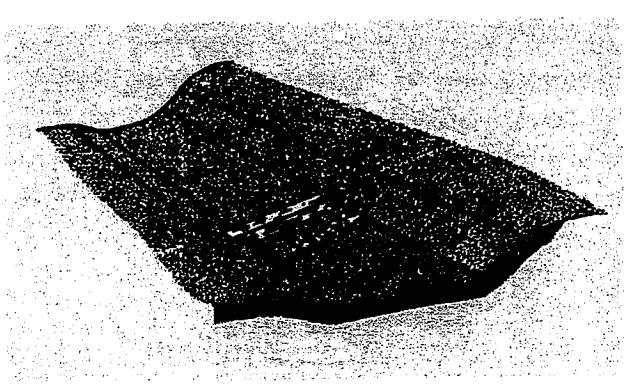
9. The inspector should check the overall workmanship of the pavement area to ensure smooth transitions between existing and new paving. A small compacted section should be tested by pouring a few gallons of water onto the pavement to ensure that the water infiltrates into the pavement.

E. ***Infiltration Swales*** are closely related to biofiltration swales. The primary difference is these swales use infiltration as their primary means of pollutant and total runoff volume reduction. However, they are still considered as a subset of biofilters since vegetative filtration is also important. While biofiltration swales and filters rely on passage of water through vegetation for pollutant reduction, infiltration swales have designed blockages, such as swale blocks or check dams, which pond water and promotes infiltration. In both situations, slopes must be very gradual to increase residence time and reduce flow velocities. Appendix 6-5E contains an inspection check list for infiltration swales.

1. To help preserve the natural infiltration rate of the subgrade soils prior to excavation, the infiltration swale area should not be excessively traveled by heavy construction equipment that causes excessive compaction of soil pores. The area should be marked off and traffic kept off the area to the greatest extent possible. This is especially important at residential construction sites where individual residential contractors enter building sites with numerous trucks. The driveway areas should be the access points for contractors.



Schematic of an infiltration swale.
Adapted from Schueler, 1987

2. The infiltration swale dimensions and location should be verified onsite prior to construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

3. Excavated materials should be placed a sufficient distance from the sides of the excavated area to prevent migration of the soils back into the swale area.

4. During excavation of the swale cross-section, poor soils, organic material, or rocks should be removed and replaced with permeable soils.

5. Excavation should be done by lightweight equipment to minimize compaction of the soil profile.

6. The approved design plan will have specifications for the composition of the swale block or check dam (height, slopes, materials, etc.). They will generally be earth material and should be compacted to minimize seepage. Stone or sod may be required on the face of the check dam to prevent possible erosion during high storm flows.

7. The final inspection will verify infiltration swale dimensions, and assure that the number of check dams

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agrees with the approved plans. ***It is absolutely essential that excess sediment loadings be kept out of the swale and that good vegetative stabilization of the swale be accomplished.*** Infiltration swales, due to their small impounded areas behind the check dams, are very susceptible to clogging of the pool areas, so good stabilization of the site and swales is essential.

Infiltration swale adjacent to a highway.

8.4 Filtration Systems

Filtration systems are becoming more recognized and accepted as another option for treatment of urban stormwater. There are three primary approaches which are being used around the country. These approaches require very different responsibilities for an inspector.

Austin, Texas

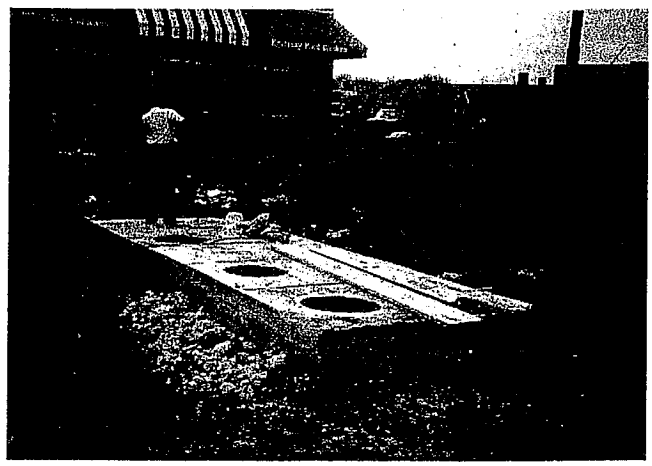
The City of Austin has pioneered the use of sand filter systems as a means to protect their ground water aquifers. Austin has significant limestone areas in which discharge of stormwater could increase the potential for sinkhole development and allow pollution of ground water resources by direct discharge of untreated stormwater into the ground water. They use impermeable lin-

Austin sand filter system sediment forebays on either side with sand filter in the center.

ers under their sand filters to prevent the potential migration of pollutants into the ground water while treating the runoff. The program requires management of both stormwater quantity and quality, with treatment of runoff from pervious and impervious areas.

Washington D.C.

The City of Washington, D.C. is on a combined sewer system. Their sand filter systems also are designed to control the peak rate of discharge from a site while providing stormwater treatment. The stormwater quantity criteria are intended to prevent overloading the combined sewer capacity. The basic sand filter design used is an underground vault since land is either very expensive or unavailable for use of surface stormwater BMPs.



Washington, D.C. sand filter.

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Delaware Sand Filter

Delaware's stormwater program has developed a sand filter design for use on highly urbanized sites where available stormwater treatment options are limited. This filter is designed for water quality only, and is used to treat runoff from totally impervious drainage areas at smaller sites. The filter is a shallow system which can be built underground resulting in no loss of site use for buildings.

Delaware sand filter.

There are other variations to these three basic designs. The City of Alexandria uses variations of all three approaches. Their variation of the Delaware Sand Filter uses a precast concrete top for the filter which significantly reduces the cost compared to the original Delaware version where cast iron grates are commonly used. Florida's stormwater program pioneered the use of detention with filtration systems in the early 1980s. Side bank and vertical recovery filters, made of sand and gravel, are used in association with detention systems to provide stormwater treatment on sites that can not use wet detention.

8.4.1. Important Inspection Aspects Related to Design

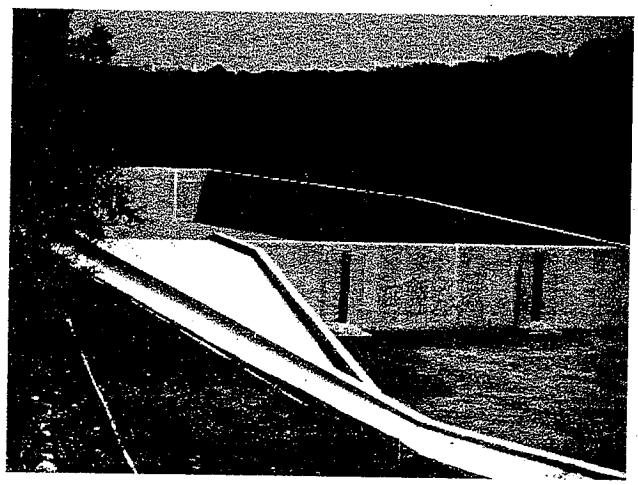
Design of filter systems is fairly straightforward when compared with ponds or other practices. Their design criteria are clearly detailed in available guidance manuals. One similarity of all of the different confined filters is a two chamber facility. The first chamber is for sediment deposition of larger suspended solids. The second, a filtration chamber, contains the filter media, generally sand. Other filter media including compost, peat, and alum sludge have been used on specific projects. Appendix 6-6 is an inspector check list for filtration systems. In addition, the plans should include the following information:

A. Dimensions and structural details of the filtration facility.

B. Sequence of construction for overall site development and construction of the filtration facility.

C. Volumes and size of both the sedimentation and filtration chambers.

D. Specifications of the filter media. The media should be specified as being clean, washed material.



City of Austin sand filter for new highway construction. The chamber in the foreground is the sedimentation chamber, the filtration chamber is in the background.

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E. Sediment control provisions during construction to prevent the facility from premature clogging. The Austin filters include a dry detention component. Accordingly, these facilities may have more construction sediment control notes than the other systems.

F. In the Delaware sand filter, the filter may be prefabricated in standardized lengths. The means of sealing the joint connections between units should be specified on the approved plans.

City of Alexandria variation of the Delaware sand filter using prefabricated concrete tops for the filter.

8.4.2. Important Inspection Aspects Related to Construction

As can be seen from the illustrations, sand filters may involve reinforcing steel, concrete, and significant site preparation prior to construction. The inspector should carefully review the approved plans and discuss any concerns at the preconstruction meeting. From an inspection standpoint the following construction times and items are important to recognize during the site inspection.

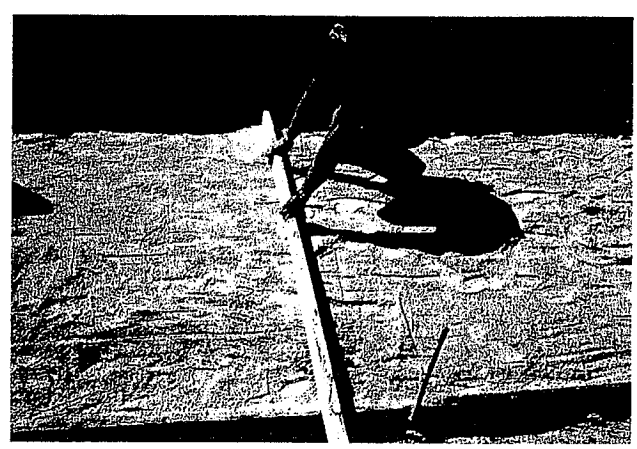
A. Site location for the filtration facility should be staked out. This is especially important when installing the Austin filter as it encompasses more site area than do the Washington D.C. or Delaware filters. In general, filters should not be used for sediment control during construction.

B. Structural components should be available on-site to verify adequacy of materials. Reinforcing bars should meet specifications as should all other structural components such as any pipes, aggregate material, and filter fabric.

C. Foundation areas should be cleared of any organic material which could cause uneven settlement at the material decomposes. Unsuitable foundation material should be removed and replaced by suitable material.

D. The foundation area should be compacted to sustain the load placed on it by the filtration system. The foundation should then be leveled as detailed on the plans to ensure proper drainage of the facility.

E. The inspector should be on site when the facility has been formed up with reinforcing bars in place but prior to pouring of the concrete.



Foundation grade being established prior to placement of concrete floor of the filtration facility.

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F. During concrete pouring, the inspector shall verify that the concrete meets design specifications for the design load.

G. If the filtration facility is composed of prefabricated units, the inspector shall approve the means of joining the sections and the steps taken to prevent leakage from between the prefabricated units.

Sealing of joints on a prefabricated delaware sand filter.

H. Delaware and Washington D.C. filters should be filled with water once the concrete has set (or joints sealed on prefabricated units) and allowed to sit for 24 hours to observe whether the unit has any leaks.

I. When installation has been completed, meets size and volume requirements, has no leakage, and the contributing drainage areas have been stabilized, placement of the underdrains should then be done. These drains should be placed on the proper slope and wrapped in filter fabric to prevent migration of the filtration material out of the facility.

J. The filter material shall then be placed in the facility. The material should meet criteria specified on the design plans. A common material used at this time is C-33 concrete sand. This is clearly defined in highway design standards. The sand should be clean, washed aggregate. Other materials, such as peat or compost, may become more accepted if their performance demonstrates their value.

K. A final inspection should verify that the filter material is placed correctly and the first sedimentation chamber is clean of any accumulated sediments or other construction debris.

8.5. Biofiltration Systems

Biofiltration practices rely upon several processes to treat runoff. These include filtration, infiltration, adsorption, and the biological uptake of pollutants from runoff as it flows through a vegetated stormwater treatment system. Biofiltration can effectively function in any location where natural vegetation and landscaping intercept runoff. ***A key requirement of any vegetative treatment system is to obtain a stand of vegetation that can effectively filter runoff.*** Ideal vegetation characteristics include a dense, uniform growth of fine-stemmed plants that can tolerate soil saturation and the climatological, soil, and pest conditions of the area. Drainage areas are generally fairly small, less than 5 to 7 acres. Appendix 6-7 is an inspector check list for biofiltration practices.

It is essential to maintain proper hydraulic conditions to avoid uneven, channelized flows through the biofiltration BMP. Uneven flow across the width of a biofilter reduces pollutant removal effectiveness because runoff bypasses vegetation, shortening treatment time. Channelized flow also may erode biofilters and exacerbate downstream water quality prob-

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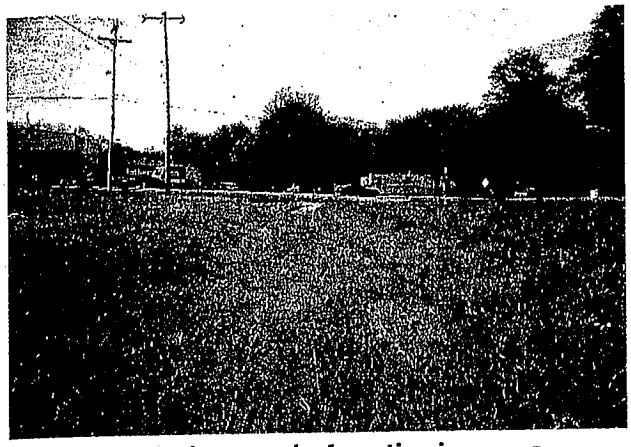


Vegetative swale functioning as a biofiltration facility.

lems that the BMP was intended to mitigate.

8.5.1. Important Inspection Aspects Related to Design

Design of biofiltration facilities is fairly straight forward. Their primary treatment process is filtering runoff through vegetation. When an inspector first reviews the approved plans, it is important to note the following essential design aspects of biofiltration BMPs.

A. Dimensions and structural details of the biofiltration system. The bottom width of swales should be no less than 2 feet if it is to be mowed. The bottom width should be no greater than 8 feet unless it will be hand finished to get a completely level bottom.

B. Sequence of construction for overall site development and construction of the biofiltration system.

C. Do the post-development drainage patterns resemble the pre-development ones? Placement of swales and biofilters along natural flow paths and contours should be detailed on the approved plans.

D. To assure even sheet flow in a biofilter, and avoid channelized flow, ***the bottom of the biofiltration BMP must be flat with no lateral slope*** (across the bottom of the swale or vegetative filter strip).

E. ***The design of inflow to the biofilter should quickly dissipate runoff velocity to minimize erosion potential.*** Dissipation practices such as riprap pads and level spreaders should be used.

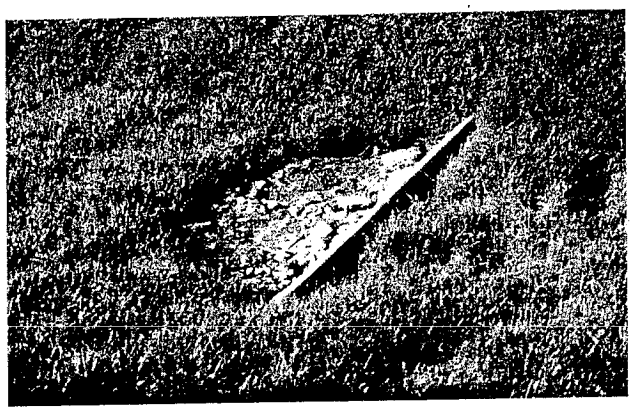
Swale inlet energy dissipator and flow spreader.

F. Outflow from biofilters should be diffuse to avoid erosion damage to downstream facilities or water bodies. Swales should be equipped with raised storm drain outlets to prevent erosion.

G. Generally, biofiltration swales are longer than 100 feet to reduce short circuiting, with their total length depending upon the flow and the minimum required residence time. No minimum width has been established for biofiltration filter strips since this is a very site specific design parameter. All of the above distances are general recommendations to provide effective stormwater treatment. Exact dimensions and residence times will be specified by the state or local stormwater program depending on their

performance standard. These dimensions must be specified on the approved plans. When an inspector finds that a biofiltration system is not built according to the design plans, the plan approval agency should be contacted to determine corrections needed to ensure proper performance of the constructed BMP.

H. Longitudinal slopes should be fairly slight with maximum slopes of 4% (can be greater with use of check dams).



Check dam with energy dissipator.

I. Plant specifications must be contained on the approved plans. ***Grasses tend to be the superior choice of vegetation as they are resilient, provide abundant surface area, and can sprout through thin deposits of sand and sediments.*** The plants should be those of common use in the geographic area and be somewhat stiff, dense, and a greater leaf area.

J. If the site's soils are sandy, topsoil should be specified on the biofilter's plans. Eliminating hardpan, rocks, and gravel near the surface will help to prevent persistent bare spots in biofilter plant cover.

K. Pretreatment should be provided when high sediment inputs to biofilters are likely.

8.5.2. Important Inspection Aspects Related to Construction

Construction activities should be phased to ensure the greatest practical amount of plant cover during the course of construction. If permanent swales and filter strips are installed during site construction, they either must be protected from construction site runoff or restored for long term use once site construction is completed. The inspector should note the following important aspects of construction:

A. Site location for the biofiltration facility should be staked out. This will allow for dimensions, shapes, and slopes to be verified per the design plans.

B. ***Ensure that lateral slopes are completely level to avoid any tendency for the flow to channelize.***

C. Ensure that inlets, outlets, and other auxiliary structures, such as check dams or flow bypasses, are installed as specified.

D. ***Make sure that vegetation complies with planting specifications.*** Ensure that vegetation becomes uniformly dense for good filtration and to prevent erosion. Grass can be established by seeding or using sod. Seeding is generally preferred due to it's lower cost and the greater flexibility it allows in selecting grass species. ***The method of vegetative stabilization should be discussed and approved at the preconstruction meeting.***

E. ***The biofilter should be placed so that no portion will be in the shade of buildings or trees throughout the entire day***, which would cause poor plant growth.

F. Make sure that construction runoff is not entering the biofilter. If it is, require re-

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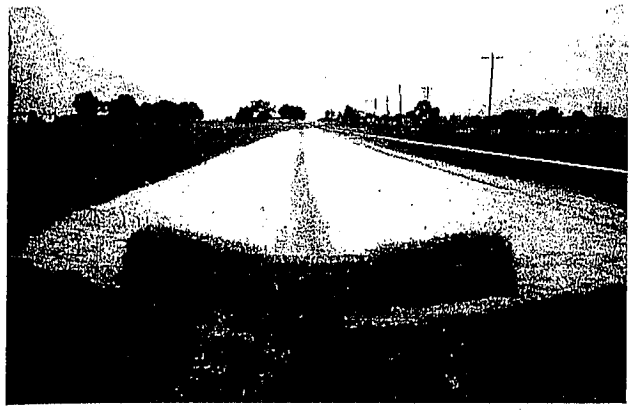


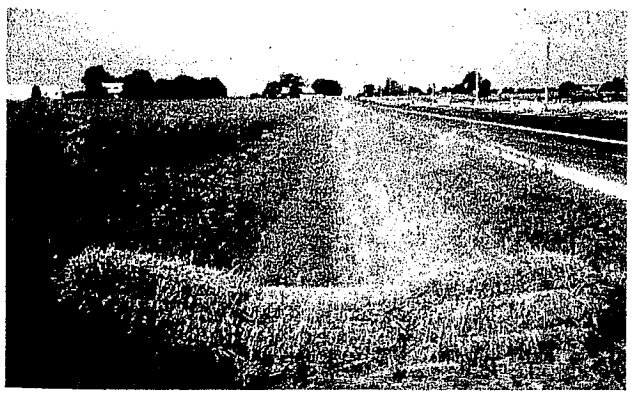
Swale biofilter having erosion control matting installed prior to permanent vegetative stabilization.

moval of sediments and reestablish vegetation upon the completion of construction.

G. Ensure that measures are in place to divert runoff while vegetation is being established. If runoff is probable and cannot be diverted, ensure that adequate erosion control measures are in place.

H. Inspect liners, underdrains, riprap, and check dam spacing, if they are included in the approved plan.

I. Make sure that any level spreaders are completely level and sufficiently stable to remain level during their operation.



The same biofiltration swale with permanent vegetative stabilization three weeks later.

J. Check for proper installation of pretreatment devices, if required.

K. Ensure that curb cuts and their locations are as specified. ***Ensure that the vegetation is not higher than the curb cut.***

9. ONCE CONSTRUCTION IS COMPLETED

Upon satisfactory completion of construction, there are several actions that should be taken with respect to the completed project and its files. The information can be entered in any many ways. It can include microfilming the plans, having a data spreadsheet for pertinent information, or maintaining a physical file of the completed project containing all information needed for future inspections and actions. ***It is very important that this process includes a means of notifying the inspection agency to make them aware of the need for future inspections.***

This process starts upon completion of the construction phase of the project. Specific tasks include:

- Entering pertinent information from the completed files into a database. Future retrievals of this information will provide the basis for future maintenance inspections.

- The "As-Builts" or Record Drawings should be attached to the file and made an essential part of the permanent record. It is becoming more common for electronic cad (autocad) drawings to be required, allowing communities a more efficient means of updating system-wide stormwater inventory maps.

- Copies of all inspection reports and the final inspection report should be placed in the file.

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- The permanent file should tell who is responsible for subsequent maintenance inspections and physical maintenance of the completed facility. These responsibilities should be set forth in a legal document, signed by the individual assuming maintenance responsibility. This will help to assure their commitment to assuming and performing these tasks.

- The date for a subsequent maintenance inspection should be established at this time to ensure the initiation of permanent ongoing inspections of the completed facility.

10. RECOMMENDATION FOR INSPECTOR TRAINING AND CERTIFICATION PROGRAMS

Initial and subsequent on-going training are essential for inspectors to learn the initial skills and maintain their level of understanding. It is also important that they be aware of their obligations on new types of BMPs or variations in design of existing BMPs.

Inspector training should include a specific course designed to provide inspectors with the minimum information necessary to conduct site inspections during and after construction. This course should be given to public inspectors and private individuals who are responsible for inspecting and maintaining stormwater management systems. This training is a mandatory program component if the program's law or rules require inspections during or after stormwater system construction. The educational program should include, at a minimum, the following items.

- Why implementation of stormwater management facilities is important.
- Applicable laws and regulations.
- What the individual types of facilities are and how they function in various scenarios.
- How to read a design plan and accompanying specifications.
- How to inspect a site.
- How to complete an inspection form.
- How to read a topographic map.
- Soils information including knowledge of soil texture, consistency, etc. to be able to recognize various soils in the field.
- Site erosion and sediment control strategies and practices for consideration in protection of stormwater management facilities.
- Enforcement procedures and penalty provisions.
- Detailed information on local vegetation including information on suitability of various types of vegetation for different purposes. This would include vegetation that is water and drought tolerant.

Education is essential to effective program implementation. Education on stormwater system construction is an important component of this overall educational process. ***Without education, the expectations for successful construction of stormwater management systems is reduced.*** The training recommended in this chapter could be supplemented with the educational program discussed in Chapter 7. The training probably is best done by including it in an educational program on site construction which should include erosion and sediment control and stormwater management system construction. The issue of how many educational programs and the extent of each program is best made at the local level where the programs are most appropriately given.

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APPENDICES

Construction Inspection Forms for Stormwater Management Facilities

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APPENDIX 6-1

Preconstruction Inspection Meeting Topics Form

A014152

State of New Jersey
Department of Environmental Protection
Stormwater Management Facility Maintenance Manual

Example Preconstruction Meeting Topics

A. GENERAL INFORMATION

1. Attendance
2. Purpose of project and background information
3. Emergency telephone numbers
4. Construction photograph requirements
5. Project sign requirements
6. Starting date
7. Review of contract documents, including insurance certifications, bonds and subcontractors documents
8. Field office requirements
9. Responsibility for notification of affected property owners and residents
10. Chain of command for communications and correspondence
11. Construction schedules
12. Key personnel and their degree of involvement in the project (inspector, owner, engineer, agencies, etc.)

B. POLICE AND FIRE DEPARTMENT CONCERNS

1. Traffic control
2. Barricades and signs conforming to the uniform manual
3. Noise ordinance considerations
4. Working hours, including weekend and holidays
5. Vandalism and preventative measures
6. Flagmen and traffic control officers
7. Equipment storage and vehicle parking
8. Emergency vehicle access
9. Underground tank locations and precautionary construction procedures
10. Storage and use of hazardous materials

C. UTILITIES

1. Utility locations and mark-outs
2. Coordination of utility relocations
3. Emergency phone numbers of utility companies

D. FUNDING AND PAYMENTS

1. Funding sources and availability
2. Procedures and dates for payment estimates
3. Dates for payments to contractor
4. Breakdown of lump sum items for partial payment
5. Policy for payment for materials on site at the close of a payment period

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6. Retained monies during and after construction
7. Requirements of funding agencies

E. CHANGE ORDERS AND EXTRA CLAIMS

1. Requirements for additional work and submittal of change orders
2. Procedures and schedule for review and recommendations of change orders
3. Procedures for negotiating extra claims and change orders

F. CONSTRUCTION ACCESS AND EASEMENTS

1. Easement locations and maps
2. Responsibility for locating and staking easements
3. Available survey data for the site
4. Access requirements and staging areas
5. Easement restrictions and restoration requirements

G. CONSTRUCTION DETAILS

1. Unique or complex aspects of the project
2. Testing laboratories and sampling procedures
3. Cold and hot weather protection measures
4. Blasting requirements
5. Dump site location for construction related materials
6. Shop drawing requirements and review procedures
7. Specific construction techniques and procedures
8. Review of technical section of the specifications

H. PERMITS

1. Status of all required federal, state, and local permits
2. Permit restrictions and conditions
3. Start-of-work notifications

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APPENDIX 6-2

General Site Inspection and Notice to Comply Forms

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Construction Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Weather Conditions _____

Site Status _____ (active, inactive, completed)

Site Conditions:

acceptable _____
Unacceptable _____
In compliance with approved plan _____
Approved plan is adequate for the site _____

Written Comments:

_____
_____
_____
_____
_____
_____
_____

Action to be taken:

No action necessary. Continue routine inspections _____
Correct noted site deficiencies by _____
1st notice _____
2nd notice _____
Submit plan modifications as noted in written comments by _____
Notice to Comply issued _____
Final inspection, project completed _____
Other _____

_____
Received by

_____
Inspector

I acknowledge receipt of this inspection report. My signature does not imply agreement or disagreement with its content.

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number report.

white: developer/contractor yellow: file pink: legal/enforcement

A014156

Notice to Comply Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date _____

To: _____

Address: _____

_____

Project/Site/Contract Name _____

An inspection of the above referenced project on _____(Date) revealed that the site is not in compliance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations, and the following violations exist:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Notice is hereby given that the above violations shall be corrected in accordance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations on or before _____ (Date). The site will be re-inspected at that time to determine if the site has been brought into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

Failure to comply with this notice will result in the initiation of legal action by the Department in order to bring the site into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

_____ Received by

_____ Inspector

I hereby acknowledge receipt of this notice to comply. My signature does not imply agreement or disagreement with its content.

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number

white: developer/contractor yellow: file pink: legal/enforcement

A014157

APPENDIX 6-3

Sediment/Stormwater Management Basin Construction Inspection Checklist

A014158

Sediment/Stormwater Management Basin Construction Checklist

For Permanent structures per Delaware NRCS Pond Code 378 and Delaware Sediment and Stormwater Regulations
(Developed by Randy Greer, Environmental Engineer)

KEY	*PROJECT INFORMATION*
✔ Item meets standard	Project ID: _____
✖ Item not acceptable	Contractor: _____
N/A Item not applicable	Inspector: _____
C Item requires engineer's certification	Date(s): _____

I. Materials and Equipment

_____ Pipe and appurtenances on-site prior to construction and dimensions checked.
- _____ 1. Material (including protective coating, if specified)
- _____ 2. Diameter
- _____ 3. Dimensions of metal riser or pre-cast concrete outlet structure
- _____ 4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans
- _____ 5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope
- _____ 6. Number and dimensions of prefabricated anti-seep collars
- _____ 7. Watertight connectors and gaskets
- _____ 8. Outlet drain valve

_____ Appropriate compaction equipment available, including hand and small power tamps

_____ Project benchmark near pond site

_____ Equipment for temporary de-watering

II. Subgrade Preparation

_____ Area beneath embankment stripped of all vegetation, topsoil, and organic matter

_____ Cut-off trench excavated a minimum of 4 feet below subgrade and minimum 4 feet below proposed pipe invert, with side slopes no steeper than 1:1

_____ Impervious material used to backfill cut-off trench

III. Pipe Spillway Installation

_____ Method of installation detailed on plans

A. Bed preparation
- _____ Installation trench excavated with 1:1 side slopes
- _____ Stable, uniform, dry subgrade of relatively impervious material *(If subgrade is wet, contractor shall have defined steps before proceeding with installation)*
- _____ Invert at proper elevation and grade

A014159

B. Pipe placement

_____ Metal/Plastic pipe

_____ 1. Watertight connectors and gaskets properly installed

_____ 2. Anti-seep collars properly spaced and having watertight connections to pipe

_____ 3. Backfill placed and tamped by hand under "haunches" of pipe

_____ 4. Remaining backfill placed in max. 8" lifts using small power tamping equipment until 2 feet cover over pipe is reached

_____ Concrete pipe

_____ 1. Pipe set on blocks or concrete slab for pouring of low cradle

_____ 2. Pipe installed with rubber gasket joints with no spalling in gasket interface area

_____ 3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set

_____ 4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant

_____ 5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix

_____ 6. Upper half of anti-seep collar(s) formed with reinforcing steel set

_____ 7. Concrete for collar of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ 8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary

C. Backfilling

_____ Fill placed in maximum 8" lifts

_____ Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment

IV. Riser/Outlet Structure Installation

A. Metal riser

_____ Riser base excavated or formed on stable subgrade to design dimensions

_____ Embedded section of aluminum or aluminized pipe to be painted with zinc chromate or equivalent on **inside and outside** surfaces

_____ Set on blocks to design elevations and plumbed

_____ Reinforcing bars placed at right angles and projecting into sides of riser

_____ Concrete poured so as to fill inside of riser to invert of barrel

B. Pre-cast concrete structure

_____ Dry and stable subgrade

_____ Riser base set to design elevation

_____ If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely

_____ Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway

C. Poured concrete structure

_____ Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set

_____ Structure formed to design dimensions, with reinforcing steel set as per plan

_____ Concrete of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

A014160

V. Embankment Construction

A. Fill material
_____ Soil engineer's test
_____ Visual test by inspector

B. Compaction
_____ Soil engineer's test
_____ Visual test by inspector

C. Embankment
_____ Fill placed in maximum 8" lifts and compacted with appropriate equipment
_____ Constructed to design cross-section, side slopes and top width
_____ Constructed to design elevation plus allowance for settlement

VI. Impounded Area Construction

_____ Excavated/graded to design contours and side slopes
_____ Inlet pipes have adequate outfall protection
_____ Forebay(s)
_____ Wet pond requirements
_____ 1. 10 feet reverse slope bench one foot above normal pool elevation
_____ 2. 10 feet wide level bench one foot below normal pool elevation

VII. Earth Emergency Spillway Construction

_____ Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.
_____ Excavated to proper cross-section, side slopes and bottom width
_____ Entrance channel, crest, and exit channel constructed to design grades and elevations

VIII. Outlet Protection

A. End section
_____ Securely in place and properly backfilled

B. Endwall
_____ Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified
_____ Endwall formed to design dimensions with reinforcing steel set as per plan
_____ Concrete of an approved mix and vibrated into place. (Protected from freezing, if necessary
_____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

C. Riprap apron/channel
_____ Apron/channel excavated to design cross-section with proper transition to existing ground
_____ Filter fabric in place
_____ Stone sized as per plan and uniformly placed at the thickness specified

A014161

IX. Vegetative Stabilization

_____ Approved seed mixture or sod
_____ Proper surface preparation and required soil amendments
_____ Excelsior mat or other stabilization materials, as per plan

X. Miscellaneous

_____ Toe drain
_____ Temporary dewatering device installed as per plan with appropriate fabric, stone size and perforations if included
_____ Drain for ponds having a permanent pool
_____ Trash rack/anti-vortex device secured to outlet structure
_____ Trash protection for low flow pipes, orifices, etc.
_____ Fencing (when required)
_____ Access road
_____ Set aside area for clean-out maintenance

A014162

APPENDIX 6-4

Stormwater/Sediment Pond Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

A014163

Stormwater/Sediment Pond Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

(Developed by Randy Greer, Environmental Engineer
Delaware Department of Natural Resources and Environmental Control
Sediment and Stormwater Program)

1. NOTIFY PLAN REVIEW/CONSTRUCTION REVIEW AGENCY AS REQUIRED

   a. Arrange the preconstruction meeting
   b. Clear up any questions regarding the approved plan

2. PRE-CONSTRUCTION MEETING WITH CONSTRUCTION REVIEW AGENCY

   a. Review the site plan and layout and discuss any problems or changes needed to the plan
   b. Obtain approvals for the plan changes from the appropriate inspection or plan review agency
   c. Discuss the stages of construction which notification to the construction review agency is needed

3. SITE LAYOUT

   a. Make sure site layout agrees with the plan
   b. Check elevation of the proposed outfall structure
   c. Physically mark any areas not to be disturbed, such as limit of disturbance, wetlands, property lines, etc.

4. INSTALL PERIMETER EROSION AND SEDIMENT CONTROLS

   a. Sediment controls will be needed at the downstream perimeter during the clearing and grubbing for the pond wherever sediment may leave the site.

5. INSTALL TEMPORARY CHANNEL DIVERSION

   a. Divert clean water flow away from pond area
   b. Stabilize the diversion

6. CLEAR AND GRUB THE POND AREA

7. REMOVE TOPSOIL FROM THE POND AREA

   a. Stockpile the soil in an approved location
   b. Stabilize the stockpile area

8. FACILITY STAKEOUT

   a. Stakeout centerline of embankment, outside and inside toe of slopes

A014164

9. CORE TRENCH/EMBANKMENT AREA

a. Arrange to meet the site reviewer to discuss location of core trench
b. If core trench is needed, determine where material will come from before trench is opened.
c. Make arrangements for de-watering of the core trench if necessary
d. Excavate for core trench
e. Fill core trench with suitable material assuring proper compaction to existing ground elevation

10. CONSTRUCT OUTFALL CHANNEL

a. Rock outlet protection with filter cloth
b. Remaining channel constructed and stabilized

11. INSTALL BARREL WITH ANTI-SEEP COLLARS

a. This should be done BEFORE any embankment work
b. Prepare the bedding for the barrel
c. Place barrel and anti-seep collars checking pipe grade
d. Watertight pipe connections to be checked
e. Backfill of barrel with particular attention to the compaction requirements. All structural backfill shall be completely free of rocks and other objectionable material

12. RISER PLACEMENT

a. Check riser structure for conformance to specifications
b. Check elevation of structure
c. Set riser and pour concrete riser base

13. INSTALL ANY EROSION CONTROL STRUCTURES REQUIRED

14. CONSTRUCT REMAINING CORE AND EMBANKMENT

a. Most impervious material placed in core of embankment
b. Material should be checked and approved for suitability
c. Compact the embankment according to specifications
d. Check UNSETTLED elevation and top width of embankment
e. Stabilize embankment

15. DIVERT FLOWS INTO PIPE SYSTEM

16. CONSTRUCT EMERGENCY SPILLWAY

a. If earth spillway, construct in undisturbed ground
b. Check elevation of control section and exit channel

17. INSTALL INFLOW CHANNELS

a. Stabilize according to plan including pipe outfalls into pond

A014165

18. COMPLETE EXCAVATION OF POND TO FINAL GRADE

19. VEGETATIVELY STABILIZE ALL DISTURBED AREAS

20. COMPLETE POND CONVERSION

    a. Requires approval of inspector to convert from sediment to stormwater control
    b. Properly de-water the pond in an approved manner
    c. Remove accumulated sediment and restore pond to design grade. Complete final stabilization
    d. Make any structural modifications to the riser for permanent function

A014166

APPENDIX 6-5

Construction Checklists
Infiltration Practices

Basins (Appendix 6-5A)
Trenches (Appendix 6-5B)
Dry Wells (Appendix 6-5C)
Paving (Appendix 6-5D)
Swales (Appendix 6-5E)

A014167

Infiltration Basin Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Embankment		
Cut-off trench	_____	_____
Fill material	_____	_____
4. Final Excavation		
Drainage area stabilized	_____	_____
Sediment removed from facility	_____	_____
Basin floor tilled	_____	_____
Facility stabilized	_____	_____
5. Final Inspection		
Pretreatment facility in place	_____	_____
Inlets/outlets	_____	_____
Site stabilization	_____	_____
Access to facility provided	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____
Correct noted site deficiencies by _____
1st notice _____
2nd notice _____
Submit plan modifications as noted in written comments by _____
Notice to Comply issued _____
Final inspection, project completed _____

A014168

Infiltration Trench Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Material		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Observation Well		
Pipe size	_____	_____
Removable cap/footplate	_____	_____
Initial depth = _____ ft.	_____	_____
6. Final Inspection		
Pretreatment facility in place	_____	_____
Stabilization	_____	_____
Outlet	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A014169

Infiltration Drywell Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Material		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Observation Well/roof leader		
Pipe size	_____	_____
Removable cap/footplate	_____	_____
Initial depth = _____ ft.	_____	_____
6. Final Inspection		
Pretreatment facility in place	_____	_____
Debris/gutter screens	_____	_____
Stabilization	_____	_____
Outlet	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

A014170

Infiltration Paving Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Filter Fabric Placement		
Fabric specification	_____	_____
Placed on bottom, sides, and top	_____	_____
4. Aggregate Base Course		
Size as specified	_____	_____
Clean/washed material	_____	_____
Placed properly	_____	_____
5. Aggregate Filter Course		
Size	_____	_____
Clean/washed material	_____	_____
Placed Properly	_____	_____
6. Porous Surface Course		
Proper temperature/compaction	_____	_____
7 Final Inspection		
Smooth Surface & Transition	_____	_____
Test section	_____	_____
Final stabilization	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

A014171

Infiltration Swale Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Area stabilized	_____	_____
2. Excavation		
Size and location	_____	_____
Side slope stable	_____	_____
Soil Permeability	_____	_____
Groundwater/Bedrock	_____	_____
3. Check dams		
Dimensions	_____	_____
Compaction	_____	_____
4. Final Inspection		
Dimensions	_____	_____
Check dams	_____	_____
Proper outlet	_____	_____
Effective stabilization	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A014172

APPENDIX 6-6

Construction Checklist for Filtration Practices

A014173

Filtration Facility Construction Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Facility area cleared	_____	_____
Facility location staked out	_____	_____
2. Excavation		
Size and location	_____	_____
Side slopes stable	_____	_____
Foundation cleared of debris	_____	_____
Foundation area compacted	_____	_____
3. Structural Components		
Dimensions and materials	_____	_____
Forms adequately sized	_____	_____
Concrete meets standards	_____	_____
Prefabricated joints sealed	_____	_____
Underdrains (size, materials)	_____	_____
4. Completed Facility Components		
24 hour water filled test	_____	_____
Contributing area stabilized	_____	_____
Filter material per specification	_____	_____
Underdrains installed to grade	_____	_____
5. Final Inspection		
Dimensions	_____	_____
Structural Components	_____	_____
Proper outlet	_____	_____
Effective site stabilization	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A014174

APPENDIX 6-7

Construction Checklist for Biofiltration Practices

A014175

Biofiltration Construction Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Contacted _____

Site Status _____ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	_____	_____
Facility area cleared	_____	_____
Facility location staked out	_____	_____
Facility not in heavily shaded area	_____	_____
2. Excavation		
Size and location	_____	_____
Lateral slopes completely level	_____	_____
Longitudinal slopes within design range	_____	_____
3. Check dams and Level Spreaders		
Dimensions, spacing, and materials	_____	_____
Compaction	_____	_____
Level spreaders are completely level	_____	_____
4. Structural Components		
Inlets and outlets installed correctly	_____	_____
Flow bypasses installed correctly	_____	_____
Pretreatment devices installed	_____	_____
Curb cuts installed per plans	_____	_____
5. Vegetation		
Complies with planting specs.	_____	_____
Topsoil adequate in composition and placement	_____	_____
Adequate erosion control measures in place	_____	_____
4. Final Inspection		
Dimensions	_____	_____
Check dams and level spreaders	_____	_____
Proper outlet	_____	_____
Effective stand of vegetation and stabilization	_____	_____
Construction generated sediments removed	_____	_____

Action to be taken:

No action necessary. Continue routine inspections _____

Correct noted site deficiencies by _____

1st notice _____

2nd notice _____

Submit plan modifications as noted in written comments by _____

Notice to Comply issued _____

Final inspection, project completed _____

A014176

Chapter 7
Inspection and Maintenance After Construction

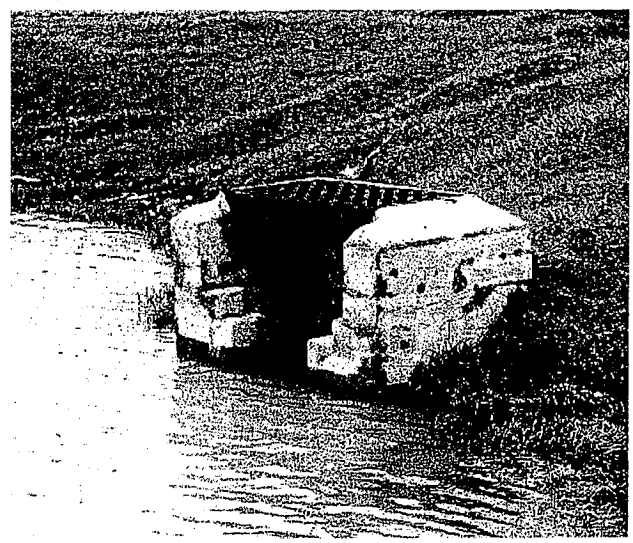
1. OVERVIEW

Once construction is satisfactorily completed, the long term assurance of adequate facility performance begins. Stormwater management systems are expected to perform their stormwater quality and quantity control functions as long as the land use they serve exists. Failure to maintain these systems can create the following adverse impacts:

- increased discharge of pollutants downstream.
- increased risk of flooding downstream.
- increased downstream channel instability, which increases sediment loadings and reduces habitat for aquatic organisms.
- potential loss of life and property, resulting from catastrophic failure of the facility.
- aesthetic or nuisance problems, such as mosquitoes or reduced property value, due to a degraded facility appearance.

All of these adverse impacts can be avoided through proper and timely maintenance of stormwater management facilities. A major concern created by these impacts is the general public's expectations about their quality of life which is provided, in part, by construction of stormwater management systems. Inadequate maintenance means the general public may have a false sense of security. ***If we are not going to adequately address the maintenance issues of stormwater management system implementation, the facilities should not be constructed in the first place.*** The most common cause of stormwater system failure is the lack of adequate and proper operation, maintenance, and management.

As discussed in Chapter 5, the owners of stormwater management systems must be educated to understand the importance of the facility, and their obligations to assure its continued function. A case study illustrates the importance of education in assuring proper OMM. One of the authors conducted a site visit to an extended dry detention system that serves a residential subdivision. The facility has a perennial or dry weather flow through it which it passes through an orifice in the outlet structure. During the winter months, children in the subdivision plugged up the orifices in the outlet structure so water would back up in the pond. This ponding let them ice skate when temperatures allowed. As a result, when spring came water could not discharge properly, water depths increased, and all of the flow was passing through the emergency spillway, which was intended to only convey infrequent emergency flows. As a result, the emergency spillway eroded and the



Broken up outlet structure. Having the grate on top doesn't really provide any factor of safety.

A014177

entire pond embankment failed. This was subsequently repaired at considerable county expense. ***This problem could have been avoided if members of the community had known why that facility was built in their community, and knew the importance of all facility components working properly.***

Good design and construction can reduce subsequent maintenance needs and costs, but they cannot eliminate the need for maintenance altogether. ***Maintenance will always be needed. It will require a long term commitment of time, money, personnel, and equipment by the individuals responsible for operation and maintenance. At the same time, assuring maintenance represents a long term commitment of public agency staff. They are needed to conduct maintenance inspections to ensure that the responsible maintenance entity is adequately performing its responsibilities.***

1.1 Intended Readers

This Chapter is equally important to:

- **Agency maintenance inspectors,**
- **Facility owners, and**
- **Facility maintenance personnel.**

In addition, individuals responsible for facility design and review should be aware of the equipment used for maintenance and normal maintenance activities. This awareness will enable them to select stormwater management system locations and develop designs that will facilitate, rather than hinder, maintenance efforts.

2. HOW MAINTENANCE CAN REDUCE ADVERSE DOWNSTREAM IMPACTS

It will be helpful to further discuss the adverse impacts of maintenance neglect mentioned in the overview. Understanding the impacts caused by inadequate or improper system OMM is very important. While some of these impacts may be obvious, an expanded discussion may lead to a greater understanding by all individuals responsible, in some way, for stormwater system operation, maintenance, and management.

2.1. Increased Discharge of Pollutants Downstream

Stormwater management systems treat stormwater runoff through a number of processes:

- Gravity settling of particulate materials. This is normally achieved by increasing the detention time of water in BMPs, so that the particle settling velocity is greater than the flow velocity of the particle towards the facility outlet.

- Filtering of particulate material by vegetation or media mixtures, such as soil, sand, gravel, compost, or other materials.

- Adsorption of pollutants onto or absorption into organic material.

Any reduction in the volume or area of storage reduces detention time or effective area of flow. This will decrease the ability of the BMP to remove pollutants. For stormwater management facilities that are designed for stormwater treatment only, lack of maintenance may negate any benefits derived from its construction. In these situations, the lack of maintenance means that the original investment of funds for stormwater treatment is, to a large extent, wasted.

A014178

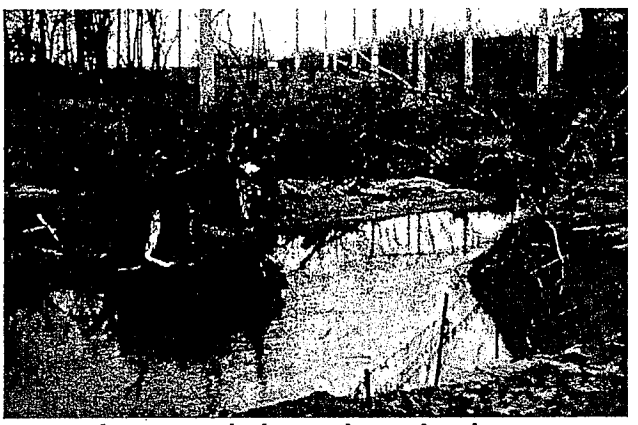
2.2. Increased Risk of Downstream Flooding

In addition to water quality reductions, there is an increased risk of flooding downstream if the necessary storage volumes are not available when they are needed. Sediments deposited on the bottom of ponds gradually accumulate and take up volume that is needed during flood events. Many times downstream land use decisions are made with the knowledge that upstream stormwater management systems reduce (or prevent increases in) floodplain elevations downstream. Development may be allowed downstream in areas protected from flooding by the upstream facilities. ***If these facilities are not maintained, a false sense of security exists within the community which could eventually result in significant loss of property and even loss of lives.***

Downstream flooding is directly related to the volume of water traveling through a watershed, together with the time needed for the water to flow through it. With respect to flooding concerns, stormwater management programs generally do not attempt to significantly reduce the total volume of water traveling downstream. Even if infiltration practices are used, they sometimes are sized only for stormwater treatment. They do not have adequate volume available to significantly reduce runoff volumes from larger storms such as the 50 or 100 year event. Instead, stormwater systems modify the time needed for water to travel through a watershed. While the volume is the same, stormwater systems detain runoff, altering the timing of the delivery of water. The end result is that the increased volume of water traveling through the watershed flows for longer periods of time even though the peak discharges are reduced.

2.3 Increased Downstream Channel Instability

Increased downstream channel instability, which increases sediment loadings and reduces habitat for aquatic organisms, may result from a lack of facility maintenance. Stormwater management facilities, depending on the local, regional, or state program, may have channel erosion prevention as a major program goal. In these situations, inadequate stormwater system maintenance may not achieve stated goals or may actually exacerbate channel erosion scour problems. This may occur because of increased stormwater discharges from sediment filled ponds, or increased volumes of stormwater being discharged from clogged infiltration practices.



Increased channel erosion in an urban environment.

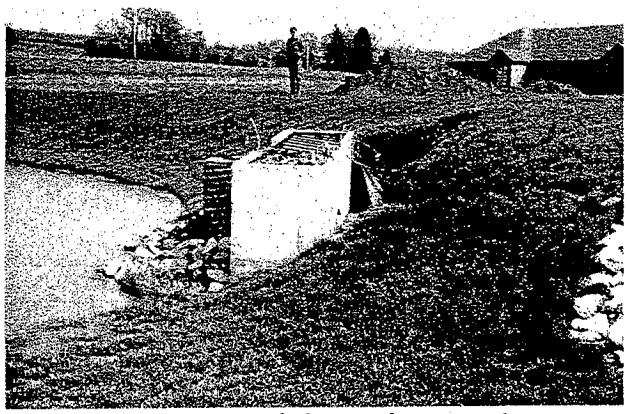
With respect to downstream habitat, the scouring of channel boundaries increases channel sedimentation which, in turn, reduces available habitat and smothers bottom dwelling organisms. Beside sediments resulting from channel erosion, improper maintenance of a stormwater management system may result in the release of eroded sediments from the facility itself, or from sediments in upstream contributing drainage areas traveling through the facility and then downstream.

A014179

2.4. Potential Loss of Life and Property

Interwoven with the increased risk of flooding and channel instability is the issue of loss of life and property. This can result from a catastrophic occurrence, such as the sudden failure of a pond embankment, or through the creation of a hazardous condition such as steep stream banks or water flowing deeper than expected.

Safety must be the single most important purpose of a stormwater management system. Loss of life associated with OMM of a stormwater management facility could have long term repercussions for the entire program. For example, a drowning in a sediment basin in Anne Arundel County, Maryland in the mid-1980's led to a County requirement that all sediment basins be fenced. The general public should be aware of any dangers associated with stormwater management systems, but they should not be adversely impacted by a poorly functioning facility.



Erosion around the outlet structure of a stormwater management pond.

Loss of property can also occur from stream channel erosion losses or through increased floodplain damage to channel boundaries resulting from inadequate performance of upstream stormwater management systems.

2.5. Aesthetic or Nuisance Problems

Aesthetic problems are generally related to the appearance of a stormwater management system. Landscaping issues such as grass mowing, tree or shrub appearance, and litter control are all aesthetic issues. They generally are not a serious concern with respect to proper functioning of a facility. However, failure to take corrective actions on small problems can eventually create a significant facility performance problem.

Trees in this stormwater detention basin are an indication that aesthetic maintenance has not been accomplished.

One common problem frequently seen around stormwater management ponds is the dumping of grass cuttings along the pond edge. The cuttings can clog outlets or increase nutrient loadings resulting in increased algae blooms. Another important aesthetic maintenance task is the management of aquatic vegetation in wet detention littoral zones or constructed wetlands. Often the vegetation will change over time, sometimes beneficially and sometimes not. The landowner must consider the aesthetics of basin maintenance initially and during the lifespan of the basin.

Mosquitoes, stagnant water, erosion around the shoreline, or vandalism are examples of nuisance problems. Nuisance problems also represent little structural concern and they are not considered a safety issue. However, nui-

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sance problems, together with aesthetic problems, can result in reduced property values due to a degraded facility appearance and reduced quality-of-life for people living or working near the facility.

3. IMPORTANCE OF CHECKLISTS

Checklists are very important to ensure that all system components are functioning as originally constructed. They are important not only during facility inspection, but they also provide a historical record of facility function. Inspection checklists help to ensure a degree of consistency. It can be expected that different individuals will inspect a facility over the years. By providing common important items in an inspection report, continuity is more easily provided. ***Inspection reports should always be provided to the individual responsible for facility maintenance so that they are aware of the status of their facility.***

3.1. Checklists for Inspection

Checklists provide for consistency of site inspection. They help to assure that all relevant facility components are inspected. Any stormwater system will function only as well as its component parts. Each component must be inspected to ensure effective overall OMM and facility performance.

Checklists, when completed and filed with facility information, provide proof that an inspection was done on a routine basis. This documentation is important in case an outside party requests to review the information, or for liability reduction to demonstrate responsible care. The inspection report also identifies any needed maintenance activities and establishes a schedule for their completion. Finally, the inspection report forms the basis for reinspection following maintenance activities to ensure satisfactory completion of the activities in accordance with the initial inspection report.

Examples of sample inspection report forms are included in the Appendices at the end of this chapter. They should be used as a template by individuals or entities responsible for facility maintenance. They should be modified to address additional or modified local criteria for facility components.

3.2. Checklists to Evaluate Stormwater System Function and Performance

When inspections are regularly conducted, checklists can provide a barometer of facility performance and they can help to determine maintenance scheduling and needs. Rates of sedimentation can be determined by comparing data from previous inspection reports. This can assist in scheduling periodic sediment removal. In a stabilized watershed, the rates of accretion should be fairly consistent. If there is a subsequent increase in the rate of sedimentation, then areas contributing stormwater to the facility should be inspected for erosion problems or sediment sources and corrective steps taken. The responsible maintenance entity must realize that elevated sediment loadings into the facility will lead to increased maintenance costs. In stormwater BMPs such as infiltration facilities, increased sedimentation could necessitate costly reconstruction of the entire facility.

Most importantly, OMM budgeting can be more accurately done if regular inspections and completion of inspection reports are done. Larger budget items can be planned for if inspection reports indicate a growing problem. An example is a riser assembly for a stormwater pond developing rust problems. This situation can be watched and minor steps taken to retard deterioration of the riser assembly, but the riser must be replaced eventually. Knowledge of the increasing rate of

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corrosion allows for funding to be generated over a longer period of time so the impact of replacement can be minimized.

4. HIGHLIGHTED EXPECTED OMM NEEDS AS A FUNCTION OF SYSTEM COMPONENTS

This section of the chapter will focus on the long term operation, maintenance, and management needs of the different types of stormwater management practices. Since each type of practice includes different components and processes, the OMM requirements are best discussed individually. For each type of BMP, information will be presented on several types of stormwater pollutants and the maintenance activities which ultimately will be needed to remove them before their accumulation adversely affects BMP performance. In addition, the sensitivity of a practice to impaired performance resulting from capture of pollutants will be discussed.

To a large extent, the type of stormwater management system will depend on the goals of a specific state/regional/local stormwater program and the problems for which it was implemented. If flooding is a major concern, retention and the various types of detention practices likely will be used. BMP design will then be based on stormwater quantity objectives. If stormwater quality is an important goal, filtration practices, along with retention and detention systems modified to improve pollutant capture, will be more common. In either case, maintenance concerns are best discussed in terms of the type of facility implemented.

With regards to pollutant reduction, most stormwater management systems are designed to remove sediments. There is enough variation in the types of facilities being used to warrant a more detailed discussion by facility type. One point constantly made is that stormwater management program implementation is best done by using a BMP treatment train concept. Infiltration facilities can reduce the total volume of stormwater runoff while other types of facilities would assist in removal of nutrients, toxic materials, metals, and oil and grease. Accordingly, good operation, maintenance, and management of stormwater systems requires awareness of most available types of BMPs since not just one type may be installed on a site.

Individuals need to be aware of the sensitivity that individual BMPs have to reduced performance caused by accumulation of pollutants. It is important to recognize that stormwater systems are not equal in terms of their ability to remove pollutants, the occurrence of storms which could cause structural damage, and their sensitivity to clogging or impaired performance. Implementing pretreatment practices can significantly reduce the potential for impaired facility performance. For facilities impacted by excess sedimentation, the primary concern is sediments resulting from construction activities. Construction of facilities must be done with a sensitivity to their impaired performance, especially if construction related sediments are allowed to enter the facility while it is being built or after construction but before overall site stabilization.

4.1. Detention and Retention Ponds

Ponds are effective at removing a variety of pollutants. For some pollutants, the performance is well documented and can be expected. For other pollutants, removal mechanisms and processes are less well defined and may vary depending on the design, expected pollutant load, and frequency of maintenance. The variation in performance for some pollutants depends, to a large extent, on whether the pollutant is in a particulate or soluble form. Ponds are less effective at removing soluble

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pollutants than removing particulates. Exceptions to this rule include BMPs such as wet detention systems or constructed wetlands, where longer detention times together with the biological processes associated with aquatic plants, provide significant reduction in soluble pollutants. These differences will be discussed in the sections on individual pollutants.

A. Sediments

Ponds are most effective at removing sediments from the water column. Figure 7-1 shows that ponds remove sediment by slowing water velocity down, thus allowing time for the sediment's downward velocity to remove the sediment from the water column. As a result, ponds need periodic maintenance to remove sediments deposited on the bottom. The use of sediment forebays can reduce the maintenance problems by reducing the frequency that sediments must be removed from the entire pond. However, this requires more frequent maintenance in the forebay areas. **As discussed in Chapter 9, more frequent maintenance can reduce the risk that accumulated sediments may be considered to be a hazardous waste.**

B. Toxic materials and metals

Toxic materials and metals may either become attached to sediments as a result of cation exchange, or they may be in a soluble form. Ponds are very effective at removing these substances when they are attached to sediments, but they are less effective at removing soluble materials. This is especially true for ponds with traditional detention times of 12 to 48 hours. Wet detention systems, with littoral zones planted with aquatic vegetation, along with constructed wetlands can provide greater removal of soluble toxics and metals. Pollutant removal effectiveness increases with residence time, with a minimum residence time of 14 days recommended. Ponds are especially effective at reducing the release of toxic substances that are inadvertently spilled during a commercial or industrial accident. The pond can function as a holding area until cleanup can be accomplished.

To assure that toxics, especially heavy metals, remain sequestered in the pond's bottom sediments, it is essential that the bottom environment remain aerobic (have oxygen) and that the pH remain neutral. Failure to do this will lead to a release of

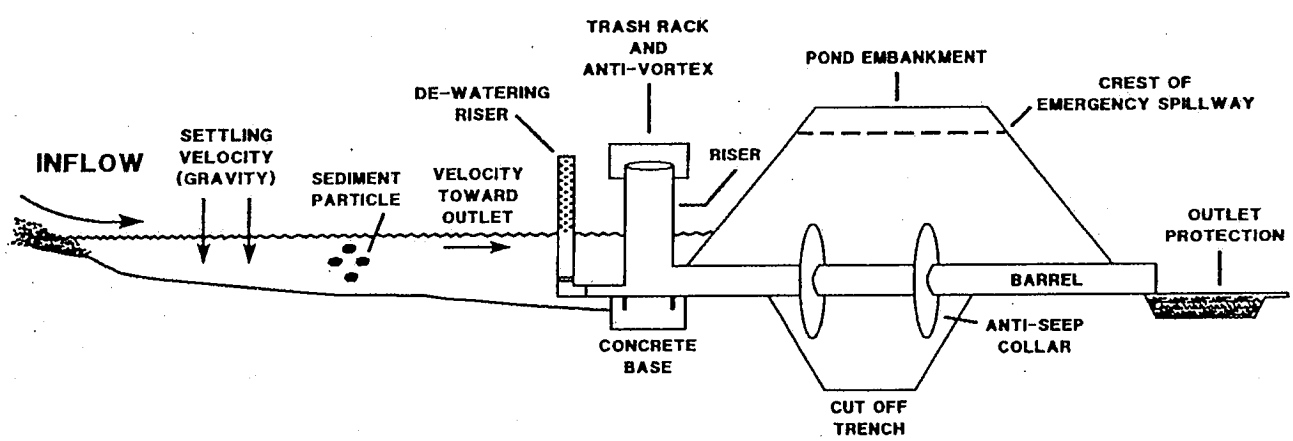

Figure 7-1. Schematic of a pond and the sedimentation process.

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the pollutants from the sediments and their reintroduction into the water column.

C. Nutrients

Like metals, nutrients, such as nitrogen and phosphorus, in stormwater can be in either particulate or soluble forms. The particulate form of phosphorus can be very effectively removed through adsorption and sedimentation. As with toxics, ponds will only remain effective at removing particulate nutrients if the bottom sediments and water remain aerobic with a pH near 7. If the pond bottom develops an anaerobic (no oxygen) zone or pH rises or falls, phosphorus previously captured can then be converted to a soluble form and reenter the water column.

Most nitrogen forms, on the other hand, are soluble. They are not removed by sedimentation but through the processes which occur during the nitrogen cycle. A key component of the nitrogen cycle is the role of anaerobic bacteria that live on a pond bottom dominated by wetlands vegetation.

If nutrients in general are of concern in program implementation, the treatment train concept is vital. Phosphorus, in particulate form, must be removed via settling and adsorption in a facility maintaining an aerobic environment. Nitrogen could then be removed in a downstream BMP with a two week residence time and anaerobic conditions. Two types of facilities are needed for total nutrient reduction. Biofiltration practices, such as vegetative swales, would be effective at reducing particulate pollutants with the stormwater then entering a constructed wetland for soluble pollutant reduction.

D. Oils and greases

Ponds provide for reduction in oils, greases, and other hydrocarbons through volatilization (vaporization). The effectiveness of this process depends on air and water temperatures, winds, and surface turbulence. One seldom mentioned benefit of stormwater management ponds, especially at a commercial or industrial site, is their ability to capture pollutants released during a site spill. For example, a constructed wetland at a Delaware shopping mall received approximately 500 gallons of fuel oil that was spilled on the mall parking lot. The oil entered one of the forebays of the constructed wetland where it was fairly easily cleaned up. Without the pond, the oil would have traveled through the storm drain system and entered receiving waters. This would have created a serious environmental impact and cleanup would have been much more difficult and costly.

On residential sites, oil or automotive fluids may be inappropriately disposed by individual property owners. ***The single most important maintenance recommendation for residential property owners is pollution prevention and pollutant source control in their day to day activities at home.***

E. The Sensitivity of the Facility to Impaired Performance

One of the greatest benefits of stormwater management ponds is their resilient performance even when excessive pollutant loadings enter the facility. However, performance will suffer if sediment is introduced in large amounts over a lengthy time frame. Sediments reduce the volume of storage and reduce detention times which ultimately reduce the pond's pollutant reduction effective-

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ness. This impaired function is not be expected to dramatically occur in a short time frame, but occurs cumulatively over a longer time period if the incoming pollutant loads are consistently elevated.

4.2. Infiltration Facilities

Infiltration facilities, when properly designed and constructed, provide significant pollutant reduction benefits. They also are very effective at reducing the total volume of runoff. By reducing the runoff volume, they reduce downstream channel erosion, reduce the decline in stream baseflow, and reduce pollutant delivery downstream. ***Infiltration practices are sensitive to pollutant clogging of the sides and bottom at the soil/stormwater interface.*** Excessive sedimentation can clog these facilities quickly.

A. Sediments

Infiltration practices are effective at reducing the downstream movement of sediments. Removing coarser sediments does not significantly impair their function, but finer grained sediments (below 43 ug) can cause clogging of the facility.

B. Toxic materials and Metals

Infiltration facilities can also be effective at removing toxic materials and metals. ***To minimize the potential that pollutants will move through the soil and into the ground water, infiltration practices should have an organic layer of soil which allows the toxics or metals to attach to the soil particles. Additionally, infiltration practices should be vegetated to help reduce soluble forms of metals. The vegetation's roots also help to maintain the soil's permeability.*** Using coarse sandy materials for infiltration will have limited pollutant reduction benefits.

C. Nutrients

Infiltration practices are effective at phosphorus removal as they capture a large percentage of particulate phosphorus and maintain an aerobic environment that keeps the particles attached to the soil in the facility bottom. Nitrogen, on the other hand, can travel through the infiltration system's soils and into the underlying ground water unless the bottom contains organic soils. If nitrogen removal is a program goal, constructed wetlands may be a more appropriate stormwater management practice, especially in areas with coarse sandy soils.

D. Oils and greases

Infiltration facilities may not be effective in areas where significant oil and grease delivery to the facility is expected. Pretreatment of runoff to remove oil and greases should be done before it enters the infiltration system. Significant loadings of oil and greases will cause premature clogging of these facilities and dramatically increase maintenance obligations.

E. The Sensitivity of the Facility to Impaired Performance

Infiltration facilities are very sensitive to impaired performance if excessive amounts of sediments or oils and greases are introduced into the facility. The greatest problem is clogging of soils in the sides and bottom of the infiltration system. This can occur fairly rapidly if inflow pollutant levels are not reduced by pretreatment practices. Other pollutants which are attached to sediments, such as toxic materials, metals, and phosphorus, are not considered a clogging concern. Another problem is poor drainage as a result of high water table, groundwater mounding, or a confining soil layer.

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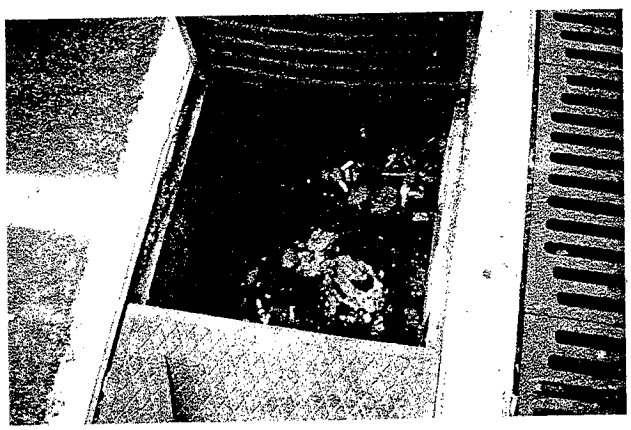
Prolonged wetness encourages microorganism growths that tend to clog the soils.

4.3. Filtration Facilities

Filtration practices have many variations which can enhance their ability to remove a variety of pollutants. Most filters, such as those used in Austin, Texas, Washington, D.C., Florida, and Delaware, use sand as the filter media. To be effective in reducing stormwater pollutants, the sand needs to be fairly fine grained. However, finer grained sands have a slower flow rate than coarser sands creating a careful balancing act in the design of filters. Other filtering materials being developed around the country include compost, activated carbon, and peat. The potential benefits of using these alternative media will not be discussed in this document as they are still somewhat experimental and little is known about their OMM requirements.



Sand filter showing trapped oils and greases.

A. Sediments

Filtration systems are very effective at removing sediments from stormwater. Since most filter designs include some type of detention, sediments are removed from runoff through settling and filtration. Most filter designs require at least 18 inches of sand, which has proven effective in trapping sediments. Another reason at least 18 inches of filter media is recommended is to allow maintenance by scraping an inch or two of sand from the surface of the filter. After several maintenance operations reduce the sand thickness to 12 inches, new sand can be added to restore the thickness to 18 inches. Experience has shown that most pollutants will only penetrate down a few inches into a filter made of fine sands. However, the coarser the sand, the farther pollutants will travel and the more filter media that will need to be removed or replaced when maintenance is finally done.

B. Toxic materials and metals

Toxic materials and metals are removed in filters when they attach to sediments or when they pass through organic materials. This occurs in most sand filters since the surface of the filter becomes very organic as a result of trapping fine sediments and oils and greases. The organic material enhances the ability of the sand filter material to remove toxics and metals. The use of alternative filter media, such as peat, also can enhance the ability of filters in removing toxic materials.

C. Nutrients

Filtration systems only remove particulate nutrients. As such, they can be somewhat effective at removing phosphorus from stormwater. As currently designed, however, they have very little ability to remove nitrogen. Experimental systems and various filter media may improve the nitrogen removal efficiency of sand filters.

D. Oils and greases

Filtration facilities are very effective at removing oil and greases. The Delaware fil-

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ter was developed primarily for removal of hydrocarbons from small, intensely urban sites, such as gas stations or fast food restaurants. The sedimentation chamber is important in removing hydrocarbons as oil and solids adhere to each other. Oils and greases penetrate only an inch or so into the filter media before being bound up in the sand. However, expectations of performance depend on the gradation of the filter media. Several filter designs recommend C-33 concrete sand as the specified filter media.

E. The Sensitivity of the Facility to Impaired Performance

With respect to maintenance, the question is not if a filter system will clog, but when. Filter systems are very sensitive to excessive loadings of oil and grease which can clog the surface of the filter. The sand filter in Rehoboth Beach, Delaware, provides a good case study. The filter normally requires monthly inspection, with cleanout of the sand surface twice per year. In one instance, an individual dumped waste oil into the facility and immediately caused the sand filter to clog. On one hand, the filter was effective at preventing the downstream migration of waste oil, but this effectiveness caused it to quickly clog.

Sediments can also be a problem for stormwater filters, especially if they are fine grained sediments in the silt/clay category. Coarser sediments do not cause a significant reduction in permeability of the sand and they are generally removed in the sedimentation chamber of the facility.

4.4 Biofiltration Facilities

Biofiltration facilities generally include vegetative filter strips and swales. Physical filtration by vegetation is an important pollutant removal component of biofiltration facilities. Another important filtration mechanism, depending on their character, may be infiltration of stormwater runoff through the surrounding surface and subsurface soils.

A. Sediments

Biofiltration facilities are very effective at removing sediments from stormwater. Their effectiveness is based, to a large extent, on the duration of flow through them. The longer the flow path and residence time, the higher the effectiveness in removing sediments.

B. Toxic materials and metals

There is little information available on the effectiveness of biofiltration facilities in removing organic toxic materials. They are moderately effective (60-75%) at removing metals from stormwater. Removals are fairly low for soluble metals such as zinc or copper.

C. Nutrients

Biofiltration facilities are not very effective at nutrient removal. Phosphorus removal is very modest while nitrogen removal is negligible. A greater level of performance can be expected for nutrient reduction if the biofilter is mowed and the grass cuttings removed from the drainage system. This may not be a realistic expectation as it may rely on numerous individual property owners to do, especially for biofiltration facilities located in residential communities.

D. Oils and greases

Biofiltration practices are effective at oil and grease reduction. They are most effective in removing fairly low levels of oil

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and grease and can be overwhelmed by excessive loadings.

E. The sensitivity of the facility to impaired performance

Biofiltration facilities are susceptible to impaired performance primarily as a result of excess sediment loadings smothering vegetation. Oils and greases can also be a serious concern as their entry could kill vegetation. These impacts could occur very quickly if large amounts of these pollutants are introduced in a short time frame.

5. INSPECTION FREQUENCY

Suggested inspection frequencies are included in the inspection forms in the Appendices at the end of this chapter. These frequencies should be considered as the maximum interval between inspections. ***It is important to remember that inspections can never be done frequently enough.*** More frequent inspections, especially for certain practices such as filters and infiltration practices, should be done whenever possible.

Inspection frequency for stormwater management system maintenance depends on two principal factors:

- local climate and precipitation
- the type of stormwater system

The influence of local climate and precipitation on maintenance frequency will be discussed in the following section, while the influence of practices was discussed in the previous section.

5.1. Local Climate and Precipitation

The frequency of maintenance depends on how much and how often it rains, the potential for large events, and the occurrence of snow and ice. Climate provides one of the foundations upon which stormwater management systems are designed and constructed. ***The recommended time frames for inspection and maintenance will vary depending on local climate and rainfall conditions. It is very important to carefully consider these factors when determining inspection frequencies for a specific stormwater management program.***

A. Local climate

An important local climate consideration is the seasonal aspect of rainfall. A region of the country having a defined wet or dry season will need to consider the maintenance requirements associated with these distinct seasons. This is especially true of practices for which inspections are recommended monthly. During a normal wet season, inspections should be done according to the recommended schedule. However, monthly inspections are probably too frequent during a normal dry season when less frequent inspections will suffice. There is value to conducting inspections more frequently. However, unless they are done voluntarily by an assigned maintenance entity, public inspections will cost money and require staff resources typically unavailable to most stormwater programs. ***Reducing the frequency of inspections during a dry season may be appropriate and allow resources to go farther. However, the appropriateness of less frequent inspections during the dry season ultimately will depend on the type of practices and the drainage area it serves.*** The recommended inspection frequencies presented in this Handbook are for those areas which receive rainfall throughout the year.

In addition to the seasonality of rainfall, vegetation growing seasons, especially the dormant seasons, will have an impact on how of-

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ten a biofiltration or constructed wetland will need to be inspected. The dormant season may provide a good opportunity to inspect a facility for erosion problems due to a winter die back of the vegetation. Areas which could not be inspected during the growing season may be visible when the vegetation dies back.

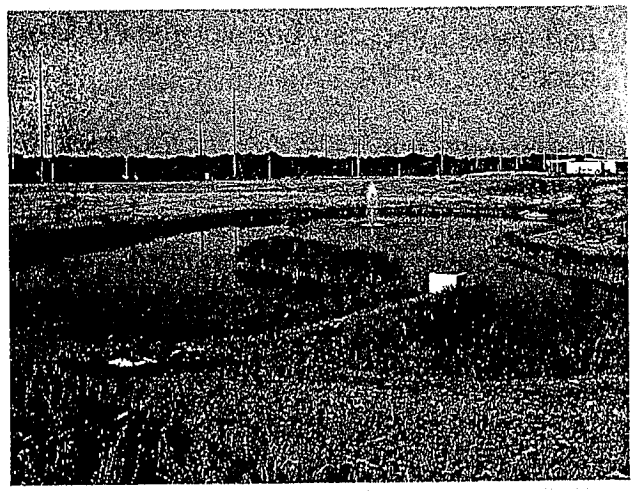
B. Precipitation

The characteristics of storms, such as rainfall intensity, depth, inter-event time, and percentage of annual precipitation as snow or rain, is also an important factor in determining inspection frequency. Total annual precipitation in the Pacific Northwest is similar to rainfall depths in the mid-Atlantic region, but the nature of rainfall in terms of inter-event dry period, average depth of individual storms, and the seasonal nature of the rainfall is very different. Thus, far different inspection frequencies are merited.

Simply stated, the more rainfall events and the greater the pollutant loading, the more work a stormwater management facility must do. Increased use or loading is directly related to the need for maintenance. ***Inspections may be needed more frequently in areas having a greater number of storms and greater depths per event.***

6. AESTHETIC AND FUNCTIONAL MAINTENANCE

Maintenance can be broken down into a number of different categories, but two primary categories are aesthetic/nuisance maintenance and functional maintenance. These two categories can overlap at times. They are mutually important to each other and each is equally important. ***Functional maintenance is important for performance and safety reasons, while aesthetic maintenance is important primarily for public acceptance of stormwater facilities, and because it may also reduce needed functional maintenance activities.***



A well landscaped pond in Newark, Delaware is a centerpiece for the office park.

Both forms of maintenance are needed and both must be combined into an overall stormwater management system maintenance program. Both forms of maintenance are included in the checklists in the Appendices to this chapter.

6.1. Aesthetic Maintenance

Aesthetic maintenance primarily enhances the visual appearance and appeal of a stormwater facility. A stormwater system with a good appearance will allow the facility to more easily become an integral part of a community. Aesthetic maintenance is obviously more important for those facilities that are very visible. Underground stormwater systems do not have the need for aesthetic maintenance that above ground, open air systems have. Generally, aesthetic maintenance is more important at ponds and biofiltration facilities, although it may also be important for certain types of filtration and infiltration facilities, such as Austin's sand filter design or landscape infiltration basins. The following activities can be included in an aesthetic maintenance program:

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A. Graffiti removal

The timely removal of graffiti will improve the appearance of a stormwater system. Timely removal will also tend to discourage further graffiti or other acts of vandalism.

B. Grass trimming

Trimming of grass around fences, outlet structures, hiker/biker paths, and structures will provide a more attractive appearance to the general public. As much as possible, the design of stormwater facilities should incorporate natural landscaping elements which require less cutting and/or trimming. However, there often are areas where mowing will be necessary to maintain attractiveness as perceived by the average individual.

C. Control of weeds

In situations where vegetation has been established, undesirable plants can be expected. These undesirable plants can adversely impact the aesthetics of a stormwater facility. This can also apply to wetland stormwater systems and wet detention littoral zones which may be invaded by undesirable aquatic plant species. These undesirable plants can be removed through mechanical or chemical means. If chemicals are used, the chemical should be used as directed and left over chemicals disposed of properly.

D. Miscellaneous details

Careful, meticulous, and frequent attention to performing maintenance tasks such as painting, tree pruning, leaf collection, debris removal, and grass cutting (where intended) will allow a stormwater management system to maintain an attractive appearance and help maintain its functional integrity.

6.2. Functional Maintenance

Functional maintenance is necessary to keep a stormwater management system operational at all times. Functional maintenance has two components:

- Preventive maintenance
- Corrective maintenance

6.2.1. Preventive maintenance

Preventive maintenance is the maintenance which is done on a regular basis as detailed in the checklists contained in the Appendices to this chapter. Preventive maintenance tasks include upkeep of any moving parts, such as outlet drain valves or hinges for grates, or maintenance of locks. Preventive maintenance can also include maintenance of vegetative cover to prevent erosion. Examples of preventive maintenance include:

A. Grass mowing

Actual mowing requirements at a facility should be tailored to the specific site conditions, grass type, and seasonal variation in climate. Local soil conservation districts or cooperative extension service offices can provide assistance in determining maintenance requirements for various types of vegetation.

Routine mowing of a detention facility.

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B. Grass maintenance

Grass areas require limited periodic fertilizing, de-thatching, and soil conditioning in order to maintain healthy growth. Provisions may have to be made to reseed and reestablish grass cover in areas damaged by sediment accumulation, stormwater flow, or other causes.

C. Vegetative cover

Trees, shrubs, and other ground cover require periodic maintenance, including fertilizing, pruning, and pest control.

D. Trash and debris

A regularly scheduled program of debris and trash removal will reduce the potential for outlet structures, trash racks, and other facility components from becoming clogged and inoperable during storm events. In addition, removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats. Disposal of debris and trash must comply with all local, county, state, and federal waste control programs. Only suitable disposal and recycling sites should be used.

Example of clogged inlet causing erosion when water overflowed onto vegetated areas adjacent to a stormwater pond.

E. Sediment removal and disposal

Accumulated sediments should be removed before it threatens the operation or storage volume of a stormwater management system. Disposal of sediments is discussed in Chapter 9 and must comply with local, county, state, or federal requirements. Only suitable disposal areas should be used. Sediment removal in infiltration systems must also include monitoring the porosity of the subbase, replacing or cleaning the pervious materials as necessary, and reestablishing vegetation.

F. Mechanical components

Valves, sluice gates, pumps, fence gates, locks, and access hatches should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations. All mechanical components should be operated during each maintenance inspection to assure continued performance.

G. Elimination of mosquito breeding habitats

The most effective mosquito control program is one which eliminates potential breeding habitats, or, in the case of open

Potential mosquito habitat resulting from inadequate drainage.

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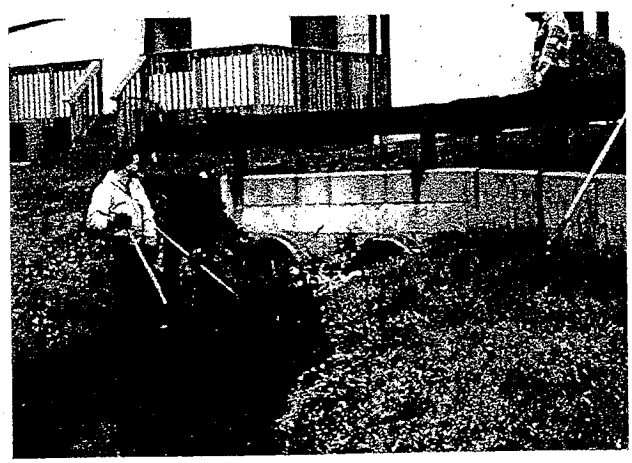
water ponds or wetlands, ensures that optimal conditions are maintained for the survival of mosquito control organisms. ***Any stagnant pool of water can become a mosquito breeding area within a matter of days.*** Ponded water in open cans, tires, and areas of sediment accumulations or ground settlement can become mosquito breeding areas. Local mosquito control programs can be contacted for assistance and advise on minimizing mosquito problems.

H. Facility maintenance

A maintenance program for monitoring the overall performance of the stormwater management system should be established. Wet detention and wetland systems, are especially, complex environments. They require a healthy aquatic ecosystem to provide maximum benefits and to minimize needed maintenance. It is important to remember that potentially large problems can be avoided if preventive maintenance is done in a timely fashion.

6.2.2. Corrective maintenance

Corrective maintenance is required on an emergency or non-routine basis to correct problems and to restore the intended operation and safe function of the stormwater management system. Corrective maintenance is not done on a scheduled basis but on an as needed basis. Failure to promptly address a corrective maintenance problem may jeopardize the performance and integrity of the facility. It may also present a potential safety problem to those living adjacent to or downstream of the facility. Corrective maintenance activities include:.



Rermoval of debris from the entrance of an outlet structure in a detention facility.

Sediment cleanout of a stormwater management pond.

A. Removal of debris and sediment

Sediment, debris, and trash which threaten the ability of the facility to store or convey water should be removed immediately and properly disposed of to restore proper functioning of the facility. A blocked inlet or outlet means that stormwater will travel in an area that was not normally designed as a flow path. In the case of an inlet, the stormwater could travel over a curb onto a grassed area and scour that area. If the outlet is blocked, water will back up in the facility and may travel through the emergency spillway or overflow area. These areas are not designed for frequent flow and may become eroded. If sediments are clogging a facility component, the lack of an available disposal site should not delay removal of the sediments. Temporary arrangements should be made for handling

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the sediments until a more permanent arrangement is made.

B. Structural repairs

Repairs to any structural component of the facility should be made promptly. Equipment, materials, and personnel must be readily available to perform repairs on short notice. The immediate nature of the repairs depends on the type of damage and its effects on the safety and operation of the system. Where structural damage has occurred, the design and conduct of repairs should be undertaken only be qualified personnel.

C. Dam, embankment and slope repairs

Damage to dams, embankments, and slopes must be repaired quickly. Typical problems include settlement, scouring, cracking, sloughing, seepage, and rutting. A concern in an embankment with a barrel assembly or outflow pipe through it is seepage around the outside of the barrel. This can also cause movement of embankment soils, which can weaken the embankment. Repairs need to be made promptly. Other temporary activities may be needed, such as drawing down the water level in the facility to relieve pressure on a dam or embankment, or to facilitate repairs. Crack repair in a concrete structure may necessitate draining the facility and cleaning the area of the crack prior to repair. If the facility is to be dewatered, pumps may be necessary if there is no drain valve.

D. Elimination of mosquito breeding areas

If neglected, a stormwater system can become a mosquito breeding area, especially facilities which are designed to drain and dry out, but which do not. Corrective action may be needed if a mosquito problem exists and the stormwater facility is the source of the problem. Local mosquito control experts should be consulted for advice. If mosquito control in a facility becomes necessary, the preventive maintenance program for mosquitoes should be reevaluated, and more emphasis placed on control of mosquito breeding habitats.

E. Erosion repair

Vegetative cover is necessary to prevent soil loss, maintain the structural integrity of the facility, and maintain it's pollutant removal benefits. Where a reseeding program has been ineffective, or where other factors have created erosive conditions (i.e., pedestrian traffic, concentrated flow, etc.), corrective steps should be taken to prevent further loss of soil and any subsequent danger to the performance of the facility. There are a number of ways that corrective action can be taken. These include erosion control blankets, riprap, sodding, or reduced flow through the area. Local experts should be consulted to address erosion problems if the solution is not evident.

F. Fence repair

Fences can be damaged by any number of factors, including vandalism and storm events. Timely repair will maintain the security of the site.

G. Elimination of trees, woody vegetation and animal burrows

Woody vegetation or animal burrows can present problems for dams or embankments. The root system of woody vegetation can undermine dam or embankment strength. If the vegetation dies and the root system decomposes, voids can be created in the dam or embankment which weaken the structure. Preventive maintenance can avoid this problem. However, when it oc-

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curs through lack of a preventive maintenance program, steps must be taken to eliminate the problem. Vegetation, including root systems, must be removed from dams or embankments and the excavated materials replaced with proper material at a specified compaction (normally 95% of the soils maximum density). Animal burrows should be filled and steps taken to remove the animals if burrowing problems continue to occur. In an urban environment, animals of concern are usually muskrats or beavers. If the problem persists, local wildlife officials should be consulted regarding removal steps. This consulting is necessary as the threat of rabies in some areas may necessitate the animals being destroyed rather than relocated.

H. Snow and ice removal

Accumulations of snow and ice can threaten the functioning of a stormwater management system, particularly at inlets, outlets, and overflow emergency spillways. Providing equipment, materials, and personnel to monitor and remove snow and ice from these critical areas is necessary to assure the continued functioning of the facility during the winter months.

I. General facility maintenance

In addition to the above elements of corrective maintenance, general corrective maintenance should address the overall facility and it's associated components. If algae growth becomes a problem for ponds, or if an infiltration facility does not totally drain, steps must be taken to reestablish the original performance of the system. ***Stormwater facilities often are very complex systems. They will work only as long as each individual element functions correctly. If corrective maintenance is being done to one facility component, other components should be inspected to see if maintenance is needed. There may be a cost savings in conducting numerous maintenance activities if equipment is on site which could improve a number of needed maintenance items.***

What individual would have three different keys to open the gate to enter a facility?

7. TRAINING NEEDS, INCLUDING AN INSPECTOR TRAINING AND CERTIFICATION PROGRAM

There are going to be many individuals who are involved in stormwater management system maintenance activities. Having individuals conduct these activities, including inspection, without training reduces the potential for proper facility inspection and maintenance.

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It is important that educational programs be developed and implemented to ensure long term performance and function of stormwater management facilities.

7.1. Mandatory Versus Voluntary Educational Programs

It is recommended that an inspector's training program be mandatory. An inspector must know what components of a stormwater management facility are integral to proper function and safety. This recommendation is consistent with that made in Chapter 4.

A training program for owners and operators of stormwater facilities is best done on a voluntary basis where the appropriate regulatory agency provides educational materials and programs for facility owners and operators. In addition to these materials and programs, annual interaction is important. When public agency inspections are done on stormwater systems, the owner and/or operator should also be present. This interaction can provide owners and operators with a greater understanding of various facility components and their importance to overall facility function.

The inspection agency should also contact all facility owners and operators and offer to conduct an inspection with them at the convenience of the owner or operator. This may represent somewhat of a hardship on the inspection agency, especially for residentially-owned facilities, since inspections may be necessary after normal work hours or on weekends. ***It is vital to make owners and operators aware of their obligations and responsibilities for their stormwater systems. Meetings on site are necessary to instill that recognition.***

7.2. Components of an Inspector Training Program

A required inspector training program must be structured, have classroom or lecture sessions that must be attended, and a program manual that is kept by those taking the course. The course curriculum should include much of the material in this Handbook and should include the following components:

1. Institutional background for the stormwater management program.
2. Discussions of why stormwater facilities are important for stormwater quantity and quality control.
3. Basic soils and geology information.
4. Basic hydrology and hydraulics so inspectors have an understanding of the processes involved in rainfall and runoff).
5. Explanation of the specific legal authority and regulatory requirements of the stormwater management program. This should detail the inspection requirements and penalty options.
6. Discussion of the different types of stormwater management facilities being used in a given jurisdiction. This discussion will include the treatment processes of the individual facilities and the maintenance issues associated with each type of facility.
7. The impacts of maintenance on water quality, including disposal of waste material.
8. How to read plans and understand specifications.
9. How to inspect a stormwater management facility. This will include use of the maintenance inspection checklists similar to those presented in the appendices at the end of this Chapter.
10. Enforcement options including available inspection and enforcement report forms.
11. Case studies showing construction and

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maintenance of stormwater management facilities. The case studies should include construction techniques and sequences so the inspectors would understand the importance of components that are not normally visible.

12. Issues related to actual maintenance of stormwater management facilities. This would include disposal of materials removed from the facility and any concerns regarding the hazardous nature of removed sediments.

7.3 Components of an Operators Training Program

For the most part, individuals responsible for maintenance of stormwater management systems seldom have that job as their primary responsibility. For example, this may include the officers of a residential property owners associations, or staff charged with overall property maintenance at commercial or industrial sites. ***These individuals need basic education about stormwater management systems, their operation, and maintenance. They do not need to know about more "abstract" topics such as institutional backgrounds, etc.*** That information should be available upon request, but isn't important during a workshop or training session where they are giving up their own time to attend.

An operator's training program will have many of the same components as the inspector's training program but with less emphasis in some areas. The training program should focus instead on practical aspects of stormwater facility operation, maintenance, and management. The focus should be on matters which are directly applicable to OMM situations. The operators program should consist of a stormwater system operator's manual, in conjunction with classroom or lecture sessions where the individual course topics can be added or removed depending on the audience. The manual would be more comprehensive than the training course, and would provide information that is not necessary in a training course but which could be beneficial depending on an individual's interest. The course could consist of the following components:

1. Discussions of why stormwater facilities are important for stormwater quantity and quality control.
2. Specific legal authority and regulatory requirements for the maintenance of stormwater management systems. This would clearly state the obligations associated with facility ownership.
3. Discussion of the different types of stormwater management facilities which are being used in a given jurisdiction. This discussion will include the treatment processes of the individual facilities and the maintenance issues associated with each type of facility. It should include a series of modules for each type of facility which would be provided in a specific discussion.
4. The impacts of maintenance on water quality, including disposal of waste material.
5. How to read the plans and understand appropriate specifications.
6. How to inspect a stormwater management facility. This includes the use of maintenance inspection checklists similar to those in this chapter's appendices. This would also consist of topics or presentations for individual types of facilities which could be presented depending on the BMPs of particular interest to the attendees.
7. Issues related to actual maintenance of stormwater facilities. This would include disposal of materials removed from the facility and any concerns regarding the hazardous nature of removed sediments.

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8. EQUIPMENT AND RESOURCES NEEDED

Inspector equipment needs are discussed in Chapter 6 and they are again provided and expanded on here for inspectors who may be responsible for stormwater management facility maintenance only. Essential equipment for an inspector includes:

- A locke level or other surveying equipment.
- Flashlight
- Crowbar
- Tape measure and other measuring device (survey rod), such as a clear PVC tube, to determine sediment accumulation depths in facilities.
- Local erosion and sediment control or stormwater management handbooks.
- Rain and foul weather gear.
- Copies of necessary inspection reports and forms.
- Business cards or other means of identification.
- A camera to document field conditions in case an enforcement action becomes necessary.

Insufficient staff is a chronic problem for most stormwater system inspection and maintenance programs. ***Since most public agencies will never have enough inspectors, the issue of public versus private inspectors to conduct annual maintenance inspections should be considered. Regardless of the program structure, some individual must be responsible for conducting maintenance inspections or assuring that some qualified entity or person is performing inspections.*** The public entity responsible for ensuring maintenance of stormwater facilities must have resources available to conduct periodic inspections to ensure facility performance.

Maintenance inspections, like construction inspections, offer an opportunity to use private inspectors who have attended and passed the inspector certification course. As part of the permit approval process, a stormwater system approval should require the land owner or developer to establish a legal maintenance infrastructure. This could include requiring the permittee to retain the services of a certified private inspector to conduct annual inspections of completed stormwater systems. Copies of the inspection reports would be transmitted to the public agency responsible for maintenance and the property owner or stormwater system operator. This approach may reduce the necessity for public agency inspection. However, public inspectors will still be needed to periodically ensure the accuracy of the private inspector's reports and to initiate necessary enforcement action.

Another key requirement of all stormwater management programs is requiring operators to have the financial capability to ensure that they meet their facility maintenance obligations. The agreements provided at the end of Chapter 4 contain legal authority to conduct needed maintenance in the event of default by the responsible private entity. Chapter 8 provides cost information for many maintenance tasks. Stormwater system owners or operators must be made aware of these costs, how often they can be expected to be incurred, and have a mechanism to collect money to accomplish the maintenance. These can be in the form of monthly or annual assessments within a community, or the ability to assess individual owners when the need arises.

9. TYPICAL OMM TOOLS

There are a number of tools which are used in the maintenance of stormwater management systems. These are discussed to assist inspectors and facility owners in developing specific facility maintenance programs. Actual

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equipment and material requirements should be determined on an individual basis for each facility. The information presented here is adapted from the "Stormwater Management Facilities Maintenance Manual" (NJDEP, 1989).

Grass maintenance equipment

1. Tractor-mounted lawn mowers
2. Riding lawn mowers
3. Hand mowers
4. Gas powered trimmers
5. Gas powered edgers
6. Seed spreaders
7. Fertilizer spreaders
8. De-thatching equipment
9. Pesticide and herbicide application equipment
10. Grass clipping and leaf collection equipment

Vegetative cover maintenance equipment

1. Saws
2. Pruning shears
3. Hedge trimmers
4. Wood chippers

Transportation equipment

1. Trucks for transportation of materials
2. Trucks for transportation of equipment
3. Vehicles for transportation of personnel

Debris, trash, and sediment removal equipment

1. Loader
2. Backhoe
3. Grader
4. Dragline
5. Vacuum equipment

Miscellaneous equipment

1. Shovels
2. Rakes
3. Picks
4. Wheel barrows
5. Fence repair tools
6. Painting equipment
7. Gloves
8. Standard mechanics tools
9. Tools for maintenance of maintenance equipment
10. Office space
11. Office equipment
12. Telephone
13. Safety equipment
14. Tools for concrete work (mixers, form materials, etc.)

Inspector equipment during a routine maintenance inspection

1. Flashlight
2. Locke level or survey equipment
3. Approved facility plans
4. Measuring rod (to determine depth of sediment accumulation)
5. Crowbar (removal of cast iron covers)
5. Inspection report form
6. Pen or pencil

Inspector equipment (when on site during the maintenance of a stormwater facility)

1. Gloves
2. Safety hat
3. Safety glasses
4. Safety boots
5. Inspection report form
6. Pen or pencil
7. Lock level or survey equipment
8. Approved facility plans

Materials

1. Topsoil
2. Fill material
3. Seed
4. Soil amendments (fertilizer, lime, etc.)
5. Chemicals (pesticides, herbicides, etc.)

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6. Mulch
7. Paint
8. Paint removers (for graffiti)
9. Spare parts for equipment
10. Oil and grease for equipment and stormwater management facility maintenance of mechanical components
11. Concrete

10. IMPORTANCE OF TRACKING • OPERATION, MAINTENANCE, AND MANAGEMENT

Facility tracking and recording are important components of stormwater facility maintenance programs. In this day and age, there is no reason why maintenance cannot be tracked using computerized data bases. This would allow inspectors to be assigned an inventory of facilities to inspect and provide easily accessible information on when OMM was done last and when the next inspection may be needed. The data entered into the computer tracking system could include identification numbers for each facility, facility type, facility locations, special maintenance needs, and data from previous inspections. At the conclusion of each site visit, the inspector enters a maintenance needs assessment into the computer data base. The computer could then generate a maintenance work order.

This approach would help to ensure that problems are corrected in the order of the risk that they pose. This type of system would also ensure that no facilities "fall through the cracks" in terms of annual inspections and maintenance. ***Tracking of when a facility was last inspected and the facility's status should never rely on the memory of individual inspector.***

11. PRIORITIZING MAINTENANCE TASKS

In terms of prioritizing maintenance, corrective maintenance is a high priority whenever it is needed. Preventive maintenance is next, followed by aesthetic maintenance. All of these forms of maintenance are needed, but **prioritizing is necessary, especially when there is a safety or potential safety concern, or when there is limited staff and/or equipment.**

The items previously considered as corrective maintenance include, in order of priority from most important to least important:

- Structural repairs
- Dam, embankment and slope repairs
- Erosion repair
- Removal of debris and sediment
- Elimination of mosquito breeding areas
- Elimination of trees, woody vegetation, and animal burrows
- General facility maintenance
- Fence repair
- Snow and ice removal

Preventive maintenance importance and priority depends to a large extent on the type of BMP. Biofiltration facilities perform only if mowing is routinely accomplished, yet wet ponds may only need mowing on an annual basis. As such, prioritizing is not as important as ensuring that preventive maintenance is accomplished. Preventive maintenance, as discussed earlier, includes:

- Grass mowing
- Grass maintenance
- Vegetative cover
- Trash and debris
- Sediment removal and disposal
- Mechanical components
- Elimination of mosquito breeding habitats
- Other specific facility maintenance items

The City of Bellevue, Washington has developed a stormwater facility maintenance

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TABLE 7-1. BELLEVUE (WA) STORM FACILITY MAINTENANCE PRIORITIZATION SYSTEM

Priority	Criteria	Example
A	Hazard to life or health - a situation presenting substantial likelihood of injury.	Partial collapse of an occupied structure creates roadway hazard which has a reasonable likelihood of causing a traffic accident; hazardous working conditions for utility crews
B	Hazard to structures - a situation presenting a reasonable liklihood of damage to structures.	Damage to buildings, roadways,utilities, etc.
C	Hazard to property - a situation presenting a reasonable likelihood of property damage	Erosion; landscape damage; sedimentation
D	Nuisance	Inconvenient situation for maintenance crews, small amounts of standing water.

prioritizing system, which is shown in Table 7-1.

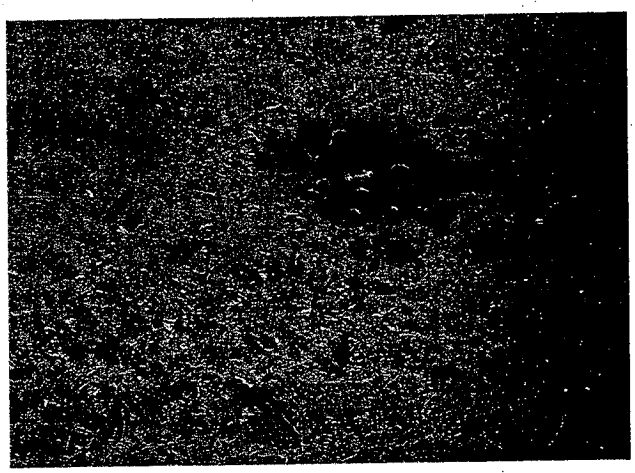
12. SAFETY ISSUES DURING MAINTENANCE INSPECTIONS AND DURING ACTUAL MAINTENANCE

The importance of inspector and maintenance personnel safety when conducting maintenance inspections and activities cannot be overemphasized. Individual safety must be a paramount consideration when conducting maintenance inspections or performing maintenance.

12.1 Safety Issues During Maintenance Inspections

Safety issues during maintenance inspections are, for the most part, common sense items which should be considered in any outdoor activity. Possible concerns or issues include:

- Look out for holes. A hole can be very small in circumference but deep. In the vicinity of a stormwater management facility a hole can be an indication of a serious problem. When conducting a



Example of a hole on a stormwater pond embankment. This indicates two concerns: (1) watch where you walk; and (2) the pond has serious problems with piping around the barrel assembly. If you see this, get assistance.

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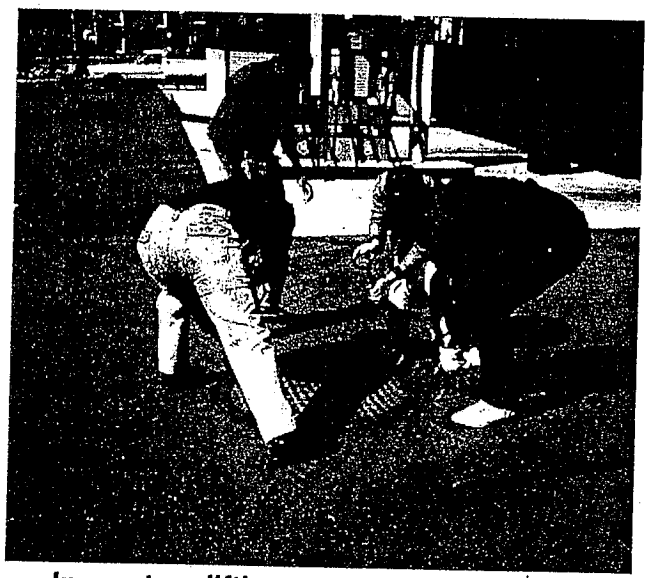
maintenance inspection, ***look where you walk.***

- Animals can present a serious concern. Rabies is a concern with wildlife and animal bites which could have severe consequences. Be careful around geese. Geese are very territorial, and can be extremely aggressive. Look out for snakes.

- Be careful lifting manhole covers or other structural covers in stormwater facilities. These items can be very heavy, can slip, and cause serious injury, such as the loss of a finger. In addition, since they are heavy, back problems can occur if covers are lifted alone or incorrectly.



Inspectors lifting a manhole cover of a Washington, DC sand filter. Care must be taken in cover removal and replacement.

- Poison ivy, poison oak, or other plants can present a problem depending on the individual's allergic reaction to them. This can also present a problem during maintenance when vines from cutting woody vegetation may lie all over a site.

- Never enter a confined space unless you have been trained and have proper safety equipment in accordance with OSHA Regulations. Do not enter pipes or conduits unless another individual is present during the inspection. Do not enter a pipe or conduit, even with others present, if there is any concern regarding the structural strength of the pipe or conduit.

- Be careful not to walk in water when the depth is unknown or where there may be steep slopes below the water line.

- Be careful of nails, broken glass, or other sharp objects. Soft bottom shoes, such as athletic shoes, may be more comfortable for general wear, but they are not as safe as hard soled shoes. Fences can tear clothing or cause cuts, which may necessitate medical treatment.

- Gloves should be worn if any mechanical parts or structural components are going to be handled. This should be done for safety reasons (cuts, abrasions, etc.) and for health reasons, especially where pollutants or other materials can coat the hands then get rubbed into eyes or the mouth. Always wash hands after an inspection where items are manipulated, especially if gloves are not worn.

- In systems which are somewhat sealed with poor ventilation, be careful with cigarettes, lighters, or other open flames. Also be sure to allow a facility to vent for a period of time if a peculiar odor is present. Do not enter any confined space unless the atmosphere has been checked and proper safety equipment is worn and/or erected.

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12.2. Safety Issues During Maintenance Activities

During maintenance activities, the typical concerns exist around any construction equipment. ***Remember, you can see equipment while they are operating, but equipment operators may not see you.***

- Equipment should always be operated safely and in accordance with manufacturers specifications.
- Call utility companies before initiating any maintenance activity involving any excavation. Look for overhead wires before operating any equipment which could touch the wires.
- Before starting any maintenance activity, be sure that all necessary equipment or replacement parts are onsite or are readily available. In the case of sediment removal, have the disposal location staked out or identified.
- Excavated areas that cannot be filled at the end of a work day should be covered, when possible, or clearly identified and marked off.
- When working in a residential community, the residents should be educated about the maintenance activity and how long it will take.
- Don't cut corners when doing maintenance activities. Be careful. Always be aware of what is around you. Take the time needed to do the job right. Recognize that things go wrong, and taking time to do quality work will save time and money in the long run.
- Wear a hard hat, steel toed shoes, safety glasses, ear plugs, etc. if in an area where construction equipment (or operating equipment) is operating.
- Mowing can be hazardous so be careful around mowers that are running. Take special care when mowing steep slopes. Be sure to wear safety glasses, steel toed shoes, and ear plugs while mowing.
- Gloves should be worn if any mechanical parts or structural components are going to be handled. As stated before, this needs to be done for both safety and health reasons. Always wash hands after an inspection where items are manipulated, especially if gloves are not worn.

13. SPECIFIC MAINTENANCE ACTIVITIES FOR EACH TYPE OF FACILITY

Specific BMP design criteria varies from jurisdiction to jurisdiction, so the frequency of maintenance for the range of BMPs will vary also. An example of this variation in criteria may be the design of sediment forebays in ponds, or the requirement for pretreatment practices. This section will provide information that is generally applicable to the individual types of facilities. However, it cannot be too specific regarding time frames since they are influenced by local criteria. Recommended frequency of inspections is provided in the checklists in the chapter's appendices.

This section will also present specific examples of maintenance problems associated with individual practices. It is extensively illustrated to clearly show examples of functional maintenance problems that may occur at different types of BMPs. Some general recommendations on the frequency of maintenance activities will be provided. ***However, maintenance needs are so specific to the land being served by the stormwater facility and the pollutant load being delivered***

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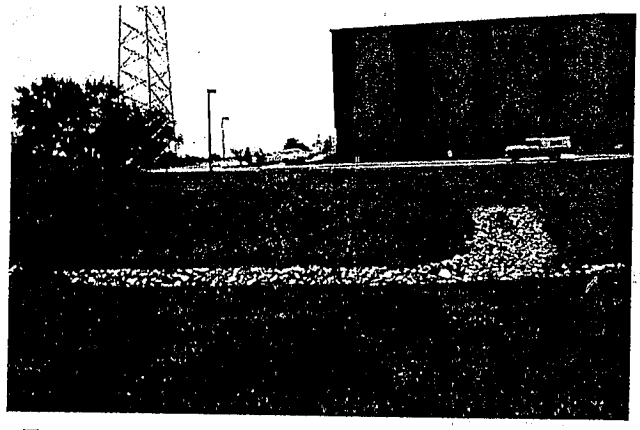
to the facility, that actual conditions will vary from site to site. Actual maintenance frequency should depend on the results of routine inspections which can determine the rate of accumulation of materials in the individual facility.

The discussion will be broken down into the four main classes of stormwater practices:

- Detention and retention ponds, including wetlands
- Infiltration facilities
- Filtration facilities
- Biofiltration facilities



Example of a dry detention facility showing the degree of mowing required and the riprap pilot channel.

13.1 Detention and Retention Ponds

Maintenance activities for detention and retention ponds have many similarities, but there also are some differences in the types of maintenance that are needed. Dry detention systems have more lawn areas that must be mowed. Mowing of dry detention facilities should be done at least once per year to prevent the growth of woody vegetation on the embankment. Monthly or more frequent mowing is necessary if good turf grass cover is expected or desired.

In addition, dry detention systems frequently have pilot or low flow channels to convey smaller flows. These pilot channels may become undermined, if made of concrete, or if made of stone, may become choked with vegetation and require chemical treatment to reestablish flow conveyance ability. Maintenance efforts for pilot channels will be done on an "as needed" basis. Careful inspection should be done on concrete pilot channels, as their undermining will jeopardize the structural integrity of the pilot channel.

Wet detention systems with their normal water pool are effective at converting inorganic nitrogen to organic nitrogen. Consequently,

Example of trees all around the detention facility perimeter. It is obvious that maintenance has not been done in years.

A constructed wetland without sediment forebays filling in. This facility is about 10 years old and will need to be dredged of sediments within the next 10 years. Constructed wetlands are very susceptible to filling in if inflow sediments are significant.

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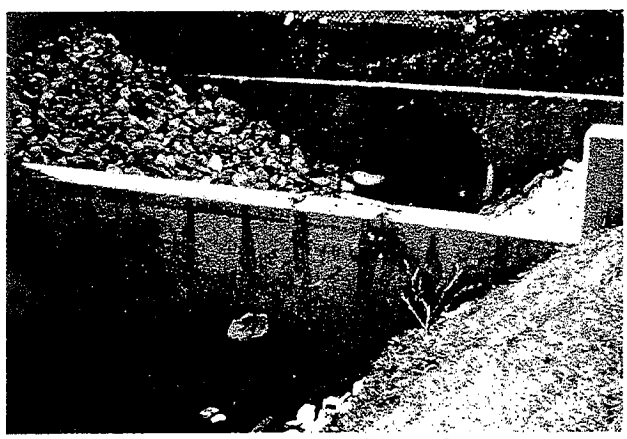
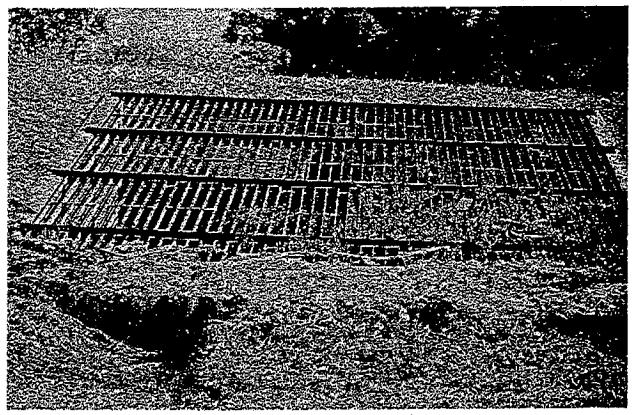
Example of a forebay prior to flow entering the wet pond, which is located in the rear of the picture.

this may create algae problems unless littoral zones are planted with aquatic vegetation. Wet detention systems also more commonly have forebays to remove heavier sediments. As such, forebay maintenance is an important issue for wet detention systems which must be considered. Frequency of forebay maintenance depends on the incoming pollutant load and the forebay size.



Extended detention facility where water quality is provided by the small orifice at the bottom of the weir. Maintenance should be mainly concerned with keeping the grate unclogged.



Example of debris which is beginning to clog the outlet structure of a detention facility.

Both dry and wet detention systems have the potential for debris clogging an inlet or outlet structure. There can be a surprising amount of debris generated in residential communities, and commercial facilities can expect debris of all sorts. Inspections for debris should be made on a monthly basis or after rain events to ensure that all components of the stormwater facility are operating as required.

Removal of sediments will also be needed on a periodic basis. Coarser sediments can be expected to be found close to the pond inlet, with finer sediments expected to be deposited closer to the pond outfall. In terms of volume, the coarser sediments will occupy a greater volume and maintenance removal of these sediments will be needed more frequently than removal of finer sediments. **Studies of detention ponds used by the Florida Department of Transportation indicate that sediments need to be removed about once every 10 to 20 years.** Using forebays, which can be more easily cleaned out more frequently, can increase the time before sediments will need to be removed from the entire pond. Recommendations for disposal of collected sediments are presented in Chapter 9.

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Pond inflow point clearly showing the coarser sediments dropping out of suspension .

Erosion behind the grouted riprap wingwall will eventually cause failure of the riprap, which will increase sediment loadings downstream negating the BMP's benefit.

Removing sediment from a wet pond should be done by draining the water down to the lowest possible elevation. If possible, a small pool of water should be left to provide habitat for the resident fish population. Removing sediment while having a normal pool of water will cause significant turbidity with the finer sediments traveling downstream. When the sediments are removed from the pond, they should be placed at a location where they can dry prior to final placement. It is important to have sediment control provisions included in the maintenance costs to prevent downstream increases in pollutant loadings or to prevent removed sediments from reentering the facility. Sediment removal from dry detention systems is more straightforward. Since these facilities are normally dry, sediments can be removed by an appropriate means and disposed of properly. ***Experience has shown that it is easier and more effective to remove sediments when they are dry and cracked, and thereby separated from the vegetation.*** Sediment control during maintenance is still necessary in case of storms that could mobilize stockpiled materials or erode exposed soils.

Erosion problems can occur with either dry or wet detention systems. For the most part they start as small problems which, if uncorrected, can grow into large problems and possibly threaten the integrity of the detention facility. Inspections to locate erosion problems should be done at least annually or after major storms. Evidence of significant foot or bike traffic in areas where vegetation has died indicate potential erosion areas in the future. These areas should be protected from traffic

Gate valve for a stormwater management pond. When maintenance inspections are done, the valve should be operated and lubricated to ensure proper function.

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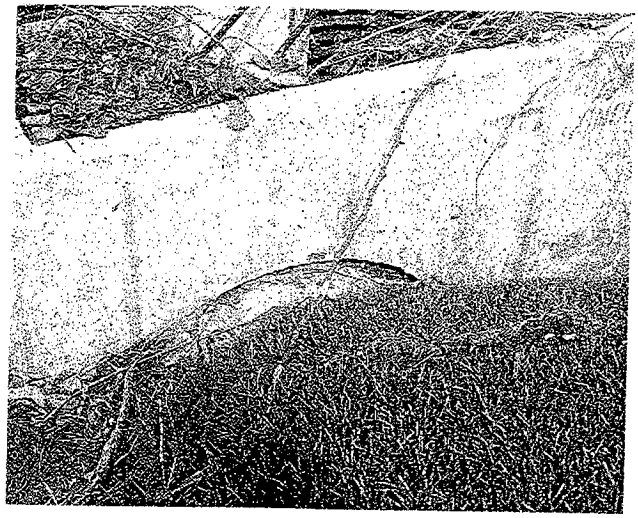


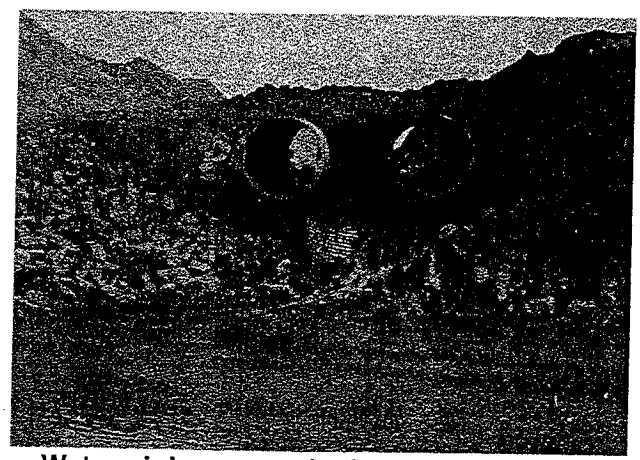
Leakage around the barrel and riser assembly. This could cause piping of water adjacent to the barrel which would jeopardize the structural strength of the facility.

This may be as bad as it gets. This retention facility was in a state of failure. The embankment had to be breached and completely rebuilt. The problem resulted from seepage around the barrel causing embankment soil to move with the flow of water. This failure resulted from poor construction.

or provided with a more erosive resistant ground cover.

Periodic maintenance of structural components must be done to ensure their continued operation. This includes inspecting any joints for possible leakage or seepage. Areas should also be checked for corrosion, valves should be manipulated and lubricated when needed, and all moving parts inspected for wear and tear.

The most important concern of stormwater management detention and retention ponds is safety. Situations may occur which, if no action is taken, may cause imminent structural failure of the facility. Inspections must be made at least annually to ensure the safety of a facility. If there is any concern that the facility is unsafe, assistance must be requested from an individual who has expertise in dam safety. ***Failure to take action, when confronted with a potential problem, can increase liability if a failure occurs.*** Complete failures of stormwater management systems generally do not occur overnight. They start as small problems and increase gradually.



Water piping around a barrel. The water is flowing with considerable velocity.

Ponds are rather unique when compared to other types of stormwater systems. If filtration, biofiltration, or infiltration facilities fail or clog, their reduced performance generally will not result in downstream safety concerns. Ponds provide effective water quality performance, but that performance is gained at the cost of increased safety concerns. They must be designed correctly, built satisfactorily, and

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actively maintained. A failure in any one of the three aspects of detention or retention facilities could result in significant problems. Ponds are a valuable tool in controlling stormwater runoff, but care must be taken to ensure that the service they were constructed to provide continues.

13.2 Infiltration Practices

Infiltration facilities encompass a wide range of BMPs as previously discussed. Maintenance issues are generally related to one or two major concerns:

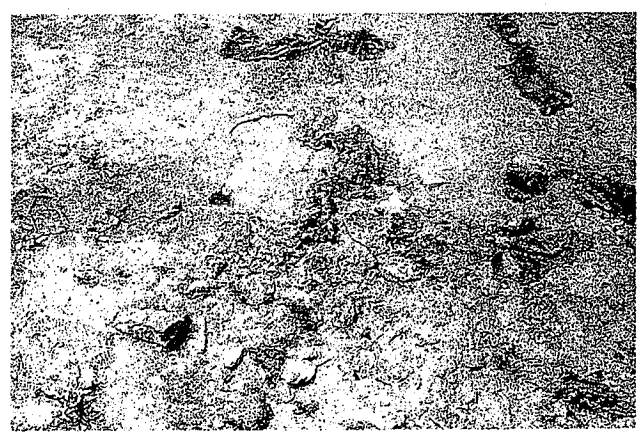
- clogging
- standing water

Clogging of these practices can occur from sediments entering the facility and sealing the soil surface, preventing infiltration of runoff. Clogging can also occur from excess oils and greases entering the facility, or from microorganism growth which results when water stands too long in the facility. As water infiltrates into the soil, the algae can clog the soil surface and prevent infiltration. Whatever the reason, clogging will cause failure of infiltration practices creating long term problems.

Infiltration facilities must go dry between storm events to provide maximum stormwater management benefits. Their clogging means less runoff is infiltrated and more goes into the overflow system on a more frequent basis. Clogging may also mean that water is permanently present in the facility, which can then become a mosquito breeding area.

Close up sediments clogging an infiltration basin. Silt and clay sediments are the greatest concern since they can seal the basin/soil interface area.

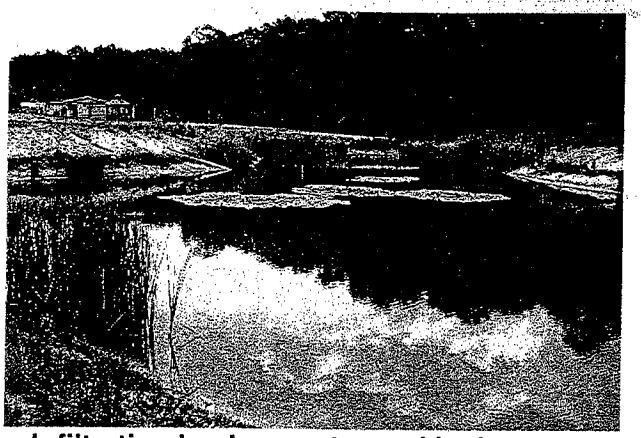
Excessive silt-clay sediments have clogged the basin floor causing this infiltration basin to fail.



Algae on an infiltration basin floor has caused failure of the facility by preventing infiltration of stormwater.

A014207

Standing water results from clogging which obstructs the flow of water into the ground. Standing water can also result from seasonal high water tables or ground water mounding in the vicinity of the facility. If either of these problems occur, the facility's performance will depend on exfiltration out of the sides instead of the bottom.



Infiltration basin constructed in the water table. Excellent exfiltration out of the basin sides maintaind proper functioning.

Example of a failed infiltration basin caused by clogging and not seasonal or mounded water table. The basin should be pumped of water and allowed to dry out before sediment is removed.

If ground water problems persist at the facility, contingency plans may be needed. These could include conversion of the infiltration system to a practice which includes a permanent pool of water such as a wet detention or constructed wetland system. Another alternative is to provide the facility with a structural outlet to prevent seasonal or permanent water pooling. If either of these options are necessary, the appropriate inspection and/or approval agency should be contacted to ensure approval of the modifications. In such cases, future inspections will be based on the modifications rather than maintaining expectations associated with the originally approved and constructed facility.

With respect to maintenance activities, the first step is to inspect the infiltration facility to determine if there is standing water during a period of time when it hasn't rained. ***If standing water exists, then it needs to be determined whether the cause is clogging of the facility, seasonal water table conditions, or ground water mounding.*** This analysis is crucial for determining the next steps. If the problem is caused by a high water table or mounding, an entire new strategy will be needed to correct the problem. If clogging is the reason, maintenance activities will need to be performed to restore desired infiltration rates.

Ideally, the inspection will find only partial clogging, allowing sediments to be removed when the facility dries out. If the facility is totally clogged, correction is much more difficult. The facility should be drained and allowed to dry out before removing sediments. If sediment removal is attempted while water is standing in the facility, the finer sediments will become suspended and not be removed from the facility. These suspended sediments are responsible for the initial clogging of the practice, and their resuspension will last only until quiescent conditions allow for resettlement.

A014208

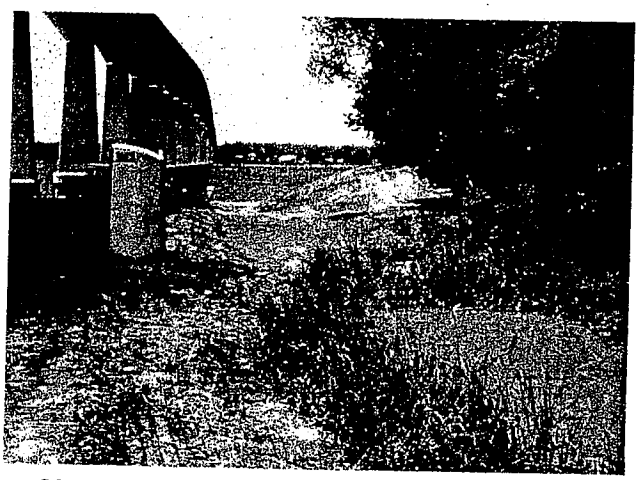
The facility will never achieve the desired re-establishment of infiltration rates.

Safeguards should be installed during construction to reduce maintenance concerns. However, even with design and construction being sensitive to future maintenance, maintenance problems will occur as they do for all stormwater management facilities. For example, to facilitate maintenance, rock filled infiltration trenches should be designed to have filter fabric placed approximately one foot below the surface of the facility. This fabric is a design point of failure which allows the underlying stone to remain clean. If standing water persists on the surface of the facility, the top foot of stone should be removed and the filter fabric removed and replaced. This design prevents the need to replace the entire stone reservoir base.

The use of vegetative filters as a pretreatment BMP to improve long term performance of infiltration facilities cannot be stressed too much. The pictures on this page of infiltration trenches at the same site clearly show the partial clogging of the trench abutting the parking lot. The ten feet wide buffer strip between the paved surface and the trench significantly reduces the maintenance concerns associated with trench clogging.

Of primary importance to the long term function of infiltration practices is the need to keep all contributing drainage areas stable. Sediment loadings into the facility must be kept to a minimum. All inspections of these facilities must include inspection for site stabilization. All areas draining to the infiltration facility must be stabilized or premature clogging of the facility will result. The infiltration system checklists recommend annual inspections for sediment accumulation. The frequency of actual maintenance activities depend on loadings from contributing drainage areas.

Two infiltration trenches on the same site. The value of the vegetative buffer strip can clearly be seen.



Clogged infiltration swale. The individual swale blocks must be dewatered before accumulated sediments are removed.

A014209

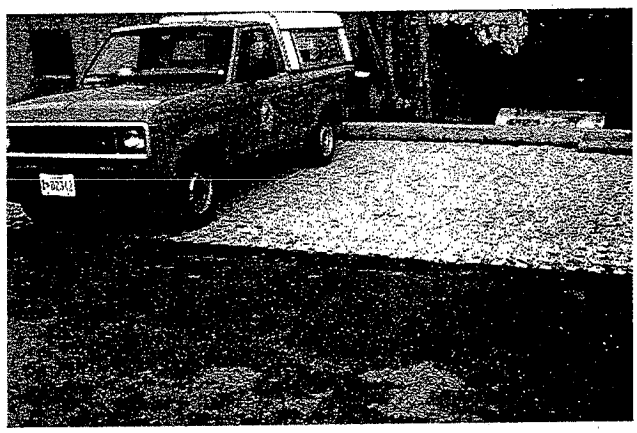
Porous paved parking lot clogged due to excess sediment on parking surface.

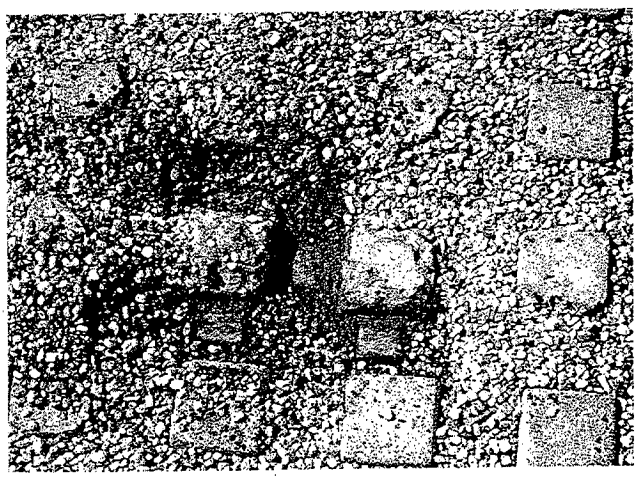
Porous paving or lattice block systems are somewhat unique. Reduced maintenance cannot be designed into the BMP as is done for other infiltration facilities by using biofiltration, fabrics, or forebays to help pretreat runoff. Design options to reduce maintenance for infiltration paving is predominantly limited to using them in areas of low traffic, where paving is still necessary, or criteria specifying a certain frequency of vacuum sweeping. In general, vacuum sweeping should be done weekly with an annual pressure washing using biodegradable cleaners.

Sign at a hotel porous pavement parking lot. If paving needs to be replaced, the sign clearly states maintenance requirements.

Education is especially important in reducing OMM of infiltration paving practices. It is very important that owners are aware of the pervious nature of the paving surface. A common approval condition is to require that signs be placed around the parking area to notify all users that the surface is pervious, and that sediment tracking needs to be minimized. Signage also alerts owners of the need for in-kind replacement of the pervious pavement, if needed.

One type of porous parking surface is lattice block paving. This surface comes in modular units which can be placed down in blocks. Lattice block paving can include filter fabric under the blocks to facilitate future mainte-





Lattace block infiltration system at a commercial parking lot. The open areas are filled with pea gravel to provide support for shoe heels.

A014210

nance. When maintenance is necessary, the lattice block can be lifted up in individual sections, the filter fabric under the block replaced, and the blocks restored to their original places. However, some form of maintenance will probably be necessary on an annual basis. Porous paving facilities may require more frequent maintenance, depending on the vehicular traffic using the paved area. In heavily trafficked areas, vacuum sweeping should be done on a monthly, or at least quarterly basis.

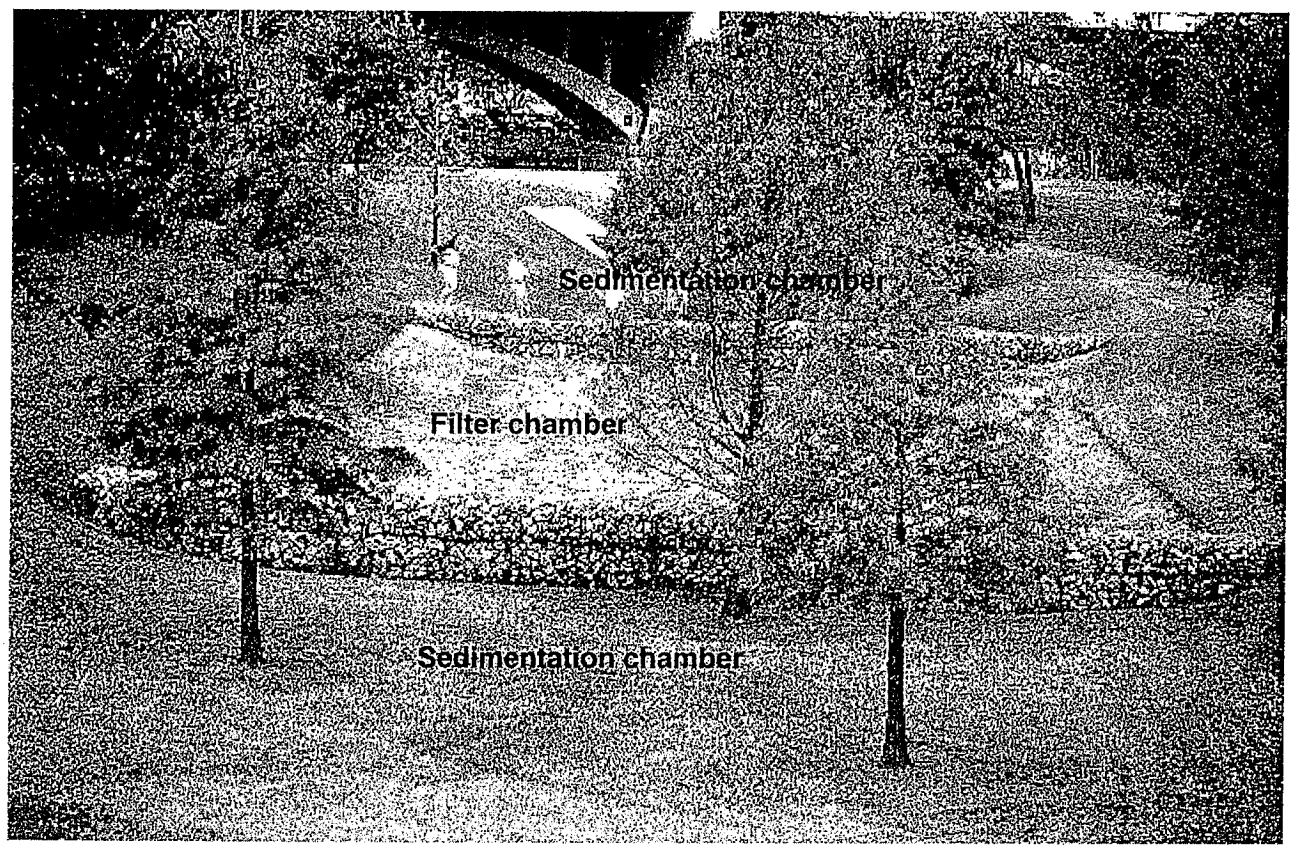
13.3 Filtration Practices

There are three distinctly different types of filtration systems, depending on whether the Austin, Delaware, or Washington, DC approaches are used. The Austin filter accepts runoff from entire drainage areas, which includes pervious areas where sediments may be finer sized than sediments from impervious areas only. The Washington, DC filter provides stormwater quantity and quality management from smaller drainage areas. The Delaware filter only provides stormwater quality treatment from impervious drainage areas. In a similar fashion, though, the frequency of maintenance of all of these facilities depends on the loadings entering the facilities, regardless of the type of facility.

All three approaches have two major components of their systems which include:

- a sedimentation chamber
- a filtration chamber

The sedimentation chamber provides a volume of storage for coarser sediments and debris. Maintenance inspections should consider the depth of materials which have been deposited in the sedimentation chamber and the potential for those trapped materials to



Austin sand filter serving a commercial facility. The sediment chambers are on both sides of the filter with the sand filter accepting flow through the gabion baskets.

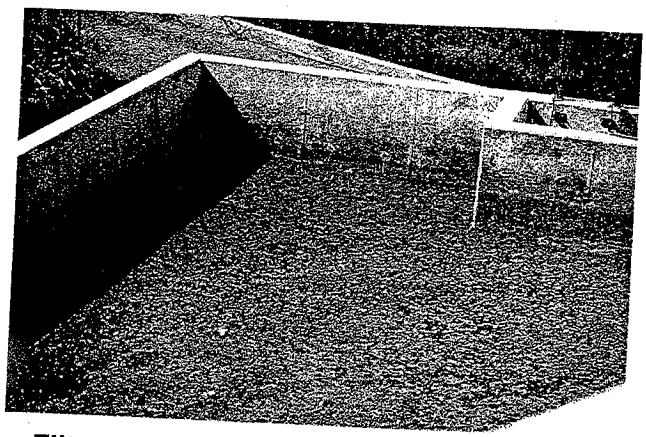
A014211

migrate to the filtration chamber. The depth of accumulated sediments will be relatively easy to measure in all three types of facilities.

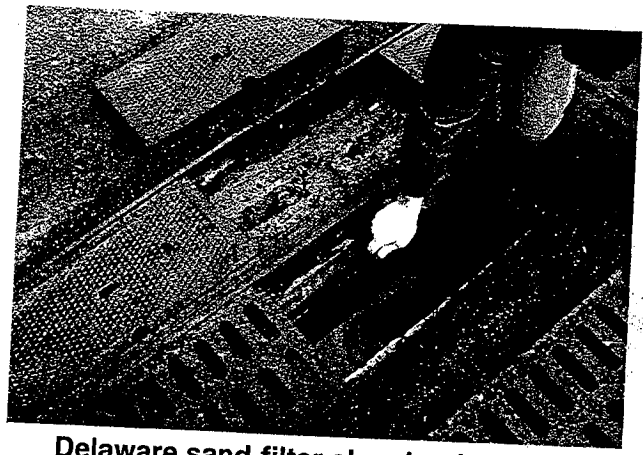
A. Austin Sand Filter

The sedimentation chamber for the Austin sand filter is designed for larger drainage areas and normally remains dry between storms. Consequently, it is normally maintained in the same fashion and with the same equipment as a dry detention facility. The frequency of maintenance depends on the stabilization of soils in the contributing watersheds. Maintenance of the sedimentation chamber is generally not needed more frequently than every five to ten years. It is important that access be provided to the sedimentation chambers for maintenance equipment to enter and perform needed maintenance.

The frequency of maintenance for the filter component of the Austin sand filter depends on the magnitude of the incoming pollutant loadings. However, in general, filters may require cleanout every year. The finer sediments may be raked from the surface of the sand and removed, or a flat bottom shovel could skim the surface of the sand to reestablish sand permeability.



Filtration chamber of an Austin sand filter showing overflow spillway. The sand media needs to be inspected regularly to determine if design permeabilities are reduced.



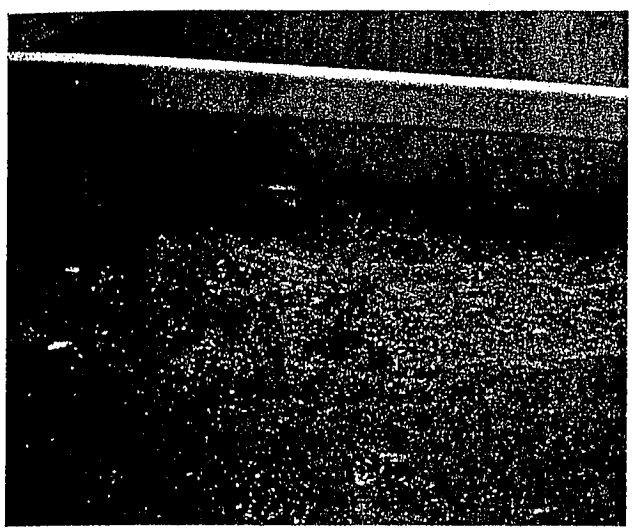
Delaware sand filter showing both the sedimentation and filtration chambers. The sedimentation chamber is permanently filled with water to prevent resuspension of the accumulated sediments.

B. Washington, DC and Delaware Sand Filters

The Washington, DC and the Delaware sand filter sedimentation chambers are normally wet. As such, the accumulated material will be wet and removal is best accomplished by using vacuum type equipment. In general, the volumes of water to be removed from each system are fairly small since the facilities serve smaller drainage areas than the Austin approach. This makes vacuuming a practical alternative. The frequency of vacuuming will depend on the loading contributed from the drainage areas. However, experience indicates that maintenance cleanout of the sedimentation chambers is not often needed in less than 10 years of active service.

The filtration chambers are more sensitive than the sedimentation chambers to clogging by sediments and other fine grained materials, such as oils and greases. While the sedimentation chamber functions primarily through gravity settling of the incoming materials, the filtration chamber is where filtering of pollutants occurs. This chamber will be more effective at removal of the finer sediments, which will be retained in the top several inches of the filter media.

A014212



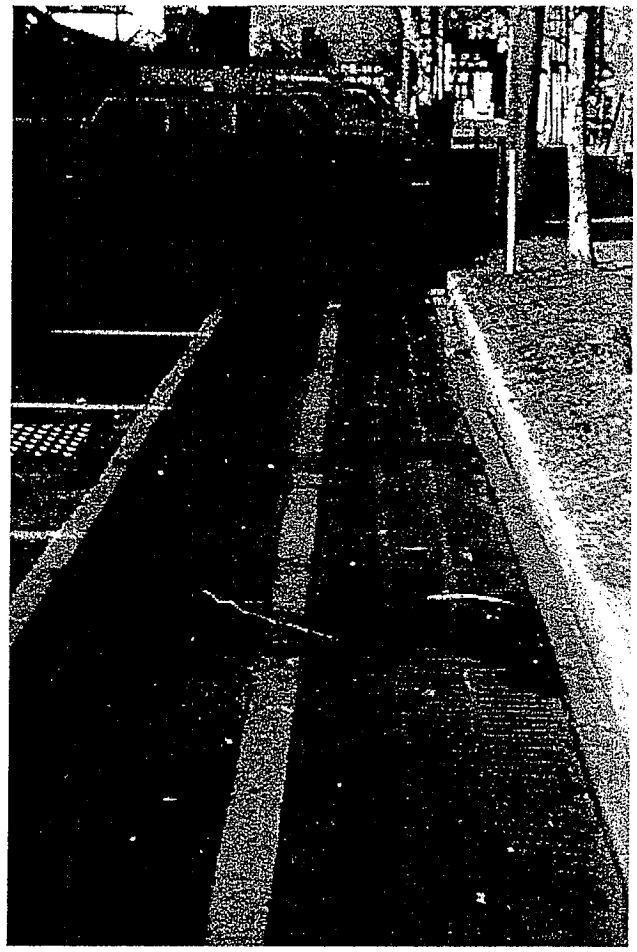
Evidence of scour at the entrance to the filtration chamber from the sedimentation chamber. The connecting areas between chambers should be protected with a nonerosive material, such as stone or a splash pad.

The filtration chamber will need maintenance on a much more frequent basis than will the sedimentation chamber. If the sand filter is in an area with a significant pollutant loading, filter maintenance may be needed at least twice per year to ensure that the design flows travel through the facility. Diminished permeability of the sand will result in more frequent overflows into the conventional drainage system with less stormwater treatment. Replacement of the filter media is most easily accomplished with a flat bottom shovel to remove the accumulated materials. It will be fairly easy to see the depth of penetration of the pollutants and how much filter media needs removal. Usually, it is not necessary to replace all of the filter media, only the top layer.

Sand filter in Auckland, New Zealand. The sand filter serves a commercial parking lot. Vegetation growing in the filtration chamber may indicate a need for maintenance.

C. Information Applicable to all Three Filter Designs

When portions of the filter media must be replaced, only materials which meet the stormwater program's filter specifications should be used. There is a lot of research being done



Waste oil was dumped in this Delaware sand filter and sealed the filter media almost immediately. The top several inches of sand had to be replaced. On the good side, if the filter were not present, the oil would have been discharged on the community beach.

A014213

with alternative filter media such as compost, activated carbon, alum, etc. If the approving agency allows or specifies an alternative filter media as a replacement, there must be documentation in the inspection and owner's files on the use of a media different than specified on the approved plans. Most commonly used at this time for filter media sand is ASTM designation C-33 concrete sand.

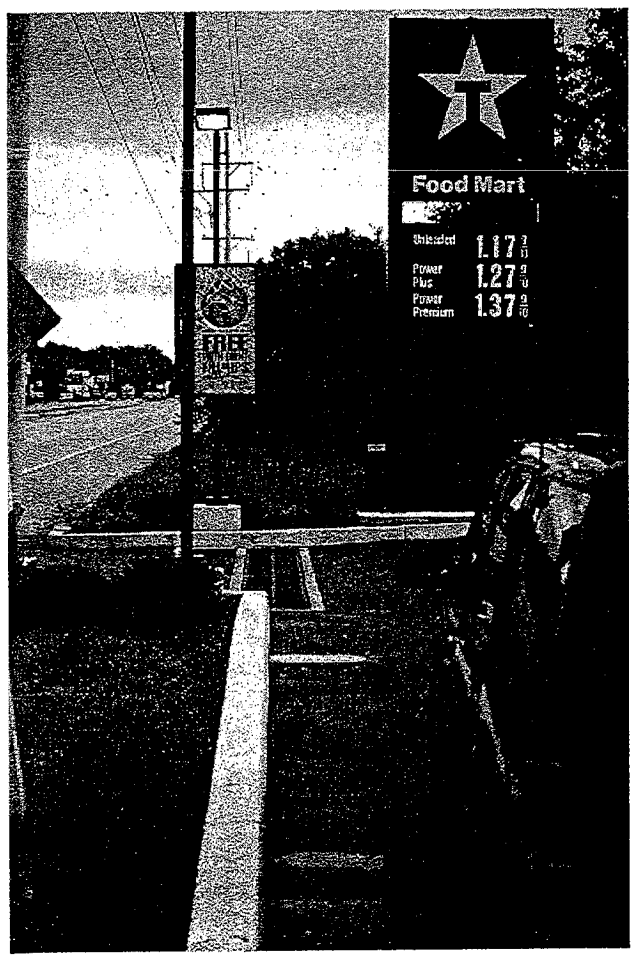
Depending on the pollutants which can be expected in the filter system, testing of the material to be removed should be done to determine a suitable location for its disposal. In general, existing information indicates that disposal at a landfill is appropriate, but if the filtration facility serves an industrial facility, the sediments should be tested to determine if they are considered hazardous materials. There is a greater discussion of sediment testing and disposal in **Chapter 9**.

Stenciled pollution message adjacent to a filtration facility.

As with all stormwater management facilities, there is always the potential for vandalism. This can include damage to the facility itself, theft of facility components, or illegal dumping of waste products such as waste oil. These problems must be expected, and although not specifically anticipated, remedial action must be quickly accomplished.

A primary method to reduce vandalism is a community education program explaining stormwater pollution generation, the importance of BMPs such as filter systems, and the need to limit pollutant entry into BMPs. One component of this education program could be stenciling of the inlets to the filter. This may limit some individuals conducting the vandalism through ignorance of the facility's purpose.

Other maintenance concerns such as scour, leakage, spalling of concrete, cracks in concrete or grates need to be addressed when they are discovered. Washington, DC and Delaware filter systems have a permanent pool of water in the sedimentation chambers. If these chambers become dry, there is leakage, and the leakage must be stopped for the facility to function correctly. If the leaking area



Delaware filtration facility subject to live loads at a gasoline station.

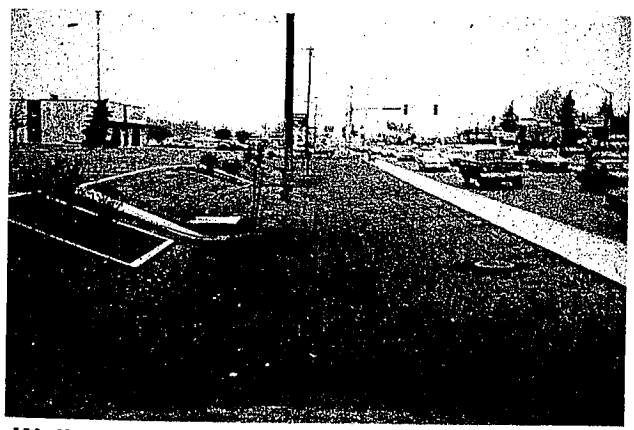
A014214

cannot be identified, a dye test may be necessary to track the flow of water in the leaking chamber. In addition, all three of these types of filters use concrete in their construction. Concrete will deteriorate over time, especially if subject to live loads. The concrete must be routinely inspected, and repaired when necessary.

13.4 Biofiltration Systems

Biofiltration facilities treat runoff by filtering it through dense growths of vegetation. This filtering can be done by passing stormwater through a vegetated swale or through a designed buffer strip. Biofiltration functions rely primarily on flow traveling through the facility in a dispersed condition, preventing concentrated flow of runoff. Besides vegetative filtration, treatment in biofilters often also relies upon infiltration of runoff into underlying soils. Therefore, maintenance of biofiltration facilities is primarily concerned with:

- Maintenance of dispersed flow through the biofilter.
- Maintaining a thick growth of vegetation.
- Preventing undesired overgrowth vegetation from taking over the area.
- Removal of accumulated sediments.

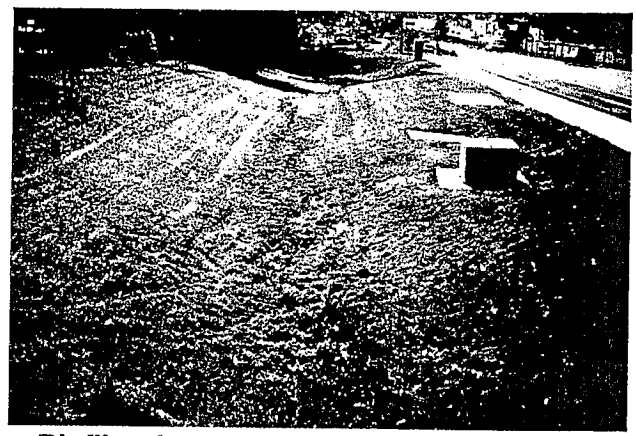


Well maintained biofiltration swale serving a commercial development. There is some evidence of oil staining of the vegetation.

- Debris removal.

Maintenance of dispersed flow through the biofiltration facility is critical if its stormwater treatment effectiveness is to be maintained. Concentrated flow travels at a higher velocity than does dispersed flow, and may transport pollutants through the biofiltration system before they are removed from the runoff.

A dense growth of vegetation enhances biofiltration facility performance for stormwater treatment. Therefore, vegetation maintenance will require close attention by system owners or operators. Mowing is needed on a periodic basis, but mowing must be correctly done. Mowing grass too short will damage the grass, increase runoff flow velocities, and thereby decrease pollutant removal effectiveness. If the grass grows too tall, it may lie down during a storm instead of filtering runoff, also decreasing treatment effectiveness.



Biofiltration swale showing mowing wear and other signs of spotty vegetation demonstrating the need for maintenance.

Inspections must be done to ensure that the desired vegetation remains in the facility. The invasion of undesired vegetation can occur if site conditions promote its growth. In some situations the replacement of the planted vegetation by a volunteer species may be beneficial, but only if the invasive species pro-

A014215

Biofiltration swale with little slope, poor drainage, and baseflow. The swale is well vegetated with wetland plants.

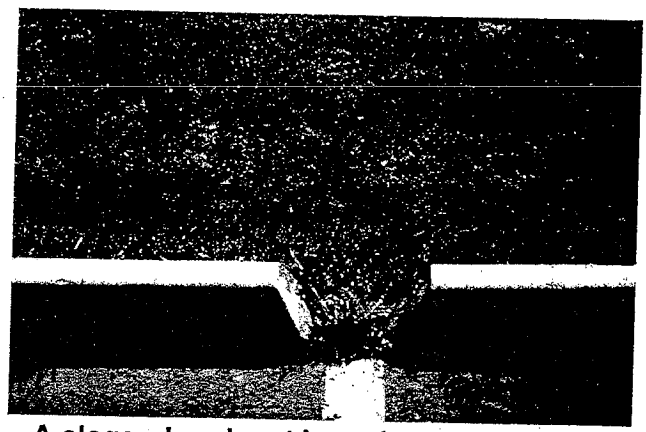
vides equal or increased water quality benefits and is accepted by the owners of the site. If site slopes are very flat, the biofiltration facility could become dominated by wetland plants. The dense growth of wetland plants may be desired for stormwater treatment and also will reduce the typical mowing costs associated with biofiltration facilities. ***In this situation, the maintenance file documents the shift in the plant community and provide guidelines for how to take care of the modified site condition.***

Sediments will accumulate in biofiltration systems and their removal may be the most expensive aspect of biofiltration maintenance.

Sediment accumulation in a biofiltration facility reduces the effectiveness of that facility in removing pollutants. This swale is in need of maintenance to reestablish desired water quality control conditions.

When sediments are to be removed, it is essential to restore the slope and elevations to the originally constructed condition. Sediment removal will necessitate disturbance of the vegetation in the facility, so steps will have to be taken to reestablish the vegetation upon completion of sediment removal. Erosion control in the contributing drainage area also will be necessary to prevent scour of the facility until there is once again a dense stand of vegetation. Examples of erosion control techniques are shown in Chapter 6.

Sediment may also impeding effective performance of a biofiltration facility by clogging its inlets, preventing design storms from being treated in the facility. If stormwater backs up into the upstream drainage area, overflow may occur to an area not designed to accept additional flow. In this situation, erosion and site instability may result from an inlet becoming clogged with sediments.



A clogged curb cut impedes flow entering the biofiltration system. A better design would have a wider opening with a small vertical drop to prevent sediment clogging of the opening.

Similar to other types of practices, debris removal is an ongoing maintenance function at all biofiltration systems. Debris, if not removed, can block inlets or outlets, cause flow to become concentrated, and can be unsightly if located in a visible location. Inspection and removal of debris should be done on a monthly

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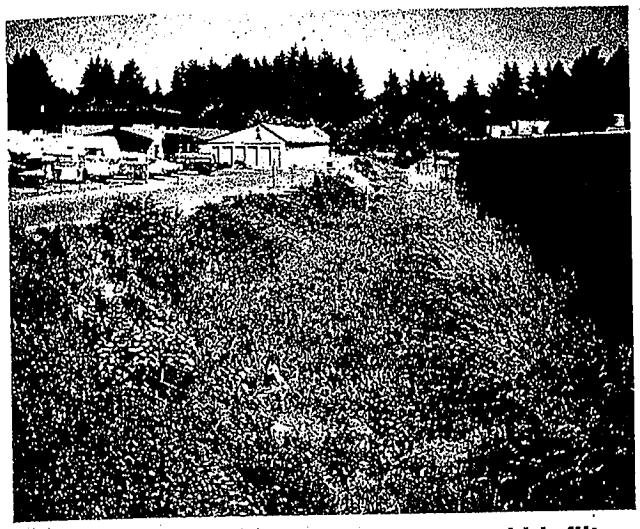


An unmaintained, but well vegetated biofiltration system. Debris needs to be removed from the facility.

basis, but debris should be removed whenever it is observed on site.

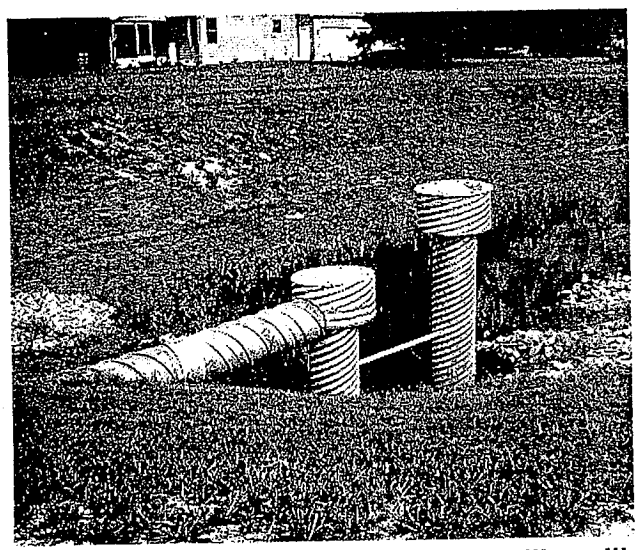
Just as it is important to know when a facility needs to be maintained, it is important to know when you don't have to do maintenance. The original plan for the site provides the best information at that time on the design and construction of the biofiltration facility. Over time the facility may change in appearance and function. These changes may not necessarily be bad. Having a knowledgeable inspector conduct regular inspections may be one way to allow a facility to evolve into an improved facility with reduced maintenance costs. The emergence of wetland plants in a biofilter, or the growth of native vegetation, may improve its value and performance.

This is a natural well vegetated biofiltration facility. It is not regularly mowed but is performing its water quality function.

If you are unsure of the value of performing a maintenance activity, discuss the specific situation with the inspector or plan approval agency to see if there can be an improvement made to the facility.

14. GENERAL DISCUSSION

If there is any confusion about the type of stormwater management facility, it's purpose, or what specific maintenance activities are important, ASK FOR HELP! Stormwater systems can be simple in concept and function, but they can also be complex and confusing to the average individual who is far too often responsible for the facility's long term performance.



The design and operation of this facility will need to be clearly understood if effective maintenance is to occur. The taller riser contains a pump to drain the water quality volume to a higher elevation for discharge.

The inspection agency and approval agency must be available and receptive to public requests for assistance with stormwater man-

A014217

agement system operation, maintenance, and management. Often, this technical assistance will include conducting site inspections with the owner or operator to go over the approved plan, discussing maintenance inspection checklists, and providing advice to the owner or operator.

It is expected by this time, that the inspector knows to ask the plan review agency about specific aspects of facility design and construction, but that information must also be transmitted to the eventual owner/operator. A site meeting between the inspector and owner upon the owner's assumption of maintenance responsibility is very important. At this time, checklists can be given to the owner along with other educational information that may provide the owner with increased awareness about the need for proper maintenance and how it can be accomplished. At the same time, the inspector should give the owner a list of individuals who can provide assistance if problems are encountered.

Design and approval of a stormwater management system is done to the best degree possible without complete awareness of individual site development characteristics. In addition, development of a specific site may necessitate a different approach to stormwater management. In such situations, the approved plan is a springboard to water resources protection. As the developed site matures, changes may be necessary to the stormwater facility. A good relationship between the approval agency, inspection agency, owner, and operator can provide the flexibility needed to assure resource protection while allowing consideration of specific site conditions. ***Communication and commitment are essential for assuring the long term operation, maintenance, and management of stormwater management systems.***

The operation of this stormwater management system appears very confusing. The inspector must work closely with the owner/operator to ensure that proper performance is maintained.

A014218

APPENDIX 7-1

Operation, Maintenance, and Management Inspection Checklist for Ponds

A014219

Operation and Maintenance Inspection Report for Stormwater Management Ponds

(Adapted from Anne Arundel County, Maryland)

Inspector Name _____ Community _____

Inspection Date _____ Address _____

Stormwater Pond _____

Normal Pool _____ _____

Normally Dry _____ Watershed _____

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
I, Pond components						
A. Embankment and Emergency spillway					A,S	
1. Vegetation and ground Cover adequate						
2. Embankment erosion						
3. Animal burrows						
4. Unauthorized plantings						
5. Cracking, bulging, or sliding of dam						
a. Upstream face						
b. Downstream face						
c. At or beyond toe						
Upstream						
Downstream						
d. Emergency spillway						
6. Pond, toe & chimney drains clear and functioning						
7. Seeps/leaks on downstream face						
8. Slope protection or riprap failures						
9. Vertical and horizontal alignment of top of dam as per "As-Built" plans						
10. Emergency spillway clear of obstructions and debris						
11. Other (specify)						
B. Riser and principal spillway					A	
Type: Reinforced concrete ___						
Corrugated pipe ___						
Masonry ___						
1. Low flow orifice obstructed						
2. Low flow trash rack						
a. Debris removal necessary						
b. Corrosion control						
3. Weir trash rack maintenance						
a. Debris removal necessary						
b. Corrosion control						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

A014220

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
4. Excessive sediment accumulation inside riser						
5. Concrete/Masonry condition Riser and barrels						
a. Cracks or displacement						
b. Minor spalling (<1")						
c. Major spalling (rebars exposed)						
d. Joint failures						
e. Water tightness						
6. Metal pipe condition						
7. Control valve						
a. Operational/exercised						
b. Chained and locked						
8. Pond drain valve						
a. Operational/exercised						
b. Chained and locked						
9. Outfall channels functioning						
10. Other (specify)						
C. Permanent pool (wet ponds)					M	
1. Undesirable vegetative growth						
2. Floating or floatable debris removal required						
3. Visible pollution						
4. Shoreline problems						
5. Other (specify)						
D. Sediment forebays						
1. Sedimentation noted						
2. Sediment cleanout when depth < 50% design depth						
E. Dry pond areas					M	
1. Vegetation adequate						
2. Undesirable vegetative growth						
3. Undesirable woody vegetation						
4. Low flow channels clear of obstructions						
5. Standing water or wet spots						
6. Sediment and/or trash accumulation						
7. Other (specify)						
F. Condition of outfalls into pond					A,S	
1. Riprap failures						
2. Slope erosion						
3. Storm drain pipes						
4. Endwalls/headwalls						
5. Other (specify)						
G. Other					M	
1. Encroachments on pond or easement area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
2. Complaints from residents (describe on back)						
3. Aesthetics						
a. grass mowing required						
b. graffiti removal needed						
c. Other (specify)						
4. Any public hazards (specify)						
5. Maintenance access						
H. Constructed wetland areas					A	
1. Vegetation healthy and growing						
2. Evidence of invasive species						
3. Excessive sedimentation in wetland area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

II. Summary

1. Inspectors Remarks: _____

2. Overall condition of Facility (Check one)

_____ Acceptable

_____ Unacceptable

3. Dates any maintenance must be completed by:

_____

APPENDIX 7-2

Operation, Maintenance, and Management Inspection Checklists for Infiltration Practices:

Basins (Appendix 7-2A)
Trenches (Appendix 7-2B)
Dry Wells (Appendix 7-2C)
Paving (Appendix 7-2D)
Swales (Appendix 7-2E)

A014223

Infiltration Basin Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Basin bottom clear of debris		_____	_____
Inlet clear of debris		_____	_____
Outlet clear of debris		_____	_____
Emergency spillway clear of debris		_____	_____
2. Sediment traps or forebays	(Annual)		
Obviously trapping sediment		_____	_____
greater than 50% of storage volume remaining		_____	_____
3. Vegetation	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion			
4. Dewatering	(Monthly)		
Basin dewaters between storms		_____	_____
5. Sediment cleanout of basin	(Annual)		
No evidence of sedimentation in basin		_____	_____
Sediment accumulation does not yet require cleanout		_____	_____
6. Inlets	(Annual)		
Good condition		_____	_____
No evidence of erosion		_____	_____
7. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____
8. Structural repairs	(Annual, After Major Storm)		
Embankment in good repair		_____	_____
Side slopes are stable		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A014224

	Satisfactory	Unsatisfactory
9. Fences/access repairs (Annual)		
Fences in good condition		
No damage which would allow undesired entry		
Access point in good condition		✓
Locks and gate function adequate		

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____
Signature of Inspector

A014225

Infiltration Trench Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

	Satisfactory	Unsatisfactory
1. Debris cleanout (Monthly)		
Trench surface clear of debris	_____	_____
Inlet areas clear of debris	_____	_____
Inflow pipes clear of debris	_____	_____
Overflow spillway clear of debris	_____	_____
2. Sediment traps, forebays, or pretreatment swales (Annual)		
Obviously trapping sediment	_____	_____
greater than 50% of storage volume remaining	_____	_____
3. Vegetation (Monthly)		
mowing done when needed	_____	_____
Fertilized per specifications	_____	_____
No evidence of erosion		
4. Dewatering (Monthly)		
Trench dewaters between storms	_____	_____
5. Sediment cleanout of trench (Annual)		
No evidence of sedimentation in trench	_____	_____
Sediment accumulation does not yet require cleanout	_____	_____
6. Inlets (Annual)		
Good condition	_____	_____
No evidence of erosion	_____	_____
7. Outlets/overflow spillway (Annual)		
Good condition, no need for repair	_____	_____
No evidence of erosion	_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A014226

	Satisfactory	Unsatisfactory
8. Aggregate repairs (Annual)		
Surface of aggregate clean	_____	_____
Top layer of stone does not need replacement	_____	_____
Trench does not need rehabilitation	_____	_____
9. Vegetated surface (Monthly)		
No evidence of erosion	_____	_____
Perforated inlet functioning adequately	_____	_____
Water does not stand on vegetative surface	_____	_____
Good vegetative cover exists	_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____

_____
Signature of Inspector

A014227

Infiltration Dry Well Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Roof drains and downspouts clean		_____	_____
2. Vegetation on top of dry well	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
3. Dewatering	(Monthly)		
Dry well dewaters between storms		_____	_____
4. Inlets	(Annual)		
Good condition of down spouts		_____	_____
No evidence of deterioration		_____	_____
Roof gutters drain correctly into dry well		_____	_____
5. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

A014228

Infiltration Paving Maintenance Inspection Report Form

Date_____ Time_____

Project_____

Location_____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris on infiltration paving parking area	(Monthly)		
Paving area clean of debris		_____	_____
2. Vegetation (any buffer areas or pervious areas in drainage area)	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
3. Dewatering	(Monthly)		
Infiltration paving dewaters between storms		_____	_____
4. Sediments	(Monthly)		
Area clean of sediments		_____	_____
Area vacuum swept on a periodic basis		_____	_____
5. Structural condition	(Annual)		
No evidence of surface deterioration		_____	_____
No evidence of rutting or spalling		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____

Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____

Signature of Inspector

A014229

Infiltration Swale Well Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Swales and contributing areas clean of debris		_____	_____
2. Vegetation	(Monthly)		
mowing done when needed		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
Minimum mowing depth not exceeded		_____	_____
3. Dewatering	(Monthly)		
Swale dewaters between storms		_____	_____
4. Check dams or energy dissipators	(Annual, After Major Storm)		
No evidence of flow going around structures		_____	_____
No evidence of erosion at downstream toe		_____	_____
5. Sediment deposition	(Annual)		
Swale clean of sediments		_____	_____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

A014230

APPENDIX 7-3

Operation, Maintenance, and Management Inspection Checklist for Filtration Practices

Filtration Facility Maintenance Inspection Report Form

Date _____ Time _____

Project _____

Location _____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Warning: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Contributing areas clean of debris		_____	_____
Filtration facility clean of debris		_____	_____
Inlets and outlets clear of debris		_____	_____
2. Vegetation	(Monthly)		
Contributing drainage area stabilized		_____	_____
No evidence of erosion		_____	_____
Area mowed and clippings removed			
3. Oil and grease	(Monthly)		
No evidence of filter surface clogging		_____	_____
Activities in drainage area minimize oil & grease entry		_____	_____
4. Water retention where required	(Monthly)		
Water holding chambers at normal pool		_____	_____
No evidence of leakage		_____	_____
5. Sediment deposition	(Annual)		
Filtration chamber clean of sediments		_____	_____
Water chambers not more than 1/2 full of sediments		_____	_____
6. Structural components	(Annual)		
No evidence of structural deterioration		_____	_____
Any grates are in good condition		_____	_____
No evidence of spalling or cracking of structural parts		_____	_____
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		_____	_____
No evidence of erosion (if draining into a natural channel)		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A014232

		Satisfactory	Unsatisfactory
8. Overall function of facility	(Annual)		
No evidence of flow bypassing facility		_____	_____
No noticeable odors outside of facility		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

A014233

APPENDIX 7-4

Operation, Maintenance, and Management Inspection Checklist for Biofiltration Practices

A014234

Biofiltration Facility Maintenance Inspection Report Form

Date_____ Time_____

Project_____

Location_____

Individual Conducting the Inspection _____ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Biofilters and contributing areas clean of debris		_____	_____
No dumping of yard wastes into biofilter		_____	_____
Litter (branches, etc.) have been removed		_____	_____
2. Vegetation	(Monthly)		
Plant height not less than design water depth		_____	_____
Fertilized per specifications		_____	_____
No evidence of erosion		_____	_____
Grass height not greater than 6 inches		_____	_____
Is plant composition according to approved plans		_____	_____
No placement of inappropriate plants		_____	_____
3. Dewatering	(Monthly)		
Biofilter dewaters between storms		_____	_____
No evidence of standing water		_____	_____
4. Check dams/energy dissipators/sumps	(Annual, After Major Storm)		
No evidence of sediment buildup		_____	_____
Sumps should not be more than 50% full of sediment		_____	_____
No evidence of erosion at downstream toe of drop structures		_____	_____
5. Sediment deposition	(Annual)		
Swale clean of sediments		_____	_____
Sediments should not be > than 20% of swale design depth		_____	_____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		_____	_____
No evidence of erosion		_____	_____
No evidence of any blockages		_____	_____
7. Integrity of biofilter	(Annual)		
Biofilter has not been blocked or filled inappropriately		_____	_____

Inspection Frequency Key Annual, Monthly, After major storm

A014235

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections _____
Correct noted facility deficiencies by _____

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on _____

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

_____ _____
Signature of Inspector

A014236

Chapter 8
Costs and Financing of Stormwater Facility Operation and Maintenance

1. OVERVIEW

Even if a stormwater management program has established effective institutional mechanisms to help assure that stormwater systems are operated and maintained properly, problems can arise because of inadequate knowledge about the costs of maintenance. Annual program budgets must include adequate staffing and financial resources to conduct the maintenance activities needed to assure that stormwater systems operate properly. Additionally, the stormwater program must assure that financial mechanisms are implemented to provide the needed funding.

The fundamental role that proper budgeting and financing plays in the successful performance of effective stormwater system maintenance cannot be overemphasized. The specific objectives of this chapter are:

- To provide operating and maintenance cost information from several stormwater programs around the country.
- To provide methods by which stormwater programs can estimate operation and maintenance costs.
- To provide general information on various alternative methods of financing stormwater system operation, maintenance, and management.

1.1. Intended Readers

This chapter is intended to provide information on the costs of stormwater system operation, maintenance, and management to:

- **Stormwater system owners.**
- **Directors of stormwater utilities, public works, stormwater programs, and other public and private agencies responsible for stormwater system maintenance.**
- **Purchasing agents, managers, and directors.**

The chapter also discusses various methods of obtaining adequate public and private funds for required stormwater system operation, maintenance, and management. This information is intended specifically for:

- **Elected officials and other leaders of state, regional, and local governments responsible for stormwater system maintenance.**
- **Stormwater program administrators, business administrators, comptrollers, financial directors, and other public and private sector officials responsible for financing stormwater system maintenance.**

2. STORMWATER SYSTEM MAINTENANCE COSTS

To develop sound stormwater system operation, maintenance, and management budgets and determine adequate funding levels, a comprehensive data base of OMM costs is

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needed. Unfortunately, there is very little hard data on the actual costs of stormwater system OMM, especially for stormwater treatment BMPs. ***This chapter will present data on general OMM costs along with specific cost data from several stormwater programs around the country.***

It is important to remember that the cost of stormwater system OMM is very site specific. Factors that determine the frequency, type, and cost of OMM include the type and size of BMP, use of source controls, land use, contributing drainage area, rainfall characteristics, climate, vegetation growing system, maintenance access, and disposal requirements.

Table 8-1 presents cost estimates for various equipment and materials used in typical stormwater management system OMM. Costs are provided both for equipment purchase and rental. ***In many cases, renting equipment, is a preferred alternative. This is especially true for infrequently used equipment or larger, very expensive equipment. Additionally, local governments often find it advantageous to contract for the use of highly specialized equipment since staff may not have the experience needed to operate it.*** Purchasing these types of equipment, and especially more commonly used equipment, may be justified when it can be used for activities other than stormwater facility maintenance, such as by road, public works, or recreation departments. For larger equipment, it may be less expensive to lease for a short time instead of renting by the day.

These cost estimates are intended to provide generalized cost data to those in both the public and private sectors involved either in the actual OMM of stormwater systems, or in the planning, budgeting and financing for stormwater system OMM. The reader should develop more detailed cost estimates based upon local data or data pertaining to a specific program or type of stormwater system. Sources of more specific data include local equipment sales, lease, and/or rental companies, and local maintenance and construction contractors. Valuable information can be obtained from local government stormwater, public works, parks, or road departments. Consultation and coordination between these various departments within local governments or private companies is strongly recommended.

Table 8-2 summarizes the estimated person-hours associated with many of the more common stormwater system operation, maintenance, and management activities. These values can be used with applicable personnel rates to determine labor costs for a specific stormwater program or facility. The reader should note that the estimates are based on the entire area of a stormwater system. Additionally, dry BMPs are assumed to be entirely covered with grass which requires regular mowing, fertilizer, and other management. Appropriate adjustments should be made for wet BMPs and for facilities that are larger than one acre.

In addition to labor and materials costs, an additional allowance needs to be made for the disposal of trash, debris, leaves, and sediments. These costs can be minimized by having a dedicated area where materials can be composted or where sediments can be dewatered and reused. These areas can either be on-site near the stormwater system or at a centrally located materials yard within the community. Disposal of these materials must comply with federal, state, and/or local regulations **(See Chapter 9)**. Accordingly, costs and requirements can vary widely.

3. OMM COSTS FROM SPECIFIC STORMWATER MANAGEMENT PROGRAMS

This section will present cost information from

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TABLE 8 -1.
Stormwater System OMM Equipment and Material Costs (1997).

GRASS MAINTENANCE EQUIPMENT		
EQUIPMENT	PURCHASE	RENT (Per Day)
Hand mower	$300 - $500	$25 - $50
Riding mower	$3,000 - $7,000	$75 - $150
Tractor mower	$20,000 - $30,000	$150 - $450
Trimmer/edger	$200 - $500	$25 - $35
Spreader	$100 - $200	$20 - $30
Chemical sprayer	$200 - $500	$25 - $40
VEGETATIVE COVER MAINTENANCE EQUIPMENT		
Hand saw	$15 - $20	$5
Chain saw	$300 - $800	$15 - $35
Pruning shears	$25 - $40	$5
Shrub trimmer	$200 - $300	$25 - $35
Brush chipper	$2,000 - $10,000	$100 - $300
SEDIMENT, DEBRIS, AND TRASH REMOVAL EQUIPMENT		
Vactor truck	$100,000 - $250,000	$700 - $1200
Front end loader	$60,000 - $120,000	$250 - $500
Backhoe	$50,000 - $100,000	$250 - $500
Excavator	>$100,000	$400 - $1,000
Grader	>$100,000	$400 - $1,000
TRANSPORTATION EQUIPMENT		
Van	$18,000 - $30,000	$50 -$100
Pickup truck	$15,000 - $25,000	$50 - $100
Dump truck	$40,000 - $80,000	$100 - $200
Light duty trailer	$3,000 - $6,000	$50 - $100
Heavy duty trailer	$10,000 - $20,000	$100 - $250

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TABLE 8 -1.

Stormwater System OMM Equipment and Material Costs (Cont.).

MISCELLANEOUS EQUIPMENT		
EQUIPMENT	PURCHASE	RENT (Per Day)
Shovel	$15	$5
Rake	$15	$5
Pick	$20	$5
Wheel barrow	$100 - $250	$15 - $25
Portable compressor	$800 - $2,000	$50 - $150
Portable generator	$750 - $2,000	$50 - $150
Concrete mixer	$750 - $1,500	$50 - $100
Welding equipment	$750 - $2,000	$50 - $100

MATERIALS	
MATERIAL	PURCHASE
Topsoil	$35 - $50/cubic yard
Fill soil	$15 - $30/cubic yard
Grass seed	$5 - $10/pound
Soil amenties (fertilizer, lime, etc)	$0.10 - $0.25/sq. ft.
Chemicals (ie,pesticides, herbicides, etc)	$10 - $30/gallon
Mulch	$25 - $40/cubic yard
Dry mortar mix	$5/50 pound bag
Concrete delivered	$60 - $100/cubic yard
Machine/motor lubricants	$5 - $10/gallon
Paint	$20 - $40/gallon
Paint remover	$10 - $20/gallon

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TABLE 8 - 2.

Typical Hours Needed To Perform Stormwater OMM Tasks.

PREVENTATIVE MAINTENANCE TASKS (Values expressed in person-hours)		
TASK	SMALL FACILITY (Total area < 0.25 acre)	LARGE FACILITY (Total area > 1 acre)
Grass cutting	1	1 - 4
Grass management	0.5	1 - 2
Trash & debris removal	0.5	1 - 2
Sediment removal	4	6 - 10
Mobilization	1	1
Inspection & reporting	1	2
CORRECTIVE MAINTENANCE TASKS		
Trash & debris removal	4	6 - 10
Sediment removal	8 -12	8 - 40
Dewatering	4	8 - 16
Aquatic vegetative mgmt.	4	6 - 16
Structural repairs	24	36 - 72
Erosion repair	1 - 4	3 - 8
Fence repair	2 - 4	4 - 10
Snow & ice removal	1 - 4	2 - 6
Mosquito extermination	1	2 - 4
Mobilization	2	2 - 4
AESTHETIC MAINTENANCE TASKS		
Grass trimming	0.5 - 1	1 - 4
Weed control	0.5 - 1	2 - 4
Landscape maintenance	1 - 2	2 - 8
Graffiti removal	2 - 4	4 - 8

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country associated with their facility operation, maintenance, and management activities. Because the information from each program varies so greatly, information from each program will be presented separately and in different formats.

3.1. City of Orlando, Florida

Orlando has required the treatment of stormwater since 1984, with recent emphasis on retrofitting older drainage systems to reduce stormwater pollutant loadings into the City's lakes. The City conducts a wide range of operation, maintenance, and management activities on its stormwater systems and has a very active lake management program. Summarized below are costs associated with major OMM activities:

Activity	Cost
Herbicide (Rodeo) application to ditch bottoms	$170.00 per acre
Street grass control with herbicide (Roundup)	$ 6.40 per city block
Ditch mowing by hand using weed-eaters and mowers	$ 60.00 per acre
Ditch mowing by large tractor	$ 12.00 per acre
Cleaning of stormsewers and catch basins with Vactor	$160.00 per hour
Repair of structures (less materials)	$ 50.00 per hour

3.2. City of Fresno, California

Fresno developed and is implementing a stormwater master plan which relies upon regional stormwater retention (infiltration) facilities. The city's facilities are classified as "stormwater systems", "recharge systems" or " fully landscaped systems", with the latter also serving as 10 to 20 acre parks. The respective annual OMM costs for these facilities are $125/acre (stormwater systems), $197/acre (recharge systems), and $1,506/acre (landscaped systems). When accumulated sediments need to be removed from any of these systems the annual cost is approximately $275/acre. Table 8-3 provides a more detailed summary of these costs.

3.3. Somerset County, New Jersey

The primary focus of the stormwater management program in Somerset County is flood control. The program, which began in 1975, operates an extensive flood control network with radiotelemetry controls of its main drainage structures. As part of its stormwater management system, a large number of dry detention basins, with concrete low flow channels, have been constructed. Maintenance of these systems primarily consists of grass trimming and mowing. When mowing is performed, erosion problems are identified and repaired, debris and litter are removed, as is sediment which has accumulated in the low flow channel. The County is responsible for the OMM of 52 dry detention systems with a land area of 164.5 acres. These range in size from 0.5 to 21.5 acres.

Until 1992, the County used its own maintenance crew to perform all OMM operations. In

A014242

TABLE 8 - 3.

Maintenance Activities and Costs for Stormwater Management Systems in Fresno, California (1996).

STORMWATER SYSTEMS (No landscaping, 10 systems, 92.2 acres)		
Activity	**Cost**	
Weeding	$110/acre/year	
Special (erosion control)	$ 6/acre/year	
Extra work (structural repairs)	$ 4/acre/year	
Miscellaneous	$ 4/acre/year	
FULLY LANDSCAPED SYSTEMS (10 basins, 84.1 acres)		
Mowing	$770/acre/year	
Water	$416/acre/year	
Extra work (erosion, structural repairs)	$185/acre/year	
P G & E	$130/acre/year	
Rodent control	$ 5/acre/year	
RECHARGE BASINS		
Basin/Size	**Cost**	**Cost/Acre/Yr**
A - 10.0 acres	$3,500	$350
S - 26.9 acres	$4,000	$149
OO - 9.3 acres	$ 57	$ 61
AC - 10.4 acres	$2,500	$240
AE - 21.6 acres	$1,728	$ 80
BO - 15.0 acres	$4,112	$274
CL - 14.7 acres	$4,400	$299
CN - 21.0 acres	$5,000	$238
CO2 - 13.2 acres	$1,535	$116
CW - 15.3 acres	$3,602	$235

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1993, the county solicited bids for the work and hired a private contractor who did an excellent job. In 1994, the county once again solicited bids and received the following bids:

Bidder	Bid Price	$/OMM Visit	$/Acre
County	$68,236	$ 312	$414.81
Bidder A	$62,200	$ 284	$378.12
Bidder B	$56,100	$ 256	$341.03
Bidder C	$51,635	$ 236	$313.89

The three bid prices include $8,000 in County costs for supervision and inspection. This cost is based on three hours of supervision/inspection per day, assuming 2 to 3 basins per day, for a total of 110 days at $25 per hour personnel costs. Based on these bids, the County awarded the work to the low bidder, a different contractor than the County had used in 1993. This contractor did not perform as well as the previous contractor. The County received many complaints from residents about the contractor's poor OMM work. Consequently, County staff performed many remedial OMM tasks resulting in $6,000 in additional costs. In 1995, the County's elected officials decided to allow the County maintenance crew to once again perform all OMM operations. ***Even though the cost was about $5,000 more than using a private contractor, advantages of using the County crew included better workmanship, quicker response time to resident requests, fewer complaints from residents, and greater accountability.***

Table 8-4 summarizes the activities and costs associated with the maintenance of 52 dry detention systems in Somerset County. The table shows the costs of maintenance for all basins and for those with an area of 2 to 2.5 acres, the size of the typical system. It also shows the costs of performing stormwater maintenance activities two, three, and five times per year.

TABLE 8 - 4.
Summary of 1994 Stormwater System OMM Costs in Somerset County, New Jersey.

ITEM	ALL 1994 BASINS	2 - 2.5 ACRE BASINS	2 OMM/YR	3 OMM/YR	5 OMM/YR
Total cost	$62,450	$22,037	$6,039	$2,792	$53,669
Total #OMM	219	89	22	12	185
Total area	164.5	49	25.5	8	131
# Basins	52	22	11	4	37
$/OMM	$285.16	$247.61	$274.50	$232.67	$290.10
$/Acre	$379.64	$449.73	$236.82	$349.00	$409.69
$/Basin	$1,200.9	$1,001.68	$549.00	$698.00	$1,450.51
OMM/Basin	4.21	4.04	2	3	5
Acre/Basin	3.16	2.23	2.32	2	3.54
$/Acre/OMM	$90.18	$111.32	$118.41	$116.33	$81.94

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3.4. City of Austin, Texas

Austin, Texas began requiring the treatment of stormwater in 1984 as part of the city's program to protect its surface and ground water resources. The city's stormwater program annual budget has varied in recent years from $16.28 million in FY93-94 to $16.76 million in FY94-95 to $15.28 million in FY95-96. Stormwater OMM costs within these three budget years amounted to $3.16 million, $3.69 million, and $4.34 million. The primary funding source is from the city's stormwater utility which collected $14.87 million, $15.42 million, and $13.56 million respectively in these three budget years. Additionally, stormwater OMM funding is obtained from inspection and maintenance fees which brought in $128,241, $170,000, and $260,131. The number of employees at the utility has increased from 74 FTEs in FY93-94 to 78 in FY94-95 to 86 in FY95-96, with increased maintenance of stormwater systems accounting for five of the eight new positions in this last year.

Tables 8-5 A-E present information from the city's most recent five year stormwater maintenance plan. The city's budget also includes the following performance measures for OMM:

Outcome	1993-94	1994-95	1995-96(goal)
Removed sediments from creeks (cyds)	n/a	n/a	10,000
Restore water quality ponds	8	12	20
# restored ponds/maintenance FTE	0.8	2.0	4.0
# water quality ponds maintained	161	273	327

3.5. Urban Drainage and Flood Control District (Denver, Colorado)

The UDFCD coordinates regional stormwater management in the metropolitan Denver area, covering 1608 square miles and 36 local governments. The District charges an annual drainage fee which raises approximately $4 million per year. The District is responsible for OMM operations at selected regional, multi-jurisdictional stormwater facilities, primarily drainage conveyances and dry detention systems. The District contracts most OMM work and conducts inspections to assure that the work is performed satisfactorily.

Routine OMM activities include mowings of non-irrigated natural grasses along drainage channels, regularly scheduled collection and disposal of debris and litter from the drainageway, and unscheduled debris removal that become necessary because of large storms. Non-routine OMM activities include erosion repair and construction to rehabilitate or replace existing drainage structures.

Table 8-6 summarizes information on the cost of OMM operations conducted for the UDFCD. It is important to note that the per foot costs of maintenance varies greatly depending on the width of the channel and its associated right of way, the type of bottom, the slope of the channel sides, the type channel side slope stabilization, the type and extent of vegetation, and the ease of maintenance access.

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TABLE 8 - 5 A.
City of Austin
Stormwater Maintenance Plan
FY 1995
(Note: 2X,3X,4X =two times, three times, four times).

Activity	Inventory	Estimated Need	Actual Output	Actual Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	64 miles 3X	$700,000
Contract pond vegetation removal	161	161ponds 3X	136 ponds 4X	$100,000
Complaint handling	N/A	1,500	1,500	$199,169
Storm sewer locating (utility coord)	N/A	2,000 loc./yr	2,000 loc./yr	$91,152
Maintenance scheduling/planning		N/A	N/A	$206,239
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	5 miles	$578,984
Bridge/culvert clearing	1,000	2,400	1,800	$579,384
Erosion control projects	150	150	6	$200,548
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	2,000 4X	$51,073
Storm sewer inlet cleaning	18,000	13,500 2X	1,500 4X	$207,542
Storm sewer inlet filter cleaning	178	7,476	7,476	$34,048
Wet debris dewatering	N/A	300	100	$293,097
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,400 feet	$277,145
Storm sewer cleaning	400 miles	unknown	10,000 feet	$102,145
Storm sewer inspection	400 miles	unknown	6 miles/yr	$151,073
POND MAINTENANCE				
Water quality pond restoration	142	35	4	$212,078
Water quality/detention pond OMM	161	126	50	N/A
TOWN LAKE CLEANUP	N/A	200	130	$34,048

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TABLE 8 - 5 B.
City of Austin
Stormwater Maintenance Plan
FY 1996.

Activity	Inventory	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	50 miles 3X	$600,000
Contract pond vegetation removal	273	273 ponds 3X	136 ponds 4X	$100,000
Complaint handling	N/A	1,650	1,650	$175,870
Storm sewer locating (utility coord)	N/A	2,330 loc./yr	2,330 loc./yr	$87,935
Maintenance scheduling/planning		N/A	N/A	$179,170
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	8 miles	$1,010,061
Bridge/culvert clearing	1,000	2,400	1,800	$533,374
Erosion control projects	150	150	10	$342,750
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	6,000 2X	$66,996
Storm sewer inlet cleaning	18,000	13,500 2X	1,900 4X	$223,319
Storm sewer inlet filter cleaning	178	8,544	8,544	$44,664
Wet debris dewatering	N/A	300	110	$89,328
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,400 feet	$173,991
Storm sewer cleaning	400 miles	unknown	10,000 feet	$133,991
Storm sewer inspection	400 miles	unknown	4 miles/yr	$86,996
Special projects	N/A	unknown	6 projects	$89,238
POND MAINTENANCE				
Water quality pond restoration	240	56	30	$542,541
Water quality/detention pond OMM	273	217	200	N/A
TOWN LAKE CLEANUP	N/A	200	140	$134,164

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TABLE 8 - 5 C.
City of Austin
Stormwater Maintenance Plan
FY 1997.

Activity	Inventory	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	72 miles 3X	$700,000
Contract pond vegetation removal	327	327 ponds 3X	327 ponds 4X	$240,441
Complaint handling	N/A	1,825	1,825	$181,146
Storm sewer locating (utility coord)	N/A	2,650 loc./yr	2,650 loc./yr	$90,573
Maintenance scheduling/planning		N/A	N/A	$538,146
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	9 miles	$1,100,063
Bridge/culvert clearing	1,000	2,400	2,000	$549,375
Erosion control projects	150	150	20	$228,145
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	6,000 2X	$69,006
Storm sewer inlet cleaning	18,000	13,500 2X	4,500 2X	$275,018
Storm sewer inlet filter cleaning	178	8,544	8,544	$46,003
Wet debris dewatering	N/A	300	130	$112,008
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,600 feet	$309,011
Storm sewer cleaning	400 miles	unknown	10,500 feet	$138,011
Storm sewer inspection	400 miles	unknown	14 miles/yr	$119,005
Special projects	**N/A**	unknown	7 projects	$92,007
POND MAINTENANCE				
Water quality pond restoration	288	38	38	$207,176
Water quality/detention pond OMM	327	289	289	N/A
TOWN LAKE CLEANUP	N/A	200	170	$46,004

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TABLE 8 - 5 D.
City of Austin
Stormwater Maintenance Plan
FY 1998.

Activity	Inventory	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	78 miles 3X	$750,000
Contract pond vegetation removal	382	382 ponds 3X	382 ponds 4X	$240,441
Complaint handling	N/A	2,000	2,000	$186,580
Storm sewer locating (utility coord)	N/A	3,000 loc./yr	3,000 loc./yr	$93,290
Maintenance scheduling/planning		N/A	N/A	$186,580
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	15 miles	$1,347,784
Bridge/culvert clearing	1,000	2,400	2,200	$720,856
Erosion control projects	150	150	30	$234,989
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	9,000 2X	$71,076
Storm sewer inlet cleaning	18,000	13,500 2X	6,750 2X	$236,920
Storm sewer inlet filter cleaning	178	8,544	8,544	$47,384
Wet debris dewatering	N/A	300	140	$94,768
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,800 feet	$289,151
Storm sewer cleaning	400 miles	unknown	13,500 feet	$142,151
Storm sewer inspection	400 miles	unknown	16 miles/yr	$191,076
Special projects	**N/A**	unknown	7 projects	$94,768
POND MAINTENANCE				
Water quality pond restoration	336	12	12	$762,089
Water quality/detention pond OMM	382	370	370	N/A
TOWN LAKE CLEANUP	N/A	200	170	$47,384

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TABLE 8 - 5 E.
City of Austin
Stormwater Maintenance Plan
FY 1999.

Activity	Inventory	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	82 miles 3X	$850,000
Contract pond vegetation removal	400	400 ponds 3X	400 ponds 4X	$300,000
Complaint handling	N/A	2,050	2,050	$192,177
Storm sewer locating (utility coord)	N/A	3,100 loc./yr	3,100 loc./yr	$96,089
Maintenance scheduling/planning		N/A	N/A	$192,177
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20 miles	17 miles	$1,106,248
Bridge/culvert clearing	1,000	2,400	2,400	$582,832
Erosion control projects	150	150	30	$242,039
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	18,000 2X	$73,208
Storm sewer inlet cleaning	18,000	13,500 2X	13,500 2X	$438,026
Storm sewer inlet filter cleaning	178	8,544	8,544	$48,805
Wet debris dewatering	N/A	300	150	$97,611
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	3,000 feet	$557,415
Storm sewer cleaning	400 miles	unknown	15,000 feet	$146,416
Storm sewer inspection	400 miles	unknown	20 miles/yr	$193,208
Special projects	**N/A**	unknown	8 projects	$97,611
POND MAINTENANCE				
Water quality pond restoration	385	15	15	$439,584
Water quality/detention pond OMM	438	423	423	N/A
TOWN LAKE CLEANUP	N/A	200	170	$48,805

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TABLE 8 - 6.

Stormwater System OMM Costs in Denver, Colorado.

Channels with Earth Bottoms

Years	Channel Length	Channel Width	ROW Width	Side Slopes	Slope/ROW Material	# Mows/ Debris PU	Total Cost	$/Ft	$/Ft/Yr
91-94	14,000	40	60	Flat	Grass	0/3	$14,189	$1.01	$0.25
86-94	7,750	25	150	4:1	Riprap/ Grass	5/3	$117,108	$15.11	$1.68
86-94	17,315	35	80	Flat	Boulder/ grass	6/30-40	$397,022	$22.93	$2.55
86-94	7,550	15	100	Flat	Grass	5/5	$110,990	$14.70	$1.63
89-94	10,300	20	40	Flat	Earth	0/3	$9,945	$0.97	$0.16
86-94	22,750	45	65	1:1/ Flat	Earth	0/3	$59,895	$2.63	$0.29
88-94	4,600	20	40	Flat	Earth	0/5	$7,374	$1.60	$0.23

Channels with Concrete Trickle Channels

90-94	4,700	8	125	4:1	Grass	3/3	$15,759	$3.35	$0.67
86-94	4,550	6	50	2.5:1	Grass	3/3	$35,071	$7.71	$0.86
86-94	1,100	12	150	Flat	Grass	3/3	$11,387	$10.35	$1.15
86-94	4,150	6	100	4:1	Grass	3/5	$52,821	$12.73	$1.41

Dry Detention Systems with Grass Bottoms

Years	Channel Length	Sediment Removal	Area (Acres		Channel Material	# Mows/ Debris PU	Total Cost	$/Acre	$/Acre/Yr
88-94	253	No	1.4		Concrete	4/4	$7,983	$5,702	$814.59
89-94	752	No	6.6		Concrete	3/3	$15,353	$2,326	$387.70
86-94	3,700	No	9.3		Earth	0/2	$9,076	$976	$108.43
86-94	3,085	Yes	15.5		Earth	0/2	$29,521	$1,905	$211.62
88-94	300	No	1.8		Concrete	4/4	$8,852	$4,918	$702.54

3.6. City of Bellevue, Washington

Bellevue's stormwater program has required the construction of facilities to minimize flooding and reduce pollutants since 1984. The City's Surface Water Management program maintains the stormwater management system. The system consists of a combination of 146 miles of open streams, ditches, and culvert, 290 miles of enclosed storm pipe, 14,000 catch basins and manholes, and 225 neighborhood and ten regional detention facilities. Program staff install, clean, repair, and inspect all components of the system and respond to emergency flooding situations.

In 1974 the City was one of the first local governments to implement a stormwater utility in 1974, providing a dedicated funding source for stormwater management and the OMM of the city's stormwater system. The budget for stormwater system OMM for the past three years is summarized below:

Year	Salary/Benefits	Supplies/Services	Capital	Total
1994	$ 636,171	$ 330,485	$ 247,621	$1,381,508
1995	$ 664,267	$ 383,043	$ 184,325	$1,422,232
1996	$ 661,801	$ 434,415	$ 67,280	$1,305,543

Table 8-7 summarizes Bellevue's stormwater OMM costs during 1994 and 1995. As part of its stormwater OMM planning process, City staff have been compiling cost information on specific BMPs. Annual OMM costs for some of these BMPs are summarized below:

Constructed wetland	Sediment removal	= $1,500
	Staff vegetation removal	= $ 530
	Contracted vegetation removal	= $ 975
	Total cost with overhead	= $3,846
Coalescing plate filters		= $ 832
API filters		= $ 512
Small wet vaults	Sediment removal	= $ 300

In addition to these costs, the city has installed several innovative stormwater treatment systems for which some OMM cost information is available, and has collected OMM data from nearby cities which are using other types of stormwater treatment BMPs. This information is summarized below:

A. Alum Injection System

Alum injection within stormsewer to precipitate stormwater pollutants has been used in Florida since 1986. In 1995, the City of Bellevue constructed an alum injection system to treat runoff from 5.4 acres of a new development at a cost of $92,000. The estimated annual OMM costs are:

Personnel (1 person, 12 hrs weekly @ $35/hr)	= $21,840
Aluminum sulfate (600 gallons/year)	= $ 1,000
Magnesium hydroxide (Buffer, 55 gal/yr)	= $ 240
pH probes (replacements, two/yr)	= $ 300
Electricity	= $ 504
Total annual OMM costs	$23,884

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TABLE 8 - 7.
Stormwater System OMM Costs in Bellevue, Washington.

OMM ACTIVITY	1994 COMPLETED	1994 LABOR DAYS	1994 TOTAL COST	1995 COMPLETED	1995 LABOR DAYS	1995 TOTAL COST
Vacuum C/B, inlets	1,457	62.44	$21,586	2,134	101.06	$29,355
Vacuum Manholes	308	46.94	$15,877	436	58.69	$19,372
Vacuum Ditch	2653 ft	23.94	$7,244	3,582	40.63	$11,114
Vacuum Res. Pond	106	75.31	$26,690	41	30.25	$9,841
Jetrod Pipelines	29,620 ft	88.94	$31,196	38,750 ft	116.00	$39,413
Root Saw Pipelines	4,706 ft	45.63	13,863	5,356 ft	56.19	$16,064
Vacuum Oil Separator	8	4.63	$1,441	8	3.00	$965
Brush Res. Pond	43	163.56	$33,484	42	212.75	$36,350
Brush Region. Pond	7	34.00	$7,143	11	36.81	$7,942
Manually Clean Basins	4,897	165.63	$31,943	2,795	125.50	$24,117
Ditch Cleaning	9802 ft	63.25	$12,766	16,643 ft	96.63	$35,478
Repair CB Inlets, MH	249	141.56	$33,433	326	193.34	$41,263
Repair Pipelines	76 ft	20.56	$6,333	222	73.31	$32,420
Repair Res. Pond	62 hrs	33.25	$8,320	642 hrs	80.19	$17,331
Repair Region. Pond	532 hrs	66.44	$13,794	506 hrs	63.19	$14,316
Clean/repair Streams	53 hrs	93.69	$21,668	877 hrs	109.59	$26,247
Inspect Res. Pond	222	59.69	$11,597	251	56.38	$12,737
Inspect Oil Separators	70	8.25	$1,505	64	8.97	$1,897
Customer Requests	362	81.38	$19,320	504	102.94	$24,205

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B. Lakemont Filter System

Part of the stormwater system for the Lakemont Development, a single and multifamily residential development, included a BMP treatment train to serve 252.3 acres. The stormwater system consists of an underground wet vault, two filters, and a dry detention system. The total construction costs of this system in 1992 was $4.6 million. The estimated annual OMM costs are:

Personnel (2 people, total of 15 hrs/week @ $35/hr)	=$13,650
Phone for telemetry, flow gages	=$ 1,200
Electricity	=$ 720
Contracted maintenance of electrical controls	=$ 2,500
Filter media replacement	=$20,000
Vault sediment removal	=$ 1,500
Total	=$39,570

C. Compost Stormwater Filters

King County, Washington performed a cost study of these stormwater treatment systems (Table 8-8). Additionally, CSF Treatment Systems, Inc. which construct and maintain these systems, provided King County staff with the following estimates for two potential applications of this innovative BMP:

Assumptions:

Average annual OMM cost is based on a four year service contract with a 5% inflation factor. Maintenance includes two annual inspections and two minor OMM visits in the spring and early fall.

Disposal cost of $35 per cubic yard although often the material can be used for on-site landscaping or erosion control.

Cost estimates:

Filter 1 treats 12 acres of residential area with a peak discharge rate of 1.49 cfs. The filter area is 12' by 30' (360 sf) with a construction cost of $18,800 and an average annual OMM cost of $2,480.

Filter 2 treats 5 acres of commercial development with a peak discharge rate of 1.22 cfs. The filter area is 10' by 31' (310 sf) with a construction cost of $16,200 and an average annual OMM cost of $2,175.

3.7. Kitsap County, Washington

Like many local governments within the Puget Sound watershed, Kitsap County began requiring the treatment of stormwater in 1994. To provide a dedicated funding source for its stormwater management program, the county implemented a stormwater utility which generates $4 million through its user fees. Stormwater system OMM is a major component of the county's program, receiving 24% of the annual budget. Table 8-9 summarizes cost information on stormwater system OMM in Kitsap County. Costs are based on a labor cost of $25 per hour and a $55 per ton handling and disposal cost.

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TABLE 8-8.

Stormwater Compost Filter System Costs
(Compiled by King County Surface Water Management).

Tributary Area	Flow Rate (2 yr storm)	Construction Cost	Cost per Tributary Acre	Annual OMM Cost
12 Acres, Residential	1.49 cfs	$18,800 Drop-In Filter	$1,570	$2,480
5 Acres, Commercial	1.22 cfs	$16,200 Drop-In Filter	$3,240	$2,175
50 Acres Residential	5.5 cfs	$47,900 Open Filter	$960	$5,600

TABLE 8 - 9.

Stormwater OMM Costs in Kitsap County, Washington.

CATCH BASIN SEDIMENT REMOVAL						
FACILITIES	# OMM/YR	PERSON HRS	PERSONNEL COSTS	CUBIC FEET SEDIMENT	DISPOSAL COSTS	ANNUAL $/FACILITY
549	549 (Once each)	284.3	$7,107.50	2,611.50	$9,797.75	$30.79
CONTROL STRUCTURE SEDIMENT REMOVAL						
49	49 (Once each)	147	$3,675.00	696	$2,587.44	$127.81
VEGETATION CONTROL						
$27.00	47 (1-4 each)	860	$2,150.00	$45.77/Operation	N/A	$79.63

4. FINANCING STORMWATER SYSTEM OPERATION, MAINTENANCE, AND MANAGEMENT

To provide the flood control, water quality protection, and other benefits for which stormwater systems are constructed, it is essential that maintenance and management be performed on a regular basis. As both the number of systems and the reliance upon them grows, the importance of stormwater system OMM grows accordingly. Unfortunately, experience through-

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out the country has shown that, for several reasons, stormwater system OMM is often neglected or, at best, performed only sporadically. This maintenance deficiency poses a serious threat to the safe and effective operation of the stormwater systems we have come to rely upon and to the health and safety of the people and water bodies the facilities are intended to protect.

While there are several reasons for this maintenance neglect, including lack of inspectors or institutional mechanisms, the primary cause is a lack of adequate maintenance funding. The problem of inadequate funding manifests itself in several ways, including insufficient staffing, inadequate equipment, lack of or inattentive facility inspections, and ineffective operation, maintenance, and management efforts.

Similarly, the problem of inadequate stormwater maintenance (or program) funding also has several causes. These include legal and regulatory constraints, a shortage of overall operating funds, poor stormwater program planning, and a lack of commitment by elected officials and by citizens. ***Unfortunately, stormwater management has always been "the orphan infrastructure" - only receiving public attention and funding in times of crisis.*** At budget time, stormwater program funding seldom competes well against other community needs such as police protection, fire protection, ambulance service, etc. Accordingly, funding stormwater maintenance and management programs from traditional general fund sources has led to inadequate funding.

These causes signify an overall failure to recognize stormwater system OMM as a key component of any stormwater management program. ***The only way to solve this dilemma is through a comprehensive public information program which educates elected officials, citizens, and the private sector about the importance of stormwater management programs, proper stormwater system OMM, and the need for adequate funding.*** Because of limitations on traditional general funding sources, the solution requires both commitment and creativity.

4.1. Public Financing of Stormwater OMM

A major policy issue facing local governments is whether they should assume responsibility for stormwater system OMM. Assumption of stormwater OMM may take the form of direct involvement by local government staff or by contracting with private maintenance services.

Where local governments already have assumed such maintenance, the lack of adequate funding has led to a seriously high level of facility maintenance default. This not only creates severe health and safety hazards for their residents and threatens the health of their water bodies, but it may also threaten the continuation of the overall stormwater management program. ***It is extremely difficult to generate the vital public support that a successful stormwater program requires if the local residents are surrounded by stormwater systems that are unsightly, unsafe, and ineffective.***

In addition, a local government may wish to assume the maintenance of all or some of the privately constructed stormwater systems within its borders. Traditionally, this has been the exception rather than the status quo. ***Most local governments prefer to require systems serving private land uses to be owned, operated, and maintained by private landowners or property owner associations. Unfortunately, history has shown that most private owners do an inadequate job of stormwater system OMM.*** Consequently, as a last resort, more local governments are considering assumption of OMM

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responsibilities to restore and maintain existing systems which have already suffered continued neglect from owners or to avert anticipated defaults by potentially negligent owners. In either case, a lack of adequate funds will prevent the local government from assuming this maintenance, which in turn will only add to the growing list of unsightly, unsafe, and ineffective stormwater management systems within the community.

The problem of inadequate stormwater system OMM funding described above indicates that the traditional methods of public financing may either be ill-suited for this purpose or are not being used to their fullest extent. In response to these factors, four stormwater funding sources have been identified and are being used widely around the country. These funding sources, individually or in combination, offer a greater opportunity to provide an adequate source of funds to meet local government stormwater system OMM obligations. ***These four recommended funding sources are:***

- ***General tax revenues***
- ***Stormwater utility fees***
- ***Inspection or permit fees***
- ***Dedicated contributions***

Details about these four funding sources will be subsequently presented, along with suggested criteria for evaluating the suitability of each. Prior to a discussion of each one, however, it is important to note some fundamental aspects of public stormwater system OMM financing.

The success or failure of any proposed financing program which must receive public support and approval is often determined by the degree of information the public receives. For many reasons, the public is generally protective of its dollars and initially suspicious of any new public program which proposes to spend them. Often, this suspicion is beneficial, for it helps promote sound fiscal planning and spending programs.

However, where this suspicion is unwarranted and cannot be overcome, it may also prevent a valuable and fiscally sound program form advancing beyond the proposal stage. Therefore, ***the value of a comprehensive public information program can not be overemphasized. Such a program must explain the basis, purpose, and details of the financing proposal and must convince the public and their elected officials that it is both necessary to implement and beneficial to their interests.*** Experience has shown that citizens and elected officials don't mind spending money if they know exactly what the money will be used for and what benefits the expenditures will provide to the community.

All successful stormwater management maintenance (or program) funding programs should possess certain fundamental elements or characteristics. These include:

- ***Be based upon a stable source of consistent funds.*** Proper stormwater system OMM must be continually and consistently performed on a regularly scheduled basis. This requires a long term commitment of personnel, equipment, and materials. As a result, the funds to support this commitment must be based upon a stable, secure, and reliable source.

- ***Be compatible with the local organizational structure.*** The overall effectiveness of a stormwater OMM program is based to a large extent upon the efficiency of its funding program. The most efficient funding program is that which is most compatible with the organizational structure of the managing department, agency, or authority. Wherever possible, the funding program should use the billing, collection, and bookkeeping operations of an existing public system.

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- ***Include provisions for the four essential operations - Program Administration, Accounting and Budgeting, Revenue Management, and Information Management.*** Program Administration is needed to insure the effective and efficient operation of the overall program. Accounting and Budgeting procedures are needed to accurately track operations and determine required funding levels. This may include the use of detailed work orders and time sheets by maintenance and inspection personnel and their supervisors. Revenue Management must insure a secure and reliable source of program funds to meet expenses and oversee their expenditure. Information Management must provide all of the above with comprehensive and accurate data upon which operational decisions can be based. It must also foster program understanding and support by providing government leaders and the public with timely information, explanations, and answers.

- ***Be based upon an equitable, understandable, and defensible fee or rate structure.*** Stormwater OMM funding programs may require complex procedures and operations in order to provide adequate funding levels. However, to obtain public acceptance and support, the program's fees or rates must be based upon a formula or method that can be readily explained to and understood by the public. The fees or rates must be perceived as being both reasonable and equitable and based upon accurate data and sound decisions.

- ***Be continually reviewed and updated.*** Program costs, revenues, and responsibilities must be regularly evaluated and adjusted as needed to maintain maximum cost effectiveness. The do this, the program must possess a flexibility of approach which will allow it to quickly respond to such changes. This is especially true when a large storm occurs and OMM needs are increased significantly.

- ***Be consistent with applicable state laws and regulations.*** The final details of a specific public stormwater OMM financing program will depend to a great extent upon the general authorities and requirements established in state law or regulations. Prior to the adoption of any financing program, the local government's general counsel should review all details of the program to assure it is compatible with state law.

4.1.1. General Tax Revenues

Around the nation, t***he general tax fund is the most commonly used source of funding for stormwater programs and stormwater system OMM.*** General tax revenues are an obvious source of funding since the purpose of local government taxes is to fund activities necessary to provide for the community's health, safety, and welfare through the implementation of a number of social, economic, recreational, and environmental programs. Accordingly, since properly functioning stormwater systems provide public heath, safety, and environmental benefits, and since neglect of stormwater system OMM can create serious health, safety, and environmental hazards, the use of general tax revenues to provide for the maintenance of stormwater systems can be construed as being consistent with this purpose.

However obvious, ***general tax revenues may also be the least suitable source of stormwater program or maintenance funding.*** As the name implies, "general" tax revenues originate at a number of sources and are used to finance an equally diverse number of public programs, including police and fire protection, civil and criminal courts, social

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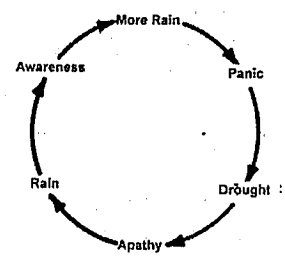
and economic support programs, roadways, utilities, and recreational activities and facilities. This combination of broad base and use creates two distinct problems which must be overcome if general tax funds are to be used to support public OMM of stormwater systems.

First, with such a broad base, it may be difficult to justify the expenditure of general funds to maintain a stormwater system that will only benefit a portion of the taxpaying community. Second, with an equally broad use, ***stormwater programs and maintenance must compete against a large number of other vital public programs for a very limited number of tax dollars.*** This is one reason why so many stormwater programs are inadequately funded and why so many stormwater systems are improperly operated and maintained. This problem has been compounded in recent years by tax caps and the public's general opposition to new or higher taxes.

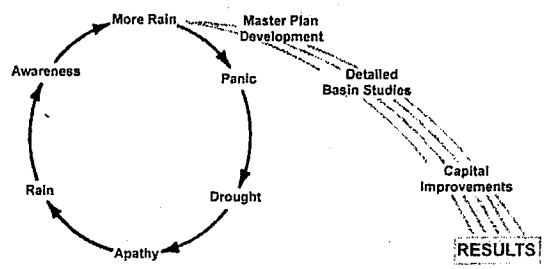
Elected officials have discretionary authority in allocating general tax revenues through the annual budget process. However, both a government' s responsibilities and its political realities tend to define how these funds are actually spent. Mandatory services such as police and fire protection must receive priority over more discretionary budget items such as stormwater system OMM. Therefore, to win use of general tax funds to finance stormwater system OMM, it must be demonstrated to the public and to elected officials that this activity has greater importance than other discretionary budget items.

The success of this effort will depend upon many factors, including the overall costs and community benefits of the maintenance program, the severity and extent of the maintenance neglect problems, and the effectiveness of the methods used to inform and educate the public and their elected officials. ***Experience has shown that this effort is often successful after a recent "crisis" such as a major flood or contamination of an important community water body. These calamities present an opportunity to gain public support and to prevent future disasters. They are an excellent time to break the "hydro-illogical cycle" and implement the "hydro-rational cycle".***

HYDRO-ILLOGICAL CYCLE



HYDRO-RATIONAL CYCLE



4.1.2. Stormwater Utility Fees

The unreliability of using general tax funds to finance stormwater programs or stormwater system OMM has led many communities around the country to implement either a stormwater utility fee or a stormwater special assessment. The use of utility charges to finance publicly owned water and sewer systems began in the early 1900s and, today, provides a stable source of funds for local utility authorities and agencies around the nation. In recent years, with the adoption of tax limitations, utility charges and

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special assessments have become increasingly popular as local governments attempt to maintain an adequate level of public services in the face of limits on expenditure growth.

The concept of a utility charge to publicly finance stormwater system OMM is a sound one in several respects. Unlike general tax revenues, utility charges are not subject to state "tax cap" limitations. The public is used to utility charges because of the precedent set by water and sewer charges. Most importantly, a more direct relationship between costs and benefits of stormwater system OMM can be demonstrated than through the general assessment of local taxes. Finally, similar to general tax revenues, the stormwater utility charge can be used to publicly finance the maintenance of both new and established stormwater systems.

A variation of a city or county-wide stormwater utility fee is the establishment of a stormwater benefit area in which all property owners pay a special assessment charge. The charge generally is assessed on a per acre basis to fund construction and OMM of stormwater facilities within the benefited area. Additionally, if different land uses within the benefit area receive substantially different levels of stormwater benefits, the assessment of per acre fees from subarea to subarea should vary in proportion to the benefits received. The boundaries of the benefit area should be based on the contribution of runoff to the stormwater system. This may include the tributary drainage area for a single stormwater system, especially if it is a regional facility, or more commonly, for an entire network of facilities within a watershed or subwatershed.

Special assessment charges within a benefit area should meet the following criteria:

- Fees should not exceed the amount of the benefit received by any particular property.
- Fees should be properly allocated to the benefited properties.
- Property owners should have an opportunity to comment, or even vote, on how the assessments are allocated to their properties.

Whether for a stormwater utility fee or a special assessment fee, an important need is to establish a relationship between the fee and the benefits received. Unlike charges for water or sewer, a readily measured commodity is not delivered to the stormwater utility or benefit area customer. To a lesser extent, the service provided by stormwater system OMM is not as readily perceived or quantified as the service provide by a wastewater system which continually disposes of sanitary wastes from homes or businesses. As a result, the services provided to, and the benefits received by, the utility customer or special benefit property owner must be more broadly defined if an acceptable and equitable utility charge or special assessment is to be developed. ***The goal is to show that assessed fees are used to cover costs of stormwater system OMM or other stormwater services benefiting each property and that the benefits to each property are at least equal in value to the assessment fee.*** Constitutional standards require that property owner benefits be special benefits which are generally not shared by the community as a whole.

The utility rate structure for a stormwater facility maintenance district should be based on several considerations. The most fundamental of these is the concept of payment based upon contribution to the need for the maintenance rather that the benefits provided by it. For example, a typical stormwater system OMM charge may be based upon the size of the property contributing runoff to the facility. This rate may be refined to reflect the percentage of impervious surfaces on the prop-

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erty, the runoff potential of the remaining pervious areas, the type of land use, and other factors affecting the rate, volume, or pollutant loading of stormwater. For example, a one acre property containing a single family residence with 20 percent impervious area would pay proportionally less than a similarly sized industrial property with 80 percent impervious cover for the OMM of the stormwater system to which these lands contributes runoff .

While a certain degree of complexity may be required to equitably distribute OMM costs throughout the community or special district, the rate structure should remain as simple as possible. This simplicity will help make the rate structure more understandable to the rate payer and, as a result, more acceptable. The rate structure should also retain a degree of flexibility to accommodate changes in program revenues, expenses, and responsibilities.

The rate structure also must reflect the costs of providing the essential stormwater program elements listed in pages 8-21 and 8-22. These administrative and support costs are estimated to range from 10 to 25 percent of total program costs.

If a local government does not wish to own, maintain, and operate private stormwater systems, stormwater utility fees can provide an economic incentive to increase the likelihood that the private property owners will actually conduct OMM activities. Several local stormwater utilities provide "credits" if a property or subdivision has an on-site stormwater management system which is being maintained properly. An administrative problem with this system that must be addressed is how to assure that the private systems are being maintained properly. Some local governments have established Stormwater Operating Permits which require an annual inspection by staff or certification by a private inspector that the facility is being maintained and is operating as constructed. Since state and local government stormwater programs often have too few inspectors, the programs in Delaware and Florida have implemented training and certification programs for public and private sector personnel who wish to conduct inspections.

4.1.3. Inspection or Permit Fees

Similar to utility fees or special assessments, the use of inspection or permit fees to publicly finance stormwater system OMM represents a relatively new application of an established component of government revenues. In many states, local governments have the general authority to establish fees and other charges to pay for the operational expense of various programs and services. Often, these fees are associated with the issuance of a permit, such as a building permit, clearing or grading permit, stormwater permit, or sewer connection permit. Alternatively, these fees may be associated with building or stormwater program requirements for inspections.

Implementing a successful stormwater system OMM program funded entirely or partially by inspection or permit fees requires the establishment of two primary relationships. First, the permit program itself must be directly related in some manner to stormwater systems and, preferably, their operation and maintenance. For example, the use of fees from a sanitary sewer connection permit program to finance stormwater system OMM may not be feasible, permissible, or acceptable to the public. However, the use of fees from a storm sewer connection program may be. Other potentially feasible permit fees include those for a local construction permit, stormwater permit, or stormwater discharge permit. Inspection fees can be required when the local government's stormwater program requires a periodic inspection of private stormwater systems. The public inspections can determine whether the

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owner is maintaining the facility properly. If not, they can help identify what OMM activities are needed and notify the owner. A permit program based upon fees for annual inspections, such as a stormwater discharge or stormwater operating permit, can provide a continuing source of funds. However, many permit or inspection fees are a one time charge, typically when the facility is first constructed. These are not a good funding source for continuing stormwater system OMM.

Second, a relationship should be established, if possible, between the payer of the inspection or permit fee and the use of the fee itself. For stormwater inspection fees, this relationship is relatively easy to establish. For permit fees, it is recommended that the fees be placed into dedicated accounts. To demonstrate that the fees are being used for the OMM of specific facilities, it is recommended that computer data bases be established to track facility maintenance activities and costs. This data base will also allow the stormwater program to more accurately estimate future resources and funding needed to adequately maintain stormwater systems. The more directly either of the above relationships can be established, the greater the chances of public acceptance.

Similar to utility charges, inspection and permit fees should reflect the concept of payment based upon contribution to the need for facility OMM rather than the benefits provided by it. For example, factors to consider in establishing a stormwater construction permit fee might include the size of the proposed facility, its contributing drainage area, the number of BMPs or structures, and whether it is for stormwater quantity control, stormwater quality control, or both. Therefore, a relatively small facility serving a residential area and intended only for quality control would be charged a proportionately lower permit fee than a larger facility providing both quantity and quality control to a commercial area. The same factors could be considered when establishing an inspection fee along with the number of inspections, time to conduct inspections, and time to travel to the site.

As with stormwater utility fees, permit or inspection fees need to be as simple as possible but still provide for an equitable distribution of costs. The fee schedule should also provide flexibility to accommodate changes in program revenues, expenses, and responsibilities. It also needs to reflect the costs of program administration, accounting and budgeting, and revenue and information management.

4.1.4. Dedicated Contributions

The use of dedicated contributions from land developers to finance public maintenance of stormwater systems represents an extension of an established procedure in a new direction. Under this program, the local government assumes the OMM of a stormwater system constructed as part of a private development. The actual OMM can be provided either by local government staff or through contract with a private maintenance service. ***All or a portion of the required funding for the OMM is obtained through a one-time contribution by the land developer to a dedicated account which is controlled by the local government. Often the developer is responsible for OMM during a "warranty period", frequently the first two years.***

The amount of contribution to the dedicated account could be based upon several factors including:

1. The type of stormwater BMP and the anticipated OMM activities.
2. The total number of years in which facility OMM would be provided.
3. The present annual maintenance, administrative, insurance, and support costs.

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4. The anticipated annual increase in present costs due to inflation, equipment depreciation and replacement, increases in labor and insurance rates, rising disposal costs, and other factors.
5. The anticipated interest earned by the dedicated contribution.
6. The percentage, if any, of cost sharing between the developer and the local government.

The type of stormwater BMP will determine the frequency and types of needed OMM operations. Unfortunately, an extensive data base on this information is not available. However, the information presented earlier in this chapter can help to develop cost estimates of stormwater facility OMM. Administrative and support function costs are estimated to range from 10 to 25 percent of total program costs. An annual cost of 2 percent of the dedicated funds may be required to cover the administrative costs of the dedicated accounts themselves. This information can be used to help estimate the present annual OMM, administrative, insurance, and support costs.

The total number of years for which OMM will be provided will vary with the policies of each local stormwater program. Often the dedicated contribution is based on public OMM for 25 years, after which stormwater OMM costs are financed through either the local governments general tax revenues or stormwater utility fees.

The Township of West Windsor, New Jersey has established a Dedicated Contribution Program and will be used as an example for calculating the developer's contribution. The program is based upon the Township providing 25 years of OMM after which the stormwater OMM will be financed through the Township's general tax revenues. Participating developers are required to furnish 75 percent of the estimated annual stormwater system OMM costs in the form of a one-time payment. The amount of this payment is calculated for each facility through the use of a standardized Developer Contribution Worksheet (Table 8-10).

In the West Windsor program, annual OMM costs are based upon the performance of four major maintenance tasks by Township personnel. These tasks are grass mowing; landscape maintenance; general maintenance, which includes trash and debris removal and erosion repair; and periodic sediment removal and bottom restoration. Grass mowing is estimated at the rate of one acre per hour. Other required tasks are estimated based upon an hourly, yearly, or per task basis. Appropriate factors are used to reflect infrequent OMM tasks such as sediment removal and bottom restoration. Annual liability insurance costs are also estimated and combined with the estimated annual costs of the four major maintenance tasks to produce a total first-year OMM cost for the facility. This value is multiplied by an appropriate Present Worth Factor and then by 0.75 to determine the actual amount of the developer's dedicated contribution. This Present Worth Factor is based upon an average annual interest rate on the dedicated funds of 8 percent and an average annual cost increase of 6 percent over the 25 year OMM period.

The use of dedicated contributions to finance stormwater OMM has many advantages. First and foremost, they provide a secure, dedicated funding source for future stormwater OMM activities. Unlike general tax revenues, contributions to dedicated accounts are not subject to state tax cap limits. A disadvantage is that dedicated contributions are only applicable to new stormwater systems. The use of these funds and the activities they pay for need to be closely tracked. This is fairly easily done through account and expense records. This information can be used to demonstrate a direct relationship between the contributed funds and their use for facility OMM.

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Equally important, this type of a data base can help the local government to better estimate the OMM costs of future new facilities and to estimate funding needs for OMM of older stormwater systems. To minimize overall administrative costs, it is recommended that a single dedicated account be established for all developer contributions.

TABLE 8 - 10.

Sample Worksheet for Calculating Dedicated Contribution To Stormwater Management System OMM.

NAME OF DEVELOPMENT: _____
LOCATION: _____
TYPE OF STORMWATER SYSTEM: _____
NUMBER OF ACRES OF STORMWATER SYSTEM: _____
NUMBER OF ACRES CONTRIBUTING TO THE SYSTEM: _____

1. MOWING

A. Rate per hour for labor and equipment		=$_____
B. Base number of hours for labor and equipment for mobilization and mowing up to one acre:	_____	
C. Number of hours for mowing additional area (based on one hour per acre)	_____	
D. Hours needed for mowing = B + C		=_____
E. Cost per mowing = A X D		=$_____
F. Number of mowings per year:	_____	
G. Annual mowing cost = E X F		=$_____
H. Materials cost		=$_____
I. Total cost = G + H		=$_____

2. LANDSCAPE MAINTENANCE

A. Rate per hour for labor and equipment		=$_____
B. Number of hours of required landscape maintenance per year:	_____	
C. Annual landscape maint. cost = A X B		=$_____
D. Materials cost		=$_____
E. Total cost = C + D		=$_____

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3. GENERAL MAINTENANCE

A. Rate per hour for labor and equipment =$_____
B. Number of required hours of trash and debris removal per occurrence: _____
C. Number of required hours of erosion and sediment repair per occurrence: _____
D. Number of required hours of sediment removal per occurrence: _____
E. Number of required hours of other specific maintenance per occurrence: _____
F. Cost per occurrence = A X (B + C+ D+ E) =$_____
G. Number of occurrence per year: _____
H. Total cost = F X G =$_____

4. INSURANCE

A. Annual insurance cost =$_____

TOTAL FIRST YEAR COST

1. MOWING (1.I.) =$_____
2. LANDSCAPE MAINTENANCE (2.E.) =$_____
3. GENERAL MAINTENANCE (3.H.) =$_____
4. INSURANCE (4.A.) =$_____

TOTAL FIRST YEAR MAINTENANCE COST =$_____

CALCULATION OF DEVELOPER CONTRIBUTION

A. TOTAL FIRST YEAR COST =$_____
B. FOR 25 YEARS = x 19.79
C. TOTAL REQUIRED AMOUNT = A X B =$_____
D. DEVELOPER CONTRIBUTION PERCENTAGE = X 0.75
E. DEVELOPER CONTRIBUTION = C X D =$_____

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Chapter 9
Disposal of Stormwater Sediments

1. OVERVIEW

Assuring that stormwater management systems will provide their desired benefits is no easy task. There are many challenges to overcome. The stormwater management system must be properly designed and constructed. The stormwater program's institutional framework must assure that periodic inspections occur during and after construction of the stormwater system, and that an operation and maintenance entity is clearly identified and legally responsible for the long term operation, maintenance, and management of the stormwater system.

Once these hurdles are cleared, new challenges arise. ***A growing concern, as more and more stormwater treatment systems are constructed, is how should the sediments that accumulate in them be disposed.*** The stormwater pollutants that accumulate in the sediments are highly variable, but they often include several contaminants such as heavy metals, petroleum hydrocarbons, and other organic compounds, such as pesticides or solvents, which may be considered hazardous wastes.

This chapter will discuss the applicability of federal and state solid and hazardous waste laws which may affect the proper disposal of stormwater sediments. It will also summarize data on stormwater sediments from the few studies which have been conducted to characterize them. Recommendations will be provided on whether stormwater sediments need to be characterized before disposal and what types of tests need to be conducted. Finally, recommendations will be made on how stormwater sediments should be safely disposed.

1.1. Intended Readers

This chapter is intended primarily for:

- **Public Officials and Regulatory Personnel**, who need to be aware of the applicability of federal and state regulations which may apply to the disposal of stormwater sediments.

- **System Owners or Operators**, who need to know how to properly test and dispose of sediments which accumulate in their stormwater systems.

2. POTENTIALLY APPLICABLE LAWS AND REGULATIONS

Stormwater pollutants include a wide variety of substances that are deposited on pervious and impervious surfaces and then transported by the next rainfall. Additionally, especially in older urbanized areas, there are often connections to the stormwater system which should go to the sanitary sewer system. Consequently, a wide variety of contaminants that may be classified as hazardous or toxic may enter stormwater management systems. These contaminants include heavy metals, petroleum hydrocarbons, pesticides, and a wide variety of organic chemicals. ***Consequently, several federal and state laws and regulations may apply to the disposal of sediments which accumulate in stormwater systems or which are captured by street sweepers.***

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Unfortunately, few state or local governments have established clear policies, guidance, or rules on disposal of stormwater sediments or the applicability of federal, state, or local laws and rules. Seldom do current laws, ordinances, rules, or guidelines governing solid waste handling and disposal address waste removed from stormwater systems. This ambiguity makes it difficult for public and private operators to comply with relevant laws and regulations in their stormwater management system maintenance programs. As a result of these unanswered handling and disposal questions, many stormwater management agencies have been discouraged from performing routine maintenance of stormwater systems.

This section will discuss laws and regulations that may be potentially applicable to stormwater system sediment disposal.

2.1. Federal Laws and Regulations

A. Resource Conservation and Recovery Act of 1976 (RCRA)

RCRA requires generators of hazardous wastes to monitor and manage them in accordance with specified procedures. A solid waste may be considered a hazardous waste if it contains materials which are specifically listed in Sections 261.31 through 261.33 of 40 CFR or because it possesses any of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity). In nearly all cases concerning stormwater sediments, the reason that they could be classified as hazardous wastes is because they contain listed chemicals rather than because the sediments are hazardous by characteristic. However, ***it is possible for stormwater sediments to be classified hazardous wastes because they exhibit toxicity. Stormwater sediments would exhibit toxicity if, using the Toxicity Characteristic Leaching Procedure (TCLP), the extract contains contaminant concentrations which exceed the limits listed in Table 1 of Section 261.24 of 40 CFR*** (See Table 9-3 for a partial listing of these limits).

Key aspects of RCRA and its implementing regulations which may affect stormwater sediment disposal include (Jones et. al., 1995):

- *The Mixture Rule.* RCRA regulations include lists of a number of chemicals and their by-products that are considered hazardous wastes when used and discarded (see Sections 261.31 through 261.33 of 40 CFR). Under the mixture rule, a mixture of any solid waste (including dirt) and the listed waste is considered by regulation to be a hazardous waste. Even small concentrations of a listed waste can render large volumes of material hazardous waste.

- *The Derived-From Rule.* If solid waste is considered hazardous waste, even if by operation of the mixture rule, then any residue from the treatment, storage, or disposal of the hazardous waste is also considered to be hazardous waste.

- *The Contained-In Policy.* Under existing EPA policy, environmental media, such as soil, water, or debris, that contain a hazardous waste must be handled as a hazardous waste.

- *The Nature of the Source Material.* Simply because a chemical listed in RCRA rules is detected in stormwater sediments does not make the sediments hazardous waste, even after discard. For example, if a spent halogenated solvent listed as hazardous waste is detected in stormwater sediments, the sediments would be hazardous waste under the mixture rule only if the source of the spent solvent contained more than ten percent of that solvent by volume.

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The Mixture and Derived-From rules do not apply to stormwater sediments until they are removed from the BMP. Only then are the sediments considered to be discarded. It is the Contained-In Policy, rather than the mixture or derived-from rules, that is most likely to bring stormwater sediments within the scope of RCRA regulations. A de minimis exception to the contained-in policy can be used on a site-specific basis. EPA must then demonstrate that contaminated media contain hazardous waste before applying RCRA requirements. It is likely that EPA will apply the Contained-In policy to stormwater sediments, but the policy, as applied to contaminated media, has not been adopted as a rule.

B. Federal Water Pollution Control Act - NPDES Regulations

Discharges of pollutants to waters of the United States or to certain master stormwater systems owned or operated by local government may require a NPDES permit from EPA or the state water quality agency. For example, these regulations would apply to discharges of vactor truck water to storm sewers.

2.2. State Laws and Regulations

The owner, operator, or responsible maintenance entity of a stormwater management system should request the stormwater permitting or program agency to provide information about the potential applicability of state or local laws and regulations to the disposal of stormwater system sediments. This request may not bring a quick or simple answer depending on how long the stormwater program has been in operation and whether this issue has been addressed.

The laws and regulations in different states and local governments are going to vary considerably. Be sure to consult your appropriate local or state agency. The following discussion will summarize how laws and rules in two states - Washington and Florida - address the issue of stormwater sediment disposal.

A. Washington State

The *Washington State Solid Waste Management Act (R.C.W. 70.95)* classifies solids collected from stormwater systems and street cleaning as solid wastes. The Act defines these wastes as street waste solids. Such wastes must be stored and handled according to relevant solid waste regulations.

One of the highest priorities of the Act is to encourage waste recycling over landfill disposal. Government agencies can frequently use street waste solids for fill or other uses permitted by local health departments. To be designated as street waste solids in Washington state, and avoid handling as a hazardous waste, contaminant concentrations in solids must not exceed the levels presented in Table 9-1.

If garbage, refuse, and other contaminants are removed from stormwater facility sediments, they may not even require handling as solid waste. Such solids must consist only of soil, sand, gravel, or sediment. However, these materials should not be used as residential topsoil or in locations where they could have contact with wetlands, surface waters, ground water, wells, or utility trenches.

The *Washington State Model Toxics Control Act (MTCA)* establishes waste contamination thresholds, above which materials must be handled as hazardous waste (see Table 9-2). ***The hazardous waste threshold of 200 milligrams per kilogram (mg/kg) total petroleum hydrocarbons (TPH) is particularly relevant to disposal of stormwater sediments.***

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TABLE 9-1. Maximum Contamination Limits for Street Waste Solids[1] in Washington State

Contaminant	Analytic Method	Max. Concentration (ppm)[2]
Heavy fuel hydrocarbons (C_{24}-C_{30})	EPA WTPH 418.1	2000
Diesel (C_{12}-C_{24})	EPA WTPH-D	500
Gasoline (C_6-C_{12})	EPA WTPH-G	250
Benzene	EPA 8020	0.5
Ethylbenzene	EPA 8020	20
Toluene	EPA 8020	40
Xylenes (total)	EPA 8020	20

[1]Solids collected from stormwater facility and street cleaning [2]ppm = parts per million

TABLE 9-2. Standards for Disposal of Wastes under TCLP[1], MTCA[2], and Pretreatment Standards[3] in Washington State.

Type of Waste/ Contaminant	Legal Standard	Maximum Concentration Limits
Solids		
Lead	TCLP[1]	5.0 mg/L = 100 mg/kg
TPH	MTCA[2]	200 mg/kg
Vactor Water		
Copper (daily average)	Pretreatment standards[3]	2.00, 3.00 mg/L
Copper (grab maximum)	Pretreatment standards[3]	8.00 mg/L
Lead (daily average)	Pretreatment standards[3]	1.50, 2.00, 3.00 mg/L
Lead (grab maximum)	Pretreatment standards[3]	4.00 mg/L
Zinc (daily average)	Pretreatment standards[3]	1.50, 4.00, 5.00 mg/L
Zinc (grab maximum)	Pretreatment standards[3]	10.00 mg/L

[1] Toxic Characteristic Leaching Procedure (US Environmental Protection Agency)
[2] Model Toxics Control Act (enacted in Washington state)
[3] Pretreatment standards are from Lynnwood, Everett, and Seattle, WA.

TABLE 9-3. Florida Criteria for Clean Soils, Rule 62-770, F.A.C.

Parameter	Max. Conc. TCLP (mg/l)	Max. Conc. (mg/kg)(1)	Parameter	Max. Conc. (mg/kg)(1)	Parameter	Max. Conc. (mg/kg)(1)
Arsenic	5	0.8	Benzene	1.1	PAHs	2300
Barium	100	87000	Toluene	300	TRPHs	370
Cadmium	1	640	Xylenes	290	MTBE	350
Chromium	5	290	Pyrene	2200	Anthracene	19000
Lead	5	500	Fluorene	2100	Naphthalene	1000
Mercury	0.2	3.7	Chrysene	140	Phenanthrene	1900
Selenium	1	390	Dibenzo(a,h)-		Benzo(a)pyrene	0.1
Silver	5	390	anthracene	0.1	Benzo(a)anthracene	1.4

(1) Values based on residential land use assumptions.

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Wastewater treatment plants typically set maximum influent pollutant concentration levels (see Table 9-2). These pretreatment standards are established to avoid disruption to plant operations by toxic substances and impacts to receiving waters by contaminants that the plant cannot adequately remove. ***The applicability of these pretreatment standards is especially relevant to discharges of water collected by vactor trucks.***

B. State of Florida

Florida was the first state in the country to require the use of best management practices to treat stormwater from all new development. The adoption of Section 17-4.248, Florida Administrative Code (F.A.C.), in 1979, and the subsequent adoption of Chapter 17-25, F.A.C. (now 62-25), in 1981, along with the incorporation of stormwater treatment requirements into the Management and Storage of Surface Waters (MSSW) regulations of the water management districts has led to the construction of tens of thousands of BMPs throughout the state. These stormwater treatment practices are an essential component of the state's management programs to protect, maintain, or restore the quality of Florida's surface and ground waters.

In response to numerous questions concerning proper procedures for disposing of sediments which accumulate in stormwater BMPs, the Stormwater/Nonpoint Source Management Section at the Florida Department of Environmental Regulation published Guidelines for Sampling, Analyzing, and Disposing of Stormwater Sediments in November 1992. The guidelines outline biological, chemical, and toxicity leaching testing procedures which could be used to determine the characteristics of the stormwater sediments. The paper also outlines recommendations for disposal of the sediments after they have been characterized.

In developing these guidelines, staff coordinated with the staff in the Divisions of Waste Management and Water Facilities to assure compatibility with the rules and policies imposed by other Department programs. A major policy issue concerned which program's criteria to apply to stormwater sediments. Rules and criteria used by the following programs were reviewed and analyzed for applicability to disposal of stormwater sediments:

- Domestic wastewater residuals
- Solid waste management facilities
- Compost made from solid waste
- Soil thermal treatment facilities
- Interim soil cleanup goals
- Sediment quality assessment guidelines

Ultimately, the stormwater sediment disposal recommendations were based on the Waste Clean Up Program's "Clean Soil Criteria" found in Chapter 62-775, F.A.C. (Table 9-3).

The Florida Department of Environmental Protection currently is reevaluating the applicability of the limits of the various above programs to stormwater sediments. ***One of the major problems is the lack of consistency between programs and the apparent conflict between the values for allowable concentrations of metals in materials to be land-applied. One reason for the differences in allowable concentrations is that the assumed risk level varies depending on the program.*** The Clean Soils Criteria were developed using a risk level of 1×10^{-6}. The Residuals criteria also are based on a 1×10^{-6} incremental cancer risk goal for carcinogens, but use a 1×10^{-4} incremental cancer risk for non-carcinogens. EPA's proposed Bright Line concentrations were developed using a 1×10^{-3} risk factor.

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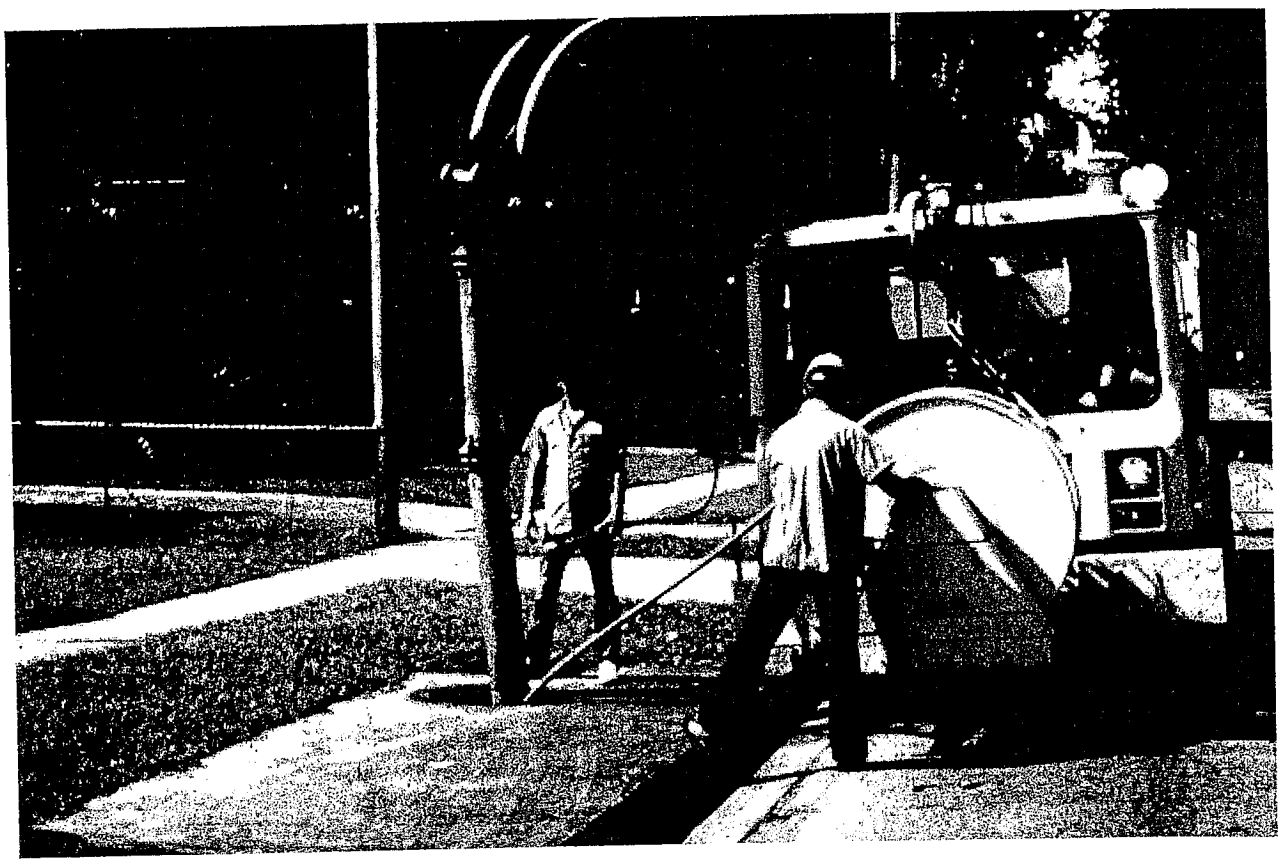
3. CHARACTERISTICS OF STORM-WATER SEDIMENTS AND WASTES

This section will present a summary of data, primarily from Washington and Florida, on the concentrations of different contaminants typically found in stormwater sediments and vactor water.

Preliminary studies have indicated that vactor wastes can surpass dangerous waste levels for several metals and petroleum hydrocarbons. ***A study by Herrera Environmental Consultants (1991) found that vactor truck sediments generally exceeded the Washington Model Toxics Control Act criteria for polyaromatic hydrocarbons (PAHs) and TPH. Concentrations of the most often detected compounds were greater in wastes from industrial areas than from residential and commercial areas.***

Disposal of decant water, the liquid fraction of storm facility wastes removed by vactor trucks, also poses risks to water quality. Decant water has the potential to carry solids, metals, toluene, xylenes, and volatile and semi-volatile compounds. Total suspended solids (TSS) are a principal pollutant in street waste liquids. Many contaminants, particularly metals, bind to fine particles, organic material, and clay particles. Total Kjedahl nitrogen is associated with particles in the 250 to 2000 micron size range. Total phosphorus and nitrate-nitrogen bind to particles smaller than 100 microns, but most nitrate-nitrogen is in solution. Liquids can also contain large numbers of fecal coliform bacteria. Toluene, xylene, and ethylbenzene are among the most frequently detected organic compounds in decant water. Table 9-4 presents pollutant ranges for street waste solids and liquids, as reported by Serdar (1993). Illicit dumping and property owner practices can greatly increase contaminant concentrations in stormwater management facilities.



Vactor truck crew removing stormwater sediments and liquids from a catch basin.

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TABLE 9-4. Ranges of Toxics and Other Materials Concentrations in Street Waste Solids and Liquids (from Serdar, 1993)

Substance	Concentration Ranges in Solids	Concentration Ranges in Liquids
Solids	61 - 85%	-
Gravel fraction	1 - 33%	-
Sand fraction	57 - 90%	-
Silt fraction	4 - 28%	-
Clay fraction	0 - 3%	-
Fecal coliforms	-	400 - 9000 MPN/100 mL
TSS	-	265 - 111,000 mg/L
Settleable solids	-	2 - 234 mL/L/hour
Dissolved solids (total)	-	95 - 550 mg/L
Arsenic	Undetected - 24 mg/kg	0.030 - 1.240 mg/L
Cadmium	0.5 - 1.8 mg/kg	-
Chromium	19 - 241 mg/kg	0.013 - 1.81 mg/L
Copper	18 - 560 mg/kg	0.081 - 7.6 mg/L
Lead	24 - 194 mg/kg	0.255 - 13 mg/L
Mercury	0.04 - 0.16 mg/kg	Undetected-0.022 mg/L
Nickel	33 - 86 mg/kg	-
Zinc	80 - 558 mg/kg	0.401 - 18 mg/L
TPH	0.040 - 4.600 mg/kg	-
PAHs (total)	0.890 - 146 mg/kg	-
Toluene	-	0.096 - 0.180 mg/L
Xylenes (total)	-	0.020 - 0.360 mg/L
Phenol	-	0.002 - 0.075 mg/L

A paper produced by the Center for Urban Water Resources Management at the University of Washington collected and summarized data from Washington state research on catch basin and vactor waste contamination (Jacobson, 1993). The objective of the study was to determine any correlations between land uses and pollutant concentrations in storm facility wastes. Results of the study are presented in Tables 9-5 and 9-6.

Contamination levels in sediment wastes and vactor liquids from residential and commercial areas were quite similar. Solids and vactor liquids from industrial areas were generally significantly more polluted than those of residential and commercial areas. However, several commercial and industrial results overlapped, indicating that these two land uses sometimes have similar pollution potential.

The Jacobson study concluded that stormwater system solids must be disposed of with caution because of high TPH concentrations. Similar results were found in a 1995 analysis of vactor sediments that had been stockpiled at a maintenance yard in Bellevue, Washington. Although such wastes are probably not so contaminated that they require hazardous waste landfilling, they are too polluted for some standard landfills.

Although copper and lead concentrations in vactor water from residential and commercial areas were not high enough to cause concern, zinc frequently exceeded standards. ***Vactor***

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TABLE 9-5. Ranges of Pollutant Contamination in Washington State Catch Basin and Vactor Wastes, by Land Use (from Jacobson, 1993).

Type of Waste/ Contaminant	Residential (ppm)[1]	Commercial (ppm)[1]	Industrial (ppm)[1]	Highway (ppm)[1]
Catch Basin Solids				
Copper	20-126	18-117	165-456	-
Lead	101-636	95-1726	230-500	-
Zinc	174-336	165-997	228-455	-
TPH	499	52,400-60,000	5400	-
Vactor Sediments				
Copper	24-28	36	88-229	-
Lead	69-92	91	109-175	-
Zinc	106-138	208	219-338	-
TPH	401-1293	-	2197	276
Vactor Water				
Copper	0.120-0.933	0.265	1.481-3.418	5.456
Lead	0.600-1.300	0.510	3.835-5.775	28.478
Zinc	0.608-2.498	3.057	5.672-10.200	26.754
TPH	5.2	-	8.2	7.7

[1]ppm = parts per million (mg/kg for solids; mg/L for liquids)

TABLE 9-6. Percentages of Washington State Catch Basin and Vactor Waste Samples Exceeding TCLP[1], MTCA[2], and Pretreatment[3] Standards, by Land Use (from Jacobson, 1993).

Type of Waste/ Contaminant (Legal Standard)	Residential % x No. of Samples	Commercial % x No. of Samples	Industrial % x No. of Samples	Highway % x No. of Samples
Solids				
Lead (TCLP)	43% x 35	60% x 35	71% x 21	-
TPH (MTCA)	78% x 14	100% x 5	80% x 5	-
Vactor Water[3]				
Copper (2.0 mg/L standard)	0% x 11	0% x 4	50% x 12	44% x 9
Copper (3.0 mg/L standard)	0% x 11	0% x 4	25% x 12	44% x 9
Copper (8.0 mg/L max. grab)	0% x 11	0% x 4	17% x 12	22% x 9
Lead (1.5 mg/L standard)	9% x 11	0% x 4	100% x 12	89% x 9
Lead (2.0 mg/L standard)	9% x 11	0% x 4	92% x 12	78% x 9
Lead (3.0 mg/L standard)	0% x 11	0% x 4	75% x 12	78% x 9
Lead (4.0 mg/L max. grab)	0% x 11	0% x 4	50% x 12	78% x 9
Zinc (1.5 mg/L standard)	36% x 11	25% x 4	100% x 12	100% x 9
Zinc (4.0 mg/L standard)	27% x 11	25% x 4	92% x 12	78% x 9
Zinc (5.0 mg/L standard)	9% x 11	25% x 4	92% x 12	67% x 9
Zinc (10.0 mg/L max. grab)	0% x 11	0% x 4	25% x 12	55% x 9

[1]Toxic Characteristic Leaching Procedure (US EPA) [2]Model Toxic Control Act (enacted in Washington state) [3]Pretreatment standards are from Lynnwood, Everett, and Seattle, WA.

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water samples from industrial and highway areas frequently surpassed the highest wastewater treatment plant pretreatment standards for all three metals. Thus, vactor liquids from these land uses would certainly require pretreatment before discharge to wastewater treatment plants.

Sediments collected from Tacoma, Washington catch basins one year after they were cleaned were significantly less contaminated than samples collected from the same catch basins before cleaning. ***These results strongly suggested that annual cleaning of catch basins helps to reduce contaminant levels in wastes.*** By controlling contamination levels in catch basin wastes through regular cleaning, stormwater utilities could reduce hazardous waste disposal costs. Similar results are likely to be attained in larger treatment facilities, which can accumulate sediments over a longer periods than catch basins.

As part of the reevaluation of Florida's policy on the land application of solid wastes, including sediments from stormwater systems, Livingston and Cox (1995) summarized data from Florida stormwater investigations. A comprehensive review of the stormwater literature found 17 reports which included data on the concentrations of contaminants within stormwater system sediments. These investigations contained considerable data on concentrations of heavy metals and nutrients in stormwater sediments but relatively little data on organic contaminants such as petroleum hydrocarbons. More data were available on stormwater sediments from wet detention systems than from infiltration or filtration practices.

Table 9-7 summarizes the concentrations of heavy metals in stormwater sediments from different types of BMPs, while Table 9-8 summarizes the concentrations of heavy metals in the sediments of BMPs serving different land uses. The data in both tables are for surficial sediments - the top one inch. Five of the sites also included data from different layers of the stormwater sediments. ***As with the data from Washington state, the concentrations of heavy metals were highest in surficial layers, but diminished rapidly within the top eight inches of sediments.***

Livingston and Cox (1995) presented the following conclusions on the concentrations of contaminants in stormwater system sediments in Florida:

- Stormwater sediments, especially in the top one inch of sediment, can exceed Florida's Clean Soil Criteria for chromium and lead. The average chromium concentration in the top inch of sediments from wet detention systems (83.3 ug/g) and from dry swales (69.7 ug/g) exceeded the 50 mg/kg clean soil criterion. However, of the 430 samples from wet ponds, less than 20 percent had chromium concentrations above the clean soil criterion. In sediments from dry swales, chromium concentrations exceeded 50 mg/kg more frequently. All nine top layer samples and two of the 0-4 inch samples had chromium concentrations above this value. The average chromium concentration in the top inch of swale sediments was 69.7 mg/kg while the average in the 0-4 inch samples was 51.3 mg/kg.

- The average lead concentration in the top inch of sediments from a retention system, wet ponds, dry swales, wet swales, and roadside shoulders exceeded the 108 mg/kg clean soil criterion as did sediments collected by street sweepers. Sediment lead concentrations greater than this level were found in the sediments from seven wet ponds, all three dry swales, the lone wet swale, all four highway shoulder sites, and in one street sweeper investigation, one conducted in 1977 when leaded gas was still available. Even the deeper sediment

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TABLE 9-7. Comparison of Heavy Metal Concentrations (ug/g) in the Top One Inch of Sediments from Various Types of Stormwater Systems in Florida.

BMP	No. Obs/ Sites	Cd	Cr	Cu	Ni	Pb	Zn
Dry Retention Basin	3/1	1.00	4.00	13.00	NA	200.00	100.00
Wet Detention Basin	430/21	3.60	83.30	25.60	13.10	227.00	150.30
Grassed Swale - dry	9/3	5.50	69.70	89.50	35.60	1060.0	497.30
Grassed Swale - wet	5/1	1.60	8.40	14.60	6.00	438.60	112.60
Exfiltration Trench	2/1	3.00	14.50	8.00	NA	80.00	80.00

TABLE 9-8. Comparison of Heavy Metal Concentrations (ug/g) in the Top One Inch of Sediments from Florida Stormwater Systems Serving Various Land Uses.

Land Use	No. Obs./ Sites	Cd	Cr	Cu	Ni	Pb	Zn
SF Residential	75/3	2.10	17.40	9.10	8.00	29.20	29.90
MF Residential	15/1	1.20	3.20	21.20	7.20	32.00	22.20
Commercial	17/4	2.30	14.20	26.30	6.40	110.20	150.90
Mixed Com/Res.	57/3	2.70	14.80	26.10	4.00	351.60	176.10
Highways	313/14	5.70	51.30	54.00	26.10	676.80	298.40

layers exceeded the clean soil criteria for lead in the FDOT highway ponds (0-4 inch layers), and at both the East-West Expressway dry swales and the Interstate 4 wet swale (0-4 and 0-8 inch layers).

- Table 9-8 compares the levels of heavy metals in sediments from stormwater systems serving different land uses. Similar to stormwater loadings, concentrations of trace metals in sediments increased with the intensity of the land use and the associated stormwater loadings. As expected, because of the characteristics of pollutants left on surfaces over which motor vehicles travel, sediments in BMPs capturing highway runoff have the highest concentrations of trace metals. The average chromium concentration in highway BMP sediments barely exceeds the clean soil criterion (51.3 mg/kg vs 50 mg/kg). However, the average lead concentration in sediments from BMPs serving highways (676.8), industrial (578), mixed commercial/residential (352), and commercial (110.2) land uses exceeds the clean soil criterion for lead (108 mg/kg).

- Table 9-9 contains data allowing a comparison of heavy metal concentrations in three different layers of stormwater BMP sediments. As expected, concentrations decline as the loose surface sediment is combined with more consolidated deeper sediments. However, even in the samples compositing the top 0-8 inches of BMP sediments, lead concentrations in sediments from highway wet ponds and dry

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Table 9-9. Concentrations of Heavy Metals (ug/g) in the top 1 inch, top 0-4 inches, and top 0-8 inches of Sediments from 6 Florida Stormwater Systems.

	Land Use/Site Name/Reference					
Metal Sites/Obs.)	SF Res. Essex Point Harper 1988 (1/6)	MF Res. Unknown Harper 1988 (1/15)	SF Res. Greenview Yousef 1990 (1/48)	Comm. Hwy. Int. Mkt. Pl. Harper 1988 (1/4)	Hwy FDOT Ponds Yousef 1990 (9/161)	Swales Harper 88 USGS 88 (3/9)
Cd	1.6	1.2	2.3	2.9	15.0	5.5
	1.5	0.9	2.7	1.8	7.4	3.5
	1.5	0.3	ND	1.1	ND	ND
Cr	7.2	21.2	9.5	12.2	61.0	69.7
	5.8	9.8	8.7	11.3	28.5	51.3
	5.2	6.2	ND	8.9	ND	ND
Cu	9.0	3.2	11.8	6.8	28.0	89.5
	7.5	1.8	7.0	4.7	10.6	77.4
	7.3	1.4	ND	3.4	ND	ND
Ni	3.0	7.2	8.0	6.4	52.0	35.6
	2.5	3.8	4.7	5.1	33.9	20.9
	2.0	2.7	ND	6.3	ND	ND
Pb	13.8	32.0	34.2	46.0	374.0	1060
	11.2	14.0	17.7	31.5	141.9	653.5
	9.9	9.3	ND	22.8	ND	ND
Zn	11.6	22.2	31.0	127.0	161.0	497.3
	6.9	13.3	12.4	68.5	48.4	269.0
	5.7	10.4	ND	36.8	ND	ND

ND = Not determined for the soil profile listed due to insufficient data.

swales can exceed the clean soil criterion.

- A growing concern among ecologists is the effects of petroleum hydrocarbons and volatile organic compounds on the biota of water bodies receiving stormwater discharges. Unfortunately, few investigations have been undertaken to determine the ecological effects of these materials, which have become almost ubiquitous in the urban environment because of civilization's reliance upon the motor vehicle. Additionally, very few investigations have determined the levels of volatile organic aromatics or petroleum hydrocarbons in stormwater BMP sediments. Only six Florida studies included measurements of these contaminants, with only the Lake Tuscawilla project in Ocala providing data that allows a comparison of stormwater sediment characteristics to the clean soil criteria. The levels of total recoverable

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petroleum hydrocarbons and the polynuclear aromatic hydrocarbons in sediments from Lake Tuscawilla greatly exceeded the clean soil criteria. The cause of these elevated levels is believed to be a leaking underground fuel tank. This required the City of Ocala to "treat" these sediments by spreading them in sludge drying beds, exposing them to light and oxygen.

- Another interesting observation can be made with respect to lead concentrations in the soil along the edges of highways. At the edge of the pavement and in a swale located 18 feet away from the pavement's edge, the lead concentrations greatly exceeded the clean soil criteria in the top two inches of soil. Does this mean that all soils adjacent to highways need to be cleaned up or disposed? Of course, this investigation was conducted back in 1978 before leaded gas had been eliminated, and the results should be different today.

- A key question that must be addressed is whether sediments taken from stormwater BMPs are a "hazardous waste" because of their toxicity? ***Based on Florida data, stormwater sediments generally are not toxic based on the results of TCLP tests. Not a single sample in the data base exceeded the TCLP limits that would cause stormwater sediments to be classified as a hazardous waste.***

To augment the information summarized above, the Florida Dept. of Environmental Protection Stormwater Section conducted additional sampling of stormwater sediments in late 1996. A primary goal of this effort was to obtain data on organic contaminants such as petroleum hydrocarbons and pesticides. Samples were collected from twelve different stormwater BMPs serving eight different land uses. A total of 102 samples were collected by 14 different local stormwater programs throughout the state of Florida.

Each sample was analyzed for physical characteristics and 128 pollutants including:

- Total solids
- Sediment grain size
- Total Organic Carbon
- Metals - As, Cd, Cr, Cu, Ni, Pb, Zn
- 26 Chlorinated pesticides and PCBs
- 34 Volatile Organics
- 60 Semivolatile PAHs, phthlates, phenols
- Total recoverable petroleum hydrocarbons

In addition, Toxicity Characteristic Leaching Procedure (TCLP) was conducted on sediments collected at 44 sites.

The results of this project confirm the results and recommendations of Livingston and Cox (1995). Notable results include (Cox et. al. 1997):

- Only about 10% of the 15,506 analyses performed resulted in levels above the laboratory minimum detection levels (MDL).

- Only 53 pollutants were found in detectable concentrations. Similar to previous studies, several traffic related metals (chromium, lead, and zinc) were found at all sites, while copper, cadmium, nickel, and arsenic were detected in samples at frequencies of 94%, 72%, 67%, and 64% respectively.

- Of the 35 organic compounds detected, only 8 were found in at least half of the 87 sites. These include total recoverable petroleum hydrocarbons (TRPH), chlordane, pyrene,benzo(b)fluoranthene, fluoranthene, chrysene, DDE-p,p', and benzo(a)pyrene.

- TRPH were found at 78 sites while the pesticide Chlordane was found at 71 sites (82%). Chlordane previously was widely used for termite control but was banned in 1989. While detectable levels of Chlordane would be expected in sediments from older

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stormwater BMPs, high concentrations also were found in sediments recently collected by street sweepers and catch basins.

- The NURP results found that only about 20% of stormwater samples had detectable levels of organic pollutants and that only four PAHs were found in more than 10% of the samples (EPA, 1983). However, these same four PAHs were found in 47 to 64% of the stormwater sediment samples. A total of 13 PAHs, 2 pesticides, 2 phthalates, and PCB 1260 were found in 10 percent of more of the sediment samples.

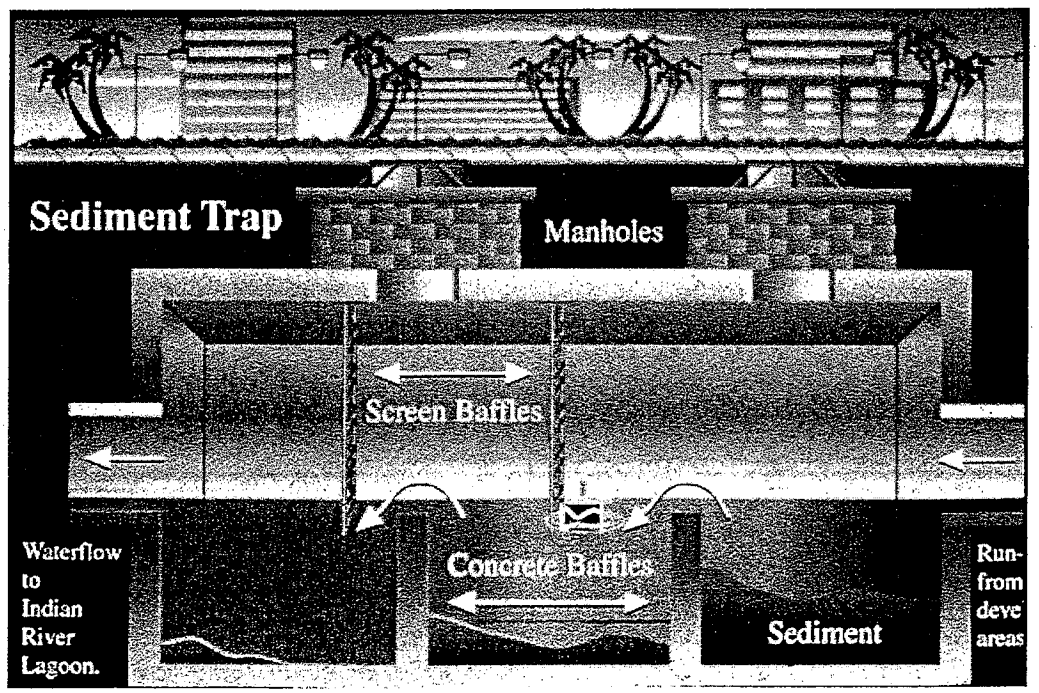
- Only 3 of the 36 organic pollutants tested for TCLP were detected at levels above the minimum detection limit. These included toluene, total xylenes, and m,p-cresols. None of the levels exceed RCRA levels.

- All four metals (As, Cd, Cr, Pb) tested for TCLP were detected in levels above the MDL. Only two lead samples from canals in South Florida exceeded TCLP levels for hazardous wastes.

3.1. Contaminants Levels in Sediments of Ultra-Urban BMPs

Confined sand filters and baffle boxes are two BMPs which often are used on highly impervious, land-limited sites. Because of their inherent design and limited storage volume, these two BMPs typically require frequent maintenance to remove accumulated sediments or clogged filter sand.

In a Seattle, Washington study to monitor the performance of a sand filter system, filter sand and sediment were analyzed for TCLP metals, copper, zinc, FOG, and TPH. ***After seven months of filter operation at a busy shipping facility, no sample came close to violating hazardous and dangerous waste standards for metals. However, TPH concentrations in settling chamber sediments greatly exceeded the Washington Model Toxics Control Act hazardous waste criterion of 200 mg/kg.*** Results for the two monitored filters were close, 25,454 and 34,018 mg/kg, despite their divergent water quality conditions. None of the full sand cores closely approached the Model Toxics Control Act limit



Baffle box used to retrofit stormwater systems along the Indian River Lagoon, Florida.

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for TPH. However, the two most concentrated segments, taken from the 0 to 1.2 inch segment of the sand cores, did exceed the criterion.

As part of the Indian River Lagoon (Florida) National Estuary Program's efforts to reduce stormwater pollutant discharges to the lagoon, local governments have installed several three chambered baffle boxes. These are underground, "on-line" systems installed at the end of existing storm sewers before they discharge to the Indian River Lagoon. The treatment effectiveness of these baffle boxes was investigated by Royal and Vanderbleek (1994). They collected samples from each of the three chambers of a baffle box and analyzed them for heavy metals. The concentrations of all heavy metals were extremely low. This probably reflects the frequent pumping out of the baffle boxes. The boxes, which accumulated over 8,500 pounds of sediment in less than six month of operation, are cleaned out approximately every four months. The interval between pump outs has varied from one to six months.

4. RECOMMENDATIONS ON SEDIMENT TESTING

4.1. Storm Facility Solids and Liquid Waste Testing

Maintenance personnel should examine the appearance and odor of solids and liquids removed from stormwater BMPs to determine whether chemical analyses are necessary. Personnel should be alert to an especially oily appearance, coloration by antifreeze, or odors of gasoline, solvents, hydrogen sulfide, or other noxious substances. Hazardous waste will stain, corrode, or otherwise alter the look of catch basins. These characteristics could be signs of illicit dumping.

Material from a contaminated catch basin should not be pumped into a vactor truck containing cleaner wastes. Mixing wastes of differing qualities could contaminate the whole load and make its disposal more difficult. The suspected hazardous waste should be analyzed to determine the appropriate disposal method. Field test kits are available to detect petroleum and polyaromatic hydrocarbons.

Maintenance workers should also note the land uses in the catchment of a stormwater facility. Stormwater sediments from industrial areas and highways are much more likely to exceed hazardous waste standards than those from residential and commercial areas. Personnel should be particularly vigilant when any of the following activities are present in a catchment: electroplaters; industrial parks; vehicle repair facilities; wrecking yards; cemeteries; golf courses; pesticide blending and mixing areas; electrical vaults; hydraulic lift pumps; animal product handlers; and waste storage areas.

Characterization of stormwater facility wastes is a central feature of the Washington State Department of Transportation's (WSDOT) strategy to minimize waste disposal costs by using clean wastes in maintenance activities. WSDOT follows a two-step disposal process, consisting of interim and final disposal. In the interim stage, waste will be characterized to determine proper final disposal. Vactor waste will be placed a minimum of 100 feet from property boundaries, surface water bodies, and water supply wells. Following the decanting of vactor liquids, the solids are to be placed on impermeable surfaces surrounded by berms of straw bales or dirt. The piles will be covered by plastic or other impervious materials to minimize the amount of water that drains through the solids. Waste piles are not to exceed 100 cubic feet in volume. The dirtiest wastes will be segregated from those that are relatively cleaner. Wastes will be characterized by appearance, odor, and field test kits

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that detect total petroleum and polyaromatic hydrocarbons.

WSDOT will perform periodic laboratory analyses to confirm the results of the test kits. The ***selection of stormwater sediment pollutants for laboratory analysis depends on the location of the facility and the initial characterization of the waste.*** Sediments from stormwater systems in heavily urbanized and industrial catchments should be analyzed for petroleum hydrocarbons (TPH), FOG, toxic metals (*e.g.*, lead, zinc, copper, and cadmium), nutrients (*e.g.*, phosphorus), and, if appropriate, organic pesticides, which can accumulate on pond bottoms. ***The Washington Department of Ecology recommends that street waste solids be tested for chromium, TPH, and PAHs, the pollutants that are the most likely to exceed the criteria for street waste solids designation (i.e., acceptable for reuse).*** Vactor wastes collected by the WSDOT will be periodically analyzed for total metals, TCLP metals, TPH, gasoline, diesel, heavy fuel hydrocarbons, PAH, and benzene-toluene-ethyl benzene-xylene (BTEX).

4.2. Testing of the Sand Filter Medium and Accumulated Sediments

Key analytes to determine sediment and sand disposal requirements are fats, oils, and grease (FOG), TPH, and the TCLP and other metals. If TCLP metals concentrations in solids are reported in mg/kg, they can be compared to TCLP standards (defined in mg/L) by multiplying the TCLP standard by 20 to convert to mg/kg. This approximate equivalents method is used by the US EPA. The equivalents method implicitly assumes that the analytic method for determining metals concentrations in solids was followed precisely and that the metals were completely extracted. The presence of oil and grease in sediments can reduce extraction efficiency. Because the dilution factor of 20 is extremely conservative, samples found to exceed hazardous waste standards according to the equivalents method frequently do not exceed TCLP standards in reality.

5. RECOMMENDATIONS ON THE DISPOSAL OF STORMWATER SEDIMENTS

5.1. Waste Collection Considerations

A drawback to vactor trucks is that they can mix wastes that are relatively clean with those that are very dirty. An effective, but costly solution would be to have "clean" and "dirty" trucks. Alternatively, cleaning only facilities associated with a single type of land on a given vactor truck run would reduce the risk of mixing wastes with different contaminant levels. ***Because of their great potential to cause contamination, vactor wastes should never be mixed with street sweepings or debris from ditch cleaning.***

5.2. Disposal Methods

Guidelines are necessary, but generally do not exist, for disposing sediments from stormwater BMPs. The best programs now send them to lined municipal landfills unless they fail a "looks bad and smells bad" test. If wastes fail to pass this subjective test, they are treated as hazardous wastes and tested.

Reuse, recycling, and other non-landfill end solutions for stormwater sediments can help to reduce disposal costs. Many state solid waste laws, such as Washington's Solid Waste Management Act and its Model Toxics Control Act, give the highest priority to this waste handling strategy. When disposal of stormwater system wastes is necessary, they should be transported to lined landfills where they can be used for cover material or, if necessary, to hazardous waste disposal facilities.

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In Washington state, some entrepreneurs have set up an incineration facility at an old, unused cement plant kiln to cook vactor wastes. This has been shown to be a cost-effective option when compared to landfilling the wastes.

Where only petroleum hydrocarbon contamination prevents the recycling of storm facility wastes, they could be bioremediated at an approved pit site. The WSDOT (1994) classifies treated soils as follows:

Class 1 Soils — These soils contain residual concentrations of petroleum contaminants at or below analytical detection limits. They are considered clean and can be used as fill for any project.

Class 2 Soils — These soils contain detectable levels of petroleum contaminants below the Cleanup Regulation Method A cleanup standard — 100 parts per million of TPH. Appropriate uses include fill or other uses that will not cause a threat to human or environmental health.

Class 3 Soils — These are soils with high levels of heavy hydrocarbons that may not meet cleanup standards even after treatment. Soils receiving adequate treatment should be able to meet the cleanup levels for light petroleum fractions. Those soils that cannot attain cleanup standards should be used at the original site or disposed of in an existing, permitted municipal landfill.

Class 1 soils can be used in the following applications: road and parking lot subgrade; road construction fill; street sweeping sand; pipe bedding, except for drinking water pipes; utility trench backfill, except for drinking water pipes; controlled density fill; fill in commercial and industrial zones; prefabricated concrete manufacturing; Portland cement manufacturing; asphalt manufacturing; daily cover or fill in permitted landfills, provided they are dewatered; or other end uses approved by local health departments. Street waste solids should not be reused for surface mining reclamation, in a wastewater disposal mound system, or as cover or fill in an inert demolition waste landfill.

5.3. Decant Water Disposal

Disposal of decant water picked up by vactor trucks is another important problem. Not only do storm drain liquids contain pollutants in their own right, but the vactoring process could further contaminate the water column by resuspending solids. Vactor trucks must decant water two or three times per day to make room for more solids. A common and practical method of decant water disposal is to drain it into catch basins in nonsensitive areas. Another practice is to discharge decant water into sanitary sewers. However, discharge of vactor waste into sanitary sewers may still allow pollutants to enter surface waters if treatment at the wastewater treatment plant is inadequate. Moreover, high toxics loadings can also upset biological processes at wastewater treatment plants.

The three options that have been suggested for managing decant water are (1) reducing the amount of liquids removed from storm facilities; (2) eliminating discharges in the field; and (3) using field settling sumps. There is a lack of data on the filtration of vactor liquids in the field, so this method is not recommended. Similarly, data on the treatment efficiencies or the maintenance safety of stormwater inserts and on-line filtration systems are not widely available.

Reducing the amount of liquids removed from stormwater facilities (option 1) would be accomplished by modifying vactor suction tubes to reduce the amount of liquid removed during cleaning. To eliminate field discharges (option 2), liquids are transported in vactor

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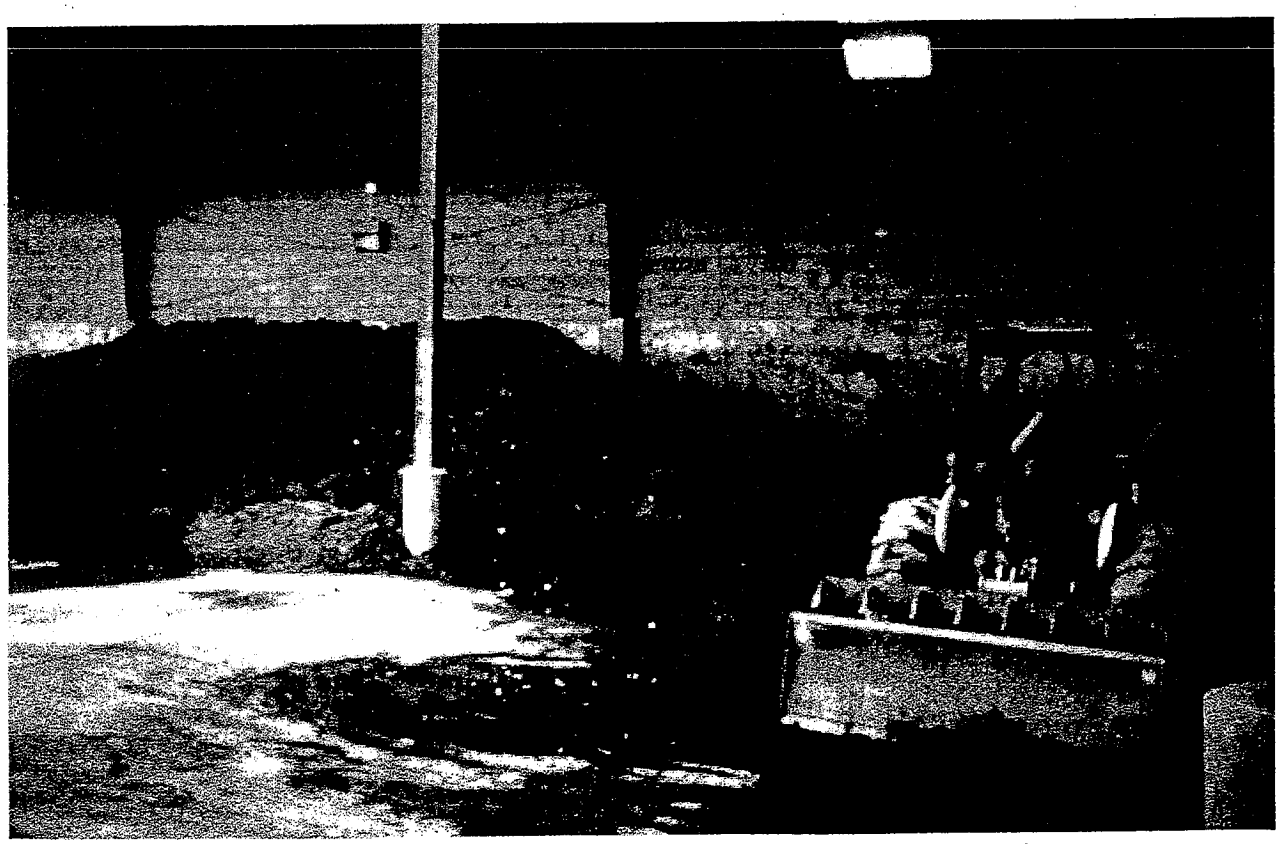
trucks with the solids and treated at decant stations. Decant station treatment techniques include (1) using drying pads and lagoons to eliminate all discharges; (2) gravity settling of solids and possible treatment with a coalescing plate oil/water separator, followed by discharge to a sanitary sewer; and (3) treatment with a sand or a sand/peat filter. One decant station design includes a 9-foot deep sump for the settling of solids from decant water. Solids are removed approximately every other day. Some cities dewater combined liquid and solid street wastes and filter the liquids before discharging to sanitary sewers.

The field sump method (option 3) would use gravity settling over 4 to 8 hours to reduce decant water contamination. The sump could be any type of detention or retention BMP. Sumps, vaults, and tanks are the most practical facilities for settling because they can be installed in a wide variety of locations, are easily maintained, and solids can be removed by vactor truck. A modified catch basin could also serve as a sump. Use of twin sumps would allow one to settle solids and drain while the other received new wastes.

The removal of solids from vactor liquids by settling has been found to occur at the following rates: 54% removed after 0.5 hour; 67% after 1 hour; 79% after 2 hours; 87% after 3 hours; 90% after 4 hours; and 97% after 8 hours. In five hours, the settling of 1750 pounds (795 kg) of solids from 1500 gallons (5678 liters) of water reduced pollutants by the following amounts: sediments -- 55 to 85%; chemical oxygen demand -- 11 to 54%; total organic carbon -- 6 to 35%; total phosphorus -- 4 to 50%; total nitrogen -- 2 to 61%; zinc -- 4 to 60%; and lead -- 31 to 83%.

5.4. Sand Filter Waste Disposal Methods

The researchers in the Seattle sand filter moni-



Settled vactor solids at Bellevue, WA. vactor decant station. Photo courtesy of Ventilation Power Equipment, Inc. , Seattle.

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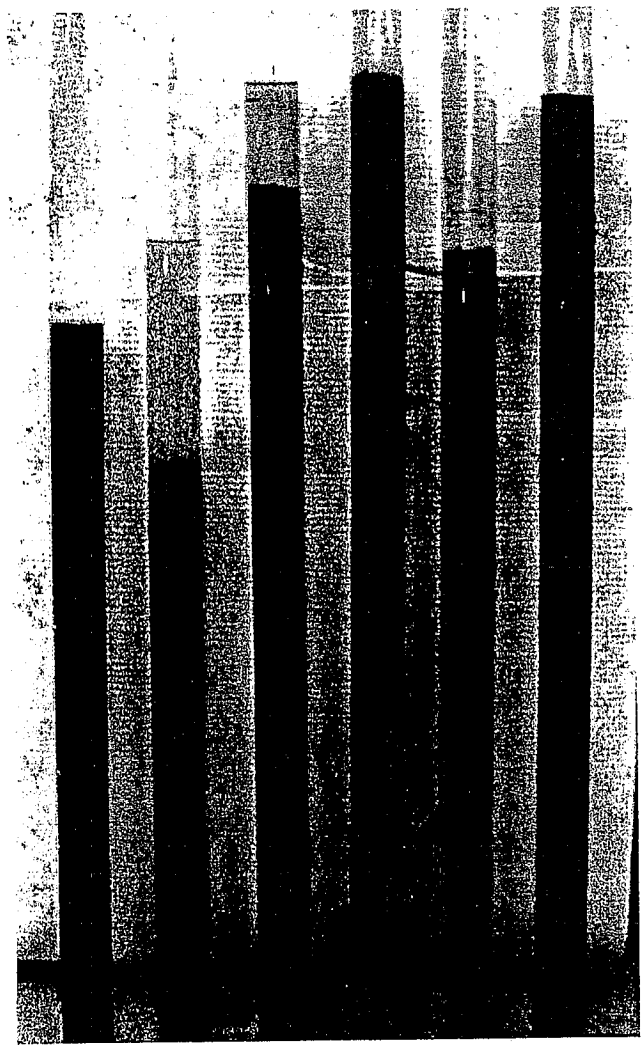
toring study decided that settling chamber water could be drained through the sand bed instead of removed for off-site disposal when cleaning of the chamber became necessary. The rationale for this decision was that, because sand filters are flow-through systems, settling chamber water normally is treated by the sand bed anyway. Thus, disposal regulations do not directly affect the settling chamber water, provided that it is treated by the sand bed. However, when siphoning liquid out of the settling chamber, maintenance personnel should be careful not to resuspend sediments. Alternatively, if costs are not an objection and appropriate methods are available for disposal of the liquid and sediment, removing both materials simultaneously could reduce time and labor costs.

The variable sand core sampling results from the Seattle study created a dilemma about how to dispose of filter sand, when removal became necessary. Because inconsistencies in concentrations could make identifying the portions that are hazardous waste difficult, occasional disposal of the entire upper layer might be the best option. Maintenance should be fairly infrequent, only every few years, and generate a relatively small volume of waste (top few centimeters of the soil column). Bioremediation, the decomposition of organic molecules by microorganisms, has been well demonstrated for hazardous material and contaminated soil renovation. However, this technique needs to be assessed for use in stormwater sand filters. Full rejuvenation by bioremediation might not be possible when mineral solids cause the filter to clog.



Sediments from stormwater discharges accumulated on the bottom of Megginnis Arm, Lake Jackson, in Florida before implementation of the state's stormwater treatment rules in 1982. Removal of sediments from water bodies and the restoration of water bodies is much more difficult and expensive than the implementation of BMPs and their proper maintenance.

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Chapter 10
Information Sources

Information used in this publication was obtained from a variety of sources which are listed in this chapter. The interested reader is urged to review these information sources if more detailed information is desired. Additionally, because of the rapid growth of the stormwater management state-of-the-art, readers are encouraged to consult more recent literature to assure that they have the most recent data and information.

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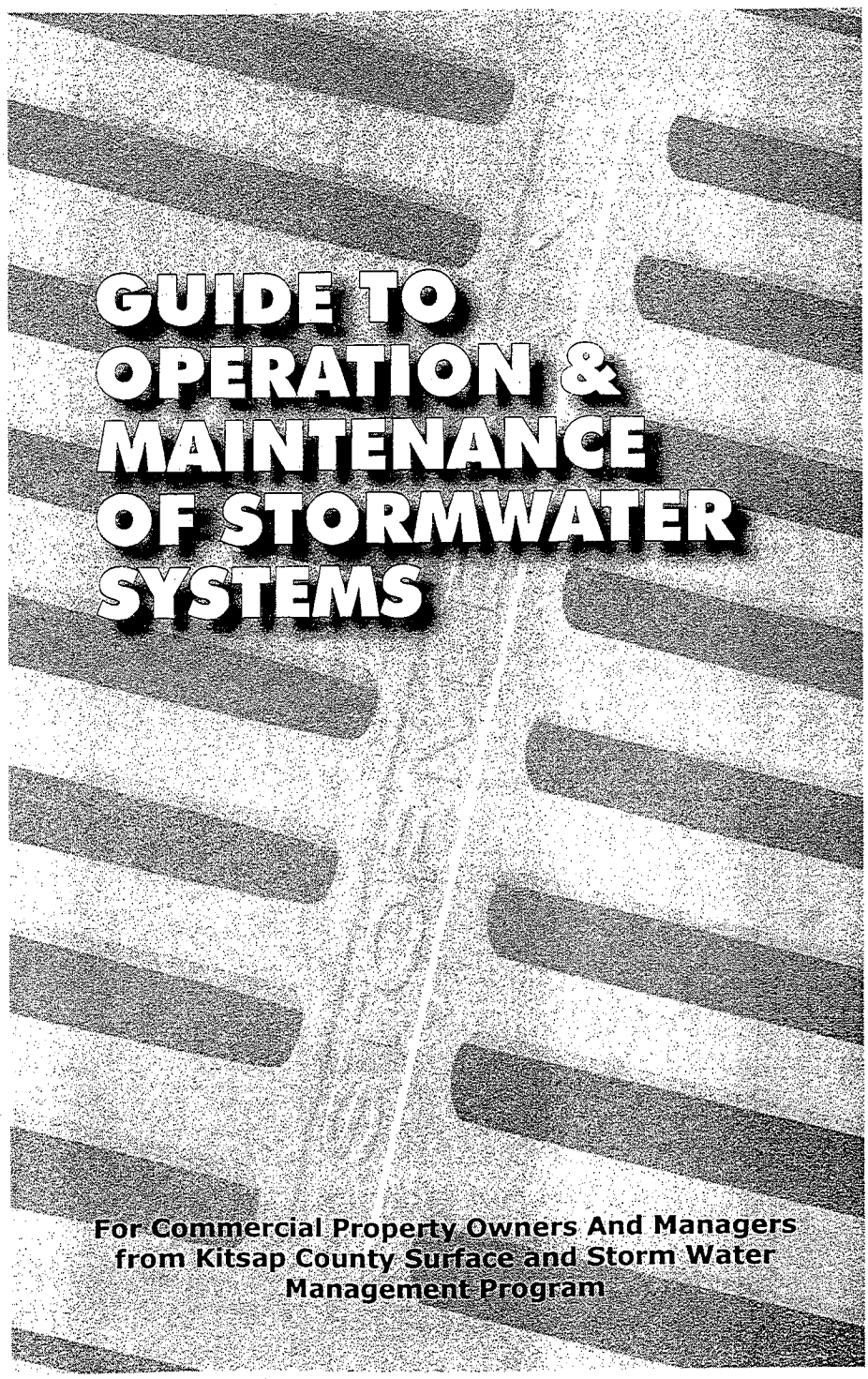
Notes



GUIDE TO OPERATION & MAINTENANCE OF STORMWATER SYSTEMS

For Commercial Property Owners And Managers from Kitsap County Surface and Storm Water Management Program

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Stormwater Structure Cleaning Schedule

Drains or Catch Basins

These structures are located beneath many, but not all, storm drain grates. They are underground boxes designed to pass water through an outlet pipe while trapping sediment that settles to the bottom.

Cleaning is required when the sediment has filled half the distance from the bottom of the catch basin to the bottom of the outlet pipe.

Oil/Water Separators

Separators are designed to remove oil and sediment from water before the water is discharged to the storm drainage *or* sewer system. It is an underground structure with above ground access for maintenance. It may have baffles (vertical plates) *or* absorbent pads to retain floating oil. You need to identify which type of oil water separator you have and if it discharges to stormwater or sanitary sewer.

Cleaning and the replacement of absorbent pads is required after each spill or by October 1 of each year. Additional cleaning and/or replacement may be required throughout the year.

Detention Facilities

These facilities temporarily store stormwater runoff and release it at a controlled rate to reduce the chance of flooding and downstream impacts. These can be located underground (within a parking lot, vaults, barrels) or above ground (pond).

Cleaning is required when the sediment depth exceeds 10% of the storage depth or ½ the length of storage vault or any point depth that exceeds 15% of storage depth.

Retention Facilities

These facilities store stormwater runoff and allow it to infiltrate into the ground. They can include retention ponds, tanks, vaults, and/or infiltration systems.

Cleaning is required when the sediment depth exceeds 10% of the storage depth or ½ the length of storage vault or any point depth that exceeds 15% of storage depth.

Biofiltration Swales

Swales are broad, vegetated areas that direct and filter runoff. Dense vegetation in swales provides filtration to help improve water quality.

Cleaning is required when the vegetation or debris interferes with the flow of water. Grass should be no higher than three to six inches.

Outfalls and Discharges

Be sure you know where your system discharges water, or where it connects to another stormwater system.

Cleaning your outfall is required when the water flow out of the system is impeded by debris or by damage to parts of the system.

More detailed maintenance guidelines are available by contacting the Kitsap County SSWM Program at (360)337-5777. Newer buildings may have an Operations and Maintenance manual on file with the county as well.

As a property owner or manager, you are responsible for the maintenance and upkeep of your building and surrounding property. You are also responsible for the maintenance of things you cannot see—like underground utilities. Backups of sewer or plumbing lines force you to maintain them, but many people forget about maintaining their storm drainage system. Over time, these systems can get plugged with debris and sediment (sand, gravel, etc.) causing flooding which can impact neighboring properties as well as your own. Regular inspection and maintenance of this system helps protect our water for fish, recreation, and drinking.

The storm drainage system is meant to carry only uncontaminated stormwater runoff, since it discharges the water to streams, rivers, groundwater, or Puget Sound without treatment. Unless you know otherwise, assume any outdoor drain is a storm drain and keep all contaminants out of it. Putting oil, antifreeze, detergents, and other materials into a storm drain is the same as dumping them straight into a stream, lake or Puget Sound.

3 Steps to Avoid Flooding

❶ Identify Your Stormwater System

In order to maintain the system, you need to know where it is and where it goes. Most outdoor drains lead to the stormwater system. As you walk through your property, use the maintenance record enclosed to draw a sketch of your property and stormwater system. Your building's "as-built" plans or the property owner may be able to help you. If you have trouble identifying your system, contact the SSWM Program at (360) 337-5777 for assistance.

❷ Inspect and Maintain Your Stormwater System

Like any other system, your stormwater system needs to be inspected and maintained regularly. How often maintenance is required will depend on your system, the area that drains to it, and the amount of rain we've had. Inspecting the system at least quarterly will give you a good idea of the need for maintenance. Follow the guidelines on the cleaning schedule on the next page. When you determine maintenance is required, contact a drain cleaning company to have your system maintained. These companies can also inspect the system for you. Check the yellow pages of the local phone book under drain cleaners, or contact the SSWM Program for a list of maintenance providers

❸ Dispose of Waste Properly

Waste generated by cleaning stormwater systems will usually be taken away by the contractor who performs the maintenance on your system. If your system is located in unincorporated Kitsap County, the vendor will be able to dispose of this waste at the Kitsap County Stormwater Maintenance Waste Processing Facility in Brownsville **at no charge**, provided they have completed the facility training. Waste from sites within incorporated cities are charged a per load fee. When choosing a company to clean your system, ask if they have access to this facility. If unsure, contact Kitsap County's SSWM Program at (360) 337-5777 for assistance.

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Kitsap County Surface and Stormwater Management Program

The Surface and Stormwater Management Program (SSWM) is a multi-agency program designed to address non-point pollution and flood control. The program was developed in response to the Federal Clean Water Act, the Puget Sound Water Quality Management Plan, and locally developed Watershed Action Plans. The core purpose of the program is to address non-point pollution, which has been identified as the primary source of pollution in Kitsap County's streams, lakes and marine waters. Non-point pollution is pollution carried from roofs, yards, streets and other land surfaces by stormwater runoff. The agencies receiving funding and providing services include Kitsap County Public Works, Kitsap County Department of Community Development, Kitsap County Health District, and Kitsap Conservation District.

Fees are charged on properties in unincorporated Kitsap County as follows based on an Equivalent Service Unit (ESU) of 4200 square feet of impervious surface. The fees are incorporated into the annual tax billings and collected by the Kitsap County Treasurer. Fees can be paid once annually, due by April 30 or in 50% increments (the first payment due April 30 and the second due October 31).

- A single family residence (one ESU) is charged the base unit rate*.
- Multifamily residences (duplexes, triplexes and four-plexes) are charged the number of dwelling units times the unit rate*
- Apartments, commercial, industrial and institutional uses are charged according to the estimated or measured impervious surface area divided by the square footage of one ESU, rounded to the nearest ESU but not less than one, times the unit rate*. A 50% fee credit is available for commercial properties that use rainwater harvesting, 100% infiltration, or direct discharge to Puget Sound for all site runoff after proper water quality treatment. For more information visit http://www.kitsapgov.com/sswm/admin_fees.htm or call 360-337-5777.
- Undeveloped and forest land are not charged.

*See Kitsap County Code 12.40.055, www.kitsapgov.com/resources.htm, for the current unit rate.

Kitsap County Surface and Stormwater Management Program
614 Division Street, Mail Stop 26A
Port Orchard, Washington 98366
360•337•5777

KCPW FORM #7028 (REV 11/05)

A014297

OPERATIONS AND MAINTENANCE OF STORMWATER FACILITES

Blake C. Guilory, P.E.
Florida Water Resources Program Manager

Why do we need stormwater facilities?

- Flood Control
- Water quality protection and improvement
- Regulatory requirements
  - 62-25, 17-25, SWIM, NPDES, PLRG, TMDL

A61299

Stormwater BMP Definition

- A practice or combination of practices that are determined to be the most cost effective and practicable means of controlling point and nonpoint pollutants at levels compatible with environmental quality goals. – Soil Conservation Society of America.

A014300

TYPES OF BMPs

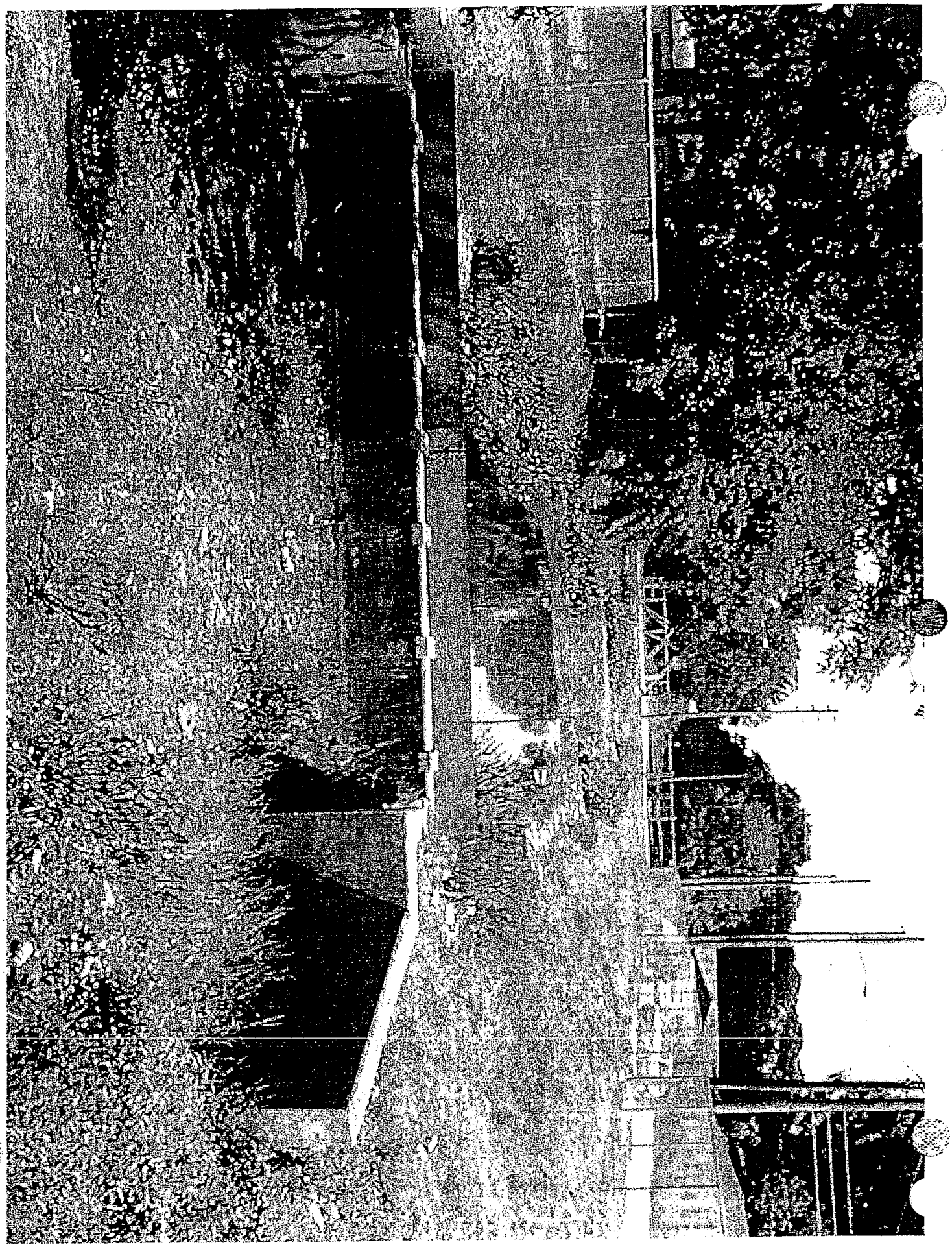
Stormwater BMP Technique			
Structural BMPs	Nonstructural BMPs	In-Lake BMPs	Miscellaneous BMPs
Extended Dry Detention	Street Sweeping	Hypolimnetic Withdrawal	Coagulant Treatment
Wet Detention	Litter Control Laws	Hypolimnetic Aeration	Surface Water Reuse
Sediment Sump	Public Education	Sediment Removal	
Extended Wet Detention	Traffic Flow Regulation	Water Level Drawdown	
Stormwater Wetlands (created)	Pesticide, Herbicide and Fertilizer Use Control	Harvesting	
Extended Wetland Detention	Illicit Discharge Elimination	Biological Control	
Natural Wetlands	Facility Inspection and Enforcement	Littoral Shelf Construction	
Pond/Wetland Systems	Improved Maintenance		
Infiltration Systems: Trenches			
Infiltration Systems: Basins			
Stormwater Filters			
Porous Pavement			
Concrete Grid Pavement			
Swales			
Water Quality Inlets			
Off-Line Retention			
On-Line Retention			
Overland Flow-Grass			
Overland Flow-Grass/Soil			

A01U301

Why is O&M Necessary?

- Without O&M the facility will not function as intended or permitted.
  - Head loss (flooding)
  - Loss in pollutant removal efficiency

A01 14302



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STORMWATER FACILITY INSPECTION & MAINTENANCE GUIDELINES

FACILITY / BMP	RECOMMENDED INSPECTION FREQUENCY	DESIRED MAINTENANCE FREQUENCY
Wet Ponds	6 months	
Mowing		3-4 times / yr.
Plant Maintenance		1-2 times / yr.
Hydrilla Harvesting		2-3 times / yrs.
Sediment Dredging		7-10 years
Dry Ponds	6 months	
Mowing		3-4 times / yr.
Sediment Removal		3-5 years
Filter Replacement		3-5 years
Cross Drains, Culverts & Inlets	6 months	3-5 years
Roadside Ditches	6 months	2-3 years
Outfall Canals	6 months	3-5 years
Baffle Boxes	6 months	1-2 times / yr.
CDS Units	3-4 months	3-4 times / yr.
Alum Treatment	Continued Monitoring	Pump Maintenance

A011391

Wet Pond Maintenance

- Mow berms and open areas
- Litter removal
- Erosion control
- Sediment dredging
- Structure maintenance
- Aquatic plant management/harvesting

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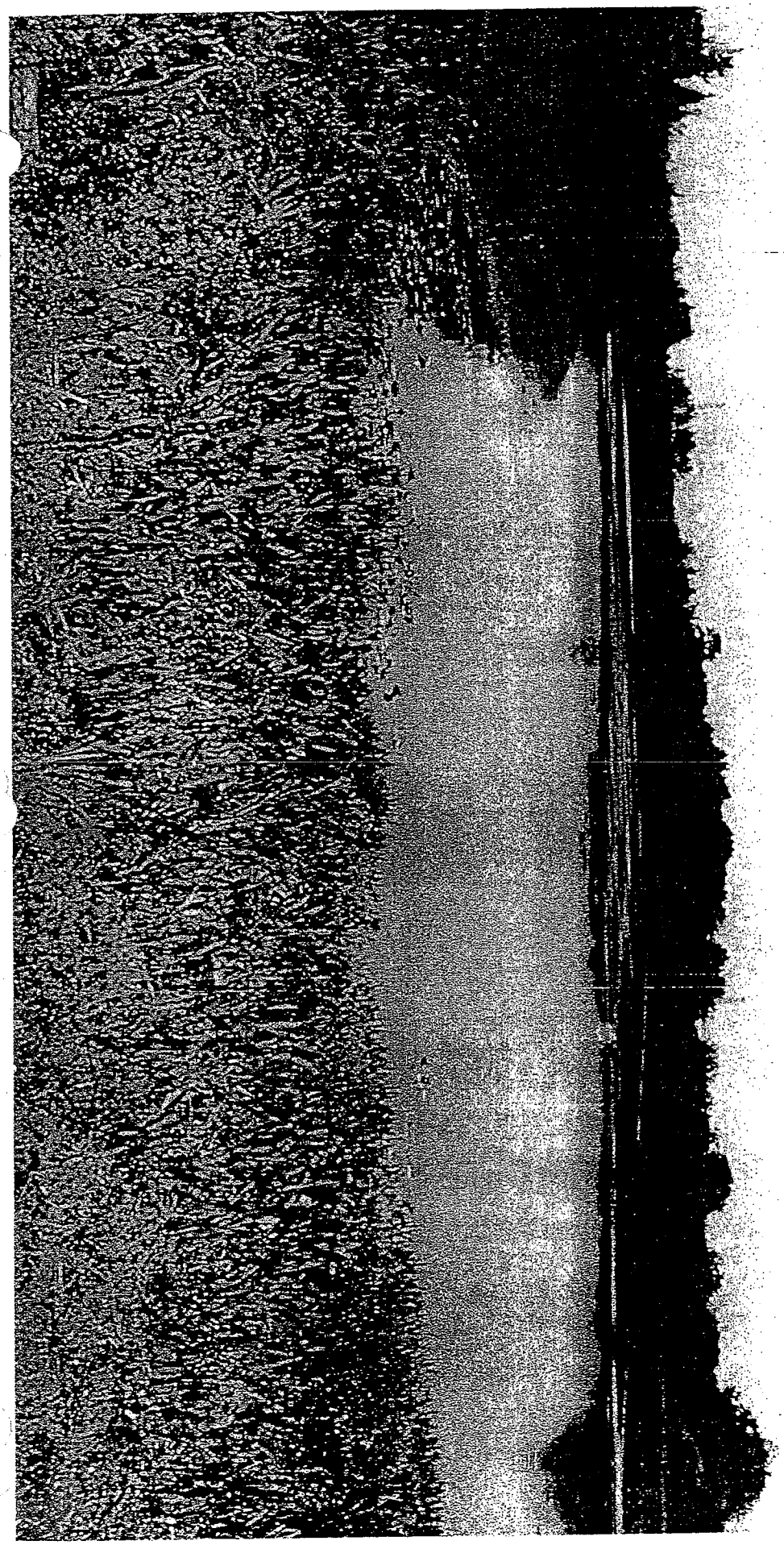

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Wet Pond Maintenance Equipment and Crew Needs

- Mower
- Hand Clearing Crew
- Cement Crew
- Aquatic Plant Management Crew
- Aquatic Harvester
- Dragline or Dredge

A014307

Wet Pond O&M Costs

- Mowing - $35-$40 / acre ($500 to $2000 / year)
- Exotic plant removal (routine)
  - Chemical and hand removal
  - $100 to $300 per acre
  - Brazillian Pepper, Primrose Willow extra
- Hydrilla harvesting
  - 0.3 to 0.6 acres per hour
  - $40 to $80 per acre (600 to 200 hours)
- Dredging every 2-10 years (Average 4 years)
  - $15 to $25 per cubic yard

A014368

A014309

Dry Pond Maintenance

- Mowing
- Structure repair
- Erosion control
- Sediment removal
- Bottom or filter replacement

A014310

A01H311

Dry Pond Maintenance Equipment and Crew Needs

- Brush-Hog Mower
- Hand Clearing Crew
- Litter Removal Crew
- Cement Crew
- Bulldozer/loader w/dump trucks

401e12

NOTHING

Dry Pond O&M Costs

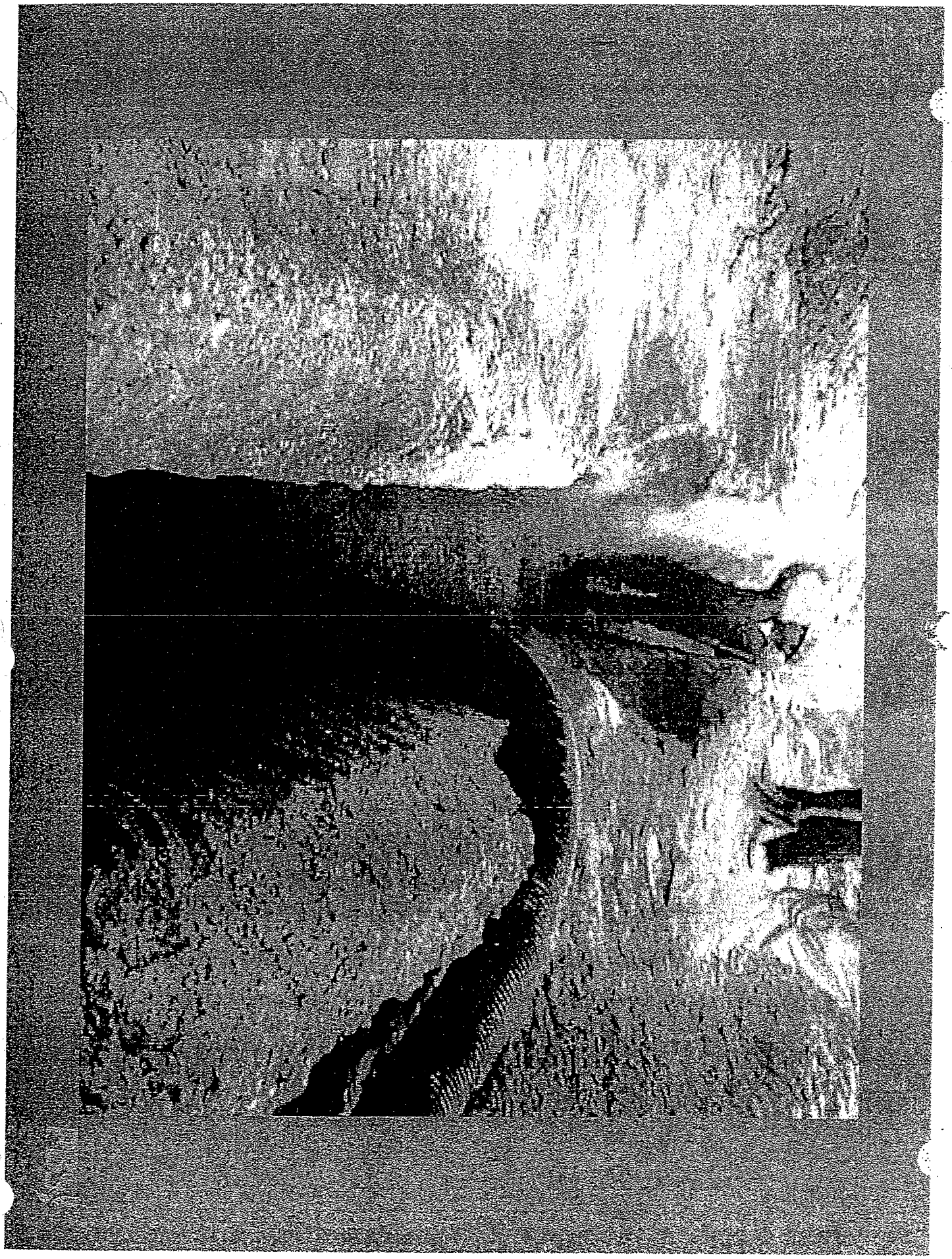
- Mowing - $35-$40 / acre ($500 to $2000 / year)
- Remove sediment and/or replace filter or sand bottom - $5,000 - $20,000 every 3-7 years ($15,000 /acre /1.5 ft depth)

A014314

Infiltration Trenches Maintenance

- Inspect frequently following construction
  - Semi-annual inspections thereafter
- Maintenance includes unclogging of inlets, drain pipes, repair of fabric, gravel sand or other filter material.
- Rehabilitation expected every 10-15 years if properly maintained.
- Underdrain Maintenance Cost = $1 to $5 / lf
- Replacement of filter material - $40 - $50 / lf

001915



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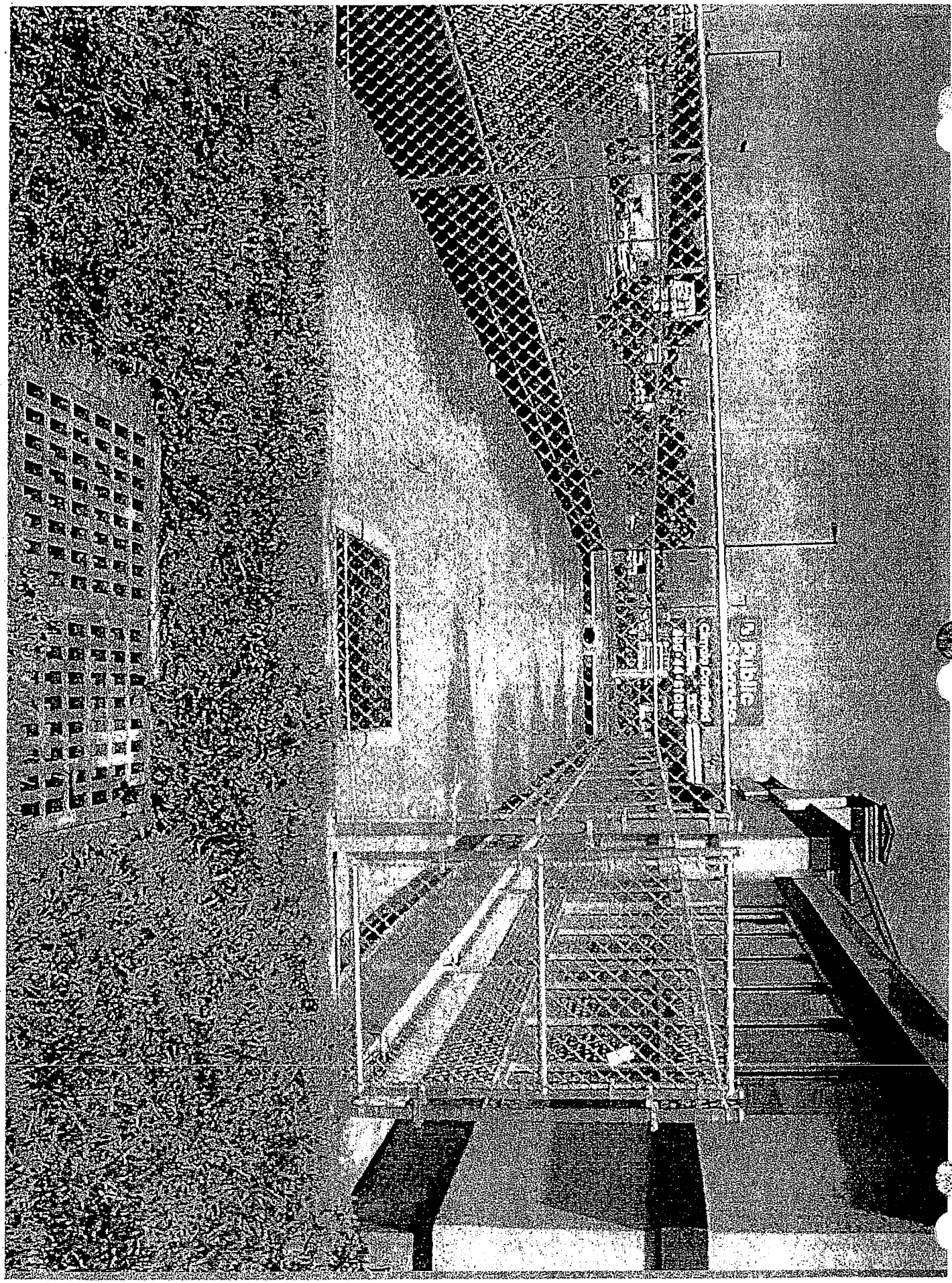

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Grass Swale Maintenance

- Semi-annual inspection
- Regular mowing - $6 to $15 / lf
- If fails to percolate in 72 hours aerate bottom with disc. Otherwise, replace bottom sediment with clean sand and seed or sod over. Approximate 5-yr maintenance schedule.

001918

A014319

A014320

Roadside Ditch Maintenance

- Litter removal
- Mow 4 times per year
  - Boom-axe, bat-wing or brush-hog
  - Hand clear
- Erosion control measures
- Excavate excess sediments

A014321

Roadside Ditch Work Rates

- Brush-Hog Mower
  - 4 roadway miles per day
- Boom-Axe Mower
  - 1 roadway mile per day
- Hand Clearing Crew (12-man crew)
  - 1 roadway mile per day ($3,000 /mile)
- Litter Removal (12-man crew)
  - 5 roadway miles per day ($600 / mile)

A01422

Roadside Ditch Work Rates

- Excavate Excess Sediments
  - Gradall and 2-3 dump trucks
    - 1800 roadway feet per day

A014323

Roadway Ditch O&M Costs

- Gradall excavation $4000-$5000 per mile
- Mowing costs vary

A014324

ROADSIDE DITCH MAINTENANCE CREW

STAFF	NO	ANNUAL LABOR COST
Grodall Operator	1	$28,000
Dumptruck Operator	2	$40,000
Raw Labor Subtotal		$68,000
Fringe Benefits (40%)		$27,200
Total Labor		$95,200
Approximately 1800 L.F. ditch per day 200 working days/yr. = 68 miles/yr.		

CULVERT MAINTENANCE CREW

STAFF	NO	ANNUAL LABOR COST
Vacuum Truck Operator	1	$20,000
Raw Labor Subtotal		$20,000
Fringe Benefits (40%)		$ 8,000
Total Labor		$28,000
Approximately 4 culverts / day 800 culverts / year		

A014325

Inlet and Cross Culvert Maintenance

- Litter and debris removal
- Cement repair crew
  - Headwall and structure repair
- Erosion control
  - Cement bags and rip-rap
- Sediment removal
  - Vacuum truck – 2 to 4 inlets / day
  - $300 - $500 / day

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A014328

Primary Channel Maintenance

- Easements needed for many channels
- Many have not been maintained since constructed.
- Hand clear when access is a problem
  - 8 to 12 man crew @ ¼ mile / day ($12,000 / mile
- Spyder, track back-hoe, or dragline when access is available
  - 1200 feet per day

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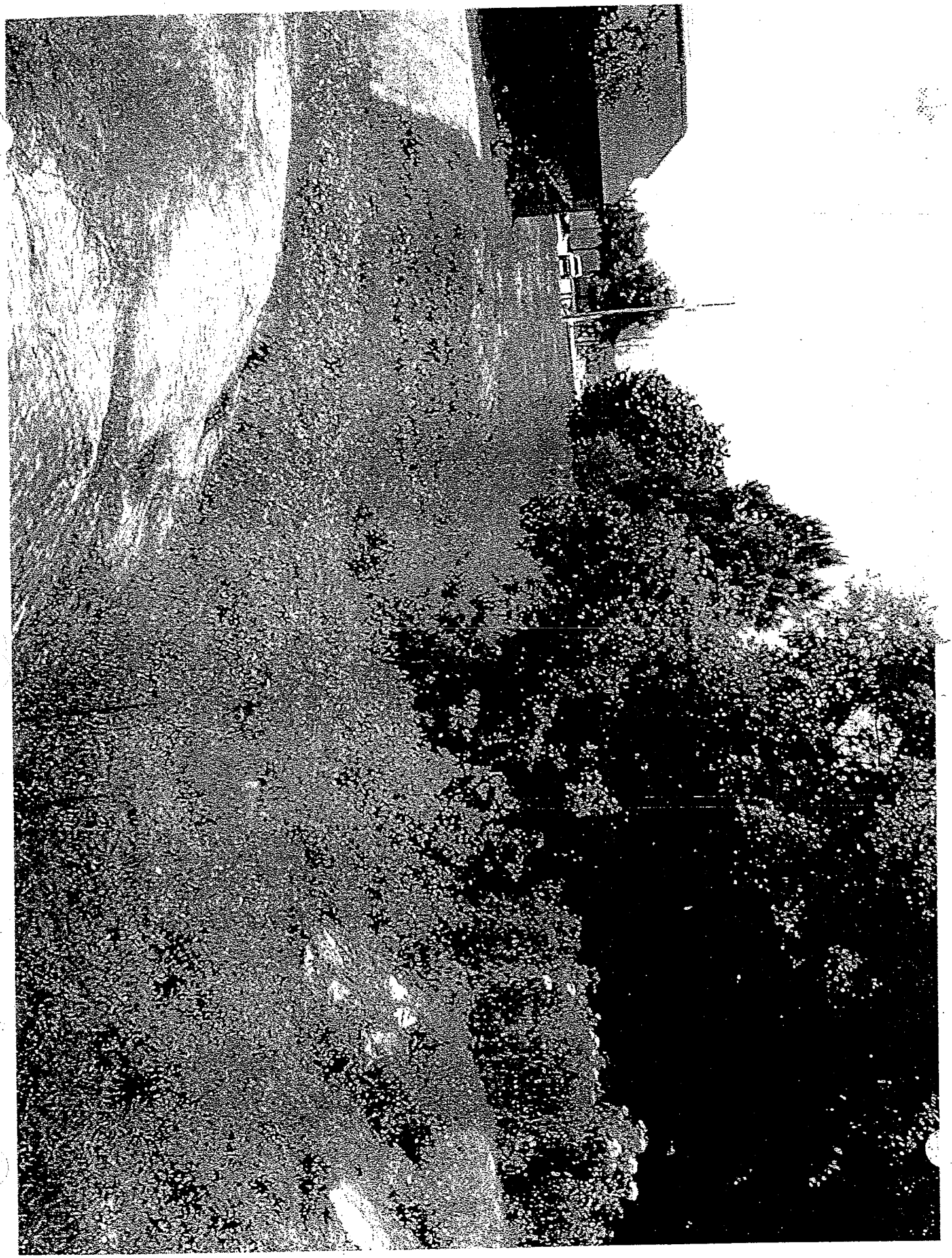

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Baffle Box

- Trash screens or skimmer maintenance
- Sediment removal by vacuum truck
- Construction cost $20,000 - $40,000
- Maintenance cost $1000 to $2000 per year

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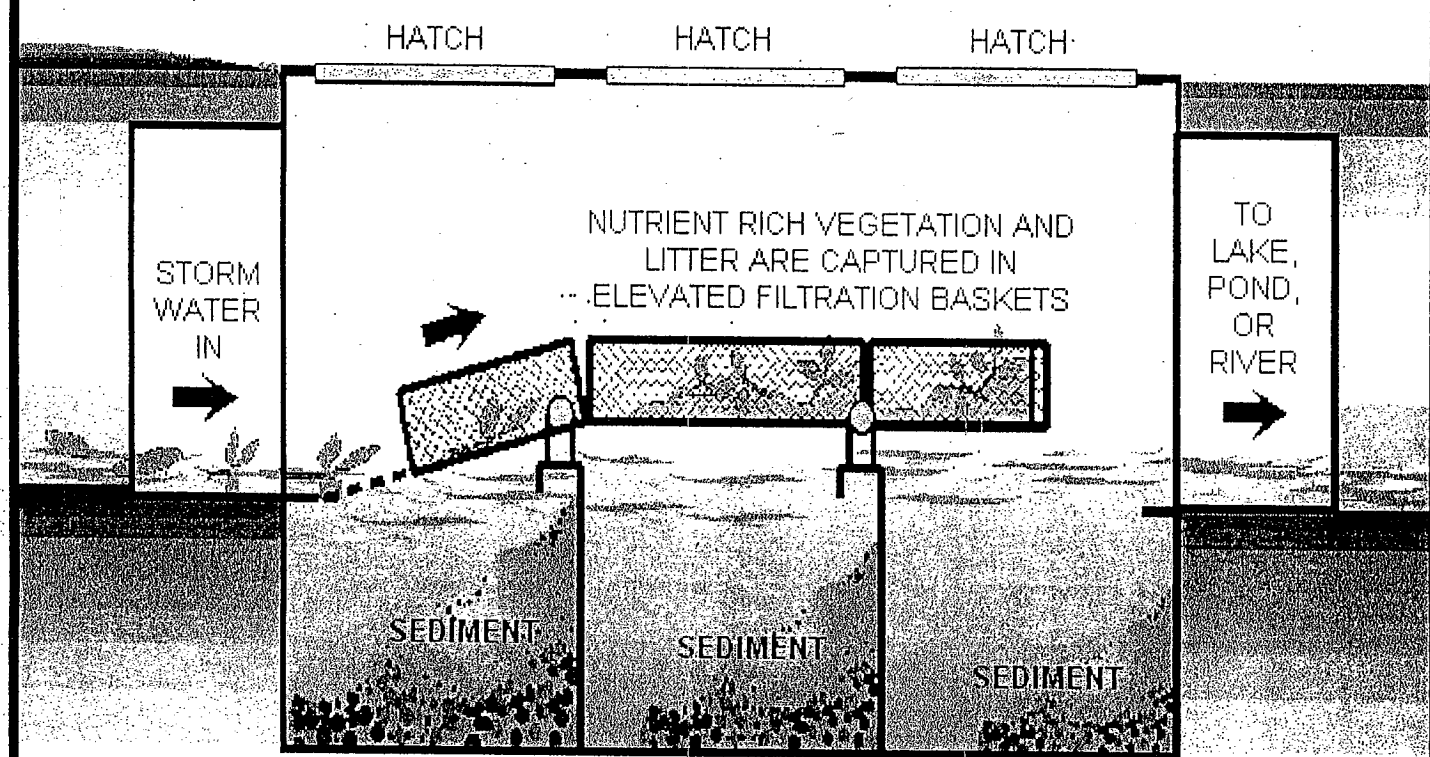

Advanced Baffle Box With Nutrient/Vegetation/Litter Separation

SEDIMENT GETS SEPARATED OUT AND FALLS TO BOTTOM TO STAY

A014334

A014335

CSR Stormceptor

Area (acres)	Cost Installed ($)
1	23,000
2	33,000

Maintenance: $500 - $1,200

PBS

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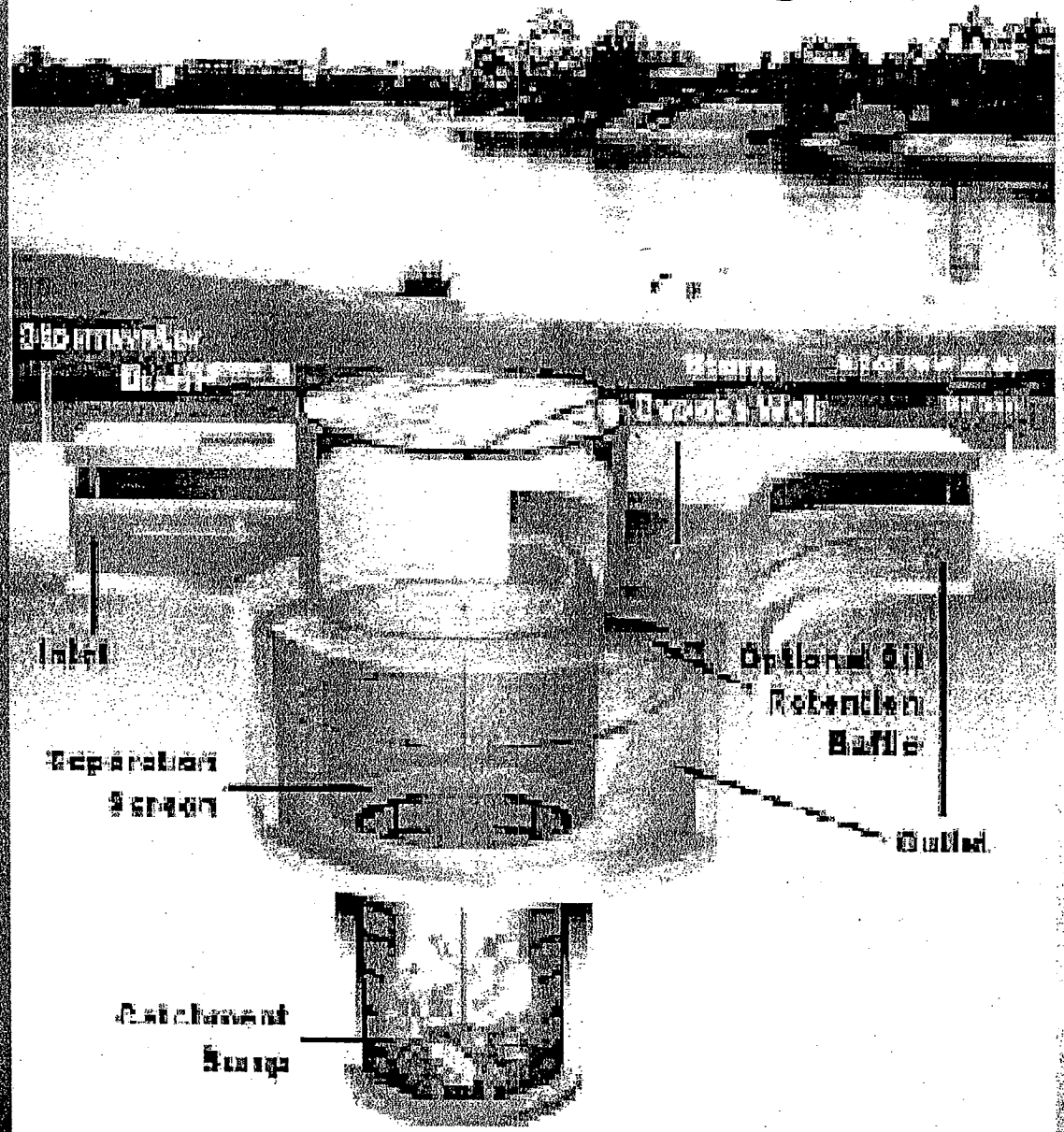
A014337

CDS Technologies



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Continuous Deflective Separation Unit (CDS)

- 90% efficiency for particles >= 0.9 mm
- Approximate cost installed : $8,500 / cfs
- Maintenance cost $600 to $1,200 per year

A014339

Alum Treatment Systems

- Pump equipment
- Power
- Chemical replacement
- Continuing monitoring of water quality
- Construction costs - $250,000 (approx)
- Maintenance - $25,000 - $50,000 per year

A014340

STORMWATER MAINTENANCE EQUIPMENT

Equipment	Useful Life (Yrs.)	Approximate Capital Cost
Loader/Backhoe	6-8	$150,000
Boom Axe Mower	6-8	$70,000
Bat Wing Mower	6-8	$60,000
Brush Hog Mower	6-8	$50,000
Gradall	7-10	$180,000
Vacuum Truck	8-10	$200,000
Sand & Cement Truck	8-10	$60,000
Crawler Backhoe	7-10	$180,000
Bulldozer	8-10	$140,000
Dump Truck (tandem)	6-8	$60,000
Flatbed Dump Truck	6-8	$40,000
Dump Truck (single)	6-8	$40,000
Dragline (mobile)	10-15	$240,000
Road Grader	8-10	$140,000
Spray Truck	6-8	$40,000
Spyder All Terrain Excavator	8-10	$200,000
Hydrilla Harvester	8-10	$200,000

A014341

Findings

- Stormwater asset numbers are stunning
- Inspection based program recommended
- Much training is needed
- Cost data is lacking

PBS

A014342

Sources

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- Pasco County Stormwater Management Master Plan, CDM, 1994
- Bay County Master Storm Drainage Plan, CDM, 1997
- City of Maitland – Best Management Plan Alternatives, PBS&J 1996
- City of Clearwater – North Greenwood Stormwater Retrofit Project, PBS&J, 1997
- Stormwater Retrofitting Techniques for Existing Development, England, Dee and Stein, 1999
- Suggested Maintenance Schedule for Structural Controls, Livingston, 1997
- Orange County Roads and Drainage Division
- Brevard County Surface Water Improvement Division
- CSR Stormceptor
- CDS Technologies
- Suntree Technologies, Inc.
- R.H. Moore & Associates, Inc.
- PMC Production, LLC
- Aquarius Sysems, Inc.

A014343

STORM WATER PHASE I MS4 PERMITTING: WRITING MORE EFFECTIVE, MEASURABLE PERMITS

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Fairfax, VA

Abstract

Approximately 1,000 municipal separate storm sewer systems (MS4s) are permitted under Phase I of EPA's storm water program. These Phase I MS4 permits require MS4s to reduce the discharge of pollutants to the maximum extent practicable and prohibit illicit discharges to the MS4. Permit writers have discretion to write permits specific to each MS4, or group of MS4s, resulting in a wide variety of permit requirements. When these permit requirements are not specific, determining compliance with the permit can become difficult.

The storm water Phase II program requires Phase II MS4s to include "measurable goals" in their program for each BMP. Phase I storm water MS4 permits are beginning to include these measurable goals allowing the permitting authority to assess whether each permitttee is in compliance. Specific examples of MS4 permits with 'enforceable' permit language are presented and discussed.

Introduction

On November 16, 1990, the U.S. Environmental Protection Agency (EPA) published regulations (the 'Phase I rule') requiring National Pollutant Discharge Elimination System (NPDES) permits for certain industrial, construction and municipal sources of storm water runoff and fundamentally changing the way storm water runoff is regulated at the state and federal levels. Approximately 1,000 MS4s ('municipal separate storm sewer systems'), consisting primarily of city and county government agencies responsible for storm water, have been permitted under the Phase I regulations. The Phase I MS4 regulations generally require MS4s to reduce discharges of pollutants to the maximum extent practicable and to prohibit illicit discharges to the MS4. Specific elements in a Phase I Municipal Storm Water Management Program include public education, public agency or municipal maintenance activities, new development, construction, industrial/commercial facilities, illicit discharges and improper disposal, monitoring and reporting.

Most Phase I MS4 permits have been individual NPDES permits, often issued to multiple co-permittees. Individual permits are written specifically to address the activities, pollutant sources, and discharges of the covered co-permittees.

Phase II of the storm water program, established in 1999, extends NPDES storm water permit coverage to include municipalities within urbanized areas. Phase II permits, to be issued beginning in March 2003, will in most cases be general permits issued to a broad range of permittees.

A014344

Storm Water Phase I Regulations

The Phase I storm water rule defines "municipal separate storm sewer" at 40 CFR 122.26(b)(8) to include any conveyance or system of conveyances that is owned or operated by a state or local government entity and is designed for collecting and conveying storm water which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer). The Phase I MS4 regulations apply to MS4s serving populations of 100,000 or more. Some MS4s with populations under 100,000 can be designated for Phase I permit coverage. In addition to larger cities and counties, many state Departments of Transportation were also permitted under Phase I.

Phase I MS4 permits are required to establish controls to the maximum extent practicable (MEP) and effectively prohibit non-storm water discharges to the MS4. MEP has not been defined by EPA, but is intended to be flexible to allow the development of site-specific permit conditions based on the best professional judgment of the permit writer.

The Phase I regulations required a two-part application process for Large and Medium MS4s (40 CFR 122.26(d)). The regulations only specified application requirements, not permit requirements. Therefore, permitting authorities have various interpretations as to what should be required in an MS4 permit.

The Part 1 application required information regarding existing programs and the means available to the MS4 to control pollutants in its storm water discharges. In addition, Part 1 required field screening of major outfalls to detect illicit connections. Part 2 of the permit application required a limited amount of representative quantitative data and a description of proposed storm water management plans. The purpose of the two-part application process was to develop information that would build successful MS4 storm water programs and allow the permit writer to make informed decisions with regard to developing permit conditions.

State and EPA permit writers used the information contained in these Part 1 and Part 2 permit applications to write the individual NPDES permits. NPDES permits are issued for 5-year permit terms, with most of the first round MS4 permits containing fairly general requirements. In many cases, these permits simply require the permittees to implement the storm water management plan contained in the Part 2 application. Subsequent MS4 permits, particularly many implemented in California, are more specific and include more detailed requirements.

Permit examples: Unenforceable language

NPDES permitting authorities must be able to determine compliance with individual permits. In traditional wastewater NPDES permits, this is a relatively simple process of verifying wastewater sampling results with permit discharge limits. MS4 permits are BMP-based, therefore determining compliance with the MS4 permit is more difficult. The examples presented below illustrate MS4 permit language that is vague and therefore difficult for an NPES permitting authority to determine compliance. Without specific, measurable elements, almost any activity an MS4 takes could be deemed to be in compliance with the permit.

The permittee and permitting authority names have been removed, and the specific problems associated with determining compliance with this permit language are discussed.

A014345

Example 1

Permit Language:

> The permittee shall demonstrate compliance with this Order through the timely implementation of control measures and other actions to reduce pollutants in discharges to the maximum extent practicable in accordance with their SWMP…"

This permit does not define what "timely implementation" is, allowing the permittee to determine what is timely. Timely implementation could be up to 5 years in the view of the permittee, or within 6 months in the view of the permitting authority. In addition, "other actions" are mentioned in the permit, but never described. If the permit is going to require "other actions," then these actions should be specifically described in the permit.

Example 2

Permit Language:

> "Structural controls for water quality improvements are considered for inclusion in site drainage plans, storm drain projects, and flood control projects where applicable."

A permit should not require the permittee to "consider" an action; it should require the permittee to take an action. Also, "where applicable" leads to additional interpretation problems. If there are only certain circumstances where this permit provision should be applied, then those circumstances should be spelled out in the permit.

Example 3

> Minimum best management practices (BMPs) include: standard plans and specifications, maintenance of storm drain systems, street sweeping, litter control, spill response, and hazardous material disposal.

This permit language lists a series of BMPs, but doesn't specify where, how much, or how often the BMPs must be employed. For example, how often should the MS4 conduct street sweeping and how many miles need to be swept in order to be in compliance with the permit? The permit language above does not specify this.

Example 4

> The permittee shall control pollutants in storm water discharges to the maximum extent practicable, and to demonstrate compliance with this requirement, the permittee shall implement in its entirety the proposed storm water management program (SWMP) described in …

This permit requirement repeats the regulation language to control discharges to the "maximum extent practicable" without specifying exactly how that will be achieved. Implementation of a storm water management program (again, unspecified in the permit) is assumed to meet this standard. Unless the SWMP describes the activities and set specific performance expectations for those activities, compliance will be difficult to determine.

Permit Examples: Enforceable permit language

The most difficult aspect of writing MS4 storm water permits is drafting permit language whereby compliance can be easily determined.

A014346

The following sections provide examples of permit language that provides more measurable permit language where compliance can be more easily determined.

Construction Inspections Example:
From the Orange County Municipal Storm Water NPDES Permit: (Board Order No. R8-2002-0010, NPDES Permit No. CAS618030)

> Each permittee shall conduct construction site inspections for compliance with its ordinances (grading, Water Quality Management Plans, etc.) and local permits (construction, grading, etc.). Inspections shall include a review of erosion control and BMP implementation plans and an evaluation of the effectiveness and maintenance of the BMPs identified. Inspection frequency will, at a minimum, include the following:
>
> a. During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance. During the 2001-2002 wet season, prior to the development of the inventory database, all construction sites must be visited at least twice. If a site is deemed out of compliance, an inspection frequency adequate to bring the site into compliance must be maintained;
> b. During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented; and,
> c. Information including, at a minimum, inspection dates, inspectors present and the results of the inspection, must be maintained in the database identified in Section VIII.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

This permit language describes what needs to be conducted (inspections), when (October 1 through April 30) and how often (once a month). This ensures that both the permitting authority and the permittee understand what needs to happen to ensure compliance.

Construction Training Example:
From the Municipality of Anchorage and the Alaska Department of Transportation and Public Facilities NPDES permit: (NPDES permit No. AKS 05255-8)

> "Permittee shall develop a training program for construction site operators and developers…within 24 months of the effective date of this permit. Permittee shall ensure that such training is provided at a minimum of once per year…"

This permit language specifies the action (a training program), a deadline for achieving the action (within 24 months), and a frequency for continuing performance (once a year).

Illicit Discharge Example:
From the City of Long Beach Municipal Storm Water NPDES Permit" (Board Order No. 99-060, NPDES Permit No. CAS004003)

A014347

"The Permittee shall inspect those portions of the storm drain system consisting of storm drain pipes 36 inches in diameter or greater, for illicit connections within 5 years after the permit is adopted."

This permit provision specifies the minimum pipe size expected to be inspected and specifies that the permittee has up to five years to complete this task. Interim deadlines could also have been set here by, for example, requiring that at least 50% of these pipe are inspected within 3 years.

Public Education Example:
From the City of Stockton and County of San Joaquin Municipal Storm Water NPDES Permit: (Board Order No. R5-2002-0181, NPDES Permit No. CAS083470)

> At least three times during the life of the permit, Permittees shall send information on problems caused by storm water runoff and potential solutions to each household within the service area.

Both a timeframe (life of the permit, or 5 years) and a target number (each household within the service are) are specified along with a quantity (three times) in this public education example.

Industrial storm water inspection example:
From the Orange County Municipal Storm Water NPDES Permit: (Board Order No. R8-2002-0010, NPDES Permit No. CAS618030)

> "After July 1, 2003, all high priority sites are to be inspected at least once a year; all medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle."

This permit language sets specific inspection frequencies for high, medium and low priority industrial facilities. In order to be effective, the permit must also specify, or provide a clear expectation, of the types of facilities that should fall into each priority category.

Municipal Maintenance Example:
From the City of Long Beach Municipal Storm Water NPDES Permit: (Board Order No. 99-060, NPDES Permit No. CAS004003)

> Catch basin maintenance, under Permittee's jurisdiction, shall include:
>
> a. All catch basins will be cleaned out and inspected one time between May 1 and September 30 of each year; and,
> b. All catch basins that are at least 40% full of trash and debris between October 1 and April 30, shall be cleaned-out.

This permit provision sets the amount expected (all catch basins), the time frame (May 1 to September 30), and the frequency (each year). It also establishes a performance expectation for when a catch basin should be cleaned.

New Development – Maintenance example:
From the Los Angeles Region Municipal Storm Water NPDES Permit: (Board Order No. 01-182, NPDES Permit No. CAS004001)

> "Maintenance Agreement and Transfer
> Each Permittee shall require that all developments subject to SUSMP and site specific plan requirements provide verification of maintenance provisions for Structural and Treatment Control

A014348

BMPs, including but not limited to legal agreements, covenants, CEQA mitigation requirements, and or conditional use permits. Verification at a minimum shall include:

a) The developer's signed statement accepting responsibility for maintenance until the responsibility is legally transferred; and either
b) A signed statement from the public entity assuming responsibility for Structural or Treatment Control BMP maintenance and that it meets all local agency design standards; or
c) Written conditions in the sales or lease agreement, which requires the recipient to assume responsibility for maintenance and conduct a maintenance inspection at least once a year; or
d) Written text in project conditions, covenants and restrictions (CCRs) for residential properties assigning maintenance responsibilities to the Home Owners Association for maintenance of the Structural and Treatment Control BMPs; or
e) Any other legally enforceable agreement that assigns responsibility for the maintenance of post-construction Structural or Treatment Control BMPs."

In this example, SUSMP stands for Standard Urban Storm Water Mitigation Plan and is a relatively new requirement in California MS4 permits to address post-construction storm water impacts. CEQA is the California Environmental Quality Act that requires environmental review of certain projects.

These permits provide more specifics, including set frequencies, deadlines, and detailed expectations for the permittees. This allows both the permittees and the permitting authority to determine compliance.

Effective MS4 Permit Writing

NPDES MS4 permits and MS4 stormwater management programs must contain quantifiable, measurable elements so that compliance can be determined. Storm water permits vary significantly in their level of detail. For example, some third-term permits issued in California contain very specific, measurable elements which are clear for permittees to implement and relatively straightforward for the state to determine compliance. For nonspecific permits that simply require the MS4 to "implement a storm water management plan," compliance becomes more difficult. More importantly, the permit does not specify, or measure, the level of effort expected, so MS4s do not have a clear target to achieve.

The storm water Phase II regulations require small MS4s to develop "measurable goals" for each BMP in their programs. These measurable goals are intended to provide quantifiable targets for the MS4s to achieve in the implementation of BMPs. Although a similar requirement does not specifically exist for Phase I, permits and programs developed under Phase I should also contain these measurable goals. This provides a level of certainty to the MS4 that they are successfully implementing the permit and allows the state to more easily evaluate compliance.

Some MS4 permits in California include specific, measurable requirements that make determining compliance easier. Also, the City and County of Sacramento have developed stormwater plans that are clear, well-written, and begin to address the issue of measurable goals which are called 'minimum performance standards' and 'performance and effectiveness measures', respectively, in each plan (City of Sacramento, 2000 and County of Sacramento, 2000).

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In order to be measurable, each permit requirement should specify:

- *What* needs to happen
- *Who* needs to do it
- *How much* they need to do
- *When* they need to get it done
- *Where* it is to be done

For each permit requirement, "*what*" is usually the BMP or activity required, "*who*" in most cases is implied as all the permittees (although in some cases the permitting authority may need to specify exactly who the require applies to), "*how much*" is the performance standard the permittee is expected to meet (how many inspections), "*when*" is a specific time (or a set frequency) when the BMP or activity should be complete, and "*where*" is the specific location or area (if necessary). Without these specifics, it is almost impossible for the permitting authority to determine compliance with a vague MS4 permit.

Writing more specific, measurable permits will take more time and resources than writing less specific ones. For Phase I MS4 permits, which are in some cases entering their 3rd round of MS4 permits, these more specific permits are becoming a necessity. States are finding that both the regulated community and the public are demanding more accountability, which the specific, measurable permits provide.

Conclusions

With over 1,000 large cities, counties, and other governmental organizations under storm water Phase I MS4 permits, a significant amount of money is being spent implementing these programs. Unless the permits are written with specific, measurable requirements, determining compliance with permits is often difficult, if not impossible.

Permit writers can develop these specific, measurable permit requirements by building upon existing storm water permit programs and ensuring that permit elements address:

- *What* needs to happen
- *Who* needs to do it
- *How much* they need to do
- *When* they need to get it done
- *Where* it is to be done

As Phase II MS4s begin the process of identifying measurable goals for each of the BMPs in their program, permits issued to the larger, more mature Phase I MS4 programs should include these same measurable elements.

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LESSONS LEARNED FROM IN-FIELD EVALUATIONS OF PHASE I MUNICIPAL STORM WATER PROGRAMS

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Abstract

Tetra Tech is assisting EPA in the evaluation of a number of storm water Phase I MS4 permit programs in California and selected other States. These evaluations consist of two components: a programmatic review of individual city and county programs implementing permit requirements and an on-site/in-field verification of these program elements. This in-field verification allows EPA and the State to assess whether a program is actually being implemented as described 'on paper.' The overall goals of these evaluations are to complete a baseline assessment of each program area, determine compliance with permit requirements and the stormwater management plan, collect information for permit reissuance, and determine how municipalities measure program effectiveness. In addition, the 'lessons learned' from these evaluations can be directly applied by many of the Phase II jurisdictions, which will begin permit coverage in March 2003.

Introduction

On November 16, 1990, the U.S. Environmental Protection Agency (EPA) published regulations (the 'Phase I rule') requiring National Pollutant Discharge Elimination System (NPDES) permits for certain industrial, construction and municipal sources of storm water runoff fundamentally changing the way storm water runoff is regulated at the State and Federal levels. Approximately 1,000 MS4s ('municipal separate storm sewer systems'), consisting primarily of City and County government agencies responsible for storm water, have been permitted under the Phase I regulations. The Phase I MS4 regulations generally require MS4s to reduce discharges of pollutants to the maximum extent practicable and to prohibit illicit discharges to the MS4. Specific elements in a Phase I Municipal Storm Water Management Program include public education, public agency or municipal maintenance activities, new development, construction, industrial/commercial facilities, illicit discharges and improper disposal, monitoring and reporting.

Phase II of the storm water program, established in 1999, extends the coverage to include municipalities within urbanized areas and all construction disturbing at least one acre. Permits for these Phase II sources, which will include over 5,000 additional MS4s, are scheduled to become effective on March 10, 2003. Phase II Municipal Storm Water Management Programs are required to address public education, public involvement, illicit discharges, construction, new development, and municipal operations.

Although many Phase I MS4 permits are in their second or third permit cycle, EPA has not yet completed a comprehensive compliance assessment of these MS4 permits. A General Accounting Office report published in June 2001 (GAO, 2001) found that neither the overall costs of implementing the storm water

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program nor the program's effectiveness had been determined. This GAO report followed an EPA report on the Phase I storm water regulations (EPA, 2000) that found many effective Phase I program components, but admitted that EPA did not have a system in place to comprehensively measure the success of the Phase I program on a national scale.

Storm Water Phase I MS4 Evaluations

EPA Region IX hired Tetra Tech, Inc. in 2001 to begin a series of MS4 evaluations in the State of California to assess the compliance status of individual storm water Phase I MS4 permittees. In order to assess on-the-ground implementation of the programs, these program evaluations are conducted on-site. The on-site evaluation consists of two components: a programmatic review of individual MS4 programs implementing permit requirements and an in-field verification of these program elements. This in-field verification allows EPA and the State to assess whether a program is actually being implemented as described 'on paper.'

The project goals of the on-site MS4 evaluations include obtaining an overall picture of MS4 compliance, documenting effective elements of existing Phase I programs, identifying methods to improve MS4 program reporting, and developing a guidance document to assist State and/or EPA inspectors in conducting future MS4 evaluations.

Determining compliance with MS4 permits is in many cases subjective. Unlike some other environmental programs such as the pretreatment program, there is no checklist, list of BMPs, or objective criteria that all MS4s need to meet. In addition, EPA has not defined 'maximum extent practicable' or MEP which is the regulatory standard that MS4s must meet. This leaves it up to individual permit writers to define for each MS4 permit. Therefore, the MS4 inspectors have been using their best professional judgment and experience to identify program elements that are 'effective' or 'deficient.'

The MS4 on-site evaluations conducted to date have typically consisted of a 3-4 day on-site review. This on-site review has been conducted on a single MS4, and has also included multiple co-permittee MS4s evaluated with up to three investigators. For each of the MS4s evaluated, a number of staff from multiple departments were typically involved. Typical departments involved in the MS4 evaluations included public works, transportation, planning, development, and parks/recreation. As of December 2002, 14 MS4 evaluations have been conducted in EPA Region IX, covering 41 separate permittees.

The MS4 inspectors typically do not review or make recommendations on financial resources. Where a program element is clearly not being implemented to the maximum extent practicable – for example, when compliance with local construction erosion and sediment control requirements is poor due to lack of inspections – that will be noted as a deficiency. The MS4 inspectors will suggest improvements to the program so resources can be used for effectively, but responding to those suggestions or how to resolve the identified deficiencies is up to each individual MS4.

A wide variety of storm water permits, storm water management programs, and compliance with those permits and programs were found during the evaluations. However, some common trends were observed as indicated in the following sections. The trends and evaluation findings are grouped into the broad categories of program management/planning, implementation, and evaluation.

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Program Management/Planning Findings

A clear, well-written permit and plan are critical for successful implementation of a storm water management program. This requires the permitting authority to describe the required actions clearly in a permit and the permittee to clearly articulate how it will meet these requirements in a storm water plan. The Phase I MS4 evaluations conducted by Tetra Tech have found that the more advanced storm water programs generally have more detailed, well-written permits and plans. Several findings common to most of the programs evaluated are described below.

NPDES MS4 permits and MS4 stormwater management programs need to contain quantifiable, measurable elements so compliance can be determined.
Storm water permits vary significantly in their level of detail. Some third-term permits issued in California contain very specific, measurable elements which are clear for the permittee to implement and relatively straightforward for the State to determine compliance. For nonspecific permits that simply require the MS4 to "implement a storm water management plan," determining compliance becomes more difficult. More importantly, the permit does not specify, or measure, the level of effort expected, so MS4s do not have a clear target to achieve.

The storm water Phase II regulations require small MS4s to develop "measurable goals" for each BMP in their program. These measurable goals are intended to provide a quantifiable target for the MS4s to achieve in the implementation of that BMP. Although a similar requirement does not specifically exist for Phase I, permits and programs developed under Phase I should begin to include these measurable goals. For example, the permit and program should specify the number of industrial inspections expected per year and the number of catch basins that should be inspected and cleaned. This provides a level of certainty to the MS4 that they are successfully implementing the permit and allows the State to more easily evaluate compliance.

Some MS4 permits in California are including specific, measurable requirements that make determining compliance easier. Also, the City and County of Sacramento have developed stormwater plans that are clear, well-written, and begin to address the issue of measurable goals which are called 'minimum performance standards' and 'performance and effectiveness measures', respectively, in each plan (City of Sacramento, 2000 and County of Sacramento, 2000).

Programs are not designed to specifically address pollutants of concern.
The primary goal of programs under the Clean Water Act is to achieve fishable, swimmable waters by meeting water quality standards. Many MS4 programs are not designed to address the specific pollutants of concern already identified in their watershed. Where pollutants of concern have been identified, MS4 programs should be modified to include BMPs and programs that specifically target a reduction in these pollutants.

Some Phase I programs in California are developing plans to address identified pollutants of concern in their community, including those pollutants identified on the State's Section 303(d) list. Pollutants of concern can also be identified from local studies or watershed research. Several programs, including programs in Alameda County and Sacramento County, have developed strategies to more specifically target and reduce pollutants of concern. For example, Sacramento County is developing a series of Target Pollutant Reduction strategies to focus some program resources on pollutants that cause or are likely to cause impairments in local receiving waters. Target pollutants for the Sacramento area include diazinon,

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chlorpyrifos, coliform/pathogens, copper, and lead. Sacramento County still implements baseline activities, but uses the target pollutant reduction strategies to ensure activities are developed to address specific pollutants.

Combining resources and expertise into a committee can save MS4s time and money. Many MS4s that have been permitted together have joined resources in a committee structure. This sharing of resources and experience can help all participating MS4s by more efficiently developing public education materials, guidance, standard forms and other materials for all of the MS4s to use. Also, for smaller MS4s with more limited budgets, the committee structure provides assistance these MS4s may not have been able to otherwise obtain, such as use of a centralized database for entering and managing reporting information. Examples of storm water management committees can be found in several California counties, including Alameda, Sacramento, Ventura, San Diego, and Los Angeles.

Implementation Findings

As the stormwater Phase I program is implemented and matures, Phase I MS4s are continuing to struggle with the implementation of several common aspects of the program. On-the-ground activities such as inspections of construction sites and industrial facilities appear to be a common problem, while other programs like public education and municipal maintenance are often more advanced. Below are several of the common findings associated with implementation of the storm water Phase I program.

Compliance with local construction site erosion and sediment controls is a challenge for all MS4s. Storm water Phase I regulations require MS4s to develop a local program to control construction site runoff. Many MS4s, however, find this program a challenge to implement. The frequency of inspections at construction sites required to ensure proper installation and maintenance of erosion and sediment control BMPs is often lacking. Some MS4s count all inspector visits to construction sites, even inspectors who have nothing to do with erosion and sediment controls. Also, some MS4s have different requirements for public and private construction sites. All of these factors can contribute to a program that is ineffective in preventing erosion and sediment control problems at construction sites.

Tetra Tech has found that successful programs often have dedicated erosion and sediment control inspectors for local construction projects. These inspectors are involved in not only inspections, but also participate in the plan review process so they are aware of what erosion and sediment controls and post-construction BMPs the construction sites are required to implement. Also, these inspectors have adequate enforcement mechanisms such as stop work authority or the ability to fine contractors to ensure compliance.

Local MS4 industrial and construction inspectors are often unaware of State permit requirements. The State of California, like all states, has issued statewide general permits for controlling storm water runoff from industrial facilities and construction activity. Within Phase I areas, however, industrial facilities and construction operators also need to comply with the local MS4 program to address industrial or construction runoff. Many local inspectors, although they are trained in the local requirements, are often unaware of the requirements contained in the statewide permit. In some cases this is intentional, as the MS4 does not want the responsibility of enforcing the statewide permit requirements. However, MS4s can provide a valuable service to their local construction and industrial facilities by explaining the difference between the two sets of requirements, and what these facilities need to do to comply with the statewide requirements.

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Some programs avoid this problem by simply adopting the statewide permit requirement for a stormwater pollution prevention plan (SWPPP) as their own requirement. This ensures that local construction operators only need to develop one plan to comply with both local and state stormwater requirements, and local construction inspectors only need to know one set of requirements.

Pretreatment inspectors, if available, can efficiently conduct industrial stormwater inspections.
The pretreatment program is a well-established program with existing staff trained in water quality practices and enforcement techniques. Some MS4s have expanded the role of pretreatment inspectors to also conduct industrial stormwater inspections. Many of these industrial facilities are already included in the pretreatment program, therefore the on-site inspector simply needs to also include several stormwater elements in their inspections. For MS4s with an existing pretreatment program, this expansion of pretreatment inspector duties to include stormwater inspections effectively implements the program without creating a separate inspection program. Of course, this approach may not be as effective in areas where the sanitary sewer system does not fully coincide with the storm drainage system (e.g., areas on septic systems).

Many MS4s fail to identify and eliminate dry weather discharges.
A separate storm drain system is designed to carry only storm water runoff. Dry weather, therefore, presents MS4s an excellent opportunity to identify and eliminate non-stormwater discharges to their storm drain system. The evaluations have found that many MS4s, however, fail to identify and eliminate dry weather discharges. These MS4s either fail to look for any discharges during dry weather, or assume that all dry weather discharges are attributable to landscape irrigation, groundwater infiltration, or some other uncontaminated source.

Municipal maintenance and spill response programs are often more advanced than other program areas.
Due to the need to minimize episodes of flooding, MS4s often have effective maintenance programs of their storm drain systems. The municipal maintenance staff are often well trained, equipped, and have detailed records of their maintenance activities. Also, other related programs such as street sweeping, which are often initiated for different reasons (e.g., aesthetics), also have significant stormwater benefits. In addition, for obvious public safety reasons, many MS4s have effective spill response programs.

Many MS4s have extensive public education programs.
Public education programs are often an 'easy' and 'fun' program for MS4s to implement. Many MS4s have been very innovative in finding new methods to reach target audiences. This includes websites, classroom educational programs, radio and TV commercials, mascots, and public involvement programs such as storm drain stenciling programs. Some MS4s have also taken surveys of their residents to determine the overall level of awareness and effectiveness of their public education programs.

Evaluation Findings

As EPA found with its 2000 Report to Congress (EPA, 2000), evaluating the effectiveness of the stormwater program is a difficult task. However, successful programs are developing local measures by which progress or effectiveness can be evaluated, including the use of environmental indicators. Tetra Tech found that many programs share common problems in terms of program evaluation, as described in the findings below.

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MS4 programs are not evaluating their data and are therefore not modifying programs in response to trends in this data.
EPA envisioned the storm water program to be an iterative process. Storm water permits, and programs, should evaluate what is working and be able to make modifications in response to changing conditions. Many programs, however, are not collecting the data, such as monitoring or other performance and effectiveness data, necessary to determine needed changes.

At a minimum, programs should complete a comprehensive outcome evaluation at the end of each permit term, and should complete an annual process evaluation at the end of each year with the submittal of the annual report. This will ensure that programs are responsive to changing priorities and needs.

MS4 programs should develop different methods to evaluate the effectiveness of their programs.
All Phase I MS4s collect monitoring data, but few programs are collecting enough water quality data to show statistically significant changes. Other evaluation techniques, such as environmental indicators, should be considered by these programs as a way to characterize water quality conditions and provide a benchmark for evaluating the success of the stormwater management program. These indicators (Claytor and Brown, 1996) should include a mixture of programmatic indicators, physical and hydrological indicators, biological indictors, social indicators, programmatic indicators and site indicators. Examples include toxicity testing as a water quality indicator and the number of illicit connections identified/corrected as a programmatic indicator. These indicators are important due to the difficulty and expense in documenting water quality improvements solely from water quality monitoring data. Environmental indicators can also be used to ascertain that high quality waters are being maintained or provide an early warning of when their beneficial uses are at risk of being degraded.

Annual reports provide useful information, but are not always good indicators of program effectiveness.
The on-site evaluations have revealed that, although annual reports *can* indicate the success of a program, poor programs can hide behind well-written annual reports and some aspects of effective programs can be hidden or missing from annual reports. Because there is not a standardized reporting process for all Phase I MS4s, this allows each MS4 to choose the type of information it wants to present. A knowledgeable report writer can selectively report certain information, such as the total number of municipal inspectors visiting a construction site instead of the number of inspectors specifically evaluating stormwater controls.

The absence of a standardized report could become especially important as the 5,000+ stormwater Phase II MS4s begin to submit annual reports. A consistent reporting format will allow states to compare information collected from MS4s and will also allow EPA to compare reporting results across states.

Compliance with a permit may not always indicate that a program is successful in protecting water quality.
There is a significant variability in the requirements within the Phase I MS4 permits, even within the State of California. This variability, along with the iterative nature of stormwater permitting, allows MS4s to operate under different guidelines, and implement different programs. A programs success should be tied not only to meeting permit requirements, but also to meeting water quality goals.

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Conclusions

Before the storm water Phase I program, most municipal storm water programs were primarily designed to address water quantity issues (e.g, minimize flooding). The storm water Phase I program is beginning to mature and learn from mistakes in the past, however a significant amount of work remains in developing guidance or programs to document these lessons. Improved reporting, monitoring, and evaluation techniques are needed, but will likely only be implemented in many programs through changes in NPDES permit requirements.

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EVALUATION OF NPDES PHASE 1 MUNICIPAL STORMWATER MONITORING DATA

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Abstract

The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) municipal stormwater permit holders. The data are being collected and reviewed to both describe the characteristics of this data and to provide guidance to permit writers for future sampling needs.

There have been serious concerns about the reliability and utility of Phase 1 stormwater NPDES monitoring data, mainly due to the wide variety of experimental designs, sampling procedures, and analytical techniques used. On the other hand, the cumulative value of the monitoring data collected over nearly a ten year period from more than 200 municipalities throughout the country has a great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. This project is creating a national database of Phase 1 stormwater monitoring data, providing a scientific analysis of the data, and providing recommendations for improving the quality and management value of future NPDES monitoring efforts.

Each data set is receiving a quality assurance/quality control review, based on reasonableness of data, extreme values, relationships among parameters, sampling methods, and a review of the analytical methods. The statistical analyses is being conducted at several levels. Probability plots are used to identify range, randomness and normality. Clustering and principal component analyses are also being utilized to characterize significant factors affecting the data patterns. The master data set is also being evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. We are testing for regional and climatic differences, the influences of land use, and the effects of storm size and season, among other factors.

This paper describes our data collected to date and presents some preliminary data summaries. We have been collecting much data to date, and encourage any other communities with wet weather outfall data collected as part of their NPDES permit program to contact us so we can include as much data as possible in our final effort.

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Project Description and Background

The importance of this project is based on the scarcity of nationally summarized and accessible data from the existing NPDES stormwater permit program. There have been some local and regional data summaries, but little has been done with nationwide data. A notable exception is the CDM national stormwater database (Smullen and Cave 2002) that combined historical NURP (Nationwide Urban Runoff Program) (EPA 1983), available urban USGS, and selected NPDES data. Their main effort has been to describe the probability distributions of this data (and corresponding EMCs, the event mean concentrations). They concluded that concentrations for different land uses were not significantly different, so all their data was pooled.

Other regional databases also exist, mostly using local NPDES data. These include the Los Angeles area database, the Santa Clara and Alameda County (CA) databases, the Oregon Association of Clean Water Agencies Database, and the Dallas area stormwater database. These regional data are (or will be) included in this comprehensive NPDES national database. However, we will not be including the USGS or historical NURP data in this NPDES database due to lack of consistent descriptive information for the older drainage areas. Much of the NURP data are available in electronic form at the University of Alabama student American Water Resources Association web page at: http://www.eng.ua.edu/~awra/download.htm The results from these other databases will be compared to our results during our final analyses to indicate any important differences.

This new NPDES database is unique in that detailed descriptions of the test areas and sampling conditions are also being collected, including aerial photographs and topographic maps for many locations which we are collecting from public domain Internet sources. The land use information used is as supplied by the communities submitting the data, although aerial photographs and maps are also used to clarify any questions. Most of the sites have homogeneous land uses, although many are mixed. These characteristics are all fully noted in the database.

This project is collecting stormwater runoff data from existing NPDES permit applications and permit monitoring reports; we are conducting QA/QC (quality assurance/quality control) evaluations of these data; and statistical analyses and summaries of these data. The final information will be published on the Internet (such as on an EPA OW-OWM, Office of Water and Office of Wastewater Management, site and on the Center for Watershed Protection's SMRC, Stormwater Manager's Resources Center, site at: http://www.stormwatercenter.net/). Some of the information is currently located at Pitt's teaching and research web site at: http://www.eng.ua.edu/~rpitt/.

The phase 1 NPDES communities included areas with:

- A stormwater discharge from a MS4 serving a population of 250,000 or more (large system), or
- A stormwater discharge from a MS4 serving a population of 100,000 or more, but less than 250,000 (medium system)

More than 200 municipalities, plus numerous additional special districts and governmental agencies were included in this program. Part 2 of the NPDES discharge permit application specified that sampling was needed and that the following was to be included in the application:

- Proposed monitoring program for representative data collection during the term of the permit.
- Quantitative data from 5 to 10 representative locations,

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- Estimates of the annual pollutant load and event mean concentration (EMC) of system discharges,
- Proposed schedule to provide estimates of seasonal pollutant loads and the EMC for certain detected constituents during the term of the permit.

The permit applications were due in 1992 and 1993. For Part 2 of the application, municipalities were to submit grab (for certain pollutants) and flow-weighted sampling data from selected sites (5 to 10 outfalls) for 3 representative storm events at least 1 month apart. In addition, the municipalities must have also developed programs for future sampling activities that specified sampling locations, frequency, pollutants to be analyzed, and sampling equipment.

Numerous constituents were to be analyzed, including typical conventional pollutants (TSS, TDS, COD, BOD_5, oil and grease, fecal coliforms, fecal strep., pH, Cl, TKN, NO_3, TP, and PO_4), plus many heavy metals (including total forms of arsenic, chromium, copper, lead, mercury, and zinc, plus others), and numerous listed organic toxicants (including PAHs, pesticides, and PCBs). Many communities also analyzed samples for filtered forms of the heavy metals. Our database includes information for about 125 different stormwater quality constituents, although the current database is mostly populated with data from 44 of the commonly analyzed pollutants (as summarized later in Table 3). Therefore, there has been a substantial amount of data collected during the past 8 or 9 years from throughout the country, although most of these data are not readily available, nor have detailed statistical analyses been conducted and presented.

Data Collection and Analysis Efforts to Date

As of mid-December 2002, 3,757 events from 66 agencies and municipalities from 17 states have been collected and entered into our database. These locations are listed in Table 1. Table 2 lists 27 states where municipalities have been contacted and we plan to target for our next phase of data collection. Figure 1 shows the locations of these municipalities on a national map. We anticipate excellent national coverage, although we may have few municipalities from the northern west-central states of Montana, Wyoming, North and South Dakota (where cities are generally small, and few were included in the Phase 1 NPDES program).

Some of the municipalities that we have contacted (and some where we actually received data) have information that could not be used for various reasons. One of the most common reasons for not being able to use the data was that the samples had been collected from receiving waters (such as Washington state, Nashville, and Chattanooga). We are using data only from well-described stormwater outfall locations. These can be open channel outfalls in completely developed areas, but are more commonly conventional outfall pipes. The other major problem is that the sampling locations and/or the drainage areas were not described. We are using data with some missing information for now, with the intention of obtaining the needed information later. However, there will likely still be some minor data gaps that we will not be able to fill. In addition, the list of constituents being monitored has varied for different locations. Most areas evaluated the common stormwater constituents, but few have included organic toxicants. The most serious gap is the frequent lack of runoff volume data, although all sites have included rain data. Finally, if we collect all the data we have asked for, our current project resources will not permit us to fully utilize them, as it requires a great deal of time to enter and review this information.

The assembled data has been entered into a database which contains site descriptions (state, municipality, land use components, and EPA rain zone), sampling information (date, season, rain depth, runoff depth, sampling method, sample type, etc.), and constituent measurements (concentrations, grouped in categories).

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In addition, more detailed site, sampling, and analysis information has been collected for each sampling site and included as supplemental information. We are using the reported land use information supplied by the communities, and are verifying some with aerial photographs and maps. In many cases, the sampled watersheds have multiple land uses and those designations are included in the database (we list the percentages of the drainage as residential, commercial, industrial, freeway, institutional, and open space). Our final data analyses will consider these mixed sites also, although the following preliminary results are only for the homogeneous land use sites.

Preliminary Summary of Phase 1 Stormwater Data

We plan to acquire additional stormwater data before our final data analysis, and to complete many of the missing records. The following data and analysis descriptions should therefore be considered preliminary and will change with these additional data and analyses. However, we are presenting only our most basic and robust analyses here for consideration. Our final report and data presentations will obviously be much more comprehensive.

Table 1. Municipalities whose Data has been Entered into Database

ALABAMA	IDAHO	MINNESOTA	TEXAS
Jefferson County	Ada County Highway District	Minneapolis	Arlington
Mobile			Dallas
	KANSAS	**NORTH CAROLINA**	Dallas County
ARIZONA	Topeka	Charlotte	Fort Worth
Maricopa County	Wichita	Fayetteville	Garland
Tucson		Greensboro	Harris County
	KENTUCKY		Houston
CALIFORNIA	Jefferson County	**OREGON**	Irving
Alameda	Louisville	Clackamas County	Mesquite
Caltrans	Lexington	Eugene	Plano
		Gresham	Tarrant County
COLORADO	**MASSACHUSETTS**	Portland	
Denver	Boston	Salem	**VIRGINIA**
Colorado Springs		ODOT	Arlington County
	MARYLAND		Chesapeake County
GEORGIA	Anne Arundel County	**PENNSYLVANIA**	Chesterfield County
Clayton County	Baltimore County	Philadelphia	Fairfax County
Cobb County	Baltimore City		Hampton County
De Kalb County	Carroll County	**TENNESSEE**	Henrico County
Fulton County	Charles County	Knoxville	Newport News County
Gwinnett County	Harford County	Memphis	Norfolk County
Atlanta	Howard County		Portsmouth County
	Montgomery County		Virginia Beach County
	Prince Georges County		
	State Highway		

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Table 2. Communities Targeted for Next Phase of Data Collection

ALABAMA	ILLINOIS	NEBRASKA	PENNSYLVANIA
Madison	Rockford	Lincoln	Allentown
Huntsville - Madison		Omaha	
Montgomery	**INDIANA**		**SOUTH CAROLINA**
	Indianapolis	**NEVADA**	Greenville County
ALASKA		Las Vegas	Richland County
Anchorage	**KANSAS**	Reno	Columbia
	Kansas City	Clark County	
ARIZONA			**TEXAS**
Pima County	**LOUISIANA**	**NEW MEXICO**	Abilene
Mesa	New Orleans	Albuquerque	Amarillo
Phoenix	Shreveport		Austin
Tempe		**NEW YORK**	Beaumont
	MASSACHUSETTS	Various Communities	Corpus Christi
CALIFORNIA	Worcester		El Paso
Various Communities		**NORTH CAROLINA**	Laredo
	MICHIGAN	Durham	Pasadena
COLORADO	Ann Arbor	Raleigh	San Antonio
Aurora	Flint	Winston-Salem	Waco
Lakewood	Grand Rapids		
Littleton	Sterling Heights	**OHIO**	**UTAH**
	Warren	Akron	Salt Lake County
DELAWARE		Columbus	Salt Lake City
Wilmington	**MISSISSIPPI**	Dayton	
New Castle County	Jackson	Toledo	**WISCONSIN**
			Milwaukee
FLORIDA	**MISSOURI**	**OKLAHOMA**	
Various Communities	Independence	Oklahoma City	
	Kansas City	Tulsa	
HAWAII	Springfield		
Honolulu County			

Table 3 is a summary of the Phase 1 data we have collected and entered into our database as of mid December 2002. The data are separated into six major land use categories: residential, mixed residential (but mostly residential), commercial, industrial, institutional, and freeways. Our open space and other mixed land use data are not included on these tables due to lack of space in this paper. This table also summarizes all data combined. The total number of events included in the database is 3,757, with most in the residential category. Many of the monitoring locations are characterized by mixed land uses. With the exception of the mixed residential area, only the main land use categories are shown separately on this table. For most common constituents, we have detectable values for almost all monitored events. However, filtered heavy metal observations, and especially organic analyses, have many fewer detected values. This table shows the percentage of analyzed samples that had detected values. The median and coefficient of variation (COV) values are only for those data having detectable concentrations. If we included the non-detected results in these calculations, extreme biases would invalidate many of the COV calculations. Our final analyses will

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further examine issues associated with different detection limits, multiple laboratories, and varying analytical methods on the reported results and statistical analyses. See Burton and Pitt (2002), and the many included references in that book, for further discussions on these important issues.

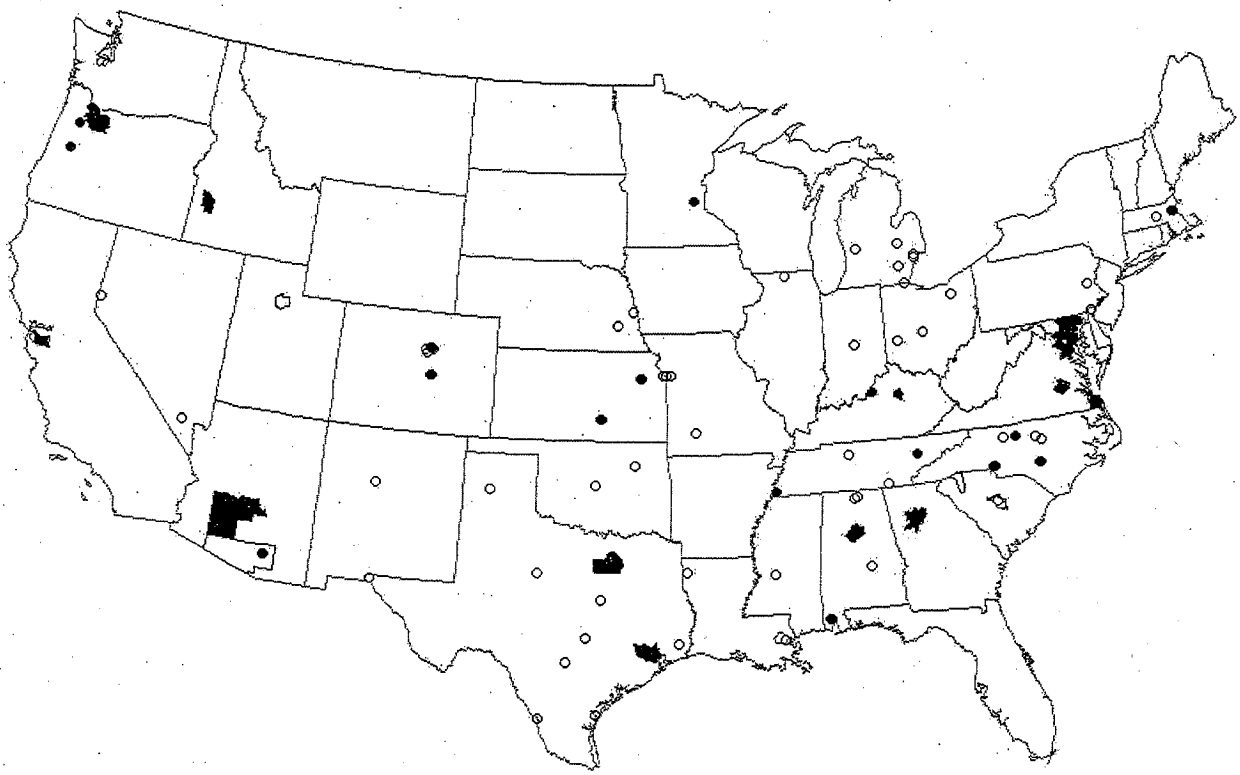

Figure 1. Data has been obtained and entered in our database for the communities shown in black. The other communities are targeted for our next data collection phase (plus Delaware, Alaska, Wisconsin, Southern California, Florida, and Hawaiian communities).

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Table 3. Summary of Available Stormwater Data Included in NPDES Database

Land Use (Number of Events)	Area (acres)	% Imperv.	Precip. Depth (in)	Cond. (uS/cm @25°C)	Hardness (mg/L $CaCO_3$)	pH
All Data Combined (3757)						
Number of observations	3562	2036	3063	887	1115	1690
% of samples above detection	94	100	100	78	81	86
Median of detected values	45	50	0.47	121	39	7.4
Coefficient of variation	7.79	0.44	0.97	1.75	1.45	0.11
Residential (983)						
Number of observations	937	558	831	164	223	247
% of samples above detection	94	100	100	65	76	74
Median of detected values	57.3	37	0.455	96	31	7.13
Coefficient of variation	4.91	0.44	0.99	1.51	0.98	0.12
Mixed Residential (584)						
Number of observations	582	239	421	137	146	341
% of samples above detection	97	100	100	77	75	88
Median of detected values	104	40	0.56	116	43.4	7.3
Coefficient of variation	2.46	0.28	0.75	1.15	0.90	0.10
Commercial (464)						
Number of observations	442	211	399	73	120	152
% of samples above detection	90	100	99	90	94	91
Median of detected values	32	80	0.39	118.5	36	7.1
Coefficient of variation	4.83	0.11	1.05	0.98	1.04	0.13
Industrial (471)						
Number of observations	448	255	395	129	114	205
% of samples above detection	93	100	100	84	79	86
Median of detected values	37.9	71.8	0.47	136	37.3	7.2
Coefficient of variation	1.70	0.32	1.00	1.31	1.09	0.11
Institutional (18)						
Number of observations	18	18	17	0	0	0
% of samples above detection	100	100	100	n/a	n/a	n/a
Median of detected values	36	45	0.18	n/a	n/a	n/a
Coefficient of variation	0.00	0.00	0.91	n/a	n/a	n/a
Freeways (185)						
Number of observations	182	154	182	86	128	111
% of samples above detection	85	100	100	100	99	100
Median of detected values	0.99	80	0.54	99	34	7.1
Coefficient of variation	0.72	0.13	1.05	1.01	1.85	0.11

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	TDS (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Fecal Coliform (mpn/ 100 mL)	Fecal Strep. (mpn/ 100 mL)
All Data Combined (3757)						
Number of observations	3062	3525	3135	2796	1764	1142
% of samples above detection	97	98	94	96	89	91
Median of detected values	78	63	8.3	52	5000	16000
Coefficient of variation	4.13	6.05	4.45	4.79	4.64	3.85
Residential (983)						
Number of observations	802	923	867	746	382	267
% of samples above detection	97	98	96	97	87	90
Median of detected values	69	50	9.05	55.5	7750	24000
Coefficient of variation	2.17	6.25	3.34	3.49	5.06	1.89
Mixed Residential (584)						
Number of observations	470	570	557	444	342	160
% of samples above detection	98	99	92	98	93	94
Median of detected values	85	74.8	7.16	40	11000	25000
Coefficient of variation	5.68	7.89	1.37	1.47	3.21	2.21
Commercial (464)						
Number of observations	378	446	410	353	215	152
% of samples above detection	98	98	94	96	87	90
Median of detected values	74	48	12	60	3000	9200
Coefficient of variation	1.92	4.85	1.12	1.01	3.93	2.84
Industrial (471)						
Number of observations	380	434	377	339	272	176
% of samples above detection	97	98	94	96	86	92
Median of detected values	84	90	9	61	2400	13050
Coefficient of variation	4.11	4.74	6.34	2.17	6.11	6.89
Institutional (18)						
Number of observations	18	18	18	18	0	0
% of samples above detection	100	94	89	89	n/a	n/a
Median of detected values	52.5	17	8.5	50	n/a	n/a
Coefficient of variation	0.67	0.83	0.70	0.91	n/a	n/a
Freeways (185)						
Number of observations	97	134	26	67	49	25
% of samples above detection	99	99	85	99	100	100
Median of detected values	77.5	99	8	100	1700	17000
Coefficient of variation	0.80	2.53	1.26	1.06	1.95	1.21

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	$N0_2$+NO_3 (mg/L)	Ammonia (mg/L)	Nitrogen, Total Kjeldahl (mg/L)	Phos., filtered (mg/L)	Phos., total (mg/L)	Oil and Grease (mg/L)
All Data Combined (3757)						
Number of observations	3127	1874	3304	2470	3307	1830
% of samples above detection	96	75	95	89	96	71
Median of detected values	0.6	0.44	1.32	0.12	0.27	4
Coefficient of variation	1.99	3.45	3.64	2.44	8.74	4.50
Residential (983)						
Number of observations	863	564	879	656	885	473
% of samples above detection	97	87	96	90	96	66
Median of detected values	0.58	0.31	1.42	0.16	0.31	3.3
Coefficient of variation	1.93	2.14	3.87	0.98	8.13	7.79
Mixed Residential (584)						
Number of observations	542	255	562	399	554	254
% of samples above detection	96	57	94	90	95	74
Median of detected values	0.56	0.36	1.2	0.11	0.27	4
Coefficient of variation	1.01	2.96	1.85	3.70	7.98	2.53
Commercial (464)						
Number of observations	415	285	426	295	425	260
% of samples above detection	96	85	95	85	96	77
Median of detected values	0.62	0.57	1.6	0.1	0.23	5
Coefficient of variation	1.07	2.52	4.86	3.25	7.36	3.13
Industrial (471)						
Number of observations	398	243	411	301	403	287
% of samples above detection	94	91	95	90	97	74
Median of detected values	0.75	0.52	1.4	0.1	0.27	4
Coefficient of variation	0.96	3.60	2.53	1.25	6.79	3.28
Institutional (18)						
Number of observations	18	18	18	18	18	0
% of samples above detection	100	89	100	83	94	n/a
Median of detected values	0.6	0.31	1.35	0.14	0.17	n/a
Coefficient of variation	0.64	0.53	0.50	0.53	1.04	n/a
Freeways (185)						
Number of observations	25	79	125	22	128	60
% of samples above detection	96	87	97	95	99	72
Median of detected values	0.28	1.07	2	0.197	0.25	8
Coefficient of variation	1.23	1.73	1.37	2.13	1.76	0.62

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	Sb, total (µg/L)	As, total (µg/L)	As, filtered (µg/L)	Be, total (µg/L)	Cd, total (µg/L)	Cd, filtered (µg/L)	Cr, total (µg/L)
All Data Combined (3757)							
Number of observations	755	1425	209	842	2481	389	1561
% of samples above detection	9	49	27	10	49	31	63
Median of detected values	3	3.3	1.5	0.31	1	0.5	7
Coefficient of variation	2.56	2.42	1.00	2.74	4.42	1.69	1.47
Residential (983)							
Number of observations	214	366	32	239	599	85	383
% of samples above detection	2	37	6	11	38	6	50
Median of detected values	40	3	1.48	0.4	0.5	0.7	4.55
Coefficient of variation	1.11	2.42	0.50	2.92	5.20	0.55	1.31
Mixed Residential (584)							
Number of observations	74	170	18	76	398	30	172
% of samples above detection	4	65	28	16	51	40	72
Median of detected values	1	4	2	0.3	0.9	0.3	8
Coefficient of variation	1.59	3.78	0.84	2.86	3.53	0.64	1.62
Commercial (464)							
Number of observations	91	165	21	112	303	48	201
% of samples above detection	3	38	10	6	54	25	66
Median of detected values	69	2.5	1.5	0.5	0.86	0.33	6
Coefficient of variation	0.79	0.79	0.47	1.99	5.02	2.26	1.38
Industrial (471)							
Number of observations	123	219	23	164	329	42	215
% of samples above detection	18	58	13	12	60	55	72
Median of detected values	4.8	5	1	0.345	1.9	0.6	15
Coefficient of variation	1.37	0.94	0.43	2.55	3.77	1.10	1.13
Institutional (18)							
Number of observations	0	0	0	0	18	0	15
% of samples above detection	n/a	n/a	n/a	n/a	17	n/a	0
Median of detected values	n/a	n/a	n/a	n/a	0.5	n/a	n/a
Coefficient of variation	n/a	n/a	n/a	n/a	0.69	n/a	n/a
Freeways (185)							
Number of observations	14	61	72	12	95	114	76
% of samples above detection	50	56	50	17	72	26	99
Median of detected values	3	2.4	1.43	0.3	1	0.68	8.3
Coefficient of variation	0.25	0.70	1.15	0.47	0.90	1.03	0.71

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	Cr, filtered (µg/L)	Cu, total (µg/L)	Cu, filtered (µg/L)	CN, total (µg/L)	Pb, total (µg/L)	Pb, filtered (µg/L)	Hg, total (µg/L)
All Data Combined (3757)							
Number of observations	260	2770	413	1012	2902	446	1014
% of samples above detection	61	86	83	8	80	50	11
Median of detected values	2.08	16	8	5	15.9	3	0.2
Coefficient of variation	0.74	2.24	1.68	2.62	1.89	2.01	1.17
Residential (983)							
Number of observations	33	719	91	325	704	109	252
% of samples above detection	27	84	64	7	75	34	10
Median of detected values	1.28	11.1	7	5	12	3	0.2
Coefficient of variation	0.59	1.60	1.92	1.93	1.95	1.84	1.14
Mixed Residential (584)							
Number of observations	21	421	30	82	501	30	100
% of samples above detection	52	85	73	6	78	47	19
Median of detected values	2	18.7	5.75	0.01	19	3	0.3
Coefficient of variation	0.80	1.31	2.33	2.20	1.34	0.68	0.85
Commercial (464)							
Number of observations	27	360	49	144	345	59	133
% of samples above detection	41	96	80	15	95	54	11
Median of detected values	2	15	8	0.013	17	5	0.2
Coefficient of variation	0.59	1.55	1.50	1.69	1.70	1.61	0.79
Industrial (471)							
Number of observations	36	372	42	177	372	51	178
% of samples above detection	56	91	90	10	83	53	11
Median of detected values	3	21.8	8	5.92	23.7	5	0.1
Coefficient of variation	0.73	2.01	0.67	1.60	1.90	1.58	1.89
Institutional (18)							
Number of observations	0	17	0	0	0	0	0
% of samples above detection	n/a	41	n/a	n/a	n/a	n/a	n/a
Median of detected values	n/a	17	n/a	n/a	n/a	n/a	n/a
Coefficient of variation	n/a	0.59	n/a	n/a	n/a	n/a	n/a
Freeways (185)							
Number of observations	101	97	130	3	100	126	34
% of samples above detection	78	99	99	0	100	50	6
Median of detected values	2.3	34.7	10.9	n/a	27.5	1.8	0.19
Coefficient of variation	0.70	0.95	1.50	n/a	1.44	1.65	0.80

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	Ni, total (µg/L)	Ni, filtered (µg/L)	Se, total (µg/L)	Ag, total (µg/L)	Zn, total (µg/L)	Zn, filtered (µg/L)
All Data Combined (3757)						
Number of observations	1602	246	912	1149	3053	383
% of samples above detection	40	64	9	14	95	96
Median of detected values	9	4	2	3	112	51
Coefficient of variation	2.08	1.47	1.48	4.63	4.59	3.91
Residential (983)						
Number of observations	381	25	246	297	728	90
% of samples above detection	33	44	7	17	96	90
Median of detected values	6	2	2	5	73	32
Coefficient of variation	1.19	0.51	0.54	4.33	4.33	0.85
Mixed Residential (584)						
Number of observations	179	25	80	92	505	28
% of samples above detection	28	72	9	10	92	100
Median of detected values	10	5.5	4	2800	97	48
Coefficient of variation	0.84	0.87	0.89	2.02	1.06	0.88
Commercial (464)						
Number of observations	203	23	118	148	366	49
% of samples above detection	58	48	7	20	100	100
Median of detected values	7	3	2.5	5	150	59
Coefficient of variation	1.82	0.84	0.82	3.02	1.26	1.37
Industrial (471)						
Number of observations	225	36	175	216	387	42
% of samples above detection	53	58	10	23	98	95
Median of detected values	20	5	2	1	220	111.5
Coefficient of variation	0.87	1.43	0.98	4.28	2.28	3.62
Institutional (18)						
Number of observations	15	0	0	0	18	0
% of samples above detection	0	n/a	n/a	n/a	100	n/a
Median of detected values	n/a	n/a	n/a	n/a	305	n/a
Coefficient of variation	n/a	n/a	n/a	n/a	0.81	n/a
Freeways (185)						
Number of observations	79	95	16	21	93	105
% of samples above detection	87	67	6	19	97	99
Median of detected values	9.2	4	2	0.35	200	51
Coefficient of variation	0.92	1.38	n/a	0.87	1.01	1.86

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	Methylene-chloride (µg/L)	Bis(2-ethylhexyl) phthalate (µg/L)	Di-n-butyl phthalate (µg/L)	Fluoranthene (µg/L)
All Data Combined (3757)				
Number of observations	251	250	93	259
% of samples above detection	36	30	16	19
Median of detected values	11.2	9.5	0.8	6
Coefficient of variation	0.77	1.13	1.03	1.31
Residential (983)				
Number of observations	104	143	22	145
% of samples above detection	33	20	18	3
Median of detected values	11.3	4.5	10	3
Coefficient of variation	0.93	1.68	0.64	1.21
Mixed Residential (584)				
Number of observations	23	26	8	26
% of samples above detection	43	15	13	0
Median of detected values	9.05	5.1	14	n/a
Coefficient of variation	0.51	0.38	n/a	n/a
Commercial (464)				
Number of observations	42	72	20	75
% of samples above detection	21	44	25	35
Median of detected values	9.2	10.1	0.7	5.9
Coefficient of variation	0.40	1.07	1.39	4.38
Industrial (471)				
Number of observations	33	49	12	51
% of samples above detection	33	43	25	25
Median of detected values	9.7	10	0.7	3.8
Coefficient of variation	0.40	0.81	0.09	0.97
Institutional (18)				
Number of observations	0	0	0	0
% of samples above detection	n/a	n/a	n/a	n/a
Median of detected values	n/a	n/a	n/a	n/a
Coefficient of variation	n/a	n/a	n/a	n/a
Freeways (185)				
Number of observations	0	0	0	0
% of samples above detection	n/a	n/a	n/a	n/a
Median of detected values	n/a	n/a	n/a	n/a
Coefficient of variation	n/a	n/a	n/a	n/a

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Table 3. Summary of Available Stormwater Data Included in NPDES Database (cont.)

	Phenanthrene (µg/L)	Pyrene (µg/L)	Diazinon (µg/L)	2, 4-D (µg/L)
All Data Combined (3757)				
Number of observations	233	249	79	101
% of samples above detection	13	14	22	35
Median of detected values	3.95	5.2	0.06	3
Coefficient of variation	1.00	1.24	1.90	0.86
Residential (983)				
Number of observations	136	140	11	11
% of samples above detection	3	4	36	64
Median of detected values	1.7	2.2	30	8
Coefficient of variation	0.70	0.30	0.40	0.72
Mixed Residential (584)				
Number of observations	23	26	1	2
% of samples above detection	0	0	0	50
Median of detected values	n/a	n/a	n/a	5
Coefficient of variation	n/a	n/a	n/a	n/a
Commercial (464)				
Number of observations	70	75	19	13
% of samples above detection	31	35	42	69
Median of detected values	4.05	5	0.045	3
Coefficient of variation	4.50	4.57	0.49	0.94
Industrial (471)				
Number of observations	47	47	9	3
% of samples above detection	17	21	33	100
Median of detected values	9	7.2	0.72	2
Coefficient of variation	0.72	0.73	1.40	1.14
Institutional (18)				
Number of observations	0	0	0	0
% of samples above detection	n/a	n/a	n/a	n/a
Median of detected values	n/a	n/a	n/a	n/a
Coefficient of variation	n/a	n/a	n/a	n/a
Freeways (185)				
Number of observations	0	0	1	1
% of samples above detection	n/a	n/a	100	0
Median of detected values	n/a	n/a	0.05	n/a
Coefficient of variation	n/a	n/a	n/a	n/a

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Data Analyses

Statistical analyses are being conducted at several levels. First, probability plots are used to identify range, randomness, and normality. Figure 3 (end of paper) is an example of log-normal probability plots for some of the constituents and for all data pooled. Probability plots shown as straight lines indicate that the concentrations can be represented by log-normal distributions. This is important as it indicates that data transformations, or the use of nonparametric statistical analyses, will be needed. Other plots with obvious discontinuities (such as for bacteria, phosphorus, lead, and zinc) imply that multiple data populations may be included. Our future analyses will identify the significance of these different data categories (such as land use, region, and season).

Clustering and principal component analyses (PCA) are also being utilized to characterize expected factors influencing sample variability. Figure 4 is an example dendogram from a cluster analysis of all of the preliminary data combined. This plot indicates very close relationships between rain depth and the nutrients (total phosphorus, dissolved phosphorus, nitrite plus nitrate, ammonia, and Total Kjeldahl Nitrogen). Some of the heavy metals (cadmium, nickel, and chromium) are closely related to each other, but copper, lead and zinc are much more independent. BOD_5, COD, dissolved solids, and suspended solids are poorly related to other pollutants for the pooled data. Pearson correlation analyses did show relatively strong relationships between suspended solids and the total forms of most of the heavy metals, substantiating the observation that most of the stormwater metals are not in filtered forms.

The master data set will also be evaluated to develop descriptive statistics, such as measures of central tendency and standard errors. The runoff data will then be evaluated to determine which factors have a strong influence on event mean concentrations, including sampling methods. We will test for regional and climatic differences, the influence of land use, and the effect of storm size, among other factors. Figure 5 includes example scatter plots of COD vs. BOD_5 and filtered copper vs. total copper, illustrating these suspected close relationships. Also shown on this figure are scatter plots of suspended solids and phosphorus concentrations for different rain depths. Little variation of these concentrations with rain depth are seen when all of the data are combined, implying little likelihood of important "first-flush" effects at stormwater outfall locations. Specific comparisons of concentrations from first-flush samples with concurrent composite samples will be a more direct test and will be conducted later.

Figures 6 and 7 are example grouped box and whisker plots of suspended solids, total Kjeldahl nitrogen, fecal coliforms, and copper, grouped for different major land uses and for different seasons. The TKN and copper observations are lowest for open space areas, while the freeway locations had the highest values. Suspended solids and fecal coliform variations are not as obvious, although it is likely that the freeway bacteria values are significantly lower than those found in residential areas. The seasonal variations are not as obvious, except that the bacteria values appear to be lowest during the winter season (a similar conclusion was obtained during the NURP, EPA 1983, data evaluations). Preliminary statistical ANOVA analyses for all land use categories (using SYSTAT) found significant differences for land use categories for all pollutants. Our final analyses will further investigate this important finding and will also examine possible confounding factors.

A major goal of these analyses will be to provide guidance to stormwater managers and regulators. Especially important will be the use of this data as an updated benchmark for comparison with locally collected data. In addition, this data may be useful for preliminary calculations when using the "simple method" for predicting mass discharges for unmonitored areas. This data can also be used as guidance when

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designing local stormwater monitoring programs (Burton and Pitt, 2002), especially when determining the needed sampling effort based on expected variations.

We will also be examining trends of concentrations with time. A classical example would be for lead, which is expected to decrease over time with the current use of unleaded gasoline. Older stormwater samples from the 1970s typically have had lead concentrations of about 100 μg/L, or higher, while most current data indicate concentrations in the range of 1 to 10 μg/L. Figure 8 is a plot of lead concentrations for residential areas only, for the time period from 1991 to 2002. This preliminary plot shows likely decreasing lead concentrations with time for all residential sites combined. However, more work is needed to investigate interacting factors and other relationships of potential interest in order to reduce the variability inherent in this (and the other preliminary) plots.

Our final analyses will expand on these preliminary examples and will also investigate other stormwater data and sampling issues. As an example, we will compare "first flush" samples with composite samples for a number of locations and conditions (the above data only represent composite samples) and will also compare data collected manually vs. automatically.

As we are still collecting information for the database, we encourage all local and state agencies who have Phase 1 municipal stormwater data but have not previously sent it to us, to please contact us so we can arrange to have your data included in our final analyses.

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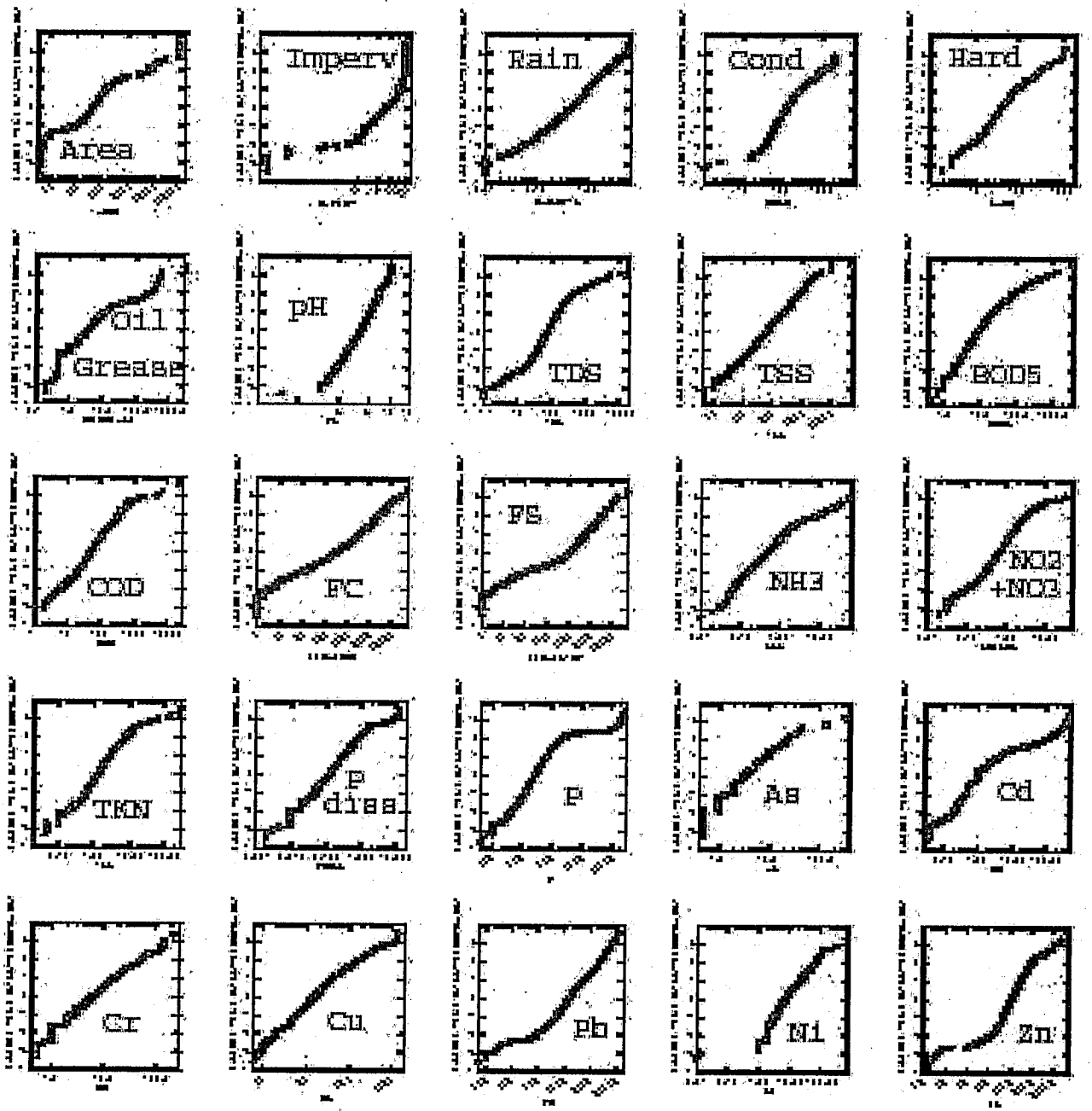

Figure 3. Log-normal probability plots of selected stormwater quality data.

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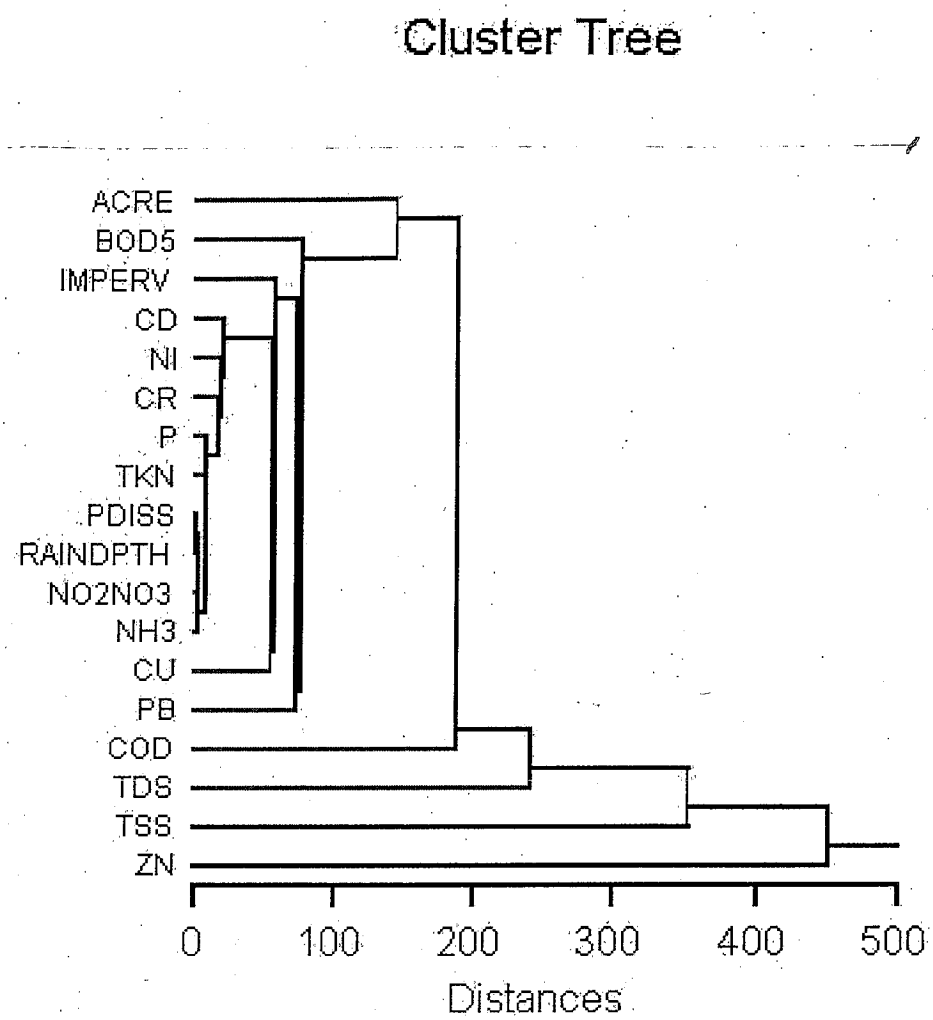

Figure 4. Cluster analysis (dendogram) showing relationships between stormwater pollutants.

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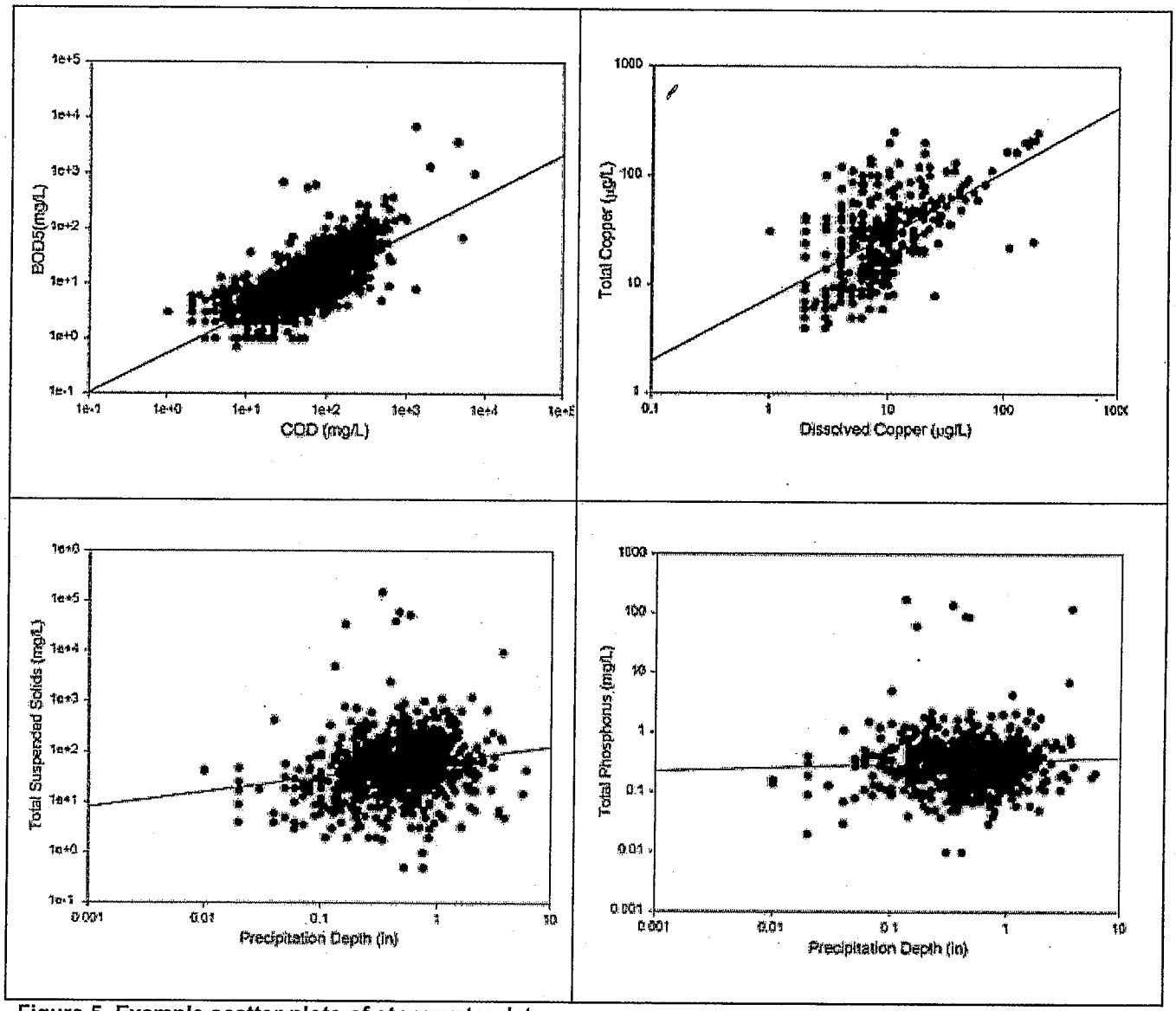

Figure 5. Example scatter plots of stormwater data.

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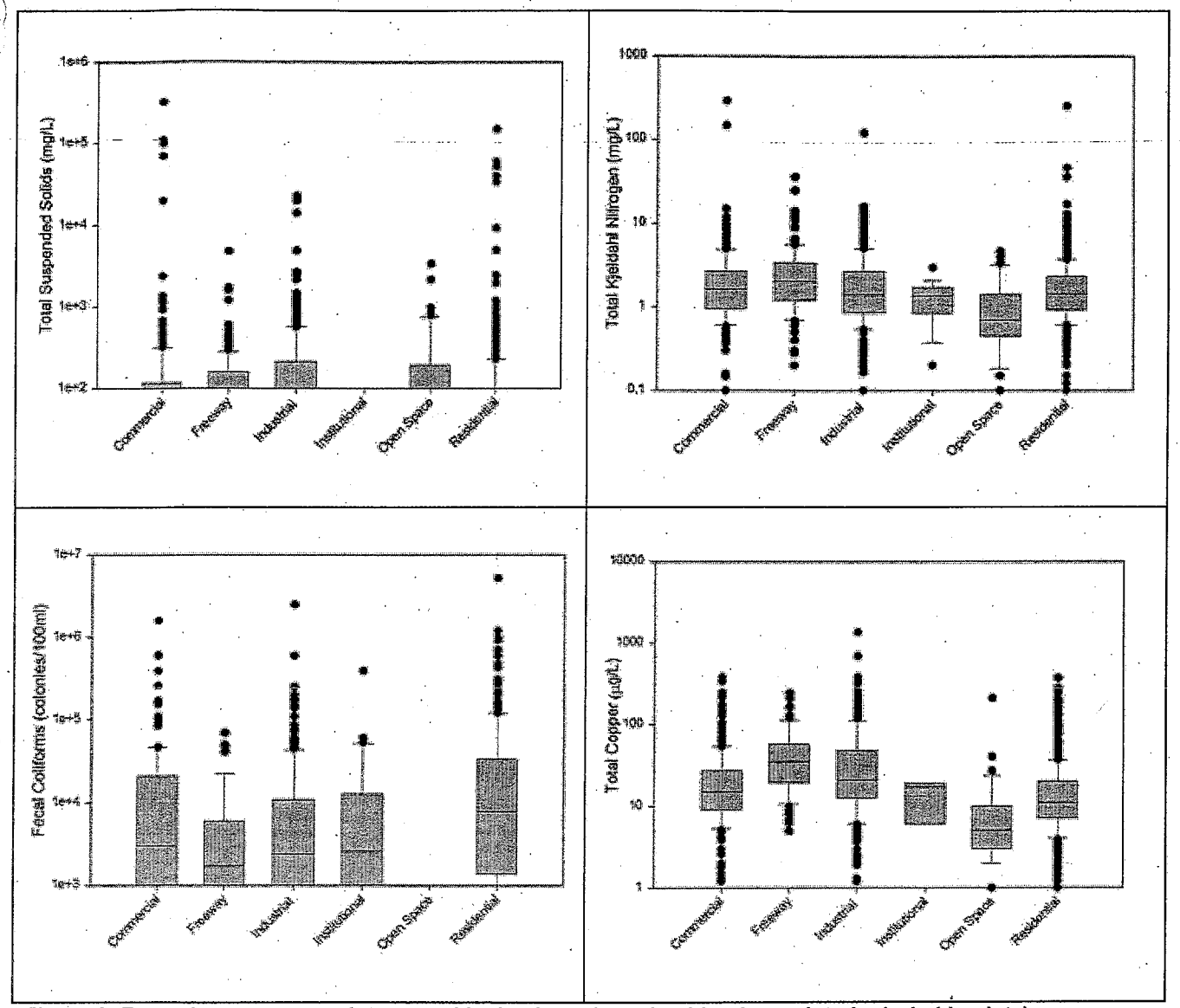

Figure 6. Example stormwater data sorted by land use (no mixed land use data included in plots).

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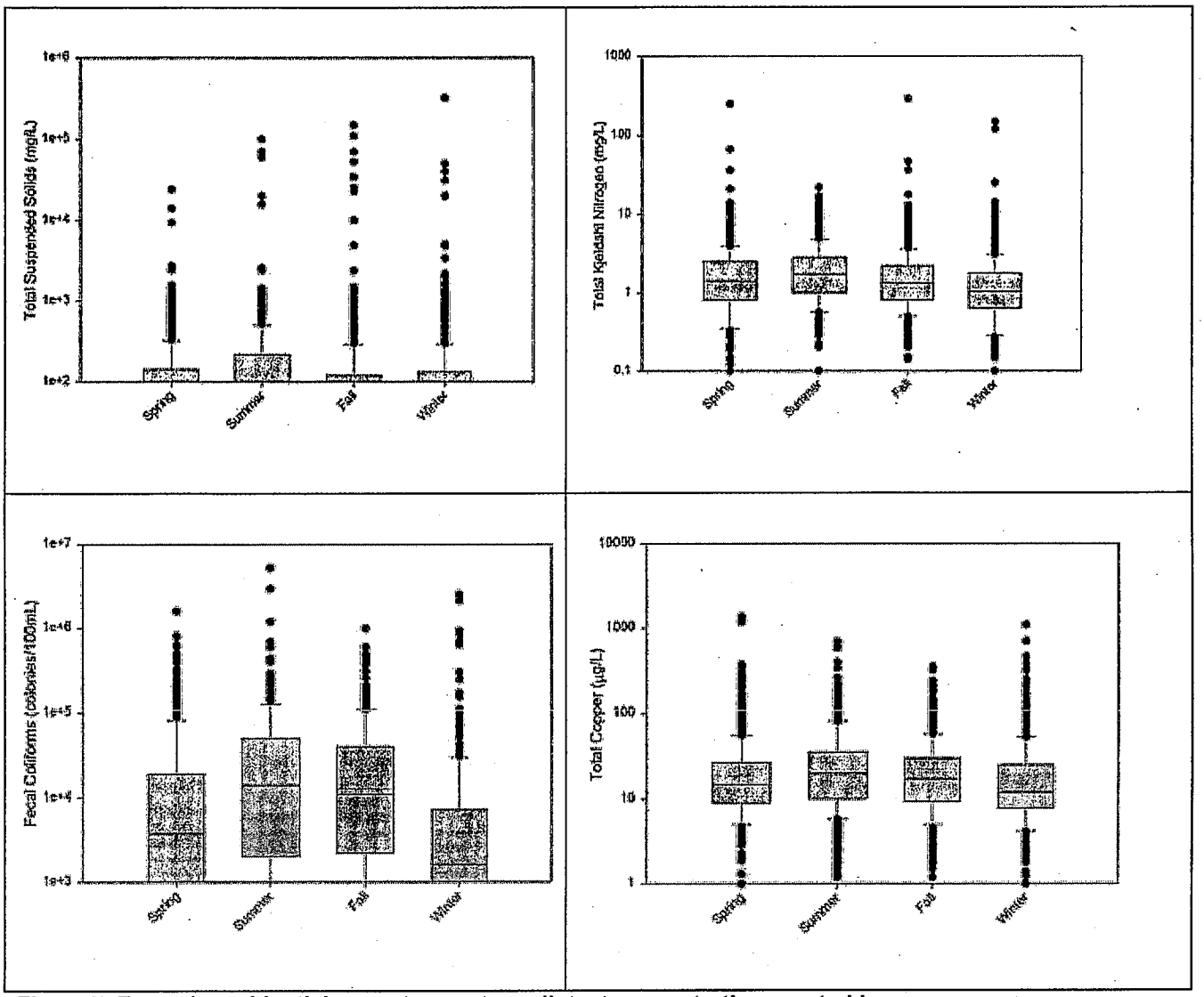

Figure 7. Example residential area stormwater pollutant concentrations sorted by season.

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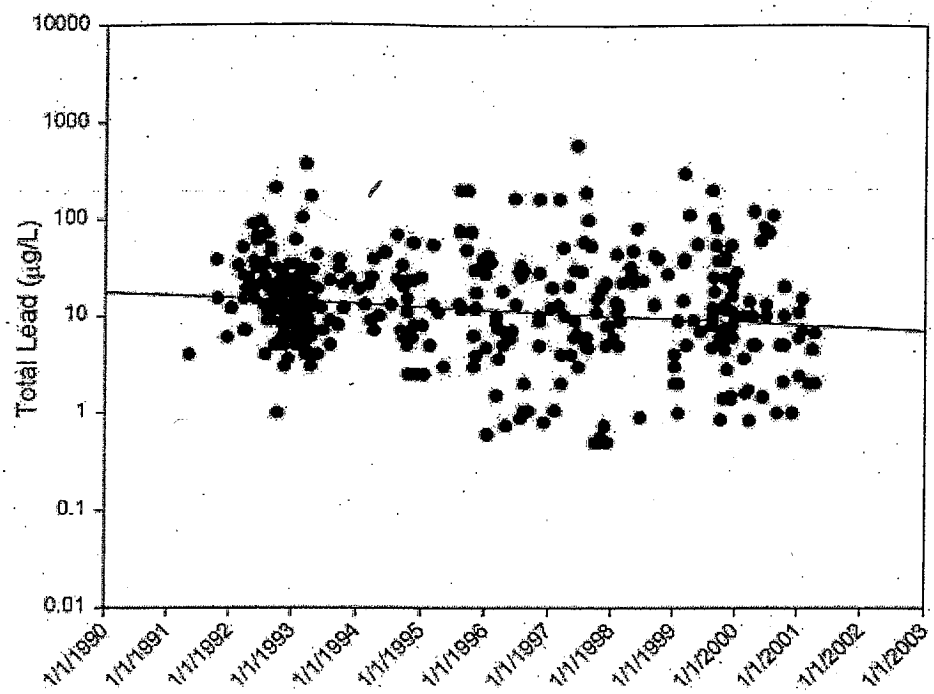

Figure 8. Residential lead concentrations with time.

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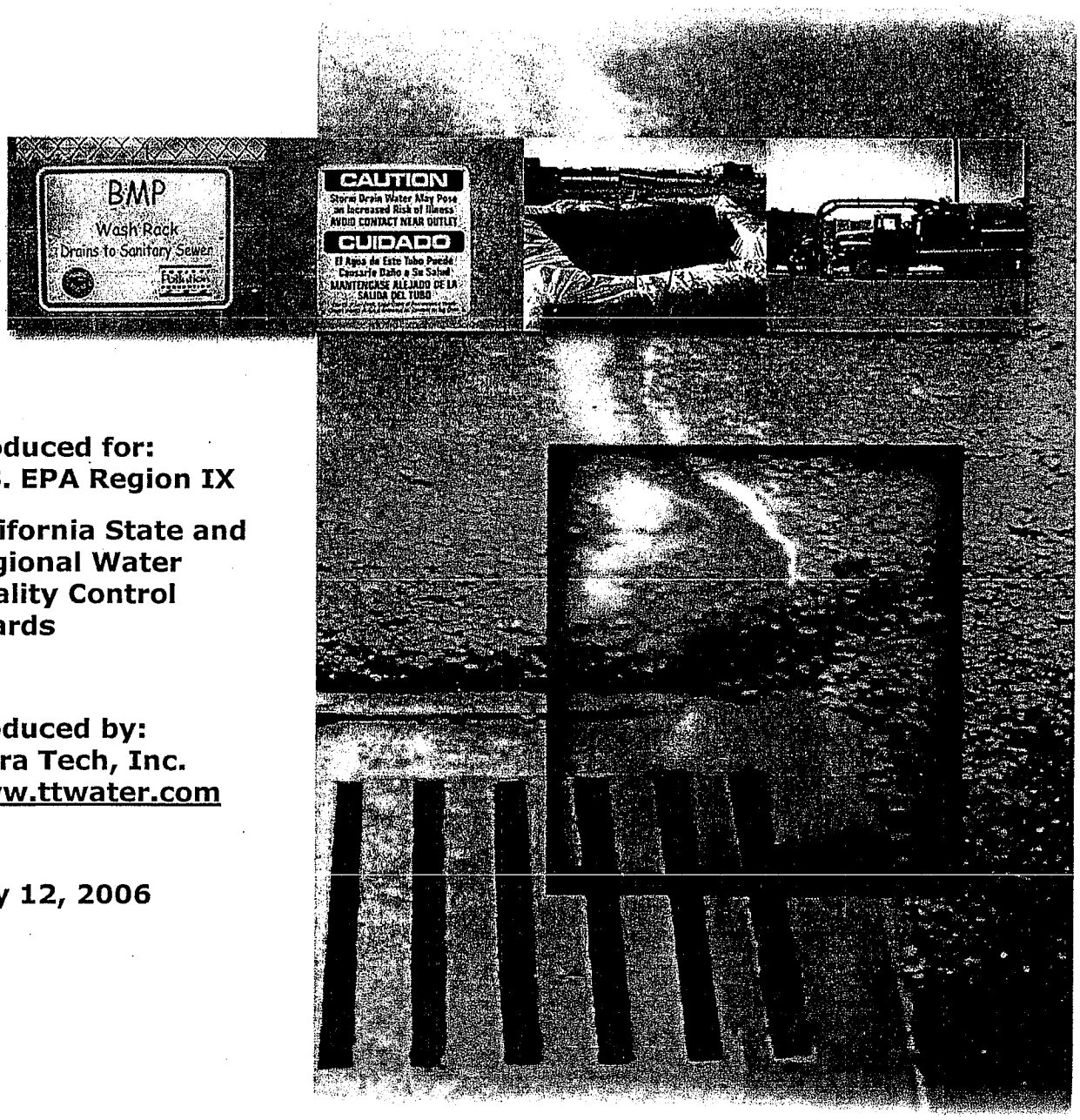
Assessment Report on Tetra Tech's Support of California's MS4 Stormwater Program



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Assessment Report on Tetra Tech's Support of California's MS4 Stormwater Program

Acknowledgments

This report was prepared under US EPA contract number EP-C-05-046, Work Assignment 0-22 and provides an assessment of support Tetra Tech provided to U.S. EPA Region IX and the State of California from July 2001 to July 2006 under several different contracts. The lead author of this report was John Kosco with support from Martina Keefe and Christy Williams.

For questions about this assessment report, please contact John Kosco, Tetra Tech, at John.Kosco@tetratech-ffx.com.

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Appendix A. MS4 Audits Conducted by Tetra Tech in California, July 2001 – July 2006 24

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1.0 Introduction

Tetra Tech, Inc. (Tetra Tech) has supported the California State and Regional Water Quality Control Boards with implementation of the MS4 stormwater program since July 2001 under and EPA Region 9 contract. This support has largely consisted of on-site audits of municipal separate storm sewer system (MS4) programs, along with training and special projects. Tetra Tech has completed 36 MS4 audits in the state that addressed 122 permittees. Special projects have included an evaluation of post-construction development standards, review of a series of stormwater Phase II stormwater management plans (SWMPs), MS4 permit development, and evaluations of stormwater monitoring programs.

Information and data collected during these activities were compiled and disseminated to EPA Region 9, the State Board, and the Regional Water Quality Control Boards through audit reports, progress reports, and presentations to the California Stormwater Quality Association, and telephone conversations with regulatory staff. Prior to this report, Tetra Tech had not performed a holistic analysis of information collected during MS4 audits to identify broader trends, lessons learned, and opportunities for advancing these regulatory programs. This report is intended to do the following:

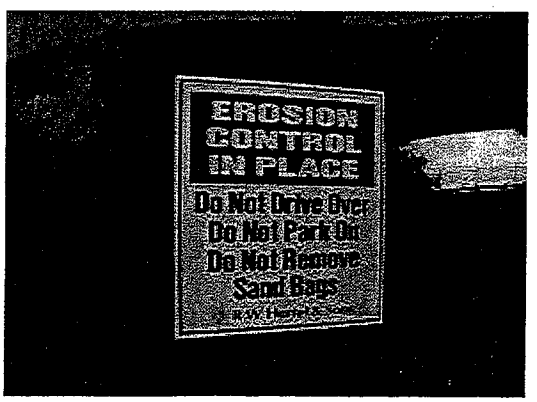
- Describe MS4 audit procedures
- Discuss special projects completed
- Present an analysis of the MS4 audit findings

The focus of this report is on summarizing the work that Tetra Tech has performed to assist EPA Region 9 and California in assessing the compliance status and quality of MS4 stormwater programs throughout the state. The report also includes a discussion of lessons learned from conducting the MS4 audits and provides some brief recommendations for improvements to California's MS4 stormwater program.

EPA Region 9 has placed copies of the MS4 audit reports on their web site at http://www.epa.gov/region9/water/npdes/ms4audits.html. This web site also includes a link to a series of stormwater case studies that describes how MS4s have implemented specific aspects of the stormwater program.

1.1 Purpose and Goals of an MS4 Audit

MS4 audits are conducted to address several goals. These goals, discussed further below, include determination of compliance status, providing assistance with permit issuance or renewal, developing Phase II stormwater management programs (SWMPs), and assessing pollutants of concern and assigning wasteload allocations.



Determining Compliance Status

The principal goal of an audit is usually to assess the compliance status of a permittee with respect to its NPDES MS4 permit and SWMP. Where

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NPDES permits and SWMPs are specific (e.g., inspect construction sites monthly), then determining compliance status is straightforward. When NPDES permits and SWMPs are written more generally (e.g., retrofit flood control BMPs where applicable), then compliance can be more subjective. If previous audits found permittees to be noncompliant, follow-up reviews might be performed to determine whether issues resulting in permit violations areas for program improvement were addressed adequately.

Assisting with Permit Issuance or Renewal

Tetra Tech has performed audits of municipalities in advance of permit renewals to identify areas of the permit that might require further clarification, detail, or refinement. The audits are especially helpful in opening a dialog between permittees and the Regional Water Quality Control Board (Water Board) about the meaning of specific permit language or the intended goal of an individual requirement, for example. On-site program audits also can be helpful after the issuance or renewal of a permit to address implementation questions and clear up potential misunderstandings about the nature and intent of the permit requirements.

Assisting with Phase II SWMP Development

Tetra Tech has performed audits of Phase II MS4 stormwater programs in part as a compliance assistance tool to correct deficiencies in permittees' SWMPs at an early stage of the program. Phase II municipalities are relatively new to the stormwater permitting world and can benefit from the combined knowledge and experience of the auditors, EPA, and Water Board staff, as well as from *lessons learned* from Phase I municipalities who have been implementing the program for more than a decade.

Assessing Pollutants of Concern and Assigning Wasteload Allocations

Where waterbodies have been determined to be impaired for pollutants that are commonly found in urban stormwater, TMDLs are developed and wasteload allocations assigned to dischargers of those pollutants, including MS4 stormwater programs. Therefore, it is helpful to identify and assess the effectiveness of the activities and best management practices (BMPs) of each MS4 stormwater program in the watershed. This assessment can assist the Water Board in assigning wasteload allocations that are appropriate for each stormwater discharger.

1.2 Benefits of an MS4 Audit

In addition to the goals listed above, numerous ancillary benefits are achieved through the audit process, both for the permittee and the Water Board. These include the following benefits:

- Three days discussing the details of the stormwater program foster stronger coordination and improved working relationships between the Water Board and permittees
- In-depth examinations of permit requirements and program elements yield greater understanding by the permittees of expectations and permit requirements
- Audits provide an opportunity to clarify any misunderstandings in the permit requirements or SWMP
- Direct contact with permittee staff yields improved Water Board knowledge of permittees' operations, priorities, constraints, and challenges faced when implementing a municipal stormwater program

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1.3 Roles of Tetra Tech, the Water Board, and EPA

For the past 5 years, Tetra Tech has been assisting the state of California and EPA Region 9 with MS4 stormwater audits. These audits have included large cities, small towns, counties, port authorities, and a California Department of Transportation (Caltrans) district program. Audits covered both Phase I programs and a few Phase II programs, as well as new Phase II programs throughout eight of the Water Board regions. Tetra Tech has enjoyed a strong, effective relationship with Water Board, State Water Quality Control Board, and EPA Region 9 staff.

Typically, Water Board staff members select the programs to be audited; however, Tetra Tech has assisted in making this determination when requested. Once the programs are selected, Water Board staff work with Tetra Tech to determine what type of audit is needed and if any program component focus is necessary. Audit logistics are coordinated with MS4 staff by both Water Board staff and Tetra Tech. Often Water Board staff members participate in the audits as well.

Tetra Tech staff generate audit reports. These reports are subject to rigorous internal Tetra Tech quality assurance protocols before being sent to the Water Board and EPA Region 9 for review and comment. Any requested changes are made, and the reports are then submitted to the Water Board for distribution to the MS4s audited.

2.0 Tetra Tech MS4 Stormwater Audit Approach

2.1 MS4 Audit Preparation

Selecting Permittees

Tetra Tech staff work with Water Board contacts to maximize the value to be gained from each audit. For example, auditing one-fourth to one-half of the permittees covered under a single permit can be very useful in determining the *big picture* of the MS4 program. Of course, an audit of a specific MS4 is sometimes necessary to determine individual compliance with a permit.

Determining Audit Focus

Once the Water Board determines which programs are to be audited, the type of audit must be determined. A component-specific audit focuses on a specific stormwater program area, such as construction activities or new and significant redevelopment. This type of audit is especially helpful if the Water Board has specific concerns about implementation of a particular component (i.e., National Pollution Discharge Elimination System [NPDES] inspections of construction sites

Advance Preparation

- Select permittees
- Identify audit focus
- Organize logistics
- Review documentation
- Hold conference call

To prepare in advance of an audit, Tetra Tech works with RWQCB staff to identify which permittees will be audited and which topics will be covered. Then Tetra Tech organizes logistics with the permittee contacts and obtains and reviews permits, annual reports, SWMPs, and other relevant documents. Tetra Tech then holds a conference call to brief all parties about the purpose and details of the audit and to answer questions about the audit and logistics.

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within the MS4 revealed a high degree of noncompliance with the MS4's construction requirements).

In contrast, a comprehensive audit addresses all the generally accepted primary stormwater program areas (i.e., program management, municipal activities, construction, post-construction, industrial/commercial, illicit discharge detection and elimination, and public education/participation). The intent of a comprehensive audit is to assess the MS4's entire program and possibly identify specific areas or issues that might require a more detailed, component-specific audit in the future.

A third type of audit, which Tetra Tech has not yet performed, is a program compliance screening. This type of audit is composed of a basic interview with the MS4 SWMP coordinator or main contact with the program. A program compliance screening could be an efficient and cost-effective method for getting a basic impression regarding the compliance status of the program. This type of review might be the precursor to an in-depth compliance audit at a later date.

MS4 Audit Logistics

The number of permittees and the type of audit determines the logistics necessary to conduct the audit. Tetra Tech staff typically work with Water Board staff and primary MS4 contacts in setting up the audit dates, developing the schedule, identifying meeting places, and creating the audit teams. Depending on the type of audit and size of the program, one to two auditors are necessary for each permittee being audited. Tetra Tech typically organizes a pre-audit conference call 1 to 2 weeks before the audit and includes the audit teams and all interested contacts at the MS4s. Tetra Tech and the Water Board review the schedule, the audit process is explained, and any questions are answered.

Materials to Review before the Audit

Tetra Tech typically reviews the following information before conducting an on-site audit:

- MS4 permit
- Stormwater Management Plan document
- Latest annual report
- Water Board correspondence with the permittee
- Water Board inspections within the MS4
- Permittee Web sites
- Legal authority (i.e., ordinances, memorandums of understanding)

Conducting the Audit

- Kickoff meeting
- Staff interviews
- Inspector evaluations
- Maintenance yard inspection
- Outbrief

On the first day of the audit, Tetra Tech leads a kickoff meeting, providing an overview of the agenda and facilitating introductions. Tetra Tech then interviews staff regarding specific SWMP activities, accompanies inspectors in the field, and inspects the permittee's primary maintenance yard.

Once the interviews and site visits are complete, Tetra Tech provides a brief overview of the positive program elements and program deficiencies seen during the audit. This allows the permittees to provide feedback and clarification directly and in a timely manner. When multiple permittees are audited during the same week, Tetra Tech holds a joint outbrief so the permittees, Regional Board staff, and EPA staff can hear what the other permittees are doing.

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If this information is not available prior to the audit, Tetra Tech staff members obtain it during the audit for consideration and review using the audit process.

MS4 Program Audit Guidance

For the State Board's Water Training Academy, Tetra Tech developed a 2-day course and training manual on *Conducting Audits of Municipal Storm Water Programs*, June 2004. Tetra Tech uses this manual to prepare for and conduct audits in California. The manual was developed to assist state and EPA NPDES permitting authority staff in assessing the compliance and effectiveness of Phase I and Phase II MS4 programs.

2.2 Conducting the MS4 Audit

Depending on the size of the MS4 area, the scope of the SWMP, and the type of audit to be conducted, Tetra Tech requires a maximum of 3 days for a comprehensive, in-depth office and in-field program audit.

Kickoff Meeting and Audit Overview

Tetra Tech auditors prefer to organize a *kickoff* meeting at the start of the audit. The kickoff is typically held separately with each permittee. An audit overview is given and any remaining questions are asked and answered by all parties. The logistics are reviewed and the audit teams are introduced.

Audit Process

Approximately 2 to 4 hours are necessary for an adequate in-depth office audit of each program component. The office audit consists of interviews with essential staff and a review of applicable documents. For example, when auditing the construction component of an MS4 program, Tetra Tech staff reviews ordinances, plan review checklists, any relevant guidance or BMP specifications used, and 3–5 approved and pending erosion and sediment control site plans.

In addition, 4 hours per component (e.g., construction, industrial/commercial) is necessary to audit inspection staff in the field. Tetra Tech staff accompany MS4 inspectors to determine their understanding of the MS4 permit, ordinances, and required stormwater BMPs.

Outbrief

Tetra Tech staff perform an outbrief at the conclusion of each audit to present a tentative summary of findings from the audit. Tetra Tech staff are careful to caveat all findings as preliminary at that time subject to change on the basis of further review of audit materials, permit or SWMP and consideration by Water Board staff.

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2.3 MS4 Audit Reporting

Documenting MS4 Audit Findings

After the audit is completed, Tetra Tech staff review all notes and supporting information then write a report summarizing all findings. The findings are divided into three categories: (1) permit violations, (2) deficiencies, and (3) positive or commendable program elements. Permit violations are areas where the audit found the permittee not in compliance with a specific permit requirement or SWMP commitment. Use of the qualifier *potential* is used depending on the severity of the violation.

After an MS4 audit report is developed, the Water Board typically distributes the report to the permittee(s) audited with a cover letter summarizing the findings of the audit and any enforcement action being taken or corrections required.

Using Photographs

Tetra Tech staff sometimes use photos to highlight issues on-site that could lend credence to an issue described in the MS4 audit report or to help recall conditions at the sites visited. For example, stormwater problems at a municipal maintenance yard should be documented with photos to provide additional documentation of problems.

After the Audit

- Prepare the report
- Follow up if needed
- Review and comments
- Distribute final report

Once back in the office, Tetra Tech prepares the report, summarizing key findings and providing examples of model programs where appropriate. If needed, Tetra Tech contacts permittee staff to clarify any ambiguities. The report is then submitted to the RWQCB and EPA for review and comment. A final version is then sent via the RWQCB to the permittees.

3.0 Special Projects

Tetra Tech has conducted a number of special projects for the Water Boards that do not fit in with a typical MS4 audit. A summary of these projects is provided below.

3.1 Los Angeles Construction Inspections

For the Los Angeles Water Board, Tetra Tech conducted a series of 31 NPDES compliance inspections at construction sites primarily in Santa Clarita and Simi Valley. Over half the construction sites were residential development projects, with the average site size approximately 10 acres. Tetra Tech inspectors reviewed the stormwater pollution prevention plans (SWPPPs), inspected BMPs on-site, and documented their inspection findings in an inspection report and photo log.

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3.2 Review of Post-Construction Development Standards Implementation

To assist the associated Water Board, Tetra Tech conducted audits to determine the implementation of post-construction development standards in three different permit geographic areas—Los Angeles Region (CAS004001, Board Order No. 01–182), Ventura County Region (CAS004002, Board Order No. 00–108), and the San Diego Region (CAS0108758). The primary goal of each audit was to determine the status of each permittee's implementation of the post-construction controls permit requirements. Secondary goals included collecting program implementation information that could be used by the Water Board to compile a model or *recommended* post-construction program and verifying the plan review process itself, collecting information for permit reissuance, and providing assistance to the permittees in implementation of the post-construction requirements. Each permittee was assessed regarding overall success in meeting post-construction conditions and requirements contained within each permit, with a focus on how each permittee reviewed, approved, and implemented the requirements for individual development projects.

The Los Angeles report summarized the findings from the four permittees audited, described the type of development planning program (or post-construction program) recommended by the Water Board, and described recommendations for conducting future SUSMP program reviews. The Water Board used this report to describe to the other 80+ MS4 permittees in the Los Angeles program not audited what type of development planning program they should implement.

3.3 Review of Phase II SWMPs

In June 2005 Tetra Tech audited two Phase II MS4 SWMPs—the cities of Napa and Petaluma. Each SWMP was audited for compliance with permit conditions and implementation of the six minimum measures:

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

The goals of the audit were to review the overall effectiveness of the program, identify and document positive elements of the program that could benefit other Phase I and Phase II municipalities, and identify program areas for further review by the Water Board.

Each audit took approximately 2 days and resulted in a report of findings that was divided into program deficiencies with recommendations and positive attributes.

Tetra Tech also reviewed approximately 14 city/county stormwater Phase II SWMPs, and over 50 school district stormwater Phase II SWMPs.

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3.4 City of Salinas Phase I MS4 Permit Development

In September of 2003 Tetra Tech developed a draft permit and fact sheet for the city of Salinas to regulate stormwater discharges from the MS4. The draft permit package was written in conjunction with the Central Coast Water Board. The permit and fact sheet included the following 10 components:

- Development of a stormwater management plan
- Development of an annual work plan
- Determination of legal authority
- Construction site management
- Development standards
- Commercial/Industrial facilities
- Municipal maintenance
- Illicit discharge detection and elimination
- Public education and participation
- Assessment of program effectiveness

To facilitate developing the permit and fact sheet, Tetra Tech performed an audit of the city of Salinas to identify program areas that required more detailed requirements and direction.

3.5 Stormwater Monitoring Program Evaluations

Tetra Tech has evaluated the monitoring programs of two MS4 programs in California—the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and San Diego County. Tetra Tech supported the California Water Boards (San Francisco and San Diego) in their assessment of permit-required monitoring activities, reporting, and continuity in the long-term monitoring plan for these two MS4 programs.

The SCVURPPP assessment and evaluation included detailed review of monitoring plans and reports for consistency and compliance with permit requirements and continuing initiatives, as well as for responsiveness to specific requests and requirements of the Water Board. The purposes of this evaluation were to evaluate the overall monitoring program components and their respective contributions toward satisfying the requirements of the permit (CAS029718 and Board Order No. 01–024 and 01–119) and to evaluate the current implementation status of the multiyear monitoring plan with respect to the overall purposes of the monitoring program: to characterize drainage areas and stormwater discharges; assess existing or potential adverse impacts on beneficial uses; identify potential pollutant sources; and collect data that will assist in the evaluation of the effectiveness of the overall stormwater pollution prevention program. Other goals of this evaluation included reviewing the overall effectiveness of the monitoring program relative to the permit goals and requirements, identifying strengths of the program that could benefit other Phase I and Phase II municipalities, and identifying weaknesses in the program that might prevent satisfaction of permit requirements.

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The San Diego monitoring program evaluation was conducted differently in that the following two specific requests were presented to the evaluation audit team:

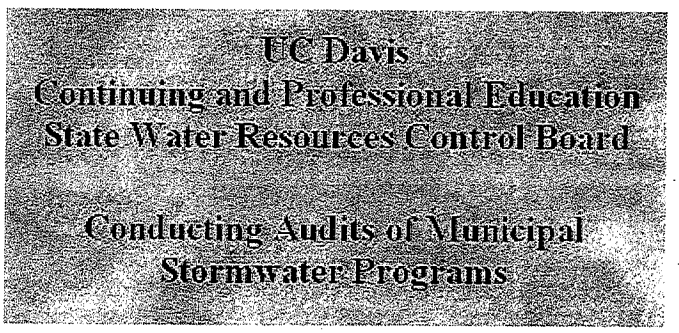
1. Review the existing monitoring program and proposed changes for comparison with the recommendations included in the Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California (Model Monitoring Program, or MMP)

2. If appropriate, identify a suite of recommendations that could improve the proposed monitoring program but were not specifically included in the proposed changes

A report was generated to address these requests and was organized into four sections: (1) brief overview of the MMP, (2) brief overview of the current monitoring program and proposed changes, (3) broad recommendations for the San Diego monitoring program, and (4) detailed analysis of current and proposed monitoring program adherence to the MMP.

3.6 Stormwater Training

Tetra Tech developed three 2-day stormwater training courses for state water quality staff as part of the State Water Training Academy. The courses were intended to instruct the staff on all aspects related to managing, reviewing, auditing and issuing municipal stormwater permits. These courses were developed and taught in the first half of 2004 and covered the following topics:



- Reviewing Stormwater Management Plans
- Conducting Audits of Municipal Stormwater Programs
- Municipal Stormwater Permit Writer's Course

Each course was presented by two Tetra Tech stormwater experts, and consisted of a series of modules covering specific program topics, examples, and photographs. Exercises were also included, and ample discussion time was allotted for attendees. In addition to development of the course materials, Tetra Tech also developed an *MS4 Audit Guide* as a reference for the municipal audit course.

4.0 MS4 Audit Analysis

Tetra Tech has audited 84 different MS4 permittees during the past 5 years. These permittees are covered by 23 different permits from eight of the nine Regional Water Boards and one statewide permit issue by the State Board. Most audits were program-wide audits, but some assessed only certain program components. Tetra Tech performed stormwater audits of small municipalities (e.g., Walnut Grove) and of very large urban areas such as Orange County. Several nontraditional MS4s have also been audited such as Caltrans District 5 and the Sonoma County Water Agency.

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Table 1: Summary of Phase I MS4 audits performed by Tetra Tech

Permit no.	Permit name or sole permittee	Water Board	Co-permittees	Co-permittees audited[1]	Program components audited						
					Program management	Municipal activities	Construction	Post-construction	IDDE	Public education participation	Industrial/ commercial
CAS004003	Long Beach	Los Angeles	1	1	●		●	●	●	●	
CAS0029831	Alameda Countywide	San Francisco	17	5	●				●		●
CAS004002	Ventura Countywide	Los Angeles	12	5	●	●	●	●	●	●	●
CA0025038	Santa Rosa	North Coast	3	3	◘	●	●	●	●	●	●
CAS0082597	Sacramento Area	Central Valley	4	4	◘	●	●	●	●	●	●
CAS108758	San Diego Area (County)	San Diego	20	19	●	●	●	●	●	●	●
CAG616001	Lake Tahoe Hydrologic Unit	Lahontan	3	3		●	●	●	●	●	●
CAS0029921	San Mateo Area	San Francisco	21	6	●	●	●	●	●	●	●
Order No. 99-06-DWQ	Caltrans, District 5	Central Coast	1	1	●	●	●			●	
CAS0108758	City of San Diego	San Diego	20	1	●	●	●	●	●	●	●
CA00883399	Bakersfield/Kern County	Central Valley	2	2	●	●	●	●	●	●	●
CAS083470	City of Stockton/ Joaquin County	Central Valley	2	2	●	●	●	●	●	●	●
CA0029912	Contra Costa Clean Water Program	San Francisco	18	7	◘	†	†	†	†		†
CAS0108740	Orange County	San Diego	13	8	●	●	●	●	●	●	●
CA0049981	City of Salinas	Central Coast	1	1	●	●	●	●	●	●	●
CAS029718	Santa Clara	San Francisco	15	2	●	●	●		●		●
CAS083526	City of Modesto	Central Valley	1	1	◘	●	●	●	●		●
CAS6188033	Riverside Area	Santa Ana	14	3	●	●	●	●	●	●	●
CAS618036	San Bernardino	Santa Ana	16	3	●	●	●	●	●	●	●
CA0083313	Contra Costa Clean Water Program	Central Valley	5	3	●	●	●	●	†	†	
CA0083800	Fresno Metropolitan	Central Valley	5	3	●	●	●	●	●	●	●
CAS082597	City of Elk Grove	Central Valley	1	1	●	●	●	●			●

◘ Includes an evaluation of the water quality monitoring program
† Components not audited for each co-permittee
[1] Includes all co-permittees audited by Tetra Tech to date, possibly during multiple audits

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4.1 Summary of Positive Findings

In summary, many permittees have found unique and notable ways to implement aspects of their stormwater programs. Even small programs have invested creativity, staff time, and capital into building strong procedures and practices. Some of the key positive elements to highlight include

- Effectively using technology to organize data and schedule day-to-day activities
- Involving multiple stakeholders in stormwater decision making (e.g., interdepartmental, elected officials, members of the public) using stormwater committees
- Developing concise, transparent, enforcement escalation procedures to address stormwater-related violations
- Focusing BMPs and activities to address pollutants of concern that are specific to local water quality problems
- Allocating staff efficiently, either by training staff from other departments to address stormwater concerns as part of their work or by dedicating one or more positions solely to stormwater compliance
- Actively tracking and assessing progress using measurable goals and performance standards

The following are 10 positive findings that have recurred in multiple audit reports. They are not ranked because they had nearly the same frequency of incidence.

Using GIS to track the location of projects, priority facilities, inspections, and illicit discharges

Many permittees are using a geographic information system to geo-locate potential and actual sources of illicit discharges, which allows staff to target resources and educational efforts most effectively.

Using well-organized (often electronic) methods to track and document inspection and enforcement activities

Effective tracking and documentation is not only crucial to developing the annual reports, but is absolutely necessary to effectively follow up on noncompliance activities. Reinspections must be conducted in a timely manner, and enforcement actions must be issued according to an established timeline. These activities are best tracked using a database or time management software. Some MS4s are able to effectively track these activities using hard copy files, but an electronic system typically works best to remind staff of important deadlines. In addition, very effective tracking systems allow staff to geo-locate noncompliant sites using addresses or GIS.

Performing routine dry-weather inspections of outfalls

All permits issued in California do not require that permittees conduct dry-weather inspections; however, the Tetra Tech audit teams feel that they are a valuable illicit discharge detection tool. The appropriate location and necessary frequency of the inspections vary among permittees on the basis of land uses, size of the MS4, *hotspots* for illicit dischargers, or other factors.

Implementing exemplary public education programs

Permittees are required to educate the general public about stormwater issues; however, several MS4s that were audited had implemented exceptional educational efforts. The audit teams

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especially recognize those that are based on pollutants of concern, behaviors of concern, are assessed regularly for effectiveness, and carefully consider the method of delivery according to the desired audience.

Using enforcement response plans to respond to illicit discharge reports

Permittees are typically required to *eliminate illicit discharges*, however, few develop an approved enforcement response plan (ERP) to consistently deal with discharge cases. It is critical that permittees have a documented protocol for the receipt of reports, investigation and follow up, and the issuance of enforcement actions. Some MS4s modify existing ERPs, such as those developed for pretreatment violations or code enforcement.

Using stormwater committees to manage various aspects of the stormwater program

This finding describes committees that are composed of representatives from each of the co-permittees or of staff members from various applicable departments within the same MS4. Regardless of whether the permit covers multiple permittees, managing an MS4 stormwater program generally requires the cooperation of many different departments or agencies. Even in small MS4s, the stormwater coordinator will typically communicate with other departments or contractors to implement various programs. A central committee or task force helps to encourage ownership in the program by various departments, facilitate the necessary reporting, assist in the education of the necessary staff people, and establish a responsible party or contact person from each affected department or agency.

Dedicating staff members solely to inspect construction sites or industrial facilities for stormwater compliance

While it is often impossible for some MS4s to dedicate an inspector to stormwater issues, some MS4s have budgeted for this level of staffing. Typically, having staff dedicated to stormwater issues increases the frequency of project and facility inspections, improves the level of follow up for noncompliance, and improves facility compliance because of the heightened level of technical assistance and oversight provided by the inspector.

Targeting stormwater resources and activities to address pollutants of concern

Most MS4s have limited resources to dedicate to stormwater programs; therefore it is critical that funding and staff time are targeted appropriately. The audit team commends MS4 stormwater managers for proactively implementing programs that address specific pollutants of concern (i.e., 303(d) listed pollutants) and the associated behaviors of concern such as how the public handles pet waste. While general stormwater awareness is important (i.e., stormwater is not treated), to make real progress toward measurable stormwater goals, it is important to focus resources on the most important water quality issues.

Using measurable goals or other performance standards to assess the effectiveness of the program and compliance with the permit

All Phase I MS4 programs are required to assess the effectiveness of the SWMP components; however, many permits in California do not specify that official measurable goals be developed and assessed as is required of Phase II MS4s. Some permittees audited, however, have established stormwater management plans with appropriate goals or standards and regularly assess progress toward meeting those goals. These types of goals are essential in assessing the effectiveness of individual program components and the program in general. Being able to

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quantify progress is important not only to the permitting authority, but to the permittee itself to justify budget requests, staffing requirements, and the like.

Using inspectors from other departments to monitor compliance with construction and industrial/commercial stormwater requirements

Often, inspectors from various departments or agencies within an MS4 will visit a construction site or industrial/commercial facility for different reasons. For example, a restaurant will be regularly inspected by the health department for food-related requirements and a pretreatment inspector will inspect the grease trap in the kitchen to determine compliance with source control regulations designed to protect the wastewater treatment plant. It is important that these inspectors be educated about stormwater issues to act as additional *eyes and ears* for the stormwater program during their regular inspections. Or if the MS4 does not have dedicated stormwater inspectors, these existing staff could be used to monitor stormwater compliance at the industrial/commercial facilities they regulate or at additional facilities as necessary. The same concept applies to the various inspectors that visit a site during active construction. Some MS4 programs train grading, right-of-way, electrical, plumbing, or other inspectors in basic erosion and sediment control principals to ensure that stormwater issues are being monitored during all phases of construction.

4.2 Innovative Approaches

Tetra Tech has observed a number of MS4 programs using new or innovative approaches to stormwater management. A few of these innovative approaches are summarized below.

Measuring the Effectiveness of Stormwater Programs

Many stormwater Phase I permittees analyze water quality samples and report the data, but are unable to determine whether their stormwater program is effective in protecting and improving water quality. In order to address the question of how effective MS4 programs are, the San Diego co-permittees formed a program effectiveness assessment workgroup to develop a regional approach to assessing the long-term effectiveness of municipal stormwater programs in San Diego County. The workgroup developed a *Framework for Assessing the Effectiveness of Jurisdictional Urban Runoff Management Programs* (the *Framework*), and a *Baseline Long-Term Effectiveness Assessment*. Both of these documents are available at http://www.projectcleanwater.org/html/wg_assessment.html. The workgroup is also coordinating closely with the California Stormwater Quality Association (CASQA) as it addresses effectiveness assessment on a statewide level.

The *Framework* describes six levels of targeted outcomes that municipalities can use to measure their efforts (illustrated below). The higher levels provide a more direct link to water quality improvements, but are much harder to measure. Municipalities must develop a plan that takes into account all levels of targeted outcomes in order to measure and quantify progress. San Diego's effectiveness assessment reports are a large step forward as municipal stormwater programs attempt to demonstrate how their activities protect water quality.

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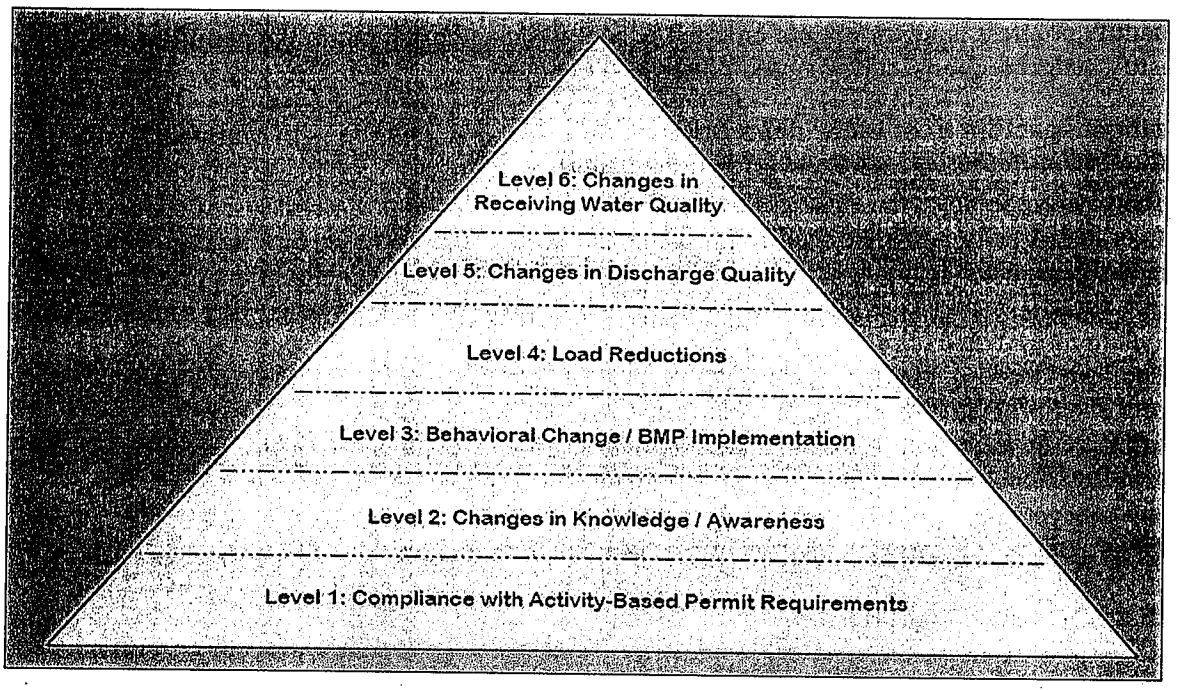
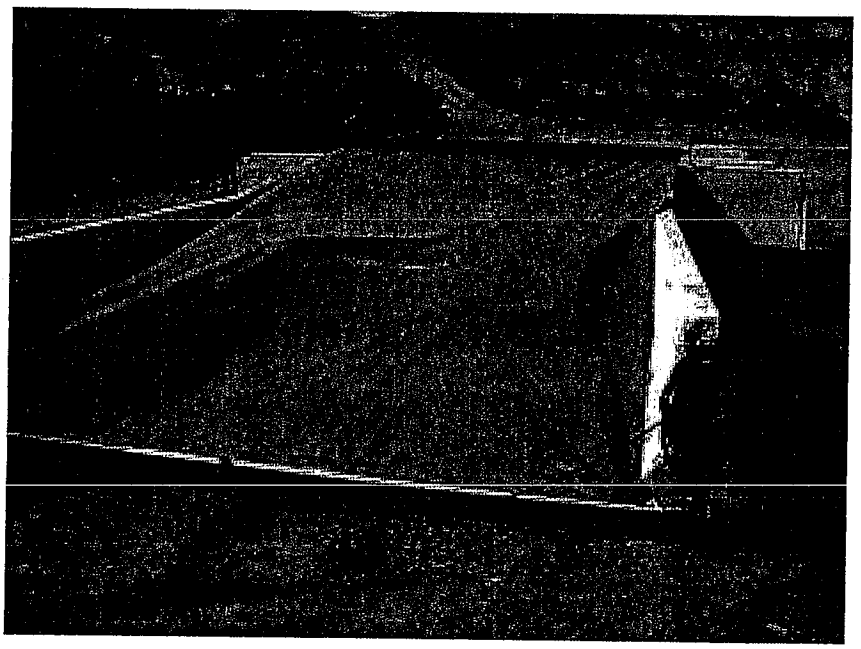


Corporation Yard BMPs

Not every innovation needs to be complicated or expensive. A county in southern California needed to cover a stockpile at their maintenance yard. They found that maintenance staff were not replacing the tarp used to cover the stockpile, so a maintenance supervisor came up with a solution to use a roll-on cover that is typically used on large trucks. Now, maintenance staff can quickly and easily access the stockpile and replace the cover.



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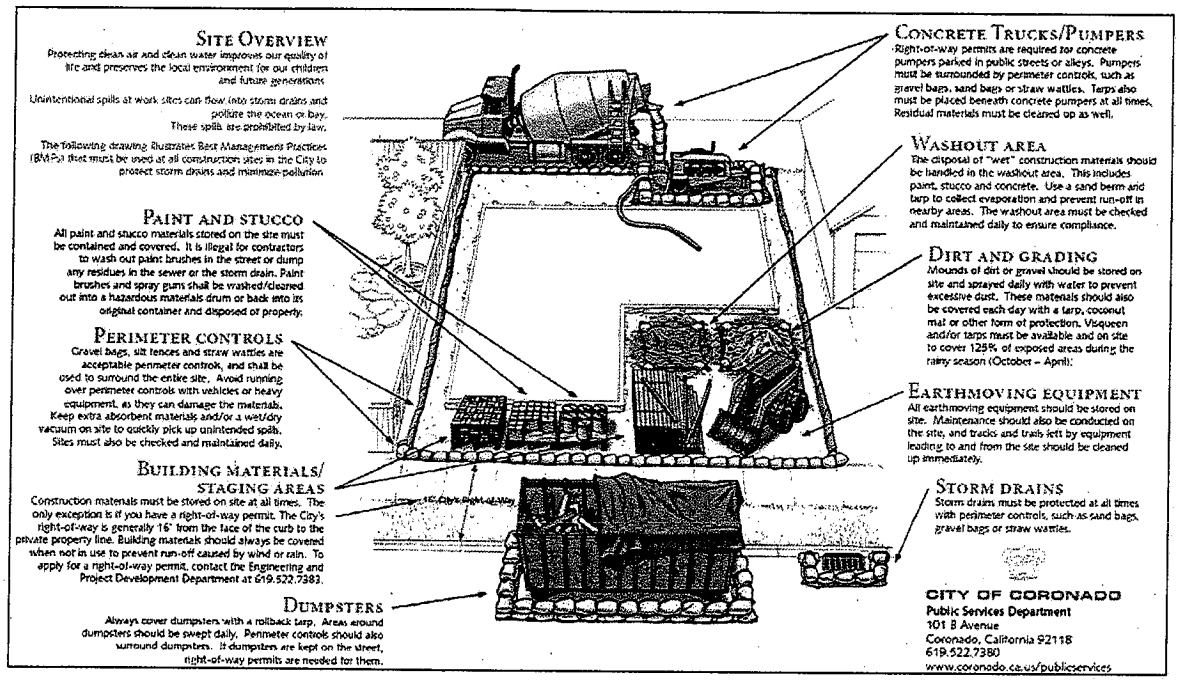
Education/Outreach for Construction Operators

Providing clear outreach to construction operators is necessary to ensure they are aware of the local stormwater requirements and what the MS4 expects of them. The City of Coronado developed a simple and graphic brochure was developed for construction site operator. The brochure illustrates the typical construction project within the city and shows what type of BMPs should be installed and where. This gives the operator a clear idea of what the City expects to see at the site in an easy to use format.



4.3 Summary of Program Deficiencies

For the purposes of this report, program deficiencies, potential permit violations, and permit violations all are considered *deficiencies*. Each Regional Water Board determines which, if any, audit finding constitutes a permit violation; therefore, it is too subjective a term to be categorized in this document. The deficiencies noted have been summarized and ranked according to incidence in the reports reviewed, as summarized in Figure 1.

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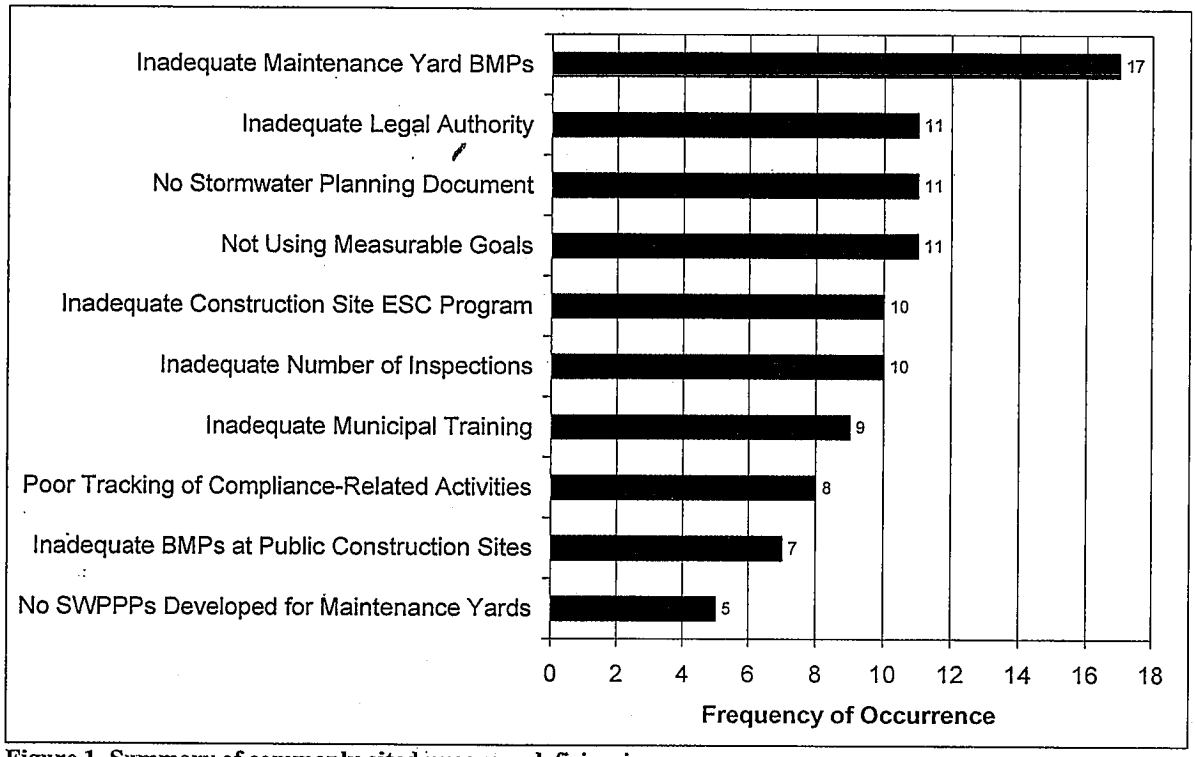


Figure 1. Summary of commonly cited program deficiencies.

Inadequate maintenance yard BMPs

By far the most prevalent program deficiency noted during the audits (17 instances) was the lack of appropriate BMPs at municipally owned and operated facilities, such as corporation or transportation yards. Problems included unprotected storm drains, lack of containment for potentially polluting materials, lack of spill-control measures, and generally poor housekeeping. Often evidence was found of spills that had entered storm drains.

No SWPPPs developed for maintenance yards

Many of the audited permittees had not developed SWPPPs for their corporation yards (5 instances). Typically, these facilities include auto maintenance shops, chemical storage areas, truck-washing facilities, refueling stations, and other facilities and activities that can pose a threat to water quality. Therefore, a plan should be in place that identifies potentially polluting locations and activities, specifies BMPs for each, and outlines spill control and response measures. The SWPPP or similar document should be in place even if the facility is not required to have permit coverage under the industrial stormwater general permit.

A014399

No stormwater planning document

Tetra Tech found that several permittees (11 instances) had not developed a stormwater management plan (SWMP) or other document that describes the different activities of the program and includes standard operating procedures and other details. Without a master planning document that lays out current program activities and future goals, it will be difficult for permittees to progress the program in a focused manner. This document also provides a detailed description of the program that state regulators can use to assess compliance, especially if the SWMP is a *living document* that is updated with new program elements and procedures.

Not using measurable goals

One important element that is commonly described in the SWMP but was often lacking in programs audited in California was a clear method for evaluating program effectiveness (11 instances). In many cases, permittees implement their programs and individual BMPs without developing measurable goals, monitoring programs, or other methods to track progress over time. One of the ways in which permittees can show progress is to demonstrate effectiveness, for example, that increased frequency of inspection yielded fewer violations or that field screening results showed fewer *hits* for bacteria the year after a focused effort to eliminate improper connections to the storm drain. Without these measures, permittees cannot know whether their activities are having a positive effect on stormwater quality, nor can they gauge which activities provide the most benefit.

Permittees can also measure program progress by comparing a current year's activities to past years' activities. Tracking and evaluating program data can provide insights into where improvements have been and still need to be made. For example, if after 5 years of program implementation there has been no change in the number or type of violations found at construction sites, a new approach might be needed that focuses on education or that includes increased penalties for noncompliance. If, on the other hand, repeated inspections at a sector of commercial businesses never or rarely yield a violation, the permittee might consider using those resources to target a different business type that is more likely to contribute to stormwater pollution.

Inadequate legal authority

Another common finding (11 instances) is that permittees lack adequate legal authority to implement one or more elements of their program. This could have resulted from a number of factors, including

- Lack of political support from elected officials
- Inability of inspectors to obtain code enforcement capabilities
- Lack of an ordinance that prohibits nonstormwater discharges to the MS4
- The permittee is a nontraditional institution that does not have enforcement authority

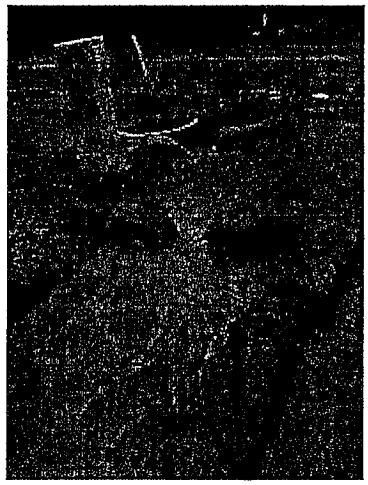
Because there are several different causes for this lack of legal authority, each instance would need to be addressed on a case-by-case basis in the context of the permittee's municipal structure, organization, and unique constraints.

A014400

Inadequate number of inspections

Many permittees were lax in performing inspections and enforcing their stormwater ordinance (10 instances). These permittees had no or few inspectors dedicated to addressing stormwater concerns, and they did not train inspectors in other departments, such as pretreatment, fire safety, or health department inspectors, to look for stormwater violations.

Inadequate construction site erosion and sediment control program



In some cases (10 instances), inspectors were performing inspections inadequately, using *drive by* inspection techniques that would not identify problems with individual BMPs, whether they be design flaws or poor maintenance. As a result, sites can be *in compliance* even though water quality is not being protected adequately. Better training and more careful oversight of inspectors can help to remedy this quality control situation. It is also important that permittees with multiple inspectors foster consistency in terms of inspection protocols, level of stringency, and types of BMPs that are acceptable. Permittees can team inspectors together from time to time to share knowledge and advice, develop a standardized checklist for all inspectors to use, or develop a BMP standards manual that clearly outlines a permittee's expectations for its inspectors and construction sites.

In addition, several programs had inspectors who were knowledgeable and thorough in their inspection technique but were unable to bring facilities into compliance because they lacked adequate authority to levy fines and other sanctions (see "Inadequate Legal Authority" above).

Inadequate BMPs at public construction sites

Many permittees had separate approval and oversight procedures for private construction projects when compared to procedures for public capital improvement projects. In several cases, this division has led to lax implementation of BMPs at publicly owned construction sites (7 instances). Permittees should hold their own project proponents and contractors to the same standards as private construction operators and developers, not only to maintain compliance with the permit and avoid illicit discharges from public construction sites, but also to set a good example for the regulated community.

Inadequate municipal training

Lack of training for municipal personnel was another common finding (9 instances). Many times when street or parks maintenance crews were observed working in the field, BMPs were either inadequate or absent, and storm drains were unprotected. Permittees either do not offer training to field crews or only provide minimal training that is not reinforced regularly. Stormwater-related training should be offered to all staff involved with spill response, those handling materials that could enter storm drains, and street crews who can spot spills or illicit discharges while they go about their daily routine in the permit area.

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Poor tracking of compliance-related activities

Some permittees fail to track their compliance-related activities (8 instances) and, therefore, are unable to demonstrate that such activities were performed, nor can they document the compliance status of industrial facilities or construction sites. Paperwork might be lacking because it is not part of the permittee's protocols, individual inspectors are lax in filling out paperwork or only partially fill it out, or forms are not filed or entered into a database in such a way as to facilitate data retrieval.

A related problem is that the universe of construction sites or industrial and commercial facilities to be inspected is not updated regularly or systematically. Whether permittees track construction activities on the basis of grading permits issued or requests for engineering inspections or other methods, a list of active sites should be maintained at all times. The same is true for industrial and commercial facilities to be inspected—business licenses can be tracked, windshield surveys of commercial areas can be performed, and so on. Having these site and facility inventories allow inspectors to know where to go and how to schedule inspections and budget their time. It also allows permittees to track progress toward achieving one or more measurable goals in terms of the number or percentage of total sites inspected each year.

5.0 Lessons Learned

Over the past 5 years, a number of patterns have emerged from discussions with both state regulators and municipal stormwater permittees. The following is a set of *lessons learned* that can offer opportunities to streamline and improve both NPDES permits and local stormwater management programs.

5.1 MS4 Permit Language Greatly Affects SWMP Development and Compliance

Tetra Tech has found that programs with more specific permit requirements generally result in more comprehensive and progressive stormwater management programs. For example, the more specific permit requirements in the Los Angeles or San Diego MS4 permits require permittees to be more specific in how they implement their stormwater program. Programs with more general stormwater permit requirements, where the emphasis is on implementation of a stormwater management plan, generally did not have as comprehensive a stormwater program.

5.2 Need for Clear Guidance and Direction from the Water Boards

Beyond the NPDES permit requirements, many MS4s do not have clear guidance or direction from the Water Boards on how they should implement specific aspects of their stormwater program. Some municipal programs have developed guidance for specific topics, such as the C.3 new development requirements in Contra Costa County, or the SUSMP requirements in Los Angeles.

One example of where the Water Boards provided more specific direction on an MS4 program area is the November 2003 Development Planning Program Review Report for Los Angeles developed by Tetra Tech and the LA Water Board. The report included a section on a "development planning program recommended by the Water Board." MS4s were told to consider the recommended program as they implement their new development and SUSMP programs.

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Providing this additional guidance is particularly effective in areas such as the LA Board where there are too many permittees for the Water Board to audit on a regular basis.

5.3 Communication Provides Many Benefits

Tetra Tech audit staff believe that almost all municipal stormwater programs want to be in compliance and implement effective programs. However, some municipalities stated they did not receive frequent communication and feedback from their Water Board contacts. The MS4 audits conducted with Water Board participation provide an opportunity for permittees and Water Board staff to spend three days together This often leads to a better understanding of the challenges each face in implementing a stormwater management program and regulating MS4 permit programs.

As an unbiased third party, Tetra Tech can interview staff to clarify program details, while at the same time establish a forum for discussion between the state regulators and permittees. This has been beneficial to the State and to the permittees. Many communities have expressed their appreciation of the feedback that Tetra Tech provides with respect to how their activities measure up to the state's expectations. One city engineer wrote,

> I really appreciate the time you spent with us and the feedback and suggestions you were able to provide. As I am sure you can imagine, from a local program standpoint the term "audit" naturally sparks apprehension and curiosity. I believe we all take this program seriously, but having an objective review for the first time gives us an opportunity to benchmark ourselves against the expectations of the RWQCB and outside experts. I can honestly say that your style and approach to the whole process made it a very enjoyable and enlightening experience. As an auditor it would be easy to be critical and judgmental, but instead you use your experience and insight to be helpful and constructive. I can't tell you how welcome that is from our end.

5.4 A Well-Written SWMP Plan is Critical for Compliance

MS4s without a document or plan describing stormwater management program components, implementation mechanisms and responsible parties are more apt to be disjointed, disorganized, and vulnerable to noncompliance, especially if staff turnover is high. Permits should include a requirement that a single planning document or a series of component-specific documents be developed that describe implementation procedures, BMPs, schedules, responsibilities, and goals. This SWMP Plan would also allow state regulators to assess a permittee's procedures through document review in lieu of, or in addition to, site visits.

5.5 Measurable Goals Should Be Outcome-Based

Permittees should be required to develop measurable goals based on the desired outcomes of the stormwater program. These goals should be developed on the basis of the pollutant of concern, sources of the pollutant, behaviors associated with the sources, and the indicator most appropriate to demonstrate a change in those behaviors. For example

Pollutant of concern	Sediment
Source	Erosion from construction sites

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Behavior	Construction site operators install and maintain BMPs poorly
Goal	Increase the number of operators who are aware of, understand, and comply with the erosion control regulations and plans
Indicators	(1) percent of contractors in the city who have attended a training (to increase as the program progresses); (2) percent of operators who repeatedly violate regulations (to decrease as the program progresses)

5.6 Annual Reports are not Effective Indicators of Program Compliance

Largely due to the lack of specificity in annual reporting requirements, Tetra Tech has found that the annual reports submitted by Phase I MS4s are not always effective indicators of program compliance. Although annual reports are useful to review before an MS4 audit and should be used to spot compliance "red flags," they are usually inadequate determine compliance by themselves. This is because, without specific reporting requirements, municipalities are reluctant to voluntarily report non-compliance.

6.0 Recommendations for Improvements to California's MS4 Stormwater Program

The following brief recommendations, based on Tetra Tech's past experience in the state, are made to help improve the effectiveness of California's MS4 stormwater program:

6.1 Continue MS4 Audits and Conduct Targeted MS4 Audits of Specific Program Components

Some MS4s have not been audited yet. These MS4s could be prioritized for audits, along with MS4s for which the Water Boards will soon be reissuing their NPDES MS4 permit. In cases where the Water Board staff is familiar with the program, the audit could be brief and cover only what has changed since the last permit issuance.

Additionally, the Water Boards could conduct targeted MS4 audits of specific program areas. Tetra Tech has already conducted targeted MS4 audits of the new development, or SUSMP, programs in Los Angeles, Ventura, and San Diego Counties. Additional targeted MS4 audits could be conducted focusing on the illicit discharge, municipal maintenance, or construction components of a permittee's SWMP. Water Boards could select the MS4s and program components to audit based on watershed specific issues, pollutants of concern, TMDLs, or other factors. In addition to determining compliance, the findings from these targeted MS4 audits can also be used to develop guidance from the Water Board on these program components.

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6.2 Develop Compliance Tools for Regulators and MS4s

A number of compliance tools should be developed to help MS4s implement the program and help Water Board staff ensure compliance. For example, Tetra Tech has developed an *MS4 Audit Guide* for the state and is currently expanding and revising this guide for U.S. EPA. The *MS4 Audit Guide* will help Water Board staff in conducting MS4 audits, but it also helps MS4 programs conduct a self-assessment to ensure they are complying with their permit requirements.

Additional tools could include a BMP selection guide MS4s would need to use to ensure they were in compliance with the MEP standard. The guide would also be used by Water Board staff to evaluate the adequacy and effectiveness of BMP programs and determine compliance with permit requirements. The guide could include:

- Minimum requirements for BMP siting, sizing and design standards, and operation and maintenance specifications,
- Assessment tools, methods to measure effectiveness, an surveillance and monitoring requirements for each BMP that must be implemented by the permittee to demonstrate compliance, and
- Minimum recording and reporting requirements.

6.3 Develop a Consistent Format for MS4 Permit Language

Presently, the State develops permits on a regional basis, and the level of specificity and individual requirements vary widely. Some permits detail individual BMPs that should be implemented for each program area and include guidance on how and to what extent they should be implemented. This specificity can assist the permittees in knowing how best to meet permit requirements and reduces ambiguity. However, this can result in municipalities implementing substantially similar programs but with significantly different details and requirements.

One factor for the state to consider when writing permit language is to be clear enough to set appropriate standards and establish required outcomes, but still allow permittees to be creative and innovate solutions to stormwater management that are appropriate for their situations. The audits of the past 5 years have shown that each permittee approaches implementation from its own unique perspective and with unique attributes and constraints that sometimes facilitate and other times confound implementation. The *one size fits all* mantra does not apply to MS4 stormwater programs because the ways in which they are implemented depend on each permittee's organizational structure, staff availability, and budget, along with legal constraints and more- or less-favorable political climates. Each MS4 may develop and work toward different measurable goals, but still be able to achieve the required outcome.

However, a consistent format to the MS4 permit and the basic requirements in the permit will provide some statewide consistency to the stormwater program and allow programs to share resources more easily. This consistent format will also require MS4s to be on more of a level playing field as they implement their programs.

6.4 Provide Guidance on Annual Reporting

Often annual reports are the only official communication from year to year between the permittee and the state, so it is important that the report be informative and relevant. Many times

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permittees tend to send too much information, and, as a result, state regulators receive huge binders full of hard copy forms and outreach materials that do not provide useful information to assess compliance. Because of the time involved in preparing such large documents, less time could be spent preparing summary information and compiling data that would be useful to assess compliance.

To remedy this, the state could develop a set of guidelines that clearly describe the information they would like included in the report. For example, the following program information is necessary when assessing construction inspection programs:

- Number of active construction sites a permittee needs to inspect
- Number of staff are performing inspections
- Frequency of inspections
- Total number of inspections performed
- Number of violations found and follow-up actions performed

This information allows state regulators to determine if staffing levels are adequate, if inspections are being performed, and if enforcement activities are occurring. Other information, such as a list of "bad actor" operators with violation frequency and other summarized tracking data maintained by the permittee, could be helpful to provide a clearer picture of the permittee's procedures. Submission of materials such as individual forms or notices of violation would be burdensome for both the permittee and the reviewer and should be discouraged in the guidelines. The information included in the annual report should clearly demonstrate progress towards reaching measurable goals, and therefore may vary by permittee.

6.5 Provide Guidance on Developing Measurable Goals

The state should include guidance on how permittees can develop measurable goals and performance standards so they can track their own progress and share this information as part of the annual report. Permittees will need to tailor their measurable goals to their specific pollutant sources, behaviors, activities, and protocols; therefore, the state should provide examples of the types of quantifiable goals they would consider acceptable in different kinds of situations. For example, the state might want to know how effectively the permittee has been advertising household hazardous waste collection events. The permittee could track attendance at the event from year to year and, if their methods are effective, expect to see a steady increase in first-time attendees (10 percent, for example) over time. Permittees have in the past described measurable goals in non-numeric terms, such as "track the number of first-time attendees at events," but it is important that there be a numeric target or rate of change incorporated into each goal. This is particularly important for Phase II MS4s under the general permit.

EPA has issued guidance on developing measurable goals that could be referenced by the Water Boards or serve as the starting point for a new guidance (see http://cfpub.epa.gov/npdes/stormwater/measurablegoals/index.cfm).

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Appendix A. MS4 Audits Conducted by Tetra Tech in California, July 2001 – July 2006

Location	MS4 Audited	Date of Audit
Alameda	Cities of Dublin, Fremont, Hayward, Livermore, and Oakland	November, 2001
American Canyon	City of American Canyon	June, 2005
Bakersfield	City of Bakersfield and Kern County	November, 2002
Caltrans	District 5	July, 2002
Contra Costa	Cities of Antioch, Brentwood, and Oakley	March, 2005
Contra Costa	Cities of Concord, Pinole, Pittsburg, Richmond, and San Pablo	September, 2004
Contra Costa	Cities of Hercules and Pittsburg, Walnut Creek, and Concord, Contra Costa County, and Contra Costa Clean Water Program	May, 2003
Elk Grove	City of Elk Grove	April, 2005
Fresno	Cities of Fresno and Clovis, and the Fresno Metropolitan Flood Control District	January, 2005
Lake Tahoe	City of South Lake Tahoe, El Dorado County and Placer County	June, 2002
Long Beach	City of Long Beach	August, 2001
Los Angeles	LA County and Cities of Glendale, Los Angeles, and Santa Monica. Review of Standard Urban Stormwater Mitigation Plan (SUSMP) requirements.	March, 2003
Los Angeles	Cities of Calabasas, Carson, Glendora, Pomona and Santa Clarita. Review of city's construction program	June, 2004
Modesto	City of Modesto	February, 2004
Napa	City of Napa	June, 2005
Orange County	Cities of Laguna Beach, Laguna Hills, Lake Forest, Rancho Santa Margarita	May, 2005
Orange County	Orange County and Cities of Mission Viejo, San Clemente, and San Juan Capistrano	June, 2003
Petaluma	City of Petaluma	June, 2005
Riverside	Cities of Corona, Moreno Valley and Riverside	May, 2004
Sacramento	County of Sacramento and the Cities of Folsom, Galt, and Sacramento	March, 2002
Salinas	City of Salinas	July, 2003
San Bernardino	Cities of Fontana and Redlands and San Bernardino County	October, 2004
Santa Clara	Cities of Milpitas, Palo Alto, Santa Clara, and Santa Clara County	April, 2005

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Location	MS4 Audited	Date of Audit
Santa Clara	City of San Jose and County of Santa Clara	December, 2003
San Diego	Cities of Carlsbad, Chula Vista, and El Cajon	May, 2002
San Diego	Cities of Encinitas, Lemon Grove, Poway, and Santee	April, 2004
San Diego	Cities of Escondido, National City, Oceanside	February, 2003
San Diego	Cities of Imperial Beach, La Mesa, San Marcos, and Vista	October, 2003
San Diego	City of San Diego, County of San Diego	October, 2002
San Diego SUSMP	Cities of San Diego, Carlsbad, Lemon Grove, Chula Vista, Oceanside, National City, Poway, El Cajon, Escondido and San Diego County. Review of Standard Urban Stormwater Management Plans (SUSMPs)	March, 2005
San Diego	Cities of Solana Beach, Coronado, and Del Mar and Port of San Diego	November, 2004
San Mateo	County of San Mateo and Cities of South San Francisco, Foster City, Pacifica, Redwood City, and San Mateo	August, 2002
Santa Rosa	City of Santa Rosa, Sonoma County, and the Sonoma County Water Agency	March, 2002
Stockton	City of Stockton and San Joaquin County	December, 2002
Ventura	Ventura County Flood Control District and the Cities of Ojai, Oxnard, Santa Paula, and Simi Valley	October, 2001
Ventura SQUIMP	Cities of Fillmore, Moorpark, Port Hueneme, Ojai, Oxnard, Santa Paula, Simi Valley, the County of Ventura, and the Ventura County Watershed Protection District. Review of Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) requirements	August, 2004

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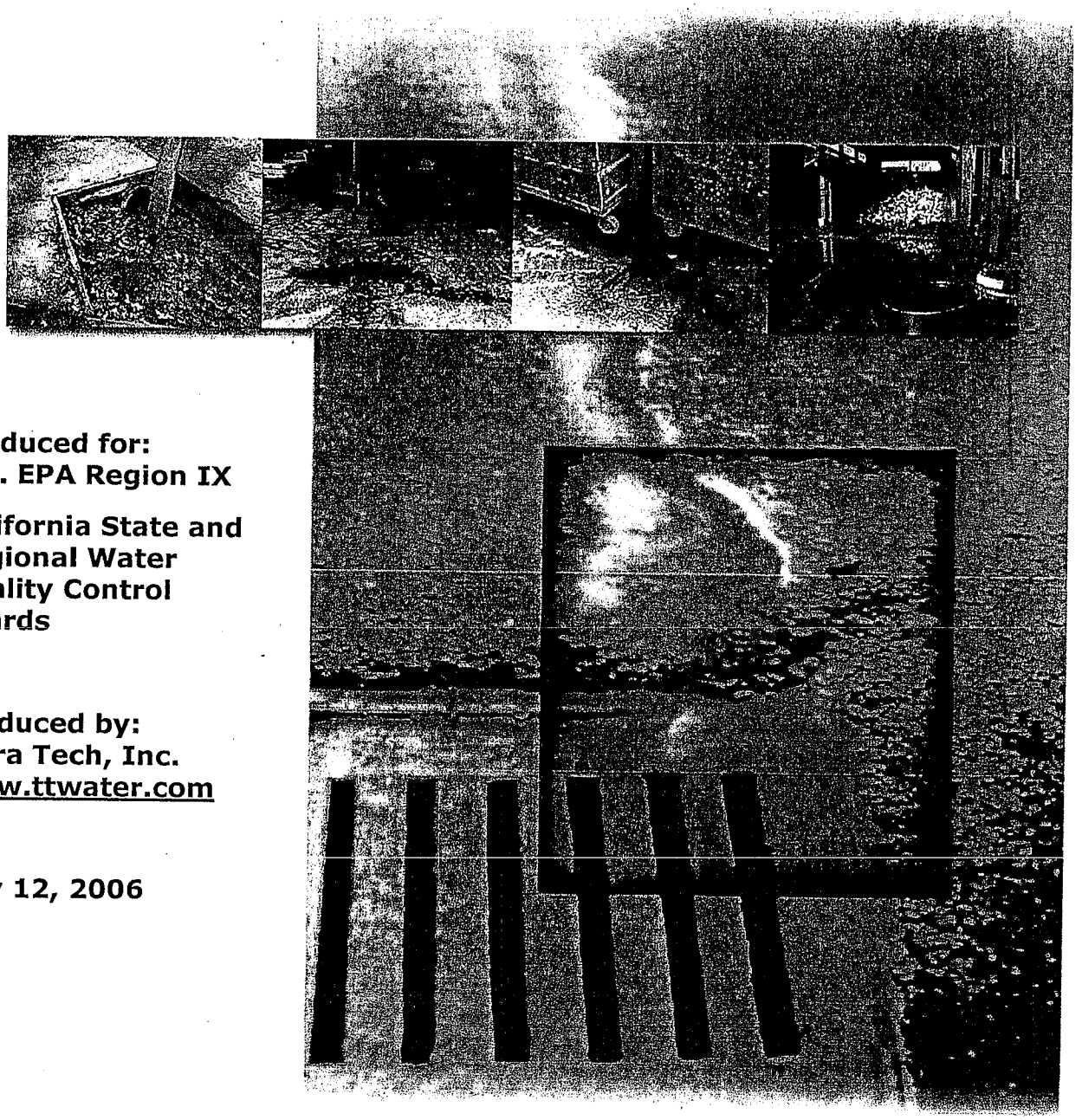
Assessment Report on Tetra Tech's Support of California's Industrial Stormwater Program



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Assessment Report on Tetra Tech's Support of California's Industrial Stormwater Program

Acknowledgments

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1.0 Introduction

Tetra Tech, Inc., (Tetra Tech) has supported the California State and Regional Water Quality Control Boards with implementation of the industrial stormwater program since July 2001 under an EPA Region 9 contract. The support has consisted of industrial stormwater inspections, training, and special projects. Tetra Tech has completed more than 2,000 inspections of industrial facilities covered under the program and provided industrial inspection training to municipal employees of the Los Angeles and San Francisco Regional Water Quality Boards. Special projects in support of the industrial stormwater program have included targeted re-inspections in Los Angeles, non-filer identification in the City of Industry, and an evaluation of stormwater best management practices (BMPs) at truck transportation facilities.

Information and data collected during these activities were compiled and disseminated to EPA Region 9, the State Board, and the Regional Water Quality Control Boards through inspection and audit reports, progress reports, presentations to the California Stormwater Quality Association (CASQA) and StormCon, and telephone conversations with regulatory staff. Prior to this report, Tetra Tech had not performed a holistic analysis of information collected during industrial stormwater inspections to identify broader trends, lessons learned, and opportunities for advancing these regulatory programs. This report is intended to do the following:

- Describe training and inspection procedures
- Describe data collection and analytical tools (i.e., an industrial stormwater inspection database)
- Present discussions of the results of analyses focused on various aspects of the data collected during 4 years of inspections.

The focus of the report is on examining the information currently available from Tetra Tech's industrial stormwater inspection activities in the state of California with an eye toward opportunities to improve stormwater compliance in the state. The report also provides some brief recommendations for improvements to California's industrial stormwater program.

2.0 Tetra Tech Industrial Stormwater Inspection Approach

Tetra Tech was tasked in July 2001 to perform more than 500 industrial stormwater inspections per year for the various California Regional Water Quality Control Boards (Water Boards). The inspections, for the most part, were to occur at industrial facilities that had submitted notices of intent (NOIs) for coverage under the California General Permit for Stormwater Discharges Associated with Industrial Activity (General Permit, or CAS000001).

At the beginning of each state fiscal year (July 1–June 30), each Water Board identified a specific number of inspections to be completed by Tetra Tech. The Water Boards were

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responsible for identifying the total number of inspections, as well as the specific facilities. Tetra Tech was responsible for scheduling and staffing the inspections.

To accomplish the inspections in an organized, efficient, and consistent manner, Tetra Tech established a dedicated industrial stormwater inspection team (industrial team). The industrial team consisted of 10 inspectors (employed by Tetra Tech or Tetra Tech subcontractors) willing to devote 50 percent of their time, or more, to performing industrial inspections between October 1 and April 30 (California's wet weather season) each year.

2.1 Internal Training

Each Tetra Tech inspector goes through a training process consisting of internal training followed by joint inspections with a more experienced inspector prior to conducting solo inspections. The process has been for the entire industrial team to convene in the region of one of the Water Boards for a week of training and joint inspections (kickoff week) at the beginning of each wet weather inspection period. Prior to this week the inspectors are responsible for reviewing the General Permit to re-familiarize themselves with the provisions and identify provisions that are confusing as written or difficult to evaluate in the field.

The first 2 days of the kickoff week are spent in classroom sessions, where the project manager and other experienced inspectors present the overall inspection approach, expectations, and issues specific to General Permit requirements. The classroom sessions provide an opportunity for the inspectors to discuss complicated compliance situations identified during the previous year's inspections and, through group discussions, come to a resolution as to how these items should be addressed in future inspections.

Typical discussion points include

- Establishing a link between stormwater monitoring data and BMP implementation
- Determining what constitutes appropriate BMP implementation
- Discussing stormwater sample collection with facility representatives
- Determining how to evaluate facilities for which required paperwork was prepared but is not at the site on the day of the inspection
- Working with uncooperative facility representatives.
- Reporting perceived issues of noncompliance
- Using the inspection checklist and report-writing tools

In addition to the broader discussions related to compliance determinations, the inspectors are presented with the Tetra Tech inspection approach. Delineating a very specific inspection approach was determined to be critical to ensure that each inspection is conducted in the same manner. A consistent inspection approach has ensured quality control and provided permit holders with a consistent message within and across the individual Water Boards.

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The Tetra Tech inspection approach is as follows:

- Facilities are not notified of the inspection in advance, consistent with EPA and Water Board inspection protocol.
- Upon arrival at the facility, the inspector asks to see the responsible official, produces credentials (EPA Region 9-issued "Contractor" badge), and presents the responsible official with an "inspection notification letter" signed by the Water Board's responsible official.
- The inspector then reviews paperwork required by the General Permit: stormwater pollution prevention plan (SWPPP); stormwater monitoring plan (SWMP); 5 years' worth of annual reports; and 5 years' worth of monitoring data.
- If a photocopier is available, the inspector makes a copy of the facility map and BMP list from the SWPPP.
- The responsible official and the Tetra Tech inspector then tour the facility yard, evaluating implemented BMPs against the SWPPP BMP list.
- The yard inspection occurs even if the responsible official is unable to produce the required paperwork.
- Photos are taken of potential yard violations, one or more general yard views, and the facility sign.
- Following the yard inspection, the inspector conducts an exit interview with the facility representative identifying areas of potential noncompliance. When a SWPPP is available, the exit interview emphasizes the link between the SWPPP BMP list and implemented BMPs,
- The inspector begins the inspection report and photo log on the day of inspection, to be completed no later than 7 days after the inspection.

2.2 Joint Inspections

Following the 2 days of classroom orientation, the inspectors are teamed up for 3 days of industrial inspections. Joint inspections are conducted: one inspector serves as the lead, while the other inspector acts as an evaluator. Over the course of one joint inspection day, each of the two inspectors will lead at least one inspection.

The purpose of joint inspections is site-specific training and quality control. The two inspectors are able to share approaches and provide direct input as to aspects that went well and aspects that could be improved. Participating in inspections with a different set of eyes looking at the same yard also provides an opportunity for inspectors with expertise in different technical areas to share their perspectives and broaden their experience.

The inspectors also prepare inspection reports together, again so that each can benefit from the approaches and expertise of the other. Inspection teams are rotated daily to provide the broadest possible exposure to other team members.

2.3 Solo Inspections

For the remainder of the wet weather season, inspections are conducted solo, with each inspector responsible for organizing his or her inspection week, communicating with the

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Water Boards, and preparing reports. Tetra Tech schedules inspections in weeklong bundles. Each inspection week consists of two or more inspectors working in one Water Board's region. The inspectors perform two to three inspections per day with a minimum obligation of eight inspections per week. The weeklong approach was established because the inspectors are often required to travel to the inspection area and periods of less than 1 week were generally not cost-effective. Periodically the project manager spends a day with each inspector evaluating and refining his or her inspection approach and ensuring consistency among the members of the industrial team.

2.4 Inspectors Training Inspectors

As the inspectors gain experience, they are asked to train other industrial stormwater inspectors. These other inspectors might be Tetra Tech employees, Water Board staff, or municipal inspectors associated with a municipal separate storm sewer system (MS4) permit. To date, Tetra Tech industrial inspectors have provided training to Water Board staff (through informal ride-along inspections) and municipal inspectors from MS4 co-permittees in Los Angeles County, Orange County, and Contra Costa County.

2.5 Calibration with the Water Boards

Each inspection week starts with a kickoff meeting at the Water Board. The purposes of the meeting are to receive feedback from Water Board staff regarding previous inspection reports, to identify particular areas of focus important to the Water Board, and to have Water Board staff provide additional information pertaining to the upcoming inspections. Water Board staff are welcome to participate in any of the scheduled inspections, although the Tetra Tech inspector always leads the inspection.

3.0 Tetra Tech Compliance Reporting Tools

3.1 Inspection Checklist

Tetra Tech developed an industrial inspection checklist in fall 2001. It was compiled from checklists provided by the Santa Ana Regional Water Quality Control Board, the San Diego Regional Water Quality Control Board, and the Los Angeles Regional Water Quality Control Board. The checklist includes questions related to all General Permit provisions (paperwork and BMP implementation), a table for recording stormwater monitoring data (including EPA and Water Board benchmark values), a photo reference sheet, and several pages for notes.

The checklist provides the first-order record of the inspection. The inspectors are required to keep their checklists and all paperwork collected during the inspection should EPA, the Water Boards, or other interested parties request copies in addition to the inspection report.

The checklist also provides a useful summary of the General Permit provisions and can be provided to a facility representative as a summary of what needs to be included in a SWPPP, for example, or what the stormwater monitoring benchmark values are.

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3.2 Electronic Tools

Tetra Tech developed an electronic industrial stormwater inspection-reporting tool in 2001. The tool is based in Microsoft Access and allows inspectors to enter inspection data through a series of check boxes and memo fields; each permit requirement is reflected in the database. The database also contains additional information such as physical location of the facility, receiving water, regional board, pertinent stormwater monitoring data, facility Standard Industrial Classification (SIC) codes, and overall facility ranking as determined during the inspection.

Tetra Tech inspectors have been using this database for all industrial stormwater inspections conducted in California between August 2001 and May 2005 (the most recent month when inspections were conducted). To date, the database contains information on permit compliance from 1,848 General Permit inspections. The only inspections not reflected in the database are the non-filer audits performed in the City of Industry during the winter of 2005 (see Section 5.1).

The Water Boards were provided with a copy of the database, and data, following each round of inspections. EPA Region 9 was provided with a database of all Water Board stormwater inspections at the end of each contract year.

4.0 Quantitative Analysis of Data

The following data analysis and summary statistics are based on information collected during 1,848 California industrial stormwater inspections conducted between August 2001 and May 2005. Tetra Tech was not tasked with conducting industrial stormwater inspections in fiscal year 2005/2006.

Data from each inspection were entered into Tetra Tech's industrial stormwater inspection database. In the database, compliance is denoted by a check mark. The absence of a check mark indicates potential noncompliance[1] and is usually accompanied by a memo discussing the potential noncompliance issue. The database retained the same basic structure across all inspection years; as the process matured, additional fields were added but none were deleted. The data reported below are from fields that were carried forward from the original database constructed in August 2001.

Appendix A presents the same information for each of the five most frequently inspected SIC codes. The following sections refer to the Appendix A data, where appropriate, to highlight different compliance issues in these specific SIC codes.

[1] Tetra Tech inspectors were tasked with identifying all areas of potential General Permit noncompliance. The Water Boards were responsible for determining whether these areas of "potential noncompliance" required follow-up.

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The State Board's industrial stormwater NOI database contains 9,543 active participants. Based on this number, Tetra Tech inspected approximately 19 percent of the regulated community and 45 percent of the 947 auto dismantlers in the State Board's current NOI database.[2]

4.1 SIC Codes Inspected and Number of Facilities Inspected in Each SIC Code

The General Permit requires coverage based on the SIC codes listed in the General Permit, Attachment 1. Tetra Tech inspected industrial facilities representing more than 124 different SIC codes. Table 1 presents the 10 SIC codes inspected most frequently by Tetra Tech inspectors. These 10 codes represent 67 percent of the total number of facilities inspected.

Table 1. Ten SIC Codes Most Frequently Inspected

SIC code	No. of inspected facilities	Percentage of total (1,848 facilities)
5015 - Auto Salvage/Dismantling	433	24%
5093 - Scrap Recycling Facilities	168	9%
42XX - Motor Freight Transportation and Warehousing	163	9%
327X - Concrete, Gypsum, and Plaster Products (Except 3274 Lime)	158	8%
347X – Coating, Engraving, and Allied Services	86	5%
41XX - Local and Highway Passenger Transportation	58	3%
344X - Fabricated Structural Metal Products	46	2%
349X - Miscellaneous Fabricated Metal Products	42	2%
4953 - Hazardous Waste Treatment Storage or Disposal	40	2%
36XX - Electronic and Other Electrical Equipment and Components, Except Computer Equipment	36	2%

Auto dismantlers were the most frequently inspected industry. This stems in part from the fact that auto dismantler stormwater compliance was a high priority for the Los Angeles and Santa Ana Water Boards and in part from the fact that the Los Angeles metropolitan area has the greatest concentration of auto dismantlers in the United States (estimated to be 25 percent of all U.S. auto dismantlers).

Although not specifically reflected in the compliance data, auto dismantlers' stormwater compliance is positively related to the market price of scrap metal, as identified by the presence (or absence) of scrap material stored within these yards. The amount of scrap

[2] California State Water Resources Control Board, Download Statewide Industrial Stormwater Database Active Notice of Intent (NOIs) (July 10, 2006).

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material stored can directly affect the quality of stormwater runoff from the facilities. Tetra Tech started visiting auto dismantlers in 2001 when the price of scrap metal was at a recent low ($77 per ton[3]). Because of the low prices, auto dismantlers were stockpiling scrap metal until the price increased. The price began to climb after 2003 with the growth of the Chinese economy ($318 per ton in 2004[4]), and the stockpiles dwindled as auto dismantlers sold their scrap metal to capitalize on these higher prices.

4.2 Number of Facilities Inspected in Each Water Board by Year

Table 2 presents the number of industrial stormwater inspections performed for each Water Board, by fiscal year (July 1–June 30). The Los Angeles, Central Valley, Santa Ana, and San Francisco Bay Water Boards were Tetra Tech's largest clients. Conversely, Tetra Tech performed only one industrial stormwater inspection for the Central Coast Water Board and none for the Lahontan Water Board's Victorville office. However, Tetra Tech inspected all the regulated facilities for the Lahontan Water Board's South Lake Tahoe office, twice.

Table 2. Number of Industrial Facilities Inspected by Water Board and California Fiscal Year

	California fiscal year			
Water Board	**2001–2002**	**2002–2003**	**2003–2004**	**2004–2005**
North Coast (1)	1	0	33	32
San Francisco Bay (2)	66	43	83	98
Central Coast (3)	1	0	0	0
Los Angeles (4)	336	20	89	57
Central Valley, Sacramento (5s)	0	84	86	50
Central Valley, Redding (5r)	0	53	0	15
Central Valley, Fresno (5f)	0	0	13	20
Lahontan, Victorville (6)	0	0	0	0
Lahontan, South Lake Tahoe (6)	0	25	26	0
Colorado River Basin (7)	0	8	24	16
Santa Ana (8)	222	59	33	58
San Diego (9)	137	0	4	56
Fiscal year total	**763**	**292**	**391**	**402**

Tetra Tech's first year of industrial stormwater inspections, 2001/2002, was also the largest. Tetra Tech inspectors visited 763 facilities that year. The number dropped to 292 in 2002/2003, in part because it was determined that the Water Boards did not have enough staff to efficiently process the Tetra Tech inspection reports.

4.3 Summary Statistics for All Inspections

Summary statistics follow for General Permit paperwork requirements (SWPPP, SWMP, and annual report), field implementation of stormwater BMPs, and stormwater

[3] China's need for metal keeps U.S. scrap dealers scrounging, http://www.nytimes.com/2004/03/13/business/worldbusiness/13SCRA.html?ex=1394514000&en=b6e48c65fecf26b0&ei=5007 (March 13, 2004).
[4] Soaring steel prices keep scrap yards busy, http://www.bizjournals.com/triad/stories/2004/03/29/story4.html?page=2, (March 26, 2004).

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monitoring data. The section concludes with overall rankings for the 1,848 inspected facilities reported in the database.

4.3.1 Compliance with Paperwork Requirements

The General Permit requires facilities to have, and maintain on-site, a SWPPP, a SWMP, historical annual reports, and monitoring data. Annual reports and monitoring data must be retained for a period of 5 years, or from when the NOI was submitted, if less than 5 years. Reviewed SWPPPs and SWMPs ranged from professional documents prepared by consultants to handwritten outlines. The professionally prepared documents were not necessarily better than the handwritten or operator-produced versions.

4.3.1.1 SWPPP Compliance

Seventy-four percent of inspected facilities produced a document identified as a SWPPP (Table 3). The other 26 percent had not produced a SWPPP or claimed that it was located at an off-site location or was at the consultant's office being updated. Percentages reported in Table 3 are based on the number of facilities that produced a SWPPP (1,360 facilities). Less than half of the SWPPPs produced for Tetra Tech inspectors met all General Permit requirements.

Table 3. Compliance with General Permit SWPPP Requirements

Overall General Permit requirement	Facilities in compliance	Percentage of inspected facilities (n=1,848)
A SWPPP was developed and implemented (A.1)*	***1,360***	***74%***
General Permit required SWPPP contents	**Facilities in compliance**	**Percentage of facilities with SWPPP (n=1,360)**
The SWPPP identified a specific person or persons and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	1,106	81%
The SWPPP included a site map (A.4)	1,089	80%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	1,223	90%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	1,255	92%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	1,256	92%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	1,280	94%
The SWPPP was signed and certified by the appropriate facility personnel (A.9)	911	67%
Facility SWPPP met all General Permit requirements	***648***	***48%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan."

SWPPP compliance rates for the top five SIC codes (Appendix A) are not significantly different, with the exception of 42XX – Motor Freight Transportation and Warehousing Facilities. For SIC code 42XX, 65 percent of the SWPPPs reviewed met all General Permit requirements (Appendix A, Table A.9).

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The SWPPP stormwater BMP list is the area where consultants seem to do their clients the greatest disservice. Frequently, the professionally prepared documents provide a general list of BMPs for a specific industry, regardless of whether the individual BMPs are appropriate to or implemented at a specific facility. A popular example is "Yard will be swept on a daily basis" when the yard surface is, in fact, dirt. Technically, an overzealous inspector could consider a facility out of compliance for each BMP listed in the SWPPP, whether appropriate or not, that was not implemented in the yard. Certainly it is up to the facility representative to evaluate the SWPPP BMP list before signing and certifying the SWPPP (only 67 percent of the SWPPPs were signed and certified), but consultants should emphasize that the BMP list should be evaluated for those measures that are actually being carried out.

4.3.1.2 SWMP Compliance

Sixty-seven percent of inspected facilities produced a SWMP (Table 4); however, 87 percent of the SWMPs met all General Permit requirements. The differing levels of completeness between SWPPPs and SWMPs were surprising. Data suggest that if a facility has a SWMP, it is likely to be complete; not so for a SWPPP.

A possible reason for this is that SWMPs are largely boilerplate and the information, with the exception of sampling locations, can be copied from the Internet or from another facility in the same SIC code.

SWMP compliance rates for the top five SIC codes (Appendix A) are not significantly different from the percentages in Table 4.

Table 4. Compliance with General Permit Stormwater Monitoring Plan (SWMP) Requirements

Overall General Permit requirement	Facilities in compliance	Percentage of facilities with SWMP on-site (n=1,848)
Facility developed a written SWMP (B.1)	***1,246***	***67%***
General Permit required SWMP contents	**Facilities in compliance**	**Percentage of facilities with SWMP (n=1,246)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	1,202	96%
SWMP describes stormwater discharge visual observations (B.4)	1,220	98%
SWMP describes stormwater sample collection procedures and protocols (B.5)	1,180	95%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	1,156	93%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	1,174	94%
Facility SWMP met all General Permit requirements	***1,090***	***87%***

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4.3.1.3 General Permit Sampling and Monitoring Requirements

Visual and analytical stormwater monitoring is required by the General Permit unless the facility does not discharge during any of the storm events or the storm occurs outside normal business hours. Data must be maintained and submitted with each year's annual report, due in July. The Water Boards closely track annual report submittals and follow up with facilities that do not submit on time. As a result, 89 percent of the facilities had the most recent annual report available for review (Table 5).

Table 5. Compliance with General Permit Sampling and Monitoring Requirements

Overall General Permit requirement	Facilities In compliance	Percentage of total (n=1,848)
Previous year's submitted annual report available for review	***1,647***	***89%***
General Permit required annual report contents	**Facilities In compliance**	**Percentage of facilities with annual report (n=1,647)**
Quarterly non-stormwater discharge visual observations (B.3.c)	1,541	93%
Stormwater discharge visual observations (B.4)	1,578	96%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season and (2) at least one other storm event in the wet season (B.5)	1,424	86%
Stormwater samples were analyzed for the appropriate parameters (B.5.c); includes facilities that collected fewer than the required number of samples	1,521	92%
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	1,430	87%
Facility operators conducted one comprehensive site compliance evaluation in each reporting period (July 1–June 30) (A.9)	1,560	95%
All analytical stormwater results were within EPA/Water Board benchmark values	949	58%
Annual Report met all General Permit requirements (B.14)	***1,055***	***64%***

Initially (through 2002/2003), Tetra Tech inspectors reviewed the annual reports at the Water Board. This proved to be a significant burden on Water Board staff because they had to pull the appropriate files prior to each week and re-file them at the end of each week, as well as provide photocopiers and workspace for the Tetra Tech inspectors. This process was eliminated in favor of reviewing all documents at the facility. Because the General Permit requires that all documents be maintained on-site,[5] facilities that could not provide an annual report were considered noncompliant.

[5] CAS000001, Description of General Permit Conditions, Retention of Records.

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These three notes clarify the information presented in Table 5:

1. A little less than half (42 percent) of the facilities that submitted analytical stormwater monitoring data had one or more parameters outside the EPA/Water Board benchmark values.
2. The number of samples outside EPA/Water Board benchmark values might be skewed by incorrect sample collection practices. Frequently, facilities reported collecting samples from stormwater pooling on the property rather than from stormwater discharging from the property.
3. The reported number of 86 percent of the annual reports having collected the correct number of samples includes facilities that claimed "no discharge" or "no qualifying storm event."

The third point is worth considering during future General Permit revisions. The General Permit defines *qualifying storm event* as follows:

> [s]ample collection is only required of stormwater discharges that occur during scheduled facility operating hours and that are preceded by at least (3) three working days without stormwater discharge.[6]

Determining whether a qualifying storm event occurred during the previous reporting period is challenging for inspectors. One can get a general estimate by reviewing annual reports for facilities in the same geographic area to see if others sampled from "qualifying storm events," but without visiting a facility during a rain event, one cannot be sure what amount of rain generates a discharge at a particular facility. A number of Tetra Tech's inspectors are of the opinion that facilities use "no qualifying storm event" to avoid paying for laboratory analysis and having to submit data.

An amusing illustration of poor understanding of stormwater sampling requirements was provided during a facility inspection. The Tetra Tech inspector asked to see the facility's stormwater monitoring results. Instead of returning with a spreadsheet or laboratory analysis sheets, the facility representative brought back a tray with six Mason jars filled with stormwater. The water had been collected during the previous reporting period but never submitted to a laboratory for analysis.

The most unusual excuse for not submitting analytical monitoring data was provided by a southern California auto dismantler. The facility representative stated, "Yes, a stormwater sample was collected for analysis." However, the sample had been placed in the facility refrigerator prior to delivery to the lab. A facility employee, thinking the sample was chilled water, started to drink the sample, determined that it did not taste good, and dumped it down the drain.

[6] CAS000001 Section B.5.b.

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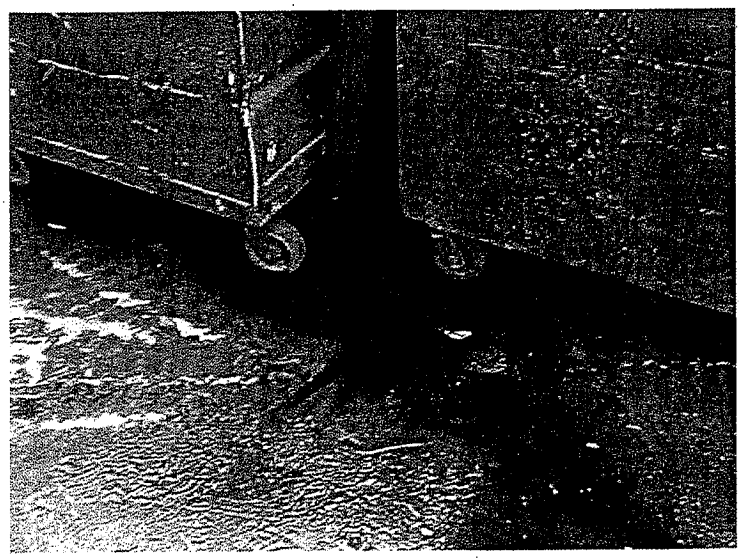
4.3.2 Stormwater Best Management Practice Implementation



Implementation of stormwater BMPs is critical to maintaining the quality of stormwater at the facility boundary or discharge point. BMPs are either structural or nonstructural; Tetra Tech did not collect quantitative data regarding implementation of structural versus nonstructural BMPs.

Anecdotal information suggests that facilities rely on nonstructural BMPs (e.g., good housekeeping, spill cleanup) until it becomes clear (through an inspection, for example) that benchmark values cannot be attained without the implementing structural BMPs. In addition, structural BMP implementation appears to be positively correlated with facility size and market capitalization.

Through the inspection process, Tetra Tech inspectors evaluated the implementation of stormwater BMPs at each facility inspected. The simplest evaluation resulted from comparing the list of BMPs from the SWPPP with BMPs implemented in facility outdoor areas. Of the 1,280 facilities with SWPPP BMP lists (Table 3), 928 were found to have adequately implemented the BMPs in outdoor areas (72 percent). That number might be misleading because it identifies facilities that had implemented SWPPP BMPs in outdoor areas; it does not capture facilities where the SWPPP BMP list was incomplete and additional BMPs should be added to the SWPPP and implemented in outdoor areas. These data are available in narrative form, but their storage in the database does not lend itself to quantitative analysis.

4.3.3 Unauthorized Non-Stormwater Discharges

Detailed data analysis is not presented for observed unauthorized non-stormwater discharges. The inspectors observed 158 facilities with unauthorized non-stormwater discharges, fewer than 10 percent of the facilities inspected. In these cases, the facilities were directed to "cease and desist" and the Water Board was immediately notified.

Of these 158 facilities, 1 facility in the Los Angeles Water Board was assessed the largest financial penalty associated with a Tetra Tech industrial stormwater inspection. Cemex Construction Materials, L.P., was assessed a penalty of $86,500 for unauthorized non-stormwater discharge (Complaint No. R4-2004-0068); however, the calculated potential maximum penalty was $4,360,000 based on the number of days between the NOI

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submittal and the date the illicit drain was sealed (436 days x $10,000 per day).[7] Tetra Tech employee Steve Hruby conducted the initial inspection on December 18, 2003, and Jonathon Bishop (Interim Executive Director) signed the complaint on July 2, 2004.

4.4 EPA/Water Board Benchmark Value Exceedances

Stormwater samples from individual facilities and group monitoring plan (GMP) members must be analyzed for four standard parameters: total suspended solids (TSS), pH, specific conductance (SC), and total organic carbon (TOC). Oil and grease (O&G) may be substituted for TOC. Specific SIC codes are required to perform analytical tests for additional pollutants, as discussed in CAS000001 Section B, Table D. Analytical results are submitted with each year's annual report for comparison against benchmark values.

Sample results above benchmark values, or outside benchmark values in the case of pH, are not considered violations of the permit because the benchmark values are guidelines, not effluent limitations. Rather, they are considered indicators of poor housekeeping or incomplete stormwater BMP implementation.

4.4.1 Analytical Stormwater Data Collection

With respect to sampling data, the inspectors reviewed previous years' stormwater analytical data. Information recorded during the inspection included the number of sampling events; stated reasons why fewer than two stormwater events were sampled (e.g., no qualifying storm event); analytical data outside the benchmark values; and required parameters for which samples were not tested. Data regarding the number of outfalls sampled at each facility or concentrations for those parameters within benchmark values were not collected.

4.4.2 Summary of Analytical Stormwater Data

Tetra Tech performed 1,848 inspections between August 2001 and May 2005 for the Regional Boards. Stormwater analytical data collected from these 1,848 facilities breaks down as follows:

- 1,424 (77 percent) collected the required number of samples (2 per year or were GMP members).

[7] http://www.swrcb.ca.gov/enforcement/docs/r04/2004/R4-2004-0068-ORDER-4412.pdf.

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- 873 facilities (47 percent) reported exceedances of 1 or more benchmark values in 1 or more sample events, including those that collected 1 sample instead of the 2 required samples (for non-GMP members).
- 1,615 individual sample results from these 873 facilities reported analytical results outside benchmark values for one or more of the following parameters: pH, TSS, SC, O&G, and TOC. Additional sample results showed exceedances of other Table D parameters, but they were not tabulated.

Monitoring data analysis was performed using two different approaches. The first method was the "facility-level" approach, and the second method was the "individual sample" approach. The primary difference between the two is that the first approach looks at facilities that reported exceedances of benchmark values for only TSS (at the request of EPA Headquarters), without regard to the number of individual sample events with reported values outside the benchmark values. The second approach uses data from the individual sample events to characterize the frequency and nature of stormwater parameters outside benchmark values.

4.4.3 Facility-level Analysis of Analytical Stormwater Data

Facility-level data were compiled for all industrial facilities inspected by Tetra Tech staff between August 2001 and May 2005. The database Tetra Tech used for entering and summarizing inspection data includes the following fields useful for this analysis:

- Did the facility collect one or more stormwater samples during the previous reporting year (as required by the General Permit)?
- If samples were collected, were any of the reported analytical data outside benchmark values? If so, then:
  - The inspectors entered data for specific sample events and outfalls for which facilities reported analytical results outside benchmark values.
  - Was TSS one of the parameters for which analytical monitoring data was outside benchmark values?[8]

Data available for the facility-level analysis were fairly robust and should provide representative statistics regarding the expected percentage of facilities that report TSS values outside benchmark values when complete samples are collected.

Of the 1,848 industrial facilities inspected between August 2001 and May 2005, 1,563 facilities (85 percent) collected one or more stormwater samples during the reporting year prior to the date of inspection or reported no qualifying storm event.

- 1,424 of the inspected facilities (77 percent) reported complete sample results (including those that identified "no qualifying storm event)—samples from two wet weather events. The remaining 139 collected samples from only one of the two required wet weather events.

[8] The analysis focused on TSS because the stormwater monitoring data analysis was initially performed for EPA Headquarters, which was interested in TSS compliance.

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- 881 facilities reported analytical results outside benchmark values for one or more parameters (56 percent of those with data from one or more sample events [n = 1,563]).
- 470 facilities reported TSS concentrations above the benchmark value (30 percent of those with data from one or more sample events [n = 1,563]).

The estimate of 30 percent for those who sampled and reported TSS exceedances is consistent with other studies reviewed during the course of this analysis—26 percent in a San Francisco RWQCB study[9] and 31.5 percent in a *Water Environment Research* article.[10]

4.4.4 Individual Sample Analysis of Analytical Stormwater Data

The individual sample analysis is based on tabulation of stormwater monitoring events with one or more parameters outside benchmark values, as identified during industrial stormwater inspections conducted by Tetra Tech staff. Unfortunately, the database structure does not allow the number of samples with one or more benchmark value exceedances to be compared with the total number of samples collected at the inspected facilities. Tetra Tech inspectors did not collect, nor were they asked to collect, information on the number of outfalls sampled at a facility during the previous reporting year. For example, a facility might have sampled three outfalls during two storms (six samples); but if exceedances were reported for only one sample, the data set only shows this one sample.

Table 6 summarizes sample results for stormwater analytical data reported to be outside benchmark values. EPA or Regional Board benchmark values are provided for reference. Table 6 is based on only data recorded for analytical results outside benchmark values. Tetra Tech inspectors did not record concentrations or values for analytical data within benchmark values.

[9] LaPlante, Alexa, and Rico Duazo to Loretta K. Barsamian, Status Report on the General NPDES Permit for Discharges of Stormwater Associated with Industrial Activities for Region 2 and Review of the 2001/2002 Annual Monitoring Reports. . . . . *http://www.waterboards.ca.gov/rwqcb2/Agenda/03-19-03/ 03-19-03-11staffreport.doc* (March 13, 2003).

[10] Lee, Haejin, and Michael K. Stenstrom, Utility of stormwater monitoring, *Water Environment Research* 77(1), 2005.

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Table 6. Summary of Stormwater Analytical Data for Individual Sample Results Outside of Benchmark Values

	pH (su)	TSS (mg/L)	SC (µmhos/cm)	O&G (mg/L)	TOC (mg/L)
Total number of samples with one or more values outside benchmark	n = 1,615				
Benchmark value	6.0–9.0	< 100	< 200	< 15	< 110
No. of samples outside benchmark limits	317 (19%)	904 (56%)	1023 (63%)	188 (12%)	101 (6%)
Min	1.64	*	*	*	*
Max	12.3	35,000	18,000	1,490	2,700
Average**	*	724	1,472	65	350
Median**	*	280	460	28	190

* Not applicable.
** Only data above the benchmark values were available for this analysis.

The data presented in Table 6 are useful for answering the following question: "If analytical stormwater sample results are outside benchmark values for one or more parameters, which parameters are these likely to be?" The answer to this question, in order of decreasing likelihood, is SC, TSS, pH, O&G, then TOC. The broader applicability of the individual sample analysis is limited by the limited total number of samples of which the 1,615 with benchmark value exceedances are a subset.

4.5 Distribution of Facility Stormwater Ratings

Tetra Tech assigned an overall rating to each facility inspected based on the types of potential violations observed. The rating system is as follows:

> **1** – Poor stormwater BMP implementation and management practices present a threat to the quality of stormwater discharged from the facility. It is recommended that the Water Board perform a follow-up inspection.
>
> **2** – Compliance issues with required General Permit paperwork requirements and minor yard issues. Facility is not deemed a threat to stormwater quality at the point(s) of discharge. Compliance can be effectively handled with a letter from the Water Board requesting updated documentation and, if appropriate, pictures of improved stormwater BMPs.
>
> **3** – Facility determined to be in compliance; no follow-up needed at this time.
>
> ***** – Facility was visited but not inspected. Reasons include the following: the facility was not open for business on the day of inspection or the facility was no longer operating at the NOI address.

Table 7 presents the overall distribution of rankings. Surprisingly, the distribution approximates a normal bell curve with around 20 percent rated "1" or "3," 52 percent rated "2," and the remainder visited but not inspected.

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Table 7. Tabulation of Stormwater Ratings		
Rating	No. of facilities	Percentage of total facilities (n=1,848)
1 – Potential threat to stormwater quality	329	18%
2 – Paperwork and minor yard violations	980	53%
3 – In compliance	415	22%
* - Visited but not inspected	89	5%

Overall facility ratings for the five SIC codes evaluated in Appendix A have a distribution similar to that in Table 7. Generalizing the percentages from Table 7 to the current number of facilities in the NOI database, statewide General Permit compliance is estimated as follows:

- 1,718 facilities present a potential threat to stormwater quality.
- 5,058 facilities are not in compliance with General Permit paperwork requirements.
- 2,099 facilities are in compliance with the General Permit.

For comparison, Table 8 presents the overall facility ratings for the 541 GMP participants inspected by Tetra Tech. These facilities are included in the tables above, so a direct comparison of overall ratings between GMP members and non-GMP members is not possible. Regardless, the data presented are useful for estimating the overall General Permit compliance of GMP members.

Table 8. Tabulation of Stormwater Ratings for GMP Members		
Rating	No. of facilities	Percentage of total facilities (n=541)
1 – Potential threat to stormwater quality	83	15%
2 – Paperwork and minor yard violations	269	49%
3 – In compliance	161	30%
* - Visited but not inspected	21	4%

Overall facility ratings for Tetra Tech inspections of GMP members are skewed slightly more toward compliance than the totals presented in Table 7. Thirty percent of GMP members were in compliance with General Permit requirements, compared with 22 percent of the total inspected population. However, one would expect the number of "1" and "2" rated facilities to be lower for GMP members. The General Permit requires GMP members to

> . . . develop and implement a written site specific SWPPP and monitoring program in accordance with the General Permit and must satisfy any group monitoring requirements." (CAS000001 Section B.15)

The GMP leader is responsible for

> [c]onducting a minimum of two on-site inspections of each participant's facility (it is recommended that these inspections be scheduled during the Annual Comprehensive Site Compliance Evaluation) during the term of

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this General Permit to evaluate the participant's compliance with this General Permit and the GMP, and to recommend any additional BMPs necessary to achieve compliance with this General Permit. Participants that join in Years 4 and 5 shall be scheduled for one evaluation. A copy of the evaluation and recommended BMPs shall be provided to the participants. (CAS000001 Section B.15.d.v)

The overall ratings presented in Table 8 suggest that either GMP members are not implementing the stormwater program as recommended by the GMP leader or (a) the GMP site inspections are not as rigorous as EPA/Water Board inspections, (b) the GMP site inspections focus on specific aspects of the General Permit and not the entire General Permit, or (c) the GMP leader is not removing noncompliant members from the GMP.

4.6 Follow-up Inspections

Tetra Tech and the Los Angeles Water Board performed 101 stormwater follow-up inspections beginning in January 2002. Facilities targeted for follow-up inspections were initially inspected in fall 2001 and rated "1" or "2." Upon receipt of the Tetra Tech inspection reports, the Water Board issued a notice to comply (NTC, for "2" facilities) or a notice of violation (NOV, for "1" facilities) directing them to come into compliance within 45 days. The re-inspections occurred at least 45 days after the Water Board delivered the compliance notice.

Table 9 presents the results of the two sets of inspections, the initial inspection and then the follow-up inspection after the facility received a compliance notice from the Water Board. The same facilities are represented in the first and second inspections.

Table 9. Compliance Data from the Same Facilities Inspected Twice

No. of facilities inspected	SWPPP available	SWPPP complete*	SWMP available	No UNSWDs**	SWPPP BMPs implemented*
First inspection (fall 2001)					
101	56 (55%)	19 (34%)	52 (51%)	90 (89%)	19 (34%)
Second inspection (winter 2002)					
101	96 (95%)	68 (71%)	93 (92%)	100 (99%)	76 (79%)

* Percentage based on the number of facilities with a SWPPP available.
**Unauthorized non-stormwater discharge.

General Permit compliance rates increased significantly by the second inspection: the number of SWPPPs and SWMPs available for review almost doubled. Moreover, the number of facilities that were adequately implementing SWPPP BMPs more than tripled. The success of the follow-up inspections suggests several important points regarding compliance by the regulated community:

- Frequent inspections provide positive results.
- Compliance inspections coupled with compliance assistance, at least during a facility's first industrial stormwater inspection, provide the strongest outcome.

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- Facility representatives begrudgingly acknowledged that the compliance inspection and follow-up provided them with information they needed to bring the facility into compliance.
- Many facility representatives, particularly those associated with larger corporations, use compliance notices as leverage to obtain additional funding from the corporate office for the stormwater program.

Overall facility ratings also improved by the second inspection. Sixty-six facilities improved by at least one rating ("1" to "2," "2" to "3," or "1" to "3"), while only four facilities dropped a rating point by the second inspection. Twenty-seven facility ratings were unchanged from the first inspection, and four facilities had gone out of business.

The ideal frequency for industrial stormwater inspections is estimated to be once every 2 or 3 years and more frequently for problem facilities. Frequent inspections enable permittees to calibrate their programs to meet General Permit requirements and Water Board expectations. Extending the inspection frequency beyond 3 years runs the risk of having the stormwater program fall below the facility's day-to-day "radar" and might affect institutional memory, particularly at facilities with regular staff turnover.

4.7 Secondary Benefits from Field Inspector Presence

The benefits of industrial stormwater inspections and a regular field presence go beyond the direct impact of General Permit compliance at inspected facilities. Secondary benefits include encouraging General Permit compliance at facilities that are not inspected, improving communication between permit holders and the Water Board or the permit holder and the consultant or GMP leader, and maintaining an ongoing awareness of the stormwater program within the regulated community. Secondary benefits are not easily quantified, but anecdotal information collected during stormwater inspections suggests that these benefits are present and potentially significant.

The regulated community tends to be in regular contact with industry peers and neighbors. For example, the auto dismantlers maintain two-way radios that are mainly used to locate parts for customers. However, during industrial stormwater inspections, the radios are used to announce that the Water Board is performing industrial stormwater inspections and the specific focus of the inspections (i.e., paperwork, BMP

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implementation, or everything). As a result, other members of the radio network might pull their paperwork together and set their staff to cleaning up the yard and repairing BMPs in anticipation of an inspection that might or might not occur.

Similarly, GMP leaders track General Permit compliance inspections and the different aspects focused on by each Water Board. Facility GMP files contain many examples of correspondence from GMP leaders to GMP members indicating that the Water Board and EPA Region 9 are performing in-depth General Permit inspections and noncompliance is being taken seriously. The GMP leader recommends that facilities have their paperwork organized and located on-site, and that stormwater BMPs be evaluated and replaced as necessary.

5.0 Special Projects

Between 2001 and 2005, Tetra Tech inspectors had the opportunity to participate in several special projects for the Water Boards. They are considered special projects because the scope of the work was more focused than simply inspecting all the facilities on a list generated by the Water Board. Special projects included non-filer audits in the City of Industry (Los Angeles), transportation sector BMP implementation (Los Angeles), and industrial stormwater compliance inspector training for several municipalities.

5.1 Non-Filer Audits

During winter of 2005, the Los Angeles Water Board, City of Industry, and Tetra Tech worked together to identify and quantify non-filers (facilities that should have applied for General Permit coverage because of their SIC codes but had not) in the City of Industry, California. The City of Industry was selected because of its large concentration of manufacturing and retail companies; 92 percent of land use in the City of Industry is delegated to industry.

Municipal representatives of the City of Industry provided a list of business names and addresses to the project manager. The list did not include facility SIC codes. The list was then crosschecked against a list of General Permit holders. Those facilities not appearing on the General Permit holder list were targeted for field evaluation to determine whether they should have submitted an NOI for coverage under the General Permit. Tetra Tech and the Water Board staff performed the targeted inspections.

Individual inspectors were assigned streets within the City of Industry. Inspectors visited all targeted facilities, as well as other facilities with potential stormwater exposure identified while traveling along assigned streets. Field visits began by meeting with business representatives to identify the types of activities conducted at the address and the business's SIC code. When a business appeared to meet the criteria for coverage under the General Permit (either operating under a regulated SIC or with outdoor industrial activities), the inspector walked the site with business representatives to collect supplemental information to determine whether the facility should be covered under the General Permit.

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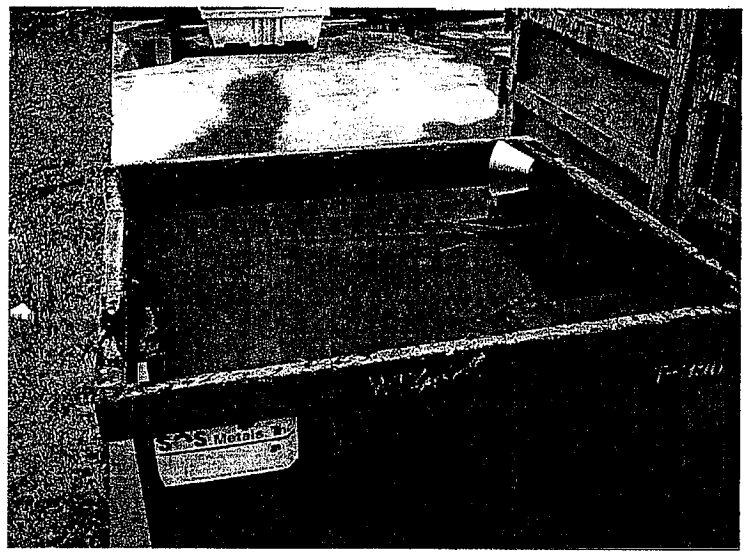
Challenges persisted throughout the inspection week. Inspectors were overwhelmed with the task of acquiring SIC codes from business representatives. Business representatives not accustomed to regulators at their doorstep were reluctant to reveal information, let alone allow inspectors on the business property. Moreover, few facility representatives were aware, or claimed to be aware, of their SIC code.

Inspectors concluded that 28 percent of the facilities evaluated were non-filers. It was estimated that more than 100,000 businesses in the state operate under an applicable General Permit SIC code. From this sample set, bringing in 28 percent of this population (28,000 industrial facilities) could generate significant revenue for the state and the stormwater program.

5.2 Survey of Transportation Sector Stormwater BMP Implementation

At the request of the Los Angeles Water Board, Tetra Tech and Water Board inspectors evaluated BMPs frequently implemented for stormwater control at motor freight transportation facilities (SIC code 42XX – Motor Freight Transportation and Warehousing). The inspections occurred during the week of February 21, 2005, immediately following a heavy storm cycle that raised the rainfall total for the season in downtown Los Angeles to 33.9 inches. Inspections were done in accordance with standard industrial inspections, with the exception of having a focus on the effectiveness of particular BMPs common to the trucking industry. BMP analysis was based on visual inspection; historical stormwater sampling data were not evaluated.



Structural and nonstructural BMP evaluations were conducted at 38 freight transportation facilities selected by the Water Board. Common industrial activities included waste disposal, maintenance, fueling, and truck washing. BMPs were visually evaluated to judge their effectiveness in mitigating pollutant runoff from these activities. Structural BMPs included overhead cover, secondary containment, spill kit presence, berms, slot drains (to convey wash water) and clarifiers (used to reduce suspended material and hydrocarbons in discharges to surface waters). Nonstructural BMPs included maintenance schedules of structural BMPs and general housekeeping practices. A

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qualitative scale was used to rate the effectiveness of the BMPs applied to these industrial activities.

Inspectors used their best professional judgment to rate the effectiveness of BMPs. Ratings were tabulated and summarized per industrial activity. The inspectors concluded that BMP maintenance schedules and design/installation practices generally depict the effectiveness of BMPs.

5.3 Industrial Stormwater Inspector Training for MS4 Co-permittees

Tetra Tech stormwater inspectors conducted training for MS4 co-permitee inspectors in Los Angeles, Orange, and Contra Costa counties. As part of the training, Tetra Tech inspectors hosted classroom sessions in the mornings and then led mock stormwater inspections at industrial facilities within the applicable county. Representatives from various municipalities covered under county MS4 permits attended the training sessions.

The training inspections were designed to introduce municipal stormwater inspectors to the stormwater inspection process, with emphasis on SWPPP review and identifying inadequate or ineffective BMP implementation. The training inspections were conducted according to Tetra Tech's industrial stormwater inspection checklist.

Each training inspection concluded with a question-and-answer session between the Tetra Tech lead inspector and the municipal participants. The Tetra Tech inspector would explain in detail why particular issues were a stormwater concern and what to expect from similar facilities. Overall, the training process appeared beneficial to all parties, and future sessions would continue to build expertise among the municipal inspection staff.

6.0 Lessons Learned

Leading General Permit compliance inspections at 1,848 industrial facilities provided a unique laboratory for evaluating the implementation of the stormwater program. Some of the lessons learned will be obvious to the reader, while others might be more obtuse.

6.1 Compliance Improves with Field Inspector Presence

As previously discussed in the "Follow-up inspections" section, facility compliance improves with awareness of the program and a regular presence of compliance inspectors at the facility or at other facilities in the same industry group or neighborhood. Regulatory presence (1) shows the facility representatives that the Water Board takes the program seriously and (2) keeps stormwater compliance in the minds of facility representatives.

6.2 Paperwork Compliance, or Lack Thereof, Does Not Always Relate to Stormwater Quality

This is a rather mundane lesson until viewed from the framework of the General Permit itself. Obviously, the goal of the General Permit is to improve or maintain the quality of stormwater discharges from regulated facilities and, as a result, minimizes degradation of

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surface waters by polluted stormwater. Evaluation of General Permit compliance begins with the required paperwork. For example, the General Permit requires that a SWPPP be maintained on-site and the SWPPP contain a list of stormwater BMPs that are implemented in the yard.

What happens if the facility does not have a SWPPP or the SWPPP does not contain a list of stormwater BMPs? The first-order violation is the lack of a SWPPP or a complete SWPPP. Without a SWPPP BMP list to compare against implemented stormwater BMPs, it is difficult for an inspector to say whether the facility is or is not in compliance. Restated, the inspector can make a visual estimation of whether the facility is operating within the spirit of the General Permit; but if it is not, and no SWPPP is available, the permit does not appear to contain provisions that address poor BMP implementation absent a SWPPP BMP list.

6.3 MS4 Stormwater Audits Focus on Different Issues than State Board or EPA Stormwater Audits

The regulated community is frequently confused by the different stormwater inspector affiliations—local, state, federal, and contractor. Often, when arriving at a facility, the facility representative says something like "I just had a stormwater inspection a couple of weeks ago." Upon retrieving the inspection report from this previous inspection, it turns out to be an MS4 industrial stormwater inspection. Following on the initial confusion, it is possible for a facility to get a good report from the municipal inspection and a bad report from the Water Board/EPA inspection.

The discrepancies result from the different level of detail employed by the two types of inspectors. The MS4 inspector asks if the facility has a SWPPP but is not required to review it in detail. Nor is the MS4 inspector expected to review monitoring data or BMP implementation beyond the four or five general classes of BMPs identified on the MS4 checklist. In comparison, the Water Board/EPA inspector reviews the SWPPP in detail, reviews the monitoring data in detail, and specifically evaluates the implementation of BMPs identified in the SWPPP, which might or might not match the general BMP categories from the municipal inspector's list.

Each type of inspection has its place, but the differing focus of the two inspectors causes confusion for the regulated community. Ultimately, the best solution is more information sharing between the MS4s and the Water Boards to ensure that minimal inspection overlaps occur, unless requested.

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7.0 Future Data Collection

The data collected to date are useful in characterizing the performance of the General Permit. However, the ultimate goal of tying stormwater discharge data into broader watershed management projects (e.g., total maximum daily load [TMDL] studies) will require the collection of additional pieces of information from each facility inspected. For example,

- Global positioning system (GPS) data for inspected facilities will allow mapping of stormwater dischargers within watersheds and other geographic areas.
- Number of stormwater outfalls, in addition to number of samples and benchmark exceedances, will allow the Water Boards and EPA to continue to refine their understanding of benchmark value exceedances and sources.
- Emphasizing facility size and impervious area will help to get a better handle on potential pollutant loading from facility stormwater discharges. Without information on loading, a ¼-acre facility with pervious surface that discharges a couple of gallons of stormwater outside benchmark values looks worse on paper than a 100-acre paved facility that has all analytical results within benchmark values. The reality is that the larger facility has a greater impact on the receiving water, but the smaller facility might receive more regulatory attention.

The addition of these sets of data will broaden the applicability of data collected during stormwater inspections. The most immediate use is assigning pollutant loadings to nonpoint sources in TMDL analyses.

8.0 Opportunities to Improve Compliance through Future Inspections and Projects

Awareness of General Permit requirements continues to increase as the Water Boards and EPA (both EPA staff and EPA contractors) continue to spend time on field inspections. The information presented in this report shows that the General Permit is reasonably successful and that with the upcoming re-issuance of the General Permit, several opportunities exist for continuing to improve compliance.

8.1 Compliance Tool Development for Regulators or Dischargers

The State Board should develop an on-line SWPPP development tool. The tool could contain pages for each of the General Permit SWPPP requirements, tailored to specific industrial practices. Permit holders would then select the industrial activities, pollutant sources, and BMPs applicable to their facilities, or type in additional ones; print out the SWPPP; add a site map; and certify. The SWPPPs could be stored in State Board computers and accessible to the permit holder for revisions and regulators for review prior to site inspections or when reviewing the annual report.

The California Integrated Water Quality System (CIWQS) should include an industrial stormwater inspection-tracking tool. The tracking tool should be available to federal, state, and local regulators. Following each inspection, the inspector could log into the

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system and identify the facility inspected, date of inspection, and major findings. Such a tool could minimize overlap and duplication of efforts by the various regulatory agencies. Moreover, Tetra Tech's industrial stormwater reporting tool could be modified from a Microsoft Access-based system to a CIWQS-based system.

8.2 Other Targeting Approaches

Targeting inspections with an eye toward a specific water quality goal or characterizing an entire industry offers opportunities to maximize benefit from limited inspection resources. Tetra Tech developed the following list of potential targeting strategies:

- Inspect all stormwater permit holders within the watershed boundaries of section 303(d)-listed waters with the goal of focusing on BMPs associated with the pollutants contributing to impairment.
- Identify local areas that have a significant industrial presence and are adjacent to a surface water. Inspect all industrial facilities within that geographic area—NOI filers and non-filers.
- Evaluate the annual reports, and inspect those that submitted analytical results outside benchmark values. The San Diego Water Board used this approach in 2004/2005 to develop Tetra Tech's inspection list.
- Emphasize facilities that did not collect the appropriate number of samples to encourage facility representatives not to game the system by reporting "no qualifying storm event." Cross reference these inspections with other facilities in the same geographic area that were able to collect samples.
- Identify particular industries, and identify and inspect all permit holders from those industries during one wet weather season.
- Develop a list of all facilities in a specific SIC code using a business-listing database such as Dunn & Bradstreet. Inspect all facilities on the list—NOI filers and non-filers—statewide

9.0 Recommendation for Improvements to California's Industrial Stormwater Program

The following brief recommendations, based on Tetra Tech's past experience in the state, are made to help improve the effectiveness of California's industrial stormwater program:

- Perform follow-up inspections at all facilities previously rated as "1" or "2" that have not yet been re-inspected.
- Focus new industrial stormwater inspections on heavy industry other than 5015 – auto dismantlers, 5093 – scrap recycling facilities, and 42XX - motor freight transportation and warehousing.
- Identify a smaller 303(d)-listed watershed segment of a larger 303(d)-listed water with a significant industrial presence within the watershed boundaries. Inspect all stormwater permit holders within the watershed boundaries with the goal of

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focusing on BMPs associated with the pollutants that are contributing to impairment.

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Appendix A

Compliance statistics for five largest SIC codes inspected

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SIC 5015 - Auto Salvage/Dismantling

Compliance with paperwork requirements

Total number of SIC 5015 facilities inspected – 433

Table A.1 Compliance with General Permit SWPPP Requirements (5015)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 5015 Facilities with a SWPPP (n=433)**
A SWPPP was developed and implemented (A.1)*	***317***	***73%***
General Permit Required SWPPP Contents	**Facilities in Compliance**	**Percentage of 5015 facilities with SWPPP (n=317)**
The SWPPP identified a specific individual or individuals and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	272	86%
The SWPPP included a site map (A.4)	254	80%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	296	93%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	301	95%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	295	93%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	302	95%
The SWPPP was signed and certified by the appropriate facility personnel	210	66%
Facility SWPPP met all General Permit requirements	***148***	***47%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan"

Table A.2 Compliance with General Permit SWMP Requirements (5015)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 5015 Facilities with SWMP on-site (n=433)**
Facility developed a written stormwater monitoring program (B.1)	***308***	***71%***
General Permit Required SWMP Contents	**Facilities in Compliance**	**Percentage of 5015 facilities with SWMP (n=308)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	297	96%
SWMP describes stormwater discharge visual observations (B.4)	302	98%
SWMP describes stormwater sample collection procedures and protocols (B.5)	300	97%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	291	94%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	302	98%
Facility SWMP met all General Permit Requirements	***279***	***90%***

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Table A.3 Compliance with General Permit Sampling and Monitoring Requirements (5015)		
General Permit Requirement	**Facilities In Compliance**	**Percentage of 5015 Total (n=433)**
Previous year's annual report available for review	376	87%
General Permit Required Annual Report Contents	**Facilities In Compliance**	**Percentage of 5015 facilities with Annual Report (n=376)**
Quarterly non-stormwater discharge visual observations (B.3.c)	358	95%
Stormwater discharge visual observations (B.4)	373	99%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season, and (2) at least one other storm event in the wet season (B.5)	355	94%
Stormwater samples were analyzed for the appropriate parameters (B.5.c), includes facilities that collected fewer than the required number of samples	354	94%
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	336	89%
The facility operator conducted one comprehensive site compliance evaluation in each reporting period (July 1-June 30) (A.9)	348	92%
All analytical stormwater results were within EPA/Water Board benchmark values	280	74%
Annual Report was complete	***258***	***69%***

BMP implementation

SWPPP BMP implementation for the 5015-sample group was determined to be 57 percent; 302 SWPPPs identified BMPs but only 175 facilities fully implemented the BMPs identified in the SWPPP.

Distribution of Facility Stormwater Ratings

Table A.4 Tabulation of Stormwater Ratings (5015)		
Rating	**No. of Facilities**	**Percentage of 5015 facilities (n=433)**
1 – Potential Threat to Stormwater Quality	92	21%
2 – Paperwork and minor yard violations	212	49%
3 – In Compliance	91	21%
* - Visited But Not Inspected	20	5%

A014441

SIC 5093 - Scrap Recycling Facilities

Total number of SIC 5093 facilities inspected - 168

Compliance with paperwork requirements

Table A.5 Compliance with General Permit SWPPP Requirements (5093)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 5093 Facilities with a SWPPP (n=168)**
A SWPPP was developed and implemented (A.1)*	***116***	***69%***
General Permit Required SWPPP Contents	**Facilities in Compliance**	**Percentage of 5093 facilities with SWPPP (n=116)**
The SWPPP identified a specific individual or individuals and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	93	80%
The SWPPP included a site map (A.4)	97	84%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	108	93%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	108	93%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	107	93%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	109	93%
The SWPPP was signed and certified by the appropriate facility personnel	63	54%
Facility SWPPP met all General Permit requirements	***48***	***41%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan".

Table A.6 Compliance with General Permit SWMP Requirements (5093)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 5093 Facilities with SWMP on-site (n=168)**
Facility developed a written stormwater monitoring program (B.1)	***108***	***64%***
General Permit Required SWMP Contents	**Facilities in Compliance**	**Percentage of 5093 facilities with SWMP (n=108)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	105	97%
SWMP describes stormwater discharge visual observations (B.4)	106	97%
SWMP describes stormwater sample collection procedures and protocols (B.5)	100	92%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	99	92%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	101	93%
Facility SWMP met all General Permit Requirements	***90***	***86%***

A014442

Table A.7 Compliance with General Permit Sampling and Monitoring Requirements (5093)		
General Permit Requirement	**Facilities In Compliance**	**Percentage of 5093 Total (168)**
Previous year's annual report available for review	***150***	***89%***
General Permit Required Annual Report Contents	**Facilities In Compliance**	**Percentage of 5093 facilities with Annual Report (n=150)**
Quarterly non-stormwater discharge visual observations (B.3.c)	143	95%
Stormwater discharge visual observations (B.4)	144	96%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season, and (2) at least one other storm event in the wet season (B.5)	132	88%
Stormwater samples were analyzed for the appropriate parameters (B.5.c), includes facilities that collected fewer than the required number of samples	123	82%
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	129	86%
The facility operator conducted one comprehensive site compliance evaluation in each reporting period (July 1-June 30) (A.9)	132	88%
All analytical stormwater results were within EPA/Water Board benchmark values	85	57%
Annual Report was complete	***92***	***61%***

Benchmark value exceedances

SWPPP BMP implementation for the 5093-sample group was determined to be 79 percent, 109 SWPPPs identified BMPs but only 86 facilities fully implemented the BMPs identified in the SWPPP.

Distribution of rankings

Table A.8 Tabulation of Stormwater Ratings (5093)		
Rating	**No. of Facilities**	**Percentage of 5093 Total facilities (n=168)**
1 – Potential Threat to Stormwater Quality	34	20%
2 – Paperwork and minor yard violations	96	57%
3 – In Compliance	28	16%
* - Visited But Not Inspected	7	4%

A014443

SIC 42XX - Motor Freight Transportation and Warehousing

Total number of SIC 42XX facilities inspected - 163 facilities

Compliance with paperwork requirements

Table A.9 Compliance with General Permit SWPPP Requirements (42XX)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 42XX Facilities with a SWPPP (n=163)**
A SWPPP was developed and implemented (A.1)*	***113***	***69%***
General Permit Required SWPPP Contents	**Facilities in Compliance**	**Percentage of 42XX facilities with SWPPP (n=113)**
The SWPPP identified a specific individual or individuals and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	89	79%
The SWPPP included a site map (A.4)	101	89%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	103	91%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	105	93%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	106	94%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	110	97%
The SWPPP was signed and certified by the appropriate facility personnel	96	85%
Facility SWPPP met all General Permit requirements	***74***	***65%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan"

Table A.10 Compliance with General Permit SWMP Requirements (42XX)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 42XX Facilities with SWMP on-site (n=163)**
Facility developed a written stormwater monitoring program (B.1)	***106***	***65%***
General Permit Required SWMP Contents	**Facilities in Compliance**	**Percentage of 42XX facilities with SWMP (n=106)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	100	94%
SWMP describes stormwater discharge visual observations (B.4)	104	98%
SWMP describes stormwater sample collection procedures and protocols (B.5)	100	94%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	95	90%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	101	95%
Facility SWMP met all General Permit Requirements	***90***	***85%***

A01 4444

Table A.11 Compliance with General Permit Sampling and Monitoring Requirements (42XX)		
General Permit Requirement	**Facilities In Compliance**	**Percentage of 42XX Total (n=163)**
Previous year's annual report available for review	150	92%
General Permit Required Annual Report Contents	**Facilities In Compliance**	**Percentage of 42XX facilities with Annual Report (n=150)**
Quarterly non-stormwater discharge visual observations (B.3.c)	140	93%
Stormwater discharge visual observations (B.4)	140	93%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season, and (2) at least one other storm event in the wet season (B.5)	130	87%
Stormwater samples were analyzed for the appropriate parameters (B.5.c), includes facilities that collected fewer than the required number of samples	159	
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	131	87%
The facility operator conducted one comprehensive site compliance evaluation in each reporting period (July 1-June 30) (A.9)	141	94%
All analytical stormwater results were within EPA/Water Board benchmark values	106	71%
Annual Report was complete	***117***	***78%***

BMP implementation

SWPPP BMP implementation for the 42XX-sample group was determined to be 71 percent, 110 SWPPPs identified BMPs but only 78 facilities fully implemented the BMPs identified in the SWPPP.

Distribution of rankings

Table A.12 Tabulation of Stormwater Ratings (42XX)		
Rating	**No. of Facilities**	**Percentage of 42XX Total facilities (163)**
1 – Potential Threat to Stormwater Quality	25	15%
2 – Paperwork and minor yard violations	86	53%
3 – In Compliance	42	26%
* - Visited But Not Inspected	8	5%

A014445

327X - Concrete, Gypsum, and Plaster Products (Except 3274 Lime)

Total number of SIC 3274 facilities inspected - 158 facilities

Compliance with paperwork requirements

Table A.13 Compliance with General Permit SWPPP Requirements (327X)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 327X Facilities with a SWPPP (n=158)**
A SWPPP was developed and implemented (A.1)*	***110***	***70%***
General Permit Required SWPPP Contents	**Facilities in Compliance**	**Percentage of 327X facilities with SWPPP (n=110)**
The SWPPP identified a specific individual or individuals and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	84	76%
The SWPPP included a site map (A.4)	86	78%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	101	92%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	103	94%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	102	93%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	98	89%
The SWPPP was signed and certified by the appropriate facility personnel	85	77%
Facility SWPPP met all General Permit requirements	***59***	***54%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan"

Table A.14 Compliance with General Permit SWMP Requirements (327X)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 327X Facilities with SWMP on-site (n=158)**
Facility developed a written stormwater monitoring program (B.1)	***97***	***61%***
General Permit Required SWMP Contents	**Facilities in Compliance**	**Percentage of 327X facilities with SWMP (n=97)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	95	98%
SWMP describes stormwater discharge visual observations (B.4)	97	99%
SWMP describes stormwater sample collection procedures and protocols (B.5)	92	95%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	82	84%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	89	92%
Facility SWMP met all General Permit Requirements	***77***	***79%***

A014446

Table A.15 Compliance with General Permit Sampling and Monitoring Requirements (327X)		
General Permit Requirement	**Facilities In Compliance**	**Percentage of 327X Total (n=158)**
Previous year's annual report available for review	***134***	***85%***
General Permit Required Annual Report Contents	**Facilities In Compliance**	**Percentage of 327X facilities with Annual Report (n=134)**
Quarterly non-stormwater discharge visual observations (B.3.c)	126	94%
Stormwater discharge visual observations (B.4)	133	99%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season, and (2) at least one other storm event in the wet season (B.5)	107	80%
Stormwater samples were analyzed for the appropriate parameters (B.5.c), includes facilities that collected fewer than the required number of samples	130	97%
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	119	89%
The facility operator conducted one comprehensive site compliance evaluation in each reporting period (July 1-June 30) (A.9)	132	98%
All analytical stormwater results were within EPA/Water Board benchmark values	88	66%
Annual Report was complete	***78***	***58%***

BMP implementation

SWPPP BMP implementation for the 327X-sample group was determined to be 79 percent; 98 SWPPPs identified BMPs but only 78 facilities fully implemented the BMPs identified in the SWPPP.

Distribution of rankings

Table A.16 Tabulation of Stormwater Ratings (327X)		
Rating	**No. of Facilities**	**Percentage of 327X Total facilities (n=158)**
1 – Potential Threat to Stormwater Quality	37	23%
2 – Paperwork and minor yard violations	71	45%
3 – In Compliance	32	20%
* - Visited But Not Inspected	17	11%

A014447

347X - Coating, Engraving, and Allied Services

Total number of SIC 347X facilities inspected - 86 facilities

Compliance with paperwork requirements

Table A.17 Compliance with General Permit SWPPP Requirements (347X)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 347X facilities inspected (n=86)**
A SWPPP was developed and implemented (A.1)*	***68***	***79%***
General Permit Required SWPPP Contents	**Facilities in Compliance**	**Percentage of 347X facilities with SWPPP (n=68)**
The SWPPP identified a specific individual or individuals and their positions within the facility organization as members of a stormwater pollution prevention team (A.3)	54	79%
The SWPPP included a site map (A.4)	48	70%
The SWPPP included a list of significant materials handled and stored at the site (A.5)	52	76%
The SWPPP included a narrative description of the facility's industrial activities, associated potential pollutant sources, and potential pollutants that could be discharged in stormwater discharges or authorized non-stormwater discharges (A.6)	59	87%
The SWPPP included a narrative assessment of all industrial activities and potential pollutant sources (A.7)	60	88%
The SWPPP included a narrative description of stormwater BMPs to be implemented at the facility for each potential pollutant (A.8)	59	86%
The SWPPP was signed and certified by the appropriate facility personnel	*15*	*22%*
Facility SWPPP met all General Permit requirements	***10***	***15%***

* Facility representative produced a document titled "Stormwater Pollution Prevention Plan"

Table A.18 Compliance with General Permit SWMP Requirements (347X)		
General Permit Requirement	**Facilities in Compliance**	**Percentage of 347X facilities inspected (n=86)**
Facility developed a written stormwater monitoring program (B.1)	***63***	***73%***
Required SWMP Contents	**Facilities in Compliance**	**Percentage of 347X facilities with SWMP (n=63)**
SWMP describes procedures for quarterly non-stormwater visual monitoring (B.3)	60	95%
SWMP describes stormwater discharge visual observations (B.4)	60	95%
SWMP describes stormwater sample collection procedures and protocols (B.5)	58	92%
SWMP describes locations and outfalls for visual observation and sample collection (B.7)	60	95%
SWMP explains how the facility's monitoring program will satisfy the monitoring program objectives (B.10)	57	90%
Facility SWMP met all General Permit Requirements	***56***	***89%***

A014448

Table A.19 Compliance with General Permit Sampling and Monitoring Requirements (347X)		
General Permit Requirement	**Facilities In Compliance**	**Percentage of 347X facilities inspected (n=86)**
Previous year's annual report available for review	***84***	***98%***
Required Annual Report Contents	**Facilities In Compliance**	**Percentage of 347X facilities with Annual Report (n=84)**
Quarterly non-stormwater discharge visual observations (B.3.c)	72	86%
Stormwater discharge visual observations (B.4)	81	96%
Facility operators collected stormwater samples during the first hour of discharge from (1) the first storm event of the wet season, and (2) at least one other storm event in the wet season (B.5)	73	87%
Stormwater samples were analyzed for the appropriate parameters (B.5.c), includes facilities that collected fewer than the required number of samples	54	64%
Facility operators visually observed and collected samples of stormwater discharges from all drainage areas that represent the quality and quantity of the facility's stormwater discharges from the storm event (B.7)	63	75%
The facility operator conducted one comprehensive site compliance evaluation in each reporting period (July 1-June 30) (A.9)	77	92%
All analytical stormwater results were within EPA/Water Board benchmark values	25	30%
Annual Report was complete	***36***	***43%***

BMP implementation

SWPPP BMP implementation for the 347X-sample group was determined to be 98 percent; 59 SWPPPs identified BMPs and 58 facilities fully implemented the BMPs identified in the SWPPP.

Distribution of rankings

Table A.20 Tabulation of Stormwater Ratings (347X)		
Rating	**No. of Facilities**	**Percentage of Total facilities (n=86)**
1 – Potential Threat to Stormwater Quality	14	16%
2 – Paperwork and minor yard violations	51	59%
3 – In Compliance	21	24%
* - Visited But Not Inspected	0	0%

A014449

Storm Water Panel Recommendations to the California State Water Resources Control Board

The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial and Construction Activities

December 14, 2006

Eric Strecker, Mike Stenstrom, and Ken Schiff

A014450

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Panel of experts was asked to consider the following:

- "Is it technically feasible to establish numeric effluent limitations, or some other quantifiable limit, for inclusion in storm water permits?
- How would such limitations or criteria be established, and what information and data would be required?"

Panel of experts was asked to consider the following:

- "The answers should address industrial general permits, construction general permits, and area-wide municipal permits.
- The answers should also address both technology-based limitations or criteria and water quality-based limitations or criteria.
- In evaluating establishment of any objective criteria, the panel should address all of the following:
  - (1) The ability of the State Water Board to establish appropriate objective limitations or criteria;
  - (2) how compliance determinations would be made;
  - (3) the ability of dischargers and inspectors to monitor for compliance; and
  - (4) the technical and financial ability of dischargers to comply with the limitations or criteria."

What we were not asked to do:

- Recommend whether or not effluent standards should be adopted
- Specify which technology(ies) should or should not be employed
- Develop details regarding how to implement our recommendations

Report

- Decided to have one report
- Municipal is discussed first
- Construction and Industrial were shorter as they refer to municipal sections on a number of points
- Panels role was not to comment on current requirements (e.g. TMDLs, BAT/BCT, whether water quality standards are correct, etc.)
- Panel did take significant time to agree on a consensus document
- Gives panel findings and then recommendations
- Did not have any staff or other resources for development of report, other then minimal editing assistance

Municipal vs. Industrial Permits and Other Considerations

- Municipal is subject to "Maximum Extent Practicable
- Industrial is subject to BAT/BCT (Best Available Technology/Best Control Technology) standards
- Construction permits are Industrial Permits
- TMDLs require that loading limits be applied in NPDES permits

Municipal Stormwater Findings

1. BMPs in general have not worked because:
   - BMP design requirements almost always don't consider
     - the pollutants and/or parameters of concern,
     - the form(s) that the pollutants or parameters are in,
     - the hydrologic and hydraulic nature of how they pollutants and flow arrive, and
     - the resulting unit processes (treatment and/or flow management processes) that would be required to address these pollutants or parameters
   - The permitting agencies generally are not accountable for the performance of BMPs
   - The developer is not responsible in most all cases for the performance of BMPs
   - BMPs typically not maintained properly except for aesthetic purposes in many cases.

Municipal Stormwater Findings

2. The principal reasons for the failure of BMP performance is improper BMP selection, design and/or lack of maintenance.
   - The California BMP Handbooks and other local requirements leave too much of the BMP selection and design to the discretion of the designer, and thus do not address many if not all of the receiving water quality issues
   - BMPs need to be *designed to facilitate maintenance*; this is rarely done because it costs the developer [or permittees] money and the BMP designer is rarely responsible for the maintenance.
   - BMPs require more maintenance than other types of stormwater control facilities
     - untrained homeowner associations and maintenance personnel for commercial properties,
     - stormwater agencies often do not have and/or apply the resources necessary to maintain agency owned BMPs nor inspect private ones.

Municipal Stormwater Findings

3. Improvements in the design of municipal BMPs, including residential and commercial as well as municipally owned facilities are necessary to ensure better performance (i.e. sizing, geometry, inlet and outlet design, etc.) and to specifically target receiving water quality issues.

Existing Effluent Limit Approaches Don't Address The Multiple Stressors:

- Increased flows and/or volumes (i.e. hydromodification) and resulting stream channel erosion/sedimentation
- Sediment contamination
- Impaired aesthetic value
- Unsafe conditions
- Dissolved and suspended pollutants that are bioavailable in the water column and/or result in downstream sediment contamination
- Elevated temperatures

Other Considerations

- Need for more rigorous design and enforced maintenance
- International BMP Database
- Other Data
- Need for treatment trains to meet multiple objectives
- Consideration of presumptive approach
- Existing vs. new development

Municipal Recommendations

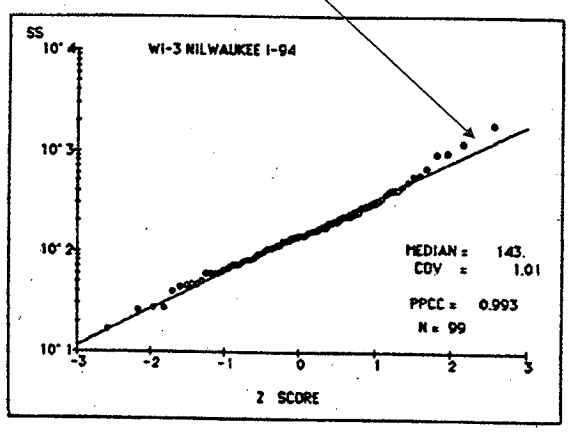
- It is not feasible at this time to set enforceable numeric effluent criteria for municipal BMPs and in particular urban discharges
- Possible to select and design BMPs much more rigorously with respect to the physical, chemical and/or biological processes that take place within them, providing more confidence that the estimated mean concentrations of constituents in the effluents will be close to design targets.
- Moreover, with this more rigorous design and an enforceable maintenance program, it can be presumed that these facilities will continue to deliver effluent qualities that are reasonably close to the design effluent concentrations over the life of the facility
- Given the number of multiple pollutants and other stressors, treatment trains will be required to meet goals

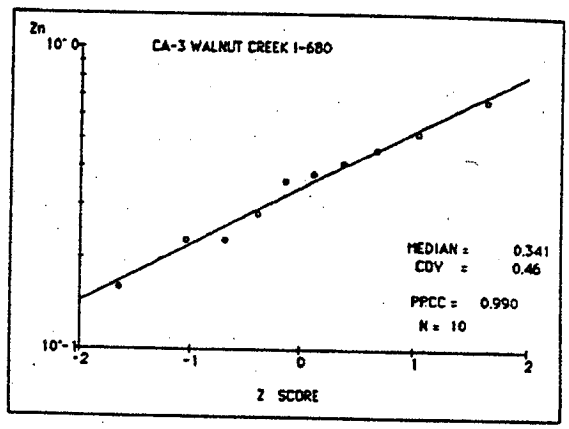
Existing Development

- For catchments not treated by a structural or treatment BMP, setting a numeric effluent limit is basically not possible.
- However, setting an "upset" (Action) value is possible using:
  - Consensus value (e.g. 100 ppb dissolved Cu is to much)
  - Percentile of observed values
  - Statistically-based population parameters of observed values

Percentile of observed values

- 95% Value





Statistically-based population parameters of observed values

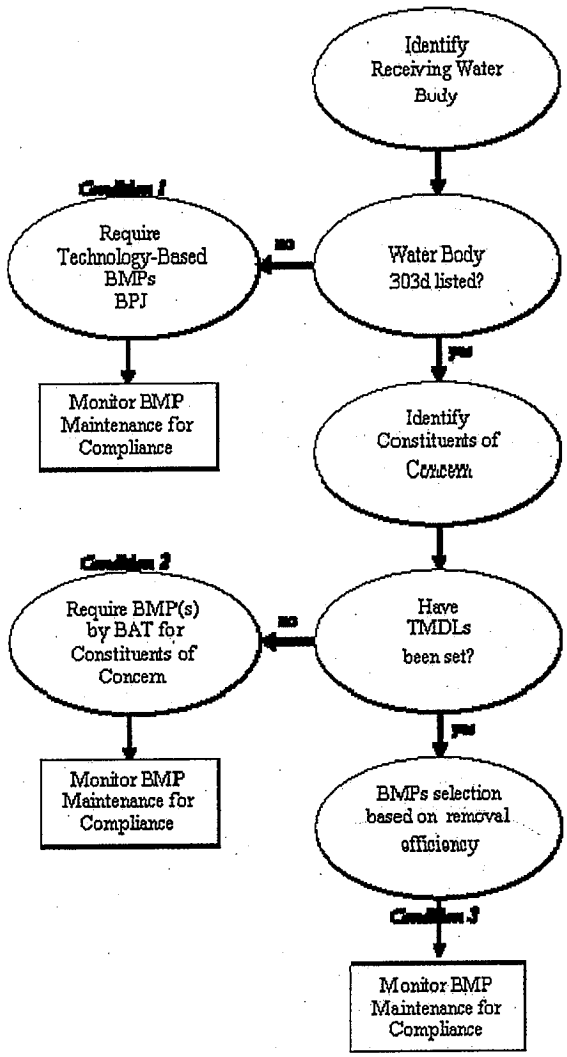
- e.g. two standard deviations above the mean urban concentration

Include Exceedance Storm or Intensity

- Concept that BMPs sizing is important
- Agencies should not be accountable for water quality in volumes or flows above a set design level

New developments

- Conditions:
  - No listings
  - 303D listings
  - TMDLs established



Construction Findings

- Traditional Erosion and Sediment Controls on a site basis are variable in performance
- Site to site variability in TSS/Turb on natural sites is also quite high
- Active treatment systems, including those that use Polymers and sedimentation (*and electro-flocculation*) have been demonstrated to achieve low turbidity consistently for a wide range of storms
- Other pollutants have not received enough emphasis
- Permits do not require training or certification
- The quality of stormwater discharges from construction sites that effectively employ BMPs likely varies due to site conditions such as climate, soil, and topography
- The States of Oregon and Washington have recently adopted similar concepts to the Action Levels described earlier

Panel's Conclusion

- It is the consensus of the Panel that active treatment technologies make Numeric Limits technically feasible for pollutants commonly associated with stormwater discharges from construction sites (e.g. TSS and turbidity) for larger construction sites.
- While the Panel concludes that Numeric Limits or Action Levels are technically feasible, the Panel has several [13 of them] reservations and concerns

Reservations and Concerns

- The active systems have generally been applied to larger sites and either smaller sites or a large site with multiple drainage may not be feasible
- Full consideration must be given to whether issues related to toxicity or other environmental effects of the use of chemicals has been fully answered.
  - longer-term effects of chemical use,
  - operational and equipment failures or
  - other accidental excess releases.
- Consideration should be given to the seasonality of applying Numerical Limits. (don't de-incentive grading timing).

Reservations and Concerns

- Apply to construction sites with exposed graded areas, not ones that have been stabilized
- Where Numeric Limits are not feasible employ Action Levels for sites where only traditional erosion and sediment controls are applied or construction sites that are considered "stabilized" for the runoff season.
  - An Action Level indicates a failure of BMPs (within some storm size limits).
- The Board should consider Numeric Limits or Action Levels for other pollutants of relevance to construction sites, but in particular pH.

Reservations and Concerns

- The Board should consider the phased implementation of Numeric Limits and Action Levels, commensurate with the capacity of the dischargers and support industry to respond.
- The Panel recommends that a Numeric Limit or Action Level should be compared to the average discharge concentration.
- The Board should set different Action Levels that consider the site's climate region, soil condition, and slopes, and natural background conditions (e.g. vegetative cover) as appropriate and as data is available.
- With active treatment systems, discharge quality is relatively independent of these conditions. In fact, active treatment systems could result in turbidity and TSS levels well below natural levels, which can also be a problem for receiving waters.

Reservations and Concerns

- The Board should consider whether the Numeric Limits or Action Levels should differ between receiving waters that are water quality limited with respect to turbidity, sediment or other pollutants associated with construction, from those water bodies that are not water quality limited.
- The Panel recommends that Numeric Limits and Action Levels not apply to storms of unusual event size and/or pattern (e.g. flood events). The determination of Water Quality Capture Volume should consider the differing climate regions to specify these events.

Reservations and Concerns

- The Board should set Numeric Limits and Action Levels to encourage loading reductions as appropriate as opposed to only numeric concentrations.
  - phased construction (e.g. limited exposed soil areas or their duration), infiltration, and spraying captured runoff in vegetated areas as means to reduce loading.
- The Panel is concerned that the monitoring of discharges to meet either the Action Levels or Numeric Limits may be costly. The Panel recommends that the Board consider this aspect.

Construction

- The recommendations do not say one must use active treatment
- The recommendations do not say that polymers are the only technology
  - Chitosan
  - Gypsum
  - Electomagnetic (e.g. no chemicals)
- The recommendations do not say use Washington States Design Storm Level
- Questionable if Active systems are even allowed in California with a WDR at this time

Industrial Observations

- The Panel believes that Numeric Limits are feasible for some industrial categories.
- The decision for the value of Numeric Limits should be made in one of two ways.
  - TMDL that defines the permissible load for a watershed, the Numeric Limits should be set to meet the TMDL.
  - When there is no TMDL, the Numeric Limits should be based upon sound and established practices for storm water pollution prevention and treatment,
    - Numeric Limits set that based upon the use of best currently available technology, and a defined period for compliance.
    - Include categories, with the recognition that each industry has its own specific problems and financial viability.

Industrial Activities Similar to Land Disturbance Activities

- e.g. landfills, gravel mines, etc.
- runoff control, capture and advanced treatments systems (e.g. systems using polymers to enhance total suspended solids removal that may make Numeric Limits feasible for new facilities, and the approach and limits should be the same as for construction permittees.
- The same conditions and issues related to active treatment discussed in the construction section apply here.

Other Industries

- In cases where there is less certainty in the data for both stormwater characterization or BMP performance to establish Numeric Limits, there may be sufficient data to establish Action Levels.
- Action Levels set for industrial sites that discharge to MS4s should not exceed those set for MS4 permittees.

Approach to Establish Numeric Limits or Action Levels at Existing or New Industrial Facilities

		Numeric Limits	Action Levels	Notes
Existing Facility	Indoor	No	Yes, similar to MS4	
	Outdoor	Yes if data are adequate for the specific industrial activity and BMP	Yes, using industrial database	Action Levels should approach MS4 action levels.
New Facility	Indoor	Yes – BMP Database		Technology based, similar to MS4 New Development
	Outdoor	No, unless sufficient data exist for the specific industrial activity and BMP	Yes when sufficient data are available	

Reservations and Concerns

- The Panel recognizes the inadequacy of current monitoring data sets and recommends improved monitoring to collect data useful for establishing Numeric Limits and Action Levels.
- Required parameters for future monitoring should be consistent with the type of industrial activity instead of the current parameters
- Insofar as possible, the Panel prefers the use of California data in setting Numeric Limits and Action Levels.
- The Panel recognizes that economies of scale exist for large facilities and large groups of single facilities.
- Industrial facilities that do not discharge to MS4s should have to implement BMPs for their non-industrial exposure (e.g., parking lots, roof runoff) similar to commercial facilities in MS4 jurisdictions.

Reservations and Concerns

- Regardless of Action Levels or Numeric Limits, the permittees should implement a suite of minimum BMPs – good housekeeping, employee training, preventing materials from exposure to rain, etc.
- SIC categories are not a satisfactory way of identifying industrial activities at any given site. The Board should develop a better method of characterizing industrial activities that can impact storm water.
- The Panel recognizes this is a large task and recommends prioritizing the implementation of this approach to achieve the greatest reduction of pollutants statewide.

Reservations and Concerns

- Increasingly, a number of industries have moved industrial activities indoors, preventing storm water pollution. The Panel recognizes that these facilities should be granted some sort of regulatory relief from industrial Numeric Limits or action levels, but should still be required to comply with MS4 permit requirements *(or similar level).*

- The Panel recognizes the need to make progress in monitoring and reducing storm water discharge from industrial facilities, but urges the Board to consider the total economic impact and not unduly penalize California industries with respect to industries outside of California.

Oakland to Tax Fast-Food Places Over Trash

Associated Press

Wed Feb 8, 5:05 PM ET

Fed up with burger wrappers, french fry containers and paper cups, Oakland officials have decided to force fast-food restaurants, convenience stores and other businesses to help pay for cleaning up street trash.

Under a tax approved Tuesday night by the City Council, businesses will be assessed between $230 and $3,815 annually, depending on their size. More than three-quarters of the affected businesses would pay only the minimum fee, which amounts to 63 cents a day.

"I don't think that's too much to ask so neighbors don't have to keep picking up trash from their doorways," said Councilwoman Jane Brunner, who proposed the measure.

The city would use the projected $237,000 a year to hire small crews to pick up litter in commercial areas around high schools and middle schools where most of the garbage is found.

The fee was opposed by the Metropolitan Oakland Chamber of Commerce and business organizations that say the costs will be passed along to customers, including low-income residents and young people who are the biggest consumers of fast food.

The California Restaurant Association said it is considering a lawsuit to keep the tax from taking effect.

In 2000, the Illinois Restaurant Association and two restaurant owners successfully sued the city of Chicago after a half-percent "litter tax" was imposed on carryout restaurants. The restaurants claimed the measure was unconstitutional.

Businesses in Oakland say the city should educate the public and enforce littering laws. Some say they already pay employees to pick up trash in their neighborhoods.

Litter from fast-food restaurants has become a major problem in communities nationwide.

Recent surveys show that fast-food packaging makes up about 20 percent of all litter, with packaging for chip bags, drink containers, candy wrappers and other snacks comprising another 20 percent, said Rob Wallace, a spokesman for Keep America Beautiful, a Stamford, Conn.-based nonprofit group.

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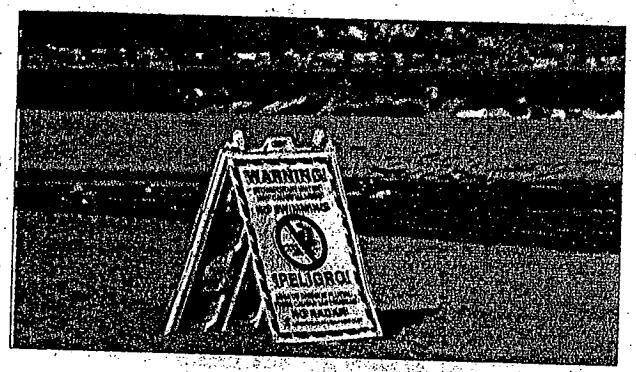
Ventura, state's beach closures increased in '98



FOUL: Swimmers are warned to avoid Malibu Lagoon waters, foreground, as surfers ride waves at Malibu's Surfrider Beach. The lagoon collects foul water from septic tanks and other creek contaminants.

The Associated Press

DIRTY WATER: *Rain, sewage spill contribute to triple number of shutdowns over '97.*

By Brett Johnson
Staff writer

Beach closures and health advisories almost tripled statewide in 1998 over the previous year because of heavy rains, an environmental group said Thursday in its annual report on beaches in California and nationwide.

Almost 90 percent of the closures and advisories occurred in the five-county Southern California region that includes Ventura County, the Natural Resources Defense Council said in its ninth annual "Testing the Waters" report. El Niño-spawned rains that brought polluted runoff to the ocean and also led to sewage spills were the prime reason for the increases, though the group admitted that increased monitoring meant greater detection of problems.

Ventura County had 237 days of beach closures and advisories in 1998, up from 1997's six days. Much of the 1998 totals stemmed from the massive sewage spill from a Thousand Oaks treatment plant that closed numerous

Please see **BEACHES** *on* **A10**

APR 1 1999

BEACHES: Sewage spill hits Ventura hard

Continued from **A1**

beaches downstream for a number of days. Under the NRDC's counting system, a beach closure or health advisory at nine beaches for 10 consecutive days would be listed as 90 days, for example.

Bob Gallagher, manager of Ventura County's ocean water quality program, said closures here are isolated. Most occur during winter months, when ocean use is not heavy. "For the most part, our beaches meet standards for bacteria," he said.

High bacteria levels in water can cause a variety of illnesses, including flu-like symptoms and hepatitis. The NRDC called for tighter controls on storm water runoff and improvements in sewage treatment plants.

"El Niño ... is not an excuse," NRDC staff attorney Alex Helperin said. "The problem isn't that it washed away stuff we leave behind. The problem is what we're leaving behind. Take those two (runoff pollution and sewage spills) away and you will reduce a large percentage of the problem. These things have to be upgraded."

State officials, Gallagher indicated, are looking at ways to reduce sewage-caused beach closures. The county has a storm water runoff program, but, Gallagher, said it will always be difficult to keep drains and creeks clear of materials that can foul water. Runoff can carry natural oil seeps, decaying vegetation, silt as well as human and animal wastes.

Helperin said solutions don't have to be costly and can be as simple as collection basins that catch oil and grease in parking lots, for example.

People are told to avoid ocean water for 72 hours after a heavy rain. Helperin said that should not excuse the need for improvements. Many of the 1998 beach closures lasted for more than three days, he noted, adding that billions of tourism dollars are tied into beach and coastal attractions.

Tourists, surfers, swimmers and others might benefit from enhanced state cleanup and preservation efforts. A record share of California's next state budget will be spent preserving the state's 1,100-mile coastline.

After dropping to a low of $4.4 million in 1994-95, the budget for purchasing and preserving coastal property jumped to $82.3 million, said Fred Klass, program budget manager for the state Department of Finance.

The NRDC found there were 7,253 beach closures or advisories nationwide last year, a 75 percent increase over 1997.

Nine states, the report said, have comprehensive monitoring of water quality at beaches and public notification. California is one of 13 states with limited monitoring. Helperin said California will move up to the highest level once a state law is fully implemented.

Ventura County is one of nine in the state that tests ocean water quality weekly. Results for 52 beach locations are available Thursdays after 3 p.m. at 662-6555 or www.ventura.org/envhlth/env.htm.

The NRDC, which has more than 400,000 members nationwide, is a nonprofit organization of scientists, lawyers and environmental specialists devoted to protecting public health and the environment.

— The Associated Press contributed to this story.

Beach monitoring standards vary

Much of the increase in beach closures and advisories is due to El Niño, but part of it is increased monitoring, the Natural Resources Defense Council said. The group warned, however, that monitoring standards are inconsistent. At the state level, it cited these variations:

WEAKEST
Lack any regular monitoring of beach water for swimmer safety
Alabama, Louisiana, Oregon and Washington

WEAK
Have monitoring programs but no public notification system
Mississippi, Texas and the territory of Puerto Rico

BETTER
Monitor and notify for "a portion" of their beaches
California, Florida, Hawaii, Maine, Maryland, Massachusetts, Michigan, Minnesota, Rhode Island, South Carolina, Virginia, Wisconsin and New York

BEST
Comprehensively monitor "most or all" beaches and notify the public of health hazards
Connecticut, Delaware, Illinois, Indiana, New Hampshire, New Jersey, North Carolina, Ohio

Source: Natural Resources Defense Council

Budget breakdown

California Coastal Conservancy 1999-2000 budget includes:

Natural Communities Conservation Planning Program	$5 million
Habitat Conservation Fund	$4 million
Unscheduled Augmentation	$7.5 million
Coastal Access Account	$700,000
Renewable Resources Investment Fund	$1.2 million
Coastal Challenge Grants	$10 million
Southern California Wetlands Clearinghouse	$5.6 million
Public Resources Account	$1.3 million
Environmental License Plate Fund	$146,000
San Francisco Bay Trail	$2.5 million
Otay River	$3.25 millic
San Francisco Bay Area Conservancy	$10 million
Gaviota Coast	$5 million
Palo Corona Ranch (Big Sur)	$5 million
Union Point Park (Oakland Waterfront)	$1.5 million
Maywood River Park (Los Angeles River Greenway)	$1.8 million
Los Angeles River (Elysian Valley)	$1.5 million
Chollas Creek	$1.25 million
Mendocino Coast	$3 million
Bolinas Lagoon	$1.5 million
Tijuana River Valley	$2 million
Total	**$73.7 million**

A014485

2005 Plastic Debris, Rivers to Sea Conference

Focusing on the Land-Based Sources of Marine Debris

September 7th

8:00-8:45	**Registration, Coffee & Light Breakfast, Exhibits**
8:45-9:30 Peninsula and Pacific	**Welcome and Introductory Remarks** Featured Speaker: Terry Tamminen, California Cabinet Secretary
9:30-10:00 Peninsula and Pacific	**Keynote Address**: Philippe Cousteau, Earth Echo International
10:00-10:40 Peninsula and Pacific	**Plastic: Current Uses and Benefits, and How It Behaves in the Ocean**
	Break Exhibits in Redondo Ballroom
10:50-12:20 Peninsula and Pacific	**Marine Debris: Sources, Distribution, Composition**
12:20-1:20 Seascape	**Luncheon** Exhibits in Redondo Ballroom **Speaker:** H. David Nahai, California Regional Water Quality Control Board, Los Angeles Region
1:20-2:25 Pacific	**Education and Outreach to Reduce Trash in Urban Runoff**
1:20-2:25 Peninsula	**Plastic Industry Efforts to Reduce Discharges to Storm Water**
2:30-3:40 Pacific	**State and Local Approaches to Solid Waste and Litter Reduction**
2:30-3:40 Peninsula	**Innovative Debris and Trash Monitoring Techniques-Aiding Our Understanding of Land-Based Discharges**
3:40-3:50	**BREAK** Exhibits in Redondo Ballroom
3:50-5:00 Pacific Ballroom	**Characterizing Sources of Debris and Trash in Urban Runoff**
3:50-5:00 Peninsula	**National and International Efforts to Reduce Marine Litter**
6:00 -	**Dinner: Splash Restaurant at the Crowne Plaza** *Each dish is delish!*

September 8th

7:45-8:45 Redondo	**Coffee, Light Breakfast, Exhibits**
8:45-9:00 Peninsula and Pacific	**Welcoming Remarks** Featured Speaker: Jerry Secundy, State Water Resources Control Board
9:00-9:40 Peninsula and Pacific	**Keynote Address for Day 2: William McDonough, William McDonough + Partners**
9:40-9:50	**Break** Exhibits in Redondo Ballroom
9:50-10:35 Pacific	**Public Perception of the Trash and Debris Problem**
9:50-10:35 Pacific	**A Hitchhikers Guide to Plastic Debris**
10:40-11:40 Pacific	**Impacts of Marine Debris on Seabirds and Efforts to Mitigate Them**
10:40-11:40 Peninsula	**Addressing Trash in Urban Runoff through Water Quality Regulation**
11:40 –12:00 Pacific	**Preview of the video:** *Plastic Debris, Rivers to Sea*
12:00-1:00 Seascape	**Luncheon** Exhibits in Redondo Ballroom
1:00-2:15 Pacific	**Structural Controls for Trash in Urban Runoff**
1:00-2:15 Peninsula	**World-Wide Trends in Solid Waste Source Reduction**
2:20-3:35 Pacific	**Developing Education and Outreach Based on Technical Data**
2:20-3:35 Peninsula	**Trash in Urban Runoff: Structural Control Measures**
3:35-3:45	**BREAK** Exhibits in Redondo Ballroom
3:45-4:45 Pacific Ballroom Peninsula Ballroom Marina Room Esplanade Room	**New Directions: Four Simultaneous Dialogues** **Error! Unknown switch argument.** Improving Coordination Among Regional Programs to Control Marine Debris. **Error! Unknown switch argument.** Degradable and Compostable Plastic: Viability and Efficacy as a Solution to Marine Debris. **Error! Unknown switch argument.** Future Monitoring and Research Needs. **Error! Unknown switch argument.** Trash TMDLs. Information Resources and Needs.
4:45-5:00 Pacific	**Closing Remarks and Conference Wrap-up**

A014487

September 9th

WORKSHOP
California Action Plan to Reduce the Discharge of Marine Debris from Land-Based Sources
(by invitation only)

9:00-12:00	**Morning Sessions**
12:00-1:00	**Lunch** Seascape Ballroom
1:00-5:00	**Afternoon Sessions**

FIELD TRIPS

9:00-12:00	**Tour of the Hamilton Bowl Debris Collection System with City of Signal Hill**
9:00-12:00	**Monitoring and Sample Collection Aboard the Research Vessel, *Alguita,*** with Algalita Marine Research Foundation (AMRF)
12:00-1:00	**Lunch** Seascape Ballroom
1:00-3:00	**Tour of the S.E.A. Lab and AMRF Lab**- opportunity to analyze samples collected aboard the *Alguita* in the morning

A014488

Conference Agenda

Day One: September 7

8:00-8:45
Redondo Ballroom

Registration, Coffee & Light Breakfast, Exhibits

8:45-9:30
Peninsula and Pacific Ballrooms

Plenary Session

Welcome and Introductory Remarks

- Mike Gin, Mayor of the City of Redondo Beach
- Charles Moore, Algalita Marine Research Foundation
- Stephen Leatherman, H. John Heinz III Center for Science, Economics, and Environment
- Meg Caldwell, California Coastal Commission
- Terry Tamminen, California Cabinet Secretary

9:30-10:00
Peninsula and Pacific Ballrooms

Plenary Session

Keynote Address

- Philippe Cousteau, Earth Echo International

10:00-10:40
Peninsula and Pacific Ballrooms

Plenary Session

Plastic: Current Uses and Benefits, and How It Behaves in the Ocean
Moderator: Charles Moore, Algalita Marine Research Foundation

- **Plastic Materials Worldwide: Quantities, Uses, Social and Economic Benefits.** Pete Grande, Command Packaging and California Film Extruders and Converters Association
- **Plastics and the Oceans: A Technical Perspective.** Anthony Andrady, Research Triangle Institute

Break Exhibits in Redondo Ballroom

10:50-12:20
Peninsula and Pacific Ballrooms

Plenary Session

Marine Debris: Sources, Distribution, Composition
Moderator: Dominic Gregorio, State Water Resources Control Board

- **Marine Debris: Onshore, Offshore, and Seafloor Litter.** Allan Williams, University of Glamorgan, Wales
- **Lost at Sea: Where Does All the Plastic Go? The Accumulation and Environmental Consequences of Microscopic Plastic Debris.** Richard Thompson, University of Plymouth, United Kingdom
- **Three Receptacles for Marine Debris in Southern California: Are the Sources and Concerns the Same?** Stephen B. Weisberg, Southern California Coastal Water Research Project
- **A Comparison of Plastic Debris in Near Coastal Waters of California and the Mid-Pacific Central Gyre.** Charles Moore, Algalita Marine Research Foundation

A014489

12:20-1:20
Seascape Ballroom

Luncheon Exhibits in Redondo Ballroom
Speaker: H. David Nahai, Regional Water Quality Control Board, Los Angeles Region

1:20-2:25
Pacific Ballroom

Concurrent Session

Education and Outreach to Reduce Trash in Urban Runoff
Moderator: Christiane Parry, California Coastal Commission

- **CalTrans "Don't Trash Fresno" Public Education Research Study.** Christie Black, APR, Ogilvy Public Relations
- **California's Coastal Cleanup Day: Changing Behaviors and Improving the Coast by Reaching Inland.** Eben Schwartz, California Coastal Commission
- **The Malibu Foundation's Adopt-A-Beach School Assembly Program.** Michael Klubock, The Malibu Foundation

1:20-2:25
Peninsula Ballroom

Concurrent Session

Plastic Industry Efforts to Reduce Discharges to Storm Water
Moderator: Deborah Neiter, Los Angeles Regional Water Quality Control Board

- **Industry Initiatives and Challenges.** Steven Jones, Society of the Plastics Industry and JATCO Corp.
- **Methods for Monitoring the Discharges of the Plastic Industry in Southern California.** Gwen Lattin and Ann Zellers, Algalita Marine Research Foundation
- **Implementation of Voluntary Best Management Practices at Plastic Industry Facilities: Measuring the Effectiveness of Operation Clean Sweep.** Charles Moore, Algalita Marine Research Foundation
- **Practical Approaches to Design and Installation of Screening Technologies.** William Harris, Stormwater360

2:30-3:40
Pacific Ballroom

Concurrent Session

State and Local Approaches to Solid Waste and Litter Reduction
Moderator: Steve Aceti, California Coastal Coalition

- **CIWMB Programs: Waste Characterization, Large Venue Recycling, and Recycling Challenges.** Michael Leaon, California Integrated Waste Management board
- **Bag-to-Bag Recycling in the City of San Juan Capistrano.** Ziad Mazboudi, City of San Juan Capistrano
- **City of Malibu Polystyrene Ban.** Katie Lichtig, City of Malibu
- **Reducing Bag Litter through a Public Private Partnership: Progressive Bag Alliance and the L.A. Ad Hoc River Committee.** Laurie Hansen, Progressive Bag Alliance

2:30-3:40
Peninsula Ballroom

Concurrent Session

Innovative Debris and Trash Monitoring Techniques-Aiding Our Understanding of Land-Based Discharges
Moderator: Ann Riley, San Francisco Bay Regional Water Quality Control Board

- **Patterns of Debris Movement: From an Urban Estuary to a Coastal Embayment.** Scott P. Wilson, Centre for Environmental Restoration and Stewardship, Australian Catholic University
- **Working Our Way Upstream: A Snapshot of Land-Based Contributions of Plastic and Other Trash to Coastal Waters and Beaches.** Gwen Lattin / Ann Zellers, Algalita Marine Research Foundation
- **A Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Measurement in Streams.** Steven M. Moore, San Francisco Bay Regional Water Quality Control Board

A014490

3:40-3:50	**BREAK** Exhibits in Redondo Ballroom
3:50-5:00 Pacific Ballroom Concurrent Session	**Characterizing Sources of Debris and Trash in Urban Runoff** Moderator: Christiane Parry, California Coastal Commission • **Waste Characterization Studies of Trash in Urban Runoff in California.** Shelly Moore, Southern California Coastal Water Research Project • **L.A. River Clean Up and Waste Characterization, and the City of Los Angeles Plastic Task Force.** Shelly Backlar, Friends of the Los Angeles River • **City of Oxnard Stormdrain Keeper Program, Combining Education, Monitoring, and Waste Characterization.** Mark Pumford, City of Oxnard Wastewater Division
3:50-5:00 Peninsula Ballroom Concurrent Session	**National and International Efforts to Reduce Marine Litter** Moderator: Sheila David, H. John Heinz III Center for Science, Economics and the Environment • **National Efforts to Reduce Marine Debris.** Holly Bamford, U.S. National Oceanic and Atmospheric Administration • **Beach Debris: Characterized through the International Coastal Cleanup and the U.S. National Marine Debris Monitoring Program.** Seba Sheavly, The Ocean Conservancy • **U.S. EPA's Role in the Prevention and Control of Marine Debris.** Katherine Bruce, U.S. Environmental Protection Agency
6:00 -	**Dinner: Splash Restaurant at the Crowne Plaza** *Each dish is delish!*

A014491

Day Two: September 8

7:45-8:45
Redondo Ballroom

Coffee, Light Breakfast, Exhibits

8:45-9:00
Peninsula and Pacific Ballrooms

Plenary Session

Welcoming Remarks

- Miriam Gordon, California Coastal Commission
- Jerry Secundy, State Water Resources Control Board
- Sheila David, H. John Heinz III Center for Science, Economics and the Environment

9:00-9:40
Peninsula and Pacific Ballrooms

Plenary Session

Keynote Address for Day 2

- William McDonough, William McDonough + Partners

9:40-9:50

Break Exhibits in Redondo Ballroom

9:50- 10:35
Pacific Ballroom

Concurrent Session

A Hitchhiker's Guide to Plastic Debris: Do Plastics Transport Persistent Organic Chemicals Pollutants?
Moderator: Eric Stein, Southern California Coastal Water Research Project

- **Marine Plastic Resin Pellets: Carrier of Organic Micropollutants to Marine Organisms and a New Tool to Monitor Persistent Organic Pollutants-** Hideshige Takada, University of Tokyo
- **AMRF Findings on Persistent Organic Pollutants in and on Plastics in Urban Runoff-** Charles Moore, Algalita Marine Research Foundation

9:50-10:35
Peninsula Ballroom

Concurrent Session

Impacts of Marine Debris on Wildlife and Efforts to Mitigate Them
Moderator: Frank Csulak, U.S. National Oceanic and Atmospheric Administration

- **Seabirds as Indicators of Plastic Pollution in the North Pacific.** Hannah Nevins, Moss Landing Marine Laboratories
- **Reducing Marine Debris: Derelict Fishing Gear Removal Programs in Hawaii, Washington and California.** Kirsten Gilardi, U.C. Davis, Sea Doc Society

10:40-11:40
Pacific Ballroom

Concurrent Session

Public Perception of the Trash and Debris Problem
Moderator: Stephen Groner, S. Groner Associates

- **Voter Opinion Research Regarding Trash, Debris and Storm Drain Runoff.** John Fairbank, Fairbank, Maslin, Maullin & Associates
- **Paper or Plastic? Deconstructing One of Life's Everyday Questions.** Daniel Imhoff, Watershed Media

10:40-11:40
Peninsula Ballroom

Concurrent Session

Addressing Trash in Urban Runoff through Water Quality Regulation
Moderator: Michael Lauffer, State Water Resources Control Board

- **Regulatory Approaches to Preventing Trash and Debris in Urban Runoff: An Overview of the Storm Water and NPDES Regulatory Program (Industrial Permits and Municipal Permits).** Jonathan Bishop, Los Angeles Regional Water Quality Control Board
- **TMDLs for Trash in Los Angeles and Ventura Counties.** Melinda Becker, Los Angeles Regional Water Quality Control Board

11:40 –12:00

Preview of the Video: *Plastic Debris, Rivers to Sea*

A014492

Pacific Ballroom

12:00-1:00
Seascape Ballroom

Luncheon Exhibits in Redondo Ballroom

1:00-2:15
Pacific Ballroom

Concurrent Session

Structural Controls for Trash in Urban Runoff
Moderator: Dominic Gregorio, State Water Resources Control Board

- **Trash in Urban Rivers and Watersheds, Structural Controls Implemented by L.A. County.** Bill DePoto, L.A. County Department of Public Works
- **Debris Nets in the San Gabriel River: Design and Physical Modeling.** Russell H. Boudreau, Moffat & Nichol
- **Netting Technology: Full Capture Certification for Trash & Floatables.** Clint Holland, Fresh Creek Technologies

1:00-2:15
Peninsula Ballroom

Concurrent Session

World-Wide Trends in Solid Waste Source Reduction
Moderator: Richard Anthony, California Resource Recovery Association

- **Searching for Source Reduction Solutions: Producer Responsibility and Other Options.** Mark Murray, Californians Against Waste
- **Stopping Plastic Beverage Bottle Debris at the Source.** Pat Franklin, Container Recycling Institute
- **Reducing the Costs of Plastic Cleanup through Local Action.** Stephanie Barger, Earth Resources Foundation

2:20-3:35
Pacific Ballroom

Concurrent Session

Developing Education and Outreach Based on Technical Data
Moderator: Stephen Leatherman, H. John Heinz III Center for Science, Economics and the Environment

- **Public Education by the Numbers: Tuning up your Outreach Plan Based on the Technical Data.** Stephen Groner, S. Groner Associates
- **Solid Waste Contamination of Tropical Beaches: From Conflict of Use to Indicator of Change.** Monica Costa, Federal Universidade of Pernambuco (UFPE), Brazil
- **The California Erase the Waste Campaign.** Tom Mays, State Water Resources Control

2:20-3:35
Peninsula Ballroom

Concurrent Session

Trash in Urban Runoff: Local and State Government Structural Control Measures
Moderator: Richard Boone, Orange County Stormwater Program

- **City of Los Angeles Trash Total Maximum Daily Load Implementation Plan.** Shahram Kharaghani, City of Los Angeles
- **Evolution of Trash Management for CALTRANS Freeways.** Timothy Sobelman, California Department of Transportation; David Alderate, Cal State University
- **City of Santa Monica's Trash Control Measures.** Neal Shapiro, City of Santa Monica

3:35-3:45

BREAK Exhibits in Redondo Ballroom

3:45-4:45

Pacific Ballroom
Peninsula Ballroom
Marina Room
Esplanade Room

New Directions: Four Simultaneous Dialogues

- **Error! Unknown switch argument.Improving Coordination Among Regional Programs to Control Marine Debris**
- **Degradable and Compostable Plastic: Viability and Efficacy as a Solution to Marine Debris**
- **Future Monitoring and Research Needs**
- **Trash TMDLs: Information Resources and Needs**

A014493

4:45-5:00
Pacific Ballroom

Closing Remarks and Conference Wrap-up

A014494

Day Three: September 9

WORKSHOP
California Action Plan to Reduce the Discharge of Marine Debris from Land-Based Sources *(by invitation only)*

9:00-12:00	**Morning Sessions**
12:00-1:00	**Lunch** Seascape Ballroom
1:00-5:00	**Afternoon Sessions**

FIELD TRIPS

9:00-12:00	**Tour of the Hamilton Bowl Debris Collection System with City of Signal Hill**
9:00-12:00	**Monitoring and Sample Collection Aboard the Research Vessel, *Alguita,*** with Algalita Marine Research Foundation (AMRF)
12:00-1:00	**Lunch** Seascape Ballroom
1:00-3:00	**Tour of the S.E.A. Lab and AMRF Lab.** Opportunity to analyze samples collected aboard the *Alguita* in the morning

A014495

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AEI-CASC Engineering, Inc

AEI-CASC Engineering, Inc. was established in 1993 to provide professional engineering, surveying, and technical support services to public agencies and private enterprises. These services are provided with the technological and innovative expertise of a large firm, and the hands-on approach of a small firm. Since 1993, AEI-CASC has united theory with practice in guiding government agencies, private developers, and contractors through the regulatory requirements of the National Pollutant Discharge Elimination System (NPDES) permits.

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Alpha Boats Unlimited

Alpha Boats Unlimited, a worldwide manufacturer of Water Management Equipment, offers well-rounded product lines for the care, treatment, conservation and maintenance of inland and coastal waterways. These include aquatic harvesters, trash and debris skimmer boats, multi-purpose Hydro-Mate, transport and work barges, dredges, crane and work boats, as well as all support equipment. We also provide reconditioning, upgrades, service, repairs and spare parts for an assortment of Aquatic Equipment.

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Bio Clean Environmental Services, Inc.

Distributor and manufacturer of various stormwater filtration systems including: catch basin inserts, flow through system, specialty filters and a wetlands system, targeting a broad range of pollutants covering: trash and debris, organics, sediments, hydrocarbons, nutrients, and bacteria. The company also offers cleaning and maintenance on the systems in the Southern California Region.

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Fresh Creek Technologies, Inc

Fresh Creek Technologies, Inc. ® originator of Netting TrashTrap® systems and services, provides products to the Stormwater, Wastewater, and CSO markets. Netting systems have been proven highly efficient for debris control at minimal installation & operation costs. A netting solution for trash/floatables is only 1 of 4 parts of the "treatment train" concept, called SiteSaver™ Managed Discharge Systems. Oils/greases reduction, grit/sediment removal, and non-chlorine disinfections are the other treatments available from Fresh Creek.

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P.J. HANNAH Equipment is the industry leader in the design and manufacture of Netting Systems for trash and floatable control. P.J. HANNAH has been providing netting systems since 1996 and offers a full range of options including end-of-pipe, in-line and floating netting system solutions.

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A Comparison of Neuston Plastic Debris in the Near Coastal Waters of California and the North Pacific Central Gyre

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Introduction

Trawls for plastic particles and debris in the North Atlantic Ocean were conducted in the 1970's[1] and in the North Pacific Ocean in the 1980's[2]. Although significant levels of plastic particulates were found, these studies failed to generate a monitoring program to assess whether and to what extent particle levels were increasing. In response to the widely held, but narrowly documented belief that plastic debris is increasing in the marine environment, Algalita Marine Research Foundation (AMRF) conducted surface trawls in the nearshore and offshore waters of the North Pacific Ocean totaling over 12,000 miles aboard its chartered Oceanographic Research Vessel (ORV) *Alguita* from 1999-2004. Three papers presenting the results of these trawls have been published in Marine Pollution Bulletin[3]. In the last of these studies, (off Ballona Creek, which drains much of Los Angeles, CA) paired bongo nets were used to assess debris quantities in the water column down to 30 meters. These nets were subsequently used in AMRF's 2002 Gyre voyage at 10m and 30m. Data from AMRF's 2000 and 2002 Gyre voyages is published for the first time in this paper.[4]

In collaboration with the Southern California Coastal Water Research Project (SCCWRP), a new way to look at plastic particulate pollution was developed, namely, to compare it to the available food of similar size in ocean samples. The mass of plastic particulates was compared to the mass of zooplankton in our trawls. The count of plastics per cubic meter of seawater, and their type and color were also recorded. AMRF's plastic research has been evenly divided between neashore and offshore marine habitats, comprising three studies in nearshore Southern California waters and three studies offshore in the eastern North Pacific from California to Hawaii. As a result of these studies, AMRF can now more completely assess the differences in plastic debris from these study areas, and can begin to characterize some aspects of debris accumulation.

Methods

Surface samples were collected using a 0.9 x 0.15 m^2 rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30 x 10 cm^2 collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets with 3 m long, 333 micron nets and 30 x 10 cm^2 collecting bags. Bottom samples were collected using a 31 cm^2 rectangular opening epibenthic sled with a 1 m long, 333 micron net and a 30 x 10 cm^2 collecting bag (Ballona study only). In the laboratory, samples were placed in fresh water and floating plastic removed. A dissecting microscope was then used to remove remaining debris and plankton. Debris was sorted by category (plastics, tar, rust, paint chips, carbon fragments, and feathers) and plastics were further categorized (fragments, styrofoam, pellets, polypropylene/monofilament line, thin plastic films, and resin). Each category was sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.70, 0.50 and 0.35 mm and counted. Plastic, plankton and plant material then oven dried at 65° C for 24 h and weighed.

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Results

The highest ratio of plastic mass to plankton mass, 128:1, was found in the nearshore during the 2000 dry season off the mouth of the San Gabriel River. The highest ratio of plastic to plankton offshore, 112:1, was found in calm conditions (wind 7kn) during AMRF's 2000 Gyre voyage (station 44 located 1700 nautical miles to the west northwest of Los Angeles at 40 degrees N. Latitude and 153 degrees W. Longitude). The highest count of plastic particulates in the nearshore, 60 pieces/m^3, was found at the mouth of the San Gabriel River (SGR) after a rain event in 2000. The highest count of plastic particulates offshore, 11 pieces/m^3, was found during AMRF's 2002 Gyre voyage (station 7, located 1300 nautical miles to the west of the SGR at 37 degrees N. Latitude and 144 degrees W. Longitude). Plastic to Plankton ratios greater than 6:1 were found near French Frigate Shoals in 2002 (at station 25, 23 degrees N. Lat., 166 degrees W. Long.) and 1800 nautical miles northeast (station 1, 39 degrees N. Lat., 137 degrees W. Long.). These two stations represent two high ratio stations with the greatest distance between them. For the three studies, ratios greater than 6:1 were found at 34 stations widely dispersed around and within the central gyre. Paired Bongo nets showed that plastic particulates were in every sample taken at 10 and 30 meters depth in the North Pacific, although amounts were less than on the surface. At 200 miles offshore from Southern California significant particulate abundance was encountered, but levels dropped off sharply from 200 to 500 miles from shore. They then rose to peak in an area bounded by 35-40 degrees N. Lat. and 135 to 155 degrees W. Lon. (Note: In the final paper geo-referenced maps of sample locations will be provided) AMRF's three voyages between 1999-2002 found an average of 127,146 plastic particles per square kilometer.

Discussion

Whether in the deep ocean or close to shore near an urban center, the maximum ratios of plastic particles to the available food, namely zooplankton, are strikingly similar, at over 100:1. Ocean currents disperse and concentrate plastic particulates in ways that need further study, especially since there is no simple dispersion model for plastic debris. Both mainland and island coasts serve as sieves, sources and sinks for ocean borne plastic debris. Very low levels and very high levels of plastic particles were found near Hawaii and the Southern California Mainland. AMRF has taken more than 200 samples from over 15,000 miles of the North Pacific Ocean to quantify neuston plastics, however, a greater number and variety of studies is needed to assess the threat posed by ocean borne plastic particulate debris, which we show exists in all trawls down to 30 meters. No studies have been done on fish or other pelagic marine life in the deep ocean, which in many areas are now exposed to more plastic particulates by weight than available zooplankton food. Many salps in our trawls had plastic particles firmly embedded in their tissues, and we also found them to have ingested plastic. Further research needs to be done on microplastics in zooplankton tissue. Between 1985 and 1988, Day, et al.[2] found a mean of 61,000 particles of neuston plastic per square kilometer in North Pacific Sub-tropical waters, or about half the number found during AMRF's three voyages between 1999-2002. Accumulation and dispersal trends in mobile systems like the North Pacific Gyre are difficult to model, but are likely to be very important to future ecosystem management.

In the nearshore, debris inputs due to rain events are apparent, yet the highest plastic to plankton ratio was found during dry conditions. In the offshore, calm conditions appear to allow debris to surface and increase amounts per sample. AMRF's results, in over 5 years of studies, show that surprisingly consistent and persistent quantities of plastic particulates exist throughout the eastern North Pacific, although they are not sufficient to show overall plastic particle accumulation trends. An impetus for further study is AMRF's desire to understand the effects of this overlooked pollutant on the ocean ecosystem.

Acknowledgements

AMRF would like to acknowledge the work of many volunteers in field collection and the analysis of samples at our S.E.A. Lab Facility in Redondo Beach, Giancarlo Cetrulo, Director.

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[4]AMRF, data, see attached

How did we survive before bottled water?

By Stephanie Barger, Executive Director, Earth Resource Foundation

In the 1980's, we ordered bottled Perrier or Evian just as we would order a fine bottle of wine. The bubbly drink was a refreshing alternative on a warm summer night. Now, bottled water is more common than drinking sodas and tap water. Viewed as undrinkable, tap water is mainly used for washing our hands and dishes.

What is so wrong with bottled water? It is more convenient to drink our eight glasses per day, the bottles are lightweight and unbreakable, and they get recycled.

The latter is the bigger problem as most plastic bottles are not recycled and plastic packaging is accumulating at an accelerating rate to create "a plastic population explosion" which has proven destructive to the environment. The entire life cycle of the plastic bottle consists of environmental, health and economic downfalls for consumers, government and businesses. Many studies have proven the water put in our bottles does not meet health standards; plastic can be leached into the water and the cost of cleanup is a heavy economic burden on our government.

The plastic bottle is made from petroleum which is extracted from exploited lands, shipped in tanks to refineries where pollutants enter the air, made into little round pellets (nurdles) which escape from trucks, railway cars and factories making their way back down to the ocean. The nurdles are then made into plastic bottles and shipped to the "water factory" where they are filled with "special" water. The plastic bottles are then wrapped in more plastic and shipped to your favorite store. The bottled water is purchased and generally drunk in less than one hour and deposited in the trash or recycling can.

Since our tax dollars subsidize petroleum extraction and refinement, plastic manufacturers are given an unfair advantage over aluminum and glass manufacturers. As producers, they have not provided the recycling structure needed to keep up with the "population explosion" of their product. For example, in 1980 there were only 7 million tons of plastic whereas in 2001 there were over 25 million tons of plastic produced with less than 3 million tons being recovered. This means that over 22 million tons of plastic per year are going into our landfills and environment. Our environment cannot handle the pressures of the increased production. Our ocean, as reported by the Algalita Marine Research Foundation, is plagued with plastic, which chokes and strangles marine wildlife and threatens fisheries.

In 1995 and 1996 plastic started to replace aluminum and glass, which have always had high recovery rates. In the early 1990's, over 70% of plastic was recycled but unfortunately the plastic recycling markets have not kept pace with the increased production. Today, less than 25% of plastics are recycled nationwide.

Furthermore, since plastic bottle manufacturing is not a closed loop system, plastic bottles are not made into another plastic bottle but instead they are made into other forms of plastic such as carpet or polar fleece. However, aluminum cans are recycled into new aluminum cans numerous times, recycled aluminum is present in the majority of cans.

Unfortunately, California has been lagging behind the rest of the nation in regards to its legislation on plastic bottles. The 1986 California Bottle Bill established a 2.5-cent redemption value, which was far below the national standard of 5 cents. In 2004, AB 28 raised the amount to 4 cents but still left California below the rest of the nation with Michigan leading the way with a 10-cent redemption value. In California over 60% of plastics covered under the Bottle Bill were not recycled leaving over 3 billion bottles going into landfill and the environment.

At an average price of $1.00 per bottle, at 8 bottles per day, we are spending $2,920 a year on bottled water, but more importantly, we are individually consuming 2, 920 plastic bottles per year. Each year we go and extract more oil, destroying more natural resources to create another 2,920 plastic bottles per person with the majority ending up littered or in the landfill.

The key is to reduce the amount of plastic we purchase and consume every year. Here are a few easy solutions to reducing plastic and returning to traditional sources of drinking water.

Alternatives for obtaining good water

- Installing a water filtration system in your entire house, which helps reduce buildup and provides softer water for your showers and laundry
- Installing a small water filtration on your kitchen sink
- Buying a Brita pitcher
- Buying the large bottled water for your home about $3.00 for five gallons (the bottles are reused)

Alternatives for carrying plastic water bottles

- Metal water bottles can be found at outdoor stores such as REI
- Glass bottles – I have been reusing my Arizona Ice Tea glass bottle for the last month. The glass also helps keep the water cooler.
- Use your durable reusable coffee cup to carry water
- A camelback pack
- Reusing your plastic bottles – although there are some health risks. The environmental and health costs of using a NEW plastic bottle outweigh reusing your bottle.
- A drinking fountain (we did once drink out of these wonderful inventions)

What YOU can do

- Ask your elected officials to support high CRV's on all bottles and containers
- Bring igloos of water to your trail and beach cleanups and ask people to bring their own cups
- Choose aluminum or glass when buying a beverage
- Join Earth Resource Foundation's "Campaign Against the Plastic Plague" www.eathresource.org

A not so fun fact

93 Billion Plastic H_2O Bottles Landfilled in US in 2002

•= reach moon & back 38 x's
•= circle equator 371 x's
•= 2,222 times the length of the Nile
•= line Interstate 80 (NY to SF) 3,196 x's
•= span length of CA 11, 556 x's

California Department of Transportation, Storm Water Program
"Don't Trash Fresno" Public Education Research Study (PERS)
Plastics Debris Presentation Remarks
Education & Outreach to Reduce Trash in Urban Runoff
September 7, 2005
1:20 – 2:30 p.m.

1) Welcome and Introduction

2) Overview
- The Department of Transportation met NPDES permit compliance for public education by completing the storm water public education research study.

3) Problem
- The Department did not have a storm water public education program.
- The public did not know what storm water pollution was.
- The public was unaware of the highway drainage system that carries highway pollutants into the water.
- The public was unaware of the transportation dollars used to meet NPDES permit compliance.

4) What causes the problem?
- Intentional littering by people who don't care
  - convenient
  - easy way to get rid of cigarette butts to keep cars smoke free
  - this group tends to be relatively young (18-34) and primarily males, all ethnicities

- Unintentional littering
  - Trash blown out of cars or trucks
  - Loads not tied down
  - Roadside displays, signs, businesses torn up
  - Equipment falls off trucks (ladders!)

5) Finding a Solution
- Research: storm water sampling and analysis; litter characterization; and visual observation study

- Raise awareness about problem – amazingly enough, people can stop "seeing" litter, or they don't know it causes water pollution

- Change attitudes about solutions and motivate people to change behavior: We realized we needed to help public understand that they contribute to the problem, and can help with the solution

- Then we needed to reinforce attitudinal and behavior change, and publicize the deterrents for negative behavior
    - Deterrent is fine for littering, and negative reaction among ones' peers towards littering

7) Goals and Objectives
- Meet statewide NPDES permit requirements
- Raise awareness among Fresno residents that highway litter is a problem
- Increase number of people who self-report a reduction in personal littering behavior
- Reduce litter along highways in the Fresno Metropolitan Area
- Determine the success of public education as a storm water best management practice (BMP).

8) Challenges
- Our biggest challenges included the competition for people's attention, making it tough to get their attention, combined with the perception that litter is someone else's problem!
- We also faced significant cultural and language diversity among area residents
- Another challenge is the fact that drivers don't believe they will be fined for littering on the highway
- And finally, advertising is really expensive!

9) Opportunities
- We had many opportunities, however including: high level of interest by local organizations, the CHP, local government and the local media
- Fresno also has a strong Local university and sports venues
- And regional environmental and beautification efforts underway

10) Tactics
- Our tactics started with Research so we could develop a baseline for measurement. This included a worldwide literature review of public education programs, trash collection, public opinion and research for developing creative materials.

- One of the most interesting research tactics was conducting surveys at the Fresno County Fair to get the public's reaction to proposed creative concepts and the "Don't Trash Fresno" slogan. Interviews were conducted by Fresno State students in English and Spanish.

11) Advertising

We conducted paid advertising in a variety of mediums including radio, billboards, theater slides, pump toppers, bus ads, TV, newspaper and magazines to reach our target audiences. The campaign negotiated public service time in addition to paid media time.

12) Partnerships

-Partnerships were an important part of the effort, to help extend reach, impact and credibility of campaign

- Our partners included such businesses and organizations as
  - College campus
  - Coffee shops
  - Rental car agencies
  - Media partners
  - McDonald's

13) Sports Marketing

- We worked with the Fresno Grizzlies to promote the campaign. This included running our TV spots on the jumbo-tron in the stadium, publicizing the campaign at games and on the game-time radio network, and having in-stadium signage.

Sports is a great way to reach our target audience. We paid for this partnership, getting quite a bit of donated exposure in addition to what we paid for.

15)

Special events

-We had our exhibit at several community events in order to reach the target audience where they "live, work and play"

16)

Collateral

We made sure the hand out material was useful and would not just become more trash. Handouts are important to reinforcing the message and giving visibility to community based partners.

17) Evaluation

We measured the effectiveness of the campaign in several ways, including a phone poll, a self-report survey done at kiosks at the Grizzlies Stadium, as well storm water sampling and analysis and litter characterization.

18) "Don't Trash California"

The success of the PERS study in Fresno led to the implementation of a statewide effort, under the banner "Don't Trash California". This campaign just kicked off this spring with an event at the state Capitol. We are focusing our efforts on big media markets for the most impact, including Sacramento, central valley, LA, San Diego and the Bay Area

and are again using media relations, advertising, sports marketing, public event participation and partnerships to reach out to our target audiences.

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2005 PLASTIC DEBRIS CONFERENCE

DEBRIS NETS IN THE SAN GABRIEL RIVER – DESIGN AND PHYSICAL MODELING

RUSSELL H. BOUDREAU, P.E.[1]

ABSTRACT

A major storm event can mobilize waterborne pollutants from throughout our watersheds. Floating debris, including plastics, polystyrene and green waste, finds its way into our tidal waterways and beaches. It degrades the visual amenity, is expensive and time consuming to clean up, and is an environmental threat to wildlife and health. This paper presents information regarding design and physical model testing of innovative debris nets intended for installation in a concrete lined trapezoidal section of the San Gabriel River in Los Angeles County. The nets are designed to intercept debris before it discharges into the tidal sections of the San Gabriel River. The paper will describe the design philosophy behind the nets, the challenges of debris capture in high current velocity regimes and demonstrate the benefits of physical modeling as a key element in the design process. Public safety issues associated with net implementation also played a major role in the ultimate project outcome.

INTRODUCTION

Moffatt & Nichol performed an engineering study for the City of Seal Beach to develop a design for a debris collection system to reduce debris flows within the San Gabriel River watershed that are ultimately discharged at the river mouth. The main goal of the project was to propose an effective design for decreasing the debris load at the mouth of the San Gabriel River, and in particular to decrease the quantity of debris that is washed up onto Seal Beach.

Key steps in the process included identification of types and quantities of debris, assessment of river conditions, development of preliminary design concepts, and refinement of the designs through physical model testing.

ANTICIPATED DEBRIS TYPES

Three types of river-borne debris can be distinguished: green waste (plant material), floating trash, and submerged trash.

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During the first flush, a large quantity of green waste is typically transported downstream. In our study, the first flush will be considered to be the runoff from the first rainstorm of the fall-winter season with 0.5 inches or more of rain. For example, materials collected at the Los Angeles River are typically two-thirds green waste and one-third trash. At the first rainstorm of the season, as much as 80% of the debris is green waste. Similar proportions are seen at Ballona Creek.

First flush runoff is often considered the worst case for stormwater pollution management, because it transports a large fraction of the pollutants that have built up on impermeable surfaces since the previous storm season. This is the case to a much lesser extent for debris loads, unless the first rainstorm of the season is also a large storm (one to two inches or more of rain). The reason for this is that the debris transported by a rainfall event is most often limited by the quantity of debris that the runoff is able to transport, not by the quantity available to be transported (Allison, Chiew and McMahon, 1997).

By volume, much of the trash transported downstream is floating: uncompacted Styrofoam, paper cups, plastic bottles and other convenience food waste. During large storm events, much larger and heavier trash items can be transported along the bed of the river: tires, shopping carts, and discarded furniture are all commonly found in the Santa Ana River / Delhi Channel. Golf balls, which do not float, are commonly washed up onto Seal Beach.

Debris collection during large storm events can conflict with effective flood control during the same large storm events. A large mass of debris built up at a debris collector can significantly restrict flood flows and pose an upstream flood risk. The same mass of debris suddenly released as the debris collector fails can be a significant downstream hazard. The failure modes of any debris collector must be carefully assessed.

GENERAL RIVER CONDITIONS

The San Gabriel River flows from North to South, from the San Gabriel Mountains and through the eastern portions of Los Angeles and Long Beach, eventually reaching the Pacific Ocean in Seal Beach. Coyote Creek flows from northeast to southwest and passes through a small portion of Long Beach before it outlets into the San Gabriel River. The San Gabriel River is concrete lined for about eight miles; the tidally influenced region and the region upstream of the concrete channel have riprap banks and a soft-bottom channel.

Any debris that reaches the River above the Whittier Narrows Dam (completed in 1957) can be assumed trapped at that dam. Therefore, as a source of debris at the mouth of the River, only the part of the watershed downstream of Whittier Narrows need be considered. Similarly, since Los Cerritos Channel feeds directly into Marine Stadium, the debris from its watershed does not feed into the San Gabriel River, even though this sub-watershed is normally considered part of the San Gabriel River watershed. Figure 1 delineates the lower watershed of the San Gabriel River, showing the sub-watersheds of the San Gabriel River (one sub-watershed between the Whittier Narrows Dam and the confluence with Coyote Creek, and one below the confluence), Coyote Creek and Los Cerritos Channel. The vast majority of this watershed is urban. Approximate drainage areas, based upon USGS gauging station descriptions, are:

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- Coyote Creek to the confluence: 150 square miles;
- Whittier Narrows Dam to the San Gabriel River at the confluence: 30 square miles;
- Confluence to the river mouth: 20 square miles.

Much of southern Long Beach is within the watershed of the Los Cerritos Channel, which drains to Alamitos Bay.

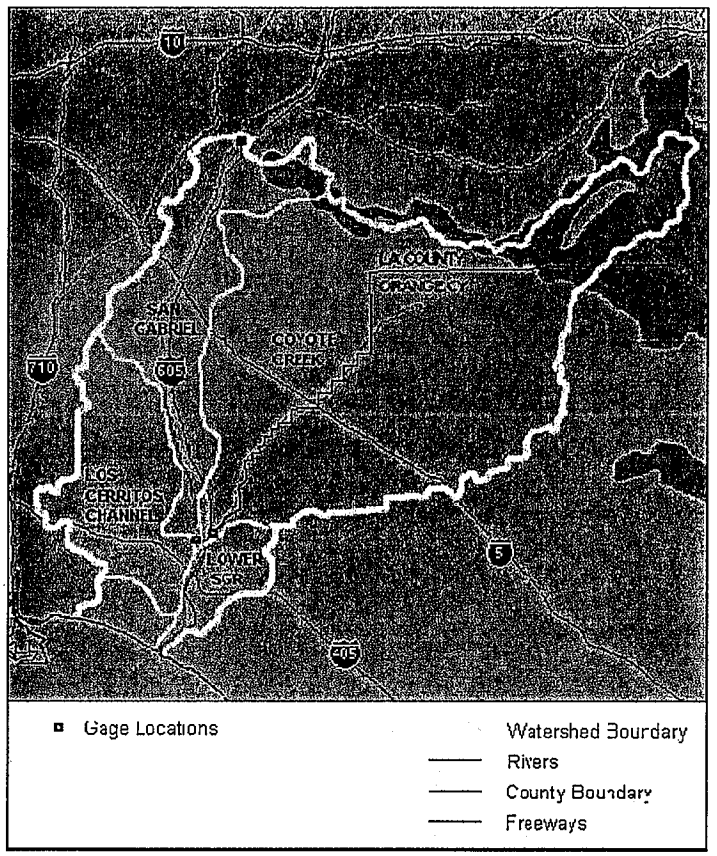

FIGURE 1 – WATERSHED OF THE LOWER SAN GABRIEL RIVER

There are flow gages at three locations below Whittier Narrows Dam: at Pico Rivera just below the Whittier Narrows Dam, on the San Gabriel River at Spring Street in Long Beach, and on Coyote Creek in Los Alamitos. The latter two gage locations lie just upstream of the confluence of the two rivers. Typical and extreme flood flow conditions at these locations are:

- Peak annual flows typically range from 3,000 to 12,000 cubic feet per second for Coyote Creek, and 2,000 to 6,000 cubic feet per second for the San Gabriel River.
- 100-year flood flows are 30,000 cubic feet per second for Coyote Creek, and 14,000 cubic feet per second for the San Gabriel River. Up to an additional 5,000 cubic feet per second may be diverted to the San Gabriel River from the Rio Hondo at peak flows.

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The Los Angeles River has much larger flows: typical flows are 10,000 to 70,000 cubic feet per second, with a 100-year flood flow of 180,000 cubic feet per second. The San Gabriel River and Coyote Creek are much more similar to Ballona Creek, with typical flows of 8,000 to 18,000 cubic feet per second, and a 100-year flood flow of 36,000 cubic feet per second.

ANTICIPATED DEBRIS QUANTITIES

Debris quantities in this paper are discussed as volumes, where possible. The volume of debris removed is more important operationally than the weight, because the volume determines the number of truckloads needed to remove the debris from the site and the landfill fees. Very often the debris is uncompacted Styrofoam, paper cups, plastic bottles, and similar trash, which has a very low dry density; operators will compact the debris to some extent while loading the truck. Since the density of debris can vary dramatically according to its source and its degree of compaction, it is not always possible to convert from weight to volume of debris; where references give quantities in tons this value may be used.

One way to estimate the debris load expected in the San Gabriel River is from the debris quantities currently collected from the mouth of the Los Angeles River in Long Beach. Since the San Gabriel and Los Angeles Rivers have similar watersheds, the relative debris quantities in the two rivers are expected to be directly proportional to their relative drainage areas. The Los Angeles River has an urban drainage area of approximately 580 square miles, with a total area of approximately 830 square miles. The City of Long Beach typically collects about 4,000 tons of debris annually from the mouth of the Los Angeles River, corresponding to 8,000 cubic yards as a slightly compacted volume, assuming a debris density of 1,000 pounds per cubic yard.[2] With an urban drainage area (below Whittier Narrows) of 200 square miles, the debris volume at the San Gabriel River can be estimated at $8{,}000 \times 200 / 580 = 2{,}800$ cubic yards per year. Only 10% of this drainage area, or 20 square miles, lies below the confluence of the San Gabriel River and Coyote Creek.

Alternatively, the anticipated quantity of trash (not including green waste) can be estimated from the baseline trash load quoted in the draft trash Total Maximum Daily Load for the Los Angeles River: 640 gallons or 3.2 cubic yards uncompressed trash per square mile per year (California Regional Water Quality Control Board, Los Angeles Region, 2001). A comparable trash load is obtained from Allison, Chiew and McMahon (1997), based on a curve for the dry trash loads as a function of total rainfall in a storm event. This would give $3.2 \times 200 = 640$ cubic yards per year of trash, or 2,000 cubic yards per year total debris, assuming two-thirds of the debris is green waste. This is comparable to the 2,800 cubic yards per year estimate from the debris collected from the Los Angeles River.

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[2] Mixed yard waste has densities between 200 and 750 pounds per cubic yard, depending on the degree of compaction; uncompacted trash has a typical density of 200 pounds per cubic yard (EPA Office of Solid Waste and Emergency Response, 1994). On the other hand, the material retained on bar racks at wastewater intakes has a typical density of 1080 to 1620 pounds per cubic yard (Metcalf and Eddy, 1991).

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Debris loads vary dramatically from year to year; figures for the Los Angeles River at Long Beach vary from 3,091 tons in 1998-99 to 9,290 tons in 1997-98. The quantity of trash reaching the river appears to depend more on the runoff volumes available to transport the trash than on the quantity of trash on the city streets (Allison, Chiew and McMahon, 1997).

Based on the above results, this report assumes typical annual debris volumes of approximately 3,000 cubic yards per year and maximum volumes of up to 10,000 cubic yards per year for the mouth of the San Gabriel River.

FLOWS AND DEBRIS LOAD SUMMARY

Table 1 provides estimated peak flow statistics and measured or estimated debris loads for the mouth of the San Gabriel River and for its tributaries at three locations (the two tributaries at its confluence with Coyote Creek and upstream near Fullerton Creek), and for the Los Angeles River and Ballona Creek – both of which have existing trash collection devices.

This table shows that the San Gabriel River has similar flows to Ballona Creek. The debris volumes trapped in the net at Ballona Creek are substantially less than the debris load estimated for the San Gabriel River and based on the load at the Los Angeles River. This may result from a difference in the raw debris loads, in turn arising from the less urbanized watershed for Ballona Creek; more probably, it reflects that only a fraction of the debris is trapped at Ballona Creek.

Table 1: ESTIMATED FLOWS AND DEBRIS LOADS FOR LOCAL RIVERS WITH EXISTING OR POSSIBLE DEBRIS COLLECTION

LOCATION	5-YR FLOOD (CFS)	10-YR FLOOD (CFS)	100-YR FLOOD (CFS)	DRAINAGE AREA (SQ. MI.)	EST. DEBRIS LOAD (CY/YEAR)
LA River Mouth	76,000 [1]	99,000 [1]	180,000 [1]	830	15,000 – 45,000
Ballona Creek	18,000 [2]	22,000 [2]	36,000 [2]	90	(20 – 200) [3]
SGR above confluence with Coyote Creek	7,000 [4]	8,000 [4]	14,000 [4]	30 [5]	500 – 1,500
Coyote Creek above confluence with SGR	14,000 [4]	17,000 [4]	30,000 [4]	150	2,200 – 7,500
Coyote Creek, Coyote Creek North Fork, Fullerton confluence	7,000 [6]	8,000 [6]	15,000 [6]	70	1,100 – 3,700
SGR near mouth	21,000 [7]	25,000 [7]	44,000 [7]	200	3,000 – 10,000

1. Source: Moffatt & Nichol, 1996
2. Source: Moffatt & Nichol, 1999
3. This is the quantity trapped in the net; the total load of the river may be substantially higher
4. Statistical analysis based on USGS and LACDPW peak flow data; note the period of record is only 20-30 years
5. Drainage area below the Whittier Narrows Dam only
6. Estimated as half the flow from Coyote Creek at the SGR, based on estimated relative watershed sizes
7. Estimated as the sum of the values at the confluence

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POTENTIAL LOCATIONS

Several potential locations for a debris collection device were identified based on field observations and discussions with personnel from the Cities of Seal Beach and Long Beach, and from Los Angeles County. A single debris collector at or near the mouth of the San Gabriel River could in principle collect all of the trash entering the river throughout the watershed. This approach, while simple, has the disadvantage of providing no backup or redundancy. Additional reasons to prefer locations in the concrete channel portion of the river (at and above the confluence of the San Gabriel River and Coyote Creek) to the soft-bottom, tidally influenced portion of the channel near the mouth of the river or above Westminster Avenue are as follows.

- Recreational navigation is common along the San Gabriel River, throughout the tidally influenced portion of the river. This would impede such navigation, and would make it difficult (although not necessarily impossible) to obtain permits from the USACE to install a net or boom that completely blocked the river. While overlapping booms can be installed without blocking navigation, as has been done at the mouth of the Los Angeles River, for example, this approach increases the complexity and cost of the system, and it is possible for floating trash to work its way around a system of this type.

- In the debris net at Ballona Creek, it has been found that collected trash is driven upstream and away from the net during flood tides – trash can only be effectively removed from the net during ebb tides. This is a significant operational constraint for all tidally influenced sites. At the river mouth, this problem would be exacerbated by the common onshore winds, which would tend to blow trash upstream and away from the net.

- Trash tends to get caught in the riprap banks along the tidally influenced portion of the river, making it difficult to clean out. This has been a problem both at Ballona Creek and at the floating boom near the mouth of the Los Angeles River.

- It would be necessary to account for the corrosive effects of seawater in a tidal location.

- During low-flow conditions, it is possible to work directly in the bed of the river in the concrete channel. This makes it much easier to remove large quantities of trash from a net.

For these reasons, the concrete, non-tidal locations were recommended for installation of a debris net. A system near the confluence of the San Gabriel River and Coyote Creek could trap much of the debris entering the river; a second system near the confluence of Fullerton Creek, Coyote Creek and Coyote Creek North could act as a backup, decreasing the total load on the downstream site.

Confluence of the San Gabriel River and Coyote Creek

A pair of pilot debris nets has been installed at this location by Los Angeles County Department of Public Works. Both channels are basically trapezoidal, with a low-flow inset. The estimated levels and flow quantities for this location are given in Table 2. These estimates are based on

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peak flows from the United States Geological Survey (2001) and Los Angeles County Department of Public Works (2001); together with rating curves provided by Leonard Davidian, LA County Public Works. Since only 20-30 years of measurements are available for each site (since the construction of Whittier Narrows Dam in the case of the San Gabriel River), return periods above 20 years are not considered.

Table 2: FLOOD FLOW RATES AND WATER LEVELS AT THE SGR / COYOTE CREEK CONFLUENCE

Flood return period	Flow rate Q (cfs)	Flow depth (feet)
San Gabriel River above confluence		
2-year	4,000	6.1
5-year	7,000	7.9
10-year	8,000	8.4
20-year	10,000	9.4
Coyote Creek above confluence		
2-year	9,000	5.7
5-year	14,000	7.2
10-year	17,000	8.1
20-year	21,000	9.2

Confluence of Fullerton Creek, Coyote Creek and Coyote Creek North

These potential sites are located about 7 miles further upstream, at the boundary between Buena Park in Orange County and Cerritos in Los Angeles County. Coyote Creek and Coyote Creek North are not gauged near this location. For the purposes of a conceptual design, these channels can be considered comparable to the San Gabriel River channel just above its confluence with Coyote Creek; the cross-sections are similar, and based on the relative watershed areas the flood flows are expected to be similar. The San Gabriel River location has been used in this report as the design example for a trapezoidal channel.

DEBRIS NET DESIGN

Two net designs are described in this section: Figure 2 illustrated the first design comprising cylindrical buoys supporting a net extending above the water surface and up to four-feet below the water surface in typical rain flows. Figure 3 shows a tetrahedral buoy system with a longer net that traps debris throughout the water column for flows up to the two-year flood (approximately 6-feet depth) and up to four feet above the water surface. The greater trapping efficiency of the tetrahedral net is offset by its greater complexity and potentially greater maintenance costs. Another issue that must be addressed in the final design is the potential backwater or damming effect: the more effective a collector is at trapping debris throughout the water column, the greater the tendency it will have to act as a dam, potentially increasing the upstream flood hazard. Each of these issues was investigated in detail in the physical model testing program.

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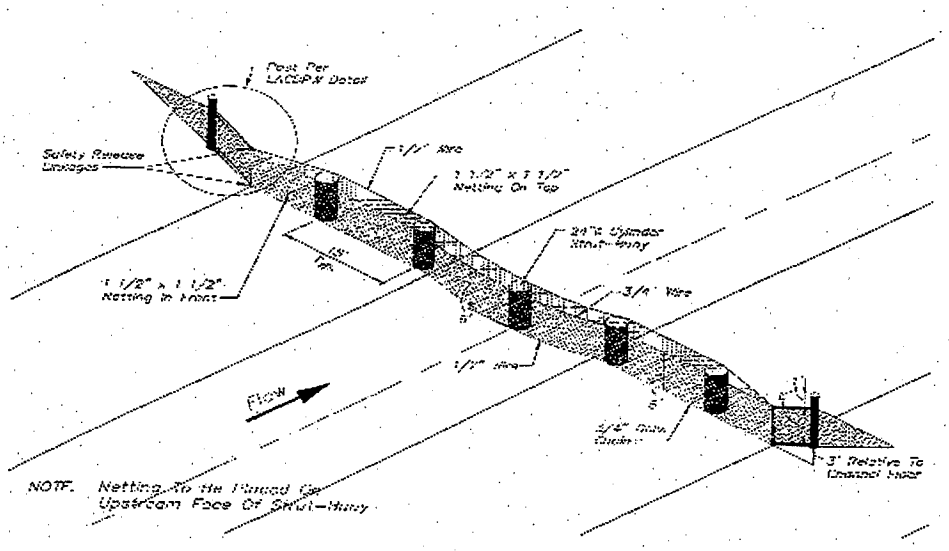

Figure 2 – Cylindrical Buoy Net Design

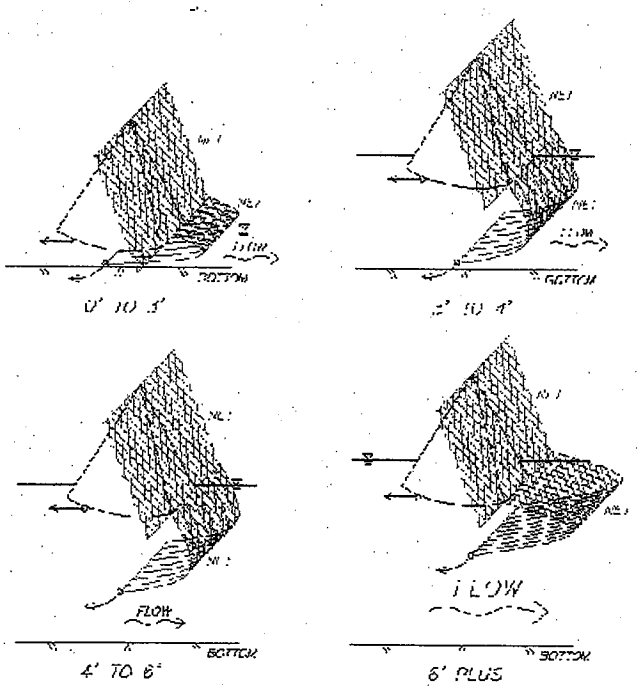

Figure 3 – Tetrahedral Buoy Net

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PHYSICAL MODEL TESTING PROGRAM

A physical model study was completed to assess the stability and overall performance of several alternative debris net designs for the San Gabriel River. The physical model study was completed at a scale of 1:14 in the Canadian Hydraulic Centre's High Discharge Flume in Ottawa, Canada. A channel was constructed to match the channel properties of the San Gabriel River at the proposed location for the debris nets to be installed. The debris nets were tested under four flow conditions.

Three debris net buoy designs were tested during the study: spherical buoys (to replicate performance of the pre-existing debris net), cylindrical buoys and tetrahedral buoys. Model scale buoys were designed and fabricated to replicate the geometry, buoyancy, and the mass distribution of the prototype buoys. Styrofoam, masonite and black ABS pipe were used as scaled debris material to represent green waste, floating trash and submerged trash as seen in the prototype channel.

The model study demonstrated that the existing net has a poor capacity to trap debris, allowing debris to pass under medium flows. Visual observations demonstrated that the model scale net acted in a manner similar to the prototype structure, allowing debris to flow overtop of the net at medium flows.

The cylindrical buoys had a good debris trapping capacity. This net design was able to trap and keep debris at high flows. The cylindrical net design was the only net design tested at extreme flow. At the extreme flow values, the cylindrical debris net was not very effective. Most of the debris was washed overtop or underneath the net. For the cylindrical buoy design case, the tension measured in the upper and lower cables under high flows with no debris were significantly lower than the tension values measured under high flow conditions with the existing debris net case.

The tetrahedral net was able to trap debris at high flows; however, once the net became overloaded, the buoys had a tendency to tip, which would release much of the debris that had been captured by the net. The tetrahedral net design was slightly altered and re-tested. The lower chain was moved up by approximately one foot. The tension measured in both cables is approximately half of the tension measured in the previous tetrahedral net design. This is likely due to the net having a smaller capacity to trap debris due to the smaller section of net hanging below the buoys. This design modification resulted in significantly improved hydrodynamic stability and debris collection performance.

PROJECT POSTSCRIPT

The City of Seal Beach was prepared to move forward with implementation of a pilot project to install and manage the cylindrical buoy net design due to its relative simplicity. However, as part of the final review and regulatory compliance process, concern was raised by swift water rescue personnel regarding public safety issues associated with implementation of the net in the proposed channel location. Their main concern was the potential for either a victim or rescuer to be pinned against the net during a storm flow event. As a result, the debris net was not installed.

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State Water Resources Control Board
Erase the Waste Storm Water Public Education Campaign
The Plastics Debris Rivers to Sea Conference
September 7-9, 2005

Erase the Waste Overview

Los Angeles County, along with many other metropolitan areas, faces major public health and environmental concerns due to storm water pollution in local neighborhoods and nearby waters. To address this critical issue in Los Angeles, the State Water Resources Control Board (SWRCB) developed and implemented a two-year, $5 million multifaceted, multiethnic storm water public education campaign, called **Erase the Waste.** The campaign focused on reducing **regional priority pollutants, including trash, cigarette butts and pet waste.** The campaign was launched in August 2005 and is concluding this summer. It marked **the first countywide storm water public education effort funded by the State of California** (with polluter fines from California's Cleanup and Abatement Account), and was a demonstration of the State's commitment to improve water quality in Los Angeles County.

The Erase the Waste campaign was designed to reach LA County's nearly 10 million residents, as well as elected officials, community organizations, business/industry and environmental stakeholders, students, educators and media. Because of the region's broad population and the need to direct budget resources where they would be most effective, the campaign used research to prioritize segments of the target audience. Key audiences were identified through existing data which confirmed **"the greatest polluters, most likely to change their behaviors."** That group represented more than 72 percent of LA County's population, including homeowners, pet owners, automotive/home improvement do-it-yourselfers, and smokers (who also have a high tendency to litter with fast-food wrappers and trash, in addition to cigarette butts).

The Erase the Waste campaign adopted a new approach to communicating about the storm water issue. It **positioned storm water pollution as a local neighborhood issue that impacted the public health and safety of families, children and pets.** Most previous storm water pollution prevention efforts, including those in Los Angeles County, focused largely on the environmental impacts of pollution (i.e., beach closures, water quality). The Erase the Waste campaign relied on research that confirmed Los Angeles residents are more willing to change their polluting behaviors when they understand the health and safety risks that pollution poses to their immediate community. The research helped develop a campaign that **encouraged the public to stop polluting close to home** (i.e., to create safe and clean playgrounds and city streets), **which reduces pollution at the community level, *and* reduces the amount of litter and debris finding its way into the storm drain system and our waterways.**

Erase the Waste prompted residents and community groups to take ownership of the problem and change their behaviors through pollution solutions. The campaign worked to: 1) ***educate*** the public on the health, safety and environmental impacts that storm water pollution creates for their families, communities and waterways; 2) ***inform and empower*** residents to take action to keep their neighborhoods clean, safe and healthy; and 3) ***reduce*** the amount of storm water pollution in Los Angeles County and improve the local environment.

Key Campaign Components

- ***Advertising*** — Los Angeles residents are bombarded with messages every day. The challenges in creating messages that "cut through the clutter" and are memorable are

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significant. The campaign developed ads that took a problem/solution approach and used both humor and drama to illustrate the health/safety impacts of storm water pollution. The print, television and radio ads (English and Spanish) included *"Excuse Me, Did You Drop Something?"* on the subject of pet waste and *"Hold on to Your Butts,"* encouraging proper cigarette disposal. To ensure that the ads were seen and heard by the largest audience possible, the campaign strategically placed them during nighttime network television newscasts and on radio during peak drive-time hours.

- ***Neighborhood Action Kit (NAK)*** – The campaign team developed a comprehensive "how-to" guide containing tips, tools and resources to enlist residents as pollution prevention advocates. The NAK offered tools to help community members create their own pollution prevention activities or support existing efforts. They were produced in five languages (English, Spanish, Chinese, Korean and Vietnamese) and distributed though a broad-based countywide network of community-based and civic organizations, elected officials and corporate partners, and downloadable on the campaign's multilingual Web site, www.erasethewaste.com. This resource is an important vehicle that gives communities the assistance they need to get involved in pollution prevention efforts and educate their neighbors, friends and family on the storm water issue.

- ***Community-Based Outreach*** – To effectively reach community members, a campaign needs both a compelling message *and* trusted, credible messengers. The campaign engaged community leaders, community/social service organizations, and healthcare agencies to conduct grassroots outreach on behalf of the campaign from a highly credible and new viewpoint. The group, known as the Water Improvement Network (WIN), also provided the State with feedback from community residents about campaign strategies and activities. The development of local campaign "advocates" was effective in encouraging residents to take ownership of their community pollution problems and create solutions. It also helped build new leaders in the storm water pollution prevention effort that can carry the Erase the Waste message and foster neighborhood participation long after the campaign "officially" ends.

- ***Strategic Partnerships*** – Partnerships with recognized and respected retailers and organizations brought the campaign many new avenues to reach residents with campaign messages. The campaign cultivated 150 innovative partnerships with various retailers, nonprofits and public agencies throughout Los Angeles County. Through these partnerships, the campaign was able to educate its partners' customers and members by conducting staff trainings, meetings and in-store promotions; developing point-of-purchase displays; and distributing campaign collateral materials. Activities strategically linked messages and messengers – so that Petco and PetSmart delivered pet waste disposal messages to pet owners, while Lowe's, OSH and The Home Depot carried messages about paint and gardening products to their home improvement customers. The campaign developed a unique partnership with the American Lung Association to join resources and outreach efforts on the issue of cigarette butt disposal. Additional partners included Wal-Mart, Target, Armstrong Garden Centers and the City of Los Angeles Parks and Recreation Department.

- ***Youth Education*** – One of the best ways to create long-term sustainability in a community environmental education campaign is by creating effective education tools that will inform youth about their local environment, and how they can protect it through personal action and initiative. Through such education it is hoped that these young residents will internalize these principals to benefit society as water stewards,

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both as young students, and as future civic leaders. In this vein, the campaign team created educational projects to reach the area's one million K-12 students including: 1) a water quality learning model for grades 4-6, consisting of classroom-based studies and school/community-based projects to help students understand polluted runoff in a campus setting (this program meets California State Standards and will be provided to educators statewide, along with teacher training sessions); 2) an interactive watershed exhibit at the Cabrillo Marine Aquarium in San Pedro; and 3) an after school program for use statewide.

- ***Media*** – People have a tendency to view messages as more credible when they are featured in news outlets, because they interpret media coverage as the media's "endorsement" of an issue's importance. The campaign utilized general interest, ethnic and community media to increase visibility on the storm water issue and position the State as an expert resource. The campaign developed a "fresh" story angle, positioning storm water pollution as a public health problem, to heighten media interest. The team conducted outreach around campaign milestones (i.e., launch of the Neighborhood Action Kit, two 8-week advertising cycles, community cleanups), local storm water stories and water policy issues. It also placed special emphasis on times during the year when storm water issues are most relevant to residents. These included spring (as gardening season began), the beginning of summer (when clean beaches are top-of-mind), and just before "first flush" (the beginning of the rainy season to point out and help prevent problems that are caused by trash and oil residue being swept into storm drains and out to the ocean).
- ***Key Campaign Events*** – To extend the reach of campaign messages through face-to-face interaction, the campaign hosted several public outreach events throughout the two-year campaign. The campaign partnered with LA Works, a local community outreach organizations, to clean up the Los Angeles River. During the local cleanup, more than 300 volunteers cleaned trash and debris from the Los Angeles River and painted over graffiti. The campaign hosted another local clean-up event in a South Los Angeles neighborhood near Compton Creek, where more than 200 local residents, school children and members of the Los Angeles Beautification Team (a South Los Angeles civic group) collected four tons of litter and debris from the streets, painted over graffiti, and planted trees throughout the neighborhood. The Erase the Waste campaign also attended diverse community fairs and festivals in Los Angeles County and hosted an interactive, educational, outreach booth. Throughout the campaign, staff attended more than 30 community fairs and festivals to reach 225,000 residents.

Campaign Results

- According to an August 2004 countywide assessment study on Los Angeles County polluting behaviors:
  - Approximately one-third of Los Angeles County residents have changed at least one of their polluting behaviors in the past year;
  - Approximately 50 percent of residents have been more active in neighborhood clean-up activities in response to messages they have seen/heard;
  - More than 70 percent of all Los Angeles County adults ages 25 to 54 and men 18 to 24 were reached through the campaign's multimedia advertising.
- Garnered media coverage surrounding the campaign that reached an approximate audience of 3.5 million with an advertising equivalency of more than $150,000.

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- Secured more than $550,000 in advertising added value elements (i.e., airing of public service announcements, Web site placements, on-air promotions), extending the campaign's reach by another 33 million impressions.
- Reached more than 225,000 residents through participation in key community events.
- Distributed an initial 15,000 Neighborhood Action Kits countywide.

Taking the Erase the Waste campaign statewide – The Los Angeles County campaign met many of its objectives in reaching the County's population on storm water prevention issues and secured measurable changes in polluting behaviors. The next step is to maintain visibility on the storm water issue and build the active involvement of residents and communities statewide. As part of this effort to build and support sustainable public education programs, the State is making a number of tools available to municipalities statewide. These include adapted versions of the Erase the Waste advertising, collateral materials, and Neighborhood Action Kit; a new service learning model and after school program; a series of public education workshops for municipalities under storm water regulations; and a Web-based resource directory (developed in partnership with the California Storm Water Quality Association), that will provide the "best of the best" storm water materials from throughout California.

Through this next phase of the Erase the Waste campaign, municipalities will be able to use these resources free of charge. This offers substantial benefits, particularly to smaller storm water programs, allowing them to conserve precious resources and budgets and tap into proven strategies and creative executions developed by public education experts.

Erase the Waste

Elimina los Desperdicios
Tu Vecindario Cuenta

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EVOLUTION OF TRASH MANAGEMENT FOR CALTRANS FREEWAYS

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ABSTRACT

Trash is a water quality problem throughout the Los Angeles Basin. The Los Angeles Regional Water Quality Control Board has determined that current levels of trash exceed the existing water quality objectives necessary to protect the beneficial uses of the Los Angeles River and Ballona Creek. As a result, the Regional Board placed reaches of these water bodies on the 303 (d) list as being impaired due to trash. The Board then developed a total maximum daily load (TMDL) designed to attain the water quality standards for trash in these reaches of the river. Trash has been defined in the TMDL as "manufactured items made from paper, plastic, cardboard, glass, metal, etc. that can be retained by a 5 mm mesh screen." In response to these TMDLs, the California Department of Transportation (Caltrans) initiated the Gross Solids Removal Devices (GSRDs) Pilot Program. The pilot study included conceptual design of non-proprietary trash removal devices, site selection, development of device design criteria, construction, monitoring, and assessment of the performance of each device. Two devices studied in the pilot program proved to meet Caltrans goals for storage capacity and maintenance, and Caltrans' criteria for drainage and hydraulic capacity. Additionally, these devices met the TMDL's criteria for clogging and particle capture. These devices were then considered to meet the TMDL's definition of "full capture treatment systems." The next major hurdle that Caltrans overcame in complying with these TMDLs is transitioning from these pilot studies to large scale implementation. Caltrans has identified numerous locations within the LA River watershed that may be candidates for a retrofit with a full capture GSRD device. The devices recommended from the pilot studies were used as the basis for developing standard details to be used for the design for the Phase I Implementation. The pilot study locations were chosen with ideal site conditions, level ground and easy access for maintenance. However, many of the sites considered to be implemented in Phase I did not exhibit the same characteristics. For example, some of these sites were at locations in a drainage system with excessive velocities. Additionally, most sites required a GSRD to be placed within an embankment with varying slopes. The main challenge to overcome was the development of a range of configurations that met a majority of these hydraulic and siting constraints. Once a set of standard details had been developed, inserting the right detail in a set of design drawings is no simple task. Caltrans has a regimented and thorough process to develop a Plans, Specification and Estimate (PS&E) package for highway construction work. This paper will describe the design criteria for the two pilot GSRDs, results of the pilot program, and the challenges overcome for wide scale implementation. Additionally, a step by step process, used by Caltrans project engineers, to incorporate a GSRD into a PS&E will be described.

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INTRODUCTION/REGULATORY BACKGROUND

Trash is currently a significant water quality problem throughout the Los Angeles River (LA River) and Ballona Creek. The Los Angeles Regional Water Quality Control Board (RWQCB) determined that current levels of trash in the LA River exceed the existing water quality objectives necessary to protect the beneficial uses of the river. There are several existing beneficial uses that are impaired by trash including contact recreation, non-contact recreation such as fishing, warm fresh water habitat, wildlife habitat, estuarine habitat and marine habitat. These beneficial uses in the river are impaired by large accumulations of suspended and settled debris throughout the river system. The problem is even more acute in the City of Long Beach where debris flushed down from the upper reaches of the LA River collects. Common items that have been observed include plastic cups, plastic food containers, glass and plastic bottles, toys, balls, motor oil containers, antifreeze containers, construction materials and cans. Heavier debris such as tires and shopping carts can be transported during storms as well.

Trash in Long Beach Harbor after a storm.

As part of California's 1996 and 1998 303 (d) list submittals, the RWQCB identified reaches of the LA River as being impaired due to trash and the Total Maximum Daily Load (TMDL) process was initiated. This Trash TMDL is a requirement of the Clean Water Act. It was initiated by the RWQCB in response to a consent decree between the USEPA and several environmental groups led by the NRDC. The consent decree specifically called for a Trash TMDL to be completed for the LA River by March 2001. Trash has been defined in the TMDL as "manufactured items made from paper, plastic, cardboard, glass, metal, etc. that can be retained by a 5 mm mesh screen." The Trash TMDL for the LA River was approved by the Environmental Protection Agency on August 1, 2002. A similar TMDL was approved for Ballona Creek. Enforcement of these TMDLs will be performed by the RWQCB through the NPDES permits of all tributary permit holders. The "permittees" are identified in the TMDLs as the California Department of Transportation (Caltrans) and the 84 co-permittees of the Los Angeles County Municipal Storm Water Permit. The Caltrans NPDES permit covers all statewide storm water discharges from their facilities and activities.

The TMDL identifies the numeric target as 0 (zero) trash in the water and calls for a 14 year implementation period. The first 2 years are optional baseline monitoring with the start of trash load reductions in year 3. A 10% reduction of the baseline trash load is required each year until 100% reduction is achieved.

The LA River watershed has an "urbanized" area of 584 square miles. Caltrans occupies about 9 square miles of that area, with predominantly major freeways. The LA River TMDL identifies a

total baseline Waste Load Allocation of 57,069 cubic feet/year of uncompressed Trash. Caltrans is responsible for eliminating 7,944 cubic feet/year of this volume while the 84 co-permittees of the Los Angeles County Municipal Storm Water Permit are responsible for the remainder.

Compliance can be achieved via 3 strategies:

> **Full Capture Treatment Systems** are any device(s) or system that will capture particles retained by a 5 mm mesh screen from all runoff generated from a 1-year storm (0.6" per hour). The TMDL mentioned vortex separation systems (VSS), floating debris traps, end-of-pipe nets and trash racks.
>
> **Institutional Controls** include enforcement of litter laws and more frequent street sweeping.
>
> **Partial Capture Control Systems with Institutional Controls** includes utilizing devices that are not certified by the RWQCB as full capture systems (such as catch basin inserts) in combination with Institutional Controls.

The permittees are free to select whichever method of compliance they choose. The Caltrans facilities tributary to the LA River and Ballona Creek include park and ride lots, maintenance stations, and State Highway Systems. Caltrans has evaluated and will continue to evaluate each of the three methods of compliance for each land use within their jurisdiction. Major, multi-lane freeways represent the majority of Caltrans land use that is tributary to the LA River and Ballona Creek. It was realized that some form of full capture device would be needed as part of the Caltrans plan to comply with the TMDL requirements. As a result, a pilot program was initiated.

PILOT PROGRAM BACKGROUND

In 2000, Caltrans initiated the Gross Solids Removal Devices (GSRDs) Pilot Program to develop and evaluate the performance of non-proprietary, full capture treatment devices that can capture gross solids and be retrofitted into existing highway drainage systems or implemented into future highway drainage systems. The term "gross solids" includes litter, vegetation, and other particles of relatively large size. As previously mentioned, litter is defined as "manufactured items made from paper, plastic, cardboard, glass, metal, etc. that can be retained by a 5 mm (0.2 in nominal) mesh screen."

The GSRD Pilot Program consists of multiple phases with each phase representing one pilot study. A pilot study consists of one or more devices that will be developed from concept, advance through design and installation, and will conduct two years of pilot testing for overall performance. To date, five phases have been constructed and monitored covering eleven designs.

PILOT PROGRAM DESIGN CRITERIA

All concepts developed for the GSRD Pilot Program were designed to meet the criteria set by the TMDL for trash in the LA River Watershed and the criteria and goals set by Caltrans. The six

design objectives listed below represent criteria and goals applied to the concepts. For this pilot study, meeting criteria held a higher importance than meeting goals.

The following two criteria were set by the TMDL for an approved full capture treatment system:

- The device or system will capture all particles retained by a 5 mm mesh screen from all runoff generated from no less than a one-year, one-hour storm.
- The device or system is designed to prevent plugging or blockage of the screening module.

The following two criteria were set by Caltrans for a GSRD:

- The device or system will pass the design flow as specified in the Caltrans Highway Design Manual.
- The device or system will drain within 72 hours to avoid vector breeding.

Additionally, the following two goals were set by Caltrans for a GSRD:

- The device or system will hold the estimated annual load of gross solids, based upon one cleaning per year.
- The device or system will not require any maintenance other than inspections throughout the storm season.

PILOT PROGRAM RESULTS

Four general types of GSRDs have been developed to date: linear, inclined screen, baffle box, and v-screen. Each general type of GSRD consists of 1 to 4 variations. Linear GSRDs consist of either a louvered modular well casing or a long rectangular rigid cage containing nylon mesh collection bags. Runoff enters the pipe or cage where gross solids are captured. Runoff then exits the pipe or cage into a shallow concrete vault and is routed back into the drainage system. These GSRDs are intended to be installed in-line with existing pipe systems and require little hydraulic head. Inclined screen GSRDs are concrete vaults equipped with a screen through which runoff drops vertically. Gross solids are captured on the top of the inclined screen and fall or are pushed down to a storage area. Both 3-mm (0.125 in) spaced parabolic wedge-wire screen and 5-mm (0.25 in) bars have been tested. These GSRDs require a minimum of one meter (3 ft) of hydraulic head. Baffle box GSRDs are concrete vaults with two chambers. The first chamber contains an underflow weir to trap floatable gross solids. The second chamber utilizes a bar rack to capture gross solids that pass through the first chamber. V-screen GSRDs are concrete vaults equipped with a screen through which runoff flows horizontally. Gross solids are captured behind the v-screen and collect in a storage area. The screen module consists of a 3-mm (0.125 in) spaced wedge wire-screen. These GSRDs require less hydraulic head than the inclined screen GSRDs.

To assess the performance of each GSRD, inspections were conducted up to eight times per year. Inspections consisted of observing the GSRDs before, during and after various storm events. Collection bags were installed in the drainage system just downstream of the GSRD to collect material that had bypassed through the screen module and/or overflowed out of the GSRD.

Visual observations were made to see: (1) how the gross solids were accumulating within the GSRD; (2) if there were bypassed or overflowed gross solids; (3) whether the screen module was self-cleaning, i.e., no plugging or clogging; and (4) if the GSRD was draining properly. Each GSRD was cleaned at least once at the end of the wet season and more if needed, i.e., an interim cleaning was performed if a GSRD became full prior to the end of the wet season. During each cleaning, the gross solids were measured for weight and volume. Gross solids captured in the collection bags were measured separately.

The overall performance of each GSRD was assessed by evaluating how well the GSRD met the design criteria, i.e., the criteria set by the TMDL and the criteria and goals set by Caltrans. Of the many configurations tested, the most promising devices, based on considerations of particle capture, clogging, passing design flow, drainage, stage capacity and maintenance requirements, were the Linear Radial (louvered modular well casing), the Inclined Screen (parabolic wedge-wire screen) and the Inclined Screen (sloped flat wedge-wire screen). These devices were selected for further development into standard details to be utilized by Caltrans District 7 (LA Basin) project engineers to incorporate into future and ongoing projects to comply with the TMDL.

TRANSITIONING FROM PILOT STUDY TO FULL SCALE IMPLEMENTATION

The District's implementation strategy for full capture devices will be carried out in 10 phases. Each phase encompasses site investigation and screening; preparation of design plans, specifications and estimates (PS&E); and construction of GSRDs. The linear radial and inclined screen devices have been certified by the RWQCB as being full capture devices. Standard designs were developed for these screen systems that provided the best solids removal performance in the pilot tests.

Linear Radial Screens: The linear radial screen is basically a water well screen with 5 mm slotted openings installed on its side and installed in a concrete vault. This device is shown in Figure 1. The debris laden storm water flows into the casing pipe. The water flows out of the screen and the debris remain inside. The casing is sized to contain one year's volume of debris. The concrete vault collects the screened flow and provides maintenance access to clean the inside of the screens.
Characteristics of the linear radial GSRD are:

- Requires minimal available head to utilize this device. This device is typically installed in level areas.
- Structure is long and narrow, with flow entering one end and exiting the other end which may limit placement in areas with narrow right of way availability.
- An integral overflow weir is incorporated to minimize concerns on screen plugging.
- Standardized screen sizes of 300 mm diameter by 1.5 m long minimize replacement inventory requirements.
- Size selection typically based on debris area instead of flow rate.
- Six standard sizes provided, ranging in design area from 0.32 to1.92 hectares in design area.

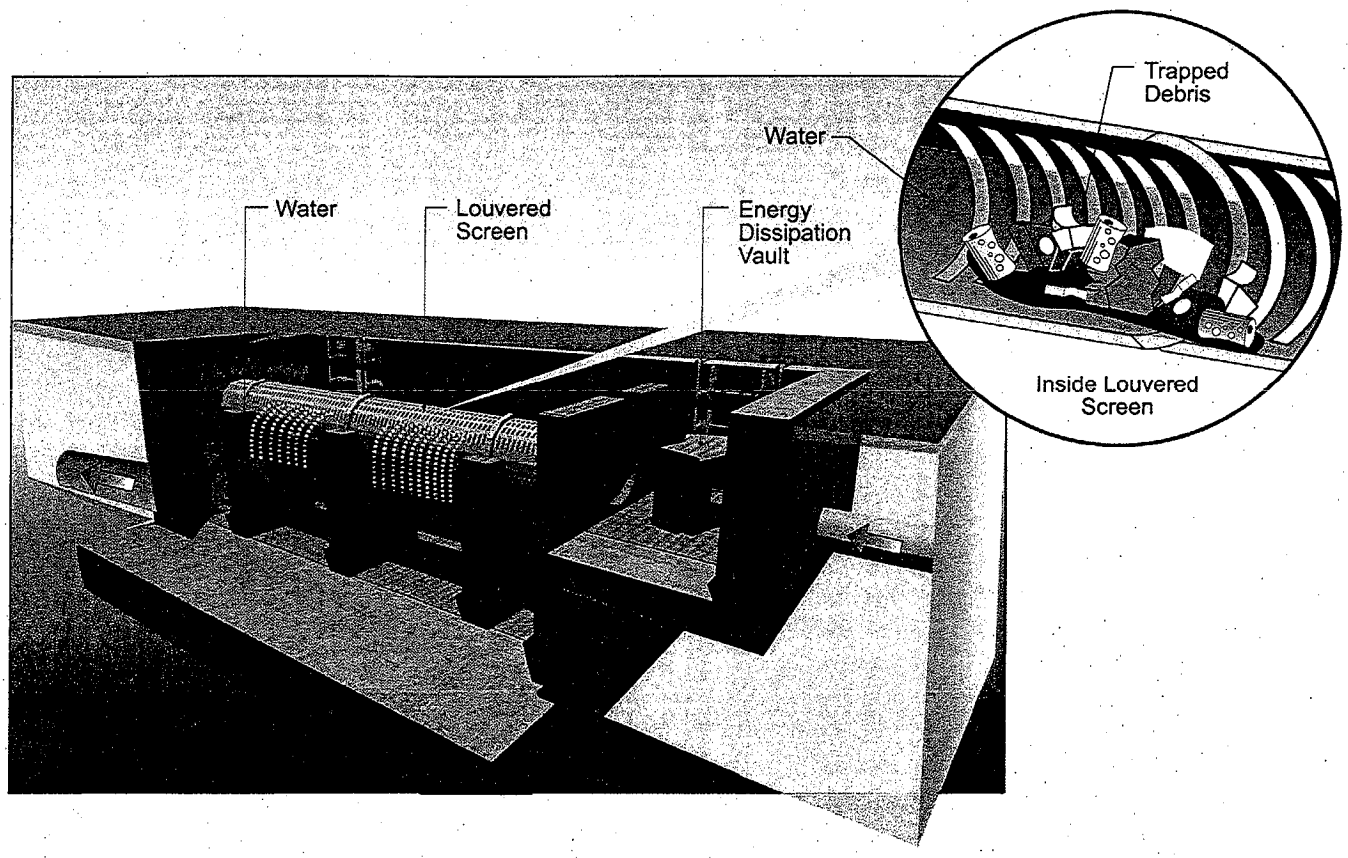

Figure 1. Linear Radial

Inclined Screens – Type 1: The Type 1 inclined screen design is a curved wedge-wire screen design (hydrasieve) with 5 mm spacing. The debris laden storm water flows into a distribution chamber, over a flow distribution weir and onto the face of the curved screen. The water flows through the screen into a collection channel and the debris collects in a concrete vault area. Two arrangements were designed to allow the Type 1 inclined screens to be installed in both flat areas and sloping areas up to a 2 to 1 slope. Figure 2 shows the sloped configuration. Characteristics of the Type 1 Inclined Screen are:

- Requires at least one meter of head to utilize this device. Typical locations utilize the head available from elevated highways.
- Structure is generally square in shape and is covered with grating to keep debris from blowing out of the structure.
- Draining the inlet distribution chamber requires screened weep holes.
- Standardized screen sizes of 1 meter high by 1 meter long were used to minimize replacement inventory requirements.
- Larger debris storage area results in size selection based on inlet flow rates instead of debris area.
- The square layout configuration is more compact than the linear radial design and may be better suited for areas with limited distance to the right of way.
- Three standard sizes provided, ranging in design flow ratings from 0.25 to 0.49 m^3/sec.

Inclined Screens – Type 2: The Type 2 inclined screen (referred to as the Configuration #4 in the Phase III of the GSRD Pilot Program) design is a sloped flat wedge-wire screen design with 5 mm spacings. This device is shown Figure 3. The debris laden storm water flows onto a energy dissipating slab and over the sloped screen. The water flows through the screen to the outlet sewer and the debris collects in a concrete vault area. The screens were designed for installation in sloping areas up to a 2 to 1 slope. Characteristics of the Type 2 Inclined Screen are:

- Requires at least one meter of head to utilize this device. This GSRD is typically placed at the toe of an elevated roadway embankment.
- Structure is generally square in shape with maintenance access from the downslope side.
- Standardized screen sizes of 1 meter high by 1 meter and 0.5 meter widths were used to minimize replacement inventory requirements.
- The debris storage area arrangement results in size selection based on inlet flow rates instead of debris area.
- Four standard sizes provide, ranging in design flow ratings from 0.06 to 0.15 m^3/sec.

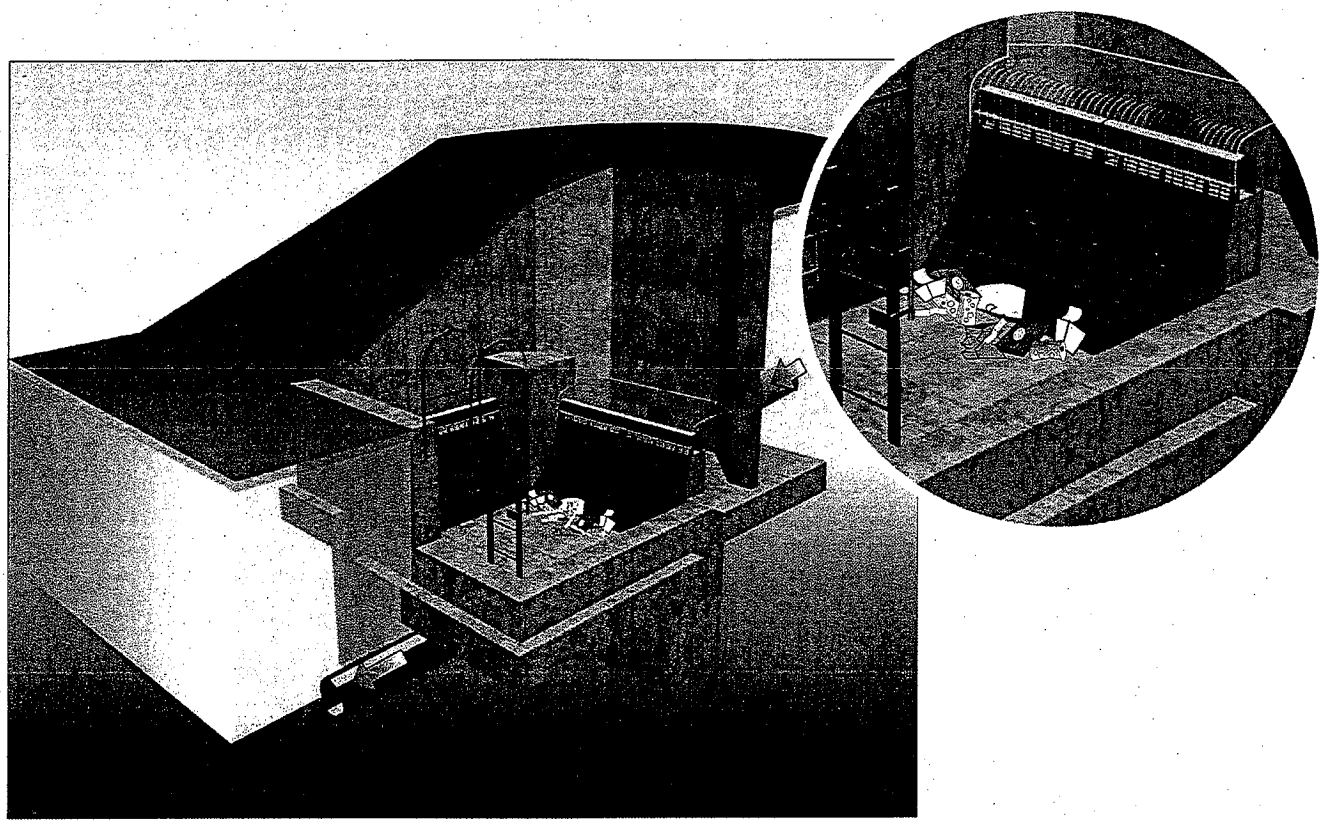

Figure 2. Inclined Screen - Type 1

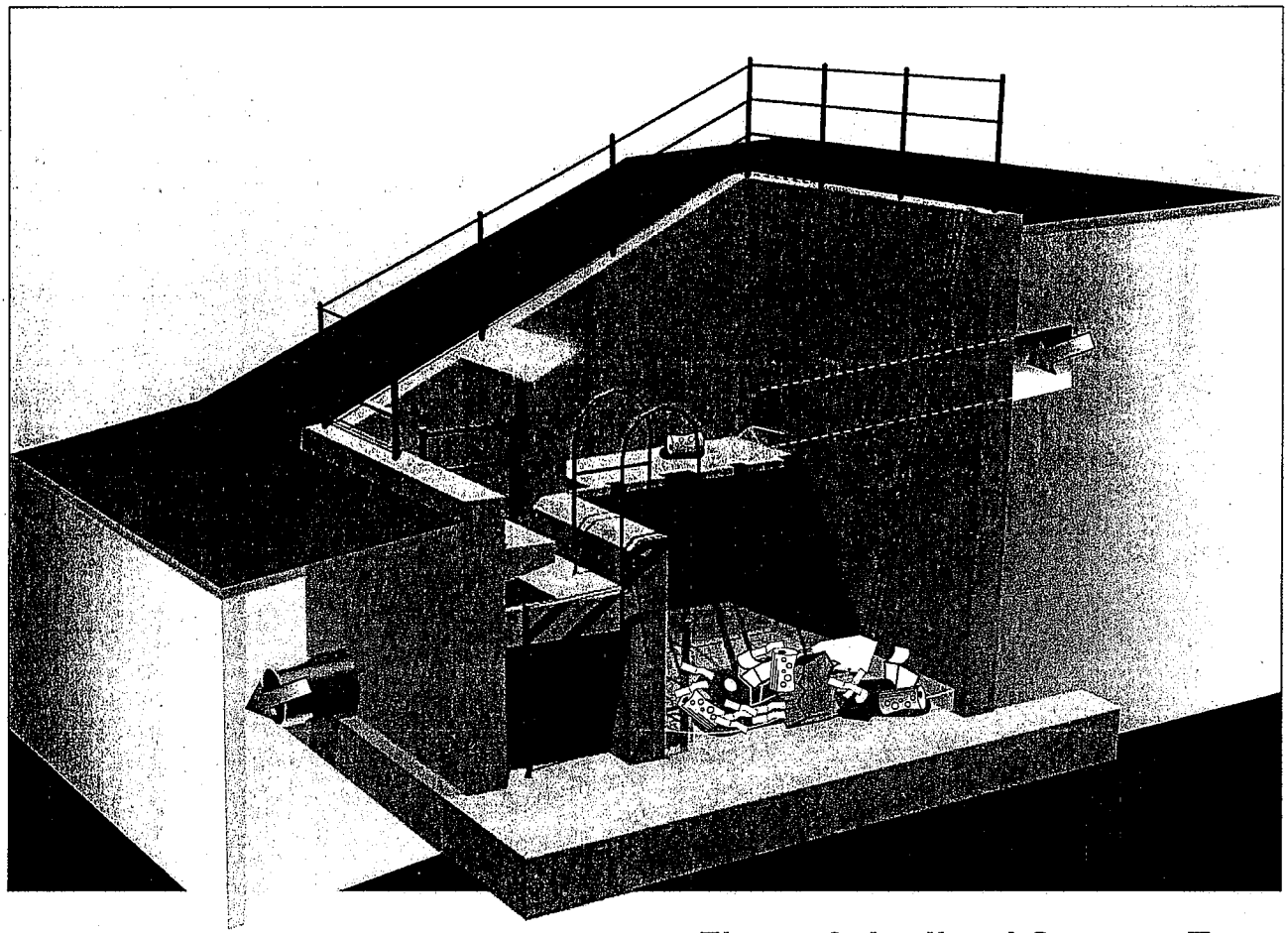

Figure 3. Inclined Screen –Type 2

A014559

HYDRAULIC CRITERIA

Screen sizing was based on screening the 25 year design storm as the design rating condition and also to be able to convey the 100 year design storm event discharge. The flow ratings through the screens were based on full scale hydraulic tests for the linear radial screens. Flow ratings for the inclined screens were based on manufacturer's flow test data for similar screens and conservative hydraulic design assumptions. Several years of Caltrans studies provided the basis for sizing the debris storage area. Each GSRD was designed for a gross solids loading rate of 0.7 m^3/ha/year (10 ft^3/ac/year) and annual removal of gross solids.

Designs for five linear radial sizes, three inclined screen type 1 sizes and four inclined screen type 2 sizes were prepared during development of the standard design drawings. The flow ratings and debris area ratings for each size and type GSRD are summarized in Table 1.

Table 1 GSRD Design Capacity Ratings

GSRD Type	Total Screen Length (m)	Design Flow Rating (m^3/sec)	Design Debris Area (hectares)
Linear Radial - Type LR-1	1.5	0.10	0.32
Linear Radial - Type LR-2	3.0	0.20	0.64
Linear Radial - Type LR-3	4.6	0.31	0.91
Linear Radial - Type LR-4	6.1	0.41	1.28
Linear Radial - Type LR-5	7.6	0.52	1.60
Linear Radial - Type LR-6	9.1	0.62	1.92
Inclined Screen Type 1 – Type 1-A	4.0	0.25	1.45
Inclined Screen Type 1 – Type 1-B	6.0	0.37	3.26
Inclined Screen Type 1 – Type 1-C	8.0	0.49	5.81
Inclined Screen Type 2 – Type 2-A	1.0	0.06	0.41
Inclined Screen Type 2 – Type 2-B	1.5	0.09	0.61
Inclined Screen Type 2 – Type 2-C	2.0	0.12	0.81
Inclined Screen Type 2 – Type 2-D	2.5	0.15	1.01

GSRD DESIGN DEVELOPMENT PROCEDURE DURING PHASE I DESIGN

Two projects in Los Angeles County (as part of Phase I implementation) were selected to be the basis for developing the standardized GSRD designs. A total of 52 drainage sites were initially selected by District 7 staff. These sites are along Interstates 405, 710 and State Route 60. The design process proceeded with the District 7 engineering staff initiating the layout plans for the selected sites.

- The tributary areas were defined as the basis for hydraulic and gross solids sizing
- Record drawings for existing storm drains were accumulated as the basis for existing pipe size, capacity and velocity calculations.
- Each site was visited to verify physical site constraints that may limit the structure configuration that could be installed due to site specific conditions.

With the existing data available for the initial 52 sites, issues began to be identified that defined real world implementation constraints for development of standardized GSRDs. Examples of the issues and the actions taken to proceed with design development are as follows:

- At one site with minimal grade, the distance between the highway and the storm pipe outlet was too short for installation of the relatively long linear radial design. This site was replaced with another site with adequate space.
- Several of the sites were at the bottom of steep embankments with design storm velocities that greatly exceeded 2.5 m/sec, often as high as 6.0 m/sec. It was recommended that energy dissipation be incorporated into the GSRDs that would be installed at these locations with high velocity. Energy dissipation provisions were incorporated into the linear radial and the type 2 inclined screen GSRDs. It was determined that the type 1 inclined screen design had inherent energy dissipation due to the flow distribution weir used in that design.
- An initially proposed site with the largest drainage area was also the site with the deepest storm drain (4.0 hectares and 6.0 meters deep). This site was deleted from the project and replaced with another site since the size and depth were not typical of standard conditions and a site specific design was needed due to the storm drain depth.
- Several of the sites were at the base or in the side slope of relatively steep elevated highway embankments. A maximum embankment slope of 2 horizontal to 1 vertical was recommended as the steepest slope for a standard condition. Site specific geotechnical investigations and recommendations were suggested for locations with steeper slopes.
- Several of the linear radial GSRDs were located at the base of an embankment slope. For some locations the preferred layout was construction partially in the embankment and partially in the flat area at the toe of the embankment. The structural design was modified to incorporate provisions for construction partially in the embankment.

CHALLENGES IN DEVELOPING RANGE OF SIZES

The challenges addressed under this project resulted in development of tools for engineers to use in implementing best management practices in meeting water quality objectives. These challenges have direct application to anyone undertaking development of similar water quality tools and are summarized as:

- Define the range of conditions that can reasonably be incorporated into a typical design as well as the conditions that warrant a site specific design.
- Drainage from elevated highway embankments will have high velocities and energy dissipation must be considered.
- The structures must be designed for a wide variety of side slope conditions and a wide variety of soil conditions. Both the hydraulic and structural designs must identify and account for all identified side and cross slope conditions.

Design Condition Definition - The challenge of developing the range of GSRD sizes was establishing what conditions should be covered by a "standard" design and what conditions needed a custom design. Some of the criteria established to determine when the "standard" design should be used were:

- Maximum side slope conditions of 2 to 1. Steeper slopes should be reviewed as a custom design.
- Maximum installation depth of 2.4 meters for the linear radial screens
- Maximum incoming storm drain depth of 3.8 meters for the type 1 inclined screens
- Maximum incoming storm drain depth of 2.3 meters for the type 2 inclined screens
- When sites are identified that require larger GSRDs than the present project, evaluate if several sites are affected and the standard sizes expanded or is a single site specific design needed.

Energy Dissipation Requirements - The conditions at many of the GSRD locations result in very high velocities flowing from the elevated roadways (up to 6 m/sec). Energy dissipation was determined to be needed for the linear radial design when approach velocities were greater that 2.5 m/sec. The inlet flow distribution on the Type 1 inclined screens provided inherent inlet energy dissipation for the range of flows in the standard designs and no additional features were needed. An inlet slab was added to the Type 2 inclined screen design since they were intended to be principally located at the toe of slope on elevated roadways and high inlet velocities would be normal. This inlet slab dissipates the energy to ensure a longer service life of the screen.

Side Slope Design Conditions Identified and Addressed - The Type 1 inclined screen was pilot tested at a flat location. When the design was adapted to the various identified sloping conditions, the height of the front wall had to be adjusted to prevent overflow from the basin as well as adjusting the structural design for the wide variety of loading conditions. The sloping wall condition also required development of grating system designs that met all of the numerous side slope design conditions. Sliding concerns in the wide variety of side sloping design conditions also required incorporation of keyway sizes and configurations to meet the wide range of soil and loading conditions The design depth and length of the deeper linear radial design required incorporation of a stiffening beam at the top edge of the concrete structure to reduce wall thickness for the deeper structures. Partial construction of a linear radial GSRD into the toe of a roadway embankment required modifying the grating design to be supported from a bracket on the side wall instead of supported on a notch at the top of the concrete wall.

INCORPORATING A GSRD INTO A CALTRANS PS&E

Caltrans is currently requiring it's project engineers to consider installing GSRDs in all locations subject to a trash TMDL or in locations where the project discharges to a 303(d) listed waterbody for trash. This consideration occurs at all phases of the project development process. It is particularly critical at the Plans, Specifications and Estimate (PS&E) phase where the project engineer prepares the final design. Caltrans project engineers need tools at their disposal to prepare a PS&E package for all facets of roadway projects, including GSRDs. Currently, standard details have been developed for these devices to include into a PS&E, with the ultimate goal of developing Standard Plans.

Regardless of whether the project engineer is using a standard detail or a Standard Plan, the process to incorporate a GSRD is similar:

1. Determine the flow rate and debris area for the proposed location. The flow rate value represents the peak flow rate anticipated during the Design Storm. The Design Storm is a particular storm event which contributes runoff which the drainage facilities are designed to handle. This storm is selected for design on the basis of its probability of exceedance or average recurrence interval. The Design Storm is typically one with a return period of 25 years for Roadway Drainage (HDM Table 831.3). The project engineer should consult with District Hydraulics for determination of the design storm and peak flow rates. The debris area represents the area which is tributary to the proposed GSRD location. This area typically consists entirely of impervious roadway surface, which generates the greatest amount of trash.
2. Determine the GSRD type. Based upon hydraulic conditions and available space at the proposed site, the project engineer should determine which of the three types (Linear Radial, Inclined Type 1, inclined Type 2) is most applicable for the proposed site.
3. Using the flow rate and debris area, select the GSRD size identified in the Hydraulic Criteria table (located on Sheet No. 1 of the standard detail sheets). This step may require some iteration to identify the GSRD type and size that best fits the site.
4. Check to ensure that the pipe sizes for the proposed site match those allowable for the selected GSRD type and size.
5. Check to ensure the footprint of the selected GSRD type and size fits within the confines of the proposed site, or whether additional Right-of-Way in needed.
6. Check to ensure that the inlet and outlet pipe elevations will match the profile of the proposed (or existing) drainage pipe. Some adjustment or modification to the existing pipes may be needed to fit the GSRD to the site and to ensure that proper flow conditions are established.
7. Determine the wall heights for the inlet wall and outlet wall. This should be based on the topography of the proposed site location.
8. The project engineer will then include only those details sheets that are applicable to the GSRD type and size that was selected for the proposed site location. These detail sheets shall be incorporated into the PS&E plans for the project.

After completion of these steps, the project engineer may determine that none of the standard configurations of GSRDs will work at the proposed site. At the present time, this situation will require a site specific design. Guidance on developing site specific designs are currently in draft stages and will be published shortly.

CONCLUSION

Trash is a significant water quality problem throughout Los Angeles County. Caltrans initiated compliance with the Trash TMDLs for LA River and Ballona Creek by evaluating and

implementing compliance options. The first part of their compliance will be the installation of full capture treatment devices that will screen all gross solids larger than 5 mm nominal diameter. Pilot studies have been conducted and proved the effectiveness of two devices that meet the full capture requirements. Caltrans District 7 developed a 10 phase implementation strategy for the installation of these full capture devices. The first phase included 52 sites which will provide the basis for future standardized GSRD plans which are not currently part of the Caltrans book of Standard Plans. The details developed for this first phase are expected to be used for the majority of sites throughout all phases of planned implementation. As such, these details provided configurations that met a majority of the hydraulic and siting constraints that are anticipated. Constraints were also realized during this process that identified siting conditions that would require site specific designs. Projects using the standardized designs are soon to be in construction. Information from these first projects will provide valuable feedback to refine and improve the Gross Solids Removal Devices as Caltrans continues in its effort to meet trash discharge reduction goals.

REFERENCES

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2. *Phase I Gross Solids Removal Devices Pilot Study 2000-2002 Final Report,* California Department of Transportation, October 2003
3. *Phase II Gross Solids Removal Devices Pilot Study 2001-2003 Final Report,* California Department of Transportation, November 2003
4. *Storm Water Quality Handbooks-Project Planning and Design Guide,* California Department of Transportation, April 2003
5. *Trash Total Maximum Daily Loads for the Los Angeles River Watershed,* California Regional Water Quality Control board – Los Angeles Region, September 2001
6. *Caltrans Public Education Litter Monitoring Study 2001-2002,* California Department of Transportation, September 2002
7. *Litter Monitoring Study*, California Department of Transportation, 2002
8. *Trash TMDL Technical Report*, California Department of Transportation, February 2002
9. *100% Design Plans-Gross Solids Removal Devices (Standard Details)*, Metcalf & Eddy/DMJM+Harris JV, March 2005.

Los Angeles Ad Hoc River Committee
City of Los Angeles, Friends of the LA River, and the Plastic Bag Industry
Working Together

Rivers to Sea Conference Paper
Session: State and Local Approaches to Solid Waste and Litter Reduction
Submitted by: Laurie Hansen, Progressive Bag Alliance
August 21, 2005

Introduction: Beginning in February, 2005, the City of Los Angeles took steps to specifically examine initiatives to eliminate plastic bags from the litter stream, reduce bag use, and keep the rivers free of these items. Following is an update on the specific action recommendations that came out of a four month process whereby the plastic bag industry, environmentalists, and city staff worked cooperatively to establish a joint public private partnership to accomplish removing plastic bags from Los Angeles waterways:

Status: The LA Ad Hoc River Plastic Bag task force wrapped up its initial phase of work in July by developing recommendations on how to eliminate plastic bags from the waterways within the City, particularly in the Los Angeles River. Following positive and cooperative forward thinking discussions among task force members, several recommendations have been developed that include increased recycling opportunities and anti-litter education programs. Overall, the Task Force fostered a spirit of cooperation among the involved parties with the acknowledgement that the city faces environmental challenges and all participants share a common desire to implement workable, mutually beneficial solutions. The city staff and environmental groups working on the recommendations were particularly helpful in attaining consensus among task force members.

The draft recommendations were approved by the City Council's Ad Hoc River Committee in August and will be considered by the full city council in September/October. The plastic bag industry, led by the Progressive Bag Alliance (PBA), is in full support of the draft recommendations and plans to provide in-kind services for the initial program development. The PBA is an alliance of the five major U.S. grocery bag manufacturers and includes Hilex Poly, Vanguard Plastics, Inteplast, Superbag, and API. The recommendations are also supported by the plastic bag trade associations including the Film and Bag Federation, and the California Film Extruders and Converters Association.

Representing the plastic bag industry on the advisory committee are Larry Johnson and Darwin Groesbeck, Vanguard Plastics; Leon Farahnik, Hilex Poly; Laurie Hansen, Progressive Bag Alliance; Donna Dempsey, Film & Bag Federation. The other multiple participants include representatives of the polystyrene industry, city sanitation and waste management staff, city council staff, and environmentalists. The President of the California Film Extruders and Converters Association also participated in final discussions on the task force-approved recommendations.

In addition, the California Grocers Association and the California Restaurant Association, end users of plastic bags, were actively involved in the recommendation development process.

Background: Under the leadership of Councilmember Ed Reyes, the city council in February officially called for the creation of the stakeholders group and required that the industry return to the council within 60 days of the first meeting with solid recommendations on solving the plastic bag litter problem. In June 2004, the LA Bureau of Sanitation characterized trash collected from storm drain catch basins. The results showed that plastics, predominantly plastic bags, were a very visible component of urban litter.

The city is under mandate to eliminate all trash going into the LA water ways by 2013 to meet US EPA Total Maximum Daily Load (TMDL) regulations imposed to improve water quality. A TMDL establishes the maximum amount of a specified pollutant, such as trash and bacteria that can be discharged into a water body without causing it to become impaired.

Relationship with Friends of the LA River (FoLAR): The benefits of working directly with the principals from the plastic bag manufacturing companies themselves became evident from the beginning of the task force process. During one of the first Task Force meetings, FoLAR discussed their upcoming annual river cleanup, La Gran Limpieza, and decided to use the event to highlight the problem of plastic bags in the River and to examine their recyclability. In quick order, the PBA produced special bags for the clean up and helped coordinate a trial recovery and recycling effort. The pilot project was testimony to good collaboration as demonstrated by the joint work of SRSSD staff, the PBA, Waste Management, and the city's contractor, City Fibers. However, the Task Force did learn that despite the efforts to segregate the plastic bag litter, the recovered plastic bags were not recyclable due to excessive contamination. FoLAR also received a $5,000 contribution towards the CleanUp from PBA members on the Task Force.

In addition to work with FoLAR, the Progressive Bag Alliance representatives worked to establish a relationship with the city's recyclers and collectors. On the market development side, City Fibers (one of the city's recyclers) began working with referrals provided by the manufacturers who offer more competitive prices to recycle the City's film plastic.

Process: The task force met a total of four times. Each meeting allowed for the participants to have an open and frank discussion. The communication between the city staff, the FoLAR representatives, environmentalists and the industry representatives was open and honest. This resulted in a good working relationship. According to the draft report conclusions, the city found that "each industry represented on the Task Force functions in a different environment with its own advantages and constraints in dealing with the impacts of plastics on their operations. It is important for Industry and Government to understand each other's functions and processes. Our goal was to arrive at collaborative opportunities that enhance the city's environmental stewardship as well as the city's business climate."

The meetings resulted in the development of criteria and goals that were used as a guideline to narrow the list of ideas that were thought to be effective, targeted, collaborative, and visible.

Specific Recommendations: The Los Angeles City Council will ultimately be asked to authorize the recommendations of the Task Force to build on the collaboration that has been

established between the City, the Plastic Bag Industry, Grocers, Restaurants, and Environmentalists. Those recommendations include:

- **Adopt-a-River Campaign:** Similar in concept to the "Adopt-a-Highway" program, this campaign will be sponsored by the City and corporate stakeholders and encompass the clean up of hot spots and natural bottom sections of the River. The Campaign will be coordinated with the Public Education/Social Marketing campaign. Funding options for the campaign are still being explored, but the establishment of a new nonprofit foundation is popular among stakeholders.

- **City-wide LA-Branded Public Education/Social Marketing Campaign:** Task Force members will participate in the development of a professional public education/social marketing campaign aimed at changing behavior to reduce plastic bag usage, increase plastic bag recycling, and deter littering in general. The campaign will be developed jointly by the City, grocers, restaurants, retailers, plastic bag manufacturers, and others with an interest in reducing litter and keeping the River/waterways free of man-made debris. Elements can be based on themes such as "Just Ask for One", "Reduce, Reuse, Recycle" and "Just Don't Litter".

- **Pilot Programs to Focus on Trash Hot Spot Areas in the City**
  The City has identified trash hot spot areas based on the amount of debris cleaned out of storm drain catch basins. Under this program, grocers, restaurants, and retailers will employ the measures described above to reduce plastic bag usage, increase recycling, and reduce littering in selected areas.

- **Market Development for Recyclable Plastic**
  The PBA will assist in the development of initial and ongoing education program upgrades/advances to continue to increase plastic bag recycling in curbside collection programs, and will work with retailers/grocers through in-store collection programs.

During the ongoing task force discussions, the Progressive Bag Alliance offered new solutions, including:

- "Just Ask for One" public education campaign to teach the public to use less bags.
- Print a consistent set of messages on plastic bags for free – anti litter and pro recycling.
- Provide resources and social marketing professionals to assist in developing and promoting an LA-branded program to help clean the River, reduce bag use, increase at-store recycling, and educate and outreach to consumers. The public campaign can include the promotion of the City's new residential curbside program to collect plastic bags for recycling. The PBA offered its assistance in designing a possible joint campaign along the theme of "take it to us or put it in curbside."
- Recruit local plastic manufacturers to participate in a specific pilot project to address trash hot spot areas.
- Assist the City in exploring possible ways to fund litter clean up, prevention, and "Adopt-a-River" programs by providing expertise and experience on establishing a new nonprofit foundation.

- Provide assistance to grocers in helping to retool store collection systems to aid in increased recycling together with development of the city-wide branded retail recycling campaign.

Conclusion: The task force met a total of four times. Los Angeles is the first city to seriously deal with this issue in a cooperative, joint public/private fashion. The issues were discussed by the company representatives in a manner that was constructive and the city and environmentalist representatives responded to this approach with a willingness to work in an atmosphere that the business members could understand. The proposed recommendations maintain the collaborative relationships that have been forged between the City, the plastics industry, and the business sector, create accountability and uniformity, allow for quick and visible successes, and have flexibility to grow and adapt.

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THE MALIBU FOUNDATION FOR ENVIRONMENTAL EDUCATION

MALIBU FOUNDATION'S
ADOPT-A-BEACH SCHOOL ASSEMBLY PROGRAM

This comprehensive environmental education program is designed to motivate children to care about the beaches, oceans and neighborhoods. The program utilizes a very basic teaching model that shows a person something they love, shows how it is being damaged and gives them something to do about it.

The 45 minute assembly presents about 100 slides of happy fish and animals in clean water and then shows them tangled in the plastic, nets and debris. The slides show how the beaches and oceans get dirty by highlighting the storm drain connection. **"Hands-On"** opportunities to make a difference are available by recycling, reducing litter and cleaning up the neighborhoods and beaches.

The Malibu Foundation coordinates an annual Kid's Adopt-A-Beach Clean-Up in celebration of Ocean Day in May. The California Coastal Commission, the City of Los Angeles Stormwater Program and the California Regional Water Quality Control Board support the program in Los Angeles. The program also runs in 5 other cities through support of the Coastal Commission's Whale Tail License Plate Fund.

The program emphasizes that clean beaches and oceans start with clean neighborhoods.

Students are motivated to develop academic skills when they are part of something that is **RELEVANT** and **INTERACTIVE** with **"HANDS-ON" REAL WORLD EXPERIENCE**. The program provides a framework to refresh a desire to learn and raise overall achievement.

This assembly also utilizes **READING** and **LITERACY** techniques:

- Repetition.
- New Vocabulary.
- Definition and Repeat.
- Review Main Idea.
- Cause and Effect.
- Audience Participation.

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THE MALIBU FOUNDATION FOR ENVIRONMENTAL EDUCATION

To date the Malibu Foundation has presented the Assembly Program over 2000 times to 425,000 children. Over 46,000 kids have participated in the last 12 annual Kid's Adopt-A-Beach Clean-Ups.

Please check out www.malibufoundation.org to see videos of the kids on the beach and talking about marine debris and www.oceanday.net to view aerial photos of the children forming messages in the sand. The Malibu Foundation's website also has a link that shows a k-5 matrix of how California Standards are introduced during the Assembly.

4,200 children on Dockweiler State Beach for Ocean Day 2005

Michael Klubock is the founder and executive director of the Malibu Foundation and will present some of the slides from the Assembly Program and share his education philosophy.

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Ride the Waves Without the Waste

The City of Malibu bans expanded polystyrene foam throughout the City

Expandable polystyrene products, when used for food service purposes, have a useful life that can be measured in minutes or hours, yet take several decades to hundreds of years to deteriorate in the environment of a landfill. There is currently no meaningful way to recycle expandable polystyrene food service products, due in part to contamination from food residue. Alternative products that are bio-degradable, less prone to wind and water transport, reusable and/or recyclable are readily available at a reasonable cost.

A member of the Malibu community requested that the Council adopt a ban against the use of polystyrene containers by take-out restaurants in an effort to reduce pollution of the City's beaches. Based on the above justification, the City of Malibu moved into action to create an environment where you can *Ride the Waves Without the Waste* and implemented a ban on expanded polystyrene foam throughout the City.

In July 2004, the Council directed staff to research the legality and practicality of an ordinance prohibiting the use of expandable polystyrene at restaurants. City staff contacted representatives from Los Angles County Beaches and Harbors who indicated their support for a ban on expanded polystyrene. It was also determined that several Southern California cities, including the cities of Huntington Beach, San Clemente, Aliso Viejo, Laguna Hills and San Juan Capistrano, have adopted resolutions prohibiting the use of expandable polystyrene (commonly, and incorrectly, referred to by the trade name "Styrofoam") food service products within City facilities and at City-sponsored events. Furthermore, in 1986, the City of Portland, Oregon, adopted an ordinance banning polystyrene foam food containers (Portland City Code Chapter 9.28). This ban is still in effect and continues to be successfully implemented and enforced.

Based on the foregoing information, as well as the Council's desire to protect the environment and reduce litter on its beaches, on February 28, 2005, the City Council adopted Ordinance No. 276, which bans polystyrene food service products (intended to take effect on July 1, 2005).

Since that time, the ordinance has been refined to clarify its applicability. This was necessary due to the fact that this was new territory for a city. On May 13, 2005, prior to Ordinance No. 276 actually taking effect, the Council reconsidered Ordinance No. 276 based on input from the business community and directed staff to bring back amendments to limit the ban to expandable polystyrene foam. Ordinance No. 286, limiting the ban to expanded polystyrene, rather than all polystyrene, was presented to the Council on June 27, 2005. When the ordinance was presented to the Council for second reading, the Council directed staff to further amend the ordinance so that the sale of multiple unit packages of expanded polystyrene intended for personal use was not affected and to add a provision prohibiting the use of expanded polystyrene foam within City facilities and at City-sponsored events.

On July 25, 2005, the City Council introduced Ordinance No. 286 on first reading and scheduled second reading and adoption for the August 8, 2005 Regular City Council meeting. The lesson learned from this experience was that when a brand new policy is being considered, a process of refining the law will be a necessity.

Madelyn Glickfeld, visiting lecturer at UCLA's Institute on the Environment, in conjunction with the Southern California Coastal Water Resource Project (also known as SCCWRP) and Heal the Bay, is working on a plan to conduct a two to three year study to monitor any changes in the amount of polystyrene trash on beaches in Malibu that might be attributable to the enforcement of the ban on expanded polystyrene in Malibu. The objective will be to develop a study design that includes a set of beach sampling sites, a sampling methodology and time schedule for taking baseline and subsequent monitoring samples. SCCWRP has published peer-reviewed studies of plastic waste on beaches in Newport Beach and Redondo Beach. Heal the Bay has agreed to provide volunteers through its extensive volunteer program and assist in the design of the sample locations and monitoring protocol. Ms. Glickfeld is working with both organizations to help design the study, and with the City to monitor enforcement and compliance of the ordinance. She is also hopeful that faculty from the Institute of the Environment can identify funding to understand the role of ocean currents in depositing plastics already in the ocean back onto beaches in the area, as well as watershed contributions, but no commitments of time or funding have been made as of this time.

City staff has been informed that the Los Angeles County Department of Beaches and Harbors is already spreading the word of the ban on polystyrene and is prepared to enforce compliance. Purchasing agents for local businesses have started buying only paper cups.

Adoption of City of Malibu Ordinance No. 286 banning expanded polystyrene food packing is one example of Malibu's dedication to protecting the beach environment and a step toward preventing debris from entering the local waterways and becoming part of the ocean marine debris problem.

Join in and help –

Ride the Waves Without the Waste!

Contacts:

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ORDINANCE NO. 286

AN ORDINANCE OF THE CITY OF MALIBU AMENDING CHAPTER 9.24 OF THE MALIBU MUNCIPAL CODE BANNING EXPANDED POLYSTYRENE FOOD PACKAGING AND REPEALING ORDINANCE NO. 276

The City Council of the City of Malibu does ordain as follows:

Section 1. Title 9, Chapter 9.24 of the Malibu Municipal Code is hereby amended to read as follows:

"Chapter 9.24 Ban on Expanded Polystyrene Food Packaging"

Section 9.24.010 Definitions

For purposes of this chapter, the following terms shall have the following meanings:

"Customer" means any person obtaining food or beverages from a restaurant or retail food vendor.

"Expanded Polystyrene" means and includes blown polystyrene and expanded and extruded foams (sometimes incorrectly called Styrofoam®, a Dow Chemical Co. trademarked form of polystyrene foam insulation) which are thermoplastic petrochemical materials utilizing a styrene monomer and processed by any number of techniques including, but not limited to, fusion of polymer spheres (expandable bead polystyrene), injection molding, foam molding, and extrusion-blow molding (extruded foam polystyrene). Expanded Polystyrene is generally used to make cups, bowls, plates, trays, clamshell containers, meat trays and egg cartons. For the purposes of this chapter, the term "polystyrene" shall not include clear polystyrene known as "oriented polystyrene."

"Food Packager" means any person, located within the City of Malibu, who places meat, eggs, baked products, or other food in packaging materials for the purpose of retail sale of those products.

"Food Packaging" means all bags, sacks, wrapping, containers, bowls, plates, trays, cartons, cups, straws and lids which are made from Expanded Polystyrene, on or in which any foods or beverages are placed or packaged on a restaurant's or retail food vendor's premises.

"Food Vendor" means any restaurant or retail food vendor.

"Non-Profit Food Provider" means a recognized tax exempt organization which provides food as a part of its services.

"Person" means any natural person, firm, corporation, partnership, or other organization or group however organized.

"Prepared Food" means food or beverages which are served on the Food Vendor's premises and are prepared on the Food Vendor's premises or within the City of Malibu by packaging, cooking, chopping, slicing, mixing, brewing, freezing or squeezing. Prepared Food does not include any uncooked meat or eggs. Prepared Food may be eaten either on or off the premises.

"Restaurant" means any establishment located within the City of Malibu, selling Prepared Food to be eaten by customers. Restaurant includes a sidewalk food vendor.

"Retail Food Vendor", "Vendor" means any store, shop, sales outlet or other establishment, including a grocery store or a delicatessen, located within the City of Malibu, which provides Prepared Food.

9.24.020 Food Packaging Prohibitions.

A. No Restaurant, Food Packager, Retail Food Vendor, Vendor or Non-Profit Food Provider shall provide Prepared Food to its customers in any Food Packaging that utilizes Expanded Polystyrene.

B. The City of Malibu shall prohibit the use of Expanded Polystyrene Food Packaging at all City facilities. The City of Malibu shall not purchase or acquire Expanded Polystyrene Food Packaging.

C. The use or distribution of Expanded Polystyrene Food Packaging at special events sponsored or co-sponsored by the City of Malibu shall be prohibited. This prohibition shall apply to the event organizers, agents of the event organizers, event Food Vendors and any other party (including non-profit organizations) who enter into an agreement with one or more of the co-sponsors of the event to sell Prepared Food at the event or otherwise provide an event-related service.

D. All facility rental agreements for any City-owned property or facility shall include a provision requiring contracting parties to assume responsibility for preventing the utilization and/or distribution of Expanded Polystyrene Food Packaging at the associated function. The facility rental agreement shall indicate that the violating contractor's security deposit will be forfeited if the Parks and Recreation Director, or his/her designee, determines that Expanded Polystyrene Food Packaging was utilized in violation of the rental agreement.

9.24.030 Exceptions.

A. Food items packaged outside the boundaries of the City of Malibu are exempt from the provisions of this chapter.

B. The City Council, or its appointee, may exempt a Food Vendor, Food Packager or Non-Profit Food Provider from the requirements of this Code for a one year period, upon showing by the applicant that the conditions of this Code would cause undue hardship. The phrase undue hardship, shall be construed to include, but not be limited to:

1. Situations where there are no acceptable alternatives to Expanded Polystyrene Food Packaging for reasons which are unique to the Vendor, Packager or Non-Profit Provider;

2. Situations where compliance with the requirements of this Code would deprive a person of a legally protected right.

C. Coolers and ice chests made of Expanded Polystyrene are exempt from the provisions of this chapter.

D. Food Packaging required to be purchased under a contract entered into one year prior to the effective date of this chapter is exempt from the provisions of this chapter. This exemption will apply up to one year from the effective date of this chapter.

9.24.040 Enforcement and Notice of Violations.

A. The City Manager or his/her designee shall have primary responsibility for enforcement of this chapter. The City Manager or his/her designee is authorized to promulgate regulations and to take any and all other actions reasonable and necessary to enforce this chapter, including, but not limited to, inspecting any Vendor's premises to verify compliance.

B. Anyone violating or failing to comply with any of the requirements of this chapter shall be guilty of an infraction punishable pursuant to Malibu Municipal Code Chapter 1.16.010.B.

C. The City Attorney may seek legal, injunctive, or other equitable relief to enforce this chapter.

D. The remedies and penalties provided in this section are cumulative and not exclusive of one another.

9.24.050 Severability.

If any part or provision of this Code or the application thereof to any person or circumstances is held invalid, the remainder of the Code, including the application of such part or provision to other persons or circumstances, shall not be affected thereby and shall continue in full force and effect. To this end, provisions of this Code are severable.

Section 2. The City Council hereby repeals Ordinance No. 276.

Section 3. The City Clerk shall certify the adoption of this ordinance.

PASSED, APPROVED AND ADOPTED this 12th day of September, 2005.

ANDY STERN, Mayor

ATTEST:

LISA POPE, City Clerk

APPROVED AS TO FORM:

CHRISTI HOGIN, City Attorney

MARINE DEBRIS – ONSHORE, OFFSHORE, SEAFLOOR LITTER

A T Williams, M Gregory & D T Tudor, 2005. *Encyclopaedia of coastal processes*, (ed.), M Schwartz, 623-628, Springer.

Introduction

Marine debris is a problem that affects beaches/coastlines and the sea floor at all depths and its impact is of global significance. It has been recognized as a serious pollutant for around 30 years, but has only gained widespread recognition in the past decade or so. Clean up schemes, particularly those requiring public participation, have led to greater public awareness. This though does not appear to have led to any great reduction in the amounts of debris being found on beaches worldwide. Marine debris has been defined as 'any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source'. (Coe and Rogers, 1997, xxxi). Marine debris is also often termed marine or beach litter. The sources of this form of pollution may be the from the land (e.g. either direct from beach users or from rivers) or from the ocean itself. Once in the marine environment debris may remain for many years, particularly if it is plastic and numerous world-wide beach based debris studies have recorded plastic as the dominant material (e.g. Gilligan *et al.*, 1992, in the USA; Garrity and Levings, 1993, in Panama; Benton, 1995, in the Pitcairn Islands; Jones, 1995, in Australia; Bowman *et al.*, 1998, in Israel). Indeed, plastics have been considered an environmental and pollution threat to the marine realm whose importance will incrementally increase through the 21stcentury (Goldberg, 1995,1997). The problems created are chronic and potentially global, rather than acute and local or regional as many would contemplate.

Sources

Marine debris sources can be broadly classified into two groups: sea-borne sources and land-based sources (Fowler, 1987; Corbin and Singh, 1993; Rees and Pond, 1995a). Sea-borne sources include, commercial fishing vessels, cruise ships, recreational vessels and merchant and military ships (Williams and Simmons, 1995). Most concern has focused on debris discharged from vessels. There is now extensive evidence that land-borne discharges are a major source of marine debris and it has been stated that land-borne sources are believed to be a much more significant contributor of pollutants to the marine environment than are vessels (Bean, 1987; Faris and Hart, 1995). Land-based debris can enter the sea through rivers, or can be blown, washed or discharged directly from land. The absence of sewage treatment installations, the presence of combined sewer overflows, storm water discharges, run-off from landfills sited nearby rivers and in coastal areas, the absence of waste services or landfills in rural areas, recreational beach users, and fly tipping all contribute to debris ending up on beaches or in the oceans (Nollkaemper, 1994).

Identifying from which source debris has originated is an altogether more difficult task. On occasions the source of the pollution is clear and local (Johnson, 1989;

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Walker *et al.,* 1997). But all too often the sources are not so obvious and can be international either in terms of shipping (Dixon, 1995), or land based litter from other continents e.g. American litter on west coast European shores (Olin *et al.*, 1995). The movement patterns, sinks, and degradation rates of marine debris are still not completely understood, although there is significant recent research in this area (Williams and Simmons, 1997; Bowman *et al.,* 1998; Williams and Tudor, 2001; Williams *et al,* 2003). In these circumstances one cannot generalize or make assumptions about sources, site specific measurements will almost always be required (Earll *et al.,* 2000). Possible sources, whether geographical or socio-demographic, can only be established by recording the maximum amount of detail concerning the debris item. (Williams *et al.,* 1999). At present there is no accepted methodology that enables researchers to link litter items to their source (Tudor and Williams, 2004): the conceptual step taken to link litter to a source requires the following:

- the identity of the item is known or at least described systematically
- the function and application of the item is understood, and
- that quantities of the item are measured.

Studies of why littering takes place in particular situations e.g. fly-tipping, or failure to use port reception facilities, are likely to be very important in future as greater emphasis is placed on this aspect (Earll *et al.,* 1999).

Case studies- Extent of problem

The source of marine debris found on beaches world-wide varies widely. As previously stated, there are certain site specific elements that influence the source of litter and these can differ from beach to beach. Comparisons of debris amounts are generally complicated by differences in methodology among studies, beach substrates and environmental factors influencing the transport of debris items. Although comparisons are difficult, certain similarities can be noticed. In a survey of debris along the Caribbean coast of Panama, Garrity and Levings (1993) found that 56% of the items were made of plastic; 89% of this plastic debris being related to consumer or household goods; that the country of origin of the debris was related to distance from the survey site This agreed with the findings of Dixon and Cooke (1977). Garrity and Levings (1993) concluded that *1.* Local household waste, *2.* Shipping, and *3.* Near shore marine activities were the major sources of debris. They found no evidence of substantial input from industrial, recreational or offshore commercial fishery sources.

Corbin and Singh (1993) in a study of Caribbean island coastlines showed that the amount and kind of items found were associated to types of coastal activities and variations in population density. Even though the study area was a busy lane for liners and other ships passing through the Panama Canal, little evidence was found of debris from distant sources or debris discarded from cruise ships washing up on the coast. This result is in contrast to other studies (Morris, 1980; Shiber, 1987).

A study of marine debris at Bird Island, South Georgia, by Walker *et al.,* (1997) helps to illustrate the problem of generalizing the sources of such wastes. The findings were that the source of much of the marine debris found was from local fisheries, with the majority of debris originating from jettisons by long-line fishing vessels.

Williams and Simmons (1997) conducted surveys on beaches fringing the Bristol Channel, UK, an estuarine area with relatively low levels of shipping. The authors stated that 'the higher number of beverage and dairy product containers tend to indicate greater contributions from land-based sources, either from beach users or riverine inputs' (Williams and Simmons, 1997, 1161). Very low amounts of foreign material were encountered during the study, suggesting low levels of ship discards. In contrast to this, studies carried out by the Tidy Britain Group in other parts of the UK. have found that the primary sources of debris within their study area originated from shipping vessel sources (Dixon, 1995). As stated earlier, comparisons between locations are difficult and any generalization about sources, persistence and dynamics of marine litter would therefore be unwise.

Results from studies initiated in the Mediterranean showed that certain portions of this area do not have large amounts of litter emanating from sea-borne or riverine sources, but rather from the high numbers of beach users (Golik and Gertner, 1992). The importance of location is shown in that, 'there are indications that most Mediterranean coastal litter is land-based, in contrast to the reported marine-based litter on the western European shores (Gabrielides *et al.*, 1991, 437). Additionally, areas such as Indonesia have also seen a rise in the impact of tourism on marine debris (Willoughby *et al.*, 1997).

Debris on beaches is a world-wide problem and there is no region that has escaped this form of pollution. From the remote Pitcairn Islands (Benton, 1995), to Europe (Phillip *et al.*, 1995; Williams and Markos, 1995; Velander and Mocogni, 1998), Australasia (Gregory 1977; Jones, 1995; Haynes, 1997), North America (Gilligan *et al.*, 1992; Ribic, 1998; Thornton, and Jackson, 1998), Southern Africa (Ryan and Maloney, 1990), the Middle East (Anbar, 1996), and South America (Bourne and Clark, 1984; Goodall, 1990), litter can be found on beaches.

Problems - socio-economic - tourism, fishing, health, aesthetic.

Effects on Humans

Numerous studies of beach litter have commented on the potential danger to visitors, mainly from foot lacerations caused by stepping on glass or discarded ring pull tabs (Olin *et al.,* 1995; Philipp *et al.*, 1995, Williams *et al.*, 2000). Other, more dangerous items have been encountered on beaches that are less expected. Munitions and containers of corrosives have been found washed ashore (Dixon and Cooke, 1977), along with pyrotechnics, packaged hazardous goods. Eleven types of partly used drugs, classed as medium to high hazard rating based on quantity found and if taken orally, were found on a 3 km stretch of beach at Sandwich Bay by Dixon and Dixon (1981). A further example occurred in 1993, off the coast of France, with an accident involving the ship '*Sherbo*' in which 60,000 bags of a pesticide similar to nerve gas were lost overboard (Olin, *et al.,*1995).

Attention has turned recently to the less obvious health risks that can feature on beaches. These items are medical waste and sewage related debris. Although the risks

are considered to be relatively low (Rees and Pond, 1995b, Nelson and Williams, 1997), any contact with infected sanitary products or fluids in syringes or other medical equipment, or ingestion of any of these could cause disease. Forty needlestick accidents on bathing beaches were reported between 1988 and 1991 to the UK Public Health Laboratory Service Communicable Disease Surveillance Centre (Philipp, 1993). Medical wastes have appeared on holiday beaches (Godlee and Walker, 1991) and in some places sharps containers are now being issued to lifeguards, who are advised not to go barefoot on these beaches. Studies carried out in Panama by Garrity and Levings (1993) also encountered significant levels of medical waste.

Debris on beaches is not just a health problem for those visitors who always remain on land, as bathers are also at risk. It provides information on ocean debris even though it is uncertain whether beach litter is representative of the ocean litter (Jones, 1995). It is however the *only* realistic indicator of the amount and type of debris present in the ocean (Walker *et al.*, 1997). Sewage related debris on a beach would seem to suggest that the adjacent waters are contaminated with sewage which means a health risk to sea users. Bathers exposed to sewage contaminated water have a higher risk of skin and ear infections (McIntyre, 1990). In 1990, it was reported to the UK House of Commons that the aesthetic quality of recreational waters is 'becoming increasingly important as the public become more aware of, and sensitive to, the risks,' (House of Commons Environment Committee, 1990).

Public attention to problems relating to the coastal zone have been based more upon public perception than on any scientific knowledge or evaluation of sources, fates and environmental effects (Windom, 1992). Associations have indeed been made between the public perceptions of items affecting the aesthetic appearance of bathing water and bathing beaches and the gastro-intestinal symptoms experienced after bathing in sewage polluted water (University of Surrey, 1987, Nelson *et al.*, 1999). It has been reported that 'overt filth seemed to correlate with microbial filth' (Eykyn, 1988, 1484). Conversely there are suggestions that the public debate on sewage in bathing water rarely makes any distinction between aesthetic impact and actual health risk (Jones *et al.*, 1991). To try and counter any ambiguities the Government White Paper *'The Health of the Nation'* (1992) stated that there should be priority 'for research to pinpoint more accurately the linkage between the quality of the environment and the health consequences'.

Economic Effects

The problem of litter in the environment leads not only to potential health risks, but also to economic losses. Stranded debris has direct and indirect social and economic costs to shoreline communities, with the financial strains imposed by such debris not always easy to quantify, or to appreciate. Economic loss has been split into two areas, firstly loss to fisheries, and also loss to tourism.

Fisheries

The economic impact of debris on fishing has been studied over many years. Such losses have occurred due to the fouling of trawl nets by bottom debris, blocking of water intake pipes by plastic sheeting and, propeller foulings (Jones, 1995; Lart,

1995). Damage to ships following collisions with metal drums or wooden pallets at sea have also been reported (Dixon and Dixon, 1981). Costs result mainly from repair of damage and lost time.

'Ghost fishing' affects commercial fishing interests. This hazard occurs as a result of lost or abandoned nets and traps, which leads to the capture of target and non-target species. This will reduce reproductive potential, as immature fish that have not produced offspring are removed from the population (Pollard *et al.,* 1999). Large items of debris are capable of tearing nets and other fishing gear and the presence of certain debris can lead to entire catches being discarded. Data is limited as to the costs incurred due to these encounters with litter. Jones (1995), found that for commercial fishing vessels reporting damage in Australia, the average cost was AUS$500 for repairs and AUS$200 for lost time in the period 1990-1992. The total cost world-wide is likely to be substantial for the commercial fishing industry.

An extensive study carried out by Nash (1992), concerned the impacts of debris on a group of subsistence fishermen. The findings were similar to others relating to commercial fishing, including propeller entanglements, fouling of nets, damage to fishing gear. One exception was that during the gathering of shellfish and molluscs by hand, waste such as glass can lead to foot or hand injury.

An important distinction between commercial and subsistence fisherman is that even a minor decrease in yield can lead to a lack of provision for the latter with respect to basic needs, such as food. This can lead to abandonment of fishing completely (Nash, 1992). The knowledge that marine debris can cause livelihoods to be lost might be a greater spur for authorities to deal with the problem than knowing about the damage to wildlife.

Hall, (1998), in a study in the Shetlands, UK, found that the costs associated with the time spent to clear and repair nets and lost catch due to contamination amounted to £57 - £114 Stirling per week in time, £300 - £1,000 loss due to contamination and £2000 - £10,000 for repair and replacement of damaged equipment The total cost world-wide is likely to be substantial for the commercial fishing industry. Hall, (1998) showed that there is also the potential for farms adjacent to the coast to become affected by marine debris; wind blown litter can collect on fences, accumulate in drainage ditches, and be ingested by or entangled around livestock.

Aesthetic Quality, Perception and Tourism

The loss of tourism and recreational potential are very real impacts of marine debris (Nollkaemper, 1994; Nelson *et al.,* 2000). A coastal community that relies heavily on tourism for its livelihood can have its income severely depleted by marine debris (Corbin and Singh, 1993). Indeed, Windom (1992), suggested that the greatest impact associated with marine litter is not to organisms, but to the economic loss associated with the reduction of amenities. The money that can be made, or indeed lost, from tourism and related industries is enormous; the UK maritime leisure industry is worth £8 billion Stirling a year, with £6 billion relating to seaside holidays (Maritime Technology Foresight Panel, 1996).

The aesthetic value of beaches can be reduced by the appearance of plastics, sewage related debris and, other items of litter (Jones, 1995; Pruter, 1987). People prefer to visit clean beaches, with both land and water free of litter, rather than those containing various assortments of marine debris. The public may avoid certain beaches if they find their appearance unacceptable (Williams *et al.*, 2000). The effect of aesthetic issues on the amenity value of marine and riverine environments has been defined by the WHO as: Loss of tourist days; resultant damage to leisure/tourism infrastructure; damage to commercial activities dependent on tourism; damage to fishery activities and fishery-dependent activities; damage to the local, national and international image of a resort (Philipp, 1993). Many of these problems are manifest in developing regions such as the small island states of the Caribbean and South Pacific, where natural resources may be limited and economic development is largely dependent upon coastal tourism (e.g. Siung-Chang, 1997; Gregory, 1999a). Particular problems lie with waste disposal and management whether it is generated on land or by visiting and passing cruise vessels (Morrison and Munro, 2000). On an atoll or small high island an ever expanding mountain of waste is difficult, if not impossible to handle (Tutangata, 1999). There are sharply conflicting interests between the sophisticated demands of most tourists and the environmental degradation inflicted upon local inhabitants who also have aspirations for a better life-style.

When considering aesthetics one must remember that it is usually a subjective and intangible concept. Aesthetics is a branch of philosophy concerned with the essence and perception of beauty and ugliness. Aesthetics also deals with the question of whether such qualities are objectively present in the things they appear to qualify or whether they exist only in the mind of the individual. In essence, whether objects are perceived by a particular mode - the aesthetic mode, or whether instead the objects have, in themselves, special qualities - aesthetic qualities. Logbook entries by visitors to a remote beach from southernmost New Zealand, highlight the visual and emotive impact wrought by fouling marine debris. For example, 'Most dirty man polluted beach I've seen in NZ – what a shame...we did our best to clean it up but only scratched the surface', Gregory (1999b, 207), is a revealing expression of the aesthetic values of an ecotourist.

With regard to marine debris and aesthetics it would seem that the perception is almost universal amongst the population and therefore the consideration of litter is perhaps less subjective (Tudor and Williams, 2003). Cause and effect relationships have been established regarding public perception and lost revenue. Beach closures along with public perception of contaminated bathing areas in 1987 and 1988 resulted in approximately US$2 billion of lost revenue for New Jersey and New York states. The losses were ascribed to debris (Rees and Pond, 1995a). Other studies have found that 'sand and water quality' to be the most important aspect of a beach to visitors (Williams and Morgan, 1995).

As well as losses from tourism there are continual costs of beach clean up efforts that take time and money. Cleaning the coast costs local authorities thousands of US$ per year, additional costs are incurred when hazardous containers are found and have to be recovered from beaches (Dixon, 1992). The cities of Santa Monica and Long Beach in California, USA, each spent more than US$1 million in 1988-9 to clean their beaches and costs continue to rise (Kauffman and Brown, 1991). It has been estimated that the

county of Kent, UK, has incurred direct and indirect costs of around £12 million Stirling resulting from marine and coastal pollution (Gilbert, 1996). Another European example is the Swedish Skagerrack coast where more than 6,000 m^3 of litter was collected in 1993. Approximately 9,000 working days over 4-5 months with a total cost of around £1 million Stirling, gives the fiscal price of clearing marine litter at £156 / m^3 (Olin *et al.*, 1995). Harbor authorities in the UK also have to pay for the costs of keeping navigational channels free from litter, Lerwick Harbour, Shetland, for example accrues costs of £720 Stirling per annum for harbor clearance (Hall, 1998). At Studland, Dorset, UK, one million visitors per year along a 6km stretch of beach results in 12/13 tonnes of litter collected weekly in the summer months at a cost of £36,000 Stirling per annum (Williams *et al.*, 2000). If any area is consistently polluted with debris then this can lead to falls in property values (Rees and Pond, 1995a).

Biologic interactions

The impacts of marine debris on wildlife are generally divided into two groups: entanglement and ingestion although fouling organisms and blanketing effects also warrant serious consideration (Winston *et al.*, 1997). Entangled animals can drown, be fatally or seriously wounded, or have reduced ability to catch food, travel or avoid predators. Ingested material can block and damage digestive tracts and reduce feeding (Jones, 1995). It is estimated that over one million birds and 100,000 marine animals and sea turtles die each year from entanglement in, or ingestion of, plastics (Faris and Hart, 1995). Of the 115 species of marine mammal, 47 have been known to become entangled in and/or ingest marine debris (Pollard and Parr, 1997).

Entanglement

Entanglement of marine animals in debris can be broadly split into four areas:

- Large items of debris trap animals, which may result in the drowning of air-breathing species, asphyxiation of fish species that need constant movement to respire, or death by starvation or predation (Pollard and Parr, 1997). Large or heavy pieces of debris are also liable to drag animals down.

- Smaller items of debris greatly increase drag factors. This will lead to an increased vulnerability to predators and, a decreased ability to forage, which ultimately leads to starvation (Feldkamp, 1985; Loretto, 1995).

- Smaller debris items can become snagged on the sea floor trapping animals, or entangling birds and other animals on land.

- Entangled objects can tighten around the animal leading to restrictions in growth. This can lead to death or inhibit the ability to reproduce (Faris and Hart, 1995). Entanglement can also affect feeding. Emery and Simmonds (1995) reported that the majority of entangled seals have debris wrapped around their heads and necks which can affect ingestion of food.

The dangers to marine animals and birds caused by entanglement in man-made debris have been well documented (Carr, 1987; Fowler, 1987; Arnould and Croxall, 1995; Jones, 1995). In areas of particularly heavy maritime traffic or where oceanic currents naturally accumulate surface material, these problems can be particularly acute (Walker *et al.*, 1997).

A study carried out by Lucas (1992) on Canadian beaches between May 1984 and September 1986 produced data on beach litter composition and entanglement of marine animals. Results found that Harbour and Grey seals were entangled on Sable Island beaches in strapping, net, rope, and other items. Of 241 Grey seal pups handled during research, 2.5% were entangled. Further findings included, seabirds tangled in trawl net, six-pack yokes and balloon ribbons; a Sable Island horse was also found on the beach, with both hind legs entangled in a bundle of plastic strapping. The discovery of the entangled horse indicates the threat posed to terrestrial animals, as well as marine species, from marine debris.

Ingestion

The problem of ingestion appears to have attracted less attention and research than the entanglement of animal species. Plastic ingestion often leads to a less acute effect than entanglement; this could be due to the gradual accumulation of plastic debris in the guts of some animals (Fry *et al.*, 1987; Faris and Hart, 1995). Compared to entanglement, much larger proportions of populations ingest marine debris - up to 100% in some seabird species (Loretto, 1995). Some species may be able to regurgitate or excrete debris, but plastics do not appear to pass through the intestines of seabirds as there is a marked absence of debris from droppings (Faris and Hart, 1995). Seabirds and turtles appear to confuse litter for food (primary ingestion), or ingest litter within other food (secondary ingestion), these items can then pass to the chicks (Loretto, 1995).

Bjorndal *et al.,* (1994) studied the digestive tracts for the presence of debris of forty three juvenile green turtles (*Chelonia mydas*) carcasses stranded in Florida. Fifty six percent had ingested marine debris. The most important conclusion drawn from the study is that even small quantities of debris can kill. It is the predictability of such an event occurring that is unclear. It can take only one transit of debris in the gut of an animal to render the animal incapable of feeding, resulting inevitably in death. Therefore, even in areas where low amounts of debris are recorded the threat to wildlife is still relevant.

Epibionts, encrusters, fouling and associated biota

Freely drifting plastic artifacts and other synthetic materials provide habitats for many opportunistic colonizers, and may act as attachment surrogates for natural floating substances such as logs, pumice and some surface-dwelling, free-swimming larger marine animals. Studies of beach-cast plastic debris from shores of the western North Atlantic and the South West Pacific have revealed more than 100 epibiont and associated motile taxa (Winstone *et al.*, 1997). The initial colonizers following biofilm development, are filimentous algae, hydroids, ascidians and other soft fleshy organisms. These do not long survive desiccation and disintegration once exposed to

the elements in harsh beach environments. As a consequence the record is biased towards resistant, hard-shelled and crustose organisms, that typically includes barnacles, bryzoans, tube worms, mollusks, foraminifera and coralline algae, as well as some more resistant sponges and hydrozoans. Of these the most common taxon is bryozoa with over 60 identified species represented. The extent of bryozoan cover and species diversity is latitudinally dependent. Species richness is greatest in low latitudes and decreases polewards in both hemispheres (Winston *et al.,* 1997; Barnes and Sanderson, 2000).

The biologic communities of pelagic plastics may find side by side associations of related species inhabit quite different environmental niches. A single item recovered from a northern New Zealand beach hosted barnacles typical of sheltered shores (*Balanus modestus*), more exposed coasts (*Balanus trigonus*) and drifting objects (*Lepas anatifera*) and another carried a motile crab fauna represented by common algal dwellers, rocky shore taxa and a pelagic species. There is also evidence that some other taxa may reproduce as they are bouyed along on their floating debris island (Winston, 1997). Larger floating objects or aggregations of debris may also attract resident schools of fish, which in turn bring birds and marine predators.

There is evidence that passively drifting islands of plastic and other debris may be a vector for local, regional and transoceanic dispersal of marine organisms and perhaps even some terrestrial ones (Ryan and Gregory, 1997). For example the common Indo-Pacific oyster *Lopha cristagalli* has been found on a southernmost New Zealand beach attached to a tangled mass of rope, while Florida debris carried a previously unrecorded bryozoa (*Thalamoporella* sp) similar to a Brazilian species (Winston *et al.,* 1997). It has also been suggested that some terrestrial flora and fauna elements could be picked up during a stranding episode, to be later floated off and carried away by offshore winds. REF While pelagic plastics may have less potential than ballast waters for the introduction of aggressive, habitat-harming alien taxa, it is not a threat that should be ignored. Gregory (1991) suggested that alien species rafted on drifting plastic could pose threats to the biota of sensitive and /or protected near-shore environments and perhaps the delicately balanced terrestrial ecosystems of small oceanic islands. These are factors that need to be taken seriously by those having stewardship responsibilities for conservation or heritage estate. An example is Codfish Island lying a short distance offshore from Stewart Island, Southern New Zealand. This is a managed refuge for a small population of a large flightless parrot, the kakapo (*Strigops* habroptilus) which is nearing extinction. The arrival of rats, mustellids or cats on the island through rafting from the mainland some 4 km away could be disastrous for the survival of this species (Gregory,1999b).

Public perception

The appearance of clear water does not necessarily mean that the water is uncontaminated, but the presence of certain items on a beach may, however, imply poor micro-biological water quality. Likewise, a beach that is free from any trace of litter does not imply that the sanitary quality of the sand is good. Particular litter items attain a higher degree of emotional response within the general public than others. Sewage related debris (SRD), medical and hazardous items arouse greater levels of

offense, or feelings of unpleasantness, than do more general items of litter such as beverage containers or confectionery wrappers (Williams *et al.*, 2000). Herring and House (1990) established that sewage derived debris had a greater social impact than any other aesthetic pollution environmental parameter, but there are suggestions that the public debate on sewage in bathing water rarely makes any distinction between aesthetic impact and actual health risk (Jones *et al.*, 1991). TheUK. House of Commons Committee stated that 'while the risk of infection by serious disease is small, the visible presence of faecal and other offensive materials carried by the sewerage system can mean serious loss of amenity and is therefore an unacceptable form of pollution' (HCEC, 1990, xvii).

Methodologies

Surveys can be focused on beaches, seas or rivers where debris is used as an indicator of oceanic, riverine, estuarine or lake conditions (Williams *et al.,* 1999). Many studies monitoring marine debris have concentrated on specific items or categories: Morris (1980), and Pruter (1987) concentrated on plastics; Day and Shaw (1987), and Debrot *et al.,* (1995) focused on tar; Jones (1995) dealt with fishing debris. Other studies though have been less specific and these have assessed areas of land or water for amounts and composition of marine debris (Dixon and Cooke, 1977; Corbin and Singh, 1993; Dufault and Whitehead, 1994; Galgani *et al.,* 1995). Beach surveys are often based on relatively small areas of study (Simmons and Williams, 1993; Frost and Cullen, 1997), with low numbers of surveyors involved in the collection of data. Larger scale studies often require many more people to collect data if they are to be completed at low cost within an acceptable time frame, and not all of these surveyors can be expected to have had previous experience of carrying out litter surveys. However, the use of members of the public or local interest groups in such studies has the added value of raising public awareness and indirect education (Williams *et al.,* 1999). This can be witnessed in public participation schemes such as Beachwatch in the UK., the Campaign for Marine Conservation in the USA. and Pitch-In-Canada.

Surveys are used to determine the amount and type of debris in a specified area at a certain time and to determine how types and amounts of debris change with time (Ribic, 1990). Studies may be simple enumeration studies, assessing types and litter quantities, or they can be more detailed, indicating age and origin of items. For example, (Dixon and Dixon, 1981; Simmons and Williams, 1993), in Europe (Gabrielides *et al.*, 1991; Golik and Gertner, 1992; Bowman *et al.*, 1998), North America (Gilligan *et al.*, 1992; Ribic, 1998), and extensively around the world (Gregory, 1977; Corbin and Singh, 1993; Galgani *et al.*, 1995; Jones, 1995; Walker *et al.*, 1997).

Beach studies face problems in that the amount of debris is influenced by beach dynamics, oceanic circulation patterns, weather, debris characteristics, cleaning operations, and offshore recreation and commercial practices (Faris and Hart, 1995). The many different methods employed in collecting data for beach debris surveys make result comparisons very difficult. There is as yet no single accepted methodology for assessing beach litter. The aim of a study, along with other factors, often influences the technique chosen (Velander and Mocogni, 1999).

Campaigns and initiatives to combat marine debris

There are a number of campaigns and public participation schemes that aim to raise awareness and reduce the marine debris problem. Education and public awareness are key elements in the reduction of marine debris. Public involvement in beach litter management takes two forms: Direct action such as beach clean-ups and monitoring; and indirect action, such as education, award schemes and legislation. The involvement of the public in beach monitoring and clean-up programs has a dual advantage in that it allows a large sample size to be achieved, and raises awareness among society which will then translate into effective individual action to reduce litter at source (Van Maele *et al.*, 2000). Some of the campaigns world-wide are: The Center for Marine Conservation in the USA. which is the largest network organizing beach clean events (Van Maele *et al.,* 2000); Coastwatch Europe involves many thousands of volunteers each year (Dubsky, 1995); Beachwatch in the UK., run by the Marine Conservation Society; and Pitch-In-Canada. There has been some concern that where volunteers are in involved in the collection of data that it can lead to spurious results. Trials by the Tidy Britain Group in the UK showed that volunteers frequently incorrectly identify litter items (Dixon, 1992). An opposing view has been presented in other research (Pond 1996; Williams *et al.,* 1999), although it has been found that particular *items* are consistently mis-identified by the public e.g. cotton bud sticks (Q tips).

Beach Cleaning

Beach cleanups provide a way of collecting data on the types and quantities of marine debris. Beach cleans cannot permanently solve the problem of marine debris as they do not reduce quantities at source (Simmons and Williams, 1993). However, clean-ups are really only applicable locally, are expensive if undertaken by mechanical means and labor intensive. Conversely if volunteers are employed the costs are minimal. However, clean-ups *per se* do not resolve the problem if they do not address the *issues of prevention at source* and it is the links to sources that represents the future challenge (Earll *et al.,* 2000; Williams *et al.,* 2000).

There are, in essence, two methods of beach cleaning: Mechanical beach cleaning involves motorized equipment utilizing a sieve effect which scoops up sand and retains the litter, therefore it is not selective. Most sieve machines are coarse grained allowing items such as cigarette stubs and cotton bud sticks to pass (Williams *et al.,* 2000). The use of mechanical beach cleaners may threaten the stability of some beaches, through the removal of organic matter which forms the 'glue' holding sand grains together (Pollard *et al.,* 1999). The passage of such vehicles over the beach interferes with beach ecology and it is a costly method (Davidson *et al.,* 1991; Acland, 1994; Llewellyn and Shackley, 1996). This method though is limited in that it cannot be used on pebble beaches. Pressure to clean a beach is intense especially by authorities wishing to promote tourism. The advantages of such mechanical clean-ups are that it is fast and can provide an apparently pristine beach for visitors and can cover a large area. In areas with hazardous or sanitary waste it negates the need for picking up material so reducing potential health risks to individuals (Williams *et al.*, 2000). The alternative to mechanical methods is manual beach cleaning. These are often carried out where the expense of a mechanical device is prohibitive, or the

substrate is not receptive to such machines. Manual cleans organized as community events on small areas may ensure that the beach is cleaned of small items missed by mechanical cleans (Pollard, 1996).

The Offshore: (pelagic marine debris)

While significant quantities of land-sourced debris and litter have been reported from harbor and inshore waters for some time, knowledge of amounts and distributions is limited. Heyerdahls's (1971) observations from the raft *Ra* on its slow drift across the equatorial Atlantic provided an initial demonstration of the extent to which surface waters were becoming contaminated by pelagic marine debris. Whether it is for shore line or high seas surveys it is convenient to separate plastic litter into four size categories (Micro litter < 1mm; meso - 1-10mm, mostly pellets or nibs of virgin resin; macro- mostly de-gradational flakes and smaller items to 10cm; mega- larger items > 10cm.). Systematic investigations to establish quantities and distribution of pelagic plastic litter have been sporadic and are based on either surface towed neuston (or pleuston) nets (e.g. Colton *et al.*, 1974) or have used sighting surveys from vessels on passage (e.g. Matsura and Nasu,1997). The former have focused primarily on meso-litter, mostly plastic pellets or nibs, and the latter on macro and mega-litter items identifiable with the naked eye from a vessel's deck or bridge.

There is little information available about the quantities and distribution patterns of plastic micro litter. The source lies in some propriety hand cleaners and cosmetic preparations, and air-blast cleaning media as well as from degradation and disintegration of larger debris items. There can be little doubt that micro-litter is now globally dispersed and there are suggestions that it could impact sea-surface micro-layer ecosystems and the meiofauna of inter-tidal and beach sediments (Gregory, 1996).

Plastic meso-litter, mainly in the form of nibs or pellets of virgin polystyrene and polyethylene, has a universal presence in oceanic surface waters. The greatest densities have been noted in coastal and shelf waters off major urban and manufacturing centers – some quoted maximum pellet densities include >100,000/sq. km off the eastern seaboard of North America (Colton, *et al.*,1974); >40,000/sq. km in waters of Cook Strait, New Zealand (Gregory, 1990); 1,500/sq. km in the Sargasso sea (Wilber,1987) and 1,500 – 3,600/sq. km in the Cape Basin Region of the South Atlantic west of South Africa.

Mega-litter quantities have been reported from all marine waters but the most extensive sighting surveys have taken place across the North Pacific (e.g. Matsumura and Nasu, 1997) and the Whale sanctuary of the Indian Ocean (Grace and Frizell, 2000). There are numerous other casual or anecdotal comments since Hyerdahl (1971) brought this problem to the fore. Distribution patterns for plastic litter in all size categories across the high seas are similar. The greatest densities, whether measured by weight or item count are to be consistently found in coastal and shelf waters adjacent to and down drift from major urban and manufacturing regions. On the open ocean, distant from land-based sources it tends to concentrate along oceanic fronts and in large eddy systems or gyres.

Concentrations of macro and mega litter are also present along many shipping routes particularly those of the North Atlantic and North Pacific. They are much less across

the South Pacific where shipping traffic is sparser and industrial developments are fewer and distant.

The Seafloor: (benthic marine debris)

The sea floor from inter-tidal and shallow sub-littoral to outer shelf, slope and abyssal depths has been identified as an important sink for marine debris (Williams *et al.*, 1993; Goldberg, 1997). An early demonstration of this came with the recognition of plastic film accumulating on the floor of the Skaggerack by Holmstrom (1975). The problem is now appreciated to be a global one with many observations made by divers, through video footage from ROV's as well as sampling by bottom trawls. Data has been obtained from varying depths and at many widely separated places, including Antarctica (Lenihan *et al.*, 1990), the Bay of Biscay and other European waters (Galgani *et al.*, 2000), the western (Galgani *et al.*, 1995,1996) and eastern Mediterranean (Bingel *et al.*, 1987; Galil *et al.*, 1995; Stefatos *et al.*, 2000); Alaska (Hess, *et al.*, 1999); California (Moore *et al.*, 2000): Indonesia (Uneputty and Evans,1997); Japan (Kanehiro, *et al.*, 1995); South Africa and New Zealand (Gregory and Ryan, 1997). Many of the early reports are generalized and descriptive. Latterly there have been several studies with substantial quantitative data on amounts and types of debris although the methodologies adopted are not necessarily the same. REF

The quantities of sunken litter being reported are high. Litter densities on the sea floor of central Tokyo Bay, Japan, ranged from c25,000 to c60,000 items/sq. km (Kanehiro *et al.*, 1995). Of this plastics comprised 80-85% with fishing related items between 2.7 and 9.0%. Quantities had not significantly changed over a four year period (1989-93) and land based sources were considered to be of most importance. In water depths of less than10m at French Frigate Shoal, in the Hawaiian chain, Bowland (1997) estimated that netting fragments were 94 items/sq. km. Stefatos *et al.*, (1999), recognized that marine debris concentrations on floors of the enclosed Patras and Echinadhes Gulfs, western Greece, reached 240 and 89 items/sq. km respectively. They noted that these differences could be related to land-based sources for the former and shipping traffic in the latter. From studies of inshore waters around Kodiak Island, Alaska, Hess *et al.*, (1999) showed that fisheries-related and other plastic debris quantities were greatest in inlets (20-25 items/sq. km) and least in open waters outside inlets (4.5-11 items/sq. km). These differences were considered to reflect variations in fishing effort and water circulation patterns. Moore and Allen's (2000) shelf survey of the Southern California Bight, ranked quantities of anthropogenic and natural debris into four broad categories (trace, low, moderate, high) on the basis of number and weight of items determined from standardized trawl times along isobaths between depths of 20 and 200 m. Bathymetrically, the proportion of area with anthropogenic debris increased with increasing distance along a broad offshore front, from inner to outer shelf. This suggested a source that lies in disposal practices from boating activities. The most comprehensive and thorough reports are those coming from European and western Mediterranean waters (see Galgani *et al.*, 2000 and earlier papers quoted above). Densities found were highly variable between and within separate sampling areas. Near metropolitan areas they could exceed 100,000 items/sq. km but elsewhere maximum values were lower (50,000 items/sq. km in the Bay of

Biscay; 600 items/sq. km in the North Sea 200 km west of Denmark). It was also noted that concentrations of debris (to densities >50,000 items/sq. km) were encountered at depths of >2000metres on floors of canyons along the Mediterranean coast of France. Variations in distribution patterns were attributed to geomorphologic factors, local anthropogenic activities and land-based river inputs.

Mechanisms by which the mostly neutrally buoyant plastics in marine debris reaches the deep-sea floor are poorly understood. Oshima (2000) for instance recorded a fleet of flimsy, white, supermarket shopping bags upended and suspended at depths of 2000 m. and drifting like an assembly of ghosts. Significant quantities of land-sourced materials on submarine canyon floors to considerable distances offshore, suggest rapid transport through near-shore zones and entrainment in bottom hugging currents. It has been argued (Ye and Andrady, 1991; Stevens,1992) that density increases following rapid and heavy fouling may be sufficient to permanently sink them. On the other hand, grazers may clean covered surfaces leading to 'yoyo-like' episodes of submergence and resurfacing until permanent settlement to the sea floor is effected. As well as biofilm development, plastic sheeting may also attract non-living detritus, which with photo-degradation and progressive embrittlement leads to density increases taking it to the sea floor (Powlik1995) without the need for invoking down-welling and/or entrainment.

The epibionts of benthic plastic debris are not as well known as those of pelagic items. Accounts are limited (e.g. Holmstrom, 1975; Harms,1990; Powlik, 1995) but indicate a hard ground biota characterized by bryozoans, sponges and foraminifera, with barnacles, mollusks and polychaetes is typical. At shallow, photic zone depths, there is development of crustose (coralline) red algae as well as soft brown and green algae. Bryozoa are generally the dominant epibiont of both pelagic and benthic plastics.

Plastic sheeting together with larger, more solid items and discarded fishing gear is an undesirable addition to the deep-sea floor and potentially damaging to the environment
(Williams *et el.*, 1993; Goldberg,1997). The blanketing effects of sheeting may damage biotas of both soft sediment and rocky hard ground substrates at all depths from inter-tidal to the abyss. They may lead to anoxia and hypoxia induced by inhibition of gas exchange between pore water and sea water (Goldberg, 1997). Ironic as it may seem, could benthic plastic debris standing proud of the sea floor enhance or enrich local biotic diversity in the short term, for in the long term it is doomed to permanent internment in a slowly accumulating sediment cover?

Degradation

Breakdown of plastics mainly takes place through photo-degradation which leads to surficial cracking followed by embrittlement and ultimately complete disintegration into powder. Bio-degradation is seldom important with most plastics that enter the marine realm. Physical abrasion is also a mechanism for the breakdown of plastics along shorelines – particularly high energy cliffed and rocky shores. Degradation performance is generally measured through changes in tensile strength and viscosity although UV and laser spectroscopy are other approaches. Several studies have shown that the rates of weathering of polyethylene and other plastics are substantially

reduced when floating in sea water compared to those when exposed outdoors to normal atmospheric conditions e.g. Andrady (1990). Enhanced photo-degradable polyethylene also degrades more slowly under marine conditions (Andrady *et al.*, 1993). Alternatively, expanded polystyrene foam is known to deteriorate more rapidly in sea-water than on atmospheric exposure (Andrady and Pegram, 1991). Material that has been buried for some time in beach/riverine sediments retains much of its tensile strength - *circa* 80% (Williams and Simmons, 1996) and may be exhumed during episodes of erosion (Gregory,1999). Plastics sinking to the deep sea floor will not be subject to photo-degradation and if resistant to bio-degradational processes will be preserved there until burial is completed.

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Methods used for Monitoring the Discharges of the Plastic industry in Southern California

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Introduction

Land-based sources of plastic and trash, especially in urban areas of Southern California, are the most significant source of marine debris impacting coastal waters in that area. The recently approved regulations for Total Maximum Daily Load (TMDL) for trash for the Los Angeles and San Gabriel River watersheds focused on large debris greater than 5 millimeters (mm). However, recent studies (1999-2004) conducted by the Algalita Marine Research Foundation (AMRF) and the Southern California Coastal Water Research Project (SCCWRP) aboard the Oceanographic Research Vessel (ORV) *Alguita* suggest that plastic fragments less than 5mm in size occur in a mass six times higher than the mass of plankton in the mid-Pacific Gyre and, in near coastal waters of southern California, the average mass of plastic was two and a half times greater than that of plankton. Three papers presenting the results of these trawls have been published in Marine Pollution Bulletin[1]. One of the most notable components of the plastic debris studied that is less than 5 mm has been pre-production pellets. These pellets are uniform in size and come in a variety of shapes, including rounded, flattened oval, and cylindrical. The major plastic producers make these pellets, then ship them to the various plastic manufacturers to be melted and made into consumer products.

Trash, plastics, and anthropogenic debris impair the beneficial uses of the Los Angeles River and San Gabriel River watersheds, as well as other watersheds in urban areas of California. Current policies and programs adopted by California including the (1) "Plan for California's Nonpoint Source Pollution Control Program," (2) Total Maximum Daily Loads (TMDLs), and the(3) "Watershed Management Initiative Chapter" identify the need to adequately protect water quality in inland waterways and coastal waters with respect to pollutant loading from trash and plastics.

Implementation of existing Best Management Practices (BMPs) and the trash TMDL is necessary to determine whether these measures are adequate to control the pellet loading and trash problem. If current methods are not successful in reducing the contribution of plastic pellets and other trash from inland waterways to coastal beaches and waterways, then other source reduction methods need to be developed and implemented. Industry, the public and policy-makers lack adequate information about the impacts of plastic debris and source reduction measures and should be educated as a means to effect behavior and policy changes that will reduce pollution.

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The primary goal of this project is to provide information in order to reduce the land-based inputs of plastic debris, which degrade water quality and impair beneficial uses of inland and coastal waters. The long-term goals include encouraging public policy-makers, local governments, industry, and the general public to reduce the sources of plastics and trash discharges by developing pro-active source reduction strategies that go beyond trapping and catch basins and industrial housekeeping practices. Another long-term goal is to further reduce the incidence of plastic and trash discharges in urban runoff by developing an action plan for the state to control all sources of plastic debris.

Methods

The focus area of this study was the Los Angeles River Watershed and the San Gabriel River Watershed in Southern California. The areas of interest for this study were Best Management Practices Evaluation at plastic industry sites, sampling mass emission sites on each river, sampling the beaches adjacent to each river and the forebay at the mouth of each river. The mass emission site for each river was selected because it was the convergent area, at which all materials coming down the river from the watershed would have to pass before reaching the ocean, and it was also upstream enough not to be influenced by ocean tides. The mass emission samples and the forebay samples focus on the plastic particles in the rivers that are less then 5 mm. Many of these plastic particles are pre-production pellets, shavings from cuttings, regrinds, and sprues from drilling during the manufacturing process. They come from industry but cannot be linked to an individual industry site. These smaller plastic particles also come from post-consumer products broken down to the smaller size. The beach samples collected were analyzed for Persistent Organic Pollutants (POPs). (For analysis of POPs, see proceedings "AMRF Findings On Pops Contained In And On Plastics In Urban Runoff," C.J. Moore). It is difficult to determine how long some plastic particles sampled at the mass emission, forebay, and beach locations have been in the environment due to resuspension and redistribution by fluctuating water flows, changing tides, and winds.

Due to the wide variety of plastic industries in the LA basin, and the difficulty of rigorous quantification of sporadic inputs to watershed runoff from these facilities, a case study approach with qualitative goals for the project was adopted after consultation with the project's Technical Advisory Committee. While AMRF and other researchers have developed peer-reviewed methods for collecting pellets from the ocean and beach environments, no established methods have been developed for collecting pellets from plastic pellet handlers and processors. Therefore, it was decided that comparing all plastic industries to a single standard would not be possible. A methodology was developed that would compare each industrial facility to itself before and after implementation of Best Management Practices (BMPs) recommended by the project. Many of these BMPs were taken from "Operation Clean Sweep," an industry publication designed to help plastic facilities minimize pellet loss. When quantitative results

are given, they should be understood to represent a "snapshot" of a facility using a methodology developed specifically for the project, reviewed by the project's Technical Advisory Committee and Advisory Board, which includes plastic industry representatives.

Ten plastic industry sites were monitored to study the effectiveness of Best Management Practices (BMPs). These companies comprised different specialties within the plastic industry: Injection Molding, Plastic Bag Manufacturing, Bulk Transporters and Shippers, and Roto-Molding. The study area involved the industry site and the nearest storm drain. Two of the industrial sites had unique delivery conduit systems, a storm drain on the facility leading directly to the river or to a channel leading directly to the river. There were five sites selected for each river. Each facility was sampled during a dry season before the Best Management Practices were suggested and again during a dry season at least two months after the Best Management Practices were suggested, which allowed the facility time for implementation. Each storm drain was sampled during a wet season and a dry season, both before and after the implementation of the BMPs. The wet season was defined in this study as greater than 0.25" of rain and a dry season was defined as a period of at least two weeks after a rain event of 0.25" of rain.

The industry sites were identified by using publicly available sources. We first identified the pertinent Standard Industrial Codes (SIC) for the various plastic industry specialties and then we located the plastic industries through the listings of the Thomas Registry, Enforcement and Compliance History Online (ECHO), and the Regional Water Quality Control Board (RWQCB). We called each facility on the list to see if they were still in business. The remaining industries were then visited to determine the type of facility and to rank each for cleanliness. Each facility was given a ranking between 1 to 10 for cleanliness, 1 being the cleanest and 10 indicating massive plastic spills. All of the visits were preformed from the public access locations that surrounded each facility. The rankings were plotted on a histogram and the sites were selected across the spectrum of the histogram to avoid bias by picking only the cleanest sites or ones with the higher plastic debris rankings. The ranking visits provided only snapshots of the facilities and did not indicate what the cleanliness might be on a regular basis. This would have taken numerous visits to determine. Different types of facilities were also selected from the rankings to determine how the implementation of the Best Management Practices at these types of facilities would differ.

Each site selected was visited for pre-BMP purposes as a "cold call." They didn't know they were going to be visited before the project was introduced to the management. The project was described to the management and they were asked if they would like to participate on a voluntary basis. If the management agreed to participate, samples were taken immediately. The reason for this protocol came from previous communications with other plastic companies where

we found that any notification of a visit initiated some sort of clean up. Possibly the biggest reason the industrial sites agreed to participate in our project is that they would remain anonymous. We identified them by code numbers and letters.

Storm Drains associated with the sites were sampled using storm drain inserts, which would collect the material that entered the storm drain and prevent it from reaching the rivers and finally the ocean. A few industry sites already had a basket or insert installed; at other sites inserts were installed with 1 mm mesh. If the storm drain was on the facility and didn't have an insert, the insert was added only with the permission of the facility. One company decided to install a sump with a pump to pump out any water collected and retain the debris; however, their overflow to the storm drain was not screened. At the sites which already had the insert installed, we found that the facility often removed the liner when a rain event occurred. Inserts with 1 mm mesh were also manufactured and installed at street storm drains near the facility. All street storm drains inserts that the field team could not clean out were vacuumed by a company that installs and maintains storm drain inserts. We were on site when the inserts were vacuumed and retained the samples to be analyzed at the AMRF Lab. The pre-BMP sample included both the site visit and the storm drain sample. Storm drains were sampled during a dry and wet season, both pre-BMP and post-BMP.

After the pre-BMP sample, another visit was made a couple of weeks later to have an on the site walk-through with the management to evaluate the site for Best Management Practices. Suggestions were made for other BMPs, verbally at the site, followed by written recommendations. Posters advocating pellet retention on site from the American Plastics Council were given to each facility. We worked with the plastic industry on the modification of the industry Best Management Practices guidelines "Operation Clean Sweep" (OCS). Most of the recommendations were in the OCS. Some sites had unique situations that other industry sites might not have. The participants were given time to implement any modifications we suggested or any other modifications they wanted to try. Any type of modification was strictly voluntary. If they didn't want to change anything, they didn't have to. The time frame for the follow up visit was to be at least 2 months following the BMP evaluation visit. Another on-site survey with the management personnel of the participating business was conducted to determine which of the BMP recommendations were implemented and in what manner. This was to be during dry weather. Rain delayed us for several months.

Post-BMP sampling was the same as the pre-BMP sampling. We made another blind visit to the facility; at this time they knew we would be coming after the follow up evaluation, but they didn't know when. The sampling was the same as the pre-BMP visit with industrial site and storm drain sampling during dry weather. (See proceeding "Measuring The Effectiveness of Voluntary Industry Efforts: AMRF's Analysis of Operation Clean Sweep," C.J. Moore, G.L. Lattin, A.F. Zellers, for results and findings of Best Management Practices Evaluation.)

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"Summary of NOAA's Marine Debris Prevention and Removal Program Efforts"
Overview of Presentation by Dr. Holly A. Bamford
Plastic Debris Rivers to Seas Conference
September 7, 2005 Redondo Beach, CA

Introduction

Marine debris poses a serious threat to our oceans and coasts, natural resources, human health and safety, and navigation. It also threatens the safety of aquatic animals that can be injured or killed by entanglement or ingestion of debris, including protected and endangered species. The mission and management responsibilities of the National Oceanic and Atmospheric Administration (NOAA) include protecting and sustaining fisheries, marine mammals, endangered marine species, beach and shoreline management, and coral reefs. All these can be adversely impacted by marine debris and it is NOAA's mission to conserve and manage coastal and marine resources.

NOAA Marine Debris Efforts

From 1985 to 1996, NOAA administered the Marine Entanglement Research Program, a marine debris research and management program that was created in response to growing public concern over the impacts of marine debris on wildlife. Since then, NOAA has continued to support marine debris clean-up and prevention activities, such as the debris assessment and removal project in the Northwestern Hawaiian Islands, the use of satellite and aerial remote sensing to locate and track oceanographic features likely to accumulate floating marine debris, and support for the development and testing protocols for removing derelict fishing gear (DFG) from coastal waters. However, many of these activities were not coordinated under a centralized program.

In 2005, Congress appropriated funds for NOAA's Office of Response and Restoration to re-establish a centralized marine debris program within the agency to organize, strengthen, and increase the visibility of the marine debris efforts. By re-establishing a program, we hope to shed light on and better understand the sources and impacts of marine debris to our oceans and coasts, and contribute to the development of solutions.

Re-centralized Program

Since the beginning of the year, NOAA has been very active to meet this request. NOAA has re-established a cohesive program, inventoried marine debris-related activities within the agency, and identified key elements of the program. The program's objective is to undertake a national effort focused on identifying, removing, reducing, and preventing the occurrence of marine debris. The program seeks to bring greater attention to this environmental problem. To facilitate the overall reduction of the impacts of persistent debris on marine and coastal resources, habitats, and commerce, the program aims to accomplish the following actions:

- support research and monitoring activities to more precisely determine impacts of persistent marine debris on human, fish, and wildlife populations;

- develop and test cost-effective methods of detection, tracking, and removal of debris in the ocean and coastal waters, leading to an operational procedure for finding and removing hazardous marine debris;
- work with our partners to develop comprehensive educational materials on problems caused by marine debris and actions people can take to reduce the impacts of marine debris on the environment;
- work with other Federal agencies to re-establish the Interagency Marine Debris Coordinating Committee as stated in the U.S. Ocean Action Plan; and
- seek opportunities to work with external partners in various regions to co-sponsor projects aimed at reducing marine debris relevant to that area.

Marine Debris Projects

The program has already begun to support activities related to these key actions. For example, the program is supporting a marine debris location, assessment, and removal pilot project in the Main Hawaiian Islands, as well as a marine debris port reception feasibility project in Honolulu. There are also a number of marine debris educational and outreach awareness projects that are being developed that target boaters, anglers, general public, and local schools.

Another area of study is looking at the impact and potential removal of DFG from our coastal waterways. DFG are nets, lines, crab/shrimp pots, and other recreational or commercial fishing equipment that has been lost, abandoned, or discarded in the marine environment. Entanglement of marine animals in DFG can injure animals, impair their mobility, and often result in their death. Because much fishing gear today is made of plastic, it can last for years, and continue to fish and entangle marine animals after it is lost or disposed at sea. NOAA has begun working with our partners to identify, map, and assess DFG in various regions around the country.

The ultimate goal of this program is to work with our partners to have clean oceans, waters safe for navigation and marine wildlife, and an informed society that acts as steward of the oceans.

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Composition and Distribution of Beach Debris in Orange County, California

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Many studies have quantified debris collected on beaches around the world. Only a few of those studies have been conducted in the United States, and they are largely limited to semi-quantitative efforts performed as part of volunteer clean-up activities. This study quantifies the distribution and composition of beach debris by sampling 43 stratified random sites on the Orange County, California coast, from August to September 1998. We estimated that approximately 106 million items, weighing 12 metric tons, occur on Orange County beaches. The most abundant items were pre-production plastic pellets, foamed plastics, and hard plastics. Debris density on the remote rocky shoreline was greater than that on high-use sandy beaches for most debris items. This finding partially reflects the periodic clean-up of high-use beaches by local municipalities, and also indicates that a high percentage of the observed debris was transported to the site from waterborne sources. **© 2001 Elsevier Science Ltd. All rights reserved.**

Keywords: beaches; debris; plastics; pellets; southern California; pollution monitoring.

Beaches along the southern California coast are used extensively for a variety of recreational purposes, attracting almost 150 million visitors annually (Schiff *et al.*, 1999). Recreational uses such as boating, swimming, surfing, sunbathing, and picnicking generate debris along the shoreline including food bags and wrappers, cups and utensils, trash bags, fast-food and other product containers, toys, fishing lures and floats, and plastic. In addition, southern California has the highest coastal population density of any area in the country (Culliton *et al.*, 1988), providing an additional source of debris via urban runoff and maritime disposal (including accidental spills).

Debris is one of the most highly visible expressions of human impact on the marine environment, which is one of the factors that has led to the popularity of public clean-up efforts along the shoreline (Ribic *et al.*, 1997). More than an aesthetic issue, debris can threaten marine mammals, birds, and turtles through ingestion and entanglement (Bjorndal *et al.*, 1994; Fowler, 1987; Robards, 1993; Ryan, 1987). Marine debris is also becoming a regulatory focal point. The Los Angeles Regional Water Quality Control Board recently implemented legal limitations, through the total maximum daily load (TMDL) process, on the amount of trash that local governments can allow to enter the ocean through storm drains.

Many studies have enumerated the types and amount of marine debris on beaches (Corbin and Singh, 1993; Garrity and Levings, 1993; Golik, 1997; Golik and Gertner, 1992; Lucas, 1992; Ross *et al.*, 1991; Ribic *et al.*, 1997; Walker *et al.*, 1997; Willoughby, 1986), and a few studies have quantified subsurface nearshore debris (June, 1990; Moore and Allen, 2000). Most of the debris data for beaches outside of the United States have been collected through systematic, scientifically rigorous studies, while most of the information within the United States has been derived from volunteer beach cleaning efforts. Although cleaning efforts are valuable for removing debris from beaches, they provide only semi-quantitative estimates of debris. Here we present the first study to quantitatively assess the types and amount of debris on the California coast, with a secondary objective of describing how debris differs among shoreline types.

Materials and Methods

Beach debris was surveyed and collected at 43 sites from Seal Beach to San Clemente, on the Orange County, California coast, between 2 August and 18 September 1998 (Fig. 1). Sites were selected using a stratified random design, stratified by shoreline type (rocky shoreline and sandy beach). Sample sites were randomly selected within the strata and a systematic component was overlayed to minimize clustering, following the sampling design used in the National Stream Survey (Overton, 1987). Each stratum was subdivided into a series of sections (each identified by a count variable) of like-strata joined together into a stratum line. A partition

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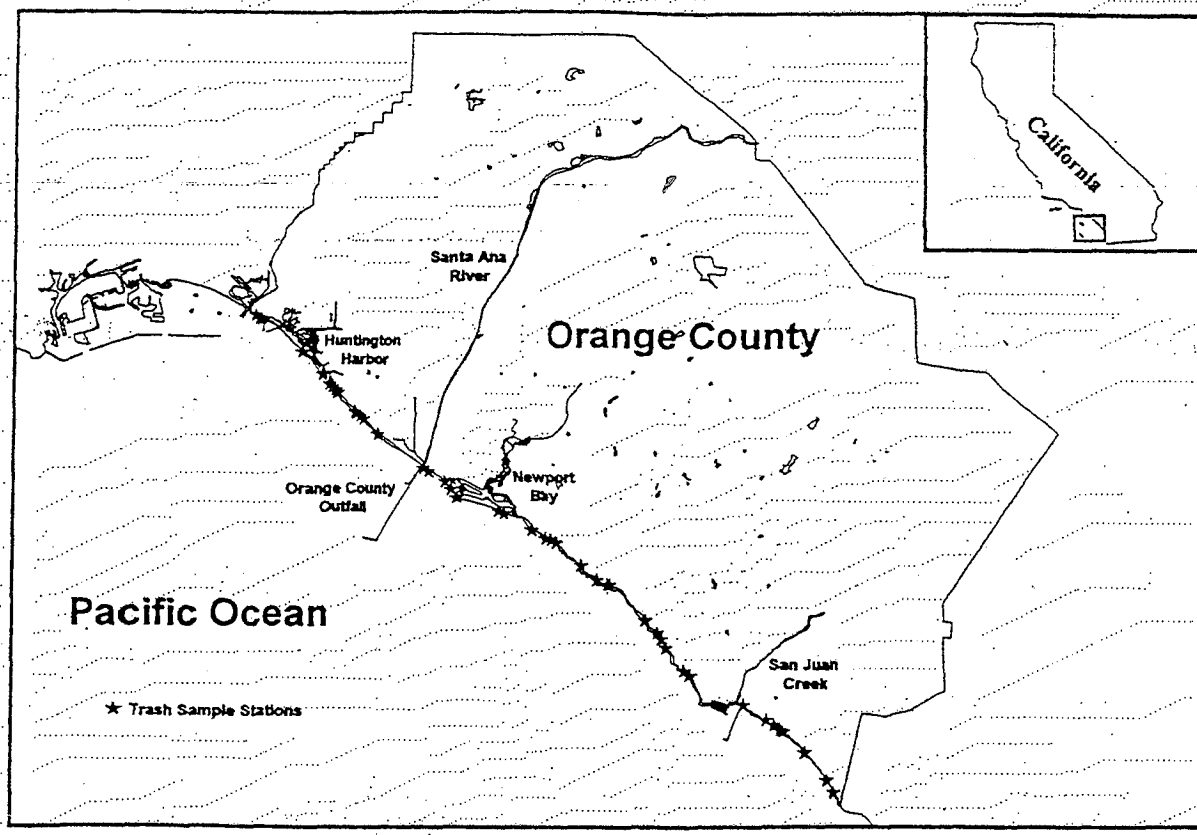

Fig. 1 Sample sites for the Orange County beach debris study, August 1998–September 1998.

was created for each stratum line, with the number of intervals in the partition equal to the sample size. The partition was placed over this stratum line by selecting a random starting point for the beginning of the first interval. Based on this starting point, the intervals were defined as consecutive equal-width lengths. A simple random sample of one point was then chosen from within each interval. Each point was translated back to the shoreline using the section count variable. The partition structure ensures systematic separation of the sampling, while the random selection of sites within partitions ensures an unbiased estimate of beach debris.

Each sample site was delineated as an area 22.9 m in length that extends from the water's edge to the first pavement or rocky cliff. All trash at the site was collected by at least three people walking systematically along transects to ensure that all areas within the sample site were examined. All debris was bagged and transported to the laboratory for identification and quantification. In addition, an 18.9 l bucket was used to sieve one bucket of sand at each site to quantify the small items that were undetectable by visual examination. In the laboratory, debris was sorted into the broad categories used by the Center for Marine Conservation during their Coastal Clean-up days (i.e., glass, metal, plastics, foamed plastics, rubber, paper, wood, and cloth). From each broad category, debris was further sorted into more specific subcategories (e.g., cups, plates, etc.), enumerated, and weighed. Within the specific categories, brand names were recorded, when possible, to establish cross-brand trends.

The total amount of debris along the Orange County coast was estimated by calculating a mean amount of trash for a 22.9 m segment within each strata and then weighting those means by the relative amount of shoreline distance in each strata. Estimates for smaller debris collected by sieving were calculated using a similar methodology, after estimating the number of meters from the water's edge to the first pavement or rocky cliff for each site then extrapolating the abundance for each sample site area.

Results

More than 106 million items, weighing approximately 12 metric tons, were estimated to occur along the Orange County shoreline (Table 1). Three categories of plastics (pre-production plastic pellets, foamed plastics, and hard plastics), accounted for 99% of the total abundance and 51% of the total weight. Cigarette butts were fourth in abundance and accounted for less than 1% of the total abundance and weight. Cigarettes, candy, fast-food products, beer, and other beverages were the most identified brand-related debris (Table 2). Marlboro®,

A014608

TABLE 1

Estimated total abundance and weight of trash on Orange County beaches, August 1998–September 1998.

Debris type	Estimated totals for Orange County	
	Abundance	Weight (kg)
Pre-production plastic pellets	105 161 101	2168
Foamed plastics	742 296	692
Hard plastics	642 020	3588
Cigarette butts	139 447	156
Paper	67 582	394
Wood	27 919	2066
Metal	23 500	1368
Glass	22 195	882
Rubber	10 742	371
Pet and bird droppings	9388	8
Cloth	5949	650
Other	10 363	182
Total	106 862 502	12 525

TABLE 2

Percent of total of top three brands in main brand categories collected on Orange County beaches, August 1998–September, 1998.

Brand name	Percent of total	Percent market share
Cigarette products		
Marlboro	62	32.3
Camel	7	4.6
Benson and Hedges	7	<2.4
Candy products		
Starburst	16	na[a]
Snickers	13	na
Blow Pop	9	na
Fast food products		
Jack in the box	27	3.6
Carls Jr	19	1.9
KFC	12	<0.9
Beer products		
Budweiser light	27	12.9
Budweiser	16	18.3
Corona	7	2.0
Drink products		
Coca Cola	16	20.6
Pepsi	15	14.2
Capri Sun	8	<1.2

[a] na – not available.

Starburst®, Jack in the Box®, Budweiser Light®, and Coca Cola® all led in their respective categories.

Most of the plastics encountered were in the form of small pieces of plastic (Table 3). Foamed plastic pieces accounted for 88% of the total foamed plastics and hard plastic pieces accounted for 50% of the total hard plastics. Of the whole plastic items, food and beverage items were the most abundant.

The distribution of debris differed among shoreline types. Sandy beaches are eight times more abundant than rocky shoreline in Orange County, but most debris did not reflect this ratio (Table 4). Foamed and hard plastics, glass, rubber, and animal droppings all occurred at higher proportions on rocky beaches. Pre-production plastic pellets, paper, wood, and cloth all occurred at higher proportions on sandy beaches. Cigarette butts and metal were found at approximately equal ratios between beach types.

TABLE 3

Estimated total abundance of plastics on Orange County beaches, August 1998–September 1998.

Trash type	Abundance
Foamed plastics	
Foamed plastic pieces	652 639
Fast food containers	43 167
Other foamed plastics	25 415
Cups	10 595
Packaging material	9940
Plates	270
Meat trays	180
Buoys	90
Total	742 296
Plastics	
Plastic pieces	318 790
Caps and lids	88 548
Straws	84 990
Food bags and wrappers	58 394
Other plastic	48 799
Cups and utensils	9641
Other plastic bags	7164
Cigarette lighters	5810
Beverage bottles	4550
Trash bags	3729
Toys	2159
Buckets	1973
Rope	1848
Other bottles	1563
Milk and water bottles	1182
Diapers	1003
Strapping bands	449
6-pack holders	321
Fishing line	321
Tampon applicators	301
Fishing lures and floats	281
Oil and lube bottles	114
Light sticks	90
Total	642 020
Total plastics	1 384 316

Discussion

The most abundant item found on southern California beaches was pre-production plastic pellets, which are probably lost in transport from the raw material producers to the processors who mold the pellets into plastic products. The pellets, collected primarily through sieving the surface layers of sand, come in a variety of shapes (ovoid, cylindrical, etc.) and are typically less than 5 mm in diameter. Approximately one quadrillion of these pellets, representing 60 billion pounds of resin, are manufactured annually in the United States alone (USEPA, 1992). The presence of these pellets is not unique to US beaches (Gregory, 1977, 1978, 1983; Shiber, 1979, 1982). Gregory (1977, 1978) estimated that the number of these pellets on New Zealand beaches could possibly exceed 1000 t.

A014609

TABLE 4

Estimated total abundance of trash by beach type on Orange County beaches, August 1998–September 1998.

Debris type	Beach type		
	Sandy	Rocky	Sandy:Rocky ratio
Percent of shoreline	89	11	8:1
Pre-production plastic pellets	96 211 029	8 950 072	11:1
Foamed plastics	557 319	184 977	3:1
Hard plastics	424 257	217 763	2:1
Cigarette butts	124 422	15 025	8:1
Paper	64 729	2853	23:1
Wood	25 611	2308	11:1
Metal	20 468	3032	7:1
Glass	4055	18 140	1:4
Rubber	9039	1703	5:1
Pet and bird droppings	7217	2171	3:1
Cloth	5529	420	13:1
Other	10 300	63	163:1
Total	97 463 975	9 398 527	10:1

The relative distribution of brand-name products in the debris we collected largely reflects the product's relative market share. For example, we collected 10 times more Marlboro cigarette butts than any other brand, consistent with Marlboro's 32% market share. Similarly, Budweiser and Budweiser Light dominated the beer debris category, as they do in sales. One exception to the high correlation between brand-related debris quantity and market share was in the fast-food container category. Industry leader McDonalds constituted less than 10% of the total debris measured, while Jack in the Box accounted for nearly three times that level. Perhaps the geographic distribution of fast-food restaurants in relation to Orange County beaches was responsible for the discrepancy in the amount of fast-food product debris collected compared to the brand's respective market share.

Four major sources have been identified as pathways in the transport of debris to the Orange County shoreline: (1) littering by beachgoers, (2) wind currents from upland sources, (3) runoff from land-based activities, and (4) overboard disposal from boating activities (including accidental spills). Each of these sources requires a different management action to effect a reduction in beach debris. Although our study was not designed to differentiate sources, our data suggest that water-based sources (runoff and overboard disposal) were more important than direct littering or wind. One line of evidence for this is that plastic pellets were found in abundance on all shoreline areas and are unlikely to originate from littering or wind. The second line of evidence is the greater density of most debris items found on less-frequented rocky shoreline compared to the sandy beaches (Table 4). While this pattern was true for most debris, an exception was the greater amount of paper products, such as food wrappers, found on sandy beaches, suggesting that they were left by beachgoers.

The only previous quantification of debris on the Orange County shoreline was from data collected by volunteers during the annual California Coastal Clean-up Day. Their 1998 clean-up event occurred the week after the present survey was completed and their estimate of the amount of debris was 50 times lower than our data (Table 5). Moreover, our estimate for Orange County debris exceeded the California Coastal Clean-up Day estimate for the entire state.

The estimates provided by the two surveys differ for several reasons. First, the California Coastal Clean-up Day is conducted by volunteers whose purpose it is to clean the beach rather than to quantify debris. As a result, it is likely that the some of the debris collected during this event was not recorded. Second, the volunteers focus their cleaning efforts on a subset of the coastline, which excludes the rocky shoreline where 10% of the debris was encountered in the present study. Third, the California Coastal Clean-up Day event

TABLE 5

Comparison of abundance for the Orange County summer trash survey and Center for Marine Conservation 1998 California Coastal Clean-up Day.

Debris type	Summer Survey	Coastal Clean-up Day	
	Orange County	Orange County	California
Pre-production plastic pellets	105 161 101	–	–
Foamed plastics	742 296	8170	211 406
Hard plastics	642 020	10 860	382 380
Cigarette butts	139 447	6717	309 910
Paper	67 582	2504	133 335
Wood	27 919	720	27 136
Metal	23 500	1456	110 201
Glass	22 195	1033	94 333
Rubber	10 742	643	25 666
Pet and bird droppings	9388	–	–
Cloth	5949	317	10 620
Other	10 363	–	–
Total with pellets	106 862 502	32 420	1 304 987
Total without pellets	1 701 401	32 420	1 304 987

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TABLE 6

Comparison of beach debris amounts between Coastal Clean-up Day volunteers and the Orange County beach debris follow-up study.

Trash type	Total abundance of beach debris			
	Sunset Beach		Salt Creek	
	CCD[a]	OC[b]	CCD	OC[b]
No. of volunteers	56	8	197	5
Total weight (kg)	62	48	184	16
Foamed plastics	313	19219	1057	6336
Hard plastics	1419	13658	1775	5667
Cigarette butts	222	9293	1646	2464
Paper	139	3133	711	1338
Wood	28	387	121	246
Metal	26	1126	244	2534
Glass	15	950	257	–
Rubber	67	282	157	387
Cloth	5	634	48	141
Total	2234	48682	6016	19113

[a] CCD – Coastal Clean-up Day.
[b] Orange County beach debris follow-up study abundances are estimates of trash found in 0.8 km based on a 22.9 m sample.

focuses on many of the popular, easily accessible beaches that are regularly cleaned by mechanical combers. Moreover, the clean-up events usually only cover an area 0.4–0.8 of a kilometer from their starting locations (Mark Patrick, County of Orange. Harbors, Beaches, and Parks, pers. comm.), rather than the whole beach.

Another variable that could partially account for the discrepancy in the two survey results is that volunteers traditionally focus on larger, more visible debris to the exclusion of small, undetectable debris. To assess the impact of this variable, two beach sites (Salt Creek Beach and Sunset Beach) were sampled using the same methods as the present study. Sampling occurred immediately after the 18 September 1999, California Coastal Clean-up Day. While more than 8000 pieces of debris were collected from these beaches as part of the clean-up effort, we estimated 67795 pieces remaining (Table 6). Most of the remaining items were small: the majority of large items, such as glass bottles, were effectively removed by the California Coastal Clean-up Day volunteers.

The authors wish to thank the following organizations and their volunteers/employees for assistance with this project: Divers Involved Voluntarily in Environmental Rehabilitation and Safety, Southern California Marine Institute, Southern California Coastal Water Research Project, Cabrillo Marine Aquarium, and the Long Beach Conservation Corps. We would also like to thank Mark Patrick for his assistance in the comparison with the 1999 Coastal Clean-up Day activities.

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A014611

CITY OF OXNARD STORMDRAIN KEEPER PROGRAM

Characterizing Debris and Trash in Urban Runoff

Watershed Protection District
VENTURA COUNTY

LEARNING
WORK
SERVICE
Learning Through Work and Service

A014612

EXECUTIVE SUMMARY

The City of Oxnard, as with many other coastal communities, has a recognized trash problem, especially in areas that input to enclosed bays or estuaries. Public outreach had limited success in addressing the problem, so the City developed a plan to identify sources of trash to the open channels leading to the harbors and other enclosed areas. Using funds available to Supplemental Environmental Projects (fine money made available through the Regional Water Quality Control Board), the City employed local youths to clean and categorize trash inputs to the channels.

Goals

The Oxnard City Corps Stormdrain Keeper Program has the following goals:

- Provide an effective and economical method of maintaining storm drain open channels free of trash and other debris;
- Provide an educational opportunity to teenagers participating in the City Corps program; and,
- Provide information on quantity and sources of trash inputs to the open channels

Effectiveness

The Oxnard City Corps Stormdrain Keeper Program has been effective in meeting program goals. Among the accomplishments for this half year are:

- Removal of 8.29 tons of trash and other material from the open channels in the Oxnard area
- Training for 21 of the City Corps staff
- The categorization of 17,382 pieces of material
- The identification of potential sources of material
- The identification of areas of excessive trash input

This information will now be refined in the next phase of the Stormdrain Keeper Program and the results of this phase will be used to enhance trash removal management practices currently in place in the City of Oxnard.

INTRODUCTION

Ventura County-wide Municipal Stormwater Program

In 1972, the Federal Water Pollution Control Act (the Clean Water Act, CWA) was amended to provide that the discharge of pollutants to waters of the United States from any point source be prohibited, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program. The regulations require metropolitan areas with a population greater than one hundred thousand and specific categories of industrial facilities, to obtain an NPDES permit for stormwater discharges. The City of Oxnard is one of the municipalities that has a population of greater than one hundred thousand, but, as there were two other cities expected to exceed one hundred thousand in the 2000 census, a county-wide stormwater program approach was proposed. A county-wide permit was issued to Ventura County co-permittees 1994, and renewed with more prescriptive requirements in 2000.

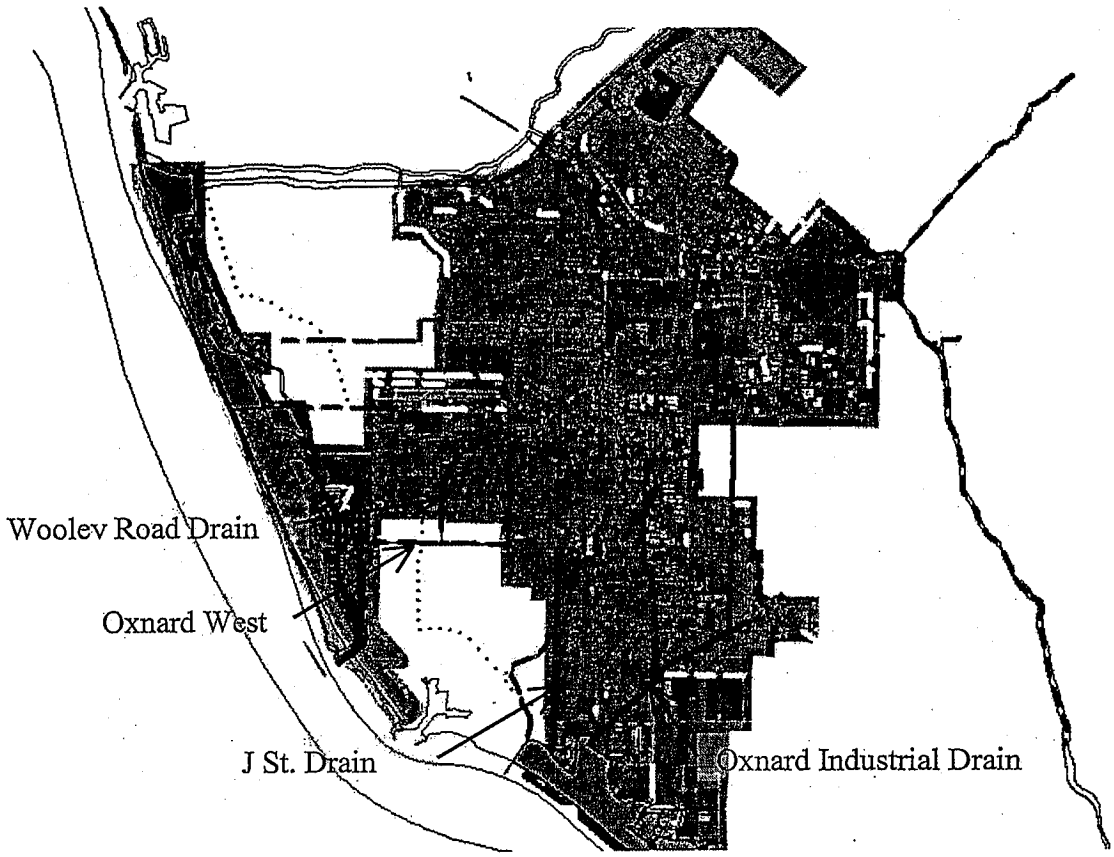
The City of Oxnard is a co-permittee to the Ventura Countywide Municipal Stormwater Program's National Pollutant Discharge Elimination System (NPDES) permit. This permit requires the development and implementation of a stormwater management program that reduces pollutants carried in urban runoff to the maximum extent practicable (MEP). While MEP is not defined by the regulatory agencies, it generally means the application of best management practices (BMPs) that achieve a balance between effective reductions of a pollutant of concern and economic achievability. One of the potential pollutants of concern to any stormwater program is trash. BMPs to address trash consist of traditional of source control (education, street sweeping, and catch basin cleaning) and treatment control (e.g., trash grates and CDS devices).

The City Corp's Stormdrain Keeper Program began when Supplemental Environmental Project (SEP) money was allocated by the Regional Water Quality Control Board, Los Angeles, to Ventura County Flood Control District (now Watershed Protection District, or WPD) for the removal of trash in WPD open channels.

Oxnard City Corps Storm Drain Keeper Program

In December 2001, VCWPD successfully applied for a Supplemental Environmental Project (SEP) to form a Storm Drain Keeper Program. This program brought together Oxnard City Corps members, the cities of Oxnard, Port Hueneme, the Ventura County Harbor Department and VCWPD to address water quality concerns in the Oxnard West, "J" Street and Oxnard Industrial drains located in and adjacent the City of Oxnard (see map below).

CITY OF OXNARD



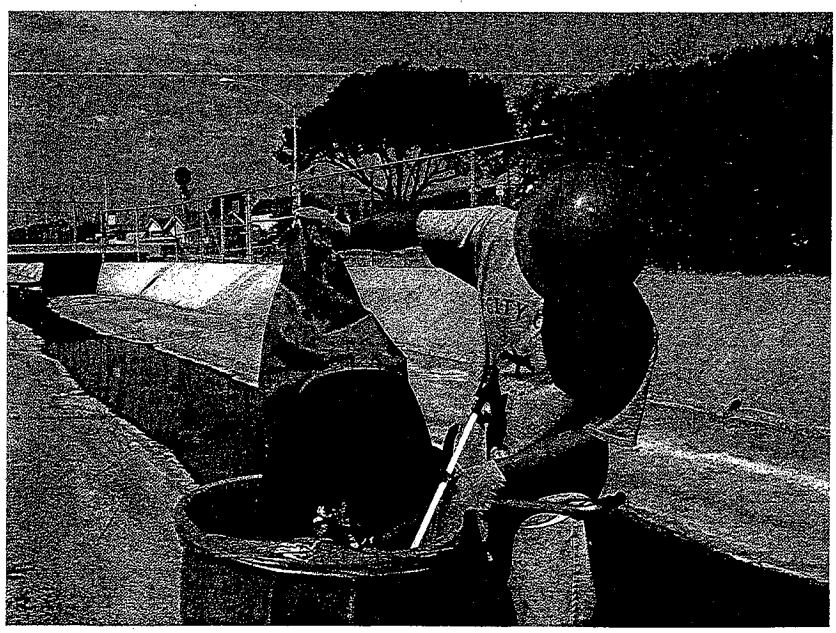
The Oxnard City Corps is a program that seeks at-risk youth within Oxnard from the ages of 14 to 21 and provides them with needed job skills. Money from SEP funds went to the Oxnard City Corps to pay for teens to help protect the Channel Islands Harbor, Ormond Beach, and the Ormond Beach Wetlands by patrolling and cleaning the Oxnard West, Wooley Road, "J" Street, and Oxnard Industrial storm drains. Workers inspected drains and used existing equipment from City Corps (hand tools, vactor and boom trucks) to remove trash, vegetation, sediment, and graffiti. In recognition of the potential adverse impact to these waterbodies, City Corps members did not use any herbicides, pesticides or chemicals in the course of their work.

Additionally, City Corps members met with staff from VCWPD, City of Oxnard, City of Port Hueneme, and Ventura County Harbor Department on a monthly basis for safety, technical and educational training. They learned about stormwater pollution and prevention measures. As they become more educated, they became mentors within their own communities, thus educating friends, family, and other community members about important environmental issues. This project was a huge success, removing over nine tons of trash and debris from the channels and highlighted the impact that agencies working together can have on the community and on our most important asset, our youth.

Following completion of the SEP, the City of Oxnard determined that additional benefit could be obtained from continuing the Stormdrain Keeper Program. The program is currently funded by the City's Wastewater Division, and the tasks performed by the City Corps staff have been modified to provide more detail on the sources of trash in the storm drain open channels. This information has been included in this document, as well as an analysis of the data.

RAW DATA

The raw data for the program consists of the Stormdrain Keeper Debris Data Forms and the Del Norte Regional Recycling Station weight receipt for the day. The Debris Data Forms list the counts for trash, broken down by category (e.g., household item, paper product, glass) for a given day (and accordingly, a given channel). Additionally, the form contains an "I.D." column that allows for insertion of a code to identify the source of the trash (e.g., product, fast food chain, or market). The Del Norte Recycling Center receipt provides the day's trash weight collected.



LOCATION _____ DATE _____

([A.] "J" Street, [B.] Oxnard Industrial, [C.] Oxnard West and [D.] Wooley Road) TABULATOR _____

1. Household Items	Tally	ID.
carpets		
sofas		
chairs		
tables		
television sets		
radios		
lawnmowers		
recliners		
water heaters		
windows		
chain link fences		
broken light bulbs		
mattreses		
empty buckets		
ropes		
Other _____		

Landscape Materials		
garden soil		
wood chips		
tree branches		
palm fronds		
clay pots		
bricks		
Other _____		

3. Sports Equipment		
skate boards		
bikes		
scooters		
basketballs		
golf clubs/balls		
Other _____		

4. Paper Products		
newspapers		
magazines		
fast food wrappers		
fast food bags		
grocery bags		
cardboard boxes		
Other _____		

5. Aluminum/Metal		
cans		
scrap metal		
Other _____		

6. Plastic/Cellophane	Tally	ID.
grocery bags		
garden trash bags		
scrap plastic		
bottles		
food snack wrappers		
PVC items		
Other _____		

7. Automotive		
car batteries		
car parts		
tires		
Other _____		

8. Styrofoam		
fast food cups		
food containers		
Other _____		

9. Personal Effects		
clothing		
condoms		
Other _____		

10. Glass		
bottles		
broken glass		
Other _____		

11. Animal Carcasses		
rats/rodents		
roosters		
dogs		
cats		
rabbits		
ducks		
birds		
Other _____		

12. Hazardous Materials		
paint		
oil		
aerosols (paint)		
aerosols (other)		
Other _____		

Debris Source/Identification

a. Aquafina
b. Arrowhead
c. Bud Light
d. Budweiser
e. Burger King
f. Carl's Jr.
g. Cheetos
h. Circle K
i. Coke (Coca Cola Co.)
j. Corona
k. Doritos
l. Evian
m. Fritos
n. Gatorade
o. Jack in The Box
p. KFC
q. Kmart
r. Lifestyles
s. Miller
t. M & M's
u. McDonald's
v. Papa Johns Pizza
w. Pepsi Co.
x. Pollo Loco
y. Power Aide
z. Ralph's
aa. Red Bull
bb. Rite Aide
cc. Round Table
dd. Shasta
ee. Snickers
ff. Sprite
gg. Starbucks
hh. Taco Bell
ii. Toppers
jj. Vons
kk. 99 ¢ Store Only
ll. Unmarked bags
mm. Unmarked cups
nn. Unmarked food containers
oo. Unmarked water bottles
pp. Unknown Source

Comments:

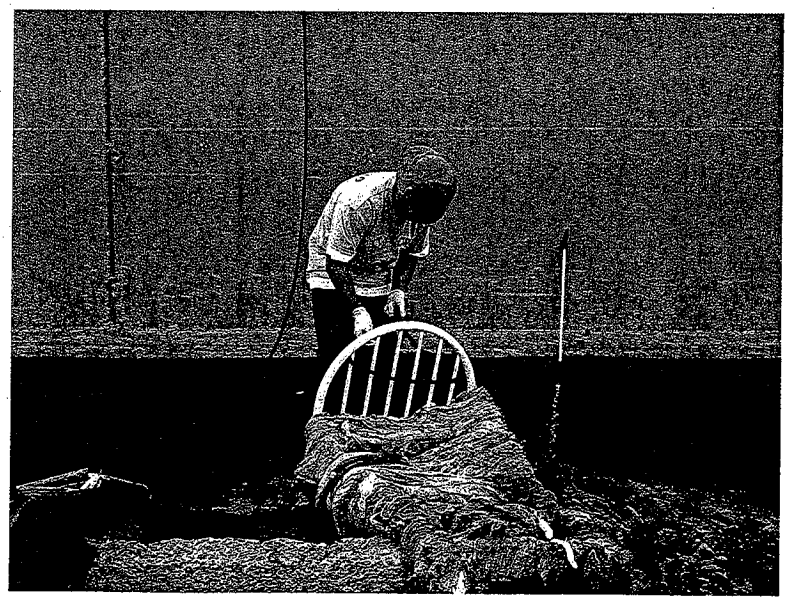
TABULATED DATA

The tabulated data section of program reportsprovides various spreadsheets that organize the raw data and make the analyses of information easier. Information is available for amount of trash removed by weight, number, date, and channel.

DATA ANALYSES

The data were analyzed in an attempt to identify:

1. What are the most problematic types of trash by weight?
2. What are the most problematic types of trash by number?
3. What areas of the channels tend to accumulate the most trash?
4. What approaches might be used to target these areas?
5. What types of trash might contribute other pollutants of concern?



Most of the trash collected by City Corps, both by weight and number of pieces, can be categorized as styrofoam, glass, plastic, and paper.

By noting areas where trash accumulation is most problematic, enhanced outreach to residential and commercial stakeholders may be effective. Targeting of areas of contribution can be done using water bill enclosures regarding stormwater pollution, or door hangers in the specific areas of concern.

While much of the trash removed from the storm drain open channel is unmarked, an attempt was made to summarize key contributors of marked trash to the specific open channels, especially from fast food businesses, markets, and beverage containers. This effort is summarized below:

- Wooley Road Drain
  - Fast food businesses contributed large amounts of paper and styrofoam. The main identifiable sources were McDonald's, Carl's Jr, Jack in the Box, and Taco Bell.
  - Markets contributed large amounts of plastic, but most were from unidentifiable sources. Marked plastics were mostly contributed by Vons and 99¢ Store.
  - Glass containers were a big source of trash, with Miller bottles being the largest source.

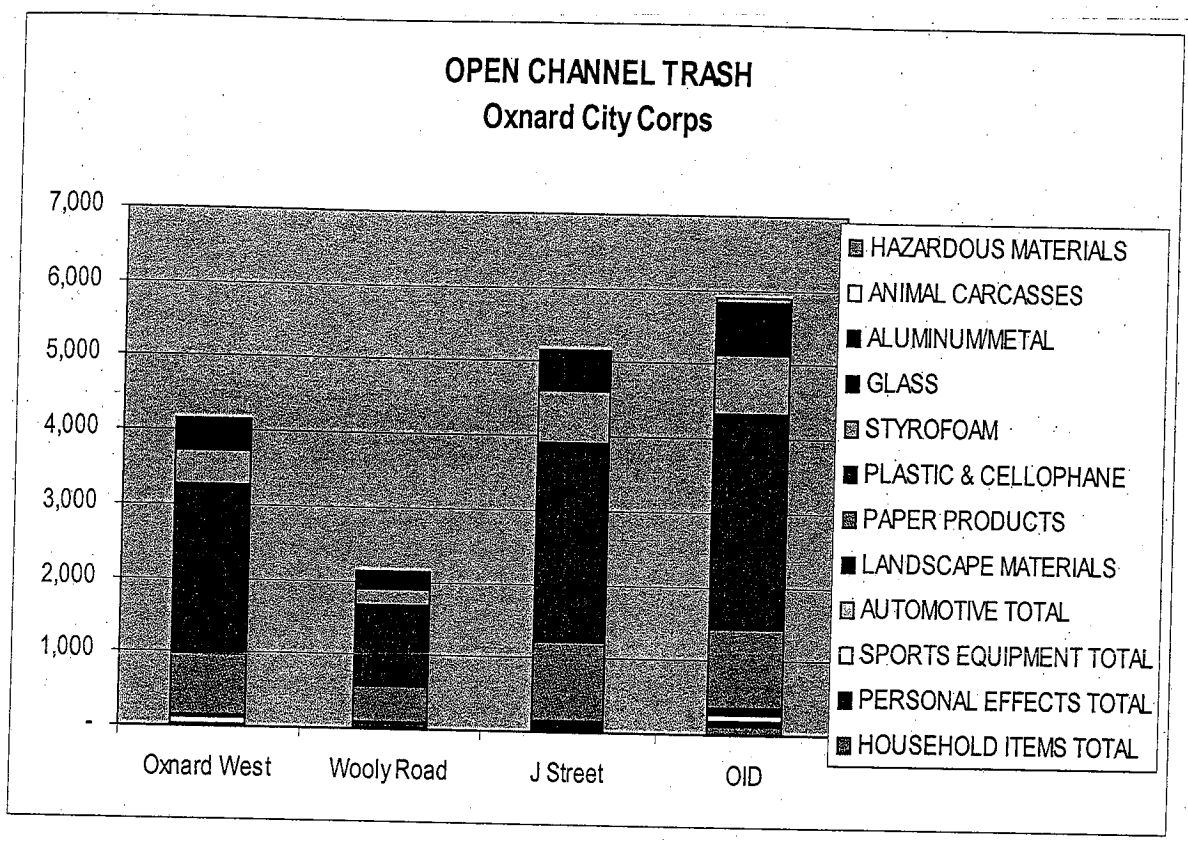
- Oxnard West Drain
  - McDonald's was the clear leader as the source of paper and styrofoam in this drain. Other large contributors included Papa Johns, KFC, and Burger King.
  - 99¢ Store was the clear leader for plastic contributed by markets. Vons and Rite Aid were also major contributors.
  - Budweiser was the winner for most glass trash in this drain; however, Gatorade and Coke were major sources of plastic beverage containers.

- "J" Street Drain
  - Most of the fast food trash is unmarked. Of the marked sources, McDonald's, Carl's Jr., El Pollo Loco, and Taco Bell were the major contributors.
  - Most of the plastic grocery bags were unmarked. Small contributions came from Vons, Rite Aid, and others.
  - Less glass beverage container trash was noted, but an increase in plastic containers was noted, with the majority coming from Gatorade, Aquafina, Arrowhead, Coke, and Power Aid.

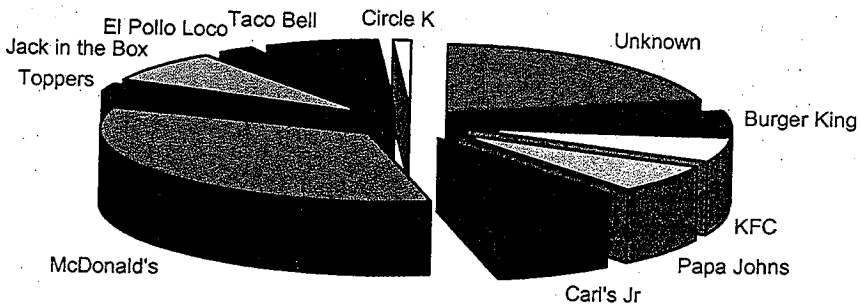
- Oxnard Industrial Drain
  - High numbers of trash were tabulated from unmarked fast food and market contributors; however, the clear majority of the paper and Styrofoam came from McDonald's, Taco Bell, and KFC. Most of the plastic bags came from Vons.

- Most of the beverage containers came from glass Budweiser trash. Miller bottles placed a distant second.

Analysis of the data is graphically represented in the reports to better view a relative comparison of inputs for all drains:



Or to view specific information for a specific drain (here sources of plastic and Styrofoam trash for the Oxnard West Drain):



An attempt was also made to link trash collected to the revised pollutant of concern list, developed as a part of the Ventura County-wide Stormwater Management Program's annual report. The pollutants of concern, by rank, are:

Rank	Updated POC List
1	Total Nitrogen
2	Total DDT
3	Chlorpyrifos
4	Copper
5	Total Coliforms
6	Ammonia
7	Zinc
8	Lead

There is suspected link between trash, in general, and total coliform as a pollutant of concern. This is more evident when taking into account, as this study did, of the number of animal carcasses removed. This is an area of the stormwater program that will need to be addressed in future outreach.

Lead, another pollutant of concern in the Ventura County Stormwater Program, had the only other probable link to the trash collected. Under "Automotive", car batteries found were noted and tabulated. While most of the channels claimed no car batteries found, eleven batteries were found in the Oxnard Industrial drain. This is also an area of the stormwater program that will receive enhancement this fiscal year, beginning with the addition of automotive supply houses to the list of businesses inspected for source control and stormwater concerns.

CONCLUSION

Summary

The Stormdrain Keeper Program has proven to be a reliable and cost-effective method of maintaining open channels in the Oxnard area, while developing a usable database of trash types, quantities, and areas of concentration. This information may be used county-wide to target outreach and other BMPs for the reduction of trash to the MEP standard. The data show that urban runoff from the City of Oxnard potentially contributes a significant amount of trash; however, enhancement of existing programs, in combination with Oxnard City Corps Stormdrain Keeper Program and other treatment control BMPs, can bring the impact of trash to the surface water bodies in the Oxnard area down to a negligible level.

Future Actions

The project has developed sufficient information to go on to the next step of further narrowing the sources. This summer, City Corps crews are moving the focus of cleanup and data tabulation to the City-owned channels that lead to the major Ventura County owned channels. Additionally, crews have been hired to inspect all of the catch basins within the City, using an abbreviated version of the checklist used for the channels, in order to prioritize scheduling of maintenance and provide additional data on trash sources.

Paper or Plastic?
Deconstructing One of Life's Everyday Questions

Daniel Imhoff

For many people, the seemingly innocuous supermarket checkout question of paper or plastic touches a nerve that drills at our humanity. Many of us would like to have an easy answer, a simple choice of the better material, so we can go on with our extremely busy lives. Most of us know deep down, however, that things are not so simple. We live in a "systems world," and when we scratch below the surface of a question like paper or plastic, we unravel a whole universe of complexities.

This decision between paper and plastic is actually not as much about packaging as it is about how life's everyday choices have much larger repercussions for the world as we know it. Answering the question honestly requires confronting a series of more detailed and potentially troubling related conundrums:

forests versus fossil fuels;
global versus local;
familiar versus branded;
fast versus slow;
industrial versus biological;
processed versus fresh;
intentional versus convenient;
reusable versus disposable;
values versus bargains ...

Until we eventually find ourselves chipping away at some of life's consummate questions: *Why are we here? What are we leaving behind?*

To make matters even more challenging, when talking about the packaged universe, it is hard to make generalizations, although some generalizations can be made. Let's instead look at a few of the complexities.

Packages have been with us for millennia and are almost indispensable in modern life. They provide essential services: product protection, transportation, convenience, pleasure, health and safety, hygiene, nutrition, spoilage prevention, information, branding, theft-proofing, regulatory compliance. They in fact optimize resources when they safely deliver a material- and energy-intensive product to an end consumer.

However, this increasingly relied upon packaged world also comes to us at a price.

Packaging has a significant ecological footprint. Making packaging consumes enormous amounts of energy and raw materials, and requires a significant infrastructure to produce. The big three are: forest impacts, of which upwards of 2/3 of all packaging is derived; the ubiquitous release of toxic materials through the

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manufacture and incineration of paper and plastics that sweep through the biosphere; the transportation of goods, now part of the largest contributor to global warming and climate change.

Just a few statistics to make demonstrate the scope:

In the U.S. alone we generate 75 million tons of waste per year, almost 600 pounds per person, of which 32 percent is packaging —the largest segment of the waste stream.

There are approximately 1 billion transport pallets moving around North America in any given year; and to keep that fleet afloat we need 500 million new wood pallets of which 85 percent are used once before being chipped, burned, or landfilled. That's almost 2 pallets per person per year and accounts for 40 percent of all hardwoods used annually.

We use more than 300 million throwaway cups every day of which more than 75 percent are made of paper.

One out of every three servings of water consumed in the United States now comes in a container, for a total of 45 million bottles per day of which less than 10 percent are recycled.

Today the total volume of plastics produced worldwide has surpassed that of steel and continues to increase; 30 percent of all plastics are made into packaging, the largest use by far.

Beach litter is between 40 and 60 percent plastic.

Polyethylene accounts for 40 percent of all plastics produced worldwide—80 billion pounds per year which corresponds to a global consumption rate of 16 pounds per person.

We are over-packagers: 80 percent of pet owners surveyed in 2000 said they buy Christmas presents for their pets, and 67 percent admitted that they wrapped them!

Probably most significant of all, in many cases, the upstream impacts of a package are almost 100 times the impacts of recycling or disposal. (This is why reuse is so essential .)

There are other issues to consider …

Packages replace human relationships. Packaging, particularly of the shelf-competitive variety, essentially has replaced traditional human interactions in the marketplace with a packaged environment.

Packages divide and conquer. Packaging increasingly divides us into a world of billions of single-serving consumers. The amount of energy used per unit of product is substantially more for smaller containers than bulk packages.

Packaging can be predatory. Fancy graphics on a package may appeal to us, but they don't necessarily tell the real story about a product's history, and that includes where it came from, the infrastructure necessary to produce it, or impacts on surrounding ecosystems.

Material dissonance. The shelf-lives of many industrial packages and packaging materials are out of balance with the products they serve and protect. A styrofoam coffee cup, for example, may outlast a marble statue while the coffee is consumed in a matter of minutes.

Packaging is waging a war on freshness. Packaged foods have become such a fixture of modern life that many people no longer trust foods and beverages—including such basics as eggs, milk, and water. Up to 70 percent of all packaging is now used for food and beverages.

The package is the product. A package is simply the last stage of product design, and shouldn't be separated from the product it delivers. Therefore, a bottle of foreign mineral water packaged in lightweight potentially recyclable plastic is still a single-serving of water shipped across borders or oceans that more often than not is going to become waste, including marine debris. A fast food item in a biodegradable wrapper may still be a high sodium, high fat, high calorie junk food item. In order to assess ecological effectiveness, it is essential to view a product and its package within the systems in which they function.

A Few Myths About Modern Packaging

1. There is a conceivable general case answer to the paper versus plastic debate.
In fact there is a generally conceivable answer to this but it's not paper or plastic. It's neither.

2. Change can't be legislated. Finland introduced legislation in the mid-1990s requiring all beverages to be sold and distributed in reusable containers. This has been extremely effective.

3. Change can be legislated. A few years ago a municipality in Ontario spent millions of dollars on a program to launch a refillable bottle system which failed at least partially due to citizen apathy.

4. If it's picked up at the curbside, it re-enters the materials stream. The fate of a recyclable package really depends on the local collection infrastructure, proximity to recycling centers, national and global demand for certain types of post-consumer materials, as well as a wide variety of other factors. In some cases, it has been argued, the

presence of curbside recycling systems has served to increase consumption. The reasoning follows that people feel justified in maintaining high consumption levels because they are avid recyclers.

5. Packaging biodegrades in landfills. In the anaerobic, oxygen-free, compacted confines of modern landfills, many biodegradable materials and castaway products remain preserved for decades. In fact, we are creating a new geological form in modern landfills: stratified industrial waste.

Taking Action

Having mentioned just a few of the many challenges and contradictions of modern packaging, there is still quite a bit that we can do in our daily lives and in all of our work lives to affect positive change. In fact, our future depends upon rapid and earnest action.

Here are a few ideas:

See yourself invested in change and approach the everyday choices you make as a positive and enjoyable part of living a curious and engaged life.

Demand change from the companies and businesses where you shop. Consider withdrawing participation from companies whose packaging, product manufacturing and other behavior you disapprove of.

Look for systems solutions that can short-circuit and intervene in harmful forces.

Set a course for change at work:

- Make a position on wood reduction;
- Make a position on chlorines and other hazardous compounds;
- Make a packaging directive for your company;
- Maximize post-consumer content of glass and boxes;
- Look at your office practices through a thorough eco-audit;
- Contribute to the conservation economy.

Dan Imhoff is the award-winning author of many essays, articles, and books, including: *Paper or Plastic: Searching for Solutions to an Overpackaged World* (2005); *Farming with the Wild: Enhancing Biodiversity on Farms and Ranches* (2003); *Building with Vision: Optimizing and Finding Alternatives to Wood* (2001); and *The Guide to Tree-free, recycled, and Certified Papers* (1999), among others. He is the director and co-founder of Watershed Media and the current board president of the Wild Farm Alliance.

Patterns of Debris Movement: From an Urban Estuary to a Coastal Embayment

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Introduction

Beach or shoreline surveys are the most common form of quantifying human generated debris. They reveal a lot about the amounts and types of persistent wastes that end up in these environments, however, the movement and specific source of these items have not commonly been categorically defined. Sourcing debris items has been difficult due to their mobile nature (Williams and Simmons 1999) and usually left to an individual's discretion. Some items can easily be identified and sourced (e.g. fishing nets), other items are reliant on weight of evidence to determine where they originated. Statistical techniques and modelling have shown some success in determining sources (Kubota 1994; Belas *et al.* 2001; Tudor *et al.* 2002) but are reliant on background studies or site specific testing to verify results.

Water–based surveys of floating debris provide valuable information on distribution patterns and extent of movement of these types of items (Moore *et al.* 2001) but the residence times and individual patterns of movement cannot be examined by this method alone. One approach that goes some way to answering these issues is through tagging studies. This has been applied to selected items on coastal beaches (Bowman *et al.* 1998; Johnson & Eiler 1999; Williams and Tudor 2001) but does not target the main source of coastal debris, particularly in urban areas, the rivers. Bulk movement patterns of selected riverine litter have been detailed by Williams and Simmons (1997), however there have been few studies looking at individual movement patterns of a range of debris types from river/estuary sources. To this end, tracking of debris from a potential source to an end

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destination was undertaken along the Cooks River and in Botany Bay, Sydney. The importance of tidal movement, riparian vegetation and rainfall is highlighted.

Methods

The study area was the Cooks River, a heavily urbanised river in Sydney, Australia (Fig. 1). The main river channel is approximately 15 kilometres long and tidal for approximately 11 kilometres. There are also a number of smaller creeks that feed into the Cooks River. The river has a history of high levels of pollution, draining residential, commercial and industrial areas. The river has been progressively channelised with concrete, iron or rock walls since the 1940s. Over this time sediment has built up and mangroves have colonised the upper and middle reaches of the brackish parts. The river flows out into Botany Bay, a major port facility for Sydney but also contains important wetlands and fisheries stocks.

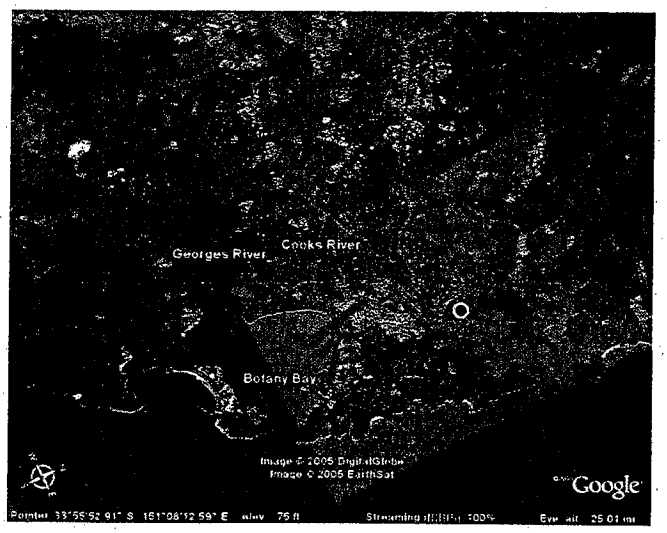

Figure 1: Cooks River and Botany Bay Location Map

The experimental design involved a repeated three-week tag/release study, whereby items were monitored during this period for recovery rates and patterns of movement. The two

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tests conducted were separated by a two week period. Selected items included: plastics (bottle - 600 ml; kitchen tidy bag - 50 x 75 cm; cigarette butt; ear bud piping; polystyrene block – 9 x 9 x 2.5 cm; confectionary wrapper – 18 x 12 cm), glass (bottle - 375 ml), metal (aluminium can – 375 ml), rubber (balloon – 8 cm long) and wood (ice cream stick – 10 cm long). Each experiment was colour coded with fluorescent paint and individually numbered 1 to 30 for each item type. Items were selected based on their common presence in the river system. All items were released approximately 10 km from the river mouth directly into the water column on an outgoing tide.

Selected tidal portions of the river shoreline and waterway were searched at low tide for tagged items every 72 - 96 hours for three weeks. Intermittent searching of bay beaches was also carried out. Items located during this time were logged with a GPS and left until the end of the experiment. All items relocated during the experiment were mapped revealing pathways of movement and residence times along the river.

A background survey of shoreline debris was also conducted during the study to aid in the understanding of accumulation rates. Three 10 m x 5 m strand line belt transects were taken at selected sites along the river every five weeks. All litter, excluding tagged items, was collected at each survey time and categorised. The initial collection time was discounted from any sample time comparisons because of residual debris loads.

Results

The overall recovery rates of tagged litter declined for the first half of both Tests 1 and 2, dropping below 40% after 4 days, below 30% after 7 days and below 15% after 11 days. The rates remained around this level for the rest of the experiment. The most recovered individual items were plastic bags, plastic bottles and polystyrene blocks (Fig. 2). Test 1 recovery rates for these items ranged between 17 - 30% by Day 21. Test 2 recoveries were generally higher with between 33 – 57% recovery of those aforementioned items. Other items with moderate recovery rates were glass bottles and aluminium cans.

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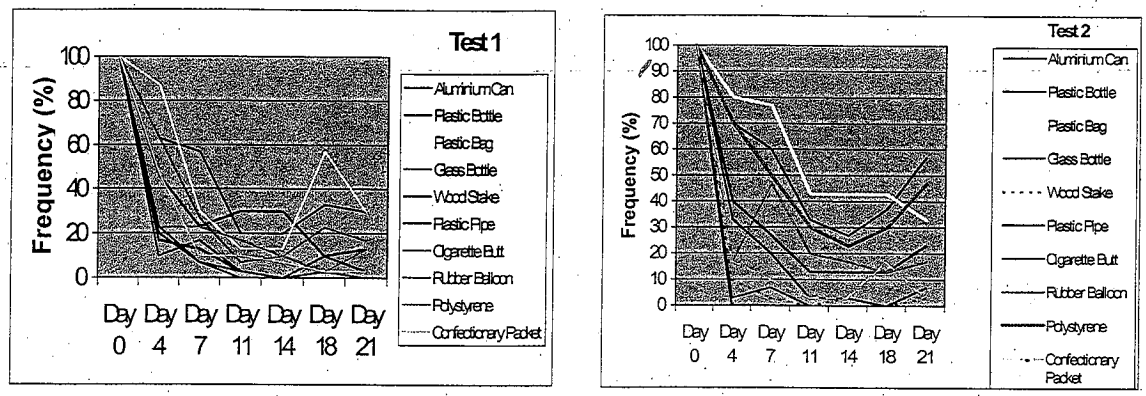

Figure 2: Recovery of tagged litter items from Tests 1 & 2 over 21days

Sites closer to the release point (up to 2.5 km downstream) had higher proportions of debris in the first 0 – 11 days for Test 1 (Fig. 3). This trend persisted for a longer period in Test 2. A higher proportion of debris was seen to shift to the mid river reaches in the latter stages of the tests. In particular the Beaman Park site (3.5 – 4.2 km downstream from release point) had accumulated close to 60% of all tagged items found on Days 18 and 21 in Test 1. There were few items found at the lower river sites during both tests.

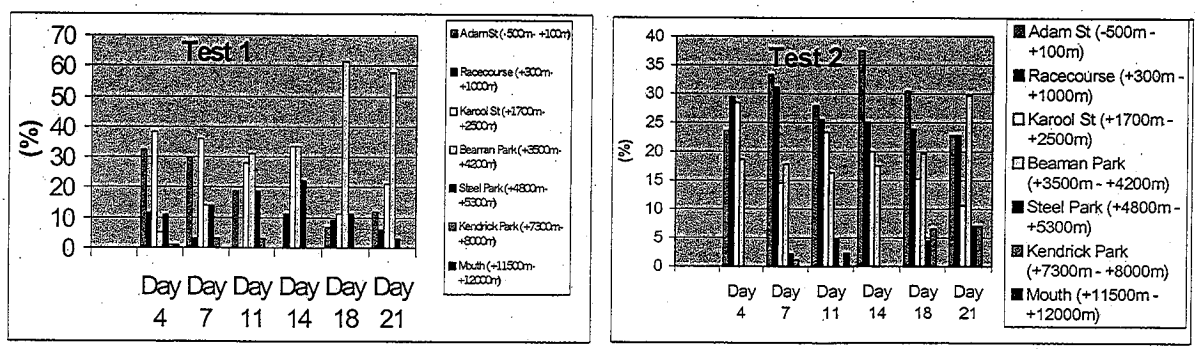

Figure 3: Frequency of tagged litter items per site over 21 days for Test 1 & 2

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The trends in the mean distance moved for litter items revealed that the large solid floatable items (plastic bottles, polystyrene, aluminium cans) moved consistently down river to between 3 – 3.5 km after 21 days (Fig. 4). Plastic bags appeared to move downstream in Test 1 but were relatively static for Test 2. Confectionery wrappers were very mobile over the sample period. Glass and rubber varied in their patterns of movement between tests. Other items were not sufficiently recovered to accurately determine movement patterns. Individual items were tracked during the course of the tests. Examples of the variable patterns in movement are illustrated in Figures 5-8.

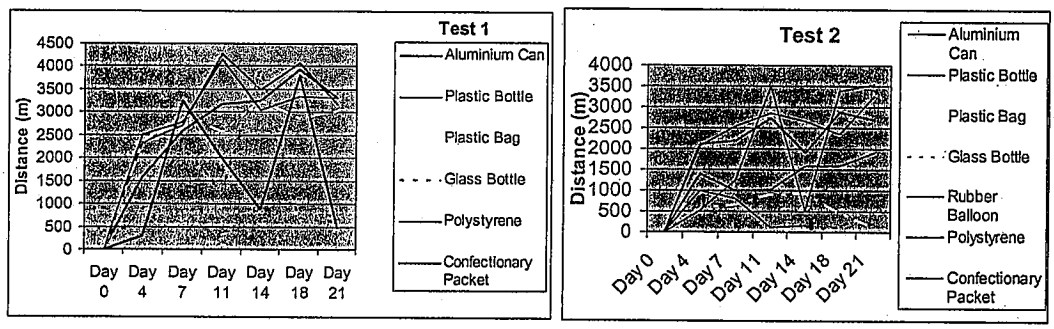

Figure 4: Mean distance moved for tagged litter items from two tests over 21 days

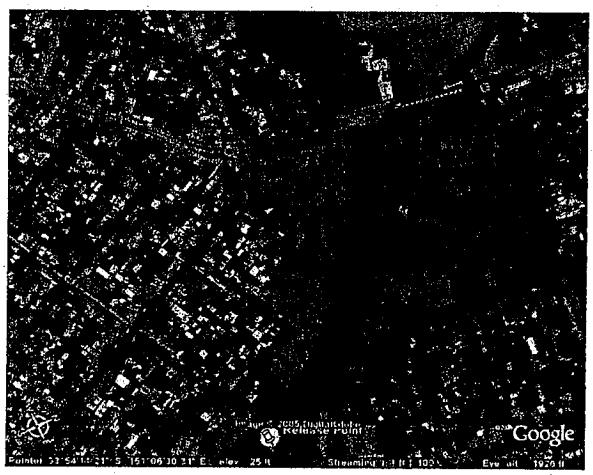

Figure 5: Tracking of Plastic Bag 27 (Test 2)

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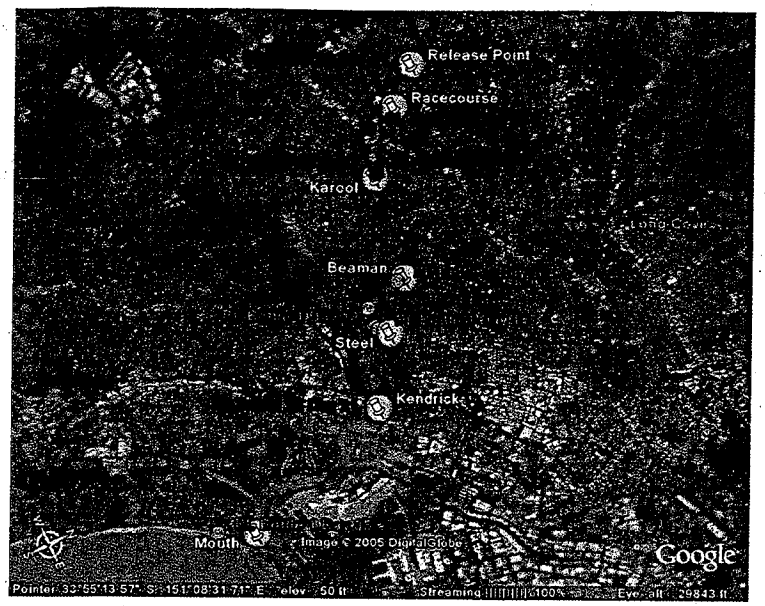

Figure 6: Tracking of Plastic Bottle 1 (Test 1) and Plastic Bottle 28 (Test 2)

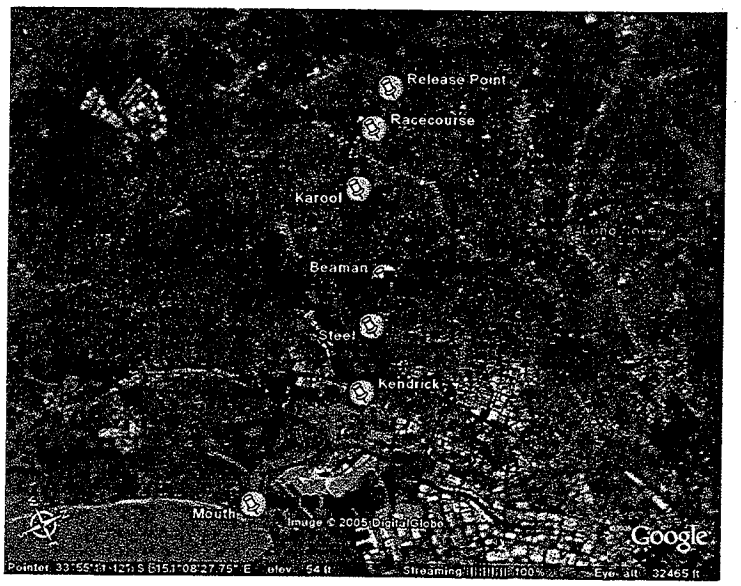

Figure 7: Tracking of Polystyrene 22 & 29 (Test 2)

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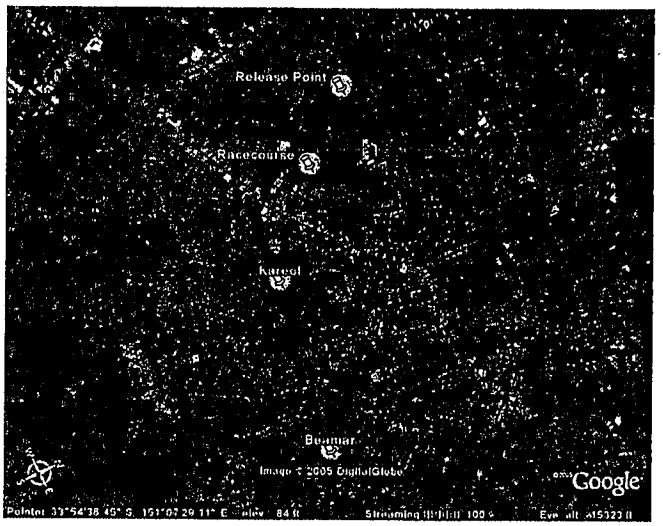

Figure 8: Tracking of Glass Bottle 18 (Test 1) and Glass Bottle 15 (Test 2)

The background shoreline survey revealed that plastics were the most common item, making up over 80% of all items found at each site. The greatest contributors were hard plastics, polystyrene or sheet plastic which varied with site (Figure 9). The litter items found at the Mouth had the greatest difference to the other sites with a higher proportion of cigarette butts (sheet plastic) and fishing line or rope. Glass, metal and paper/wood was also present in considerable amounts. At all sites except Adam St., there was proportionally less debris over the subsequent samples. The Adam St. site remained relatively stable in debris amounts during the time of study and still had less litter overall than the other sites.

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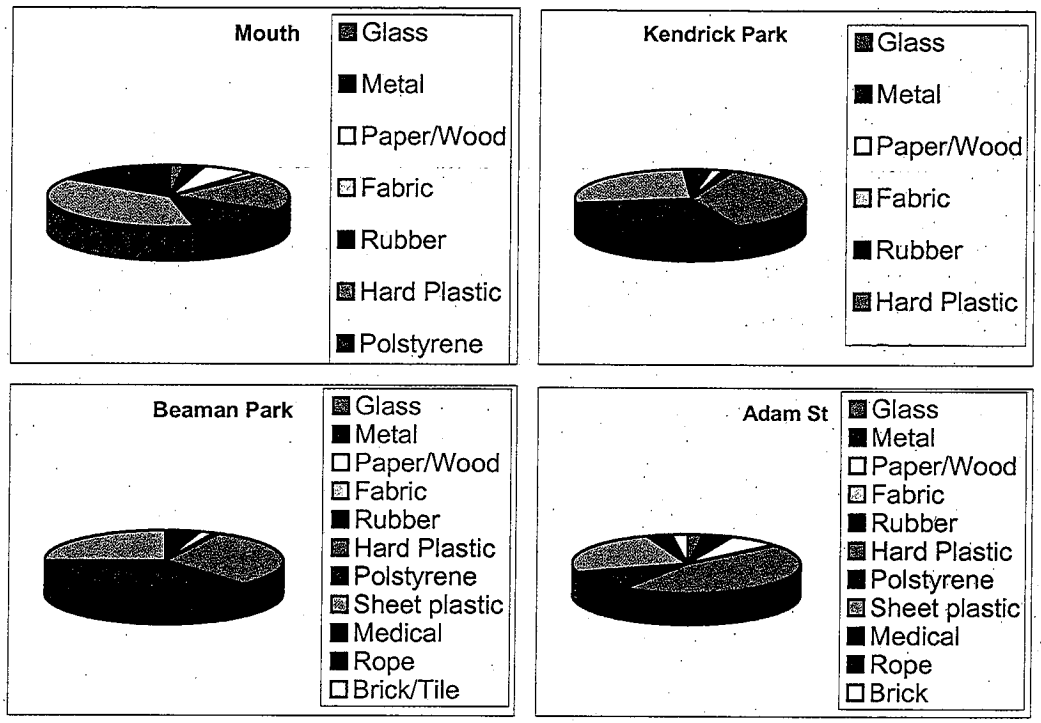

Figure 9: Proportional shoreline litter data per Cooks River sites

Discussion

The tagging experiment revealed that the larger, more visible items (bottle, cans, bags) were recovered more often than the smaller items (butts, piping, stakes). This trend is more than likely due to the burial of these smaller items in the other refuse and leaf matter that accumulated along with the tagged items. Williams and Tudor (2001) found similar trends on a cobble beach, where smaller fragments were lost from the surface between the spaces in the cobbles.

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The trend over time saw a considerable drop in numbers of tagged items and for Test 2 a slight increase in recovered items over the last two sample periods. The trend for Test 2 was highly correlated (Pearson's Correlation 0.95, $P < 0.05$) with rainfall figures for the region. High rainfall (67-98 mm) between Days 11 and 14 was seen to be related to depressed recovery rates during this time. The higher water level makes spotting of debris more difficult. Flood events are also responsible for increases in litter accumulation in the days following such events (Williams and Simmons 1997). Test 1 was conducted during a period of low rainfall and no trends were apparent. Further testing of this model is required.

There was an obvious trend in Test 1 of net movement over time of items downstream from the release point. The majority of items stayed within the first 2.5 kms up to at least Day 11 and then moved to the middle reaches. Tides may play a part in the general patterns of debris movement and may help to explain the slow movement downstream. At high tide most items were re-suspended but because of the small tidal ranges evident in this region (0.7 -1.8 m) their movement was minimal. Tracking of individual items revealed an upstream/downstream movement of some items before being flushed down stream further (see Fig. 6). The importance of the mangrove vegetation in holding these items in place should also be highlighted. In Test 2 there was still over 50% residence of items in the upper reaches until Day 18. The mangrove systems with numerous pneumatophores along these shores played a role in halting downstream movement. A similar trend was found by Williams and Simmons (1997) with riparian vegetation along riverine watercourses. The eventual shift in Test 2 items could be related to the rainfall pattern described in the previous paragraph. These factors may all play a role in the movement patterns found and along with the relative short time of the tests might be a reason why few items reached the lower reaches. As there were fewer vegetated areas in the lower parts of the Cooks River what items that did make it to these parts would be quickly flushed into Botany Bay. The bay beaches recording a 10% recovery of plastic bottles were evidence for this.

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An analysis of movement patterns of individual items revealed that the more buoyant objects (plastic bottles, polystyrene, aluminium cans) moved on average greater distances downstream than the other items over both test periods. Variable patterns of movement within a test were found for some items. These can be attributed to dispersion characteristics of an item, the physical nature of the site (eg. depositional zones, vertical walls), losses from the system or erratic recovery rates. To highlight the last point the mean distance that balloons had moved by Day 11 in Test 1 was approximately 5 kms, (this however was based upon one recovered item) but by Day 18 the mean distance was less than 1.5 kms (based on three items). Plastic bags followed the trend of the larger floatables in Test 1 but were found to reside in the upper reaches more so in Test 2, when items became stranded in the mangroves. There was however a significant correlation (Pearson's Correlation 0.82, $P < 0.05$) with bag movement and rainfall. Other items such as glass bottles and balloons also followed this Test 2 trend but there were however no other correlations.

The background shoreline survey revealed plastics to be the most prevalent type of debris. These levels corresponded to proportions of debris found in surveys undertaken on coastal beaches of the Sydney region (Cunningham and Wilson 2003) and highlight the importance of rivers as sources of debris to the nearshore coastal environment. Variations between sites in types of debris related to the site characteristics or activities carried out there. For example fishing activities were relatively high at the Mouth and so there was an increased abundance of line and rope as well as cigarette butts. The sampling and clearance of litter over time revealed a decrease in accumulated debris at three sites. The regular cleaning of these middle and lower reach sites may go some way in improving the aesthetics of the area. Adam St. in the upper reaches was the exception. The description of the patterns of movement from the tagging experiment may help in understanding the accumulation of debris at all these sites.

Conclusions

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The tracking of individual items over the short term has revealed the varied nature in debris movement. A generalisation of patterns of movement based on few samples or indicator items can be misleading. Testing using large sample sizes and a suite of items will provide a more indicative account of litter residence times and therefore allow more accurate management decisions. The influence of site characteristics such as vegetation, tidal ranges and rainfall events have been highlighted in this study. A prolonged tagging study using radio transmitters may aid in further understanding the processes involved in litter movement.

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Reducing marine debris: derelict fishing gear removal programs in Hawaii, Washington, and California

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Derelict fishing gear is lost or abandoned commercial and recreational fishing nets, lines, pots, and traps that sits on the seafloor, gets caught on rocky and coral reefs, or floats on the ocean surface. Because the majority of fishing gear is made of synthetic materials, it can remain in the marine environment for decades and negatively impacts the marine environment in several ways: by entangling and trapping marine organisms; by damaging habitat upon which it snares; by posing a navigational hazard for mariners; and by similarly endangering humans, especially divers.

The impacts of derelict fishing gear on marine wildlife are dramatic. In Hawaii, derelict fishing gear is the most serious human-related threat to the fragile coral reefs of the Northwestern Hawaiian Islands where it abrades, enshrouds, encrusts and breaks corals. It also injures and kills wildlife, including the endangered Hawaiian monk seal and protected sea turtles and cetaceans: between 1982 and 2000, over 200 Hawaiian monk seals were entangled in derelict nets (Boland and Donohue, 2003). In Washington State's Puget Sound and Northwest Straits region, hundreds of derelict crab pots and gill nets have been documented on the seafloor. Divers observed 1 to 3 foot deep accumulations of bird bones under just one derelict net off the San Juan Islands, where presumably bones had drifted down from decomposing carcasses, likely for years (NRC 2004).

Through public-private partnerships, both Hawaii and Washington have successfully removed significant amounts of derelict fishing gear from their marine waters. Since 1998 the NOAA Fisheries Service and 16 other state and federal agencies and organizations have removed 495 tons of derelict gear from the coral reef habitats of the Northwestern Hawaiian Islands, utilizing scientific surveys and skilled divers. Since 2002, the Northwest Straits Commission, working with Natural Resources Consultants, Inc. (Seattle, WA), the Washington Department of Fish and Wildlife, and commercial harvest divers, has removed 265 nets and over 750 pots and traps weighing over 30 tons from inland marine waters in Washington (NWSC 2005). With seed funding

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provided by the Laurel Foundation, the California State Coastal Conservancy and the SeaDoc Society (UC Davis Wildlife Health Center) are partnering to establish a derelict fishing gear removal program in California. In the pilot year, the focus is on locating and removing derelict fishing gear from state marine waters at specific sites off the Humboldt, Monterey and San Luis Obispo County coasts, and around Santa Catalina Island.

The following websites provide information regarding Hawaii, Washington, and California's derelict fishing gear removal programs, including program background, protocols, and reports:

For Hawaii: http://www.nmfs.noaa.gov/habitat/ead/dfgissues.htm
For Washington: http://www.nwstraits.org and http://wdfw.wa.gov/fish/derelict
For California: http://www.seadocsociety.org

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Pellet Watch : Global Monitoring of Persistent Organic Pollutants (POPs) using Beached Plastic Resin Pellets.

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What's plastic resin pellet?

Plastic resin pellets are small granules generally with shape of a cylinder or a disk with a diameter of a few mm. These plastic particles are industrial raw material transported to manufacturing sites where "user plastics" are made by re-melting and molding into the final products. Resin pellets can be unintentionally released to the environment, both during manufacturing and transport. The released resin pellets are carried by surface run-off, stream, and river waters eventually to the ocean. Resin pellets can also be directly introduced to the ocean through accidental spills during shipping. Because of their environmental persistence, they are distributed widely in the ocean and found on beaches and on water surfaces all over the world (Carpenter and Smith, 1972; Gregory, 1978; Moore *et al.*, 2001a; Moore *et al.*, 2001b; Derraik, 2002; Moore *et al.*, 2002). A growing production of plastic leads to a measurable increase in plastic pollution in the ocean. In 2001, we revealed the existence of various organic micropollutants (i.e., polychlorinated biphenyls : PCBs, DDE, and nonylphenol) in plastic resin pellets collected from Japanese coasts (Mato *et al.*, 2001). Since ever, we have been conducting studies on organic micropollutants in marine plastic resin pellets (Mato *et al.*, 2002; Endo *et al.*, 2005). In the present paper, we will introduce the results of our recent studies. Also ***Pellet Watch*** : Global Monitoring of Persistent Organic Pollutants (POPs) using Beached Plastic Resin Pellets will be proposed.

Additive-derived pollutants in marine plastic resin pellets

Marine plastic resin pellets carry two types of organic micropollutants (i.e., additive-derived pollutants and sorbed pollutants). First type includes plastic additives (e.g., anti-oxidants) and their degradation products. Nonylphenols (NP) were detected in plastic resin pellets collected from Japanese coasts. Endocrine disrupting potency of NP has been recently revealed (Jobling *et al.*, 1996) and distributions, sources, and environmental behavior of NP has been studied by many researchers (Ahel *et al.*, 1994; Bennet and Metcalfe, 1998; Blackburn *et al.*, 1999; Isobe *et al.*, 2001). Plastic resin pellets were collected from 9 beaches in Japan in 1998 – 2000. The pellets were classified according to their polymer types (i.e., polyethylene : PE and polypropylene : PP) using near-infrared spectroscopy (PlaScan-SH, OPT Research Inc. Tokyo, Japan). PE and PP pellets were extracted with dichloromethane (DCM) using Soxhlet extractor and the extracts were purified using silica gel column

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chromatography. NP was determined by gas chromatograph equipped with mass spectrometer (GC-MS). Details of analytical conditions were described in Isobe *et al.* (2001) and Mato *et al.* (2001).

Concentrations of NP in the plastic resin pellets are shown in Figure 1. NP concentrations ranged from 18 ng/g to 17000 ng/g. These concentrations were similar to those observed in bottom sediments in Tokyo Bay, one of the most polluted bay in the world. NP detected in the plastic resin pellets is likely to be derived from trisnonylphenol phosphite (TNP), polymer antioxidants, as shown in Figure 2. TNP antioxidant contains significant amounts of NP as an impurity (Gilbert *et al.*, 1986) and also TNP can be easily oxidized and hydrolyzed to be NP in ambient conditions (Murata, 1999). Nonylphenolpolyethoxylates (NPEO; Fig.2), surface active agents, are also added to plastics and are a potential source of NP in the resin pellets. Figure 1 shows a tendency of PP pellets to have a higher amount of NP than PE pellets. This is probably because PP requires more additives. Marine plastic pellets may act as significant source of NP to marine organisms. It is thought that biomagnification of NP through the food chain could not be occurring due to their hydrophilic group and metabolizable nature, although these conclusions have not been well proved. Several studies suggest that biomagnification may not play an important role to transfer NP, unlike PCBs and DDE, to animals and birds in higher trophic levels (Ahel *et al.*, 1993). In these contexts, direct ingestion of plastic pellets could be a direct and important route of NP to higher animals.

Sorption of organic micropollutants on marine plastic resin pellets

Another type of micropollutants in the marine plastic resin pellets is pollutants sorbed from ambient seawater. Polychlorinated biphenyl (PCBs), dichloro-diphenyl-dichloroethylene (DDE; degradation product of organochlorine pesticide), and polycyclic aromatic hydrocarbons (PAHs) were detected in the marine plastic resin pellets collected from Japanese coasts (Mato*et al.*, 2002). Plastic resin pellets were collected from 9 beaches in Japan in 1998 – 2000. The resin pellets were classified into PE and PP by the spectroscopic method and were analyzed for PCBs, DDE, and PAHs using gas chromatograph equipped with electron capture detector (GC-ECD) and GC-MS following purification of DCM extracts by two-step silica gel column chromatography. The details of the analytical procedure were described in Endo *et al.* (2005). Concentrations of PCBs in the resin pellets are shown in Figure 3. The range of PCB concentrations in the pellets was from 5 ng/g to 892 ng/g. There observed a trend that PE pellets had higher concentrations of PCBs than PP pellets.

Because the surface of the resin pellets is highly hydrophobic, adsorption of PCBs from seawater onto the pellet surface was likely to be the mechanism of the accumulation of PCBs in the marine pellets. A field adsorption experiment, where virgin plastic pellets were deployed on the sea surface, was conducted to examine whether plastic pellets can adsorb hydrophobic pollutants from seawater (Fig.4). The experiment was carried out in port of Tokyo Fishery University which is located in northern head of Tokyo Bay from December 20, 1998 to January 6, 1999. During this period, there were no rainy or windy days and the sea was calm. Three types of plastic materials were used for the experiment and were compared in their adsorption. Virgin PE pellets (Suntch LD M 652) and two types of PP resin pellets (Grandpolymer J104W and J705M) were obtained from polymer companies and deployed. Our prior analysis showed no significant PCBs (<0.01ng/g) in the virgin pellets. Approximately 8 g each of the pellets were placed in stainless steel mesh baskets (30 cm diameter and 13 cm height) and the baskets were left drifting on the sea surface (Fig.4). Under these conditions, the

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pellets were in a single layer and could float freely in the basket in full contact with surface seawater. Three baskets were placed out for each pellet type at the beginning of the experiment, and one basket was recovered on 9 days and 16 days after the deployment. The recovered pellets were stored in glass bottles at –30 °C in the laboratory. Just before analysis, the pellets were air-dried in the clean room for 3 days. Eight g of the dried pellets were analyzed as described above. Non-deployed virgin pellets were also analyzed along with the sample pellets and considered as Day-0 sample.

The field adsorption experiment results demonstrate that PCBs adsorb to plastic resin pellets from seawater. During the experiment, PCBs in the deployed pellets showed steady concentration increase with time (Figure 5; Mato*et al.* 2002). These increasing trends clearly indicate that ambient seawater is the source of PCBs found in the marine plastic resin pellets and that adsorption to pellet surfaces is the mechanism of enrichment. As PE and PP resin pellets are made of saturated hydrocarbon units, their surfaces are nonpolar and adsorb hydrophobic pollutants such as PCBs through hydrophobic sorption. Figure 5 also indicated an interesting result that PE pellets adsorbed more PCBs than PP pellets. This result means a higher affinity of PE pellets for hydrophobic compounds than PP pellets. The result was consistent with the tendency observed for stranded pellets on beaches, that is, PE pellets had a higher amount of PCBs than PP pellets, as shown in Figure 3. This difference is probably caused by the different surface chemistry between PP and PE.

Comparison of PCBs concentrations in marine plastic resin pellets with those in seawater suggests their high degree of accumulation (apparent adsorption coefficient : 10^5 - 10^6). The high accumulation potential suggests that plastic resin pellets serve as a carrier of toxic chemicals to marine biota (e.g., seabird) which intakes the plastic resin pellets. Further studies must be done on the transfer of the chemicals from pellets to biological tissue while they transit through the digestive system of birds and other animals. On the other hand, the high accumulation potential of the marine plastic pellets suggests the potential use of plastic pellets as a tool for monitoring of organic micro-pollutants in seawater. In the following sections, their potential for monitoring tool is examined through studying regional differences in PCB concentrations in beached resin pellets.

Regional difference in PCBs concentrations between countries

Beached plastic resin pellets were collected from 11 Japanese coasts and 6 Malaysian coasts (Fig.6). Japan has used larger amounts of PCBs for industrial use than Malaysia and difference in PCBs contamination has been demonstrated between both coastal environments through various monitoring. Thus, PCBs concentrations in the beached resin pellets were compared between Japan and Malaysia. The resin pellets were classified according to their polymer types using near-infrared spectroscopy (PlaScan-SH, OPT Research Inc. Tokyo, Japan) and PE pellets were subjected to the analysis of PCBs. Approximately 50 pellets were extracted with DCM and analyzed for PCBs as described above. As shown in Figure 7, PCB concentrations in PE pellets collected from Japanese coasts were one to two orders of magnitude higher than those from Malaysian coasts (Mato*et al.*, 2002). This difference is consistent with regional difference in PCBs concentrations in the indicator organisms (i.e., mussels). Mussel has been used as sentinel organisms to detect marine pollution because of their nature to accumulate contaminants in their tissue and cosmopolitan habitats. "Mussel Watch", that is monitoring of marine pollution using mussel, has been applied worldwide (Goldberg, 1975; Farrington *et al.*, 1983; Tanabe *et al.*, 2000; Tsutsumi *et al.*, 2002). PCBs concentrations in

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mussels collected in Tokyo Bay (Yamaguchi *et al.*, 2000) were two orders of magnitude higher than those in Malaysia (Monirith *et al.*, 2000), as shown in Figure 7. The regional difference for mussel is well correlated with those for PE pellets. The correlation suggests that beached plastic pellets can be used as monitoring tool of marine pollution.

Piece-by-piece variability in PCB concentrations in a single beach

However, before beached resin pellets will be applied for pollution monitoring, we should recognize that beached resin pellets have different materials (e.g. polypropylene [PP], polyethylene [PE]), surface conditions (e.g. fouled, weathered), and colors (e.g. clear, discolored, pigmented). This implies that the potential as a sorbent and the history before stranding may vary considerably among particles. Concentrations of the sorbates in resin pellets could thus vary significantly, even in pellets collected on a single beach. This piece-by-piece variability on a beach should be taken into account when concentrations of contaminants in the resin pellets from various beaches are compared and the regional variation of the concentrations is discussed. Thus, we investigated the variability of PCB concentrations among individual resin pellets from a single beach and the relationship of the concentrations to materials, weathering, fouling, and discoloration of the pellets (Endo *et al.*, 2005).

Sixty resin pellets were collected from a beach in Kasai Seaside Park, Tokyo, in July 2001 for studying the variation in PCB concentrations between pellets. The pellets were picked up along the high tide line within a range of 30 m, using solvent-rinsed stainless steel tweezers. The type of material, discoloration, fouling, and weathering of the pellets were examined using macroscopic, spectroscopic, and calorimetric methods and the individual resin pellets were characterized. The concentrations of PCBs in the individually characterized resin pellets were determined as described above.

Of the 60 resin pellets collected from Kasai Seaside Park, 35 were classified as PE and 20 as PP. These 55 pellets were analyzed individually for sorbed PCBs. The PCB concentrations ranged from below the detection limit (i.e., <28 ng/g; 24 pellets) to 2300 ng/g (Figure 8; Endo *et al.*, 2005). The pellet with the highest concentration accounted for ~50% of the sum of PCBs in the 55 pellets, and the top 3 pellets comprised ~60% of the total PCBs. The arithmetic mean of PCB concentrations of the 55 pellets was 93 ng/g, and 50 pellets had concentrations less than the mean. These results clearly indicate that the concentration of sorbates varies considerably (i.e., over 2 orders of magnitude) among the pellets collected from one beach, and that a small proportion of the pellets contains a large proportion of the chemicals. For the application of beached resin pellets as monitoring tool, this variability, especially occurrence of a few pellets with sporadically high PCBs concentration, should be taken care carefully. Figure 8 also shows a tendency of PE pellets to have a higher amount of PCBs than PP pellets. This result is consistent with the results described above. This also suggests that PE pellets are preferable for the monitoring purpose. We also investigated the relationship of the variability in PCB concentrations to materials, weathering, fouling, and discoloration of the pellets. Discolored and/or fouled PE resin pellets had higher concentrations of PCBs than non-discolored and non-fouled ones, but no clear relationship between crystallinity and weathering with PCB concentrations was found. The piece-by-piece analysis of the beached resin pellets suggested that discolored and/or fouled PE resin pellets are suitable for the application of marine plastic resin pellets to pollution monitoring, because they had relatively higher concentration of PCBs.

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Regional variability in PCB concentrations in plastic resin pellets stranded on 47 beaches in Japan.

To examine the utility of marine resin pellets as monitoring indicators, we studied the regional variability in PCB concentrations in plastic resin pellets stranded on 47 beaches in Japan. The resin pellets were collected from 47 beaches (Figure 9) in 2001 and 2002 in partnership with local volunteers. The samples were collected from sandy beaches. More than 100 pellets were collected from each beach. Solvent-rinsed stainless steel tweezers were used to pick up pellets, and the samples were stored in a stainless steel container and sent to the laboratory by mail. The resin pellets were classified as PE, PP, or other by near-infrared spectroscopy (PlaScan-SH, OPT Research Inc. Tokyo, Japan). PE pellets from each beach were sorted according to discoloration (yellowing) and fouling. Pellets with being discolored and/or fouled were analyzed for PCBs. Five discolored pellets or 10 fouled pellets were pooled (grouped) and extracted as below, because at least 5 – 10 pellets were necessary to extract enough amounts of PCBs for reliable analysis of pellets collected from less polluted area than Tokyo Bay. Multiple pools (groups) from each location were analyzed so that regional PCB concentrations could be shown as a range, and any high-concentration pellets could be recognized and excluded from the mean. The pellets were extracted by maceration in n-hexane for 72 h at 20 °C. The solvent was replaced twice during the maceration, and all the extracts were combined. The clean-up procedure and instrumental analysis were as described above.

While wide ranges of PCB concentrations were recorded from the individual beaches, regional differences can be also recognized among the beaches (Endo et al., 2005). As can be seen in Figure 10, high PCB concentrations were most frequently found in the pellets from Tokyo Bay and its vicinity and Osaka Bay, whereas low PCB concentrations were found in the Tohoku and Hokkaido region, the region around the Sea of Japan, and the Pacific Ocean side of Shikoku. This regional difference in PCBs concentrations in the pellets is consistent with a spatial trend of PCB pollution in other environmental media. Tokyo Bay and Osaka Bay are surrounded by the most industrialized areas in Japan, where large amounts of PCBs were used in the past (i.e., 1960s), polluting the bays and the vicinities with PCBs. In these regions, high concentrations of PCBs are still present in bottom sediments, seawater, and marine organisms (Japan Coast Guard, 2003; Yamaguchi et al., 2000). On the other hand, the Tohoku and Hokkaido region, the Sea of Japan region, and the Pacific Ocean side of Shikoku Island are less industrialized, and lower concentrations of PCBs have been reported in sediments from these areas (Japan Coast Guard, 2003).

In addition to regionally appropriate concentrations, some sporadic high concentrations of PCBs were found in resin pellets from remote islands such as Tanegashima, Shikinejima, and Sadogashima (locations 1, 12, and 42, respectively, in Figure 10). Their concentrations are remarkably higher than others from the same regions. This occurrence indicates that contaminant concentrations in ambient seawater are not the only factor that determines the concentration in resin pellets, and that some other factors should be also taken into account. A long residence time on the ocean surface or the presence of certain additives may have facilitated the adsorption of PCBs from the ambient seawater. In addition, during their time on the sea, the pellets may have passed close to an industrial area where they may have sorbed high amounts of PCBs, although their final stranding points were remote. Although the cause of these sporadic high concentrations is still unclear, the occurrence of resin pellets with high

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PCB concentrations on remote islands may pose ecotoxicological problems to marine organisms. Organisms living on the remote islands are normally exposed to low concentrations of PCBs through seawater and the food web. Resin pellets with extremely high concentrations of PCBs could become the dominant exposure route of the organisms to PCBs.

For the application of the resin pellets to pollution monitoring, the pellets with sporadic high concentrations of PCBs can be excluded through calculating median of multiple pools (groups), as shown in Figure 11. Calculating median successfully eliminated the sporadic high concentration of PCBs found at st. 1, 12, and 42. The regional pattern in PCBs concentrations in the beached resin pellets was compared with those for mussels (indictor organisms). Mussels were collected from 24 locations over Japan in 2001 – 2003 and were analyzed for PCBs. The results of our mussel samples echo this regional trend of PCBs in the beached resin pellets in Japan (Figure 11). Figure 11 indicates that the distributions of the concentrations in pellets and mussels are consistent. Through selecting 11 locations where pellets and mussels were collected within 10 km distance, correlation of PCB concentrations in the pellets with those in the mussel was examined. Figure 12 also indicates that PCBs concentrations in PE pellets (median of multiple bulks of discolored/fouled pellets) had good correlation with those in mussels. Considering that mussels well reflect the concentrations of hydrophobic organic contaminants in seawater and are therefore used widely around the world for marine pollution monitoring, we can conclude that the degree of pollution in the ambient environment is one of the most important factors that determine PCB concentrations in resin pellets.

Call for Beached Resin Pellets

Pellet Watch : Global Monitoring of Persistent Organic Pollutants (POPs) using Beached Plastic Resin Pellets

Based on above discussions, we propose the use of beached resin pellets as a tool to monitor persistent organic pollutants (e.g., PCBs and organochlorine pesticides) pollution in world coastal waters, as illustrated in Fig.13. In this project, we call for beached plastic resin pellets. Through various networks and internet, we will ask world citizens to collect beached resin pellets at nearby beaches and send them to our laboratory via air mail. More than 100 resin pellets (ideally 200 pellets) per a location are necessary for reliable monitoring. The collected pellets will be sent to our laboratory in Tokyo via Air mail. Discolored and/or fouled PE pellets will be selected by using spectroscopic method and multiple 10-piece-pools will be extracted are analyzed for organochlorine compounds (e.g., PCBs) by the method that we developed. Based on the analytical results, global POPs pollution will be mapped. The analytical results will be sent to the persons who collected the samples via internet and released on web. Advantage of ***Pellet Watch*** includes extremely low cost for sampling and shipping and easiness to collect samples (i.e., no special training is required for sampling) compared with the existent monitoring media (e.g., water, sediment, biological samples such as mussel). Collect pellets on your nearby beach and send 100 pellets to Tokyo via air mail!

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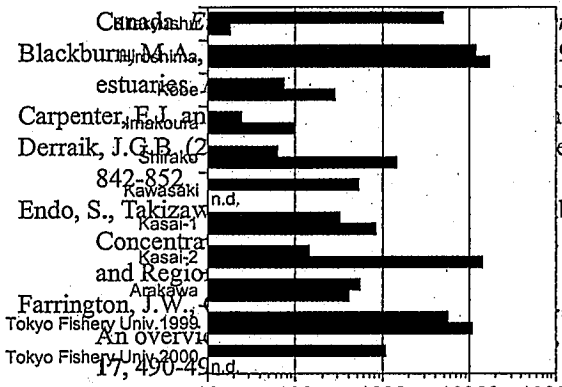

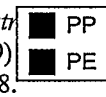

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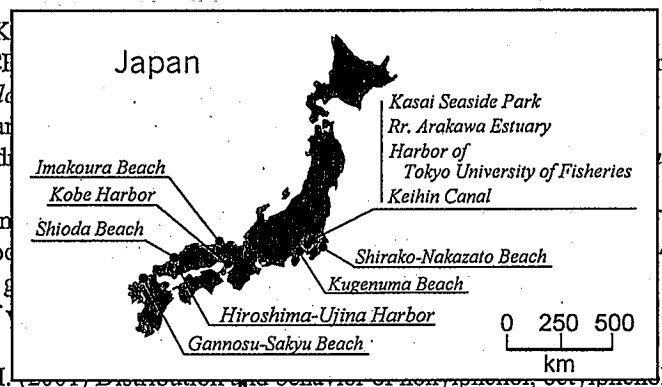

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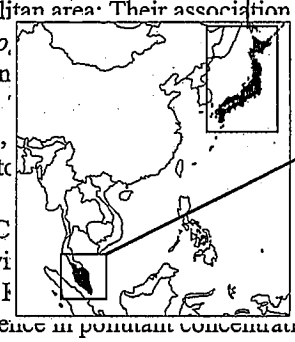

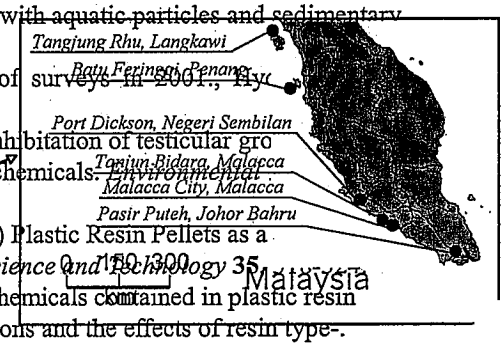

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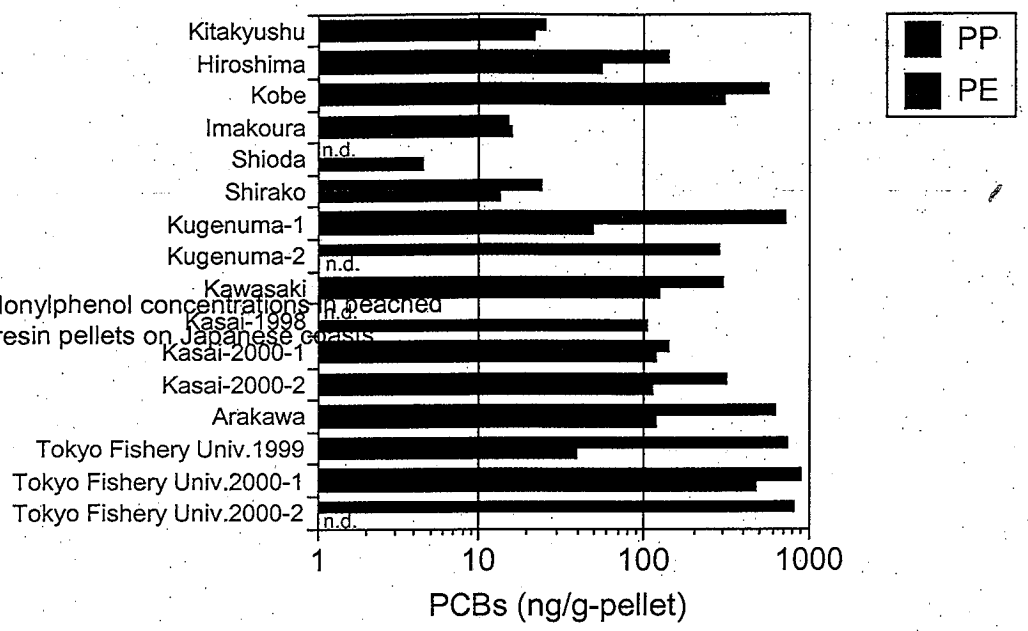

Fig.1 Nonylphenol concentrations in peached resin pellets on Japanese coasts

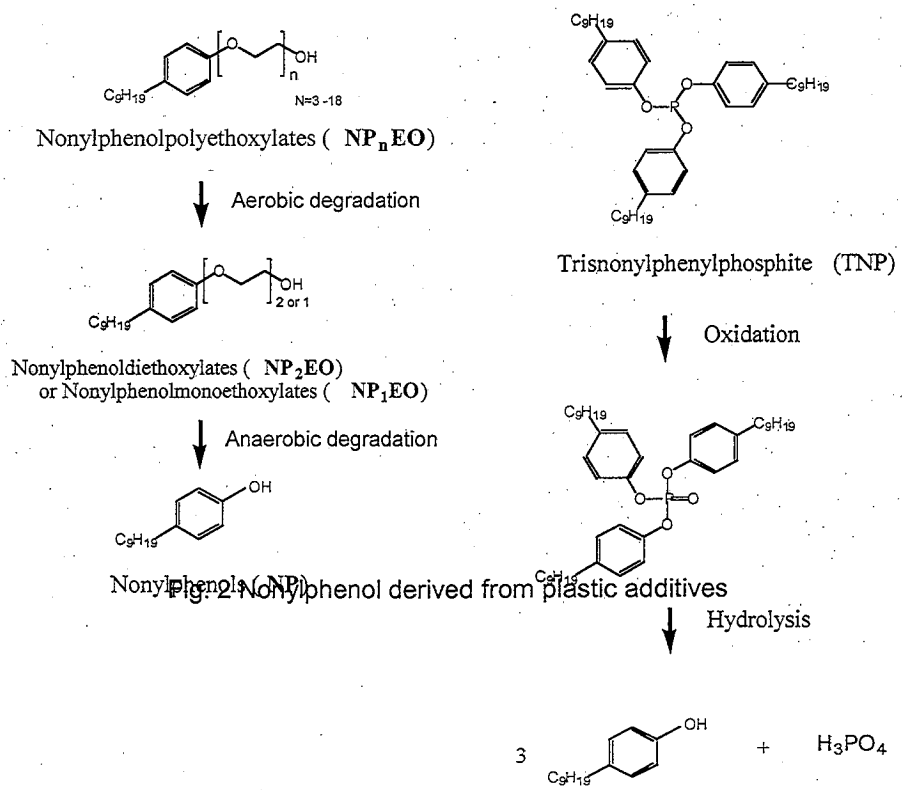

Fig.2 Nonylphenol derived from plastic additives

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Fig.3 PCB concentrations in beached resin pellets on Japanese coasts

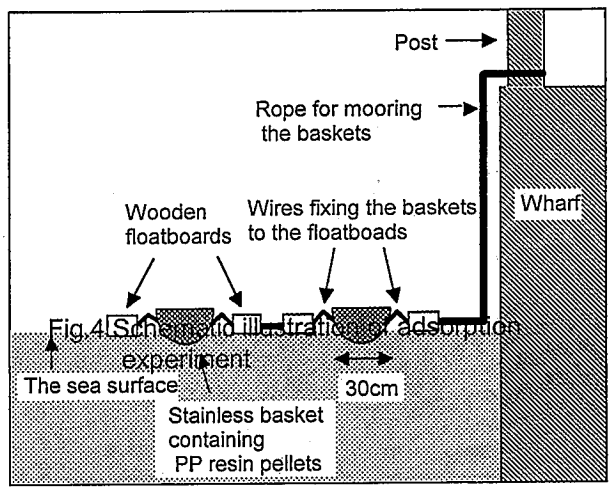

Fig.4 Schematic illustration of adsorption experiment

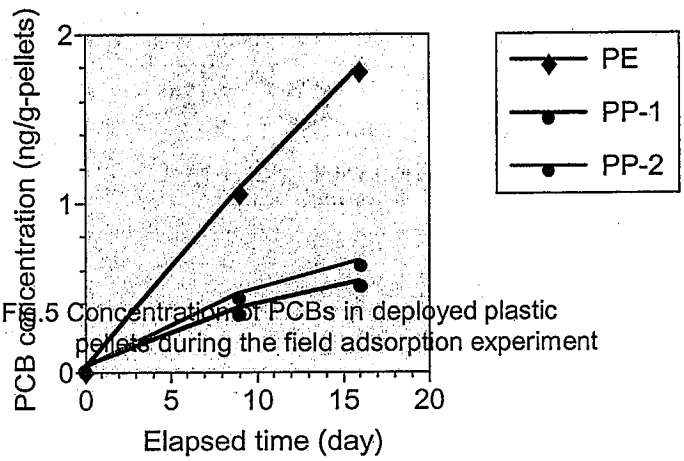

Fig.5 Concentrations of PCBs in deployed plastic pellets during the field adsorption experiment

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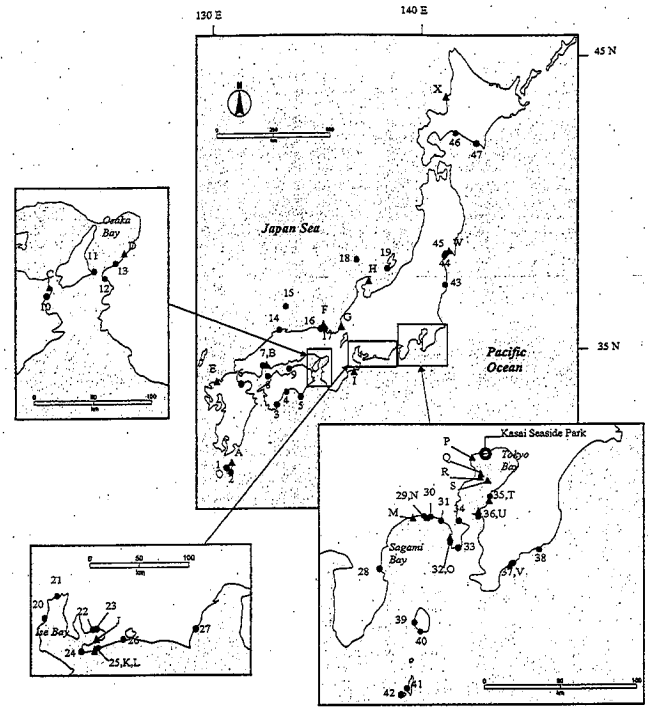

Fig.6 Sampling locations of plastic resin pellets and mussels in 1998 - 2000

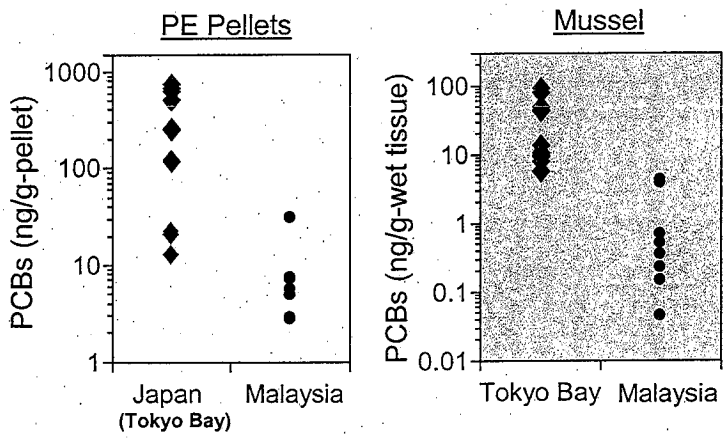

Fig.7 PCB concentrations in beached plastic resin pellets (left) and mussels (right).
Red diamonds : Tokyo Bay; black diamonds : the other Japanese locations than Tokyo Bay; blue circles : Malaysia

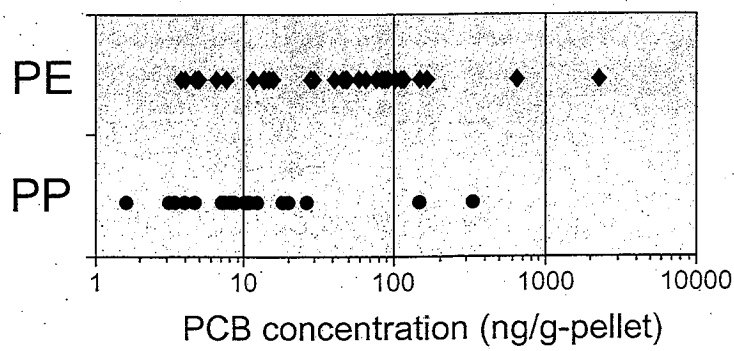

Fig.8 PCBs concentration in PE and PP resin pellets derived from piece-by-piece analysis.

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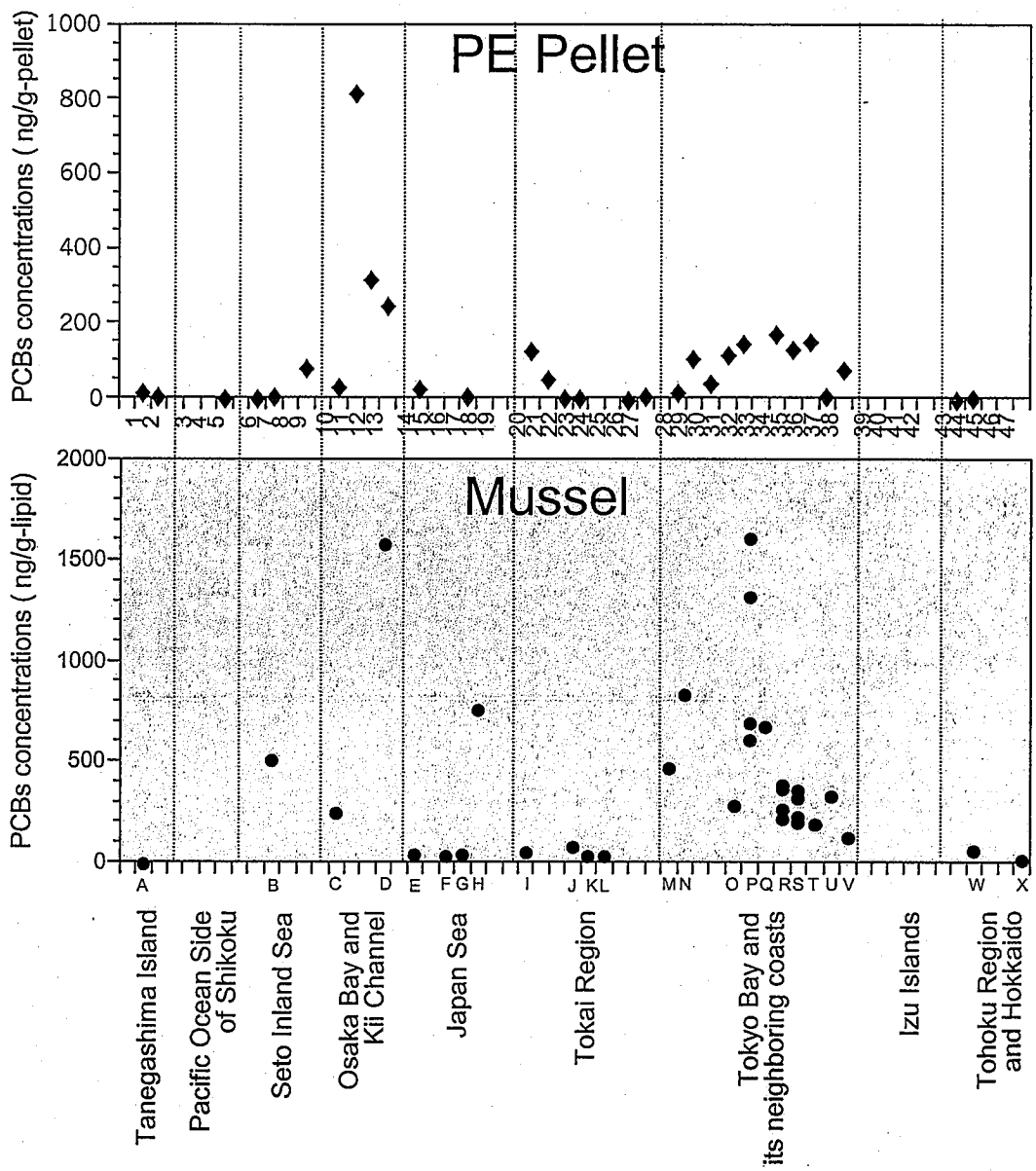

Fig.9 Sampling locations of plastic resin pellets and mussels in 2001 – 2003
Numbers : locations of the resin pellets; alphabets : locations for mussels

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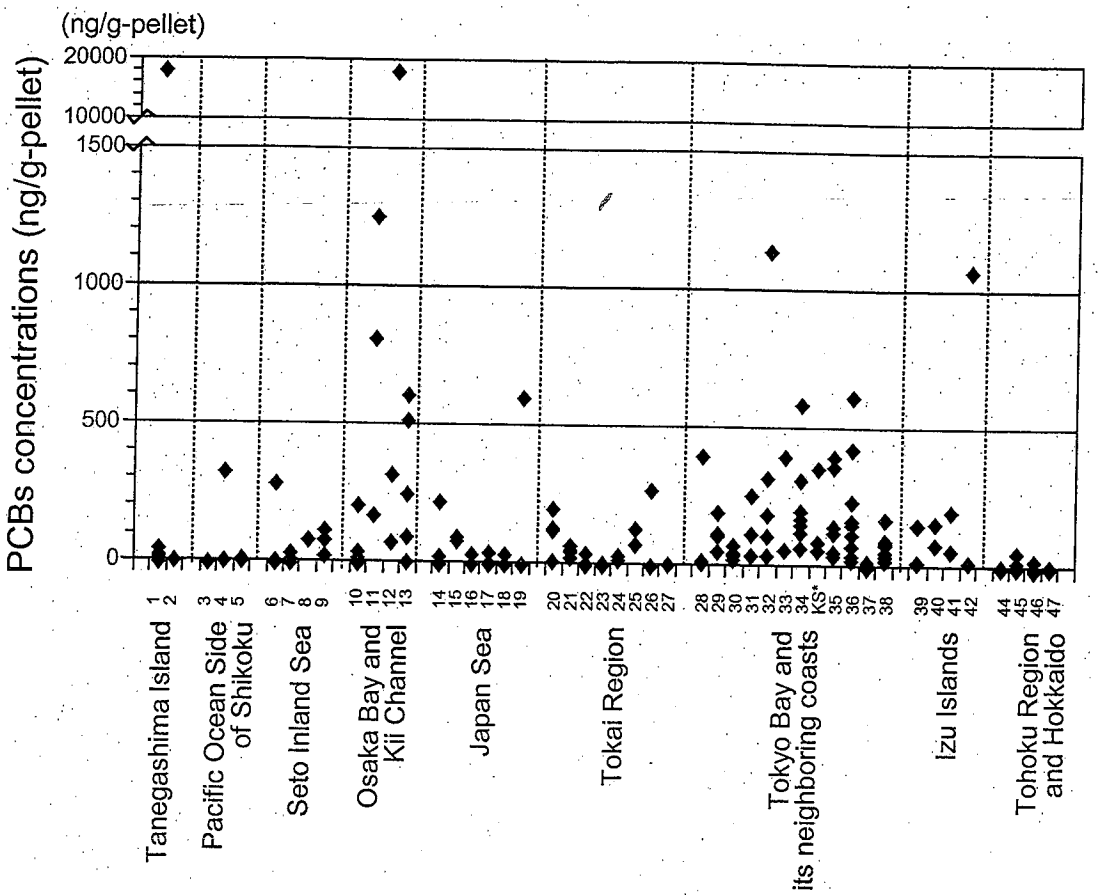

Fig.10 PCBs concentration in discolored and/or fouled PE resin pellets from 47 Japanese beaches.
Each pool is shown as a plot.

Fig.11 PCBs concentration in discolored and/or fouled PE resin pellets from 47 Japanese beaches and in mussels from 24 Japanese coasts.
Median concentrations are plotted for PE pellets.

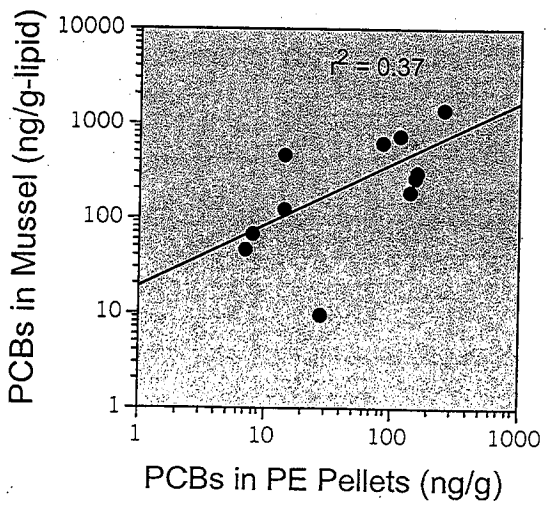

Fig.12 Relationship between median concentrations of PCBs in discolored and/or fouled PE resin pellets and PCBs concentrations in mussels.

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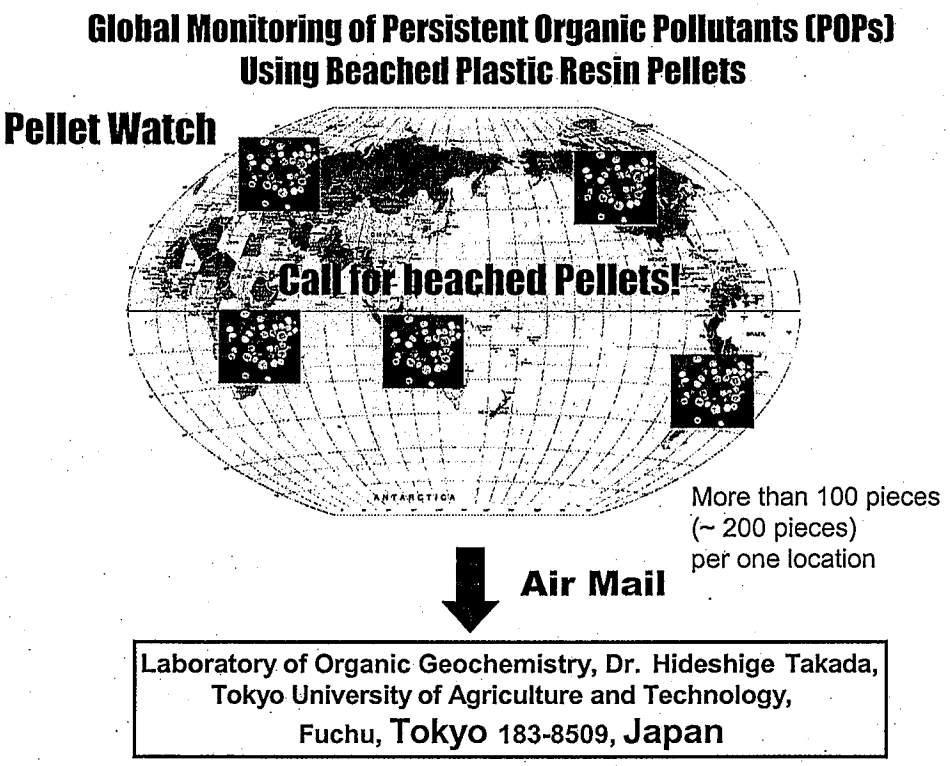

Fig.13-1 ***Pellet Watch*** project: Call for beached pellets

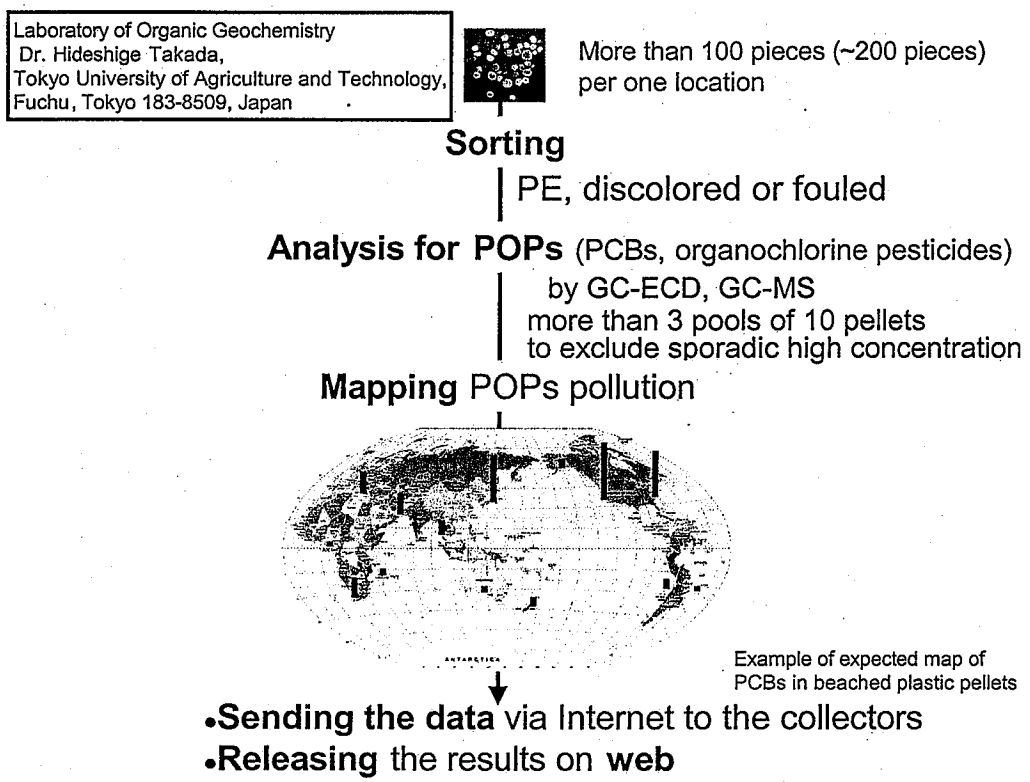

Fig.13-2 ***Pellet Watch*** project: Call for beached pellets

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A comparison of neustonic plastic and zooplankton at different depths near the southern California shore

Gwen L. Lattin[1], Charles J. Moore[1], Ann F. Zellers[1], Shelly L. Moore and Stephen B. Weisberg

ABSTRACT - Previous studies of neustonic debris have been limited to surface sampling. Here, we measure debris and zooplankton density at three depths in Santa Monica Bay, California, using one trawl survey before a rain event and one trawl survey shortly after a rain event. Surface samples were collected using a manta trawl, mid-depth samples using a bongo net, and bottom samples using an epibenthic sled. All collection devices were equipped with 333 micron nets. Density of debris was greatest near the bottom, and least in mid-water depths. Debris density increased after the storm, particularly at the sampling site closest to the shore, reflecting inputs from land-based runoff and resuspended matter. The mass of plastic collected exceeded that of zooplankton. However, zooplankton mass was three times that of debris when the comparison was limited to plastic debris similar in size to most of the zooplankton.

INTRODUCTION

Most studies of marine debris have focused on material along the coastal shoreline easily identified through visual inspection, with only a few studies describing abundances of small material in the water column (Derraik 2002). The earliest of these was Shaw and Mapes (1979), who found a high density of plastics near the surface in the central Pacific. Recent studies have identified neustonic plastic mass comparable to that of zooplankton in both the mid-Pacific gyre (Moore, C. *et al.* 2001) and along the California coast (Moore, C. *et al.* 2002).

Studies of neustonic debris in the water column have been limited to surface water sampling. Plastics make up a high percentage of neustonic debris and many plastics are positively buoyant. Therefore, studies limited to sample collection in surface waters have the potential to overestimate the prevalence of debris in the water column. In addition, while some animals, such as birds, feed on plankton near the surface and could potentially consume surface debris, other animals participate in filter feeding below the surface and could be exposed to the same risk from debris in the water column.

This study extends previous work by comparing the density of neustonic debris and zooplankton at several depths along the California coast. The study also addresses changes in the water column following a storm event, when higher wind conditions and increased urban runoff have the potential to enhance vertical mixing.

METHODS

Sampling was conducted at two Santa Monica Bay sites offshore of Ballona Creek, which drains the heavily developed western area of Los Angeles. The first site was located approximately 0.8 km offshore and the second approximately 4.5 km offshore. Sampling took place on March 21, 2001, following six weeks without rain, and on March 25, 2001, following a 20 mm rain event.

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The sampling site closest to shore was 15 m deep and samples were collected near the surface and at 5 m depth. The second site was 30 m deep and samples were collected at three depths: surface, 5 m, and near the bottom. Surface samples were collected using a 0.9 x 0.15 m^2 rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30 x 10 cm^2 collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets with 3 m long, 333 micron nets and 30 x 10 cm^2 collecting bags. Bottom samples were collected using a 31 cm^2 rectangular opening epibenthic sled with a 1 m long, 333 micron net and a 30 x 10 cm^2 collecting bag. The net on the epibenthic sample was located 20 cm from the bottom. Visual inspection by scuba divers showed no sediment stirred from the bottom and entering the net. All samples were fixed in 5% formalin in the field, and later soaked in fresh water and transferred to a 70% isopropyl alcohol solution.

Trawls were conducted parallel to shore for 10 minutes. Trawl speed varied between 1.0 to 2.3 m/s as measured with a B&G paddlewheel sensor (Clearwater, Florida), resulting in a trawl distance of between 0.5 and 1.0 km. A General Oceanics flowmeter (Miami, Florida) was mounted across the net mouth during all deployments to measure the volume filtered.

In the laboratory, samples were placed in fresh water and floating plastic was removed. A dissecting microscope was used to remove any remaining debris and plankton. Debris was sorted by category (plastics, tar, rust, paint chips, carbon fragments, and feathers) and plastics were further categorized (fragments, Styrofoam®, pellets, polypropylene/monofilament line, thin plastic films, and resin). Each category was sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.71, 0.50, and 0.35 mm and counted. Plastics were oven dried at 65° C for 1 h and plankton and plant material were oven dried at 65° C for 24 h, then weighed.

Results

Plastics were present throughout the water column on both sampling dates, but relative concentrations within the water column varied between dates and sites. The site closest to shore had nearly equal density at the two sampling depths before the storm (Figure 1), but density on the surface was considerably higher after the storm.

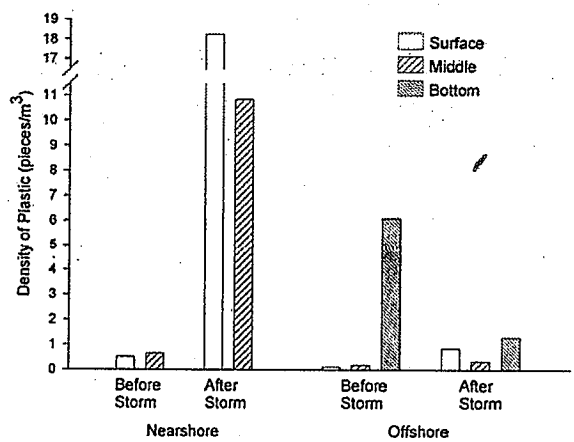

Figure 1. Amount of plastic (pieces/m3) before and after a storm at different depths and proximities to shore.

Debris densities at surface and mid-water depths of the offshore station were similar to that at the nearshore station; the increase in density after the storm was not nearly as large as at the inshore site. Debris density near the bottom at the offshore station was considerably greater than at surface and mid-water depths. Unlike surface samples, debris density was reduced at the bottom following the storm.

The spatial patterns for mass were similar to that of density, though the differences between dates were exaggerated (Figure 2). For example, the weight of plastic increased by more than two hundred times on the surface after the storm. Much of this increase was attributable to the presence of larger items at the surface after the storm (Table 1).

The average mass of plastic was 1.4 times that of plankton in this study, but much of the plastic mass was large material that is unlikely to be confused for planktonic prey (Table 2). When the comparison was limited to smaller particles (less than 4.75 mm), the mass of plankton was approximately three times that of plastics. This ratio was consistently higher near the surface and on the bottom than at mid-depth (Figure 3).

Discussion

The plastic-to-plankton ratio observed near the surface was similar to that found in previous studies (Table 2); however, this study was the first to measure this ratio at other depths. While more debris was found near the surface than in mid-water, the highest mass of plastic was found at the bottom. When only

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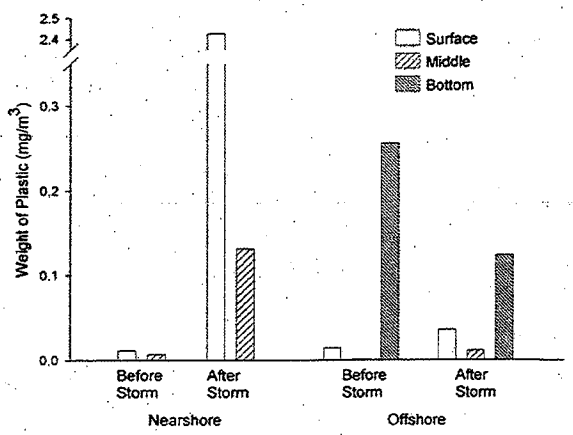

Figure 2. Mass of plastic (mg/m3) before and after a storm at different depths and proximities to shore.

Table 1. Percent weight and density of plastic by size and depth category.

Size Class	Category	Depth: Surface	Middle	Bottom
0.355 to 0.499	Weight	0.5	10.6	6.1
	Density	3.2	5.7	0.3
0.500 to 0.709	Weight	0.8	19.7	36.5
	Density	2.9	2.3	9.1
0.710 to 0.999	Weight	1.9	12.5	23.0
	Density	33.4	10.6	22.7
1.000 to 2.799	Weight	7.0	27.6	17.9
	Density	24.4	21.2	17.8
2.800 to 4.749	Weight	2.5	4.6	12.6
	Density	23.5	31.8	36.1
>4.750	Weight	87.2	25.0	3.9
	Density	12.6	28.4	14.0

small size classes were considered, surface and mid-water densities were nearly equal.

Plastics are commonly perceived to be positively buoyant, but research has shown this to be true with only 46% of manufactured plastics (U.S. EPA 1992). Many buoyant plastic products have been injected with air, the most common of which is Styrofoam®. Even plastics manufactured to be positively buoyant can become negatively buoyant as the result of fouling by biota or accumulation of debris. Environmental factors also contribute to the buoyancy of plastics. We observed sand embedded in many negatively buoyant items, such as plastic bags, that might otherwise float.

The absence of turbulence leads to natural separation of debris from top to bottom in the water column. The amount of turbulence necessary for resuspension of debris into mid-water appears to be small. Bottom density declined and mid-water density was elevated after a storm, suggesting that storm-related or wind-related turbulence may be adequate for resuspension. This finding is consistent with studies that indicate that the density of most plastics differs from that of seawater by a small amount (U.S. EPA 1992).

While mixing occurred in the shelf waters sampled, the influence of resuspension in deeper waters is less clear. The distance from the bottom to the middle of the water column is greater in deeper waters, and the influence of wind on mixing decreases with depth. Therefore, more turbulent energy is required to resuspend bottom material to the middle of the water column. Our study found sufficient routine turbulence to indicate that potential biological effects of plastics in the water column extend below the surface waters.

Table 2. Comparison between this study, San Gabriel River study (Moore, C. *et al.* 2002), and North Pacific Gyre study (Moore, C. *et al.* 2001).

	Average Debris (g/m^3)	Average Debris ($pieces/m^3$)	Ratio of Plastic to Plankton for Mass: All Debris	Ratio of Plastic to Plankton for Mass: Debris <4.75 mm
This Study	0.003	3.92	1.4:1	0.3:1
San Gabriel River Study	0.002	7.25	2.5:1	0.6:1
Gyre Study	0.034	2.23	6.1:1	0.3:1

Many marine fauna are known to ingest debris (Fowler 1987, Bjorndal *et al.* 1994, Robards *et al.* 1995, Blight and Burger 1997), but few studies have examined whether they become artificially sated on this non-nutritive material (Ryan 1987). Mato *et al.* (2001) found that contaminants adsorb to plastics, creating a potential for indirect effects of debris consumption; however, no study has considered whether this is a viable pathway for contaminant uptake by biota. These types of studies need to be conducted

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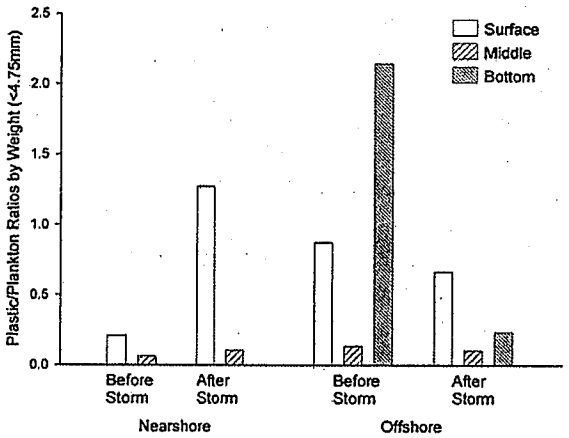

Figure 3. Plastic/plankton ratios (pieces less than 4.75mm) before and after a storm at different depths and proximities to shore.

before the importance of debris in the water column can be fully assessed.

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Acknowledgements

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Plastics in the Marine Environment: A Technical Perspective

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The marine resource covering 70 percent of the earth's surface is a key asset in the biosphere. Of the nearly 1.5 million species known, nearly a quarter million live in the world's oceans. More importantly, nearly 50 percent of the global primary production (amounting to 45×10^{15} g/yr) takes place in the upper stratum of sea water. The health of the marine food web and the fisheries resources invariably depend upon the long-term viability of the autotrophic algae and the zooplankton primary consumers in the food pyramid. Pollution from land-based sources, solar UV irradiation, and global warming can interfere with the plankton species that form the foundation of the food web, adversely affecting the delicate balance in the marine ecosystem.

Plastics represent the latest contaminant in the marine environment. However, plastics without doubt represent a uniquely valuable material particularly in construction, packaging and fishing gear applications. The global as well as the national trend has been for consistent growth in the use of plastics consumption. In applications where the use of plastics lead to waste reduction or reduce the burning of fossil energy, this growth is environmentally desirable. In other areas such as in marine applications, the increased use of plastics has lead to negative environmental impacts. Being a particularly efficient material in packaging and gear fabrication, it is very unlikely that the growth in plastic materials will plateau out or decrease in the foreseeable future.

Most of the research on ghost fishing by derelict gear, entanglement of marine mammals or birds, and ingestion hazard to turtles or birds, has studied the negative impacts of plastics waste on these more visible marine species that are of commercial or aesthetic value. Plastic-related distress to over 250 species has been documented worldwide. The focus has very much been on larger species in surface waters or beaches, despite the fact that 99 percent of marine species live in the benthos. The impact of negatively buoyant plastic waste (such as nylon net fragments) on benthic species has remained virtually unaddressed.

Plastics as a Waste Material

No good estimate of the amount of plastic waste annually introduced into the marine environment is available. But, plastic waste is well known to result primarily from fishing-related activities, and from non-point source influx from beaches. Seafood presently represents 20% of the protein in global diet. As the population

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increases, more intensive fishing relying even more heavily on strong, light, and low-cost plastic gear will be increasingly used. Packaging, already accounting for nearly a third of plastic resin produced, is increasingly switching to plastics as the material of choice. Correspondingly, the plastic component of beach litter (already predominantly plastics) will increase over the years.

A majority of the plastics found in beach litter or at sea belong to the several resin types used in packaging and in gear fabrication. Of these, the positively buoyant types are readily encountered in beach clean-up data as well as in floating debris counts. Nylons used extensively in gill nets and trawl fisheries, for instance negatively buoyant and therefore less likely to be seen in beach litter. The table 1 below lists the types of plastics likely to be found at sea, and their specific gravity.

Table I. Plastics Likely to be Found in the Oceans

	Specific Gravity
Gear-related plastics	
- polyethylene	[0.92-0.97]
- polypropylene	[0.91]
- nylon	[1.14]
- polyester	[1.38]
Packaging-related plastics	
- polyethylene, polypropylene	
- PVC	
- polyester	
- polystyrene (styrofoam)	[<0.2]

Specific Gravity of Sea Water {T, Salinity, pressure} ~ 1.025

There are two clear differences between the fate of plastics debris in the ocean environment as opposed to on land environments.

a) The rate of UV-induced photo-oxidative degradation of plastics floating or submerged at sea is very much slower than that exposed to the same solar radiation on land.

b) Unlike on land there is no easy means of retrieval, sorting and recycling of plastic waste that enters into the ocean environment.

These two factors generally result in extended lifetimes for plastics at sea. To further exacerbate the situation several observations have shown that floating plastics debris is rapidly inhabited by epibenthic foulant communities and tend to be negatively buoyant over a period of time. Once submerged, the plastic receives in even less of sunlight (the UV component of which is efficiently absorbed by the water column) and the surface coverage prevents even the little light that is available from reaching the surface of the plastic. The only exception to this

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observation is expanded polystyrene foam material that disintegrates faster at sea than on land; yet, whether the same holds for the microparticulate residue of polystyrene has not been investigated.

Measuring Plastics Degradation

Plastic debris generated on beaches can undergo some degradation prior to being washed into the oceans. It is important to realize that the measure of 'degradation' is user-defined. There are various procedures available to measure degradation of plastics and the one that is adopted depends on the objectives of the experiment.

For research focusing on the conventional entanglement or ingestion concerns, degradation of a plastic to the point of 'embrittlement' is often adequate. As a plastic material is exposed to solar UV radiation its mechanical integrity decreases at a rate dictated by the temperature (hence the retarded breakdown in sea water that acts as a heat sink). This is best illustrated by the decrease in ultimate extensibility of the material; more degraded the plastic is less extensible it will be without breaking. At a high level of degradation the extensibility reduces to less than 5 percent and the material is weak and friable (and is said to be embrittled). Embrittled material poses no danger to large animals via entanglement or ingestion.

A more rigorous criterion of degradation, based on the carbon cycle would require the polymer to be completely reduced to inorganic components via oxidative or biological degradation. The process is called 'mineralization'. Materials such as cellulose as well as some synthetic polyesters (polyglycolic acid, polycaprolactone, etc.) are fully mineralized by this definition. However, some of the natural polymeric materials such as humus and lignins undergo very slow mineralization similar to most of the plastics.

The fact that embrittlement has been achieved and the bulk plastic product (Styrofoam floats, or net fragments) has been fragmented to particles, does not remove it from the marine environment. Studies show that increased surface area of the particles do help these to biodegrade at an enhanced rate, but the material remains for extended periods of time in the marine environment. If mineralization does take place, it must indeed be a slow process especially if it happens in the anoxic cold benthic environments. Exactly how long such a process would take is not known.

In between these rather extreme criteria for degradation of plastics are measures that may require the plastic material to be reduced to a particle size that can be safely ingested by marine birds, or that is indistinguishable from the sand and pebbles in a beach setting.

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In practical terms these finding has serious implications: the plastic waste that has been introduced into the world's oceans must accumulate for the most part intact and unmineralized in the marine environment. While the fate of such plastics is not clear, it is reasonable to expect at least some of it to continue disintegrating into microparticulate debris. That such microparticlulates exist in the oceans is of course well established; studies, both in the US and in Europe, have established their presence in the oceans. Recent reports even indicate an increase in their counts over the last two decades. However their quantification, especially in the estuarine regions and the continental shelf where most of primary production occurs has been a challenging task.

Impact of Microparticles

The full ecological consequences of the presence of microparticulate polymer in the marine environment are not clear. However, their interaction with filter feeders, specially the zooplankton species that are primary consumers, can be easily anticipated.

Challenging the Antarctic krill and other zooplankton with plastic beads that are about 20 microns or so in size has demonstrated that these microparticulates are readily ingested by these organisms. They appear to ingest the particles unselectively, and the ingestion rates depend on the concentration of particles in the environment. Plastics are bio-inert and are not expected to be toxic to the animal in the conventional sense. While physical obstruction or indirect interference with physiology is always possible (as with sea birds showing satiation on ingesting plastics) the material will pass through the animal virtually unchanged.

The concern, however, is that plastics exposed to sea water tends to concentrate toxic and non-toxic organic compounds present in the sea water at low concentrations. These, including PCBs, DDT, and nonylphenols, have very high partition coefficients and are very efficiently concentrated in the plastic material. This has been demonstrated effectively in Japan (by Hideshige Takada et.al. a presenter at this event). There are two key issues as yet unaddressed in the research literature.

First, while fresh uncontaminated plastic miroparticles are readily ingested by zooplanktons, will an aged particle loaded with possibly toxic chemical compounds from sea water, be equally palatable to the organisms? Despite the unselective ingestion generally displayed by these organisms, avoidance of ingestion of toxic algae by the same species has been reported. The existence of a chemotactic safeguard mechanism that would make zooplankton reject the contaminated microparticles cannot be ruled out.

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Secondly, if such microparticles are ingested will the chemical components be bioavailable to the organism? If the compounds are bioavailable in the residence timescale within the gut region, then one needs to address the question of physiological consequences of the chemicals to the zooplankton. From an ecological standpoint, the transfer coefficients for the chemical moving up the food pyramid need to be also evaluated. These questions remain unanswered in the literature.

Conclusions

Despite years of interest on the topic little research has been carried out by the government agencies or the plastics industry to address the key issues relating to plastics in the marine environment. Extensive documentation of entanglement, ingestion, and danger of plastic gear to vessels, has been achieved over the years. However, the focus has always been biased and limited to the visible fauna.
The most serious threat, if any, of plastics in the marine environment is likely to be their impact on the very foundation of the food web - on the zooplanktons and other filter feeders. The possible impact plastic microparticles on the long-term sustainability of the marine food web needs to be unambiguously established.

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The Role of Producer Responsibility Policies in Reducing Waste

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Californians Against Waste

"2005 Plastic Debris Conference"
September 7-9
Redondo Beach, CA

Abstract

The oceans of our world are increasingly imperiled by a multitude of threats, and one of the most prominent dangers comes from plastic litter. Ensuring the safety of our marine habitats requires that we dredge the proposed solutions of the day, asking where we should apply our efforts and energy. One of the sectors with the greatest potential for wide-reaching change is source-reduction at the production level, but how does one create and support source-reduction?

A mainstream philosophy which has evolved over the last two to three decades in response to this inquiry is "Extended Producer Responsibility" legislation (EPR). Understanding how EPR may help reduce marine litter requires understanding how EPR has played out in real-life situations. From these examinations and current research on EPR policy applications, we may begin to extrapolate what has and has not worked throughout the world, and how it may apply to the American situation.

For the purposes of this paper, existing research on EPR was collected with the intent of examining global examples. Focus was drawn to three different levels of governmental organization implementing EPR, looking at the California Bottle Bill, Germany's Green Dot System, and some of the progress made within the EU. Policy advice and general guidelines for EPR were highlighted and examined in light of their potential within the U.S.

Public Policy Options for Reducing Packaging Waste

For the last three decades, governments around the globe have employed diverse policies addressing various aspects of the packaging waste problem. While reducing litter has been consistently identified as a common priority for packaging waste, the specific approaches have been far from homogeneous in form. Policies often overlap, and coexist within different levels of government, so that a national government with a product-specific fee may have a state, province, or city with a ban. Some governments will utilize completely different approaches for addressing seemingly similar packaging waste problems. Or, states may feature deposit-return schemes which are not utilized by the nation as a whole.

Despite the multiplicity of government approaches, some guidance has been provided by previous research. In 2002 OCED - or Organisation for Economic Co-Operation and

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Development - published, "Towards Sustainable Household Consumption", a paper outlining consumption practices and policies for OCED Member countries. The paper noted that, "Municipal Waste Generation continues to grow in OCED countries despite a significant expansion in waste recycling. Packaging and organic waste are priority areas of concern."[1] The paper recognizes that source reduction is a necessary focus within this area, surveying the innovations with which governments have responded. Outside of environmental education, these innovations may be separated into regulatory tools and economic instruments.

Regulatory tools include environmental standards for waste management, EPR, mandatory recycling systems and product labels, whereas economic instruments include taxes and fees on waste generation, and deposit-refund schemes.[2] Most of these tools contain variations themselves, and sometimes overlap. For instance, environmental standards are varied in the form they assume. One example is Korea, where excessive packaging is being addressed in over-sized boxes. Standardized boxes are common in packaging, often resulting in excess void space for smaller products in larger boxes. Legislation has now mandated that processed foods cannot have more than 15% void space within a package, nor more than two layers enclosing an item.[3] In contrast, Standards Australia was requested by the Environment Protection and Heritage Council of Australia to develop standards for degradable Plastics in October 2003.[4] As such, materials, designs, and particular products may have various standards applied and set by national or local government.

Bags See Fees, Bans, and MOUs

Specific items have also been banned by different governments. China banned the use and production of disposable expanded polystyrene food containers as of 2000.[5] Cities within the United States have seen similar bans on expanded polystyrene food containers, such as Portland, OR in 2002; Malibu, CA is considering the same ban this very year.[6] In 2003, Taiwan banned disposable plastic tableware as well as plastic bags;[7] Kenya, Rwanda,[8] Germany, Sweden, and 30 towns in Alaska,[9] are some additional notables which have banned the bag.

Plastic bags have also been seeing fees as of late; Taiwan imposed fees in 2001 before they instituted the more recent ban.[10] Scotland, as well as the cities of Ottawa, Ontario,[11] and San Francisco, California are all currently considering a fee on plastic bags, following the exemplary performance of similar legislation in Ireland, Denmark and Switzerland.[12] Ireland has seen a drop of 108 million plastic carrier bags used annually in the country since the fee was imposed in March, 2002, simultaneously generating revenues of 13 million Euros.[13]

MOUs, or memorandums of understanding, have also been advocated by some, though this topic was not overviewed in the OECD 2002 report. The U.S. Geological Survey Describes MOUS as,

> ...an area of mutual interest or concern that may be addressed cooperatively by two or more agencies or organizations. MOUs generally do not include specific information regarding detailed scope of work or the exchange of funds or human resources. An MOU may address cooperation that ranges from a single state to activities at multi-state, regional, multi-regional, national, or international levels.[14]

MOUs generally represent a compromise between political actors and industrial representatives. Usually, a political actor - who sees environmental goals potentially impeded by industrial interests - will propose altered production or manufacturing activity in exchange for less

stringent political actions. MOUs are another tool which is being explored in the context of plastic bag litter. For instance, in Los Angeles, California, councilmember Ed Reyes mentioned aspirations to meet with plastics manufacturers and grocery chain representatives in a partnership to help with bag clean-ups and recycling programs.[15]

Similar ventures have had positive effects in Australia, with the National Packaging Covenant managing the impacts of consumer packaging since 1999. The Covenant, recently revised in 2004, is a voluntary co-regulator developed and implemented by the government and stakeholders in the packaging supply chain.[16] In 2003 the Environmental Protection and Heritage Council (EPHC) for Australia challenged retailers to reduce the number of plastic bags issued by 20% by 2004 and 50% by 2005.[17] A report issued in March of 2005 on their progress reported a rough 20% reduction in the first year. While some doubts remain about continued progress, the report validates the ability of industry to achieve some environmental targets.[18]

In fact, all of the tools overviewed in the OCED 2002 report and researched in current policy applications, have potential positive benefits, including those not discussed in this paper - such as mandatory recycling systems, PAYT (Pay-as-You-Throw) programs, and eco-design. However, the question remains, does EPR lead to source reduction?

Extended Producer Responsibility

Extended Producer Responsibility (EPR) refers to a policy approach whereby manufacturers are accountable for their products' impacts. This responsibility may span the entire product lifecycle, though policies tend to focus on their 'end of life' and require take-back, recycling and/or safe disposal.[19] The term was coined in the early 1990's by Swedish Professor Thomas Lindhqvist, though its nameless incorporation as a policy began much earlier. Better K. Fishbein, a respected author on the subject of EPR, suggests that EPR policies share three common features:

1. They extend [producer] responsibility to the post-consumer stage.
2. The responsibility of the producer is always physical and/or financial - producers either physically take back and recycle their own products or pay a third party to do so.
3. Guidelines (usually set by government) require specific recycling rates, define what counts as recycling, and require data collection and reporting. [20]

...in theory

Generally, the aim of most enacted EPR policies is to shift the responsibility of who pays for packaging and product waste, and when it is paid for. It relates to the economic support and general health of a nation by addressing the concepts of responsibility, incentives for manufacturers, and directing the choices of consumers appropriately.

Product packaging is often perceived as "free" to consumers: when they buy coke, they focus on the product consumed (the liquid) as opposed to its packaging (the container). When consumers buy a "to-go" product, such as a burrito, or ask for a "take-home" container at a restaurant, they often perceive that these wrappings are free. However, these items are not free - governments fund waste hauling and litter clean-up, managing an expansive infrastructure and environmental mitigation efforts. These expensive operations are funded by taxpayers, but people often fail to make a connection between a product's packaging and their pocketbook because they pay for

these items separately. In the mean time, manufacturers get a free ride when it comes to product design; they are rarely forced to address the effects of their products and packaging as this dross is conveniently collected by the government.

EPR is founded on the obligations of producers, and seeks to integrate the negative external costs of products into the products themselves. Contemporary international opinion is that product responsibility - while inherently shared by multiple actors - is best when focused around one entity. In addition, policies should be incorporated which center on environmental accountability at the design phase of products, not oriented around their eventual repercussions in society.[21] As producers have the greatest control over the substance of their products, it is logical that they assume partial or full responsibility for what they design.

Extended Producer Responsibility is a market-based approach to environmental protection and resource conservation, requiring manufacturers to internalize the environmental externalities of their products and packaging, and using financial signals to motivate changes in materials, product design, and/or product price.[22]

...in practice

While EPR is based on sound theory, its ideal application has been hampered by the real world of interest group politics and compromise. Today, what we have to show as actual 'EPR' policies in place is several different legislative models, each with its own degree of success.

Actual lifecycle environmental and societal costs can be difficult to pinpoint. For that reason, most EPR policies focus on waste management costs, as it is easier to measure and observe. Overall, EPR policies have been applied to a wide array of products, including general categories such as packaging and pharmaceuticals, as well as specific categories such as plastic bottles, drink containers, computers, batteries, cell phones, sundry electronic waste items, oil, and tires.

The spectrum of 'environmental' policies which include EPR elements is also wide, including deposit-refund programs, required recycling levels (rates and dates), mandated refillables production, packaging/product take-back systems, fee-based recovery systems, voluntary initiatives, Producer Responsibility Organizations, environmental levies, leasing arrangements, governmentally managed systems, and governmentally regulated systems.

Making the Case: Bottles (Deposit-Refund Systems)

Bottle bills, which have now seem so natural in California, are not often the first subject that leaps to mind for EPR, as it is a political phenomena that has largely taken off in the last decade. However, any assessment of the affect of EPR with source reduction and litter would be sorely lacking without understanding deposit-refund systems in general, and California in particular.

Deposit refund-systems began gaining ground in 1960 when the Netherlands established minimum deposits for beverage containers.[23] Since then, the system has spread and transformed. In 1970 British Columbia became the first North American jurisdiction with a mandatory deposit-return program for beverage containers (soft drinks and beer),[24] followed soon by Oregon in 1971 as the first state in the U.S. with this system. By 1987, over one quarter of the American population, spread throughout ten states, had enacted similar legislation.[25]

In general, bottle bills reduce waste, litter, and are a beginning step in the right direction of wise waste management policies. Granted, more than one author on the subject has acknowledged that recycling is not the lone goal of EPR. However, using recycled products reduces the use of virgin material and reduces the amount of waste produced in a given year; it is, "a catalyst for more sustainable product design".[26] A beverage container recycling study[i] reported that states with container deposit laws recycled an average of 299 *more* containers (at a total of 490) per capita that non-deposit states in 1999.[27] Not only does such work represent less material going into landfills, but numerous state studies also show it results in less litter. One example would be New York, who found that their deposit law reduced beverage-container litter by 70% to 80 % and total litter by 30%;[28] similar percentages have been reported in other states.[29] In addition, reports have shown reductions in the marine litter levels of these containers. For instance, 1995 waste characterizations of litter collected on the beaches of Maine, Massachusetts, and New Hampshire found, respectively, 30, 60 and 280 bottles for every mile of beach. Maine and Massachusetts have seen modest reductions over time, both in bottles collected and overall litter, while New Hampshire has seen increases in both through the years.[ii] The study attributed the wide gap of containers collected to bottle bills, as Maine and Massachusetts have bottle deposit/refund laws, while New Hampshire does not.[30]

California Dares to Differ

However, traditional bottle bills within the United States are questionable examples of EPR, as the money changing hands goes between distributors and retailers and customers and *does not target the producer* except that it increases their product prices to at the point of sale. California's bottle bill (AB 2020) differs in that it is an excellent example of EPR legislation whose design makes good on its theoretical aims. It varies from other states in that the deposit-refund system overlaps with a form of EPR, an advance-disposal fee system.[31] AB 2020 was the first advanced disposal fee system, predating the German green dot system (which was initially a flat fee), and required that beverage manufacturers pay a "processing fee" (the advance disposal fee). This processing fee is calculated as the difference between a container's scrap value and the cost to recycle that container.[32] As such, it provides an incentive for manufacturers to engage in a system of production which:

1) Increases the price and amount of scrap material they retrieve and

2) Increases eco-design. Incorporating design-for-recycling in this case would include thinner bottles, reduced use of composites, increased consideration to recyclability, and so forth. It becomes the producer's best interest to follow ecological design and support recycling.

AB 2020 stimulated the plastics industry to set up an institution to further recycling of its low-retrieval-rate containers. The Plastic Recycling Corporation of California, the PRCC, is a private, non-profit corporation which was established to inform the public of, and aggressively promote, plastic's recyclability. PRCC also purchases and re-sells recovered plastics to help encourage the recycling industry. All these efforts increased the scrap value of their product material,[33] hence lowering the processing fee they would have to pay for every container sold. The birth and functions of the PRCC demonstrates the effectiveness of AB 2020 as an EPR bill, as it mandated financial involvement, and incited increased attempts on the part of industry to

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[i] P. Franklin cited a 2002 study by Business and Environmentalists Allied for Recycling (BEAR) for their Multi-Stakeholder Recovery Project, *Understanding Beverage Container Recycling: A Value Chain Assessment*

[ii] It is pertinent to remember that these years have seen an increasing number of individualized beverages sold. Hence, results imply that bottle bills are effective even against an upward trend of like items being produced.

promote physical recovery for their own product waste. In addition, EPR was implemented in a bill form that has a history of reducing waste and litter levels. However, has there been a demonstration of source reduction as well?

California and Waste Prevention

Although source reduction and the implementation of deposit-return and advanced disposal fees for beverage containers have been occurring in the same time period, it is difficult to assert absolute causality. However, there is little evidence that container designs were unaffected by the legislation, either. Several examples of source reduction began in close proximity to these laws. For instance, the EPA notes that since 1977, 250 million pounds of plastic has been kept out of the waste stream every year because the weight of 2-liter plastic soft drink bottles decreased from 68 grams to 51 grams.[34] Historically, these bottles were composite constructions featuring a thicker #2 HDPE plastic bottom and a #1 PETE body.

In fact, prior to the California bottle bill, two-liter containers were one of the few made of PETE at the time. Increasingly since then, non-composite PETE and HDPE containers have become the norm for single-serve plastic bottle. It is not surprising that these plastic types have moved to the forefront, as #1PETE is known for its clarity and durability among plastics, as well as its utility for re-molding with available, cleaner volume recovery.[35] With PETE bottles and other packaging alterations, designers were producing containers that were more recyclable and which avoided double processing fees for composite forms, hence lowering the overall fee they would be assessed. Some innovations such as the "plastic can" with an aluminum top faded from view, presumably from higher cost assessments, although some have recently re-appeared, confusing recyclers and recycling handlers alike.[36]

Traditional cans have fared well with source reduction in the same time period. Although Coca-cola has been repeatedly criticized lately for its lag time to incorporate recycled plastic in its containers, it has done well with its single-serve aluminum cans. In fact, the company was highlighted in national studies by the EPA for its source reduction with aluminum cans throughout the years. Efforts outlined in the study point to decreasing the weight of one end, shaving over 4 millimeters off the necks, and reducing the sidewall thickness. Company efforts have led to a 41% source reduction of the container.[37]

Overall, because data collection and methods for measuring source reduction at the time the legislation was implemented were not standardized, it is difficult to determine how much of this was inspired by the legislation. Also, it is difficult to separate the motivations, stimulation, and actions of various manufacturers. Source reduction often leads to economic benefits, so manufacturers may pursue it independent of political influences. Measuring source reduction may also lead to emphasis being placed on the wrong variables. For instance, there is often an emphasis placed on the weight of a material as opposed to type, so switching from heavier wood to lightweight plastic may be considered source reduction by some U.S. standards, ignoring the ramifications of converting to a material that may be less recyclable.

In summary of this EPR example, the California Bottle Bill, demonstrates the effectiveness of this type of legislation on matters of waste reduction, litter reduction, and increased recycling, with financial accountability directed away from government and towards producers. While there are examples of source reduction occurring in a similar time frame to the California bottle

bill, other case studies need to be evaluated to lend credence to the claim of EPR causing waste prevention among cities and nations.

What is Deutschland Doing?

The Duales System Deutschland (DSD) system, also known as, "The Green Dot System", has persisted through much international scrutiny to the present day, resulting in increased recovery, recycling, source reduction, and the foundation to a system which integrates producers, to a degree. Similar infrastructures have been adopted in other countries and have room for improvement, though that does not mean that the achievements of the DSD or its counterparts should be negated. Instead, the history of the DSD may be traced to see where this EPR scheme has floundered and where it has flourished, allowing for comparisons with other systems.

In 1989, Germany's former Environment minister, Klaus Töpfer, proposed a law requiring that all producers and retailers take back transport and sales packaging. However, the law gave an optional way to comply: industry could set up a third party to collect and sort the packaging. The following year, 600 companies joined together to organize the "Duales System Deutschland" (DSD), which began to collect transport packaging in 1991. By 1992, a parallel waste collection system was in operation and also collecting sales packaging;[iii] by 1995 the system was serving almost 100% of German households.[38]

The DSD works by a licensed recycling system fee and it has worked well, both for specific industries and packaging overall. System participants are identified by a "green dot"; manufacturers of packaged products and packaging itself pay a fee to the DSD. The fee licenses them to affix the green dot to their product, which signals consumers that it is part of the DSD collection system and should be disposed of in their collection bin. The DSD has a network of more than 400 municipal and private waste haulers who collect and do the sorting throughout the country, with their contracts paid for by the system fees.[39] Over 19,000 licenses have been issued to producers, with fees tiered according to the weight of the product (and later on, the material type),[iv] encouraging companies to incorporate lightweight, pared down, and recyclable packaging.[40] Theoretically, these fees cover the cost of collection.

Results of the program had immediate effects, especially in source reduction with lightweighting, product innovation, refillables, and increased use of recyclables. The steel can industry nearly halved the material needed for cans; refillable-containers were used for milk, fabric softner and motor oils, and innovative packaging designs arrived such as impermeable, edible "waffle" packaging for yogurt cups.[41] Unessential packaging elements, such as toothpaste boxes, were eliminated, while concentrates became more emphasized. Producers shifted away from plastics, especially PVC and composites, because these materials had less recycling potential and made them less economical than their paper/board substitutes.[42]

[iii] DSD was named "Dual System" because it institutes a second system which operates beside the traditional waste management infrastructure.

[iv] Initially, all fees were uniform by weight, without material differentiation. Given the difficulties associated with plastic, however, the fee structure was continually altered until it was 15 times more expensive to recycle plastic than glass {whose fee price decreased, along with paper} by the end of 1993. - Update by Sascha Kranendonk (Original by Andreas von Schoenberg) *3.14 DSD : Industry-Run Packaging Waste Reduction System* EPE Sourcebook.

Following the German Packaging Ordinance of 1990, recycling rate capacity and collection levels for all materials increased, while the packaging amounts which individuals had to deal with decreased. For instance, Germany's recycling capacity for plastics increased from 20,000 tons in 1990 to 500,000 tons in 1997.[43] Between 1993 and 1996, packaging recycling increased from 52% to 84%; plastic packaging recycling increased to 68%.[44] Other studies have slightly different rates cited, depending on the variables examined, but most give packing decreases given are between 10-15%. Between 1991 and 1995, German packaging waste decreased by 14 %, while the U.S. packaging rate simultaneously increased by 13%.[45] By 2000, the rate decrease cited was at 17% since 1991.[46]

Despite these gains it should be noted that the German DSD program, while showing progress with waste reduction and prevention, has not been, nor currently is, a totally satisfactory system. Previous advances have slipped somewhat since 2000, and the program had many criticisms and flaws at the outset which have not yet been entirely resolved. Collection levels in 2003 were down somewhat from 2002, decreasing 5.2% from 6.32 million metric tons to 5.99 million metric tons. Glass collection levels are dropping from conversion to PET plastic bottles, although costs paid by producers dropped a little as the efficiency of the DSD recycling system has increased.[47] Also, while this system has stopped the growth in German packaging for now, the same programs have not been as successful in the EU as was initially hoped for. This last aspect is covered in more detail later, though.

Hurdles in the Race: Money

The dawn of the DSD system saw many hurdles, with recovered items not going all the way through recycling processes, "feedstock-recycling", misinterpretation of the green dot, difficulty with the chemicals industry, free-riding and late-payments, as well as overload and complication with plastics handling.

The biggest problem at the outset was the economic situation, complicated by fees, plastics, and contamination. Within one year of beginning their packaging collection, it was announced that the DSD was nearing bankruptcy. Over half the signatories into the green dot program were either late with their payments or were "free-riders" (they failed to pay at all, but still benefited from the system), seriously eroding the DSD's available income. Also, Germany's plastic recovery was four times what was estimated in 1992, at 400,000 tons, requiring storage until infrastructure was established that could take in that much waste.[v] In addition, the contamination costs of non-recyclable and dirty products entering the collection stream had not been taken into account when setting fees. By the end of 1993, direct government intervention and financial assistance by all partners, along with a re-structuring of the DSD board and shareholder structure, managed to save DSD - and also allowed them henceforth to collect their license fees in advance.[48]

Despite some recent small reductions in fees, many environmentalists have claimed that the cost of the system is too high.[49] In 1996, the system cost $2.2 billion for 5.5 million metric tons of recovered material. This is the equivalent of $356 per ton, and evens out to $28 per person annually.[50] This amount is considerable, seeing as an OECD report released in March 2005 covered estimations of cost and benefits of various waste prevention and handling programs. In

[v] Plastic stockpiles also raised concerns over their potential fire hazards. - by Ann Kulik, January 1, 1994, "INTERNATIONAL: German Recycling System Braces For", Waste Age, January 1, 1994;

Germany, 2005, the total cost tabulating external, private, and energy gain costs ranged from $52-100 for trash to go to landfills or incineration.[51]

However, the cost of landfilling per ton, and the cost of the system overall, is an incorrect gauge of economic implications. The cross-over in processing options, hard-to-quantify variables, and the economic gains of the DSD confuse easy answers on what is financially optimal. Some recycled material already goes through incineration in Germany, so it is hard to separate out the costs of incinerating "trash" from incinerating recyclables. Also, the numbers do not account for the potential cost increases if all collected recyclables were suddenly dumped in landfills. Moreover, it is difficult to account for the avoided costs of increased litter in municipal collections, ocean clean-ups and environmental mitigations, etc. To balance the view that the green dot program is costly, it should be noted that recovery has continued to increase since that time, and costs have (as noted before) recently decreased. In fact, DSD customers paid 23% less for Green Dot licensing in 2003 than in 1998, signifying a trend of reduced expenses with increasing efficiency. Also, of no small consequence, the DSD system has created nearly 17,000 jobs in the country and led to over EUR 20 billion in investments by German industry.[52]

Given the challenges faced by the initial implementation of the system, Klaus Topfer himself acknowledged that the initial program structure was an attempt to move, "too far, too fast".[53] One lesson which could be derived is that countries who establish similar programs must have producers provide assistance for appropriate end-markets and infrastructure support. If direct support is not integrated, then it should be accounted for when attempting to estimate fees in advance. At the same time, there are multiple economic gains to be found in EPR systems that are currently not studied in their entirety and continued research to the effects of implementation should be applied consistently and carefully.

Other Obstacles: "Recycling" Defined/ Minor Confusions

The other larger criticism for the German green dot program is the lack of uniformity in defining "recycling", and problems the program initially faced with product overload. Bette K Fishbein noted in 1998 that half of the plastic that DSD recovers goes to environmentally contentious "feedstock recycling", such as using waste plastic in place of oil in steel production, and heating up trash with pyrolysis and hydrogenation.[vi] However, she also noted that even when these plastics were subtracted from recovery totals, Germany's recycling rate would still exceed the United States'.[54] There were also some scandals in the beginning over illegal dumping of the waste that exceeded Germany's infrastructure capabilities in other (often less wealthy) countries;[55] Green dot waste was found to be illegally dumped in Romania, Indonesia, the oceans, and even in parts of France. Recycling via "exports" has since subsided somewhat, and now the program deals with handlers whose recycling capabilities have been verified. By 1995, highs of 50% "exported recycling" had decreased to 30%,[56] and the country's domestic recycling capacity has continued to expand since then.

Some additional minor, but still valid, criticisms include complaints with the chemical industry, and misinterpretation of the green dot. The chemical industry was criticized for failing to make good on it recycling obligations. In addition, many consumers misinterpreted the Green Dot as a type of eco-label,[57] which may influence consumer behavior. The Hungarian Ministry of Water

[vi] End-products or process usually with the intention of energy extraction.

and Environment sponsors a page about their Eco-label and overviews various other labels used throughout the world. On the Green Dot, or Grüne Punkt, the ministry noted,

> This label is NOT an eco-label, it does not mean that the labelled product has better environmental characteristics than its competitors; it only means that the manufacturer has signed a contract with a subcontractor for collecting its waste.[58]

Granted, waste management implies environmental benefits, but the green dot does not necessarily signal intention on the part of producers to design their products by any environmental standards, or with environmental considerations in mind, beyond what is required by their national laws.

Germany Now

Despite early criticisms, the Duales System Deutchland has made remarkable progress. As of 2003, Germany not only met but exceeded every one of its recovery collection categories. Some categories[vii] exceed 100% collection because of material in the bins from producers who are not participating in the program (they meet their legal requirements via other means); the highest collection rate is paper cardboard, at 161%. The system has successfully led to source reduction, waste reduction, and packaging reductions.

However, the winds of change continue to stir throughout the country, surrounding containers, and recent international acquisitions. In 1997, refillable-container quotas fell below their required levels, and by January 2003, the government was developing a law for mandatory deposits on one-way (disposable, as opposed to refillable) containers. In December of 2004, the European Court of Justice concluded that the deposit rules hampered the free movement of goods within the EU. However, the amendments which passed were not in accord with the court ruling, and may necessitate additional changes before the new laws come into force in May, 2006.[59]

Another factor which may greatly affect the future of German recycling and packaging levels is a change of ownership. In 2001, the European Commission charged that DSD had a monopoly, preventing competitors from entering the market.[60] Despite appeals and attempts to re-structure, the DSD was instructed to sell to a for-profit company to ensure that there was no waste-management cartel.[61] In 2005, the European Commission approved a subsidiary of US company[viii] to buy a 75% stake of the DSD, making them a for-profit firm.[62]

How these new angles will affect pricing, packaging, and Germany, remains to be seen. However, Germany demonstrated that EPR potentially builds a foundation from which source reduction may increase while packaging, and the potential for plastic litter, may be reduced.

The European Union: Success Questioned

Any discussion of the EU, for the purposes of this research, must be necessarily abbreviated because the European experience with EPR in the past decade has been so extensive and varied.

[vii] Aluminum recovery at 128%, tinplate at 121% and paper cardboard
[viii] Kravis Roberts and Co. (KKR)

However, a general overview is provided as it has utilized EPR and hence its results are indicative of how EPR may influence national packaging and waste patterns.
The European Union issued its Packaging Directive in 1994 to bring its member country policies into accord with one-another. Although the systems varied in their form and level of operation, the mandated base recycling levels for packaging waste were 25% to 45%, with a minimum of 15% for each material.[63] The following year DSD transferred the right to use the Green Dot symbol for licensing to a European organization, and PRO Europe, founded by the original fifteen EU member states,[64] was born. PRO Europe stands for Packaging Recovery Organization Europe,[65] and it should be noted that this acronym differs from the other "PROs" (covered later on), or Producer Responsibility Organizations, associated with EPR.[66]

PRO-Europe operates similarly to DSD, and has continued to grow and evolve as has the EU itself. Nationally recognized collection and recovery systems, which follow certain uniform regulations, may become shareholders in the organization and enjoy equal rights with other licensees. Most countries have non profit sub-entities who operate and oversee the program within their nation specifically, such as ECOPACK Bulgaria, Turkey's ÇEVKO, and Eco-Emballages of France. Currently, 24 countries within the EU (or whose candidacy is in consideration) are participating in PRO Europe and variations on its producer-responsibility scheme.[67] The UK stands out as one of the few who does not operate by an obligatory green dot system, and varies significantly from other EU-members by using a shared-responsibility approach, similar to the U.S. national stance in some ways. The UK, (as well as Canadian) programs are instead considered cooperation partners.[68]

Early on, Bette Fishbein noted the multiple arenas of variation for the programs and listed the following:

> "The allocation of responsibility between government and industry actors in the packaging chain. The level of mandated recycling rates. The time frame for achieving mandated recycling rates. What counts as recycling. What packaging materials are included in the program. The types of collection systems used. The use of deposit/refund mechanisms. Implementation through third-party organizations."[69]

Some were disappointed by early results within the EU, as the packaging growth reversal achieved in Germany was not duplicated in Europe. However, the degree of variation between countries, combined with lower targets and fines, is a likely cause of this disparity. A 2004 speech given by the Executive Director of the European Environment Agency, noted that despite the fact that most EU states have met and exceeded recycling and recovery levels in most EU states, the desired goal of waste prevention was not met. Seven countries have already achieved the 60% recovery target for 2008, while almost all have met the current 50% recovery target.[70] Unfortunately, 10 countries still saw increases in packaging waste levels, and the EU overall saw an increase of 7% between 1997 and 2001.[71] The Director stated that, "...it is difficult to draw any other conclusion from this than that the EU and most Member States have so far failed to meet the waste prevention objective of the Packaging Waste Directive."[72]

In Defense of the EU

To fairly assess the influence of EPR, though, a comparison to packaging trends in the United States, and target recycling levels in Germany, may balance out this EU perspective. While packaging consumption increased 7% in Europe from 1997 to 2001, it increased almost twice as fast in the U.S. at 13.2% during a slightly earlier period, 1991 to 1955. In that same time span, it

actually decreased in Germany by 10.8%.[73] In trying to understand this disparity, especially with the EPR programs in place in Europe, closer examination of the EU situation provide some clues.

The countries connected to the EU had varying levels of infrastructure in place, and have used different mechanisms to achieve their recovery levels. For instance, 15 countries applied a tax or charge to packaging items, seventeen applied taxes to waste disposal and/or incineration, at least 13 used packaging deposit-refund schemes, and six developed packaging covenants.[74] Some have had greater success than others. Austria's packaging infrastructure was already developed before its EU entrance, and it utilized an array of instruments that have led to positive results. Waste prevention was largely carried out with mandatory producer responsibility, aided by additional landfill taxes/bans.[75] Meanwhile, some nations have only begun their work; Cyprus' Green dot organization was only established in 2003, making it one of the many attempting to catch up.[76] Also, given the diverse levels of experience and political commitment, the recovery goals set within the packaging directive were necessarily set at a lower level. A minimum 15% for every material category is far below Germany's recovery standards, as the German Packaging Ordinance set the recycling level for each category at 60% or above.[77]

Given the multiplicity of European recovery approaches and the lesser recycling goals of the EU Packaging Waste Directive, the slower progress achieved within Europe does not necessarily indicate a flaw in the theory or use of EPR legislation. Instead, it points to transition times for countries and potential flaws in its method of application. Higher recycling goals per category and stricter enforcement within material types may be necessary to achieve additional reductions of packaging waste growth. As the Director for the European Environment Agency also pointed out, "Countries who have put in place a mix of instruments seem to have been the most effective in meeting their objectives and targets."[78] As such, the levels of EPR applied, and the way it is accomplished, seems more in question than EPR itself.

At this stage, it is also good to note that attempts within the EU have led to positive results. A reduced rate of growth packaging indicates some progress, and in 2003, the Green Dot trademark was protected in over 150 countries, and printed on over 460 billion pieces of packaging.[79]

General Policy Guidelines

As EPR policies have continued to spread and grow, they have displayed multiple distinctive features, such as the development of PROs, voluntary initiatives, physical take-back versus financial responsibility, implementation of complementary measures, consideration of social justice issues, and variations in product targets. Some of these features have been researched more extensively than others, producing advice and examples for those connected to EPR.

PROs

In March 2003, a report on PROs by the French Agency ADEME states that a Producer-Responsibility Organization (PRO) is, "...any private or public body taking partial or total financial and/or organizational responsibility for managing end-of-life products on behalf of producers or market operators."[80] They are considered most useful for manufacturers of "high-volume, low-value products".[81] As such, it is more common to see PROs with items like batteries (the RBRC in the U.S.) or packaging (Germany's DSD) than it is to see them with cars.

In Europe, for instance, out of a total of 100 PROs identified in 2003, 47 of them were for packaging and 21 were for batteries. In contrast, end-of life vehicles had four pros.[82] While the ADEME report points out similarities, and poses interesting questions, there are few policy recommendations listed. A key point made by Bette Fishbein, however, is applicable in analyzing PROs, and that is that fee structures, "...reward companies that choose to design less wasteful and more economically recyclable products." Flat fees for companies provide no incentive to design for the environment, unlike fees based on product material, packaging waste, and/or which take stock of management/recycling costs. Germany and California both provide examples of variable fee rates that follow market, waste, and recycling movements.

Voluntary Versus Mandated

Several countries have experienced voluntary initiatives on the part of producers to take responsibility for their products, stimulated either by other industry movements or the threat of EPR legislation. While some of these have experienced degrees of success, it is commonly held that voluntary initiatives are not a viable vehicle for effective environmental results. A 2003 OECD study, responding to the subject, stated the following:

> This report concludes that the environmental effectiveness of voluntary approaches is often questionable, and their economic efficiency is generally low. While administrative and transaction costs vary greatly among voluntary approaches, it is clear that if too few resources are spent in their preparation, negotiation and enforcement, their environmental impacts are likely to be modest. Combining a voluntary approach with a tax or a tradable permit system can trigger quite significant additional administrative costs, and the environmental integrity of the other instrument can be weakened.[83]

A voluntary initiative which has been criticized in the United States is the RBRC, or the Rechargeable Battery Recycling Corporation, which failed to meet its 70% recycling rate; recent estimates have place it between 10% to 15%. The Thermostat Recycling Corporation has also been recently criticized along with the RBBC for lacking accountability, transparency, and clear recovery targets.[84] Fishbein pointed out that Germany and France initially attempted Voluntary Packaging EPRs and the results were unsatisfying.[85] When EPR is mandated by law, it levels the market amongst competitors and decreases the potential for free riders.[86]

Prospects for EPR Policies in the US

For the last 20 year, Federal policy makers in the United States have completely abdicated any responsibility for addressing any kind of national waste management or recycling policy, and that is unlikely to change. For the foreseeable future, and policy action will need to be initiated by individual states.

Our Findings

Some points regarding fees, policy mixes and recovery targets, have already been established, such as variable rates which reward companies whose products have a lesser negative impact on the environment. In addition, a diversity of policies has been determined to have highly effective results in multiple countries. When policy makers keep their focus on source reduction, clear and appropriate targets with established financial consequences have been shown to work well to motivate industry and its response to its own waste, especially when accountable to the public This experience has been proven in Germany and some other European countries.

Follow-Up Policies

The Extended Producer Responsibility Working Group had several applicable policy positions it advocated within an EPR framework, some of which are crucial to successful programs. Complementary measures, detailed accountability provisions, social justice, plus historic and orphan waste are addressed.

Complementary measures are advocated with ERP, such as using detailed procurement policies and minimum recycled content laws.[87] Recycled content mandates are important because it helps support the market for recovered products. It also encourages cleaner designs and increased recovery efforts on the part of manufacturers, because they will eventually have to buy back a certain amount of product and would want to keep those costs low. Re-use is frequently promoted by tying refillables into EPR legislation; countries such as Denmark, Finland, Germany, and Canada have container-refill levels that meet or exceed 65%, and far outstrip U.S. levels of 5%.[88] Overall, complimentary policies can support waste prevention efforts, and should be considered carefully when framing EPR proposals.

Accountability includes sub-requirements of clear labeling, monitoring, enforcement, and public participation.[89] Each element is important, helping to ensure that goals are set and met, that consumers understand what they are purchasing, that consumer feedback is received and that data is collected to weigh the success of EPR programs and aid in future research efforts. In addition, accountability helps determine whether programs are successful or not.

Social justice actually spills over to two considerations of the EPR Working Group, including issues of banning waste exports. Countries without established infrastructure to handle recovered waste in the manner deemed domestically appropriate (meeting our recycling standards) should not be receiving it. Policies must ensure that any organization receiving said waste should have demonstrated and certified that they possess the capacity and the method to effectively handle the material. The EPR Working group states that,

> ...hazardous or unsanitary used products must not be exported from developed to developing countries either for disposal or for recycling... EPR programs ensure that people in industrialized and developing countries are not exposed to toxic materials in their workplaces or their communities. Workers receive a living wage and do not bear the costs of a transition to cleaner production.[90]

Such requirements are only ethically just.

Historic and orphan waste were also topics that legislatures were urged to consider.[91] Some specific producers can no longer be targeted for their waste because they are no longer in business. Also, some products were manufactured prior to the institution of the program date. Both categories of items need to be integrated in policy structures, as such product disposal still has ramifications on society.

Thoughts on Strategies

In the context of marine litter, there are several angles which should be emphasized when Non-profits and policymakers begin to design their EPR foci. These include focusing on variations

within products, or problem categories (fast food packaging, regular food packaging, bottles, etc.) and perhaps nationally coordinating such strategies across multiple states.

In the U.S., California, Connecticut, Delaware, Maine, Massachusetts, New York, and Oregon, are all states both with coastal territory and bottle bills.[92] Bottle bills following an EPR structure, such as that utilized in California, and introduced simultaneously in Washington, Florida and East-coast states would potentially strain beverage company anti-lobbying efforts, and increase the chances of additional bills being passed. Since this legislative form has demonstrated to have positive effects on reducing plastic waste and litter, it would additionally reduce some of the litter our oceans are exposed to if other states adopted such policies. Non-profits interested in producer responsibility, waste management, and marine-environment health, could potentially coordinate their efforts in multiple states and launch a campaign towards that end.

Alternatively, such collective power could be directed towards other legislative targets. General EPR packaging laws in these same states could be pursued, as could other types of waste categories, such as plastic packaging, food packaging, or fast-food packaging, as these all seem be proportionately more threatening to waterways than other waste forms. In any case, the EPR form advocated and eventually adopted should follow the general EPR guidelines laid out in contemporary EPR theory, and also encourage source reduction.

Conclusions and the Future

EPR leaves producers room for innovation to meet targets, and new forms of EPR continue to evolve. Leasing products – like carpeting-[93] or advocating selling services as opposed to selling disposable goods[94] have been some of the notions advanced lately, but it is hard to tell whether governments will develop a policy framework which mandates implementing such efforts. Currently, EPR is enjoying renewed attention as a potential solution to e-waste concerns and other hazardous consumer products. This has resulted in the adoption of myriad e-waste EPR polices, though its applicability to packaging remains and should continue to be explored.

Some products or materials may be immediately threatening to local regions, or may be connected with specific problems of consumer behavior. In such cases, bans, fees, and MOUs may be more viable than drawn out political negotiations. Also, while consumer behavior and mitigation should not be ignored, neither should they be exclusively advocated in lieu of exploring EPR options. Financial investments in EPR may prove more productive and easier to coordinate than larger, consumer-oriented behavioral programs.

Frequently, technological improvements and new policy enhancements are integrated slowly among the nations of the world, as predictable patterns provide the illusion of safety. However, static ways may lose their viability in newly developing environments. Extended Producer Responsibility is a vehicle that makes businesses take stock of the world as it evolves, to integrate flexible and aware design schemes, preparing for approaching trends in global politics, the global market, and the natural world. It can produce source reduction, encourage waste diversion, and result in less material for consumers to handle and dispose of.

In America, the states themselves are perched at a precious point, where we can begin to influence the sway of the nation by incorporating EPR policies within state borders, incrementally advancing towards a general national policy. The issues of plastic waste, plastic litter, and increasing packaging will not disappear nor dissipate until producers are brought to

bear the brunt of their waste- a burden which our general society has unconsciously shouldered for far too long. EPR may not be the only answer, but it certainly is a viable one, and states should hence consider its implementation with diligent care.

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Public Education By The Numbers
Tuning Up Your Outreach Plan Based On The Technical Data

Abstract

The City of Los Angeles is faced with the task of educating over three million residents regarding the various pollutants effecting water quality. With limited resources, the City is challenged with effectively reaching and influencing the greatest number of residents who have the greatest impact on improving water quality.

To develop this program, the City hired S. Groner Associates to create and implement a strategic social marketing plan based on technical data and marketing research. The goal of the plan was to target audiences who have the greatest impact on water quality. With those key groups in mind, outreach efforts were developed based on the specific audiences' attitudes, styles, and behaviors. This then focused resources on the efforts with the greatest chance to influence behavior change and thus prevent pollution.

In developing the plan, we used technical data analysis and existing market research information to determine the following:

- What activities posing the greatest threat to water quality
- What activities/behaviors most influenced by public education
- Which audiences engaged in those activities
- What are the psychographics of the audience (i.e., attitudes, characteristics, lifestyles, etc.)
- What methods of delivery will best reach our audience and influence behavior change

These key points served as the foundation for developing outreach efforts as well as the emphasis, style, and tone of our communication pieces.

This presentation reviews the role of market research and data analysis in developing a social marketing plan, in addition to designing marketing materials and implementing the outreach efforts. We will also illustrate how incorporating new marketing data helped gage the outreach's successes and areas for further refinement.

Building a Foundation for the Marketing Plan

Effective outreach requires developing a solid information base about behaviors you want to change. The information ascertained assists in determining how and who to target in order to maximize the impact on improved water quality.

This information is highly effective when developing a social marketing plan for stormwater pollution. Building the marketing plan's foundation, however, is still very difficult because of the complexity of stormwater. By its very definition, stormwater pollution or non-point pollution is not one single source, but a complex collection of problems to target. In turn, developing a marketing plan for stormwater pollution is not just about developing one plan to address one issue. It requires a multi-pronged campaign that attacks the various causes of stormwater pollution. The plan must be composed of several focused marketing strategy's each addressing the most problematic pollutants/behaviors.

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Because of the issue's complexity, understanding the limits of your resources and strategically focusing your outreach to maximize impact is essential. In determining our outreach, we used both technical data and existing market research information to strategically lay out our direction for public education. This process included the following steps:

- Determine the pollutants/activities posing the greatest threat to water quality
- Determine what corresponding activities/behavior are best influenced through public education
- Identify the audiences engaged in those activities/behaviors
- Understand the psychographics of the audiences (i.e., attitudes, characteristics and styles of the audiences)
- Understand the motivators that will best influence our audiences

Any effective marketing plan or outreach effort must be designed with an intimate understanding of the audience that you are targeting. Many times, there is a misconception that because the issue is important people will automatically listen to it. But the message is competing for attention with thousands of other messages that bombard residents everyday; everything from ads selling cars and beer, to other social marketing ads like recycling campaigns, anti-smoking campaigns, or drug prevention campaigns. In the end, if the outreach piece is generic and does not in someway connect with a specific audience and compel them to listen, they won't.

This paper lays out the methodology used to develop a solid social marketing plan and introduces the City of Los Angeles' public education program as an example of this type of strategic planning's success.

Prioritizing Pollutants

The first step in targeting outreach is determining the pollutants that pose the greatest threat to water quality. This effort requires an analysis of water quality data and reconciling this information across watersheds if the jurisdiction covers more than one watershed.

In conducting this technical research for the City of Los Angeles, S. Groner Associates initially worked with GeoSyntec Consultants, Inc. to evaluate and analyze water quality data from the City and County of Los Angeles. The City of Los Angeles lies within three primary watersheds and a multitude of subwatersheds. The three primary watersheds all have broad similarities of a mostly urban environment. However, at the subwatershed level, there were vast differences in the environment. After results were evaluated, five pollutants were selected for the campaign:

- Bacteria/Pathogens
- Pesticides
- PAH's
- Nutrients
- Trash and Debris

Prioritizing Activities to Target

Prioritizing activities requires balancing technical information about pollutants with an understanding of which pollutants are most effectively targeted through public education.

Based on this, we looked at activities that produce pollutants and prioritized which activities could most effectively be targeted. The following criteria served as a guideline for prioritization:

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- How pervasive the activity is across the target area
- How active or passive is the polluting activity
- How effective behavioral BMPs are vs. structural BMPs
- How complex or simple the solutions are to implement and
- Where possible evaluate the proportion of pollution the activity contributes to the total pollutant load

Ideally, this process begins with analyzing pollutant source data. However, given the nature of stormwater/non-point source pollution, this information may not available for most jurisdictions, so there is a need for best judgment.

In addition, the area and process of evaluation, be it individual watershed, across a jurisdiction, or across a regional area, must be determined. This issue is important for obvious environmental science reasons as well as strategic marketing reasons. For example, a pollutant or activity in one watershed may be prioritized differently if evaluated in different areas because of the watershed's maximum sustainable load. But from a marketing perspective, this determination will be critical in determining what outreach methods are most effective and available in the area to reach the target audience. For example in some areas billboard advertisements or newspaper advertisement may target the area and activity well, while in other areas an activity may be best targeted through point of purchase advertising.

Applying the above criteria helped prioritize the activities as the following:

- **Bacteria/Pathogens**
  - ***Leaks from sewer systems – low***
  - ***Improper BMPs at Restaurants – medium***
  - ***Owners picking up after their dogs – high***
  - ***Improper BMPs by horse owners – low region wide - high in certain subwatersheds***
  - ***Proper maintenance by septic system owners – low region wide - medium in certain subwatersheds***

- **Pesticides**
  - ***Residential users - high***
  - ***Commercial users - low***
  - ***Government users – medium***

- **PAH's**
  - ***Vehicle leaks – low***
  - ***Improper BMPs at auto repair shops/gas stations – medium***
  - ***Improper disposal of vehicle fluids by residents – high***

- **Nutrients**
  - ***Fertilizer application by residents – high***
  - ***Proper maintenance by septic system owners – low region wide - high in certain subwatersheds***

- **Trash/Debris**
  - ***Active littering by residents - high***

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- *Litter from uncovered trash containers – low*
- *Litter from uncovered commercial vehicles - low*

Identifying Audiences

In selecting a target audience, the program's developmental focus shifts from the technical field to the marketing arena. Marketing research is key to identifying which audiences, or in marketing terms "segments of the population," are engaged in the problematic behavior. The next step is discovering common characteristics among the audience and developing a focused message that is tailored to their interest and motivations.

The best way of collecting this information is to conduct surveys of residents. The survey would incorporate questions to ascertain what types of residents are engaged in the improper behavior. Cross referencing the results with psychographic information (i.e., attitudes, behaviors, lifestyles, which "segments of the populations"), helps target how to best address the issue and change behavior.

This approach, however, can be expensive. Depending on the campaign's size, less expensive and simplified research can yield similar information. One effective method is matching up behavior with a consumer market. For example, when targeting people who improperly dispose of their oil, you can target people who buy oil and identify them as consumers at auto parts stores. While this will not narrow your audience down to only those who are illegally dumping their oil, it serves as a solid starting point for further refinement. Later, a simple intercept survey conducted at auto parts stores can help better assess the audience and hone strategies to target the audience.

Another cost-effective way to understand your audience is through the use of the US Census Bureau's Web site. The Census Bureau's site gives demographic and socio-economic information broken down by city, zip code, and census tract. The site allows you to import the data to spreadsheets or even use a Web based GIS software program to map the data. This information is extremely valuable in targeting an activity that may focus in on a specific area. One example would be targeting homeowners in a specific area. From the website, you could identify homeownership rates and then correlate that to other demographic and socio-economic information such as income levels, languages most commonly spoken, ethnic background, employment rates, etc.

Understanding Psychographics

Once the target audience is identified, the next step is understanding the "psychographics" of the audience (their attitudes, interests, and styles). This information provides insight into the audience's thoughts and is an essential step in designing effective outreach. Without outreach efforts/messages that connect directly to a group's sensibilities, interests, or concerns, changing a habit is almost impossible.

Obtaining an audience's psychographic information is more difficult than merely identifying the audience. To gather information regarding attitudes, marketing surveys are critical. The surveys gather relevant information by correlating residents' interests and priorities with their activities and behaviors. The resulting information helps isolate key issues and motivators relevant to the audience.

Depending on survey results regarding a target audience's priorities and motivators, an issue could be positioned in various ways. For example, the issue of pesticide use could be presented with three different focuses depending on the audiences' psychographics:

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1) as an environmental issue (chemicals impact on the watershed),
2) as a "dollars and cents" issue (addressing the source is cheaper than treating the problem), or
3) as a family/child safety issue (safety concerns of children playing on a lawn with chemicals).

Understanding the psychographics of the target audience, simplifies choosing the most meaningful and effective message.

If creating and/or performing a survey is not possible, relevant information based on a similar issues or audiences can be frequently found in marketing surveys completed by other organizations. In researching segmentation information for the City of Los Angeles, information on three previously completed marketing research surveys that could be analyzed for information relevant to the City's demographics characteristics: two were conducted by the County of Los Angeles (one on stormwater issues and one focused on do-it-yourselfers) and one conducted by the State (on residential used oil recycling).

The resulting information gave a full picture of various target audiences and helped differentiate our messages based on each particular audience. Based on the results from our marketing research and technical data, we identified and prioritized our three main target audiences:

1) Neat Neighbors -

Description - Younger families with children who want to do the right thing but needed a little coaxing
Motivators to change – Concern about children, concerned about the neighborhood, interested in doing what's good for the environment
Activities/Behaviors – Picking up after pets, pesticide and fertilizer use

2) Fix-it Foul-ups -

Description - Middle class homeowners who are do-it-yourselfers
Motivators to change – Put family first, want to follow rules, not interested in the environment
Activities/Behaviors – Pesticide and fertilizer use

3) Rubbish Rebels -

Description - Younger males who are just getting out on their own
Motivators to change – Concern with their image and peer's perception of them; following rules is not "cool"
Activities/Behaviors – Littering and used oil disposal

Strategic Outreach

The last element is determining the best outreach efforts to effectively reach the target audiences. The goal is to identify outreach efforts that strategically delivers the message and increases the message's influence on their behavior. The City looked at three elements in evaluating the outreach strategy:

1) How timely is the message in relation to the activity
2) How well placed is the message to reach the target audience
3) How well delivered is the message to catch the attention of the audience

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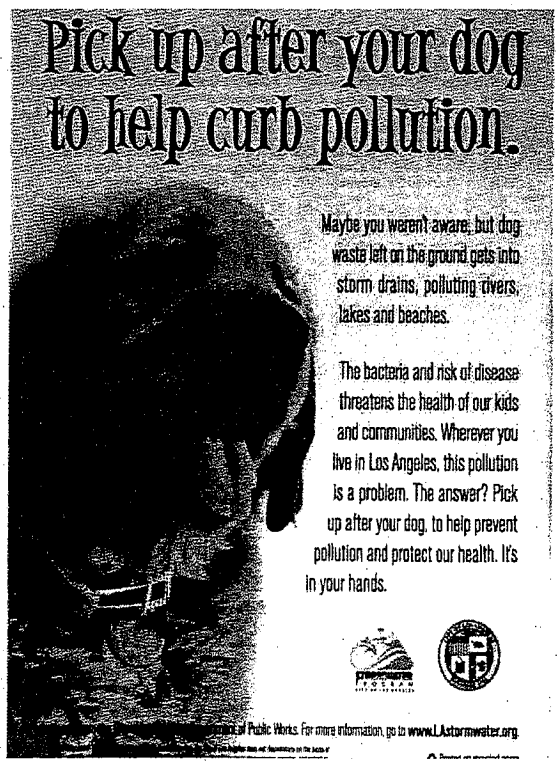
These three elements help compare potential outreach methods in terms of the ability to reach and influence the audience. The first element addresses the issue that people receive information all the time, but unless it is delivered at a relevant time, the audience may not focus their attention and note the information. A good example of this is giving out information on pet care when one gets a pet. The timing is perfect because the owner is excited about the pet and is open to learning about them. Delivering the pet message at this time also increases the likelihood of changing behavior because the owner has not developed bad habits yet.

The second element addresses the quality and focus of outreach aimed at the target audience. For example, an ad in a newspaper regarding pesticide use may reach a large number of residents but may not be strategically placed, and therefore, does not effectively reach the target audience. However, an ad placed in the weekly "Home and Gardening" section of the newspaper would be far more effective because it was strategically placed in an area relevant to the specific readers of that section.

The third element addresses how effectively the outreach method catches the audience's attention. For example, a small logo placed on a banner for an event may not be noticed next to a dozen other logos. However, a well placed booth at an event with a staff member actively approaching the target audience (as opposed to waiting for them to approach the booth) can be far more effective.



Examples of how these evaluations helped in developing strategic outreach methods to address high priority activities for the City are the following:

Picking Up After Your Pet

- **Material placement at animal shelters and inclusion with pet adoption materials**
- **Participation a pet adoption events held by animal shelters**
- **Point of purchase displays at pet stores**
- **Material placement at veterinary clinics**

In this effort, we partnered with animal shelters. This allowed us to deliver our message to residents who were planning on adopting new pets. We accomplished this by placing our information in animal shelters' adoption package- an item given to all new pet owners. To reach the same audience, we also set up a booth and distributed information at pet adoption events. This outreach strategically accomplished three goals:

1) ensured our information would be received by the new pet owner,
2) allowed us to get our information to the owner at a point in time when they are most interested in learning about the new pet and
3) delivered the information to the owner before they developed bad habits regarding their pet's care.

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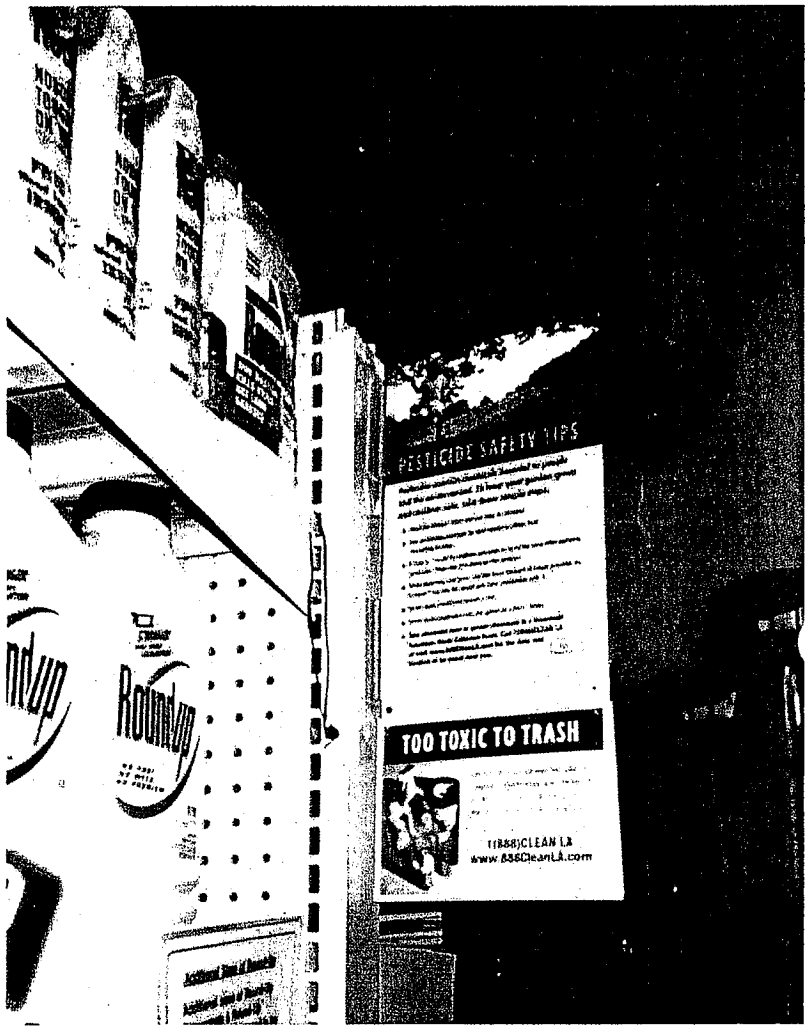
In addition to animal shelters and pet events, pet stores and veterinary clinics were utilized as key venues for outreach. Materials were strategically placed in immediate view of our target audience at a time when they were thinking about their pet (i.e., shopping for their pet or bringing the pet in for medical attention).

Pesticide and Fertilizer Use

- **Partnership with home improvement stores**
  - Develop point of purchase displays
  - Conduct staff training to enable employees to answer questions

- **Placed radio ads on a local weekend gardening show**



This effort entailed partnering with the major home improvement chains (Home Depot, Lowe's, OSH) and obtaining pro bono placement of materials on the shelves where pesticide and fertilizer products are sold. This put the information in the audience's direct view at the point in time when they were deciding what product (toxic or non-toxic) to purchase. We then trained store staff on the issues concerning urban runoff and pollution prevention issues. The result gave us credible advocates for our message right on the "frontlines."

Along with that effort, we sponsored a local weekend talk show about gardening. This effort was strategic in two ways:

1) it was targeted directly at residents most likely to use fertilizers and pesticides and,
2) the program aired on the weekend, a time when residents are likely to be engage in their gardening or lawn care activities.

Used Oil Recycling

- **Partnerships with car clubs**
- **Strategic radio advertising**
- **Partnerships with auto parts stores**

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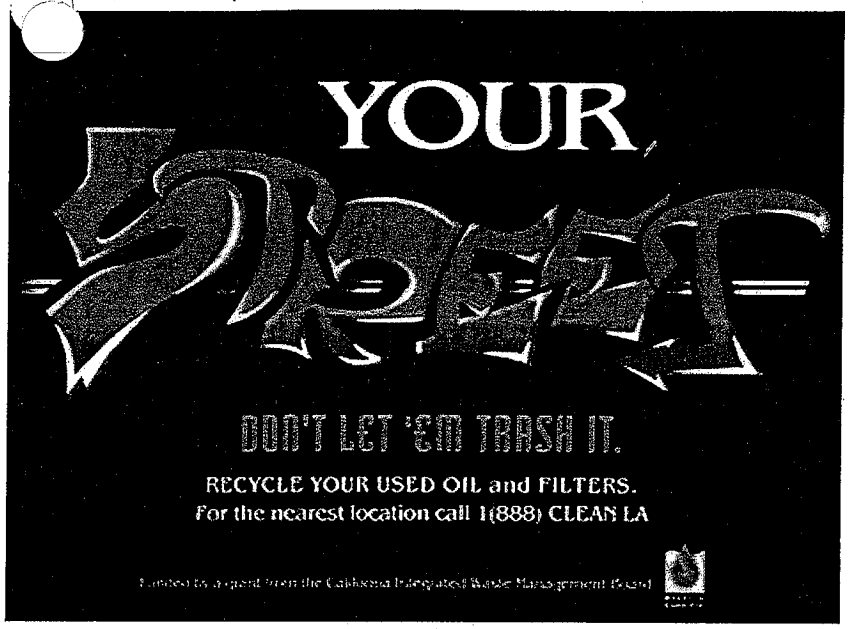
In this effort, we faced the challenge of reaching an audience that did not want to be reached; younger males who didn't care about the environment or recycling their oil.



To reach this audience, we focused less on the message and more on the campaign's image as well as the person delivering the message. In reaching the audience, the messages were delivered through peers and at familiar venues. For example, booths were set up at lowrider car shows, but rather than staffing the booth ourselves, the City teamed up with lowrider car clubs. The car clubs then brought their cars and distributed our message. This gave the campaign credibility with our audience, helped build a brand image for the campaign and made the campaign "peer to peer."

Another part of this effort was placing ads on radio stations our audience identified with. Based on the marketing research, we were able to identify the radio stations our audience listened to most. We then placed ads on their weekend program, which allowed us to air our ads around the time when do-it-yourselfers change their oil.

The last effort was to place materials in auto parts stores. The City did this by placing floor graphics in front of the oil products shelf, posters in storefront windows, and counter cards by the cash register. This effort ensured that our message reached those buying new oil and hit them when they were focused on their vehicle.

Results/Evaluation

Determining the effectiveness of outreach is a critical element in any public education campaign. Obtaining results and feedback allows you to refine your outreach efforts and tweak your strategy to improve your efforts. However, in tackling outreach on stormwater pollution, certain targets may be extremely difficult to obtain good information on, while other activities may be straightforward. The key is to set up several feedback points. While none may be perfect, the goal is to collect enough data to determine a trend and give a sense of the program's effectiveness.

This was exactly the case in the City's campaign. In evaluating our outreach on used oil, the City had two solid methods of obtaining feedback. The methods were 1) surveying auto parts stores regarding how much used oil they were collecting and 2) tracking the number of calls to the environmental hotline asking for information on used oil recycling. In both cases, our numbers went up.

1) Used oil collection – 9% increase over the previous year
2) Call to the hotline – 120% increase over the previous year

In evaluating pesticide/fertilizer and pet outreach, we could only rely on indirect methods.

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For outreach targeting pesticides and fertilizers, we evaluated participation at household hazardous waste collection events and conducted qualitative quizzes during employee training classes. The results from collection events showed over a 10% increase in volume collected, however the training classes showed only an adequate retention of information (based on trainer's judgment no actual data collected). The feedback on the training classes, while not positive, proved helpful. The City concluded from the information that shorter periods between training classes are needed to address employee attrition and bring new employees up to speed on the program.

In our outreach to target pets, we focused our evaluation on surveying pet owners at adoption events. At this point, we have no clear feedback yet. Our goal is to build up a database of information regarding the habits of pet owners and then determine if habits change over time.

Conclusion

Overall, there are a multitude of outreach efforts that can be implemented; however, most programs have very limited resources as well as the tough challenge of trying to change someone's behavior. Many consumer marketing campaigns have huge budgets completely dedicated to marketing and advertising a simple message such as switching brands. Our challenge is marketing an issue and pushing for a behavioral change that require our audience to do something that is less convenient (i.e., it is much easy to drop a piece of trash). This challenge is increased when combined with a lack of resources.

Developing a social marketing plan helps guide and direct a strategic public education campaign. Given the complexity of stormwater pollution, it is an invaluable tool in analyzing all the potential options for the campaign. To effectively maximize limited resources, strategic planning using technical data to target the activities combined with the use of marketing research, is critical. These two pieces of information (the data and research) help ensure that the outreach is targeted at the highest priorities. In the end, the more information gathered about pollution, behaviors, and your audience, the better your chance of success.

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A Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Measurement in Streams

California Regional Water Quality Control Board
San Francisco Bay Region
August 23, 2005

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This report was authored by Steven M. Moore, Matthew Cover and Anne Senter of the Regional Water Quality Control Board, San Francisco Bay Region, Surface Water Ambient Monitoring Program.

Cover Photo of Peralta Creek at Cesar Chavez Park, Oakland, CA, by Anne Senter

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Introduction

Trash is a term used in water quality control, synonymous with litter, debris, rubbish and refuse. Trash in urban waterways of coastal areas can become "marine debris," known to harm fish and wildlife and cause adverse economic impacts (Moore and Allen, 2000). Trash is a regulated water pollutant that has a large range of characteristics of concern to water quality. It accumulates in streams, rivers, bays, and ocean beaches throughout the San Francisco Bay Region of California, particularly in urban areas. Absent numeric guidelines or standard assessment methodologies, assessing trash levels and prioritizing water bodies for trash management remain a challenge for the California Regional Water Quality Control Board, San Francisco Bay Region (Water Board). This report documents a pilot effort to systematically assess trash levels in streams, which are in turn sources of marine debris to the San Francisco Bay and Pacific Ocean. Results from year-round surveys of 26 sites around the San Francisco Bay Region are presented and discussed. A map of surveyed sites is included as Figure 1.

The goal of this report is to provide a regional scale of assessment of trash deposition in fresh waters of the San Francisco Bay Region, documenting dry and wet weather deposition rates, longitudinal variability in a watershed, and variability across watersheds in representative urban and rural residential settings. The site scores, number of pieces per 100-feet, and types of trash are summarized and likely sources of trash analyzed and potential management measures discussed. At each survey the trash was removed, and subsequent surveys documented the deposition rate of trash in pieces per 100-feet per day. Sites with the highest trash deposition rates in dry and wet weather conditions are discussed in more detail to identify sources of trash pollution and potential management actions.

Trash and Water Quality Standards

Water quality standards consist of designated beneficial uses for specific water bodies, water quality objectives (narrative and/or numeric) to protect the uses, and the State's Antidegradation Policy, which mandates the maintenance of high quality waters, preventing degradation to the minimally acceptable standard. Water quality standards for the San Francisco Bay Region are contained in the San Francisco Bay Region Water Quality Control Plan (Basin Plan).

Trash adversely affects numerous beneficial uses of waters, particularly recreation and various aquatic habitats. Not all litter and debris delivered to streams are of equal concern to water quality. Besides the obvious negative aesthetic effects, most of the harm of trash in surface waters is imparted to aquatic life in the form of entanglement or ingestion (Laist and Liffmann, 2000; McCauley and Bjorndahl, 1998). Some elements of trash exhibit significant threats to human health, such as discarded medical waste, human or pet waste, and broken glass (Sheavly, 2004). Also, some household and industrial wastes may contain toxic substances of concern to human health and wildlife, such as

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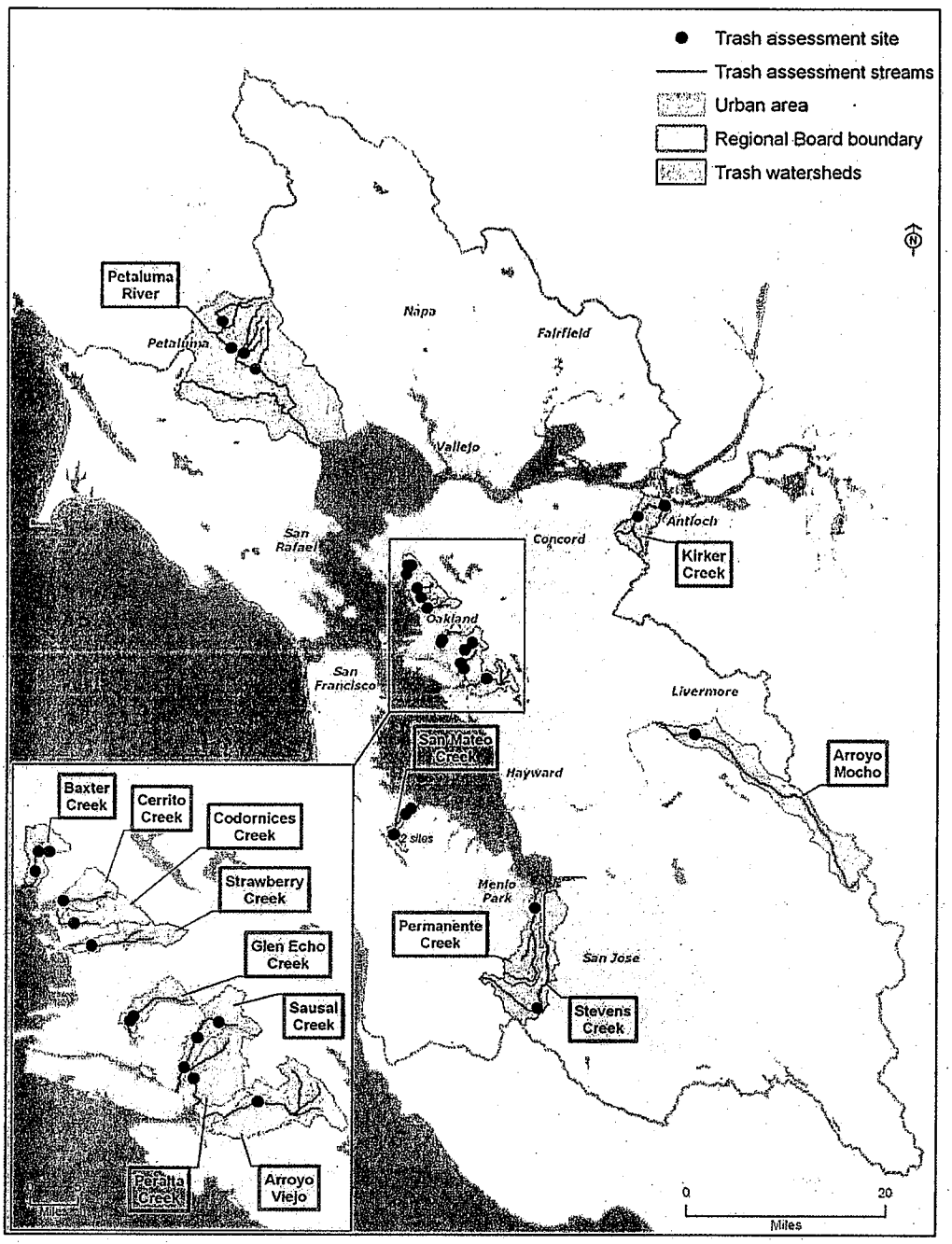

Figure 1 – Map of Trash Assessment Sites, San Francisco Bay Region SWAMP Program, 2003-2005

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batteries, pesticide containers, and fluorescent light bulbs that contain mercury. Larger trash such as discarded appliances can present physical barriers to natural stream flow, causing physical impacts such as bank erosion. From a management perspective, the persistent accumulation of trash in a water body is of particular concern, and signifies a priority for prevention of trash discharges. Also of concern are trash "hotspots" where illegal dumping, littering, and/or accumulation of trash occur.

The narrative water quality objectives applicable to trash are Floating Material (*Waters shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses*), Settleable Material (*Waters shall not contain substances in concentrations that result in the deposition of material that cause nuisance or adversely affect beneficial uses*), and Suspended Material (*Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses*).

The Basin Plan prohibits discharge of rubbish and refuse to waters of the state (Table 4-1, Discharge Prohibitions, No. 7). This prohibition was adopted by the Water Board in the 1975 Basin Plan, primarily to protect recreational uses such as boating.

Several water bodies in California are listed under Section 303(d) of the Clean Water Act (CWA) as impaired by trash, which means they are not meeting water quality standards. The 303(d) List includes Lake Merritt of Oakland as impaired by trash. In 2001, the Los Angeles Regional Water Board began adopting Total Maximum Daily Loads (TMDLs) for trash in its jurisdictional area, so that certain water bodies including the Los Angeles River can eventually meet the water quality standard in relation to trash. The San Francisco Bay Regional Water Board keeps an informal "watch" list for impaired water bodies, and has placed trash in all urban creeks, lakes and shorelines on this list. As part of this action in November 2001, the Water Board identified the need for better information on trash assessment in order to discern which water bodies should be included on the 303(d) Impaired Water Bodies List.

Assessment Method Development

Recognizing the need for assessment procedures to support 303(d) listing decisions, as part of its Surface Water Ambient Monitoring Program (SWAMP), the staff of the Water Board developed, refined, and implemented a rapid trash assessment method from 2002 through 2005 (Water Board, 2004, Appendix A). The method was refined through field experience and by conferring with representatives from local government and nonprofit groups. The method generates site-specific scores on a scale from 0 to 120, with higher scores indicating cleaner sites. The method also documents the number of pieces of trash per one hundred feet of stream or shoreline, and the rate of return of trash under different weather conditions. The results can be used to identify problem areas where trash accumulates even during dry weather, and to provide baseline information against which to compare future assessments after targeted management measures are implemented, in order to evaluate the effectiveness of such measures.

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Trash assessment includes a visual survey of the water body (e.g., streambed and banks) and adjacent areas from which trash elements can be carried to the water body by wind, water, or gravity. The delineation of these adjacent areas is site-specific and requires some judgment and documentation. The rapid trash assessment worksheet is designed to represent the range of effects that trash has on the physical, biological, and chemical integrity of water bodies, in accordance with the goals of the CWA and the California Water Code. The worksheet also provides a record for evaluation of the management of trash discharges, by documenting sites that receive direct discharges (i.e., dumping or littering) and those that accumulate trash from upstream locations. The specific items on the tally sheet were determined based on common items retrieved during numerous pilot surveys.

There is a need to systematically measure trash levels in Bay Area and California water bodies to establish baseline conditions, and evaluate the success of educational, institutional, operational and structural efforts to control trash. In some systems that behave as trash "catchments," such as Lake Merritt, overall tons of trash removed may be an appropriate indicator to measure over time to gauge success, as long as it is measured consistently. The Water Board staff developed the rapid trash assessment method to provide such a systematic approach for non-catchment systems such as streams and shorelines, where "tons of trash removed" may not provide an accurate tracking mechanism. Trash weight can be a misleading indicator, since the trash of most concern to beneficial uses is small, buoyant and persistent (U.S. EPA, 2001).

Water Quality Impacts of Trash

For aquatic life, buoyant (floatable) elements tend to be more harmful than settleable elements, due to their ability to be transported throughout the water body and ultimately to the marine environment. Persistent elements such as plastics, synthetic rubber and synthetic cloth tend to be more harmful than degradable elements such as paper or organic waste. Glass and metal are less persistent, even though they are not biodegradable, because wave action and rusting can cause them to break into smaller pieces that are less sharp and harmful. Natural rubber and cloth can degrade but not as quickly as paper (U.S. EPA, 2002). Smaller elements such as plastic resin pellets (a by-product of plastic manufacturing) and cigarette butts are often more harmful to aquatic life than larger elements, since they can be ingested by a large number of small organisms which can then suffer malnutrition or internal injuries. Larger plastic elements such as plastic grocery bags are also harmful to larger aquatic life such as sea turtles, which can mistake the trash for floating prey and ingest it, leading to starvation or suffocation. Floating debris that is not trapped and removed will eventually end up on the beaches or in the ocean, repelling visitors and residents from the beaches and degrading coastal and open ocean waters.

Trash in water bodies can threaten the health of people who use them for wading or swimming. Of particular concern are the bacteria and viruses associated with diapers, medical waste (e.g., used hypodermic needles and pipettes), and human or pet waste. Additionally, broken glass or sharp metal fragments in streams can cause puncture or

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laceration injuries. Such injuries can then expose a person's bloodstream to microbes in the stream's water that may cause illness. Also, some trash items such as containers or tires can pond water and support mosquito production and associated risks of diseases such as encephalitis and the West Nile virus.

Leaf litter is trash when there is evidence of intentional dumping. Leaves and pine needles in streams provide a natural source of food for organisms, but excessive levels due to human influence can cause nutrient imbalance and oxygen depletion in streams, to the detriment of the aquatic ecosystem. Clumps of leaf litter and yard waste from trash bags should be treated as trash in the water quality assessment, and not confused with natural inputs of leaves to streams. If there is a question in the field, check the type of leaf to confirm that it comes from a nearby riparian tree. In some instances, leaf litter may be trash if it originates from dense ornamental stands of nearby human planted trees that are overloading the stream's assimilative capacity for leaf inputs. Other biodegradable trash, such as food waste, also exerts a demand on dissolved oxygen, but aquatic life is unlikely to be adversely affected unless the dumping of food waste is substantial and persistent at a given location.

Wildlife impacts due to trash occur in creeks, lakes, estuaries, and ultimately the ocean. The two primary problems that trash poses to wildlife are entanglement and ingestion, with entanglement the more common documented effect (Laist and Liffmann, 2000). Marine mammals, turtles, birds, fish, and crustaceans all have been affected by entanglement in or ingestion of floatable debris. Many of the species most vulnerable to the problems of floatable debris are endangered or threatened by extinction.

Entanglement results when an animal becomes encircled or ensnared by debris. It can occur accidentally, or when the animal is attracted to the debris as part of its normal behavior or out of curiosity. Entanglement is harmful to wildlife for several reasons. Not only can it cause wounds that can lead to infections or loss of limbs; it can also cause strangulation or suffocation. In addition, entanglement can impair an animal's ability to swim, which can result in drowning, or in difficulty in moving, finding food, or escaping predators (U.S. EPA, 2001).

Ingestion occurs when an animal swallows floatable debris. It sometimes occurs accidentally, but usually animals feed on debris because it looks like food (e.g., plastic bags look like jellyfish, a prey item of sea turtles). Ingestion can lead to starvation or malnutrition if the ingested items block the intestinal tract and prevent digestion, or accumulate in the digestive tract, making the animal feel "full" and lessening its desire to feed. Ingestion of sharp objects can damage the mouth, digestive tract and/or stomach lining and cause infection or pain. Ingested items can also block air passages and prevent breathing, thereby causing death (U.S. EPA, 2001).

Common settled debris includes glass, cigarettes, rubber, construction debris and more. Settleables are a problem for bottom feeders and dwellers and can contribute to sediment contamination. Larger settleable items such as automobiles, shopping carts, and furniture can redirect stream flow and destabilize the channel.

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In conclusion, trash in water bodies can adversely affect humans, fish, and wildlife. Not all water quality effects of trash are equal in severity or duration, thus the trash assessment methodology was designed to reflect a range of trash impacts to aquatic life, public health, and aesthetic enjoyment. When considering the water quality effects of trash while conducting a trash assessment, remember to evaluate individual items and their buoyancy, degradability, size, potential health hazard, and potential hazards to fish and wildlife. Utilize the narratives in the worksheet, refer to the technical notes and trash parameter descriptions in the text as needed, and select your scores after careful consideration of actual conditions.

Sources and Fate of Trash

Movement and fate of trash in the landscape and waterways varies based on its size, buoyancy, and degradability. Small, buoyant and persistent trash items such as plastic or synthetic rubber may travel from land all the way to mid-ocean locations, whereas other trash items may have a more transient or localized presence in waters.

The primary sources of trash to waters of the state are urban runoff in nearshore areas such as creeks and San Francisco Bay, and fishing boats in offshore areas (Moore and Allen, 2000). In most of the region, storm drainage in urban areas had been designed to move water as quickly as possible to surface waters. One unfortunate by-product of this design is that medium to heavy rain events move trash deposited on streets and hard surfaces directly to waters of the state, if it is not screened out by coarse metal grates in urban gutters.

Surveys of the ocean floor of the Southern California Bight for trash and natural debris concluded that land-based trash sources contributed the most to the ocean bottom trash levels near the shoreline, but the trash on the outer continental shelf was dominated by discarded fishing gear and incidental waste from recreational and commercial fishing boats (Moore and Allen, 2000).

Surveys of the North Pacific central gyre for floating plastics and plankton suggest that the amount of plastic material in the ocean is increasing over time (Day and Shaw, 1987). Plastic degrades slowly in the ocean (Andrady, 1990; U.S. EPA, 1992). The eddy effects of the gyre probably serve to retain plastics, whereas plastics may wash up on shore in greater numbers in other areas. This is based on the observation that a large fraction of the materials in the central gyre study appeared to be remnants of offshore fishing-related activity and shipping traffic. The survey indicated that the mass of plastics is about six times that of plankton, but the abundance of plankton is still about five times that of plastic pieces (Moore et al., 2001).

Methods

In order to generate consistent and comparable results, the methods of site definition, data collection, scoring, and overall monitoring program design are discussed in this section.

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Monitoring Design Considerations

The rapid trash assessment method can be used for a number of purposes, such as ambient monitoring, evaluation of management actions, determination of trash accumulation rates, or comparing sites with and without public access. In this report, the data collected is used for all of these purposes. Ambient monitoring provides information at sites distributed throughout a water body, located in similar locations across different water bodies, and several times a year to characterize spatial and temporal variability. Additionally, the ambient sampling design should document the effects of episodes that affect trash levels such as storms or community cleanup events. Pre- and post-project assessments can assist in evaluating the effectiveness of management practices ranging from public outreach to structural controls, or to document the effects of public access on trash levels in waterbodies (e.g., upstream/downstream). Such evaluations should consider trash levels over time and under different seasonal conditions. Revisiting sites where trash was collected during previous assessments enables the determination of accumulation rates. This methodology was developed for sections of wadeable streams, but can be adapted to shorelines of lakes, beaches, or estuaries. Ultimately, the monitoring design strongly affects the usefulness of any rapid trash assessment information.

SWAMP Trash Monitoring Design

In accordance with the goal of this report, sites were selected to represent the range of conditions found in the tributaries to San Francisco Bay, from rural residential areas in the foothills to dense, urbanized areas in the plains. All sites were near or within city limits, representing areas of public access (e.g., parks) or at the bottom of watersheds.

The SWAMP program rotates water quality monitoring through 46 planning watersheds in the San Francisco Bay Region, as budget allows. Trash assessments were conducted at sites where water quality was monitored in the SWAMP program from 2003 to 2005. The 26 sites assessed using the rapid trash assessment methodology are located in five of the nine Bay Area counties (see Figure 1). Two of the 26 sites were surveyed only once, due to dangerous field conditions and extremely high trash levels, while other sites were surveyed three to four times over a year in order to calculate deposition rates of trash during dry and wet weather conditions. Surveys sometimes integrated both dry and wet conditions, but these assessments were classified as "wet weather" due to the observed overwhelming effect of wet weather conditions on trash deposition. Of the 26 sites, 13 were located at the bottom of the watershed (BOTW), representing areas just upstream of the San Francisco Bay intertidal zone. The remainder of the sites were located further upstream, allowing for longitudinal analyses of trash deposition in the San Mateo Creek, Baxter Creek (Richmond), Petaluma River, and Sausal Creek (Oakland) watersheds. This report presents results and discussion for a total of 85 individual site surveys.

Site Definition

Defining site-specific characteristics facilitates the comparison of trash assessments conducted at the same site at different times of the year. Upon arrival at a designated

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monitoring site, a team of two people or more defined or verified a 100-foot section of the stream or shoreline to analyze, associated with a SWAMP water quality sampling location or station. When a site was first established, the 100-foot distance was accurately measured. The length was measured not as a straight line, but as 100 feet of the actual stream or shore length, including sinuous curves. Where possible, the starting and ending points of the survey were easily identified landmarks, such as an oak tree or boulder, and noted on the worksheet ("Upper/Lower Boundaries of Reach"), or documented using a global positioning system (GPS), so that future assessments could be made at the same location. The team conferred and documented the upper boundary of the banks to be surveyed, based on evaluation of whether trash could be carried to the water body by wind or water (e.g., an upper terrace in the stream bank). At each site, the team documented the location of the high water line based on site-specific physical indicators, such as a debris line found in the riparian vegetation along the stream channel. If the high water line could not be determined, bank full height was documented in the field sheets, noting that the high water line could not be determined. Trash located below the high water line can be expected to move into the streambed or be swept downstream during the next significant rain event.

Trash Data Collection

The trash assessment protocol involves picking up and tallying all of the trash items found within the defined boundaries of a site. When repeated several times throughout a year, this procedure allows for the assessment of temporal changes in impairment, usage patterns, and trash deposition rates under wet and dry weather conditions. Surveys, including trash collection, note taking, and scoring, typically took one to two hours, depending on how trash-impacted the site was and the number of people on the survey crew. The first time a site was assessed the process generally took longer than on subsequent visits.

All surveys are initiated at the downstream end of the selected reach so that trash is not obscured after disturbing the streambed. Tasks are divided according to the number of team members. For a team with two members, both persons, equipped with gloves and garbage bags, pick up trash. A trash grabber, metal kitchen tongs, or a similar tool can also be used to help pick up trash. One team member begins walking along the bank at the edge of the stream or shore, looking for trash on the bank up to the upper bank boundary, above and below the high water line. This person picks up trash and tallies the items on the trash assessment worksheet as either above or below the high water line. The other person walks along the streambed and up and down the opposite bank, picking up and calling out trash items found in the water body and on the opposite bank, both above and below the high water line, for the tally person to mark down appropriately on the trash assessment sheet. A three-member team has one designated note-taker and two trash collectors.

To make sure that trash items are not missed from the survey, team members look under bushes, logs, and vegetation to see if trash has accumulated underneath. The ground and substrate is closely inspected to ensure that small items such as cigarette butts and pieces

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of broken glass or Styrofoam are picked up and counted. Special attention was paid to items that can affect human health such as diapers, fecal matter, and medical needles; these items can strongly affect the total score. The person tallying the trash indicates on the worksheet whether the trash was found above the high water line on the bank, or below the high water line either on the bank or in the stream (i.e., tally dots or circles (•) for above high water line, tally lines (|) for below). If itis evident that items have been littered, dumped, or accumulated via downstream transport, notes are made in the designated rows near the bottom of the tally sheet - this helps when assigning scores.

Once the team is finished collecting trash, the recorder indicates in the margins of the tally sheet the total number of items in each category found above and below the waterline. All worksheets are completed before leaving the site, while everything is still fresh in the memory. The team discusses each scoring parameter (described below under "Scoring") and agrees on a score for each of the condition categories, The team also discusses and records hypotheses of potential sources of trash, such as neighboring or upstream land uses.

Scoring

The rapid trash assessment includes six condition categories that capture the breadth of issues associated with trash and water quality. The first two parameters focus on qualitative and quantitative levels of trash, the second two parameters estimate actual threat to water quality, and the last two parameters represent how trash enters the water body at a site, either through on-site activities or downstream accumulation.

Within each trash parameter, narrative language is provided to assist with choosing a condition category. The worksheet provides a range of numbers within a given category, allowing for a range of conditions encountered in the field. For instance, trash located in the water results in lower scores than trash above the high water line. Not all specific trash conditions mentioned in the narratives need to be present to fit into a specific condition category (e.g., "site frequently used by people"), nor do the narratives describe all possible conditions. Scores of "0" should be reserved for the most extreme conditions. Once team members assigned the scores for the six categories in the field, the final scores were summed and specific notes about the site included at the end of the sheet. Each site was assessed three or four times in a given year, during different seasons, to characterize the variability and persistence of trash occurrence for water quality assessment purposes.

The scoring categories include:

1. *Level of Trash.* This assessment parameter is intended to reflect a qualitative "first impression" of the site, after observing the entire length of the reach. Sites scoring in the "poor" range are those where trash is one of the first things noticeable about the water body. No trash should be obviously visible at sites that score in the "optimal" range.

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2. *Actual Number of Trash Items Found.* Based on the tally of trash along the 100-foot stream reach, total the number of items both above and below the high water line, and choose a score within the appropriate condition category based on the number of tallied items. Where more than 100 items have been tallied, assign the following scores: 5: 101-200 items; 4: 201-300 items; 3: 301-400 items; 2: 401-500 items; 1: 501-600 items; 0: over 600 items. Use similar guidelines to assign scores in other condition categories. Sometimes items are broken into many pieces. Fragments with higher threat to aquatic life such as plastics should be individually counted, while paper and broken glass, with lower threat and/or mobility, should be counted based on the parent item(s). Broken glass that is scattered, with no recognizable original shape, should be counted individually. The judgment of whether to count all fragments or just one item also depends on the potential exposure to downstream fish and wildlife, and waders and swimmers at a given site. Concrete is trash when it is dumped, but not when it is placed. Consider tallying only those items that would be removed in a restoration or cleanup effort.

3. *Threat to Aquatic Life.* As indicated in the discussion above, certain characteristics of trash make it more harmful to aquatic life. If trash items are persistent in the environment, buoyant (floatable), and relatively small, they can be transported long distances and be mistaken by wildlife as food items. Larger items can cause entanglement. Some discarded debris may contain toxic substances. All of these factors are considered in the narrative descriptions in this assessment parameter.

4. *Threat to Human Health.* This category is concerned with items that are dangerous to people who wade or swim in the water, and with pollutants that could accumulate in fish in the downstream environment, such as mercury. The worst conditions have the potential for presence of dangerous bacteria or viruses, such as with medical waste, diapers, and human or pet waste.

5. *Illegal Dumping and Littering.* This assessment category relates to direct placement of trash items at a site, with "poor" conditions assigned to sites that appear to be dumping or littering locations based on adjacent land use practices or site accessibility.

6. *Accumulation of Trash.* Trash that accumulates from upstream locations is distinguished from dumped trash by indications of age and transport. Faded colors, silt marks, trash wrapped around roots, and signs of decay suggest downstream transport, indicating that the local drainage system facilitates conveyance of trash to water bodies, in violation of clean water laws and policies.

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Quality Assurance

To address concerns about observer bias and differences in interpretation of narrative language, SWAMP and Alameda County stormwater staff performed a methods repeatability study in July 2002. Three teams of two members assessed and scored the same two sites in a blind comparison. A summary of the study is included as Appendix B, Rapid Trash Assessment Method Evaluation.

Results and Discussion

There are two major manifestations of trash in streams of the San Francisco Bay Region: ***direct littering or dumping***, and ***downstream transport and accumulation***. Littering and dumping was usually documented in dry weather conditions between sampling events, while downstream transport and accumulation of trash occurred at the bottom of watersheds in wet weather conditions between sampling events. Results confirmed that these two phenomena occur at remarkable rates of deposition and levels of trash per 100-feet of stream in every watershed studied. In this section, the sites with the highest dry and wet weather deposition are described, sources of trash are identified, and potential management measures are discussed. In addition, two public access sites with high RTA scores and relatively low trash deposition rates are discussed to identify what appears to be working to keep trash out of the water body.

Regional Conditions

The 85 site visits conducted by Water Board staff and students over three years and multiple seasons confirmed that high levels of trash are present throughout urban streams in the San Francisco Bay Region. On average, across all sites and seasons, 293 pieces of trash were collected per 100 foot reach of stream, equaling 2.93 pieces per linear foot of stream (Figure 2). Over 50% of this total, or 1.51 pieces per linear foot of stream, was composed of plastic items. Glass (21%) and biodegradable items (10%) were also commonly found. Most sites contained less than 500 pieces of trash, while several sites contained many more pieces, up to a maximum of 1133 pieces, or 11.33 pieces per linear foot of stream (Figure 3). Overall, 72% of all trash items were found below the high-water line, while 28% of items were found above the high-water line. Certain types of items were found almost exclusively below the high-water line, including toxic items (88%), construction debris (87%), and glass (82%). Forty-one percent of biodegradeable items were found above the high water line, indicative of the frequency with which paper is transported by wind into stream channels. The average total Rapid Trash Assessment (RTA) score was 47, with a range from 8 to 112 (out of a possible 120) (Figure 4). Lower RTA scores reflect higher levels of trash. A high RTA score, overall or in a specific category, represents more desirable, less trashed conditions. Total RTA scores were strongly related to the number of plastic pieces found at sites (Figure 5).

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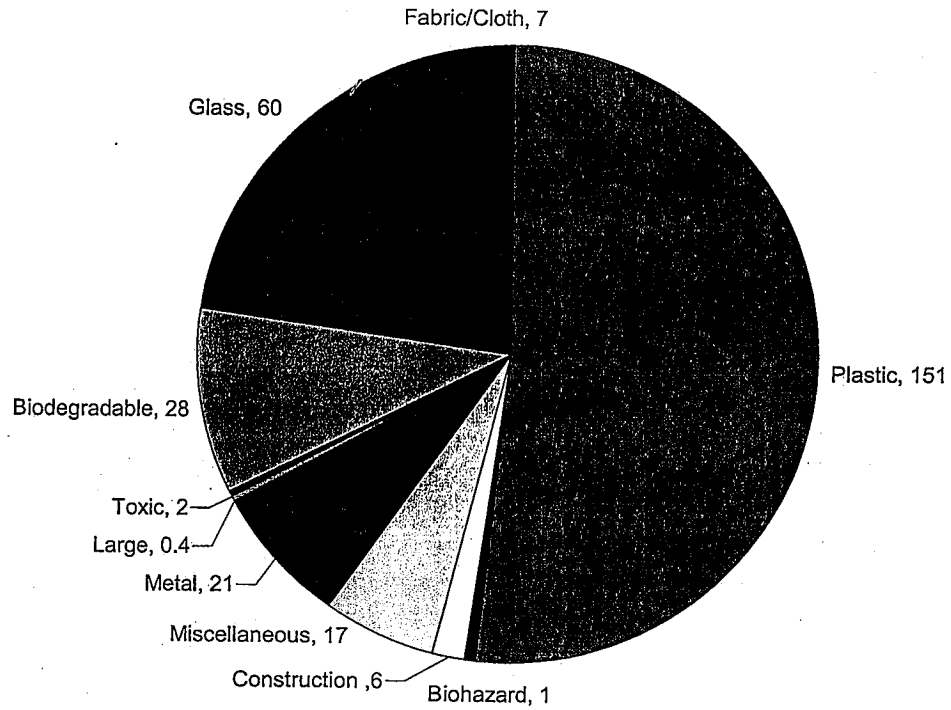

Figure 2: Average number of pieces of trash, by category, per 100 foot reach for all sites and all seasons.

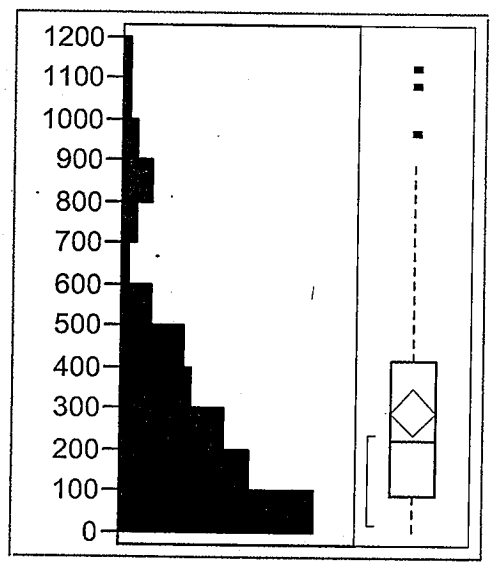

Figure 3: Frequency histogram of the number of pieces of trash found per 100 foot reach (site). The diamond indicates the mean and the standard error about the mean. The box indicates the median and the 25th and 75th percentiles, while the whiskers indicate the 5th and 95th percentiles.

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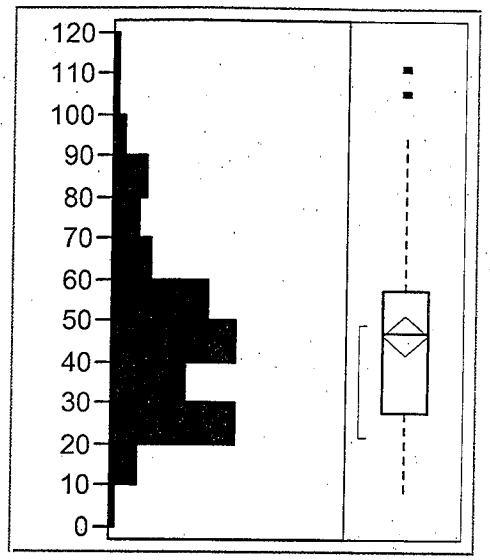

Figure 4: Frequency histogram of total RTA trash scores for each site visit. Symbols are the same as in Figure 3.

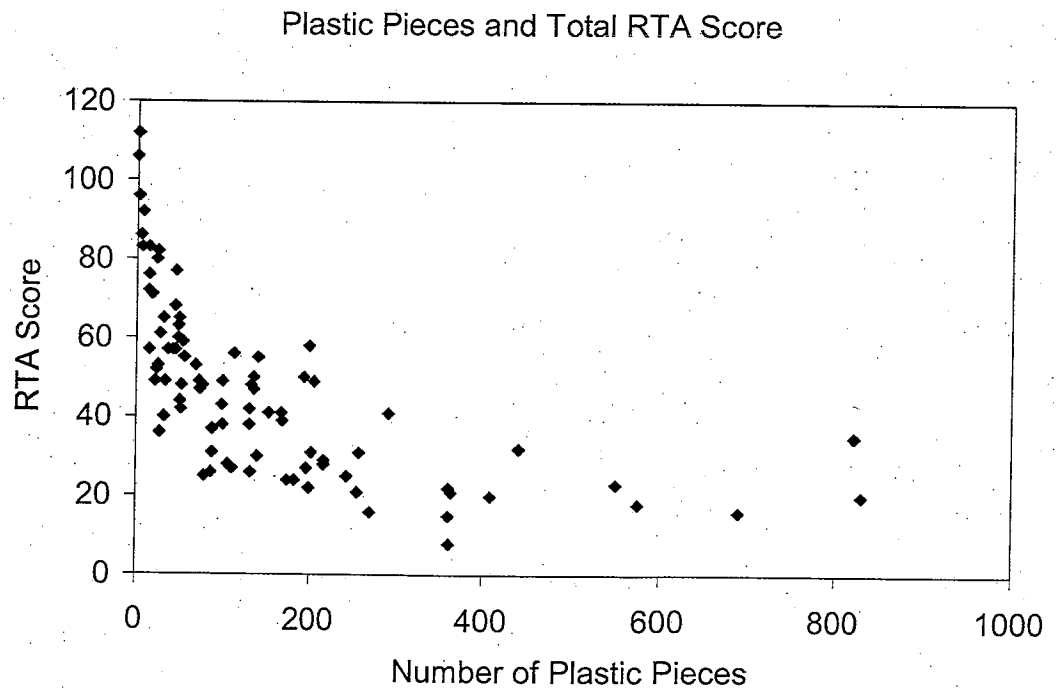

Figure 5: Total RTA score relative to the total number of plastic pieces found at sites.

The 26 sites surveyed did not include the worst-case conditions of trash in the region (Figure 6, below, for example), where obstructions can cause buildup of floating trash in

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wet weather conditions. Other problem sites not surveyed include homeless encampments, although some of the sites were downstream of such major sources of trash. The most trash pieces per 100 feet of stream documented in this report was 1,133 pieces at Baxter Creek at Booker Park in Richmond. Figure 6, in comparison, shows a level of trash that may exceed 10,000 pieces per 100 feet.

Figure 6: Photo of the trash buildup behind a fallen tree immediately downstream of the Julian Street bridge, Coyote Creek, San Jose, CA, January 27, 2004. Photo by Friends of Coyote Creek.

There were significant differences in amounts and types of trash found at sites located at the bottom of watersheds and sites located in parks with high public access. Bottom-of-the-watershed (BOTW) sites (Table 2) received very low upstream accumulation scores (average score 3.3) relative to sites located higher in the watershed (average score 8.5). Conversely, littering was more important at sites with high public access (average score 3.9) than at sites without high public access (average score 5.4). Many more pieces of plastic were found below the high water line at BOTW sites (average 192) than at non-BOTW sites (average 52). Glass, however, was much more common at public access sites (average 92) than at non-public access sites (average 14). Overall, BOTW sites tended to most adversely affected by trash, in terms of highest total number of pieces (average 398) and lowest total RTA scores (average 35).

Condition category scores within the total RTA score reflected differences in trash deposition between both (1) wet and dry seasons and (2) BOTW and sites further upstream. Figure 7 presents a comparison of average RTA scores at a subset of sites where site revisits well-bracketed both the wet and dry seasons. Bottom of the watershed (BOTW) sites tended to score lower than sites further upstream in the watershed in nearly all trash condition category scores, with the exception of dumping and littering (Figure

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7). Qualitative scores were much lower at BOTW sites than upstream sites, indicating the "first impression" of BOTW sites is consistently more negative with respect to trash.

Accumulation scores were also much lower at BOTW sites than upstream sites, but wet season scores are much lower for both site locations than dry season scores, reflecting the seasonality of trash accumulation. At BOTW sites, the dry season scores for accumulation were markedly lower than the wet season accumulation scores for upstream sites, shown at the far right of Figure 7. As noted above, at BOTW sites the trash is dominated by plastics. The graph at the far right of Figure 7 therefore shows that plastics continue to be delivered to the bottom of watersheds and into the San Francisco Bay during the dry season. Trash can be delivered to streams, the topographic low points in watersheds, by wind and dry season urban runoff (e.g., over-irrigation), and these data suggest it is a significant source. Trash control efforts in the Los Angeles region associated with TMDL implementation tend to focus on runoff events to capture the largest volume of trash, but the observations documented in this report show that dry season delivery of trash is likely significant.

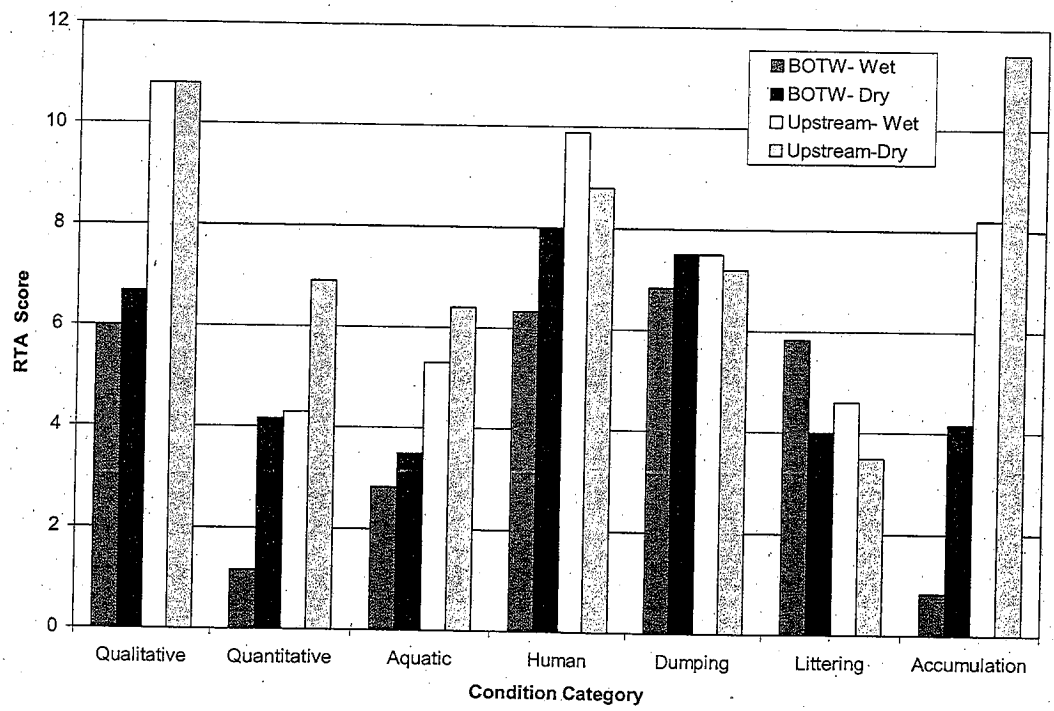

Figure 7: Average condition category scores from a subset of sites that were sampled during revisits that bracketed both and wet dry seasons. Data is presented for both wet and dry season surveys from 6 BOTW sites and 10 upstream sites. Maximum RTA scores for all condition categories is 20, except littering and dumping which is 10.

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Trash Deposition Rates

Trash deposition rates for the different sites were calculated and ranked from highest to lowest, as presented in Table 1. The monitoring design provided the opportunity to estimate trash deposition rates because the trash was removed from the landmarked 100-foot reach of stream at the initial site visit. Therefore, when the field team returned to a given site several months later, the only trash in the landmarked reach was trash deposited since the previous survey. A rate of deposition in pieces per 100-feet per day was calculated for all sites for wet and dry weather conditions. Excluding initial site visits, sites were revisited 59 times. The sites with the top wet weather and dry weather deposition rates are presented in more detail below. Also, the two sites with the lowest deposition rates are discussed.

Wet Season Deposition

Table 1 shows that the highest measured trash deposition rates were associated with wet weather, particularly at BOTW sites, listed in Table 2. Following the wet season, the BOTW sites had a higher number of plastic pieces, indicating that this type of trash is more transportable in runoff events. The average number of plastic pieces found below the water line at BOTW sites, in all weather conditions, was 192 pieces per 100 feet. The average number of plastic pieces found below the water line at non-BOTW sites was 57 pieces per 100 feet. Deposition rates also reflect the importance of upstream accumulation versus littering and dumping. The highest deposition rates tended to occur at sites that received low accumulation condition category scores relative to littering and dumping scores, indicating that most trash was deposited at these sites via accumulation from upstream transport (Figure 8). Based on condition category scores, littering and dumping was believed to be the dominant process resulting in trash deposition at relatively few sites, and generally during the dry season.

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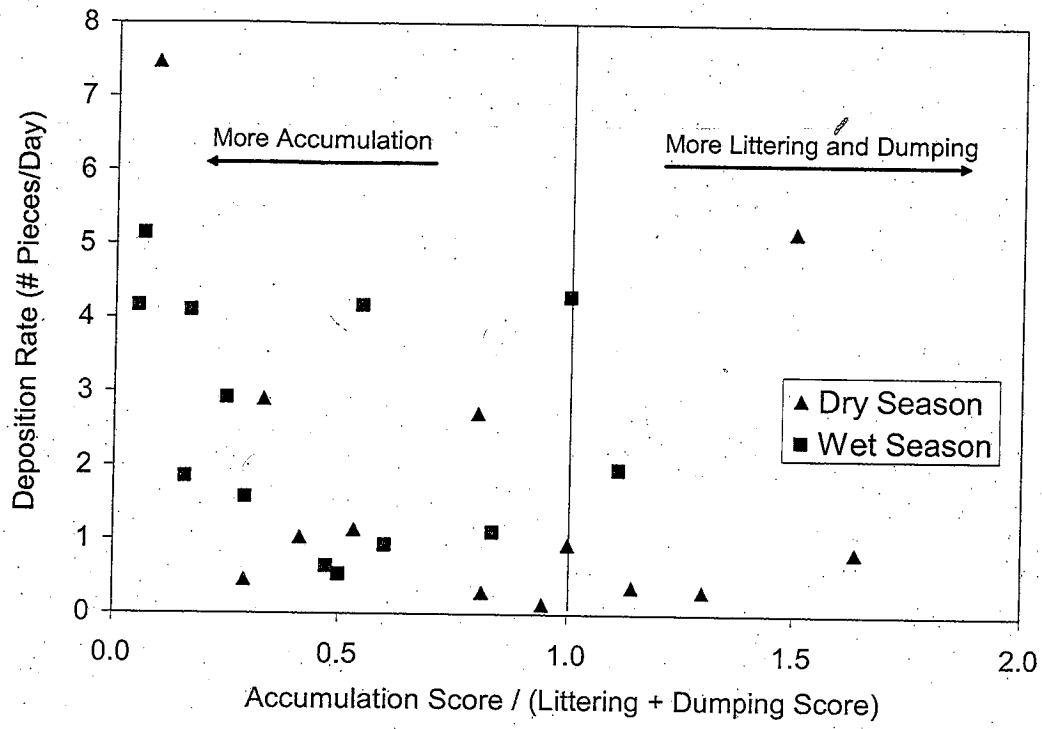

Figure 8: Deposition rates at sites versus the relative importance of accumulation from upstream and localized littering and dumping.

Dry Season Deposition

Deposition rates were much lower in the dry season than the wet season, generally below 1 piece of trash per day (Table 1, Figure 8). Several sites had high deposition rates during the dry season, associated with localized littering (Figure 9). Many of these high dry season deposition rates occur at public parks. Management priorities at these sites should focus on encouraging the proper disposal of trash in and around the stream.

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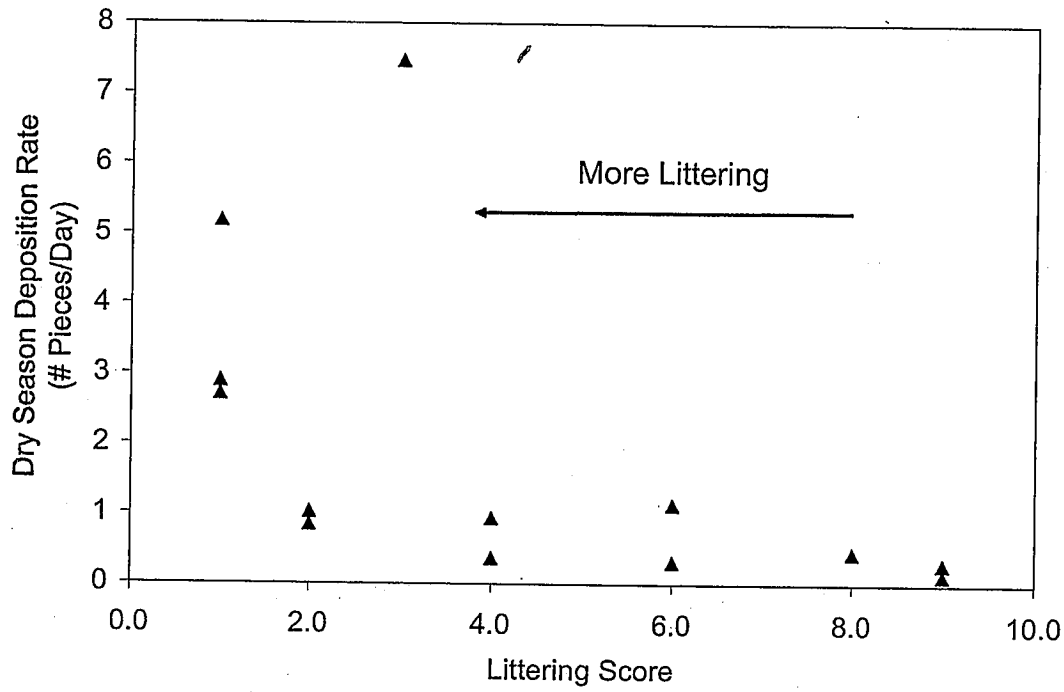

Figure 9: Dry season trash deposition rates relative to the RTA littering score.

Wet Season Deposition Site – Case Study

Booker T. Anderson Park, Baxter Creek

The highest trash deposition rate recorded in the study occurred at the BOTW site of the Baxter Creek watershed in Richmond and El Cerrito. The initial site survey, prior to trash pickup, yielded the most pieces of trash per 100 feet of any survey conducted (1,133). This site absorbs the impact of trash delivered from upstream during storm events, but there is much evidence of local littering and dumping as well, which combine to register the highest rates of deposition recorded in the regional study.

The site is surrounded by residential areas. A stream restoration project occurred here a few years ago, with the concrete channel removed and a riparian corridor established, which has developed well (though at most 20' in width). There was evidence of park use at each survey, particularly on the east bank where there is grass, a playground, and a ball field. The trash site is about ¼ of the way into the park from the upstream culvert. At the culvert is a large pool. Many dumped items were observed in this pool, but it is not within the 100-foot reach. The culvert is at the top of the park, with easy access for dumping from vehicular traffic. Some of the dumped items get carried downstream, for instance mattresses were observed in the stream at the lower end of the park. Littering is prevalent here also, though trash cans and a dumpster are present. On the west side of the creek is the recreation center and a large parking lot. The parking lot is clean. A street sweeper was observed cleaning the lot. The recreation center has a dumpster at the curb.

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Large items such as appliances were observed in this dumpster, therefore it probably prevents at least some dumping.

The highest deposition rate was recorded during the survey of November 19, 2004, soon after the first significant rain events of the season. Despite the trash removal associated with the survey, the site received a lower RTA score than the initial site visit, indicating that trash management at the site is not improving and perhaps getting worse. Because this survey took place after seasonal rains had begun, the high water line and downstream transport were evident based on a distinct debris line. There were 543 plastic pieces below the water line, and 33 above. This ratio of plastic below:above indicates significant downstream transport. The same types of trash were observed here as in prior surveys. Other than plastics, there was foil (47 below water line), paper (138 below water line), and glass (92 below water line). Glass tends to be from more local sources due to its density. The combination of significant downstream transport, with notable littering and dumping, to the Booker T. Anderson site.

Potential Management Measures

As noted above, trash is managed at the park, but the data from the creek show that the management is not having a measurable benefit to water quality. Many park patrons simply ignore the trash receptacles that have been made available. With respect to littering and dumping, a major change in behavior of park patrons and illegal dumpers is needed to improve the trash issue in Baxter Creek. But since downstream transport is so significant at Booker T. Anderson Park, there appears to be a need to manage trash in the entire watershed. For instance, the longitudinal analysis of Baxter Creek, discussed below, shows that the next site upstream, where the creek runs under the major arterial road San Pablo Ave., received a lower RTA score on November 12, 2004 than this site where the highest deposition rate was documented. This watershed appears to be a significant source of floatable trash to the Bay, and warrants special attention. A progressive program of education, warnings, and penalties may be needed in order to achieve behavioral change. Given the ubiquitous nature of trash in this watershed, structural trash removal alternatives should be evaluated as well.

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Figure 10: View looking upstream from Booker T. Anderson Park trash survey site (BAX030), showing dumped mattress and low gate above culvert at street crossing, upstream of park. Photo by Steve Moore, August 23, 2005.

Dry Season Deposition Site – Case Study

Washington and McDowell, Washington Creek (Petaluma River Watershed)

The highest dry season trash deposition rate recorded in the study occurred at a tributary of the Petaluma River, Washington Creek, in the City of Petaluma, at the corner of Washington and McDowell. This is a very heavy vehicle traffic area, with an off-ramp from Highway 101, a busy intersection, a gas station, and a mall next to the creek at this station.

Washington St. is located parallel to and directly southeast of the creek. A concrete channel encloses the stream, with the top of the ~ 15' tall southeast wall (left bank) ending at the sidewalk adjacent to Washington St. To the northwest is a plaza-style shopping mall. Dumpsters for the closest store are located about 100 feet from the creek, with no enclosure. Directly north of the site, near the intersection, is a gasoline station. One dumpster is located behind the gas station in a concrete block enclosure with a semi-solid gate. A chain link fence separates the creek corridor from the gas station trash enclosure and the mall. The creek is accessible by climbing over the chain link fence (about 4' high). The trash station starts at the mouth of a large culvert that encloses the creek as it runs under McDowell.

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The trash at this location was plastic wrappers, cigarette butts, paper, and aluminum foil or cans. Plastic wrappers are probably from adjacent land use at the gas station. Cigarette butts are probably from people flipping their butts out of their vehicles along both streets and the butts blowing over the sidewalk edges. Butts could also be accumulated from downstream transport. Paper and aluminum cans and pieces are also probably from adjacent land use at the gas station and the mall. In the summer survey, the overflowing dumpster at the gas station and land use observation of wind blowing trash from shopping center parking lot contributed most of the plastics. 59% of the pieces found above high water line were plastics. 62 of 92 (67%) plastic pieces found above were plastic wrappers. 46 of 157 (29%) above were paper pieces. 130 of 233 (56%) total pieces were plastic in origin.

The winter rains brought a high % of plastic: 291 of 338 pieces. The counts also included one sleeping bag and 4 cigarette butts.

Potential Management Measures

There is no management of trash at this urban, channelized creek. This site, which had the highest dry season deposition rate in the study, is best characterized as a site where trash is mis-managed. The overflowing dumpsters, untreated runoff from the intersection, and trash blowing off the large shopping mall parking lot combine to create a continuous loading of trash to waters of the state. The implied message to the public at this site, due to its perpetually polluted condition, is that it is okay to dispose of solid waste in this manner.

The trash that is generated at suburban sites such as this one should be managed more carefully. Businesses should be held accountable for delivery of trash from their property. The public needs to be better educated about the harmful effects of disposing trash near water bodies. Education efforts should be followed up by regulatory and enforcement efforts. This site is a great example of how trash will continue to be delivered to waters at a high rate unless landowners are somehow held accountable. It is a good case study for assessing the contribution from roadside litter.

Low Trash Deposition Sites

1. Dimond Park, Sausal Creek

This site is directly adjacent to the Dimond Park Recreation Center and Swimming Pool. The recreation center has been full of children at each survey. There is a jungle gym play area on the left bank just upstream of our trash boundary. There are trashcans dotted throughout the area, particularly along the sidewalk that runs next to the building. We have seen maintenance people outside picking up trash and taking care of the lawn and vegetation each time we have been there.

Above this location there is still public access through the restored area. A mile or two upstream the canyon deepens considerably, and a golf course is located in the canyon.

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There is an active creek group in this area, Friends of Sausal Creek. A restoration project occurred recently upstream of the road that crosses the creek in this canyon, 200' upstream. The recreation center staff said that the creek group had picked up trash in May 2005, shortly before our June 2005 trash assessment. At least some trash blows in from the lawn, and the staff maintains the lawn but not the creek. Some downstream accumulation was noted, but no illegal dumping. Littering was evident.

On June 17, 2005, recreation center staff said that they had just completed a grounds trash pickup the previous day, and that the Sausal Creek group had been by about a month ago picking up trash in the creek. Most of the items in the June 2005 survey were found in the right bank vegetation, and not in the stream itself. It seems to be all local littering measured at the creek in this survey.

Potential Management Measures

This site is actively managed for trash by City staff in the lawn areas and volunteer citizens from Friends of Sausal Creek in the creek itself. This active management has not completely precluded trash from entering the creek, but the RTA values shown in Figure 13 for SAU060 show that in this dense urban area a creek can exhibit trash levels that are significantly lower than other creeks in similar settings.

2. Joaquin Miller Park, Palo Seco Creek (Sausal Creek Watershed)

This site is near the top of the watershed. It is located above Hwy. 13, and while it is public access, the trailhead is not well-marked. The trail is very steep once further along the hike (past the trash measurement site), so that may hold down the number of people who use the trail. The trail is well-maintained, with two trash cans at the small parking area (fits three cars). There are also plastic bags available for dog waste. Our site is about ¼ mile in from the trailhead, where the creek crosses the trail. We assessed ~30' below the crossing and 70' above it. Blackberry bushes prevented us from getting further downstream. The upstream boundary is a small waterfall that on close inspection appears to be man-made. We encountered walkers while we were there, as well as seeing vehicles in the parking area.

In August 2004, the trash we found was attached; a piece of rope with a thumb tack attached at a knot. We counted the rope, the plastic coating, and the metal. This is the best trash site that we have assessed – 3 pieces.

In December 2004, 4 pieces were counted below the water line, including one golf ball, two food waste items, and one glass piece. This visit was after the rainy season had started.

In June 2005, there were 4 pieces below water line and one above. The RTA score was lowered due to pet waste above the high water line, just down-slope of the trail that is the upper extent of the right bank. Other items included two plastic wrappers (small pieces), one aluminum foil and one synthetic rubber. Above the waterfall upstream of the site, a woody debris pile lies across the stream channel. A few old bottles have been snagged

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in the pile, so there does appear to be some historic (and probably current) littering, but at very low levels.

Potential Management Measures

This site may have less public use than many parks, which explains the remarkably low levels of trash in the stream. Still, evidence of littering is present, probably commensurate with the density of use of the site by dog walkers and urban hikers. The lowering of the score through successive site visits (Figure 13) is based on human health indicators like pet waste, which can lower scores significantly due to the adverse effects on water quality. The management of trash at this location is related to the users of the park, the availability of pet waste containers, and its relatively remote location. Park staff have not been contacted as to the frequency of trash pickup, but the Friends of Sausal Creek, with their active stewardship, probably influence the level of trash at this site as well. It is not a coincidence that the active citizen group is correlated with the higher RTA scores consistently recorded at the two upper Sausal Creek sites. Local citizens concerned about quality of life in their neighborhood largely carry out trash management in 2005. Most people in these types of organizations believe that high trash levels in neighborhood creeks lowers the quality of life.

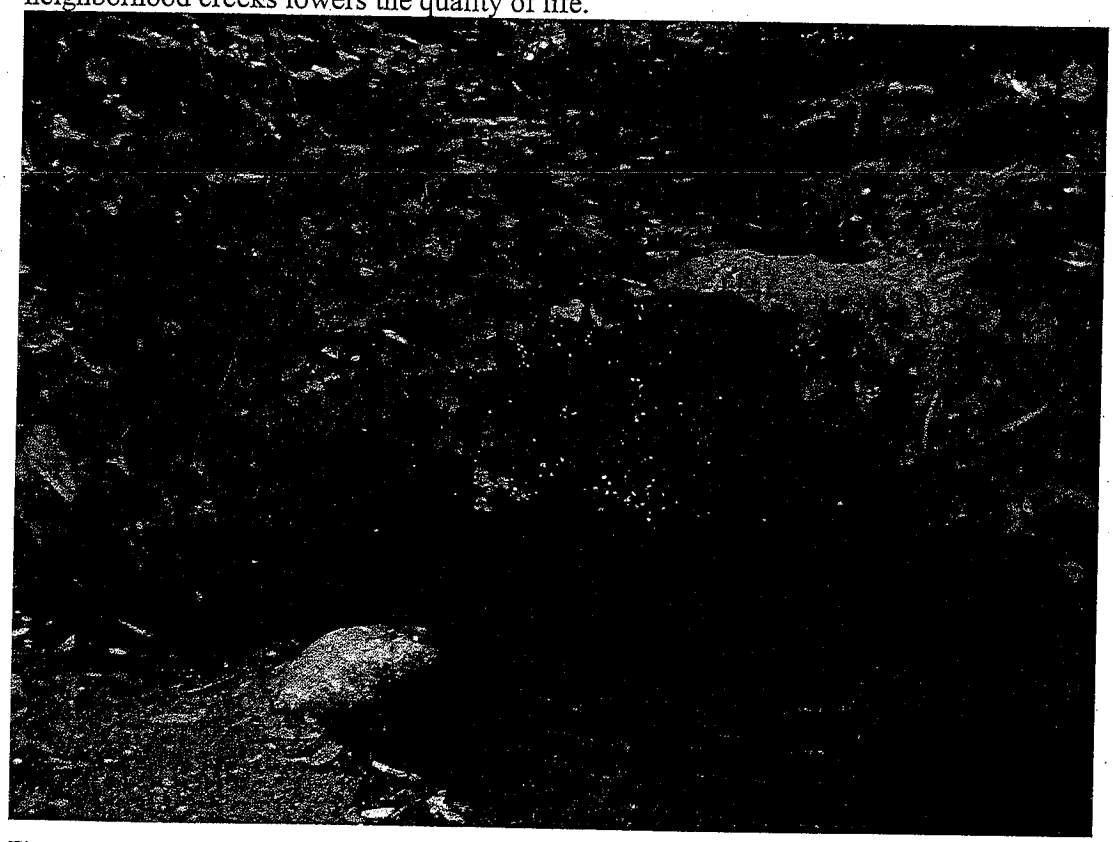

Figure 11: View of trash survey site on Palo Seco Creek in Joaquin Miller Park, Oakland, CA, showing no trash during dry season survey. Some dog waste was in the creekbed, lowering the RTA score from optimal due to the threat to human health. Photo by Steve Moore, August 23, 2005.

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TABLE 1

SAN FRANCISCO BAY REGION TRASH ASSESSMENT STUDY
SITES RANKED BY TRASH DEPOSITION RATE

Date	Rank	Location	Creek	City	Season (dry, wet)	Days between surveys	Trash Deposition Rate (pieces/100 ft-day)
11/19/2004	1	Booker T. Anderson Park	Baxter Cr.	Richmond	w	130	7.47
12/10/2004	2	Oak Glen Park	Glen Echo Cr.	Oakland	w	100	7.17
12/10/2004	3	Strawberry Creek Park	Strawberry Cr.	Berkeley	w	114	5.61
11/7/2003	4	Washington @ McDowell	Washington Cr.	Petaluma	d	108	5.19
2/6/2004	5	Schollenberger Park	Petaluma R.	Petaluma	w	91	5.14
11/5/2004	6	Albany Hill/Creekside Park	Cerrito Cr.	El Cerrito	d	116	5.03
6/10/2005	7	Oak Glen Park	Glen Echo Cr.	Oakland	w	182	4.53
2/20/2004	8	Buchanan Park	Kirker Cr.	Pittsburg	w	210	4.30
1/27/2004	9	Washington @ McDowell	Washington Cr.	Petaluma	w	81	4.17
2/20/2004	10	Dow Wetlands	Kirker Cr.	Pittsburg	w	210	4.17
7/12/2004	11	Albany Hill/Creekside Park	Cerrito Cr.	El Cerrito	d	108	4.11
2/13/2004	12	Gateway Park	San Mateo Cr.	San Mateo	w	116	4.10
12/3/2004	13	Lower Sausal Cr.	Sausal Cr.	Oakland	w	109	3.83
7/12/2004	14	Lower Codornices Cr.	Codornices Cr.	Albany	d	122	3.40
6/8/2005	15	Booker T. Anderson Park	Baxter Cr.	Richmond	w	201	2.92
11/7/2003	16	Schollenberger Park	Petaluma R.	Petaluma	d	108	2.90
7/12/2004	17	Booker T. Anderson Park	Baxter Cr.	Richmond	d	115	2.77
7/25/2003	18	Buchanan Park	Kirker Cr.	Pittsburg	d	128	2.74
3/12/2004	19	Lower Codornices Cr.	Codornices Cr.	Albany	w	300	2.70
11/5/2004	20	Lower Codornices Cr.	Codornices Cr.	Albany	d	116	2.47
12/10/2004	21	Lower Glen Echo Cr.	Glen Echo Cr.	Oakland	w	100	2.41
1/27/2004	22	Petaluma Factory Outlets	Petaluma R.	Petaluma	w	81	1.96
3/14/2004	23	Lower Permanente Cr.	Permanente Cr.	Mountain View	w	135	1.85
7/22/2003	24	Washington @ McDowell	Washington Cr.	Petaluma	d	124	1.85
7/29/2003	25	Lower Permanente Cr.	Permanente Cr.	Mountain View	d	124	1.68
2/13/2004	26	Lower Polhemus Cr.	Polhemus Cr.	San Mateo	w	116	1.58
6/8/2005	27	Baxter Cr. below San Pablo Av.	Baxter Cr.	Richmond	w	208	1.52
6/10/2005	28	Lower Glen Echo Cr.	Glen Echo Cr.	Oakland	w	182	1.43
6/17/2005	29	Lower Sausal Cr.	Sausal Cr.	Oakland	w	196	1.42
7/29/2003	30	Moss Rock	Stevens Cr.	Cupertino	d	124	1.38
10/31/2003	31	Lower Permanente Cr.	Permanente Cr.	Mountain View	d	94	1.14
2/13/2004	32	Arroyo Court Park	San Mateo Cr.	San Mateo	w	116	1.11
6/8/2005	33	Canyon Trail Park	Baxter Cr.	El Cerrito	w	208	1.11
7/22/2003	34	Schollenberger Park	Petaluma R.	Petaluma	d	124	1.07
10/31/2003	35	Moss Rock	Stevens Cr.	Cupertino	d	94	1.03
8/20/2004	36	Madeiros Pkwy. @ Stanley	Arroyo Mocho	Livermore	d	119	0.99
10/20/2003	37	Gateway Park	San Mateo Cr.	San Mateo	d	89	0.94
3/14/2004	38	Moss Rock	Stevens Cr.	Cupertino	w	135	0.93
10/7/2004	39	Gateway Park	San Mateo Cr.	San Mateo	w	237	0.86
11/7/2003	40	Petaluma Factory Outlets	Petaluma R.	Petaluma	d	108	0.85
7/23/2003	41	Gateway Park	San Mateo Cr.	San Mateo	d	124	0.79
12/3/2004	42	Dimond Park	Sausal Cr.	Oakland	w	109	0.72
8/18/2004	43	Strawberry Creek Park	Strawberry Cr.	Berkeley	d	159	0.70
1/27/2004	44	Penngrove Park	Lichau Cr.	Petaluma	w	81	0.64
2/13/2004	45	Upper San Mateo Cr.	San Mateo Cr.	San Mateo	w	116	0.53
6/10/2005	46	Madeiros Pkwy. @ Stanley	Arroyo Mocho	Livermore	w	294	0.53
7/23/2003	47	Arroyo Court Park	San Mateo Cr.	San Mateo	d	124	0.51
7/23/2003	48	Lower Polhemus Cr.	Polhemus Cr.	San Mateo	d	124	0.51
7/25/2003	49	Dow Wetlands	Kirker Cr.	Pittsburg	d	128	0.45
11/7/2003	50	Penngrove Park	Lichau Cr.	Petaluma	d	108	0.37
10/20/2003	51	Arroyo Court Park	San Mateo Cr.	San Mateo	d	89	0.31
10/20/2003	52	Upper San Mateo Cr.	San Mateo Cr.	San Mateo	d	89	0.29
7/23/2003	53	Upper San Mateo Cr.	San Mateo Cr.	San Mateo	d	124	0.25
6/17/2005	54	Dimond Park	Sausal Cr.	Oakland	w	196	0.17
7/22/2003	55	Penngrove Park	Lichau Cr.	Petaluma	d	124	0.15
7/22/2003	56	Petaluma Factory Outlets	Petaluma R.	Petaluma	d	124	0.14
10/20/2003	57	Lower Polhemus Cr.	Polhemus Cr.	San Mateo	d	89	0.13
12/3/2004	58	Joaquin Miller Park	Palo Seco Cr.	Oakland	d	109	0.04
6/17/2005	59	Joaquin Miller Park	Palo Seco Cr.	Oakland	w	196	0.03

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TABLE 2

BOTTOM OF THE WATERSHED (BOTW) TRASH MEASUREMENT LOCATIONS

Location	Water Body	City
Booker T. Anderson Park	Baxter Cr.	Richmond
Albany Hill/Creekside Park	Cerrito Cr.	El Cerrito
Lower Codornices Cr.	Codornices Cr.	Albany
Strawberry Creek Park	Strawberry Cr.	Berkeley
Lower Glen Echo Cr.	Glen Echo Cr.	Oakland
Lower Sausal Cr.	Sausal Cr.	Oakland
Cesar Chavez Park	Peralta Cr.	Oakland
Arroyo Viejo Rec. Center	Arroyo Viejo	Oakland
Schollenberger Park	Petaluma R.	Petaluma
Dow Wetlands	Kirker Cr.	Pittsburg
Madeiros Pkwy. @ Stanley	Arroyo Mocho	Livermore
Gateway Park	San Mateo Cr.	San Mateo
Lower Permanente Cr.	Permanente Cr.	Mountain View

Longitudinal Trends Within Watersheds

To represent levels of trash in streams in the longitudinal gradient (i.e., headwaters to mouth), four watersheds were targeted for multiple sites, including San Mateo Creek, Petaluma River, Baxter Creek, and Sausal Creek. The RTA scores for these sites over the study period are shown in Figures 10-13. As expected, a trend was observed of trash levels in watersheds in the San Francisco Bay Region increased (and RTA scores decreased) as one traveled from the hills toward the Bay. Temporally, the sites further upstream in the watersheds had increased RTA scores over time, with some lowering of scores after the wet season, due to reintroduction of trash in wet weather. BOTW sites exhibited less improvement over time, signifying ongoing reintroduction of trash throughout the year, though more significant during wet weather.

Because trash is removed in the protocol, an expected trend over successive sampling events would be increasing RTA scores and decreasing trash levels in the study reaches. In most cases, especially at the lower watershed sites, RTA scores returned to initial study conditions after wet weather. This trend shows no improvement in trash levels over time with the minimal management measure of picking up trash in 100-foot segments.

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1. San Mateo Creek Watershed

The San Mateo Creek watershed, in San Mateo, CA, is a relatively narrow, urbanized watershed, with two main tributaries coming together in the hillside portion of the city. Polhemus Creek drains a residential area and the upper San Mateo Creek runs along a roadway, downstream of the Crystal Springs Dam with minimal land use. Two sites were measured in the urban plain, Arroyo Court Park (SMA060) and the BOTW site Gateway Park (SMA020), and two sites were measured upstream of the confluence of the two main tributaries.

In Figure 12, the longitudinal trash characteristics of San Mateo Creek are apparent. The lower Gateway Park, though not initially having highest trash levels, had higher sustained trash levels and hence lower RTA scores. Arroyo Court Park, located 2 miles upstream but within urbanized portions of the city, tracked closely with Gateway Park, with higher scores in each season. Polhemus Creek, with the lowest initial score, had higher levels after trash was removed, but wet weather brought a significant return of trash from this residential area. The upper San Mateo creek site saw less return of trash with wet weather, due to less upstream urbanization. This site, known as SMA120 in Figure 12, exhibited the desirable pattern of higher initial levels and less return of trash after "management," or cleanup associated with the RTA protocol, during both dry and wet seasons. Dry season RTA scores were lower at the Gateway and Arroyo Court Park sites, due to direct littering documented at these more publicly accessible sites.

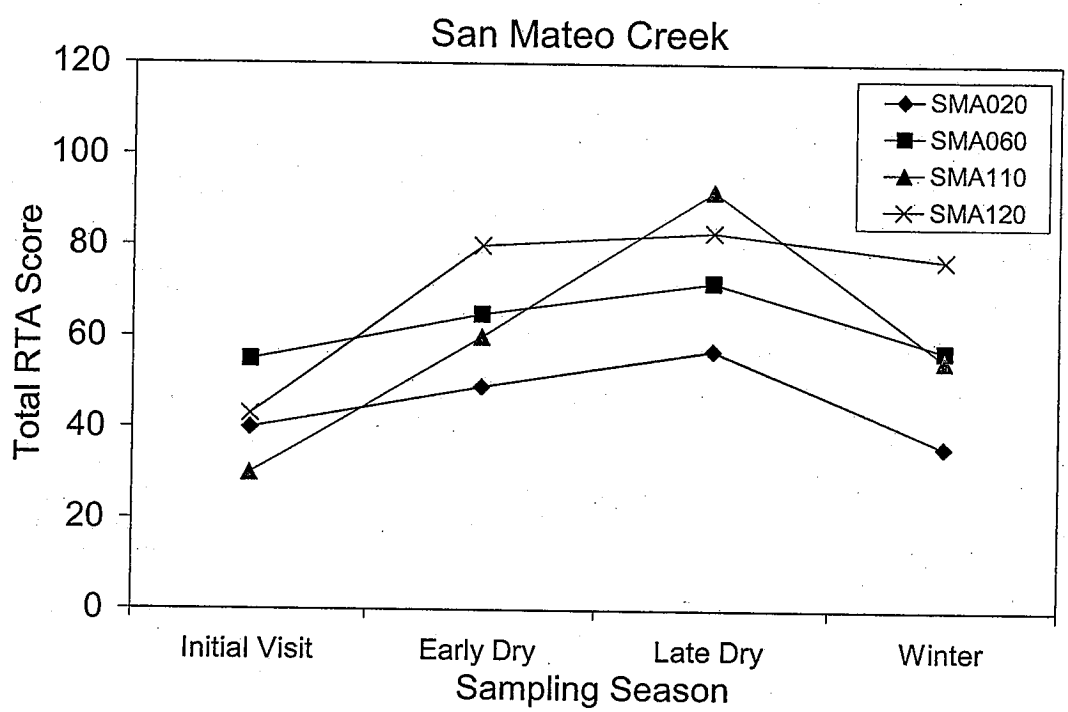

Figure 12: RTA Scores at four sampling sites in the San Mateo Creek watershed along a longitudinal gradient. SMA020 is the lowest site, and SMA110 and SMA120 are the highest sites, both upstream of a confluence of Polhemus and San Mateo creeks.

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2. Petaluma River Watershed

The Petaluma River watershed, in Petaluma, CA, is a broad, low gradient watershed with several small creeks tributary to a large tidal slough, the Petaluma River. The land use is mixed urban, rural residential, and rangeland. The BOTW site is Schollenberger Park (PET100), located along a tidal shoreline downstream of the confluence of Petaluma River with Adobe Creek, and downstream of the City of Petaluma. The next site upstream at the Petaluma Factory Outlets is PET310, and two tributary sites are on Washington Creek (PET220) at a busy intersection at Washington and McDowell including a shopping plaza and gas station, and Lichau Creek at Penngrove Park (PET400). RTA scores for these four sites, surveyed four times each over one year, are shown in Figure 13.

As with San Mateo, this watershed had one site with the desirable pattern of lower trash rate return in dry and wet seasons, the Penngrove Park site, higher in this low gradient watershed. The mid-watershed site at the Outlets showed low initial dry season deposition, but successive deposition through the dry season, and then further degradation the following winter (at levels worse than initial conditions).

A tributary site at Washington Creek, discussed above under Trash Deposition Rates, showed degradation over the dry season, and improvement in the wet season, a sign of high direct deposition and then "cleaning out" by storm flows and delivery to downstream locations and the San Pablo Bay. This site, with an adjacent shopping plaza, large paved parking lot, gasoline station with overflowing dumpster, and an upstream golf course, showed significant levels of litter entering the stream, and represents a trash source area that should be targeted in watershed-wide trash reduction efforts. At site surveys, the wind was observed carrying plastic trash into and over a 4-foot cyclone fence separating the commercial land uses from the stream corridor.

A similar disturbing pattern was seen at the BOTW site in the tidal Petaluma River – indicative of both littering and accumulation in an area characterized by bi-directional flows and deposition on higher tides. The BOTW site in this watershed was unique due to the tidal characteristics and high dry season deposition rates that are not distinguishable from wet season deposition. It calls into question the management of trash at Schollenberger Park; indeed the trash receptacles are not located in a convenient place for use by the park visitors (trash cans are quite distant from the beach), and there is no evidence that the responsible jurisdiction is cleaning trash from the beach.

Figure 13 shows that the Petaluma River watershed had lower overall scores after the surveys and cleanups than initial scores. While it may be premature to conclude that trash levels are getting worse, it can be reasonably concluded that trash levels in streams are not improving in this watershed.

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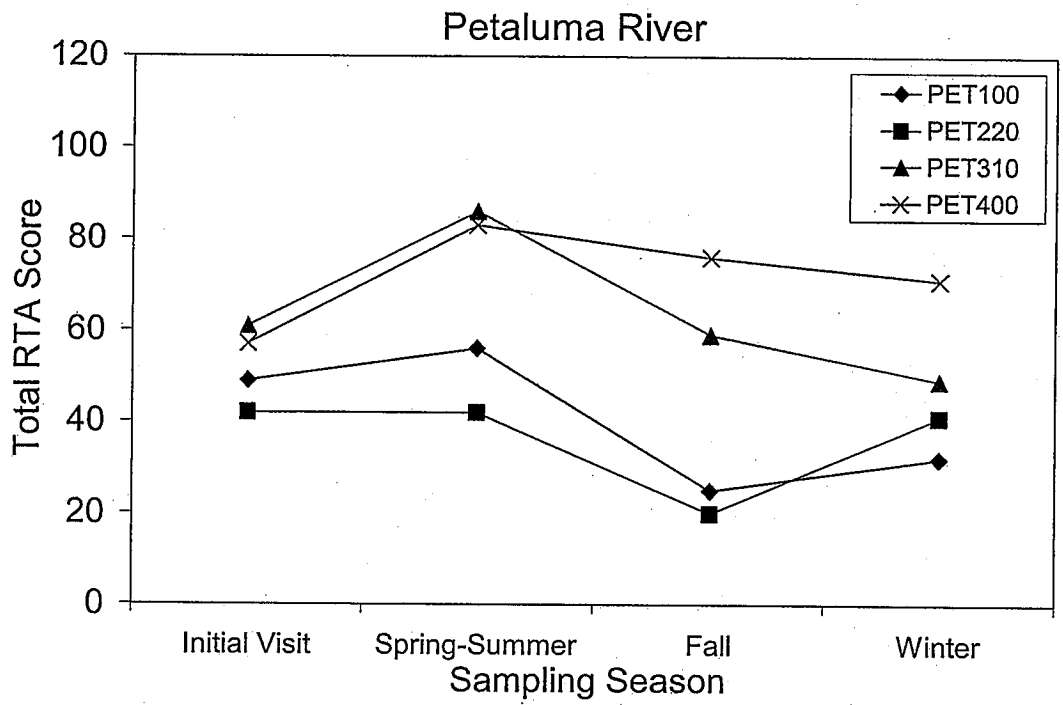

Figure 13: RTA Scores at four sampling sites in the Petaluma River watershed along a longitudinal gradient. PET100 is the lowest site, PET310 is upstream on the main branch, and PET220 and PET400 are the tributary sites. PET220 tributary (Washington Cr.) enters the main branch downstream of PET310. Except for PET400, the final scores are below the initial scores, indicating that trash levels may be getting worse in this watershed.

3. Baxter Creek Watershed

The Baxter Creek watershed is a smaller watershed that originates in the hills of El Cerrito, and drains to San Francisco Bay through the City of Richmond, in a densely urbanized area. There have been recent efforts to restore portions of the creek channel to more natural conditions, but these areas have been plagued by trash deposition, discussed above under the Trash Deposition Rates section.

The lowest site at Booker T. Anderson Park has been discussed above, and exhibits both dry and wet season inputs of trash. The flatline pattern of scores in Figure 14, at or around the low score of 20, shows a steady level of trash regardless of the trash removal conducted in the surveys, and regardless of season. Similar problems were documented at the next site upstream, but there was less wet season deposition effects than at Booker T. Anderson Park. The site at Canyon Trail Park in the El Cerrito hills had significantly higher RTA scores in dry and wet seasons, demonstrating the longitudinal pattern of trash levels seen region-wide.

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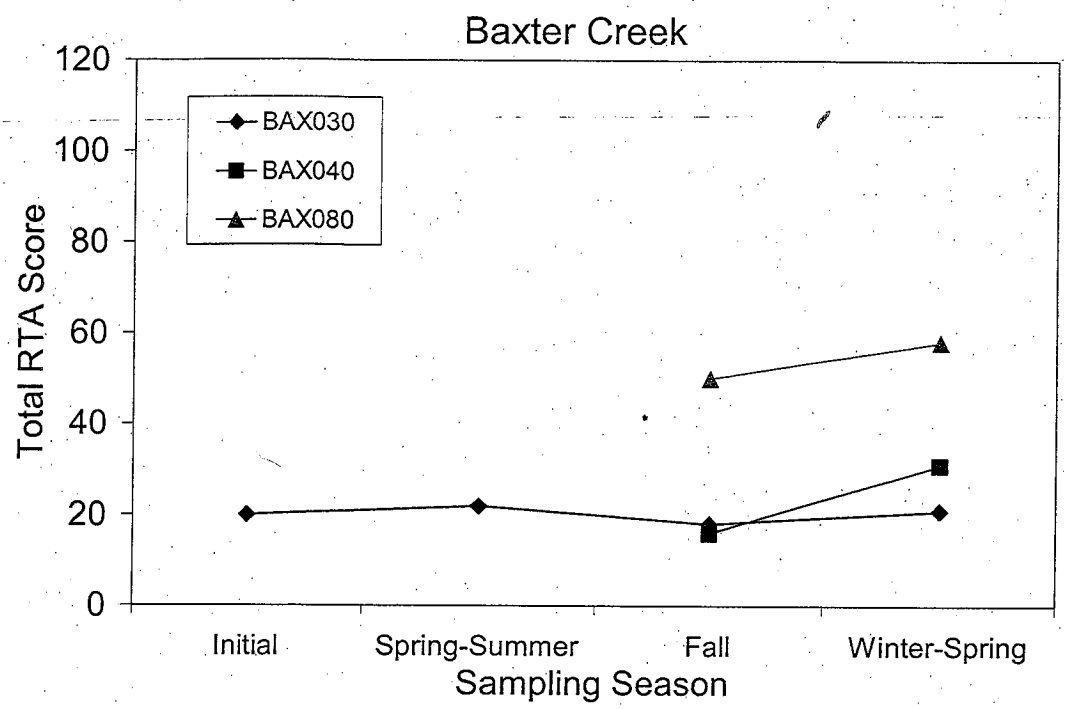

Figure 14: RTA Scores at three sampling sites in the Baxter Creek watershed along a longitudinal gradient. BAX030 is the lowest site, BAX040 is upstream on the main branch at San Pablo Avenue, and BAX080 is at Canyon Trail Park, also on the main branch, in El Cerrito.

4. Sausal Creek Watershed

The Sausal Creek watershed is another smaller watershed that begins in the hills above Oakland, CA, and drains through the dense urban landscape to the Oakland Inner Harbor. The active Friends of Sausal Creek have elevated the importance of the creek to the City and the neighbors, and effective cleanup and restoration projects have been implemented in this watershed.

This watershed was discussed above under the low trash deposition sites, because the two upper sites, Dimond Park (SAU060) and Joaquin Miller Park (SAU130) have the lowest deposition rates in the regional study. The City's park department and the local volunteers of the Friends of Sausal Creek actively manage trash in Dimond Park. In Figure 15, this site exhibits the desirable pattern of improvement with successive site surveys – the higher RTA score was recorded at the last site visit after the wet season, showing a measurable effect of active site management by the City and the local residents. The site on Palo Seco Creek in Joaquin Miller Park is publicly accessible, but above most of the urban areas and not as frequently visited. This site serves as a regional "reference" site in this study, with very low trash levels, showing that an urban creek site with minimal trash is achievable.

The lower Sausal Creek site at E 22nd St. shows a significantly different picture of a site heavily impacted by trash. The open channel upstream of the site appears to attract

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illegal dumpers and litterers, and adjacent landowners were observed dumping their household trash into the stream area. This area could be a focus for progressive education, warning and enforcement of existing littering laws.

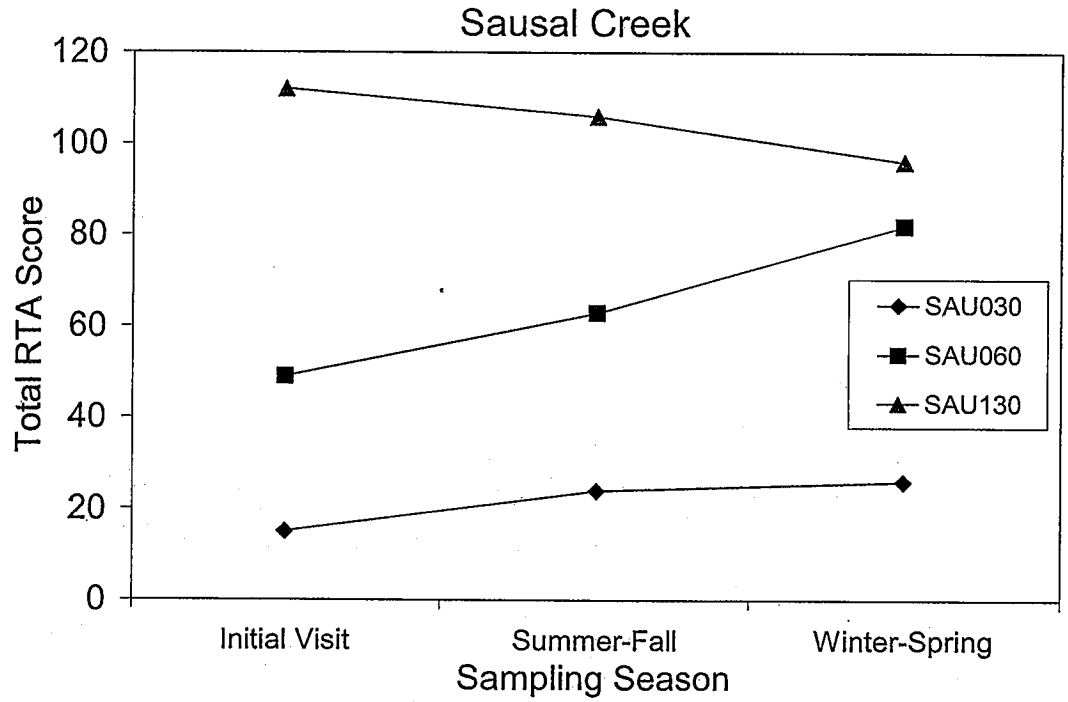

Figure 15: RTA scores at three sampling sites in the Sausal Creek watershed along a longitudinal gradient. SAU030 is the lowest site at E. 22nd Street, SAU060 is at Dimond Park, and SAU130 is on Palo Seco Creek in Joaquin Miller Park, all in Oakland, CA.

Conclusions

The data collected and presented in this report, over the 2003-2005 period, suggest that the current management approach to managing trash in water bodies is not improving the problem. The levels of trash in the waters of the San Francisco Bay Region are alarmingly high, considering the Basin Plan prohibits discharge of trash and that littering is illegal with potentially large fines. Even during dry weather conditions, a significant quantity of trash, particularly plastic, is making its way into waters and being transported downstream to San Francisco Bay and the Pacific Ocean. Based on 85 surveys conducted at 26 sites throughout the Bay Area, we have found an average of 2.93 pieces of trash for every foot of stream, and all the trash was removed when it was surveyed, indicating high return rates of trash over the 2003-2005 study period. There did not appear to be one county or region with higher trash in waters – the highest wet weather deposition rates were found in western Contra Costa County and the highest dry weather deposition was found in Sonoma County. Without an assessment method such as the one used in this study, people could draw the wrong conclusion that adjacent neighborhoods pollute the sites at the bottom of the watershed. This study shows that these areas, which tend to have lower property values, are polluted cumulatively by the entire watershed.

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A number of key conclusions can be made based on the trash measurement in streams:

- Lower watershed sites have higher densities of trash.
- All watersheds studied in the San Francisco Bay region (Figure 1) have high levels of trash.
- There are trash source hotspots, usually associated with parks, schools, or poorly kept commercial facilities, near creek channels, that appear to contribute a significant portion of the trash deposition at lower watershed sites.
- Dry season deposition of trash, associated with wind and dry season runoff, contributes measurable levels of trash to downstream locations.
- The majority of trash is plastic at lower watershed sites where trash accumulates in the wet season. This suggests that urban runoff is a major source of floatable plastic found in the ocean and on beaches as marine debris.
- Parks that have more evident management of trash by City staff and local volunteers, including cleanup within the creek channel, have measurably less trash pieces and higher RTA scores.

The ubiquitous, unacceptable levels of trash in waters of the San Francisco Bay Region warrant a comprehensive and progressive program of education, warning, and enforcement, and certain areas warrant consideration of structural controls and treatment. It seems that the public-at-large do not grasp the risks associated with littering on streets that drain to waters, let alone in parks that have running streams. A more aggressive campaign for educating the public about the ultimate fate of litter is overdue.

This program should begin with implementation within municipal jurisdictions. Employees of parks and schools that pick up trash need to be instructed to pick up trash near and within streams, and equipped accordingly. Trash receptacles need to be placed near publicly accessible waters, with educational messages about marine debris and human health risks of trash. These receptacles need to be actively managed so they do not become a source of trash to waters.

As with most issues, not every member of the public will follow littering rules, even if better educated about the harm litter can do to people and animals. Certain watersheds with chronic trash problems will warrant structural controls, as has been the case with the 303d-listed Lake Merritt in Oakland. The results documented in this report suggest that the structural removals should not be limited to wet weather loading.

Businesses need to do a better job of keeping trash associated with their operations from waters of the state. Styrofoam pellets were one of the most common and abundant types of trash surveyed and removed in this study, and the literature shows that they are long-

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lived and harmful to marine life (Marine Mammal Commission, 1996). They are most often used as packing and shipping materials. Businesses should be a target of education and then enforcement with respect to management of packing and shipping materials. Large amounts of these pellets were documented downstream of downtown Berkeley in Strawberry Creek, and this serves as an example of business contribution to the trash problem. This Styrofoam (303 pellets and 125 pieces in December 2004) could be coming from careless handling of packing materials and their allowance to enter the storm drains.

Similarly, dumpsters at gasoline stations such as the one at Washington and McDowell in Petaluma should be identified and regulated as potential sources of trash to waters of the state. The adjacent shopping plaza at that location was an unmanaged, continuous source of litter and trash to waters of the state, regardless of season. These businesses need to be first educated and then regulated, preferably by municipalities as part of the municipal stormwater program, as potential sources of trash to streams, bays and the ocean.

The Rapid Trash Assessment protocol has been shown to be useful in distinguishing trash levels in streams between sites, in determining trash deposition rates, in ranking sites, and determining whether deposition of trash occurs in dry season, wet season or both. In many cases the protocol confirmed what could be simply observed, but it allows a systematic quantification and indexing of sites that can facilitate prioritization for pollution abatement. The San Francisco Bay Region has a problem with trash in streams and the Bay. The protocol has assisted the Water Board in understanding the sources, management issues, and the overall scope of the problem of trash in waters of the state. It is hoped that the protocol will be as useful in evaluating the success of management efforts yet to come.

Figure 16: Water Board staff remove a shopping cart from the Booker T. Anderson Park trash site. Photo by Kim Harrison, August 23, 2005.

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APPENDIX A

RAPID TRASH ASSESSMENT PROTOCOL WORKSHEET

A014729

Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

WATERSHED/STREAM: _____ DATE/TIME: _____
MONITORING GROUP, STAFF: _____ SAMPLE ID: _____
SITE DESCRIPTION (Station Name, Number, etc.): _____

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
1. Level of Trash	On first glance, no trash visible. Little or no trash (<10 pieces) evident when streambed and stream banks are closely examined for litter and debris, for instance by looking under leaves.	On first glance, little or no trash visible. After close inspection small levels of trash (10-50 pieces) evident in stream bank and streambed.	Trash is evident in low to medium levels (51-100 pieces) on first glance. Stream, bank surfaces, and riparian zone contain litter and debris. Evidence of site being used by people: scattered cans, bottles, food wrappers, blankets, clothing.	Trash distracts the eye on first glance. Stream, bank surfaces, and immediate riparian zone contain substantial levels of litter and debris (>100 pieces). Evidence of site being used frequently by people: many cans, bottles, and food wrappers, blankets, clothing.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Actual Number of Trash Items Found	0 to 10 trash items found based on a trash assessment of a 100-foot stream reach.	11 to 50 trash items found based on a trash assessment of a 100-foot stream reach.	51 to 100 trash items found based on a trash assessment of a 100-foot stream reach.	Over 100 trash items found based on a trash assessment of a 100-foot stream reach.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Threat to Aquatic Life	Trash, if any, is mostly paper or wood products or other biodegradable materials. Note: A large amount of rapidly biodegradable material like food waste creates high oxygen demand, and should not be scored as optimal.	Little or no (<10 pieces) transportable, persistent, buoyant litter such as: hard or soft plastics, Styrofoam, balloons, cigarette butts. Presence of settleable, degradable, and non-toxic debris such as glass or metal.	Medium prevalence (10-50 pieces) of transportable, persistent, buoyant litter such as: hard or soft plastics, Styrofoam, balloons, cigarette butts Larger deposits (< 50 pieces) of settleable debris such as glass or metal. Any evidence of clumps of deposited yard waste or leaf litter.	Large amount (>50 pieces) of transportable, persistent, buoyant litter such as: hard or soft plastics, balloons, Styrofoam, cigarette butts; toxic items such as batteries, lighters, or spray cans; large clumps of yard waste or dumped leaf litter; or large amount (>50 pieces) of settleable glass or metal.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Threat to Human Health	Trash contains no evidence of bacteria or virus hazards such as medical waste, diapers, pet or human waste. No evidence of toxic substances such as chemical containers or batteries. No ponded water for mosquito production. No evidence of puncture and laceration hazards such as broken glass or metal debris.	No bacteria or virus hazards or sources of toxic substances, but small presence (<10 pieces) of puncture and laceration hazards such as broken glass and metal debris. No presence of ponded water in trash items such as tires or containers that could facilitate mosquito production.	Presence of **any one** of the following: hypodermic needles or other medical waste; used diaper, pet waste, or human feces; any toxic substance such as chemical containers, batteries, or fluorescent light bulbs (mercury). Medium prevalence (10-50 pieces) of puncture hazards.	Presence of **more than one** of the items described in the marginal condition category, or high prevalence of any one item (e.g. greater than 50 puncture or laceration hazards).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

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Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
5. Illegal Dumping	D: No evidence of illegal dumping. No bags of trash, no yard waste, no household items placed at site to avoid proper disposal, no shopping carts.	D: Some evidence of illegal dumping. Limited vehicular access limits the amount of potential dumping, or material dumped is diffuse paper-based debris.	D: Presence of one of the following: furniture, appliances, shopping carts, bags of garbage or yard waste, coupled with vehicular access that facilitates in-and-out dumping of materials to avoid landfill costs.	D: Evidence of chronic dumping, with **more than one** of the following items: furniture, appliances, shopping carts, bags of garbage, or yard waste. Easy vehicular access for in-and-out dumping of materials to avoid landfill costs.
Illegal Littering	L: Any trash is incidental litter (< 5 pieces) or carried downstream from another location.	L: Some evidence of litter within creek and banks originating from adjacent land uses (<10 pieces).	L: Prevalent (10-50 pieces) in-stream or shoreline littering that appears to originate from adjacent land uses.	L: Large amount (>50 pieces) of litter within creek and on banks that appears to originate from adjacent land uses.
D-SCORE	10 9	8 7 6	5 4 3	2 1 0
L-SCORE	10 9	8 7 6	5 4 3	2 1 0
6. Accumulation of Trash	There does not appear to be a problem with trash accumulation from downstream transport. Trash, if any, appears to have been directly deposited at the stream location.	Some evidence (<10 pieces) that litter and debris have been transported from upstream areas to the location, based on evidence such as silt marks, faded colors or location near high water line.	Evidence that (10 to 50 pieces) trash is carried to the location from upstream, as evidenced by its location near high water line, siltation marks on the debris, or faded colors.	Trash appears to have accumulated in substantial quantities at the location based on delivery from upstream areas, and is in various states of degradation based on its persistence in the waterbody. Over 50 items of trash have been carried to the location from upstream.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Total Score _____

SITE DEFINITION:

UPPER/LOWER BOUNDARIES OF REACH: _____

HIGH WATER LINE: _____

UPPER EXTENT OF BANKS OR SHORE: _____

_____

NOTES:

_____

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Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

TRASH ITEM TALLY (Tally with (•) if found above high water line, and (|) if below)

PLASTIC # Above___ # Below___	**METAL** # Above___ # Below___
Plastic Bags	Aluminum Foil
Plastic Bottles	Aluminum or Steel Cans
Plastic Bottle Caps	Bottle Caps
Plastic Cup Lid/Straw	Metal Pipe Segments
Plastic Pipe Segments	Auto Parts (specify below)
Plastic Six-Pack Rings	Wire (barb, chicken wire etc.)
Plastic Wrapper	Metal Object
Soft Plastic Pieces	**LARGE (specify below)** # Above___ # Below___
Hard Plastic Pieces	Appliances
Styrofoam cups pieces	Furniture
Styrofoam Pellets	Garbage Bags of Trash
Fishing Line	Tires
Tarp	Shopping Carts
Other (write-in)	Other (write-in)
BIOHAZARD # Above___ # Below___	**TOXIC** # Above___ # Below___
Human Waste/Diapers	Chemical Containers
Pet Waste	Oil/Surfactant on Water
Syringes or Pipettes	Spray Paint Cans
Dead Animals	Lighters
Other (write-in)	Small Batteries
CONSTRUCTION DEBRIS #Above___ #Below___	Vehicle Batteries
Concrete (not placed)	Other (write-in)
Rebar	**BIODEGRADABLE** # Above___ # Below___
Bricks	Paper
Wood Debris	Cardboard
Other (write-in)	Food Waste
MISCELLANEOUS # Above___ # Below___	Yard Waste (incl. trees)
Synthetic Rubber	Leaf Litter Piles
Foam Rubber	Other (write-in)
Balloons	**GLASS** # Above___ # Below___
Ceramic pots/shards	Glass bottles
Hose Pieces	Glass pieces
Cigarette Butts	**FABRIC AND CLOTH** # Above___ # Below___
Golf Balls	Synthetic Fabric
Tennis Balls	Natural Fabric (cotton, wool)
Other (write-in)	Other (write-in)
Total pieces Above: **Below:** **Grand total:**	
Tally all trash in above rows; make notes below as needed to facilitate scoring.	
Littered:	
Dumped:	
Downstream Accumulation:	

SPECIFIC DESCRIPTION OF ITEMS FOUND:_____

_____

_____

A014732

APPENDIX B

RAPID TRASH ASSESSMENT METHOD EVALUATION
OCTOBER 2002

A014733

Evaluation of the Rapid Trash Assessment Methodology

October 20, 2002

The rapid trash assessment methodology was developed by Steve Moore and Matthew Cover of the San Francisco Bay Regional Board's Surface Water Ambient Monitoring Program. The scoring system is based on the physical habitat evaluation forms associated with the federal and state guidance on rapid bioassessment. This methodology was developed with three goals: to be representative, sensitive, and objective.

To be representative, the generated scores need to represent an assessment of impairment of beneficial uses by trash. Beneficial uses affected by trash include aquatic life uses, water contact uses, and aesthetic enjoyment of waters. Also, the assessment methodology needs to consider how trash gets to the water body (direct dumping vs. accumulation in drainage systems) to represent an evaluation of management actions related to controlling dumping, littering, or accumulation of trash. The six trash assessment parameters of the methodology cover this range of issues associated with beneficial uses and management actions related to trash in water bodies. The assessment methodology has been structured to balance these issues in a scoring system, which we believe has achieved the necessary level of representativeness.

To be sensitive, the generated scores need to be able to distinguish light, medium, and heavy states of impairment of beneficial uses by trash at different sites and seasons. The overall score range of 0 to 120 should provide this sensitivity, where sites with scores of 60 +/- 15% can be distinguished in threat to beneficial uses from sites with scores of 80 +/- 15%.

To be objective, variability needs to be minimized. The generated scores by different teams on the same reach should not range too widely. The scores should not be more than 15% different than one another.

To evaluate sensitivity and objectivity of this methodology, three teams were deployed on the same day at four sites located along East Bay creeks. One site was located on Wilkie Creek, a tributary to San Pablo Creek in El Sobrante (next to a high school). Another site was located on Wildcat Creek in Alvarado Park in Richmond. These two sites were surveyed by Regional Board staff on August 14, 2002. Two sites were located on Sausal Creek in Oakland, at Dimond Park and at Barry Street (residential area), surveyed on August 20, 2002 by staff of the Regional Board and the Alameda and Santa Clara urban runoff programs.

Of these test sites, the two urban park sites are considered to be more actively "managed" for trash, with nearby trashcans and available park and volunteer personnel. The high school site and the residential site had no evident active management, and these sites had higher trash tallies. Therefore, in evaluating whether the assessment methodology is sufficiently sensitive, we believe the scores generated for the park sites should be statistically higher (more optimal) than the other sites.

A014734

TABLE 1
RAPID TRASH ASSESSMENT
RESULTS OF METHODOLOGY EVALUATION

Site	Water Body	Date	Staff	1 Qual.	2 Quant.	3 Aq. Life	4 Hum. Health	5 Dumping	6 Accum.	Total Score	Trash Item Tally Total
				Trash Assessment Parameter Scores							
Alvarado Park	Wildcat Creek	8/14/02	NW, GC	10	5	10	13	15	15	**68**	**55**
Alvarado Park	Wildcat Creek	8/14/02	SM, PE	14	4	9	10	8	15	**60**	**68**
Alvarado Park	Wildcat Creek	8/14/02	MC, KT	10	5	6	6	13	16	**56**	**50**
	Coefficients of Variation:			0.20	0.12	0.25	0.36	0.30	0.04	0.10	0.16
Anza School	Wilkie Creek	8/14/02	GC, MC	5	0	3	16	10	2	**36**	**334**
Anza School	Wilkie Creek	8/14/02	SM, PE	3	1	3	13	14	2	**36**	**140**
Anza School	Wilkie Creek	8/14/02	KT, NW	6	0	6	13	12	2	**39**	**444**
	Coefficients of Variation:			0.33	1.73	0.43	0.12	0.17	0.00	0.05	0.50
Dimond Park	Sausal Creek	8/20/02	GC, Alej.	13	0	11	20	15	15	**74**	**138**
Dimond Park	Sausal Creek	8/20/02	MC, PR	10	4	10	15	11	14	**64**	**70**
Dimond Park	Sausal Creek	8/20/02	SM, NW	8	4	9	10	13	14	**58**	**75**
	Coefficients of Variation:			0.24	0.87	0.10	0.33	0.15	0.04	0.12	0.40
Barry Street	Sausal Creek	8/20/02	MC, PR	2	1	5	10	6	8	**32**	**291**
Barry Street	Sausal Creek	8/20/02	NW, SM	3	1	3	12	5	9	**33**	**293**
Barry Street	Sausal Creek	8/20/02	GC, Alej.	4	0	5	11	6	10	**36**	**404**
	Coefficients of Variation:			0.33	0.87	0.27	0.09	0.10	0.11	0.06	0.20

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The tallies and scores from the test assessments are summarized in Table 1. Overall, they demonstrate that the assessment methodology is sufficiently sensitive and objective to be useful in evaluating ambient conditions, trash management actions, and the effect of public access on trash levels. Except for two experienced staff persons, these test assessments were conducted mostly by staff with little or no experience, but some limited training in the use of the methodology. As such, the test assessment is a reasonable representation of what would be expected if a team of municipal employees or interested citizens conducted the assessment. The consistency of the scores in the test assessment underscores the confidence that Regional Board staff have in the methodology. Nevertheless, a few lessons were learned through this exercise and improvements made to create Version 6 of the Rapid Trash Assessment, discussed below.

As shown in Table 1, the total scores for the 4 sites were clustered closely, with some variability noted in individual trash assessment parameters. The exception was the Dimond Park site at Sausal Creek, with scores ranging from 58 to 74. During the field exercise, the staff discussed this difference and traced it to the variable human health score (20, 15, and 10). The key to the scoring difference was that one team noted the presence of a used diaper on the stream bank near the water, and others had mis-characterized it as paper or fabric waste. Also, some broken glass on the bank was noted by the team that scored a "15." This example shows the importance of identifying human health hazards, if any, and how the presence of one or two items can change the score significantly. The instructions have been modified accordingly, emphasizing that tallying can be estimated, but that bio-hazards must be carefully tallied to allow consistent scoring. All field staff agreed that the scores would have been less variable if all the teams had correctly identified the diaper.

Despite some variability between teams, the assessment methodology achieved the desired level of sensitivity. As hoped, the urban park sites had significantly higher scores than the unmanaged sites, demonstrating the desired sensitivity of the methodology. Alvarado Park (mean=61, CV=0.10) and Dimond Park (mean=65, CV=0.12) were clearly distinguishable from Anza School (mean=37, CV=0.05) and Barry Street on Sausal Creek (mean=34, CV=0.06).

In Table 1, the coefficient of variation (CV), which is the standard deviation divided by the arithmetic mean, expresses the variability of the scores and tallies of the rapid trash assessment. The CV overstates variability at the low end (scores of 0, 1, and 2), so the relatively high CVs associated with these scores for the quantitative level of trash (assessment parameter 2) can be ignored and the scores visually compared. For the overall score, a CV of 0.15 or less is desirable for demonstrating objectivity of the methodology. As discussed above, the only case where significant variability occurred was Dimond Park, and the variability was due to improper field identification of trash. As with the physical habitat evaluation associated with the rapid bioassessment procedures, such skills are expected to be acquired by a field technician through experience, and variability of that technician's scoring subsequently minimized.

The total trash tallies were substantially more variable than the assessment scores, as expected (Table 2). The rapid trash assessment procedure does not emphasize that these tallies be exact, but rather be used to help guide the assessment scoring by characterizing relative levels of different trash items and materials. Much of the variability in the overall tallies in Table 2 is ascribed to different teams' conventions of counting broken items as individual pieces or just as one item (e.g., a broken glass bottle). Additional guidance is now provided in Version 6 regarding conventions to be used for tallying "broken" trash items, rooted in the principle of exposure to fish, wildlife, or human users of the water body. Tallies less than 50 are expected to be less variable and with the additional guidance, we expect tallies to exhibit less variability than these test assessments.

A014736

TABLE 2
RAPID TRASH ASSESSMENT METHODOLOGY EVALUATION
TRASH ITEM TALLY RESULTS

Site	Water Body	Date	Staff	Trash Item Tally: Plastic in*	Plastic out*	Biohaz. in	Biohaz. out	Const. in	Const. out	Misc. in	Misc. out	Metal in	Metal out	Large in	Large out	Toxic in	Toxic out	Biodeg. in	Biodeg. out	Glass in	Glass out	Fabric in	Fabric out	TOTAL
Alvarado Park	Wildcat Creek	8/14/02	NW, GC	21	4	0	0	0	0	7	1	1	1	0	1	0	0	3	7	7	0	1	1	**55**
Alvarado Park	Wildcat Creek	8/14/02	SM, PE	11	19	0	2	1	1	7	3	0	1	0	5	0	0	10	3	2	0	0	3	**68**
Alvarado Park	Wildcat Creek	8/14/02	MC, KT	15	6	0	1	0	0	3	2	5	0	0	0	1	0	7	2	3	3	1	1	**50**
	Coefficients of Variation:																							0.16
Anza School	Wilkie Creek	8/14/02	GC, MC	192	87	0	0	3	4	14	0	3	6	0	0	0	0	8	13	1	1	1	1	**334**
Anza School	Wilkie Creek	8/14/02	SM, PE	21	69	0	0	11	4	7	0	3	3	0	0	0	0	3	19	0	0	0	0	**140**
Anza School	Wilkie Creek	8/14/02	KT, NW	200	147	0	0	3	4	1	17	7	8	0	0	0	0	10	46	1	0	0	0	**444**
	Coefficients of Variation:																							0.50
Dimond Park	Sausal Creek	8/20/02	GC, Alej.	8	88	0	0	0	0	2	2	5	4	0	0	0	3	23	0	0	0	3	0	**138**
Dimond Park	Sausal Creek	8/20/02	MC, PR	20	17	0	0	0	0	1	0	5	3	0	0	0	0	9	8	2	2	3	0	**70**
Dimond Park	Sausal Creek	8/20/02	SM, NW	16	25	0	1	6	0	2	1	2	3	0	0	0	0	6	9	0	0	3	1	**75**
	Coefficients of Variation:																							0.40
Barry Street	Sausal Creek	8/20/02	MC, PR	59	26	0	0	26	2	35	1	25	1	0	1	1	2	13	9	82	2	5	1	**291**
Barry Street	Sausal Creek	8/20/02	NW, SM	65	42	0	0	49	8	9	2	10	14	0	1	1	1	8	15	57	6	2	3	**293**
Barry Street	Sausal Creek	8/20/02	GC, Alej.	63	50	0	0	84	8	5	4	15	13	0	1	0	0	10	13	73	59	5	1	**404**
	Coefficients of Variation:																							0.20

* "in" refers to in-stream, and "out" refers to above high water line, but on banks or shore where transport to water body is probable.

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The tallies above 50 do not have a significant effect on the scoring outcome, because the assessment parameter 2, actual number of trash items, allows a small range of 0-5 scoring for sites with more than 50 items. Resolution is not required at these higher levels of trash, but items that can substantially affect the score, such as large appliances or health-related items need to be tallied to ensure consistent and accurate scoring.

In applying the methodology, it has been SWAMP staff's experience that photography does not provide adequate illustration of trash conditions, unless there are large items or the photography is very close-up (but then it only represents a few square feet). Much of the trash that can affect aquatic life or human health is not visible in a digital photograph of a sampling site, due to vegetative cover and reflection of the water surface. Based on evaluations at over 40 sites, we have determined without exception that photography is less effective at documenting trash conditions than the Rapid Trash Assessment scoring methodology.

The Rapid Trash Assessment is less sensitive at the low end of the scoring range, corresponding to conditions commonly observed in the lower watersheds of urbanized areas. Based on SWAMP surveys conducted in 2002, many of the urban sites located in the lower portions of watersheds exhibit total scores below 40. It is difficult to distinguish conditions at these "trash hotspots," since this Rapid Trash Assessment methodology covers the range of conditions from optimal to poor. Since the urban areas that register "poor" scores tend to be of most interest in cleanup programs sponsored by local organizations and agencies, some concern has been expressed that a separate hotspot evaluation methodology may need to be developed, perhaps making more use of photography. A separate methodology may be necessary to demonstrate progress at the most impacted sites, but this methodology evaluation, utilizing independent assessment teams, has shown that the Rapid Trash Assessment can distinguish sites within urban areas that are receiving more trash management from areas that are not. In both examples evaluated, the urban parks had significantly higher scores than the sites that appear to receive little or no trash management.

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APPENDIX C

RAW RTA TRASH SCORE DATA

A014739

Date	Station ID	BOTW	Park w/ High Public Access	1	2	3	4	5	6	7	Total	Plastic	
				Qualitative	Quantitative	Aquatic	Human	Dumping	Littering	Accumulation		Above	Below
3/19/2004	203BAX030	1	1	5	0	0	10	5	0	0	**20**	130	701
7/12/2004	203BAX030	1	1	9	3	1	2	3	0	4	**22**	49	150
11/19/2004	203BAX030	1	1	3	0	0	4	8	3	0	**18**	33	543
6/8/2005	203BAX030	1	1	8	1	3	5	2	2	0	**21**	29	335
11/12/2004	203BAX040			0	0	0	3	8	0	5	**16**	487	202
6/8/2005	203BAX040			5	3	4	3	1	0	15	**31**	184	18
11/12/2004	203BAX080			10	4	2	17	10	5	2	**50**	6	187
6/8/2005	203BAX080			15	4	5	13	10	9	2	**58**	10	189
3/26/2004	203CER010	1	1	3	3	4	9	5	2	2	**28**	44	172
7/12/2004	203CER010	1	1	3	2	0	4	9	0	9	**27**	132	64
11/5/2004	203CER010	1	1	1	1	1	3	8	2	0	**16**	23	247
5/17/2003	203COD040		1	7	3	8	9	7	0	5	**39**	65	103
/12/2004	203COD040		1	7	0	3	0	6	5	3	**24**	140	42
/12/2004	203COD040		1	10	3	4	3	6	0	3	**29**	33	183
5/2004	203COD040		1	8	3	4	0	7	1	4	**27**	9	101
2/2004	203STW010	1		0	0	1	3	9	9	0	**22**	312	49
8/18/2004	203STW010	1		13	5	5	9	3	8	5	**48**	0	52
12/10/2004	203STW010	1		5	0	0	5	8	5	0	**23**	2	549
4/23/2004	204AMO080		1	10	10	7	19	10	4	8	**68**	5	39
8/20/2004	204AMO080		1	7	5	6	5	4	2	15	**44**	25	25
6/10/2005	204AMO080		1	8	1	5	15	4	1	14	**48**	41	35
7/19/2004	204AVJ020		1	3	2	1	4	7	2	2	**21**	21	234
9/1/2004	204LME100	1		10	4	3	5	3	0	3	**28**	61	44
12/10/2004	204LME100	1		14	4	3	10	9	8	2	**50**	0	135
6/10/2005	204LME100	1		13	3	3	8	3	8	3	**41**	0	152
9/1/2004	204LME130		1	7	2	4	3	3	2	10	**31**	32	55
12/10/2004	204LME130		1	10	0	3	0	8	4	0	**25**	17	61
6/10/2005	204LME130		1	14	0	3	0	10	9	2	**38**	3	96
7/19/2004	204PRL020	1	1	3	0	0	0	2	3	0	**8**	19	343
8/16/2004	204SAU030	1		0	0	0	0	7	0	8	**15**	91	270

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12/3/2004	204SAU030	1		8	2	3	3	3	1	4	**24**	76	98
6/17/2005	204SAU030	1		8	4	2	2	2	5	3	**26**	26	60
8/16/2004	204SAU060		1	9	5	4	10	10	1	10	**49**	0	72
12/3/2004	204SAU060		1	13	7	7	15	10	4	7	**63**	22	26
6/17/2005	204SAU060		1	19	13	9	15	10	8	8	**82**	2	22
8/16/2004	204SAU130		1	20	19	19	15	10	9	20	**112**	0	1
12/3/2004	204SAU130		1	20	18	15	15	10	9	19	**106**	0	0
6/17/2005	204SAU130		1	20	18	14	10	10	9	15	**96**	0	2
3/21/2003	204SMA020	1	1	11	0	8	6	9	4	2	40	9	23
7/23/2003	204SMA020	1	1	6	6	8	10	8	1	10	49	7	26
10/20/2003	204SMA020	1	1	10	4	10	13	6	4	10	57	9	6
2/13/2004	204SMA020	1	1	9	2	9	2	8	4	2	36	9	18
10/7/2004	204SMA020	1	1	11	4	4	9	10	0	15	53		
3/21/2003	204SMA060		1	13	5	6	13	9	5	4	55	6	49
7/23/2003	204SMA060		1	14	9	9	10	10	7	6	65	11	20
10/20/2003	204SMA060		1	14	10	10	15	4	6	13	72	6	8
2/13/2004	204SMA060		1	12	5	9	9	7	5	10	57	20	22
3/21/2003	204SMA110			5	3	3	3	4	9	3	30		
7/23/2003	204SMA110			11	9	6	13	7	9	5	60	26	22
10/20/2003	204SMA110			17	13	14	13	9	9	17	92	2	5
2/13/2004	204SMA110			11	4	4	14	9	8	5	55	108	32
3/21/2003	204SMA120			9	4	4	13	6	2	5	43	6	92
7/23/2003	204SMA120			16	13	10	15	10	7	9	80	16	7
10/20/2003	204SMA120			17	10	10	17	7	9	13	83	13	1
2/13/2004	204SMA120			19	9	7	18	9	7	8	77	38	7
3/27/2003	205PER010	1	1	6	2	2	13	9	5	1	38		
7/29/2003	205PER010	1	1	6	3	2	13	10	5	2	41	63	104
10/31/2003	205PER010	1	1	9	7	4	4	9	6	8	47	37	36
3/14/2004	205PER010	1	1	10	3	5	7	9	10	3	47	20	115
3/27/2003	205STE100		1	12	3	9	11	7	1	14	57		
7/29/2003	205STE100		1	9	4	9	3	8	1	15	49	12	10
10/31/2003	205STE100		1	15	6	6	8	10	2	5	52	21	2
3/14/2004	205STE100		1	14	5	9	1	5	10	9	53	4	21
3/20/2003	206PET100	1	1	7	3	2	19	10	7	1	49		
7/22/2003	206PET100	1	1	10	5	3	19	10	5	4	56	15	97
11/7/2003	206PET100	1	1	7	3	0	7	5	1	2	25	8	235
2/6/2004	206PET100	1	1	6	1	0	9	10	6	0	32	235	206

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3/20/2003	206PET220			5	4	3	15	9	4	2	42		
7/22/2003	206PET220			3	3	3	14	9	1	9	42	92	38
11/7/2003	206PET220			0	1	0	10	3	0	6	20	148	261
1/27/2004	206PET220			7	3	0	15	10	0	6	41	216	75
3/20/2003	206PET310			10	8	8	13	9	9	4	61		
7/22/2003	206PET310			15	14	14	14	10	10	9	86	3	2
11/7/2003	206PET310			9	7	5	9	9	2	18	59	50	3
1/27/2004	206PET310			8	4	4	14	8	1	10	49	93	6
3/20/2003	206PET400		1	9	8	6	14	9	9	2	57		
7/22/2003	206PET400		1	16	14	13	12	6	5	17	83	5	1
11/7/2003	206PET400		1	18	12	7	9	10	4	16	76	4	10
1/27/2004	206PET400		1	14	10	9	10	10	9	9	71	7	11
3/19/2003	207KIR020	1		7	4	3	13	10	10	1	48	56	76
7/25/2003	207KIR020	1		10	10	6	17	9	8	5	65	30	19
2/20/2004	207KIR020	1		0	0	0	15	10	10	0	35	0	822
3/19/2003	207KIR110		1	9	2	3	7	8	1	7	37	58	29
7/25/2003	207KIR110		1	3	2	2	2	9	0	8	26	0	131
2/20/2004	207KIR110		1	8	2	3	3	7	0	8	31	143	114

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A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters

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Abstract

The density of neustonic plastic particles was compared to that of zooplankton in the coastal ocean near Long Beach, California. Two trawl surveys were conducted, one after an extended dry period when there was little land-based runoff, the second shortly after a storm when runoff was extensive. On each survey, neuston samples were collected at five sites along a transect parallel to shore using a manta trawl lined with 333 u mesh. Average plastic density during the study was 8 pieces per cubic meter, though density after the storm was seven times that prior to the storm. The mass of plastics was also higher after the storm, though the storm effect on mass was less than it was for density, reflecting a smaller average size of plastic particles after the storm. The average mass of plastic was two and a half times greater than that of plankton, and even greater after the storm. The spatial pattern of the ratio also differed before and after a storm. Before the storm, greatest plastic to plankton ratios were observed at two stations closest to shore, whereas after the storm these had the lowest ratios. © 2002 Published by Elsevier Science Ltd.

Keywords: Southern California; Neuston; Plastics; Zooplankton; Debris; Pollution monitoring

1. Introduction

Numerous researchers have documented the magnitude of marine debris and the threat that its ingestion poses to marine biota (Fowler, 1987; Ryan, 1987; Bjorndal et al., 1994; Moore et al., 2001). Most of these studies, however, have focused on large debris or debris that accumulates on the shoreline. Few studies (Shaw and Mapes, 1979; Day and Shaw, 1987) have examined the small floating debris that presents a potential risk to filter feeders, which have limited capacity for distinguishing small debris from planktonic food.

Moore et al. (2001) recently compared the density of neustonic plastic with that of potential zooplankton prey and found that mass of debris can rival zooplankton biomass in the upper water column. However, their study was conducted in the North Pacific central gyre, which is a large eddy system that can concentrate debris. Moreover, the gyre is a nutrient poor environment with low biological productivity, which would serve to exaggerate comparisons between debris and zooplankton. It is unclear whether a similar pattern occurs in other marine environments.

This study compares the density of neustonic debris and zooplankton along the southern California coast, an area that is subject to nutrient upwelling and has a higher biological productivity than the North Pacific central gyre. The study area is located adjacent to a major population center, providing additional geographic contrast because of the proximity to land-based sources of debris. To assess the importance land-based sources, identical surveys were conducted after an extended dry period, when there was little land-based runoff and, shortly after a storm, when runoff was extensive.

2. Materials and methods

The first neustonic trawl survey was conducted on October 30, 2000, following 63 days without rain. The second was conducted on January 12, 2001, immediately following a 9 cm rainstorm. Five sites located sequentially offshore from the San Gabriel River were sampled on each survey (Fig. 1). The first station was located approximately 200 m offshore in front of the San Ga-

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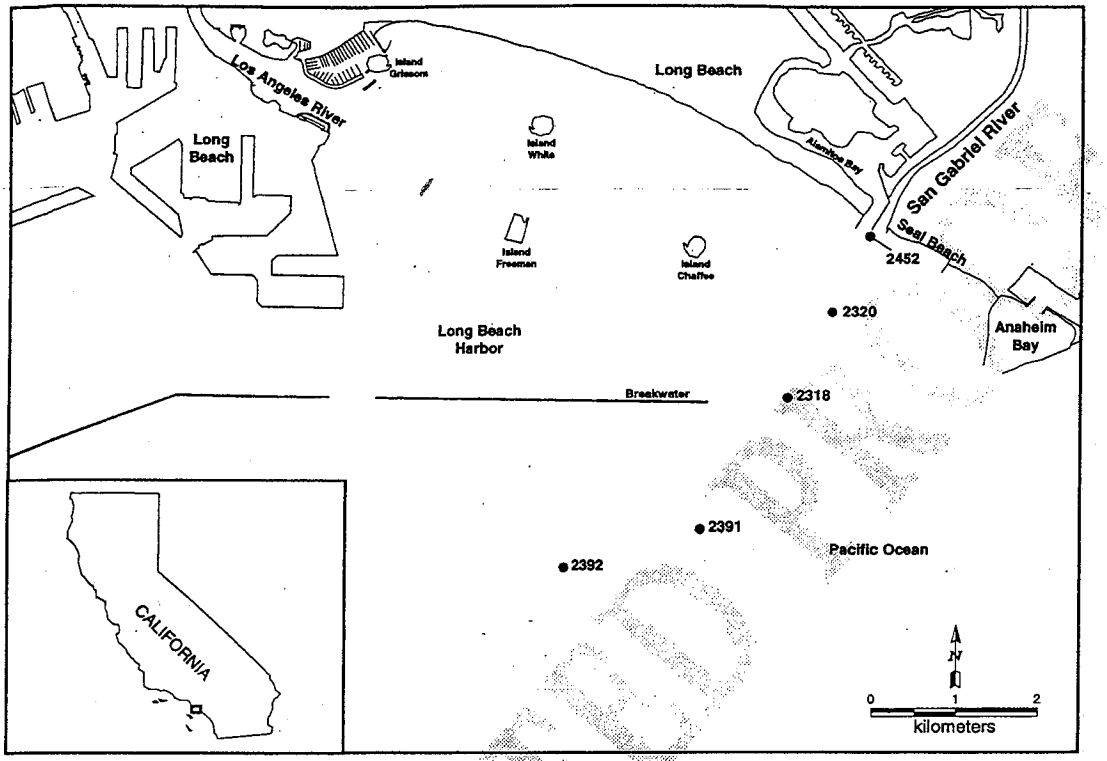

Fig. 1. Map of station locations and area of the San Gabriel River debris study, October, 2000 and January, 2001.

briel River mouth and the farthest station was about 5 km from shore.

Samples were collected using a manta trawl with a 0.9×0.15 m^2 rectangular opening (behind a G.O. flowmeter) and a 3.5 m long, 333 u net with a 30×10 cm^2 collecting bag. The net was towed at the surface at a nominal speed of 1.5 m/s. Actual speed varied from 1.25 to 2.5 m/s as measured with a B&G paddlewheel sensor. Trawl transects were between 0.5 and 1.0 km long and were laid out in an east/west orientation. Samples were fixed in 5% formalin, soaked in fresh water, and transferred to 70% isopropyl alcohol.

Samples were split using a Folsom plankton splitter after large pieces of debris and plant material were removed. Samples were sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.70, 0.50, and 0.35 mm. Debris, zooplankton and plant material were separated from the sorted fractions using a dissecting microscope; debris were categorized into fragments, Styrofoam, pellet, polypropylene/monofilament line, thin plastic films, resin and nonplastics (including tar, rust, paint chip, carbon fragment) and counted. Plankton and plant material were wet weighed and plastic, plankton and plant material then oven dried at 65 °C for 24 h and weighed.

3. Results

Abundance of neustonic debris was several fold higher on the sampling date following the storm (Fig. 2). Prior to the storm, density was around three pieces per cubic meter at the highest density station. After the storm, density was more than twice that at all stations. The mass of plastics was also generally higher after the storm, though the storm effect on mass was less than it

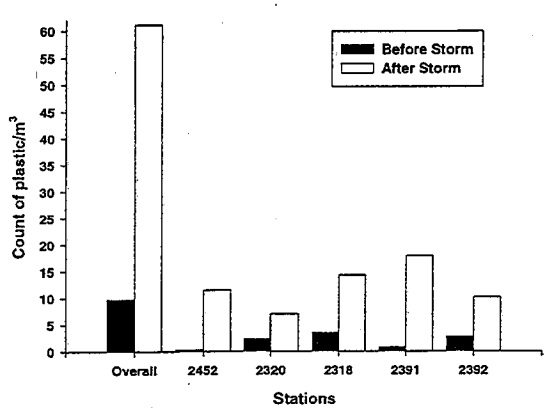

Fig. 2. Debris ratios for number of pieces (pieces/m^3) of degris before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

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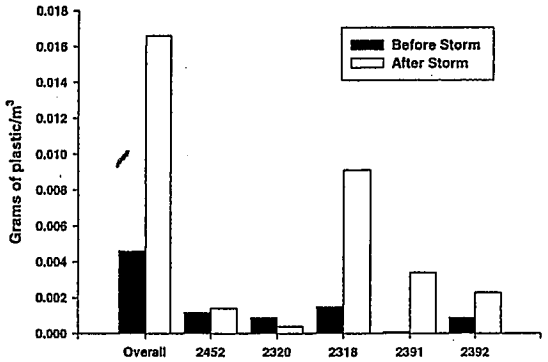

Fig. 3. Debris ratios for mass (g/m^3) of debris before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

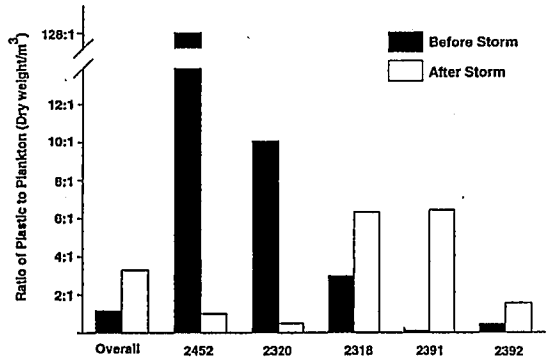

Fig. 4. Plastic and plankton ratios before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

was for abundance (Fig. 3). This reflects the smaller average size of plastic particles that we observed after the storm (Table 1).

The spatial distribution of debris also differed before and after the storm. Prior to the storm, the mass of plastic debris was greatest at the three stations closest to land (Fig. 3). After the storm, mass of debris was greatest at the three stations farthest from land.

The mass of plastic was about two and a half times higher than that of plankton across the entire study. Following the storm, this ratio exceeded 3:1 (Fig. 4). The spatial pattern of the ratio also differed before and after a storm. Before the storm, the highest plastic to plankton ratios were observed at the two stations closest to shore, whereas after the storm these stations had the lowest ratios.

Most of the debris was in the form of plastic fragments regardless of sampling date and sampling location (Table 2). Thin plastic films, such as those used in garbage and sandwich bags, was the second most common type of debris, but it exceeded 5% of the mass only at the station closest to land after the storm. Styrofoam, fishing line and plastic pellets never exceeded 2% of the mass at any station.

Table 1
Percent of each debris size class before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001

Small plastics	Percent of each debris size class by station									
Size class (mm)	2452		2320		2318		2391		2392	
	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
0.355–0.499	0.1	8.9	3.1	21.2	2.4	0.1	4.2	7.0	1.9	2.4
0.500–0.709	0.1	8.4	2.3	20.6	9.6	2.9	12.3	13.8	3.7	9.3
0.710–0.999	0.1	3.1	2.0	13.9	1.7	12.7	9.2	11.0	10.7	21.0
1.000–2.799	1.9	14.1	10.2	35.1	13.3	24.8	0.8	22.1	34.0	13.1
2.800–4.749	1.5	56.1	0.0	4.1	2.2	39.2	0.0	9.6	49.7	1.5
>4.750	96.2	9.5	82.3	5.1	70.9	20.3	73.5	36.5	0.0	52.7

BS: Before storm; AS: After storm.

Table 2
Percent of each debris type before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001

Debris type	Percent of each debris type by station									
	2452		2320		2318		2391		2392	
	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
Fragments	100.0	93.7	95.9	96.5	94.8	94.0	100.0	98.8	100.0	92.7
Styrofoam	0.0	0.6	2.1	0.9	0.0	0.0	0.0	0.3	0.0	1.8
Pellets	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.3	0.0	1.8
Line	0.0	0.6	2.1	0.9	2.6	6.0	0.0	0.3	0.0	1.8
Thin films	0.0	5.1	0.0	0.9	2.6	6.0	0.0	0.3	0.0	1.8

BS: Before storm; AS: After strom.

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4. Discussion

The density of neustonic plastic along the southern California coast was about three times higher than Moore et al. (2001) found in the mid-Pacific gyre, though the mass was 17 times lower (Table 3). This disparity between density and mass reflects the dramatic difference in size of neustonic debris between the gyre and the coast. Most of the neustonic plastic mass observed in the North Pacific central gyre was large material associated with the fishing and shipping industry. Most of the plastic we observed near the coast were small fragments attributable to land-based runoff.

The average plastic:plankton mass ratio was less in southern California, reflecting its higher plankton density. However, the plastic to plankton ratio on the day after the storm was higher in southern California than in the North Pacific central gyre. This change resulted from an increase in debris following a storm, rather than from a reduction in plankton. Moreover, the ratio in the North Pacific central gyre was driven by large debris. When the comparison of ratios between these two areas is limited to debris smaller than 4.75 mm, which is the fraction that filter feeders are most likely to confuse with plankton, the southern California ratio becomes twice that of the North Pacific central gyre.

The differences between our findings and those in the North Pacific central gyre largely reflect differences in proximity to land-based sources, but the effects of land-based runoff are probably exaggerated in southern California compared to the rest of the country. Southern California rivers are highly modified stormwater conveyance systems that are independent of the sewage treatment system, so urban debris flows unimpeded to the ocean. Moreover, southern California has an arid environment with a short rainy season and long dry periods when the rivers provide minimal runoff. Thus, land-based debris will accumulate between storms and enhance the amount of runoff following a storm compared to more temperate areas.

Reducing marine debris is a worldwide concern; however, in southern California it presents a different challenge than in the North Pacific central gyre or other open water areas. In the open ocean, the input materials are larger and the sources far more diffuse. Here, the land-based sources are more definable, but the material is smaller and therefore harder to capture. Several steps are being taken to reduce land-based contributions to the coastal ocean. Barrier nets to capture larger debris have recently been constructed on several of the largest river systems in southern California. The Los Angeles Regional Water Quality Control Board has set a total maximum daily load of zero trash for several area watersheds. However, these orders focus on the large debris (>5 mm) and the aesthetic effects they have on beaches and harbors. Presumably some of the same management steps will serve to reduce the smaller fragments, but it is unclear to what extent.

It is also unclear what effects that the plastic debris we observed in coastal waters have on planktonic filter feeders. Little is known about how ingestion of plastics affects filter feeders, though plastics have been shown to sorb contaminants (Mato et al., 2001). Moreover, our study, as well as that of Moore et al. (2001), was limited to the upper water column. While some filter feeders focus their consumption on the upper water column, most pelagic feeders use a much larger portion of the water column than we sampled and density of debris compared to that of plankton has not been investigated deeper in the water column.

Table 3
Comparison between this study and the North Pacific Gyre study (Moore et al., 2001)

	Average debris		Ratio of plastic to plankton for mass	
	(g/m^3)	($pieces/m^3$)	All Debris	Debris <4.75 mm
This study	0.002	7.25	2.5:1	0.6:1
Gyre study	0.034	2.23	6.1:1	0.3:1

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Bag 2 Bag- Residential Curbside Plastic Bag Recycling Program
City of San Juan Capistrano
Orange County, California

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Pre-program conditions :

City of San Juan Capistrano is a community of about 35,000 population, located in South Orange County. The city has one of the oldest missions in California and prides itself with its historic surroundings. The city has a large equestrian population, with a rural atmosphere. The city has 2 creeks that run through it, and is located 2 miles upstream of Doheney State Beach, Dana Point Harbor and the ocean. So, many of the city's residents enjoy beach activities, such as surfing, swimming and boating.

These parameters set the tone for an environmentally friendly community. The community prides itself for being one, and is always looking for ways to protect its environment for future generations. The city has a very large open space areas, many parks, protected ridges where no construction is allowed.

The City of San Juan Capistrano is within the jurisdiction of the San Diego Regional Water Quality Control Board.
NPDES permits are issued for a five-year term and have generally followed a progressive pattern. Our first permit provided an opportunity for Orange County municipalities to establish a program customized to local conditions. In its earliest form, the Orange County Stormwater Program focused on gathering data about existing conditions and implementing an initial set of improvement measures aimed at known water quality deficiencies. Our second permit, issued in 1996, was built upon the knowledge gained during the first permit period and was intended to improve water quality incrementally over time. During the second permit term Orange County also invested heavily in parallel efforts to implement a watershed approach, a comprehensive but lengthy planning tool for addressing water quality as well as habitat restoration, recreation, and flood control.

Our latest permit was issued in 2002. In this latest permit, the City was required to develop a Local Implementation Plan (LIP) identifying how all requirements of the permit will be managed by the City. The city has been implementing and reporting the various aspects of the NPDES permit to the San Diego Regional Board.

As the city was implementing the various aspects of the Permit, the city held annually an Earth Day event and a creek cleanup event. During the creek cleanup event, city staff noticed that among the material recovered from the creek, there were many polystyrene foam, commonly referred to as "Styrofoam" ®. The city partnered with neighboring city, San Clemente, and developed a ban on Polystyrene Foam (PF) ordinance to reduce the amount that reaches the creeks and eventually the beaches, and raise the awareness to the problem. This ban was only for the use of PF on city facilities and in parks. City

employees were encouraged to use mugs, reusable material, vs single use material. All PF was removed from city facilities, and no PF was allowed to be used at special events held on city properties.

The American Plastic Council (APC) showed up at the city's council meeting to object to the ban, but the city went through with it. This placed the city on the APC's radar.

In addition, as I developed this ordinance, I promoted it County wide, and more cities were interested in similar actions. Some considered a stricter ban, such as banning PF totally from the city, including from food facilities where it is commonly used.

The city is a member of the Task and Debris Task Force, that was set up to deal with a potential trash TMDL, similar to the one imposed on the city and county of Los Angeles. This program is expensive and could cost the local cities plenty of money to reach the TMDL "zero waste" requirements. So, the Orange County cities were looking into possible projects to deal with trash and debris to reduce the impact on the local beaches and prove that improvements could be made without the need to have a TMDL imposed. The State Water Resources Control Board was watching the local efforts and looking for improvements.

Another existing condition was that the city was mandated by the California Integrated Waste Board (CIWMB) to divert 50% or more of its solid waste away from the landfill through recycling programs, under AB 939, by year 2000. The city had not met this mandate, and applied for an extension under SB1066. The city has a landfill within its city limits, Prima Deschecha and has a great interest in extending its life. The city promotes recycling to its residents through various curbside programs including providing a 3 container program, one for trash, one for recyclables and one for greenwaste.

Other programs the city performs to prevent trash and debris from reaching the creeks and eventually the ocean include regular daily street sweeping of the downtown area, in addition to catch basin baskets to capture debris. Residential streets are swept bi-weekly. A very aggressive public education campaign supports the city activities.

Another pollutant regularly collected at creek cleanup events were plastic bags and cigarette buts. Some cities are implementing cigarette smoking ban on beaches. The city was not ready to ban plastic bag as it is a household item very popularly used.

Program concept and implementation

As members of the Trash and Debris Task Force, the city and the representatives of the Progressive Plastic Bag Alliance had the opportunity to get to discuss the various environmental programs, and a meeting was set up to discuss potential opportunities as an alternative to banning programs. The plastic bag companies were promoting a plastic bag recycling program at supermarkets and other plastic bag recycling programs.

This was the start of our curbside plastic bag recycling program. At the meeting, I informed the representative of the plastic bag companies that the supermarket "Bag 2 Bag" program was good, but a citywide residential curbside recycling program would be much better. This concept was one that the plastic bag manufacturers were interested in. Following this meeting, a follow up meeting was set up with Hilex Poly, CR&R and myself. We discussed the concept of a citywide curbside recycling program. All parties believed that it is feasible.

The plot: A pilot program to determine if the concept would work

1. The city needed to promote the program to its residents. The program needed to be simple to implement and simple to perform
2. CR&R needed a program that wouldn't impact their operation but would allow them to increase their recycling efforts
3. Hilex Poly provided a year supply of plastic bags to 8,500 residential properties in the city, and a 4 gallon container to place the bags in.
4. The bucket was stenciled with information on the program in English and Spanish. The stencil included instruction on how to recycle.
5. The program would accept all kinds of plastic bags, such as dry cleaning bags, grocery stores bags and plastic retail bags.
6. Residents would place their provided blue bags in the blue bucket. All week residents would place their plastic bags in the bucket. On trash day, residents would remove the blue bag filled with plastic bags, tie the top and place the bag in their recycling container.
7. CR&R pick up the recycling containers' content and take them to the CR&R Stanton facility, where staff separate the recyclables into categories: paper, plastic bottles,cans, plastic bags and others. The plastic bags are then piled until there is enough to be baled.
8. Once baled, Hilex Poly's trucks pick up the bale to their recycling facility, where the bags will be washed and processed to be used to make new plastic bags.

The project started with a press release from the city informing the residents of the new program. This was followed with full page ads in the local papers and articles explaining to the residents how will the program work, the benefit to the community as far as recycling and water quality. The city sent postcards to all 8,500 properties with a picture in the front showing the process and a message on the inside in English and Spanish.

A company was hired to deliver all 8,500 buckets with a roll of 52 bags each, in addition to a flyer explaining the proper way to recycle the bags and a message from the mayor encouraging the residents to recycle their plastic bags.

CR&R trained its staff to incorporate the plastic bags separation in their process. Recyclables are placed on a conveyor belt, where employees pick their specific type of recyclables and drop them in a chute. The blue bags were easily visible, which made the process easier.

Current situation:

The City has now been recycling plastic bags for 6 months.

2 cities joined in the recycling effort: Dana Point and San Clemente, in July. Several other South County cities have expressed interest in the program and are considering getting on-board.

CR&R has been receiving steady flow of plastic bags, but not as much as expected. We are not receiving 8,500 bags a week. Some of the low turnout is due to the fact that some people might just not want to bother with the program, others just use their bags as a doggy bag to pick up dog waste.

The city is currently running a PSA on Cox to educate the public. More education is necessary to keep the momentum going and reach out to residents who missed the original campaign.

Other plans include a possible school plastic bag recycling collection program where the school with the most plastic bags would be recognized and/or receive an award. This serve the purpose of educating the kids and have a community wide focused educational campaign.

In addition, the more cities get on board, the more residents are aware that this program is available to our community and neighboring ones, and plastic bag recycling becomes a 2nd nature to residents as soda cans are recycled these days.

THE MALIBU FOUNDATION FOR ENVIRONMENTAL EDUCATION

MALIBU FOUNDATION'S
ADOPT-A-BEACH SCHOOL ASSEMBLY PROGRAM

This comprehensive environmental education program is designed to motivate children to care about the beaches, oceans and neighborhoods. The program utilizes a very basic teaching model that shows a person something they love, shows how it is being damaged and gives them something to do about it.

The 45 minute assembly presents about 100 slides of happy fish and animals in clean water and then shows them tangled in the plastic, nets and debris. The slides show how the beaches and oceans get dirty by highlighting the storm drain connection. **"Hands-On"** opportunities to make a difference are available by recycling, reducing litter and cleaning up the neighborhoods and beaches.

The Malibu Foundation coordinates an annual Kid's Adopt-A-Beach Clean-Up in celebration of Ocean Day in May. The California Coastal Commission, the City of Los Angeles Stormwater Program and the California Regional Water Quality Control Board support the program in Los Angeles. The program also runs in 5 other cities through support of the Coastal Commission's Whale Tail License Plate Fund.

The program emphasizes that clean beaches and oceans start with clean neighborhoods.

Students are motivated to develop academic skills when they are part of something that is **RELEVANT** and **INTERACTIVE** with **"HANDS-ON" REAL WORLD EXPERIENCE**. The program provides a framework to refresh a desire to learn and raise overall achievement.

This assembly also utilizes **READING** and **LITERACY** techniques:

- Repetition.
- New Vocabulary.
- Definition and Repeat.
- Review Main Idea.
- Cause and Effect.
- Audience Participation.

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THE MALIBU FOUNDATION
FOR ENVIRONMENTAL EDUCATION

To date the Malibu Foundation has presented the Assembly Program over 2000 times to 425,000 children. Over 46,000 kids have participated in the last 12 annual Kid's Adopt-A-Beach Clean-Ups.

Please check out www.malibufoundation.org to see videos of the kids on the beach and talking about marine debris and www.oceanday.net to view aerial photos of the children forming messages in the sand. The Malibu Foundation's website also has a link that shows a k-5 matrix of how California Standards are introduced during the Assembly.

4,200 children on Dockweiler State Beach for Ocean Day 2005

Michael Klubock is the founder and executive director of the Malibu Foundation and will present some of the slides from the Assembly Program and share his education philosophy.

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PAPER for Plastic Debris Rivers to the Sea Conference 2005

Seabirds as indicators of plastic pollution in the North Pacific

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Abstract

As far-ranging top predators, seabirds are valuable biological indicators of climatic and human-related perturbations of marine food webs because they sample marine ecosystems over large space and time scales. These same ecological reasons make seabirds valuable indicators of plastic pollution in coastal and oceanic waters. In this paper we review studies of the incidence and impacts of plastic ingestion on North Pacific seabirds, and identify several ecological factors that influence the susceptibility of different species. Foraging mode, habitat use, and body size are important factors to consider when quantifying the magnitude of plastic ingestion and its potential impacts on seabird populations. Large-bodied, oceanic species that feed opportunistically at the surface are most susceptible to plastic ingestion. In particular, far-ranging tubenose (Procellariiformes) species, like fulmars and albatrosses, are ideal bio-indicators of marine plastic pollution. In this paper we report on plastic ingestion by Northern Fulmars (*Fulmarus glacialis*) collected in California during 2003–2004, and review past research on far-ranging Hawaiian albatrosses. These results underscore the value of studies of seabird diet and stomach contents to monitor trends in North Pacific marine pollution. Although it is difficult to quantify population-level impacts resulting from the documented patterns of plastic ingestion in seabirds, the incidence of plastic debris in many long-lived North Pacific species is an emerging ecological problem that warrants further investigation. The mitigation of plastic ingestion in seabirds is a complex problem that will require broad-reaching cooperation between industry and wildlife resource managers, as well as education and public outreach. We present an educational program, designed to increase public awareness of the threats posed to seabirds by marine pollution, and to promote public stewardship of North Pacific seabirds.

Introduction

Seabirds are abundant upper-trophic level predators in marine ecosystems, where they forage on zooplankton, fish, and squid. By virtue of their charismatic nature, their ecological position high on the marine food web, and their vast foraging ranges —seabirds provide an ideal vehicle for monitoring plastic pollution in the world's oceans (Ryan and Fraser 1988, Furness and Camphuysen 1997, Van Franeker 2004). Moreover, because seabirds eat the same zooplankton, fish, and squid prey consumed by commercially-valuable fish species

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(e.g., salmon), they also may provide valuable information on the pollutant loads of marine resources consumed by humans (e.g., Montevecchi 1993, Burger and Gochfeld 2004, Blais et al. 2005). Most research on marine debris and seabirds has been motivated by the need to understand contaminant pathways in marine ecosystems, and has been largely limited to documenting plastic ingestion. The available research has shown an increasing trend in plastic ingestion in seabird populations worldwide, from the tropics to polar regions (Collins 2005, Edwards 2005). Thus, the study and remediation of marine pollution has important implications for seabird conservation globally, and will require greater attention in the future.

Oceanic birds occupy vast ranges spanning multiple national economic exclusive zones, and often migrate across ocean basins and between hemispheres (Birdlife International 2004). Thus, international efforts are needed to study and mitigate the global conservation challenge of marine debris pollution. This presentation addresses the widespread incidence of plastic ingestion in marine birds, with an emphasis on North Pacific species, and reviews evidence of the resulting detrimental impacts. The patterns documented for North Pacific species are likely indicative of the trends and impacts in other ocean basins. Yet, no data are available for many colonies, species, and regions. Although there currently is no systematic scientific study to assess the global magnitude and impacts of plastic debris, local and regional monitoring programs of seabird populations (e.g., Van Franeker 2004) and marine litter surveys (e.g., Ryan and Moloney 1993) provide a foundation for a future comprehensive program.

Many North Pacific seabirds ingest anthropogenic marine debris, including post-consumer plastics, also called "user" plastics (Baltz and Morejohn 1976, Robards et al. 1995, Blight and Burger 1997). Many of the surface feeding species - such as albatrosses, petrels, and fulmars - which forage opportunistically on a broad range of fish and squid prey seem especially prone to ingesting a broad array of user plastics. In particular, Laysan (*Phoebastria immutabilis*) and Black-footed (*Phoebastria nigripes*) albatrosses, and Northern Fulmar (*Fulmarus glacialis*) frequently ingest a variety of large-sized (a few cm long) items such as bottle caps, cigarette lighters, toys, party balloons, and fragments of broken user plastics. During chick provisioning, adults then feed these items to their young, resulting in detrimental effects on chick growth and survival (Ryan 1987, Sievert and Sileo 1993). By virtue of their long life-spans (> 30 years), adult birds bio-accumulate the toxic compounds leached from the ingested plastics, with potential detrimental effects on fecundity rates and egg breakage rates (Jones et al. 1996, Auman et al. 1997). Other species that capture zooplankton - such as phalaropes, shearwaters, and auklets - ingest small-sized (few millimeters long) fragments of user plastics and pre-production industrial plastic pellets (a.k.a. nurdles; Robards et al. 1995, Blight and Burger 1997, Vlietstra and Parga 2002).

We are working to encourage public participation in *Coastal Cleanup Day* and *Adopt a Beach* program activities, by supporting web-based animal tracking, public outreach lectures, and teacher workshops designed to supplement the California Coastal Commission Science Activity Guide "Waves, Wetlands, and Watersheds". These efforts, which aim to link seabird ecology with the sources of marine debris, illustrate the diverse venues available to raise awareness of plastic pollution, and to promote stewardship for seabirds and ocean conservation.

Methods

In this inter-disciplinary paper we present three components of our work on plastic debris and its associated impacts on seabirds: (i) a field study of plastic ingestion in California, (ii) a literature review of plastic ingestion for North Pacific species, and (iii) the development of outreach and educational materials to disseminate this information to the public.

We investigated the incidence of plastic in the gut contents of two migratory seabirds, the gull-sized (600 g) Northern Fulmar and the small- bodied (80 g) Red Phalarope (*Phalaropus fulicarius*). During the winter of 2003-04, a "wreck" of fulmars and phalaropes occurred along the entire west coast of North America, from British Columbia, Canada to Baja California, Mexico (Nevins et al., unpublished data). In central California, the Coastal Ocean Mammal and Bird Education and Research Survey (COMBERS) documented this unusual mortality event and collected carcasses for laboratory examinations. Necropsies and stomach analyses were performed at the Moss Landing Marine Laboratories of the California State Universities, and the Marine Wildlife Veterinary Care and Research Center, California Department of Fish and Game, Santa Cruz, California. We examined the stomach contents of 190 Northern Fulmars and three Red Phalaropes, and determined the incidence (frequency of occurrence) and the magnitude (mean number of items per individual) of plastic ingestion.

To place the results of this field study in a broader context, we completed a review of the scientific literature to summarize the incidence of plastic ingestion in North Pacific seabirds. We used this information to illustrate several of the ecological and life-history factors that influence plastic ingestion in seabirds, including foraging strategy, habitat use, and body size.

Finally, we report ongoing collaborative efforts to promote marine stewardship and awareness of seabird conservation issues through creative public outreach and education.

Results and Discussion

Field Study

Plastic fragments occurred in 71% of the fulmar and 100% of the phalarope stomachs we examined. Natural prey items (e.g., squid beaks) occurred in 72% of the fulmars and 0% of the phalaropes. Fulmar stomachs contained an average of nine post-consumer fragments (range = 1–41), two pre-production pellets or "nurdles" (range = 1–8), two styrofoam fragments (range = 1–10), and two other pieces of debris (range = 1–6; including rubber bands, party balloons, fishing line and lure fragments, plastic film, artificial sponge, unidentified items). The mean size of user plastics ingested by fulmars was 5.7 ± 2.8 mm (n = 733). Fulmars ingested predominantly white plastic fragments (61%), but they also ingested a variety of colors, including green (8%), brown (8%), blue (6%), red (6%), yellow (5%), and pink (2%). Phalaropes consumed mainly plastic fragments (range = 1–25), one individual had ingested a single nurdle. Because Phalaropes have a smaller stomach capacity than the larger-sized fulmars, and thus ingested smaller plastic fragments (mean = 2.6 ± 0.6 mm, n = 22).

Literature Review

Seabirds depend upon ocean ecosystems exclusively to feed themselves and their young, and thus are likely to encounter potentially detrimental marine debris throughout their lives. Furthermore, because many seabirds are extremely long-lived (e.g., shearwaters >50 years, albatross >80 years), they are especially susceptible to chronic effects from low levels of pollutants accumulated over the long term (Jones et al. 1996, Auman et al. 1997).

A review of the literature highlights the pervasive nature of marine plastic pollution, from the tropics to sub-polar regions (Day and Shaw 1987, Van Franeker and Bell 1988, Spear et al. 1995, Auman et al. 2004). Even remote areas like Inaccessible Island, in the sub-Antarctic Atlantic Ocean, are polluted by marine debris (Ryan and Moloney 1993). Nevertheless, this research suggests that foraging mode, body size, habitat use, influence the incidence and susceptibility of seabirds to plastic ingestion. An understanding of these patterns can help wildlife managers to target those species that are especially susceptible to plastic debris, thereby defining conservation priorities for research and mitigation.

Several studies provide a broad sense of species-specific differences in the incidence of plastic ingestion among North Pacific seabirds. In a survey of breeding seabirds in Alaska, 62.5% (15 out of 24 species, n = 1799 individual birds) had ingested plastic debris (Robards et al. 1995). Overall, of the 4417 plastic items examined, 76% were industrial pellets, 22% were fragments of user plastic, and 2% were unidentified. This study highlighted the differential incidence of plastic ingestion among seabird feeding modes; surface-feeding species showed a greater rate of plastic ingestion than diving species (86% vs. 47%), and took a relatively greater proportion of user plastics (Robards et al. 1995). A comparison of plastic ingestion rates in the 1970s and the 1980s revealed a higher incidence for surface-feeding species. For example, the plastic ingestion rate for the Northern Fulmar increased from 58% (1969–77) to 84% (1988–90).

A study of seabirds incidentally killed by an experimental squid gillnet fishery off British Columbia, Canada, provided a snap-shot of plastic occurrence in a northeast Pacific seabird community (41–50 ° N, 131–134 ° W). Fifty-eight birds and 11 taxa were sampled, 100% of five surface-feeding species contained plastics while only 50% of the diving species had ingested plastics. The mean number of plastic items per bird was an order of magnitude greater for the surface feeders (20.8) than for the divers (1.4). Overall, of 353 plastic items found in seabird stomachs, 29% were industrial pellets and 71% were fragments of user plastic (Blight and Burger 1997).

Thus, of the four main types of foraging modes used by seabirds (surface-feeding, diving, piracy, and plunge-diving), surface feeders, including many of the procellariiformes (e.g., albatrosses, shearwaters, fulmars, storm-petrels) frequently encounter and ingest floating plastic debris. The incidence (frequency of individuals of a given species with plastic in the stomach) is generally high in these species, ranging from 50 to 80% (Table 1). Whereas diving birds appear to be less susceptible to plastic ingestion, they likely are more vulnerable to other types of marine debris, such as entanglement in fishing nets and monofilament line. Among diving alcids, those which feed on zooplankton (e.g., puffins, auklets) appear to ingest plastic more frequently than predominantly fish-eaters such as murres (Table 1).

Body size likely plays a vital role determining the types of plastics that seabirds can ingest (Fry et al. 1987). The larger species albatrosses are capable of ingesting large prey

and debris (up to 90–160 mm in length), including cigarette lighters, bottle tops, toy army men, and chemical light sticks used for fishing lures (Gould et al. 1997, Kinan and Cousins 2000, Cooper et al. 2004). Conversely, small-sized shearwaters, storm-petrels, and phalaropes ingest small fragments (1–5 mm diameter) of user plastics and nurdles. These seabirds likely mistake brightly colored plastic fragments for prey items (e.g., squid, crustaceans, gelatinous zooplankton). Large-bodied scavengers and predatory species, such as skuas, may ingest plastics secondarily when consuming other seabirds or regurgitated pellets containing plastic fragments (Ryan and Fraser 1988).

Habitat use is another important determinant of the type and amount of plastics ingested by seabirds (Spear et al. 1995). Whereas nearshore species (e.g., pelicans, cormorants, and murres) are most affected by coastal human activities (e.g., gillnet by-catch, entanglement in fishing gear, oil spills), offshore species are affected by more widely-dispersed human activities spread over the entire North Pacific Ocean. Far-ranging seabirds, which cover vast distances in search for food and often concentrate at frontal systems, encounter plastic debris at-sea far away from the localities where they breed (Cooper et al. 2004). In fact, due to their seasonal migrations and the action of currents, seabirds are affected by marine pollution throughout the globe. These global impacts are best illustrated by the plight of species which, despite breeding in uninhabited remote islands in the Southern Ocean, are impacted by plastic debris originating from distant sources (Auman et al. 2004).

In addition to transporting debris long distances, ocean currents and wind patterns concentrate plastics within certain oceanic regions (Wong et al. 1974, Ebbesmeyer and Ingraham 1992, Kubota 1994, Moore 2003). For instance, large (> 25 mm length) plastic fragments are on average twice more abundant within subtropical (35–39 ° N) than sub-arctic (45–48 ° N) latitudes in the North Pacific, and small fragments are 30 times more abundant (Day and Shaw 1987). Thus, we would expect subtropical seabirds to encounter and ingest greater amounts of plastics than species from higher latitudes. For instance, the Black-footed Albatross (population size: 0.2 million) and the Laysan Albatross (population size: 2.5 million) are most numerous within subtropical and sub-arctic latitudes during the summer-time (June – September) post-breeding dispersal. Conversely, the Northern Fulmar (population size: 4.6 million) is most numerous in the Bering Sea continental shelf close to its breeding colonies. These species occur in the California Current System throughout the year, though their numbers peak during the post-breeding dispersal stage (Briggs et al. 1987).

In addition to these large-scale disparities in plastic concentrations, the same smaller-scale physical oceanographic processes (e.g., frontal systems and convergence zones) that often define seabird foraging habitats, likely influence the abundance and availability of floating plastic debris to foraging seabirds. For instance, albatrosses seem especially susceptible to plastic ingestion because they forage along oceanic frontal systems, where they encounter buoyant prey (e.g., *Velella velella,* dead floating squid) and inadvertently ingest plastics accumulated at surface convergence zones (Gould et al. 1997). Off the west coast of North America, Black-footed albatrosses concentrate along shelf-slope habitats, offshore of coastal upwelling plumes (Hyrenbach et al. 2002, Ainley et al. 2005).

The negative effects of plastic ingestion at the shelf-slope habitat are transferred from the adults to their chicks on remote islands, distant from the mainland sources of plastic

pollution. Sievert and Sileo (1993), for instance, found that plastic ingestion hindered growth and survival of Laysan albatross chicks. During the chick-rearing season, Laysan albatrosses forage along the North Pacific Transition Domain (Hyrenbach et al. 2002), in a region where prevailing wind patterns concentrate floating debris (Day and Shaw 1987, Kubota 1994). While a pilot study at Kure Atoll in 1999 – 2000 revealed that all (100 %) the pellets regurgitated by chicks contained plastic, these sympatrically-breeding albatrosses differed in the types of items ingested. Namely, there was a higher incidence of cigarette lighters in the pellets of Laysans (19% of 88 boluses) compared with those from Black-foots (0% of 56 boluses; Kinan 2000). These differences in pollutant loads have been ascribed to the segregation of the foraging grounds, and the dietary differences of these two species (Gould et al. 1997, Hyrenbach et al. 2002, Finkelstein et al. 2003). This result underscores the inter-related nature of seabird foraging habitats, diets, and oceanography.

Off the west coast of North America, millions of resident and migratory seabird species rely on the food resources of the productive California Current upwelling system (Briggs et al. 1987; Table 1). Thus, pollution of coastal and offshore regions poses a threat not only to locally-breeding species, but also to far-ranging seasonal visitors from the arctic (e.g., Northern Fulmar; Black-legged Kittiwake, *Rissa tridactyla*) and from the southern hemisphere (e.g., Sooty Shearwater, *Puffinus griseus;* Pink-footed Shearwater, *Puffinus creatopus*; Short-tailed Shearwater, *Puffinus tenuirostris*; Baltz and Morejohn 1976). For example, globally-threatened Pink-footed Shearwaters migrate from a few nesting islands off Chile to forage in shelf waters of California, where they are vulnerable to oil pollution, fishery entanglement, ingestion of plastics, and other toxic pollutants. Yet, the incidence of plastic ingestion and the susceptibility of many of these species to marine debris in the California Current System has not been well documented (Table 1).

Currently, there are no standardized programs to document regional patterns in the types, amount, and provenance of plastic pollution and marine debris at-sea in the North Pacific. Nor are there any programs set up to investigate long-term trends in the magnitude of marine debris pollution and plastic ingestion by seabirds. In fact, only two studies have documented long-term (decadal) trends in seabird ingestion of plastics in the North Pacific (Robards et al. 1995, Vlietstra and Parga 2002). Robards et al. (1995) documented an increased incidence, magnitude, and number of species plastic ingestion among Alaskan seabirds between 1969–1977 and 1988–1990. Vlietstra and Parga (2002) documented a change in the types of debris, from predominantly industrial pellets (1970–1978) to user plastics (1997–2001), but no change in the incidence (86%) of plastic ingestion by Short-tailed Shearwaters in the southeastern Bering Sea. These studies underscore the need to initiate and maintain long-term standardized studies to quantify trends in the abundance, types, and origin of the plastics ingested by North Pacific seabirds.

Education program

We have formed an inter-disciplinary collaboration among scientists, non-profit groups, National Marine Sanctuaries, and marine educators to engage students and teachers in marine stewardship, and to increase the public awareness of seabird conservation issues. During 2004–2005, we shared real-time satellite tracking data of Black-footed Albatross and Sooty Shearwater migrations online via the Seaturtle.org (http://www.seaturtle.org/tracking)

and Signals of Spring (http://www.signalsofspring.net/) web-sites. In 2005, we conducted public lectures and teacher workshops during beach clean-ups in support of the California Coastal Clean-up Day. As part of this outreach effort, we have produced stickers bearing the slogan "Protect Seabirds, Prevent Plastic Pollution", for dissemination to beach clean-up participants. Education at many levels is required to reach a diverse audience both locally and globally. By educating and engaging the public, particularly young students, we hope to reduce plastic pollution in the long-term.

Conclusions and Recommendations

Concurrent increases in human activities and marine pollution in the world's oceans continue to negatively impact seabird populations. Floating plastic debris is particularly harmful to surface feeding seabirds, some of which are listed as endangered (e.g., Short-tailed Albatross *Phoebastria albatrus*; world population less than 2,000 birds). The subtle effects of plastics on oceanic and coastal seabirds, such as stomach impaction and the consequences of leaching pollutants, are difficult to document. In our field study, we were not able to attribute the primary cause of death in Northern Fulmars and Red Phalaropes to plastic ingestion, as has been found in some cases of clear stomach obstruction (Sievert and Sileo 1993, Pierce et al. 2004). However, the high incidence of plastic ingestion (71 to 100%) may have contributed to the reduced body condition (body mass) found in all the specimens collected during a large-scale seabird die-off documented off California, as suggested previously for other species (Connors and Smith 1982, Ryan 1987, Spear et al. 1995). The inability to clearly ascribe detrimental effects from plastic ingestion at the individual-level (e.g., deteriorated condition) and population-level (e.g., lower reproductive success) poses a great challenge for seabird conservation. Our review of the literature and research findings suggest that marine debris pollution affects many North Pacific seabirds, but further systematic research is necessary to determine spatial and temporal trends, and to quantify species-specific impacts. In the North Sea, an international consortium of scientists initiated a program to monitor trends in marine pollution, using the incidence of industrial plastics in the stomachs of beached fulmars collected throughout eight countries (Van Franeker and Meijboom 2002, Van Franeker 2004). This effort provides a working model upon which the North Pacific community could develop a system to quantify marine pollution impacts, and to determine the effectiveness of mitigation actions aimed at reducing marine pollution in coastal communities. Our preliminary data from Northern Fulmars recovered in California indicate a high incidence of ingested plastics (71 %) similar to those found in the North Sea. We suggest an annual systematic effort following the approach taken by Van Franker (2004) to document the incidence of plastic ingestion by fulmars along the west coast of North America. Currently, beach survey programs operate throughout the region, in collaboration with national marine sanctuaries, and university research laboratories. Beach-cast specimens could be obtained from these programs and analyzed following standardized techniques, thus providing a coast-wide perspective of the incidence of plastic ingestion and the condition of fulmars at-sea. In addition, we advocate the increased support of marine stewardship educational programs, as a way to reduce marine pollution impacts on North Pacific seabird populations.

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Table 1. Summary of plastic ingestion in seabird species which occur off California, including the foraging strategy (surface-feeding, piracy, diving) relative susceptibility to plastic ingestion (high = 50-80% incidence; moderate = 20-50%; low < 20%; ? = not enough information), foraging location (R = resident year-round; BR = breeding area; NB = non-breeding area), percent incidence of plastic ingestion (n = number of birds examined), and the source of the data, coded by the location of the study (AK: Alaska, CA: California, ENP: Eastern North Pacific, ETP: Eastern Tropical Pacific, HI: Hawaii).

Common Name *Scientific name*	**Foraging strategy**	**Plastic ingestion**	**Breeding / Foraging Locations**	**Incidence (%) (n)**	**Source**[1]
Black-footed Albatross	Surface	High	Hawaii, Japan (BR)	100 (3)	Blight & Burger 1997 (ENP)
Diomedea nigripes			North Pacific (NB)	100 (56)	Kinan & Cousins (HI) chick boluses
Laysan Albatross	Surface	High	Hawaii, Mexico (BR)	100 (106)	Kinan & Cousins (HI) chick
Diomedea immutabilis			North Pacific (NB)		boluses
Northern Fulmar	Surface	High	Boreal Pacific (BR)	100 (3)	Baltz & Morejohn 1976 (CA)
Fulmarus glacialis			Temperate North	84 (19)	Robards et al. 1995 (AK)
			Pacific (NB)	100 (3)	Blight & Burger 1997 (ENP)
				71 (190)	Nevins et al., this study (CA)
Buller's Shearwater	Diver	High	New Zealand (BR)	100 (3)	Spear et al. 1995 (ETP)
Puffinus bulleri			North Pacific (NB)		
Pink-footed Shearwater	Diver	Low (?)	Chile (BR)	20 (5)	Baltz & Morejohn 1976 (CA)
Puffinus creatopus			North Pacific (NB)		
Short-tailed Shearwater	Diver	Moderate	South Pacific (BR)	100 (6)	Baltz & Morejohn 1976 (CA)
Puffinus tenuirostris			North Pacific (NB)	80 (5)	Robards et al. 1995 (AK)
Sooty Shearwater	Diver /	Moderate	South Pacific (BR)	43 (21)	Baltz & Morejohn 1976 (CA)
Puffinus griseus	Surface		North Pacific (NB)	75 (36)	Spear et al. 1995 (ETP)
				75 (20)	Blight & Burger 1997 (ENP)
Leach's Storm-petrel	Surface	High	North Pacific (BR),	100 (1)	Blight & Burger 1997
Oceanodroma leucorhoa			Tropical Pacific (NB)	20 (354)	Spear et al. 1995 (ETP)
				48 (64)	Robards et al. 1995 (AK)
Forked-tailed Storm-petrel	Surface	High	North Pacific (R)	86 (21)	Robards et al. 1995 (AK)
Oceanodroma furcata				100 (7)	Blight & Burger 1997 (ENP)
Pelagic Cormorant	Diver	Moderate	California (R)	20 (10)	Robards et al. 1995 (AK)
Phalacrocorax pelagicus					
Red Phalarope	Surface	High	Arctic (BR)	100 (3)	Nevins et al., this study (CA)
Phalaropus lobatus			CA Current (NB)		
Pomarine Jaeger	Pirate	Low (?)	Arctic (BR)	0 (2)	Spear et al. 1995 (ETP)
Stercorarius longicaudus.					
Mew Gull	Surface	Moderate		25 (4)	Baltz & Morejohn 1976 (CA)
Larus canus				25 (4)	Robards et al. 1995 (AK)
Glaucous-winged Gull	Surface	Moderate	Boreal N. Pacific (BR)	13 (8)	Baltz & Morejohn 1976 (CA)

[1] Collection location indicated in parentheses: AK = Alaska, CA = California, HI = Hawaii, ENP = Eastern North Pacific, ETP = Eastern Tropical Pacific Region.

Larus glaucescens			CA Current (NB)	0 (21)	Robards et al. 1995 (AK)
Heerman's Gull	Surface	Low	Mexico (BR)	7 (15)	Baltz & Morejohn 1976 (CA)
Larus heermani			CA Current (NB)		
Black-legged Kittiwake	Surface	Low	Alaska (BR)	13 (8)	Baltz & Morejohn 1976 (CA)
Rissa tridactyla			CA Current (NB)	8 (256)	Robards et al. 1995 (AK)
Common Murre	Diver	Low	North Pacific (R)	0 (1)	Blight & Burger 1997 (ENP)
Uria aalge				0.8 (134)	Robards et al. 1995 (AK)
				0.2 (772)	Nevins, unpublish. (CA)
Pigeon Guillemot	Diver	Low	North Pacific (R)	3 (43)	Robards et al. 1995 (AK)
Cepphus columba					
Xantus's Murrelet	Diver	Low (?)	California, Mexico (R)	0 (5)	Blight & Burger 1997 (ENP)
Synthliborhamphus hypoleucus					
Marbled Murrelet	Diver	Low (?)	E. North Pacific (R)	0 (96)	Robards et al. 1995 (AK)
Brachyrhampus marmoratus					
Cassin's Auklet	Diver	Moderate	E. North Pacific (R)	11 (35)	Robards et al. 1995 (AK)
Ptychorhamphus aleuticus					
Rhinoceros Auklet	Diver	Low	North Pacific (R)	4 (26)	Baltz & Morejohn 1976 (CA)
Cerorhinca monocerata				0 (1)	Robards et al. 1995 (AK)
				0 (6)	Blight & Burger 1997 (ENP)
Tufted Puffin	Diver	Moderate	North Pacific (R)	89 (9)	Blight & Burger 1997 (ENP)
Fratercula cirrhata		to High		24 (489)	Robards et al. 1995 (AK)
Horned Puffin	Diver	Moderate	North Pacific (R)	37 (120)	Robards et al. 1995 (AK)
Fratercula corniculata				50 (2)	Blight & Burger 1997 (ENP)

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"Beach Debris – Characterized through the International Coastal Cleanup & the U.S. National Marine Debris Monitoring Program"

Introduction:
Marine debris is one of the most pervasive and *solvable* pollution problems plaguing the world's oceans and waterways. Successful management of the problem requires a comprehensive understanding of the pollution problem including what are the types of marine debris, their abundance and sources, and most importantly, the human behavior producing it. Effective documentation and monitoring activities to assess the types and amounts of debris, combined with public education programs, effective policies supported by national and local legislation, and governmental and private compliance and enforcement form the foundation for a successful marine pollution prevention initiative that can lead to the abatement of the marine debris problem impacting every major body of water on the planet.

Scientists define *marine debris* as any manufactured or processed solid waste material (typically inert) that enters the ocean environment from any source (Coe & Rogers, 1997). Debris is more than an unsightly inconvenience for beach-bound vacationers or pleasure boaters; it's one of the world's most pervasive pollution problems affecting our oceans and inland waterways. It affects the economies and inhabitants of coastal and waterside communities worldwide. Over the past 40 years, organic materials (once the most common forms of debris) have yielded to synthetic elements as the most abundant material in solid waste. Durable and slow to degrade, plastic materials that are used in the production of containers for beverage bottles, made into packing straps and tarps, and synthetic nylon materials used in fishing line can all become debris with staying power. In addition, many of these items are highly buoyant, allowing them to travel in currents for thousands of miles, endangering marine ecosystems and wildlife along the way. Cigarette filters and cigar tips, fishing line, rope and gear, baby diapers and nappies, six-pack rings, beverage bottles and cans, disposable syringes, tires – the litany of litter is as varied as the products available in the global marketplace, but it all shares a common origin. At a critical decision point, someone, somewhere, mishandled it – either thoughtlessly or deliberately while on land or on the water.

According to the United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), land-based sources account for up to 80 percent of the world's marine pollution (GESAMP, 1991). Much of the debris reaches the ocean after people engaged in beach-going activities have discarded it; debris is also blown into the water, or carried by creeks, rivers, and storm drains and sewers, and landfills to ocean areas. Other debris comes from activities on the water, including vessels (from small power and sailboats to large transport ships carrying people and goods), offshore drilling rigs and platforms, and fishing piers.

While there are laws regulating the dumping of trash at sea and on shore, the global nature of debris, its inability to be confined within territorial boundaries, and the complexity of identifying debris sources have made effective laws difficult to draft and even harder to enforce.

What are the Sources of Marine Debris?
Determining where all of the debris originates is no easy task since trash and litter can travel long distances before being deposited on our shorelines or settling on the bottom of the ocean, bay, or riverbed. Marine debris researchers traditionally classify debris sources as either *land-* or *ocean/ waterway-based*, depending on how the debris enters the water. Other factors such as ocean current patterns, climate

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and tides, and proximity to urban centers, industrial and recreational areas, shipping lanes, and commercial fishing grounds influence the types and amount of debris that are found in the open ocean or collected along beaches and waterways – above and below the water's edge.

Land-based debris blows, washes, or is discharged into the water from land areas. Sources include beachgoers; fishers; materials manufacturers, processors, and transporters; shore-based solid waste disposal and processing facilities; sewage treatment and combined sewer overflows; inappropriate or illegal dumping; and indiscriminate public littering. These materials are transported by:

Sewer overflows & sewage treatment plants – Public wastewater treatment facilities are prohibited from discharging plastics and other materials into the marine environment. Under normal "dry weather" conditions, most wastes are screened out of sewage. However, materials can bypass treatment systems and enter waterways when rain levels exceed sewage treatment facilities' handling capacity. During these times, sewage overflows occur and debris from these discharges may include tampon applicators, condoms, and syringes.

Shore-based Solid Waste Management Practices – Both legal and illegal waste handling practices contribute to marine debris. These include the inadvertent release of debris from coastal landfills and garbage from water transports; recreational beach and roadside litter; and the illegal dumping of domestic and industrial garbage into coastal waters and offshore areas.

Litter – People's mishandling of waste materials, the packaging from convenience items, food wrappings, beverage containers, and a host of other materials, creates the foundation for the marine debris problem.

People also generate marine debris at sea. ***Ocean/waterway-based*** contributors include commercial fishing vessels; merchant, military, and research vessels; recreational boats and cruise ships; and offshore petroleum platforms and associated supply vessels. Debris can end up in the water through accidental loss or system failure; historical waste management practices; or illegal disposal and indiscriminant littering.

Commercial Fishing – Commercial fishermen create marine debris when they discard ship-generated trash overboard or fail to retrieve fishing gear. Debris associated with commercial fishing includes nets and ropes, salt treatment bags, bait boxes and bags, fish baskets or totes, fish and lobster tags, and gillnet or trawl floats.

Recreational Boaters – Some boaters discard trash overboard. Such debris may contain food wrappers, beverage containers, bags, and monofilament fishing line and other related fishing gear.

Merchant, Military, and Research Vessels – Large vessels with extensive crews typically carry supplies for several months, and therefore produce solid wastes on a daily basis. But any of this debris can end up in the water if not properly disposed of or secured. The maritime and waste management industries have researched ways to better handle and store wastes aboard ships for long voyages.

Offshore Petroleum Platforms and Supply Vessels – Undersea exploration and resource extraction also contribute to the marine debris problem. Daily oil/gas platform operations can create large amounts of trash. Discarded or lost hard hats, sheeting, computer supplies, survey materials, and personal waste produced by platform and supply vessel crews can all become marine debris.

What are the Impacts of Debris?

Debris enters the environment by default through both accidental and intentional discharges. These impacts are felt locally, nationally and internationally and carry biological and socioeconomic characterizations that indicate that with continued population growth and development and inadequate solid waste management, this global problem will continue to get worse.

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Human Health and Safety
Items such as broken glass, medical waste, rope, and fishing line pose immediate risks to human safety. Discarded syringes, condoms, and tampon applicators can indicate more serious water quality concerns that affect human health. Swimmers, divers and snorkelers can become entangled in submerged or floating debris. Medical and personal hygiene debris often enters the waste stream through direct sewage outflows or inadequate sewage treatment systems. These items can indicate the presence of invisible pathogenic pollutants such as streptococci, fecal coliform, and other bacterial contamination. Consumption or contact with water polluted with these pathogens can result in infectious hepatitis, diarrhea, bacillary dysentery, skin rashes, and even typhoid and cholera.

Aesthetic and Economic Impacts
Clean and safe beaches promote tourism and economic health. Litter makes shorelines unattractive and potentially hazardous, and forces communities to spend funds to increase beach maintenance. The indirect costs can be even greater. Most coastal communities rely on the income generated by seaside businesses, and the clientele that support them. Marine debris discourages people from fishing, boating, swimming, and visiting coastal areas.

Wildlife Entanglement and Ingestion
Many forms of marine debris – especially derelict fishing gear – pose serious threats to wildlife through entanglement. Debris can hamper an animal's mobility, inhibit growth and development, prevent it from eating, inflict cuts and wounds, or cause suffocation or drowning. Monofilament line, fishing nets and ropes, six-pack rings, and packing strapping bands are some of the more harmful culprits related to animal entanglements. According to the U.S. Marine Mammal Commission, 136 marine species have been reported in entanglement incidents, including six species of sea turtles, 51 species of seabirds, and 32 species of marine mammals (Marine Mammal Commission, 1996). There are no accurate and comprehensive reports on global estimates of animal mortality rates. What few reports do exist on select species are deemed to radically underestimate the true levels of mortality as animals may die off and sink before they can be observed (Laist, 1997).

The Marine Mammal Commission also reports that ingestion incidents have been documented in six of seven species of sea turtles, 111 out of the world's 312 species of seabirds, and 26 species of marine mammals (Marine Mammal Commission, 1996). Many animals confuse debris for food and cannot regurgitate an item once it has been swallowed; it often becomes lodged in their throats and digestive tracts. Debris that will not pass out of the stomach gives a false sense of fullness, causing some animals to stop eating and slowly starve to death.

Derelict fishing gear also causes damage when abandoned fishing gear and nets continue to catch and kill ocean life. This process is known as *ghost fishing.* In essence, ghost nets are perpetual "killing machines" that never stop fishing (Esteban, 2002). Worldwide, this phenomenon is having an impact on the viability of already stressed fisheries. Although there is increasing recognition of the ghost fishing problem, few studies have been conducted since 1994 (Laist and Liffmann, 2000). Limited evidence from studies conducted in Atlantic areas suggests that discarded gear may cause significant losses of some commercially valuable fish and crab species (Laist, 1997).

Habitat Destruction & Alien Species Introduction
Debris affects the water quality of aquatic benthic habitats and also causes physical damage. Moved by currents and tides, ropes and nets abrade, scour, break, and destroy living corals. Ensnared debris may also cause increased siltation and turbidity, blocking essential sunlight to, or smothering, sea grass beds and coral reef systems.

Additionally, floating marine debris may serve to transport invasive species. Drifting debris can harbor entire communities of encrusting and attached organisms and carry them great distances – often to areas where they can harm or compete with native species. Researchers have identified "hitch-hiking" benthic

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invertebrates such as mollusks, polychaetes worms and bryozoans, living on floating mats of debris that are being transported by wind and surface currents potentially across the globe (Barnes, 2002).

Vessel Damage

Derelict fishing gear can cause serious damage to vessels. Nets, ropes and other derelict gear entangle vessel propellers and rudders resulting in costly repairs, loss of time, and danger to boaters and crews. Plastic bags clogging and blocking water intakes is a common cause of burned-out water pumps in recreational boats. Such incidents involve costly engine repairs, and disablement. But because most incidents go unreported, the true scope and frequency of damaging encounters between debris and vessels is difficult to calculate.

What are the Marine Debris Monitoring Programs in the United States?

On December 31, 1987, the United States ratified Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Annex V prohibits the at-sea disposal of plastic wastes and regulates the distance from shore that ships may dump all other solid waste materials. Annex V became effective on December 31, 1988. The Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 (Public Law 100-220, Title II) implements Annex V legislation and extends the dumping regulations to vessels in all navigable waterways of the United States.

Section 2204 of the MPPRCA requires the U.S. Environmental Protection Agency (EPA) Administrator, the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Administrator, and the U.S. Coast Guard to conduct a public education program in the marine environment. Section 2204 also directs the EPA Administrator, along with the Secretary of Commerce and the U.S. Coast Guard, to encourage the formation of volunteer groups to assist in the monitoring, reporting, cleanup, and prevention of ocean and shoreline pollution. These policies frame the foundation of the marine debris prevention strategy in the United States and have supported other monitoring and programming development worldwide. The result of this legislation and research conducted by The Ocean Conservancy (formerly the Center for Marine Conservation) was the development of the International Coastal Cleanup and the National Marine Debris Monitoring Program.

A. International Coastal Cleanup

The International Coastal Cleanup (ICC) engages the public to remove trash and debris from the world's beaches and waterways, to identify the sources of debris, and to change the behaviors that cause pollution. The origins of the ICC began in 1985 with research conducted by The Ocean Conservancy (then known as the Center for Marine Conservation – CMC) on plastics in the marine environment. Contracted by the U.S. Environmental Protection Agency, Office of Toxic Substances, CMC produced the report, *Plastics in the Ocean: More Than a Litter Problem,* which was the first study to identify plastics as a significant marine debris hazard. The report's findings led the U.S. Congress to adopt MARPOL 73/78 Annex V and to enact legislation (MPPRCA) to limit the dumping of garbage from boats and to help control land-based sources of marine debris, such as stormwater systems and combined sewer systems. The September 17, 2005 Cleanup is the 20th annual event coordinated by The Ocean Conservancy, partnering with nearly a thousand other organizations (e.g. conservation groups/NGOs, churches, schools, civic clubs), resource management departments, government agencies, corporate supporters and sponsors, and most importantly, a half million volunteers worldwide.

Since its first beach cleanup in 1986 in Texas, The Ocean Conservancy and its many partners have grown the ICC into a global volunteer effort devoted to the marine environment. To date, all 55 U.S. states and territories and 127 countries bordering every major body of water on the planet have participated in the ICC. In the past two decades, 5.8 million people have collected more than 100.4 million pounds of debris along 158,657 miles of shoreline and in underwater areas.

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ICC Data Collection

The ICC is characterized as a volunteer-based campaign that includes a data collection exercise using standardized data cards for tabulating the types, amounts and sources of debris found during the annual Cleanup. The information collected from the annual cleanup event are tabulated and analyzed by The Ocean Conservancy. The data cards developed through the ICC have evolved from a cataloging tool for debris forms based on material type (glass, paper, hard and foamed plastic, metal, rubber and wood) to a focus on the behaviors and activities that produce the debris as an approach for prevention and abatement. The categories used for sorting the debris collected during the ICC since 2001 include specific source and activity groups – shoreline and recreational activities, ocean/waterway activities, smoking-related activities, dumping activities, and medical/personal hygiene (see Table 1). The data card is produced in English, Spanish and French. See Appendix A to review a sample ICC data card.

Debris Sources & Activities	Key Debris Forms
Shoreline & Recreational Activities: debris from beach-goers, sports/games, festivals, litter from streets/storm drains	bags, balloons, beverage bottles (plastic) 2 liters or less, beverage bottles (glass), cups/plates/folks/knives/spoons, food wrappers/containers, pull tabs, 6-pack holders, shotgun shells/wadding, straws/stirrers, toys
Ocean/Waterway Activities: debris from recreational/commercial fishing and boat/vessel operations	bait containers/packaging, bleach/cleaner bottles, buoys/floats, crab/lobster/fish traps, crates, fishing line, fishing lures/light sticks, fishing nets, light bulbs/tubes, oil/lube bottles, pallets, plastic sheeting/tarps, rope, strapping bands
Smoking-related Activities:	cigarettes/cigarette filters, cigarette lighters, cigar tips, tobacco packaging/wrappers
Dumping Activities:	appliances, batteries, building materials, car/car parts; 55-gallon drums, tires
Medical/Personal Hygiene:	condoms, diapers, syringes, tampons/tampon applicators

Table 1. The Ocean Conservancy's data card components used in the International Coastal Cleanup listing debris sources/activities and associated debris forms.

The ICC data card, which has been researched and designed to provide a "snapshot" assessment of the types and amounts of debris found during the annual Cleanup is in the form of a survey tally card. The ICC does not employ a rigorous, scientific protocol for its methodology, as there are inherent differences and inconsistencies generated in the data based on site selection and sampling techniques. Therefore, comparisons using ICC data are limited, but do serve as a useful informational tool related to the nature of marine debris worldwide. The result is a unique, global database of debris information. Data from the Cleanup provides the framework for government action to limit marine debris and to educate the public about litter and pollution prevention.

The data collected and analyzed from the annual Cleanup is used locally, nationally and internationally to influence policy decisions, spawn campaigns for recycling programs, support public education programs, launch adopt-a-beach programs, and even stormwater system overhaul and legislative reform. In U.S. Commission on Ocean Policy Report released in September 2004, the International Coastal Cleanup and the National Marine Debris Monitoring Program (see discussions below) were recognized as significant sources of information characterizing the types, amounts and sources of marine debris collected along

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the beaches and waterways in the U.S. and its territories. In June 2005 at the sixth United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS), the ICC was presented as a model for addressing public awareness on marine debris issues and a characterization of the debris types, sources and impacts reported around the world through its 20-year campaign.

ICC Data Analysis

National:

The data collected during the International Coastal Cleanups from 2002-2004 (United States) have been compiled and analyzed for presentation in this paper to aid in characterizing the debris composition and source identification. National ICC data totals (land and underwater combined) of the debris types and amounts collected during the Cleanup in the past three years are presented in Table 2 on page 7.

The most abundant marine debris forms tabulated during the ICC in the United States from 2002-2004 were recorded in the categories of smoking-related activities (e.g. cigarette filters) and shoreline and recreational activities (e.g. food wrappers/containers, <2 liters beverage bottles–plastic, cups/plates/ forks/knives/spoons, and beverage bottles–glass). It should be noted that these debris forms are discarded materials originating as smoking products and food and beverage packaging remnants. Further review of the data collected during this period indicates that the most abundant debris forms are associated with ***land-based activities*** as evidenced in a percent source analysis of this data with land-based percentages ranging from 55.89 in 2002 to 60.69 in 2004. ***Ocean-based activities*** exhibited percent source levels of 6.16 in 2002, 6.41 in 2003 and 6.34 in 2004. See Figure 1.

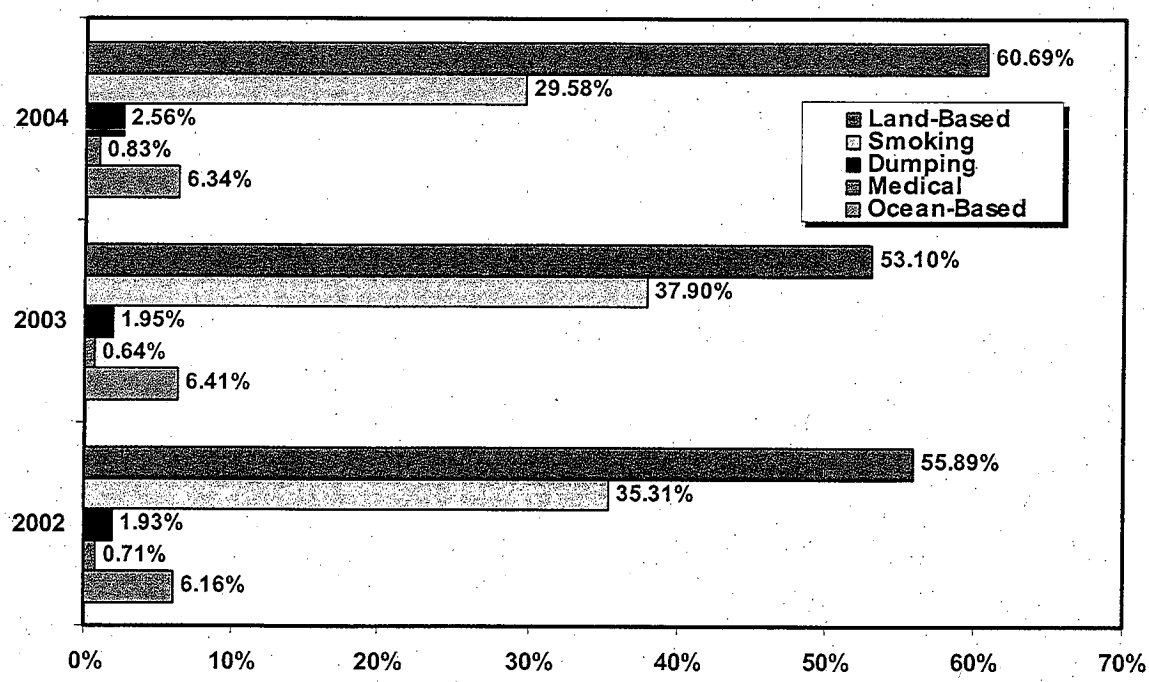

Figure 1. Source percentages for total debris for 2002-2004 Cleanups – United States. Data compiled from the *2002, 2003, and 2004 International Coastal Cleanup Reports* published by The Ocean Conservancy.

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Shoreline and Recreational Activities	2002	2003	2004
Bags	190,477	170,053	158,037
Balloons	57,387	45,996	43,136
Beverage Bottles (Glass)	226,251	211,359	199,804
Beverage Bottles (Plastic) 2 liters or less	223,029	227,220	209,075
Beverage Cans	238,826	207,225	189,132
Caps, Lids	363,857	356,513	339,841
Clothing, Shoes	50,205	48,807	48,293
Cups, Plates, Forks, Knives, Spoons	250,511	205,301	188,262
Food Wrappers/Containers	444,447	418,795	390,995
Pull Tabs	49,277	50,971	43,904
Shotgun Shells/Wadding	16,792	20,689	14,247
Six-Pack Holders	20,987	18,244	18,897
Straws, Stirrers	182,794	180,091	158,984
Toys	37,365	37,956	38,154
Ocean/ Waterway Activities	**2002**	**2003**	**2004**
Bait Containers/Packaging	21,511	21,126	18,529
Bleach/Cleaner Bottles	14,263	11,743	11,290
Buoys/Floats	19,494	18,737	12,110
Crab/Lobster/Fish Traps	6,035	7,860	3,685
Crates	2,580	2,782	2,140
Fishing Line	32,741	32,862	25,981
Fishing Lures/Light Sticks	14,082	12,593	11,955
Fishing Nets	6,278	7,737	5,359
Light Bulbs/Tubes	5,520	4,854	4,614
Oil/Lube Bottles	14,120	10,838	10,331
Pallets	2,433	2,839	2,051
Plastic Sheeting/Tarps	44,163	47,247	40,436
Rope	57,099	61,379	47,871
Strapping Bands	18,829	22,730	16,858
Smoking-Related Activities	**2002**	**2003**	**2004**
Cigar Tips	67,649	72,078	56,551
Cigarette Lighters	21,369	21,362	17,845
Cigarettes/Cigarette Filters	1,345,833	1,426,613	880,807
Tobacco Packaging/Wrappers	51,090	49,564	39,353
Dumping Activities	**2002**	**2003**	**2004**
55-Gallon Drums	769	833	864
Appliances (refrigerators, washers, etc.)	1,606	2,061	1,788
Batteries	6,304	6,135	5,836
Building Materials	55,388	54,935	59,255
Cars/Car Parts	10,447	9,891	10,206
Tires	6,828	6,916	8,031
Medical/Personal Hygiene	**2002**	**2003**	**2004**
Condoms	8,209	7,576	7,329
Diapers	7,776	5,897	5,863
Syringes	2,529	2,910	2,937

Table 2. Debris item totals compiled from 2002-2004 International Coastal Cleanups in the United States. *Source: The Ocean Conservancy: 2002, 2003 & 2004 International Coastal Cleanup Reports.*

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ICC Data Analysis (cont.)

U.S. Pacific Coast:

When studying debris composition for the purposes of source identification, regional analyses give additional insight regarding the specific debris forms that are being contributed locally per watershed dynamics, land-use practices, and select offshore current patterns. ICC data totals (land and underwater combined) for the U.S. Pacific Coast of the debris types and amounts collected during the Cleanup in the past three years are presented in Table 3 on page 9.

Comparing the composite data from the cleanups conducted along the U.S. Pacific Coast to the national ICC data regarding the most abundant debris forms, reveal a similar pattern in abundance. The most abundant marine debris forms tabulated during the ICC in the U.S. Pacific Coast from 2002-2004 were recorded in the categories of smoking-related activities (e.g. cigarette filters) and shoreline and recreational activities (e.g. food wrappers/containers, caps/lids, cups/plates/ forks/knives/spoons, and bags). It should be noted that these debris forms are discarded materials originating as smoking products and food and beverage packaging remnants. Further review of the data collected during this period indicates that the most abundant debris forms are associated with ***land-based activities*** as evidenced in a percent source analysis of this data with land-based percentages ranging from 50.03 in 2002 to 49.83 in 2004. ***Ocean-based activities*** exhibited percent source levels of 4.58 in 2002, 5.05 in 2003 and 4.32 in 2004. See Figure 2.

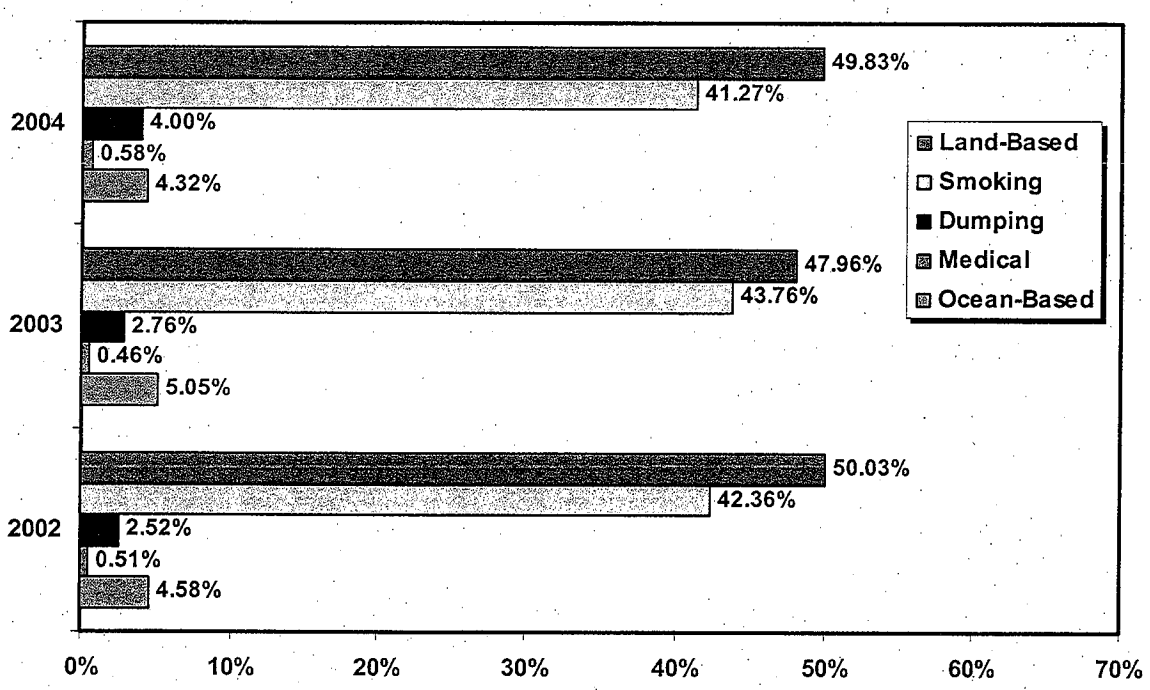

Figure 2. Debris source percentages for total debris for 2002-2004 Cleanups – U.S. Pacific Coast (CA, OR, and WA). Data compiled from the *2002, 2003, and 2004 International Coastal Cleanup Reports* published by The Ocean Conservancy.

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Shoreline and Recreational Activities	2002	2003	2004
Bags	37,086	31,333	32,907
Balloons	11,003	8,664	11,199
Beverage Bottles (Glass)	32,280	32,550	34,172
Beverage Bottles (Plastic) 2 liters or less	24,911	26,124	27,123
Beverage Cans	23,741	22,026	24,740
Caps, Lids	60,594	63,009	62,094
Clothing, Shoes	9,479	10,460	10,962
Cups, Plates, Forks, Knives, Spoons	40,499	36,970	40,162
Food Wrappers/Containers	113,200	109,827	116,180
Pull Tabs	7,728	9,344	7,647
Shotgun Shells/Wadding	2,327	5,346	3,212
Six-Pack Holders	2,182	2,560	2,259
Straws, Stirrers	32,567	36,047	31,497
Toys	7,621	9,113	8,727
Ocean/ Waterway Activities	**2002**	**2003**	**2004**
Bait Containers/Packaging	3,037	2,854	2,761
Bleach/Cleaner Bottles	1,110	1,355	876
Buoys/Floats	3,158	2,299	1,875
Crab/Lobster/Fish Traps	993	872	567
Crates	341	395	259
Fishing Line	4,389	6,312	4,291
Fishing Lures/Light Sticks	1,683	1,497	1,680
Fishing Nets	597	984	767
Light Bulbs/Tubes	693	745	799
Oil/Lube Bottles	1,519	1,124	1,473
Pallets	473	761	444
Plastic Sheeting/Tarps	7,995	9,932	9,291
Rope	7,255	8,341	6,503
Strapping Bands	3,862	5,038	4,246
Smoking-Related Activities	**2002**	**2003**	**2004**
Cigar Tips	11,846	23,006	15,798
Cigarette Lighters	3,617	3,701	2,921
Cigarettes/Cigarette Filters	318,384	331,250	313,234
Tobacco Packaging/Wrappers	9,248	10,087	9,983
Dumping Activities	**2002**	**2003**	**2004**
55-Gallon Drums	93	58	72
Appliances (refrigerators, washers, etc.)	270	256	413
Batteries	1,205	1,259	1,545
Building Materials	16,354	19,031	27,201
Cars/Car Parts	1,628	1,675	2,541
Tires	867	918	1,353
Medical/Personal Hygiene	**2002**	**2003**	**2004**
Condoms	1,908	1,741	2,283
Diapers	957	752	1,094
Syringes	412	492	407
Tampons/Tampon Applicators	871	883	1,044

Table 3. Debris item totals compiled from 2002-2004 International Coastal Cleanups along the U.S. Pacific Coast (CA, OR & WA). *Source: The Ocean Conservancy: 2002, 2003 & 2004 International Coastal Cleanup Reports.*

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ICC Data Interpretation

Winds, waves, currents, and regional land/waterway-use activities along with seasonal climatic variations can influence debris patterns and trends in deposition. Seasonality in debris patterns and trends should be considered when assessing the types, amounts and sources. In temperate areas where summer to fall beach activities are higher, summer storms and increased stormwater activity can result in a higher influx of debris and other pollutants. To better understand the debris composition analyzed from the ICC, it is recommended that the researcher have an idea as to the regional land/waterway-use activities associated to a beach area and to look at the annual data over a period of several years.

An ICC Data Story: The issue of data interpretation was expressly demonstrated in 1996 when new Cleanup programs were emerging and inland areas were being cleaned up for the first time as part of the ICC. In Arizona, one of their first cleanup efforts involved extensive efforts to retrieve debris found underwater in a popular, recreational public lake. The resulting counts of recovered cans and bottles raised Arizona's debris numbers to one of the highest in the U.S. that year for beverage containers. The media poked fun at the numbers resulting in a phone call from the Governor's office asking why CMC was insinuating that Arizonians had a drinking problem? The ICC staff reviewed the data and told them that the numbers were correct, but that it was not a problem. Arizona was actually leading in the country for inland state waterway cleanup efforts and that there had not been an organized cleanup in that lake. The debris that was collected had accumulated over many, many years deposited by visiting boaters and picnickers. Over the coming years, the data from this lake area would be studied and the numbers would go down, especially with the recycling programming that the state was implementing. Programs were implemented and their beverage container numbers dropped. There was no drinking problem in Arizona, just a need for improved solid waste handling practices!

B. National Marine Debris Monitoring Program

Through a multi-year cooperative agreement with the U.S. Environmental Protection Agency, The Ocean Conservancy developed and field-tested the National Marine Debris Monitoring Program (NMDMP). This is a scientific marine debris-monitoring program designed to assess the effectiveness of current U.S. marine debris legislation. NMDMP assesses several aspects of debris, including accumulation rates, types and amounts of debris found at specific geographic locations, oceanographic and meteorological conditions, and proximity to land-based or ocean-based sources. The study consists of a sampling protocol that examines the occurrence of 30-specific debris items in order to answer the following research questions:

1. Is the amount of debris on our coastlines decreasing?
2. What are the major sources of the debris?

NMDMP has been successfully developed and field-tested through a national network of 500 trained volunteers who monitor over 100 sites in 21 coastal U.S. states and two territories (Puerto Rico and U.S. Virgin Islands). The program developed nine regional designations, based on prevailing current patterns, marine debris information, and logistics. The results of this five-year study will provide the required data needed to scientifically assess marine debris trends and sources in the United States. Data collected through NMDMP is posted quarterly for public access through The Ocean Conservancy's website at www.oceanconservancy.org/nmdmp.

Trained NMDMP volunteers monitor randomly selected beaches for marine debris and conduct beach cleanups every 28 days during a five-year period. NMDMP takes the idea of beach cleanups a step further by standardizing marine debris collection using a scientifically valid protocol to determine the status and trends of marine debris pollution.

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NMDMP History

Prompted by the recognition of the threat posed by marine debris pollution and armed with marine debris data collected through The Ocean Conservancy's International Coastal Cleanups (ICC), the United States government ratified and enacted important marine debris legislation in 1987. Congress ratified Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). This important set of legislation was aimed at addressing marine debris pollution at its source. Annex V, which became effective in 1988, prohibits the at-sea disposal of plastic waste and regulates the distance from shore that all other solid waste materials can be dumped. Also enacted in 1987 was the Marine Plastic Pollution Research and Control Act (MPPRCA), Public Law 100-220, Title II, which extends MARPOL Annex V legislation to all navigable waterways of the United States.

In 1989, the National Oceanic and Atmospheric Administration (NOAA) and the National Park Service (NPS) agreed to conduct a five-year pilot study developing standardized methods for quantifying marine debris. In addition the EPA and other Federal Agencies established a working group to monitor marine debris status and trends as directed by the MPPRCA (section 2204). The MPPRCA required that the EPA, NOAA and the U.S. Coast Guard (USCG) form "Citizen Pollution Patrols" utilizing volunteers to monitor, cleanup and prevent ocean and shoreline pollution.

In 1990, the EPA was instructed by Congress to assess the effectiveness of marine debris legislation and other methods to control debris. The EPA and The Ocean Conservancy joined in the effort since the most geographically comprehensive and continuous set of marine debris data had been collected and compiled in The Ocean Conservancy's ICC Database. The ICC Database provided a means to assess and review the nature and characteristics of marine debris pollution over the past 20 years. The marine debris information gathered during the annual International Coastal Cleanup surveys, though useful and valuable, is a non-scientific means of collecting information that at best provides a snapshot into the nature of marine debris. It was apparent that a standardized method of monitoring marine debris was needed to statistically determine if existing legislation was working to reduce the debris in our oceans.

NMDMP Methodology

In 1990, Congress appropriated funds to the EPA for the development of demonstration programs to utilize volunteers in monitoring and removing marine debris from selected beaches in New Jersey and Maryland. As part of the program The Ocean Conservancy in conjunction with the EPA, began to test a statistically valid methodology designed by Ribic (1991) for determining trends in marine debris. Beach sites were selected in Maryland, New Jersey, Texas and Alabama and volunteers were recruited and trained in the program protocol. A methodology was developed by a working group comprised of representatives from NOAA, NPS, CMC/The Ocean Conservancy, USCG, the Marine Mammal Commission, and selected researchers and was reviewed by all federal agencies that monitored marine debris. Based on the results obtained during the pilot program, the goal of the NMDMP was set to be able to measure a 30% change in 30 selected marine debris items on the U.S. coastal shorelines, with a Type I error rate of 0.10 and power of 0.84. This requires the monthly sampling of randomly selected beach sites in nine coastal regions (see Figure 3 on page 12), for a five-year period (Ribic, 1991, Ribic et al., 1992). Each study site must be of low to moderate slope, composed of sand to small gravel, have a length of at least 500 meters (1/3 mile), have clear direct access to the sea (not blocked by breakwaters or jetties) and must be accessible to volunteers year round.

Care was also taken to select beach sites that would not impact any endangered or protected species such as sea turtles, sea birds, marine mammals, and sensitive beach vegetation. At each designated study site, trained volunteers conduct beach cleanups and marine debris surveys every 28 days.

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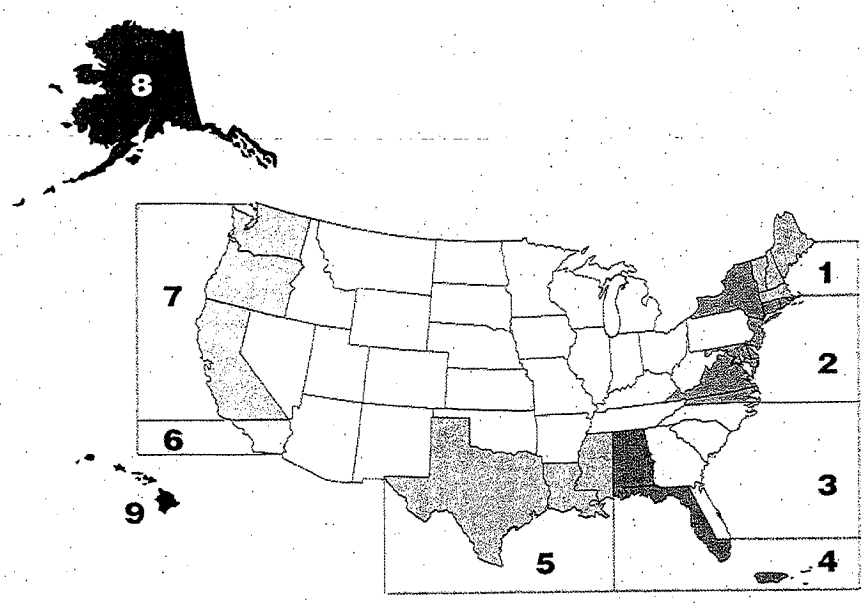

Region 1: U.S. – Canada border to Provincetown, MA
Region 2: South of Cape Cod, MA to Beaufort, NC
Region 3: Morehead City, NC to Port Everglades, FL
Region 4: Port Everglades, FL to Gulf Shores, AL, including Puerto Rico & U.S. Virgin Islands
Region 5: Dauphin Island, AL to U.S. – Mexico border
Region 6: U.S. – Mexico border to Point Conception, CA
Region 7: North of Point Conception, CA to U.S. – Canada border
Region 8: Alaska (southern coast and Aleutian Islands)
Region 9: Hawaiian Islands

Figure 3. National Marine Debris Survey Regions. Go to http:/www.oceanconservancy.org/nmdmp to access GPS coordinates for and descriptions of monitoring study sites.

NMDMP Data Collection

Data are recorded on a specialized NMDMP data card by the volunteer survey teams. Information is recorded on thirty specific debris indicator items grouped into three general categories of debris - *ocean-based, land-based, and general sources* (items that may originate as either ocean- or land-based debris).

Ocean-Based Source Indicator Items: gloves, plastic sheets (≥1 meter), light bulbs/tubes, oil/gas containers (>1 quart), pipe-thread protectors, nets (≥5 meshes), traps/pots, fishing line, light sticks, rope (≥1 meter), salt bags, fish baskets, cruise line logo items, floats/buoys.

Land-Based Source Indicator Items: syringes, condoms, metal beverage cans, motor oil containers (1 quart), balloons, six-pack rings, straws, tampon applicators, cotton swabs.

General Source Indicator Items: plastic bags (<1 meter), plastic bags (≥1 meter), strapping bands (open), strapping bands (closed), plastic beverage bottles, plastic food bottles, plastic bleach/cleaner bottles, other plastic bottles.

Table 4. The Ocean Conservancy's data card components used in the National Marine Debris Monitoring Program listing debris sources and associated debris forms.

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The 30 specific items listed on the data card will provide the information needed to measure the changes and trends in the amount of debris appearing on the U.S. coastline. See Appendix B to review a sample NMDMP data card. Additional debris items may also be tracked that are specific and meaningful to local regions (i.e. mesh bait bags in New England, fluorescent light tubes in the Gulf of Mexico). The data, which are collected by each volunteer survey team, is sent back to The Ocean Conservancy's NMDMP Project Team where the data is processed, verified and entered into the NMDMP database.

As with any scientific study, quality assurance (QA) is practiced to ensure that all data collected is reproducible and comparable. It is part of the protocol and responsibility of each monitoring site Survey Director to follow QA procedures during the survey set-up, volunteer training, and data collection activities. Throughout the course of each year of the study, Survey Directors conduct random QA procedures as part of the monitoring protocol.

The data collected from the NMDMP will be analyzed at the end of a five-year study period and will yield a more in-depth understanding into the nature and trends of marine debris in the U.S. Data will be examined both on a national basis as well as by region. Final analysis on a national level will begin in 2007 to examine trends in marine debris as well as an examination of the major sources of the debris. In the interim, preliminary data summaries will be computed to provide some insight as to debris conditions for use in local programming and pollution prevention efforts.

Preliminary NMDMP Debris Analyses

A preliminary examination of the NMDMP database was conducted to examine the amounts and sources of marine debris at the regional level (U.S. West Coast – CA, OR, WA) during the Fall Quarter (September – November) from 2002-2004 for comparison to the data collected during the 2002-2004 ICC events. The corresponding NMDMP regions associated with the U.S. West Coast are Regions 6 and 7. Refer to Figure 3 on page 12 for a geographical depiction.

During the Fall Quarter, 2002-2004 for this data comparison in Region 6, the number of sites where surveys were conducted was 6 in 2002, 4 in 2003 and 5 in 2004 with a total of 15, 9 and 9 surveys conducted respectively. In Region 7, the number of sites where surveys were conducted was 13 in 2002, 10 in 2003 and 9 in 2004 with a total of 13, 10 and 9 surveys conducted respectively.

In comparison to corresponding data collected during the annual International Coastal Cleanup, similar patterns in abundance of marine debris types and debris sources were observed. In Region 6, the top debris forms associated with land-based sources included straws, balloons, and beverage cans (metal). Ocean-based debris types were lead by rope (≥ 1 meter), floats/buoys, and fishing line. In reviewing general sources, the top debris forms included plastic bags w/seam (< 1 meter), beverage bottles (plastic) and other bottles (plastic), which in comparison to the debris source categories of the ICC, a large portion of the debris types in the general category are applicable to land-based activities.

In Region 7, the top debris forms associated with land-based sources included were identical to the data in Region 6 with straws, balloons, and beverage cans (metal) as the leading debris forms collected, as were the ocean-based debris types with rope (≥ 1 meter), floats/buoys, and fishing line as the top debris forms reported. In reviewing general sources computed for Region 7, the top debris forms included plastic bags w/seam (< 1 meter), beverage bottles (plastic) and food bottles (plastic) – a slight variation from Region 6 with other bottles (plastic).

The total debris items recorded during the Fall Quarters in Regions 6 and 7 from 2002-2004 are presented in Tables 5 and 6 on pages 14 and 15.

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Ocean-Based	2002	2003	2004
Gloves	0	0	5
Plastic sheets ≥ 1 meter	4	5	5
Light bulbs/tubes	0	2	2
Oil/gas containers	0	0	0
Pipe-thread protectors	8	3	6
Nets ≥ 5 meshes	0	1	5
Traps/pots	4	1	0
Fishing Line	9	4	10
Light sticks	7	2	6
Rope ≥ 1 meter	31	9	8
Salt bags	2	1	1
Fish baskets	3	0	0
Cruiseline logo items	0	0	3
Floats/Buoys	7	16	2
Land-Based	**2002**	**2003**	**2004**
Syringes	1	1	0
Condoms	1	1	0
Metal beverage cans	62	13	59
Motor oil containers	0	0	0
Balloons	215	152	76
Six-pack rings	0	0	6
Straws	395	180	137
Tampon applicators	1	1	5
Cotton swabs	0	0	1
General	**2002**	**2003**	**2004**
Plastic bags with seam < 1 meter	156	110	43
Plastic bags with seam ≥ 1 meter	3	8	7
Straps: Open	14	24	7
Straps: Closed	3	2	1
Plastic bottles: beverage	51	18	85
Plastic bottles: food	5	0	29
Plastic bottles: bleach/cleaner	2	0	3
Other plastic bottles	44	7	90

Table 6. NMDMP Region 6 debris totals, Fall Quarter (2002-2004). *Source:* NMDMP database, http://www.oceanconservancy.org/nmdmp.

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Ocean-Based	2002	2003	2004
Gloves	31	1	2
Plastic sheets ≥ 1 meter	10	2	0
Light bulbs/tubes	1	1	0
Oil/gas containers	3	0	0
Pipe-thread protectors	4	4	3
Nets ≥ 5 meshes	7	8	2
Traps/pots	2	1	11
Fishing Line	32	12	11
Light sticks	2	5	2
Rope ≥ 1 meter	92	65	42
Salt bags	0	2	0
Fish baskets	0	1	5
Cruiseline logo items	0	0	0
Floats/Buoys	36	7	20
Land-Based	**2002**	**2003**	**2004**
Syringes	2	1	3
Condoms	3	3	1
Metal beverage cans	66	44	60
Motor oil containers	2	1	0
Balloons	70	28	41
Six-pack rings	4	8	5
Straws	96	53	166
Tampon applicators	3	3	7
Cotton swabs	2	0	1
General	**2002**	**2003**	**2004**
Plastic bags with seam < 1 meter	237	69	83
Plastic bags with seam ≥ 1 meter	23	3	8
Straps: Open	4	3	13
Straps: Closed	0	1	0
Plastic bottles: beverage	76	51	47
Plastic bottles: food	44	31	30
Plastic bottles: bleach/cleaner	3	3	8
Other plastic bottles	32	12	17

Table 6. NMDMP Region 7 debris totals, Fall Quarter (2002-2004). *Source:* NMDMP database, http://www.oceanconservancy.org/nmdmp.

NMDMP Regions 6 and 7 – Data Summary

Data collected in Regions 6 and 7 during the Fall Quarters of 2002-2004 were pooled and sorted to produce percent source comparisons according to land- and ocean-based and general sources as prescribed in the protocol of the NMDMP study. Examination of these compilations reveals that ***land-based sources*** of debris were the most abundant as evidenced in a percent source analysis of this data with land-based percentages ranging from 63.62 in 2002, 49.69 in 2003 and 48.05 in Region 6. Region 7 shows a slightly different pattern with general sources dominating in 2002 and 2003 with percentages of 49.15 and 41.59 respectively. In 2004, land-based sources lead with 43.74 percent.

Ocean-based sources ranked at the bottom for both Regions ranging from 6.99 to 21.50 percent for both regions. It should be noted that the ocean-based sources were higher in Region 7 when compared

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to the data in Region 6. See Figures 4 and 5 to review debris source percent comparisons for NMDMP Regions 6 and 7, Fall Quarter, 2002-2004.

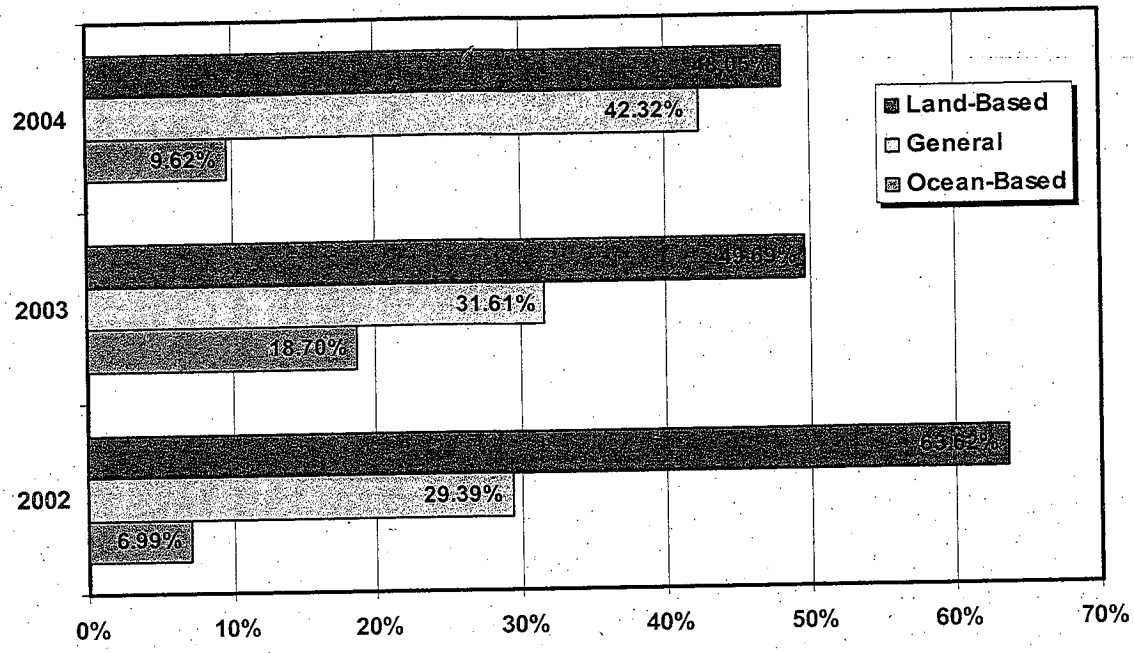

Figure 4. NMDMP Region 6, Fall Quarter (Sep. – Nov.), Debris Source Percentages. *Source:* NMDMP database, http://www.oceanconservancy.org/nmdmp.

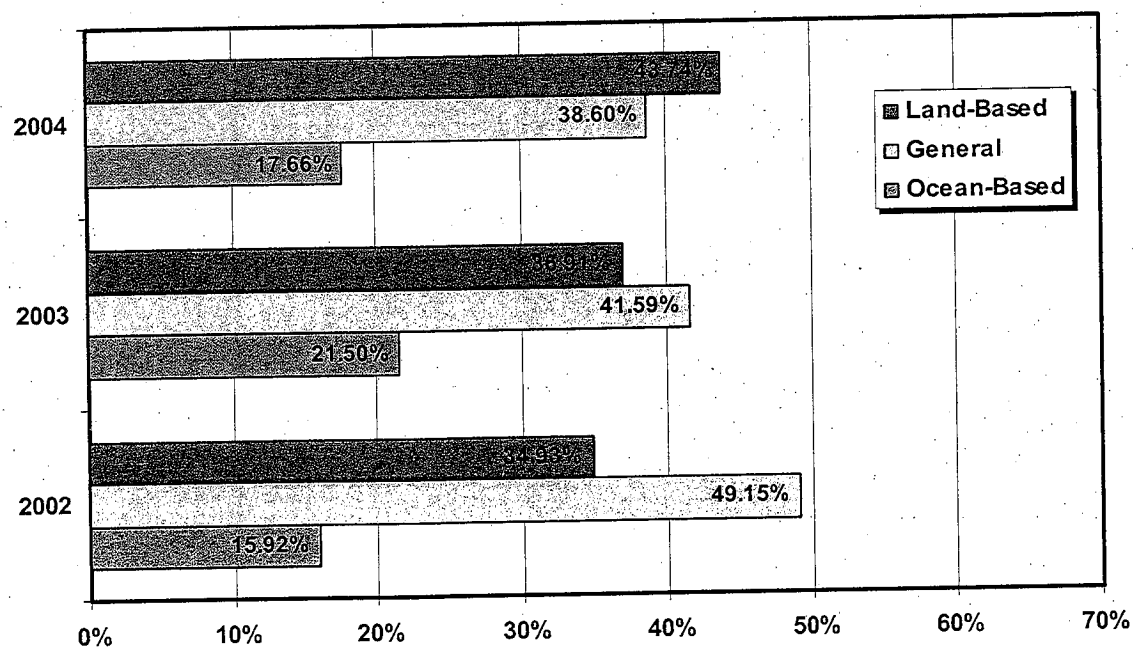

Figure 5. NMDMP Region 7, Fall Quarter (Sep. – Nov.), Debris Source Percentages. *Source:* NMDMP database, http://www.oceanconservancy.org/nmdmp.

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SUMMARY

The information that is being collected and compiled through the International Coastal Cleanup (ICC) and the National Marine Debris Monitoring Program (NMDMP) provides a valuable information base that can be used to catalog and analyze the main sources and activities responsible for marine debris pollution. The information and data presented in this paper from the International Coastal Cleanup and the National Marine Debris Monitoring Program show that the dominant sources of debris emanate from ***land-based sources and activities***. This does not mean that the other sources and activities are to be considered less important – all forms of debris can be harmful and need to be reduced and abated.

Despite knowing the causes of marine debris and how it enters the environment, we continue to facilitate its deposition. Alternative materials that are less invasive or harmful to the environment exist, but they have not been successfully integrated into the economic mainstream. Lack of enforcement and inadequate compliance with existing laws that would help to abate marine debris make those laws ineffectual. To fight these developments, we must continue with current efforts by governments and the private sector to increase awareness, establish debris abatement programs, and ultimately change human behaviors.

To effectively reduce and control marine debris and its environmental impacts, key stakeholders from diverse groups must be involved. This list includes local citizens; governments, agencies and authorities (national, regional, and municipal); organizations (international/ national, civic, religious, nongovernmental, and consumer); institutions (research, education, and medical); businesses (hotels and restaurants, outdoor recreation, manufacturers, and vendors); and industries (fisheries, tourism, dive and waste management).

A review of the available data and other information on debris found worldwide indicates that the dominant types and sources of debris come ***land-based activities*** resulting from what we consume (including food wrappers, beverage containers, cigarettes and related smoking materials), what we use in transporting ourselves by sea, and what we harvest from the sea (fishing nets & gear that leave in the sea). Industries affiliated with the aforementioned products and services play a critical role in debris management and abatement. Only with their involvement and support can we create effective solutions to the debris problem.

Numerous laws regulate litter and debris on both land and sea. Unfortunately, laws do not guarantee compliance. In addition to enforcement and penalties, a sense of environmental stewardship among ocean users is essential for laws to be effective. Recent legislation was introduced focusing on marine debris prevention. The Marine Debris Research Prevention and Reduction Program Act (S. 362) passed the Senate on July 1, 2005. As of the production of this paper, the bill is in the House for further discussion. The bill directs the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard (USCG) to establish programs for the identification of type and source, assessment, reduction, and prevention of marine debris. These programs would be carried out in cooperation with other Federal and non-Federal programs. The bill would also direct NOAA and the USCG to re-establish the Interagency Marine Debris Coordinating Committee, develop a Federal marine debris information clearing house, and work with the international community in order to reduce the problem of marine debris on a global scale. The U.S. Commission on Ocean Policy recognized marine debris as one of the major threats to our nation's marine resources and to human health and safety along our coasts. However, no Federal program currently exists that deals explicitly with the problem of marine debris. The Marine Debris Bill needs to be passed so that we can effectively deal with marine debris and bring this pervasive pollution problem to its knees.

Controlling and reducing debris in the marine environment is a significant – but achievable – challenge. If we are to conserve our ocean resources responsibly and successfully, it is a challenge that we must all face together and be willing to take the necessary steps and do what it takes. Every piece of debris on this planet has a person's face behind it. We are the cause and the only solution.

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INTERNATIONAL COASTAL CLEANUP™ DATA CARD

Data collected during The Ocean Conservancy's International Coastal Cleanup™ is used to educate people and create solutions to the problems of solid waste and litter. Through partnerships with business, government, environmental groups, and citizens, we are helping to change the behaviors and practices that create debris. Thank you for being part of this very important process.

20th Anniversary International Coastal Cleanup The Ocean Conservancy

CLEANUP LOCATION

Type of Cleanup: ☐ Shoreline/Beach ☐ Underwater Location of Cleanup: State_____ Country_____

Zone or County Cleaned:_____ Beach Site Name:_____

Today's Date: Month_____ Day_____ Year_____ Name of Coordinator:_____

Number of People Working on This Card:_____ Distance Cleaned:_____ miles or_____ km

Number of Trash Bags Filled:_____ Total Estimated Weight Collected:_____ lbs. or_____ kgs.

NAMES OF PARTICIPANTS IN YOUR GROUP

If you are interested in becoming a member of The Ocean Conservancy and/or joining our Ocean Action Network (OAN) to make your voice heard on important ocean conservation issues, please check the box(es) below your name and address. ***Thank you for helping to protect our oceans!***

1. Name:_____ Age:_____
Address:_____
City:_____ State:_____
Zip Code:_____ Country:_____
Phone: (_____) _____
Email:_____
I would like information on: ☐ The Ocean Conservancy ☐ The OAN

2. Name:_____ Age:_____
Address:_____
City:_____ State:_____
Zip Code:_____ Country:_____
Phone: (_____) _____
Email:_____
I would like information on: ☐ The Ocean Conservancy ☐ The OAN

3. Name:_____ Age:_____
Address:_____
City:_____ State:_____
Zip Code:_____ Country:_____
Phone: (_____) _____
Email:_____
I would like information on: ☐ The Ocean Conservancy ☐ The OAN

4. Name:_____ Age:_____
Address:_____
City:_____ State:_____
Zip Code:_____ Country:_____
Phone: (_____) _____
Email:_____
I would like information on: ☐ The Ocean Conservancy ☐ The OAN

ENTANGLED ANIMALS: (☐ Dead or ☐ Alive). List all entangled animals found during the Cleanup. Tell us what they were entangled in (fishing line, rope, net, etc.) _____

WHAT WAS THE MOST PECULIAR ITEM YOU COLLECTED?_____

The following national and international organizations endorse and/or support the International Coastal Cleanup:

- U.S. Environmental Protection Agency
- IUCN – The World Conservation Union
- Intergovernmental Oceanographic Commission (IOC) of the United Nations' Educational, Scientific, and Cultural Organization (UNESCO)

Please return this card to your area coordinator or mail it to:

The Ocean Conservancy
2029 K Street, NW, Suite 700
Washington, D.C. 20006 USA
Phone (202) 429-5609 Fax (202) 872-0619
www.oceanconservancy.org

100% post-consumer recycled paper. Chlorine free.

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ITEMS COLLECTED

The Ocean Conservancy
www.oceanconservancy.org

Human-made debris, trash and litter...
- Harms the environment & wildlife
- Causes communities to lose money
- Threatens human health & safety
- Looks bad!

Think about where all this debris comes from and how **we** can prevent it!

Please pick up all debris found on the beach. Record information on only the items listed below.

Keep a count of your items using tick marks and enter the item total in the box. **Example:** [8] **Beverage Cans** 𝍸 III

SHORELINE AND RECREATIONAL ACTIVITIES

(Debris from beach-goers, sports/games, festivals, litter from streets/storm drains, etc.)

- ☐ Bags_____
- ☐ Balloons_____
- ☐ Beverage Bottles (plastic) 2 liters or less_____
- ☐ Beverage Bottles (glass)_____
- ☐ Beverage Cans_____
- ☐ Caps, Lids_____
- ☐ Clothing, Shoes_____
- ☐ Cups, Plates, Forks, Knives, Spoons_____
- ☐ Food Wrappers/Containers_____
- ☐ Pull Tabs_____
- ☐ 6-Pack Holders_____
- ☐ Shotgun Shells/Wadding_____
- ☐ Straws, Stirrers_____
- ☐ Toys_____

OCEAN/WATERWAY ACTIVITIES

(Debris from recreational/commercial fishing and boat/vessel operations)

- ☐ Bait Containers/Packaging_____
- ☐ Bleach/Cleaner Bottles_____
- ☐ Buoys/Floats_____
- ☐ Crab/Lobster/Fish Traps_____
- ☐ Crates_____
- ☐ Fishing Line_____
- ☐ Fishing Lures/Light Sticks_____
- ☐ Fishing Nets_____
- ☐ Light Bulbs/Tubes_____
- ☐ Oil/Lube Bottles_____
- ☐ Pallets_____
- ☐ Plastic Sheeting/Tarps_____
- ☐ Rope_____
- ☐ Strapping Bands_____

SMOKING-RELATED ACTIVITIES

- ☐ Cigarettes/Cigarette Filters_____
- ☐ Cigarette Lighters_____
- ☐ Cigar Tips_____
- ☐ Tobacco Packaging/Wrappers_____

DUMPING ACTIVITIES

- ☐ Appliances (refrigerators, washers, etc.)_____
- ☐ Batteries_____
- ☐ Building Materials_____
- ☐ Cars/Car Parts_____
- ☐ 55-Gal. Drums_____
- ☐ Tires_____

MEDICAL/PERSONAL HYGIENE

- ☐ Condoms_____
- ☐ Diapers_____
- ☐ Syringes_____
- ☐ Tampons/Tampon Applicators_____

DEBRIS ITEMS OF LOCAL CONCERN

(Identify and count 3 other items found that concern you)

- ☐ _____
- ☐ _____
- ☐ _____

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National Marine Debris Monitoring Program Data Card

Thank you for completing this data card. Please answer the questions and return to your survey director. This information will be used in The Ocean Conservancy's National Marine Debris Monitoring Program's data base to determine trends and sources of specific debris items.

Name _____ Affiliation _____

NMDMP Region _____ Survey Site _____

Survey Number _____ Today's date: ____/____/____

Air Temperature _____ Wind Direction _____

Wind Speed _____ (1=no wind, 2=slight, 3=moderate, 4=heavy, 5=gale)

Brief Description of Weather _____

Weather Conditions from previous week: _____

Time (Beginning of Survey) _____ Time (End of Survey) _____

Other Remarks _____

Safety Tips

1. Wear gloves and closed-toed shoes.
2. Be careful with sharp objects and syringes.
3. Stay out of dunes.
4. Watch out for wildlife.
5. Don't lift heavy objects.
6. Do not go near any large drums.

Dead, Live and/or Entangled Animals: _____

Foreign Labels: _____

Survey Director: _____

Please return this card to your survey director or mail it to:

Nat. Marine Debris Monitoring Prog.
3500 Virginia Beach Blvd., Suite 212
Virginia Beach, VA 23452-4445

The Ocean Conservancy

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Items Collected

You may find it helpful to work with a buddy as you clean the area, one of you picking up trash and the other taking notes. An easy way to keep track of the items you find is by making tick marks. The box is for total items; see sample below.

Example:

Balloons 𝍸 𝍸 𝍸 II [17]

Ocean-Based

- Gloves [ ]
- Pl. sheets ≥ 1 meter [ ]
- Light bulbs/tubes [ ]
- Oil/gas containers (> 1 quart) [ ]
- Pipe-thread protectors [ ]
- Nets ≥ 5 meshes [ ]
- Traps/pots [ ]
- Fishing line [ ]
- Light sticks [ ]
- Rope ≥ 1 meter [ ]
- Salt bags [ ]
- Fish baskets [ ]
- Cruiseline logo items [ ]
- Floats/Buoys [ ]

Land-Based

- Syringes [ ]
- Condoms [ ]
- Metal beverage cans [ ]
- Motor oil containers (1 quart) [ ]
- Balloons [ ]
- Six-pack rings [ ]
- Straws [ ]
- Tampon applicators [ ]
- Cotton swabs [ ]

General Sources

- Plastic bags with seam < 1 meter [ ]
- ≥ 1 meter [ ]
- Straps Open [ ]
- Closed [ ]
- Plastic bottles: beverage [ ]
- food [ ]
- bleach/cleaner [ ]
- other pl. bottles [ ]

Comments: _____

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Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,[1]* Ylva Olsen,[1] Richard P. Mitchell,[1] Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2] Daniel McGonigle,[3] Andrea E. Russell[3]

Millions of metric tons of plastic are produced annually. Countless large items of plastic debris are accumulating in marine habitats worldwide and may persist for centuries (*1–4*). Here we show that microscopic plastic fragments and fibers (Fig. 1A) are also widespread in the oceans and have accumulated in the pelagic zone and sedimentary habitats. The fragments appear to have resulted from degradation of larger items. Plastics of this size are ingested by marine organisms, but the environmental consequences of this contamination are still unknown.

Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (*1–4*). Smaller fragments, probably also plastic, have been reported (*5*) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (*6*). Many "biodegradable" plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (*6*). Some cleaning agents also contain abrasive plastic fragments (*2*). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated by flotation. Those that differed in appearance to natural particulate material (Fig. 1A) were removed and identified with Fourier Transform infrared (FT-IR) spectroscopy (*7*). Some were of natural origin and others could not be identified, but about one third were synthetic polymers (Fig. 1C). These polymers were present in most samples (23 out of 30), but were significantly more abundant in subtidal sediment (Fig. 1D). Nine polymers were conclusively identified: acrylic, alkyd, poly (ethylene:propylene), polyamide (nylon), polyester, polyethylene, polymethylacrylate, polypropylene, and polyvinyl-alcohol. These have a wide range of uses, including clothing, packaging, and rope, suggesting that the fragments resulted from the breakdown of larger items.

To assess the extent of contamination, a further 17 beaches were examined (Fig. 1B). Similar fibers were found, demonstrating that microscopic plastics are common in sedimentary habitats. To assess long-term trends in abundance, we examined plankton samples collected regularly since the 1960s along routes between Aberdeen and the Shetlands (315 km) and from Sule Skerry to Iceland (850 km) (*7*) (Fig. 1B). We found plastic archived among the plankton in samples back to the 1960s, but with a significant increase in abundance over time (Fig. 1E). We found similar types of polymer in the water column as in sediments, suggesting that polymer density was not a major factor influencing distribution.

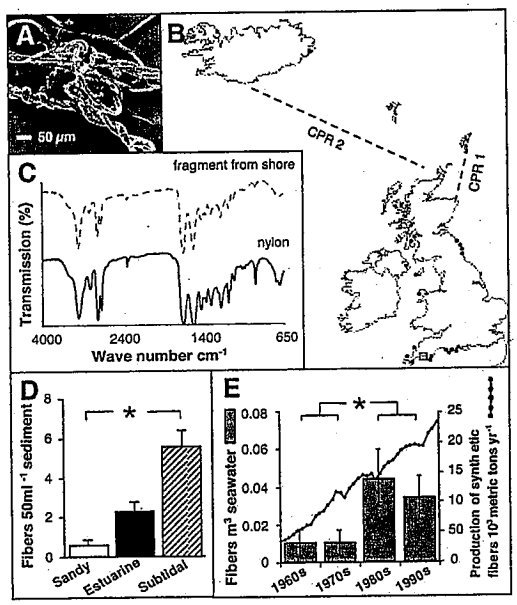

Fig. 1. (**A**) One of numerous fragments found among marine sediments and identified as plastic by FT-IR spectroscopy. (**B**) Sampling locations in the northeast Atlantic. Six sites near Plymouth (□) were used to compare the abundance of microplastic among habitats. Similar fragments (●) were found on other shores. Routes sampled by Continuous Plankton Recorder (CPR 1 and 2) were used to assess changes in microplastic abundance since 1960. (**C**) FT-IR spectra of a microscopic fragment matched that of nylon. (**D**) Microplastics were more abundant in subtidal habitats than on sandy beaches (*, $F_{2,3} = 13.26$, $P < 0.05$), but abundance was consistent among sites within habitat types. (**E**) Microscopic plastic in CPR samples revealed a significant increase in abundance when samples from the 1960s and 1970s were compared to those from the 1980s and 1990s (*, $F_{3,3} = 14.42$, $P < 0.05$). Approximate global production of synthetic fibers is overlain for comparison. Microplastics were also less abundant along oceanic route CPR 1 than along CPR 2 ($F_{1,24} = 5.18$, $P < 0.05$).

It was only possible to quantify fragments that differed in appearance from sediment grains or plankton. Some fragments were granular, but most were fibrous, ~20 μm in diameter, and brightly colored. We believe that these probably represent only a small proportion of the microscopic plastic in the environment, and methods are now needed to quantify the full spectrum of material present. The consequences of this contamination are yet to be established. Large plastic items can cause suffocation and entanglement and disrupt digestion in birds, fish, and mammals (*3*). To determine the potential for microscopic plastics to be ingested, we kept amphipods (detritivores), lugworms (deposit feeders), and barnacles (filter feeders) in aquaria with small quantities of microscopic plastics. All three species ingested plastics within a few days (*7*) (fig. S1).

Our findings demonstrate the broad spatial extent and accumulation of this type of contamination. Given the rapid increase in plastic production (Fig. 1E), the longevity of plastic, and the disposable nature of plastic items (*2, 3*), this contamination is likely to increase. There is the potential for plastics to adsorb, release, and transport chemicals (*3, 4*). However, it remains to be shown whether toxic substances can pass from plastics to the food chain. More work is needed to establish whether there are any environmental consequences of this debris.

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7. Materials and methods are available as supporting material online on *Science* Online.
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Materials and Methods
Fig. S1
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PLASTIC DEBRIS RIVERS TO SEA PROJECT
A BIBLIOGRPAGHY OF RESEARCH RELATED TO DEBRIS AND TRASH IN URBAN RUNOFF

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- Litter and Debris (strategies to reduce litter and debris)
- Marine Debris (general information, composition, quantity, and location)
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- Plastic Debris (industrial discharges of plastics)
- Trash and Debris Monitoring Methods

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Bisphenol A - Marine/ Estuarine (from Lynn Caroll, OurStolenFuture.org)

Andersen HR, Halling-Sorensen B, Kusk KO. 1999. A parameter for detecting estrogenic exposure in the copepod *Acartia tonsa*. Ecotoxicology & Environmental Safety 44:56-61.
Call Number: W 07354
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Arukwe A, Celius T, Walther BT, Goksoyr A. 2000. Effects of xenoestrogen treatment on *zona radiata* protein and vitellogenin expression in Atlantic salmon (*Salmo salar*). Aquatic Toxicology 49:159-170.
Call Number: W 07890
Abstract: Zonagenesis (*zona radiata* protein synthesis) and vitellogenesis (yolk protein synthesis) are two reproductive responses that are integral aspects of fish oogenesis. This study examines the responses of eggshell zona radiata proteins (Zrp) and vitellogenin (Vtg) to five environmental pollutants; 4-nonylphenol (NP) and o,p'-DDT [both at 25 mg/kg], lindane (gamma-HCH) [10 mg/kg], a technical PCB mixture (Aroclor 1254; A1254) and bisphenol A (BPA) [both at 5 mg/kg] in juvenile Atlantic salmon (Salmo salar). Fish were given intraperitoneal injections of o,p'-DDT, gamma-HCH, A1254 or BPA; singly, in combination with NP, and as a cocktail of all five chemicals, and later compared to NP-treated and untreated fish. In a separate experiment, fish were exposed to BPA in a dose-response manner (1, 5, 25 and 125 mg/kg fish). Based on previous studies, blood and liver samples were collected 2 weeks after injection. Zrp and Vtg levels were analyzed in plasma using immunoblotting and enzyme-linked immunosorbent assay. Liver cytochrome P4501A was analyzed by 7-ethoxyresorufin O-deethylase (EROD) activity. NP caused pronounced elevations in plasma Zip and Vtg levels. In comparison, when NP was given in combination with gamma-HCH, Vtg levels was significantly reduced, compared to NP treatment alone. Using o,p'-DDT, A1254 and BPA, significant elevations of plasma Zrp and Vtg were seen when chemicals were given in combination with NP, but not when administered by themselves. An apparent dose-response induction of Vtg and Zrp levels were observed in BPA treated juvenile salmon. In immunoblots, one component of molecular weight approximating the Zrp-beta was detected when either o,p'-DDT, gamma-HCH, A1254 or BPA were given singly. A1254 significantly induced hepatic EROD activity when

administered alone. However, when given as a mixture with all the other xenobiotics, reduction of EROD activity was observed. The data suggest a pattern of xenobiotics action which may complicate assessment of their reproductive effects. Zrp (the beta monomer) was more responsive to the xenoestrogens than Vtg, and provides a sensitive means of detecting exposure to environmental estrogens.

Baek HJ, Park MH, Lee YD, Kim HB. 2003. Effect of *in vitro* xenoestrogens on steroidogenesis in mature female fish, *Chasmichthys dolichognathus*. Fish Physiology & Biochemistry 28:413-414.
Call Number: W 11452 PDF
Abstract: In this study, fully vitellogenic oocytes of the longchin goby (Chasmichthys dolichognathus) were exposed to in vitro xenoestrogens such as diethylstilbestrol (DES), bisphenol A (BPA) and nonylphenol (NP) at concentrations of 100 ng/ml in the presence of [H-3]17alpha-hydroxyprogesterone as precursor. The major metabolites produced in vitro are progestogens [17alpha-hydroxy, 20alpha-dihydroprogesterone (17alpha20alphaOHP) and 17alpha-hydroxy, 20beta-dihydroprogesterone (17alpha20betaOHP)], androgens [androstenedione (A4) and testosterone (T)] and estrogens [estrone (E1) and estradiol-17beta (E2)]. Comparative activities of these chemicals in oocyte steroid biosynthesis showed as follows: NP treatment resulted in clear stimulation of estrogen production, while the opposite occurred in DES treated incubation. Treatment with DES resulted in a higher synthesis of 17alpha20alphaOHP. BPA treatment increased the androgen, while estrogen synthesis was slightly inhibited. These results suggest that NP exhibited clearly estrogenic activity on the three chemicals.

Basheer C, Lee HK, Tan KS. 2004. Endocrine disrupting alkylphenols and bisphenol-A in coastal waters and supermarket seafood from Singapore. Marine Pollution Bulletin 48:1161-1167.
Call Number: W 11318 PDF only

Biggers WJ, Laufer H. 2004. Identification of juvenile hormone-active alkylphenols in the lobster *Homarus americanus* and in marine sediments. Biol Bull 206:13-24.
Call Number: W 11216
Abstract: We have identified, by gas chromatography/mass spectrometry, four alkylphenols that are present in the hemolymph and tissues of the American lobster Homarus americanus and in marine sediments. These alkylphenols ire used industrially in antioxidant formulations for plastic and rubber polymer manufacturing, and are similar in structure to a known endocrine disruptor, bisphenol A. The compound 2-t-butyl-4-(dimethylbenzyl)phenol was present,At concentrations of 0.02 to 1.15 mug/ml in hemolymph and 8.95 to 21.58 mug/g in sediments. A second compound, 2,4-bis-(dimethylbenzyl)phenol, was present at concentrations between 0.07 and 19.78 mug/ml in hemolymph and 138.94 to 224.89 mug/g in sediment, while a third compound, 2,6-bis-(t-butyl)-4-(dimethylbenzyl)phenol, was found at concentrations between 0.01 and 13.00 mug/ml in hemolymph, 2.55 and 6.11 mug/g in hepatopancreas, and 47.85 and 74.66 mug/g in sediment. A fourth compound, 2,4-bis(dimethylbenzyl)-6-t-butylphenol, was found at concentrations of 0.20 to 70.71 mug/ml in hemolymph, 23.56 to 26.89 mug/g in hepatopancreas, and 90.68 to 125.58 mug/g in sediment. These compounds, along with bisphenol A, 4-dimethylbenzylphenol, and nonylphenol, display high juvenile hormone activity in bioassays. Alkylphenols at high concentrations are toxic to crustaceans and may contribute significantly to lobster mortality; at lower concentrations, they are likely to have endocrine-disrupting effects.

Breitholtz M, Hill C, Bengtsson BE. 2001. Toxic substances and reproductive disorders in Baltic fish and crustaceans [review]. Ambio 30:210-216.
Call Number: W 09398
Abstract: In the Baltic Sea ecosystem reproductive disorders have occurred in top consumers such as seals and some fish-eating birds, due to biomagnification of toxic substances, e.g. DDT and PCBs. Reproductive disturbances have also affected fish during the last 25 years. However, there is no strong evidence that toxic substances have caused these problems. Rather, the disorders seem to result from a combination of two or more biotic or abiotic factors. The M74 syndrome, which kills fry of salmon and sea trout, is characterized by a deficiency of thiamine (vitamin B1). Several factors may contribute to the thiamine deficiency, including the diet of salmon in the sea and halogenated organic compounds. Cod do not develop M74, and poor cod recruitment is mainly due to poor oxygen conditions in the spawning areas in combination with overfishing. Toxic compounds in pulp-mill effluents retard gonadal development in perch, but the mechanisms and the active substances have not been identified. Recruitment problems in perch in the

coastal waters outside some pulp mills may also be explained by a lack of food items for juvenile fish, rather than reproductive failure. There are very limited data on reproductive disorders in crustaceans from the Baltic Sea. Most data come from studies of the benthic amphipod Monoporeia affinis, which has been used in monitoring programs. Several signs of reproductive disorder have been reported in this amphipod, e.g. malformation and death of embryos, and asynchronous maturation of males and females.

Canesi L, Betti M, Lorusso LC, Ciacci C, Gallo G. 2005. 'In vivo' effects of bisphenol A in *Mytilus* hemocytes: Modulation of kinase-mediated signalling pathways. Aquatic Toxicology 71:73-84.
Call Number: W 11594 PDF
Abstract: Endocrine disrupting chemicals (EDCs) include a variety of natural and synthetic estrogens, as well as estrogen-mimicking chemicals. We have previously shown that in the hemocytes of the mussel *Mytilus galloprovincialis* Lam. both natural and environmental estrogens in vitro can rapidly affect the phosphorylation state of components of tyrosine kinase-mediated cell signalling, in particular of mitogen activated protein kinases (MAPKs) and signal transducers and activators of transcription (STAT), that are involved in mediating the hemocyte immune response. These effects were consistent with the hypothesis that 'alternative' modes of estrogen action involving kinase-mediated pathways similar to those described in mammalian systems are also present in invertebrate cells. This possibility was investigated in vivo with Bisphenol A (BPA): mussels were injected with BPA and hemocytes sampled at 6, 12, and 24 h post-injection. The results show that BPA (25 nM nominal concentration in the hemolymph) lead to a significant lysosomal membrane destabilisation at all times post-injection, indicating BPA-induced stress conditions in the hemocytes. whereas lower concentrations were ineffective. BPA induced significant changes in the phosphorylation state of MAPK and STAT members. as evaluated by SDS-PAGE and WB of hemocyte protein extracts with specific antibodies. although to a different degree at different exposure times. In particular, BPA induced a dramatic decrease in phosphorylation of the stress-activated p38 MAPK, whose activation is crucial in mediating the bactericidal activity. Moreover, BRA decreased the phosphorylation of a CREB-like transcription factor (cAMP-responsive element binding protein). The results demonstrate that BPA can affect kinase-mediated cell signalling in mussel hemocytes also in vivo, and suggest that EDCs may affect gene expression in mussel cells through modulation of the activity of transcription factors secondary to cytosolic kinase cascades. Overall, these data address the importance of investigating full range responses to EDCs in ecologically relevant marine invertebrate species.

Canesi L, Lorusso LC, Ciacci C, Betti M, Zampini M, Gallo G. 2004. Environmental estrogens can affect the function of mussel hemocytes through rapid modulation of kinase pathways. General & Comparative Endocrinology 138:58-69.
Call Number: W 11624 PDF
Abstract: Estrogens and estrogenic chemicals can affect several vertebrate non-reproductive functions, the immune response in particular. We have previously shown that in the hemocytes of the marine mollusc Mytilus the natural estrogen 17beta-estradiol (E(2)) can affect the immune function through rapid tyrosine kinase-mediated signalling pathways converging on phosphorylation of both mitogen activated protein kinases (MAPKs) and signal transducers and activators of transcription (STATs), whose activation plays a key role in the immune response. In this work the effects of synthetic estrogens (such as DES), estrogenic chemicals (such as Bisphenol A, Nonylphenol), and plant estrogens (genistein) on mussel hemocytes were evaluated. The results demonstrate that all the EDCs tested exert in vitro effects similar to those of E(2) on lysosomal membrane stability, although at concentrations 1000 times higher than those of the natural estrogen. When the effects of DES, BPA, and NP on tyrosine kinase-mediated cell signalling were investigated, estrogenic compounds showed distinct effects on the phosphorylation state of MAPK and STAT members. In particular, only DES, like E(2), induced p38 MAPK phosphorylation, whereas BPA and NP seem to have opposite effects. Moreover, different EDCs significantly decreased the tyrosine phosphorylation state of STAT3 and STAT5, showing a distinct effect with respect to E(2). Experiments with specific kinase inhibitors showed that activation of p38 MAPK, but also of ERK MAPK and PI3-kinase, plays a key role in mediating the effect of DES. On the other hand, the effects of NP were partly mediated by ERK MAPK activation. BPA-induced lysosomal membrane destabilisation was unaffected by either MAPK or PI3-K inhibitors. However, hemocyte pre-treatment with the PKC inhibitor GF109203X prevented the effects of both BPA and NP, this indicating that kinase pathways other than those involving MAPKs are also responsible for mediating the effects of certain EDCs. Overall, the results support the hypothesis that EDCs may rapidly modulate the function of mussel hemocytes through activation of

transduction pathways involving different kinase-mediated cascades. Moreover, the effects of EDCs on the phosphorylation state of transcription factor STATs suggest that these compounds may lead to changes in gene expression secondary to modulation of kinase/phosphatases. Our data address to the importance of investigating full range responses to estrogenic chemicals and may help understanding their basic mechanisms of action in ecologically relevant invertebrate species.

Christiansen LB, Pedersen KL, Korsgaard B, Bjerregaard P. 1998. Estrogenicity of xenobiotics in rainbow trout (*Oncorhynchus mykiss*) using in vivo synthesis of vitellogenin as a biomarker. Marine Environmental Research 46:137-140 .
Call Number: W 09277
Abstract: The estrogenicity of several xenobiotics was evaluated using *in vivo* vitellogenin (Vtg) synthesis in immature rainbow trout as a biomarker. 17β-estradiol, DES and ethinyl estradiol were tested as positive controls. The xenobiotic compounds tested were technical nonylphenol, bisphenol A, butylbenzylphthalate (BBP) and dibutylphthalate (DBP). Measurements of the Vtg concentration was performed with a direct sandwich ELISA. 17β-estradiol, DES and ethinyl estradiol caused up to 100,000-fold increased in the Vtg-levels. Nonylphenol and bisphenol A had the highest estrogenic potency of the xenobiotics increasing the vitellogenin level approximately 300-fold while BBP was only weakly estrogenic, increasing the concentration about 3 times. DPB did not raise the vitellogenin concentration above the detection limit.

Dinan L, Bourne P, Whiting P, Dhadialla TS, Hutchinson TH. 2001. Screening of environmental contaminants for ecdysteroid agonist and antagonist activity using the *Drosophila melanogaster* B(II) cell *in vitro* assay. Environmental Toxicology & Chemistry 20:2038-2046.
Call Number: W 09315
Abstract: The B(II) bioassay was developed as a rapid and reliable tool for detecting potential insect growth regulators acting as ecdysteroid receptor (ant)agonists. Based on an ecdysteroid-responsive cell line from Drosophila melanogaster, this microplate assay is ideally suited to the evaluation of environmental contaminants as potential endocrine disrupters. Data are presented for about 80 potential environmental contaminants, including industrial chemicals, pesticides, pharmaceuticals, phytoestrogens, and vertebrate steroids, and are compared with data for known (ant)agonists. Apart from androst-4-ene- 3,17-dione (a weak antagonist), vertebrate steroids were inactive at concentrations up to 10(-3) M. The vast majority of xenobiotics also showed no (ant)agonist activity. Among the industrial chemicals, antagonistic activity was observed for bisphenol A median effective concentration (EC50) of 1.0 x 10(-4) M and diethylphthalate (EC50 of 2.0 x 10(-3) M). Some organochlorine compounds also showed weak antagonistic activity, including o,p'-dichlorodiphenyldichloroethylene (DDE), p,p'-DDE, dieldrin, and lindane (EC50 of 3.0 x 10(-5) M). For lindane, bisphenol A, and diethylphthalate, activity is not associated with impurities in the samples and, for lindane and bisphenol A at least, the compounds are able to compete with ecdysteroids for the ligand binding site on the receptor complex, albeit at concentrations very much higher than those found in the environment. The only pharmaceutical showing any detectable antagonist activity was 17alpha-ethynylestradiol. In the context of recent publications on potential endocrine disruption in marine and freshwater arthropods, these findings suggest that, for some compounds (e.g., diethylstilbestrol), ecdysteroid receptor-mediated responses are unlikely to be involved in producing chronic effects. The B(II) assay has a potentially valuable role to play in distinguishing between endocrine-mediated, which normally occur at submicromolar concentrations, and pharmacological effects in insects and crustaceans.

Fox GA. 2001. Effects of endocrine disrupting chemicals on wildlife in Canada: Past present and future. Water Quality Research Journal of Canada 36:233-51.
Call Number: W 09305
Abstract: Within a few years of their widespread introduction into the environment, there were major concerns about the effects of man-made chemicals on wildlife in Canada. Biologists have found evidence of endocrine disruption in at least 16 species of birds (particularly fish-eating and predatory species), 3 species of terrestrial mammals and 1 whale, 1 reptile and several amphibians. These effects were seen in the Great Lakes, areas polluted with pulp and paper effluents, the forests of New Brunswick, a variety of agricultural habitats, acidified lakes in Nova Scotia, major rivers and inshore coastal waters, and the Arctic. They include decreased reproductive success, gross congenital abnormalities and interference with developmental/regenerational processes; thyroid dysfunction; metabolic abnormalities; feminization/demasculinization; alterations in sex ratios; altered brain development and behavior; and

altered immune function. These sublethal effects have the potential to alter an individual's quality of life, its survival, or reproductive fitness. Morbidity and mortality are rarely detected and grossly underestimated in wildlife populations and we are likely to have underestimated the occurrence, prevalence and severity of endocrine disruption in wildlife. There is no formal existing program in Canada for gathering long-term evidence for determining trends in the incidence and severity of effects in organisms. All of the information on endocrine disruption in Canadian wildlife reported in this review was gathered as a result of academic research or research-based monitoring. Much greater effort must be made to systematically detect and identify a much broader range of man-made chemicals, both persistent and nonpersistent, and their metabolites in wildlife tissues and environmental media. These efforts should be complimented by parallel measurements of various biological activities of extracts of the same wildlife tissues and environmental media. This monitoring information would then point to specific locations, effluents, agricultural practices, industrial processes, and products were investigations of effects should be conducted and to species and functions potentially at risk.

Goodman LR, Cripe GM, Moody PH, Halsell DG. 1988. Acute toxicity of malathion, tetrobromobisphenol-A, and tributyltin chloride to mysids (*Mysidopsis bahia*) of three ages. Environmental Contamination & Toxicology 41:746-753.
Call Number: W 05692
Abstract: Mysids of three age classes were tested for acute toxicity of three toxins found in estuaries-Malathion, Tetrabromobisphenol-A (TBBPA), and Tributyltin Chloride (TBTC). These chemicals were acutely toxic to all three age groups of mysids. TBTC was most toxic, with 96-r LC50 values of 1.1 ug/L for < 1-d- old mysids, 2.0 ug/L for 5-d-old mysids, and 2.2 ug/L for 10-d-old mysids. For all three age classes the 96-hr LC50 values for Malathion were 3.0 ug/L. TBBPA was least toxic of these compounds with 96-hr LC50 values of 860 ug/L for <1-d-old mysids, 1100 ug/L for 5-d-old mysids and 1200 ug/L for 10-d-old mysids. Age was not a large factor inthe the acute sensitivity of juvenile M. bahia, however it is recommended that in determining the acute toxicity of a particular compound at their most sensitive age multiple age groups must be tested.

Heemken OP, Reincke H, Stachel B, Theobald N. 2001. The occurrence of xenoestrogens in the Elbe River and the North Sea. Chemosphere 45:245-259.
Call Number: W 09369
Abstract: The xenoestrogens Bisphenol A (BPA), p-alkylphenols and p-alkylphenol ethoxylates were determined in water samples of the North Sea, the Elbe river, and its tributaries Schwarze Elster, Mulde, Saale and the Weisse Elster. The sampling sites of the Elbe river reached from Schmilka at the German-Czech border to Cuxhaven at the estuary. Samples of the North Sea were taken in the German Bight. Additionally, freshly deposed sediments of the River Elbe and its tributaries were analyzed. Partitioning coefficients of these compounds for the distribution between suspended particulate matter (SPM) and the aqueous phase were calculated for samples of the River Elbe at sampling site Geesthacht. The analytical procedure consisted of liquid-liquid extractions of the acidified water samples using dichloromethane. Sediments and SPM samples were extracted by Accelerated Solvent Extraction with n-hexane/acetone. Following a clean-up by HPLC, the analytes were derivatized with heptafluorobutyric acid anhydride and quantified using GC-MSD. The concentration ranges of the compounds analyzed in water samples of the Elbe river were as follows (in ng 1(-1)): BPA 9-776, alkylphenols 10-221 and alkylphenol ethoxylates 18-302. In sediment samples the concentrations were (in mug kg(-1) dry mass): BPA 66-343, alkylphenols 17-1378 and alkylphenol ethoxylates 30-1797. In samples of the North Sea the concentrations were generally about 1 order of magnitude lower. As shown by the concentration profiles following the River Elbe into the North Sea, the Elbe river must be considered as a major pollution source for the North Sea concerning the compounds analyzed. The SPM/water-partitioning coefficients calculated (mean values) amounted to: BPA 4.50, alkylphenols 5.52-5.58 and alkylphenol ethoxylates 5.60-6.38. A comparison of the results with data from other surface waters showed that concentrations of these xenoestrogens in the River Elbe and its tributaries were relatively low. The evaluation of the data based on the lowest observable effect concentration (LOEC) for alkylphenols (endpoint: vitellogenin synthesis in male trout) indicated that the concentrations were well below the effectivity threshold.

Hill M, Stabile C, Steffen LK, Hill A. 2002. Toxic effects of endocrine disrupters on freshwater sponges: common developmental abnormalities. Environmental Pollution 117:295-300.

Call Number: W 09862
Abstract: Endocrine disrupters are of substantial concern, in large part because effects of these compounds on the growth and development of many aquatic organisms are unknown. We examined toxic effects of three substances (ethylbenzene, nonylphenol, and bisphenol A), that are known to be hormonally active in many animals, on growth and development of two species of freshwater sponge. A common developmental abnormality was observed when sponges were treated with each of these compounds. The three compounds also caused significant reductions in growth rates. Lower concentrations resulted in malformed water vascular systems in several replicates. The utility of freshwater sponge bioassays is discussed as it relates to understanding possible mechanisms of action of endocrine disrupters on aquatic invertebrates.

Hosokawa Y, Yasui M, Yoshikawa K, Tanaka Y, Suzuki M. 2003. The nationwide investigation of endocrine disruptors in sediment of harbours. Marine Pollution Bulletin 47:132-138.
Call Number: W 10816
Abstract: Various types of endocrine disruptors or environmental hormones flow from their sources down into harbours through rivers and other watercourses, and are accumulated in sediment on the sea bottom. Tributyltin, which has been used as paint for ship bottoms, is considered one of the endocrine disruptors. In close cooperation with the other ministries and agencies, the Ports and Harbours Bureau of the Ministry of Land, Infrastructure and Transport carried out an investigation in 1999 to determine the actual condition of 12 endocrine disruptors in the sediment of 39 harbours, in order to gather fundamental data to be used in future examinations of policy.
Furthermore, in 2000 the bureau chose seven harbours out of the above 39 harbours as subjects of an additional investigation regarding the surface distributions of endocrine disruptors in the harbour areas and the synchronistic change of accumulation of dioxin and other substances.
As the result of the investigation regarding the surface distribution of endocrine disruptors accumulated in seven harbours, relatively high concentrations were measured in the intermost parts of harbours and the mouth of rivers.
Synchronistic changes in the amount of dioxin and other substances accumulated in sediments of five harbours were determined. Small amounts of dioxin and other substances, including an especially small amount of coplanar-PCBs, were found in the layers formed before or around 1950. Relatively large amounts of these substances were measured in the upper layers formed during roughly 1960-1990, though no significant yearly differences in concentration could be identified. This result coincides with the facts that, during roughly 1960-1980, PCP and CNP were used as agricultural chemicals and full-scale production of PCBs started in 1960.

Iguchi T, Watanabe H, Katsu Y. 2001. Developmental effects of estrogenic agents on mice, fish, and frogs: A mini-review. Hormones & Behavior 40:248-251.
Call Number: W 09286
Abstract: Laboratory experiments have demonstrated that exposure of rodents to sex hormones during prenatal or early postnatal life can cause permanent and irreversible alterations of the endocrine and reproductive organs, such as ovary, fallopian tube, uterus, cervix, vagina, and mammary gland in females; and testis, epididymis, prostate, and seminal vesicle in males; as well as non reproductive organs including bones and muscle and immune and nervous systems in both sexes. Early development of Xenopus laevis into the tadpole and Fundulus heteroclitus goes through a rapid cell division, gastrulation, neurulation, and organogenesis within 1 week after fertilization. The developing embryo is very fragile and sensitive to estrogenic agents. Thus, these animals can be used as a suitable model for examining the effect of endocrine disruptors (hormonally active agents) on the development of aquatic living beings, which are most likely to be exposed to the compounds.

Japan Environment Agency.
Call Number: W 08453
Abstract: Included are the sections 'Regarding the result of 1998 air environmental surveillance on exogenous endocrine disrupting chemicals'; 'Surveillance of endocrine disrupters at public water areas'; 'Measured results of water quality (in general water area)'; 'Measured results of water quality (in priority water area)'; 'Measured results of bottom sediments (in general water area)'; ' Measured results of aquatic animals and plant life (in general water area)'; 'Investigation report of environmental residual of agricultural chemicals related to strategic programs on environmental endocrine disrupters '98'; 'Results of research on

effects of endocrine disrupting chemicals on wildlife'; and 'Results of research on effects of endocrine disrupting chemicals on wildlife (data).'

Kawahata H, Ohta H, Inoue M, Suzuki A. 2004. Endocrine disrupter nonylphenol and bisphenol A contamination in Okinawa and Ishigaki Islands, Japan--within coral reefs and adjacent river mouths. Chemosphere 55:1519-1527.
Call Number: W 11238 PDF
Abstract: Certain chemicals possess the potential to modulate endocrine systems, and thereby interfere with reproduction and developmental processes in the wild. We analyzed endocrine disrupters nonylphenol (NP) and bisphenol A (BPA) levels at various sites in Okinawa and Ishigaki Islands, Japan. River-water samples showed undetectable to low concentrations of NP and BPA at most of the sites investigated. However, an appreciable amount of BPA was detected in sediments at one coral reef site. In addition, significant numbers of river sediment samples showed appreciable amounts of NP and BPA. Most of the sampling sites for this study are located within a distance of 1 km from the coral reefs, which are under influence of river-waters to a variable extent. Therefore, influence of endocrine disrupters may have already begun on adjacent coral reefs. Both endocrine disrupters were positively correlated with human population densities, but not with the contents of red soil generated by farm land reformation. Therefore, it is concluded that NP and BPA pollution is a consequence of human waste discharge, both domestic and industrial, and not by agricultural activities.

Khim JS, Kannan K, Villeneuve DL, Koh CH, Giesy JP. 1999. Characterization and distribution of trace organic contaminants in sediment from Masan Bay, Korea. 1. Instrumental analysis. Environmental Science & Technology 33:4199-4205.
Call Number: W 07604
Abstract: Masan Bay, located on the southeast coast of Korea, is a long and narrow inlet of a semi-closed bay that receives industrial and municipal wastewaters from the cities of Masan and Changwon. In this study, sediments collected from 28 locations on Masan Bay were analyzed for total organic carbon (TOC), nonylphenol (NP), octylphenol (OP), bisphenol A (BPA), organochlorine pesticides (HCB, HCHs, CHLs, and DDTs), individual polychlorinated biphenyl (PCB) congeners, and 16 polycyclic aromatic hydrocabons (PAHs) to characterize their spatial distribution and contamination status. Concentrations of NP in sediment ranged from 113 to 3890 ng/g on a dry weight basis (dry wt), whereas concentrations of OP and BPA were, on average, 20-110-fold less than those of NP. PAHs were predominated by 4-6-ring compounds with concentrations in the range of 54.1-1100 ng/g dry wt. Concentrations of PCBs in sediment, which were predominated by tetra- and pentachlorobiphenyl congeners, ranged from 10.3 to 148 ng/g, dry wt. Among different OC pesticides analyzed, concentrations of DDTs were the greatest, ranging from 0.4 to 12.6 ng/g dry wt. NP concentrations were greater at coastal locations proximal to the discharges of creeks from inland areas, whereas the concentrations of PCBs and PAHs were greater near the sites of industrial and shipping activities. Concentrations of target analytes were not related to TOC. Although the mean concentrations of PCBs and PAHs in sediments were less than the suggested sediment quality guidelines (SQG), their concentrations in some locations were close to or above the SQG for toxic effects in benthic organisms.

Khim JS, Villeneuve DL, Kannan K, Koh CH, Giesy JP. 1999. Characterization and distribution of trace organic contaminants in sediment from Masan Bay, Korea. 2. *In vitro* gene expression assays. Environmental Science & Technology 33:4206-4211.
Call Number: W 07605
Abstract: Extracts of sediment collected from Masan Bay, Korea were fractionated using Florisil columns. Fractions were screened for their ability to induce estrogen- and dioxinlike gene expression in vitro using MVLN and H4IIE-luc cells, respectively, both before and after acid treatment. Florisil fraction 1 (F1), which was shown to contain polychlorinated biphenyls, induced very little response in either assay. The midpolarity Florisil fraction (F2) was the most active fraction. Twenty-seven of 28 F2 samples induced significant estrogenic activity, and all 28 samples induced significant dioxinlike activity. Twelve of the F2 samples produced magnitudes of response in the dioxin-responsive H4IIE-luc cells similar to those induced by a 23,7,8-tetrachlorodibenzo-p-dioxin (TCDD) standard. Acid treatment did not markedly diminish the activity of F2 samples. These results suggested the presence of unidentified, acid stable, aryl hydrocarbon receptor (AhR) and estrogen receptor (ER) agonists in F2. Twenty-three of the 28 most polar florisil

fractions (F3) were either cytotoxic or caused morphological changes in estrogen-responsive MVLN cells, while over half of the F3 samples caused similar effects in H4llE-luc cells. Empirical evidence suggested that acid labile compounds contributed to both the estrogenic and cytotoxic responses of the MVLN cells. Mass balance suggested that known concentrations of alkylphenols and bisphenol A may account for a portion of the estrogenic response but were not great enough to account for the toxicity. Acid labile compounds also contributed substantially to the dioxinlike activity of F3 samples. This adds to a growing body of evidence which suggests the presence of unidentified, relatively polar, aryl hydrocarbon receptor agonists in sediment from some areas.

Kim H, Hong JK, Kim YH, Kim KR. 2003. Combined isobutoxycarbonylation and tert-butyldimethylsilylation for the GC/MS-SIM detection of alkylphenols, chlorophenols and bisphenol A in mackerel samples. Arch Pharm Res 26:697-705.
Call Number: W 11223 PDF
Abstract: The alkylphenols, chlorophenols, and bisphenol A were determined by gas chromatography/ mass spectrometry-selected ion monitoring (GC/MS-SIM) followed by two work-up methods for comparison: isobutoxycarbonyl (isoBOC) derivatization and tert-butyldimethylsilyl (TBDMS) derivatization. Eleven endocrine disrupting chemicals (EDCs) of phenols in biological samples were extracted with acetonitrile and then the acetonitrile layer underwent freezing filtration 60 degreesC for 2 hours. Solid-phase extraction (SPE) was used with XAD-4 and subsequent conversion to isoBOC or TBDMS derivatives for sensitivity analysis with the GC/MS-SIM mode. For isoBOC derivatization and TBDMS derivatization the recoveries were 92.3similar to150.6% and 93.8similar to108.3%, the method detection limits (MDLs) of bisphenol A for SIM were 0.062 mug/kg and 0.010 mug/kg, and the SIM responses were linear with the correlation coefficient varying by 0.9755similar to0.9981 and 0.9908similar to0.9996, respectively. When these methods were applied to mackerel samples, the concentrations of the 11 phenol EDCs were below the MDL.

Lee HC, Soyano K, Ishimatsu A, Nagae M, Kohra S, Ishibashi Y, Arizono K, Takao Y. 2004. Bisphenol A and nonylphenol bioconcentration in spotted halibut *Varaspar variegates*. Fisheries Science 70:192-194.
Call Number: W 11128 PDF
Abstract: [2-month old fish were starved for 2 weeks then exposed up to 1 week to a mixture of BPA + nonylphenol in seawater at 7 ug/L + 8 ug/L; 70 ug/L + 80 ug/L; 700 ug/L + 800 ug/L (at this concentration 95% mortality by the 2nd day). Bioconcentration factors were up to 38.14+/- 21.28 for BPA, and 17.12+/-2.37 to 141.17+/-17.75 for nonylphenol]

Lee WK, Lee KW, Kwak EJ, Yang SW, Yang KS, Park JC, Joo HS, Lee WJ, Lee WB. 2003. Effects of environmental endocrine disruptors on the sex differentiation in Korean rockfish, *Sebastes schlegeli*. Water Science & Technology 47:65-70.
Call Number: W 11482 PDF only
Abstract: The effects of estradiol-17beta, methyltestosterone, tributyltin, bisphenol A and 2,4-dinitrophenol on sex differentiation were investigated in the Korean rockfish, Sebastes schlegeli. The 51 day-old fry with undifferentiated gonads were fed with food containing the chemicals at 0.05, 0.5, 5, 50 and 100 mu/g diet for 29 days. Sex ratio and gonadal abnormality after the chemical treatment were determined by histological examination of gonads. In control group, the sex ratio of fry was 1:1.3 (female:male), and more males than females appeared. The sex of fry fed with estradiol-1 70 at 5, 50 and 100 mu/g diet was all females. Feminization of the fry was induced by exogenic estradiol-17b. In the methyltestosterone group, sex ratio of fry was 1:10.2 in 0.05 mu/g diet, 1:2.4 in 0.5 mu/g diet, 1:3.1 in 5 mu/g diet, 1:1.2 in 50 mu/g diet and 1:2.3 in 100 mu/g diet. Masculinization of the fry was induced by methyltestosterone at the lowest concentration. CO 0 Furthermore, intersex of the fry was observed. The number of intersex fry was 23.3, 25.0 and 35.3 at 0.5, 5 and 50 mu/g diet of methyltestosterone, respectively, Sex ratio of bisphenol A-group showed no difference with that of the control. The sex of fry fed with 2,4-dinitrophenol at 5, 50 and 100 mu/g diet was all females. 2,4-dinitrophenol should be considered as a new member of endocrine disruptors. In tributyltin group, the sex ratio of fry at 100 mu/g diet of tributyltin was 5.4:1. Tributyltin induced the feminization of the fry at the highest dose. Tributyltin showed an estrogenic effect in the Korean rockfish I in contrast to an androgenic effect in gastropods.

Louisiana Department of Environmental Quality2001. Baton Rouge, Louisiana: Louisiana Department of

Environmental Quality.
Call Number: W 09028
Abstract: The US EPA has just released the 1999 Toxics Release Inventory (TRI) data. Based on TRI total releases, EPA ranked Louisiana 12th among states for all reporting industries in 1999, compared to 10th for 1998. This data is the compilation of toxic chemical release and waste management activities annually submitted to both the state and EPA by manufacturing industries and certain other industries subject to the reporting requirements of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986.

Marcial HS, Hagiwara A, Snell TW. 2003. Estrogenic compounds affect development of harpacticoid copepod *Tigriopus japonicus*. Environmental Toxicology & Chemistry 22:3025-3030.
Call Number: W 11205 PDF
Abstract: The aim of this investigation was to evaluate the impact of estrogenic compounds on the harpacticoid copepod Tigriopus japonicus after continuous exposure to environmentally relevant concentrations. Natural estrogen (17beta-estradiol), three known estrogenic compounds in vertebrates (bisphenol A, 4-nonylphenol, p-t-octylphenol), and an invertebrate molting hormone (20-hydroxyecdysone) were tested for their effects on development and reproductive characters in two successive generations of T. japonicus. Less than 24-h-old nauplii (parentals) were exposed to four sublethal concentrations of these compounds for 21 d at 25degreesC. The first brood of nauplii (F,) produced was monitored further under the same culture conditions and exposures to test compounds. Results showed that all estrogenic compounds affected development (both in number of days to reach copepodid stage and sexual maturity) in the parental generation. Similar effects were apparent in the F,; however, fecundity, sex ratio, and survival were not significantly affected, even at concentrations as high as 10 mug/L (nominal concentration). The invertebrate molting hormone 20-hyroxyecdysone had no detectable effect on any of the endpoints tested but gave the lowest 48-h 50% lethal concentration (LC50) value. The results suggest that endocrine disruption could occur in copepods following exposure to environmentally relevant concentrations of estrogenic compounds, especially if they are exposed starting from embryonic development.

Mosconi G, Carnevali O, Franzoni MF, Cottone E, Lutz I, Kloas W, Yamamoto K, Kikuyama S, Polzonetti-Magni AM. 2002. Environmental estrogens and reproductive biology in amphibians. General & Comparative Endocrinology 126:125-129.
Call Number: W 10174 PDF
Abstract: In this paper, the effects of an estrogenic compound, 4-nonyl-phenol (NP), on the amphibians Rana esculenta and Triturus carnifex are described together with those on sexual differentiation in Xenopus laevis. NP increased plasma vitellogenin in male frogs and newts in a dose-related manner; moreover, inhibitory effects on gonadotropin and prolactin (PRL) secretion by pituitary were found together with an elevation of plasma androgens. NP treatment also caused a remarkable increase in number of prolactin-immunolabeled cells, suggesting that xenoestrogen might induce, at least in the newt pituitary, a PRL accumulation possibly due to a reduction of the hormone release. In addition, both NP and bisphenol A caused feminization by increasing the percentage of female phenotypes in X. laevis, and the in vivo effects were more pronounced than those of estradiol-17beta.

[Anonymous]. 1999 AprO'Shea TJ, Reeves RR, Long AK, eds. Marine Mammals and Persistent Ocean Contaminants: Proceedings of the Marine Mammal Commission Workshop. Maryland: Marine Mammal Commission.
Call Number: W 09168
Abstract: The workshop objectives were to (1) review and summarize the state of knowledge about the types and levels of potentially harmful persistent contaminants found in marine mammals, and about the known and potential effects of these substances on marine mammal health and population dynamics; (2) identify and rank in importance the critical uncertainties concerning the presence, levels, sources, fates, and effects of organochlorines, toxic elements, and other persistent contaminants on marine mammals; (3) outline research and monitoring programs needed to resolve the critical uncertainties as quickly as possible; and (4) assess how ongoing and planned research and monitoring programs should be restructured or expanded.

Oehlmann J, Schulte-Oehlmann U, Tillmann M, Markert B. 2000. Effects of endocrine disruptors on prosobranch snails (Mollusca: Gastropoda) in the laboratory. Part I: Bisphenol A and octylphenol as xeno-estrogens.

Ecotoxicology 9:383-397.
Call Number: W 08516 PDF
Abstract: The effects of suspected endocrine disrupting chemicals on freshwater and marine prosobranch species were analysed in laboratory experiments. In this first publication, the responses of the freshwater snail Marisa cornuarietis and of the marine prosobranch Nucella lapillus to the xeno-estrogenic model compounds bisphenol A (BPA) and octylphenol (OP) are presented at nominal concentration ranges between 1 and 100 mug/L. Marisa was exposed during 5 months using adult specimens and in a complete life-cycle test for 12 months. In both experiments, the xeno-estrogens induced a complex syndrome of alterations in female Marisa referred to as "superfemales" at the lowest concentrations. Affected specimens were characterised by the formation of additional female organs, an enlargement of the accessory pallial sex glands, gross malformations of the pallial oviduct section resulting in an increased female mortality, and a massive stimulation of oocyte and spawning mass production. The effects of BPA and OP were comparable at the same nominal concentrations. An exposure to OP resulted in inverted U-type concentration response relationships for egg and spawning mass production. Adult Nucella from the field were tested for three months in the laboratory. As in Marisa, superfemales with enlarged accessory pallial sex glands and an enhancement of oocyte production were observed. No oviduct malformations were found probably due to species differences in the gross anatomical structure of the pallial oviduct. A lower percentage of exposed specimens had ripe sperm stored in their vesicula seminalis and additionally male Nucella exhibited a reduced length of penis and prostate gland when compared to the control. Because statistically significant effects were observed at the lowest nominal test concentrations (1 mug BPA or OP/L), it can be assumed that even lower concentrations may have a negative impact on the snails. The results show that prosobranchs are sensitive to endocrine disruption at environmentally relevant concentrations and that especially M. cornuarietis is a promising candidate for a future organismic invertebrate model to identify endocrine-mimetic test compounds.

Oehlmann J, Schulte-Oehlmann U, Tillmann M, Markert B. 2000. Effects of endocrine disruptors on prosobranch snails (Mollusca: Gastropoda) in the laboratory. Part I: Bisphenol A and octylphenol as xeno-estrogens. Ecotoxicology 9:383-397.
Call Number: W 11058 PDF #
Abstract: The effects of suspected endocrine disrupting chemicals on freshwater and marine prosobranch species were analysed in laboratory experiments. In this first publication, the responses of the freshwater snail Marisa cornuarietis and of the marine prosobranch Nucella lapillus to the xeno-estrogenic model compounds bisphenol A (BPA) and octylphenol (OP) are presented at nominal concentration ranges between 1 and 100 micrograms/L. Marisa was exposed during 5 months using adult specimens and in a complete life-cycle test for 12 months. In both experiments, the xeno-estrogens induced a complex syndrome of alterations in female Marisa referred to as "superfemales" at the lowest concentrations. Affected specimens were characterised by the formation of additional female organs, an enlargement of the accessory pallial sex glands, gross malformations of the pallial oviduct section resulting in an increased female mortality, and a massive stimulation of oocyte and spawning mass production. The effects of BPA and OP were comparable at the same nominal concentrations. An exposure to OP resulted in inverted U-type concentration response relationships for egg and spawning mass production. Adult Nucella from the field were tested for three months in the laboratory. As in Marisa, superfemales with enlarged accessory pallial sex glands and an enhancement of oocyte production were observed. No oviduct malformations were found probably due to species differences in the gross anatomical structure of the pallial oviduct. A lower percentage of exposed specimens had ripe sperm stored in their vesicula seminalis and additionally male Nucella exhibited a reduced length of penis and prostate gland when compared to the control. Because statistically significant effects were observed at the lowest nominal test concentrations (1 microgram BPA or OP/L), it can be assumed that even lower concentrations may have a negative impact on the snails. The results show that prosobranchs are sensitive to endocrine disruption at environmentally relevant concentrations and that especially M. cornuarietis is a promising candidate for a future organismic invertebrate model to identify endocrine-mimetic test compounds.

Roepke TA, Snyder MJ, Cherr GN. 2005. Estradiol and endocrine disrupting compounds adversely affect development of sea urchin embryos at environmentally relevant concentrations. Aquatic Toxicology 71:155-173.
Call Number: W 11531 PDF

Abstract: Environmental endocrine disrupting compounds (EDCs) are a wide variety of chemicals that typically exert effects, either directly or indirectly, through receptor-mediated processes, thus mimicking endogenous hormones and/or inhibiting normal hormone activities and metabolism. Little is known about the effects of EDCs on echinoderm physiology, reproduction and development. We exposed developing sea urchin embryos (Strongylocentrotus purpuratus and Lytechinus anamesus) to two known EDCs (4-octylphenol (OCT), bisphenol A (BisA)) and to natural and synthetic reproductive hormones (17beta-estradiol (E-2), estrone (E-1), estriol (E-3) progesterone (P-4) and 17alpha-ethynylestradiol (EE2)). In addition, we studied two non-estrogenic EDCs, tributyltin (TBT) and o,p-DDD. Successful development to the pluteus larval stage (96 h post-fertilization) was used to define EDC concentration-response relationships. The order of compound potency based on EC50 values for a reduction in normal development was as follows: TBT L. anamesus > OCT > TBT S. purpuratus much greater than E-2 > EE2 > DDD much greater than BisA > P-4 > E-1 much greater than E-3. The effect of TBT was pronounced even at concentrations substantially lower than those commonly reported in heavily contaminated areas, but the response was significantly different in the two model species. Sea urchin embryos were generally more sensitive to estrogenic EDCs and TBT than most other invertebrate larvae. Stage-specific exposure experiments were conducted to determine the most sensitive developmental periods using blastula, gastrula and post-gastrula (pluteus) stages. The stage most sensitive to E-2, OCT and TBT was the blastula stage with less overall sensitivity in the gastrula stage, regardless of concentration. Selective estrogen receptor modulators (SERMs) were added to the experiments individually and in combination with estrogenic EDCs to interfere with potential receptor-mediated actions. Tamoxifen, a partial ER agonist, alone inhibited development at concentrations as low as 0.02 ng/ml and was effective at this concentration in decreasing the sensitivities of the embryos to estradiol and estrogenic EDCs. The complete antagonist ICI 182,780 inhibited development at concentrations as low as 0.03 ng/ml but increased embryo sensitivity to estradiol and estrogenic EDCs. Estradiol and estrogenic EDCs all cause developmental toxicity in sea urchins through a TAM-sensitive but an ICI-insensitive mechanism. It remains to be demonstrated whether this mechanism involves an estrogen-responsive nuclear receptor (NR), a membrane receptor (NR or non-NR-related) or a completely different mechanism of toxicity. However, early embryo sensitivity and the differential response to SERM co-incubation further suggests more than one mode of EDC action in the developing sea urchin embryo.

Rouhani Rankouhi T, Sanderson JT, Van Holsteijn I, Van Leeuwen C, Vethaak AD, Van Den Berg M. 2004. Effects of natural and synthetic estrogens and various environmental contaminants on vitellogenesis in fish primary hepatocytes: Comparison of bream (*Abramis brama*) and carp (*Cyprinus carpio*). Toxicol Sci 81:90-102.
Call Number: W 11243 PDF
Abstract: Interaction of environmental estrogens with the estrogen receptor (ER) has been shown in various fish species. Our objective was to compare the sensitivity of bream (Abramis brama) to (xeno-)estrogens with that of the carp (Cyprinus carpio), by measuring the effects of 17beta-estradiol (E2), estrone (E1), ethynylestradiol (EE2), bisphenol A (BPA), nonylphenol (NP), methoxychlor (MXCL) and halogenated aromatic hydrocarbons (HAHs) such as polychlorinated biphenyls (PCB126, PCB118), 2,3,7,8-tetrachlorodibenzo-dioxin (TCDD) and 2,3,4,7,8-pentachlorodibenzofuran (PCDF) on vitellogenesis in primary hepatocytes. Comparing the EC50 values in bream hepatocytes: EE2 (0.1-0.2 micro M) < E1 (0.6-0.2 micro M) < E2 (1.9 micro M) with those of carp hepatocytes EE2 (0.03-0.06 micro M) < E2 (0.3 micro M) approximately E1 (0.2-0.3 micro M) we found differences in sensitivity and ranking of the estrogenic potency of E2 and E1, indicating inter-species differences. Exposure to BPA, NP, MXCL and HAHs did not or only weakly induce vitellogenesis. Bream hepatocytes co-exposed to E2 and TCDD, PCB126 or PCDF showed a concentration-dependent inhibition of E2-induced vitellogenesis. IC50 values determined in bream were: TCDD (0.02-0.09 nM) < PCB126 (0.35-0.1 nM) < PCDF (2.0-0.1) and in carp were: TCDD (0.01 nM) < PCB126 (0.4 nM). PCB118 showed no (anti-)estrogenic response. IC50 values and benchmark-concentration for TCDD and PCB126 in bream and carp hepatocytes were in the same range, indicating similar sensitivity to these compounds. Due to their anti-estrogenic capacity with benchmark-concentrations in the pM range TCDD, PCDF and PCB126 may form a potential hazard for the reproductive success of fish species by inhibition of vitellogenesis.

Servos MR, Van Der Kraak G. 2001. Special Issue: Endocrine Disrupting Substances in the Canadian Environment. Water Quality Research Journal of Canada 36:169-346.

Call Number: W 09300
Abstract: This is a special issue focusing on endocrine disrupting substances in the Canadian Environment. The following is a list of the articles: 'Scientific assessment of endocrine disrupting substances in the Canadian environment'; 'Endocrine disruption: Why is it so complicated?'; 'An overview of substances present in Canadian aquatic environments associated with endocrine disruption'; 'A review of the evidence for endocrine disruption in Canadian aquatic ecosystems'; 'Effects of endocrine disrupting chemicals on wildlife in Canada: Past present and future'; 'Endocrine disruption and human reproductive effects: An overview'; 'An overview of testing procedures and approaches for identifying endocrine disrupting substances'; 'Assessment of the effects of endocrine disrupting substances in the Canadian environment'; 'Endocrine disrupting substances and ecological risk assessment in Canada for commercial chemicals'; 'Uncertainties associated with assessing the risk of an endocrine active substance in the Canadian environment'; and 'A Canadian perspective on endocrine disrupting substances.'

Stachel B, Ehrhorn U, Heemken OP, Lepom P, Reincke H, Sawal G, Theobald N. 2003. Xenoestrogens in the River Elbe and its tributaries. Environmental Pollution 124:497-507.
Call Number: W 10826
Abstract: 4-Alkylphenols, 4-alkylphenol ethoxylates, 4-alkylphenoxy carboxylates, bisphenol A, bisphenol F, 4-hydroxyacetophenon, 4-hydroxybenzoic acid and steroid hormones were analyzed in water samples of the River Elbe and its tributaries Schwarze Elster, Mulde, Saale, Havel and Schwinge. Additionally, freshly deposited sediments (FDS, composite samples) of the River Elbe and its tributaries were analyzed. The concentrations in water samples ranged from (in ng/l): bisphenol A 4 to 92, branched nonylphenol 13 to 87, branched nonylphenol ethoxylates <0.5 to 120, 4-tert. nonylphenoxy carboxylates <10 to 940 and 4-hydroxybenzoic acid 4 to 12. Steroid hormones were only detected in the Czech tributaries Jizera and Vltava in concentrations near the limit of quantification. In FDS samples the concentrations amounted to (in µg/kg d.w.): bisphenol A 10-380, branched nonylphenol 27-430, branched nonylphenol ethoxylates 24-3700, nonylphenoxy carboxylates <50 and 4-hydroxybenzoic acid 23-4400. Increased bisphenol A concentrations were found in water and FDS samples taken from the Czech-German border at Schmilka and the mouth of the Schwinge (only water sample). According to studies conducted in the Elbe Estuary and the German Bight, the River Elbe must be considered as a major source of pollution for the North Sea in respect of the compounds analyzed. A comparison of bisphenol A concentrations, 4-alkylphenols and the corresponding ethoxylates analyzed in the River Elbe and its tributaries with those found in other German surface waters indicated a low level of contamination. The evaluation of the data based on LOEC-values indicated that the concentrations were well below the effectivity threshold for some 4-alkylphenols. According to recent ecotoxicological investigations, for example, with prosobranch snails, bisphenol A concentrations found in water samples of the River Elbe and its tributaries may well be detrimental to aquatic organisms. On the basis of the monitoring data and its implications for estrogenic potency the inclusion of bisphenol A in the list of priority substances (European Union Directive 2000/60/EC, Annex X) should be considered.

Thomas P, Doughty K. 2004. Disruption of rapid, nongenomic steroid actions by environmental chemicals: Interference with progestin stimulation of sperm motility in Atlantic croaker. Environmental Science & Technology 38:6328-6332.
Call Number: W 11591 PDF
Abstract: Several nongenomic steroid actions, like genomic ones, can be disrupted by estrogenic xenobiotics (xenoestrogens), but the extent and sensitivity of this alternative mechanism of steroid action to chemical interference remain unclear. The effects of environmentally realistic concentrations of a broad range of organic contaminants on the nongenomic action of a progestin (17,20beta,21-trihydroxy-4-pregnen-3-one or 20beta-S) to upregulate Atlantic croaker sperm motility were examined in an in vitro bioassay. Pretreatment of sperm for 10 min in vitro with estrogenic compounds (estradiol-17beta, o,p'-DDT derivatives, zearalenone, bisphenol A, 2',3',4',5'-PCB-4-OH, kepone, chlordane, methoxyclor) and nonestrogenic organic compounds (p,p'-DDT derivatives, atrazine, Aroclor 1254, naphthalene, benzene) at concentrations ranging from 0.01 to 10 muM did not decrease the percent of motile sperm, but all of them partially or completely blocked the response to 20beta-S. Most of the compounds impaired this endocrine mechanism at a concentration of 0.1 muM (similar to30-40ppb), whereas o,p'-DDT and atrazine were effective at lower concentrations. The antagonistic actions of o,p'-DDT were partially reversed with 10-fold higher concentrations of 20beta-S, which is consistent with a hormone receptor-mediated mechanism of

DDT action. The finding that low concentrations of a wide range of organic environmental contaminants can interfere with a rapid, nongenomic steroid action suggests that this mechanism of endocrine disturbance is of toxicological importance.

Tillmann M, Schulte-Oehlmann U, Duft M, Markert B, Oehlmann J. 2001. Effects of endocrine disruptors on prosobranch snails (Mollusca: Gastropoda) in the laboratory. Part III: Cyproterone acetate and vinclozolin as antiandrogens. Ecotoxicology 10:373-388.
Call Number: W 09361 PDF
Abstract: The effects of suspected endocrine disrupting chemicals on freshwater and marine prosobranch species were analysed in laboratory experiments. In this last of three publications, the responses of the fresh water snail Marisa cornuarietis and of two marine prosobranchs (Nucella lapillus, Nassarius (Hinia) reticulatus) to the antiandrogenic model compounds cyproterone acetate (CPA) and vinclozolin (VZ) are presented. The snails were exposed to nominal CPA concentrations of 1.25 mg/L alone and simultaneously to a potent synthetic estrogen (ethinylestradiol), androgen (methyltestosterone) or an indirectly acting xeno-androgen (tributyltin) in experiments with adult specimens and in a life cycle test for 12 months. Marisa and Nucella were furthermore exposed to nominal concentrations of 0.03–1.0 µg VZ/L for up to 5 months. The antiandrogens induced a number of biological responses in all three species. The length of the penis and of accessory male sex organs (e.g., penis sheath, prostate) were significantly reduced. For Marisa, this effect occurred only in sexually immature specimens and was reversible as the males attained puberty. Typical androgen-mediated responses (imposex development, delayed spermatogenesis, tubulus necrosis of the testis with orchitis and Leydig cell hyperplasia) were partially or totally suppressed by a simultaneous administration of CPA. In the two marine species even adult, sexually mature males responded to antiandrogens with a reduction of the male sex organs and an advancement of the sexual repose phase. The results for CPA and VZ are compared with the effects of an exposure to xeno-estrogens (bisphenol A, octylphenol) and xeno-androgens (triphenyltin, tributyltin) in the same species. Each group of endocrine disruptors induces a characteristic set of toxicological effects in prosobranch snails which can be used as endpoints in an organismic invertebrate test for the identification of endocrine mimetic test compounds. Estrogens cause primarily an inducti on of superfemales resulting in an increased female mortality by the enhancement of spawning mass and egg production. The main effects of androgens are a virilization of females by imposex development and a marked decrease of the fecundity. Compared with estrogens and androgens, the antiandrogen responses seem to be less drastic and might have–in contrast to the two other disruptor classes–no biologically significant effects at the population level.

Tollefsen KE, Ovrevik J, Stenersen J. 2004. Binding of xenoestrogens to the sex steroid-binding protein in plasma from Arctic charr (*Salvelinus alpinus* L.). Comparative Biochemistry & Physiology C-Toxicology & Pharmacology 139:127-133.
Call Number: W 11590 PDF
Abstract: A specific sex steroid-binding protein (SBP) is believed to be involved in regulation of circulating sex steroids, steroid delivery to target cells and intracellular signalling in sex steroid-sensitive tissues. In the present work, interactions between xenoestrogens and the plasma SBP in Arctic charr (Salvelinus alpinus L.) were determined using ligand-protein binding studies. The test compounds were all able to displace tritiated 17beta-estradiol (E2) from the Arctic charr SBP (acSBP) in a competitive and dose-dependent manner. The acSBP affinities for the xenoestrogens ranged over several orders of magnitude (17beta-estradiol>>ethynylestradiol (EE2)>zearalenone (ZEA)>diethylstilbestrol (DES)>genistein (GEN)>bisphenol A (BPA), 4-t-octylphenol (OP)>>o,p'-DDT, and dieldrin (DIN)), but were consistently lower than that of 17beta-estradiol (about 4 x 10(2)-10(6)-fold less potent). The relative binding affinity (RBA) for selected chemicals were independent of both gender, age and maturation status, as well as variations of acSBP binding affinity. The affinity of endogenous steroids and estrogen mimics for the acSBP shows a high correlation to the affinity for the rainbow trout SBP, thus suggesting a phylogenetically conserved ligand-binding site between closely related species. Furthermore, it is argued that interaction with the acSBP- and SBP-mediated processes may introduce novel pathways for endocrine disruption, which may work in concert with the classical receptor-mediated effects.

Voordeckers JW, Fennell DE, Jones K, Häggblom MM. 2002. Anaerobic biotransformation of tetrabromobisphenol A, tetrachlorobisphenol A, and bisphenol A in estuarine sediments. Environmental Science & Technology 36:696-701.

Call Number: W 09774

Abstract: Biotransformation of the flame retardants tetrabromobisphenol A and tetrachlorobisphenol A, and their ultimate biodehalogenation product, bisphenol A, was examined in anoxic estuarine sediments. Dehalogenation of tetrabromobisphenol A and tetrachlorobisphenol A was examined under conditions promoting either methanogenesis or sulfate reduction as the primary terminal electron-accepting process. Complete dehalogenation of tetrabromobisphenol A to bisphenol A with no further degradation of bisphenol A, was observed under both methanogenic and sulfate-reducing conditions. Dehalogenation of tetrachlorobisphenol A under both methanogenic and sulfate-reducing conditions resulted in the accumulation of a persistent dichlorinated bisphenol A isomer, while no bisphenol A was formed. Co-amendment of sediment enrichments with either 2,6-dibromo- or 2,6-dichlorophenol did not affect the extent of dehalogenation as compared to sediments that were amended only with the flame retardants. Sediment cultures pre-acclimated on 2-bromophenol dehalogenated the flame retardants in a manner similar to that of fresh sediments. No loss of bisphenol A was observed in separate incubations within 162 days under conditions promoting either methanogenesis, sulfate-reduction, iron(III)-reduction, or nitrate-reduction. Furthermore, identical enrichments that readily degraded 4- hydroxybenzoate, a structural analogue of bisphenol A, did not exhibit bisphenol A degradation. The dehalogenation of tetrabromo- and tetrachlorobisphenol A and the potential for accumulation of bisphenol A in anoxic sediments is significant given the widespread use of these chemicals.

Yamashita Y, Okumura T, Yamada H. 2001. Intersexuality in *Acanthomysis mitsukurii* (Mysidacea) in Sendai Bay, northeastern Japan. Plankton Biology & Ecology 48:128-132.

Call Number: W 09569

Abstract: Specimens of the mysid, Acanthomysis mitsukurii, were collected monthly using a bottom plankton sampler at 6 stations with sandy bottom sediments in Sendai Bay between July 1993 and June 1994 and once in March 2000. Seven intersex individuals were found from a total of 9282 specimens. All intersex animals bear a pair of elongated fourth pleopods extending to the posterior edge of the fifth abdominal somite and a marsupium. Six of the 7 individuals have a smaller marsupium than that of a normal mature female. Genital papillae were observable neither under a binocular microscope nor from any histological section. The intersex animals subjected to histological analysis contained testicular tissue, indicating that these animals were feminized males. Intersexuality occurred only in the overwintering generation collected in January and March. Also, intersex animals were collected at only one station, which is located off a pulp mill effluent outfall. The percentage occurrence of intersex individuals in adults collected at this station in January and March 1994 and in March 2000 was 2.5%. Nonylphenol and bisphenol A, which are known to be xeno-estrogens in vertebrates, were detected only at this station, indicating that this station was more polluted than the other stations. However, the causality of intersexuality by the pollutants remains uncertain. Further studies are required to elucidate the mechanisms of induction of intersexuality in A. mitsukurii.

Ying G-G, Kookana RS. 2003. Degradation of five selected endocrine-disrupting chemicals in seawater and marine sediment. Environmental Science & Technology 37:1256-1260.

Call Number: W 10686

Abstract: We studied degradation of five endocrine-disrupting chemicals (EDCs), namely bisphenol A (BPA), 17β-estradiol (E2), 17α-ethynylestradiol (EE2), 4-tert-octyl phenol (4-t-OP), and 4-n-nonyl phenol (4-n-NP), in the marine environment using a marine sediment and seawater collected from the coastal area near Adelaide, South Australia. This laboratory study showed that all five EDCs were degraded in seawater within 56 days. However, a lag phase preceding their rapid degradation in seawater was observed for BPA, E2, and EE2. On the other hand, 4-t-OP and 4-n-NP dissipated rapidly due to abiotic as well as biotic factors without any lag phase. Under the aerobic conditions, the five EDCs were found to degrade the sediment, with E2 and 4-n-NP showing fastest degradation, with estimated half-lives of 4.4 and 5.8 d, respectively, followed by BPA ($t_{1/2}$ 14.5 d), EE2 ($t_{1/2} > 20$ d), and 4-t-OP ($t_{1/2} > 20$ d). Under anaerobic conditions in the marine sediment, little or no degradation of the five EDCs was noted, except E2 which showed a slow continuous degradation rate during the 70-day study. Approximately 50% of E2 was degraded after 70 d anaerobic incubation. The study showed that the five EDCs studied here will degrade relatively rapidly under aerobic conditions in marine sediment and seawater but are likely to show much longer persistence under anoxic conditions.

Bisphenol A - Marine & Estuarine (from Lynn Caroll, OurStolenFuture.org)

Belfroid AC, Murk AJ, de Voogt P, Schafer AJ, Rijs GBJ, Vethaak AD1999. Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat; Rijkssinstituut voor Integraal Zoetwaterbeheer; Rijkssinstituut voor Kust en Zee. RIZA rapport: 99.007; RIKZ rapport: 99.024.

Berg C, Halldin K, Brunkström B. 2001. Effects of bisphenol A and tetrabromobisphenol A on sex organ development in quail and chicken embryos. Environmental Toxicology & Chemistry 20:2836-2840.

Bolz U, Hagenmaier H, Korner W. 2001. Phenolic xenoestrogens in surface water, sediments, and sewage sludge from Baden-Württemberg, south-west Germany. Environmental Pollution 115:291-301.

Boyd GR, Reemtsma H, Grimm DA, Mitra S. 2003. Pharmaceuticals and personal care products (PPCPs) in surface and treated waters of Louisiana, USA and Ontario, Canada. Sci Total Environ 311:135-149.

Boyd GR, Reemtsma H, Grimm DA, Mitra S. 2004. Pharmaceuticals and personal care products (PPCPs) and endocrine disrupting chemicals (EDCs) in stormwater canals and Bayou St. John in New Orleans, Louisiana, USA. Sci Total Environ 333:137-148.

Caspers N. 1998. No estrogenic effects of bisphenol A in *Daphnia magna* Straus. Bull Environ Contam Toxicol 61:143-148.

Chen M-Y, Ike M, Fujita M. 2002. Acute toxicity, mutagenicity, and estrogenicity of bisphenol-A and other bisphenols. Environmental Toxicology 17:80-86.

Christiansen LB, Pedersen KL, Pedersen SN, Korsgaard B, Bjerregaard P. 2000. In vivo comparison of xenoestrogens using rainbow trout vitellogenin induction as a screening system. Environmental Toxicology & Chemistry 19:1867-1874.

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Bisphenol A - Other Wildlife-Related

Belfroid AC, Murk AJ, de Voogt P, Schafer AJ, Rijs GBJ, Vethaak AD1999. Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat; Rijkssinstituut voor Integraal Zoetwaterbeheer; Rijkssinstituut voor Kust en Zee. RIZA rapport: 99.007; RIKZ rapport: 99.024.
Call Number: W 07942
Abstract: The presence of endocrine-disruping compounds in the environment is currently the focus of a substantial amount of attention, both within the Netherlands and internationally. Generally speaking, it is difficult to establish causal relationships between the presence of endocrine-disrupting compounds in the environment and the occurrence of any such effect. Nevertheless, disruption of reproduction associated with exposure to these compounds has in the past and recently been reported from a range of organisms in aquatic ecosystems in the Netherlands and other countries of western Europe. These findings led the Netherland Health Council to conclude that there is reason for concern about the presence in the aquatic environment of endocrine-disrupting compounds, which may represent a threat to the continued existence of populations of some species. Included are tables showing the range of concentrations of estrogenic hormones, bispenol A, total phthalates and alkylphenols in each matrix and the estrogenic potency.

Berg C, Halldin K, Brunkström B. 2001. Effects of bisphenol A and tetrabromobisphenol A on sex organ development in quail and chicken embryos. Environmental Toxicology & Chemistry 20:2836-2840.
Call Number: W 09314
Abstract: The plastic monomer bisphenol A (BPA) and the flame retardant tetrabromobisphenol A (TBBPA) were examined for estrogen-like developmental effects on the reproductive organs in avian embryos. The synthetic diethylstilbestrol (DES) was used as a positive control. The test compounds were injected into the yolk of quail and chicken eggs early during incubation and the embryos were examined 2 d before anticipated hatching. At 200 ug/g egg, BPA induced Mullerian duct (embryonic oviduct) malformation in female quail embryos and feminization of the left testis (ovotestis) in male chicken embryos. The estrogenic potency of BPA compared with DES was species and endpoint specific. Mullerian duct malformation was the most sensitive endpoint in quail embryos, where ovotestis formation was the most sensitive response in chicken embyros. Tetrabromobisphenol A caused high embryo mortality at 45 ug/g egg in both species, but no estrogen-like effects were observed. Bisphenol A caused mortality only in chicken embryos at 67 and 200 ug/g egg. To our knowledge, this is the first report on estrogen-like or embryolethal effects of BPA and TBBPA in birds.

Bolz U, Hagenmaier H, Korner W. 2001. Phenolic xenoestrogens in surface water, sediments, and sewage sludge from Baden-Württemberg, south-west Germany. Environmental Pollution 115:291-301.
Call Number: W 09346
Abstract: Nine structurally different phenolic chemicals, which have been reported to mimic estrogen effects, were determined in various aquatic environmental compartments. Twenty-three water samples from five streams and rivers showed levels up to 458 ng/l for 4-nonylphenol (4NP), 189 ng/l for 4-t-octylphenol (4tOP), 272 ng/l for bisphenol A (BPA) and 47 ng/l for 2-hydroxybiphenyl (2OHBiP). Elevated levels of these compounds in a stream with a high load of effluents of sewage treatment plants (STPs), compared to a brook free of sewage, identified STPs as major sources. With a similar order, 4NP (10-259 micrograms/kg dry matter), 4tOP (< 0.5-8 micrograms/kg), BPA (< 0.5-15 micrograms/kg), and 2OHBiP (2-69 micrograms/kg) were also detected regularly in riverine sediment (n = 11). Levels in sewage sludge were one order of magnitude higher than in sediments. 4-Hydroxybiphenyl and 4-chloro-3-methylphenol were found predominantly in sludge and sediment in the lower ppb range.

Boyd GR, Reemtsma H, Grimm DA, Mitra S. 2003. Pharmaceuticals and personal care products (PPCPs) in surface and treated waters of Louisiana, USA and Ontario, Canada. Sci Total Environ 311:135-149.
Call Number: W 11127 PDF
Abstract: A newly developed analytical method was used to measure concentrations of nine pharmaceuticals and personal care products (PPCPs) in samples from two surface water bodies, a sewage treatment plant effluent and various stages of a drinking water treatment plant in Louisiana, USA, and from one surface water body, a drinking water treatment plant and a pilot plant in Ontario, Canada. The analytical method provides for simultaneous extraction and quantification of the following broad range of PPCPs and endocrine-disrupting chemicals: naproxen; ibuprofen; estrone; 17beta-estradiol; bisphenol A;

clorophene; triclosan; fluoxetine; and clofibric acid. Naproxen was detected in Louisiana sewage treatment plant effluent at 81-106 ng/l and Louisiana and Ontario surface waters at 22-107 ng/l. Triclosan was detected in Louisiana sewage treatment plant effluent at 10-21 ng/l. Of the three surface waters sampled, clofibric acid was detected in Detroit River water at 103 ng/l, but not in Mississippi River or Lake Pontchartrain waters. None of the other target analytes were detected above their method detection limits. Based on results at various stages of treatment, conventional drinking-water treatment processes (coagulation, flocculation and sedimentation) plus continuous addition of powdered activated carbon at a dosage of 2 mg/l did not remove naproxen from Mississippi River waters. However, chlorination, ozonation and dual media filtration processes reduced the concentration of naproxen below detection in Mississippi River and Detroit River waters and reduced clofibric acid in Detroit River waters. Results of this study demonstrate that existing water treatment technologies can effectively remove certain PPCPs. In addition, our study demonstrates the importance of obtaining data on removal mechanisms and byproducts associated with PPCPs and other endocrine-disrupting chemicals in drinking water and sewage treatment processes.

Boyd GR, Reemtsma H, Grimm DA, Mitra S. 2004. Pharmaceuticals and personal care products (PPCPs) and endocrine disrupting chemicals (EDCs) in stormwater canals and Bayou St. John in New Orleans, Louisiana, USA. Sci Total Environ 333:137-148.
Call Number: W 11126 PDF
Abstract: Samples were collected from two stormwater canals and a recreational urban waterway known as Bayou St. John in New Orleans, Louisiana, USA and analyzed for a range of pharmaceuticals and personal care products (PPCPs) and endocrine disrupting chemicals (EDCs). Concentrations of 7 PPCPs and EDCs were measured by a method that provides for simultaneous extraction and quantification of the following compounds: clofibric acid, naproxen, ibuprofen, fluoxetine, clorophene, triclosan, bisphenol A. The method also was used as an indicator of the occurrence of estrogenic compounds by targeting estrone and 17-estradiol. The two canals (Orleans and London) are used to drain a portion of the city's stormwater directly into the Mississippi River or Lake Pontchartrain. Bayou St. John is located between the two canals and supplied with water from Lake Pontchartrain. Results from the 6-month sampling period indicated the following concentration ranges for the two stormwater canals: naproxen (ND -estradiol) were detected above their method detection levels. Results of this study demonstrate the occurrence of PPCPs and EDCs in New Orleans stormwater canals and Bayou St. John. Results also demonstrate the use of this analytical technique as an indicator of non-point source sewage contamination in New Orleans stormwater canals.

Caspers N. 1998. No estrogenic effects of bisphenol A in *Daphnia magna* Straus. Bull Environ Contam Toxicol 61:143-148.
Call Number: W 11451 PDF

Chen M-Y, Ike M, Fujita M. 2002. Acute toxicity, mutagenicity, and estrogenicity of bisphenol-A and other bisphenols. Environmental Toxicology 17:80-86.
Call Number: W 09781
Abstract: Although abundant data are available on the toxicity of bisphenol-A (2,2-bis (4-hydroxydiphenyl)propane; BPA), little is known about the toxicities of the structurally similar compounds, namely bisphenols (BPs). A variety of BPs were examined for their acute toxicity against Daphnia magna, mutagenicity, and estrogenic activity using the Daphtoxkit (Creasel Ltd.), the umu test system, and the yeast two- hybrid system, respectively, in comparison with BPA. BPA was moderately toxic to D. magna (48-h EC50 was 10 mg/l) according to the current U.S. EPA acute toxicity evaluation standard, and it was weakly estrogenic with 5 orders of magnitude lower activity than that of the natural estrogen 17 beta-estradiol in the yeast screen, while no mutagenicity was observed. All seven BPs tested here showed moderate to slight acute toxicity, no mutagenicity, and weak estrogenic activity as well as BPA. Some of the BPs showed considerably higher estrogenic activity than BPA, and others exhibited much lower activity. Among the tested BPs, two compounds, i.e., bisphenol-S (bis(4-hydroxydiphenyl)sulfone) and bis(4-hydroxyphenyl)sulfide, have never been reported for their estrogenic activity previously.

Christiansen LB, Pedersen KL, Pedersen SN, Korsgaard B, Bjerregaard P. 2000. In vivo comparison of xenoestrogens using rainbow trout vitellogenin induction as a screening system. Environmental Toxicology & Chemistry 19:1867-1874.

Call Number: W 07910
Abstract: Vitellogenin induction in rainbow trout after intraperitoneal injection of test compounds was investigated. Vitellogenin quantification was performed by a direct sandwich enzyme-linked immunosorbant assay (ELISA) based on polyclonal, affinity purified antibodies. The system was used as a short-term in vivo screen for estrogenicity and as a tool for establishing the priority of compounds to be tested by water exposure of fish. Representatives from the group of xenoestrogens, bisphenols, phthalates, and pesticides were tested. The relative potency order bisphenol A > bisphenol A dimethacrylate, o,p'-DDT > butylbenzylphthalate was established, while no significant vitellogenin response was seen with dibutylphthalate, tetrabromobisphenol A, and methoxychlor. Of these, tetrabromobisphenol A has not previously been tested for estrogenicity in vivo. Earlier findings of diminished estrogenic activity of ortho-substituted compounds was extended to bisphenols since ortho-bromination of bisphenol A abolished the activity of the parent molecule.

Christiansen LB, Winther-Nielsen M, Helweg C2002. Feminisation of fish: The effect of estrogenic compounds and their fate in sewage treatment plant and nature.: Danish Environmental Protection Agency, Danish Ministry of the Environment. Environmental Project (Miljøprojekt) No. 729.
Call Number: W 11440 PDF only

Colborn T, Thayer K. 2000. Aquatic ecosystems: harbingers of endocrine disruption. Ecological Applications 104:949-957.
Call Number: W 08079 PDF
Abstract: In the 1950s, top predator wildlife populations in aquatic systems signaled disturbances in their environment through a series of adverse health effects. Bioaccumulation in plant and animal tissue, with accompanying biomagnification in the animals that consumed these tissues, led to extremely high concentrations of some synthetic chemicals in top predator species in aquatic trophic systems. By the late 1960s technological improvements in analytical chemistry allowed for associations between a suite of persistent chemicals in the tissues of affected animals and the health status of wildlife populations. This group of contaminants, the organochlorine chemicals, and their effects on wildlife provided the insight into the phenomenon called "endocrine disruption," where certain synthetic chemicals can interfere with the natural chemical messengers that control normal development and function. Because the effects were most often expressed in offspring that were exposed via maternal transfer before, or soon after, birth or hatching, the damage in wildlife was often overlooked. Forensic field research over the past decade has revealed far wider damage than heretofore had been realized. In addition, interest in chemicals that can interfere with the endocrine system has expanded to include natural plant and animal compounds, non-halogenated compounds, and other large volume chemicals (> 4.5×10^6 kg/yr) that had been considered benign until only recently. Concern about the effects of contaminants in wildlife and their implications for human health led to the discovery that human offspring are experiencing developmental and neurological damage. These effects have been associated with exposure to certain organochlorine chemicals and their co-contaminants at, or slightly above, ambient concentrations in the industrialized world.

Dizer H, Fischer B, Sepulveda I, Loffredo E, Senesi N, Santana F, Hansen PD. 2002. Estrogenic effect of leachates and soil extracts from lysimeters spiked with sewage sludge and reference endocrine disrupters. Environmental Toxicology 17:105-112.
Call Number: W 11270 PDF only
Abstract: Several experiments were conducted to evaluate the behavior and performance of some potential endocrine disrupters (ECDs). Two in vitro screening assays, one based on MCF7-cell proliferation (E-screen test) and the other on estrogenic receptor activity [enzyme-linked receptor assay (ELRA)], were used for the tests, which were done in lysimeters 80 cm in diameter with depths of 30 cm (shallow) or 90 cm (deep). A sandy soil was used to fill in all lysimeters, which were spiked on the surface with either: (a) a sewage sludge (SS) at a dose equivalent to 20 tons ha(-1); (b) a mixture of reference ECDs, comprising 17alpha- and 17beta-estradiol (E2), nonylphenol, octylphenol, and bisphenol A at doses 100 times higher than the maximum concentrations respectively found in the applied SS; or (c) a mixture of ECDs and SS. After percolation of the lysimeters; with rain and/or artificial water, five leachates were sampled from each lysimeter during a period of 210 days. Immediately after the lysimeter percolation experiments, four and six soil fractions were dissected from, respectively, the 30-cm and 90-cm lysimeters and extracted by water. Both the leachate and soil extract samples were analyzed for their estrogenicity using the assays

indicated above. The E-screen assay was highly sensitive only for some leachate and extract samples but gave no response for most leachates and soil extracts. The results of the ELRA assay suggests a significantly higher estrogenicity of leachate samples from shallow lysimeters compared with that of leachates from deep lysimeters. In contrast, the estrogenic effect measured for soil extracts of shallow lysimeters was lower than that measured for soil extracts of deep lysimeters. The results of the E-screen assay suggests the occurrence of a fast mobilization of applied ECDs and a moderate retardation effect of native ECDs contained in applied SS in the sandy soil used in the lysimeters. In lysimeters spiked with a mixture of SS and ECDs, the washing-out effect of ECDs in the first leachate fraction decreased, but the distribution of ECDs in the lysimeters increased. The relatively high estrogenic impact measured for soil water extracts suggests that the ECDs were mostly associated with water-soluble fractions of organic matter and/or water-suspended fractions of the mineral soil matrix. The application of SS to agricultural and forest fields may determine the immobilization of ECDs in soil or their movement to surface and/or groundwater. Therefore, an endocrine risk of exposure exists for the water and soil organisms.

Duft M, Schulte-Oehlmann U, Weltje L, Tillmann M, Oehlmann J. 2003. Stimulated embryo production as a parameter of estrogenic exposure via sediments in the freshwater mudsnail *Potamopyrgus antipodarum*. Aquatic Toxicology 64:437-449.
Call Number: W 11129 PDF
Abstract: The effects of three suspected endocrine disrupting chemicals, the xeno-estrogens bisphenol A (BPA), 4-tertoctylphenol (OP) and 4-n-nonylphenol (NP), were investigated in a whole-sediment biotest with the freshwater mudsnail Potamopyrgus antipodarum (Gastropoda, Prosobranchia). Artificial sediments were spiked with five nominal concentrations (six for NP), ranging from 1-300 mug/kg dry weight (1-1000 pg/kg for NP). After 2, 4 and 8 weeks of exposure, the responses of the test species were analysed. P. antipodarum exhibited a distinct increase in the number of embryos sheltered in its brood pouch in a time- and concentration-dependent manner in comparison to the solvent control sediment for BPA and OP. The number of "new", still unshelled embryos turned out to be the most sensitive parameter. The lowest observed effect concentration (LOEC) was equivalent to the lowest administered concentration (1 mug/kg for each test compound) for most parameters after 8 weeks of exposure. The calculation of effect concentrations resulted in even lower values for BPA (unshelled embryos after 2 weeks: EC10 0.22 mug BPA/kg, EC50 24.5 mug BPA/kg; after 4 weeks: EC10 4 ng OP/kg, EC50 5.67 mug OP/kg) and OP (unshelled embryos after 4 weeks: EC10 4 ng OP/kg, EC50 0.07 mug OP/kg). For NP, there was no clear concentration-dependent response, and therefore, no EC10 or EC50 could be estimated, but the data suggest an inverted u-shape type of curve. The LOEC in the experiments with NP was 10 pg/kg. Our results indicate that P. antipodarum is highly sensitive to the tested endocrine disruptors at environmentally relevant concentrations. Furthermore, the biotest with P. antipodarum is a useful tool for the identification of sediment-bound pollutants and for the assessment of sediment quality.

Duft M, Tillmann M, Schulte OU, Markert B, Oehlmann J. 2002. Development of a new sediment bioassay with the freshwater mudsnail *Potamopyrgus antipodarum* (Gastropoda: Prosobranchia). [Original title: Entwicklung eines Sedimentbiotests mit der Zwergdeckelschnecke *Potamopyrgus antipodarum* (Gastropoda: Prosobranchia)]. Umweltwissenschaften Und Schadstoff- Forschung 14:12-17.
Call Number: W 10053
Abstract: Currently, only few organismic biotest systems are available for the assessment of effects on reproduction, which consider an exposure toward whole sediments. A well-suited test organism is the parthenogenetic mudsnail *Potamopyrgus antipodarum*. This ovoiviparous prosobranch snail lives in the upper layers of freshwater and brackish sediments. The number of (unshelled) embryos turned out to be a very sensitive parameter for the indication of sediment components affecting reproduction. Additionally, this endpoint allows to signal possible estrogenic sediment compounds.
With this 28-day bioassay, laboratory tests on the effects of various chemicals on *P. antipodarum* were performed, e.g. triphenyltin and bisphenol A, in relevant environmental concentration ranges. Furthermore, the suitability of our test system for the investigation of complex and multiple level ranged contamination was examined by means of various natural sediments from the Neibe and Odra rivers.

Fox JE, Starcevic M, Kow KY, Burow ME, McLachlan JA. 2001. Endocrine disrupters and flavonoid signalling. Nature 413:128-129.
Call Number: W 09134 PDF

Abstract: Nitrogen fixation is a symbiotic process initiated by chemical signals from legumes that are recognized by soil bacteria. Here we show that some of the endocrine-disrupting chemicals (EDCs) also interfere with the symbiotic signalling that leads to nitrogen fixation.
".. pentachlorophenol and methyl parathion .. each reduced *nod* expression by up to 90%.... Even nanomolar concentrations of some pesticides significantly inhibited phytochemical-NodD signalling"
Other chemicals and their inhibition of *nod* expession: DDT and its metabolites (40%); bisphenol A (66%); 2,4-D (32%); 2,4,5-T (37%).
"Endosulfan, methoxychlor, aldrin, dieldrin, dursban, vinclozolin and diazinon had no effect on symbiotic signalling."
"The inhibitory EDCs are all planar phenolic compounds, whereas those that had no effect in our assay are non-planar and have no free hydroxyl group."

Fromme H, Kuechler T, Otto T, Pilz K, Mueller J, Wenzel A. 2002. Occurrence of phthalates and bisphenol A and F in the environment. Water Research 36:1429-1438.
Call Number: W 10054
Abstract: Certain xenoestrogens, namely bisphenol A (BPA), bisphenol F (BPF), butylbenzyl phthalate (BBP), dibutyl phthalate (DBP), and di(2-ethylhexyl)phthalate (DEHP), were measured in various compartments (surface water, sediments, sewage treatment plant effluents, sewage sludge, dump water, liquid manure) in order to contribute to a better understanding of exposure to these compounds in different environments.
Hundred and sixteen surface-water samples and 35 sediments from river, lakes and channels, 39 sewage effluents, and 38 sewage sludges were collected in Germany. Furthermore, ten liquid manure, two waste-dump and two compost-runoff water samples were also analysed.
BPA measurements showed low concentrations from 0.0005 to 0.45 ug/L in surface water, in sewage effluents from 0.018 to 0.702 ug/L, in sediments from 0.01 to 0.19 mg/kg and in sewage sludge from 0.004 to 1.363 mg/kg dw. Measured concentrations of BPF were clearly lower than BPA in all environmental media.
DEHP dominated the phthalate concentrations, which ranged from 0.33 to 97.8 ug/L (surface water), 1.74 to 182 ug/L (sewage effluent), 27.9 to 154 mg/kg dw (sewage sludge) and 0.21 to 8.44 mg/kg (sediment). DBP was found only in minor concentrations and BBP, only in a few samples in low amounts. Very high concentrations of BPA and phthalates were confirmed in waste dump water and compost water samples as well as in the liquid manure samples.

Fukazawa H, Hoshino K, Shiozawa T, Matsushita H, Terao Y. 2001. Identification and quantification of chlorinated bisphenol A in wastewater from wastepaper recycling plants. Chemosphere 44:973-979.
Call Number: W 09841
Abstract: Chlorinated derivatives of bisphenol A were detected in the final effluents of eight paper manufacturing plants in Shizuoka, Japan, where thermal paper and/or other printed paper is used as the raw material. Their amounts were determined by gas chromatography/mass spectrometry (GC/MS) after treatment with N, O- bis(trimethylsilyl)trifluoroacetamide, and ranged from traces to 2.0 microg/l. They are likely produced by chlorination of bisphenol A, which was released into the effluents from the pulping process of wastepaper, during or after bleaching with chlorine.

Furhacker M, Scharf S, Weber H. 2000. Bisphenol A: emissions from point sources. Chemosphere 41:751-756.
Call Number: W 07896
Abstract: Bisphenol A is widely used for the production of epoxy resins and polycarbonate plastics. Special in vitro test systems and animal experiments showed a weak estrogenic activity for Bisphenol A. Based on in vitro receptor interaction studies, the activity was estimated to be 2 x 10(-3) lower than that of estradiol. Especially aquatic wildlife could be endangered by waste water discharges. To manage possible risks arising from Bisphenol A contamination, the major fluxes need to be obtained and the contributors to the contamination of municipal treatment plants need to be determined. In this study, industrial emitters and communal waste waters were monitored simultaneously. Mixed samples were taken over periods of one week at nine sample sites. The results showed that the concentrations and fluxes were variable. The paper industry was the major Bisphenol A contributor to the influent of the waste water treatment plant. All the other fluxes measured, including two household areas, were considerably low. About 90% of the total load was removed during the waste water treatment.

Granek V, Rishpon J. 2002. Detecting endocrine-disrupting compounds by fast impedance measurements. Environmental Science & Technology 36:1574-1578.
Call Number: W 09981
Abstract: The increasing concern worldwide over the adverse effects of endocrine disruptors on human health has created a need for screening systems to detect xenoestrogens, a diverse group of environmental chemicals that mimic estrogenic actions and are hypothesized to decrease male fertility. Here, we describe a novel, class-selective detector that uses fast impedance measurements to monitor the binding of estrogen and xenoestrogens to a native estrogen receptor. We embedded the receptor in synthetic lipid bilayers attached to gold electrodes. The lipid bilayers serve as electrical circuits constructed of resistors and capacitors. Estrogen binding to the receptor-modified electrode is immediately followed by conformational changes in the lipid layer, leading to alterations of the electrical circuit components that are detected by fast impedance measurements. The electrochemical system enabled characterization of changes in the bilayer structure and quantification of estrogen binding to the receptor. To assess the effectiveness of the method for detecting environmental estrogenic chemicals, we chose two classes of xenoestrogens: bisphenol A, a synthetic xenoestrogen, and genistein, a phytoestrogen. This system is highly sensitive and amenable to use in the field, providing an efficient and economic tool for measuring minuscule amounts of endocrine-disrupting chemicals in environmental or human samples.

Gu MB, Min J, Kim EJ. 2002. Toxicity monitoring and classification of endocrine disrupting chemicals (EDCs) using recombinant bioluminescent bacteria. Chemosphere 46:289-294.
Call Number: W 09707
Abstract: A recombinant bioluminescent Escherichia coli, DPD2794, containing the recA promoter region fused to luxCDABE originating from Vibrio fischeri was used for detecting genotoxicity caused by endocrine disrupting chemicals (EDCs) to cells. As well, several other recombinant bioluminescent bacteria, including TV1061, which is sensitive to protein damage (grpE::luxCDABE), DPD2511, sensitive to oxidative damage (katG::luxCDABE), and DPD2540, sensitive to membrane damage (fabA::luxCDABE), were used for evaluating other possible modes of toxicity. It was found that the recombinant bacteria could monitor the toxic effect, not estrogenic effect, due to the presence of various EDCs through the measurement of bioluminescence (BL) and cell growth rate, which depend upon the type of toxicity occurring and which of the four strains was used. In addition, it was found that the damage caused by EDCs can be classified into several groups upon their mechanisms of toxic action.

Gushiken Y, Watanuki H, Sakai M. 2002. *In vitro* effect of carp phagocytic cells by bisphenol A and nonylphenol. Fisheries Science 68:178-183.
Call Number: W 11453 PDF
Abstract: The effect of bisphenol A and nonylphenol on carp Cyprinus carpio phagocytic cells was analyzed in vitro. Head kidney leukocytes of carp were exposed to 10 nM of bisphenol A or nonylphenol, separately. Subsequently, the production of superoxide anions was measured via the reduction of nitroblue tetrazolium (NBT) in vitro. Macrophages incubated with 0.1 nM up to 10 nM of bisphenol showed an increase in the production of superoxide anions in comparison with the control macrophages, which were not treated with bisphenol A. Nonylphenol also induced the production of superoxide anions in phagocytic cells prepared from carp kidney. Phagocytic cells treated with both bisphenol A and nonylphenol decreased phagocytic activity. However, the production of nitric oxide in carp macrophages did not change when treated only with either bisphenol A or nonylphenol. These results indicate that bisphenol A and nonylphenol affected the function of phagocytic cells in vitro.

Hahn T, Schenk K, Schulz R. 2002. Environmental chemicals with known endocrine potential affect yolk protein content in the aquatic insect *Chironomus riparius*. Environmental Pollution 120:525-528.
Call Number: W 10487
Abstract: The use of vitellogenesis as a marker for possible effects of endocrine disrupting agents on insects was tested in the aquatic midge Chironomus riparius. As test substances the synthetic ecdysoid tebufenozide, and the endocrine disruptors bisphenol a and 4-n-nonylphenol were applied in a semi-static manner. The yolk protein contents of freshly emerged (24 h) male and female midges were determined by an ELISA procedure. In males, where always low amounts of immunoreactivity were apparent, yolk concentrations were lowered by 10% after a 80 microg/l tebufenozide treatment, and by 20-25% after exposition to bisphenol A at concentrations of 1, 100, and 3,000 microg/l. 4-n-nonylphenol contamination

caused an inverted dose-response curve. At low test concentrations (1.9-30 microg/l) reduced yolk immunoreactivity occurred, while at medium concentrations (120 and 500 microg/l) no significant effects were observable. In the most highly contaminated group (2,000 microg/l) yolk protein immunoreactivity was elevated to 107% of the control. Female yolk protein contents were affected only in the 3,000 microg bisphenol A/l contaminated group, where yolk immunoreactivity was reduced by ca. 10% compared to the control.

Halldin K, Berg C, Bergman A, Brandt I, Brunstrom B. 2001. Distribution of bisphenol A and tetrabromobisphenol A in quail eggs, embryos and laying birds and studies on reproduction variables in adults following *in ovo* exposure. Arch Toxicol 75:597-603.
Call Number: W 09694
Abstract: In a previous study, we showed that bisphenol A (BPA) had oestrogen-like effects in bird embryos, causing malformations of the oviducts in Japanese quail (Coturnix japonica) and feminisation of the left testis in chicken (Gallus domesticus). In this study, uptake and distribution of BPA and tetrabromobisphenol A (TBBPA) in embryos and laying quail were examined as well as variables related to reproduction in adult quail following administration of the compounds into the yolk of embryonated eggs. The uptake of radiolabelled BPA, TBBPA and the reference compound diethylstilboestrol (DES) was studied in the embryos using beta-spectrometry. Autoradiography was employed to examine distribution in egg and embryo after yolk sac injection of BPA or TBBPA and in laying birds, following intravenous and oral administration. Following embryonic exposure to BPA or TBBPA, sexually mature male birds were examined for reproductive behaviour and testis morphology, and females were examined for egg laying and oviduct morphology. Neither BPA (200 mug/g egg) nor TBBPA (15 mug/g egg) caused any significant oestrogen-like effects on the variables studied, although effects on the female oviducts after BPA exposure were indicated. Embryonic exposure to DES is known to cause profound effects on male sexual behaviour and female oviduct morphology at doses 3-5 orders of magnitude lower than the BPA and TBBPA doses used in the present study. The proportions of BPA and TBBPA taken up by the embryos after yolk sac injection were similar to the proportion of DES taken up. Differences in bioavailability, therefore do not account for any major part of the potency differences between DES and the two bisphenol A compounds. The concentration of radioactivity in the embryo, as revealed by autoradiography, was low compared with that in the yolk at all stages studied (days 6, 10 and 15). Pronounced labelling of the bile and the allantoic fluid was observed, however, indicating that both compounds were readily metabolised and excreted. Radiolabelled BPA and TBBPA administered to laying quail were largely excreted via the bile and 9 days after oral dosing, only small amounts of the labelled compound remained within the body. Maternal transfer of labelled BPA and TBBPA to the egg was low.

Hassanin A, Kuwahara S, Nurhidayat, Tsukamoto Y, Ogawa K, Hiramatsu K, Sasaki F. 2002. Gonadosomatic index and testis morphology of common carp (*Cyprinus carpio*) in rivers contaminated with estrogenic chemicals. J Vet Med Sci 64:921-6.
Call Number: W 11218
Abstract: To study the effect of estrogenic chemicals on fish, the gonadosomatic index (GSI = [testis weight/body weight] x 100) and testis histology of mature common carp (Cyprinus carpio) from 2 contaminated sites (Ishizu and Wada rivers, Osaka) and a control site were examined between June 1998 and March 2001. The concentration of nonylphenol, bisphenol A and 17beta-estradiol in the Ishizu river was 3-4 times higher than in the Wada river. In the pre-breeding and breeding seasons, there were no significant differences in body weight among carp from the 3 sites, the body weight of Ishizu river carp being significantly lower ($p<0.05$) than that of Wada river fish only in the post-breeding season. The GSI and testis weight in fish from the Ishizu river were significantly lower ($p<0.05$) than in control fish during all phases of gonadal cycle and lower than in Wada river fish in the pre-breeding and post-breeding season. No histological abnormalities were found in the testes of the males examined. Histological observation of the testes revealed a delay in the onset of spermatogenesis in fish from the Ishizu river compared with those from the other sites. These results clearly imply that the estrogenic chemicals in the Ishizu river adversely affect the testis development of the fish.

Hassanin A, Kuwahara S, Nurhidayat, Tsukamoto Y, Ogawa K, Hiramatsu K, Sasaki F. 2003. Functional changes of the LH-immunoreactive cells in adenohypophysis of the common carp (*Cyprinus carpio*) from rivers contaminated with estrogenic chemicals. J Vet Med Sci 65:485-490.

Call Number: W 11217
Abstract: The adverse effect of estrogenic chemicals on luteinizing hormone-immunoreactive (LH-ir) cells in the adenohypophysis of common carp (Cyprinus carpio) was examined using immunocytochemical and morphometric methods. Adult male fish were collected from two contaminated sites (Ishizu and Wada Rivers) and from a control pond at Agriculture, Food and Environmental Sciences, Research Center of Osaka Prefecture. The concentration of nonylphenol, bisphenol A and 17 beta-estradiol in the Ishizu River was 3-4 times higher than that in the Wada River. The proportion and size of LH-ir cells were evaluated using the point-counting method by optical microscopy. In control carp, the proportion of LH-ir cells in the breeding season was significantly lower than in the pre- and post-breeding seasons. The same tendency was also found in Ishizu and Wada River carp, but without statistical significance. The proportion of LH-ir cells in Ishizu River carp was significantly lower than that of the control and the Wada River in all seasons. The LH-ir cells in control carp increased in size in the breeding season. LH-ir cells in Ishizu River carp were significantly ($p<0.05$) smaller than those in control fish, but not different from Wada River carp. A disturbance in the secretory function of LH-ir cells was found in carp from the Ishizu River; granulation and vacuolation were not in synchronization with those of control and Wada River fish. Our data suggest that the estrogenic chemicals in the Ishizu River interfere with functions of LH-ir cells directly or through the testis.

Haubruge E, Petit F, Gage MJG. 2000. Reduced sperm count in guppies (*Poecilia reticulata*) following exposure to low levels of tributyltin and bisphenol A. Proceedings of the Royal Society of London - Biological Sciences 267:2333-2337.
Call Number: W 09285
Abstract: There is increasing evidence that normal male reproductive function can be disrupted by exposure to pollutants in the environment that can exogenously mimic, antagonzie or block sex-hormone function. One possible consequence of exposure to these xenobiotics is disruption to spermatogenesis, but results thus far provide only indirect and incosistent evidence. In this study we exposed adult male guppies (Poeciliidae: Teleostei) to environmental relevant levels of the common xenobiotic tributyltin (11.2-22.3 ng/l) and bisphenol A (274-549 ug/l) in experimental aquaria. After 21 days of exposure, we found significant declines (by 40-75%) in total sperm counts for male fishes exposed to tributyltin and bisphenol A compared with controls. This short-term decline in sperm count is unlikely to be the result of endocrine-mediated alteration of the germ line, and we found no change in testis size or sperm lengths between treatments. However, Sertoli cells, which facilitate the transport of maturing sperm into the testicular deferent duct (where they are stored prior to ejaculation), are directly sensitive to xenobiotic action and it is therefore possiblle that spermatogenesis was inhibited through in vivo interference with normal Sertoli-cell function.

Hecker M, Tyler CR, Hoffmann M, Maddix S, Karbe L. 2002. Plasma biomarkers in fish provide evidence for endocrine modulation in the Elbe River, Germany. Environmental Science & Technology 36:2311-2321.
Call Number: W 10157
Abstract: Blood plasma samples were collected from wild bream (Abramis brama L.) in the Elbe River, Germany, and analyzed for the yolk protein precursor vitellogenin (VTG), a biomarker for estrogen exposure, and the sex steroids 11-ketotestosterone (11KT), testosterone (T), and 17beta- estradiol (E2) to investigate for evidence of endocrine modulation. In addition, the gonadal status and the prominence of spawning tubercles were investigated. Nine riverine sites were investigated on the Elbe that were influenced by different sources of endocrine-active substances. Bream were collected from a lake that received no domestic or industrial discharges as a control. Plasma VTG concentrations were significantly higher in male bream from the Czech border to the middle Elbe, with the highest concentrations in fish sampled at the locations near Magdeburg and downstream of Dresden (between 20 and 100 times higher than in the controls), regions that are characterized by high levels of effluent discharges into the river. Following the Elbe from this site to the sea, the concentrations of plasma VTG in males were lower than at Meissen but were still elevated above the controls. 11KT and E2 titers showed suppressions in their normal concentrations at some locations (those receiving the greatest industrial discharges). There were reciprocal relationships between inhibitory effects on gonadal growth, maturation, and plasma sex steroids and exposure to pollutants, such as organotins, pesticides, or metals. However, there was no single chemical that alone could explain the observed inhibitory effects on sexual development. The results indicate that the endocrine system in wild bream is disrupted in stretches of the Elbe River.

Hewitt M, Servos M. 2001. An overview of substances present in Canadian aquatic environments associated with endocrine disruption. Water Quality Research Journal of Canada 36:191-213.
Call Number: W 09303

Honkanen JO, Heinonen J, Kukkonen JV. 2001. Toxicokinetics of waterborne bisphenol A in landlocked salmon (*Salmo salar* m. *sebago*) eggs at various temperatures. Environmental Toxicology & Chemistry 20:2296-2302.
Call Number: W 09259
Abstract: Eye-pigmented eggs of landlocked salmon were exposed to waterborne [14C]-labeled bisphenol A at four temperatures (2, 6, 8, and 12 degrees C). Both in accumulation and depuration experiments, the eggs were exposed to a bisphenol A concentration of 1 microg/L for 196 h. In the depuration experiment, the exposed eggs were placed into clean water for 96 h. At each sampling time, the eggs were dissected into three parts (eggshell, embryo, and yolk sac), and all of these parts were weighed and analyzed separately in a liquid scintillation counter. The results show that waterborne bisphenol A accumulates in developing salmon eggs. Accumulation of bisphenol A showed a clear trend both in whole eggs and in dissected parts: the higher the temperature, the higher the uptake rate constant and the concentration of bisphenol A. Steady state was reached only in the embryos at the lowest temperature; in other cases, accumulation was linear. Depuration was significant only in the embryos at 2 and 6 degrees C. As the accumulation and the depuration results show, the elimination of bisphenol A was evidently more significant at lower temperatures.

Honkanen JO, Holopainen IJ, Kukkonen JVK. 2004. Bisphenol A induces yolk-sac oedema and other adverse effects in landlocked salmon (*Salmo salar* m. *sebago*) yolk-sac fry. Chemosphere 55:187-196.
Call Number: W 11130 PDF
Abstract: Accumulation and toxicity of waterborne bisphenol A were studied in landlocked salmon (Salmo salar m. sebago) yolk-sac fry. In a short-term (96 h) exposure to five bisphenol A concentrations yolk-sac fry had higher accumulation rates and bioconcentration factors (BCF96) than earlier studies have shown for salmon eggs. Furthermore, the conditional uptake rate constant tended to decrease as exposure concentration increased. Fry were also exposed to bisphenol A for 42 days at three concentrations (10, 100 and 1000 mug/l), and changes in behaviour, morphology and histological structure were observed. After 6 days of exposure, the highest concentration (1000 mug/1) of bisphenol A caused fluid accumulation (oedema) in the yolk sac and haemorrhages in the front part of the yolk sac and in the head around the gill arches. Later on, the fry at 1000 mug/l showed phlegmatic behaviour and had darker skin coloration than the fry in the other treatments. At the two highest concentrations (100 and 1000 mug/1) histological changes were seen in liver cell nuclei, where strongly stained fragments were observed. In the control fry and the fry exposed to 10 mug/l the nucleolus was clearly visible and spherical in shape and no strongly stained fragments were present. This study shows that high concentrations of bisphenol A may have both morphological and histological effects on salmon yolk-sac fry.

Hoshi H, Kamata Y, Uemura T. 2003. Effects of 17<beta>-estradiol, bisphenol A and tributyltin chloride on germ cells of *Caenorhabditis elegans*. J Vet Med Sci 65:881-885.
Call Number: W 11454 PDF
Abstract: Effects of a one-generation exposure to a natural estrogen, 17beta-estradiol (E2), and environmental pollutants such as bisphenol A (BPA) and tributyltin chloride (TBTCL) on the number of germ cells were investigated in the hermaphrodite Caenorhabditis elegans. The eggs of gravid adult worms isolated by alkaline hypochlorite treatment were seeded on a test chemical-containing NGM (nematode growth medium) agar plate without cholesterol. After incubation for 6 days at 16 degrees C, the germ cells of adult worms were stained with 4', 6-diamino-2-phenylindole dihydrochloride (DAPI). The staining procedure was completed within one hour and the stained germ cells were counted under a fluorescence microscope without dissection. The number of germ cells in the worms treated with E2 (10(-10)-10(-6) M) and BPA (10(-9)-10 (-5) M) was significantly increased. Maximal increases were observed at 10(-8) M E2 (156 +/- 15.3% of control) and 10(-5) M BPA (168 +/- 20.0 % of control). TBTCL (10(-9)-10(-6) M) significantly decreased the number of germ cells. The minimal decrease was observed at 10(-6) M TBTCL (30.2 +/- 3.51% of control). These results indicate that changes in the number of germ cells are a sensitive indicator of the effects of chemicals on the reproductive system. Since the method described in this paper is a novel, simple, time- and money-saving bioassay, C. elegans is an excellent model with which to

determine the reproductive toxicity of chemicals including environmental pollutants.

Ike M, Jin CS, Fugita M. 2000. Biodegradation of bisphenol A in the aquatic environment. Water Science & Technology 42(7-8):31-38.
Call Number: W 09349 PDF
Abstract: Biodegradation potential of bisphenol A (BPA) in the aquatic environments was investigated using 3 activated sludge and 4 river water microcosms. The biodegradation potential was exhibited by most of the tested microcosms, 3 activated sludge and 4 river water microcosms. However, only 6 river wter microcosms could completely mineralized BPA, and the others showed accumulation of common metabolites which were detected as 2 peaks according to a high pressure liquid chromatograph. In total 19 BPA degrading bacteria were isolated from activated sludge and river water samples, and their BPA degradation property was also investigated. Although all the BPA degrading bacteria could grown on BPA and remove about 70-80% of TOC derived from BPA, they accumulated 2 common metabolites, and they could not be removed by the prolonged cultivation up to more than 1 month. These 2 metabolites were detrified as 2,3-bis(4-hydroxyphenol)-1,2-propanediol and p-hydroxyphenacyl alcohol in the culture of a typical BPA degrading bacterium. The experimental results suggested that BPA-degrading bacteria ubiquitously exist in the aquatic environments, but that they cannot completely degrade BPA, leading to the accumulation of more recalcitrant metabolites. Fore complete BPA degradation the presence of microbes which can degrade the metabolites seems necessary together with BPA degrading bacteria.

Jobling S, Casey D, Rodgers-Gray T, Oehlmann J, Schulte-Oehlmann U, Pawlowski S, Baunbeck T, Turner AP, Tyler CR. 2003. Comparative responses of molluscs and fish to environmental estrogens and an estrogenic effluent. Aquatic Toxicology 65:205-220.
Call Number: W 11252 PDF
Abstract: It is now well established that there is a diverse array of chemicals discharged into the environment that can mimic or antagonise the action of hormones. These endocrine-disrupting chemicals (EDCs) can thus interact with physiological systems and cause alterations in development, growth and reproduction in wildlife that are exposed to them. As yet, however, there is little information on the relative sensitivities of different wildlife groups to these chemicals and/or mixtures of them (e.g. estrogenic effluents) and hence, there are fundamental shortfalls in our knowledge of the ecological importance of endocrine disruption in wildlife. In this study, the effects of exposure to individual estrogenic chemicals (17alpha-ethinylestradiol; EE2, bisphenol-A, and 4-tert octylphenol) and a mixture containing these chemicals (treated sewage effluent) on embryo production in the prosobranch mollusc, Potamopyrgus antipodarum, were studied and compared with the effects of EE2 and the same estrogenic effluent on vitellogenin induction and/or egg production in various species of freshwater fish (fathead minnow; Pimaphales promelas, rainbow trout (Oncorhynchus mykiss); Cyprinus carpio, carp; Cyprinus carpio). The lab-based studies demonstrated that all of the tested chemicals (known to be estrogenic and to cause reproductive effects in fish) also affected embryo production in P. antipodarum. Furthermore, exposure to EE2 induced similar reproductive responses in the snails as in the fathead minnow (Pimephales promelas), stimulating egg/embryo production at low doses (up to 1 ng/l in the minnow and 25 ng/l in the snail) and causing inhibitory effects at higher doses. A similar pattern of embryo production occurred in P. antipodarum when it was exposed to a graded concentration of treated sewage effluent containing mixtures of estrogenic EDCs and hence, the total number of new embryos produced by the snails increased steadily over the 9 weeks exposure period in treated snails. Plasma vitellogenin concentrations in two species of male fish (the rainbow trout and the carp) also increased over the same time period. These data indicate that both the nature of the response and the relative sensitivities to environmental estrogens in P. antipodarum and three different fish species fish are comparable. P. antipodarum is thus, potentially a sensitive test organism for assessing estrogenicity of chemicals with a relevance to their activity in vertebrates.

Kang IJ, Yokota H, Oshima Y, Tsuruda Y, Oe T, Imada N, Tadokoro H, Honjo T. 2002. Effects of bisphenol A on the reproduction of Japanese medaka (*Oryzias latipes*). Environmental Toxicology & Chemistry 21:2394-2400.
Call Number: W 10349
Abstract: We elucidated the effects of bisphenol A (BPA) on the reproductive capacity (fecundity and fertility) and estrogenic response of adult Japanese medaka (*Oryzias latipes*) and studied the transgenerational effects (F1 generation growth and sex) of this agent on the F1 offspring. Eight mating

pairs of medaka were exposed to BPA for three weeks at a measured concentration of 837, 1,720, or 3,120 ug/L. Throughout the exposure period, we observed no reduction of fecundity and fertility in any treatment group and no reduction in survival and growth or any imbalance of the sex ratio of the offspring. However, histologic examinations revealed testis-ova in 13% of the males in the 837 ug/L treatment group, 86% of those in the 1,720 ug/L group, and 50% of those that received 3,120 ug BPA/L. In addition, concentrations of hepatic vitellogenin were increased significantly in the males treated with BPA at 3,120 ug/L (p = 0.0148). These results suggest that BPA is a weakly estrogenic compound that has the potential to alter sexual development and induce vitellogenin in male medaka but that has no adverse effect on reproductive success.

Kashiwada S, Ishikawa H, Miyamoto N, Ohnishi Y, Magara Y. 2002. Fish test for endocrine-disruption and estimation of water quality of Japanese rivers. Water Research 36: 2161-2166.
Call Number: W 11253 PDF
Abstract: The LC50 values (72 h) of 17beta-estradiol (E2), p-nonylphenol (NP) and bis-phenol-A (BPA) to adult male and female medaka were 3.5 and 3.5, 0.85 and 0.87, and 6.8 and 8.3 mg L-1, respectively the LC50 values to embryos were 0.46, 0.13 and 5.1 mg L-1, respectively. The IC50 values for inhibition to egg hatching were 0.47, 0.85 and 9.0 mg L-1, respectively. These values were much higher than concentrations detected in river water in Japan and the chemicals were considered to have no lethal effect on the fish in an aquatic environment. Mature male medaka was continuously exposed to 0.005, 0.05 or 1.0 mug L-1 of E2, or to 0.1, 10 or 100 mug L-1 of NP or BPA. Female specific proteins (FSP) were induced in the blood of male medaka that were exposed for 5 weeks to E2 higher than 0.005 mug L-1 NP higher than 0.1 mug L-1, or BPA higher than 10 mug L-1. Based on these ESP inducible concentrations and reported concentrations of E2, NP and BPA in Japanese river water, some river water contaminated by E2 or NP could be estimated as the ESP inducible in male medaka.

Kinnberg K, Toft G. 2003. Effects of estrogenic and antiandrogenic compounds on the testis structure of the adult guppy (*Poecilia reticulata*). Ecotoxicology & Environmental Safety 54:16-24.
Call Number: W 10717
Abstract: Sexually mature male guppies (Poecilia reticulata) were exposed to 17beta-estradiol, 4-tert-octylphenol, bisphenol A, flutamide, p,p'-DDE, or vinclozolin to determine the effects of these estrogenic or antiandrogenic substances on the testis structure. Flutamide, p,p'-DDE, 4-tert-octylphenol, and bisphenol A exposure caused similar effects. These included a reduced number of spermatogenetic cysts and an increased number of spermatozeugmata in the ducts. These effects are indicative of a blocked spermatogonial mitosis. 17beta-Estradiol produced effects different from those of the other compounds studied. The effects were seen as an increased number of hypertrophied Sertoli cells/efferent duct cells. The mammalian antiandrogen vinclozolin had no observable effects on the testis structure when given in doses of 1, 10, or 100 microg/mg food.

Klečka GM, Gonsior SJ, West RJ, Goodwin PA , Markham DA. 2001. Biodegradation of bisphenol A in aquatic environments: River die-away. Environmental Toxicology & Chemistry 20:2725-2735.
Call Number: W 09319
Abstract: The biodegradability of bisphenol A (BPA) was assessed in surface waters from seven different rivers across the United States and Europe. Rapid biodegradation of BPA was observed in all rivers following lag phases ranging from 2 to 4 d. Biodegradation half-lives for BPA were typically less than 2 d following the lag phase. Mineralization of BPA was observed in all river waters, with average carbon dioxide yields of approximately 76% of the theoretical maximum (range 59-103%) at the end of the incubation period (< 18d). Short half-lives (0.5 to 3 d) were noted for BPA degradation in river waters regardless of geographic location, sampling site (i.e. upstream vs. downstream of wastewater outfalls), sediment addition (< 0.05%), and initial test chemicals concentration (50-5,500 ug/L). Subsequent studies conducted at environmentally relevant concentrations (0.05 and 0.5 ug/L) also indicated short half-lives (3-6 d) for BPA and support the extrapolation of the half-lives measured in this study over a wide range of environmental concentrations. The fact that BPA was degraded rapidly in surface waters taken from diverse locations in the United States and Europe as well as in studies recently conducted in Japan suggests that BPA degrading microorganisms are widely distributed in nature. These observations provide clear evidence that BPA is not peristent in the aquatic environment.

Kloas W, Lutz I, Einspanier R. 1999. Amphibians as a model to study endocrine disruptors: II. Estrogenic activity of environmental chemicals *in vitro* and *in vivo*. Sci Total Environ 225:59-68.
Call Number: W 06441
Abstract: Several environmental chemicals are known to have estrogenic activity by interacting with development and functions of endocrine systems in nearly all classes of vertebrates. In order to get a better insight of potential estrogenic effects on amphibians caused by environmental pollution this study aims to develop a model for investigating endocrine disrupters using the amphibian Xenopus laevis. Tn that model the potential estrogenic activity of endocrine disrupters is determined at several levels of investigation: (I) binding to liver estrogen receptor; (II) estrogenicity in vitro by inducing vitellogenin synthesis in primary cultured hepatocytes; and (III) in vivo effects on sexual development. Here we deal with establishing methods to assay estrogenic activity of environmental chemicals in vitro and in vivo. In vitro we used a semiquantitative reverse transcriptase-polymerase chain reaction (RT-PCR) technique to determine mRNA-induction of the estrogenic biomarker vitellogenin in primary cultured hepatocytes of male Xenopus laevis. Time courses of vitellogenin-mRNA in the presence and absence of 10(-6) M 17 beta-estradiol (E2) resulted in a marked loss of mRNA from controls after 2 days while E2 treatment kept vitellogenin-mRNA at a relatively stable level. After 36 h of incubation estrogenic activities of E2, Lt-nonylphenol (NP), and 2,2-bis-(4-hydroxyphenyl)-propan (bisphenol A) at concentrations ranging from 10(-10) to 10(-5) M were assayed by RT-PCR of vitellogenin-mRNA and showed the following ranking of dose-dependent potency: E2 > NP > bisphenol A. These in vitro results were confirmed further by in vivo experiments determining sexual differentiation of Xenopus laevis after exposure to E2 and environmental chemicals during larval development. Concentrations of 10(-7) and 10(-8) M E2 as well as 10-7 M of NP or bisphenol A caused a significant higher number of female phenotypes compared to controls indicating a similar ranking of estrogenic potencies in vivo as in vitro. In addition, butylhydroxyanisol and octylphenol, both showed feminization at 10(-7) M while octylphenol was also effective at 10-8 M. In summary these results demonstrate for the first time the use of a semiquantitative RT-PCR technique for screening estrogenicity by assaying mRNA induction of the estrogenic biomarker vitellogenin in vitro. The combination of this newly developed method with classical exposure experiments is necessary for determination of the biological significance of estrogenic chemicals.

Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, Buxton HT. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. Environmental Science & Technology 36:1202-1211.
Call Number: W 09690 PDF
Abstract: To provide the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in water resources, the U.S. Geological Survey used five newly developed analytical methods to measure concentrations of 95 OWCs in water samples from a network of 139 streams across 30 states during 1999 and 2000. The selection of sampling sites was biased toward streams susceptible to contamination (i.e. downstream of intense urbanization and livestock production). OWCs were prevalent during this study, being found in 80% of the streams sampled. The compounds detected represent a wide range of residential, industrial, and agricultural origins and uses with 82 of the 95 OWCs being found during this study. The most frequently detected compounds were coprostanol (fecal steroid), cholesterol (plant and animal steroid), N, N-diethyltoluamide (insect repellant), caffeine (stimulant), triclosan (antimicrobial disinfectant), tri(2-chloroethyl)phosphate (fire retardant), and 4-nonylphenol (nonionic detergent metabolite). Measured concentrations for this study were generally low and rarely exceeded drinking-water guidelines, drinking-water health advisories, or aquatic-life criteria. Many compounds, however, do not have such guidelines established. The detection of multiple OWCs was common for this study, with a median of seven and as many as 38 OWCs being found in a given water sample. Little is known about the potential interactive effects (such as synergistic or antagonistic toxicity) that may occur from complex mixtures of OWCs in the environment. In addition, results of this study demonstrate the importance of obtaining data on metabolites to fully understand not only the fate and transport of OWCs in the hydrologic system but also their ultimate overall effect on human health and the environment.

Koponen PS, Kukkonen JV. 2002. Effects of bisphenol A and artificial UVB radiation on the early development of *Rana temporaria*. Journal of Toxicology & Environmental Health. Part A 65:947-959.
Call Number: W 10167

Abstract: Ultraviolet-B (UVB) radiation is one environmental factor that may act in concert with other stressors, such as xenobiotics, to produce adverse effect on amphibian populations. Embryos (< 24 h old) of the common frog (Rana temporaria) were exposed to four concentrations (0, 10, 100, or 1000 microg/L) of bisphenol A (BPA), with and without ultraviolet-B (UVB) radiation, for 20 d in the laboratory. Throughout the experiment the biologically effective daily UVB dose, calculated with Setlow's DNA action spectrum, was 2.80 kJ m(-2). UVB radiation as such did not have any significant effect on frog embryos. However, a BPA treatment of 1000 microg/L had a significant effect on embryos in both the UVB and no-UVB treatments, with the effect being greater with UVB. UVB produced a significant decrease in survival in the newly hatched frog larvae at all BPA concentrations. These results demonstrate that simultaneous exposure to these two stress factors is more harmful to R. temporaria larvae than exposure to one stressor alone.

Kuch HM, Ballschmiter K. 2001. Determination of endocrine-disrupting phenolic compounds and estrogens in surface and drinking water by HRGC-(NCI)-MS in the picogram per liter range. Environmental Science & Technology 35:3201-3206.
Call Number: W 09001
Abstract: A method for the analysis of phenolic estrogenic active compounds in surface and drinking water in the picogram per liter range is described. Besides the widely used monomer bisphenol A, 4-tert-octylphenol [4-(1,1,3,3-tetramethylbutyl)phenol] and the technical isomer mixture of 4-nonylphenol; phenolic steroid hormones such as the endogenous estrogens estrone, 17alpha-estradiol, and 17beta-estradiol; and the exogenous estrogen 17alpha-ethinylestradiol were determined in water at the 20-200 pg/L level. Water samples from 1 to 5 L were extracted by solid-phase extraction (SPE) on a cartridge system containing LiChrolut EN as sorbent. The phenols and steroids were converted into their pentafluorobenzoylate esters in an extractive derivatization reaction. The derivatives were then determined by high- resolution gas chromatography with negative chemical ionization mass spectrometric detection (HRGC-(NCI)-MS) in the selected ion mode (SIM). All results were also confirmed by HRGC with electron capture detection (ECD). This highly sensitive and specific method gives a limit of detection (LOD) of 20 pg/L for bisphenol A and 4-tert-octylphenol in drinking water samples and 50 pg/L in STW effluent, respectively. The LODs for technical 4-nonylphenol, 17alpha-ethinylestradiol, and other estrogens are in the range of 50 pg/L in drinking water to 200 pg/L in STW effluent, respectively. In all river water samples in southern Germany, bisphenol A was found in concentrations ranging from 500 pg/L up to 16 ng/L, 4-nonylphenol was from 6 up to 135 ng/L, and the steroids were from 200 pg/L up to 5 ng/L. In drinking water, bisphenol A was found in concentrations ranging from 300 pg/L to 2 ng/L, 4- nonylphenol was from 2 to 15 ng/L, 4-tert-octylphenol was from 150 pg/L to 5 ng/L, and the steroids were from 100 pg/L to 2 ng/L. Mean recoveries over the whole analytical protocol, measured in bidistilled water, generally exceeded 70%. These results indicate that environmental endocrine-disrupting estrogens are not completely removed in the process of sewage treatment but are carried over into the general aquatic environment. After ground passage, they can eventually be found in drinking water.

Kwak HI, Bae MO, Lee MH, Lee YS, Lee BJ, Kang KS, Chae CH, Sung HJ, Shin JS, Kim JH, Mar WC, Sheen YY, Cho MH. 2001. Effects of nonylphenol, bisphenol A, and their mixture on the viviparous swordtail fish (*Xiphophorus helleri*). Environmental Toxicology & Chemistry 20:787-795.
Call Number: W 08847 PDF
Abstract: A number of fish species have been used for studies on endocrine disrupting chemicals (EDCs). However, despite the widespread use of oviparous fish, relatively little attention has been given to viviparous species. This study investigated the effects of EDCs in a viviparous fish and examined the possible usefulness of the fish as an alternative model for the studies on EDCs. Swordtails (Xiphophorus helleri) were exposed to nonylphenol (NP), bisphenol A (BPA), and their mixture. Both short-term (3-d) and relatively long-term (60-d) exposures were carried out using adult male and 30-d-old juvenile fish, respectively. Following the short-term exposure, both NP and BPA caused vitellogenin mRNA expression. Flow cytometric analysis and terminal deoxynucleotidyl transferase assay on the testes of treated fish indicated reproductive damage. Histopathological analysis found degenerative and necrotic cells in seminiferous tubules following the exposure to 100 ppb NP. The testes with lesions were also associated with highly suppressed spermatogenesis. Following the long-term exposure, both NP and BPA exposures significantly affected the growth of swordtails. In all cases, the results showed that the mixture was always more potent than a single chemical and that swordtail fish can be a useful model for the study of endocrine disruptors.

Körner W, Bolz U, Süßmuth W, Hiller G, Schuller W, Hanf V, Hagenmaier H. 2000. Input/output balance of estrogenic active compounds in a major municipal sewage plant in Germany. Chemosphere 40:1131-1142.
Call Number: W 07376
Abstract: 24 h samples of untreated and treated wastewater were taken in parallel from a modern municipal sewage plant in southern Germany in March and June 1998. After solid phase extraction, total estrogenic activity was quantitatively measured with a miniaturized E-screen assay and the levels of nine estrogenic phenolic chemicals analyzed by HRGC/LRMS. 17ß-estradiol equivalent concentrations (EEQ) were 58 and 70 ng/L in the influent and 6 ng/L in the effluent, indicating that the load of estrogenic activity of the wastewater was reduced by about 90% in the sewage plant. Less than 3% of the estrogenic activity was found in the sludge. 4-t-octylphenol, 4-nonylphenol, bisphenol A, 2-hydroxybiphenyl, and 4-chloro-3-methylphenol were detected in the untreated wastewater at levels form 0.13 to 3.6 µg/L. 4-t-octylphenol, 4-nonylphenol, and bisphenol A were present in the effluent at concentrations from 0.16 to 0.36 µg/L, 2-hydroxylbiphenyl and 4-chloro-3-methylphenol were not detectable. The contribution of the quantified levels of phenolic xenoestrogens to total estrogenic activity in the sewage was 0.7 to 4.3%.

Körner W, Spengler P, Bolz U, Schuller W, Hanf V, Metzger JW. 2001. Substances with estrogenic activity in effluents of sewage treatment plants in southwestern Germany. 2. Biological analysis. Environmental Toxicology & Chemistry 20:2142-2151.
Call Number: W 09237
Abstract: The proliferation test with human estrogen receptor-positive MCF-7 breast cancer cells (E-Screen assay) was applied for quantitative determination of total estrogenic activity in 24-h composite effluent samples from 16 municipal and two industrial sewage treatment plants (STPs) in the state of Baden-Wurttemberg, southwestern Germany. The estrogenic efficacy relative to the positive control, 17beta-estradiol, was between 26 and 74% (median, 48%) for the 16 municipal STPs. Estradiol equivalent concentrations (EEQs) were between 0.2 and 7.8 ng/L (median, 1.6 ng/L) and, thereby, were lower than those found in a pilot study, which revealed EEQs of greater than 10 ng/L in the effluents of two other STPs. The EEQs in 14 of the 16 effluent samples were very similar (0.9-3.3 ng/L), indicating a rather constant input of estrogenic substances via STPs into rivers. Additional activated charcoal filtration turned out to be very efficient in further eliminating estrogenic activity from effluents. The EEQs of the E- Screen assay and those calculated from the results of extensive chemical analysis using the estradiol equivalency factors determined for 13 natural and synthetic estrogenic substances were comparable for most of the effluent samples. 17beta-Estradiol, 17alpha- ethinylestradiol, and, to a lesser extent, estrone contributed to 90% or more of the EEQ value.

Larsson DGJ, Adolfsson-Erici M, Parkkonen J, Pettersson M, Berg AH, Olsson PE, Forlin L. 1999. Ethinyloestradiol - An undesired fish contraceptive? Aquatic Toxicology 45: 91-97.
Call Number: W 06646
Abstract: Environmental oestrogens are natural or synthetic substances present in the environment, which imitate the effects of endogenous oestrogen. Oestrogenic substances were identified by gas chromatography/mass spectrometry in effluent water from a Swedish sewage treatment works receiving mainly domestic wastewater. Substances found include the synthetic oestrogen used in contraceptives 17 alpha-ethinyloestradiol (4.5 ng l(-1)), the natural oestrogens oestrone (5.8 ng l(-1)) and 17 beta-oestradiol (1.1 ng l(-1)), and the weaker non-steroidal oestrogens 4-nonylphenol (840 ng l(-1)) and bisphenol A (490 ng l(-1)). Ethinyloestradiol exceeded levels shown to be oestrogenic to fish by 45 times. The oestrogenicity of the effluent water was investigated by introducing juvenile rainbow trout (Oncorhynchus mykiss) in cages downstream of the sewage treatment works. After 2 weeks, all oestrogens indicated were present in the bile of the fish, and the oestrogen inducible protein, vitellogenin, was found in large amounts in the plasma (1.5 mg ml(-1)), as determined by enzyme-linked immunosorbent assay and Western blotting. Thus, a widely used synthetic oestrogen affects the endocrine systems of fish exposed to sewage effluent water.

Lee HB, Peart TE. 2002. Organic contaminants in Canadian municipal sewage sludge. Part I. Toxic or endocrine-disrupting phenolic compounds. Water Quality Research Journal of Canada 37:681-696.
Call Number: W 11219
Abstract: The occurrence of toxic or endocrine-disrupting chemicals such as nonylphenol ethoxylates (NPEO), 4-nonylphenol (NP), 4-tert-octylphenol (OP), bisphenol A (BPA), triclosan (TCS), pentachlorophenol (PCP), hexachlorophene (HCP), and tetrabromobisphenol A (TBBPA) in 35 sewage

sludge samples collected from cities across Canada is documented. Samples were extracted by supercritical carbon dioxide and the phenols were converted into their acetyl derivatives using published methods. The ethoxylates were analyzed by HPLC with a fluorescence detector. The other extracts, after silica gel column cleanup, were analyzed by GUMS in either the electron impact or negative-ion chemical ionization mode. With minor exceptions, the above-mentioned compounds were present in all samples. The levels of these contaminants varied widely in the samples. The more abundant chemicals were NP as well as its mono- and di-ethoxylates, with median concentrations of 232, 69.4, and 26.4 mug/g (dry weight), respectively. Triclosan, a common antibacterial agent, BPA, and HCP were also ubiquitous in the sludge samples, with median concentrations of 12.5, 0.45, and 0.37 mug/g, respectively. Also present, albeit at much lower concentrations, were PCP and TBBPA, with median concentrations of 27.7 and 12.4 ng/g, respectively. Except for the last two compounds, all the chemicals are components or additives in various formulations of household and industrial detergents and personal care products. The potential risk of these toxic chemicals reaching the aquatic environment as a result of land spreading of sewage sludge should be investigated.

Lee HB, Peart TE, Chan J, Gris G. 2004. Occurrence of endocrine-disrupting chemicals in sewage and sludge samples in Toronto, Canada. Water Quality Research Journal of Canada 39:57-63.
Call Number: W 11132 PDF
Abstract: In recent years, many anthropogenic chemicals occurring in the environment have been shown to mimic the action of endogenous hormones. These endocrine-disrupting chemicals (EDCs) can potentially lead to a host of adverse effects on wildlife, such, as the feminization of fish, the lack of reproductive success of some species, birth defects, and the development of physical abnormality. In an attempt to establish the levels of contamination by EDCs in municipal sewage and sludge, we have collected samples in the Toronto area and analyzed them for alkylphenols, alkylphenol ethoxylates and carboxylates, 17beta-estradiol and its metabolites, testosterone, bisphenol A, as well as butyltin species. Previously developed methods using solvent extraction, solid-phase extraction, supercritical fluid extraction, GUMS, and HPLC determination have been used for such samples. Levels of these chemicals varied from <1 ng/L for 17beta-estradiol in the effluent to nearly 900 mug/L for nonylphenol ethoxylates in the influent. Levels of EDCs in sludge also varied widely from >500 mug/g for nonylphenol to <0.1 mug/g for bisphenol A. The screening of many of the above EDCs has become an integral part of an on-going wastewater quality monitoring program in Toronto.

Levy G, Lutz I, Krüger A, Kloas W. 2004. Bisphenol A induces feminization in *Xenopus laevis* tadpoles. Environ Res 94:102-111.
Call Number: W 11194
Abstract: To evaluate possible estrogenic effects of bisphenol A (BPA) in an amphibian model, *Xenopus laevis* tadpoles were exposed to BPA and 17β-estradiol (E2) during larval development. After metamorphosis, the gonadal phenotype was determined by gross morphology, and testes were further examined histologically to validate the results. BPA treatment altered the normal sex ratio towards females depending on the BPA concentrations added. Chemical analysis showed a time-dependent decline of BPA during semistatic exposure, indicating that BPA is taken up and metabolized to some extent by tadpoles. In addition, tadpoles were exposed to BPA and E2 for 2 weeks during sensitive stages of sexual differentiation. Afterward, the expression of an estrogenic biomarker, estrogen receptor (ER), mRNA, was assessed by semiquantitative RT-PCR. Both BPA and E2 up-regulated ER mRNA significantly. In conclusion, these results show clear evidence that BPA induces feminization in *X. laevis* tadpoles, revealing an estrogenic potency of BPA that influences sexual development in amphibians.

Lindholst C, Pedersen KL, Pedersen SN. 2000. Estrogenic response of bisphenol A in rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology 48:87-94.
Call Number: W 07872
Abstract: Bisphenol A (BPA) previously shows to possess xenoestrogenic activities was administered to rainbow trout (Oncorhynchus mykiss) through a continuous flow system. The estrogenic response expressed as the induction of vitellogenin (VTG) synthesis was measured during 12 days of exposure, using a direct sandwich ELISA. Quantification of internal liver and muscle concentrations of non-metabolised BPA was performed by LC-MS at the end of the exposure period. A significant induction of the VTG synthesis was obtained at 500 mu g BPA/l exposure, although an increase in the ratio of

responding animals was observed already between 40 and 70 mu g BPA/l. An increase in VTG levels was observed for the 500 mu g BPA/l group over the study period, whereas constant or decreasing levels could be detected in the low exposure groups between days 6 and 12. Average internal liver concentrations of BPA increased from 0.22 to 4.36 mu g/g for the 10-500 mu g BPA/l groups. However, BPA could not be detected in muscle tissue below an exposure level of 70 mu g BPA/l. A dose response relationship was established between the interval liver concentrations of BPA and the corresponding VTG responses, with a $P < 0.001$ and a correlation coefficient of 0.66.

Lindholst C, Pedersen SN, Bjerregaard P. 2001. Uptake, metabolism and excretion of bisphenol A in the rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology 55:75-84.
Call Number: W 09757
Abstract: The uptake, metabolism and excretion of the oestrogenic chemical bisphenol A (BPA) were studied in juvenile rainbow trout (Oncorhynchus mykiss). BPA was detectable in plasma, liver and muscle after 2 h of water exposure at 0.44 microM (100 microg BPA/l), and a steady state was reached within 12-24 h. The concentration of the glucuronidated degradation product in the plasma was about twice that of the parent compound. A plasma half life of BPA was calculated as 3.75 h following injection of the compound. The vitellogenin synthesis was measured in response to the BPA treatment, and a lag period of 5 and 7 days between injection of the compound and a significant vitellogenin response was observed for females and males, respectively. At the time of the vitellogenin response no BPA could be detected in the liver tissue from either male or female fish. These results indicate that fish briefly exposed to elevated levels of oestrogenic chemicals might develop a response several days later.

Lindholst C, Wynne PM, Marriott P, Pedersen SN, Bjerregaard P. 2003. Metabolism of bisphenol A in zebrafish (*Danio rerio*) and rainbow trout (*Oncorhynchus mykiss*) in relation to estrogenic response. Comparative Biochemistry & Physiology, C: Toxicology & Pharmacology 135:169-177.
Call Number: W 11435 PDF
Abstract: The kinetics of bisphenol A (BPA) were investigated in zebrafish (Danio rerio) exposed to 100 microg BPA/l. BPA uptake was measured during a 7-day period followed by an elimination phase of similar duration. After 2, 6, 12, 24, 48, 72, 120 and 168 h of uptake/elimination, fish were analysed for their content of BPA, bisphenol A glucuronic acid (BPAGA) and bisphenol A sulfate (BPAS). Within the first 24 h steady state levels of BPA, BPAGA and BPAS were reached and the total body concentrations were calculated to be 569, 12,600 and 39.9 ng/g fish, respectively. Elimination rates of the three compounds in zebrafish were estimated by fitting the data to a compartment model. An initial rapid elimination phase was observed for BPA and BPAS with total body half lives (T(1/2)) of <1.1 h and 30 min, followed by a slower second elimination phase with T(1/2) values of 139 and 71 h, respectively. Excretion of BPAGA occurred from a single compartment with a T(1/2) of 35 h. The steady state concentration of BPA and its metabolites were investigated in rainbow trout (Oncorhynchus mykiss) exposed to 100 microg BPA/l. The toxicokinetic parameters from zebrafish and rainbow trout were compared; including previously published data on the rainbow trout. The data indicate that the smaller estrogenic sensitivity observed for the zebrafish may be caused by a more rapid metabolism of BPA in the zebrafish liver.

Lutz I, Kloas W. 1999. Amphibians as a model to study endocrine disruptors: I. Environmental pollution and estrogen receptor binding. Sci Total Environ 225:49-57.
Call Number: W 06444
Abstract: Many chemicals released into the environment without toxicological risks have the capacities to disrupt the function of endocrine systems. These endocrine disrupters disturb normal endocrine mechanisms and have been observed in nearly all classes of vertebrates. The aim of this research is to develop a comprehensive model to study endocrine disruption using the amphibian Xenopus laevis. The assessment of estrogenic potencies of endocrine disrupters includes several levels of investigation: (I) binding to liver estrogen receptor, (II) estrogenic activity in vitro by inducing vitellogenin synthesis in primary cultured hepatocytes, and (III) in vivo effects on sexual development caused by exposure of larvae. The present paper is focused on the first part by establishing a radioreceptorassay for [H-3]17 beta-estradiol ([H-3]E2) binding using liver cytosol fraction. In order to get optimum binding conditions we performed kinetic, saturation, and competitive displacement experiments. Association of [H-3]E2 to estrogen receptor revealed that maximum specific binding is achieved between 18 and 48 h of incubation. Scatchard analyses of saturation experiments resulted in a homogenous saturable population of estrogen receptors having no

significant differences of binding parameters between both sexes. The values of K-d (dissociation constant) in males and females were 22.4 +/- 6.0 and 15.0 +/- 2.8 nM (mean +/- S.E.M.; n = 5), respectively, while corresponding B-max (maximum binding capacity) revealed 89 +/- 46 and 136 +/- 46 fmol [H-3]E2/mg protein. The specificity of estrogen receptors as shown by competitive displacement experiments demonstrated receptors being highly specific just for estrogens, but not for other endogenous steroids having the following ranking of binding affinities: E2 > estrone > dehydroepiandrosterone > aldosterone greater than or equal to testosterone greater than or equal to corticosterone greater than or equal to. progesterone. The affinity ranking of environmental chemicals compared to E2 was: E2 > tetrachlorbiphenyl > diethylphthalate > 2,2-bis-(4-hydroxyphenyl)-propan (bisphenol A)greater than or equal to 4-nonylphenol greater than or equal to 3-t-butyl-4-hydroxyanisale greater than or equal to 4-octylphenol > dichlor-diphenyl-trichlor-ethan (4,4'-DDT). Analyses of five sewage effluents for displacement of [H-3]E2 binding resulted in three samples displacing more than 50% of specific binding at their original concentration. Taken together the established radioreceptorassay for [H-3]E2 binding in Xenopus laevis liver cytosol is useful to screen estrogen receptor binding of pure compounds or complex mixtures of them, which is the prerequisite for causing either estrogenic or antiestrogenic effects.

Maczka C, Pang S, Policansky D, Wedge R. 2000. Evaluating impacts of hormonally active agents in the environment. Environmental Science & Technology 34:136A-141A.
Call Number: W 07465
Abstract: A report last year by the National Research Council (NRC) finds that there is large uncertainty about risks from exposures to hormonally active agents (HAAs)- more popularly known as endocrine disrupters. The NRC Committee on HAAs in the Environment concluded, after examining existing scientific knowledge concerning HAA exposures, that further information is needed to understand the potential for harm to developing organisms. The report stresses that although evidence shows that harmful ecological and health effects can result from exposure to certain chemicals, it remains unclear whether their hormonal properties cause the observed effects, or instead, some other toxicological mechanism is operative.

Markey CM, Rubin BS, Soto AM, Sonnenschein C. 2003. Endocrine disruptors: from Wingspread to environmental developmental biology [review]. Journal of Steroid Biochemistry & Molecular Biology 83:235-244.
Call Number: W 10789 PDF
Abstract: The production and release of synthetic chemicals into the environment has been a hallmark of the "Second Industrial Revolution" and the "Green Revolution." Soon after the inception of these chemicals, anecdotal evidence began to emerge linking environmental contamination of rivers and lakes with a variety of developmental and reproductive abnormalities in wildlife species. The accumulation of evidence suggesting that these synthetic chemicals were detrimental to wildlife, and potentially humans, as a result of their hormonal activity, led to the proposal of the endocrine disruptor hypothesis at the 1991 Wingspread Conference. Since that time, experimental and epidemiological data have shown that exposure of the developing fetus or neonate to environmentally-relevant concentrations of certain synthetic chemicals causes morphological, biochemical, physiological and behavioral anomalies in both vertebrate and invertebrate species. The ubiquitous use, and subsequent human exposure, of one particular chemical, the estrogen mimic bisphenol A (BPA), is the subject of this present review. We have highlighted this chemical since it provides an arresting model of how chemical exposure impacts developmental processes involved in the morphogenesis of tissues and organs, including those of the male and female reproductive systems, the mammary glands and the brain.

Markham DA, McNett DA, Birk JH, Klečka GM, Bartels MJ, Staples CA. 1998. Quantitative determination of bisphenol-A in river water by cool-on-column injection gas chromatography mass spectrometry. Int J Environ Anal Chem 69:83-98.
Call Number: W 06192
Abstract: A sensitive and selective method is described for the simultaneous quantitation and confirmation of bisphenol-A (BPA) in river water to support a surface water analysis study. The method employs a cool-on-column injection, gas chromatographic separation and detection by electron impact mass spectrometry (COC-GC-MS). River water samples (40 mt) were fortified with a stable isotope internal standard, deuterium labeled analog of BPA (Ds-BPA). The sample was then extracted with toluene and the extract was concentrated (400X) prior to analysis by COC-GC-MS. The analysis involves detection of the M+ ion

and the [M-CH3](+) ion (base peak) with quantitation based on the [M-CH3](+) ion response. The quantitation limit, with confirmation, for BPA for this method was determined to be 1 mu g BPA/L of river water. Confirmation of BPA was determined by monitoring the ratio of the M+ ion to the [M-CH3](+) ion. Calibration curves for standard concentrations of 1 mu g/L to 20 mu g/L resulted in correlation coefficients (r(2)) of 0.9981 to 0.9999. The extraction/concentration efficiency for this method was determined to be 81.5%. Relative recoveries of BPA from river water ranged from 84% to 113% with an overall average of 102% +/- 7% (1 to 20 mu g/L). This method was developed to support a surface water analysis study to determine the level of BPA in surface water at five sites which use BPA in a manufacturing process and was sponsored by the Bisphenol-A Task Group of The Society of the Plastics Industry, Inc.

Metcalfe CD, Metcalfe TL, Kiparissis Y, Koenig BG, Khan C, Hughes RJ, Croley TR, March RE ; Potter T. 2001. Estrogenic potency of chemicals detected in sewage treatment plant effluents as determined by *in vivo* assays with Japanese medaka (*Oryzias latipes*). Environmental Toxicology & Chemistry 20:297-308.
Call Number: W 08648
Abstract: Gonadal intersex and high prevalences of the female phenotype have been observed in fish populations in urbanized areas. Environmental estrogens discharged in sewage treatment plant effluents may be responsible for feminization of fish but many compounds with the potential to induce these responses occur in effluents, including natural and synthetic estrogen hormones, degradation products of alkylphenol ethoxylate surfactants, and plasticizers. In this study, the estrogen hormones 17 alpha - ethinylestradiol, 17 beta -estradiol, estrone, and estriol induced intersex (i.e., testis-ova) and altered sex in Japanese medaka (Oryzias latipes) when these fish were exposed to nanogram per liter concentrations of test compounds from hatch to approximately 100 d after hatch. A mix of nonylphenol mono- and diethoxylate induced a weak response and a mix of nonylphenol mono- and diethoxycarboxylate did not give a response in this assay at microgram per liter concentrations, indicating that these degradation products of nonylphenol ethoxylates have little or no estrogenic activity in fish. Bisphenol A induced testis-ova in medaka exposed to a concentration of 10 mug/L, but diethylhexyl phthalate did not induce a response. Results with the medaka assay were consistent with estrogenic responses in the yeast estrogen screening assay. Analyses of monitoring data reported in the literature indicate that concentrations of estrogen hormones detected in the final effluents of sewage treatment plants are generally greater than the lowest-observed effect levels for alterations to gonadal development in medaka.

Nieminen P, Lindstrom-Seppa P, Juntunen M, Asikainen J, Mustonen AM, Karonen SL, Mussalo-Rauhamaa H, Kukkonen JV. 2002. In vivo effects of bisphenol A on the polecat (*Mustela putorius*). Journal of Toxicology & Environmental Health. Part A 65:933-945.
Call Number: W 10149
Abstract: Bisphenol A (BPA), an environmental estrogen derived from the plastic industry, was given orally via incorporation into the food of 30 male and female polecats at 3 different doses (10, 50, or 250 mg/kg body weight/day) for 2 wk with 10 animals acting as controls. Several hormone levels in the plasma were determined as well as the activities of the phase I and II biotransformation enzymes 7-ethoxyresorufin O- deethylase (EROD), cytosolic glutathione S-transferase (GST), and UDP- glucuronosyltransferase (UDPGT). BPA did not cause any macroscopic effects on body mass or the health of the animals. UDPGT and GST activities increased significantly in direct correlation with increasing BPA exposure in females and UDPGT increased in a dose- related manner in males. There was no change in the plasma T4 and testosterone concentrations of the males with increasing BPA exposure. Discriminant analysis indicated that the group receiving 10 mg BPA/kg body weight/d was not different from the control group but the groups receiving 50 and 250 mg/kg body weight/d were different from the control group. This suggests physiological changes in the groups receiving 50 or 250 mg BPA/kg body weight/d.

Nieminen P, Lindstrom-Seppa P, Mustonen AM, Mussalo-Rauhamaa H, Kukkonen JV. 2002. Bisphenol A affects endocrine physiology and biotransformation enzyme activities of the field vole (*Microtus agrestis*). General & Comparative Endocrinology 126:183-189.
Call Number: W 10150 PDF
Abstract: Bisphenol A (BPA), an environmental estrogen, was given subcutaneously for 4 days to 48 field voles at three doses (10, 50, or 250 mg kg(-1) day(-1)). Plasma sex steroids, thyroxine, weight-regulatory hormones, and liver biotransformation enzymes were determined. There was no mortality in the control group but the mortality in the BPA-exposed animals was significant. BPA increased the plasma

testosterone concentrations at 250 mg BPA kg(-1) day(-1). The plasma ghrelin levels measured from pooled plasma increased and at the same time the leptin levels measured from pooled plasma decreased at 50 or 250 mg BPA kg(-1) day(-1). The liver 7-ethoxyrufin-o-deethylase activity decreased slightly at all doses, as did the liver cytosolic glutathione S- transferase activity at 250 mg BPA kg(-1) day(-1). The results show that wild mammals such as the field vole could be more susceptible to BPA than laboratory rodents. More studies on wild mammals are needed to determine the risks of endocrine disruptors in natural ecosystems.

Norris DO. 1997. Extrapolation of the effects of endocrine disrupting chemicals among vertebrates. In. Endocrine Disruptors: Advances in Measuring and Analyzing Their Effectsp 1-24 (Ch. 1).
Call Number: W 04880
Abstract: The predominant components of the vertebrate endocrine system are parts of several hypothalamo-pituitary axes which are rather conservative in terms of their organization and anatomical features. Even the biochemical pathways involved in synthesis and actions of hormones are rather conservative from fishes to mammals, involving similar synthetic enzymes, second messengers, gene interactions, etc. However, major differences seem to occur at the level of hypothalamic control, which can vary greatly between or within large vertebrate taxa. Hence, the same molecule in different species can have markedly different effects on an animal's physiology. Furthermore, the binding of potential endocrine disruptors to membranes or intracellular receptors may differ such that the endocrine disruptor produces different effects. Dosages presented, the developmental stage of treatment animals, and possible synergisms with other pollutants may complicate further extrapolations among species. In future planning or interpreting research on potential or known endocrine disruptors, the comparative endocrinologist may play a crucial role in predicting and interpreting the actions of potential endocrine disruptors in natural ecosystems.

Oka T, Adati N, Shinkai T, Sakuma K, Nishimura T, Kurose K. 2003. Bisphenol A induces apoptosis in central neural cells during early development of *Xenopus laevis*. Biochemical & Biophysical Research Communications 312:877-882 .
Call Number: W 11255 PDF
Abstract: Bisphenol A (BPA), known to be a xenoestrogen, is widely used in industry and dentistry. In the present study, we investigated the effects of BPA on the early development of Xenopus laevis embryos. Stage 6 embryos were exposed to 10-100 muM BPA. Developmental abnormalities were observed when the embryos were exposed to at least 20 muM BPA, with marked developmental abnormalities, such as crooked vertebrae and developmental defects of the head and abdomen, detected in all embryos up to stage 40. Interestingly, apoptosis occurred specifically in central nervous tissue cells of the brain and spinal cord, as assessed by histological analysis. BPA-induced malformations and apoptosis were not observed in embryos exposed to BPA after stage 10. When embryos were exposed to 10 muM 17beta-estradiol (E2), abnormalities were also observed until stage 40. However, the abnormalities induced by BPA and E2 were different and E2 exposure did not induce apoptosis in the central nervous system. Our results indicated that the developmental abnormalities and apoptosis induced by BPA exposure were not inhibited by the addition of E2. In conclusion, we demonstrated that BPA induced marked malformations and specific apoptosis of central nervous system cells during early development of X laevis embryos, and that these BPA effects appeared to be due to non-estrogenic activities on developmental processes.

Pascoe D, Carroll K, Karntanut W, Watts MM. 2002. Toxicity of 17alpha-ethinylestradiol and bisphenol A to the freshwater cnidarian *Hydra vulgaris*. Archives of Environmental Contamination & Toxicology 43:56-63.
Call Number: W 10361
Abstract: Estrogens and estrogen mimics that enter the environment are known to present a serious threat to the development and reproduction of vertebrates by disrupting their normal endocrine function. There is also concern that such chemicals may be damaging to invertebrates. In this study, Hydra vulgaris, a member of the Cnidaria, an evolutionarily primitive group of invertebrates present before the divergence of the protostomes and deuterostomes, was exposed to the synthetic estrogen 17alpha-ethinylestradiol (EE2) and bisphenol A (BPA), both of which are known to be estrogenic in fish. Effects on polyp survival, structure, and regeneration (and sexual reproduction for EE2) were examined and mortality was recorded at high concentrations, with 96-h LC(50)s of 3.8 mg/L and 6.9 mg/L for EE2 and BPA, respectively. The structure and physiology of polyps was adversely affected at concentrations greater than 58 microg/L EE2

and 42 microg/L BPA. There was a concentration- related inhibition of regeneration above 150 microg/L EE2 and 460 microg/L BPA. Sexual reproduction was only impaired at 500 microg/L EE2. These results clearly suggest that the signaling processes necessary for the control and regulation of cell movement and differentiation during normal development, regeneration, and sexual reproduction in H. vulgaris are not disrupted by estrogenic pollutants at low environmentally relevant concentrations.

Pastva SD, Villalobos SA, Kannan K, Giesy JP. 2001. Morphological effects of bisphenol-A on the early life stages of medaka (*Oryzias latipes*). Chemosphere 45:535-541.
Call Number: W 09374
Abstract: Bisphenol-A (BPA), a widely used polycarbonate plasticizer, has been of concern because it has been shown to leach out of plastics and other epoxy products. Primary sources of environmental releases are expected to be from BPA and epoxy manufacturing facilities. Although environmental concentrations may be limited, little is known about the effects of this compound on fish, particularly during their most sensitive early life stages, A pilot study exposing newly hatched medaka to 200 mug BPA/l for 96 h showed to be non-lethal. In addition, medaka embryos were exposed beginning at 5 h post-fertilization, for 9 days at 25 degreesC, to concentrations of 20 or 200 mug BPA/l (24 h static renewal). Embryos were monitored daily for development and gross abnormalities. Embryos exposed to 200 mug BPA/l did not exhibit abnormalities until after day 4. However, between days 4 and 8 the severity index (SI) score of embryos was significantly greater than those exposed to lesser concentrations. By day 9, SI scores were not statistically different among treatments. BPA caused transient embryonic deformities in medaka at environmentally relevant concentrations.

Quinn B, Gagne F, Costello M, McKenzie C, Wilson J, Mothersill C. 2004. The endocrine disrupting effect of municipal effluent on the zebra mussel (*Dreissena polymorpha*). Aquatic Toxicology 66:279-292.
Call Number: W 11193 PDF
Abstract: Municipal effluents have been shown to contain a cocktail of endocrine disrupting chemicals (EDCs). The estrogenic effect of these effluents has been demonstrated on both vertebrate and invertebrate species by the feminisation of the exposed males. This effect was investigated on the freshwater zebra mussel (Dreissena polymorpha) after exposure to tertiary treated effluent from a municipal sewage treatment works (STW). Mussels were exposed to the effluent in situ for 112 days during gametogenesis (December to mid-March). Levels of vitellin (Vn)-like proteins (the major protein found in oocytes) were measured indirectly using the alkali-labile phosphate (ALP) technique and confirmed by gel electrophoresis. Significant increases ($P < 0.05$) in Vn-like proteins were found in both male and female mussels after exposure to the effluent, indicating that endocrine disruption (ED) had occurred. Using high-performance thin layer chromatography (HPTLC) levels of the mussels main steroid, cholesterol were found to more than double after effluent exposure. General physiological (survival, condition, etc.) and histological effects were also investigated. Histological effects observed included a large increase in interstitial tissue between the seminiferous tubules of the gonad in male mussels exposed to effluent. Effluent samples were tested for estrogenic compounds using the toxicity identification and evaluation method (TIE). A complex mixture of compounds with estrogenic activity was found with 17beta-estradiol, 17alpha-ethynlestradiol and bisphenol A accounting for the majority of the effluents estrogenic activity. Results indicate that the zebra mussel is a suitable bioindicator of endocrine disruption in freshwater environments.

Rankouhi TR, Sanderson JT, Van Holsteijn I, Van Kooten P, Bosveld ATC, Van Den Berg M. 2005. Effects of environmental and natural estrogens on vitellogenin production in hepatocytes of the brown frog (*Rana temporaria*). Aquatic Toxicology 71:97-101.
Call Number: W 11593 PDF
Abstract: The objective of this study was to investigate the ability of the natural estrogens and synthetic estrogens as well as the estrogen mimics to induce estrogen-receptor mediated vitellogenesis in primary hepatocytes of the brown frog (Rana temporaria). Based on EC50 values the following order was determined for the potency of the estrogens: 17beta-estradiol (EC50: 19-43 nM) approximate to ethynylestradiol (EC50: 13-80 nM) > estrone (EC50: 218-241 nM) > DES (EC50: 338-3537 nM). Exposure to bisphenol A and methoxychlor concentrations up to 100 muM did not have any effect on in vitro vitellogenesis.

Rankouhi TR, van Holsteijn I, Letcher R, Giesy JP, van den Berg M. 2002. Effects of primary exposure to environmental and natural estrogens on vitellogenin production in carp (*Cyprinus carpio*) hepatocytes. Toxicol Sci 67:75-80.
Call Number: W 10035
Abstract: Vitellogenin (vtg) is a precursor of the yolk proteins lipovitelline and phosvitin and is synthesized as a consequence of estrogen-dependent gene expression in female and male hepatocytes of egg-laying vertebrates. Freshly isolated carp hepatocytes of a genetically uniform strain of adult male carp (Cyprinus carpio) were used to investigate the effects of primary exposure to estrogenic compounds on the vitellogenic response to xenoestrogens. Isolated carp hepatocytes were first exposed (primary exposure) to 50 or 100 microM of either methoxychlor (MXCL) or bisphenol A (BPA), different concentrations of estrone (E1; 1 or 10 nM) or 17beta-estradiol (E2; 0.1 or 1 nM) for 2 days. Hepatocytes were exposed to xenoestrogens (secondary exposure) at both 2 and 5 days after isolation. Hepatocytes were cultured for a total period of 8 days. A competitive indirect ELISA was used to determine the level of vtg after 8 days. The concentration of chemicals used for the primary exposure induced vtg to a level that was less than 10% of the response elicited by E2 (1000 nM). A cytotoxic response, measured by MTT, was not observed after primary exposure to any of the xenoestrogens. After primary exposure to MXCL, vtg production in response to E2 was increased by 4-fold, and vitellogenesis in response to E1 treatment was doubled compared with vitellogenesis without pretreatment. No significant differences were observed between primary exposure to 50 and 100 microM MXCL. Primary exposure to 50 and 100 microM BPA increased the maximum vtg production in response to secondary E2 exposure by about 5- and 7-fold, respectively. Primary exposure to BPA (50 and 100 microM) followed by secondary exposure to E1 showed a 4- and 5-fold increase of the vtg synthesis in comparison to E1 exposure alone. Primary exposure to the endogenous estrogens had no significant influence on the vtg synthesis in response to secondary exposure to E1 or E2. Compared to hepatocytes exposed only to MXCL or BPA, primary exposure to E2 increased the vtg synthesis in hepatocytes induced by MXCL or BPA by almost a factor of 2. Primary exposure to E1 increased vitellogenesis after secondary exposure to MXCL only marginally. The present results indicate that weakly estrogenic environmental chemicals such as MXCL and BPA can increase the sensitivity of carp hepatocytes towards endogenous estrogens with respect to VTG synthesis.

Regan F, Moran A, Fogarty B, Dempsey E. 2002. Development of comparative methods using gas chromatography - mass spectrometry and capillary electrophoresis for determination of endocrine disrupting chemicals in bio-solids. Journal of Chromatography B Analyt Technol Biomed Life Sci 770:243-253.
Call Number: W 10063
Abstract: Two analytical separation techniques are being investigated for their potential in determining a wide range of endocrine disrupting chemicals (EDCs) in the environment. Capillary electrophoresis (CE) in the micellar mode in conjunction with a cyclodextrin (CD) modifier is shown to have potential for determination of alkylphenol breakdown products. Gas chromatography with mass spectrometric (GC-MS) detection is being utilised for validation of the CE method development and in addition as a separation technique to optimise preconcentration using solid-phase extraction. GC has demonstrated potential for the separation of 26 priority chemicals suspected as being endocrine disrupting compounds. The challenge of the method development process lies in the fact that these compounds are of differing polarities, size and charge and therefore are difficult to separate in a single run. Capillary electrophoresis in the CD-MEKC (micellar electrokinetic chromatography) mode is showing potential in this regard. Limits of determination are in the low mg/l range for CE and GC, however, using preconcentration it is possible to improve detection sensitivity with >80% recovery for some analytes and up to 100% recovery for most target species.

Rehmann K, Schramm K-W, Kettrup AA. 1999. Applicability of a yeast oestrogen screen for the detection of oestrogen-like activities in environmental samples. Chemosphere 38:3303-3312.
Call Number: W 06743
Abstract: A (xeno)oestrogen bioassay was introduced, using a genetically modified yeast strain which produces a fusion protein encompassing the human oestrogen receptor hormone binding domain and the yeast GAL4-DNA binding domain. Upon binding of appropriate substances this fusion protein recognises the respective DNA sequence thereby enhancing the transcription of a beta-galactosidase reporter gene. The bioassay procedure was evaluated by screening 30 compounds, including some known or suspected (xeno)oestrogens and determining EC50-values for 17 beta-oestradiol, 1.5 nM, 4-tert.-octylphenol, 6.7 mu

M and bisphenol A, 104 mu M. Toluene extracts from different environmental matrices were tested for their oestrogenic activity. The positive test results obtained with a sewage sludge extract indicated the applicability of this bioassay for environmental monitoring.

Rutishauser BV, Pesonen M, Escher BI, Ackermann GE, Aerni HR, Suter MJF, Eggen RIL. 2004. Comparative analysis of estrogenic activity in sewage treatment plant effluents involving three in vitro assays and chemical analysis of steroids. Environmental Toxicology & Chemistry 23:857-864.
Call Number: W 11426 PDF only
Abstract: In this study, we assessed and compared the suitability of three in vitro screening tools for the measurement of estrogenic activity in sewage treatment plant effluents (STPEs). These assays were the yeast estrogen screen (YES), production of zona radiata proteins (ZRPs) in trout hepatocytes, and the induction of reporter gene expression in the transfected rainbow trout gonad cell line RTG-2. Data obtained with the YES were additionally compared with calculated estrogenicity, based on steroid analysis data of the effluents. For comparison purposes, the response of the in vitro systems toward the estrogenic chemicals P-estradiol, ethinyl estradiol. bisphenol-A. nonylphenol, and octylphenol was assessed. All three assays showed sensitivities in the same order of magnitude in response to the steroid compounds tested, with ZRP production being the least sensitive. Regarding the estrogenic environmental chemicals tested, the RTG-2 assay was more than an order of magnitude more sensitive than the other two assays. Despite their different sensitivities toward selected test chemicals, the three in vitro systems indicated estrogenic activity in the same concentration range for the tested STPEs. Calculated estrogenicity (chemical analysis) and measured estrogenicity (YES) were of the same order of magnitude for the STPEs tested. The present study indicates that all three in vitro systems, with the yeast-based system being the easiest and most robust, are applicable for the screening of estrogenic activity in effluent samples.

Sajiki J, Yonekubo J. 2003. Leaching of bisphenol A (BPA) to seawater from polycarbonate plastic and its degradation by reactive oxygen species. Chemosphere 51:55-62.
Call Number: W 10705 PDF
Abstract: In this study, (1) change in the concentration of bisphenol A (BPA) leached from polycarbonate (PC) tube to control water (BPA free), seawater and river water at 20 and 37 degrees C as a function of time, (2) the fate of BPA caused by addition of H(2)O(2) and Fe(3+) to seawater containing BPA leached from PC tube were assessed. BPA leached from PC tube to all water samples increased with the ascendant of temperature and with the passage of time. The BPA leaching velocity in seawater was the fastest in three samples (11 ng/day for seawater, 4.8 ng/day for river water 0.8 ng/day for control water at 37 degrees C).BPA leaching velocity from PC tube was significantly high at pH 8 (50 mM Na(2)HPO(4)) and increased dose-dependently. There was no difference in the velocity of BPA among the 50 mM phosphate-buffers at pH 6.5, 7.0 and 7.5. BPA was leached three times higher by addition of Na(+) than K(+). However, the higher the K(+) concentration, the larger the BPA leached from PC tube. Na(+) mixed with PO(4)(-) was effective on BPA leaching from PC tube, but not with SO(4)(-) or Cl(-). The results suggested that BPA leaching from PC tube would be attributed to the concentration of bibasic phosphate such as Na(2)HPO(4) and K(2)HPO(4) in water samples. BPA was degraded in both control water and seawater in the presence of radical oxygen species, but the degradation rate was lower in seawater than in control water, suggesting that anti- oxidative system exists in seawater. Neo-synthesized substance in both control water and seawater in the presence of reactive oxygen species was identified as BPA-quinone by LC-MS.

Shilling AD, Williams DE. 2000. Determining relative estrogenicity by quantifying vitellogenin induction in rainbow trout liver slices. Toxicol Appl Pharmacol 164:330-335.
Call Number: W 07881
Abstract: Precision cut tissue slices, by modeling the entire organ, are a valuable tool for studying protein induction or inhibition by test chemicals. This manuscript describes parameters to quantify relative estrogenicity of chemicals in rainbow trout liver slices by measuring vitellogenin (Vg) induction, a well-characterized biomarker of estrogen receptor signal transduction. Hank's medium (phenol-red free) supplemented with Hepes, sodium bicarbonate, and 1% bovine serum albumin was utilized. The experimental parameters were optimized using 1000 nM 17 beta-estradiol, a potent estrogen in rainbow trout that induces Vg production in vivo. The addition of trout serum and retention of the media was essential, probably to allow for the accumulation of Vg in the slices and media. Histological examination and ATP analyses indicated no toxicity in control or 17 beta-estradiol-treated liver slices after 120 h.

Induction was 4-fold greater with 25% serum containing media compared to media with 10% serum. We observed Vg induction as great as 500-fold over controls at 96 h in liver slices and media containing 25% serum and 1000 nM 17 beta-estradiol. Controls without 17 beta-estradiol, incubated in media with 10 or 25% serum, exhibited no detectable Vg production, indicating that the induction seen was not from the media or serum. We observed that 48 h was required for significant Vg induction in the media and liver slices. Maximum induction in slices occurred at 96 h, whereas media Vg levels continued to increase to 120 h, suggesting a time delay between Vg production and excretion by the liver. The feasibility of this model to detect weak environmental estrogens was determined with 0-250 mu M o,p'DDE and bisphenol A. Both compounds induced Vg in this model with EC50 values of 10(4) and 2 x 10(5) higher than E-2, respectively. Our results indicate the importance of media, serum, and time selection for optimal Vg induction. This model allows for the determination of relative estrogenicity of chemicals in a controlled in vitro system while utilizing the advantages of precision cut slice technology.

Shioda T, Wakabayashi M. 2000. Effect of certain chemicals on the reproduction of medaka (*Oryzias latipes*). Chemosphere 40:239-243.
Call Number: W 09493
Abstract: In order to understand the effects of estrogenic chemicals on fish reproduction, we exposed male medaka (Oryzias latipes) to a natural estrogen [17 beta-estradiol (17 beta-E2)] and three estrogenic chemicals [bisphenol-A, nonylphenol (NP) and di(2-ethylhexyl)phthalate (DEHP)]. After two weeks' exposure, one male medaka was kept together with two female medaka for spawning, and the number of eggs and hatchings were compared to those of a negative control group. The results indicated that exposure to 17 beta-E2 caused a significant decrease in the number of eggs and hatchings as compared to the negative control group at and above 3 nmol/l. Also, the highest concentrations of bisphenol-A and NP caused a decrease in the number of hatchings, but no decrease in hatchings was observed in DEHP treatments. In the treatment using these chemicals the decrease in egg numbers was not so much as in hatching numbers. When compared to other in vitro studies, concentrations observed to have adverse effects on reproduction in this study are generally lower. In addition, it was suggested that physical alterations, such as an induction of plasma vitellogenin, were caused at much lower concentrations than those at which a decline in reproductivity was actually induced.

Sohoni P, Tyler CR, Hurd K, Caunter J, Hetheridge M, Williams T, Woods C, Evans M, Toy R, Gargas M, Sumpter JP. 2001. Reproductive effects of long-term exposure to bisphenol A in the fathead minnow (*Pimephales promelas*). Environmental Science & Technology 35:2917-2925.
Call Number: W 09002 PDF
Abstract: Bisphenol A (BPA), a high-volume chemical used to make polycarbonate plastic, epoxy resins, and other chemicals has been reported to be weakly estrogenic. To investigate the effects of long-term exposure to Bisphenol A, a multigeneration study was conducted in which fathead minnows (Pimephales promelas) were exposed to water concentrations of BPA in the range from 1 to 1280 micrograms/L. In this paper, we report the growth and reproductive effects of BPA on sexually mature adults in the F0 generation (after 43, 71, and 164 d of exposure) and the effects on hatchability in the F1 generation. Mean measured concentrations of BPA in the water for all doses, over a 164-d exposure period, were between 70% and 96% of nominal. An inhibitory effect of BPA on somatic growth (length and weight) occurred in adult male fish exposed to 640 and 1280 micrograms/L (after 71 and 164 d). BPA induced vitellogenin synthesis (VTG; a biomarker for estrogen exposure) in males at concentrations of 640 and 1280 micrograms/L after 43 d and 160 micrograms/L after 71 d. In females, plasma VTG concentrations were elevated above controls only after 164-d exposure to 640 micrograms/L. Inhibition of gonadal growth (as measured by the gonadosomatic index) occurred in both males and females at concentrations of 640 and 1280 micrograms/L after 164 d. In males, a concentration of 16 micrograms/L altered the proportion of sex cell types in the testis, suggesting inhibition of spermatogenesis. Concentrations of BPA that induced VTG synthesis and affected gonadal development were lower than those that resulted in discernible effects on reproductive output. Egg production was inhibited at a BPA concentration of 1280 micrograms/L, and hatchability in the F1 generation was reduced at a BPA concentration of 640 micrograms/L (there were not enough eggs spawned in the 1280 micrograms/L group for hatchability studies to be conducted). The results demonstrate that BPA acts as a weak estrogen to fish when administered via the water, with effects on breeding at and above 640 micrograms/L.

Sone K, Hinago M, Kitayama A, Morokuma J, Ueno N, Watanabe H, Iguchi T. 2004. Effects of 17<beta>-estradiol, nonylphenol, and bisphenol-A on developing *Xenopus laevis* embryos. General & Comparative Endocrinology 138:228-236.
Call Number: W 11433 PDF
Abstract: Many chemicals released into the environment have the capacity to disrupt the normal development of aquatic animals. We investigated the influence of nonylphenol (NP), bisphenol-A (BPA), and 17beta-estradiol (E2) on developing Xenopus laevis embryos, as a model animal in the aquatic environment. Embryos were exposed to eight different concentrations of NP, BPA or E2 between 3 and 96 h post-fertilization (p.f.). Short body length, microcephaly, flexure, edema, and abnormal gut coiling were induced by 20 PM NP, BPA or 10 muM E2 by 96h p.f. To clarify sensitive stages to these compounds, embryos were exposed to chemicals for 45 or 48 h starting at different developmental stages and experiments were terminated 96h p.f. BPA and NP induced abnormalities in developing X. laevis, though the sensitive stages of embryos to these chemicals are different, BPA affecting earlier stages and NP affecting at later stages. To analyze the functional mechanisms of BPA and NP in induction of morphological changes, we adapted a DNA array technology and identified 6 X. laevis genes, XIRG, alpha skeletal tropomyosin, cyclin G1, HGF, troponin C2, and ribosomal protein L9. These findings may provide important clues to elucidate common mechanisms underlying teratogenic effects of these chemicals.

Spengler P, Korner W, Metzger JW. 2001. Substances with estrogenic activity in effluents of sewage treatment plants in southwestern Germany. 1. Chemical analysis. Environmental Toxicology & Chemistry 20:2133-2141.
Call Number: W 09247
Abstract: A gas chromatography/mass spectrometry method for the simultaneous quantitative determination of natural and synthetic estrogens (17beta- estradiol, estrone, 17alpha-ethinylestradiol, and mestranol), phytoestrogens (genistein and beta-sitosterol), and xenoestrogens (benzyl butyl phthalate, dibutyl phthalate, bisphenol A, 4-nonylphenol [NP], 4-nonylphenoxyacetic acid [NP1EC], 4-nonylphenol diethoxylate [NP2EO], and alpha-endosulfan) in effluents of sewage treatment plants (STPs) was developed. Identification and quantification were carried out with the standard addition method using analyte-specific and, in some cases, deuterium-labeled internal standards. The effluents of 18 STPs were investigated. Apart from alpha-endosulfan and mestranol, all selected substances were detected in the majority of samples. The median concentrations of steroidal estrogens were between 0.4 ng/L (17alpha-ethinylestradiol) and 1.6 ng/L (17beta-estradiol). The metabolites of the nonylphenol polyethoxylates, NP, NPIEC, and NP2EO were found in concentrations ranging from the upper-ng/L-range (NP) to the lower-microg/L range (NP1EC). For all substances except mestranol and alpha-endosulfan, median values were calculated and compared to the results of other investigations in Europe and the United States. Possible dependencies of measured concentrations on the geographical location, the capacity, the influent composition, and the technical fitting of the STPs are discussed.

Sprague LA, Battaglin WA. 2005 Jan. Wastewater chemicals in Colorado's streams and groundwater. USGS Factsheet 2004-3127:1-4.
Call Number: W 11532 PDF
Abstract: Concentrations of 62 chemicals were measured in river and well water. Caffeine, DEET, nonylphenol and triclosan were 4 of the more commonly detected chemicals at each site type.

Staples CA, Dorn PB, Klečka GM, Oblock ST, Harris LR. 1998. A review of the environmental fate, effects, and exposures of bisphenol A. Chemosphere 36:2149-2173.
Call Number: W 05895
Abstract: Bisphenol A (CAS 85-05-7) may be released into the environment through its use and handling, and permitted discharges. BPA is moderately soluble (120 to 300 mg/L at pH 7), may adsorb to sediment (Koc 314 to 1524), has low volatility, and is not persistent based on its rapid biodegradation in acclimated wastewater treatment plants and receiving waters (half-lives 2.5 to 4 days). BPA is "slightly to moderately" toxic (algal EC50 of 1000 mu g/L) and has low potential for bioaccumulation in aquatic organisms (BCFs 5 to 68). The chronic NOEC for Daphnia magna is >3146 mu g/L. Surface water concentrations are at least one to several orders of magnitude lower than chronic effects, with most levels nondetected.

Staples CA, Woodburn K, Caspers N, Hall AT, Klečka GM. 2002. A weight of evidence approach to the aquatic

hazard assessment of bisphenol A. Human & Ecological Risk Assessment 8:1083-1105.
Call Number: W 11245 PDF only
Abstract: Bisphenol A (BPA; 4,4-isopropylidene diphenol) is a chemical intermediate used primarily in the production of epoxy resins and polycarbonate products. BPA has been identified in surface waters and, hence, has been the subject of considerable research into its potential effects on aquatic organisms. Available literature on the aquatic toxicity of BPA was reviewed for quality against European Union TGD and Organization of Economic Cooperation and Development GLP principles. From this review, studies of suitable quality covering numerous ecologically relevant endpoints were identified to evaluate the survival, growth, and reproductive success of aquatic organisms exposed to BPA. Those studies yielded approximately 70 no observed effect concentrations (ranging from 16 to 3640 μg/L) and lowest observed effect concentrations (160 to 11,000 μg/L) that were considered in this weight of evidence assessment. Across all data, adverse effects on survival, growth, and reproduction occurred only at concentrations of 160 μg/L and above. Secondary biochemical (e.g., vitellogenin induction) and morphological (e.g., gonad histology) data provide insight into mechanisms of action, but do not correlate with apical endpoints related to survival, growth, and reproduction. Comparing the weight of the evidence of the aquatic toxicity data that showed chronic effects at 160 μg/L and higher with typical surface water concentrations in the range of 0.001 to 0.10 μg/ L, BPA is unlikely to cause adverse effects on aquatic populations or ecosystems.

Stoker C, Rey F, Rodriguez H, Ramos JG, Sirosky P , Larriera A, Luque EH, Munoz-de-Toro M. 2003. Sex reversal effects on *Caiman latirostris* exposed to environmentally relevant doses of the xenoestrogen bisphenol A. General & Comparative Endocrinology 133:287-296.
Call Number: W 11007 PDF
Abstract: Exposure to environmental contaminants known as endocrine disruptors (EDs) alters the development and function of reproductive organs in several species. Bisphenol A (BPA) is an estrogenic chemical that leaches from dental materials and plastic food and beverage containers. BPA has been found in sewage, surface and drinking water, and therefore poses a potentially significant risk for human and wildlife. Prenatal exposure of rodents to environmentally relevant doses of BPA alters the development of the reproductive organs of male and female offspring. Species with temperature dependent sex determination (TSD) could act as sentinels of ecosystem health by providing sensitive biomarkers of endocrine disruptor's effects. We selected Caiman latirostris as an animal model to study endocrine disruption caused by BPA. The aim of this study was to determine whether exposure in ovum to BPA could cause estrogen-like effects on the reproductive system of C. latirostris. Sex determination and gonadal histoarchitecture were the endpoints evaluated after in ovum exposure to different doses of BPA and 17beta-estradiol (E(2)). We confirmed that C. latirostris is a species with TSD and additionally demonstrated that BPA causes estrogen-like developmental effects by reversing gonadal sex and altering gonadal histoarchitecture. Differences in responses to BPA and E(2) in our in vivo system were on the order of 100-fold. In contrast published in vitro studies have reported differences on the order of 10,000x or more. These results support the utility of C. latirostris, a species in which sex determination is temperature dependent, as a tool in assessing estrogenic activity in vivo and as a sentinel to monitor EDs in aquatic environment.

Suzuki E, Kunimoto M, Nishizuka M, Imagawa M. 2004. Evaluation of ability of chemicals to bind frog (*Xenopus laevis*) estrogen receptor by *in vitro* binding assay. Journal of Health Science 50:685-688.
Call Number: W 11592 PDF
Abstract: The in vitro binding assay seems to be a useful first screening method for endocrine disrupting chemicals. Various methods have been developed and applied to the testing of chemicals. Since these assays should be applied to estrogen receptors (ER) of not only humans but also wildlife, we previously developed a standardized in vitro binding assay system for human, quail, Japanese medaka, and Xenopus laevis ERs using a competitive enzyme immunoassay. Since that was a first report on an in vitro binding assay system for Xenopus ERalpha, and the capacities of chemicals to bind Xenopus ERa were not tested yet, we here evaluated the ability of 20 test chemicals, which were selected by the Ministry of the Environment of Japan, to bind Xenopus ERalpha. Of these, 4-nonylphenol, p-octylphenol and bisphenol A had relatively high binding capacity, and these results are similar to those obtained previously in quail ERalpha.

Suzuki T, Nakagawa Y, Takano I, Yaguchi K, Yasuda K. 2004. Environmental fate of bisphenol A and its biological

metabolites in river water and their xeno-estrogenic activity. Environmental Science & Technology 38:2389-2396.
Call Number: W 11117 PDF
Abstract: Monitoring of bisphenol A [BPA; 2,2-bis(4-hydroxyphenyl)propane] and its biological metabolites [4,4'-dihydroxy-alpha-methylstilbene (DHMS), 2,2-bis(4-hydroxyphenyl)-1-propanol (BPA-OH), 2,2-bis(4-hydroxyphenyl)propanoic acid (BPA-COOH), and 2-(3,4-dihydroxyphenyl)-2-(4-hydroxyphenyl)propane (3-OH-BPA)] in river waters was performed by solid-phase extraction and GUMS determination. The concentrations of BPA, BPA-COOH, BPA-OH, and 3-OH-BPA in the river water ranged from 2 to 230 (8.8 x 10(-12) to 1.0 x 10(-9) M), from 5 to 75 (1.9 x 10(-11) to 2.9 x 10(-10) M), from 3 to 16 (1.2 x 10(-11) to 6.6 x 10(-11) M), and from 3 to 11 (1.2 x 10(-11) to 4.5 x 10(-11) M) ng L-1, respectively. DHMS, an intermediate in the main degradation pathway of BPA, was not detected in any water sample. Under the aerobic conditions in the river water, BPA disappeared within 8 d of incubation, but BPA-COOH, BPA-OH, and tetraol remained in the supernatant after 14 d of incubation. For the xeno-estrogenic activity of BPA and the metabolites, their ability to bind to recombinant human estrogen receptor alpha in competition with fluorescence-labeled 17beta-estradiol was measured. Fifty percent inhibitory concentrations (IC50) of BPA, DHMS, 3-OH-BPA, and BPA-OH were approximately 1 x 10(-5), 1 x 10(-6), 3 x 10(-5), and 1 x 10(-2) M, respectively. In human cultured MCF-7 breast cancer cells, BPA increased cell numbers in a dose-dependent manner at concentrations from 10(-7) to 10-5 M. For the BPA metabolites, DHMS, 3-PH-BPA, and BPA-COOH caused the cells proliferation at concentrations from 10(-9) to 10(-6), from 10(-7) to 10(-6), and from 10(-5) to 10(-4) M, respectively. BPA-OH did not cause MCF-7 cells proliferation. These results indicate that BPA is mainly metabolized through oxidative rearrangement by bacteria in the river water, and intermediate bisphenols via minor metabolic pathways exist in river water. The presence of the bisphenols having the xeno-estrogenic effect suggests the necessity of monitoring those in river water, in the effluent waters from sewage plants, or in landfill leachate.

Tabata A, Kashiwada S, Ohnishi Y, Ishikawa H, Miyamoto N, Itoh M, Magara Y. 2001. Estrogenic influences of estradiol-17<beta>, *p*-nonylphenol and bis-phenol-A on Japanese medaka (*Oryzias latipes*) at detected environmental concentrations. Water Science & Technology 43(2):109-116.
Call Number: W 09618
Abstract: Mature male medaka were continuously exposed to 0.005, 0.0-5 or 1.0 ppb of estradiol-17 beta (E2 or 0.1, 10 or 100 ppb of p-nonylphenol (NP) or bis-phenol-A (BPA). Female-specific proteins (Fsp) were induced in medaka exposed to 0.005 ppb of E2, 0.1 ppb of NP, or 10 ppb of BPA. Concentrations of 0.005 pbb of E2 and 0.1 ppb of NP corresponded to concentrations of these chemicals detected in river water in Japan. The abilities of the 3 chemicals to induce Fsp were E2 > NP > BPA. Embryonic medaka were exposed to E2, NP and BPA under conditions of static-renewal for 200-230 days until pre-maturity. Survival ratios of medaka exposed to E2 and NP declined in concentrations more than 25 ppb and 50 ppb, respectively. The groups of medaka exposed to E2 had individuals with testis-ova or abnormal gonad. There was no male in exposure to 1.0 ppb E2. When exposed to 100 ppb of NP or BPA, abnormal gonad was also detected. Abnormal anal fin (female-like) was observed in male exposed to 100 ppb of NP. The LC50 values for each of the 3 chemicals were much higher than the concentrations detected in water in the environment--the 3 chemicals were considered to have no lethal effect on medaka in aquatic environments. However, exposures to E2 or NP at environmental concentrations induced Fsp. BPA also had the ability to affect medaka as an environmental estrogen, although its extrogenic activity was weaker than that of E2 or NP.

Tabata A, Miyamoto N, Ohnishi Y, Itoh M, Yamada T, Kamei T, Magara Y. 2003. The effect of chlorination of estrogenic chemicals on the level of serum vitellogenin of Japanese medaka (Oryzias latipes). Water Science & Technology 47:51-57.
Call Number: W 11483 PDF only
Abstract: Mature male medaka were continually exposed to four,chemicals, p-n-nonylphenol (p-n-NP), p-nonylphenol (p-NP), bisphenol-A (BPA) and 17beta-estradiol (E2) to evaluate their estrogenic activities in the laboratory. In order to understand the effect of the chlorination that is applied widely in water and waste-water treatment, the above chemicals were chlorinated and then exposed to mature male medaka. Furthermore, in the case of vitellogenin, a [sic] is a female specific protein induced by the exposure to test waters containing, the above chemicals after 5 weeks, medaka was returned to uncontaminated tap water to determine whether male medaka have a self recovery function from, the effect of estrogenic chemicals.

Much greater vitellogenin compared to the background levels, were induced in the male medaka by separate exposure to 100 mug/L of p-NIP, 1,000 mug/L of BPA and 0.05 mug/L of E2. The levels of vitellogenin increased with increasing exposure periods. The relative potencies of these chemicals descended in the order of E2 much greater than p-NP>BPA.
Vitellogenin levels inducible by these chemicals were drastically reduced as a result of the chlorination for 24 hours. However, a moderate increase in hepatocyte somatic index (HSI) meant the hepatic fatness was observed as a result of chlorination. It is not clear at this stage whether or not the formation of chlorination byproducts is responsible for this moderate increase in HSI.
The vitellogenin concentration of male medaka exposed to chemicals for 5 weeks decreased gradually after return to the uncontaminated water. However, the vitellogenin concentration did not return to the initial normal levels even after 5 weeks.
A clear relationship between the serum vitellogenin concentration and the hepatic vitellogenin concentration was also found. Since quantitative analytical procedures for hepatic vitellogenin are easier than those of the serum vitellogenin, measuring the estrogenic effect using the measurement of vitellogenin in liver is recommended.

Tabata A, Watanabe N, Yamamoto I, Ohnishi Y, Itoh M, Kamei T, Magara Y, Terao Y. 2004. The effect of bisphenol A and chlorinated derivatives of bisphenol A on the level of serum vitellogenin in Japanese medaka (*Oryzias latipes*). Water Science & Technology 50:125-132.
Call Number: W 11434 PDF
Abstract: 2,2-bis (4-hydroxyphenyl) propane or Bisphenol A (BPA), has been reported to behave as an endocrine disrupter below acute toxic levels, and is widely present in the water environment. Although BPA is easily chlorinated, very little is reported on the effect of chlorinated BPA to the aquatic organisms. In this study, the estrogenic activities of BPA and its chlorinated derivatives were evaluated by the induction of vitellogenin (VTG) in the serum of mature male Japanese medaka. In addition, the effect of sodium hypochlorite on the decomposition of BPA was tested. The relative potencies of estrogenic activities of chlorinated BPA descended in the order 3,3'-diCIBPA>BPA> or =3-CIBPA>3,3',5-triCIBPA, and no estrogenic activity was observed in 3,3',5,5'-tetraCIBPA. Lowest Observed Effect Concentration (LOEC) and No Observed Effect Concentration (NOEC) for both 3-CIBPA and 3,3'-diCIBPA were 500 microg/L and 200 microg/L, respectively. LOEC for 3,3',5-triCIBPA was >500 microg/L. When BPA was reacted with sodium hypochlorite (24 hours; residual chlorine at 1 ppm), however, complete decomposition of BPA and its chlorinated derivatives was observed. The decrease in BPA and its chlorinated derivatives paralleled the decrease in estrogenic potency evaluated by the induction of vitellogenin (VTG) in the serum of mature male Japanese medaka.

Takahashi A, Higashitani T, Yakou Y, Saitou M, Tamamoto H, Tanaka H. 2003. Evaluating bioaccumulation of suspected endocrine disruptors into periphytons and benthos in the Tama River. Water Science & Technology 47:71-76.
Call Number: W 11484 PDF only
Abstract: There are two major routes through which fish are exposed to endocrine disruptors (EDs); one route is through water that is a habitat; the other is through aquatic food such as algae and benthos. Few studies on the bioaccumulation of EDs in food have been conducted. Therefore, we evaluated the concentration in food of nonylphenol (NP), bisphenol A (BPA) and 17beta-estradiol (E-2), which were frequently detected in river water and in final discharge of Wastewater Treatment Plants (WWTPs) in Japan. We also evaluated the estrogenicity of samples using recombinant yeast. NP concentrations ranged 0.1-0.4 mug/L in the river water, while they ranged 8-130 mug/kg-wet in the periphytons and 8-140 mug/kg-wet in the benthos. BPA concentrations ranged 0.02-0.15 mug/L in the river water, while they ranged 2-8.8 mug/kg-wet in the periphytons and 0.3-12 mug/kg-wet in the benthos. E-2 concentrations ranged 0.0001-0.0076 mug/L in the water, while they ranged 0.09-2.26 mug/kg-wet in the periphytons and <0.01-0.22 mug/kg-wet in the benthos. The estrogenicity ranged 0.0001-0.0464 mug-E-2-equivalent/L in the water, while it ranged 3.4-66.8 mug-E-2-equivalent/kg-wet in the periphytons and 7.4-5458 mug-E-2-equivalent/kg-wet in the benthos. Bioaccumulation factors of NP are estimated as 160-650 for the periphytons, and 63-990 for the benthos, respectively. Bioaccumulation factors of BPA are estimated as 18-650 for the periphytons, and 8-170 for the benthos, respectively. Bioaccumulation factors of E-2 are estimated as 64-1,200 for the periphytons, and 100-160 for the benthos, respectively. The ratios of the periphytons and the benthos to the water in terms of the estrogenicity were larger than those in terms of the

chemicals. In particularly, the ratio of the benthos to the water is about 10(6) in the maximum. The results suggest that food may be a more important route for fish exposed to EDs in water environment.

Takao Y, Lee HC, Ishibashi Y, Kohra S, Tominaga N , Arizono K. 1999. Fast screening method for bisphenol A in environmental water and in food by solid-phase microextraction (SPME). Japanese Journal of Toxicology & Environmental Health 45:P39.
Call Number: W 06979
Abstract: Extraction of bisphenol A by Solid-Phase Microextraction on polyacrylate fibers at a pH less than 2.0 was found to have a detection limit of 2.0 ppb and an identification limit of 0.1 ppb.

Tatarazako N, Takao Y, Kishi K, Onikura N, Arizono K, Iguchi T. 2002. Styrene dimers and trimers affect reproduction of daphnid (*Ceriodaphnia dubia*). Chemosphere 48:597-601.
Call Number: W 10373
Abstract: The endocrine disruptor activity of styrene in humans and other vertebrates appears to be negligible. However, offspring numbers were reduced in Ceriodaphnia dubia bred in polystyrene cups. Styrene dimers and trimers were found to be eluted from the polystyrene cups by hexane and methanol with gas chromatography-mass spectrometry. Styrene dimers and trimers at concentrations of 0.04-1.7 microg/l affected C. dubia fertility (25% reduction after seven days), suggesting that styrenes have the potential to impair crustacean populations in the aquatic environment.

Tollefsen KE. 2002. Interaction of estrogen mimics, singly and in combination, with plasma sex steroid-binding proteins in rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology 56:215-225.
Call Number: W 09721
Abstract: The plasma sex steroid-binding protein (SBP) is believed to be involved in regulating circulating endogenous sex steroids as well as cellular signal transduction to nuclear steroid receptors in sex steroid-sensitive tissues. In this study, a variety of estrogen mimics (EMs), which may contribute to the endocrine disrupting effects observed in fish, were tested for the ability to interact with the rainbow trout plasma sex steroid-binding protein (rtSBP) either singly or in binary combinations. The EMs ethynylestradiol, diethylstilbestrol, 4-hydroxytamoxifen, genistein, zearalenone, 4-t-octylphenol, bisphenol A and o,p'-DDT were all able to displace 1,2,4,6,7-[H-3]estradiol from the sex steroid-binding site at the rtSBP (K-d = 2.1 +/- 0.5 nM, B-max = 2963 +/- 303 fmol estradiol/mg protein) in a dose-dependent and competitive manner. The plastizicer n-butyl benzyl phthalate only displayed weak binding affinity for the rtSBP, whereas the pesticide dieldrin was not able to compete for the high affinity estradiol-binding sites in plasma. None of the compounds tested was able to clearly promote the binding of the others when given in combination, indicating that synergy did not occur at the ligand-SBP binding level. The rtSBP binding affinity for EMs ranged over several orders of magnitude, but were consistently lower than those for the endogenous sex steroids (about 10(2)-10(6) less potent). The results suggest that the presence of rtSBP may potentially modulate the bioavailability of EMs to estrogen receptors relative to each other and to the endogenous sex steroids themselves. Since the binding of the endogenous ligands is reversible, SBP-bound estrogens (or androgens) potentially may also become displaced by potent EMs.

Tsuda T, Suga K, Kaneda E, Ohsuga M. 2002. 4-nonylphenol, 4-nonylphenol mono- and diethoxylates, and other 4-alkylphenols in water and shellfish from rivers flowing into Lake Biwa. Bull Environ Contam Toxicol 68:126-131.
Call Number: W 09658
Abstract: Shellfish from the Fujima and Siratori Rivers (tributaries to Lake Biwa)

Watanabe M, Mitani N, Ishii N, Miki K. 2005. A mutation in a cuticle collagen causes hypersensitivity to the endocrine disrupting chemical, bisphenol A, in *Caenorhabditis elegans*. Mutation Research-Fundamental & Molecular Mechanisms of Mutagenesis 570:71-80.
Call Number: W 11589 PDF
Abstract: A novel mutant gene, bis-1 (bisphenol A sensitive) has been isolated in the nematode, Caenorhabditis elegans, that affects the response to endocrine disrupting chemicals (EDC). The bis-1 (nx3) allele is hypersensitive to bisphenol A (BPA), is allelic to a collagen gene (col-121), and is expressed in hypodermal cells. Among the collagen mutants so far studied, bis-1(nx3), dpy-2(e8), dpy-7(e88) and dpy-10(e128) showed BPA sensitivity. The isolated mutant may work as a useful tool for the assay of EDC

toxicity since the physiological effect of the collagen mutation (glycine substitution) indicates an increased sensitivity to BPA.
[dose: 1mM]

Watts MM, Pascoe D, Carroll K. 2001. Chronic exposure to 17 alpha-ethinylestradiol and bisphenol A-effects on development and reproduction in the freshwater invertebrate *Chironomus riparius* (Diptera: Chironomidae). Aquatic Toxicology 55:113-124.
Call Number: W 09798
Abstract: The effect of 17 alpha-ethinylestradiol (EE) and bisphenol A (BPA) on development and reproduction in Chironomus riparius was determined over two generations in chronic sediment exposure assays. A number of response criteria were examined in order to identify any chemical- related effects including median emergence times (EmT50), the number and sex ratio of emerged adults, egg production and egg viability. The results showed that emergence time and percentage adult emergence were affected by EE and BPA exposure. These effects were primarily associated with the second generation of test animals, most notably in the BPA study, where the emergence of male and female adults was significantly ($P<0.05$) delayed at concentrations ranging from 78 ng/l to 0.75 mg/l. At very low concentrations (1 ng/l) of EE, both the first and second generation of adults emerged significantly earlier than control animals. No effect on the percentage emergence of first generation adults was evident with either chemical or in the second generation with BPA. The number of egg-ropes produced by the first generation females varied between treatments but no dose-response pattern was evident. Although certain responses were significantly affected, results in general do not suggest that the criteria examined, although validated as indicators of general sediment toxicity, could be used to detect the oestrogenic effects of EE and BPA on C. riparius.

Watts MM, Pascoe D, Carroll K. 2003. Exposure to 17 alpha-ethinylestradiol and bisphenol A--effects on larval moulting and mouthpart structure of *Chironomus riparius*. Ecotoxicology & Environmental Safety 54:207-215.
Call Number: W 11438 PDF
Abstract: The effects of the endocrine-disrupting chemicals 17alpha-ethinylestradiol (EE) and bisphenol A (BPA) on the development of the aquatic life-cycle stages (eggs to pupa) of Chironomus riparius were investigated. The test species was exposed to sublethal concentrations of EE and BPA (10 ng/L-1mg/L) and effects on larval weight and moulting success were recorded. In addition, three mouthpart structures (mentum, mandibles, and pecten epipharyngis) present on the head capsules of fourth-instar larvae were examined for structural deformities. Moulting was delayed and larval wet weight significantly reduced ($P<0.05$) at the highest treatment concentration (1mg/L) of both chemicals. No significant effect on either of these parameters was noted in the remaining treatments. However, deformities in the mouthparts of C. riparius were observed at very low exposure concentrations (10 ng/L), although the incidence of deformities was greater in the chironomids exposed to EE than BPA. Effects were mainly associated with the mentum, with statistically significant differences in median deformity score (Kruskal-Wallis $P<0.001$) recorded for both chemicals. At similar effect concentrations, an increased percentage of exposed animals had deformities of the pecten epipharyngis; however, little evidence of deformity was noted for the mandibles. At high concentrations, where moulting and wet weight were affected, no incidence of mouthpart deformity was noted. The relevance of these results in relation to the identification of an "endocrine-sensitive" endpoint for invertebrates is discussed.

Wintgens T, Gallenkemper M, Melin T. 2003. Occurrence and removal of endocrine disrupters in landfill leachate treatment plants. Water Science & Technology 48:127-134.
Call Number: W 11485 PDF only
Abstract: Endocrine disrupting compounds can affect the hormone system in organisms. Industrial chemicals with estrogenic effects were detected in large quantities in landfill leachates. Membrane technology has proven to be an effective barrier to these substances and thus widely applied in the treatment of landfill leachate. The removal techniques under investigation are membrane bioreactors, nanofiltration, activated carbon adsorption, ozonation as well as reverse osmosis. Investigations were conducted at two different landfill leachate treatment plants with a variety of process configurations. The xenoestrogenic substances nonylphenol and bisphenol A were detected in high mug/L-ranges in raw landfill leachate. Membrane bioreactors (MBRs) were capable of removing more than 80% of the

nonylphenol load. Final effluent concentrations range between 1-12 mug/L nonylphenol and 3-30 mug/L bisphenol A respectively. Reverse osmosis treatment proved to be less effective in nonylphenol and bisphenol A removal than MBRs with further polishing stages like nanofiltration and activated carbon adsorption.

Yamamoto T, Yasuhara A, Shiraishi H, Nakasugi O. 2001. Bisphenol A in hazardous waste landfill leachates. Chemosphere 42:415-418.
Call Number: W 08407
Abstract: The levels of bisphenol A in hazardous waste landfill leachates collected in Japan in 1996 were determined by gas chromatograph/mass spectrometer (GC/MS). Bisphenol A was found in seven of 10 sites investigated. All the hazardous waste landfills with leachates contaminated by bisphenol A were controlled. The concentrations of bisphenol A ranged from 1.3 to 17,200 mug/l with a median concentration of 269 mug/l. The source of bisphenol A in landfill leachates may be the waste plastics in waste landfill. The concentrations of bisphenol A in some samples exceeded the EC50 or LC50 levels for aquatic biota. Landfill leachates may be a significant source of bisphenol A found in the environment.

Yokota H, Tsuruda Y, Maeda M, Oshima Y, Tadokoro H, Nakazono A, Honjo T, Kobayashi K. 2000. Effect of bisphenol A on the early life stage in Japanese medaka (*Oryzias latipes*). Environmental Toxicology & Chemistry 19:1925-1930.
Call Number: W 07917
Abstract: Japanese medaka (Oryzias latipes) were exposed to bisphenol A (BPA) at the sublethal concentrations of 2.28, 13.0, 71.2, 355, and 1,820 mu g/L (as mean measured concentrations) in the early life stage from fertilized eggs to 60-d posthatch. Except for the growth and sexual differentiation of the fish at 60-d posthatch, no effects were observed on hatching success and time to hatching in embryological stage and on mortality and abnormal behavior and appearance in hatched larvae. The growth of the fish was suppressed with increasing BPA concentrations, resulting in significant differences in both the total length and body weight of medaka at 1,820 mu g/L compared with the controls. When observed for their external secondary sex characteristics, no males were identified in the 1,820-mu g/L treatment. In addition, histological examination showed that 32% of fish in the 1,820-mu g/L group had testis-ova composed of both testicular germ cells and oocytes. Consequently, the lowest effective concentration for the early life stage of medaka was between 355 and 1,820 mu g/L. Since the environmental concentrations of BPA are usually three orders lower than the lowest effective concentration, BPA alone may not affect the early life stage of wild fish populations.

Phthalates - Non-Marine

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Call Number: W 07927

Belfroid AC, Murk AJ, de Voogt P, Schafer AJ, Rijs GBJ, Vethaak AD. 1999. Hormoonontregelaars in water: Oriënterende studie naar de aanwezigheid van oestrogeen-actieve stoffen in watersystemen en afvalwater in Nederland.: Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat; Rijkssinstituut voor Integraal Zoetwaterbeheer; Rijkssinstituut voor Kust en Zee. RIZA rapport: 99.007; RIKZ rapport: 99.024.
Call Number: W 07942
Abstract: The presence of endocrine-disruping compounds in the environment is currently the focus of a substantial amount of attention, both within the Netherlands and internationally. Generally speaking, it is difficult to establish causal relationships between the presence of endocrine-disrupting compounds in the environment and the occurrence of any such effect. Nevertheless, disruption of reproduction associated with exposure to these compounds has in the past and recently been reported from a range of organisms in aquatic ecosystems in the Netherlands and other countries of western Europe. These findings led the Netherland Health Council to conclude that there is reason for concern about the presence in the aquatic environment of endocrine-disrupting compounds, which may represent a threat to the continued existence of populations of some species. Included are tables showing the range of concentrations of estrogenic hormones, bispenol A, total phthalates and alkylphenols in each matrix and the estrogenic potency.

Brown D, Croudace CP, Williams NJ, Shearing JM, Johnson PA. 1998. The effect of phthalate ester plasticisers tested as surfactant stabilised dispersions on the reproduction of the *Daphnia magna*. Chemosphere 36(6):1367-1379.
Call Number: W 05558
Abstract: The phthalate ester plasticisers, di-2-ethylhexyl phthalate (DEHP), di-iso-nonyl phthalate (DINP), DINP produced by the "polygas" process (DINP-PG), di-n-nonyl/n-undecyl phthalate (L911P), di-n-octyl/n-decyl phthalate (L810P), di-iso-decyl phthalate (DIDP), di-iso-heptyl phthalate (DIHP), di-n-hexyl/n-decyl phthalate (L610P), di-undecyl phthalate (DUP), di-heptyl/nonyl phthalate (L79P), di-iso-undecyl phthalate (DIUP) and di-iso-tridecyl phthalate (DTDP) have been tested for acute and chronic toxicity to Daphnia magna. In addition, di-2-propylheptyl phthalate (DPHP) has been tested for chronic toxicity to Daphnia magna. The test organisms were exposed at a nominal concentration of 1 mg phthalate per litre presented as a dispersion with either "Tween 20" or "Marlowet R40". For the chronic studies, the nominal concentrations were verified by analysis, except for the L911P where, due to chromatographic difficulties, the test concentration could not be determined and this was estimated as 56% of nominal by analysis of the stock. The exposure period for the acute studies was 48 hours and the test organisms were monitored for notation in the surface layer and mortalities. The chronic studies were conducted over 21 days. The end points were the numbers of young produced, survival of the parent animals and the length of the parent animals at the end of the 21 day exposure period. No significant negative effects, relative to the controls, were seen in either the acute or the chronic studies.

Brown D, Thompson RS, Stewart KM, Croudace CP, Gillings E. 1996. The effect of phthalate ester plasticisers on the emergence of the midge (*Chironomus riparius*) from treated sediments. Chemosphere 32(11):2177-2187.
Call Number: W 01031
Abstract: Sediment toxicity tests with the midge, Chironomus riparius, were carried out in a natural river sediment spiked with either di-2-ethylhexyl phthalate (DEHP) or di-isodecyl phthalate (DIDP). The phthalates were each dosed at three levels in the sediment up to 10000 mg phthalate/kg (dry weight basis) and the test organisms were introduced as larvae (< 24 hours post-hatch). No effects, in any of the treatments, were found on the development of the midge based on a comparison with the controls of the numbers and sex of the emerging adults. Sediment concentrations were measured at the start and finish of the study (28 day period) and good agreement with the nominal levels was found. Accumulation of the phthalates and any metabolites was determined on a sample of the emerging adults by measuring their

radioactivity from the C-14-labelled test substances. A biota to sediment accumulation factor of 1.5 and 0.6 was found for DEHP and DIDP, respectively.

Brown V. 2004 Mar 22. New chemical issues and their impacts on the Great Lakes Basin ecosystem. Ms.
Call Number: W 11215
Abstract: There is no longer any doubt that man-made chemicals are now found throughout the world, both in places where they were intentionally used and in places where they have never been applied. Man-made chemicals are also found in the tissues of living organisms ranging from microbes to top vertebrate predators, in every climate, on land and sea and in the air. While there continue to be some doubts as to the type and extent of the biological harm these chemicals may inflict, there is stong evidence that some chemicals are indeed toxic to living organisms and ecosystems. Researchers have moved beyond the idea of acute toxicity and are beginning to explore the effects of low doses, chronic exposures, mixtures of chemicals, and the consequences of chemical exposures combined with other influences such as climatic shifts, hormonal cycles and diet. This paper summarizes recent research on emerging chemicals of concern, namely: perfluorinated compounds; polybrominated diphenyl ethers; phthalates; pharmaceuticals, including antibiotics; and pesticides and their effects on humans and wildlife. In many cases the research is still preliminary, and may not have progressed beyond in vitro tests; however, given what is known about other chemicals such as PCBs and certain pesticides that are known to be POPs and endocrine disruptors, the newer chemicasl may require similar scrutiny and regulation.

Call DJ, Cox DA, Geiger DL, Genisot KI, Markee TP, Brooke LT, Polkinghorne CN, VandeVenter FA, Gorsuch JW, Robillard KA, Parkerton TF, Reiley MC, Ankley GT, Mount DR. 2001. An assessment of the toxicity of phthalate esters to freshwater benthos. 2. Sediment exposures. Environmental Toxicology & Chemistry 20(8):1805-1815.
Call Number: W 08983
Abstract: Seven phthalate esters were evaluated for their 10-d toxicity to the freshwater invertebrates Hyalella azteca and Chironomus tentans in sediment. The esters were diethyl phthalate (DEP), di-n-butyl phthalate (DBP), di-n-hexyl phthalate (DHP), di-(2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP), diisodecyl phthalate (DIDP), and a commercial mixture of C7, C9, and C11 isophthalate esters (711P). All seven esters were tested in a sediment containing 4.80% total organic carbon (TOC), and DBP alone was tested in two additional sediments with 2.45 and 14.1% TOC. Sediment spiking concentrations for DEP and DBP were based on LC50 (lethal concentration for 50% of the population) values from water-only toxicity tests, sediment organic carbon concentration, and equilibrium partitioning (EqP) theory. The five higher molecular weight phthalate esters (DHP, DEHP, DINP, DIDP, 711P), two of which were tested and found to be nontoxic in water-only tests (i.e., DHP and DEHP), were tested at single concentrations between 2,100 and 3,200 mg/kg dry weight. Preliminary spiking studies were performed to assess phthalate ester stability under test conditions. The five higher molecular weight phthalate esters in sediment had no effect on survival or growth of either C. tentans or H. azteca, consistent with predictions based on water-only tests and EqP theory. The 10-d LC50 values for DBP and H. azteca were >17,400, >29,500, and >71,900 mg/kg dry weight for the low, medium, and high TOC sediments, respectively. These values are more than 30x greater than predicted by EqP theory and may reflect the fact that H. azteca is an epibenthic species and not an obligative burrower. The 10-d LC50 values for DBP and C. tentans were 826, 1,664, and 4.730 mg/kg dry weight for the low, medium, and high TOC sediments, respectively. These values are within a factor of two of the values predicted by EqP theory. Pore-water 10-d LC50 values for DBP (dissolved fraction) and C. tentans in the three sediments were 0.65, 0.89, and 0.66 of the water-only LC50 value of 2.64 mg/L, thereby agreeing with EqP theory predictions to within a factor of 1.5. The LC50 value for DEP and C. tentans was >3,100 mg/kg dry weight, which is approximately 10x that predicted by EqP theory. It is postulated that test chemical loss and reduced organism exposure to pore water may have accounted for the observed discrepancies with EqP calculations for DEP.

Call DJ, Markee TP, Geiger DL, Brooke LT, VandeVenter FA, Cox DA, Genisot KI, Robillard KA, Gorsuch JW, Parkerton TF, Reiley MC, Ankley GT, Mount DR. 2001. An assessment of the toxicity of phthalate esters to freshwater benthos. 1. Aqueous exposures. Environmental Toxicology & Chemistry 20(8):1798-1804.
Call Number: W 08982
Abstract: Tests were performed with the freshwater invertebrates Hyalella azteca, Chironomus tentans, and Lumbriculus variegatus to determine the acute toxicity of six phthalate esters, including dimethyl phthalate

(DMP), diethyl phthalate (DEP), di-n-butyl phthalate (DBP), butylbenzyl phthalate (BBP), di-n-hexyl phthalate (DHP), and di-2-ethylhexyl phthalate (DEHP). It was possible to derive 10-d LC50 (lethal concentration for 50% of the population) values only for the four lower molecular weight esters (DMP, DEP, DBP, and BBP), for which toxicity increased with increasing octanol-water partition coefficient (Kow) and decreasing water solubility. The LC50 values for DMP, DEP, DBP, and BBP were 28.1, 4.21, 0.63, and 0.46 mg/L for H. azteca; 68.2, 31.0, 2.64, and > 1.76 mg/L for C. tentans; and 246, 102, 2.48, and 1.23 mg/L for L. variegatus, respectively. No significant survival reductions were observed when the three species were exposed to either DHP or DEHP at concentrations approximating their water solubilities.

Carr KH, Coyle GT, Kimerle RA. 1997. Bioconcentration of [^{14}C]butyl benzyl phthalate in bluegill sunfish (*Lepomis macrochirus*). Environmental Toxicology & Chemistry 16(10):2200-2203.
Call Number: W 05211
Abstract: A short-term study was conducted to measure the bioconcentration factors for intact butyl benzyl phthalate (BBP) in whole fish, fillet (edible tissues), and viscera (non-edible) tissues of bluegill sunfish (Lepomis macrochirus). A group of 24 fish was exposed for 3.27 d to [C-14] BBP in a dynamic system. Intact BBP was quantified by chromatographic analyses for each tissue fraction. Significant metabolism of BBP was observed in the fish, with intact BBP representing less than 3% of the total radioactivity in each type of tissue. Measured bioconcentration factors (BCFs) for intact BBP (normalized to 6% lipid) were 9.4 (whole fish), 8.7 (viscera), and 1.7 (fillet). These BCFs were considerably lower than previously published BCF values, which were based on total radioactive residues in whole fish.

Christiansen LB, Pedersen KL, Korsgaard B, Bjerregaard P. 1998. Estrogenicity of xenobiotics in rainbow trout (*Oncorhynchus mykiss*) using in vivo synthesis of vitellogenin as a biomarker. Marine Environmental Research 46:137-140 .
Call Number: W 09277
Abstract: The estrogenicity of several xenobiotics was evaluated using *in vivo* vitellogenin (Vtg) synthesis in immature rainbow trout as a biomarker. 17β-estradiol, DES and ethinyl estradiol were tested as positive controls. The xenobiotic compounds tested were technical nonylphenol, bisphenol A, butylbenzylphthalate (BBP) and dibutylphthalate (DBP). Measurements of the Vtg concentration was performed with a direct sandwich ELISA. 17β-estradiol, DES and ethinyl estradiol caused up to 100,000-fold increased in the Vtg-levels. Nonylphenol and bisphenol A had the highest estrogenic potency of the xenobiotics increasing the vitellogenin level approximately 300-fold while BBP was only weakly estrogenic, increasing the concentration about 3 times. DPB did not raise the vitellogenin concentration above the detection limit.

Christiansen LB, Pedersen KL, Pedersen SN, Korsgaard B, Bjerregaard P. 2000. In vivo comparison of xenoestrogens using rainbow trout vitellogenin induction as a screening system. Environmental Toxicology & Chemistry 19(7):1867-1874.
Call Number: W 07910
Abstract: Vitellogenin induction in rainbow trout after intraperitoneal injection of test compounds was investigated. Vitellogenin quantification was performed by a direct sandwich enzyme-linked immunosorbant assay (ELISA) based on polyclonal, affinity purified antibodies. The system was used as a short-term in vivo screen for estrogenicity and as a tool for establishing the priority of compounds to be tested by water exposure of fish. Representatives from the group of xenoestrogens, bisphenols, phthalates, and pesticides were tested. The relative potency order bisphenol A > bisphenol A dimethacrylate, o,p'-DDT > butylbenzylphthalate was established, while no significant vitellogenin response was seen with dibutylphthalate, tetrabromobisphenol A, and methoxychlor. Of these, tetrabromobisphenol A has not previously been tested for estrogenicity in vivo. Earlier findings of diminished estrogenic activity of ortho-substituted compounds was extended to bisphenols since ortho-bromination of bisphenol A abolished the activity of the parent molecule.

Christiansen LB, Winther-Nielsen M, Helweg C. 2002. Feminisation of fish: The effect of estrogenic compounds and their fate in sewage treatment plant and nature.: Danish Environmental Protection Agency, Danish Ministry of the Environment. Environmental Project (Miljøprojekt) No. 729.
Call Number: W 11440 PDF only

do Nascimento Filho I, von Mühlen C, Schossler P, Caramão EB. 2003. Identification of some plasticizers

compounds in landfill leachate. Chemosphere 50(5):657-663.
Call Number: W 10646
Abstract: In this work it was described a simple method for extraction of plasticizer compounds (mainly phthalate esters and bisphenol A (BPA)) from landfill leachate samples. The samples were submitted to an extraction procedures based on precipitation, solid phase extraction (SPE) and ionic exchange chromatography (IEC). Firstly the landfill leachate sample was acidified by addition of HCl concentrated, in order to precipitate the organic compounds that are less soluble in water. The precipitate was washed with several solvents. The aqueous phase was then submitted to SPE with XAD-4 resin and IEC with Amberlyst A-27 resin. The instrumental analysis was performed by gas chromatography with mass spectrometer detector (GC/MSD) and the compounds were identified by the GC/MSD library (Wiley) and by using some standard substances. These methodologies allow the isolation and identification of the following compounds: dioctylphthalate, diisobutilphthalate, BPA, benzoic acid, palmitic acid and diisopentylphthalate. The methods are very simple, rapid and selective, for plasticizers extraction from landfill leachate matrices.

Feenstra S, Cherry JA. 1988. Subsurface contamination by dense non-aqeous phase liquid (DNAPL) chemicals. presented at. The International Groundwater Symposium, International Association of Hydrogeologists, May1-4, 1988. Halifax, Nova Scotia.
Call Number: W 08415
Abstract: Substances such as many halogenated solvents and PCBs comprise a group of organic chemicals which, in their pure form, can be categorized as dense non-aqueous phase liquid (DNAPL) chemicals. DNAPL chemicals are analogous to petroleum hydrocarbon in that they arer immiscible in water, but DNAPL chemicals have densities which are greater than that of water. Approximately one quarter of the organic chemicals on the US EPA List of Priority Pollutants are DNAPL chemicals at typical subsurface temperatures. DNAPL in the subsurface can comprise a very significant source of groundwater contamination. The potential for subsurface contamination of DNAPL chemicals is significant because large quantities of such chemicals (especially chlorinated solvents) are used in many parts of our modern society. The occurrence of spills during production, transportation and utilization if virtually inevitable. Although DNAPL chemicals are immiscible in water, their solubilities (typically 100 to 5000 mg/L) can often be many orders of magnitude higher than their respective drinking water standards. The combination of immisciblity and high density enables DNAPL released to the subsurface to pentrate downward as a separate non-aqueous phase through both the vadose (unsaturated) zone and the groundwater (saturated) zone. The tendency for DNAPL chemicals to sink through the groundwater zone differs from that of petroleum hydrocarbons which will float on the groundwater zone due to their lower density. In the subsurface, small but significant quantities of chemicals can be dissolved by the groundwater in contact with the DNAPL and can result in groundwater contamination. For many chemicals, the dissolved contaminants derived from the DNAPL can be highly mobile in groundwater because they are not strongly sorbed on geological material or attenuated by chemical or biological degradation. The presence of DNAPL chemicals in the subsurface in the form of residual concentrations retained on the soil or rock, or as pools or pure product will have enormous implications with regard to the investigation and control of groundwater contamination at chemical spill sites and waste disposal facilities. The migration of dissolved chemical plumes from DNAPL sources may be contained or controlled by other remedial measures, but groundwater contamination cannot be eliminated in the long-term without removal of the DNAPL source. Where shallow DNAPL sources can be located adequately and are accessible, it may be possible to remove the DNAPL sources by excavation. In most situations, excavation of the DNAPL source will not be possible. At the present time, there are no methods available which have been demonstrated to be effective in field situations for the removal of DNAPL sources from the subsurface. Further research is needed to develop such methods in order to provide long-term solutions to groundwater contamination problems from DNAPL chemicals. Regulatory agencies and industry must recognize the unique and exceptionally difficult nature of the problem posed by DNAPL chemicals in the subsurface in order to avoid futile or ill-conceived attempts to achieve aquifer cleanup.

Fromme H, Kuechler T, Otto T, Pilz K, Mueller J, Wenzel A. 2002. Occurrence of phthalates and bisphenol A and F in the environment. Water Research 36(6):1429-1438.
Call Number: W 10054
Abstract: Certain xenoestrogens, namely bisphenol A (BPA), bisphenol F (BPF), butylbenzyl phthalate

(BBP), dibutyl phthalate (DBP), and di(2-ethylhexyl)phthalate (DEHP), were measured in various compartments (surface water, sediments, sewage treatment plant effluents, sewage sludge, dump water, liquid manure) in order to contribute to a better understanding of exposure to these compounds in different environments.
Hundred and sixteen surface-water samples and 35 sediments from river, lakes and channels, 39 sewage effluents, and 38 sewage sludges were collected in Germany. Furthermore, ten liquid manure, two waste-dump and two compost-runoff water samples were also analysed.
BPA measurements showed low concentrations from 0.0005 to 0.45 ug/L in surface water, in sewage effluents from 0.018 to 0.702 ug/L, in sediments from 0.01 to 0.19 mg/kg and in sewage sludge from 0.004 to 1.363 mg/kg dw. Measured concentrations of BPF were clearly lower than BPA in all environmental media.
DEHP dominated the phthalate concentrations, which ranged from 0.33 to 97.8 ug/L (surface water), 1.74 to 182 ug/L (sewage effluent), 27.9 to 154 mg/kg dw (sewage sludge) and 0.21 to 8.44 mg/kg (sediment). DBP was found only in minor concentrations and BBP, only in a few samples in low amounts. Very high concentrations of BPA and phthalates were confirmed in waste dump water and compost water samples as well as in the liquid manure samples.

Goodbred S, Gilliom R, Gross T, Denslow N, Bryant W , Schoeb T. 1997. Reconnaissance of 17β-estradiol, 11-ketotestosterone, vitellogenin, and gonad histopathology in common carp of United States streams: Potential for contaminant-induced endocrine disruption. U.S. Geological Survey :1-47.
Call Number: W 05446
Abstract: A reconnaissance of sex steroid hormones and other biomarkers in comon carp was used to assess whether endocrine disruption may be occurring in fish in United States, streams, to evaluate relations between endocrine disruption and contaminant levels, and to determine requirements for further studies. 17B-estradiol, 11-Ketotestosterone, vitellogenin, and gonadal histopathology were measured in adult carp (usually 10-15 for each sex) at 25 sites (647 fish), representing a wide range of environmental settings typical of major regions of the nation. Fish were collected during August-December 1994, a period of gonadal maturation after spawning. Contaminants evaluated were organochlorine pesticides and polychlorinated biphenyls in tissue; phthalates, phenols, and polycyclic aromatic bydrocarbons in bed sediment; and dissolved pesticides in water. Mean site concentrations of steroid hormones spanned two orders of magnitude for both sexes. no significant regional differences in steroid hormones were detected for males, but females from the Northern and Southern Midcontinent were significantly different form other regions of the country in one or both hormones. Within all regions there were significant differences between sites in one or both hormones for both sexes. Most correlation coefficients between biomarkier and contaminants were negative. Contaminants that had significant (a-0.05) correlations with biomarkers were organochlorine pesticides, phenols, and dissolved pesticides. The strongest pattern common to both males and females was a negative correlation between the hormone ratio (E2/11-KT) and dissolved pesticides. The significant site-to-site difference in biomarkers, and the presenceof significant correlations betweenn biomarkers and contaminants, are evidence that fish in some streams may be experiencing endocrine disuprtion is actually occurring and if there are reproductive effects on individual or populations of carp or other species. Future studies should shift to more intensive study of fewer sites, including reference and contaminated, sites, in order to address these additional question

Goodbred S, Gilliom RJ, Gross TS, Denslow NP, Bryant WL, Schoeb TR. 1997 Apr 29. Reconnaissance of 17<beta>-estradiol, 11-ketotestosterone, vitellogenin, and gonad histopathology in common carp of United States streams: Potential for contaminant-induced endocrine disruption: U.S. Geological Survey. Open-File Report 96-627.URL: http://ca.water.usgs.gov/pnsp/rep/carp2/.
Call Number: W 11241 PDF of webpages *
Abstract: A reconnaissance of sex steroid hormones and other biomarkers in common carp was used to assess whether endocrine disruption may be occurring in fish in United States streams, to evaluate relations between endocrine disruption and contaminant levels, and to determine requirements for further studies. 17ß-estradiol, 11-ketotestosterone, vitellogenin, and gonadal histopathology were measured in adult carp (usually 10--15 for each sex) at 25 sites (647 fish), representing a wide range of environmental settings typical of major regions of the nation. Fish were collected during August--December 1994, a period of gonadal maturation after spawning. Contaminants evaluated were organochlorine pesticides and polychlorinated biphenyls in tissue; phthalates, phenols, and polycyclic aromatic hydrocarbons in bed

sediment; and dissolved pesticides in water. Mean site concentrations of steroid hormones spanned two orders of magnitude for both sexes. No significant regional differences in steroid hormones were detected for males, but females from the Northern and Southern Midcontinent were significantly different from other regions of the country in one or both hormones. Within all regions there were significant differences between sites in one or both hormones for both sexes. Most correlation coefficients between biomarkers and contaminants were negative. Contaminants that had significant (a=0.05) correlations with biomarkers were organochlorine pesticides, phenols, and dissolved pesticides. The strongest pattern common to both males and females was a negative correlation between the hormone ratio (E2/11-KT) and dissolved pesticides. The significant site-to-site differences in biomarkers, and the presence of significant correlations between biomarkers and contaminants, are evidence that fish in some streams may be experiencing endocrine disruption. Improved information is needed to evaluate whether endocrine disruption is actually occurring and if there are reproductive effects on individual or populations of carp or other species. Future studies should shift to more intensive study of fewer sites, including reference and contaminated sites, in order to address these additional questions.

Gray LE. 1998. Xenoendocrine disrupters: Laboratory studies on male reproductive effects. Toxicol Lett 103:331-335.
Call Number: W 06514
Abstract: Wildlife from ecosystems contaminated with endocrine disrupting chemicals (EDCs) display a variety of reproductive alterations including cryptorchidism in the Florida panther, small baculum in young male otters, small penises in alligators, sex reversal in fish, and altered social behavior in birds. It has been proposed that EDCs also may have contributed to increases in testicular cancer and hypospadias and the reported decline in human sperm counts. Combined in vivo and in vitro studies are necessary to fully characterize EDC induced alterations of reproduction. We have identified several pesticides (vinclozolin, procymidone, p,p'-DDE) which bind rat and human androgen receptors, block androgen-induced gene expression in vitro and in vivo, delay puberty, reduce sex accessory gland size and alter sex differentiation in the male rat. Some of the phthalates, which are estrogenic in vitro but not in vivo, cause malformations in male rats that appear to result from antagonism of androgens in utero. In contrast, xenoestrogens affect male offspring but they are not malformed or infertile. Prenatal administration of an Ah receptor agonist (2,3,7,8-TCDD or PCB 169) produces a different spectrum of effects including reduced ejaculated sperm numbers in male rats.

Gray LE Jr., Ostby J, Wolf C, Lambright C, Kelce W. 1998. The value of mechanistic studies in laboratory animals for the prediction of reproductive effects in wildlife: Endocrine effects on mammalian sexual differentiation. Environmental Toxicology & Chemistry 17(1):109-118.
Call Number: W 05394
Abstract: Wildlife populations from contaminated ecosystems display a variety of reproductive alterations, including cryptorchidism in the Florida panther, small baculum in young male otters, small penises in alligators, sex reversal in fish, and altered social behavior in birds. The formation of biologically plausible hypotheses regarding disruption of reproduction in wildlife can be facilitated by mechanistic studies on laboratory animals. To this end, we are investigating the in vivo and in vitro effects of endocrine-disrupting toxicants in rodents. In vitro studies have used receptor binding and transfected cell assays to confirm the suspected mechanism of action, whereas in vivo rodent studies examine altered sexual differentiation. Antiandrogenic pesticides compete with the natural ligands for both rat and human androgen receptors, block androgen-induced gene expression in vitro and in vivo, delay puberty, reduce sex accessory gland size, and alter male rat sex differentiation. In contrast, xenoestrogens affect female central nervous system sex differentiation and fecundity without producing malformations or infertility in-male offspring. Prenatal administration of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) or the TCDD-like polychlorinated biphenyls produce yet another profile of effects in the offspring, reducing numbers of ejaculated sperm in male progeny and inducing urogenital malformations in females. Although phthalates are reported to be estrogenic in vitro, in vivo exposure causes developmental alterations that more closely resemble antiandrogenic activity. The mammalian data indicate that exposure to endocrine-disrupting chemicals produces effects that are pathognomonic for mechanisms by which they act. Mechanistic information derived from mammalian studies can enhance our ability to predict toxicant effects on reproduction in fish and wildlife.

Gu MB, Min J, Kim EJ. 2002. Toxicity monitoring and classification of endocrine disrupting chemicals (EDCs) using recombinant bioluminescent bacteria. Chemosphere 46(2):289-294.
Call Number: W 09707
Abstract: A recombinant bioluminescent Escherichia coli, DPD2794, containing the recA promoter region fused to luxCDABE originating from Vibrio fischeri was used for detecting genotoxicity caused by endocrine disrupting chemicals (EDCs) to cells. As well, several other recombinant bioluminescent bacteria, including TV1061, which is sensitive to protein damage (grpE::luxCDABE), DPD2511, sensitive to oxidative damage (katG::luxCDABE), and DPD2540, sensitive to membrane damage (fabA::luxCDABE), were used for evaluating other possible modes of toxicity. It was found that the recombinant bacteria could monitor the toxic effect, not estrogenic effect, due to the presence of various EDCs through the measurement of bioluminescence (BL) and cell growth rate, which depend upon the type of toxicity occurring and which of the four strains was used. In addition, it was found that the damage caused by EDCs can be classified into several groups upon their mechanisms of toxic action.

Guidotti M, Giovinazzo R, Cedrone O, Vitali M. 2000. Determination of organic micropollutants in rain water for laboratory screening of air quality in urban environment. Environment International 26:23-28.
Call Number: W 08416
Abstract: Rain water may collect organic air pollutants, such as polycyclic aromatic hydrocarbons (PAHs), phthalate ester (PEs), pesticides, and polychlorinated biphenyls (PCBs), that could be present in air in consequence of different factors. The determination of these compounds in rain water samples consequently may be interesting for a first screening of air quality in urban and/or industrial areas. For this purpose, 3 areas of the city of Rieti (central Italy) were selected for rain water sampling: a) the city center, densely populated and with high road traffic; b) a suburban residential area; c) the industrial area, about 3 km out of the city center and along the state road. Wet-only precipitation collectors were used for sampling; solid-phase microextraction or liquid-liquid microextraction techniques followed by CG/MS determinations were applied for sample analysis. PCBs and pesticides were never found in the samples collected. On the contrary, some polycyclic aromatic hydrocarbons and phthalates were always found. Significant and seasonal differences in PAH levels were observed in the 3 different sampling areas, with higher values always found in the city center and during the winter period; on the contrary, PEs levels remained unchanged.

Harries JE, Janbakhsh A, Jobling S, Matthiessen P, Sumpter JP, Tyler CR. 1999. Estrogenic potency of effluent from two sewage treatment works in the United Kingdom. Environmental Toxicology & Chemistry 18(5):932-937.
Call Number: W 06908
Abstract: Rainbow trout were exposed for 3 weeks (in a Row-through system) to various dilutions of treated effluent (25, 50. 75, and 100%) from Harpenden and Chelmsford sewage treatment works (STW) during November 1994 and August 1996, respectively, and the induction of plasma vitellogenin was measured. Significant ($p < 0.05$) increases in plasma vitellogenin concentrations occurred in fish held in affluent from Harpenden STW at concentrations of 50% and above. At Chelmsford STW, the effluent appeared to be more potent. causing induction of vitellogenin in fish at concentrations as low as 25% (compared with 50% for the Harpenden effluent). Exposure to lower concentrations of effluent emanating from Chelmsford in April of the following year indicated that estrogenic activity was diluted to no-effect levels at this STW at concentrations between 12 and 25%.

Harries JE, Runnalls T, Hill E, Harris CA, Maddix S , Sumpter JP, Tyler CR. 2000. Development of a reproductive performance test for endocrine disrupting chemicals using pair-breeding fathead minnows (*Pimephales promelas*). Environmental Science & Technology 34(14):3003-3011.
Call Number: W 08039
Abstract: Existing in vivo tests (with the exception of the full lifecycle test) are not adequate for assessing the reproductive effects of endocrine disrupting chemicals (EDCs) on fish, and hence the need for partial life-cycle tests has been recognized internationally. In this paper we describe the development of a short-term (6 week) reproductive performance test for EDCs using pair-breeding fathead minnows (Pimephales promelas). In the test, reproductive performance in paired fish is assessed over two 3 week periods, one with exposure to the test chemical and one without. The test is highly integrative and measures effects of exposure to chemicals on fecundity, gonadosomatic index (GSI), vitellogenin (VTG) induction, and

secondary sexual characteristics (fat pad and tubercles in males). In this test, exposure to butyl benzyl phthalate (BBP) at a nominal concentration of 100 mu g/L (measured concentration between 69 mu g/L and 82 mu g/L) had no discernible effects on reproductive performance. In contrast, all reproductive parameters measured were affected by exposure to 4-NP, albeit some (e.g. VTG induction and reduction in the prominence of secondary sexual characteristics - lowest effective dose between 0.65 mu g/L and 8.1 +/- 1 mu g/L [measured]) were more sensitive than others (e.g. number of eggs and spawnings, where the lowest effective dose was between 8.1+/- 1 mu g/L and 57.7 +/- 3 mu g/L [measured]). Concentrations of 4-NP at or above 48 mu g/L [measured] inhibited reproduction completely.

Hemming JM, Waller WT, Chow MC, Denslow ND, Venables B. 2001. Assessment of the estrogenicity and toxicity of a domestic wastewater effluent flowing through a constructed wetland system using biomarkers in male fathead minnows (*Pimephales promelas* Rafinesque, 1820). Environmental Toxicology & Chemistry 20(10):2268-2275.
Call Number: W 09258
Abstract: The toxicity and estrogenicity of a final treated municipal effluent was examined while flowing through a constructed wetland in north- central Texas, USA. Fish data were collected, and a baseline wetland characterization was performed to assess wetland treatment potential for these effluent properties. Vitellogenin (VTG), gonadosomatic index (GSI), hepatosomatic index (HSI), and secondary sexual characteristics were biomarkers used in fish models to assess aqueous estrogenicity. Biological indicators used to assess overall fish health included hematocrit and condition factor. Estrogenic nature of final sewage treatment works effluent was screened, concurrent with a three-week fish exposure, via gas chromatography/mass spectrometry for target estrogenic compounds, including 17beta-estradiol, ethynylestradiol, bisphenol A, nonylphenolic compounds, phthalates, and DDT. The VTG in Pimephales promelas was measured after exposure at four sites in a treatment wetland and was significantly elevated ($p < 0.0001$) in fish exposed at the inflow site. The GSIs were significantly less (alpha = 0.001) at the inflow site. At wetland sites closest to the inflow, secondary sexual characteristics, tubercle numbers, and fatpad thickness were less (alpha = 0.0001) than in laboratory controls. The HSIs and density of male breeding stripes were not significantly different from those of laboratory controls. However, elevated HSIs were found at the inflow site. Hematocrit and condition factors were both less (alpha = 0.001) in effluent-exposed fish at wetland sites closer to the inflow than in control fish or fish further downstream.

Hewitt M, Servos M. 2001. An overview of substances present in Canadian aquatic environments associated with endocrine disruption. Water Quality Research Journal of Canada 36(2):191-213.
Call Number: W 09303

Hites RA. 1973. Phthalates in the Charles and the Merrimack rivers. Environ Health Perspect 3:17-21.
Call Number: W 03101 PDF only
Abstract: [Phthalate esters from the Charles River are reported at levels of 0.88-1.9 ppb, with higher levels associated with increasing distances upstream. ~Lincer 1977]

Huang GL, Sun HW, Song ZH. 1999. Interactions between dibutyl phthalate and aquatic organisms. Bull Environ Contam Toxicol 63(6):759-765.
Call Number: W 07350

Jensen J, van Langevelde J, Pritzl G, Krogh PH. 2001. Effects of di(2-ethylhexyl) phthalate and dibutyl phthalate on the collembolan *Folsomia fimetaria*. Environmental Toxicology & Chemistry 20(5):1085-1091.
Call Number: W 07091
Abstract: Lethal and sublethal effects of di(2-ethylhexyl) phthalate (DEHP) and dibutyl phthalate (DBP) on adult individuals of the collembolan Folsomia fimetaria were investigated in the laboratory by the use of small microcosms. Effects of DEHP and DBP were also tested on newly hatched collembolans in a multidish system. The endpoints were juvenile mortality, growth, and development. When exposed to DEHP, adults and juveniles were unaffected at all test concentrations, that is, up to 5,000 mg/kg. However, DBP caused increased adult mortality at 250 mg/kg and juvenile mortality at 25 mg/kg. For DBP, adult reproduction was a more sensitive endpoint than was survival, with an EC10 and EC50 of 14 and 68 mg/kg, respectively. Juvenile molting frequency seems to be a sensitive parameter, because number of cuticles produced by young springtails was reduced at 1 mg/kg. Toxicity was reduced when soil spiked

with DBP was stored at 20 degrees C for a period of up to 28 d before adding the animals. Reduction in toxicity of DBP may be due a combination of degradation, evaporation, and adsorption of DBP to soil material. This was confirmed by chemical analyses, which showed a rapid initial disappearance followed by a much slower disappearance. Our results lead to the overall conclusion that significant adverse effects of phthalates on collembolans are not likely to occur as a result of normal sewage sludge application.

Jonsson S, Baun A. 2003. Toxicity of mono- and diesters of *o*-phthalic esters to a crustacean, a green alga, and a bacterium. Environmental Toxicology & Chemistry 22(12):3037-3043.
Call Number: W 11204 PDF only
Abstract: The degradation of phthalic acid diesters may lead to formation of o-phthalic acid and phthalic acid monoesters. The ecotoxic properties of the monoesters have never been systematically investigated, and concern has been raised that these degradation products may be more toxic than the diesters. Therefore, the aquatic toxicity of phthalic acid, six monoesters, and five diesters of o-phthalic acid was tested in three standardized toxicity tests using the bacteria Vibrio fischeri, the green algae Pseudokirchneriella subcapitata, and the crustacean Daphnia magna. The monoesters tested were monomethyl, monoethyl, monobutyl. monobenzyl, mono(2-ethylhexyl), and monodecyl phthalate, while the diesters tested were dimethyl, diethyl, dibutyl, butylbentyl, and di(2-ethylhexyl)phthalate, which were assumed to be below their water solubility. The median effective concentration (EC50) values for the three organisms ranged from 103 mg/L to >4,710 mg/L for phthalic acid, and corresponding values for the monoesters ranged from 2.3 mg/L (monodecyl phthalate in bacteria test) to 4,130 mg/L (monomethyl phthalate in bacteria test). Dimethyl and diethyl phthalate were found to be the least toxic of the diesters (EC50 26.2-377 mg/L), and the toxicity of the other diesters (butylbenzyl and dibutyl phthalate) ranged from 0.96 to 7.74 mg/L. In general, the phthalate monoesters (degradation products) were less toxic than the corresponding diesters (mother compounds).

Katami T, Yasuhara A, Okuda T, Shibamoto T. 2002. Formation of PCDDs, PCDFs, and coplanar polyvinyl chloride during combustion in an incinerator. Environmental Science & Technology 36(6):1320-1324.
Call Number: W 09753
Abstract: Exhaust gases from the combustion of poly(vinyl chloride) (PVC), polyethylene (PE), polystyrene (PS), poly(ethylene terephthalate) (PET), and their various mixtures were analyzed for PCDDs, PCDFs, and coplanar PCBs by gas chromatography/mass spectromety (GC/MS) in order to investigate the role of PVC in these chlorinated compounds. Total amounts of dioxins (PCDDs + PCDFs) found in the samples were 11.7 ng/g PE alone, 1.17 ng/g from PS alone, 25.3 ng/g from PET alone, 448 ng/g from PE with PVC, 140 ng/g from PS with PVC, 126 ng/g from PET with PVC, 824 ng/g from PVC alone under low-CO level, and 8920 ng/g from PVC alone under high-CO level. CO level in high-CO level condition was 880 ppm which was 20 times greater than that in low-CO level condition. Formation of coplanar PCBs ranged from 0.095 ng/g (PE alone) to 77 ng/g (PVC alone under high-CO level). There is a clear correlation between dixoin formation and chloride content. PCDFs composed 80% (PET + OVC) - 98% (PET alone) of the total dioxins formed in the exhaust gases. The results indicate that PVC contributes significantly to the formation of PCDDs, PCDFs, and coplanar PCBs from mixtures of plastics upon combustion.

Kim EJ, Kim JW, Lee SK. 2002. Inhibition of oocyte development in Japanese medaka (*Oryzias latipes*) exposed to di-2-ethylhexyl phthalate. Environment International 28(5):359-365.
Call Number: W 10523 PDF
Abstract: Di-2-ethylhexyl phthalate (DEHP) is a widely used plasticizer known to be a suspected endocrine disrupter, but its precise effects on aquatic organisms are not yet known. When Japanese medaka (Oryzias latipes) were exposed from the time of hatching to 3 months of age to an aqueous DEHP solution at nominal concentrations of 1, 10, and 50 microg/l, DEHP- treated female fish showed distinct reproductive effects as follows. First, blood vitellogenin levels in all treated test subjects markedly decreased. Second, Gonado Somatic Index (GSI) decreased to 33% and 38% of the control GSI in 10 microg/l and 50 microg/l treated female fish, respectively. Third, 54% of female fish in the control treatment had completely matured oocytes in their ovaries, but only 37%, 0% and 22% of female fish matured to the last stage in the 1, 10 and 50 microg/l treated test subjects, respectively. Unlike female fish, no change or adverse effects were observed in the male fish. In summary, DEHP hinders the development of reproductive organs in the female Japanese medaka. In this work, the possibility of anti-estrogenic activity of DEHP is proposed as

the cause.

Knudsen FR, Arukwe A, Pottinger TG. 1998. The *in vivo* effect of combinations of octylphenol, butylbenzylphthalate and estradiol on liver estradiol receptor modulation and induction of zona radiata proteins in rainbow trout: No evidence of synergy. Environmental Pollution 103(1):75-80.
Call Number: W 06524
Abstract: Juvenile rainbow trout were given intraperitoneal (IP) injections of (i) octylphenol (OP) and butylbenzylphthalate (BBP) or (ii) octylphenol and estradiol (E). Both pairs of compounds were administered singly and in combination, at two different dose levels. Modulation of the hepatic estradiol receptor (ER) binding capacity and induction of hepatic zona radiata proteins (Zrp) were utilised as indicators of estrogenic effect. In treatment (i) OP caused a significant (similar to 2-fold) upregulation of the ER and a significant (similar to 3-5 fold) increase in Zrp at both doses compared to control, vehicle-injected fish. In contrast, no effect on the ER was observed in BBP-treated fish, but plasma Zrp levels were significantly reduced. No synergistic effect was observed on ER modulation or Zrp induction in fish receiving OP and BBP in combination. In treatment (ii) both OP and E caused a significant (similar to 2-fold) upregulation of the ER and a significant (similar to 6-7 fold) increase in plasma Zrp at both dose levels compared to controls. The effect of OP and E in combination, on both ER modulation and induction of Zrp, was additive and not synergistic.

Knudsen FR, Pottinger TG. 1999. Interaction of endocrine disrupting chemicals, singly and in combination, with estrogen-, androgen-, and corticosteroid-binding sites in rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology 44(3):159-170.
Call Number: W 06467
Abstract: The ability of chemicals with known endocrine disrupting activity to interact with three major teleost steroid-binding sites was evaluated. Representative alkylphenols and phthalates, the pesticides dieldrin and toxaphene, the mycoestrogen zearalenone and the phytoestrogen genistein were tested for their ability to displace native ligand from putative estradiol receptor (ER), testosterone receptor (TR) and cortisol receptor (CR) from rainbow trout liver and brain. The ER displayed a higher affinity for alkylphenols than for phthalates, but both groups of compounds were 10(4)-2 x 10(5) times less potent than estradiol in displacing specifically bound [H-3]estradiol. The displacement of bound [H-3]estradiol did not increase when these compounds were tested in combination. Toxaphene and dieldrin did not bind to the trout ER, either alone or in combination. Zearalenone and genistein were about 10(3)-fold less potent than estradiol in displacing specifically bound [H-3]estradiol from the trout ER and showed no increase in potency when tested in combination. None of the compounds tested showed evidence of binding to the TR or the CR, failing to displace specifically bound [H-3]testosterone and [H-3]cortisol respectively. It is concluded that the compounds tested are exclusively estrogenic in rainbow trout, albeit weakly so, and do not display any synergistic effects.

Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, Buxton HT. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. Environmental Science & Technology 36(6):1202-1211.
Call Number: W 09690 PDF
Abstract: To provide the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in water resources, the U.S. Geological Survey used five newly developed analytical methods to measure concentrations of 95 OWCs in water samples from a network of 139 streams across 30 states during 1999 and 2000. The selection of sampling sites was biased toward streams susceptible to contamination (i.e. downstream of intense urbanization and livestock production). OWCs were prevalent during this study, being found in 80% of the streams sampled. The compounds detected represent a wide range of residential, industrial, and agricultural origins and uses with 82 of the 95 OWCs being found during this study. The most frequently detected compounds were coprostanol (fecal steroid), cholesterol (plant and animal steroid), N, N-diethyltoluamide (insect repellant), caffeine (stimulant), triclosan (antimicrobial disinfectant), tri(2-chloroethyl)phosphate (fire retardant), and 4-nonylphenol (nonionic detergent metabolite). Measured concentrations for this study were generally low and rarely exceeded drinking-water guidelines, drinking-water health advisories, or aquatic-life criteria. Many compounds, however, do not have such guidelines established. The detection of multiple OWCs was common for this study, with a median of seven and as many as 38 OWCs being found in a given water

sample. Little is known about the potential interactive effects (such as synergistic or antagonistic toxicity) that may occur from complex mixtures of OWCs in the environment. In addition, results of this study demonstrate the importance of obtaining data on metabolites to fully understand not only the fate and transport of OWCs in the hydrologic system but also their ultimate overall effect on human health and the environment.

Körner W, Spengler P, Bolz U, Schuller W, Hanf V, Metzger JW. 2001. Substances with estrogenic activity in effluents of sewage treatment plants in southwestern Germany. 2. Biological analysis. Environmental Toxicology & Chemistry 20(10):2142-2151.
Call Number: W 09237
Abstract: The proliferation test with human estrogen receptor-positive MCF-7 breast cancer cells (E-Screen assay) was applied for quantitative determination of total estrogenic activity in 24-h composite effluent samples from 16 municipal and two industrial sewage treatment plants (STPs) in the state of Baden-Wurttemberg, southwestern Germany. The estrogenic efficacy relative to the positive control, 17beta-estradiol, was between 26 and 74% (median, 48%) for the 16 municipal STPs. Estradiol equivalent concentrations (EEQs) were between 0.2 and 7.8 ng/L (median, 1.6 ng/L) and, thereby, were lower than those found in a pilot study, which revealed EEQs of greater than 10 ng/L in the effluents of two other STPs. The EEQs in 14 of the 16 effluent samples were very similar (0.9-3.3 ng/L), indicating a rather constant input of estrogenic substances via STPs into rivers. Additional activated charcoal filtration turned out to be very efficient in further eliminating estrogenic activity from effluents. The EEQs of the E- Screen assay and those calculated from the results of extensive chemical analysis using the estradiol equivalency factors determined for 13 natural and synthetic estrogenic substances were comparable for most of the effluent samples. 17beta-Estradiol, 17alpha- ethinylestradiol, and, to a lesser extent, estrone contributed to 90% or more of the EEQ value.

Legler J, Zeinstra LM, Schuitemaker F, Lanser PH, Bogerd J, Brouwer A, Vethaak AD, de Voogt P, Murk AJ, van der Burg B. 2002. Comparison of *in vivo* and *in vitro* reporter gene assays for short-term screening of estrogenic activity. Environmental Science & Technology 36(20):4410-4415.
Call Number: W 10355
Abstract: Functional *in vitro* and *in vivo* reporter gene assays have recently been developed for the rapid determination of exposure to (xeno)estrogens. The in vitro estrogen receptor (ER)-mediated chemically activated luciferase gene expression (ER-CALUX) assay use T47D human breast cancer calls stably transfected with an ER-mediated luciferase gene construct. In the in vivo assay, transgenic zebrafish are used in which the same luciferase construct has been stably introduced. In both assays, luciferase reporter gene activity can be easily quantified following short-term exposure to chemicals activating endogenous estrogen receptors. The objective of this study was to compare responses by known (xeno)estrogenic compounds in both assays. Exposure to the (xeno)estrogens estradiol (E2), estrone, ethynylestradiol (EE2), o,p'-DDT, nonylphenol (NP), and di(2-ethylhexyl)phthalate (DEHP) revealed that EE2 was the most potent (xeno)estrogen tested and was 100 times more potent than E2 in the transgenic zebrafish assay, whereas in the in vitro ER-CALUX assay, EE2 and E2 were equipotent. Although the xenoestrogens o,p'-DDT and NP were full estrogen agonists in the in vitro ER-CALUX assay, only o,p'-DDT demonstrated weak dose-related estrogenic activity in vivo. To determine if differences in reporter gene activity may be explained by differential affinity of (xeno)estrogens to human and zebrafish ERs, full-length sequences of the zebrafish ER subtypes α, β, and γ were cloned, and transactivation by (xeno)estrogens was compared to human ERα and ERβ. Using transiently transfected recombinant ER and reporter gene constructs, EE2 also showed relatively potent activation of zebrafish ERα and ERβ compared to human ERα and ERβ. Zebrafish ERβ and ERγ showed higher transactivation by (xeno)estrogens relative to ER than to human ERβ.

Lewis DL, Garrison AW, Wommack KE, Whittemore A, Steudler P, Melillo J. 1999. Influence of environmental changes on degradation of chiral pollutants in soils. Nature 401(6756):898-901.
Call Number: W 07523
Abstract: Numerous anthropogenic chemicals of environmental concern--including some phenoxy acid herbicides, organophosphorus insecticides, polychlorinated biphenyls, phthalates, freon substitutes and some DDT derivatives--are chiral. Their potential biological effects, such as toxicity, mutagenicity, carcinogenicity, and endocrine disrupter activity, are generally enantiomer-selective, and different

enantiomers are preferentially degraded (transformed) by micro-organisms in various environments. Here we use field and laboratory experiments to demonstrate that environmental changes in soils can alter these preferences, and to suggest that the preferences shift owing to different groups of related microbial genotypes being activated by different environmental changes. In Brazilian soils, almost all pasture samples preferentially transformed the non-herbicidal enantiomer of dichlorprop ((RS)-2-(2,4-dichlorophenoxy)propionic acid), while most forest samples either transformed the herbicidal enantiomer more readily or as rapidly as the non-herbicidal enantiomer. Organic nutrient enrichments shifted enantioselectivity for methyl dichlorprop ((RS)-methyl 2-(2,4-dichlorophenoxy)propionic acid) strongly towards preferentially removing the non-herbicidal enantiomer in soils from Brazil and North America, potentially increasing phytotoxicity of its residues relative to that of the racemate. Assessments of the risks chemical pollutants pose to public health and the environment need to take into account the chiral selectivity of microbial transformation processes and their alteration by environmental changes, especially for pesticides as up to 25 per cent are chiral.

Lopes TJ, Furlong ET. 2001. Occurrence and potential adverse effects of semivolatile organic compounds in streambed sediment, United States, 1992-1995. Environmental Toxicology & Chemistry 20(4):727-737.
Call Number: W 08848
Abstract: The occurrence and potential adverse effects of select semivolatile organic compounds (SVOCs) in streambed sediment were assessed at 536 sites in 20 major river basins across the United States from 1992 to 1995. Fifty-six SVOCs were detected at one or more sites, and one or more SVOCs were detected at 71% of sites. The northeastern and Great Lakes regions and large metropolitan areas have the highest SVOC concentrations. Polycyclic aromatic hydrocarbons (PAHs) were detected most frequently and at the highest concentrations. Concentrations of PAHs and phthalates were about 10 times higher at sites influenced by urban activities than at sites in other land-use areas. Semivolatile organic compounds were significantly (alpha = 0.05) correlated with land use and population density, and PAHs also correlated with physical/chemical properties. On the basis of sediment-quality guidelines, adverse effects are probable at 7.5% and possible at 16.2% of the sites. Most of the potential for adverse effects is due to PAHs. The median percentage of urban land use was 8% at sites with possible adverse effects and 16% at sites with probable adverse effects. Urbanization profoundly affects sediment quality, even though it comprised a small percentage of most drainage basins.

Lutz I, Kloas W. 1999. Amphibians as a model to study endocrine disruptors: I. Environmental pollution and estrogen receptor binding. Sci Total Environ 225(1-2):49-57.
Call Number: W 06444
Abstract: Many chemicals released into the environment without toxicological risks have the capacities to disrupt the function of endocrine systems. These endocrine disrupters disturb normal endocrine mechanisms and have been observed in nearly all classes of vertebrates. The aim of this research is to develop a comprehensive model to study endocrine disruption using the amphibian Xenopus laevis. The assessment of estrogenic potencies of endocrine disrupters includes several levels of investigation: (I) binding to liver estrogen receptor, (II) estrogenic activity in vitro by inducing vitellogenin synthesis in primary cultured hepatocytes, and (III) in vivo effects on sexual development caused by exposure of larvae. The present paper is focused on the first part by establishing a radioreceptorassay for [H-3]17 beta-estradiol ([H-3]E2) binding using liver cytosol fraction. In order to get optimum binding conditions we performed kinetic, saturation, and competitive displacement experiments. Association of [H-3]E2 to estrogen receptor revealed that maximum specific binding is achieved between 18 and 48 h of incubation. Scatchard analyses of saturation experiments resulted in a homogenous saturable population of estrogen receptors having no significant differences of binding parameters between both sexes. The values of K-d (dissociation constant) in males and females were 22.4 +/- 6.0 and 15.0 +/- 2.8 nM (mean +/- S.E.M.; n = 5), respectively, while corresponding B-max (maximum binding capacity) revealed 89 +/- 46 and 136 +/- 46 fmol [H-3]E2/mg protein. The specificity of estrogen receptors as shown by competitive displacement experiments demonstrated receptors being highly specific just for estrogens, but not for other endogenous steroids having the following ranking of binding affinities: E2 > estrone > dehydroepiandrosterone > aldosterone greater than or equal to testosterone greater than or equal to corticosterone greater than or equal to progesterone. The affinity ranking of environmental chemicals compared to E2 was: E2 > tetrachlorbiphenyl > diethylphthalate > 2,2-bis-(4-hydroxyphenyl)-propan (bisphenol A)greater than or equal to 4-nonylphenol greater than or equal to 3-t-butyl-4-hydroxyanisale greater than or equal to 4-

octylphenol > dichlor-diphenyl-trichlor-ethan (4,4'-DDT). Analyses of five sewage effluents for displacement of [H-3]E2 binding resulted in three samples displacing more than 50% of specific binding at their original concentration. Taken together the established radioreceptorassay for [H-3]E2 binding in Xenopus laevis liver cytosol is useful to screen estrogen receptor binding of pure compounds or complex mixtures of them, which is the prerequisite for causing either estrogenic or antiestrogenic effects.

Maczka C, Pang S, Policansky D, Wedge R. 2000. Evaluating impacts of hormonally active agents in the environment. Environmental Science & Technology 34(5):136A-141A.
Call Number: W 07465
Abstract: A report last year by the National Research Council (NRC)* finds that there is large uncertainty about risks from exposures to hormonally active agents (HAAs)- more popularly known as endocrine disrupters. The NRC Committee on HAAs in the Environment concluded, after examining existing scientific knowledge concerning HAA exposures, that further information is needed to understand the potential for harm to developing organisms. The report stresses that although evidence shows that harmful ecological and health effects can result from exposure to certain chemicals, it remains unclear whether their hormonal properties cause the observed effects, or instead, some other toxicological mechanism is operative.

*NRC. 1999. Hormonally Active Agents in the Environment. Washington DC: National Academy Press.

Mayer FL, Stalling DL, Johnson JL. 1972 Aug 18. Phthalate esters as environmental contaminants. Nature 238(5364):411-413.
Abstract: [PAE's are given for selected samples from North America. 0.09 DNBP in Missouri River water; 200 ppb in Mississippi River channel catfish, 500 ppb in tadpoles; similar values for DEHP were 4.9, 400, and 300 ppb.]

McDowell DC, Metcalfe CD. 2001. Phthalate esters in sediments near a sewage treatment plant outflow in Hamilton Harbour, Ontario: SFE extraction and environmental distribution. Journal of Great Lakes Research 27(1):3-9.
Call Number: W 08789
Abstract: Esters of phthalic acid are ubiquitous environmental contaminants as a result of their use as plasticizers and as constituents in many other commercial products. Although the acute toxicity of phthalates is low, recent concerns over their potential to disrupt the gonadal development of vertebrates has prompted interest in determining the distribution of these compounds in the environment. However, trace analysis of phthalates in environmental samples has been hampered by their presence as ubiquitous laboratory contaminants. In this study, the problem of high background contamination was addressed by developing an analytical method using supercritical fluid extraction (SFE), which was used to extract phthalates from sediment samples collected near the outflow of a sewage treatment plant (STP) in Hamilton Harbour at the western end of Lake Ontario. GC-MS-SIM analysis of sediment samples indicated that di(2-ethylhexyl) phthalate (DEHP)was present at very high concentrations; ranging from a mean of 29.7 mug/g dry weight at a site near the STP outflow to a mean of 6.5 mug/g dry weight at a site 300 m away. Di-n-butyl phthalate (DBP), and benzylbutyl phthalate (BBP) were judged to be present in some sediment samples bur at concentrations below the Method Detection Limits (< 0.3 <mu>g/g). Di-isononyl phthalate (DINP) and diethyl phthalate (DEP) were not detected in any of the sediment samples. This study indicates that SFE can be an efficient extraction method for phthalates in sediments, which avoids the extensive use of glassware and organic solvents that may contaminate environmental samples. In addition, STP effluents are sources of phthalates in the aquatic environment; in particular, DEHP.

McLaughlin J Jr., Marliac JP, Verrett MJ, Mutchler MK, Fitzhugh OG. 1963. The injection of chemicals into the yolk sac of fertile eggs prior to incubation as a toxicity test. Toxicol Appl Pharmacol 5:760-771.
Call Number: W 01320
Abstract: An evaluation of toxicity by injection of the chemical into the yolk sac of fertile eggs prior to incubation gave the following results: Water, propylene glycol, corn oil, peanut oil, isotonic saline solution, and isotonic glucose solution showed no toxicity or a very low order or toxicity. Mercuric chloride, lead acetate, selenium, triorthocresyl phosphate, p,p'-diominodiphenylmethane, thiourea, Aroclor 1242, and dibutyl-tin-dilaurate showed a high order of toxicity and/or teratogenic effects at certain levels.

Acetone, methanol, ethanol, n-butanol, diethylene glycol, ethynol glycol, isopropanol, di-2-ethylhexyl phthalate, hydrochloric acid, carbon tetrachloride, ethyl acetate, malathion, heptachlor, and styrene showed an intermediate order of toxicity.

Metcalfe CD, Metcalfe TL, Kiparissis Y, Koenig BG, Khan C, Hughes RJ, Croley TR, March RE , Potter T. 2001. Estrogenic potency of chemicals detected in sewage treatment plant effluents as determined by *in vivo* assays with Japanese medaka (*Oryzias latipes*). Environmental Toxicology & Chemistry 20(2):297-308.
Call Number: W 08648
Abstract: Gonadal intersex and high prevalences of the female phenotype have been observed in fish populations in urbanized areas. Environmental estrogens discharged in sewage treatment plant effluents may be responsible for feminization of fish but many compounds with the potential to induce these responses occur in effluents, including natural and synthetic estrogen hormones, degradation products of alkylphenol ethoxylate surfactants, and plasticizers. In this study, the estrogen hormones 17 alpha - ethinylestradiol, 17 beta -estradiol, estrone, and estriol induced intersex (i.e., testis-ova) and altered sex in Japanese medaka (Oryzias latipes) when these fish were exposed to nanogram per liter concentrations of test compounds from hatch to approximately 100 d after hatch. A mix of nonylphenol mono- and diethoxylate induced a weak response and a mix of nonylphenol mono- and diethoxycarboxylate did not give a response in this assay at microgram per liter concentrations, indicating that these degradation products of nonylphenol ethoxylates have little or no estrogenic activity in fish. Bisphenol A induced testis-ova in medaka exposed to a concentration of 10 mug/L, but diethylhexyl phthalate did not induce a response. Results with the medaka assay were consistent with estrogenic responses in the yeast estrogen screening assay. Analyses of monitoring data reported in the literature indicate that concentrations of estrogen hormones detected in the final effluents of sewage treatment plants are generally greater than the lowest-observed effect levels for alterations to gonadal development in medaka.

Montoya J, Colborn T. Fintrol literature search & related documents.
Call Number: W 11437 RTF
Abstract: Includes: literature search and summary of mechanism of action; Minutes of the New Mexico State Game Commission 2004.05.06 (http: //www.wildlife.state.nm.us/commission/minutes/documentes/2004-05-06.htm); Fintrol page from pesticide catalog (MHT); Articles by D. Begel, High Country News 2001.05.07 (MHT); and S. Siegfried, 2004.08.20 (DOC); and Opinion and Order of the Illinois Pollution Control Board 1974.09.19, granting a variance for use of Fintrol in Lake Jacksonville (PDF).

Munn MD, Gruber SJ. 1997. The relationship between land use and organochlorine compounds in streambed sediment and fish in the central Columbia Plateau, Washington and Idaho, USA. Environmental Toxicology & Chemistry 16(9):1877-1887.
Call Number: W 05108
Abstract: We analyzed streambed sediment and fish in the Central Columbia Plateau in eastern Washington and Idaho for organochlorine pesticides and polychlorinated biphenyls (Sigma PCB). Our objective was to assess the effects of land use on the occurrence and distribution of these compounds; land uses in the study area included forest, dryland and irrigated farming, and urban. We detected 16 organochlorine compounds in streambed sediment and fish tissue; fish usually had more compounds and a greater frequency of detection. The most frequently detected compound was Sigma DDT (sum of six isomers), which was found in 52% of bed sediment samples and 94% of whole fish composite samples. The other commonly detected compounds were dimethyl tetrachloroterephthalate (DCPA), dieldrin, hexachlorobenzene, and Sigma chlordane (sum of cis-and trans-chlordane, cis-and trans-nonachlor, oxychlordane, heptachlor, and heptachlor epoxide). Forest was the only land use with no detections of organochlorine compounds in either fish or bed sediment. Hexachlorobenzene was the only organochlorine pesticide detected at concentrations that differed significantly among land uses: concentrations were higher in the dryland farming areas than in the irrigated farming or urban areas. In agricultural areas irrigated by surface water, Sigma DDT concentrations in both streambed sediment and fish tissue were related to the percentage of land irrigated by water delivered via furrows (gravity irrigation), although Sigma DDT was not detectable in bed sediments until gravity irrigation exceeded 30%. Because of the relation between gravity irrigation and soil erosion, our study supports the importance of controlling soil erosion in order to reduce the overall loading of organochlorine compounds to surface waters.

National Research Council's Committee on Hormonally Active Agents in the Environment. 1999 Jul. Hormonally Active Agents in the Environment:xv + 560 pp.
Call Number: H 09471
Abstract: This report critically evaluates the literature on hormonally active agents in the environment and identifies known and suspected toxicologic mechanisms and effects of fish, wildlife, and humans; examines whether and how exposure to hormonally active agents occurs--in diet, in pharmaceuticals, from industrial releases into the environment--and why the debate centers on estrogens; and identifies significant uncertainties, limitations of knowledge, and weaknesses in the scientific literature.

Ohtani H, Miura I, Ichikawa Y. 2000. Effects of dibutyl phthalate as an environmental endocrine disruptor on gonadal sex differentiation of genetic males of the frog *Rana rugosa*. Environ Health Perspect 108(12):1189-1193.
Call Number: W 08541
Abstract: To examine the effects of dibutyl phthalate (DBP) on gonadal sex differentiation, genetically male tadpoles of *Rana rugosa* were exposed to dilute solutions of DBP at concentrations of 0.1, 1, or 10 μM during days 19-23 after fertilization, which is the critical period of gonadal sex differentiation in *R. rugosa*. Tadpoles were necropsied on day 40. The genetically male tadpoles were produced from crossings between males (ZZ) of one local population, in which females are the heterogametic sex, and females (XX) of another local population, in which males are the heterogametic sex. As positive control groups, tadpoles were exposed to dilute solutions of 17β-estradiol (E_2) at concentrations of 0.01, 0.1, or 1 μM during the same period. The internal structure of the gonads was histologically examined in a total of 30 control tadpoles, 86 E_2-treated tadpoles, and 90 DBP-treated tadpoles. The gonads of the control tadpoles all showed the typical structure of testes. In contrast, 0.01, 0.1, and 1 μM E_2 treatments caused the undifferentiated gonads of 18, 63, and 100% of the tadpoles, respectively, to develop into gonads of complete or partial ovarian structure. After 0.1, 1, and 10 μM DBP treatment, 0, 7, and 17% of tadpoles, respectively, were similarly affected. These findings suggest that DBP was about 1,000-fold less potent than E_2. Nevertheless, DBP is an environmentally dangerous hormone that disrupts the pathways of testicular differentiation in genetically male animals.

Rhodes JE, Adams WJ, Biddinger GR, Robillard KA, Gorsuch JW. 1995. Chronic toxicity of 14 phthalate esters to *Daphnia magna* and rainbow trout (*Oncorhynchus mykiss*). Environmental Toxicology & Chemistry 14(11):1967-1976.
Call Number: W 03166
Abstract: Chronic toxicity studies were performed with commercial phthalate esters and Daphnia magna (14 phthalates) and rainbow trout (Oncorhynchus mykiss) (six phthalates). For the lower-molecular-weight phthalate esters - dimethyl phthalate (DMP), diethyl phthalate (DEP), di-n-butyl phthalate (DBP), and butylbenzyl phthalate (BBP)-the results of the studies indicated a general trend in which toxicity for both species increased as water solubility decreased. The geometric mean maximum acceptable toxicant concentration (GM-MATC) for D. magna ranged from 0.63 to 34.8 mg/L. For the higher-molecular-weight phthalate esters-dihexyl phthalate (DHP), butyl 2-ethylhexyl phthalate (BOP), di-(n-hexyl, n-octyl, n-decyl) phthalate (610P), di-(2-ethylhexyl) phthalate (DEHP), diisooctyl phthalate (DIOP), diisononyl phthalate (DINP), di-(heptyl, nonyl, undecyl) phthalate (711P), diisodecyl phthalate (DIDP), diundecyl phthalate (DUP), and ditridecyl phthalate (DTDP)-the GM-MATC values ranged from 0.042 to 0.15 mg/L. Survival was equally sensitive and sometimes more sensitive than reproduction. The observed toxicity to daphnids with most of the higher-molecular-weight phthalate esters appeared to be due to surface entrapment or a mode of toxicity that is not due to exposure to dissolved aqueous-phase chemical. Early life-stage toxicity studies with rainbow trout indicated that survival (DMP) and growth (DBP) were affected at 24 and 0.19 mg/L, respectively. This pattern of observed toxicity with the lower-molecular-weight phthalate esters and not the higher-molecular-weight phthalate esters is consistent with previously reported acute toxicity studies for several aquatic species.

Scholz N, Diefenbach R, Rademacher I, Linnemann D. 1997. Biodegradation of DEHP, DBP, and DINP: Poorly water soluble and widely used phthalate plasticizers. Bull Environ Contam Toxicol 58(4):527-534.
Call Number: W 04773

Shioda T, Wakabayashi M. 2000. Effect of certain chemicals on the reproduction of medaka (*Oryzias latipes*).

Chemosphere 40(3):239-243.
Call Number: W 09493
Abstract: In order to understand the effects of estrogenic chemicals on fish reproduction, we exposed male medaka (Oryzias latipes) to a natural estrogen [17 beta-estradiol (17 beta-E2)] and three estrogenic chemicals [bisphenol-A, nonylphenol (NP) and di(2-ethylhexyl)phthalate (DEHP)]. After two weeks' exposure, one male medaka was kept together with two female medaka for spawning, and the number of eggs and hatchings were compared to those of a negative control group. The results indicated that exposure to 17 beta-E2 caused a significant decrease in the number of eggs and hatchings as compared to the negative control group at and above 3 nmol/l. Also, the highest concentrations of bisphenol-A and NP caused a decrease in the number of hatchings, but no decrease in hatchings was observed in DEHP treatments. In the treatment using these chemicals the decrease in egg numbers was not so much as in hatching numbers. When compared to other in vitro studies, concentrations observed to have adverse effects on reproduction in this study are generally lower. In addition, it was suggested that physical alterations, such as an induction of plasma vitellogenin, were caused at much lower concentrations than those at which a decline in reproductivity was actually induced.

Spahr NE, Apodcaa LE, Deacon JR, Bails JB, Bauch NJ, Smith CM, Driver NE. 2000. Water quality in the upper Colorado River Basin, Colorado, 1996-98. U.S. Geological Survey 1214:i-iv, 1-33.
Call Number: W 08730
Abstract: This report summarizes major findings about water quality in the Upper Colorado River Basin that emerged from an assessment conducted between 1996 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings are also explained in the context of selected national benchmarks, such as those for drinking water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the content of the available untreated resource. Finally, this report includes information about the status of aqautic communities and the condition of instream habitats as elements of a complete water-quality assessment. Many topics covered in this report reflect the concerns of officials of State and Federal aganeices, water-resource managers, and members of stakeholder groups who provided advice and input during the upper Colorado River Basin assessment. Basin residents who wish to know more about wate quality in the areas where they live will find this report informative as well.

Spengler P, Korner W, Metzger JW. 2001. Substances with estrogenic activity in effluents of sewage treatment plants in southwestern Germany. 1. Chemical analysis. Environmental Toxicology & Chemistry 20(10):2133-2141.
Call Number: W 09247
Abstract: A gas chromatography/mass spectrometry method for the simultaneous quantitative determination of natural and synthetic estrogens (17beta- estradiol, estrone, 17alpha-ethinylestradiol, and mestranol), phytoestrogens (genistein and beta-sitosterol), and xenoestrogens (benzyl butyl phthalate, dibutyl phthalate, bisphenol A, 4-nonylphenol [NP], 4-nonylphenoxyacetic acid [NP1EC], 4-nonylphenol diethoxylate [NP2EO], and alpha-endosulfan) in effluents of sewage treatment plants (STPs) was developed. Identification and quantification were carried out with the standard addition method using analyte-specific and, in some cases, deuterium-labeled internal standards. The effluents of 18 STPs were investigated. Apart from alpha-endosulfan and mestranol, all selected substances were detected in the majority of samples. The median concentrations of steroidal estrogens were between 0.4 ng/L (17alpha-ethinylestradiol) and 1.6 ng/L (17beta-estradiol). The metabolites of the nonylphenol polyethoxylates, NP, NP1EC, and NP2EO were found in concentrations ranging from the upper-ng/L-range (NP) to the lower-microg/L range (NP1EC). For all substances except mestranol and alpha-endosulfan, median values were calculated and compared to the results of other investigations in Europe and the United States. Possible dependencies of measured concentrations on the geographical location, the capacity, the influent composition, and the technical fitting of the STPs are discussed.

Stahlschmidtallner P, Allner B, Rombke J, Knacker T. 1997. Endocrine disruptors in the aquatic environment. Environmental Science & Pollution Research 4(3):155-162.
Call Number: W 05216
Abstract: Possible mechanisms to explain endocrine effects on reproduction and sex differentiation are presented for selected pharmaceuticals, agrochemicals, industrial chemicals and plant sterols which are known to be present in the aquatic environment. Disruptions of the hormonal coordination can be induced by xenobiotics on various levels of the hierachically organised endocrine system of vertebrates. Phthalate plasticisers, for example, may disrupt the pituitary control of gonadal functions; prenatal/larval exposure to synthetic estrogen impairs sex differentiation and neuroendocrine sexual determination of the central nervous system; phenylurea herbicides block the androgen receptor; the biotransformation of weakly estrogenic plant sterol components of paper mill wastewater (e.g. beta-sitosterol) may lead to androgenic compounds. The effect of hypolipidemic drugs on lipid homeostasis (peroxysom proliferation) is transmitted via a receptor protein that seems to be closely related to the endocrine system both functionally as well as phylogenetically; possible interferences with the neuroendocrine control of sex differentiation are also discussed. In invertebrates, tributyltin is known to effect the biosynthesis of steroidal sexual hormones. PCBs are suspected to be competitive inhibitors of the steroid catabolism. In order to identify potential risks caused by chemicals to the reproductive capacities of aquatic animals and to the quality of drinking water, methods should be established to detect endocrine disrupters at the various levels of the endocrine system.

Stalling DL, Hogan JW, Johnson JL. 1973. Phthalate ester residues--their metabolism and analysis in fish. Environ Health Perspect 3:159-173.
Call Number: W 03461 PDF only
Abstract: [Phthalate esters are are widespread in freshwater fish, with higher residues appearing to be associated with industrial areas; they are metabolized by freshwater fishes~Lincer 1977]

Stone DJM, Blumenthal T, Bowie JH, Tyler MJ. 1992. Detection of plasticisers in skin and glandular extracts of the green tree frog *Litoria splendida*. Rapid Commun Mass Spectrom 6:400-402.
Call Number: W 01987
Abstract: Skin and glandular secretions of the green tree frog contain a mixture of the plasticisers di-octyl phthalate and di-octyl adipate.

Tollefsen KE. 2002. Interaction of estrogen mimics, singly and in combination, with plasma sex steroid-binding proteins in rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology 56(3):215-225.
Call Number: W 09721
Abstract: The plasma sex steroid-binding protein (SBP) is believed to be involved in regulating circulating endogenous sex steroids as well as cellular signal transduction to nuclear steroid receptors in sex steroid-sensitive tissues. In this study, a variety of estrogen mimics (EMs), which may contribute to the endocrine disrupting effects observed in fish, were tested for the ability to interact with the rainbow trout plasma sex steroid-binding protein (rtSBP) either singly or in binary combinations. The EMs ethynylestradiol, diethylstilbestrol, 4-hydroxytamoxifen, genistein, zearalenone, 4-t-octylphenol, bisphenol A and o,p'-DDT were all able to displace 1,2,4,6,7-[H-3]estradiol from the sex steroid-binding site at the rtSBP (K-d = 2.1 +/- 0.5 nM, B-max = 2963 +/- 303 fmol estradiol/mg protein) in a dose-dependent and competitive manner. The plastizicer n-butyl benzyl phthalate only displayed weak binding affinity for the rtSBP, whereas the pesticide dieldrin was not able to compete for the high affinity estradiol-binding sites in plasma. None of the compounds tested was able to clearly promote the binding of the others when given in combination, indicating that synergy did not occur at the ligand-SBP binding level. The rtSBP binding affinity for EMs ranged over several orders of magnitude, but were consistently lower than those for the endogenous sex steroids (about 10(2)-10(6) less potent). The results suggest that the presence of rtSBP may potentially modulate the bioavailability of EMs to estrogen receptors relative to each other and to the endogenous sex steroids themselves. Since the binding of the endogenous ligands is reversible, SBP-bound estrogens (or androgens) potentially may also become displaced by potent EMs.

U.S.Geological Survey. 1998 Oct. Investigations of endocrine disruption in aquatic systems associated with the National Water Quality Assessment (NAWQA) Program. USGS Fact Sheet FS-081-98:4 pp.
Call Number: W 11436 PDF

Abstract: [Survey of 11 river drainages across the US.]

Watanabe T. 2001. Determination of dialkyl phthalates in high altitude atmosphere for validation of sampling method using a helicopter. Bull Environ Contam Toxicol 66(4):456-463.
Call Number: W 08761
Abstract: benzyl butyl phthalate (BBP); diallyl phthalate (DALP); di-n-amyl phthalate (DnAP); di-n-butyl phthalate (DnBP); dicycrohexyl phthalate (DCHP); diethyl phthalate (DEP); di(2-ethylhexyl) phthalate (DEHP); diisobutyl phthalate (DiBP); diisopropyl phthalate (DiPP); di-n-nonyl phthalate (DNP); di-n-propyl phthalate (DnPP); dimethyl phthalate (DMP); dioctyl adipate (DOA)

Watanuki H, Gushiken Y, Sakai MS. 2003. In vitro modulation of common carp (*Cyprinus carpio* L.) phagocytic cells by di-n-butyl phthalate and di-2-ethylhexyl phthalate. Aquatic Toxicology 63(2):119-126.
Call Number: W 10963
Abstract: The modulation of common carp, Cyprinus carpio L. phagocytic cells by Di-n-butyl phthalate (DBP) and Di-2-ethylhexyl phthalate, (DEHP) were analyzed in vitro. Carp head kidney leucocytes were cultured in a RPMI 1640 medium containing DBP or DEHP at concentration of 1-1000 nM and the production of superoxide anion was measured via the in vitro reduction of nitroblue tetrazolium (NBT). Macrophages incubated with 100 up to 1000 nM of DBP showed an increase in their production of superoxide anion in comparison with the control macrophages which, were cultured without DBP. DEHP also increased the production of superoxide anion in phagocytic cells from carp kidneys. Phagocytic cells treated with 10 and 100 ng of DEHP showed increased phagocytic activity. DBP and DEHP also significantly increased the production of nitric oxide in carp macrophages. These results showed that DBP and DEHP modulate the function of phagocytic cells in vitro.

Williams DT. 1973. Dibutyl- and di-(2-ethylhexyl)phthalate in fish. Journal of Agricultural & Food Chemistry 21(6):1128-1129.
Call Number: W 03614 PDF only
Abstract: [Low levels of phthalates were found in 21 samples of processed and unprocessed fish available to the Canadian consumer ~Lincer 1977]

Woin P. 1998. Short- and long-term effects of the pyrethroid insecticide fenvalerate on an invertebrate pond community. Ecotoxicology & Environmental Safety 41(2):137-156.
Call Number: W 06282
Abstract: Direct and secondary effects of fenvalerate on the structure of pond ecosystems were studied in six freshwater mesocosms simulating natural fish-free eutrophic ponds. Exposed mesocosms were compared with nonexposed ones and the effects of the added compound on the macroinvertebrate community were followed during three vegetation seasons (years) in two mesocosms, Exposure to fenvalerate at 1.3 and 0.54 pg liter(-1) resulted in structural changes in the macroinvertebrate community. The insecticide was directly lethal to insects and other arthropods, but indirect community changes mere also observed. For example, after exposure there was a remarkable (> 10-fold) increase in oligochaetes (Stylaria lacustris), probably caused by reduced predation and interspecific competition for food. When predators (insects) recolonized the system, the oligochaetes decreased in abundance and were replaced by ostracods (Herpetocypris reptans), which use similar food resources but are less susceptible to predation, The marked increase in these two taxa is probably explained by the mass death of arthropods, resulting in increased food availability. More than 2 years after treatment, the most exposed system was still different compared with nonexposed ones, suggesting that nonpersistent pesticides may produce detrimental effects resulting in long-term changes at the ecosystem le,;el of organization.

Woodfine D, MacLeod M, Mackay D. 2002. A regionally segmented national scale multimedia contaminant fate model for Canada with GIS data input and display. Environmental Pollution 119(3):341-355.
Call Number: W 10695
Abstract: Regional scale mass balance models are valuable tools for describing the fate of chemicals in areas with defined and fairly homogeneous environmental characteristics and chemical use patterns. These models often show that contaminant inflows from outside the region of interest are significant compared with local emissions. This is most likely for persistent chemicals and those that are efficiently transported in air or water. As a result regional levels of environmental contamination are controlled by external factors

and meaningful evaluation requires assessment of contaminant fate in neighboring regions. A linked set of regional models thus has the potential to describe quantitatively the impact of chemical emissions over a wider geographic scale with significant spatial differences in environmental characteristics and chemical use patterns. We describe here a national scale contaminant fate model for Canada based on the existing 24-region ChemCAN model. The ecological regions, which were previously treated individually, are linked with flows of air and water deduced from GIS analysis to provide a comprehensive description of contaminant fate over the entire country, including long-range transport between regions. The model is applied to describe the national-scale fate of three chemicals in Canada, benzene, trichloroethene, and diethylhexyl phthalate, exploiting GIS analysis for interpretation and presentation of model results. Agreement between predicted multimedia environmental concentrations and measured values is satisfactory for all three chemicals. In total this work represents an initial attempt to address the different processes of both linking a regional model and using GIS as a tool for data analysis and management.

Yasuhara A, Katami T, Okuda T, Shibamoto T. 2002. Role of inorganic chlorides in formation of PCDDs, PCDFs, and coplanar PCBs from combustion of plastics, newspaper, and pulp in an incinerator. Environmental Science & Technology 36(18):3924-3937.
Call Number: W 10265
Abstract: The total amounts of dioxins found in exhaust gases from combustion of polyethylene (PE), polystyrene (PS), and poly(ethylene terephthalate) (PET) with approximately 3% (w/ w) NaCl were 6.07, 17.7, and 28.9 ng/g, respectively. Plastics containing benzene rings produced more dioxins than plastic containing no benzene ring. The amounts of dioxin formed in the exhaust gases from the combustion of newspapers impregnated with CaCl2, KCl, and NaCl were 18.6, 28.6, and 49.0 ng/g, respectively. Dioxin formation was associated with the bond energy between metal atom and chlorine atom. When newspapers impregnated with four different amounts of NaCl were combusted, the highest NaCl content newspaper (chlorine content 4.08%, w/w; lignin content 19.8%, w/w) produced the greatest amount of dioxins (174 ng/g). Pulp with NaCl (chlorine content 4.25%, w/w; lignin content 0.69%, w/w) produced more dioxins (6.71 ng/g) than pulp alone (0.799 ng/g) did upon combustion. The lignin content in a combustion sample correlated with the amount of dioxin formation. The results exhibited that combustion conditions with low CO concentration (<2 ppm) produced much less dioxins than conditions with high CO concentration (159 ppm).

Zou E, Fingerman M. 1997. Effects of estrogenic xenobiotics on molting of the water flea, *Daphnia magna* . Ecotoxicology & Environmental Safety 38:281-285.
Call Number: W 07012
Abstract: The effects of five xenobiotics, 2,4,5-trichlorobiphenyl (PCB29), the polychlorinated byphenyl (PCB) Aroclor 1242, diethyl phthalate, lindane, and 4-octylphenol, on molting of *Daphnia magna* were investigated. All except PCB29 are known to have unexpected estrogenicity in vertebrates. Daphnids exposed to PCB29, Aroclor 1242, and diethyl phthalate took significantly more time to complete four molts than did the controls. The inhibitory effects of these *ortho*-chlorinated PCBs suggest that certain structural features, most probably including *ortho*-chlorination, are related to the ability of a PCB to affect molting. Agents with multicyclic structures, such as PCBs, are more effective in inhibiting molting than are single-ringed xenobiotics, such as diethyl phthalate, which suggests that hydrophobicity may be a requirement for binding to the ecdysteroid receptor. These molt-inhibiting agents with multiple rings appear to bear more structural resemblance to the steroidal molting hormons of arthropods, the ecdysteroids, than do the single-ringed ones. While the possibility of alternative mechanisms, such as impairment of ecdysteroidogenesis exists, the results obtained herein support the hypothesis that some xenobiotics which disrupt endocrine processes in vertebrates can also interfere with the hormonally regulated molting process in arthropods through acting as antagonists of endogenous ecdysteroids by binding to and thereby blocking the ecdysteroid receptor.

Phthalates & Marine Environments (from Lynn Caroll, OurStolenFuture.org)

Acey R, Healy P, Unger TF, Ford CE, Hudson RA. 1987. Growth and aggregation behavior of representative phytoplankton as affected by the environmental contaminant di-n-butyl phthalate. Bull Environ Contam Toxicol 39:1-6.
Call Number: W 01049
Abstract: brine shrimp (Artemia), diatom (Thalassiosira pseudonana), green alga (Dunaliella parva), blue-green alga (Synechococcus lividus)

Adams WJ, Biddinger GR, Robillard KA, Gorsuch JW. 1995. A summary of the acute toxicity of 14 phthalate esters to representative aquatic organisms. Environmental Toxicology & Chemistry 14(9):1569-1574.
Call Number: W 02912
Abstract: Acute aquatic toxicity studies were performed with 14 commercial phthalate esters and representative freshwater and marine species. The 14 esters were dimethyl phthalate; diethyl phthalate; di-n-butyl phthalate; butyl benzyl phthalate; dihexyl phthalate; butyl 2-ethylhexyl phthalate; di-(n-hexyl, n-octyl, n-decyl) phthalate; di-(2-ethylhexyl) phthalate; diisooctyl phthalate; diisononyl phthalate; di-(heptyl, nonyl, undecyl) phthalate; diisodecyl phthalate; diundecyl phthalate; and ditridecyl phthalate. Phthalate esters with alkyl chain lengths of four carbon atoms or fewer were determined to be acutely toxic at concentrations ranging from 0.21 to 377 mg/L depending on the ester and the solubility of the test chemical in water. There was a general trend for the lower-molecular-weight phthalate esters (C-1 to C-4 alkyl chain lengths: dimethyl phthalate; diethyl phthalate; di-n-butyl phthalate; and butyl benzyl phthalate) to become more toxic with decreasing water solubility for all species tested. There were only minor differences in species sensitivity to each of the phthalate esters. Phthalate esters with alkyl chain lengths of six carbon atoms or more were not acutely toxic at concentrations approaching their respective aqueous solubilities. Insufficient mortality occurred to calculate either LC50 or EC50 values or acute no-observed-effect concentrations for these higher-molecular-weight phthalate esters. The lack of toxicity observed for the higher-molecular-weight phthalate esters resulted from their limited water solubility (less than or equal to 1.1 mg/L).

Ammann LP, Waller WT, Kennedy JH, Dickson KL, Mayer FL. 1997. Power, sample size and taxonomic sufficiency for measures of impact in aquatic systems. Environmental Toxicology & Chemistry 16(11):2421-2431.
Call Number: W 05371
Abstract: As part of a larger program to examine the relationships between laboratory and ambient toxicity, data from a series of 28 marine microcosm experiments, which included both laboratory and held studies, were reanalyzed. The statistical methods applied to the data include log-linear regression models (general and robust) for richness and taxa count data (kingdom, phylum, class, order, family, genus, and species) and Gaussian linear models (general and robust) for community metrics diversity and evenness (Shannon-Weiner's, Simpson's, and Brillouin's) and similarity (Bray-Curtis). In addition, taxonomic sufficiency was determined for each of the metrics examined. For each of the analyses performed, both the statistical power of the analysis and the sample sizes required to achieve a desired level of power were determined. New methods are presented to deal with zero count data. Suggestions on how the power of microcosm tests used in toxicity testing can be increased are provided. The statistical programs developed for the analyses applied to the data analyzed were done in S-PLUS. The programs and directions for their application have been placed on an anonymous FTP site at the University of North Texas.

Andersen HR, Wollenberger L, Halling-Sřrensen B, Kusk KO. 2001. Development of copepod nauplii to copepodites - A parameter for chronic toxicity including endocrine disruption. Environmental Toxicology & Chemistry 20(12):2821-2829.
Call Number: W 09312
Abstract: Test compounds including natural hormones, endocrine disrupters, environmental occurring compounds, and reference compounds were tested for acute toxicity and inhibitory effects on larval development in the copepod Acartia tonsa. Three compounds, 17α-ethinylestradiol, p-octylphenol, and tamoxifen, known for their differing effects on the vertebrate estrogen system, were potent inhibitors of naupliar development. Other estrogens, 17β-estradiol, estrone, and bisphenol A, had little potency. Testosterone and progesterone did not inhibit development, but the antiandrogen flutamide had inhibitory

effect. Juvenile hormone II was a potent inhibitor, as was expected based on the literature, whereas 10-hydroxyecdysone had no effect. 3,4-Dichlroraniline was inhibitory on development, whereas other control compounds, potassium dichromate and 3,5-dichlorophenol, did not inhibit development. Six of the 17 test compounds had 50% lethal concentration to 50% effective concentration (EC50) ratios higher than 10. The results suggest that naupliar development, as a parameter, is able to detect hormonal disrupters in addition to other chemicals that have other specific modes of action.

Brown V. 2003 Dec. Causes for Concern: Chemicals and Wildlife.http://www.worldwildlife.org/toxics/pubres/causesforconcern.pdf.
Call Number: W 11000 PDF

Burridge LE, Haya K. 1995. A review of di-n-butylphthalate in the aquatic environment: Concerns regarding its use in salmonid aquaculture [review]. Journal of the World Aquaculture Society 26(1):1-13.
Call Number: W 04286
Abstract: The presence and effects of di-n-butylphthalate (DBP) in aquatic environments are reviewed. Particular attention is paid to the use of DBP as a solvent in the pesticide formulation, Aquagard registered , used to treat salmonids against external parasites at aquaculture sites in Europe. DBP is sparingly soluble in water, is readily metabolized by fish, and has a high lethal threshold for aquatic organisms. It is, however, lipophilic, persistent in aquatic sediments, and is listed as a priority pollutant by the governments of Canada and United States. The dissemination of this compound directly to water raises several concerns which should be addressed by further research and increased monitoring.

Chaler R, Cantón L, Vaquero M, Grimalt JO. 2004. Identification and quantification of *n*-octyl esters of alkanoic and hexanedioic acids and phthalates as urban wastewater markers in biota and sediments from estuarine areas. J Chromatogr A.. 1046(1-2):203-210.
Call Number: W 11384 PDF only
Abstract: A gas chromatographic method for the identification and quantification of n-octyl esters (from n-octyl tetradecanoate to n-octyl hexa-cosanoate including dioctyl hexanedioate) and phthalates [dibutyl phthalate, benzyl butyl phthalate and di(2-ethylhexyl) phthalate] in sediments and biota from estuarine environments is described. Standards used for identification and quantification of some n-octyl esters were synthesized. The method has allowed the analysis of these compounds in polychaeta (Nereis diversicolor), oysters (Crassostea angulata), crabs (Carcinus maenas) and fish (Chelon labrosus, Platichtys flesus and Chondostroma polylepis) that were collected at different locations of the Urdaibai estuary (Bizkaia, Basque Country, Spain). Total phthalates and n-octyl esters ranged between 0.01 and 12 mug g(-1) and 0.05 and 9.4 mug g(-1), respectively, and were predominantly found in polychaeta and fish. Sediments did not contain these compounds in significant amount, only benzyl butyl phthalate, dioctyl hexanedioate and di(2-ethylhexyl) phthalate were found above limit of detection (0.01-0.05 mug g(-1)).

Colborn T, Smolen MJ. 2003. Cetaceans and contaminants. In: Vos JG, Bossart GD, Fournier M, O'Shea TJ, eds. Toxicology of Marine Mammals. London: Taylor and Francis. p 291-332 (Ch. 12).
Call Number: W 10573 PDF
Abstract: This chapter builds on an earlier epidemiological analysis of the literature on cetaceans that focused on the health status of individuals and populations in relation to concentrations of organochlorine contaminants in the animals. It includes recent literature on cetaceans and incorporates information about other chlorinated and non-chlorinated contaminants that are now becoming recognized as hazardous to living organisms. It also takes into consideration the growing knowledge about the physical and chemical condition of the cetaceans' environment and focuses on those contaminants, newly reported or increasing in background concentrations, in marine systems. When available, information from laboratory studies about the health effects of the contaminants is presented. In closing, this chapter relates this information to how contaminant-driven, phenotypic shifts among a sizable proportion of individuals in a population might lead to population destabilization.

Dinan L, Bourne P, Whiting P, Dhadialla TS, Hutchinson TH. 2001. Screening of environmental contaminants for ecdysteroid agonist and antagonist activity using the *Drosophila melanogaster* B(II) cell *in vitro* assay. Environmental Toxicology & Chemistry 20(9):2038-2046.
Call Number: W 09315

Abstract: The B(II) bioassay was developed as a rapid and reliable tool for detecting potential insect growth regulators acting as ecdysteroid receptor (ant)agonists. Based on an ecdysteroid-responsive cell line from Drosophila melanogaster, this microplate assay is ideally suited to the evaluation of environmental contaminants as potential endocrine disrupters. Data are presented for about 80 potential environmental contaminants, including industrial chemicals, pesticides, pharmaceuticals, phytoestrogens, and vertebrate steroids, and are compared with data for known (ant)agonists. Apart from androst-4-ene- 3,17-dione (a weak antagonist), vertebrate steroids were inactive at concentrations up to 10(-3) M. The vast majority of xenobiotics also showed no (ant)agonist activity. Among the industrial chemicals, antagonistic activity was observed for bisphenol A median effective concentration (EC50) of 1.0 x 10(-4) M and diethylphthalate (EC50 of 2.0 x 10(-3) M). Some organochlorine compounds also showed weak antagonistic activity, including o,p'-dichlorodiphenyldichloroethylene (DDE), p,p'-DDE, dieldrin, and lindane (EC50 of 3.0 x 10(-5) M). For lindane, bisphenol A, and diethylphthalate, activity is not associated with impurities in the samples and, for lindane and bisphenol A at least, the compounds are able to compete with ecdysteroids for the ligand binding site on the receptor complex, albeit at concentrations very much higher than those found in the environment. The only pharmaceutical showing any detectable antagonist activity was 17alpha-ethynylestradiol. In the context of recent publications on potential endocrine disruption in marine and freshwater arthropods, these findings suggest that, for some compounds (e.g., diethylstilbestrol), ecdysteroid receptor-mediated responses are unlikely to be involved in producing chronic effects. The B(II) assay has a potentially valuable role to play in distinguishing between endocrine-mediated, which normally occur at submicromolar concentrations, and pharmacological effects in insects and crustaceans.

Fox GA. 2001. Effects of endocrine disrupting chemicals on wildlife in Canada: Past present and future. Water Quality Research Journal of Canada 36(2):233-51.
Call Number: W 09305
Abstract: Within a few years of their widespread introduction into the environment, there were major concerns about the effects of man-made chemicals on wildlife in Canada. Biologists have found evidence of endocrine disruption in at least 16 species of birds (particularly fish-eating and predatory species), 3 species of terrestrial mammals and 1 whale, 1 reptile and several amphibians. These effects were seen in the Great Lakes, areas polluted with pulp and paper effluents, the forests of New Brunswick, a variety of agricultural habitats, acidified lakes in Nova Scotia, major rivers and inshore coastal waters, and the Arctic. They include decreased reproductive success, gross congenital abnormalities and interference with developmental/regenerational processes; thyroid dysfunction; metabolic abnormalities; feminization/demasculinization; alterations in sex ratios; altered brain development and behavior; and altered immune function. These sublethal effects have the potential to alter an individual's quality of life, its survival, or reproductive fitness. Morbidity and mortality are rarely detected and grossly underestimated in wildlife populations and we are likely to have underestimated the occurrence, prevalence and severity of endocrine disruption in wildlife. There is no formal existing program in Canada for gathering long-term evidence for determining trends in the incidence and severity of effects in organisms. All of the information on endocrine disruption in Canadian wildlife reported in this review was gathered as a result of academic research or research-based monitoring. Much greater effort must be made to systematically detect and identify a much broader range of man-made chemicals, both persistent and nonpersistent, and their metabolites in wildlife tissues and environmental media. These efforts should be complimented by parallel measurements of various biological activities of extracts of the same wildlife tissues and environmental media. This monitoring information would then point to specific locations, effluents, agricultural practices, industrial processes, and products were investigations of effects should be conducted and to species and functions potentially at risk.

Giam CS, Chan HS, Neff GS, Atlas EL. 1978. Phthalate ester plasticizers: A new class of marine pollutant. Science 199(4327):419-421.
Call Number: W 06474
Abstract: Phthalate ester plasticizers have been detected in the open-ocean environment. Samples consisting of water, sediment, air, and biota from the Gulf of Mexico and of water and air from the North Atlantic were analyzed and found to contain two phthalate esters, di-(2-ethylhexyl) phthalate (DEHP) and di-n-dibutyl phthalate (DBP): the concentrations of polychlorinated biphenyls (PCB's) and DDT's (p,p'-DDT and p,p'-DDE) were also determined. Like the ubiquitous PCB's and DDT's, the phthalate plasticizers were found in almost all samples analyzed; DEHP was present at higher concentrations than the PCB's or

DDT's in water and sediment. The environmental impact of the concentrations found in these studies, coupled with the continued high production and wise use of these plasticizers, requires assessment.

Hosokawa Y, Yasui M, Yoshikawa K, Tanaka Y, Suzuki M. 2003. The nationwide investigation of endocrine disruptors in sediment of harbours. Marine Pollution Bulletin 47(1-6):132-138.
Call Number: W 10816
Abstract: Various types of endocrine disruptors or environmental hormones flow from their sources down into harbours through rivers and other watercourses, and are accumulated in sediment on the sea bottom. Tributyltin, which has been used as paint for ship bottoms, is considered one of the endocrine disruptors. In close cooperation with the other ministries and agencies, the Ports and Harbours Bureau of the Ministry of Land, Infrastructure and Transport carried out an investigation in 1999 to determine the actual condition of 12 endocrine disruptors in the sediment of 39 harbours, in order to gather fundamental data to be used in future examinations of policy.
Furthermore, in 2000 the bureau chose seven harbours out of the above 39 harbours as subjects of an additional investigation regarding the surface distributions of endocrine disruptors in the harbour areas and the synchronistic change of accumulation of dioxin and other substances.
As the result of the investigation regarding the surface distribution of endocrine disruptors accumulated in seven harbours, relatively high concentrations were measured in the intermost parts of harbours and the mouth of rivers.
Synchronistic changes in the amount of dioxin and other substances accumulated in sediments of five harbours were determined. Small amounts of dioxin and other substances, including an especially small amount of coplanar-PCBs, were found in the layers formed before or around 1950. Relatively large amounts of these substances were measured in the upper layers formed during roughly 1960-1990, though no significant yearly differences in concentration could be identified. This result coincides with the facts that, during roughly 1960-1980, PCP and CNP were used as agricultural chemicals and full-scale production of PCBs started in 1960.

Iguchi T, Watanabe H, Katsu Y. 2001. Developmental effects of estrogenic agents on mice, fish, and frogs: A mini-review. Hormones & Behavior 40(2):248-251.
Call Number: W 09286
Abstract: Laboratory experiments have demonstrated that exposure of rodents to sex hormones during prenatal or early postnatal life can cause permanent and irreversible alterations of the endocrine and reproductive organs, such as ovary, fallopian tube, uterus, cervix, vagina, and mammary gland in females; and testis, epididymis, prostate, and seminal vesicle in males; as well as non reproductive organs including bones and muscle and immune and nervous systems in both sexes. Early development of Xenopus laevis into the tadpole and Fundulus heteroclitus goes through a rapid cell division, gastrulation, neurulation, and organogenesis within 1 week after fertilization. The developing embryo is very fragile and sensitive to estrogenic agents. Thus, these animals can be used as a suitable model for examining the effect of endocrine disruptors (hormonally active agents) on the development of aquatic living beings, which are most likely to be exposed to the compounds.

Jansson B, Alsberg T, Bergman A, Renberg L, Reutergardh L. 1987. Persistent organic compounds in the marine environment. National Swedish Environmental Protection Board Report 3395. Backgrounddocument for the Action Plan for Marine Pollution. September 1987.
Call Number: W 00766

Japan Environment Agency. 1999 Oct. Results of the 1998 Simultaneous Environmental Monitoring Survey Throughout the Country.: Japan Environment Agency.
Call Number: W 08453
Abstract: Contents:
Regarding the result of 1998 air environmental surveillance on exogenous endocrine disrupting chemicals
Surveillance of endocrine disrupters at public water areas
Measured results of water quality (in general water area)
Measured results of water quality (in priority water area)
Measured results of bottom sediments (in general water area)
Measured results of aquatic animals and plant life (in general water area)

Investigation report of environmental residual of agricultural chemicals related to Strategic Programs on Environmental Endocrine Disrupters '98
Results of research on effects of endocrine disrupting chemicals on wildlife
Results of research on effects of endocrine disrupting chemicals on wildlife (data)

Lincer JL. 1977. The impact of synthetic organic compounds on estuarine ecosystems. In. Estuarine Pollution Control and Assessment, Proceedings of a Conference, US EPA, Vol. 2p 425-443.
Call Number: W 00946
Abstract: The presence and effects of synthetic organic compounds is briefly reviewed with reference to the recent literature on the estuarine ecosystem. Pesticides and industrial chemicals are discussed in general with some attention given to the synergistic and modifying effects. Recommendations for future research are made which include elucidating the effects of synthetic organics at the ecosystem level.
[Biological effects of synthetic organics on estuarine life is discussed for pesticides and industrial toxicants. Appendix A is attached and shows the synthetic organic residues found in estuarine organisms, with additional comments for each regarding effects on spawning, biomagnification, species differences etc. Appendix B shows the effects of synthetic organic compounds on estuarine organisms. Appendix C is an overview of the field-testing of pesticides.]

Mackintosh CE, Maldonado J, Jing HW, Hoover N, Chong A, Ikonomou MG, Gobas F.A.P.C. 2004. Distribution of phthalate esters in a marine aquatic food web: comparison to polychlorinated biphenyls. Environmental Science & Technology 38(7):2011-2020.
Call Number: W 11107 PDF
Abstract: Dialkyl phthalate esters (DPEs) are widely used chemicals, with over 4 million tonnes being produced worldwide each year. On the basis of their octanol-water partition coefficients (K-ow), which range from 10(1.61) for dimethyl phthalate to 10(9.46) for di-iso-decyl phthalate, certain phthalate esters have the potential to bioconcentrate and biomagnify in aquatic food webs. However, there are no reported field studies on the trophodynamics of phthalate ester in aquatic food webs. This study reports the distribution of 8 individual phthalate esters (i.e., dimethyl, diethyl, di-iso-butyl, di-n-butyl, butylbenzyl, di(2-ethylhexyl), di-n-octyl, and di-n-nonyl) and 5 commercial isomeric mixtures (i.e., diiso-hexyl (C6), di-iso-heptyl (C7), di-iso-octyl (C8), di-iso-nonyl (C9), and di-iso-decyl (C10)) in a marine aquatic food web. DPE concentrations were determined in 18 marine species, representing approximately 4 trophic levels. Co-analysis of DPEs and 6 PCB congeners (i.e., PCB-18, 99, 118, 180, 194, and 209) in all samples produced a direct comparison of the bioaccumulation behavior of PCBs and DPEs. Lipid equivalent concentrations of the PCBs increased with increasing trophic position and stable isotope ratios WIN). The Food-Web Magnification Factor (FWMF) of the PCB congeners ranged from 1.8 to 9.5. Lipid equivalent concentrations of low and intermediate molecular weight DPEs (i.e., C1-C7 DPEs: dimethyl, diethyl, di-iso-butyl, di-n-butyl, benzylbutyl, and C6 and C7 isomers) did not exhibit statistically significant trends with trophic position or stable nitrogen isotope ratios (delta(15)N) in the food web and FWMFs were not significantly different from 1. Lipid equivalent concentrations of the high-molecular-weight DPEs (i.e., C8-C10 DPEs: di(2-ethylhexyl), di-n-octyl, di-n-nonyl, C8, C9, and C10) declined significantly with increasing trophic position and stable isotope ratios (delta(15)N), producing FWMFs between 0.25 and 0.48. These results show that all DPEs tested did not biomagnify in the studied aquatic food web whereas PCBs did biomagnify.

Mayer FL Jr., Sanders HO. 1973. Toxicology of phthalic acid esters in aquatic organisms. Environ Health Perspect 3:153-157.
Call Number: W 03255 PDF only
Abstract: [LC50's for freshwater organisms. DNBP reported less toxic to rainbow trout than to other fish tested. (96 h LC50 = 6.47 mg/l) ~ Lincer 1977]

O'Shea TJ, Reeves RR, Long AK. 1999 Apr, eds. Marine Mammals and Persistent Ocean Contaminants: Proceedings of the Marine Mammal Commission Workshop. Maryland: Marine Mammal Commission.
Call Number: W 09168
Abstract: The workshop objectives were to (1) review and summarize the state of knowledge about the types and levels of potentially harmful persistent contaminants found in marine mammals, and about the known and potential effects of these substances on marine mammal health and population dynamics; (2)

identify and rank in importance the critical uncertainties concerning the presence, levels, sources, fates, and effects of organochlorines, toxic elements, and other persistent contaminants on marine mammals; (3) outline research and monitoring programs needed to resolve the critical uncertainties as quickly as possible; and (4) assess how ongoing and planned research and monitoring programs should be restructured or expanded.

Parkerton TF, Konkel WJ. 2000. Application of quantitative structure-activity relationships for assessing the aquatic toxicity of phthalate esters. Ecotoxicology & Environmental Safety 45(1):61-78.
Call Number: W 07436
Abstract: Phthalate esters (PEs) are an important class of industrial chemicals for which an extensive aquatic toxicity database is available. The objectives of this study were to use these data to develop quantitative structure-activity relationships (QSARs) that describe aquatic toxicity for different freshwater and marine species, gain insights into toxicity mechanisms, and calculate PE water quality criteria using statistical extrapolation procedures. Results for low-molecular-weight PEs with logK(ow)<6 indicate that toxicity data conform to a simple logK(ow)-dependent QSAR, Fish were found to be more sensitive than algae while invertebrates spanned a wide range in toxicological response, Freshwater and marine species demonstrated a similar distribution of sensitivities. Comparison of species-dependent QSARs supports the hypothesis that biotransformation plays an important role in explaining toxicity differences observed between species. Estimated critical body residues (CBRs) for parent PE in fish were in the range reported for other polar organic chemicals while CBRs for parent PE plus associated metabolites were in the range reported for nonpolar narcotics (i.e., baseline toxicity) suggesting a possible putative role of PE metabolites. Depending on extrapolation procedure and assumptions, predicted no-effect concentrations (PNECs) for dimethyl, diethyl, dibutyl, and butybenzyl phthalate ranged from 3109 to 4780, 865 to 1173, 43 to 62, and 38 to 60 mu g l(-1), respectively. PNECs derived using this approach provide a transparent technical basis to support aquatic risk assessment for low-molecular-weight PEs, Results for high-molecular-weight PEs (logK(ow)>6) indicate that these chemicals are not acutely or chronically toxic to freshwater or marine organisms due to the combined role of low water solubility and limited bioconcentration potential which precludes attainment of internal concentrations that are required to elicit adverse effects, It is concluded that attempts to establish aquatic PNECs for high-molecular-weight PEs are not scientifically defensible.

Sanders HO, Mayer FL Jr., Walsh DF. 1973. Toxicity, residue dynamics, and reproductive effects of phthalate esters in aquatic invertebrates. Environ Res 6(1):84-90.
Abstract: [Although invertebrates rapidly accumulate these comounds, their 96 h TL50 (2.1 - > 32 mg/l) is appreciably greater than DDT, by comparison. However, the TL50 values for aquatic organisms are 700 to 11,000 times that which inhibited reproduction in one of the invertebrates tested (waterfleas)~Lincer 1977]

Servos MR, Van Der Kraak G. 2001. Special Issue: Endocrine Disrupting Substances in the Canadian Environment. Water Quality Research Journal of Canada 36(2):169-346.
Call Number: W 09300
Abstract: This is a special issue focusing on endocrine disrupting substances in the Canadian Environment. The following is a list of the articles: 'Scientific assessment of endocrine disrupting substances in the Canadian environment'; 'Endocrine disruption: Why is it so complicated?'; 'An overview of substances present in Canadian aquatic environments associated with endocrine disruption'; 'A review of the evidence for endocrine disruption in Canadian aquatic ecosystems'; 'Effects of endocrine disrupting chemicals on wildlife in Canada: Past present and future'; 'Endocrine disruption and human reproductive effects: An overview'; 'An overview of testing procedures and approaches for identifying endocrine disrupting substances'; 'Assessment of the effects of endocrine disrupting substances in the Canadian environment'; 'Endocrine disrupting substances and ecological risk assessment in Canada for commercial chemicals'; 'Uncertainties associated with assessing the risk of an endocrine active substance in the Canadian environment'; and 'A Canadian perspective on endocrine disrupting substances.'

Simoneit BR, Smith DH, Eglinton G, Burlingame AL. 1973. Application of real-time mass spectrometric techniques to environmental organic geochemistry. II. Organic matter in San Francisco Bay area water. Archives of Environmental Contamination & Toxicology 1(3):193-208.

Abstract: [Phthalate esters etc. in suspended organic matter in San Francisco Bay~Lincer 1977]

Spies RB, Rice DW Jr. 1988. Effects of organic contaminants on reproduction of the starry flounder *Platichthys stellatus* in San Francisco Bay. II. Reproductive success of fish captured in San Francisco Bay and spawned in the laboratory. Marine Biology 98:191-200.
Call Number: W 00002
Abstract: Gonadally mature Platichthys stellatus (Pallus) were captured at two localities in San Francisco Bay in 1983-1985 and were induced to spawn in the laboratory; they were evaluated for relationships between several measures of survival through successive early life-history stages, chlorinated hydrocarbon concentrations in maternal liver and spawned eggs, and maternal hepatic mixed-function oxidase (MFO) activity. The effect of laboratory holding on hepatic aryl hydrocarbon hydroxylase (AHH), a particular MFO activity, and concentrations of chlorinated hydrocarbons were also evaluated. Significant negative correlations were found between maternal hepatic AHH activity at the time of spawning and percent viable (floating) eggs, fertilization success, and embryological success. Embryological success was also negatively correlated with concentrations of polychlorinated biphenyls (PCBs) in eggs. Laboratory holding for 45 d, about twice the mean time to spawning, resulted in no significant changes in chlorinated hydrocarbon concentrations, but significant decreases in liver concentrations of phthalate esters and hepatic AHH activity. Female captured at the more urbanized central bay site, Berkeley (Bk), had a lesser proportion of floating eggs, poorer fertilization success, and higher hepatic AHH activities than those captured at a site in northern San Pablo Bay (SP). These results indicate the potential for a serious effect of lipophilic neutral organic contaminants on reproduction of an important estuarine flatfish species. Several mechanisms of toxic action are suggested to account for the observed effects, including the binding of toxic metabolites of contaminants to macromolecules and the alteration of sex steroids in females with contaminant induced P-450 isozyme(s).

Staples CA, Peterson DR, Parkerton TF, Adams WJ. 1997. The environmental fate of phthalate esters: A literature review. Chemosphere 35(4):667-749.
Call Number: W 05355
Abstract: A comprehensive and critical review was performed on the environmental fate of eighteen commercial phthalate esters with alkyl chains ranging from 1 to 13 carbons. A synthesis of the extensive literature data on physicochemical properties, partitioning behavior, abiotic and biotic transformations and bioaccumulation processes of these chemicals is presented. This chemical class exhibits an eight order of magnitude increase in octanol-water partition coefficients (K-ow) and a four order of magnitude decrease in vapor pressure (VP) as alkyl chain length increases from 1 to 13 carbons. A critical review of water solubility measurements for higher molecular weight phthalate ester; (i.e. alkyl chains greater than or equal to 6 carbons) reveals that most published values exceed true water solubilities due to experimental difficulties associated with solubility determinations for these hydrophobic organic liquids. Laboratory and field studies show that partitioning to suspended solids, soils, sediments and aerosols increase as K-ow increases and VP decreases. Photodegradation via free radical attack is expected to be the dominant degradation pathway in the atmosphere with predicted half-lives of ca. 1 day for most of the phthalate esters investigated. Numerous studies indicate that phthalate esters are degraded by a wide range of bacteria and actinomycetes under both aerobic and anaerobic conditions. Standardized aerobic biodegradation tests with sewage sludge inocula show that phthalate esters undergo greater than or equal to 50% ultimate degradation within 28 days. Biodegradation is expected to be the dominant loss mechanism in surface waters, soils and sediments. Primary degradation half-lives in surface and marine waters range from <1 day to 2 weeks and in soils from <1 week to several months. Longer half-lives may occur in anaerobic, oligotrophic, or cold environments. Numerous experiments have shown that the bioaccumulation of phthalate esters in the aquatic and terrestrial foodchain is limited by biotransformation, which increases with increasing trophic level. Consequently, models that ignore biotransformation grossly exaggerate bioaccumulation potential of higher molecular weight phthalate esters. This review provides the logical first step in elucidating multimedia exposure to phthalate esters.

Takei GH, Sawa TR. 1996. The distribution and characterization of organochloride residues in animal tissues - An environmental and toxicological assessment. CONFIDENTIAL DRAFT .
Call Number: W 03404 CONFIDENTIAL
Abstract: In this report, we suggest a diagnostic model, whereby results for the analyses of organochlorides

and possibly other toxic materials, in animal tissues, may be organized, evaluated and interpreted constructively at the time of the necropsies. Our proposed model includes the quantitive analyticl results for the multi-residue determination of organochlorides in at least 4 of the essential tissues from one-animal carcass. The results are evaluated then with respect to various parameters, among them being the frequencies of the numbers of different residues that are simultaneously detected in a tissue, and the total residue loads or the sum of the quantities of all residues determined in a tissue. In terms of frequencies of different residues, as many as 13 out of 20 targered materials were found in one tissue speciment, and greater than 10 parts per million, total residue loads, were not uncommon in a tissue speciment. These numbers were surprising and even more so when all the different essential tissues from one animal were determined to have similar numbers. In the cases of barn owls, we conclude that the deaths of some of them could definitely be attributed to high levels of multiple organochloride exposures. With the pelagic mammals, which have an abundance of fatty tissues, the organochlorides, being lipophilic, are stored in these tissues and are drawn away from the essential organs, thereby reducing the toxic effects on these animals to conditions of chronic exposures. The method of "reverse toxicology" is recommended particularly when quantitative analytical data that are not readily accessible are available in veterinary labs conducting routine necropsies. Environmentally, we believe that the levels of organochloride residues are approaching stages of equilibrium where they will eventually become similar throughout the world, due to the organochlorides being persistent and dynamic, along with planned and accidental mobilites of animal and plant populations. The primary tissues analyzed were the liver, kidney, brain and heart. Testes, stomach, muscle, and other miscellaneous tissues were also sampled. Species sampled include: Black Foot and Laysan Albatross, Columbia River Smelt, Squid, Smelt, Herring, Hawksbill Turtle, Haw'n Owl, Turkey, Barn Owl, Nene Goose, Flamingo, Red-footed Booby, Kolos Duck, Barn Owl, Hawaiian Monk Seal, Feral Owl, Johnston's Crocodile, Fish, Black Swan, Whale, Marsupial-Wallaroo, SunConure, Gallinule, Hermann's Gull, Nulubar Dragon, Raven, Masked Booby, Spinner Dolphin, Armadillo Edentate, Tawny Frog Mouth, Bearded Dragon, Mynah Bird, Feline, Green Sea Turtle, Red Crested Prochard, Lace Monitor, Nene, Kola Hybrid Duck, Penguin, Francolin, Sperm Whale Pygmy, German Shepherd, Muscovy Duck, Melon Headed Whale, Monk Seal, Alligator, Scottish Terrier, Atlantic Bottlenose Dolphin, Jackass Penguin, Sea Lion, Equine, Canada Goose, Wood Duck.

Thomas KV, Hurst MR, Matthiessen P, Waldock MJ. 2001. Characterization of estrogenic compounds in water samples collected from United Kingdom estuaries. Environmental Toxicology & Chemistry 20(10):2165-2170.
Call Number: W 09250
Abstract: This report describes the identification of important estrogenic compounds in surface and sediment pore-water samples collected from the Tyne and Tees estuaries (United Kingdom) through the application of toxicity identification evaluation (TIE) procedures. The Tyne and Tees estuaries represent estuaries that have been historically impacted by industrial activities and continue to receive treated domestic sewage and industrial effluent. In 1998, Dabholm Gut on the Tees received a mixture of treated and untreated effluent, while Howdon sewage treatment works (STW) discharged primary treated effluents. An estrogenically active water sample collected from Howdon STW on the Tyne was shown to contain 17beta-estradiol, androsterone, and an unknown estrogenic compound(s). Most of the activity contained in a sample collected from the Dabholm Gut combined discharges on the Tees was also due to 17beta-estradiol with additional activity from nonylphenol and (tentatively) bis(2-ethylhexyl)phthalate. The only sediment pore-water sample to demonstrate estrogenic activity was collected from Dabholm Gut.

Thomsen M, Carlsen L, Hvidt S. 2001. Solubilities and surface activities of phthalates investigated by surface tension measurements. Environmental Toxicology & Chemistry 20(1):127-132.
Call Number: W 08551
Abstract: Aqueous solutions of DEP (di-ethyl), DnBP (di-n-butyl), DnH(6)P (di-n-hexyl), and DEHP (di-[2-ethyl-hexyl])phthalates have been investigated by use of surface tension measurements at temperatures between 10 and 35 degreesC. A tensiometric approach allows for the determination of unimeric solubilities and DeltaG degrees, which is the standard Gibbs free energy change, for the dissolution of phthalates in water. The unimeric solubility of the phthalates increase with decreasing temperature. The DeltaG degrees shows a linear increase with increasing phthalate alkyl chain length. The contribution of enthalpy (DeltaH degrees) and entropy (DeltaS degrees) to DeltaG degrees were calculated from the temperature-dependent solubilities. The contributions of both DeltaH degrees and DeltaS degrees are negative and increase in

magnitude with increasing alkyl chain length, suggesting hydrophobic interactions between phthalates and water. The ability of different phthalates to lower the surface tension decreases with increasing alkyl chain length, whereas the relative affinity for adsorption in the air-water interface increases drastically for long-chain phthalates. Despite the low surface activity of phthalates compared with that of common surfactants, they show significant affinity for adsorption in air-water interfaces of natural surface waters. This property, combined with their low solubilities, may affect the fate of these compounds within the natural environment, because they form emulsions above unimeric saturation in aqueous media.

Tollefsen KE, Meys JFA, Frydenlund J, Stenersen J. 2002. Environmental estrogens interact with and modulate the properties of plasma sex steroid-binding proteins in juvenile Atlantic salmon (*Salmo salar*). Marine Environmental Research 54(3-5 (Special Issue SI)):697-701.
Call Number: W 11307 PDF only
Abstract: Environmental chemicals may modulate the endocrine system through interaction with plasma sex steroid-binding proteins (SBP) and SBP-regulated processes. Some of these chemicals, which are known to interact with the estrogen receptor (ER), were found to bind competitively to the Atlantic salmon (Salmo salar) SBP and potentially disrupt the endocrine function of these proteins. Furthermore, both weakly acting (di-n-butyl phthalate) and potent estrogen mimics (ethynylestradiol), were able to induce a substantial up-regulation of circulating levels of SBP in vivo. Interestingly, modulation of SBP-levels was found to be a more sensitive endpoint than chemically induced interference with classical ER-mediated mechanisms for weakly acting estrogen mimics like di-(n-butyl) phthalate. Interference with the endocrine function of SBPs may thus introduce a novel mechanism for endocrine disruption, and give additional answers to the question why some weakly acting xenoestrogens are causing "estrogen-like" reproductive disturbances in developing males.

Tyler CR, Jobling S, Sumpter JP. 1998. Endocrine disruption in wildlife: A critical review of the evidence. Crit Rev Toxicol 28(4):319-361.
Call Number: W 05994
Abstract: In recent years, a number of man-made chemicals have been shown to be able to mimic endogenous hormones, and it has been hypothesized that alterations in the normal pattern of reproductive development seen in some populations of wildlife are linked with exposure to these chemicals. Of particular importance are those compounds that mimic estrogens and androgens (and their antagonists), because of their central role in reproductive function. In fact, the evidence showing that such chemicals actually do mimic (or antagonize) the action of hormones in the intact animal is limited. In only a few cases have laboratory studies shown that chemicals that mimic hormones at the molecular level (in vitro) also cause reproductive dysfunction in vivo at environmentally relevant concentrations. In addition, the reported studies on wild populations of animals are limited to a very few animal species and they have often centered on localized 'hot-spots' of chemical discharges. Nevertheless, many of these xenobiotics are persistent and accumulate in the environment, and therefore a more widespread phenomenon of endocrine disruption in wildlife is possible. This article reviews the evidence, from both laboratory and field studies, that exposure to steroid hormone mimics may impair reproductive function and critically assesses the weight of evidence for endocrine disruption in wildlife.

["Phthalates are the most abundant manmade chemicasl in the environment" (p. 332, citing Peakall 1975. Phthalate esters: occurrence and biological effects, Res. Rev. 54(1))]

von Westernhagen H, Sperling KR, Janssen D, Dethlefsen V, Cameron P, Kocan R, Landolt M, Furstenberg G, Kremling K. 1987. Anthropogenic contaminants and reproduction in marine fish. Berichte Der Biologischen Ansalt Helfoland 3:1-70.
Call Number: W 03256
Abstract: Running ripe whiting from the North Sea and cod from the Baltic Sea were caught with and ottertrawl and stripped. Eggs and sperm were used for incubation experiments in uncontaminated water in order to determine viable hatch. Chlorinated hydrocarbons in ovaries and livers of female and male whiting and female cod were determined by means of gas chromatography. In whiting high ovary residues were found for PCBs (3-370 ug kg-1 wet weight), the members of the DDT group (up to 58 ng/g wet weight) and Dieldrin (up to 20 ug kg-1 wet weight). In cod ovaries contamination with PCBs was lower, not reaching 100 µg kg-1 wet weight, but contamination with DDT and derivatives was comparable to conditions found

in whiting, with maximum values of 44 ug kg-1 wet weight DDE. Viable hatch in incubation experiments with whiting eggs was low, highest values being only 50%; in cod up to 80% viable hatch was registered. In whiting at high levels of contaminants viable hatch was consistently low suggesting an effect of chlorinated hydrocarbons on reproductive success. This was not the case in cod, PCB values remained below a set effective level of 120 ug kg-1 wet weight and consequently no influence of PCBs on cod hatching was observed. No relation was found with DDT and its metabolites in cod. Eggs from herring and turbot were used to test the influence of contaminated incubation medium (sea surface microlayer) on embryonic development. Surface microlayer contained varying amounts of heavy metals in concentrations 2 orders of magnitude above those found in subsurface bulk water. Chlorinated hydrocarbon pesticides were not found in concentrations elevated above bulk water, but considerable amounts of petroleum hydrocarbons and phthalate esters were detected. Herring eggs were most affected by Helgoland microlayer (suspected effect of high metal content), while turbot eggs were most sensitive to Travemunde and Elbe microlayer (suspected effect of high petroleum hydrocarbons). General effects of pollutants on reproduction in fish are to be expected whenever substances have been accumulated either in parental tissue or in the environment.

Wennberg L, Parkman H, Remberger M, Wictor T, Williams C. 1997. DEHP in Swedish lakes. Poster :1 p.
Call Number: W 04797

Zou E, Fingerman M. 1999. Effects of exposure to diethyl phthalate, 4-(tert)-octylphenol, and 2,4,5-trichlorobiphenyl on activity of chitobiase in the epidermis and hepatopancreas of the fiddler crab, *Uca pugilator*. Comparative Biochemistry & Physiology C: Pharmacol Toxicol Endocrinol 122(1):115-120.
Call Number: W 06634
Abstract: Seven-day exposure of fiddler crabs, Uca pugilator, to diethyl phthalate at 50.0 mg l-1 significantly inhibited the activity of chitobiase (also known as N-acetyl-beta-glucosaminidase) in the epidermis and hepatopancreas. Epidermal chitobiase activity of crabs exposed to 10.0 mg l-1 4-(tert)-octylphenol for 7 days significantly decreased. PCB29 at 0.5 and 2.0 mg l-1 significantly inhibited chitobiase activity in the epidermis and hepatopancreas of crabs exposed for 3 days. The inhibitory effects rendered by diethyl phthalate and PCB29 can at least partly account for the delayed molting they cause because chitobiase is needed to break down the old exoskeleton of crustaceans prior to ecdysis. Since chitinolytic enzymes are apparently the products of ecdysteroid regulated genes in arthropods, the decline in chitobiase activity after exposure to diethyl phthalate, 4-(tert)-octylphenol, and PCB29 along with the delayed molting they cause strongly suggests that these xenobiotics disturb the Y-organ-ecdysteroid receptor axis. Such disturbance may involve an interaction between ecdysteroid receptors and steroid mimics where the steroid mimics act as antagonists of endogenous steroid molting hormones, and/or arise from the interference with synthesis and excretion of ecdysteroids by these compounds.

Zucco C, Cameron P. Seals and endocrine disruptors. WWF Briefing :3 pp.
Call Number: W 06059
Abstract: A brief introduction to some endocrine disrupting chemicals found in seals and/or their marine habitats, including PCBs, phthalates, DDT and others (see note above). Some case studies are presented showing incidences of reproductive failure correlating with high levels of contaminants. Cases cited include studies of harbour seals in Bothnian Bay with abnormalities in their reproductive tracts associated with high levels of PCB and DDT in the blubber (hormonal osteoporosis was also observed); a reduction in fecundity in harp seals in Barents Sea; reduced numbers of pups and follicles in ovaries of harbour seals in Dutch coastal waters (organochlorines?); harbour seals fed contaminated herring (PCBs) from the Baltic Sea showing a clear deficit in immunoefficiency after 2 years; and Baltic grey seals born after 1960 show abnormal skull development*. WWF recommends that OSPAR Commission should phase out known EDCs, improve toxicity tests, improve research funding, and set up an international task force and working group to assess EDC concerns. *(see text for references)

Phthalates & Marine Environments (from Lynn Caroll, OurStolenFuture.org)

Acey R, Healy P, Unger TF, Ford CE, Hudson RA. 1987. Growth and aggregation behavior of representative phytoplankton as affected by the environmental contaminant di-n-butyl phthalate. Bull Environ Contam Toxicol 39:1-6.

Adams WJ, Biddinger GR, Robillard KA, Gorsuch JW. 1995. A summary of the acute toxicity of 14 phthalate esters to representative aquatic organisms. Environmental Toxicology & Chemistry 14(9):1569-1574.

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Dinan L, Bourne P, Whiting P, Dhadialla TS, Hutchinson TH. 2001. Screening of environmental contaminants for ecdysteroid agonist and antagonist activity using the *Drosophila melanogaster* B(II) cell *in vitro* assay. Environmental Toxicology & Chemistry 20(9):2038-2046.

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Iguchi T, Watanabe H, Katsu Y. 2001. Developmental effects of estrogenic agents on mice, fish, and frogs: A mini-review. Hormones & Behavior 40(2):248-251.

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Thomas KV, Hurst MR, Matthiessen P, Waldock MJ. 2001. Characterization of estrogenic compounds in water samples collected from United Kingdom estuaries. Environmental Toxicology & Chemistry 20(10):2165-2170.

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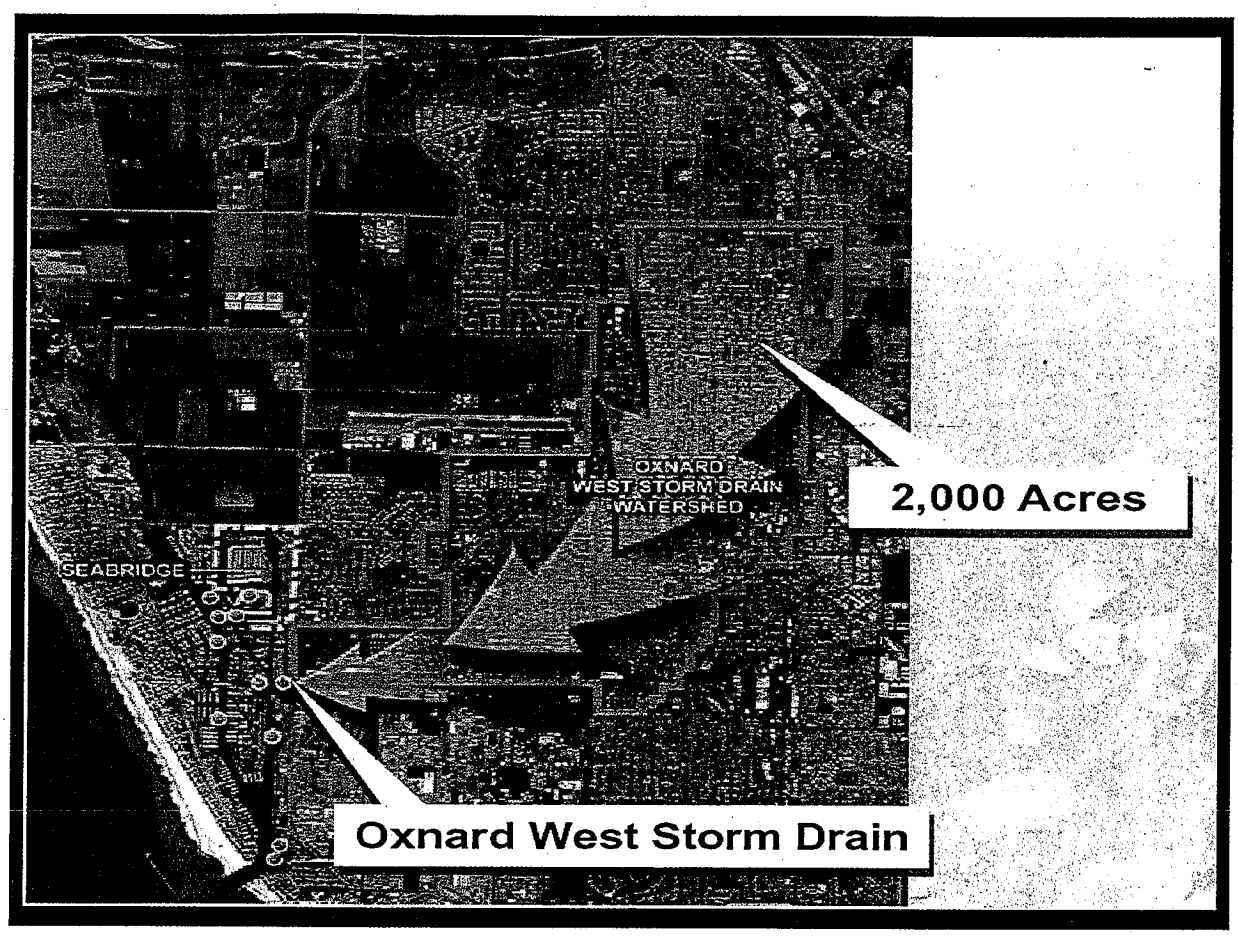
pugilator. Comparative Biochemistry & Physiology C: Pharmacol Toxicol Endocrinol 122(1):115-120.

Zucco C, Cameron P. Seals and endocrine disruptors. WWF Briefing :3 pp.

Oxnard West Drain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WEST STORM DRAIN
WATERSHED
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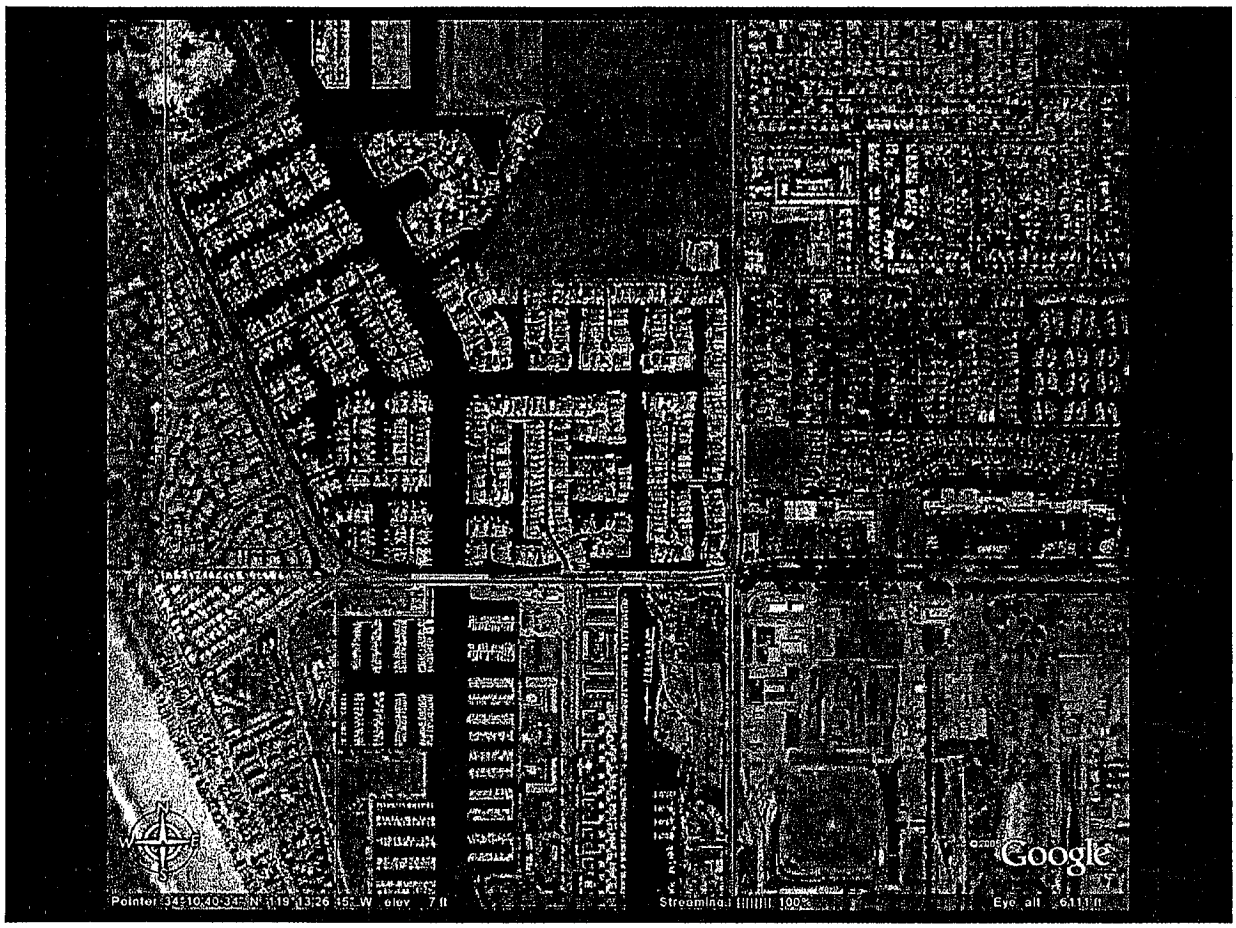
SEABRIDGE
Oxnard West Storm Drain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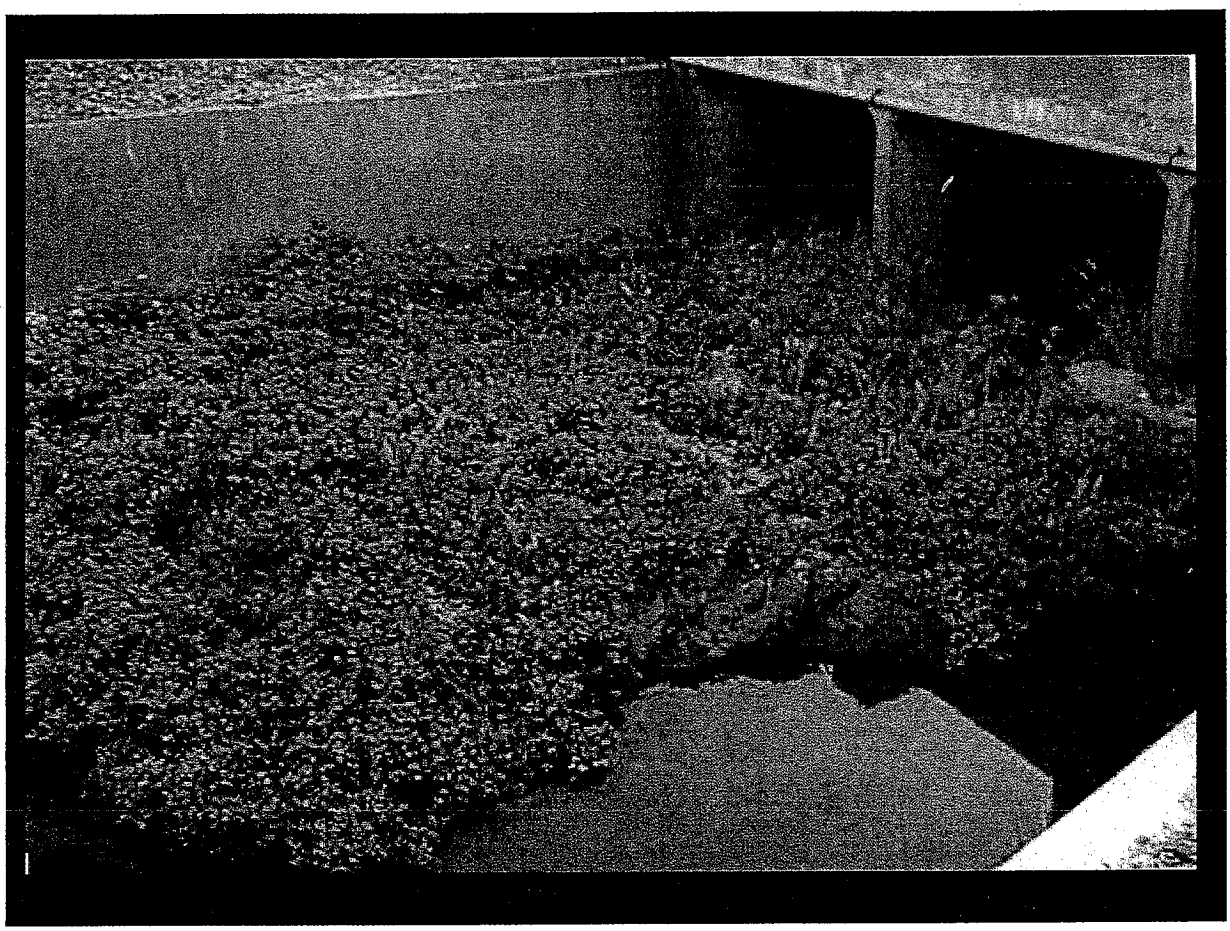

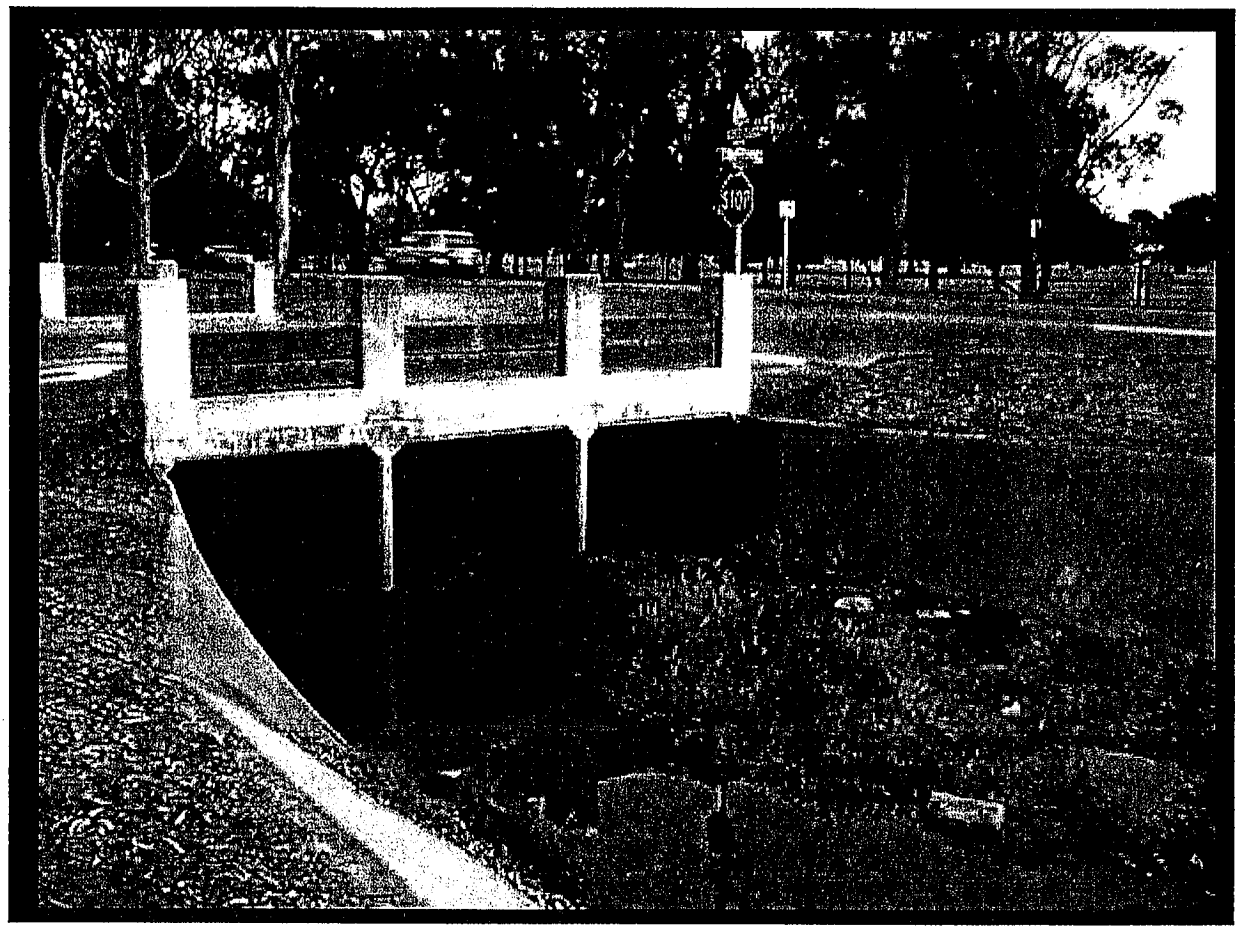
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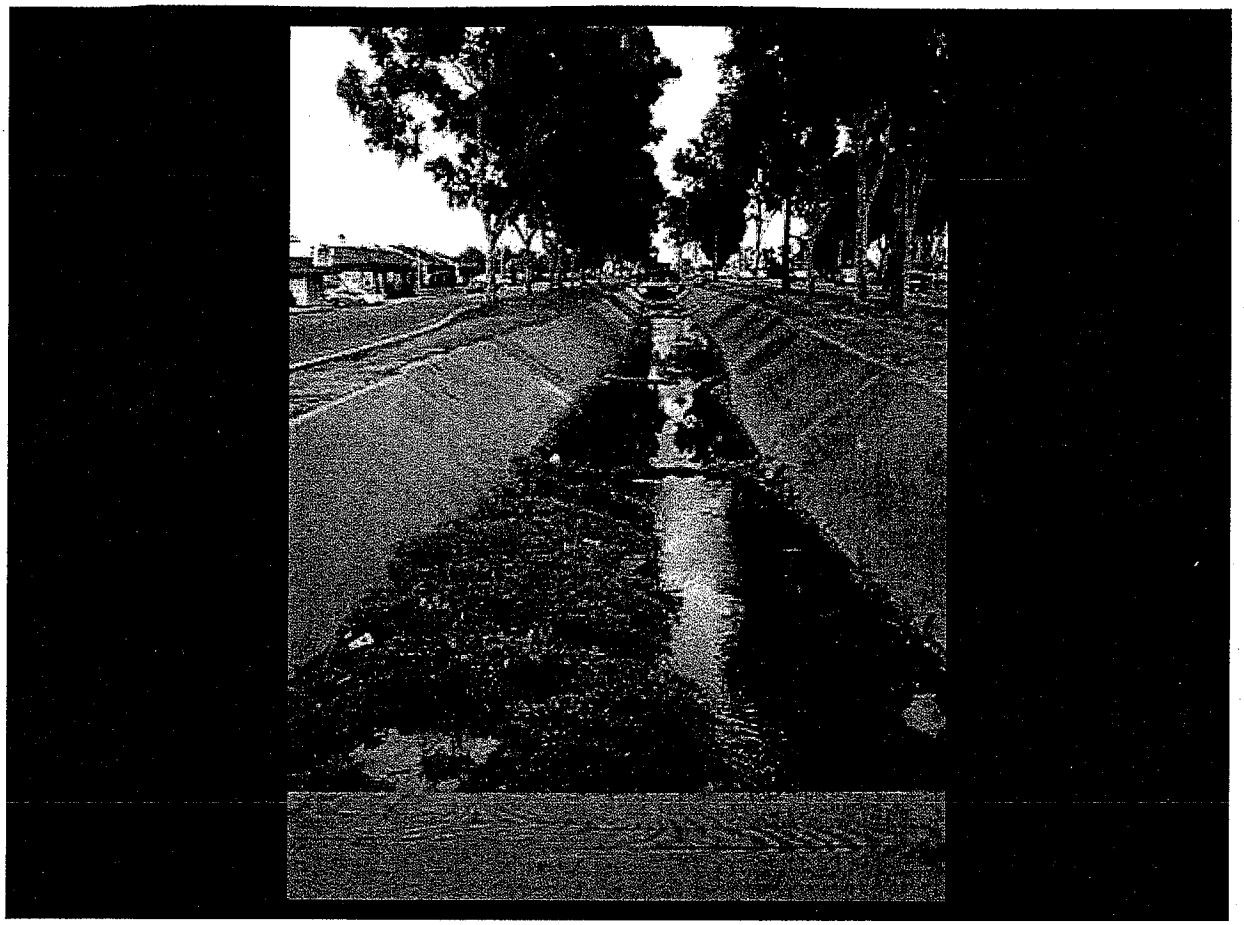

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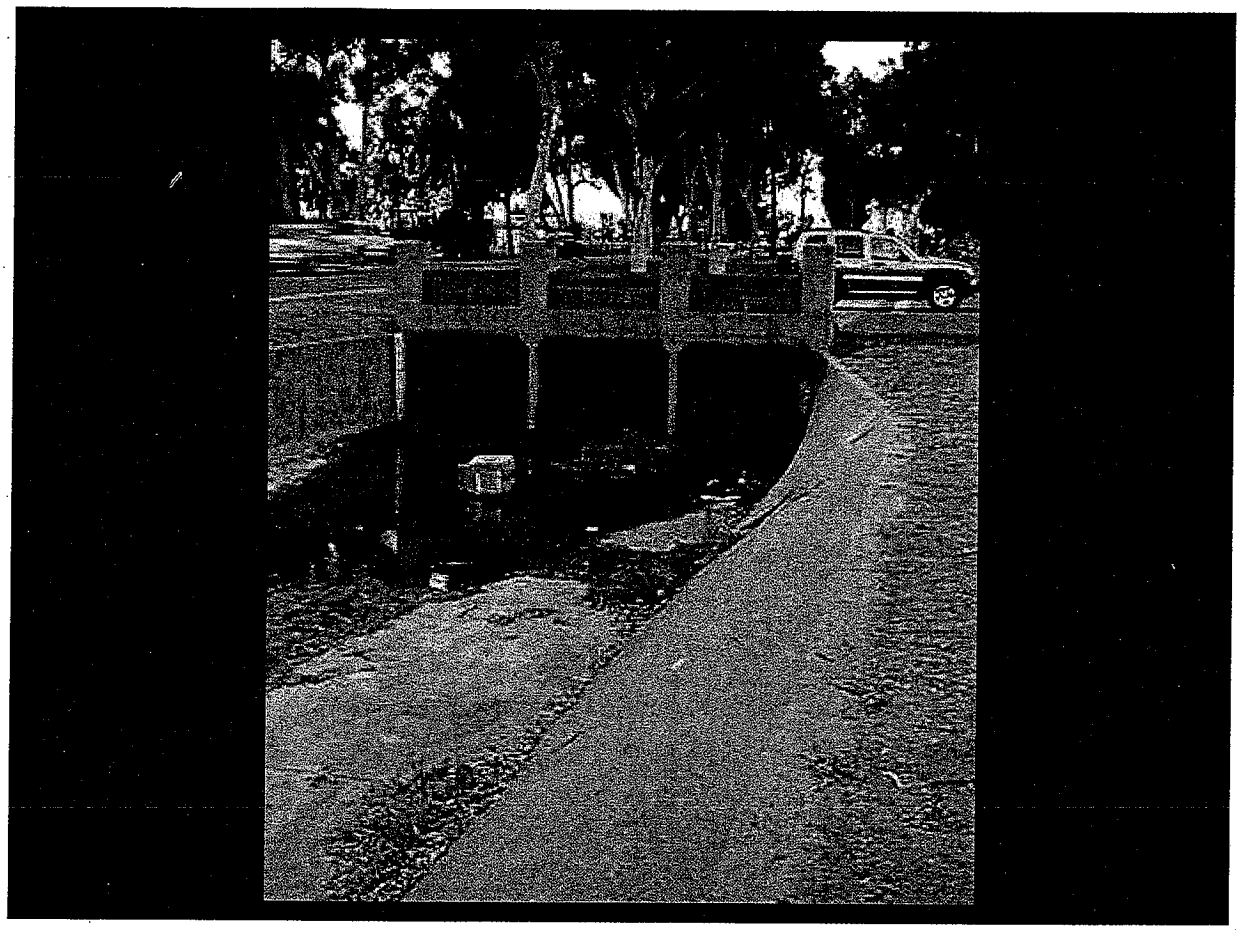

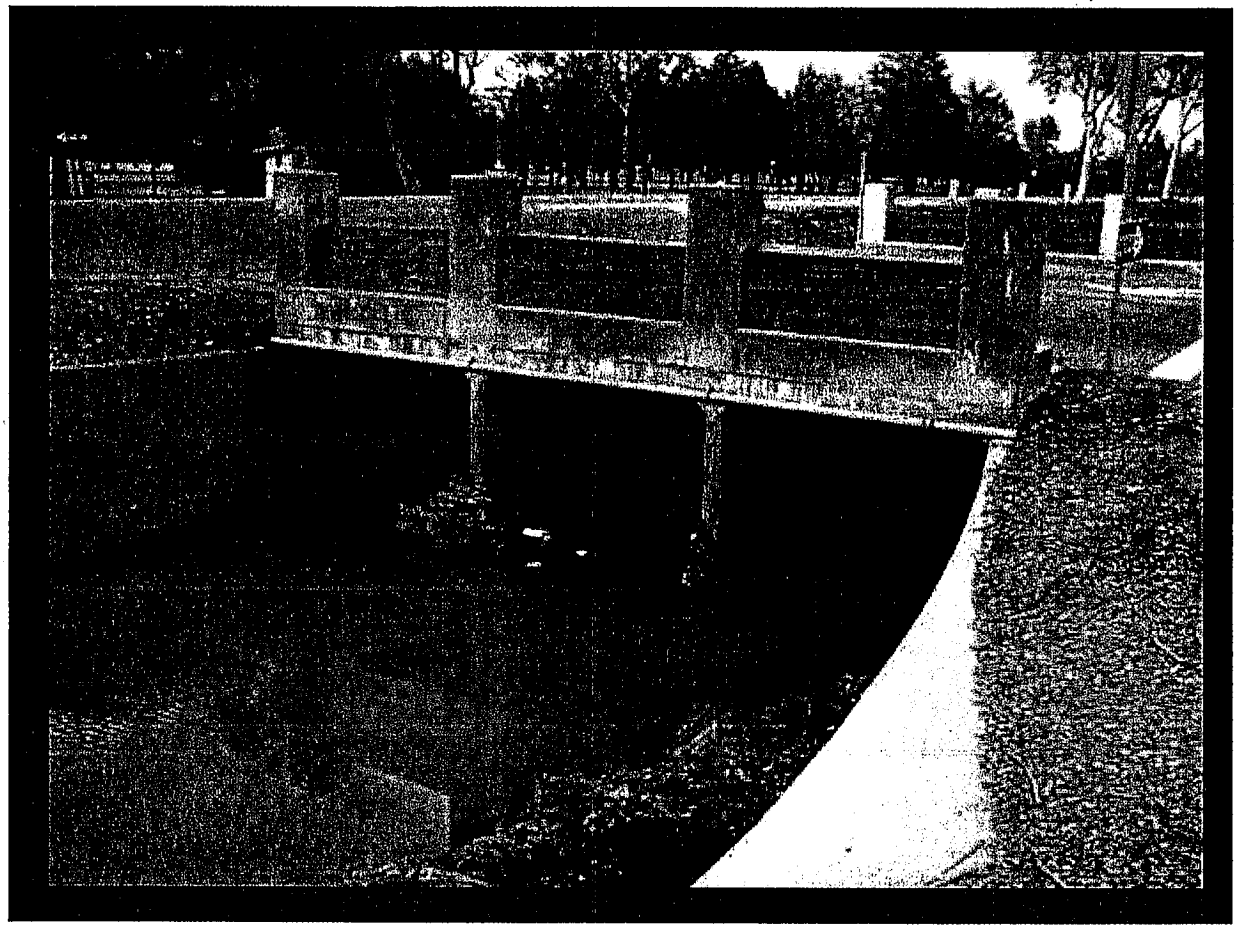

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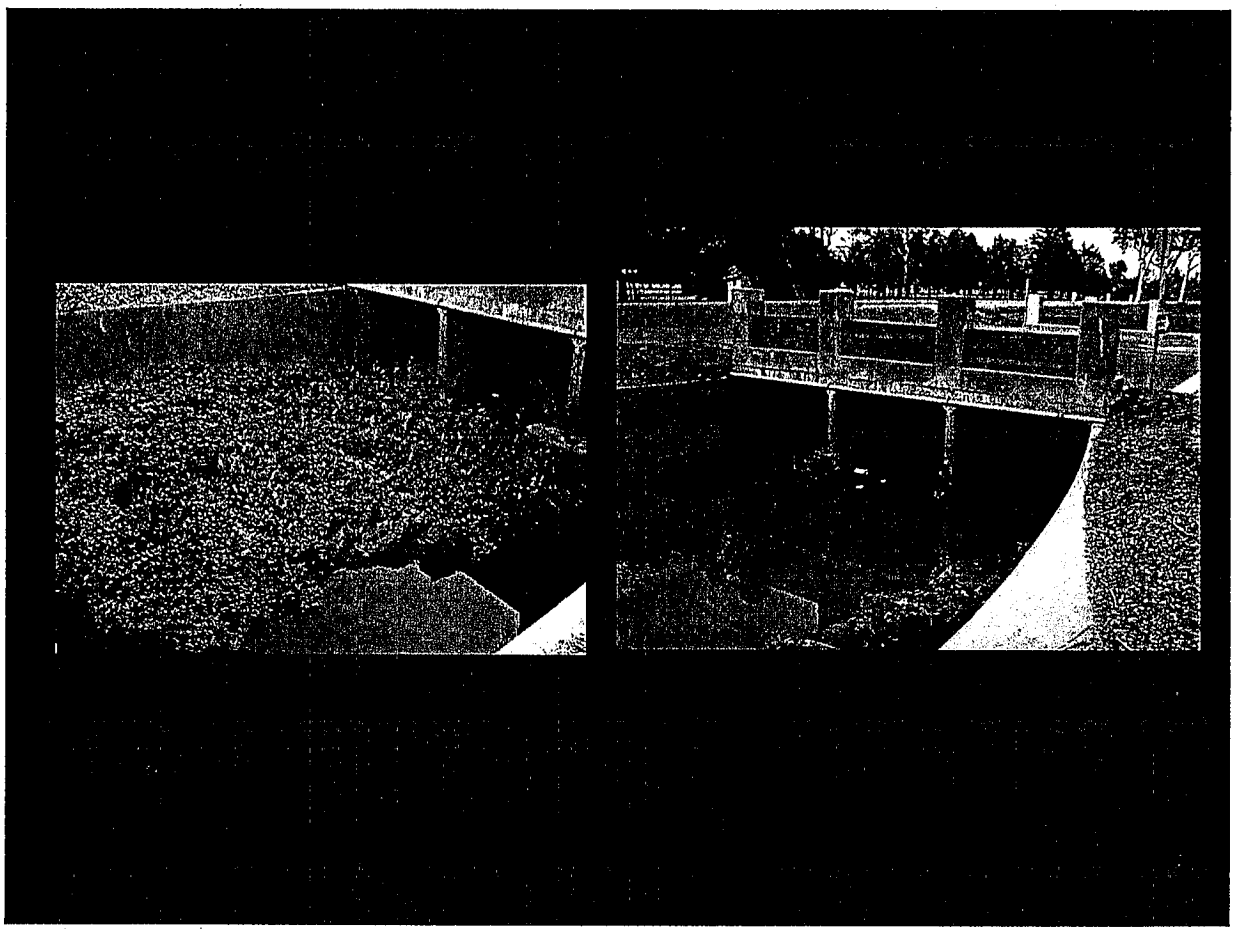
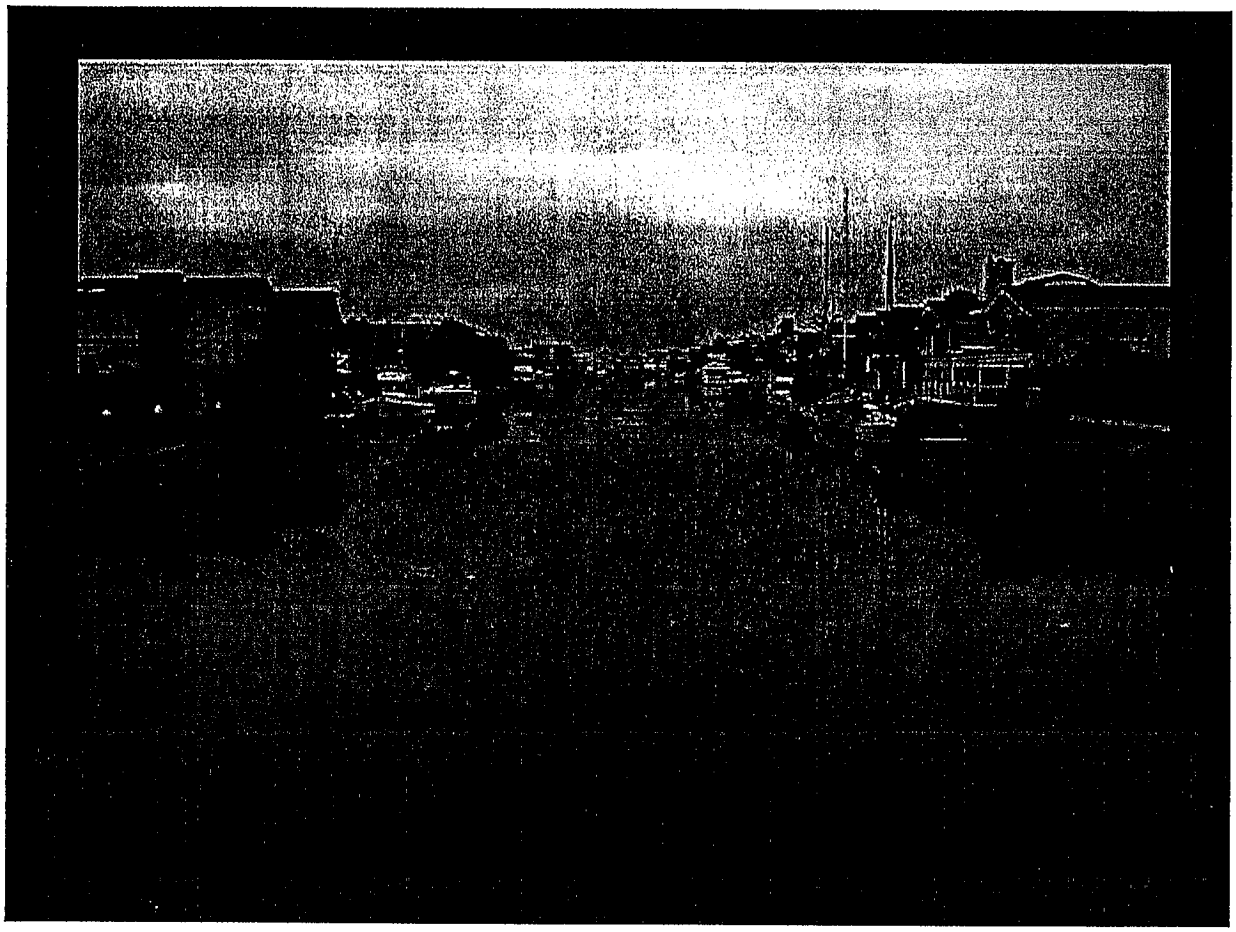
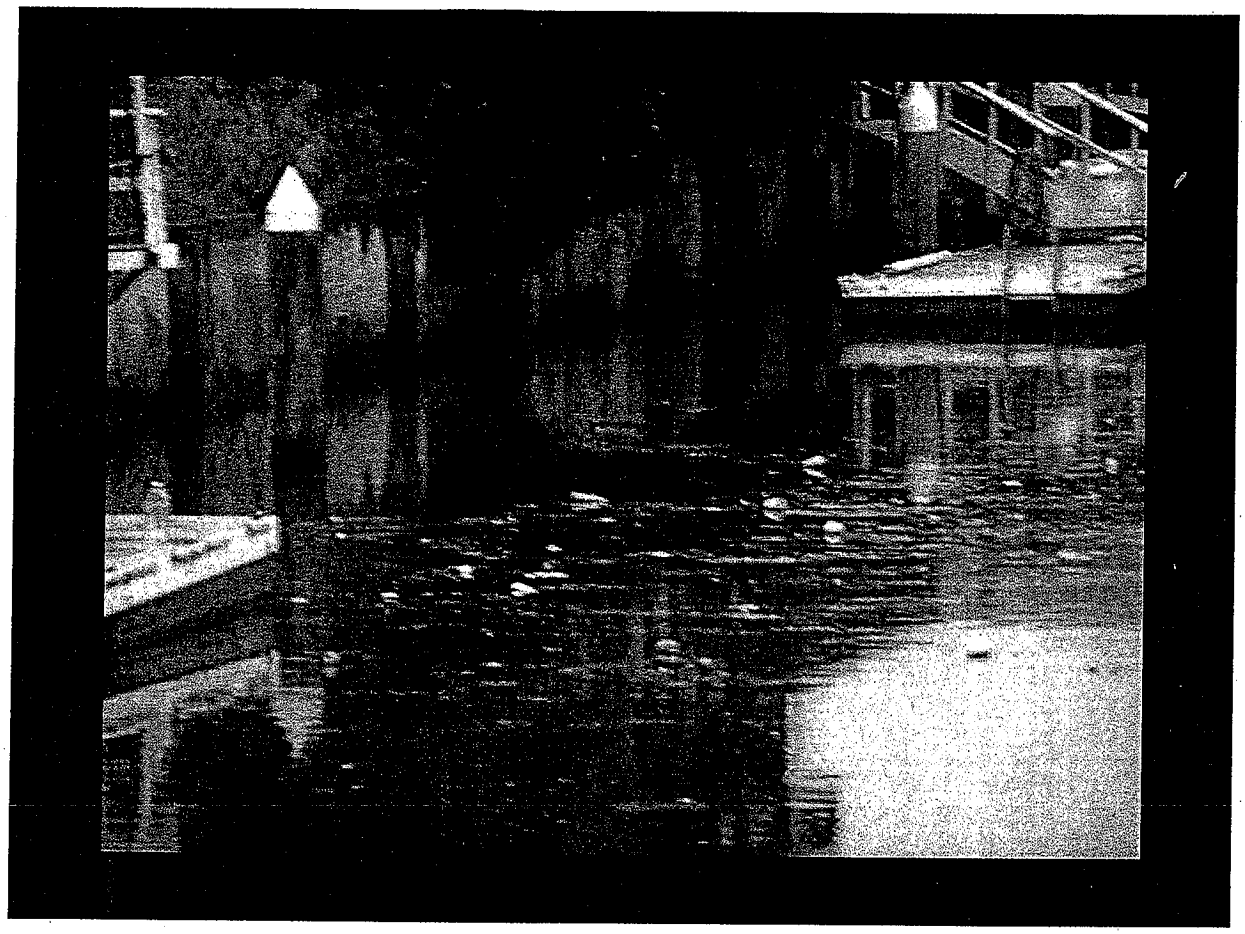
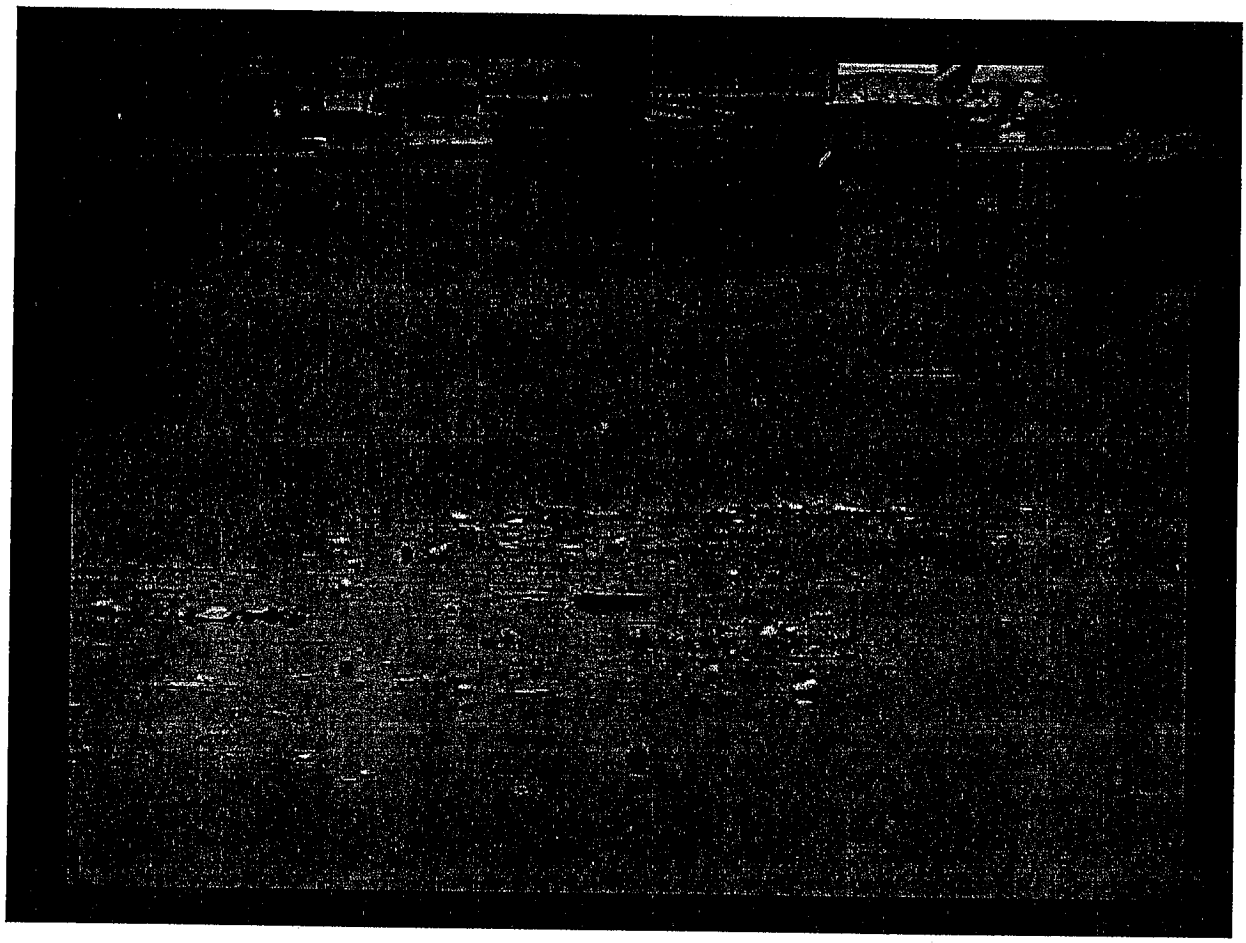
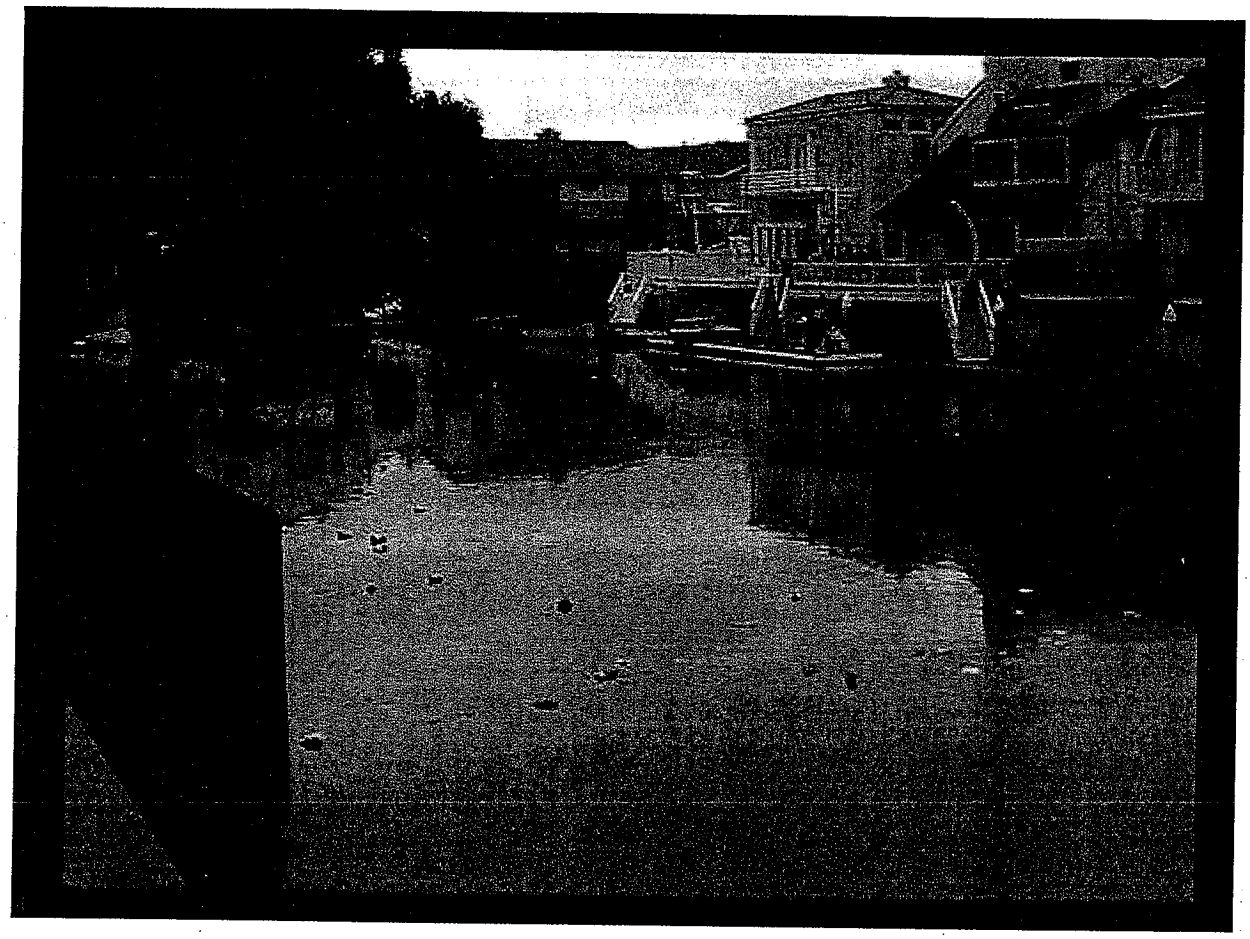
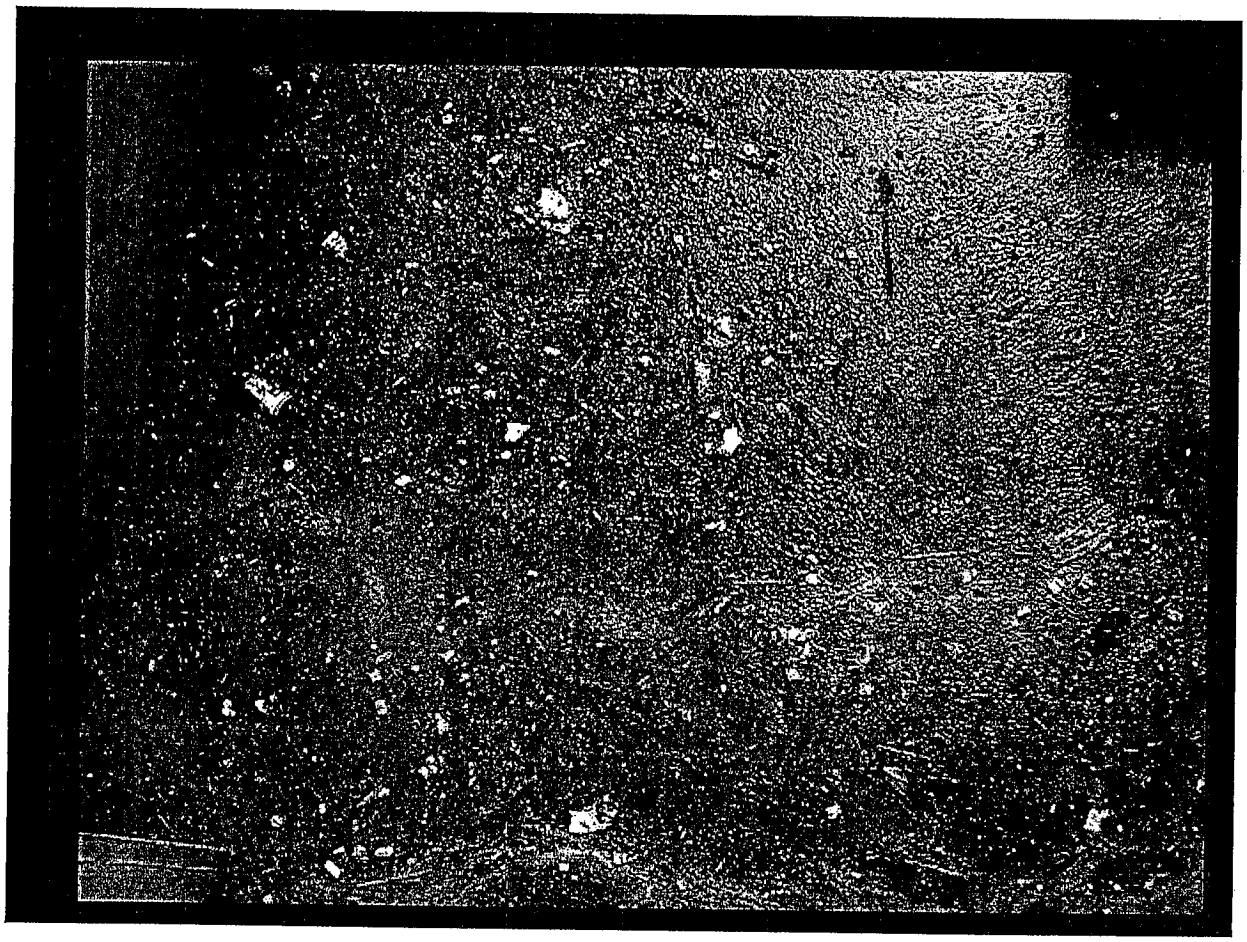


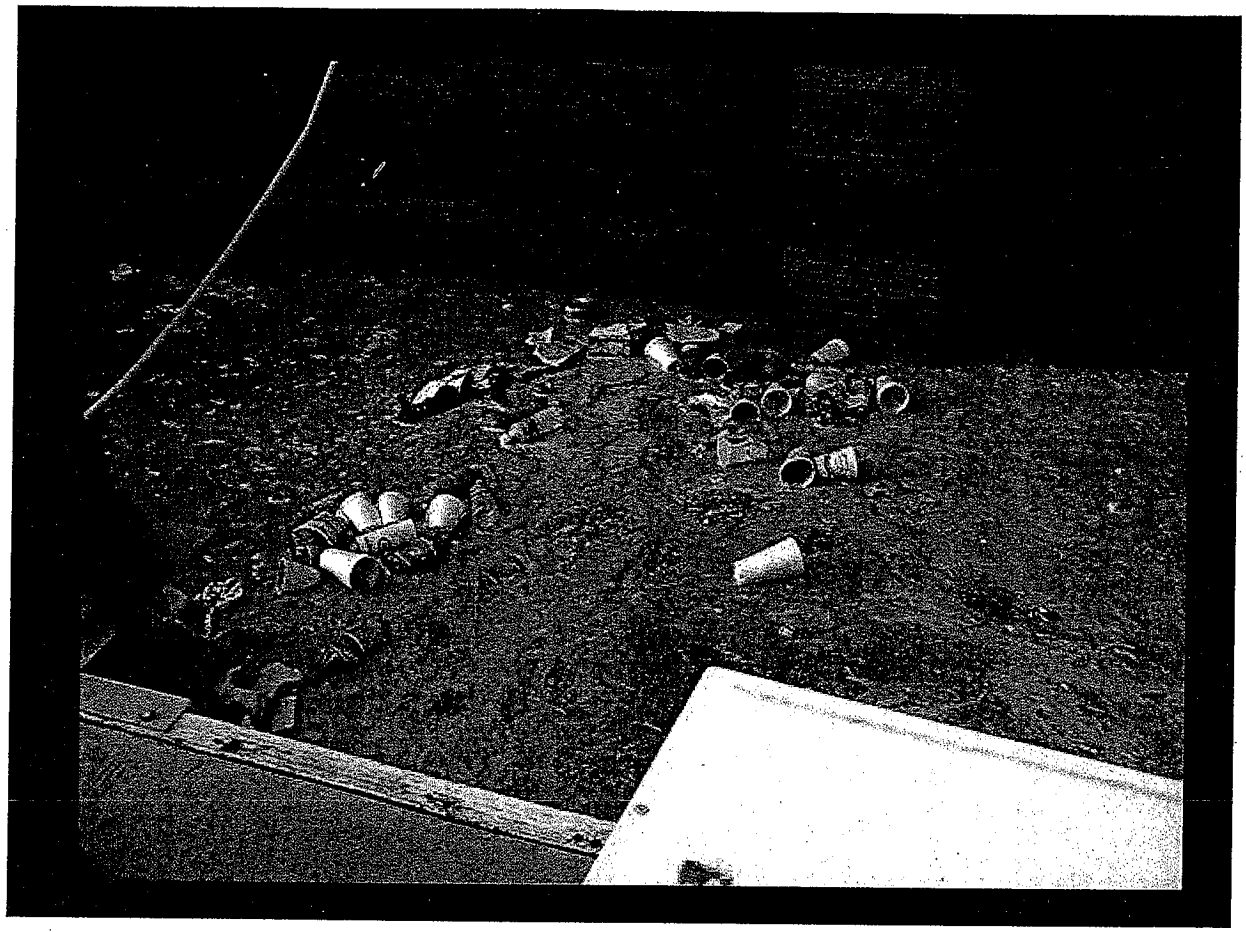


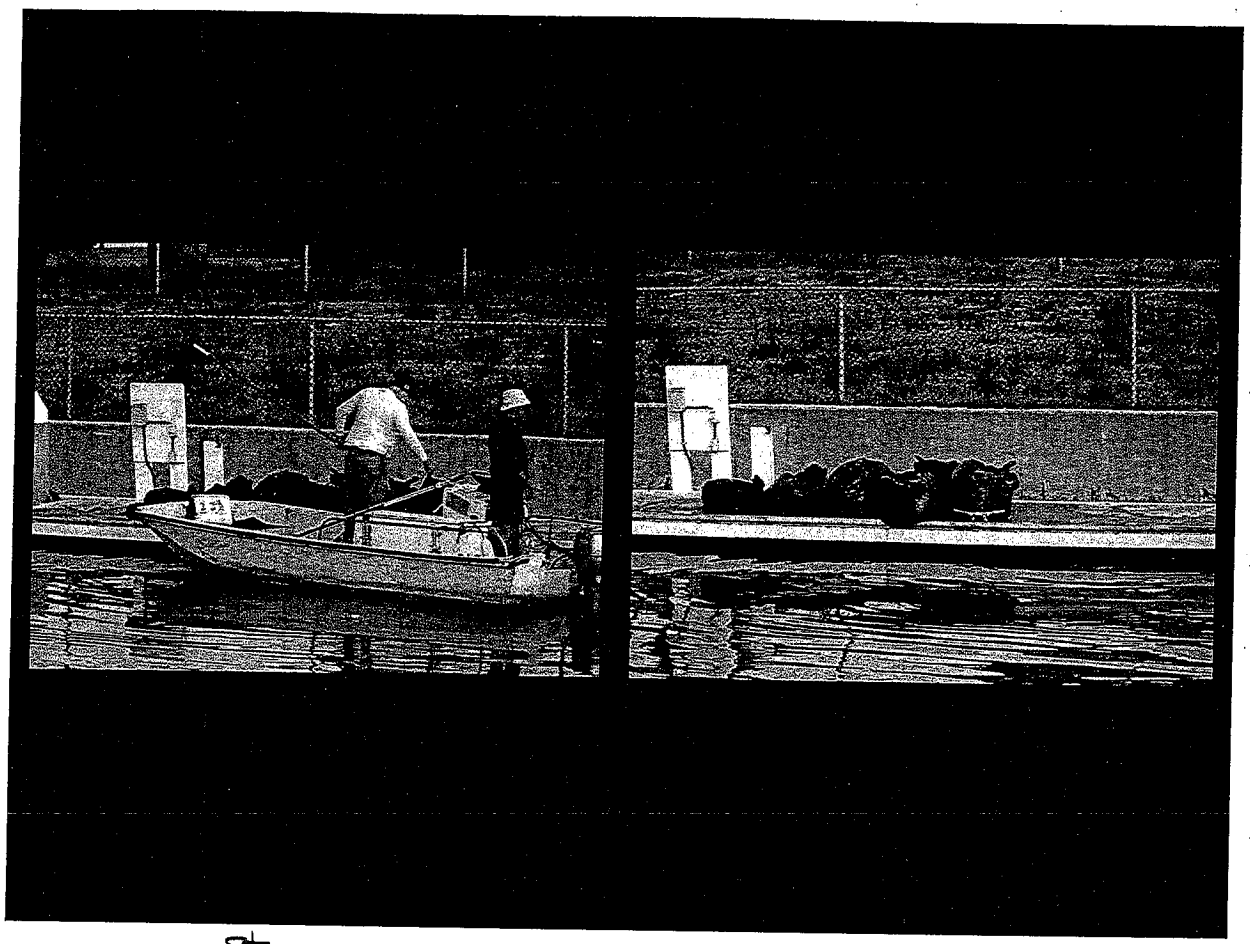






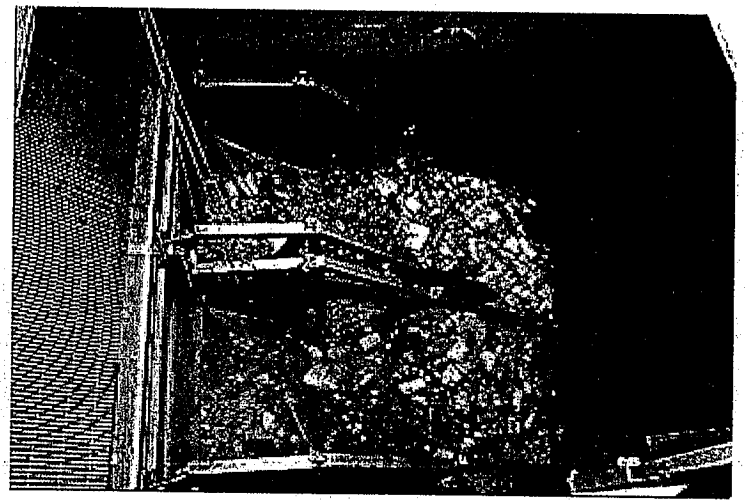






- After 1st storms of October 2004.
- Contracted workers (contract with Jim Nagel) through Harbor Offshore Engineering.
- Ray Williams with City of Oxnard is head of contract.
- Contract is paid through a special assessment district tax by marina HOA.

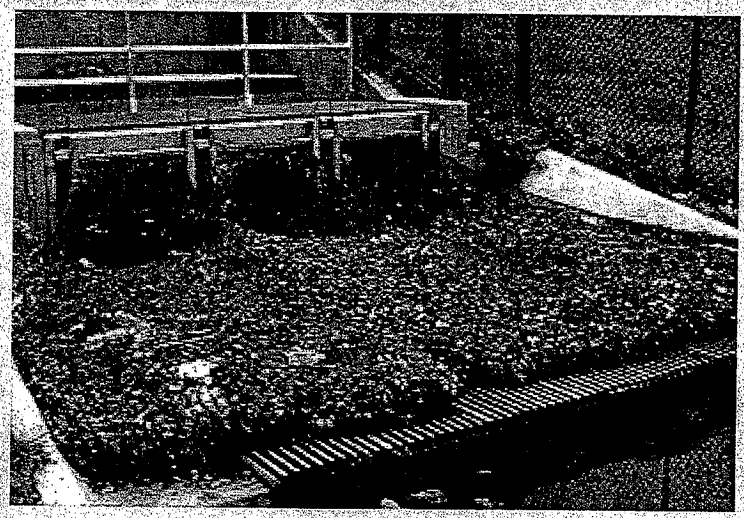
FRESH CREEK TECHNOLOGIES, INC.



In Line unit Lifting Baskets ready for changeout. North Bergen, NJ

– Example of website

FRESH CREEK TECHNOLOGIES, INC.



End of Pipe unit collects trash in nets after storm in a city park.

– Example of website.

VENTURA COUNTY
WATERSHED PROTECTION DISTRICT

PUBLIC WORKS AGENCY
RONALD C. COONS
Agency Director

Jeff Pratt
District Director

Lawrence Jackson
Water Quality/Environmental

Peter Sheydayi
Design/Construction

Sergio Vargas
Planning/Regulatory

Tom Lagier
Operations/Maintenance

Lowell Preston, Ph.D.
Water Resources Division

November 23, 2005

Mr. William Clark, President
Channel Islands Waterfront Homeowners Association
3840 Channel Islands Blvd., Box 144
Oxnard, CA 93035

Subject: Oxnard West Drain - Trash

Dear Bill:

Thank you for your follow-up letter of October 21, 2005. It seems a good idea to formally capture, and share with others, some of our many discussions on this subject matter. We at the Watershed Protection District (WPD) are concerned, as you are, about the amount of trash that finds its way to the Channel Islands Harbor (Harbor). As a consequence, and at the request of our Board of supervisors, we are investigating alternatives to the current trash removal method. We are looking at methods/programs that will reduce the trash load and we are exploring trash removal technologies.

Because your letter opens our discussions on this pressing matter to a much wider audience, it is important that we maintain a clear and factual written record. Your letter states *"...pollution from Oxnard West Drain stagnates in the water and kills the marine life within the marina."* Those unfamiliar with the situation at the Harbor will react strongly and incorrectly if they assume that any part of this assertion is true. First, to my knowledge, the Harbor supports marine life. Do you have information that would establish support for a conclusion different from this? Second, as we have discussed, the pollution (trash) is not from the Oxnard West Drain (Drain). As you are aware, the trash is generated by the many adjacent land-uses and land-users (Sources) – including a large contribution from area restaurants. The fact that the Drain exists does not lead one to the conclusion that it generates pollution. Rather, the Drain and the Harbor are the unfortunate recipients of the pollution generated by adjacent Sources.

Your letter states *"...with this trash eventually entering the ocean, it has the same effect on its marine life as well."* It is my understanding that the trash does not leave the Harbor, i.e., never enters the ocean. As it accumulates, the City of Oxnard collects the trash at a convenient collection point just below Victoria Avenue pursuant to an agreement that goes back some thirty years. In fact, this agreement allowed the development of the homes whose owners you represent.

800 South Victoria Avenue - Ventura California 93009-1610
(805) 654- http://www.vcwatershed.org

A014915

The salient objectives of the exercise that WPD is leading are two: first, reduce to the extent possible (using comprehensive best management practices [BMP's], the trash load; second, determine an appropriate treatment method(s) and location(s) for the load that remains. Any effective approach to the problem demands both the reduction and the treatment. This sounds simple. However, the exercise is complicated by the fact that the adjacent Sources are within the jurisdiction of two separate local governments over which WPD has no authority – the Cities of Oxnard and Port Hueneme Those jurisdictions have both the ability to reduce the sources of the pollution, currently benefit from the sales tax generated by the pollution sources, and have the responsibility for the pollution generated.

Because we have formed a coalition that includes the cities, the county, the HOA, the Harbor, and the WPD, we are able to approach the problem comprehensively. The coalition has discussed the problem of trash reduction with the Sources, and they have provided feedback on potential BMP's, which include a variety of reasonable source control methods. The coalition has also discussed the problem of trash removal with the Sources. The results of this discussion are that the Sources are exploring such things as Adopt-a-Stream (volunteer pick-up), curb inlet screens, drain fencing, pipe collection systems, and the Fresh Creek device(s) that you mention.

Unfortunately, the coalition has not yet agreed to a complete system of solutions. In spite of this, I would caution you against a rush to judgment, i.e., the installation of a single large Fresh Creek device. This proposal is simply another form of the current practice of picking the trash up just downstream of Victoria Avenue. The Fresh Creek device merely moves the collection point a short distance upstream, and in doing so, creates what may be an unacceptable public health and safety risk. Alone, the Fresh Creek device does nothing to reduce the load and so completely ignores a fundamental tenet of water quality improvement, i.e., that it is far more cost-effective and responsible to eliminate and treat pollutants at the source. Lastly, and equally important, is that installation of any downstream treatment facility designed to ignore possible upstream reductions in waste load, has the practical effect of turning a channel, creek, stream, or river into a de-facto waste treatment facility. Consequently, should the coalition eventually agree to the funding and maintenance issues associated with a Fresh Creek device, it must be accompanied by completely embracing the cost-effective tenet listed above -- that all reasonable steps will be taken to eliminate the sources of the pollution.

WPD will continue to work with and lead the coalition until this problem is resolved. Our Board has given us clear direction in this regard. We would request that your association remain an active member of the coalition as we work to resolution and that your previous offers of financial support remain. We

also would like to thank you for dogged pursuit of this matter. This pursuit has helped to achieve the "critical mass" necessary for cooperative problem resolution.

If you have any questions, comments, or clarifications, please do not hesitate to call me at one of the numbers below.

Sincerely,

Jeff Pratt

Jeff Pratt, P.E.
Director

C: Steve Bennett, Supervisor District 1
Carrie Mattingly, City of Port Hueneme
Mark Pumford, City of Oxnard
Marty Robinson, Ventura County Resource Management Agency
Ronald C. Coons, Ventura County Public Works Agency
Xavier Swami, Los Angeles Regional Water Quality Control Board
Gerhardt Hubner, Ventura County Watershed Protection District

800 South Victoria Avenue • Ventura, California 93009-1600
(805) 654-2001 • Fax (805) 654-3350 • http://www.vcwatershed.org

Channel Islands Waterfront Homeowners Association
3840 Channel Islands Blvd., Box 144,
Oxnard, CA 93035

October 26, 2005

Mr. Carlos Urrunaga
California Regional Water Quality Control Board
Los Angeles Region
320 West 4th Street, Suite 200
Los Angeles, CA 90013

Dear Mr. Urrunaga,

As president of the Channel Islands Waterfront Homeowners Association, I represent the 700 homeowners that live within the Channel Islands Marina. One of our biggest concerns is the amount of trash and debris entering the marina from the Oxnard West Drain. Last year, the Oxnard City Corps removed over nine tons of trash from the drain. Yet despite the City Corps best efforts, without a filtering system along the drain, a significant amount of trash still enters the marina. The pollution from the Oxnard West Drain stagnates in the water and kills the marine life within the marina. With this trash eventually entering the ocean, it has the same effect on its marine life as well.

We have met repeatedly with the County of Ventura, the Ventura County Watershed District, the City of Oxnard, and the City of Port Hueneme. In fact, we have even formed a Water Quality Task Force with the County, the Watershed District, and the Cities of Port Hueneme and Oxnard. While we have made some progress, we are still a long way away from a solution to this storm water runoff problem.

I have enclosed the letters that I have recently written to the agencies involved with this matter, as well as, photos of the marina after a recent rainstorm. I hope that the Regional Water Quality Control Board will consider our concerns prior to reissuing the Storm Water permit involving the Oxnard West Drain.

We feel that with the assistance of the Los Angeles Regional Water Board, in conjunction with the County of Ventura, the Watershed District, and the Cities of Port Hueneme and Oxnard, we can finally solve a problem that has been plaguing the marina and the ocean for the last twenty years.

Sincerely,

William Clark
President of the Channel Islands Waterways Homeowners' Association.

A014918

Channel Islands Waterfront Homeowners Association
3840 Channel Islands Blvd., Box 144,
Oxnard, CA 93035

October 21, 2005

Mayor Murray Rosenbluth
City of Port Hueneme, City Council Offices
250 North Ventura Road,
Port Hueneme, CA 93041

Dear Mayor Rosenbluth,

As president of the Channel Islands Waterfront Homeowners Association, I represent the 700 homeowners that live within the Channel Islands Marina. One of our biggest concerns is the amount of trash and debris entering the marina from the Oxnard West Drain. Last year, the Oxnard City Corps removed over nine tons of trash from the drain.

While most of the storm water within the drain originates from the City of Oxnard, over half of the trash removed by the City Corps came from businesses along Channel Islands Boulevard within the City of Port Hueneme. Despite City Corps best efforts and due to the lack of a filtering system, a significant amount of trash still enters the marina. The pollution from the Oxnard West Drain stagnates in the water and kills the marine life within the marina. With this trash eventually entering the ocean, it has the same effect on its marine life as well.

At the last meeting with the Water Quality Task Force, Ventura County Supervisor Steve Bennett agreed to commit $50,000 towards placing a filtration system at the end of the Oxnard West Drain to help reduce the amount of trash and debris entering our marina. While certainly this is not enough money to cover the entire cost of the project, it is certainly a move in the right direction. I hope the City of Port Hueneme understands the seriousness of this problem and is also willing to commit the funds necessary to solve it.

We feel that with the assistance of the City of Port Hueneme in conjunction with the County of Ventura, the Watershed District, and the City of Oxnard we can finally solve a problem that has been plaguing the marina and the ocean for the last twenty years. Thank you again for your leadership and consideration.

Sincerely,

William Clark
President of the Channel Islands Waterways Homeowners' Association.
cc: Dr. Xavier Swamikannu, Los Angeles Regional Water Board

A014919

Channel Islands Waterfront Homeowners Association
3840 Channel Islands Blvd., Box 144,
Oxnard, CA 93035

October 21, 2005

Mayor Tom Holden
City Council Offices
300 West Third Street, 4th Floor
Oxnard, CA 93030

Dear Tom,

As you know, as homeowners living within the marina, we are very concerned about the amount of trash and debris entering the marina from the Oxnard West Drain. Last year, the Oxnard City Corps removed over nine tons of trash from the drain. Despite their best efforts and due to the lack of a filtering system, a significant amount of trash still enters the marina. The pollution from the Oxnard West Drain stagnates in the water and kills the marine life within the marina. With this trash eventually entering the ocean, it has the same effect on its marine life as well.

At the last meeting with the Water Quality Task Force, Supervisor Steve Bennett agreed to commit $50,000 towards placing a filtration system at the end of the Oxnard West Drain to help reduce the amount of trash and debris entering our marina. While certainly this is not enough money to cover the entire cost of the project, it is certainly a move in the right direction. I hope the City of Oxnard understands the seriousness of this problem and is also willing to commit the funds necessary to solve it.

We feel that with the assistance of City of Oxnard in conjunction with the County of Ventura, the Watershed District, and the City of Port Hueneme we can finally solve a problem that has been plaguing the marina and the ocean for the last twenty years. Thank you again for your leadership and consideration.

Sincerely,

Bi

William Clark
President of the Channel Islands Waterways Homeowners' Association.

cc: Dr. Xavier Swamikannu, Los Angeles Regional Water Board

A014920

Channel Islands Waterfront
Homeowners Association
3840 Channel Islands Blvd., Box 144,
Oxnard, CA 93035

October 21, 2005

Mr. Jeff Pratt
Ventura County Watershed Protection District
800 S. Victoria Avenue
Ventura, CA 93009-1610

Dear Jeff:

This is a follow-up letter to our meeting with officials from Ventura County and the Watershed Protection District. As you know, as homeowners living within the Channel Islands Marina, we are very concerned about the amount of trash and debris entering the marina from the Oxnard West Drain.

Last year, the Oxnard City Corps removed over nine tons of trash from the drain. Despite their best efforts, without a filtering system, a significant amount of trash still enters the marina. The pollution from the Oxnard West Drain stagnates in the water and kills the marine life within the marina. With this trash eventually entering the ocean, it has the same effect on its marine life as well.

We feel that County of Ventura and the Watershed District must ultimately take the lead in finding a solution to this pollution problem. As the study funded by your agency concluded, the Fresh Creek Filter is a cost effective way to help solve this problem. We hope that your agency, along with Ventura County, and the cities of Oxnard and Port Hueneme can find a way to fund the installation of this filter and its maintenance. Thanks again for your work regarding this matter and your continued support.

Sincerely,

William Clark
President of the Channel Islands Waterways Homeowners Association.

cc: Dr. Xavier Swamikannu
Los Angeles Regional Water Board

Channel Islands Waterfront
Homeowners Association
3840 Channel Islands Blvd., Box 144,
Oxnard, CA 93035

October 21, 2005

Supervisor Steve Bennett
Supervisor, First District
Board of Supervisors County of Ventura
Government Center, Hall of Administration
800 South Victoria Avenue
Ventura, CA 93009

Dear Supervisor Bennett:

As president of the Channel Islands Waterways Homeowners' Association, I would like to thank you for the leadership you exhibited at the most recent Water Quality Task Force meeting. Your committing fifty thousand dollars and offering for Ventura County to assist in solving the problem of pollution emanating from the Oxnard West Drain are acts that will not only immensely benefit the marine life in the marina, but also visitors to the marina who wish to experience and enjoy its marine life.

As you know, as homeowners living within the marina, we are very concerned about the amount of trash and debris entering the marina from the Oxnard West Drain. Last year, the Oxnard City Corps removed over nine tons of trash from the drain. Despite their best efforts, without a filtering system, a significant amount of trash still enters the marina. The pollution from the Oxnard West Drain stagnates in the water and kills the marine life within the marina. With this trash eventually entering the ocean, it has the same effect on its marine life as well.

I have reviewed the Agreement for Maintenance of the Oxnard West Drain Discharge between the County of Ventura and the City of Oxnard that you sent me. While I am certainly not a lawyer, the document appears to only cover that part of the drain within Tract 1904. Tract 1904 is to the west of Victoria Boulevard. This agreement does not appear to absolve the County of any responsibility for the portion of the drain to the east of Victoria Boulevard.

We feel that with the assistance of Ventura County and the Watershed District, we can finally solve a problem that has been plaguing the marina and the ocean for the last twenty years. We look forward to continuing to work with the county and the cities of Oxnard and Port Hueneme in solving this problem and implementing a solution. Thank you again for your leadership and consideration.

Sincerely,

William Clark
President of the Channel Islands Waterways Homeowners' Association.

cc: Dr. Xavier Swamikannu, Los Angeles Regional Water Board

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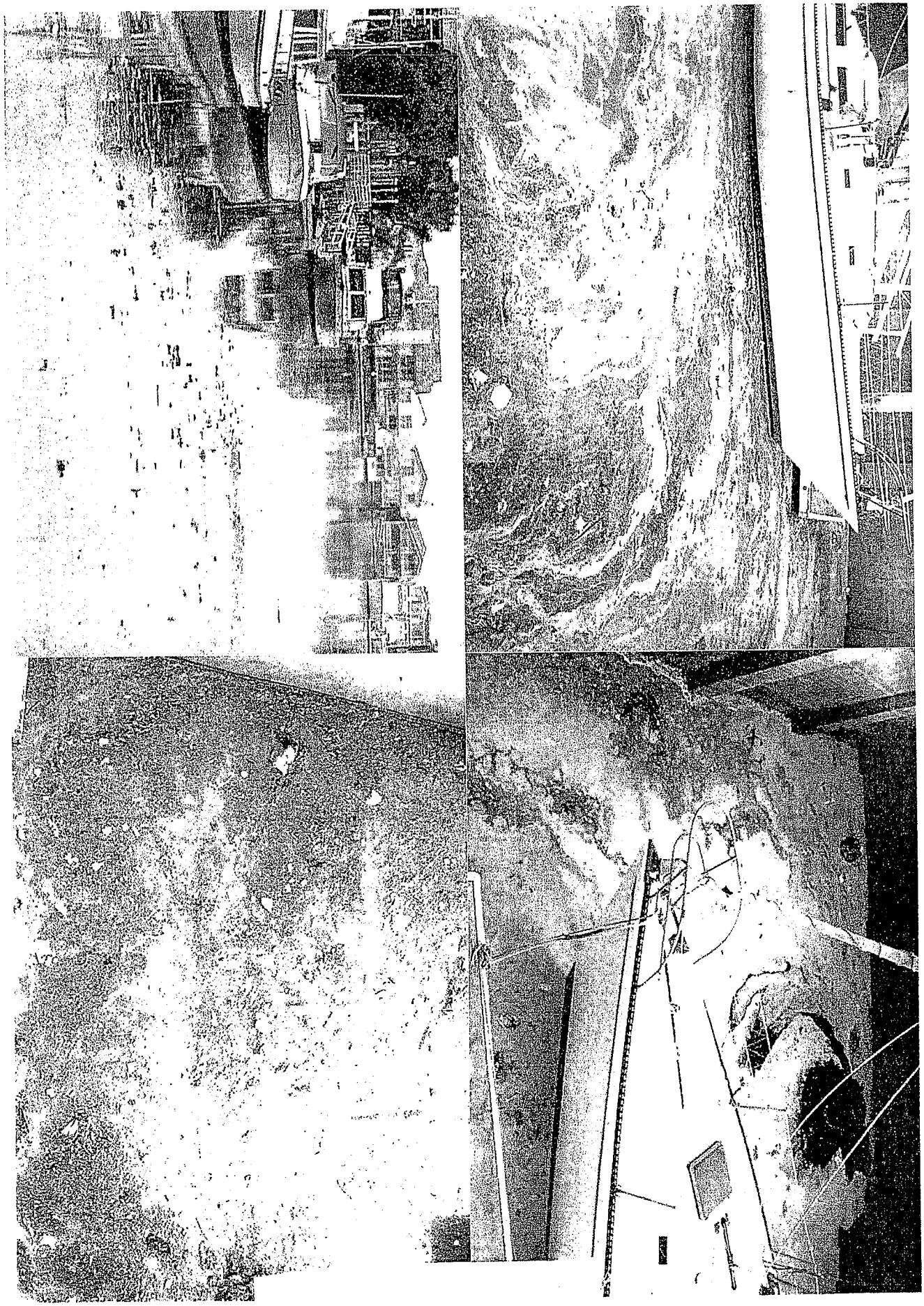

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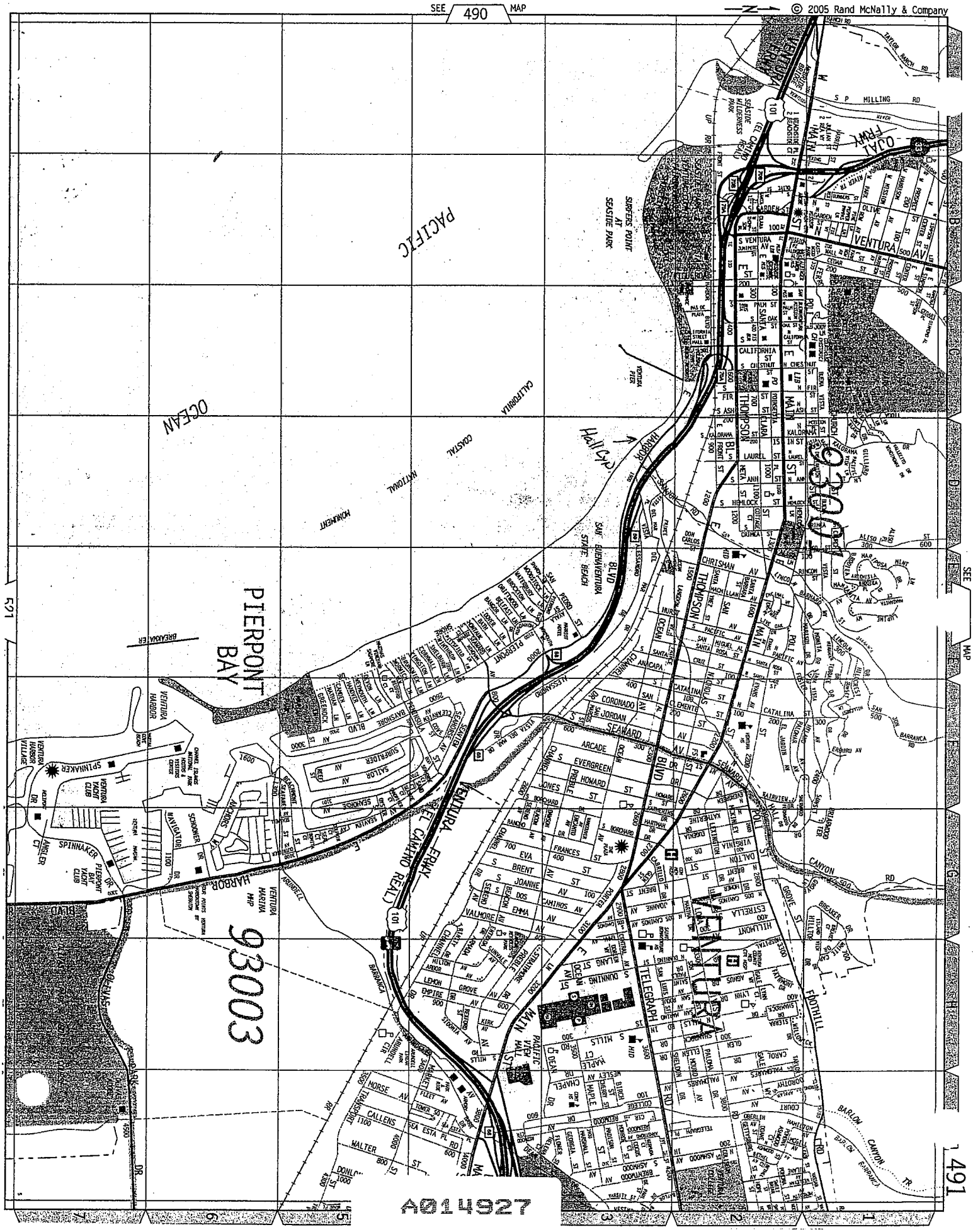
SEE 490 MAP
© 2005 Rand McNally & Company
PACIFIC
OCEAN
PIERPONT BAY
93003
93004
VENTURA
VENTURA FRWY
EL CAMINO REAL
HARBOR BLVD
SAN BUENAVENTURA STATE BEACH
SURFERS POINT AT SEASIDE PARK
VENTURA HARBOR
VENTURA MARINA MHP
SPINNAKER
SEAWARD AV
THOMPSON
TELEGRAPH
MAIN ST
VENTURA AV
OJAI FRWY
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CALIFORNIA
CHRISMAN AV
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BARLOW CANYON TR
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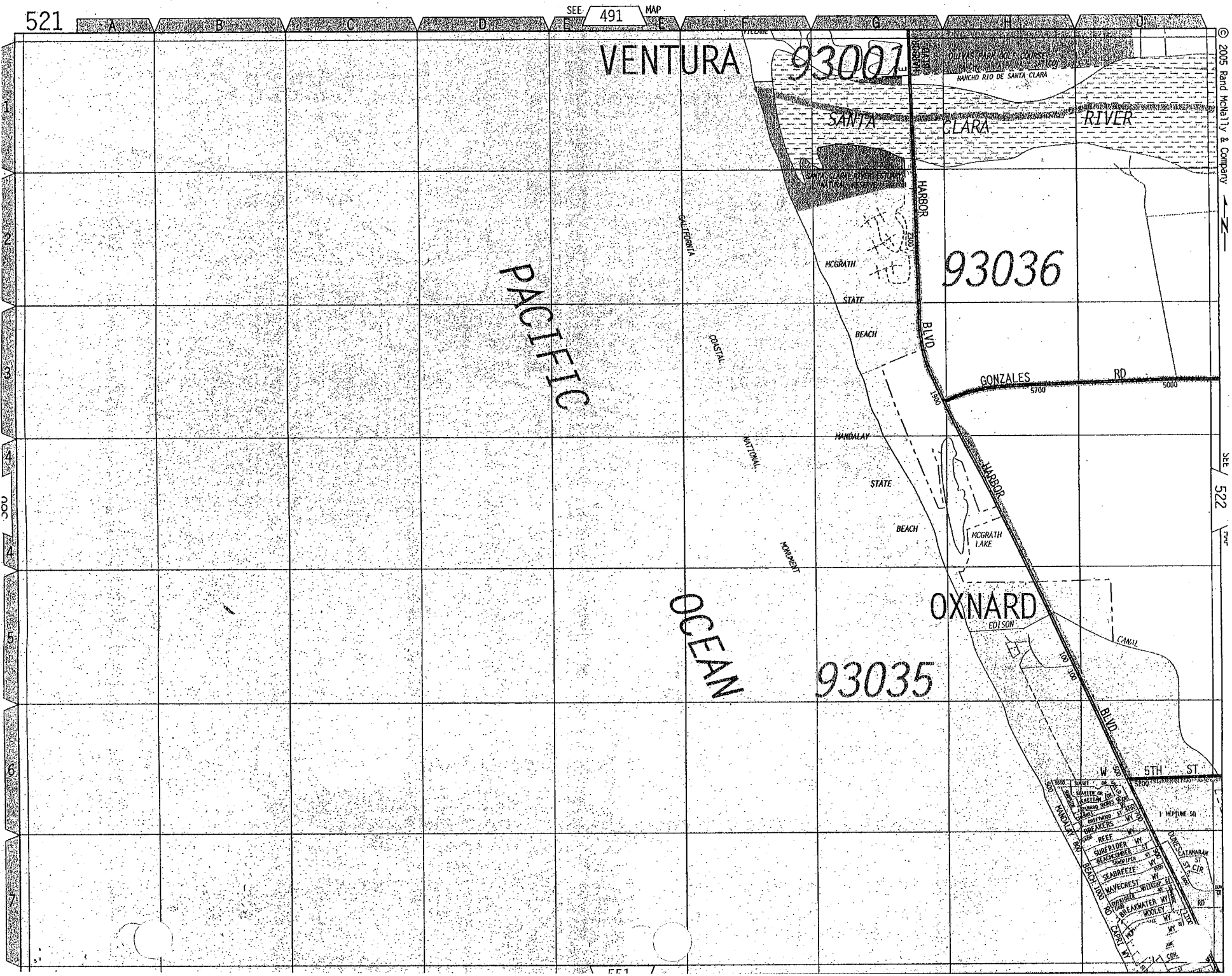
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SEE 491 MAP
VENTURA
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SANTA
CLARA
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RANCHO RIO DE SANTA CLARA
SANTA CLARA RIVER ESTUARY NATURAL RESERVE
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BLVD
MCGRATH
STATE
BEACH
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GONZALES
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PACIFIC
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MONUMENT
MANDALAY
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MCGRATH LAKE
OXNARD
EDISON
CANAL
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BLVD
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CATAMARAN ST
DUNES ST CIR
SEAGREEN
SEAHOUSE
BREAKERS
REEF
SURFRIDER
BEACHCOMBER
SEABREEZE
WAVECREST
BREAKWATER
WOOLEY
SEE 522 MAP
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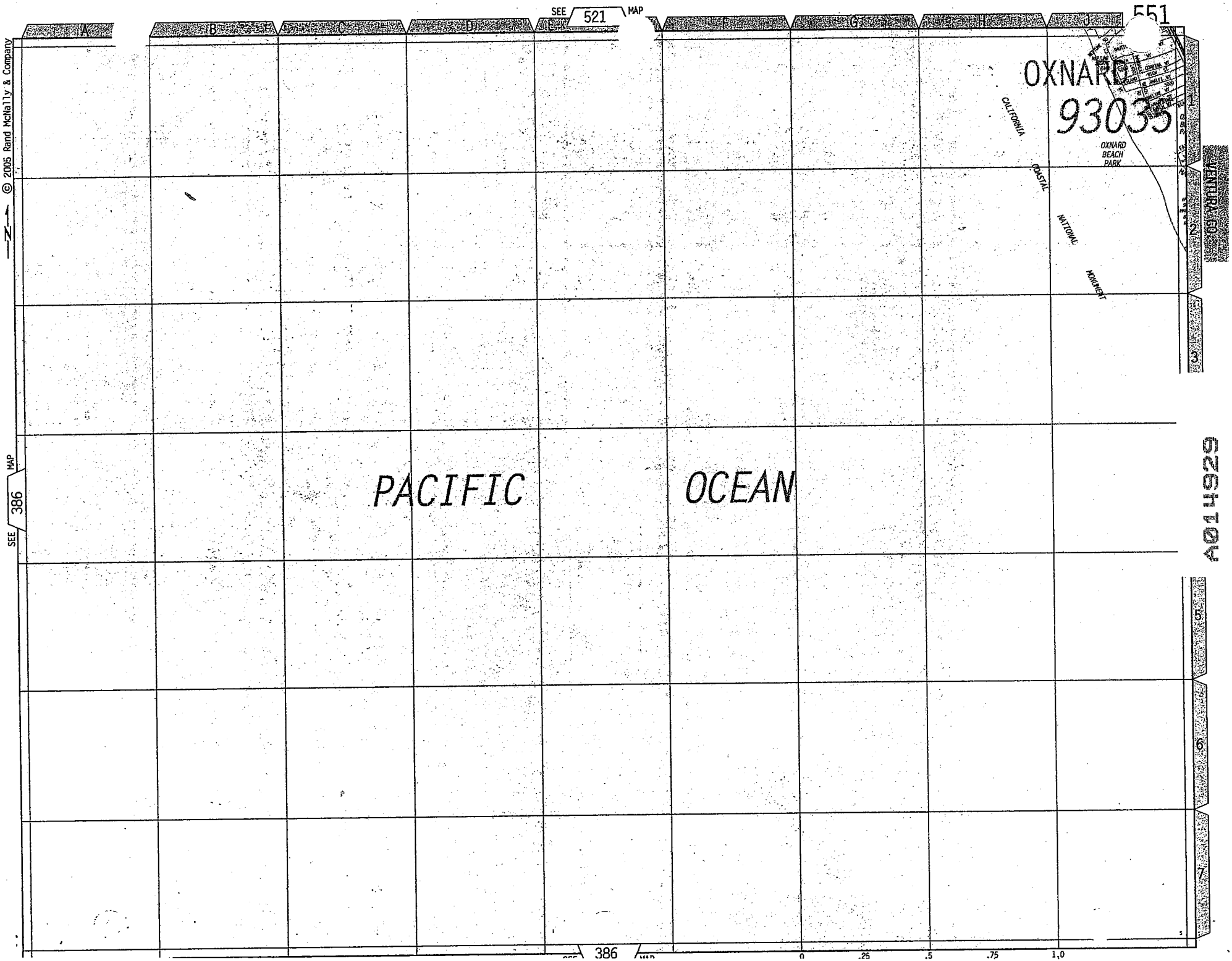

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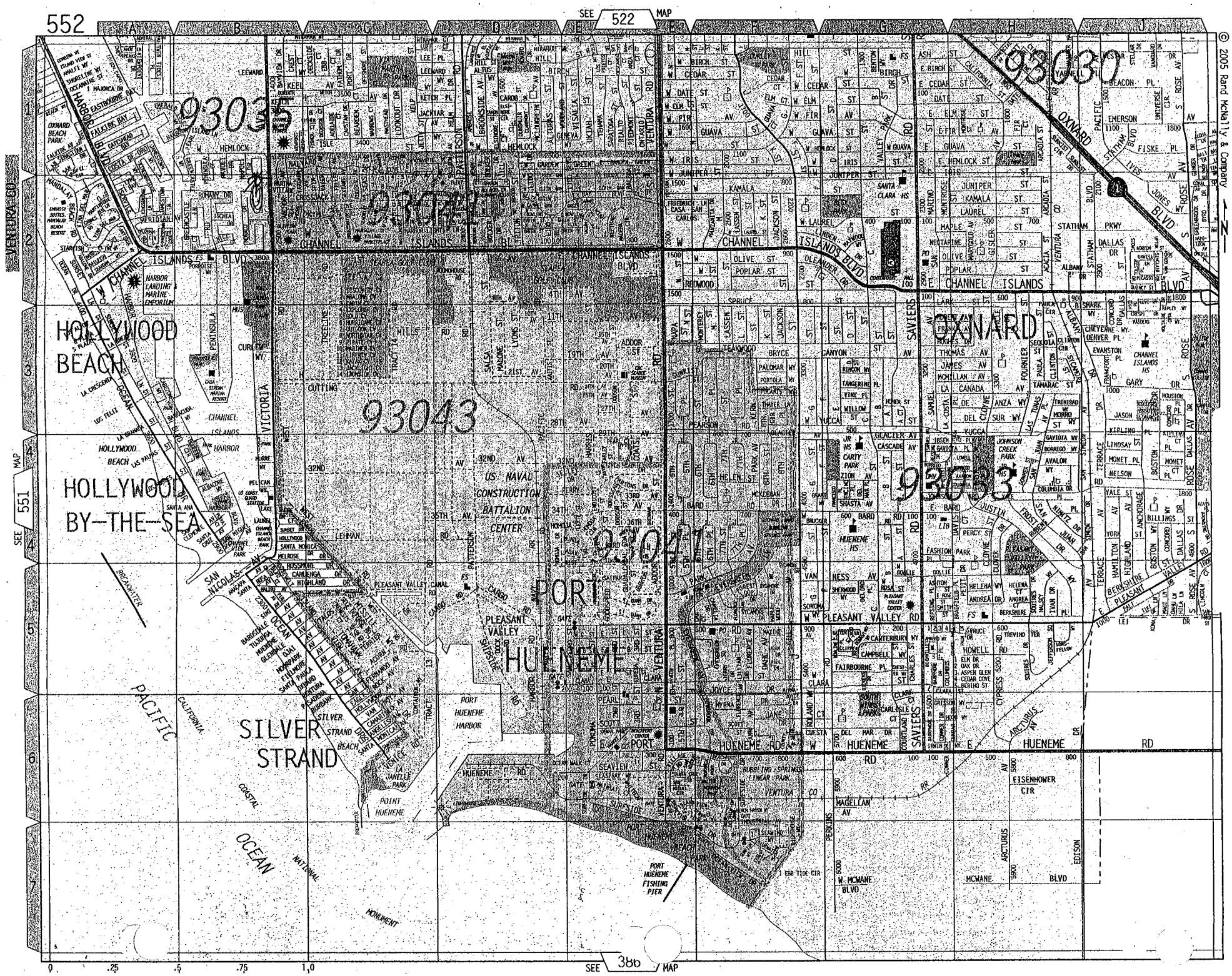

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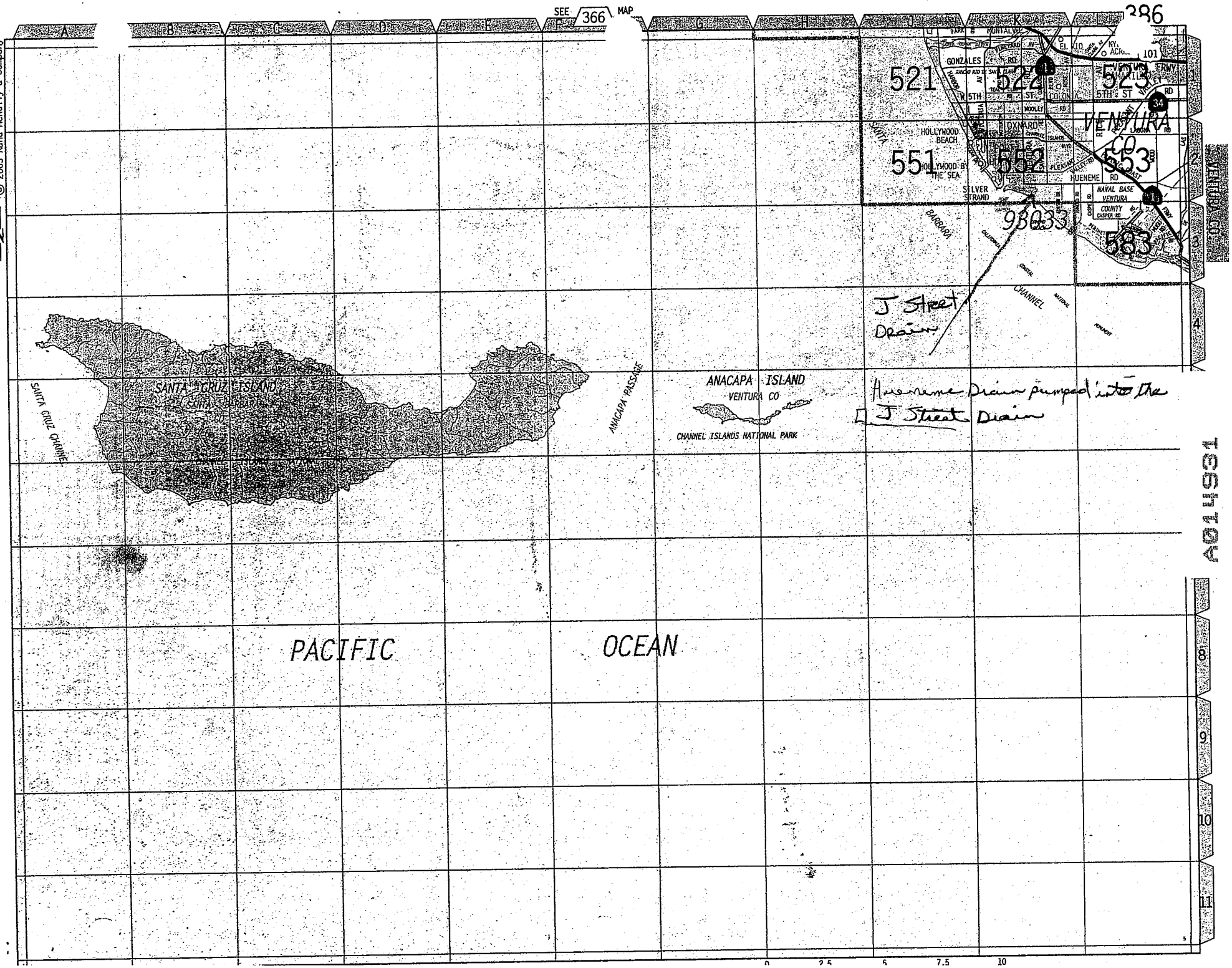
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VENTURA CO
GONZALES
OXNARD
HOLLYWOOD BEACH
HOLLYWOOD BY THE SEA
SILVER STRAND
HUENEME
NAVAL BASE VENTURA COUNTY
J Street Drain
Hueneme Drain pumped into the J Street Drain
SANTA CRUZ ISLAND
SANTA CRUZ CHANNEL
ANACAPA PASSAGE
ANACAPA ISLAND
VENTURA CO
CHANNEL ISLANDS NATIONAL PARK
PACIFIC OCEAN
© 2005 Rand McNally & Company
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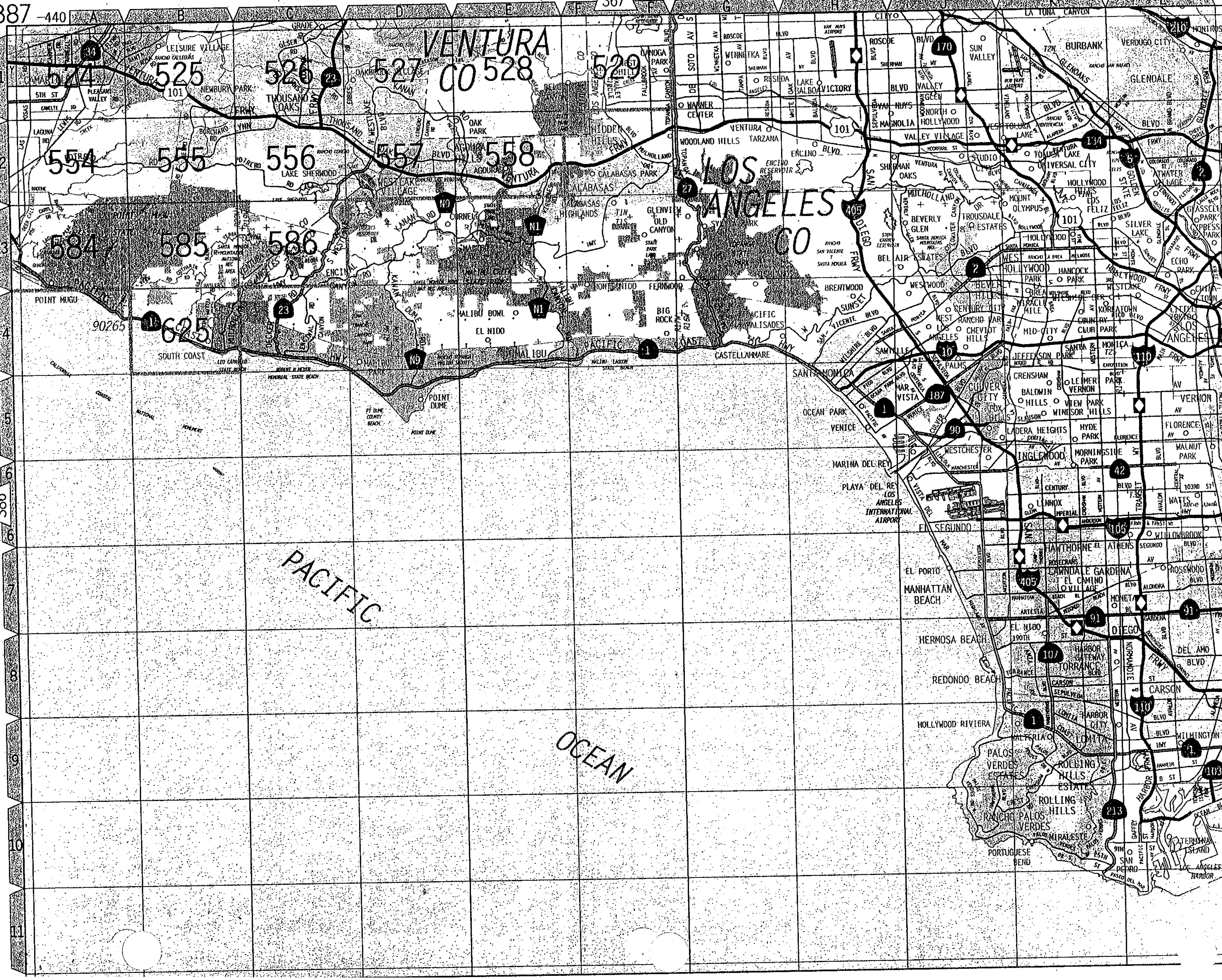
SEE 367 MAP
SEE 386 MAP
VENTURA CO
LOS ANGELES CO
PACIFIC OCEAN
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LEISURE VILLAGE
NEWBURY PARK
THOUSAND OAKS
WESTLAKE VILLAGE
OAK PARK
AGOURA
CALABASAS
CALABASAS PARK
HIDDEN HILLS
LAKE SHERWOOD
POINT MUGU
90265
SOUTH COAST
POINT DUME
EL NIDO
MALIBU BOWL
MALIBU
CASTELLAMMARE
PACIFIC PALISADES
BIG ROCK
WOODLAND HILLS
TARZANA
ENCINO
CANOGA PARK
WARNER CENTER
SHERMAN OAKS
STUDIO CITY
VALLEY VILLAGE
NORTH HOLLYWOOD
VAN NUYS
SUN VALLEY
BURBANK
GLENDALE
VERDUGO CITY
MONTROSE
UNIVERSAL CITY
TOLUCA LAKE
LOS FELIZ
SILVER LAKE
ATWATER VILLAGE
ECHO PARK
CHINATOWN
LOS ANGELES
BEL AIR ESTATES
BEVERLY GLEN
BEVERLY HILLS
WEST HOLLYWOOD
HOLLYWOOD
BRENTWOOD
WESTWOOD
SANTA MONICA
OCEAN PARK
VENICE
MAR VISTA
PALMS
CULVER CITY
MARINA DEL REY
PLAYA DEL REY
LOS ANGELES INTERNATIONAL AIRPORT
WESTCHESTER
INGLEWOOD
EL SEGUNDO
HAWTHORNE
LAWNDALE
GARDENA
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
TORRANCE
CARSON
LOMITA
HARBOR CITY
WILMINGTON
HOLLYWOOD RIVIERA
PALOS VERDES ESTATES
ROLLING HILLS ESTATES
ROLLING HILLS
RANCHO PALOS VERDES
PORTUGUESE BEND
SAN PEDRO
TERMINAL ISLAND
LOS ANGELES HARBOR
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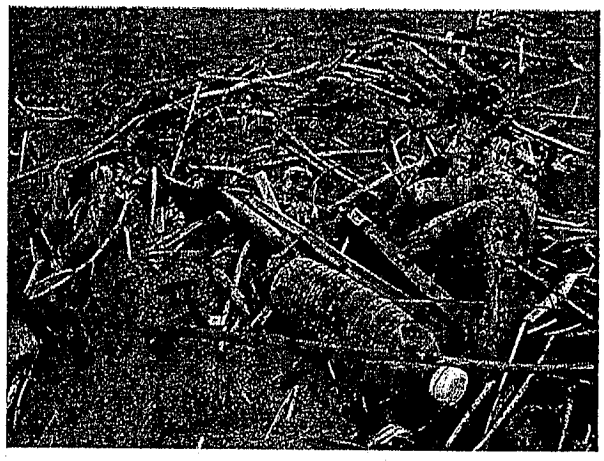
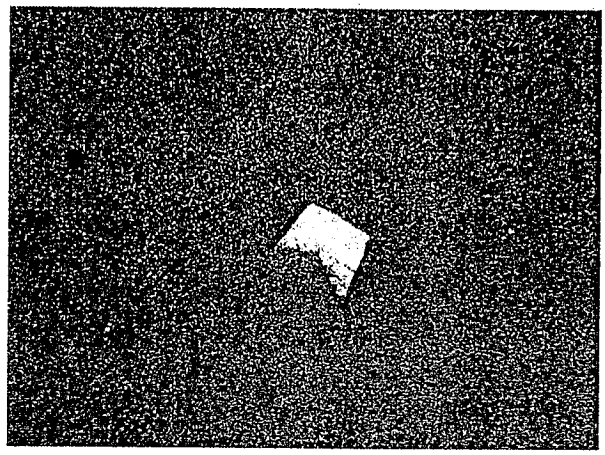
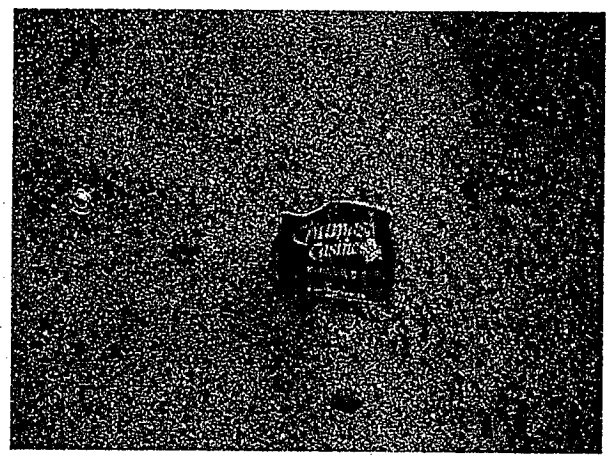
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)







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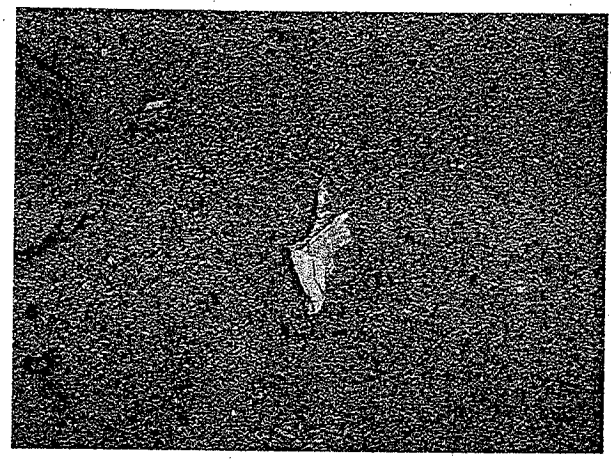
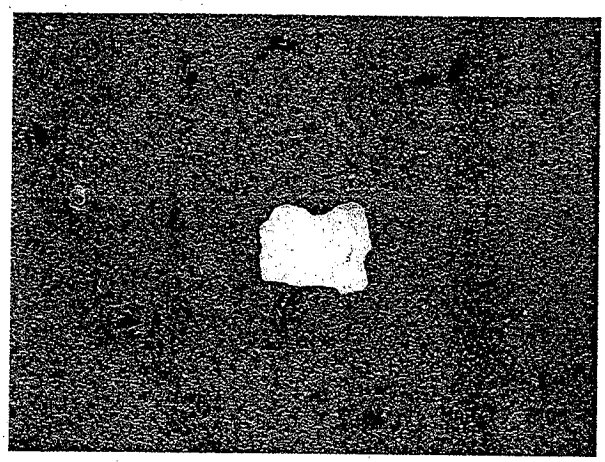
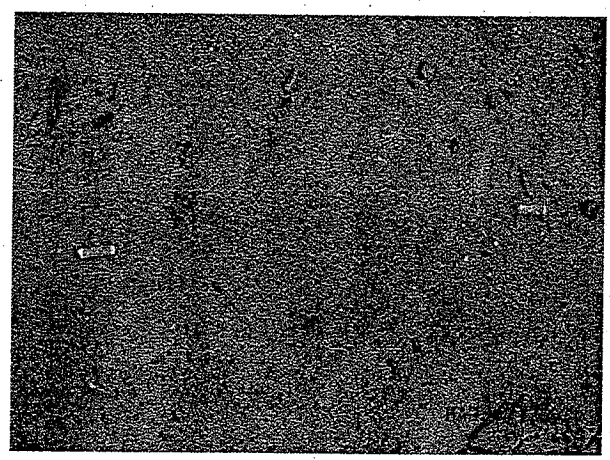
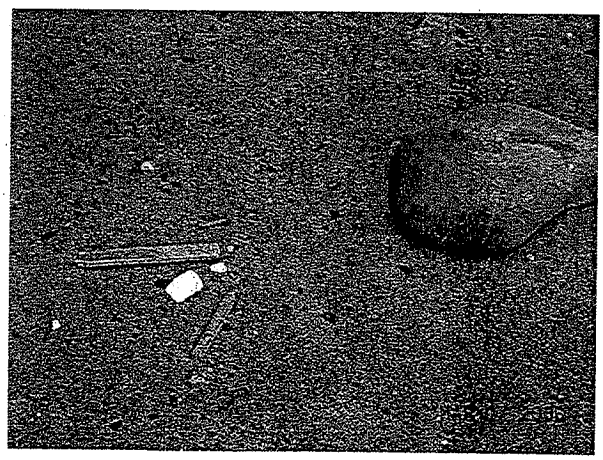
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)









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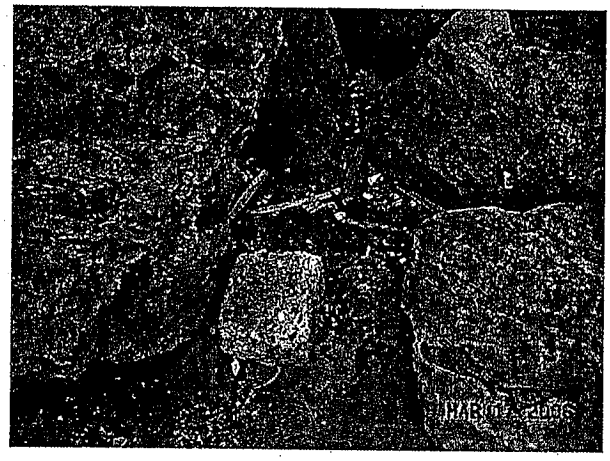
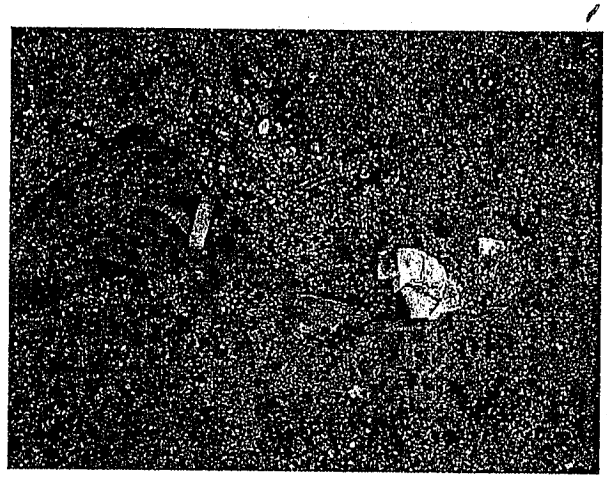
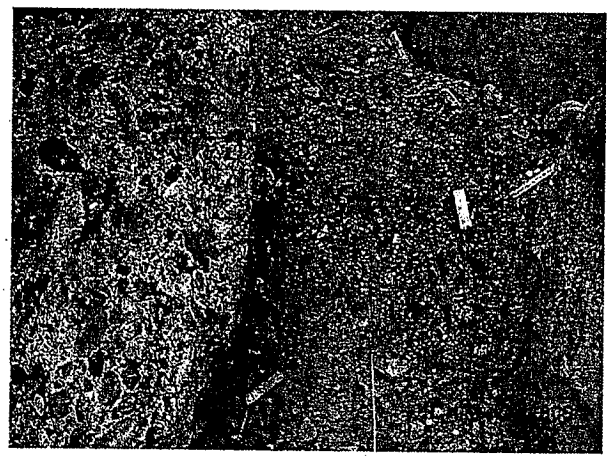
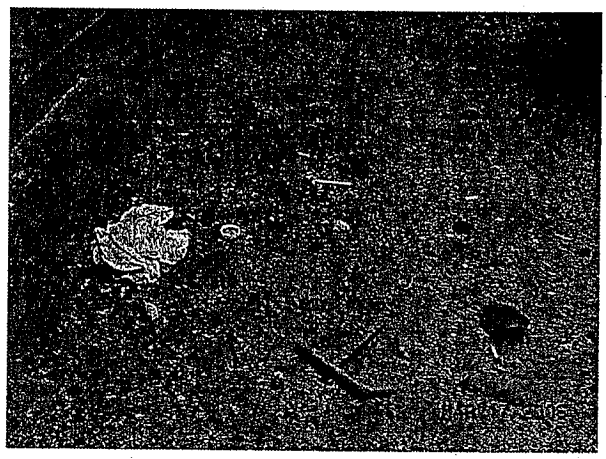
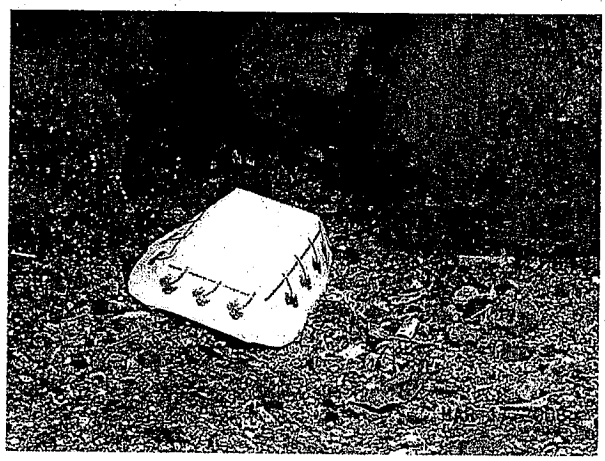
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)











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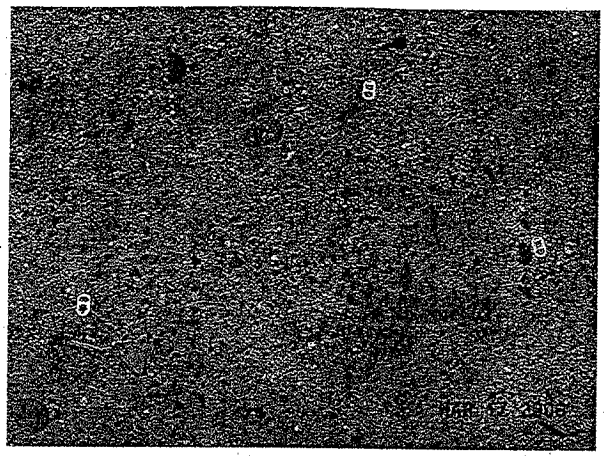
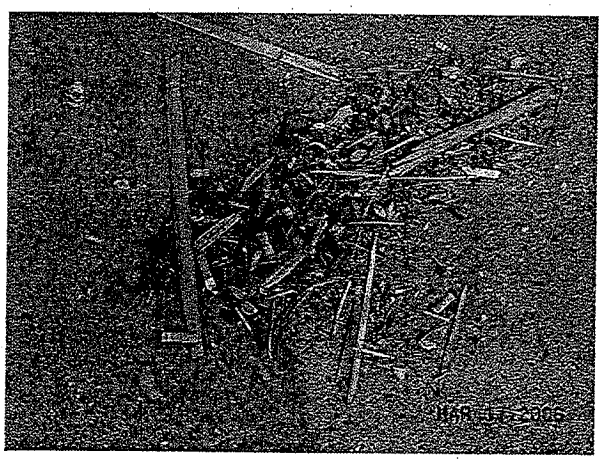
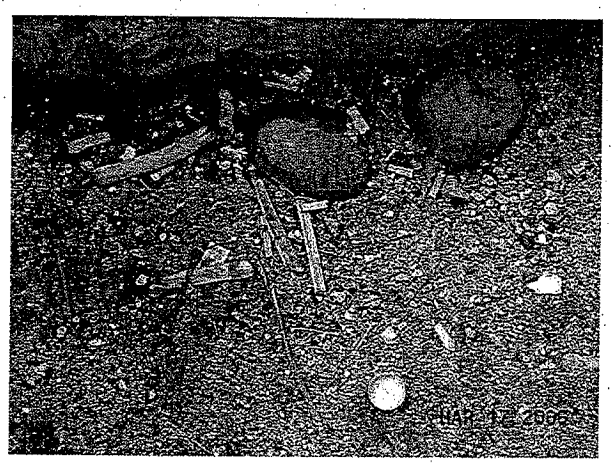
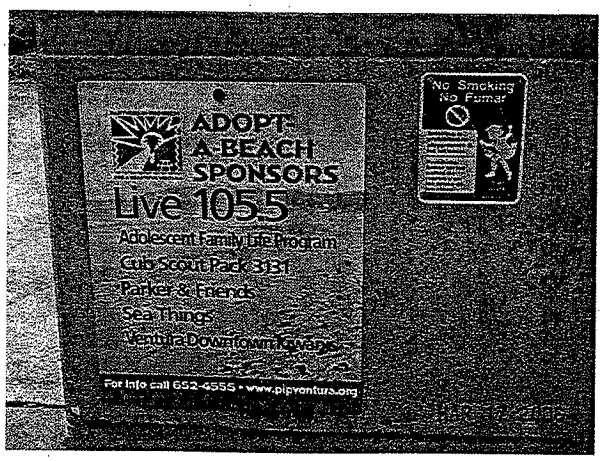
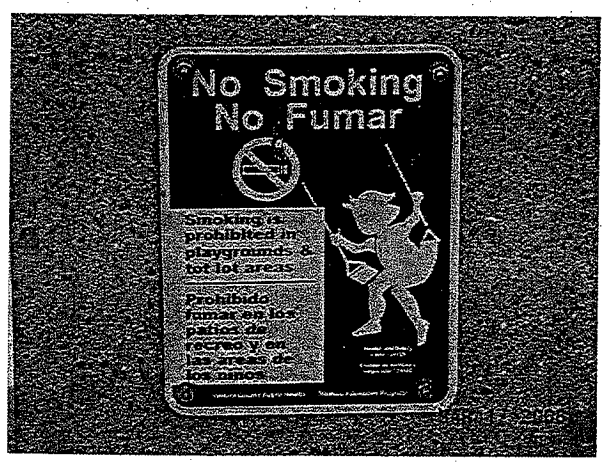
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)





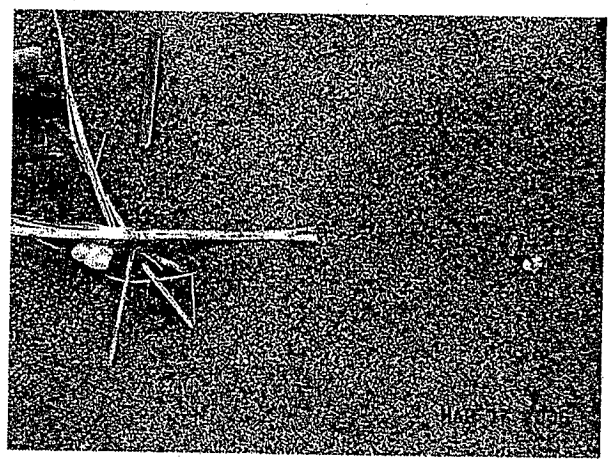


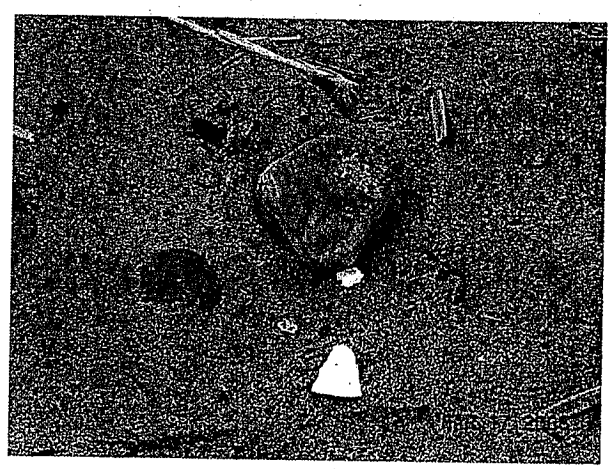




A014936

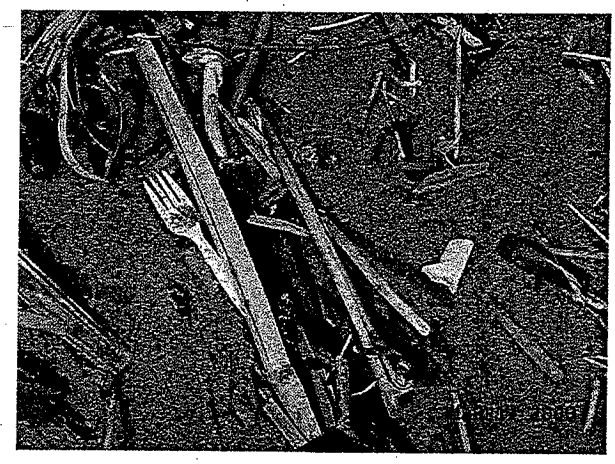
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)

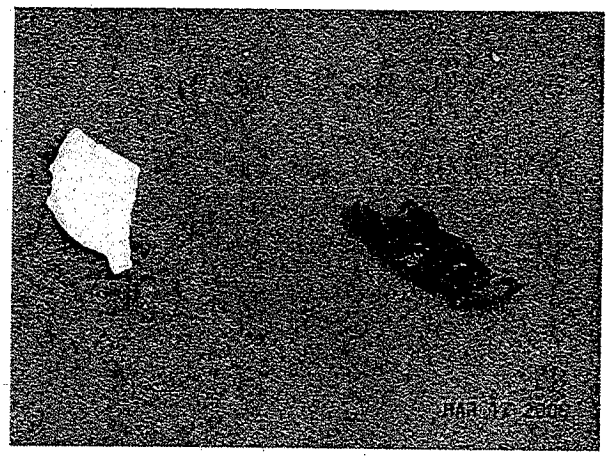


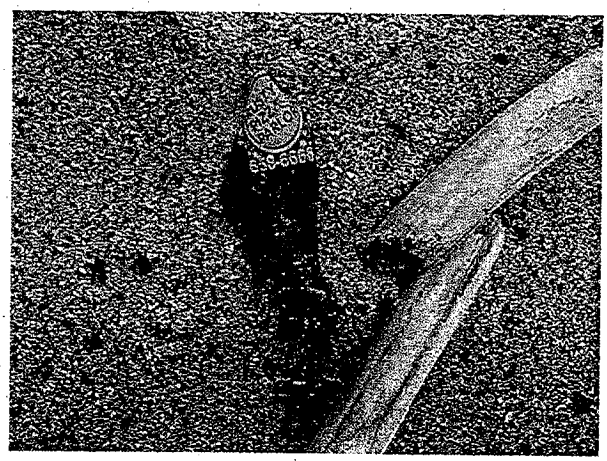


A014937

Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)

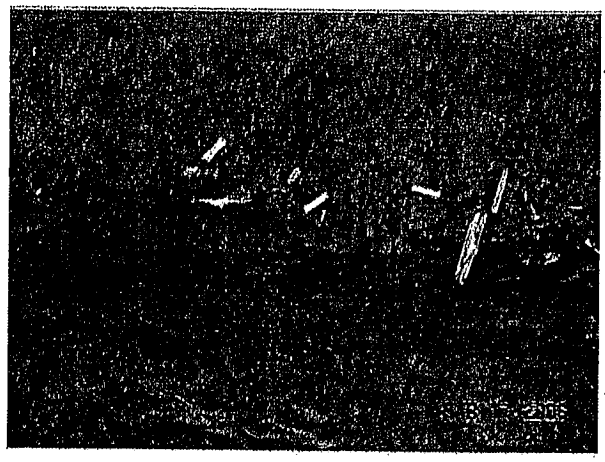






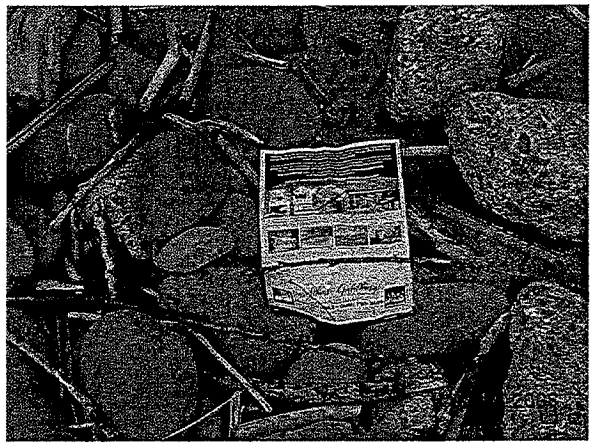
A014938

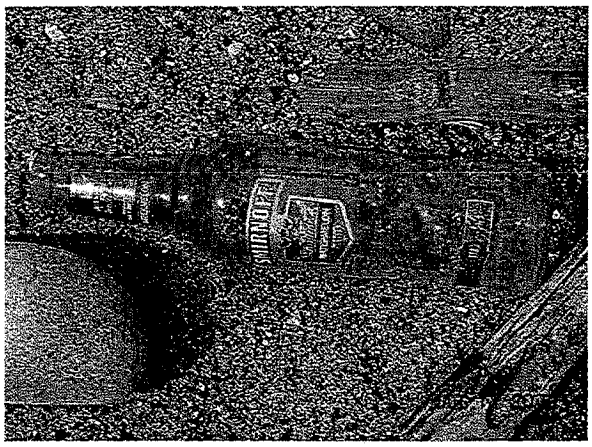
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)

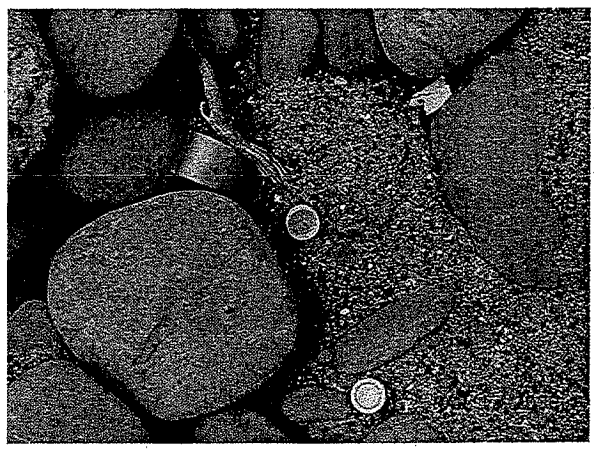


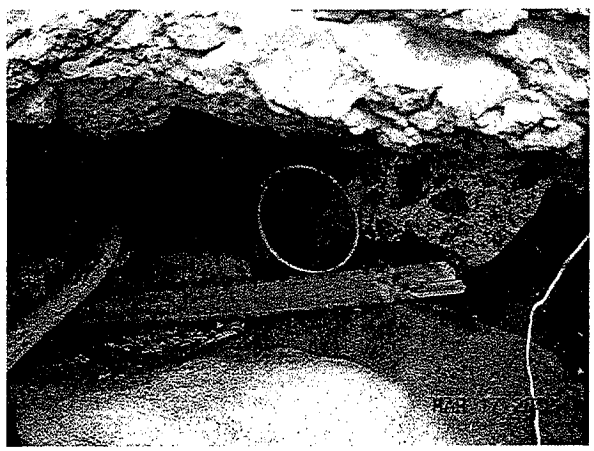
A014939

Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)



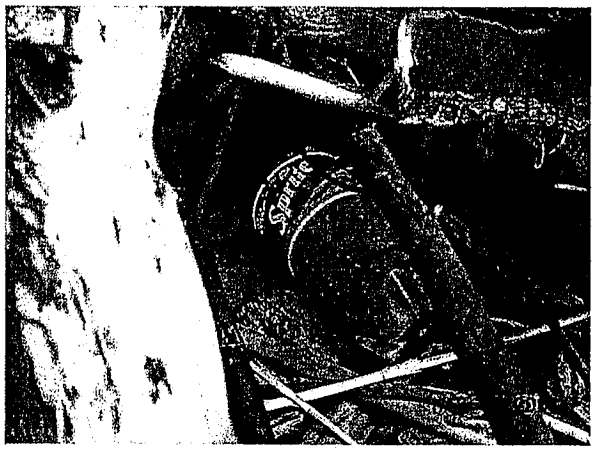


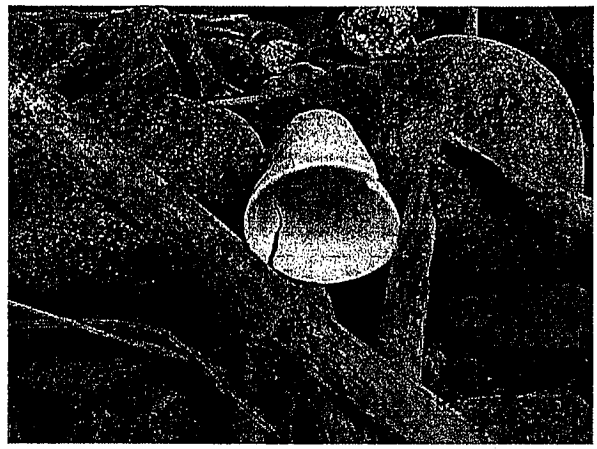


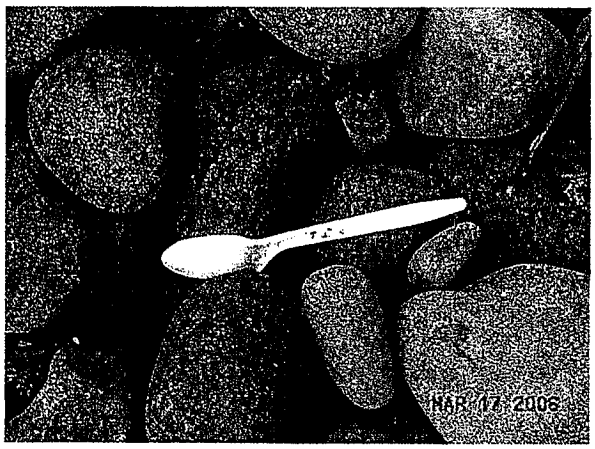


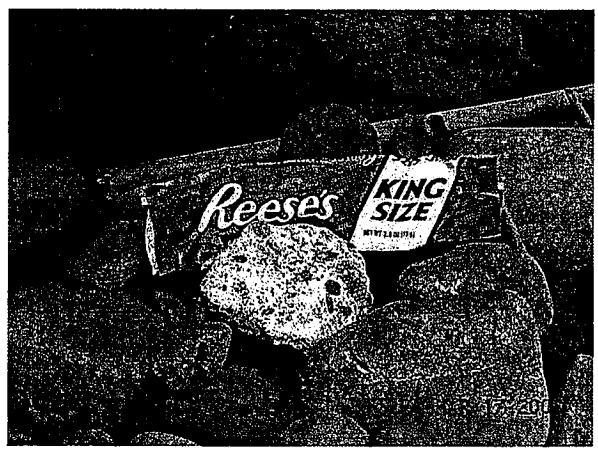
A014940

Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)



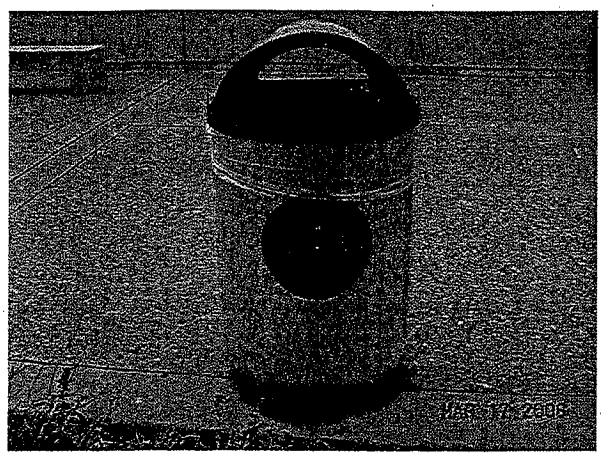


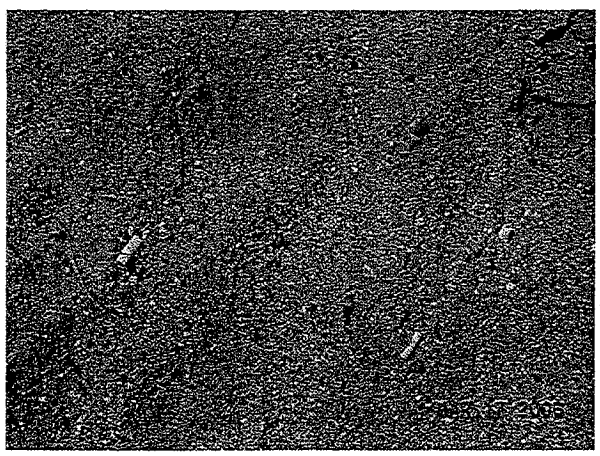




A014941

Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)



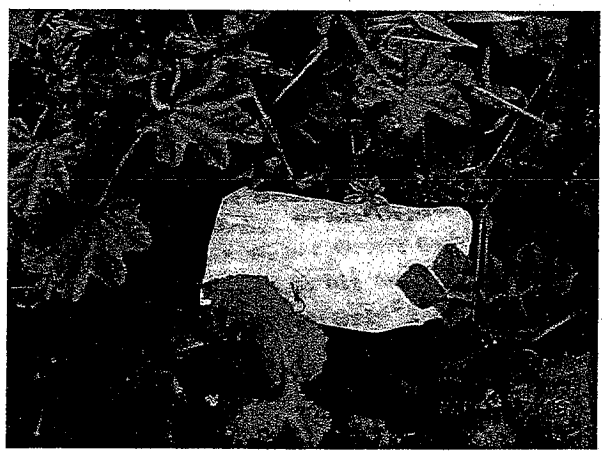


A014942

Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)

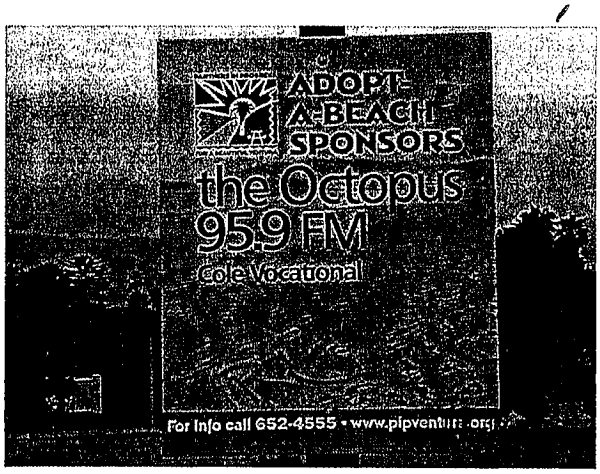
A014943

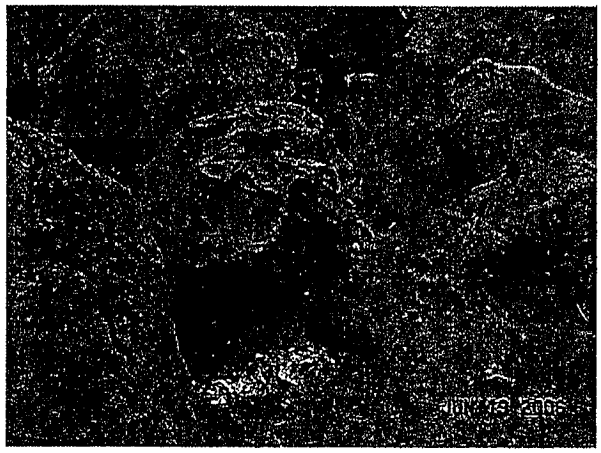
Trash & Debris Photos from Seaside Park
City of San Buenaventura
March 17, 2006 (Friday)

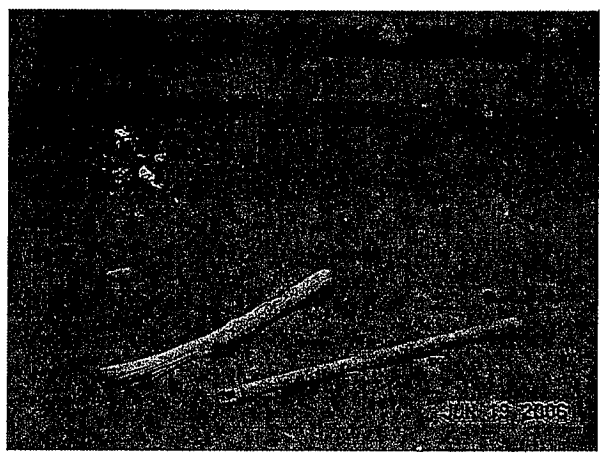


A014944

Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)





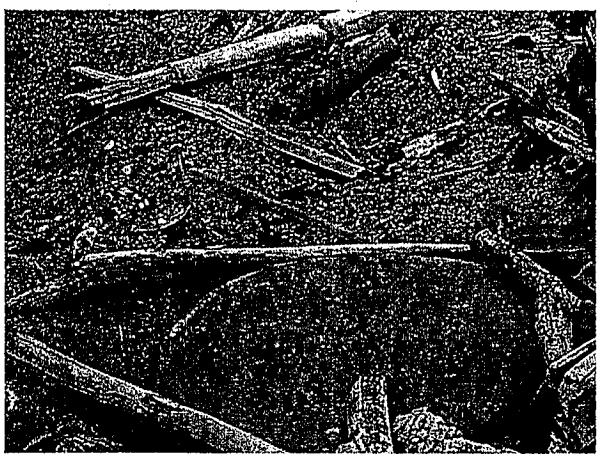


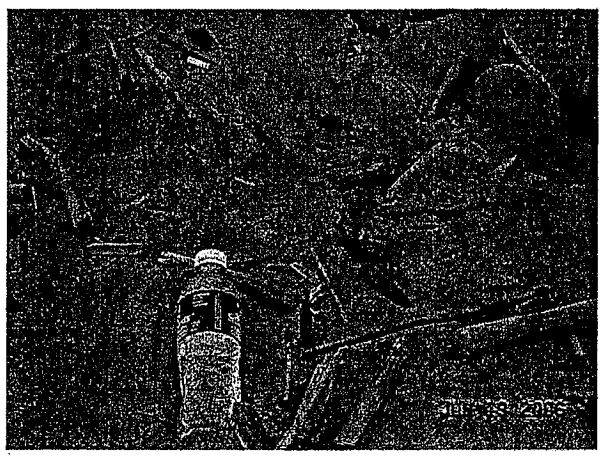
A014945

Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

A014946

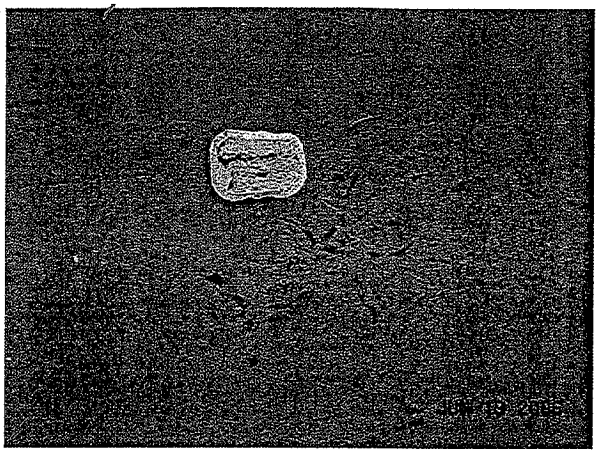
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

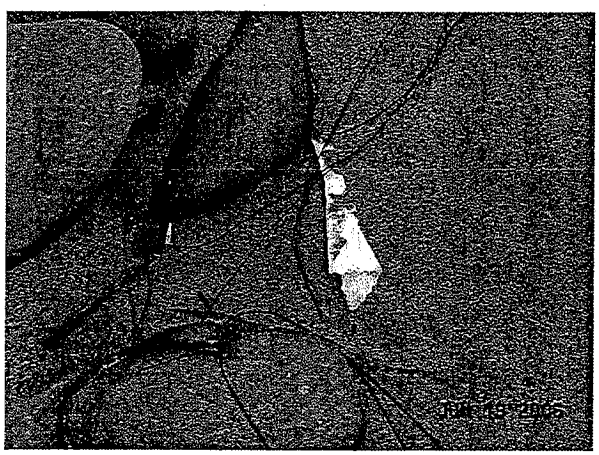




A014947

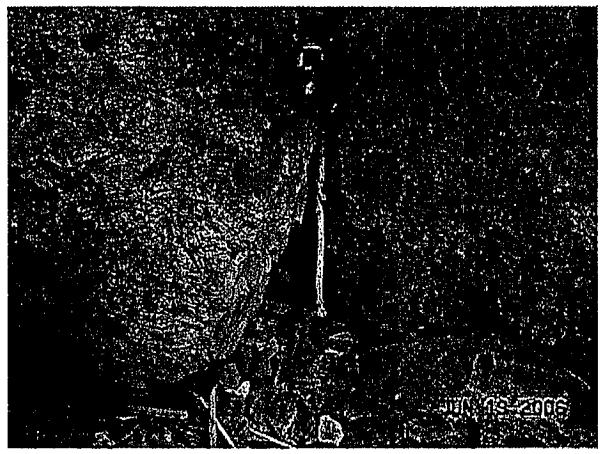
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)





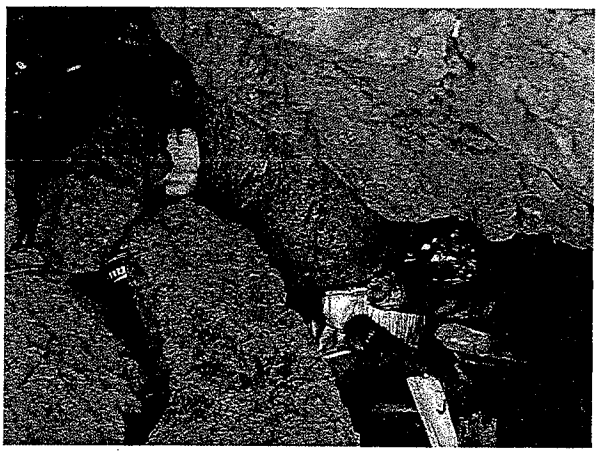
A014948

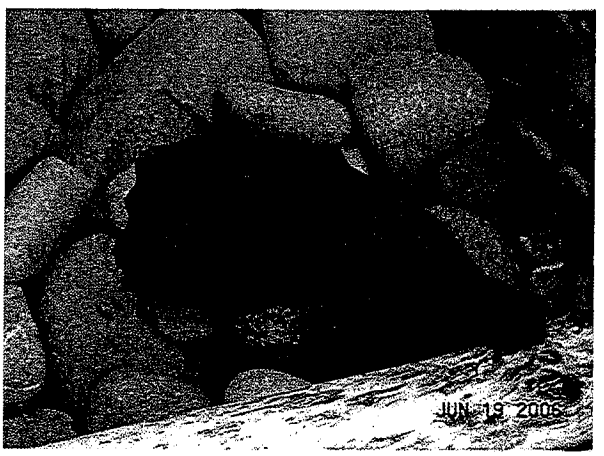
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)



A014949

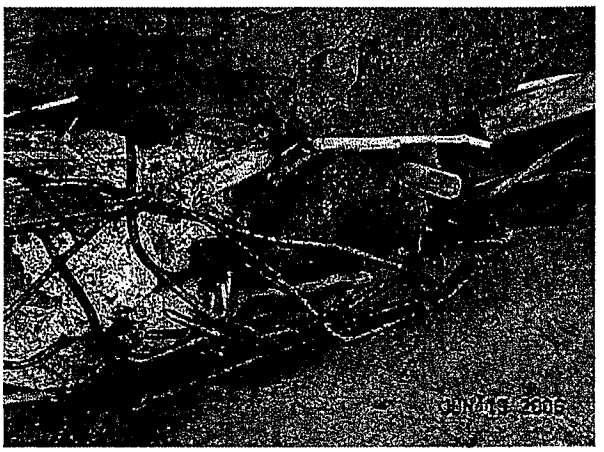
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

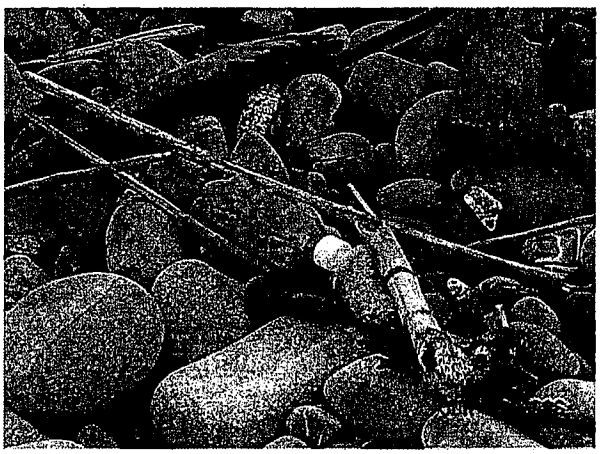




A014950

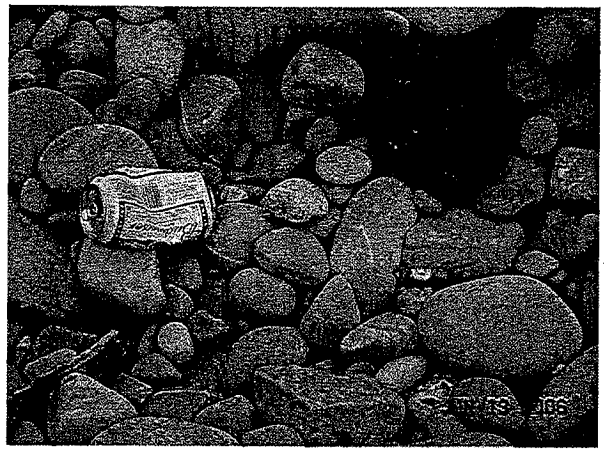
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)





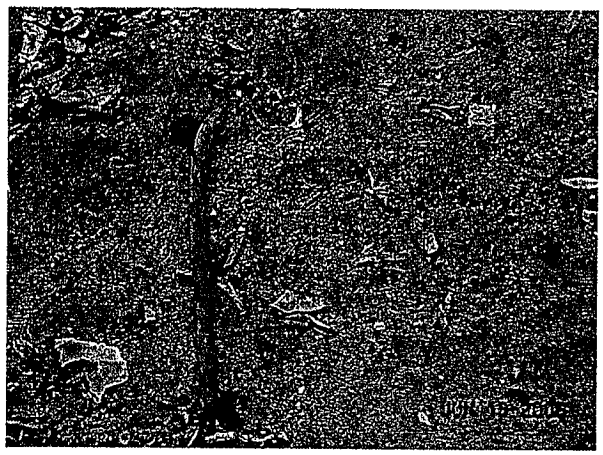
A014951

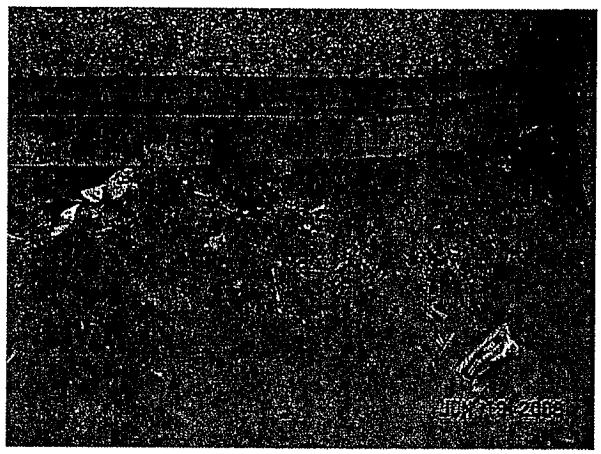
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

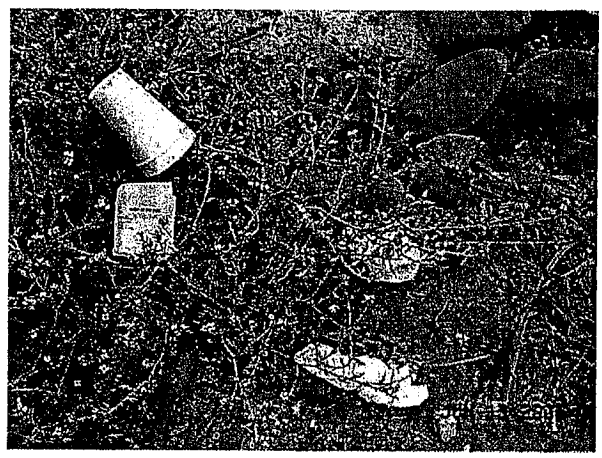


A014952

Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

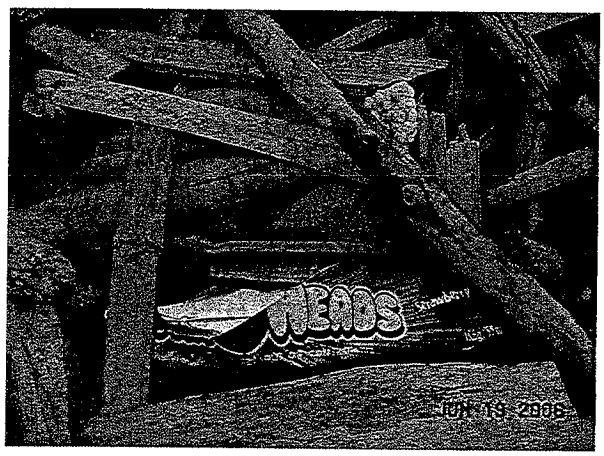




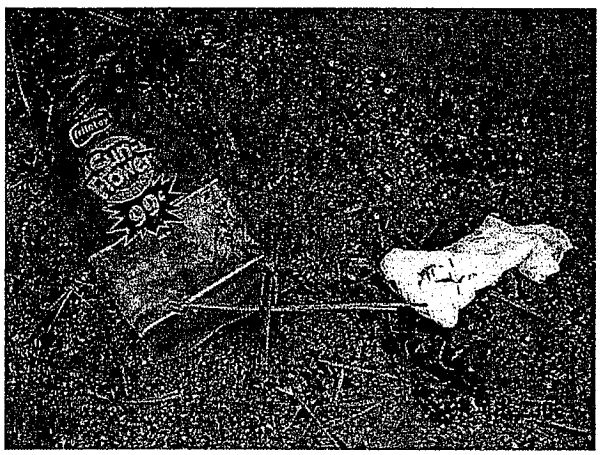


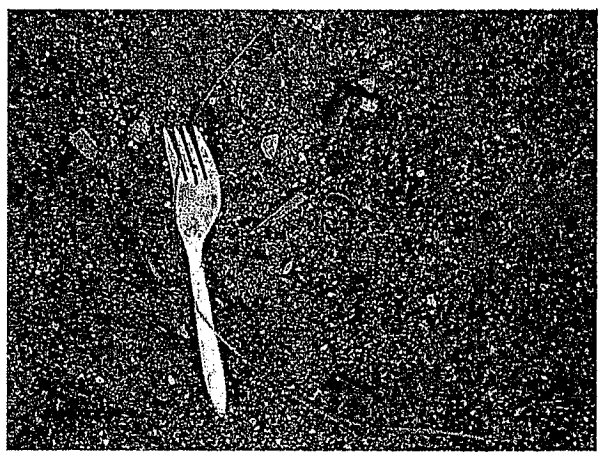
A014953

Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)



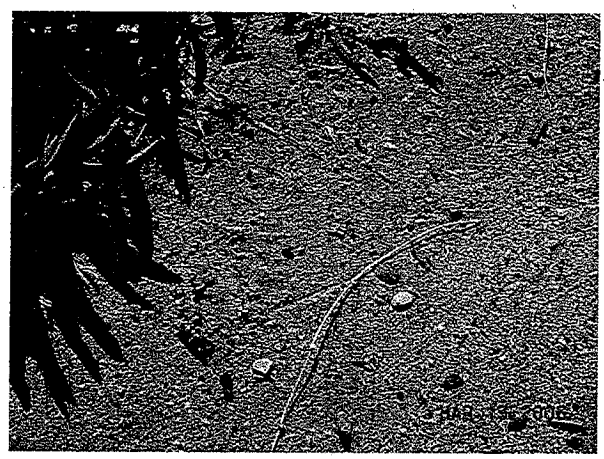
Trash & Debris Photos from Seaside Park
City of San Buenaventura
June 19, 2006 (Monday)

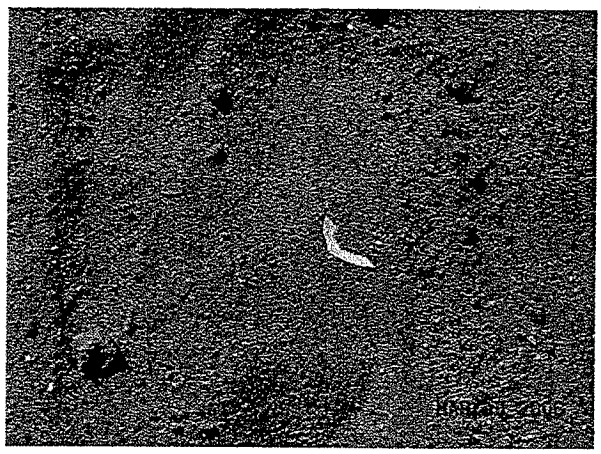


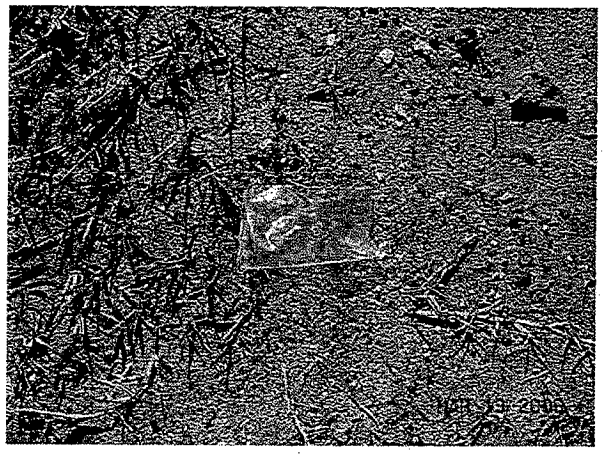


A014955

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

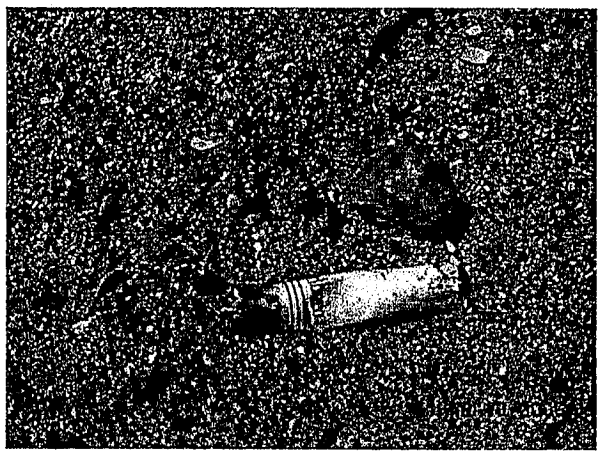


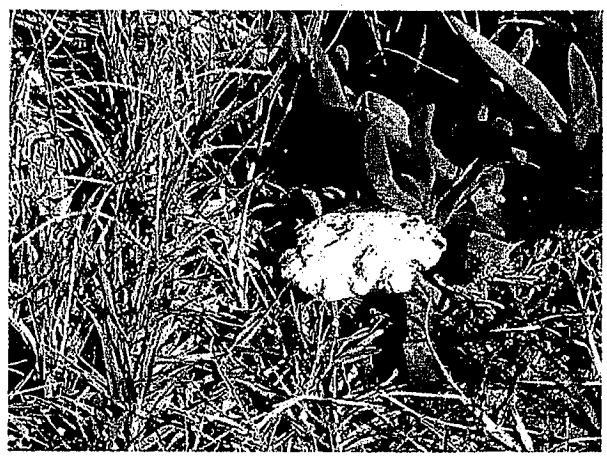




A014956

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)



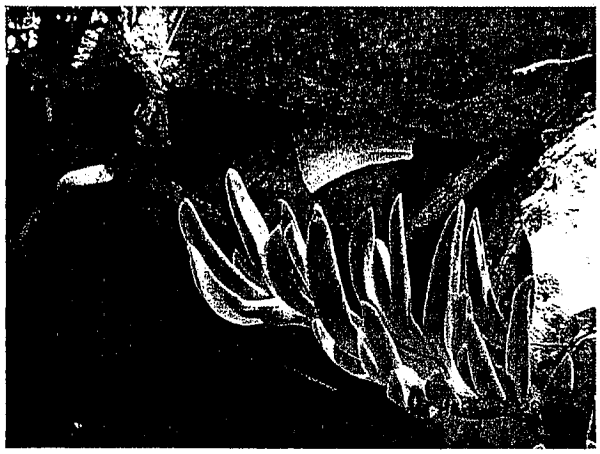


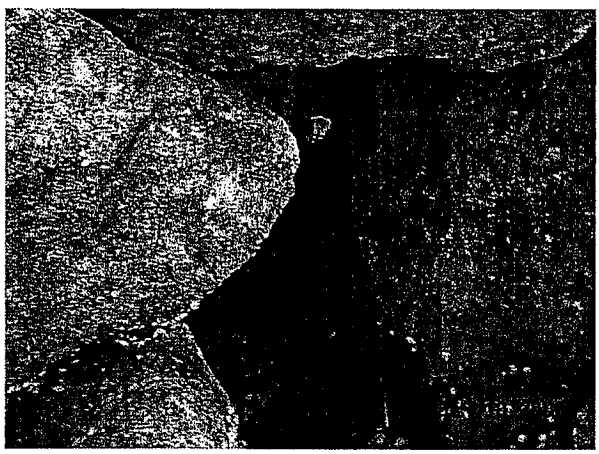
A014957

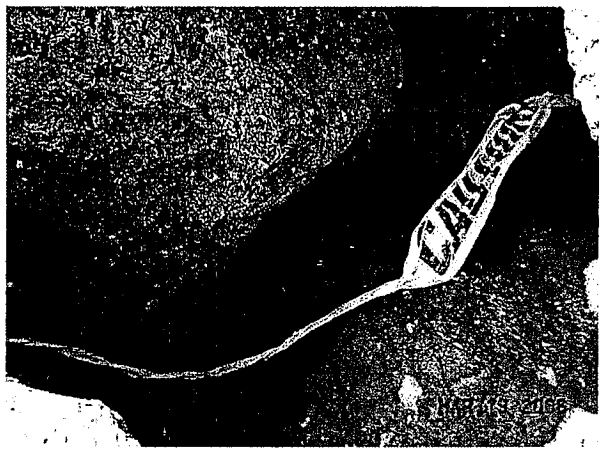
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

A014958

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

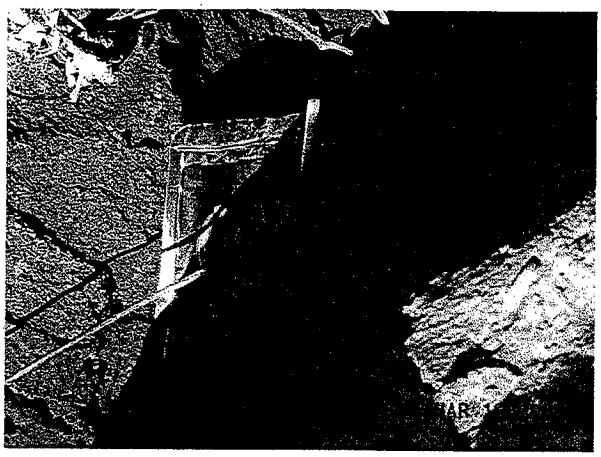


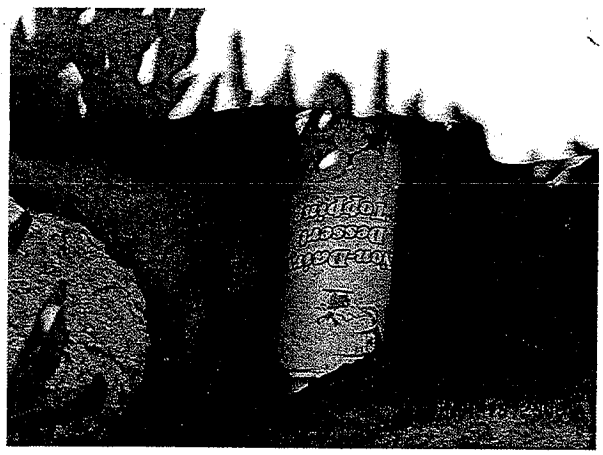




A014959

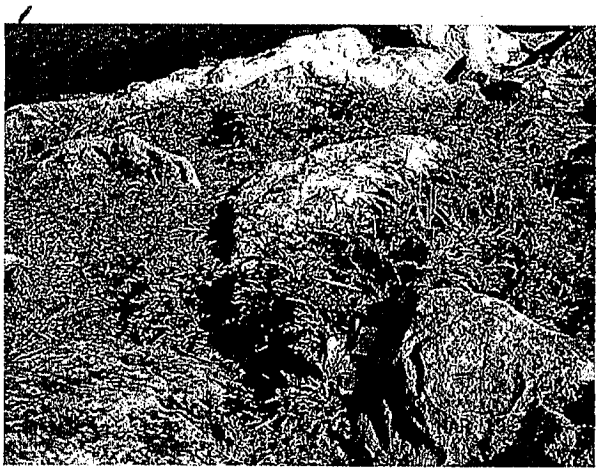
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

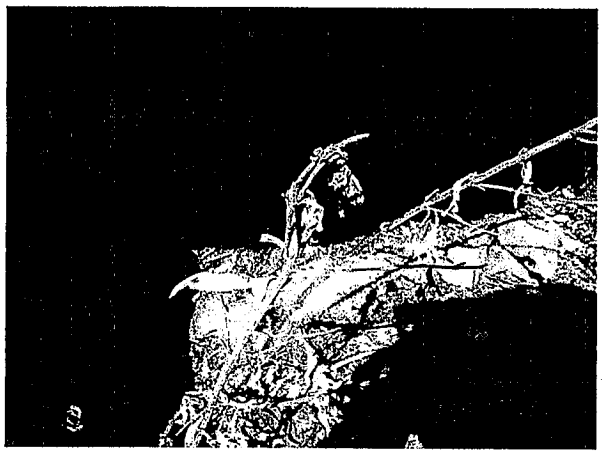




A014960

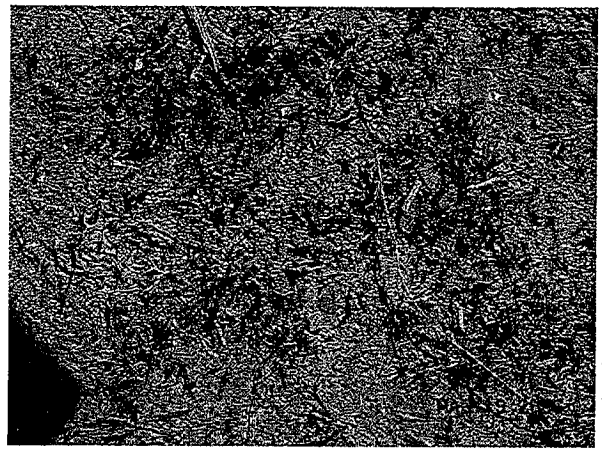
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

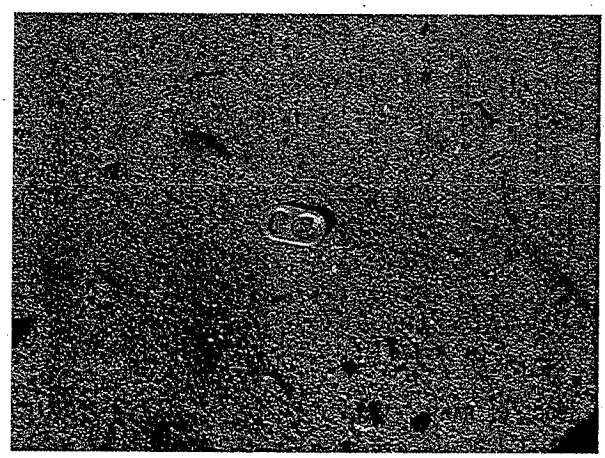


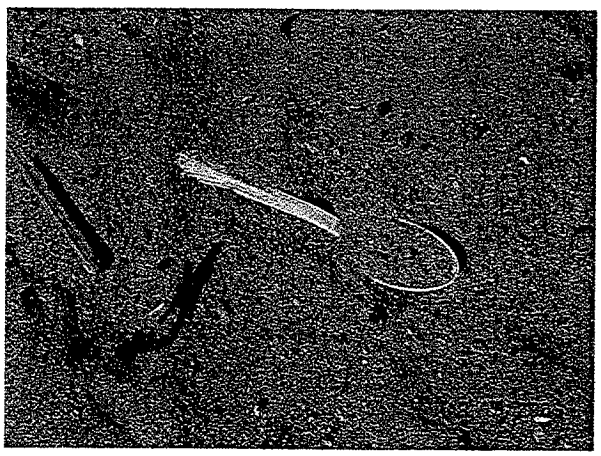


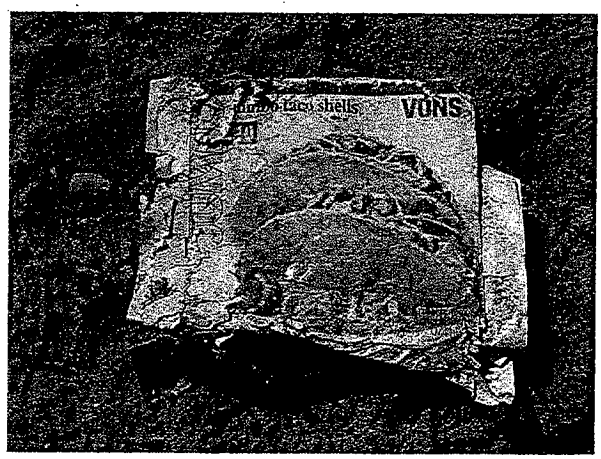
A014961

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)



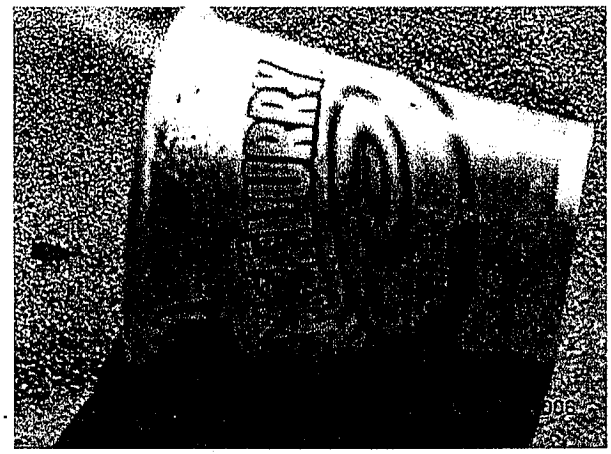


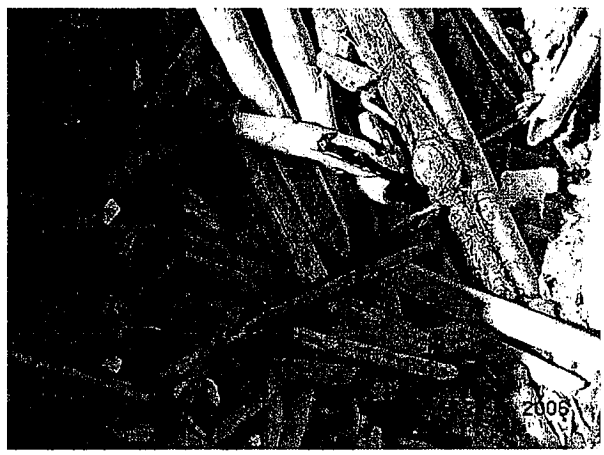




A014962

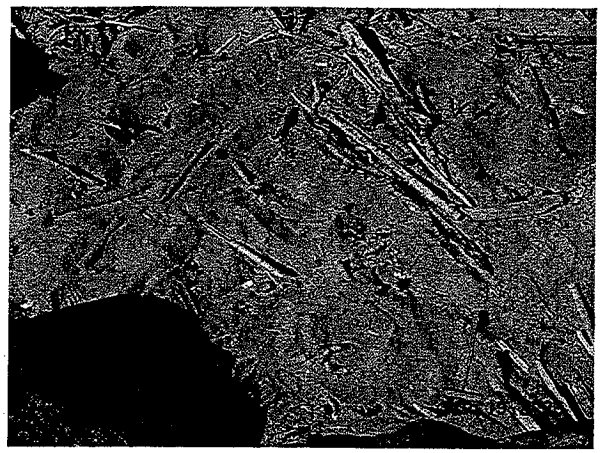
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

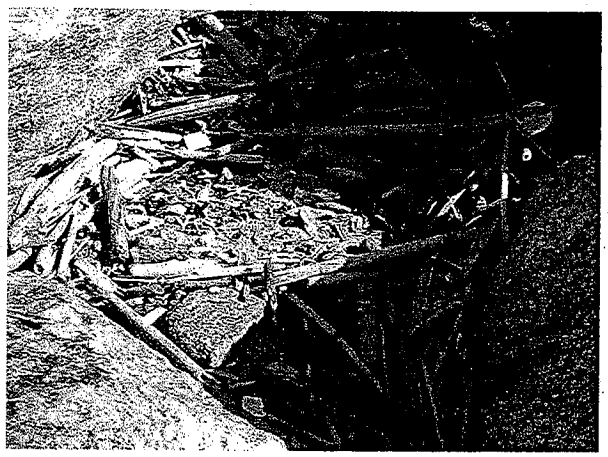


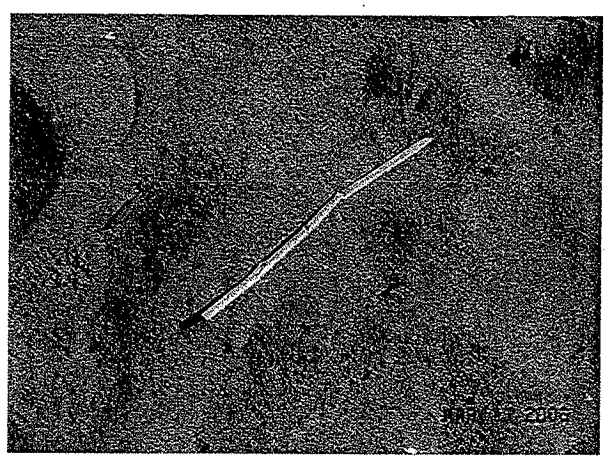


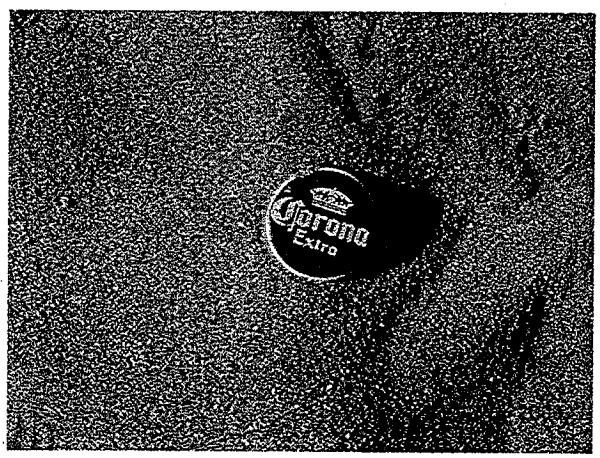
A014963

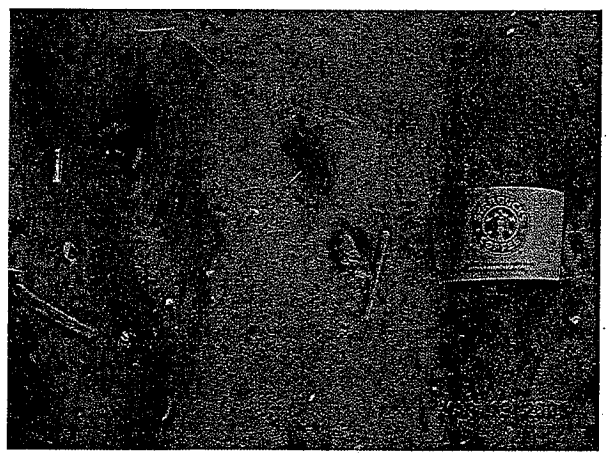
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)





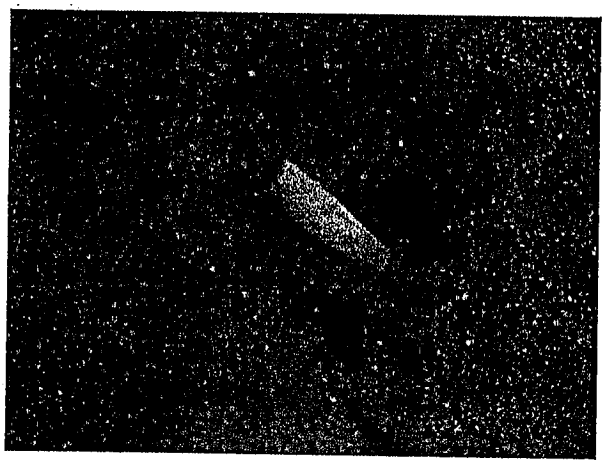


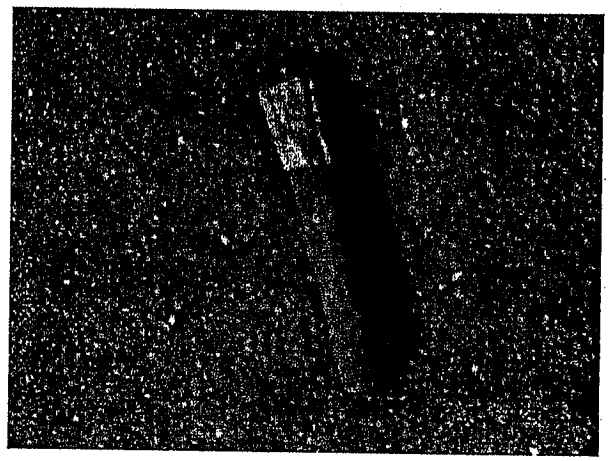




A014964

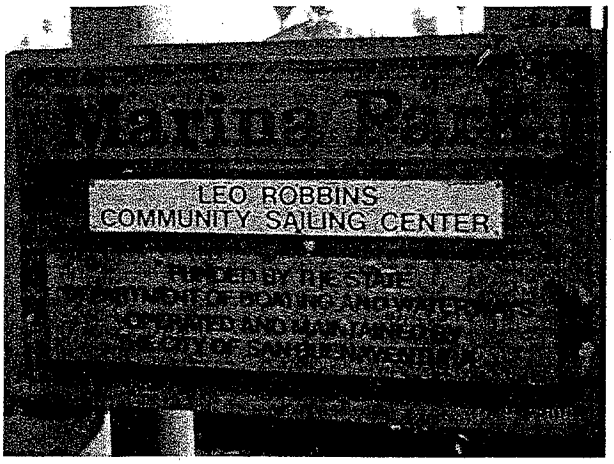
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
March 19, 2006 (Sunday)

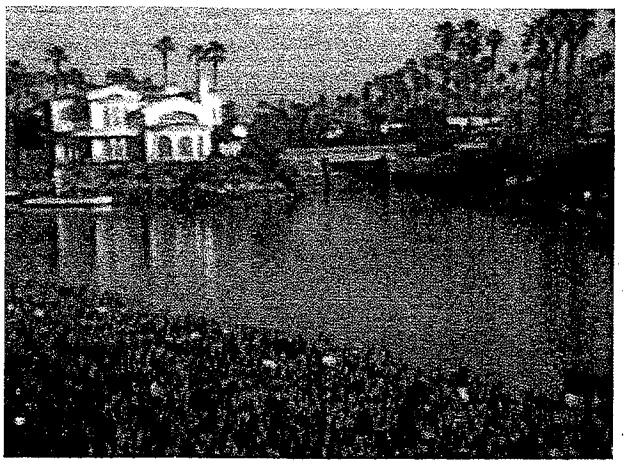


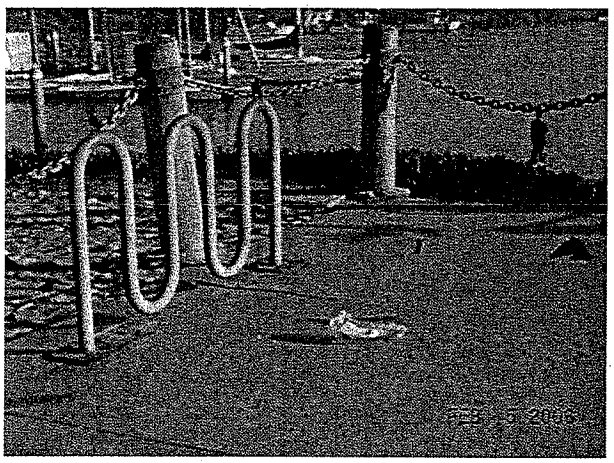


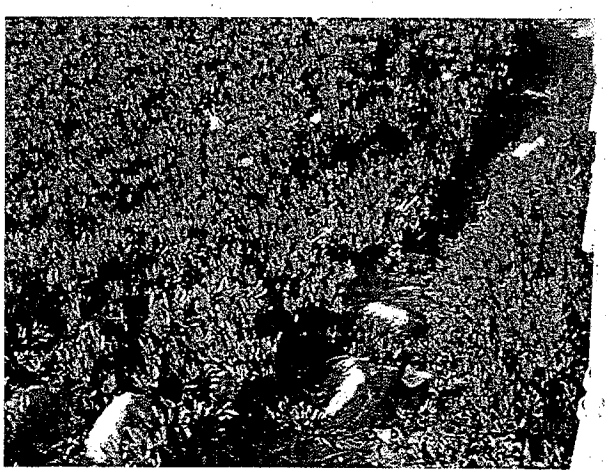
A014965

Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)



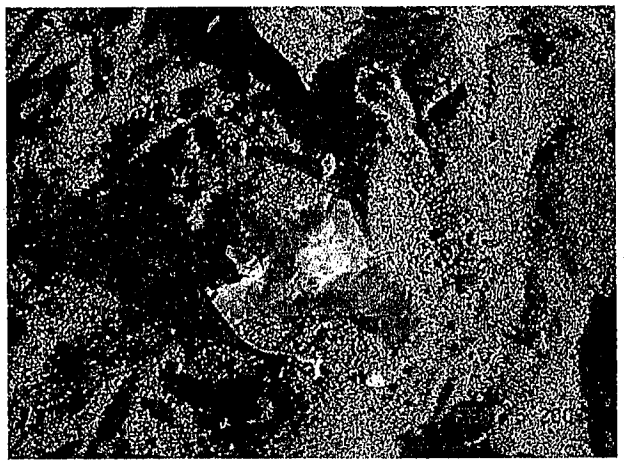


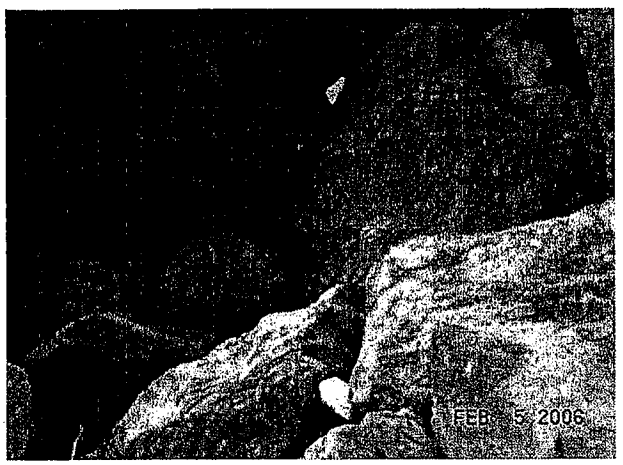




A014966

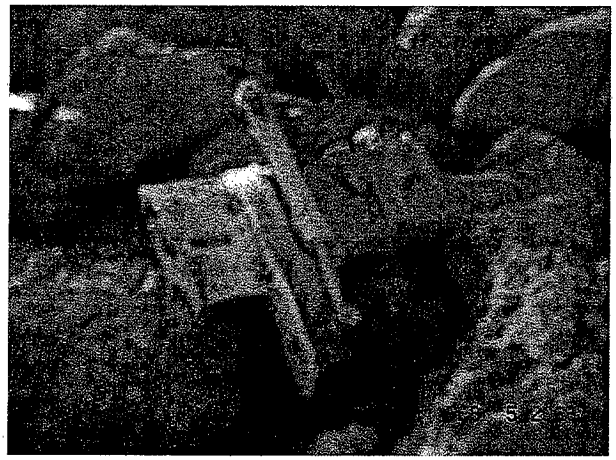
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)





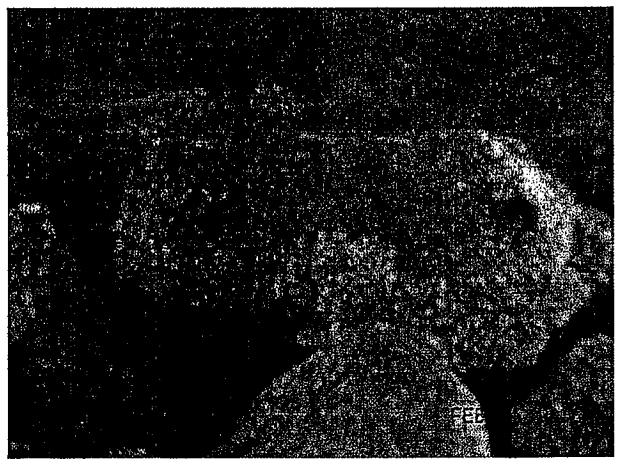
A014967

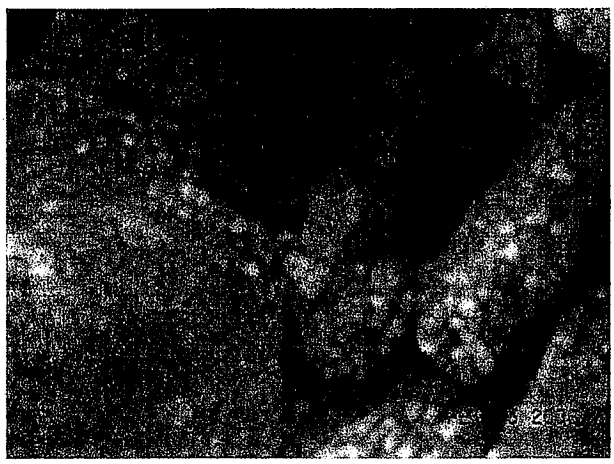
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)



A014968

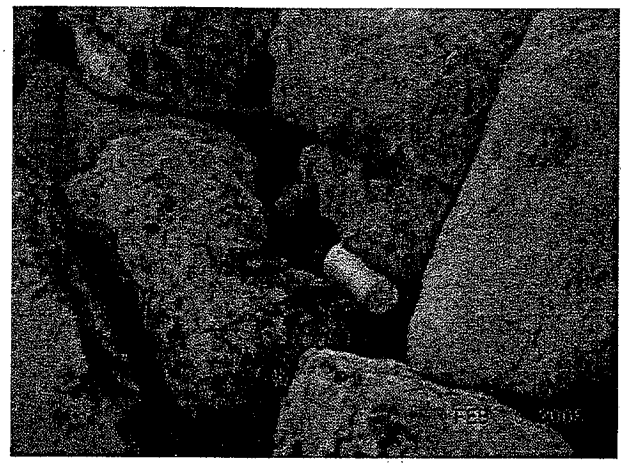
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

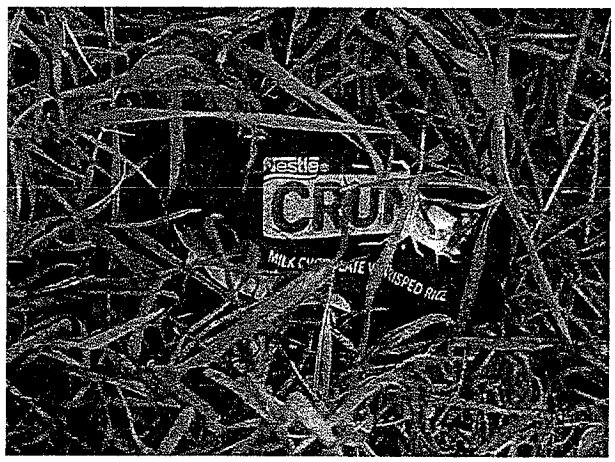




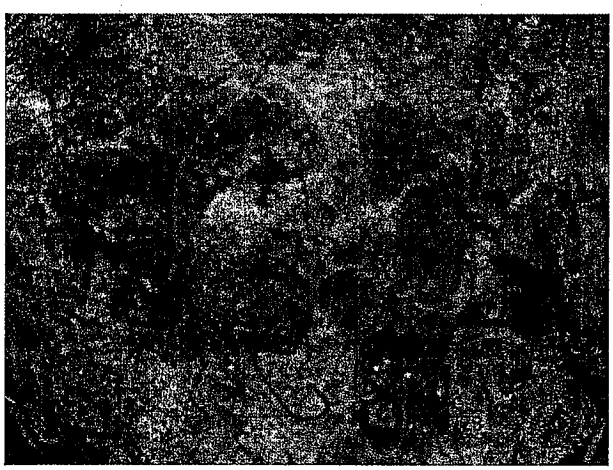
A014969

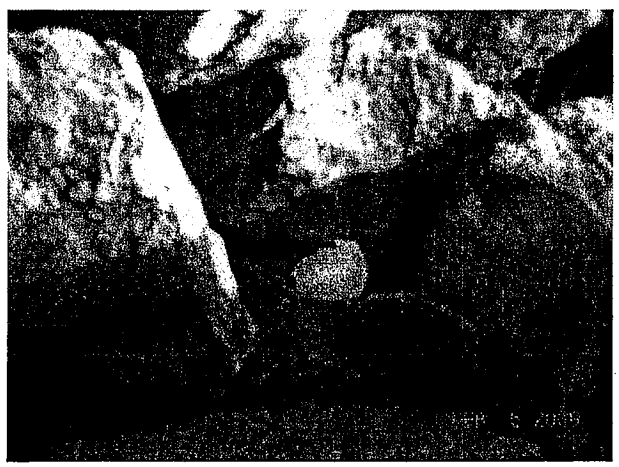
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)





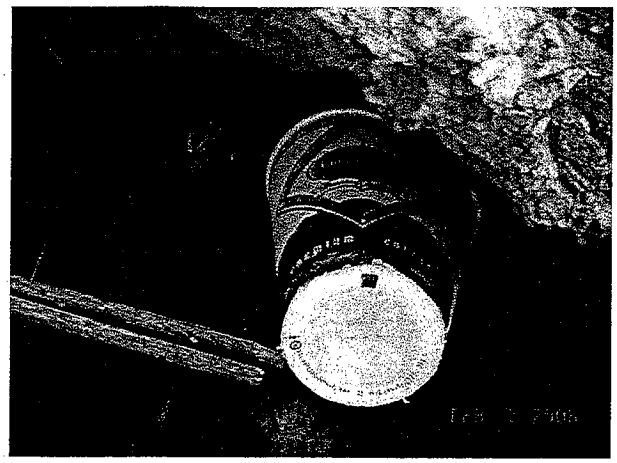
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

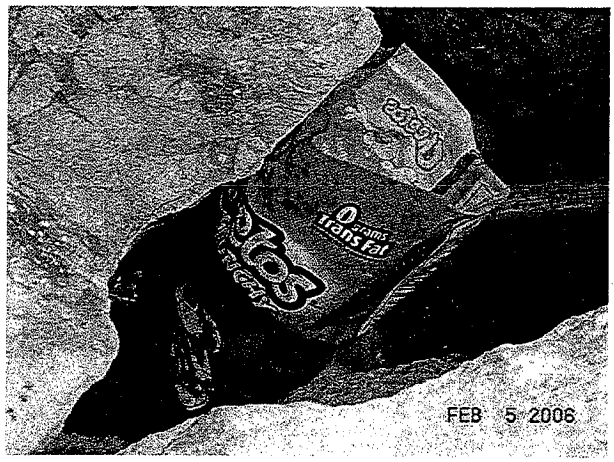




A014971

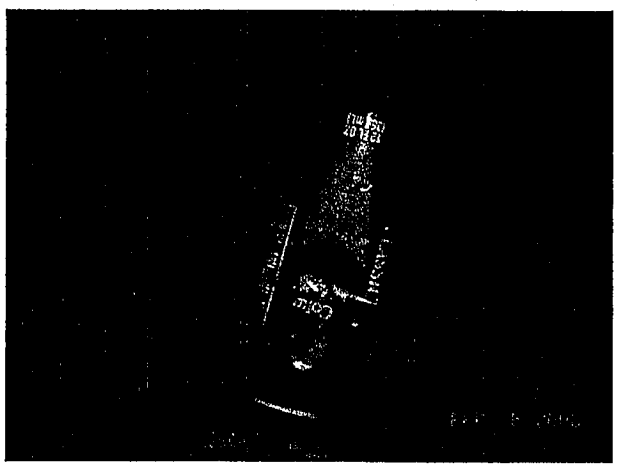
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

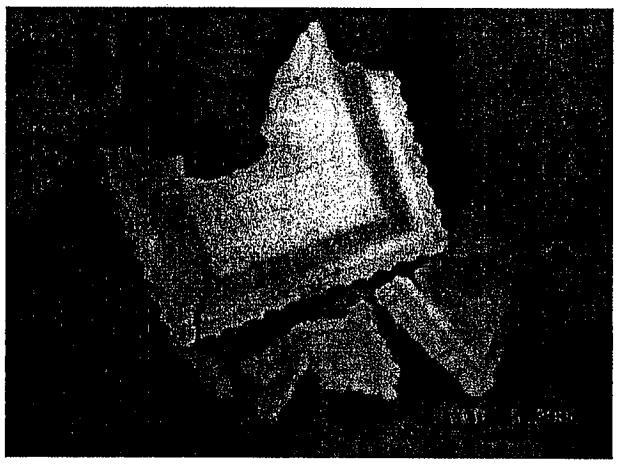


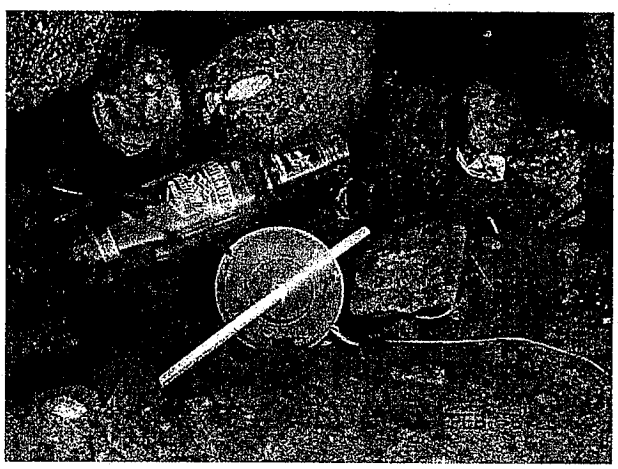


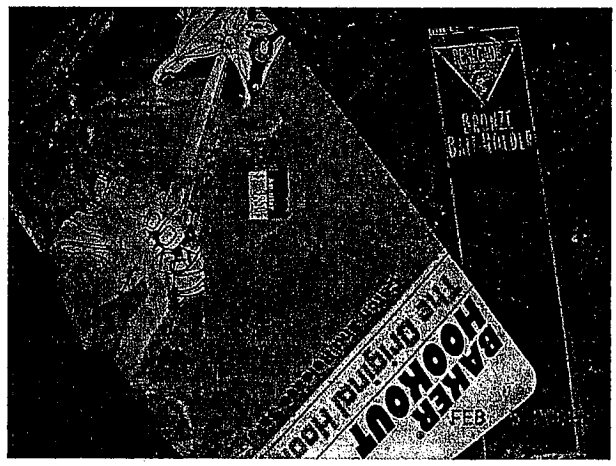
A014972

Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)



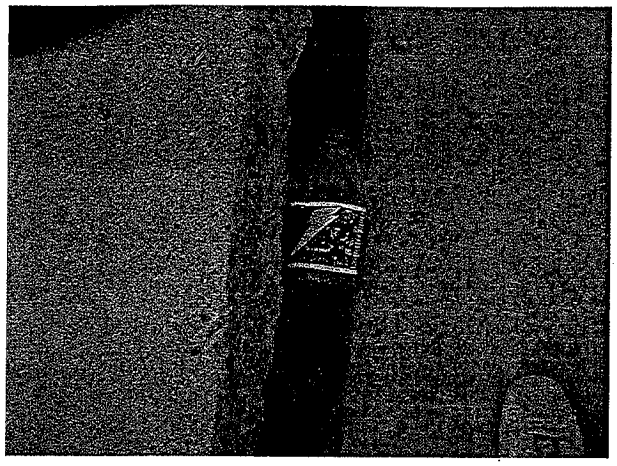


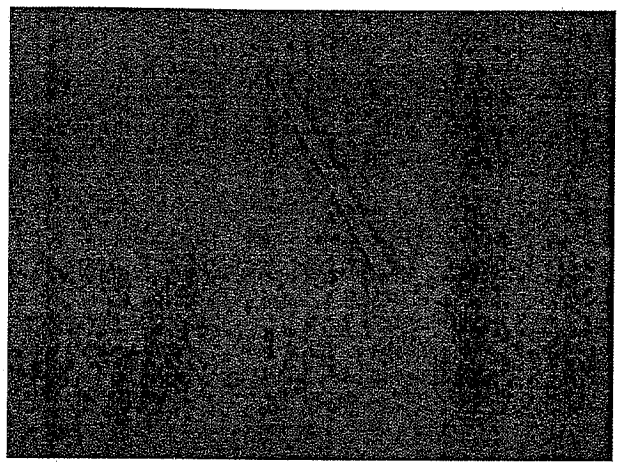


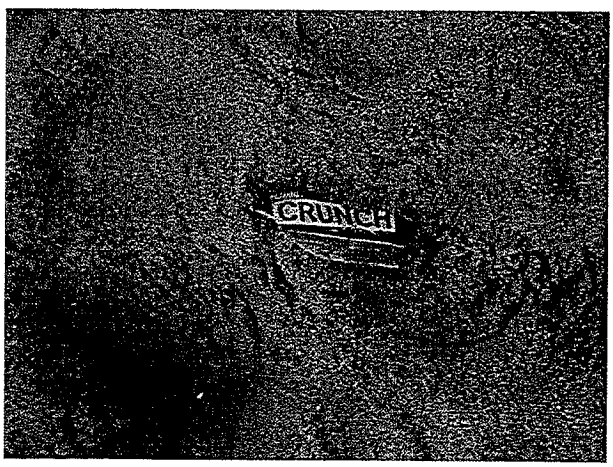


A014973

Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

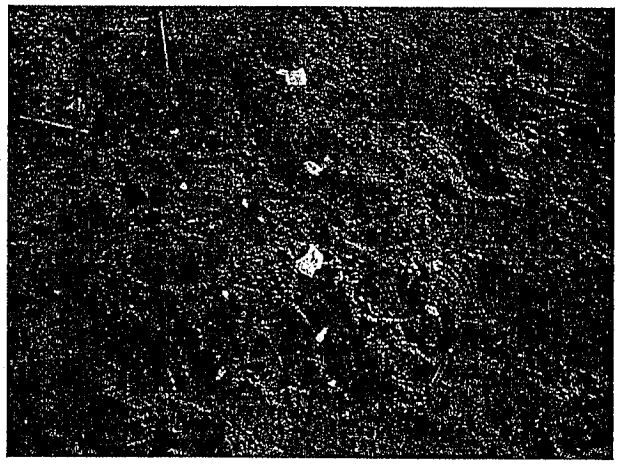


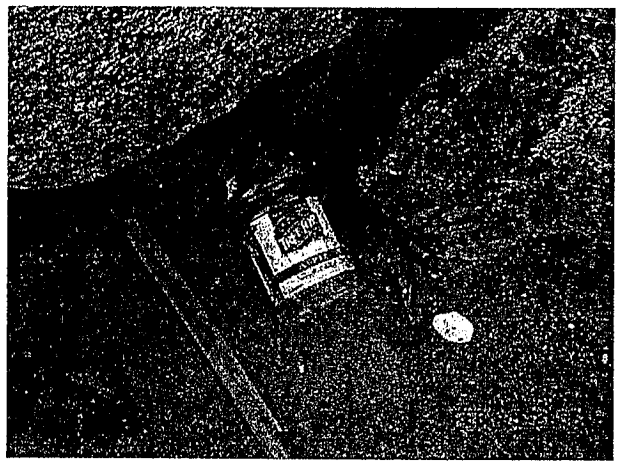


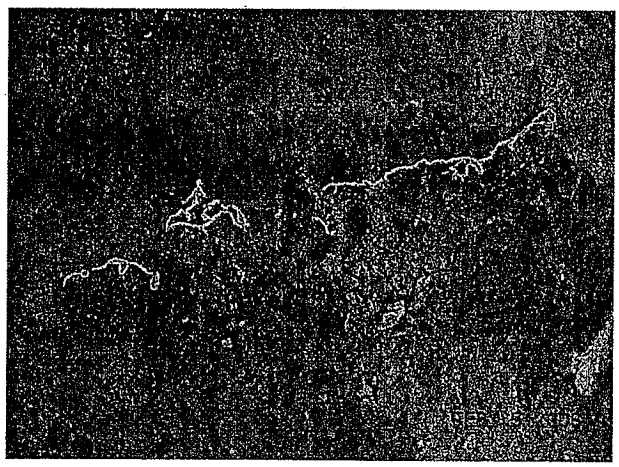


A014974

Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

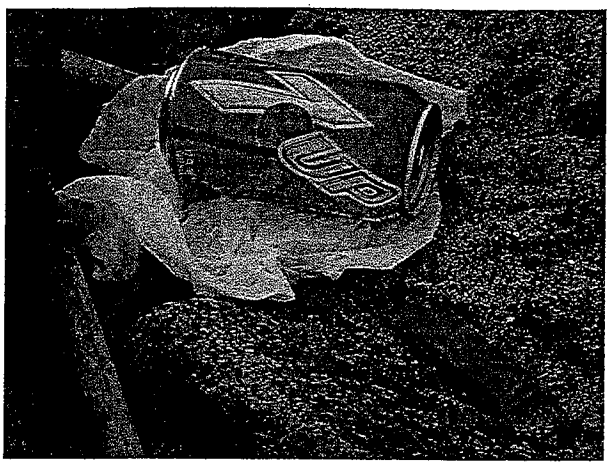


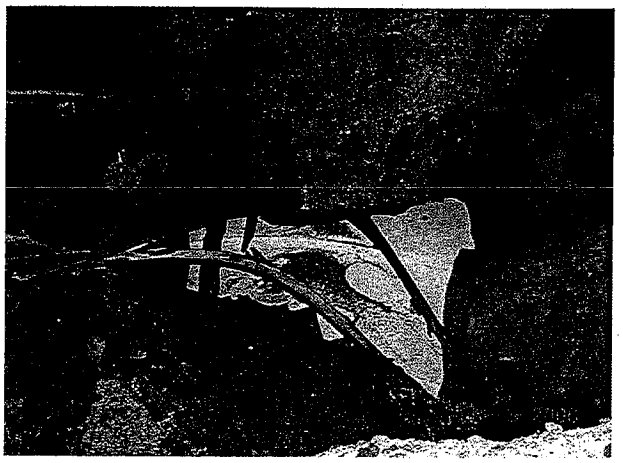




A014975

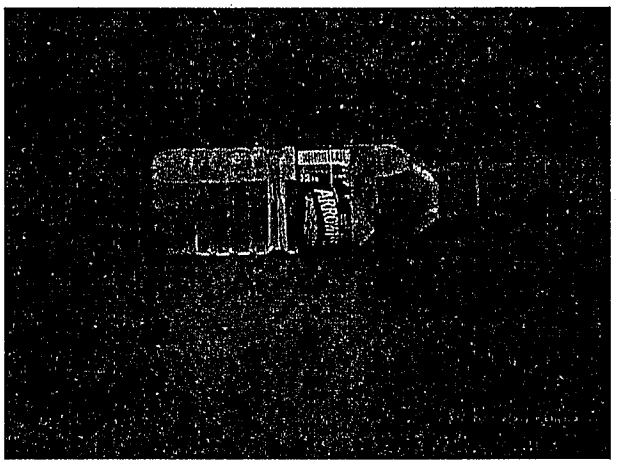
Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)

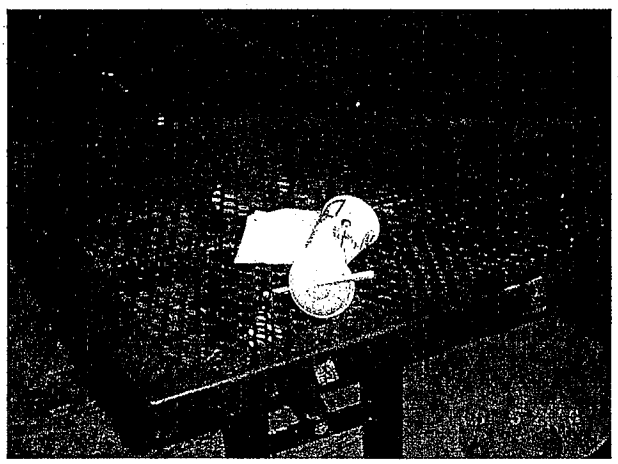


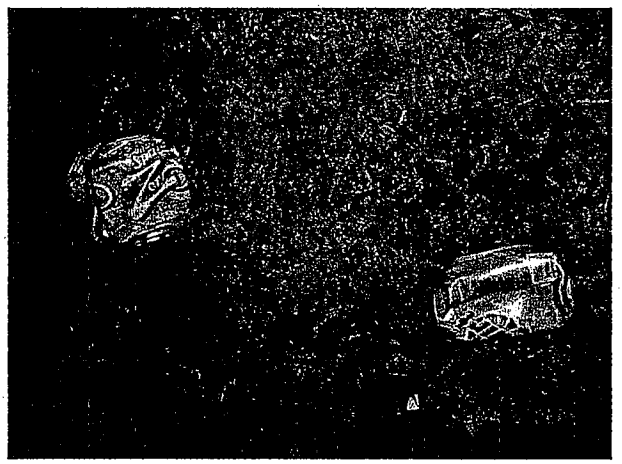


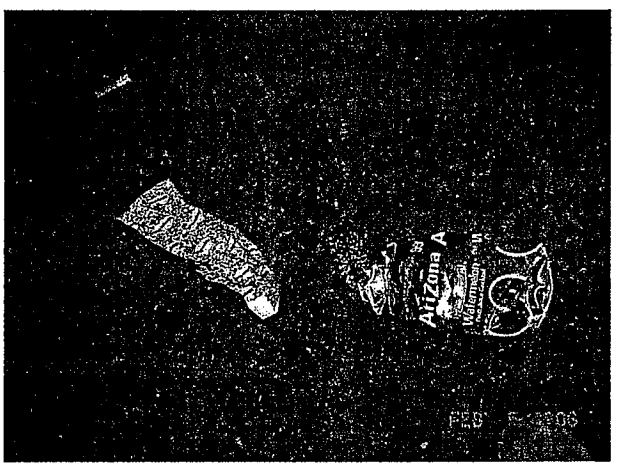
A014976

Trash & Debris Photos from San Buenaventura Marina Park, City of San Buenaventura
February 5, 2006 (Sunday)



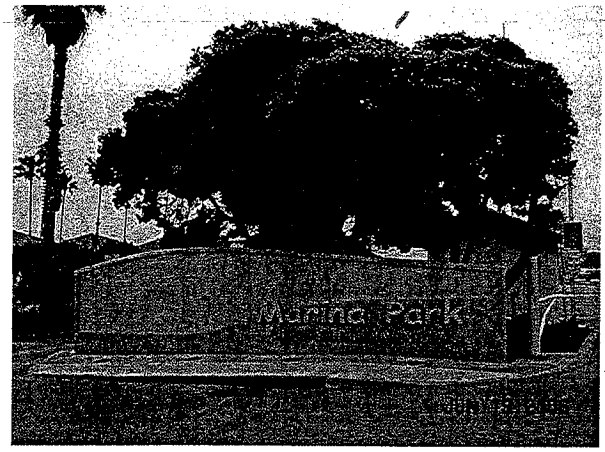


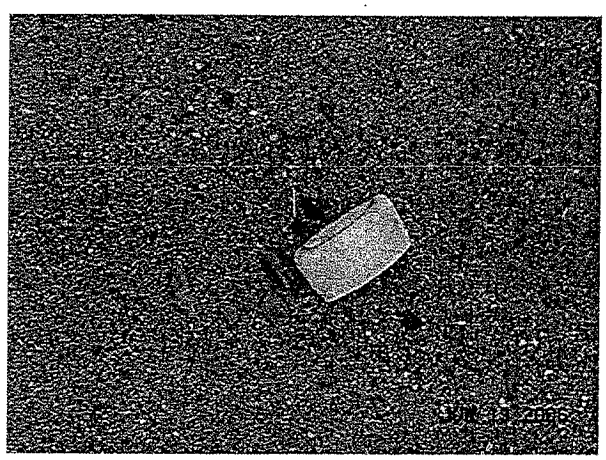




A014977

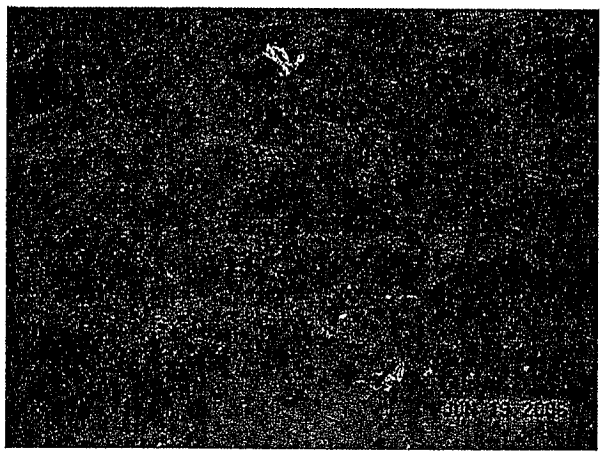
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
June 19, 2006 (Monday)

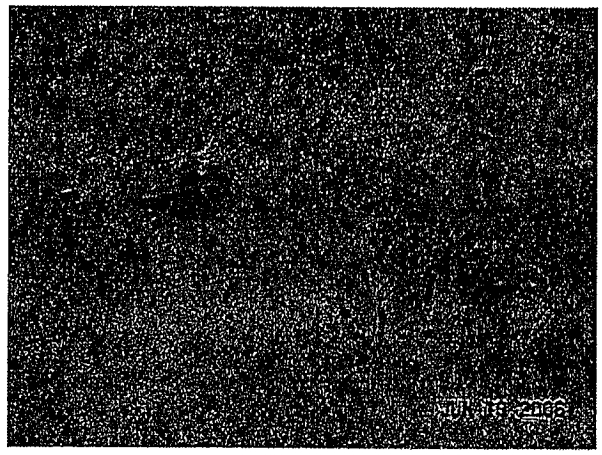


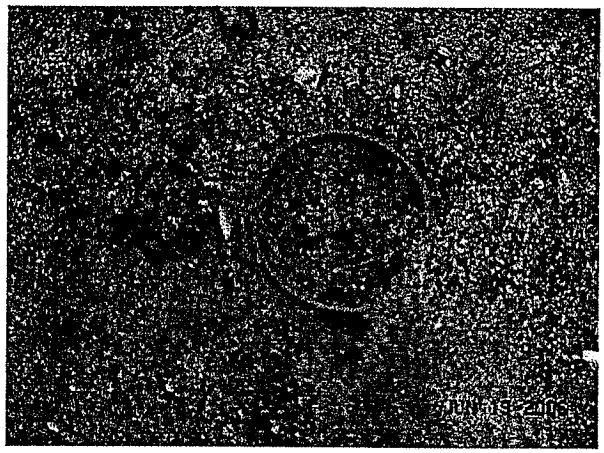


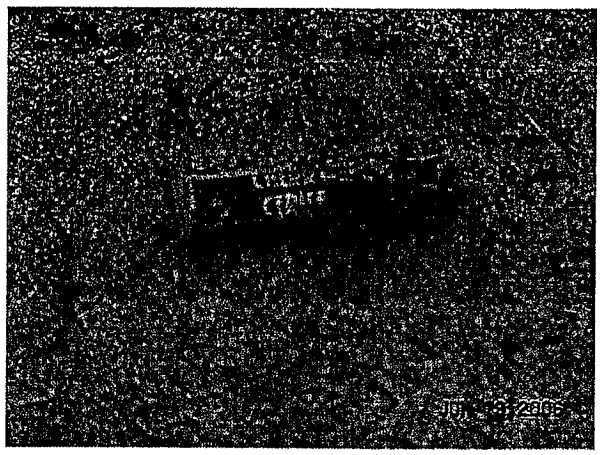
A014978

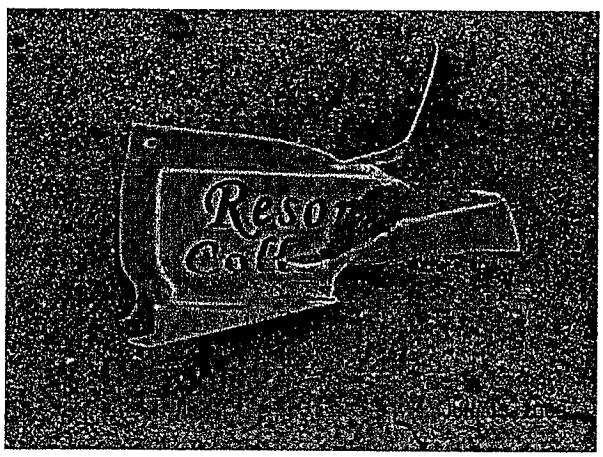
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
June 19, 2006 (Monday)

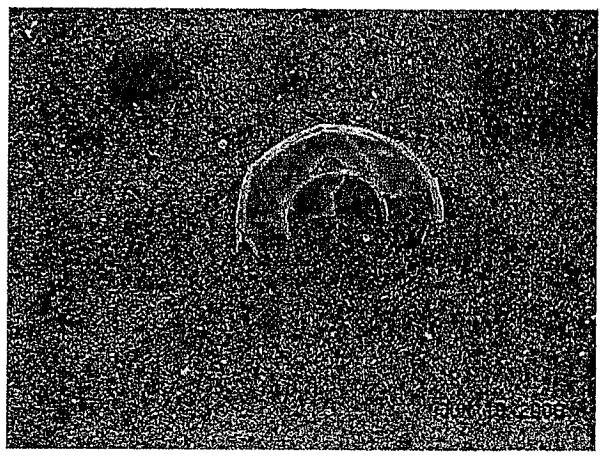






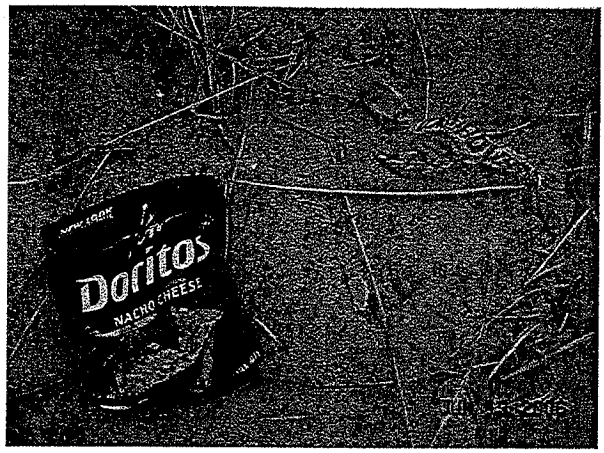






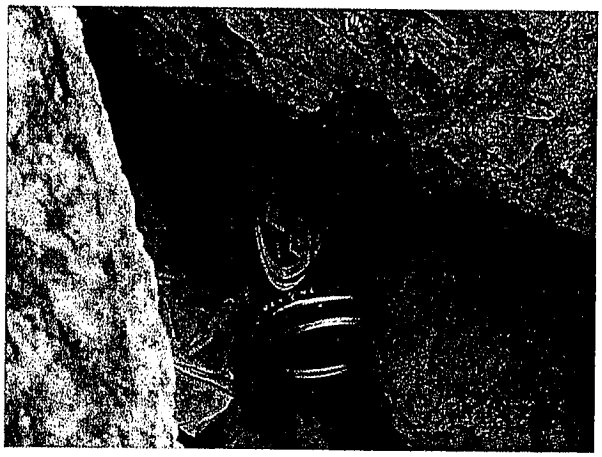
A014979

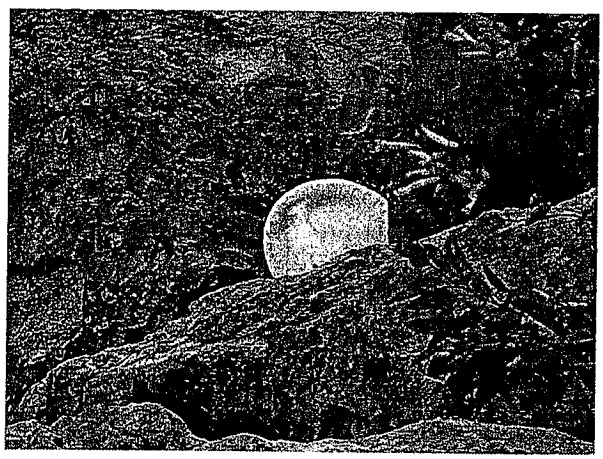
Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
June 19, 2006 (Monday)

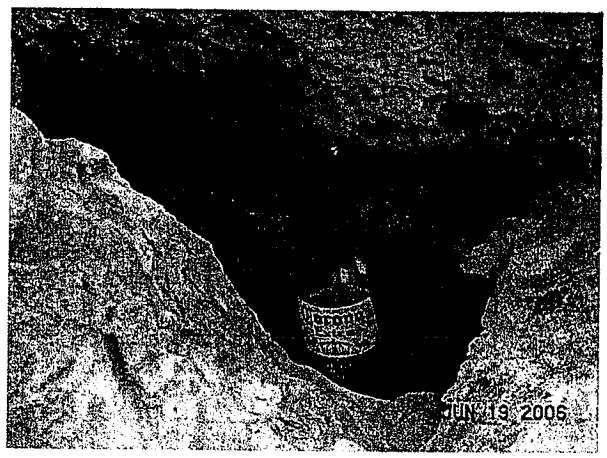


A014980

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
June 19, 2006 (Monday)

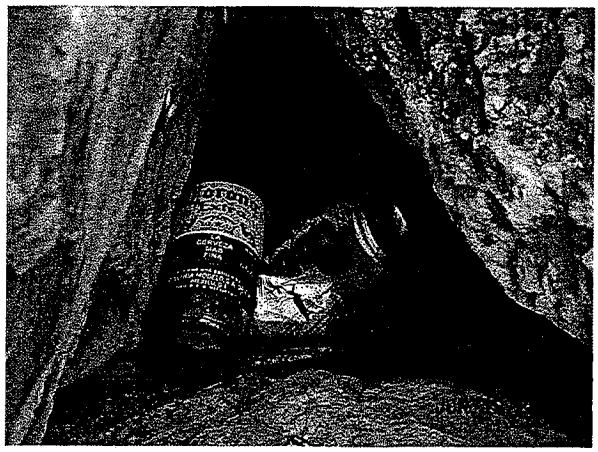


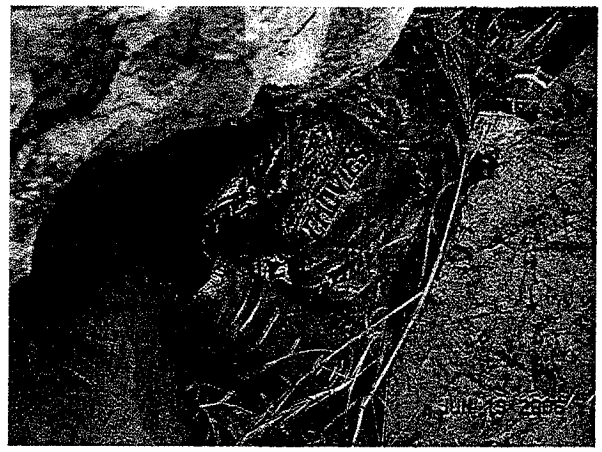


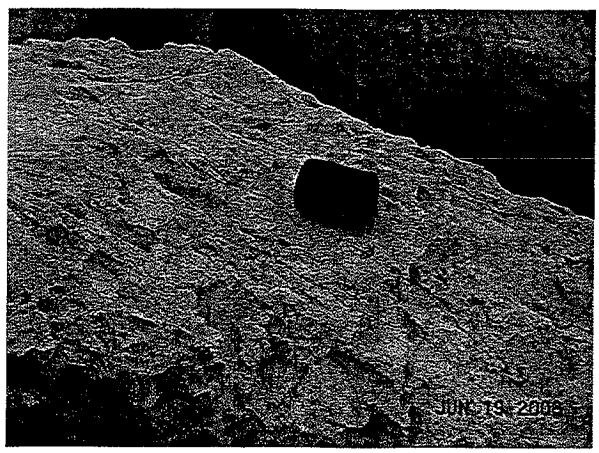


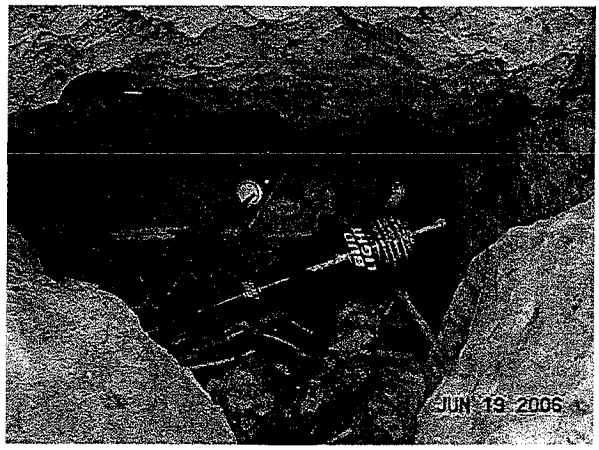
A014981

Trash & Debris Photos from San Buenaventura Marina Park
City of San Buenaventura
June 19, 2006 (Monday)



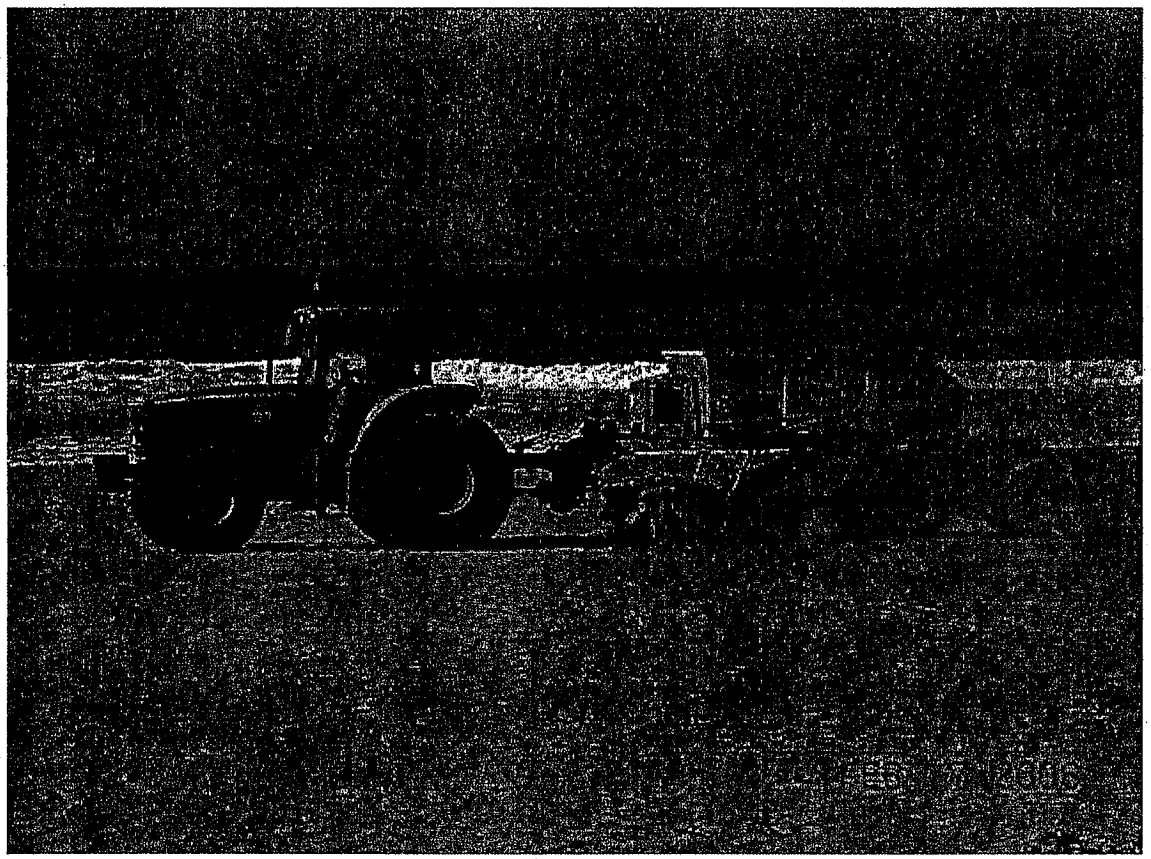






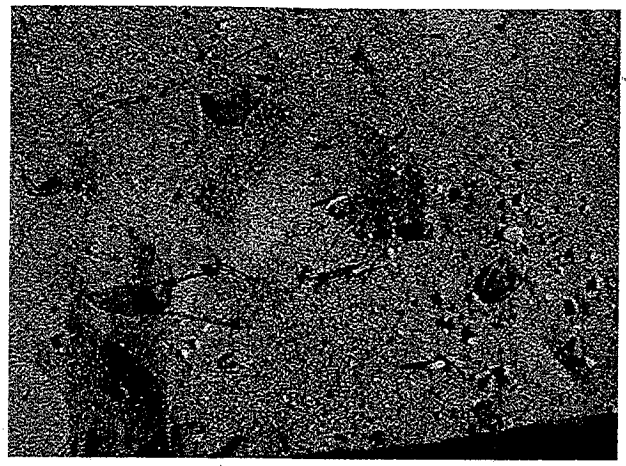
A014982

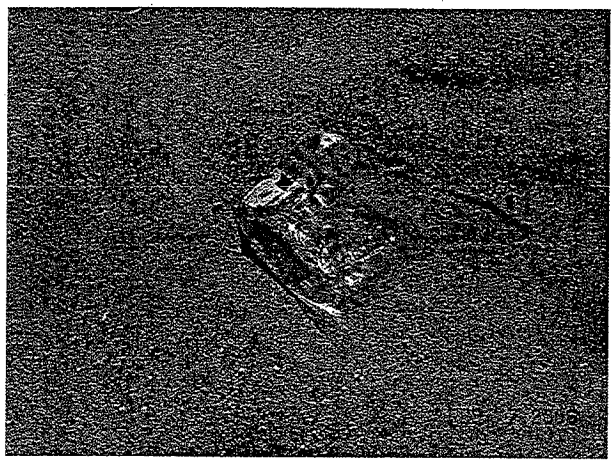
Photo of Trash & Debris Collector at Mandalay Beach Resort, City of Oxnard
February 7, 2006 (Tuesday)

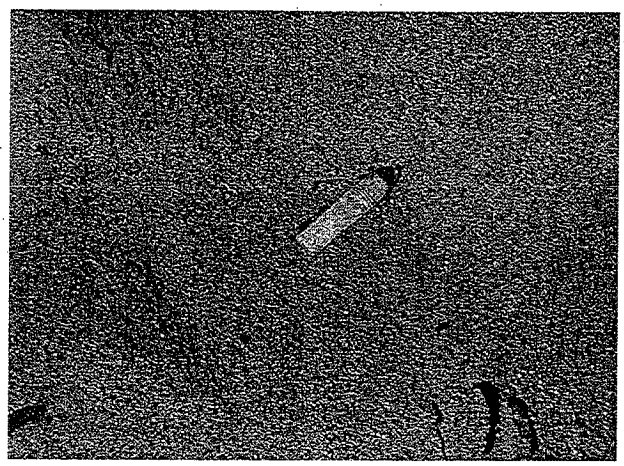


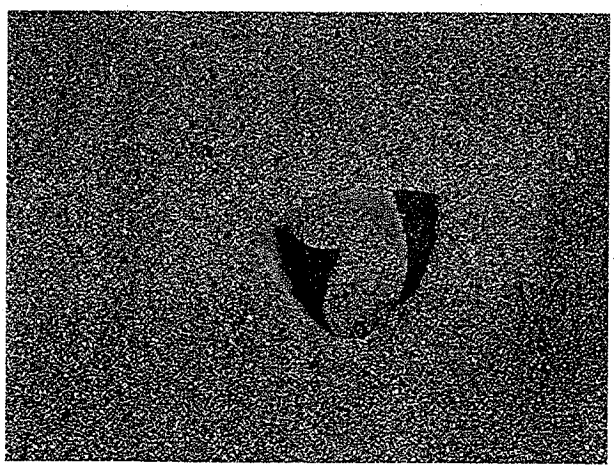
A014983

Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)



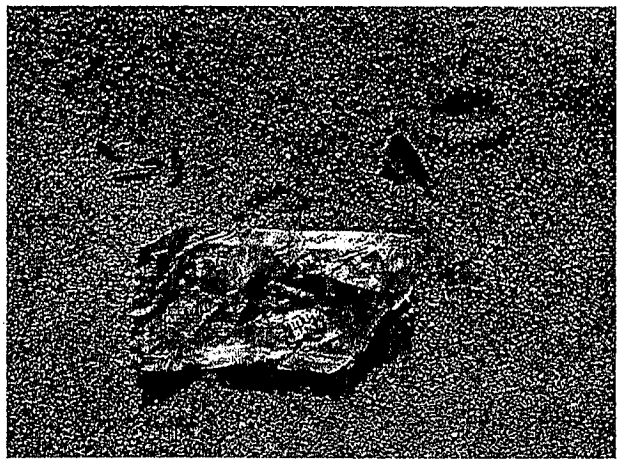


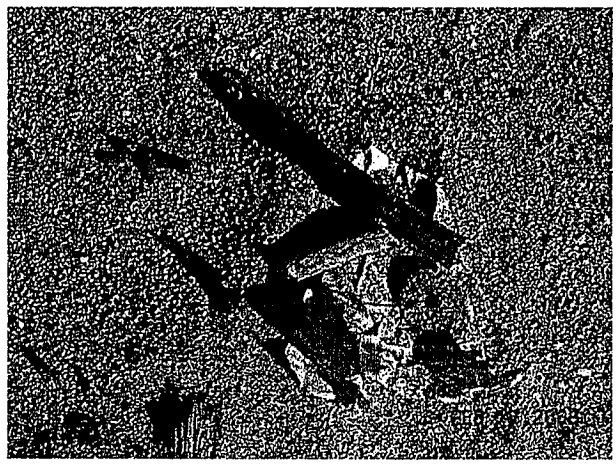


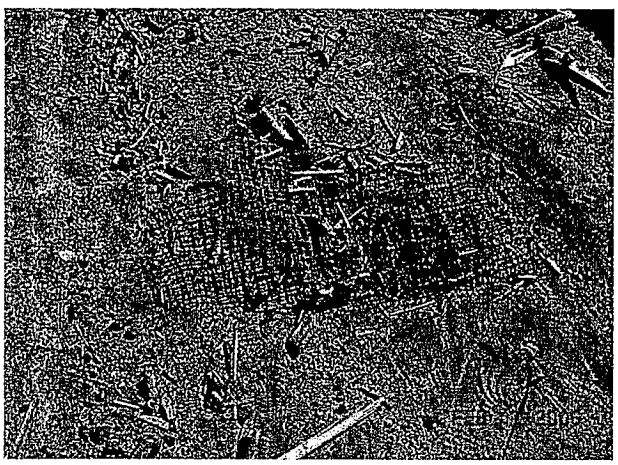


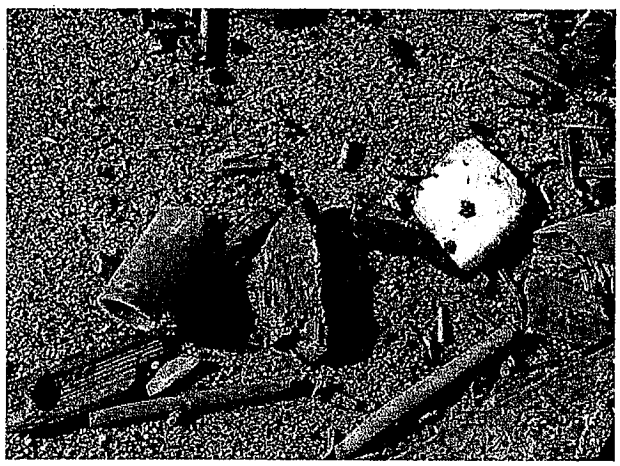
A014984

Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)



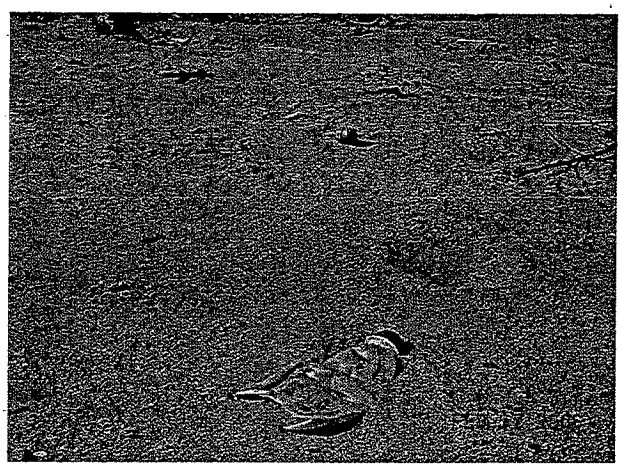






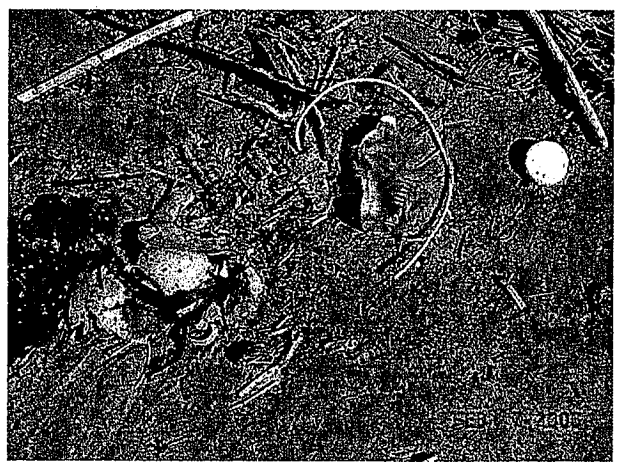
A014985

Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)



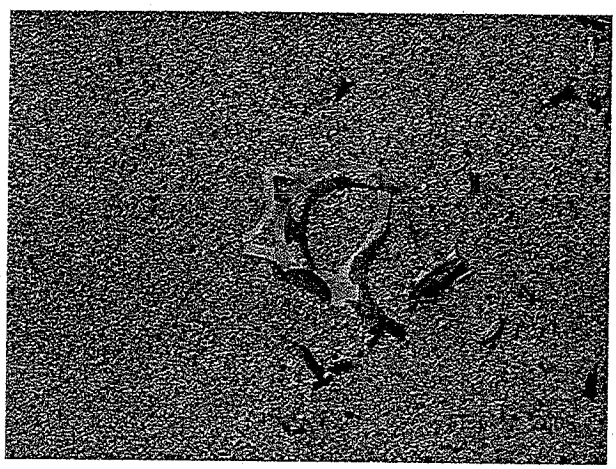
A014986

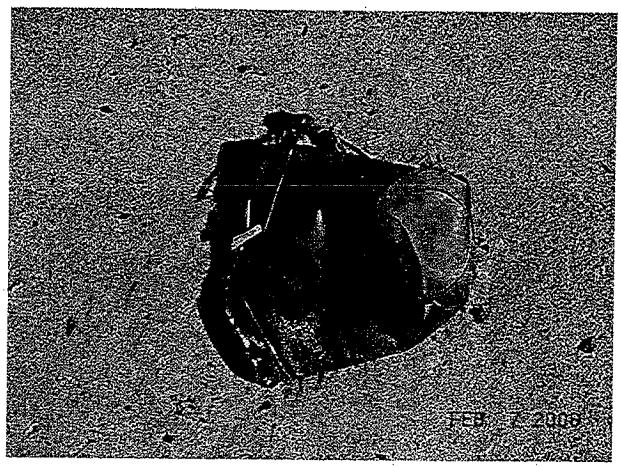
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

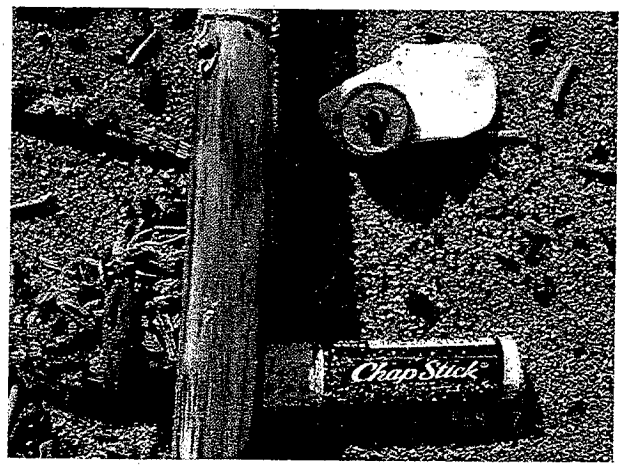


A014987

Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

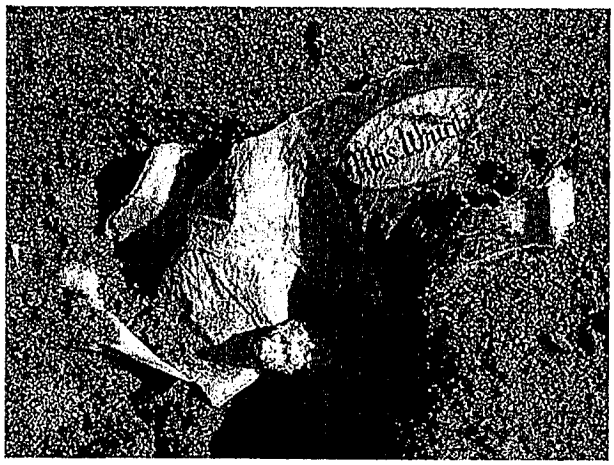


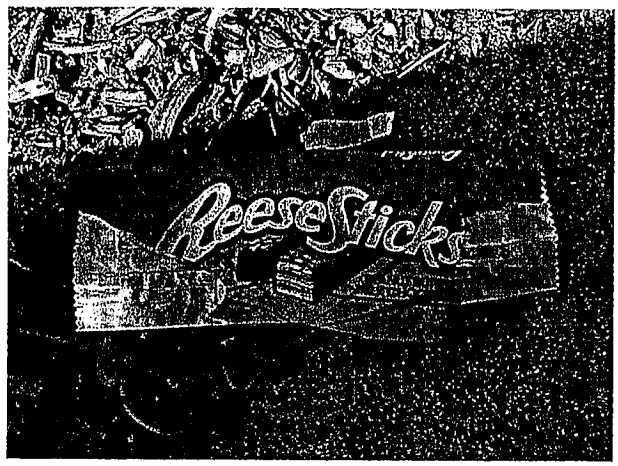


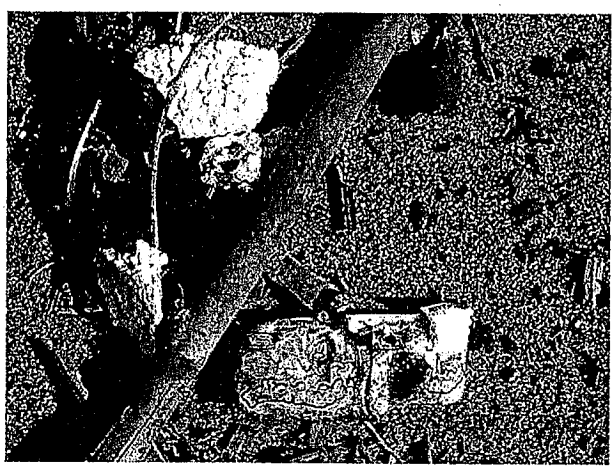


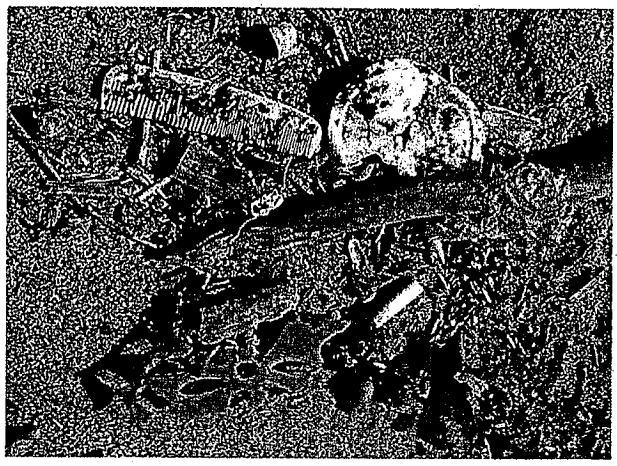
A014988

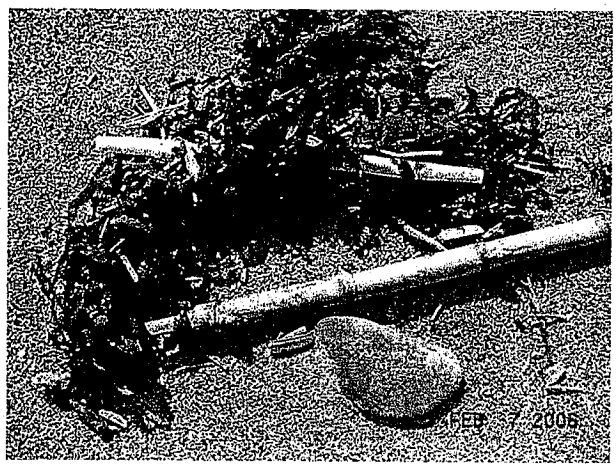
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

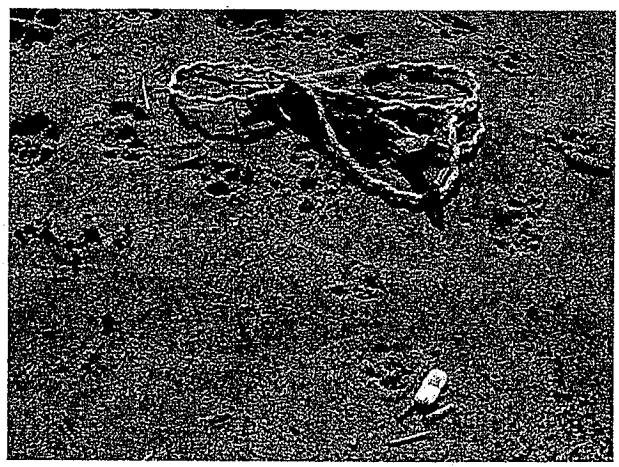






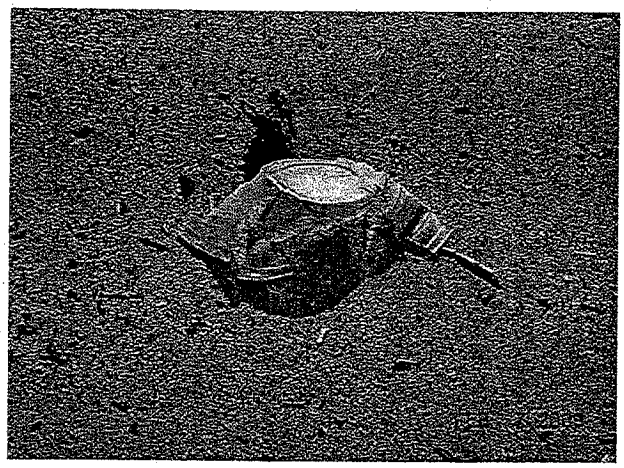
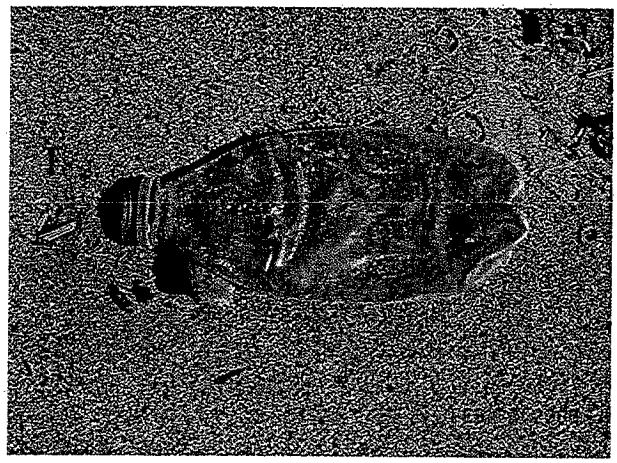


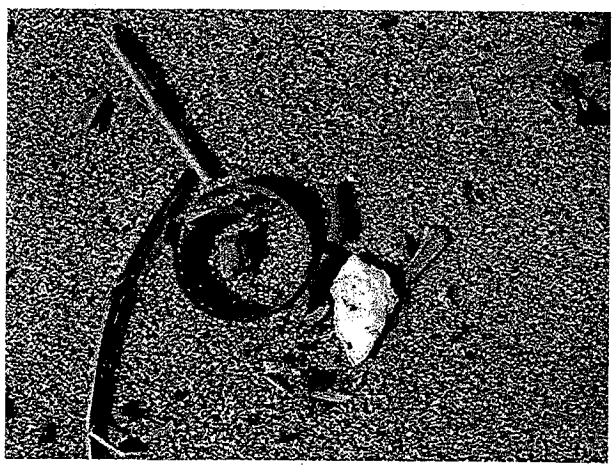




A014989

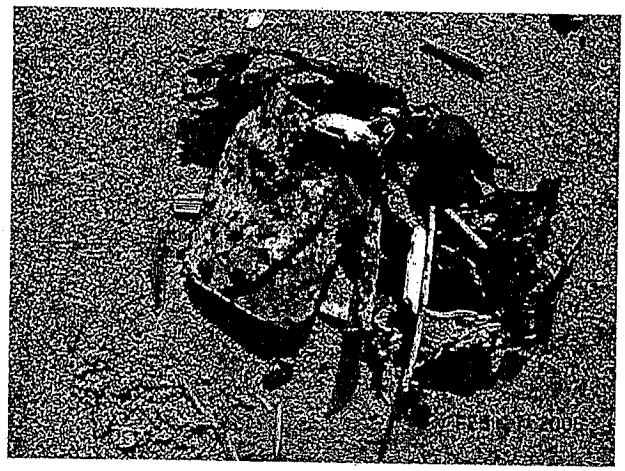
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

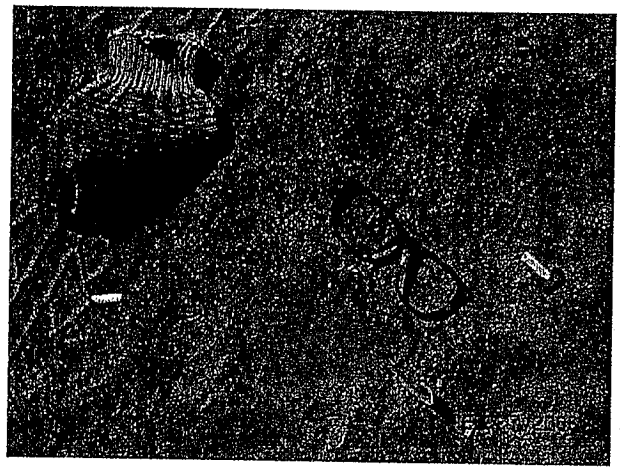



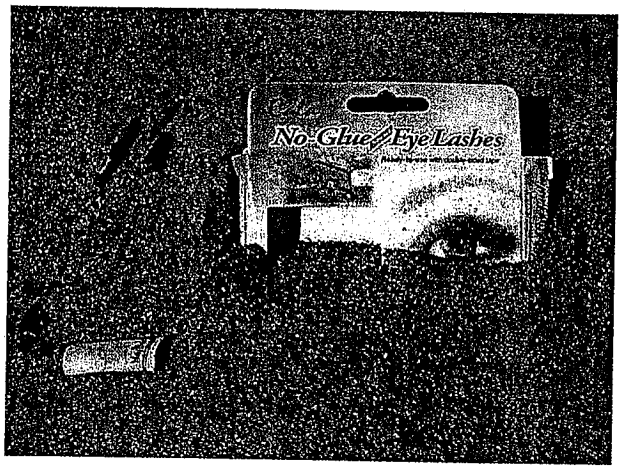


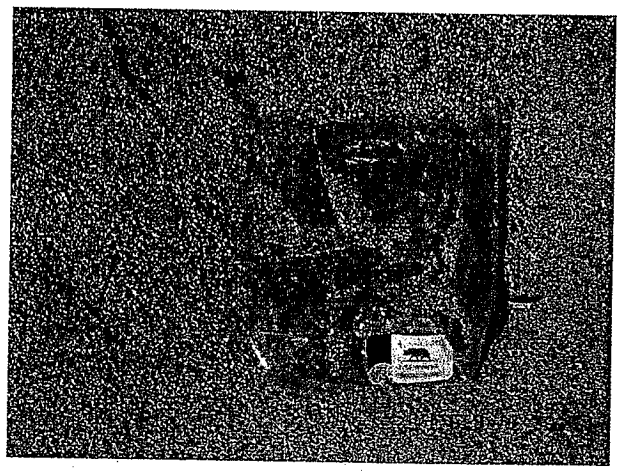
A014990

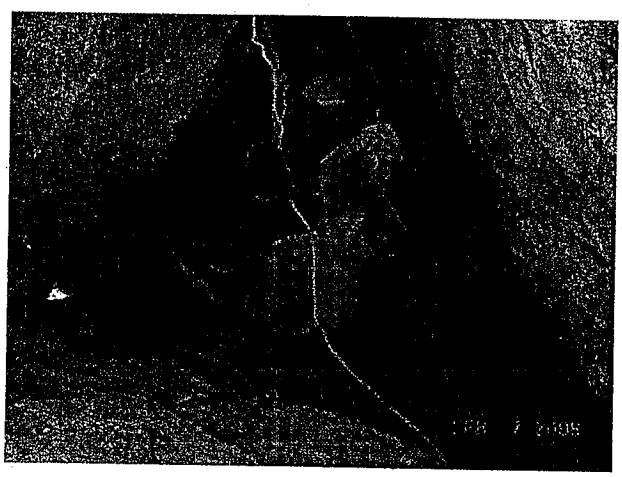
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

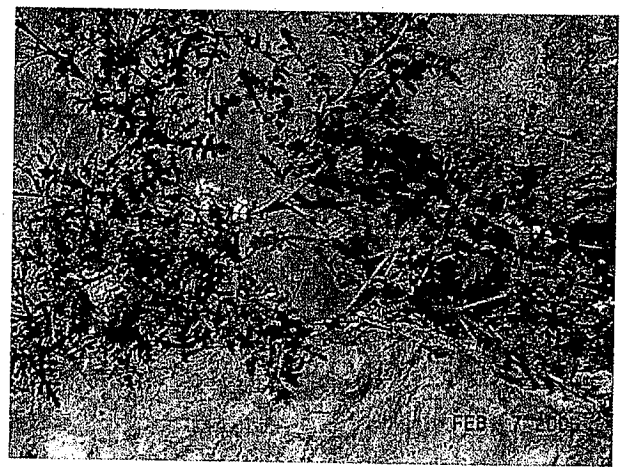






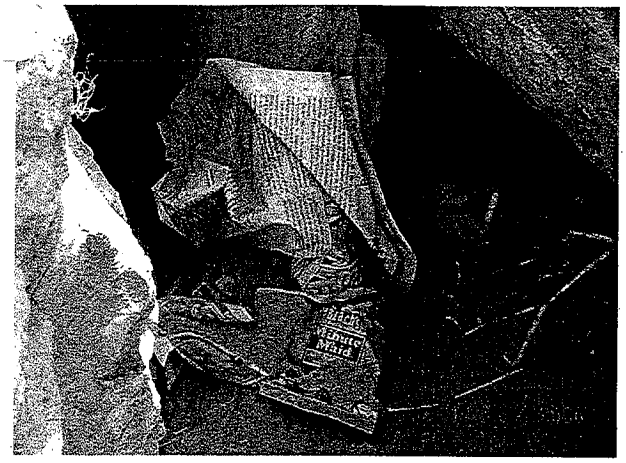


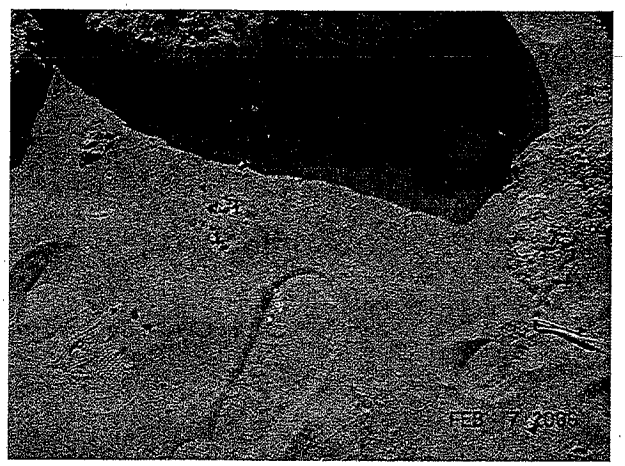


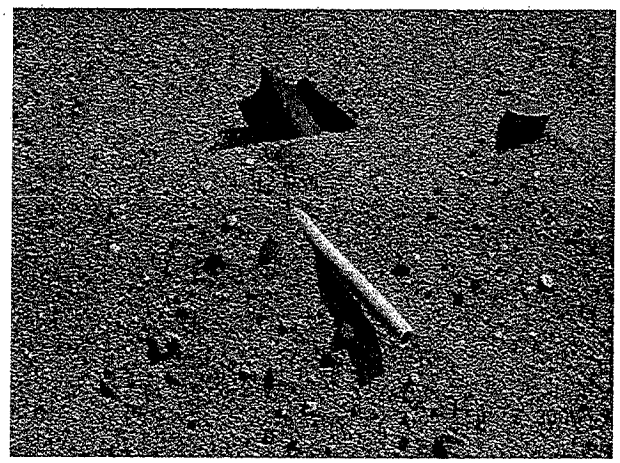


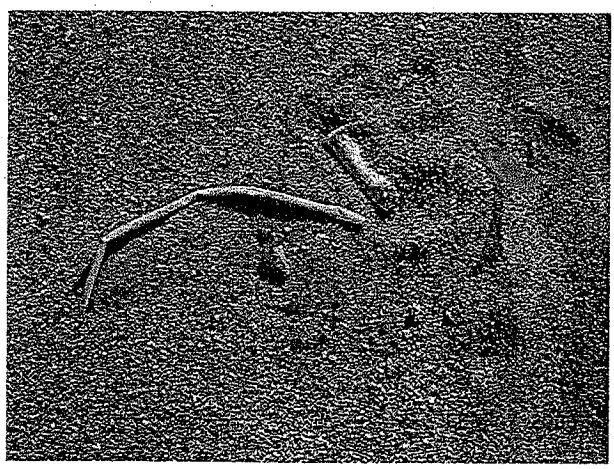
A014991

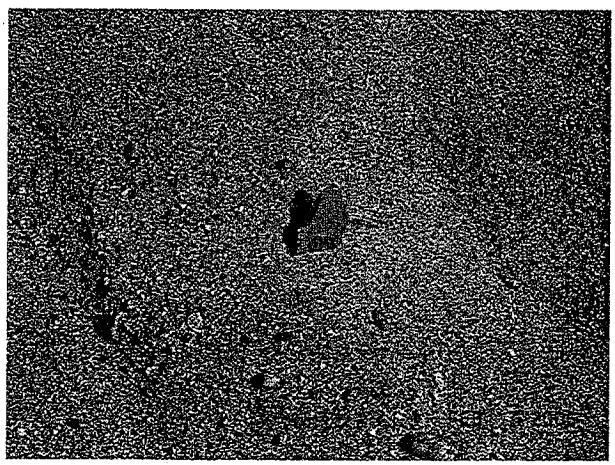
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)





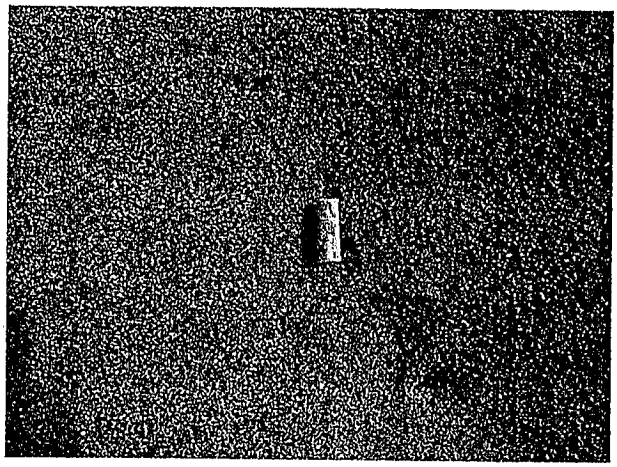


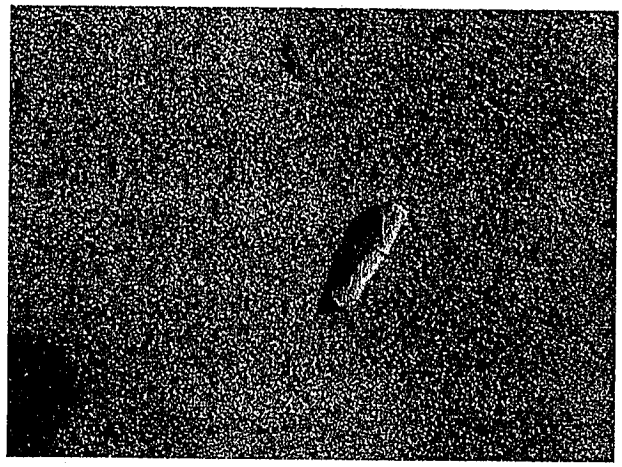


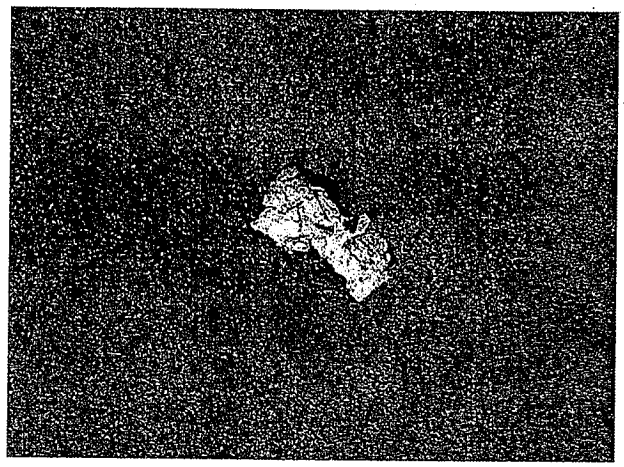


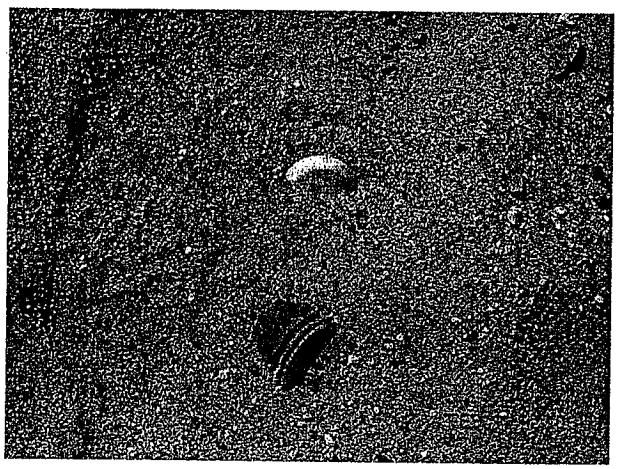
A014992

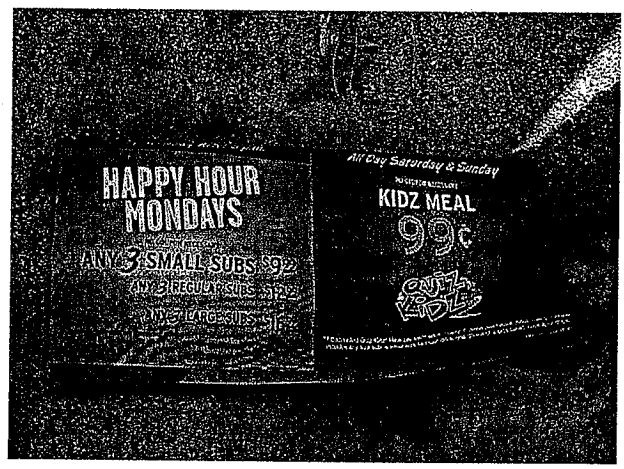
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)





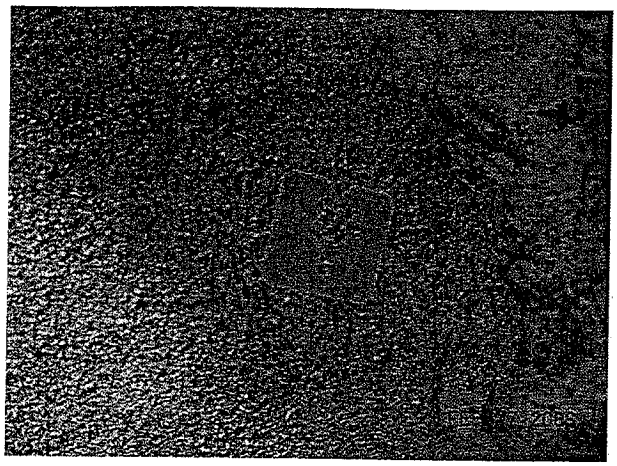






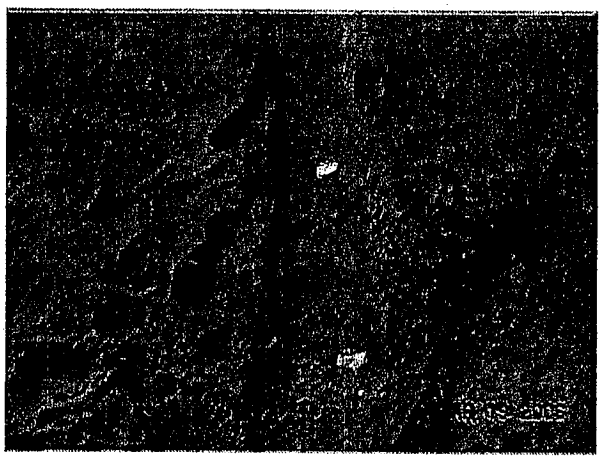
A014993

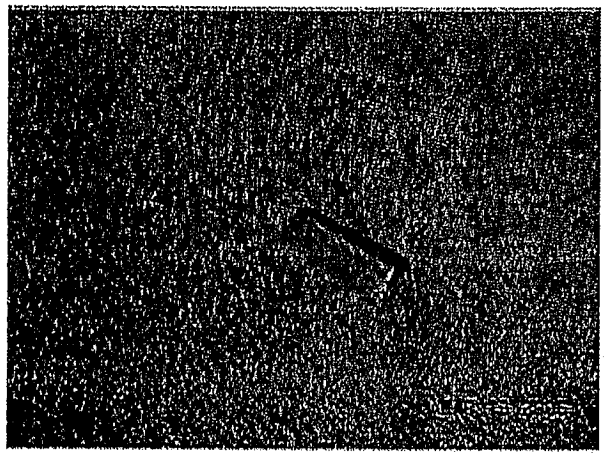
Trash & Debris Photos from Hollywood Beach, County of Ventura
February 7, 2006 (Tuesday)

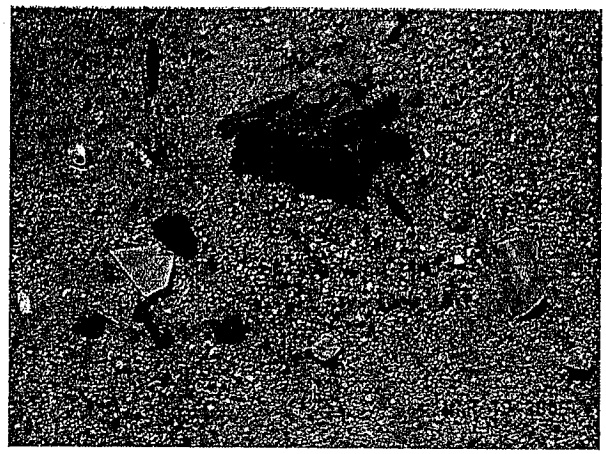


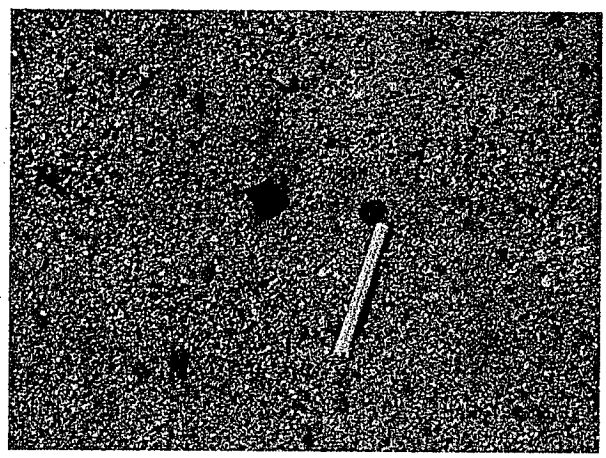
A014994

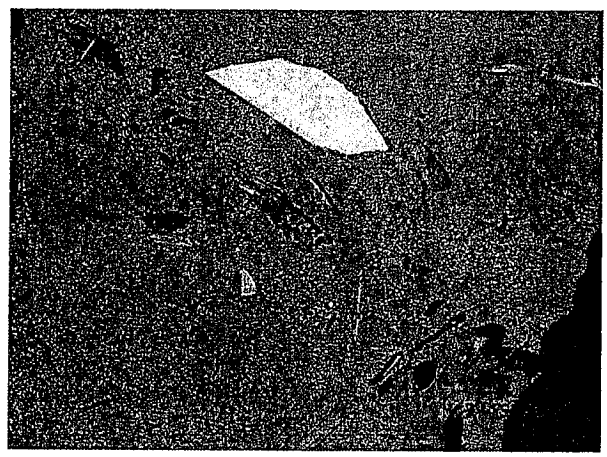
Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)





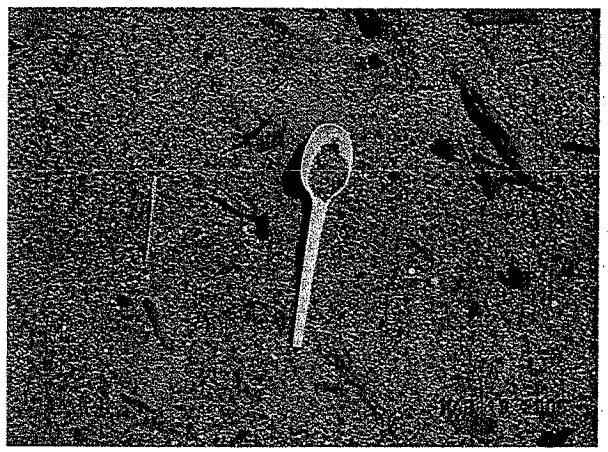


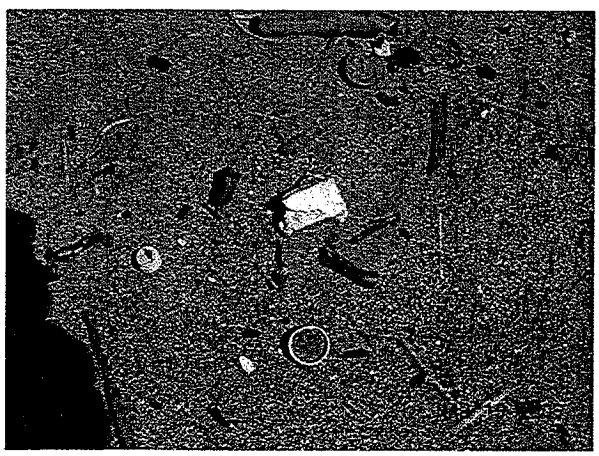


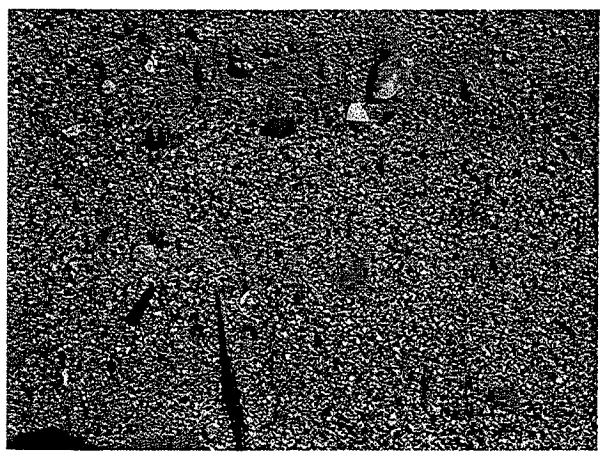


A014995

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)

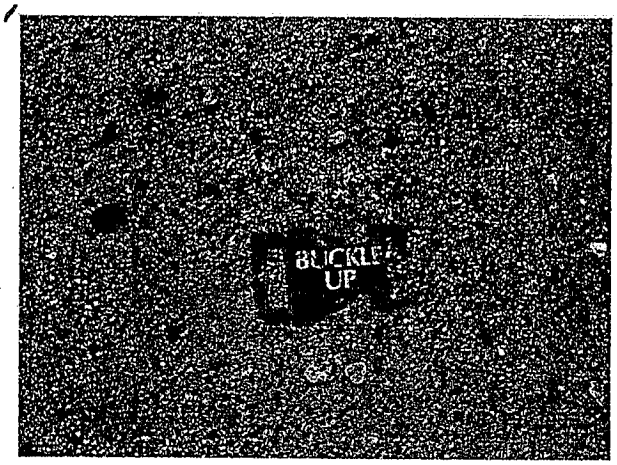


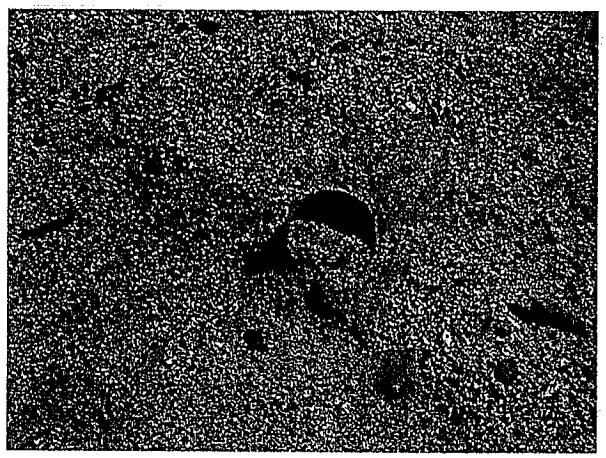


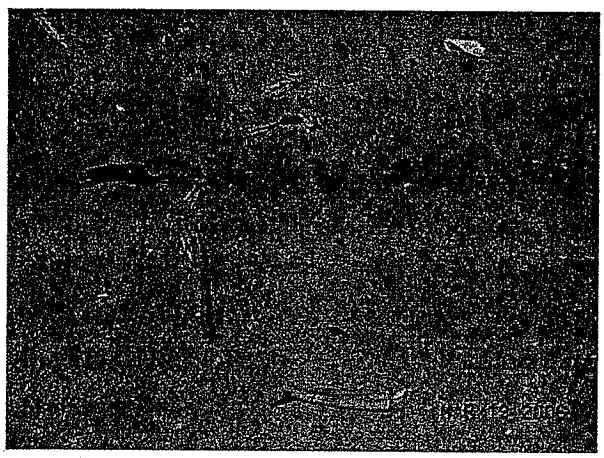


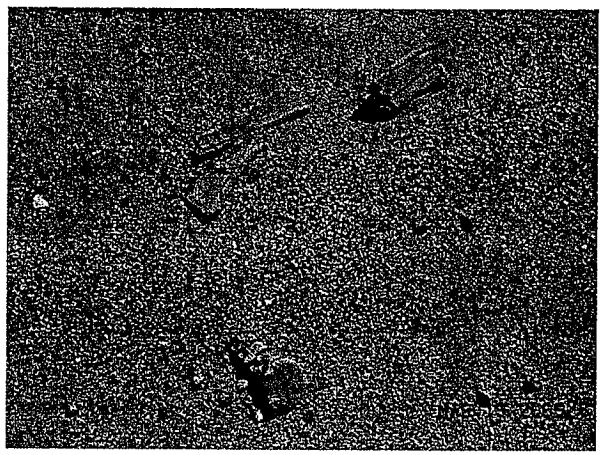
A014996

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)



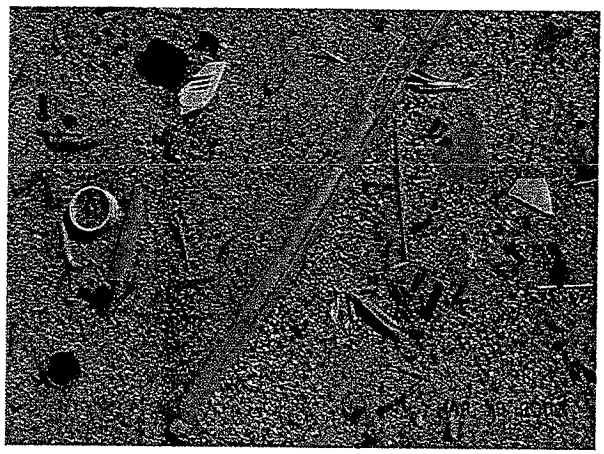


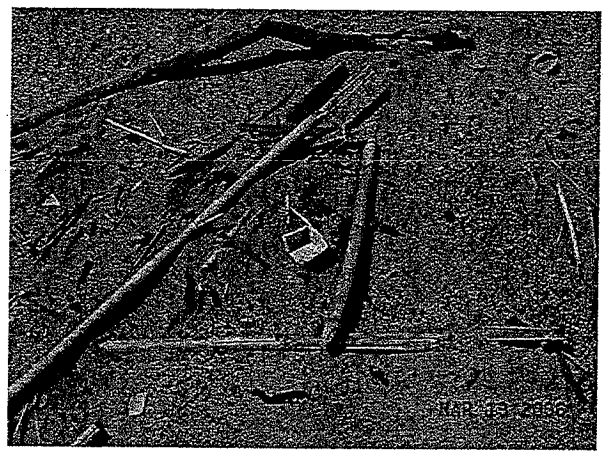


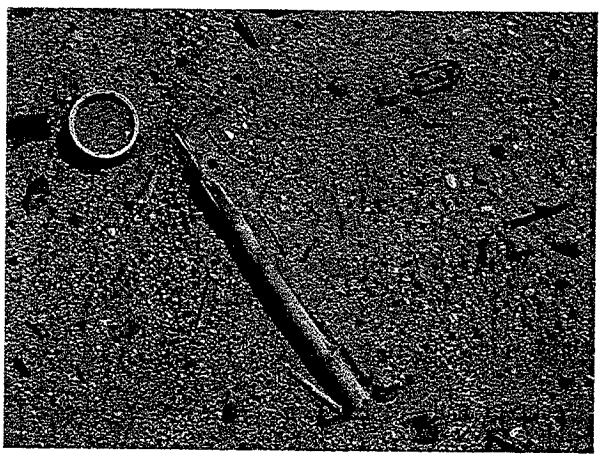


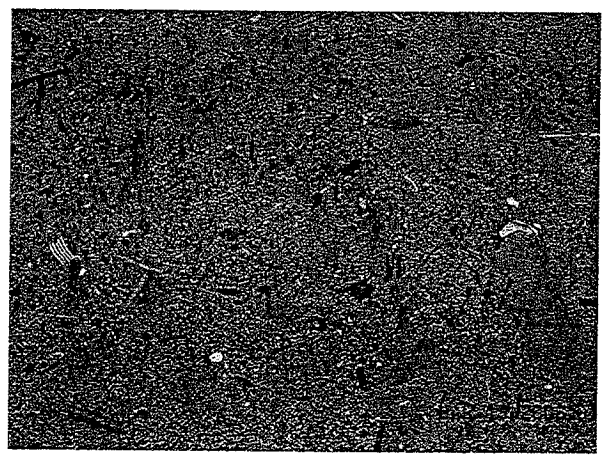
A014997

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)



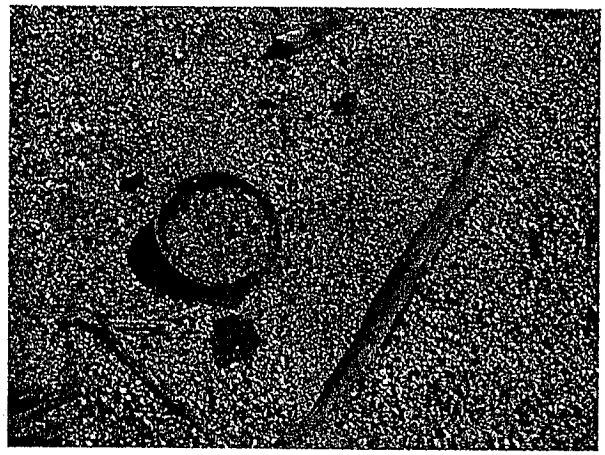


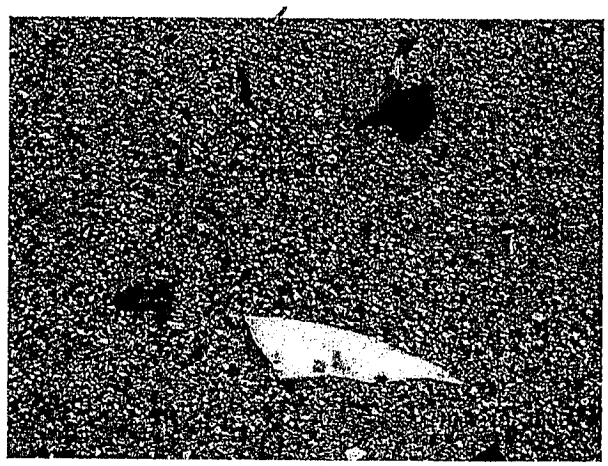


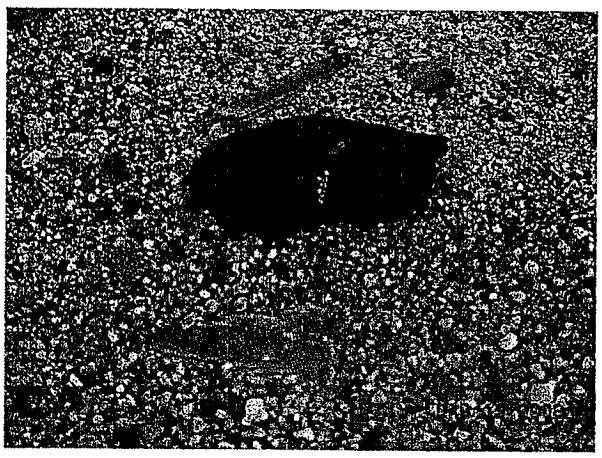


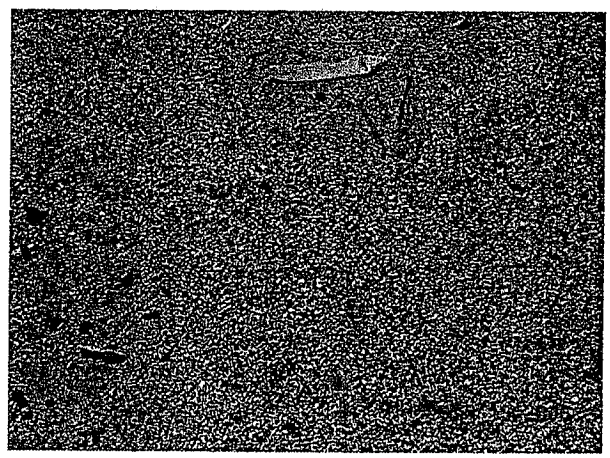
A014998

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)



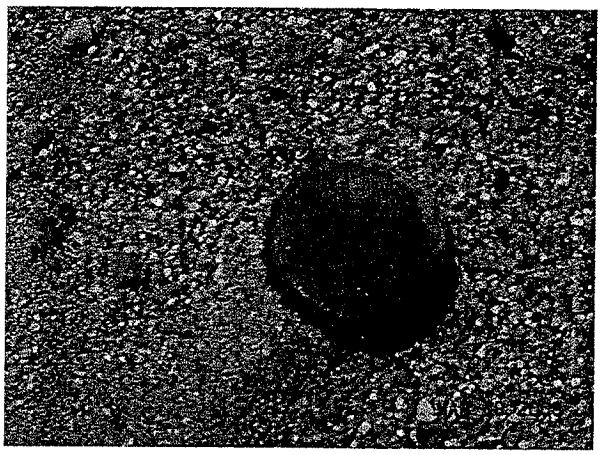


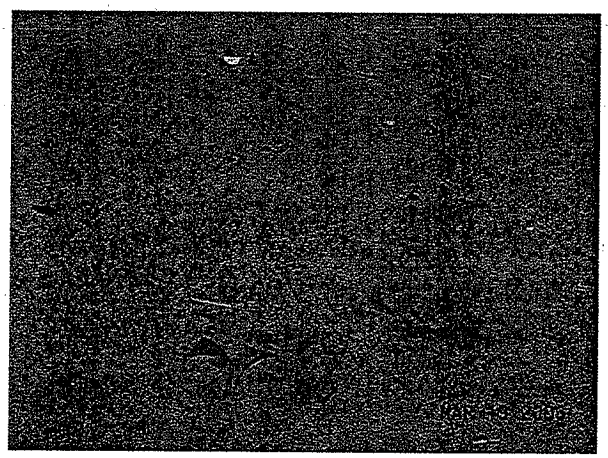


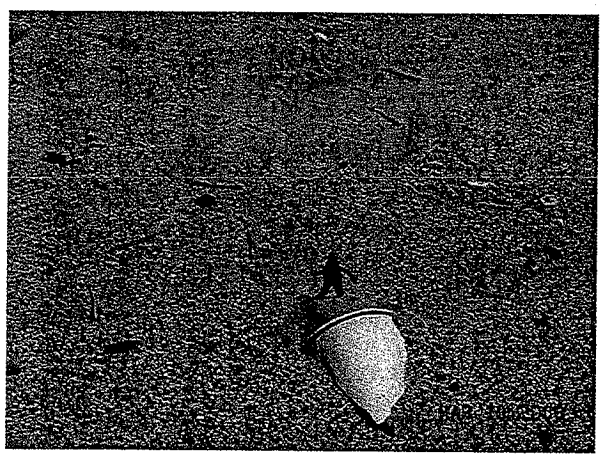


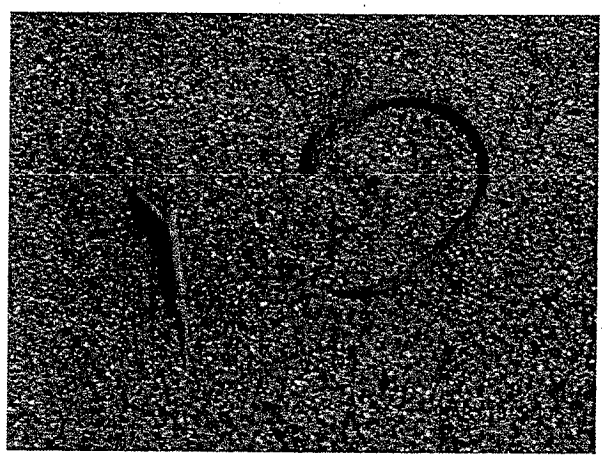
A014999

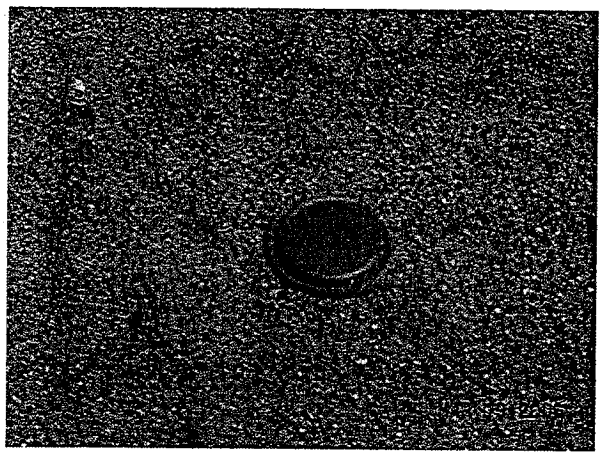
Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)

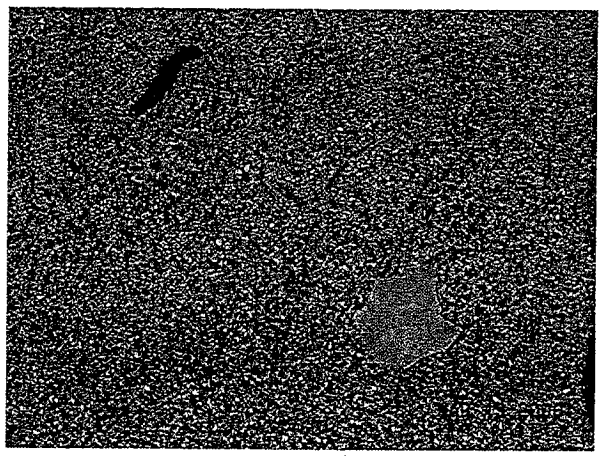






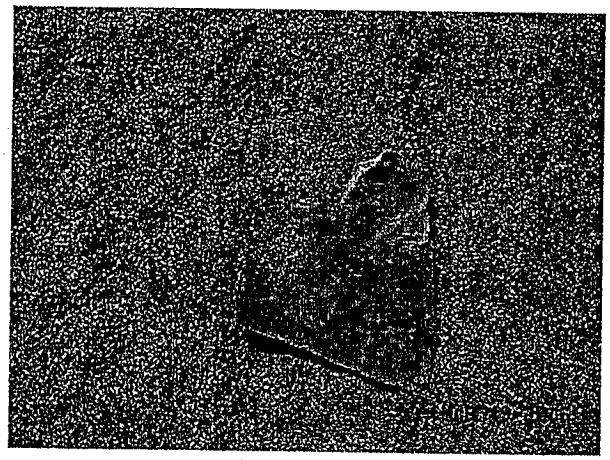


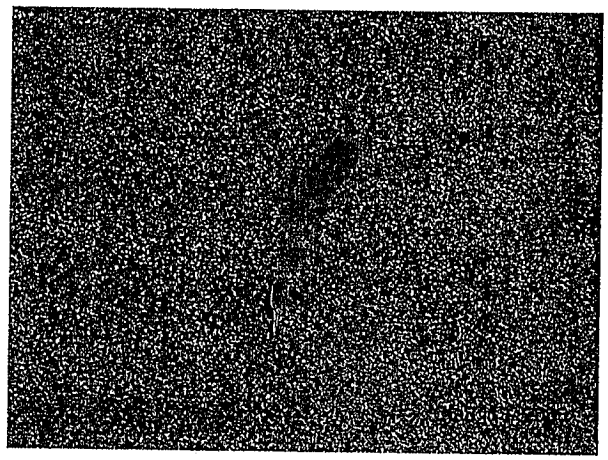


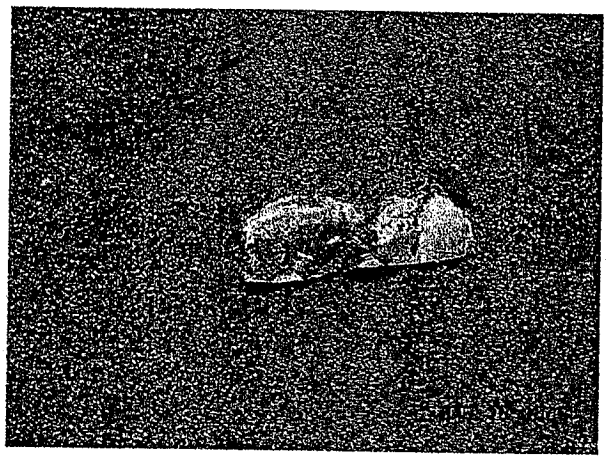


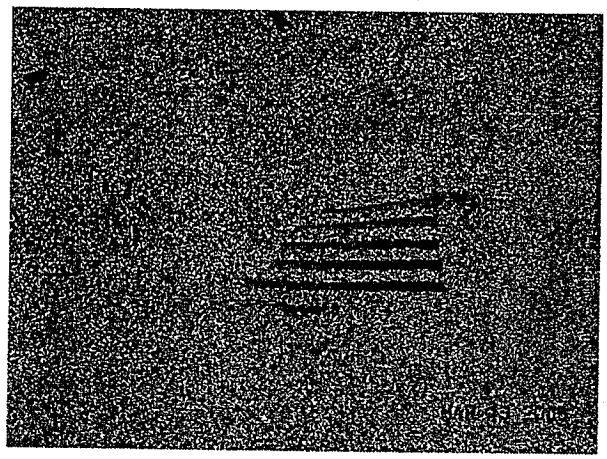
A015000

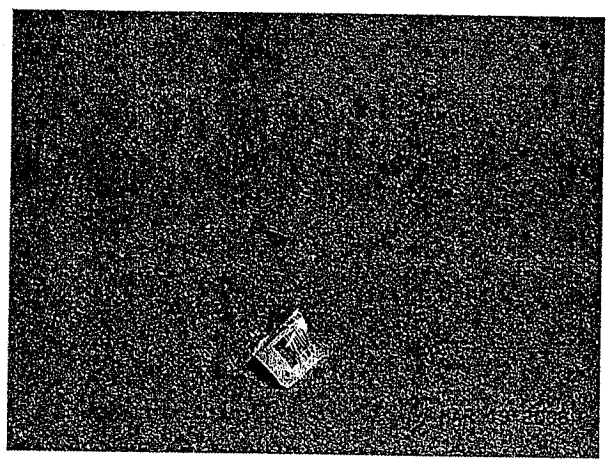
Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)

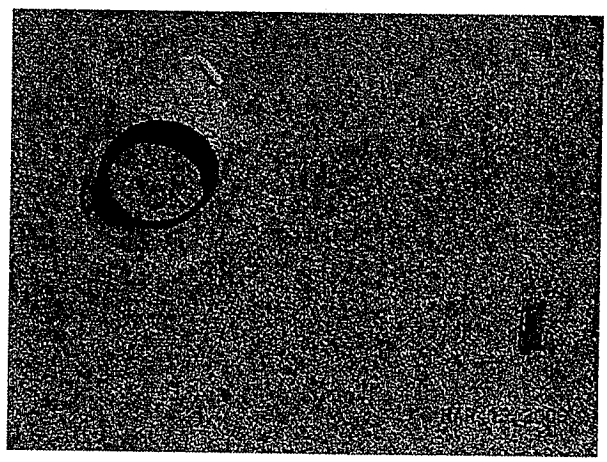




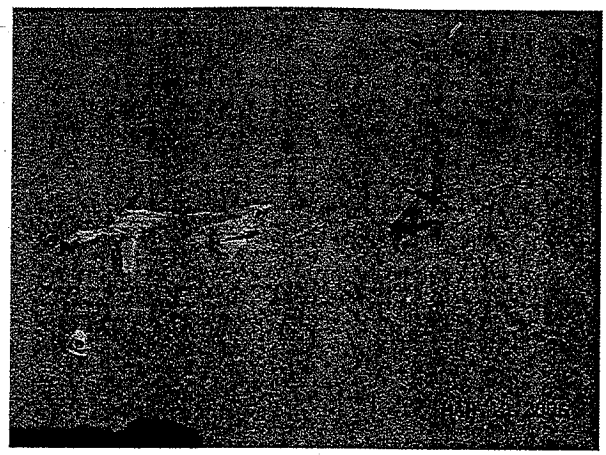


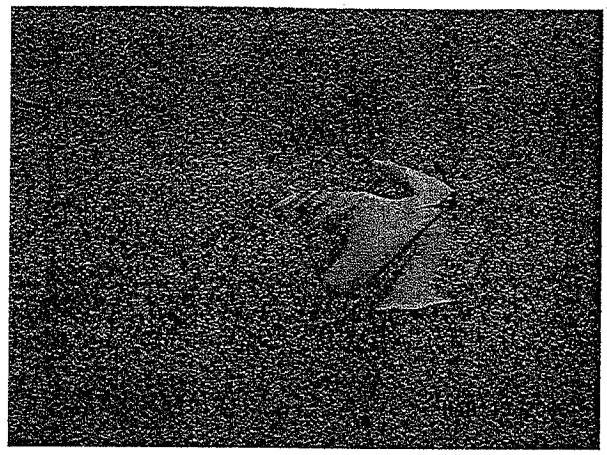


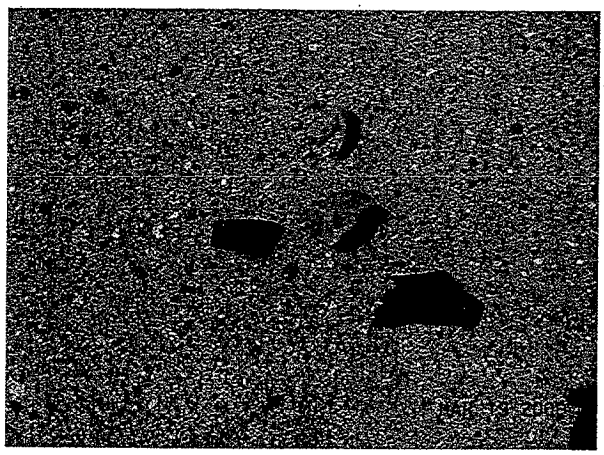


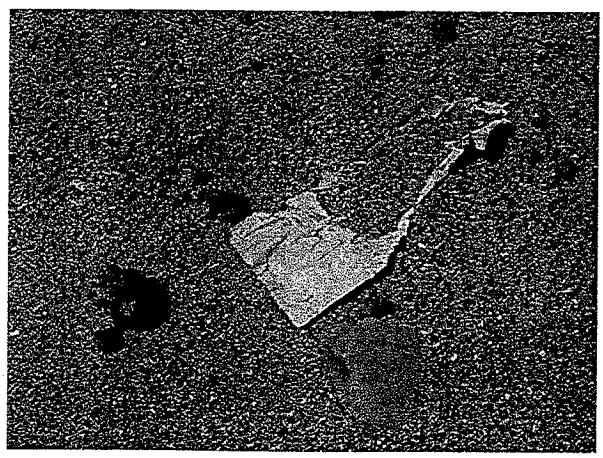


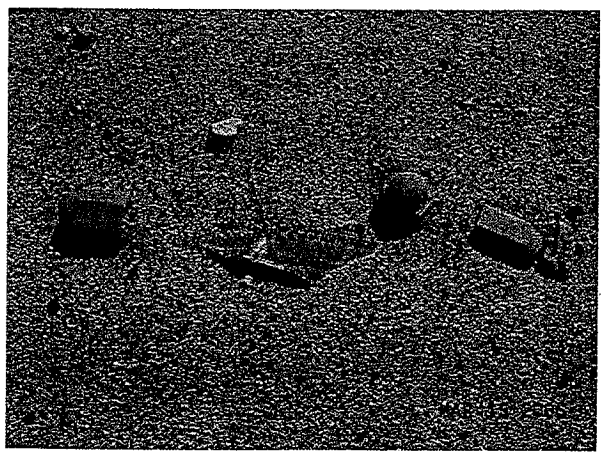
Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)





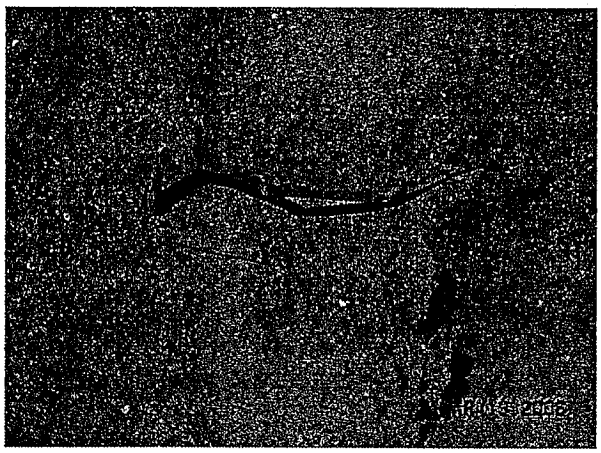


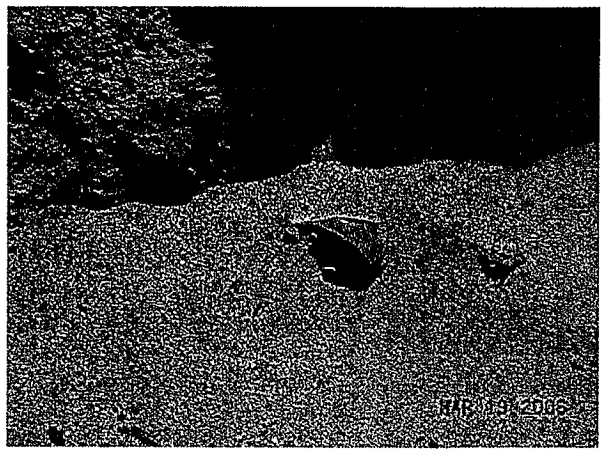


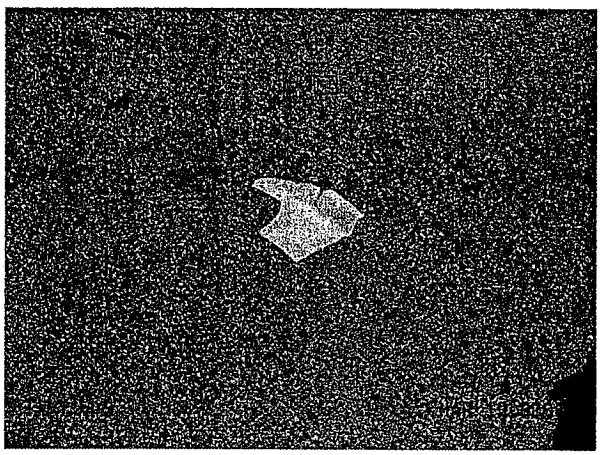


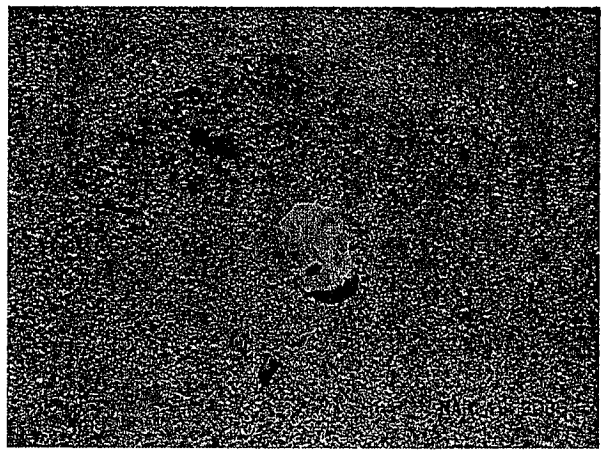
A015002

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)



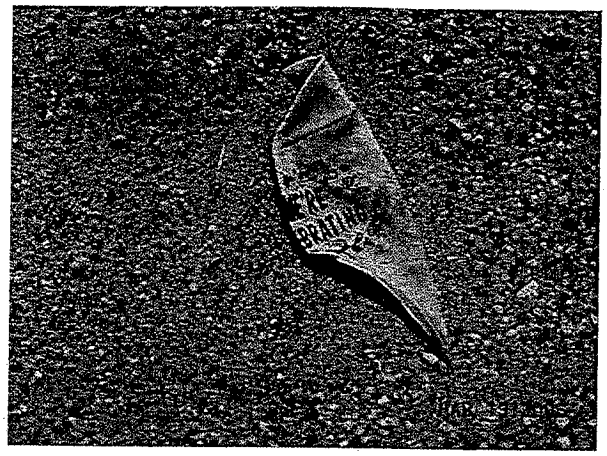


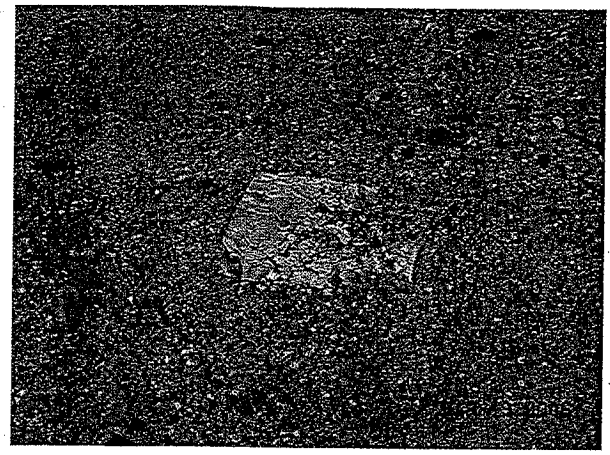


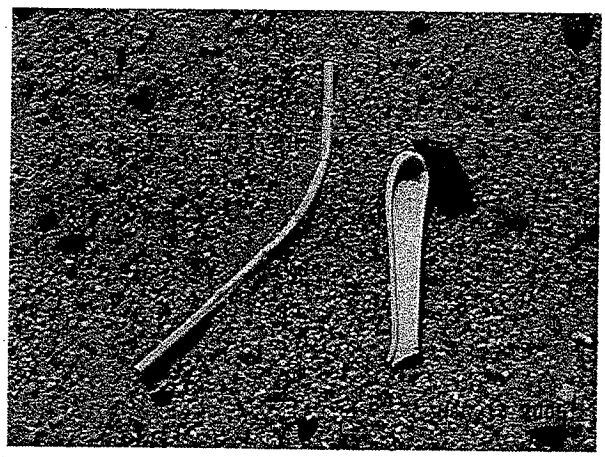


A015003

Trash & Debris Photos from Hollywood Beach
County of Ventura
March 19, 2006 (Sunday)

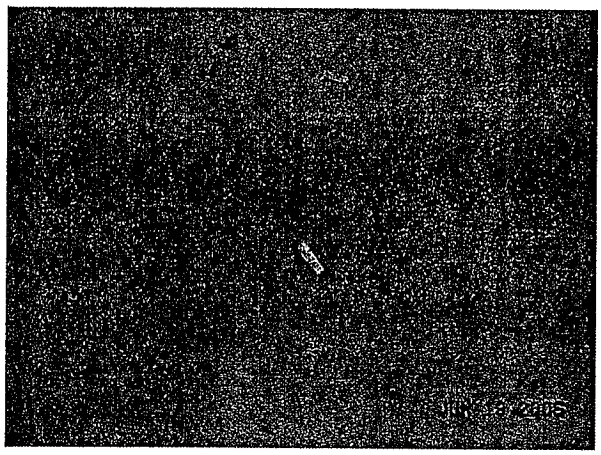


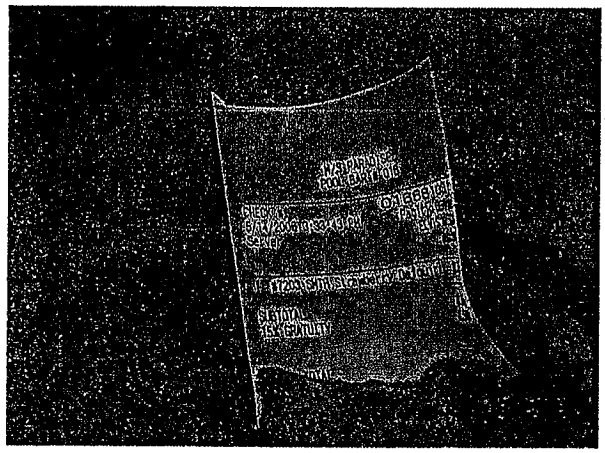


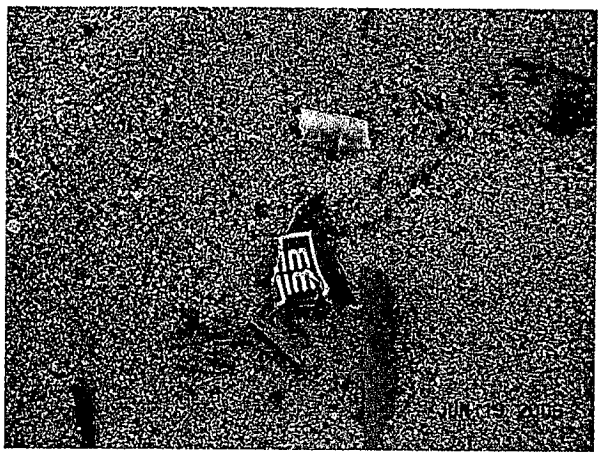


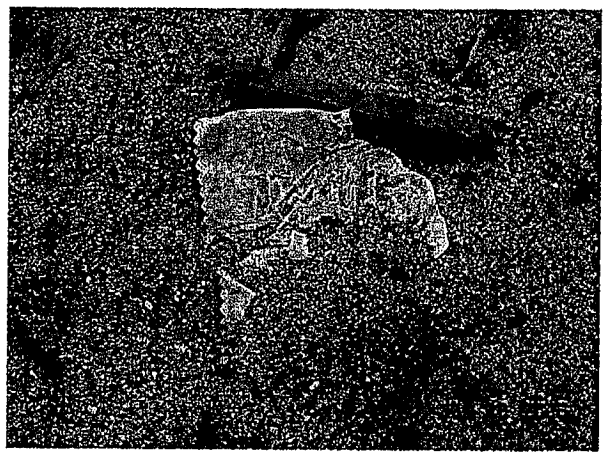
A015004

Trash & Debris Photos from Hollywood Beach
County of Ventura
June 19, 2006 (Monday)



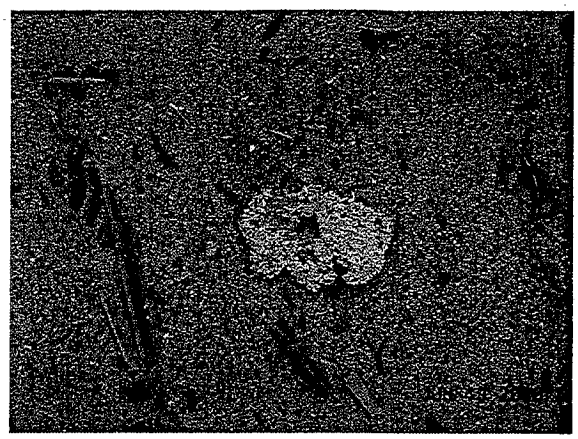


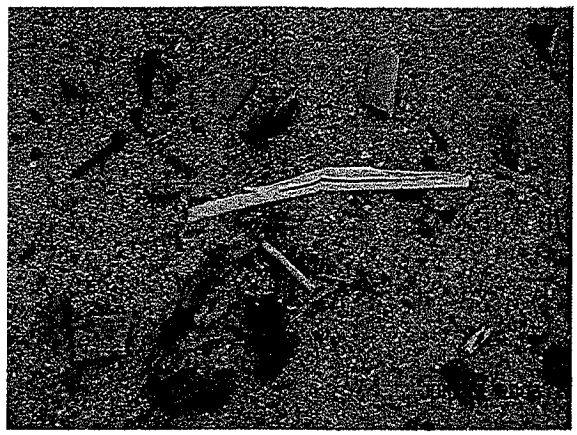


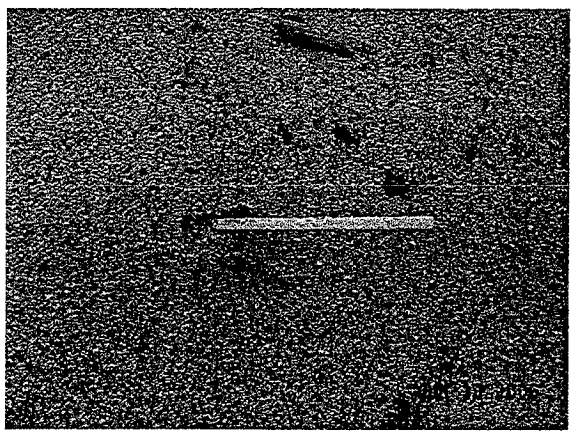


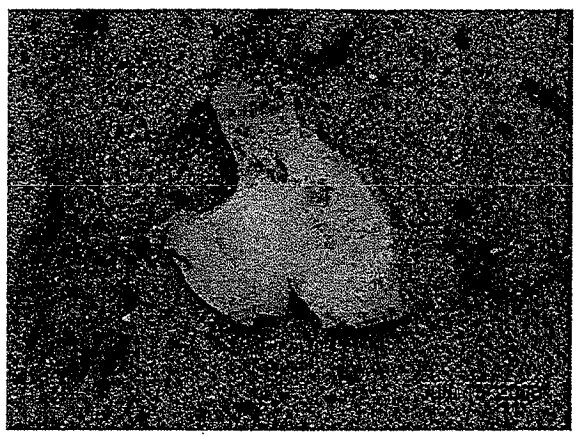
A015005

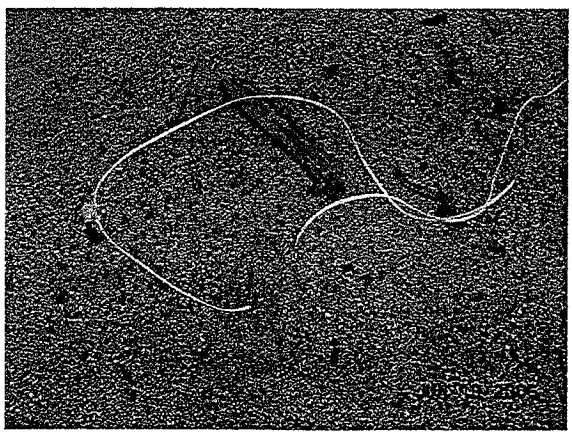
Trash & Debris Photos from Hollywood Beach
County of Ventura
June 19, 2006 (Monday

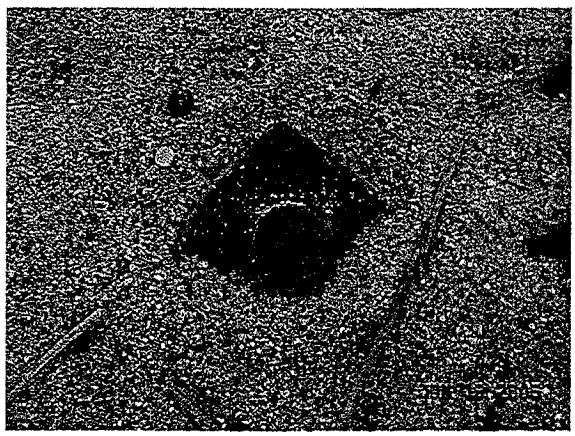






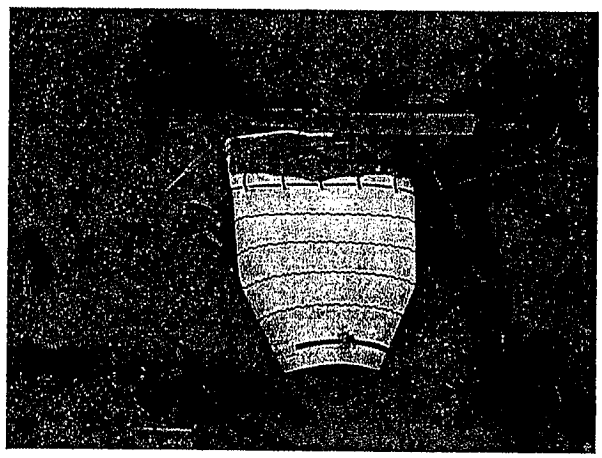


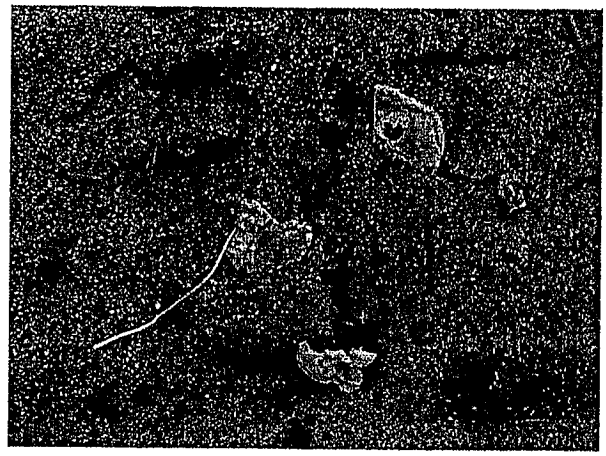


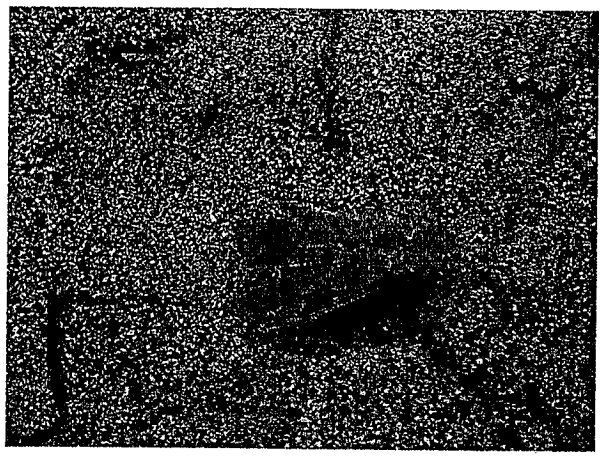


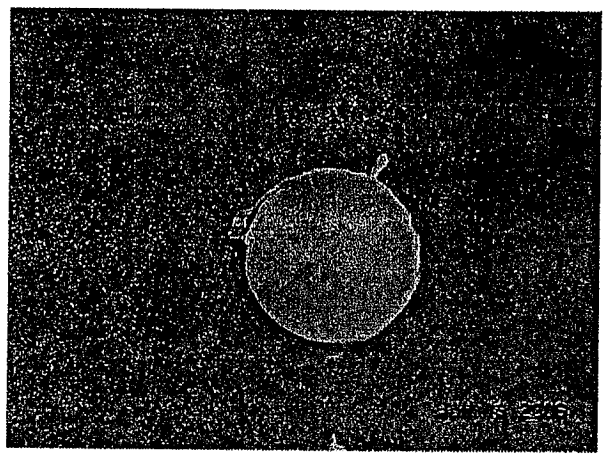
A015006

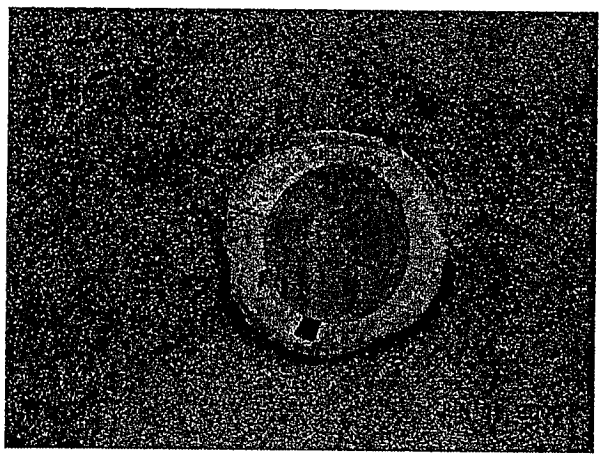
Trash & Debris Photos from Hollywood Beach
County of Ventura
June 19, 2006 (Monday)

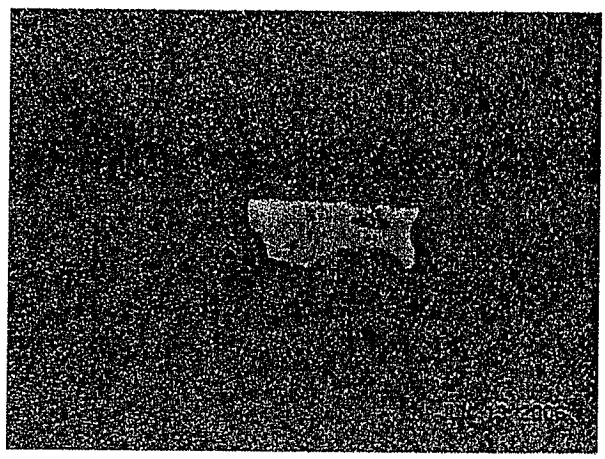






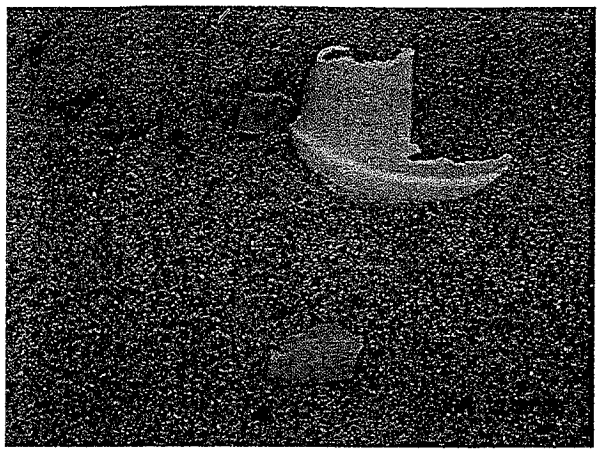


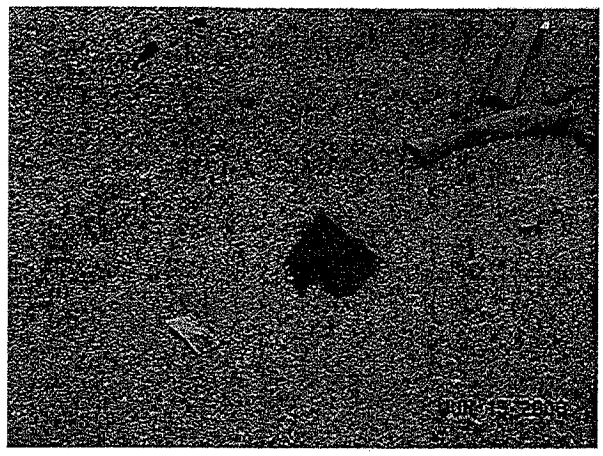


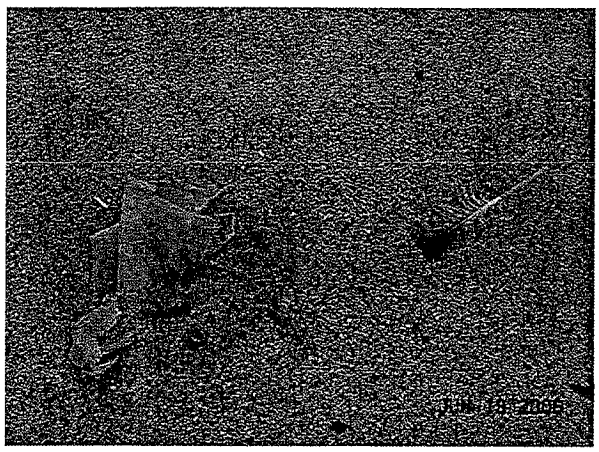


A015007

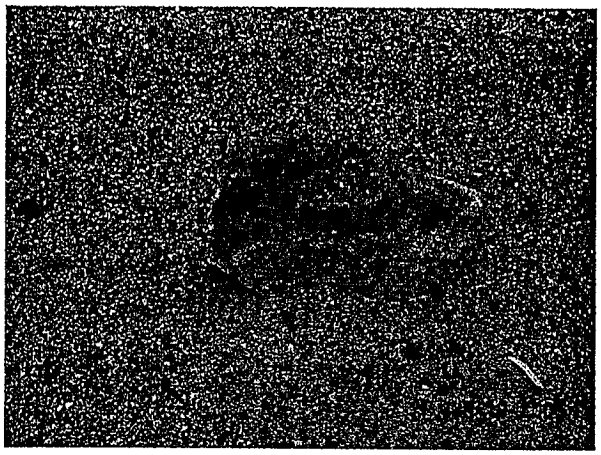
Trash & Debris Photos from Hollywood Beach
County of Ventura
June 19, 2006 (Monday)

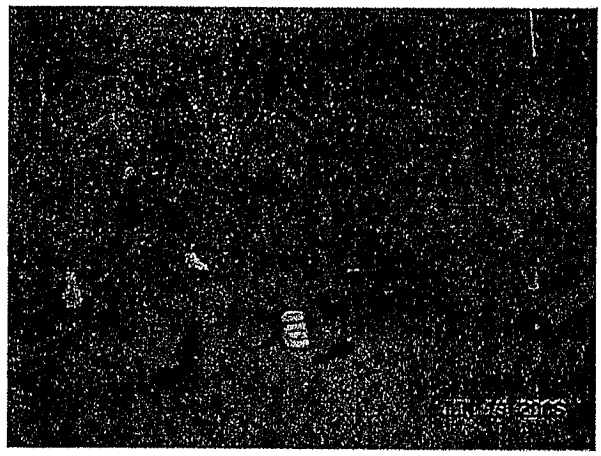


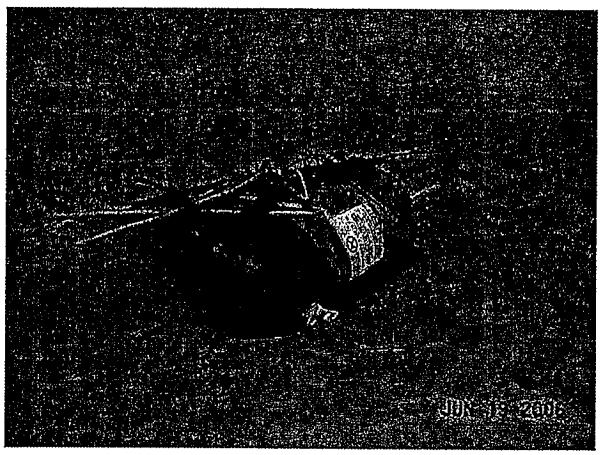




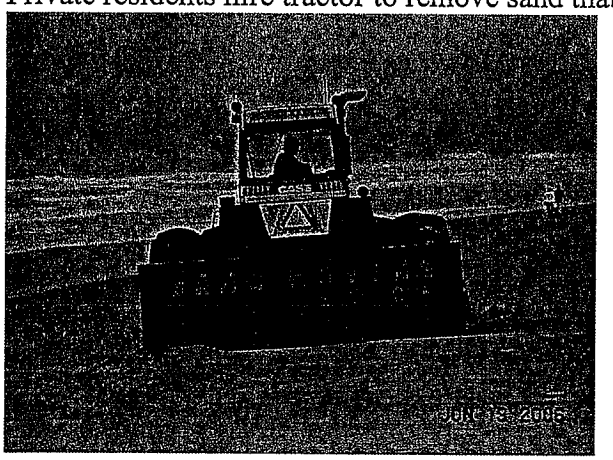
Trash & Debris Photos from Hollywood Beach
County of Ventura
June 19, 2006 (Monday)

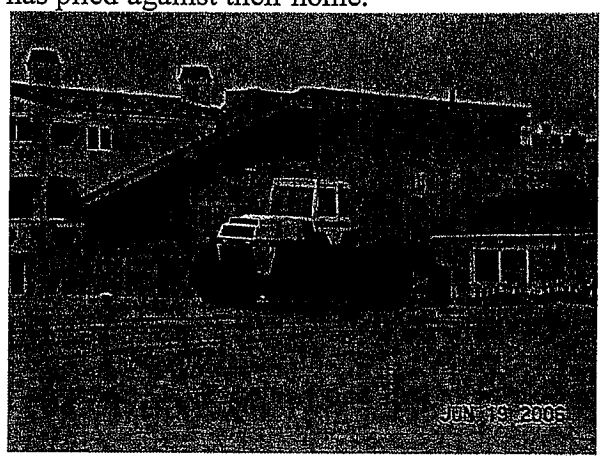






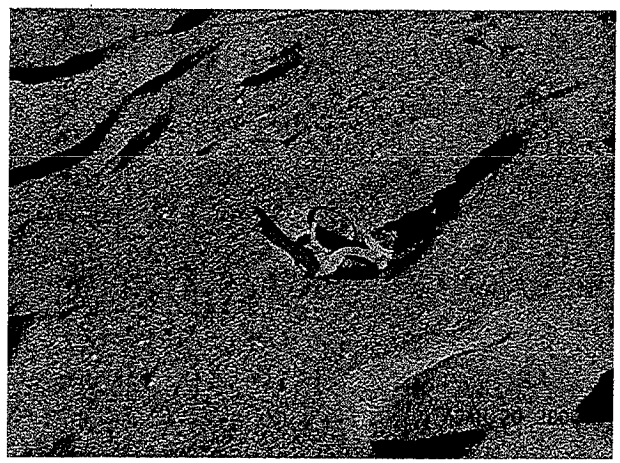
Private residents hire tractor to remove sand that has piled against their home.

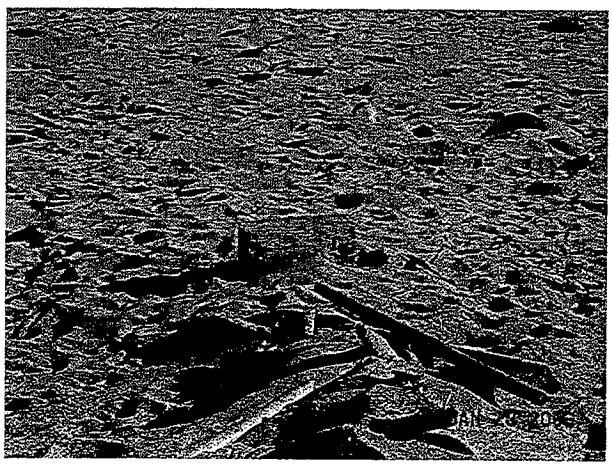




A015009

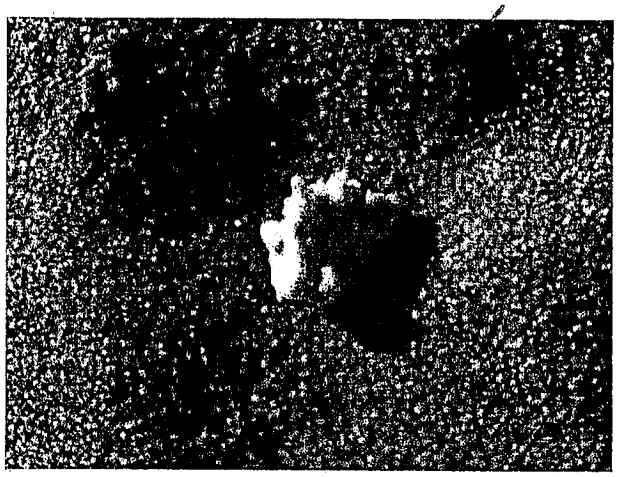
Trash & Debris Photos from Silver Strand Beach,
County of Ventura
January 20, 2006 (Friday)

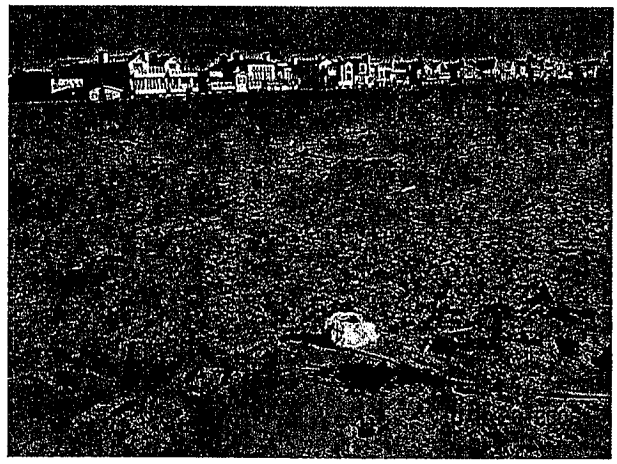


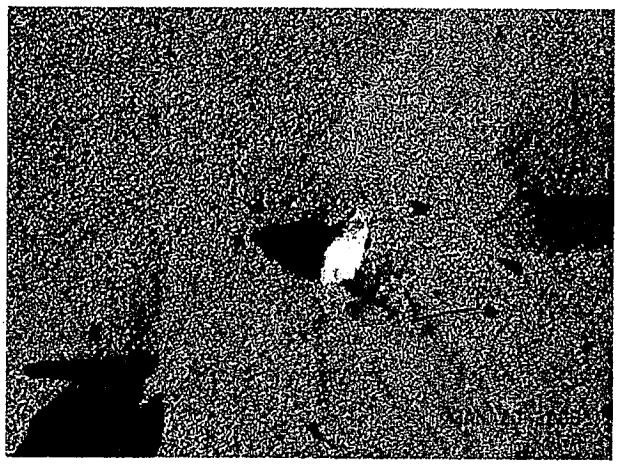


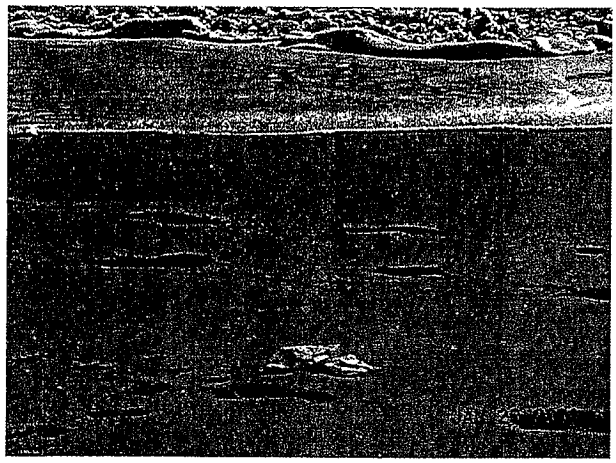
A015010

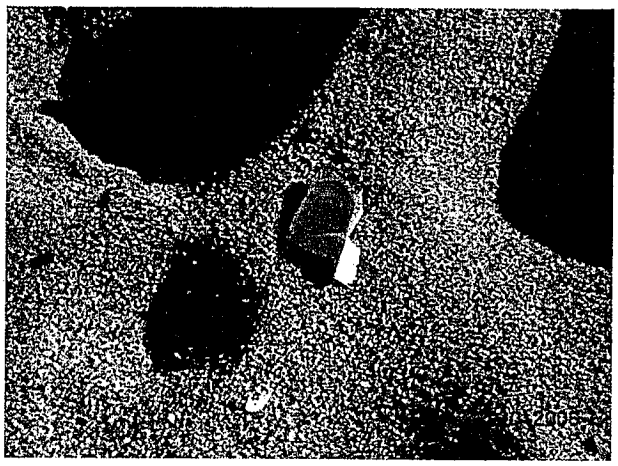
Trash & Debris Photos from Silver Strand Beach
County of Ventura
January 20, 2006 (Friday)

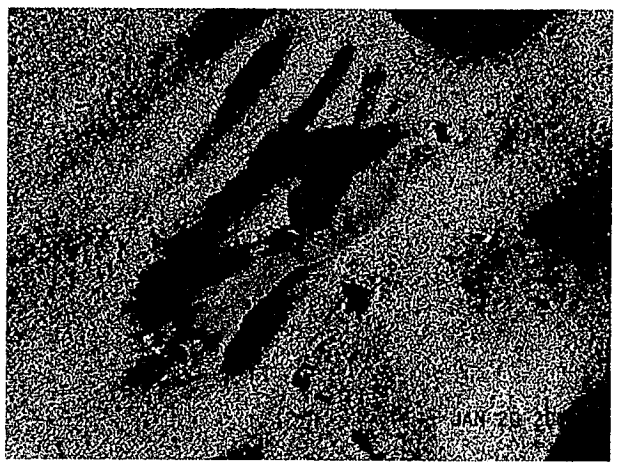






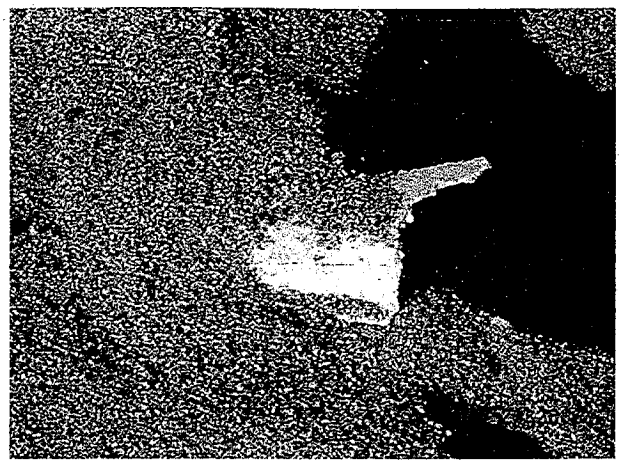


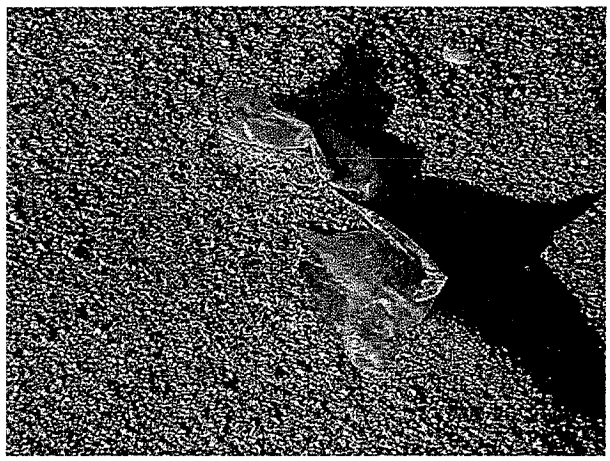


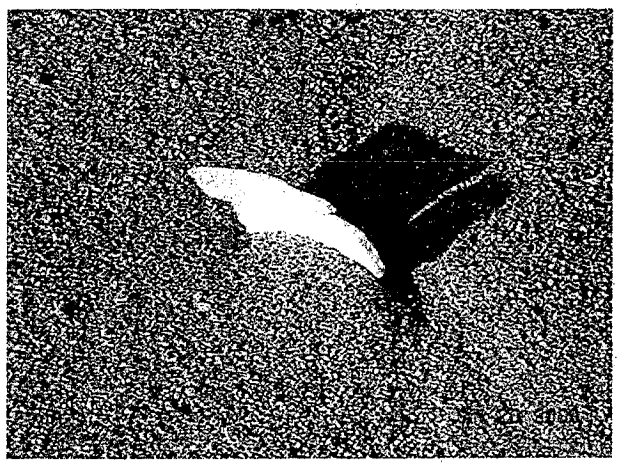


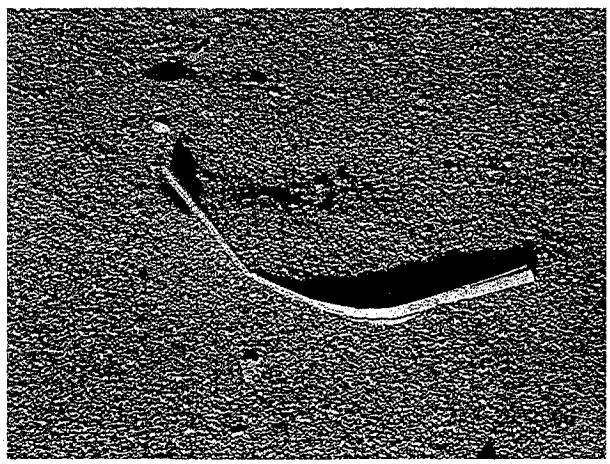
A015011

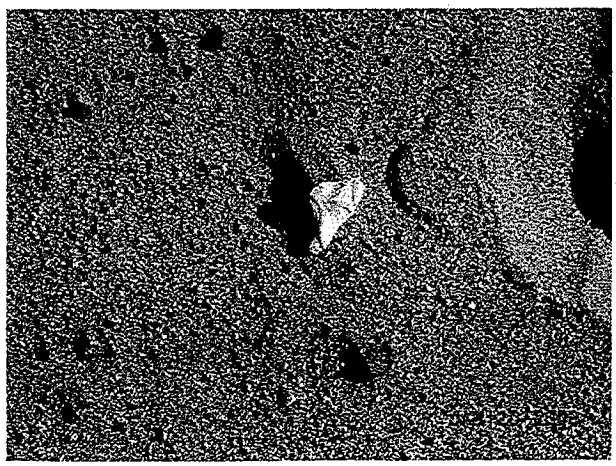
Trash & Debris Photos from Silver Strand Beach
County of Ventura
January 20, 2006 (Friday)





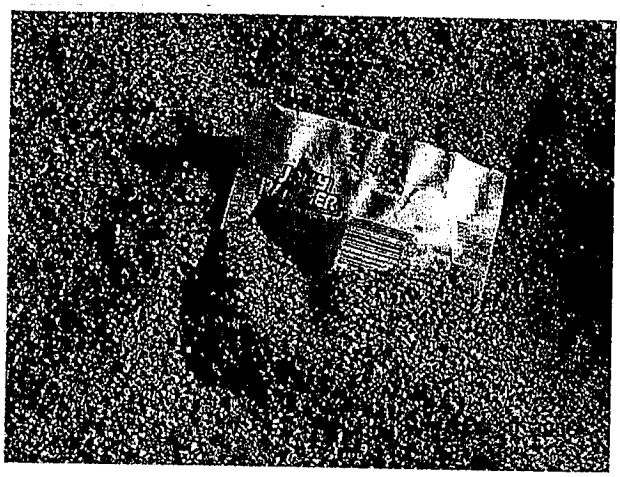


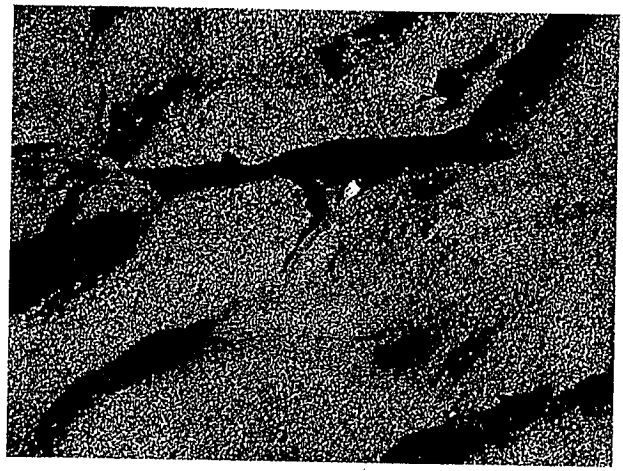




A015012

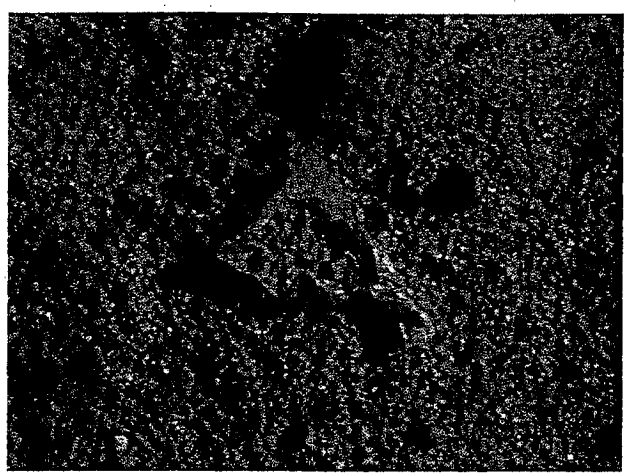
Trash & Debris Photos from Silver Strand Beach
County of Ventura
January 20, 2006 (Friday)

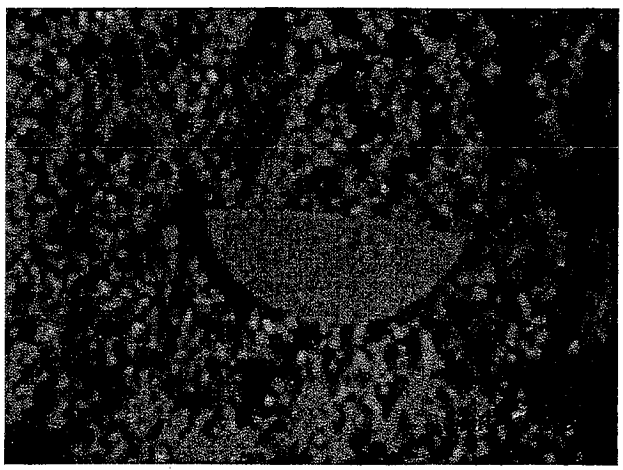


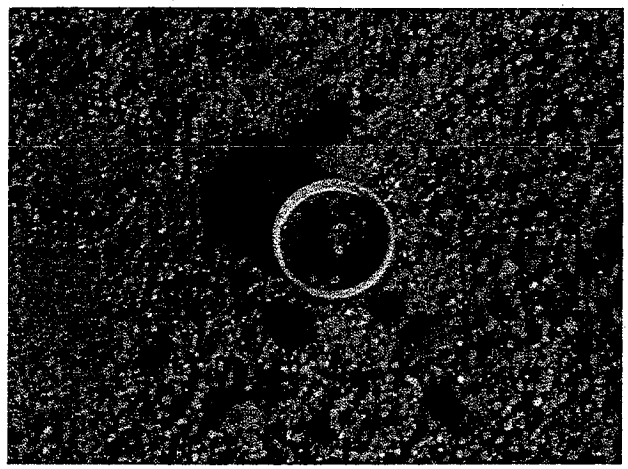


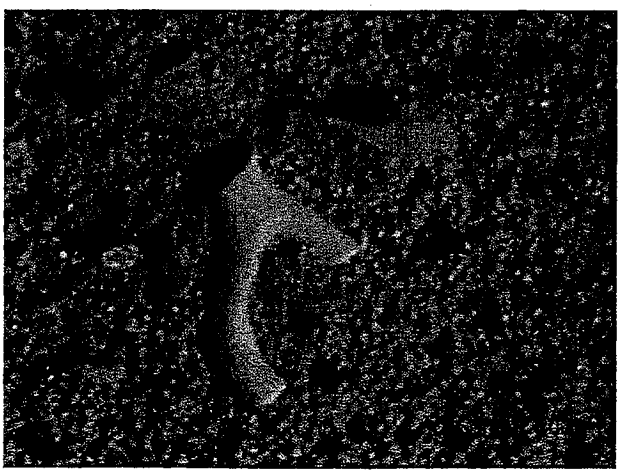
A015013

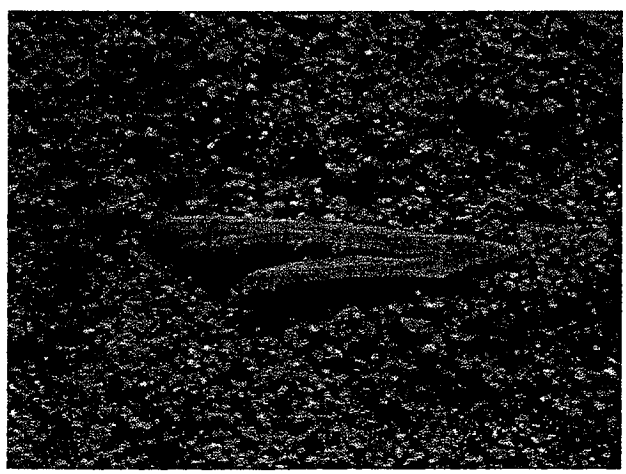
Trash & Debris Photos from Silver Strand Beach,
County of Ventura
March 11, 2006 (Saturday)





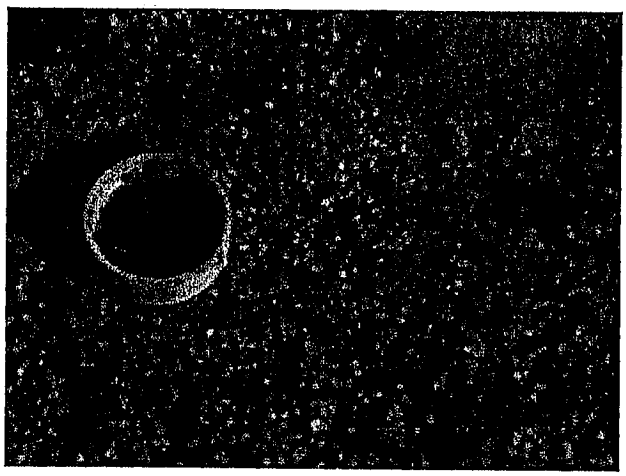


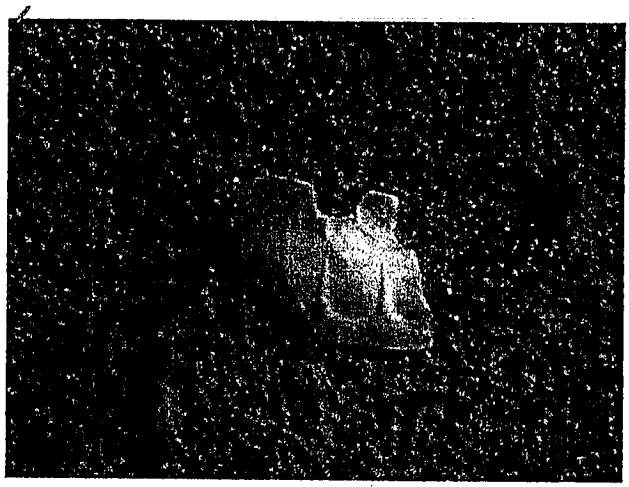


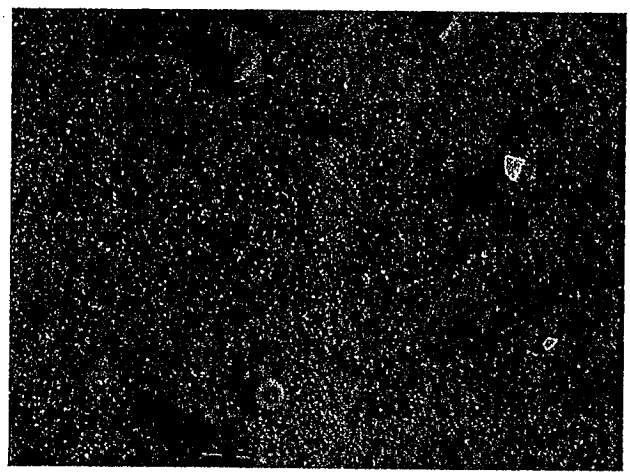


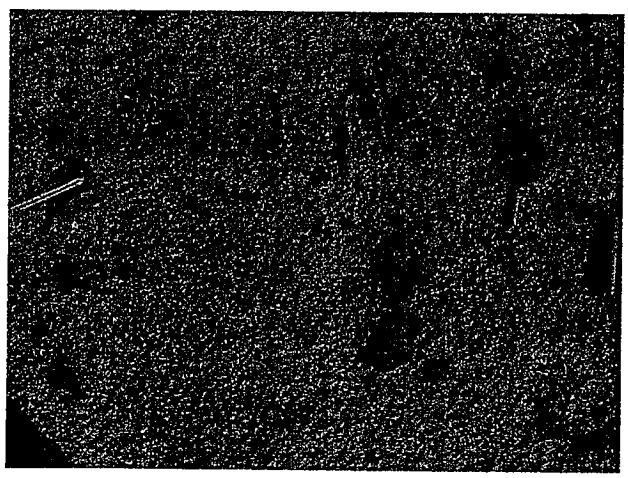
A015014

Trash & Debris Photos from Silver Strand Beach,
County of Ventura
March 11, 2006 (Saturday)



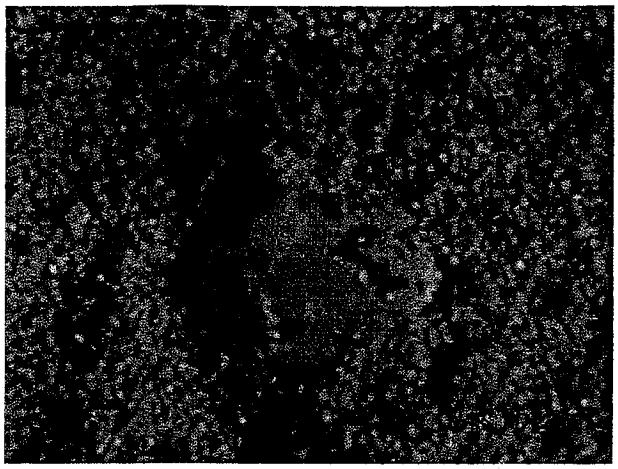


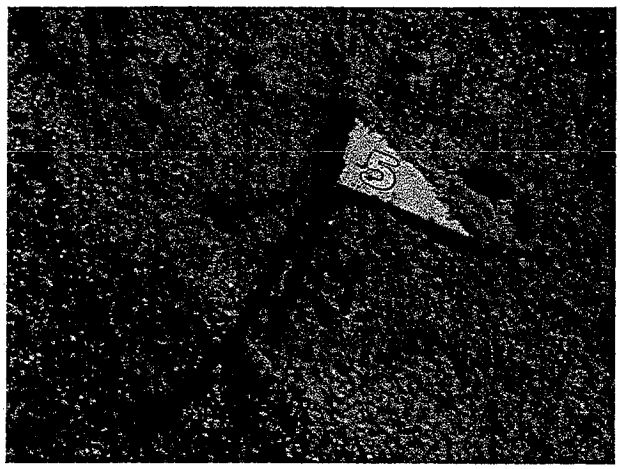


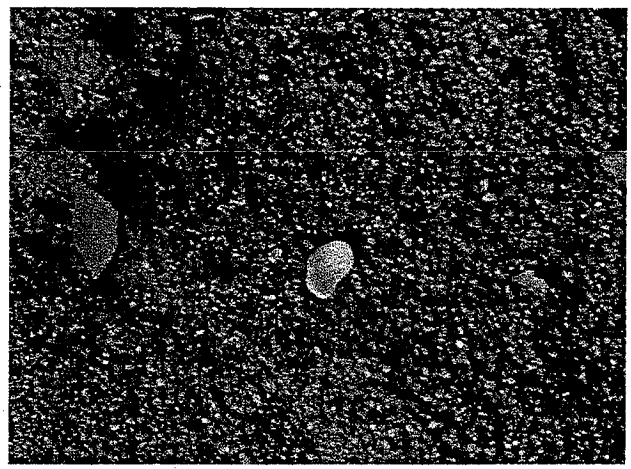


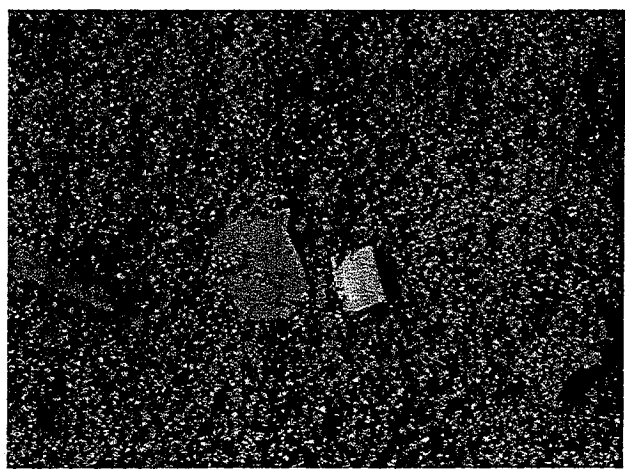
A015015

Trash & Debris Photos from Silver Strand Beach,
County of Ventura
March 11, 2006 (Saturday)

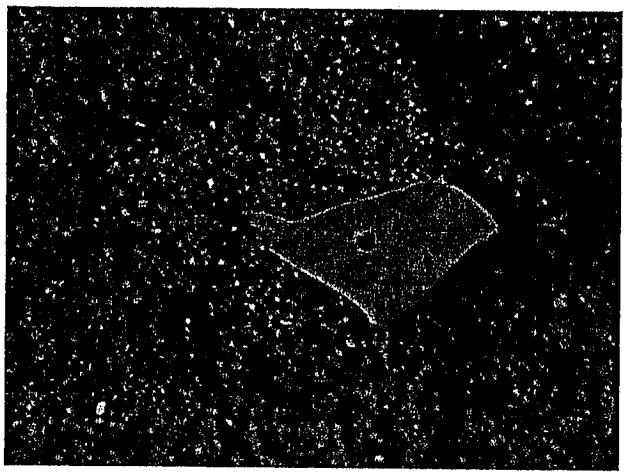


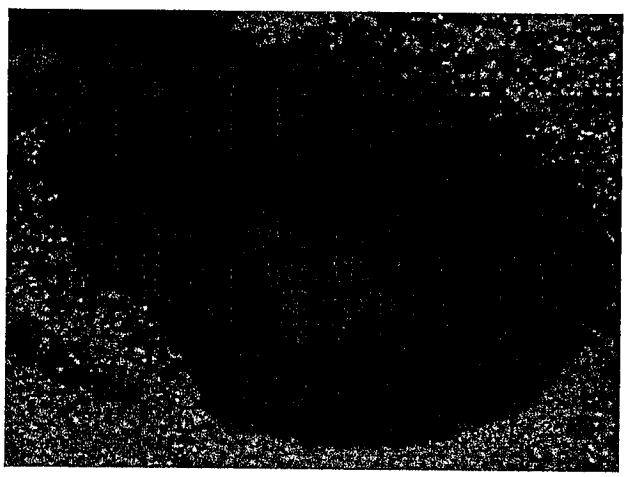


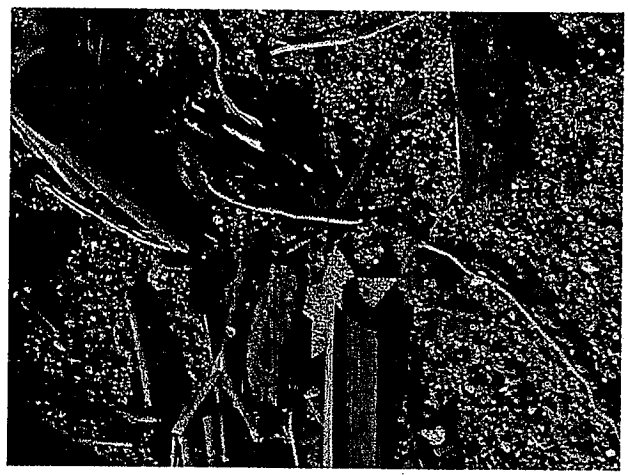


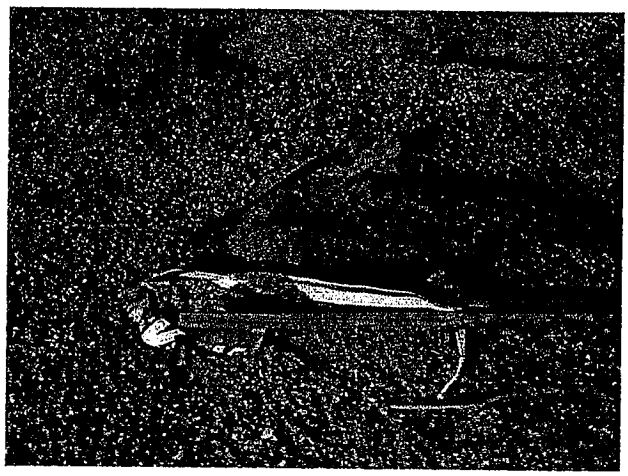


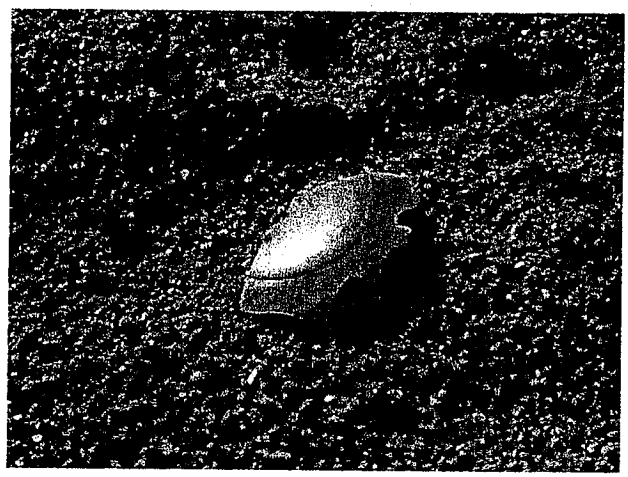
Trash & Debris Photos from Silver Strand Beach,
County of Ventura
March 11, 2006 (Saturday)





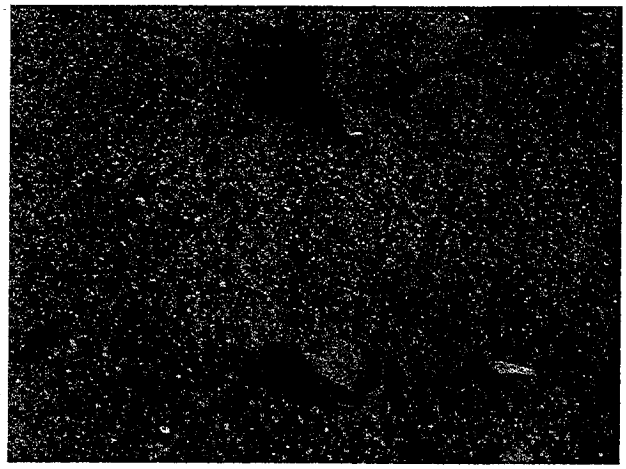


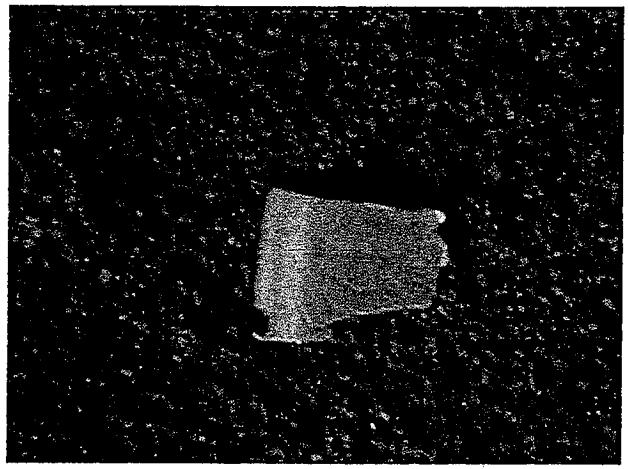


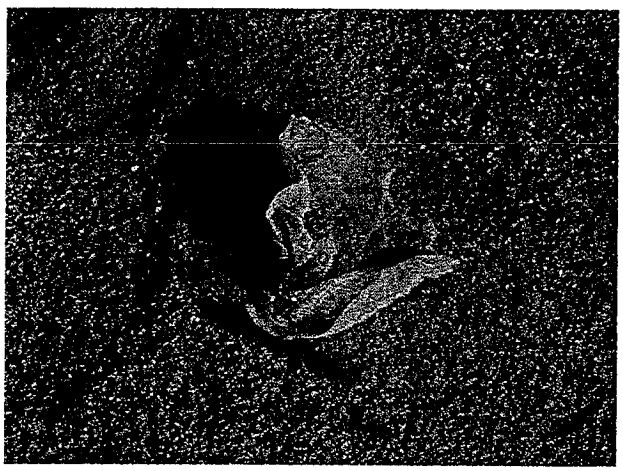


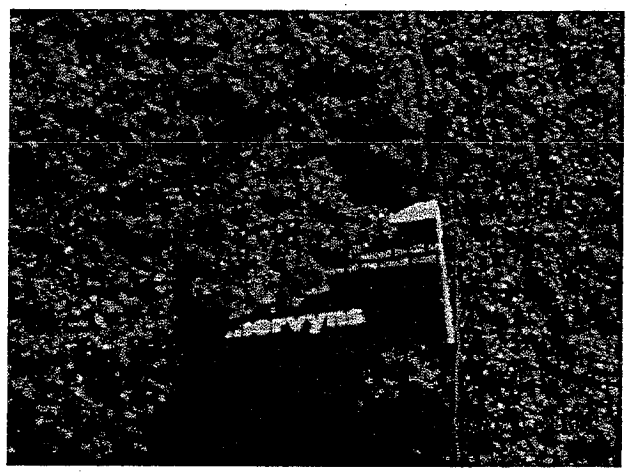
A015017

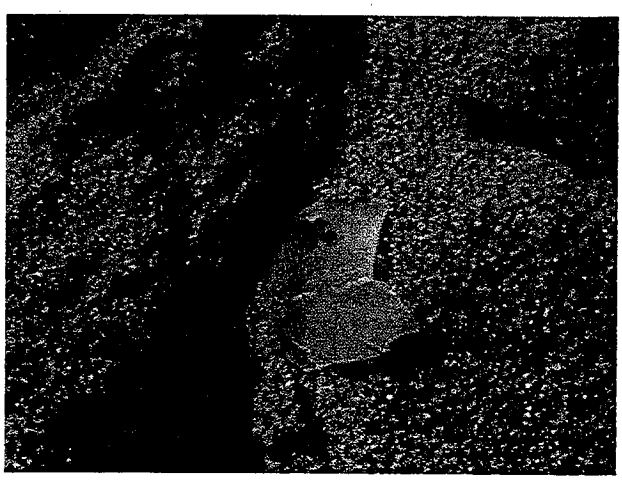
Trash & Debris Photos from Silver Strand Beach,
County of Ventura
March 11, 2006 (Saturday)

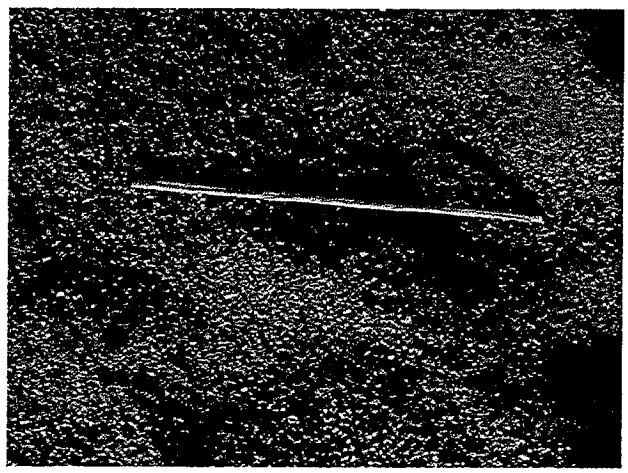






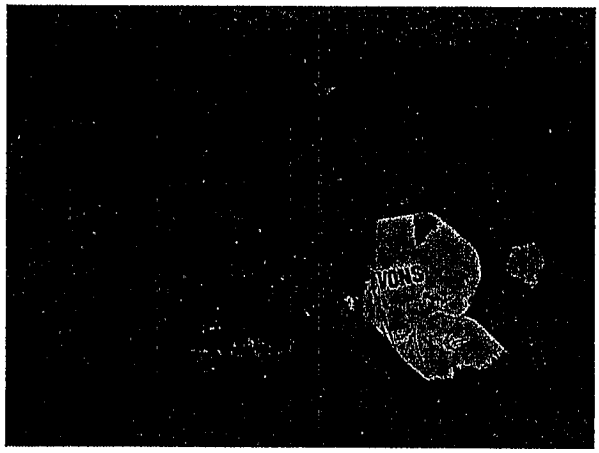


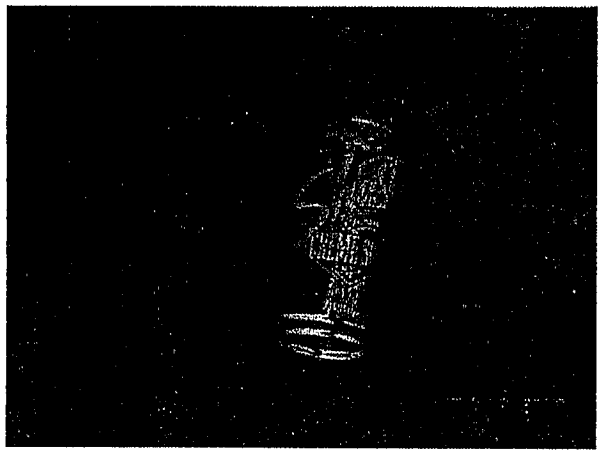


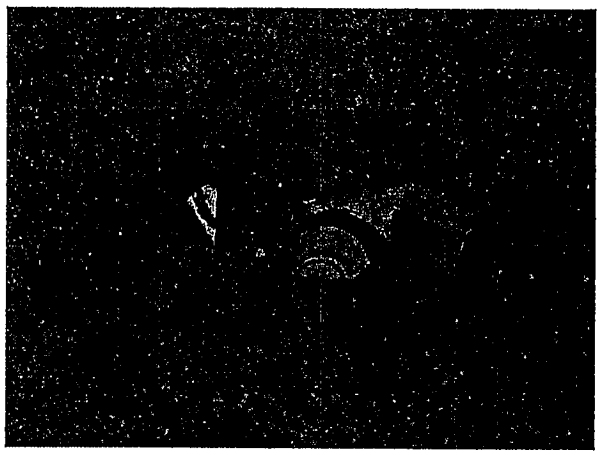


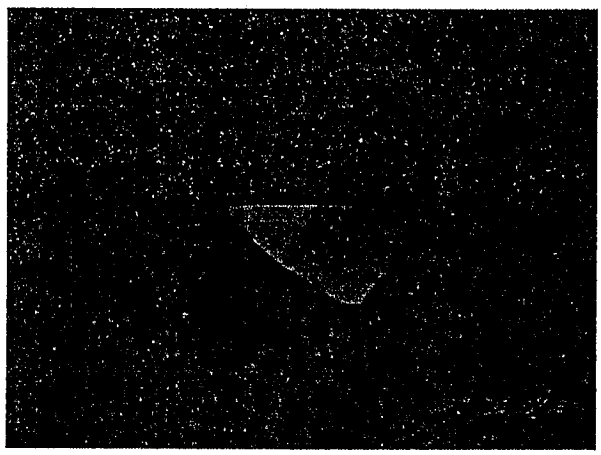
A015018

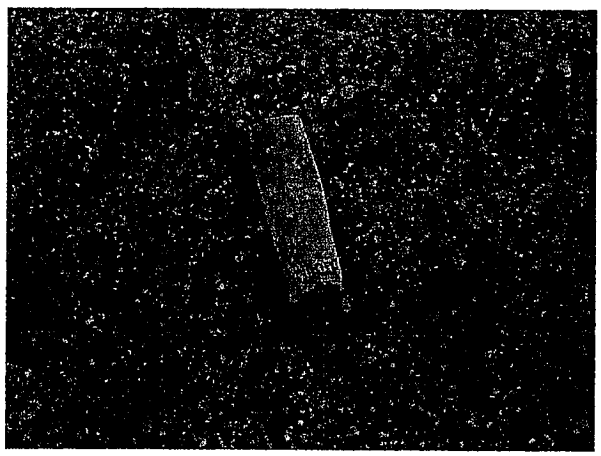
Trash & Debris Photos from Silver Strand Beach
County of Ventura
June 19, 2006 (Monday)

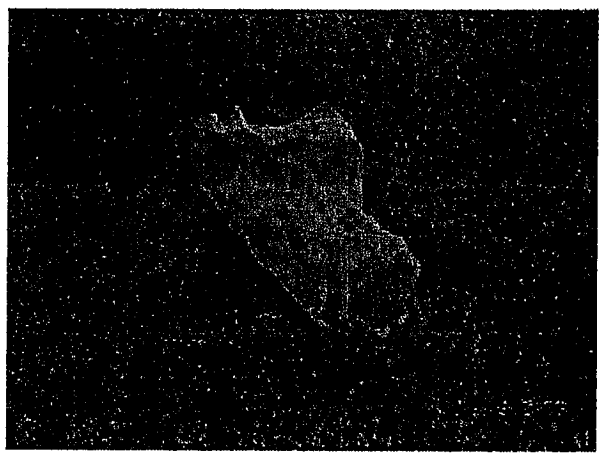






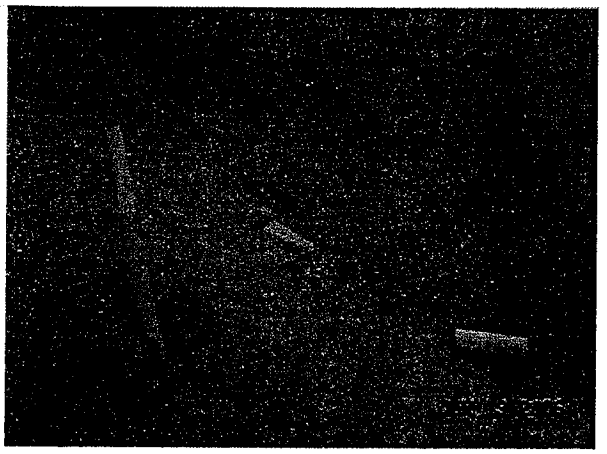


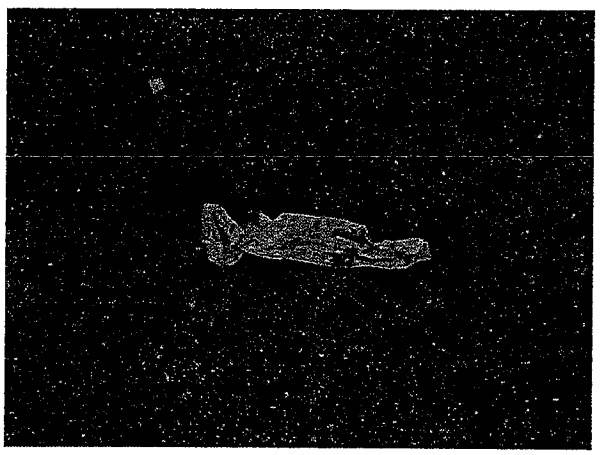


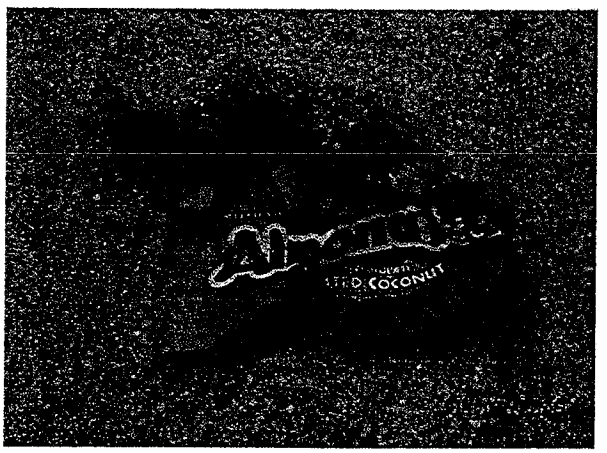


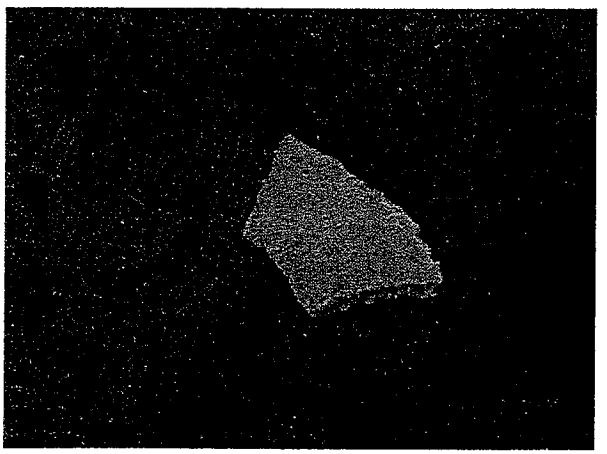
A015019

Trash & Debris Photos from Silver Strand Beach
County of Ventura
June 19, 2006 (Monday)

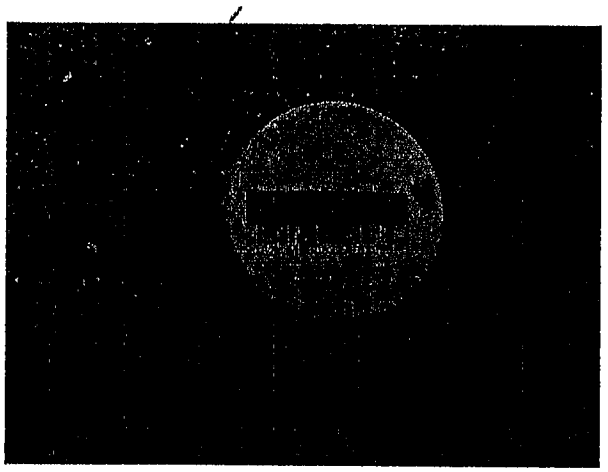


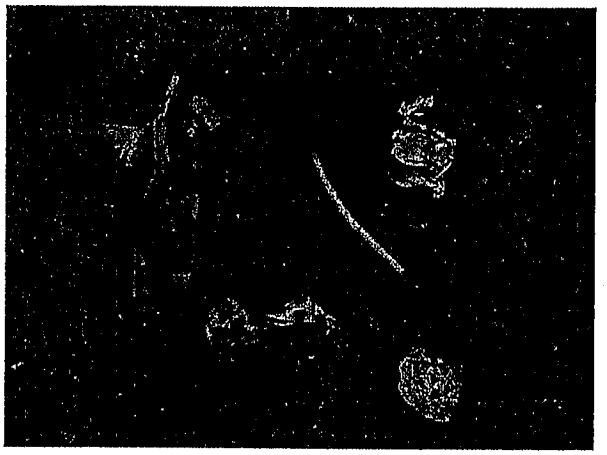


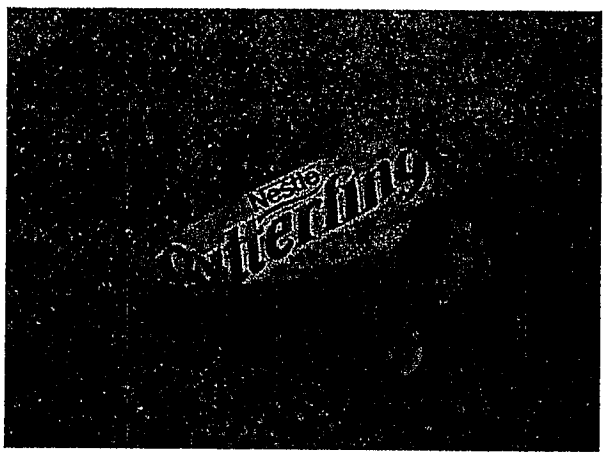


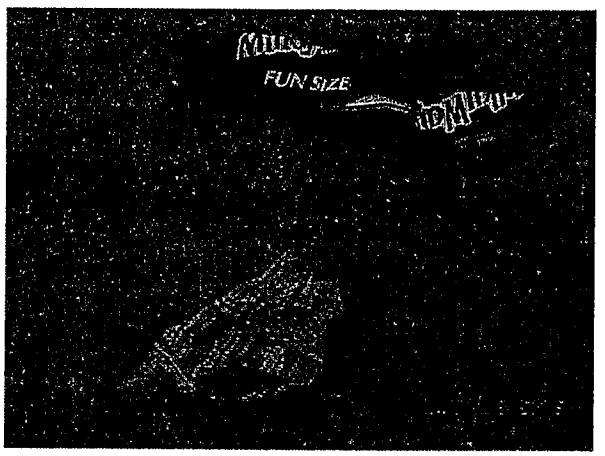


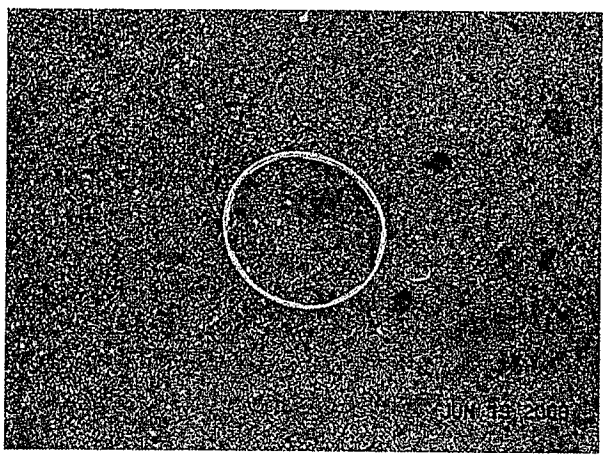
Trash & Debris Photos from Silver Strand Beach
County of Ventura
June 19, 2006 (Monday)

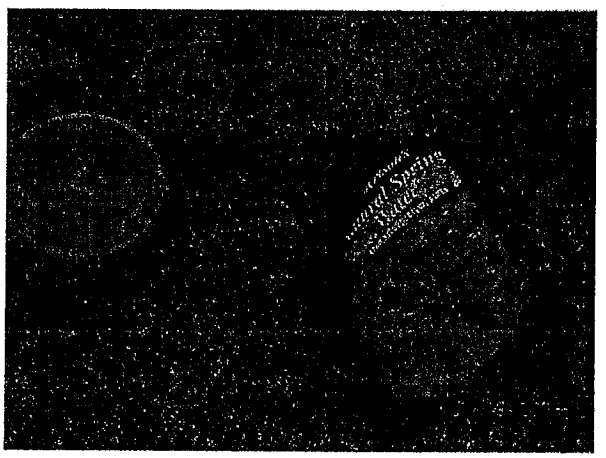




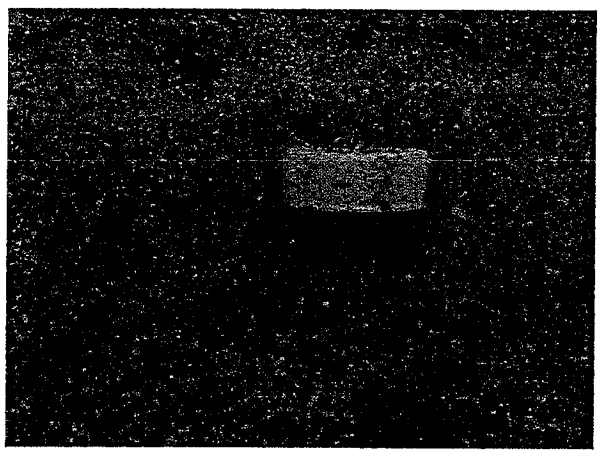






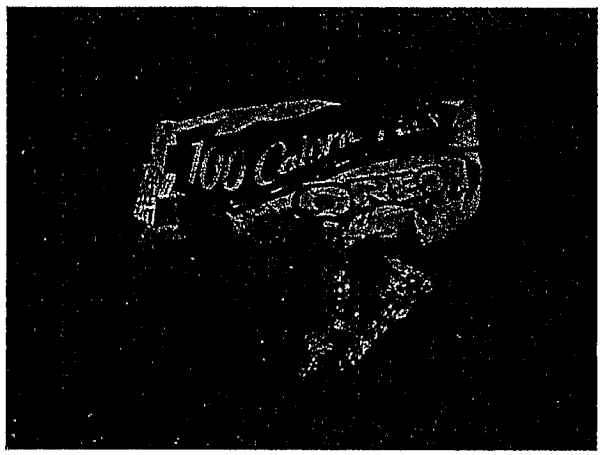


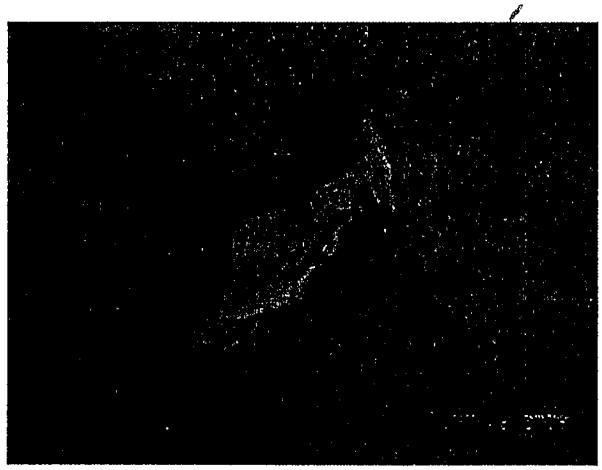
Trash & Debris Photos from Silver Strand Beach
County of Ventura
June 19, 2006 (Monday)

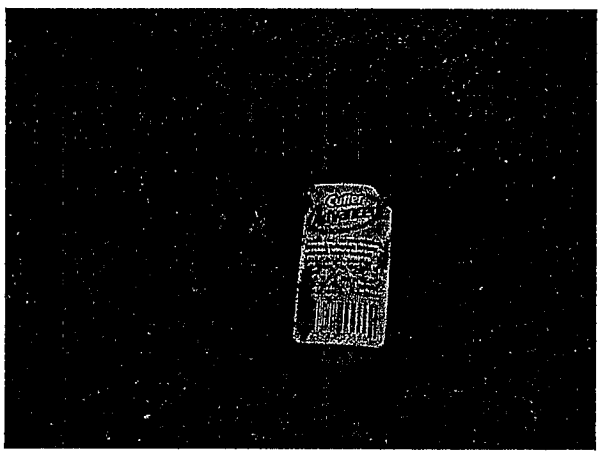


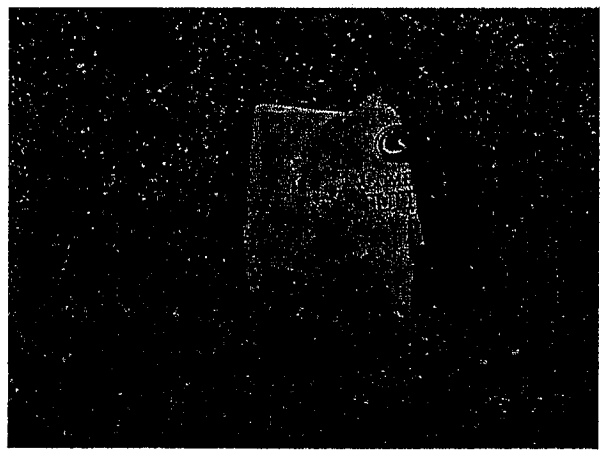
A015022

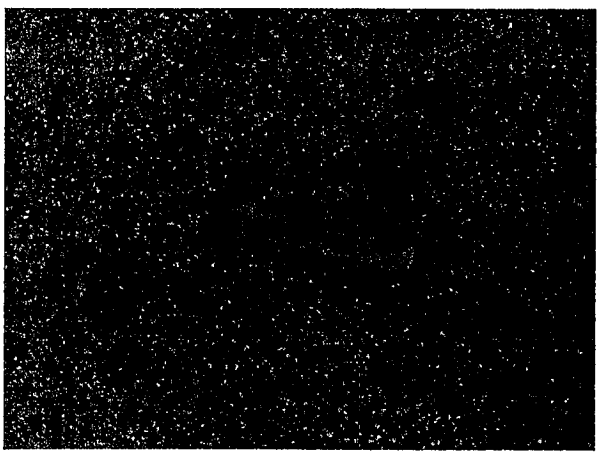
Trash & Debris Photos from Silver Strand Beach
County of Ventura
June 19, 2006 (Monday)







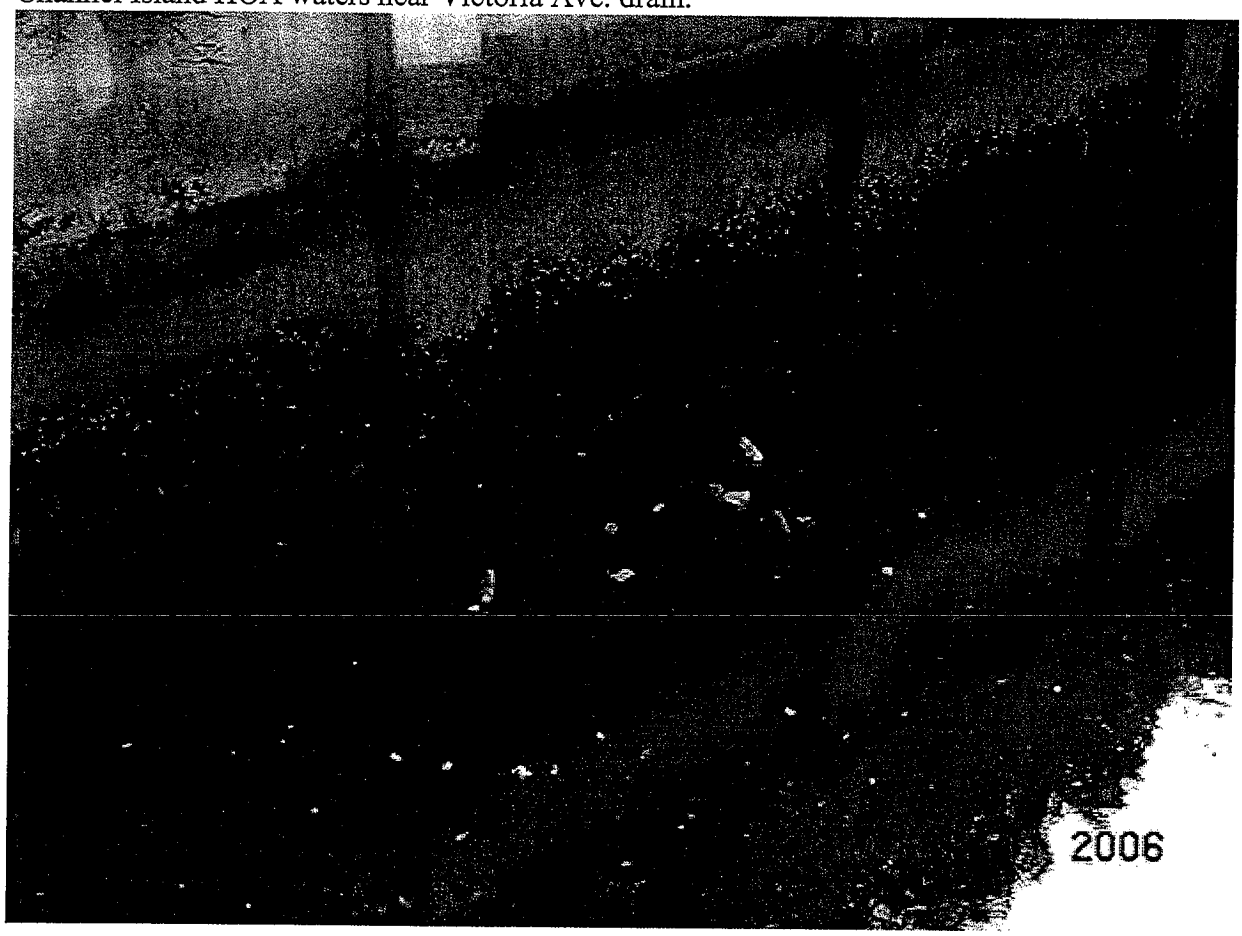




A015023

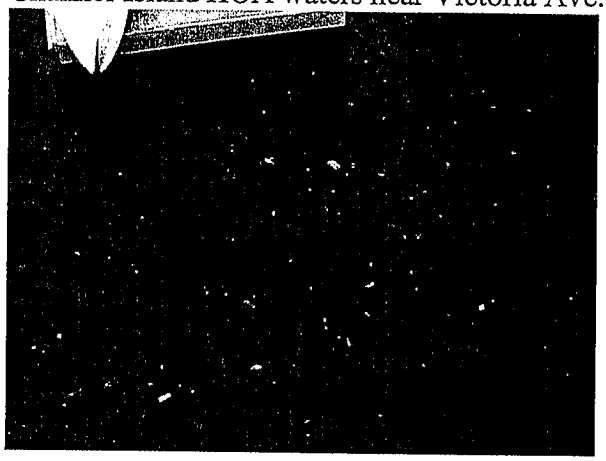
Trash & Debris Photo from Channel Island HOA
City of Oxnard
March 11, 2006 (Saturday)

Channel Island HOA waters near Victoria Ave. drain.

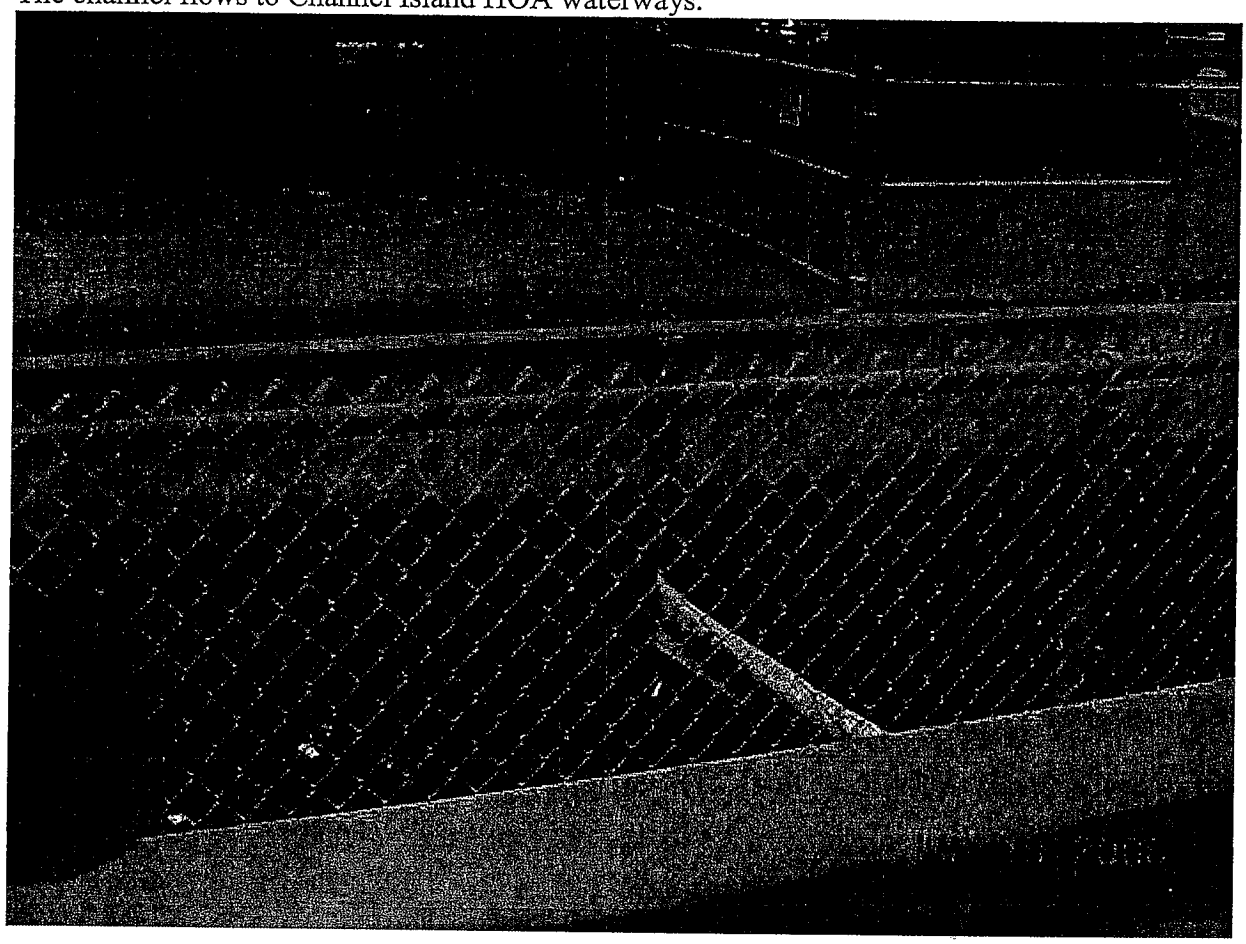


Trash & Debris Photos from Channel Island HOA & Channel Island Blvd. Channel
City of Oxnard
June 19, 2006 (Monday)

Channel Island HOA waters near Victoria Ave. drain.



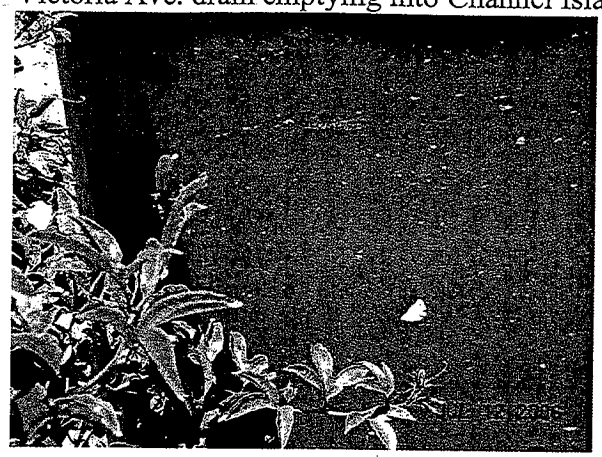
Boom in channel along Channel Island Blvd. near Victoria Ave.
The channel flows to Channel Island HOA waterways.



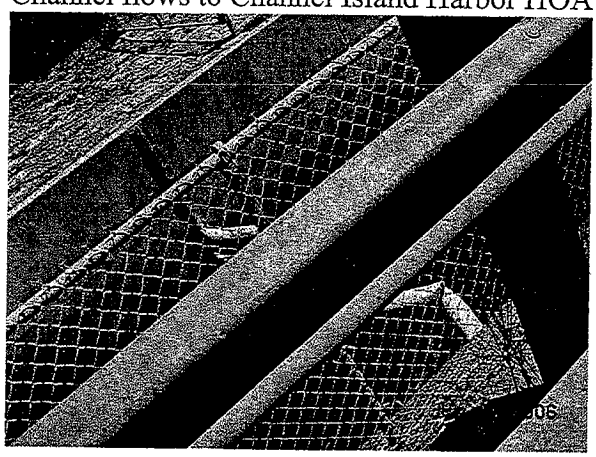
A015025

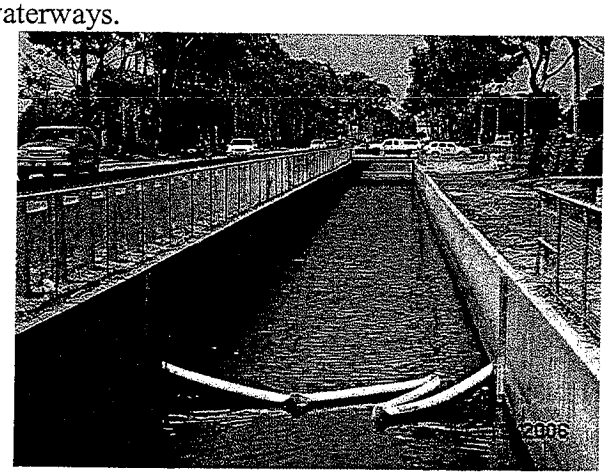
Trash & Debris Photos from Channel Island HOA & Channel Island Blvd. Channel
Victoria Ave., City of Oxnard
July 12, 2006 (Wednesday)

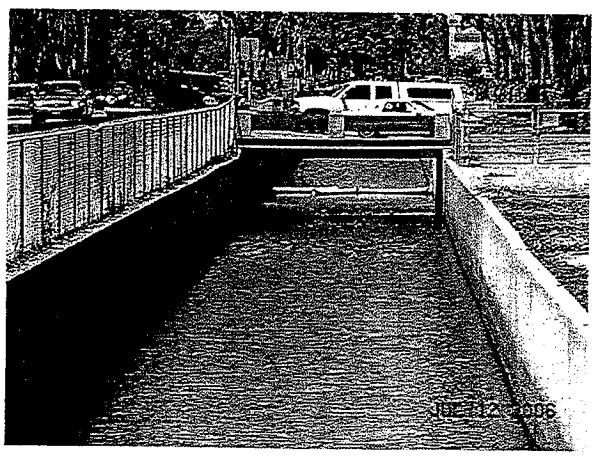
Victoria Ave. drain emptying into Channel Island HOA waters.



Boom in channel along Channel Island Blvd. near Victoria Ave.
Channel flows to Channel Island Harbor HOA waterways.

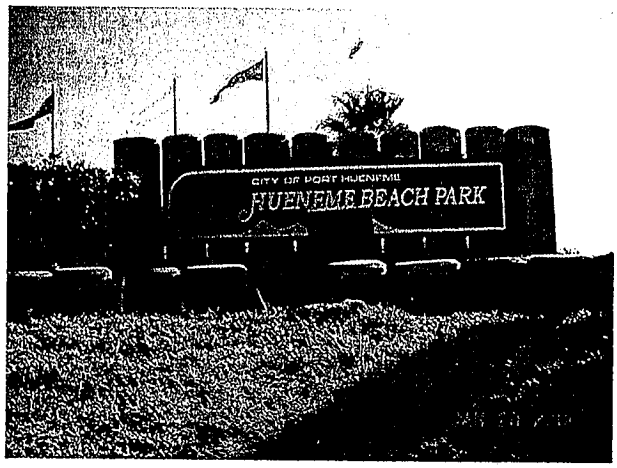


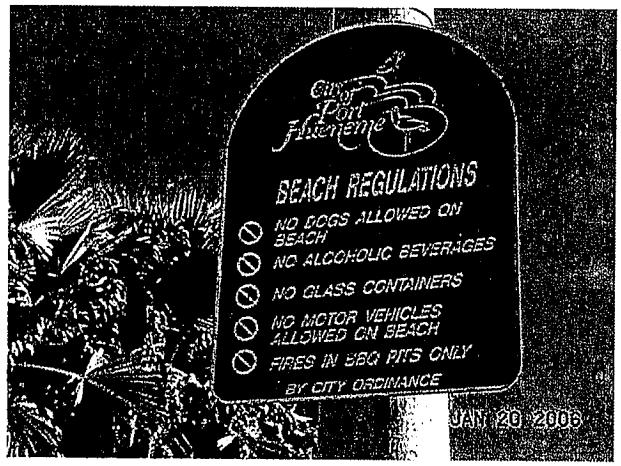


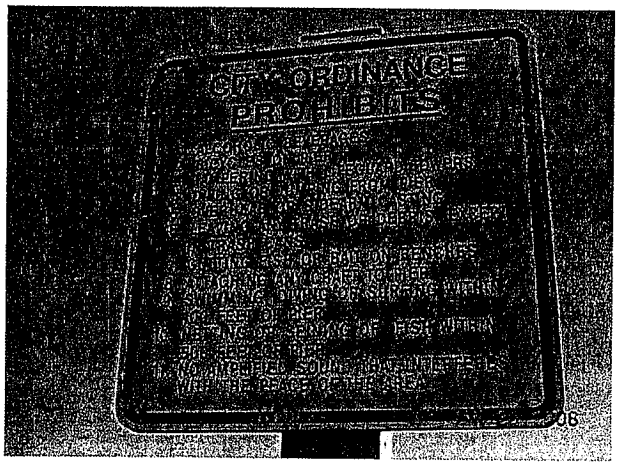


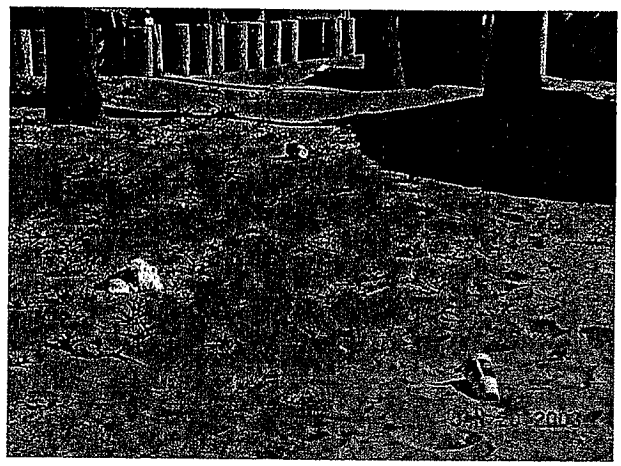
A015026

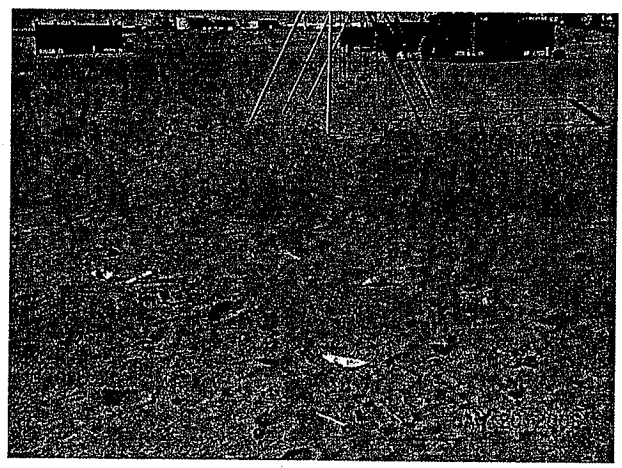
Trash & Debris Photos from Port Hueneme Beach Park, City of Port Hueneme
January 20, 2006 (Friday)

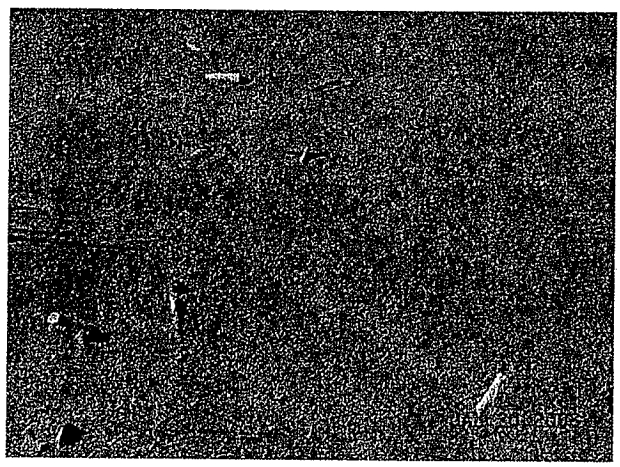






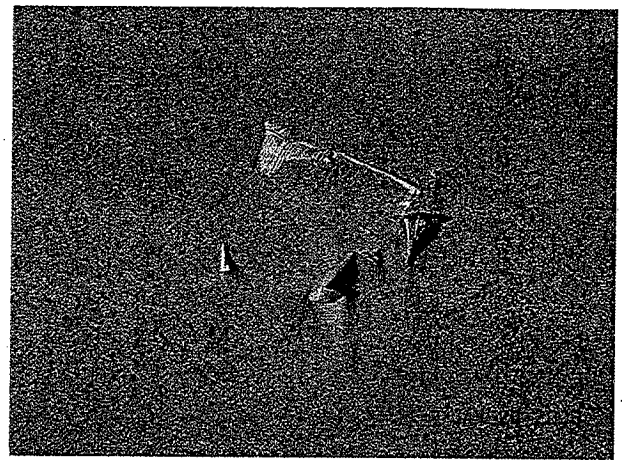


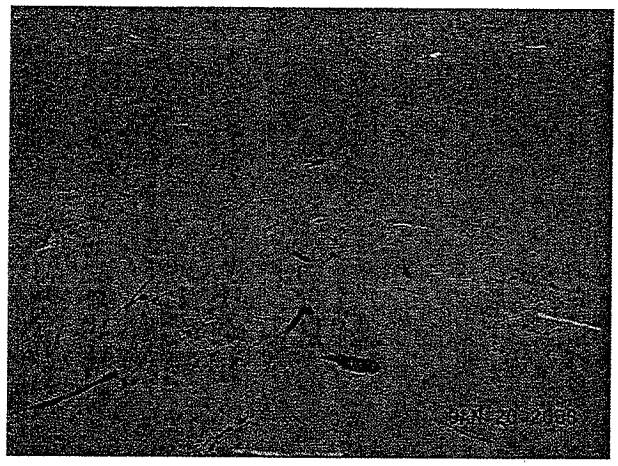


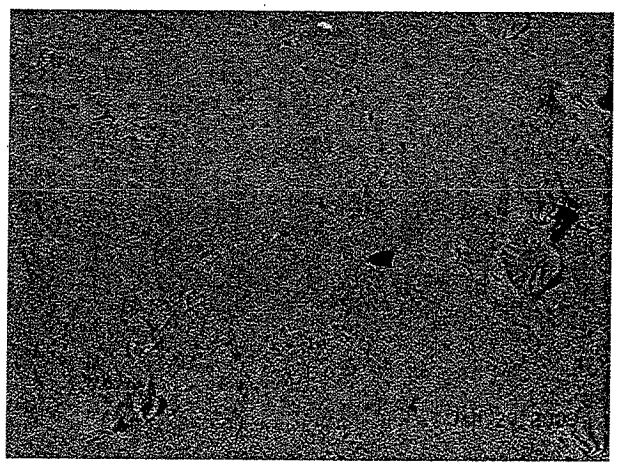


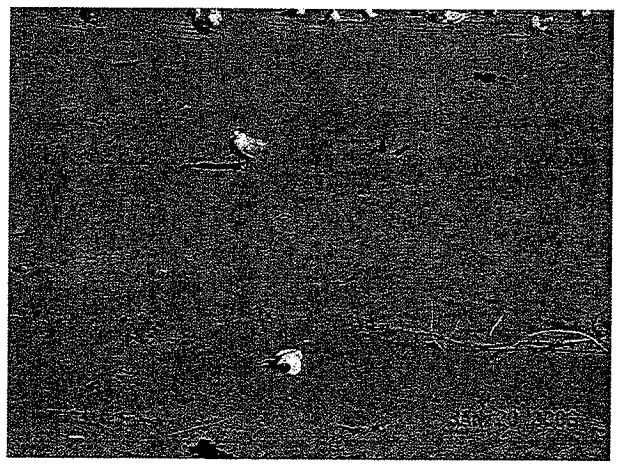
A015027

Trash & Debris Photos from Port Hueneme Beach Park, City of Port Hueneme
January 20, 2006 (Friday)



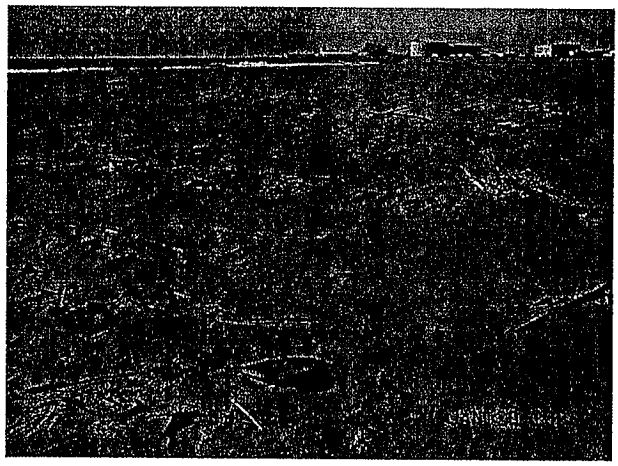


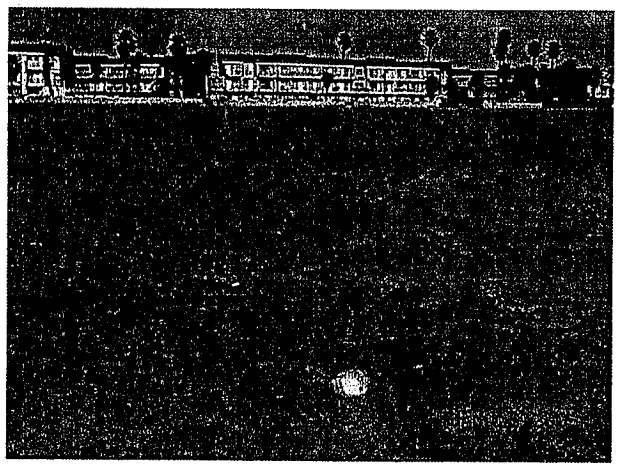


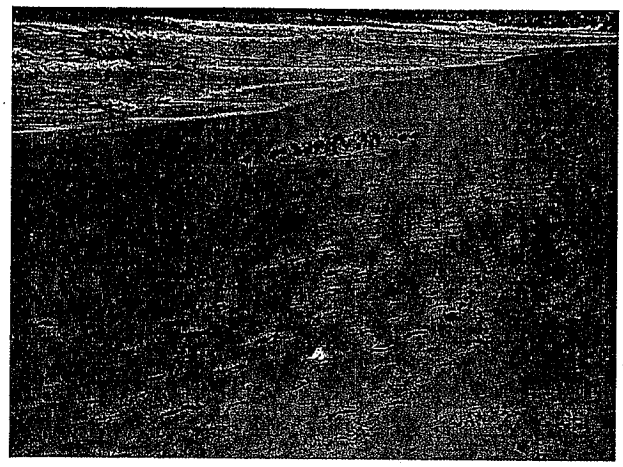


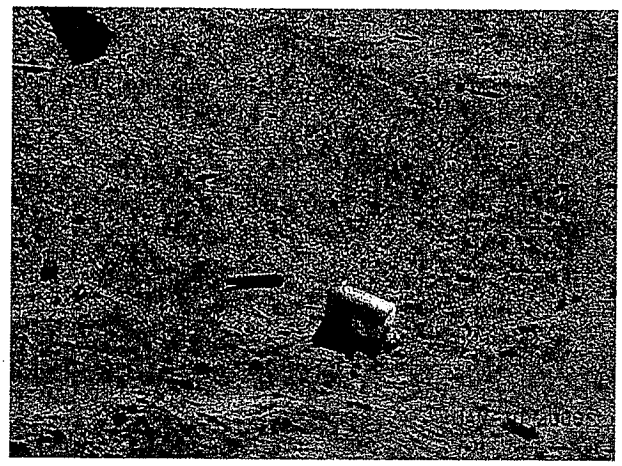
A015028

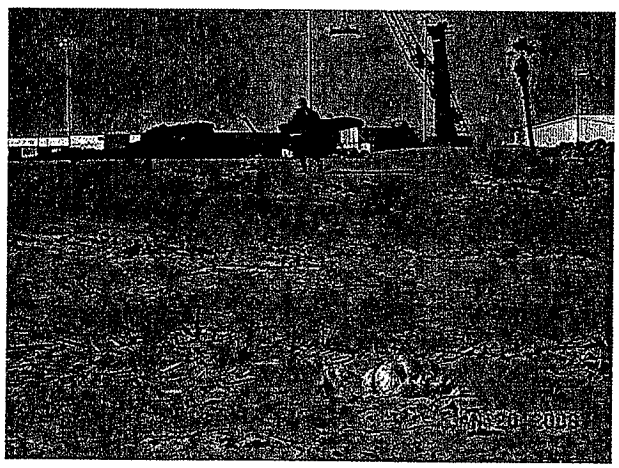
Trash & Debris Photos from Port Hueneme Beach Park, City of Port Hueneme
January 20, 2006 (Friday)

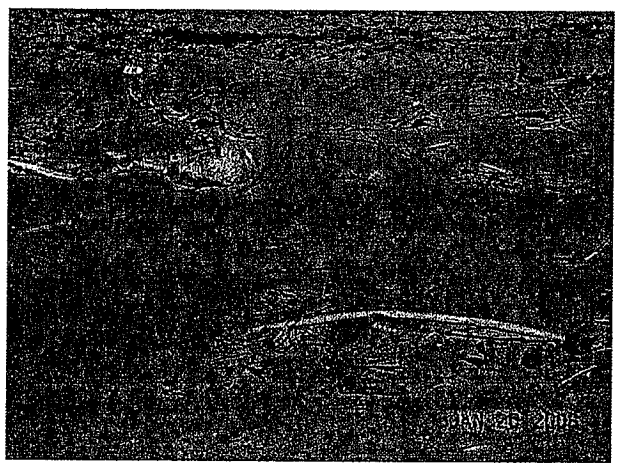






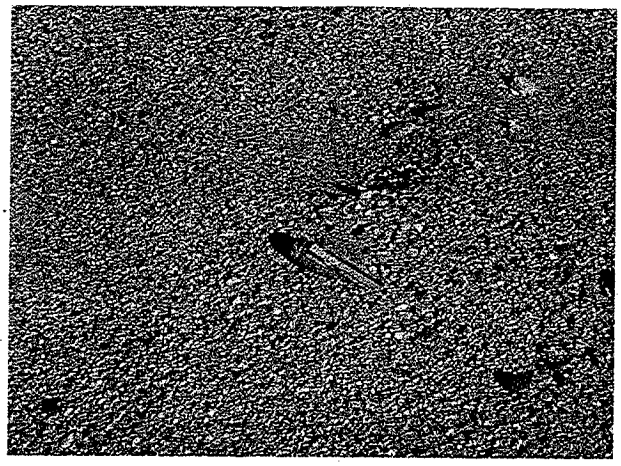


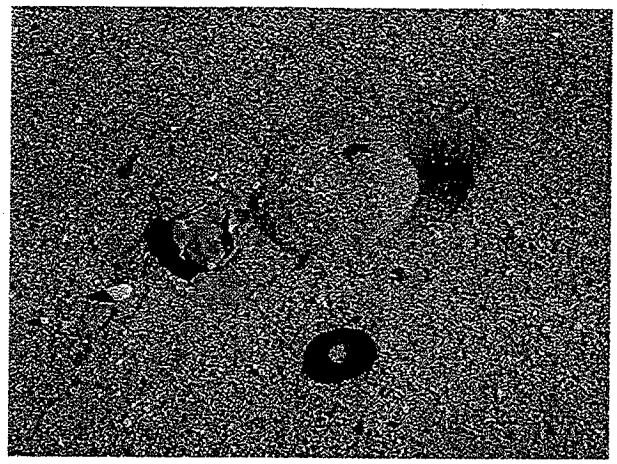


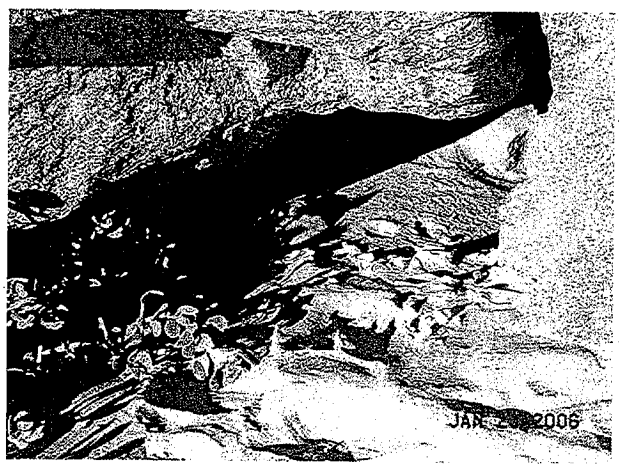


A015029

Trash & Debris Photos from Port Hueneme Beach Park, City of Port Hueneme
January 20, 2006 (Friday)

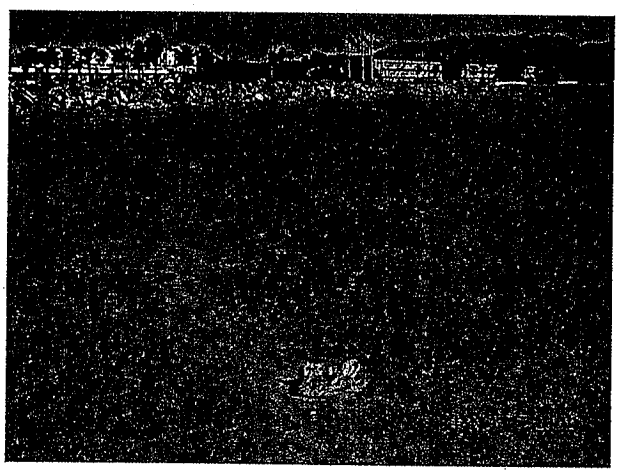


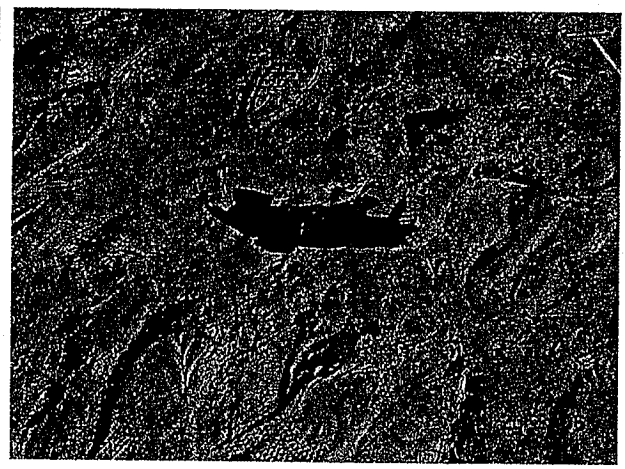




A015030

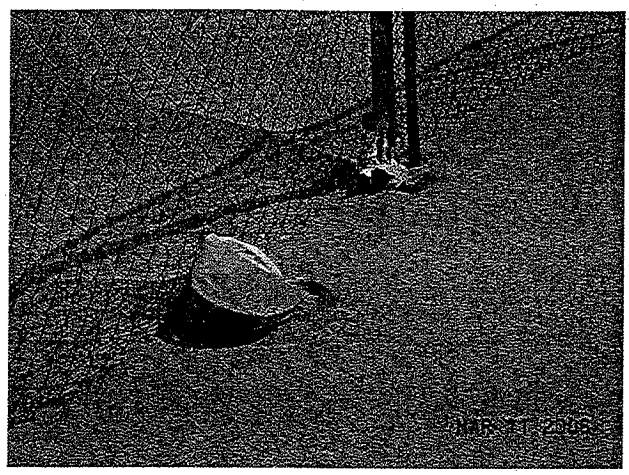
Trash & Debris Photos from Port Hueneme Beach Park, City of Port Hueneme
January 20, 2006 (Friday)

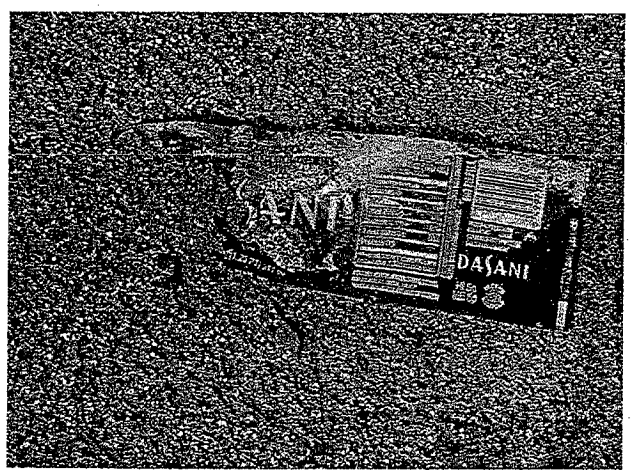


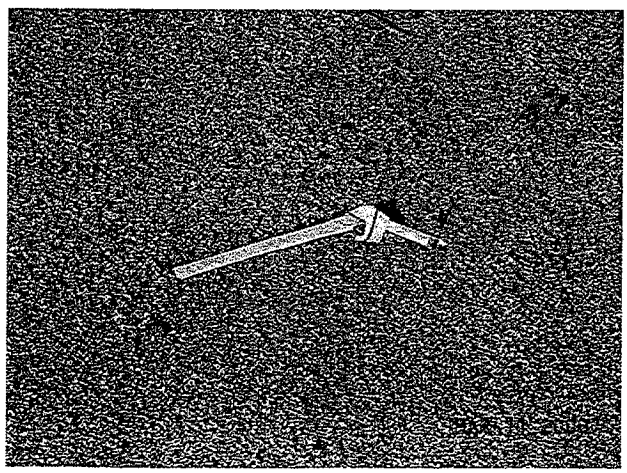


A015031

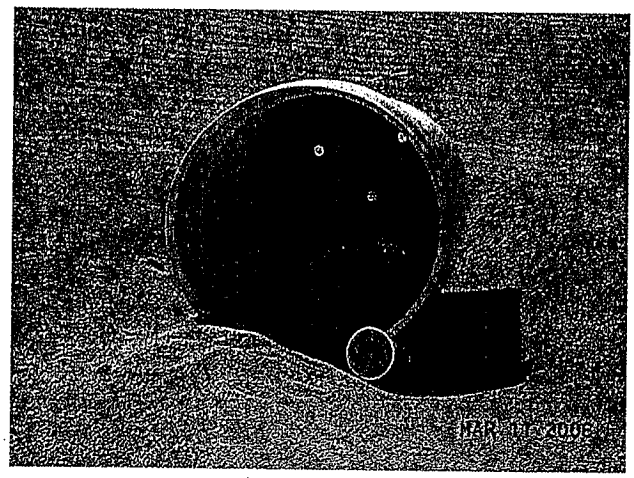
Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)

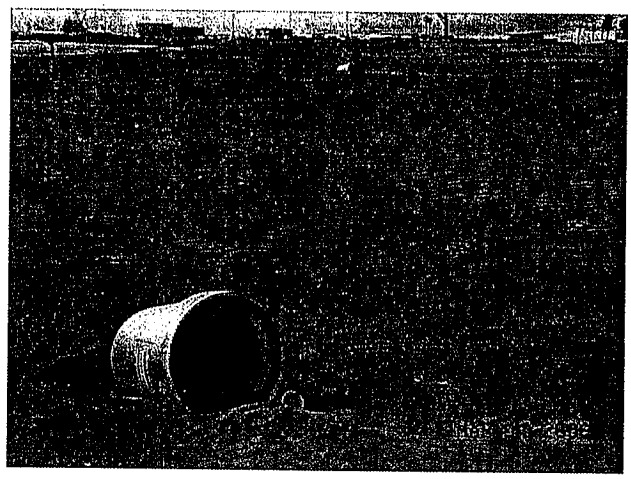


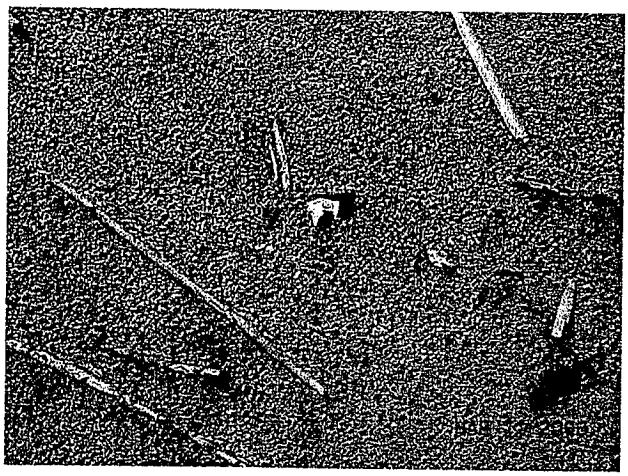


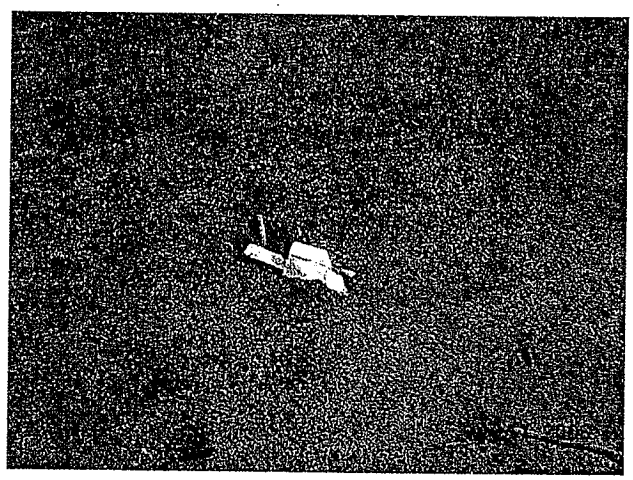


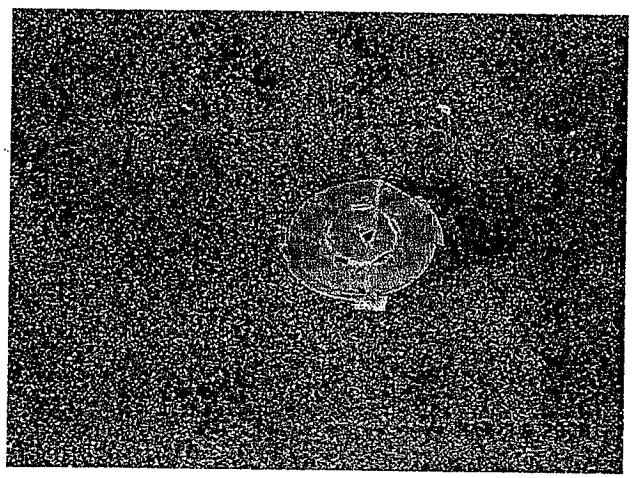
Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)

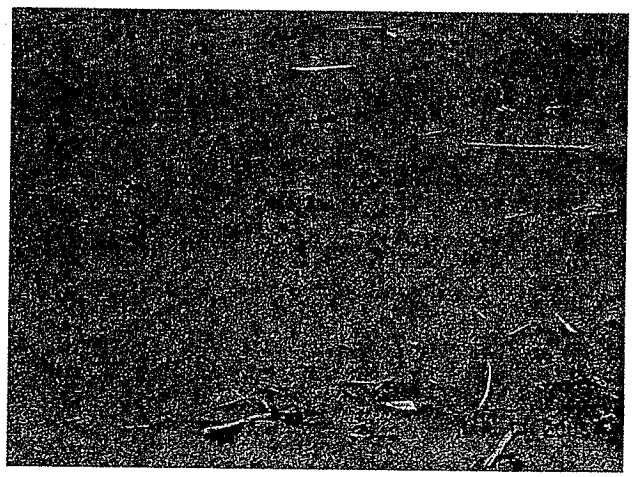






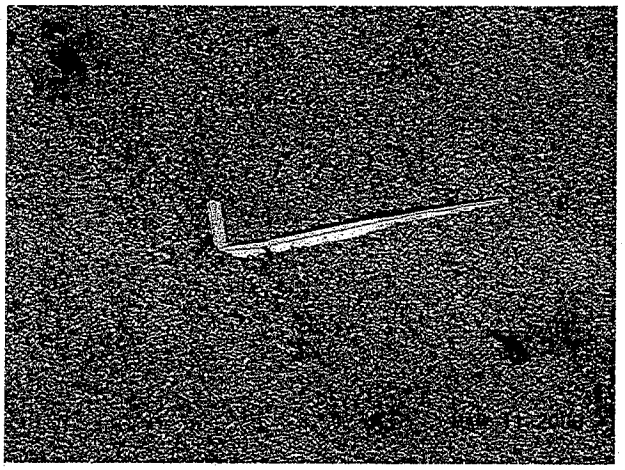


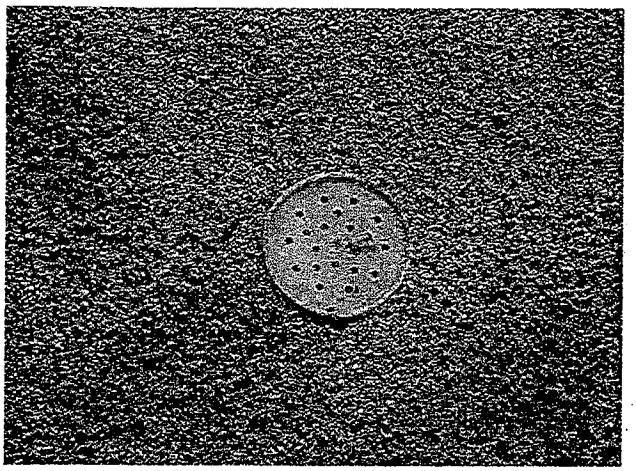


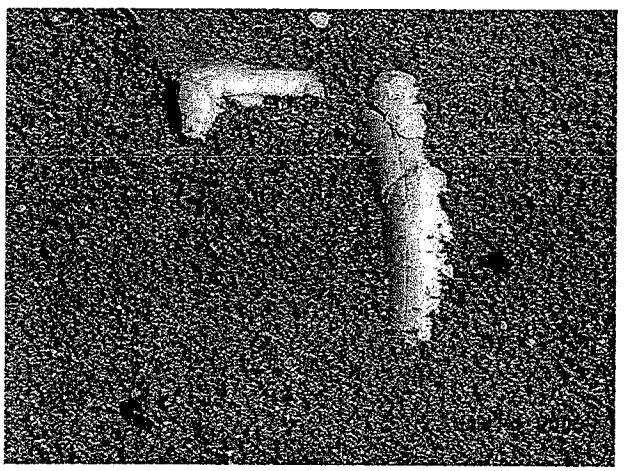


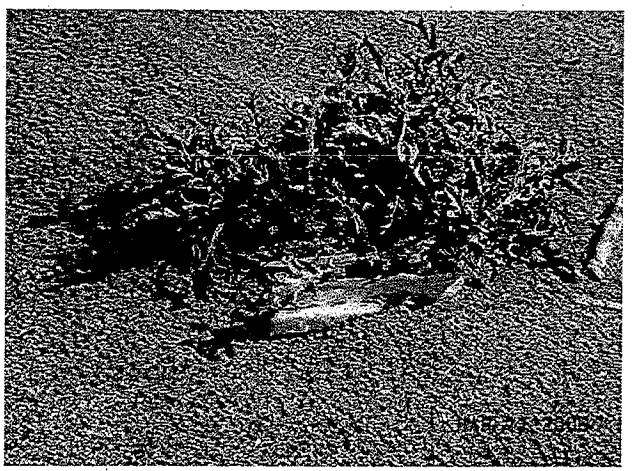
A015033

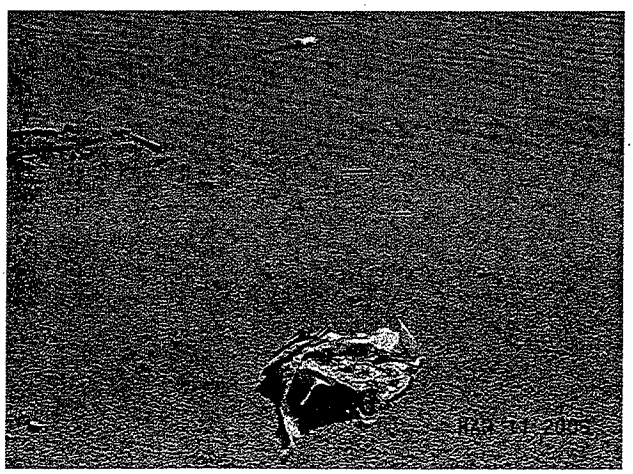
Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)





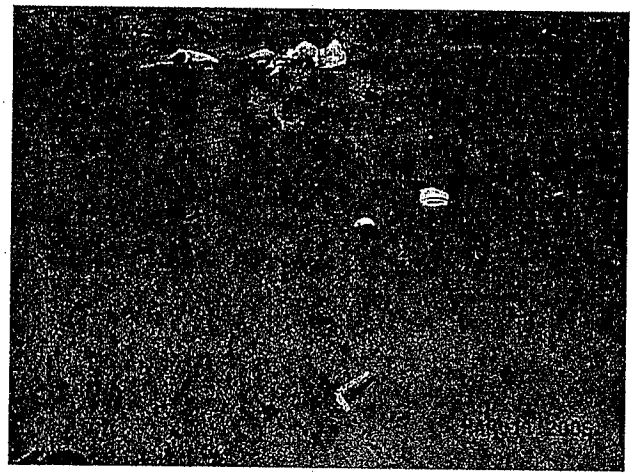


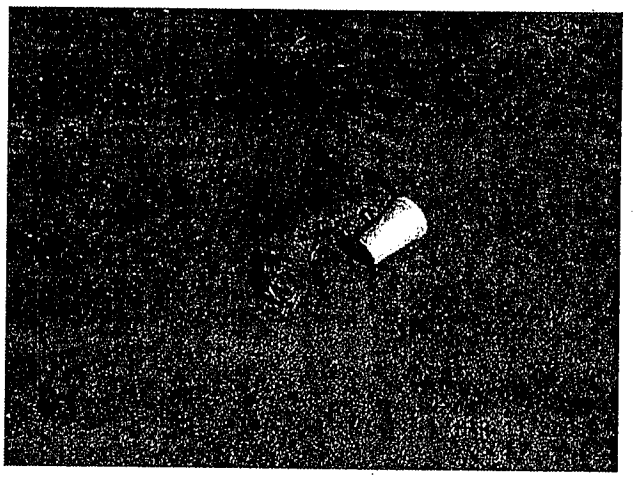


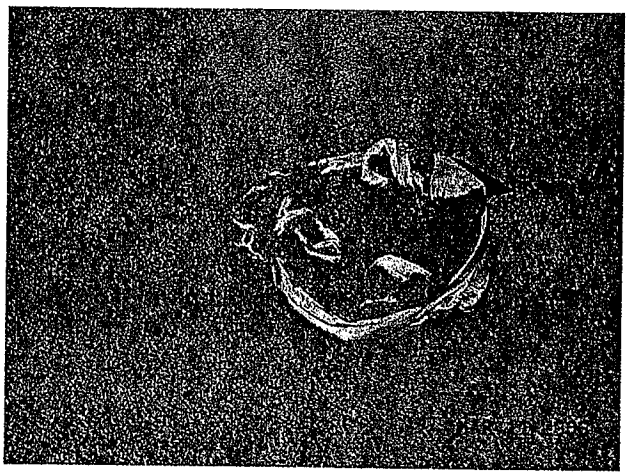


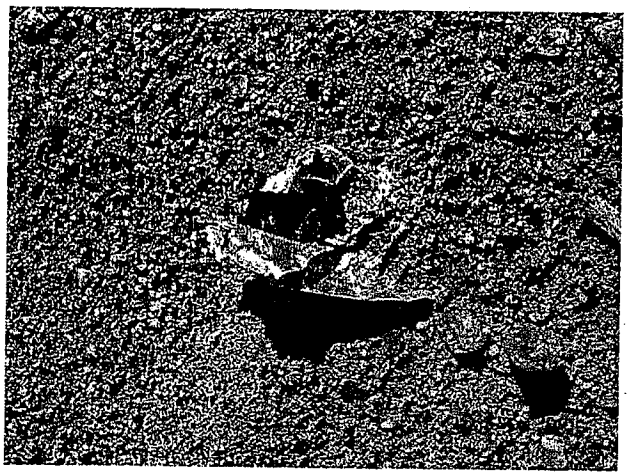
A015034

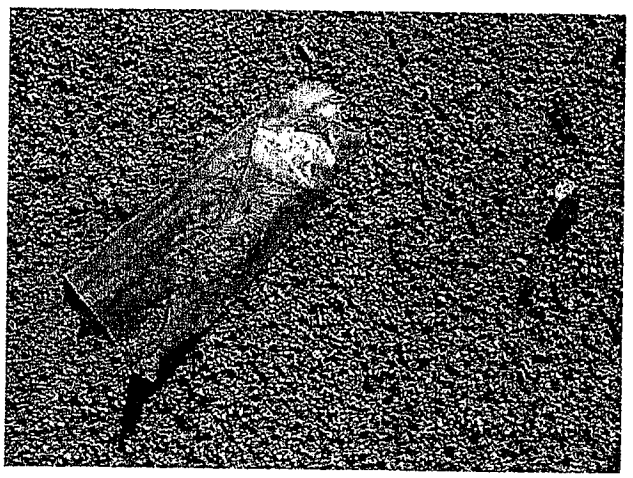
Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)

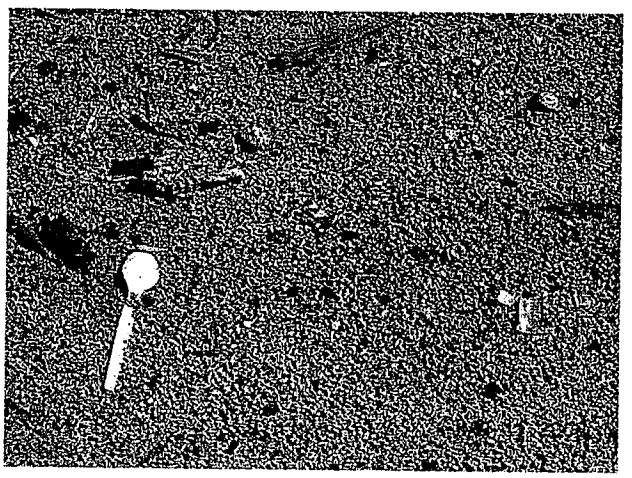






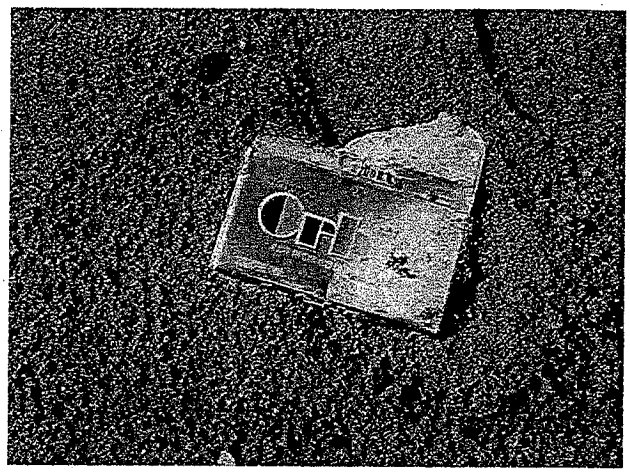


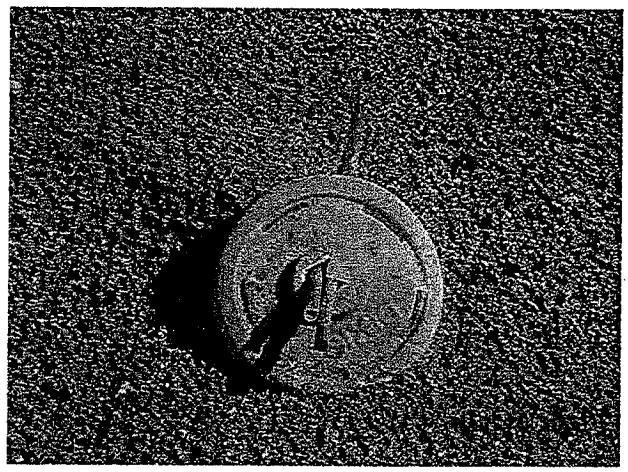


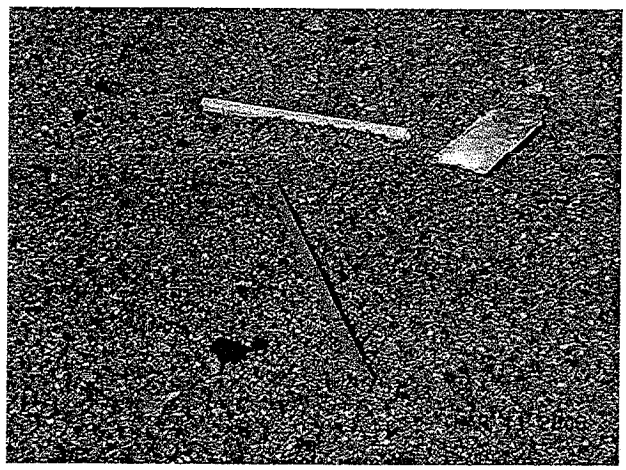


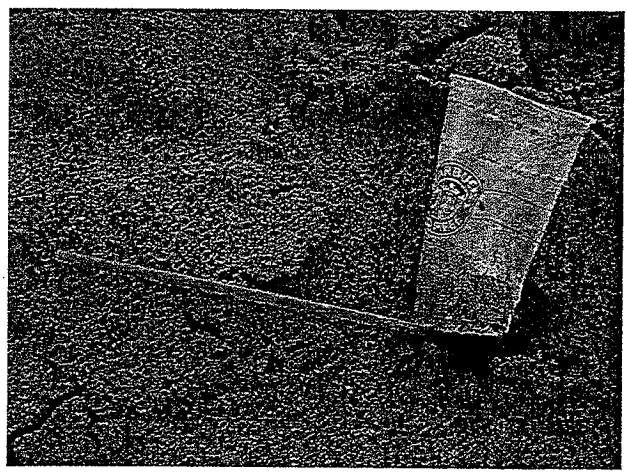
A015035

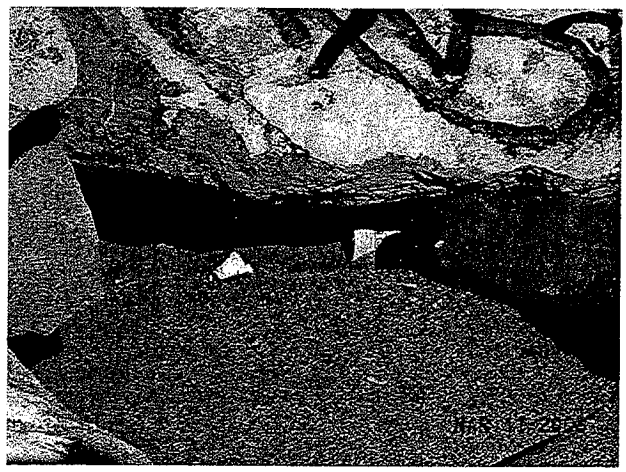
Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)





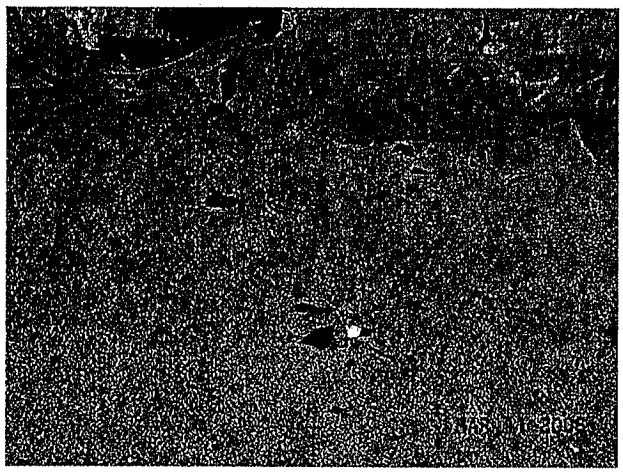


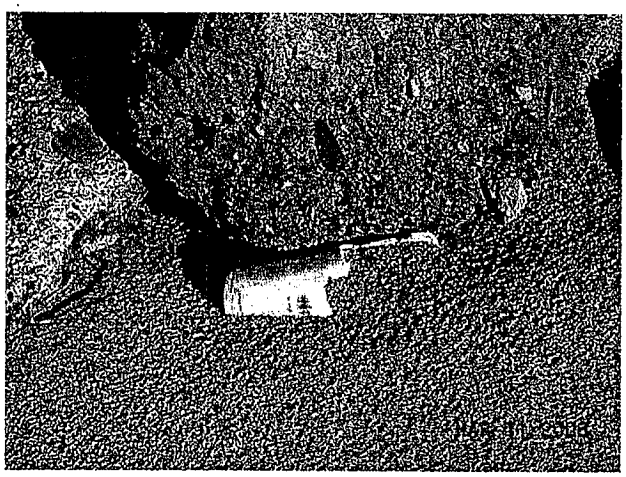


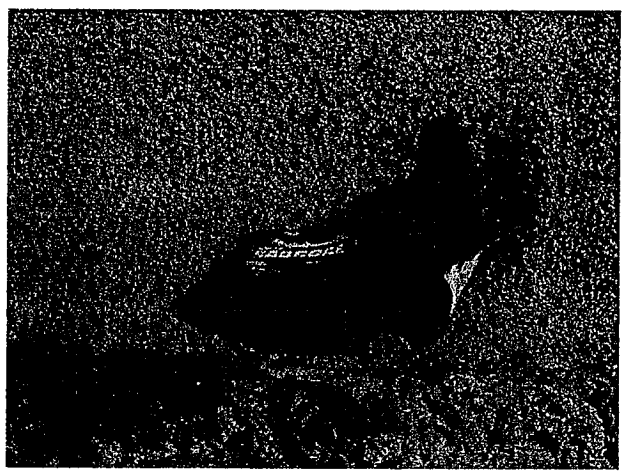


A015036

Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)

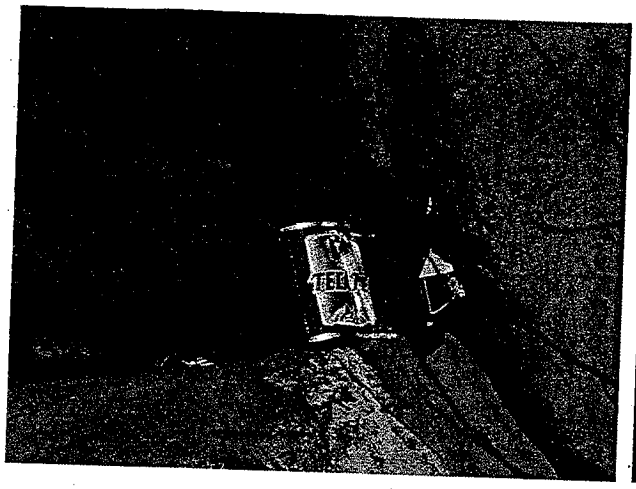


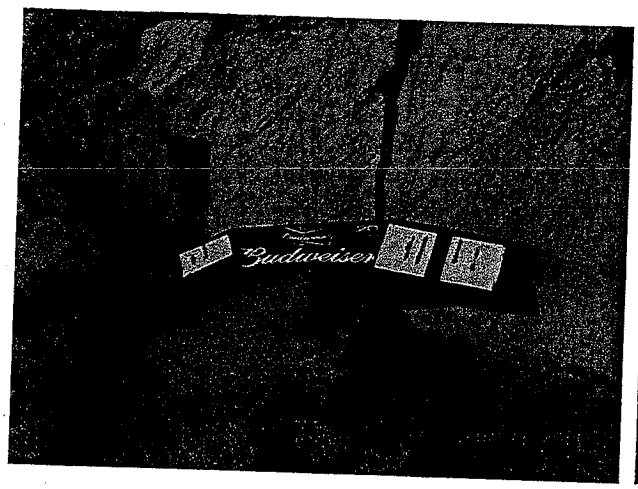


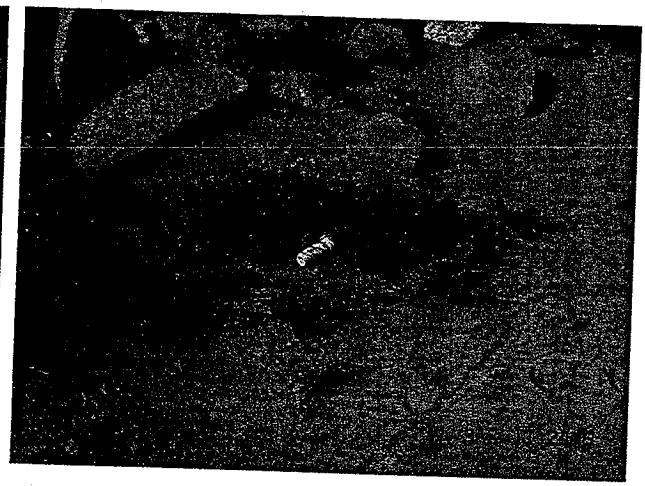


A015037

Trash & Debris Photos from Hueneme Beach Park,
City of Port Hueneme
March 11, 2006 (Saturday)

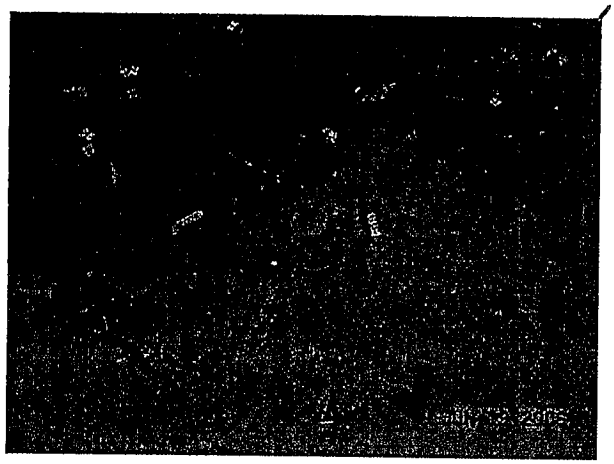


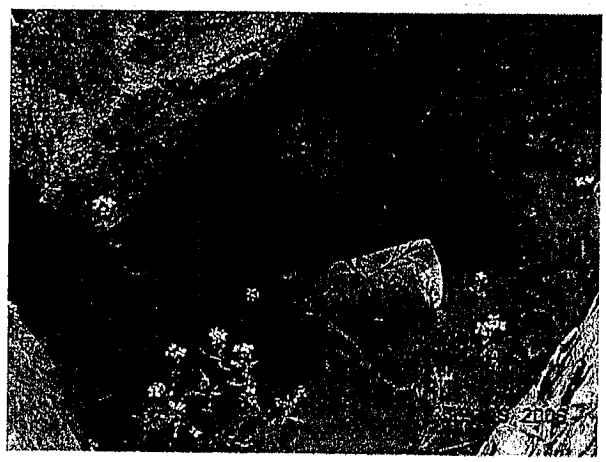


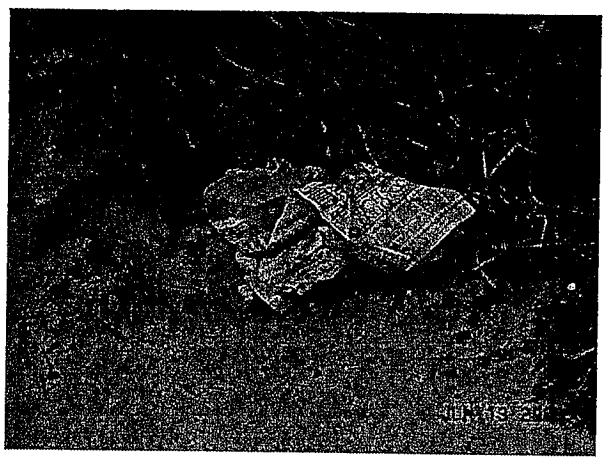


A015038

Trash & Debris Photos from Hueneme Beach Park
City of Port Hueneme
June 19, 2006 (Monday)

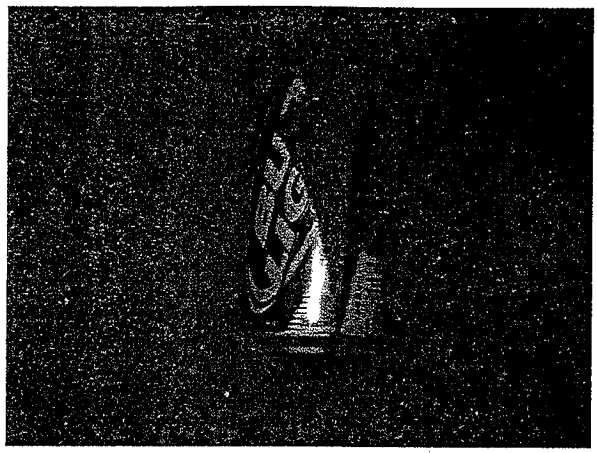


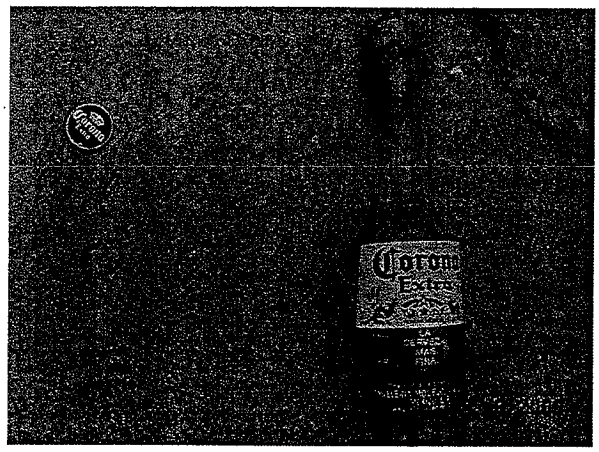


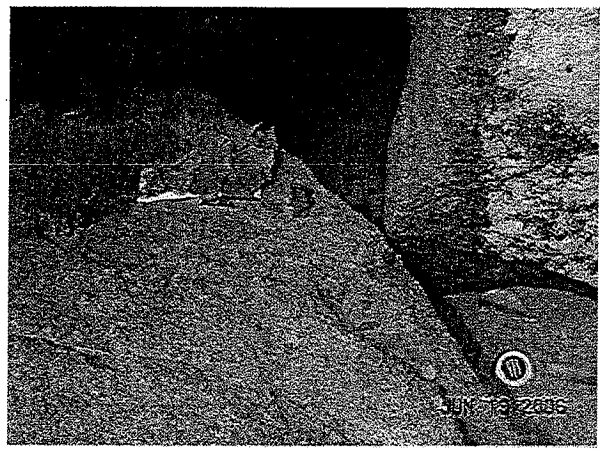


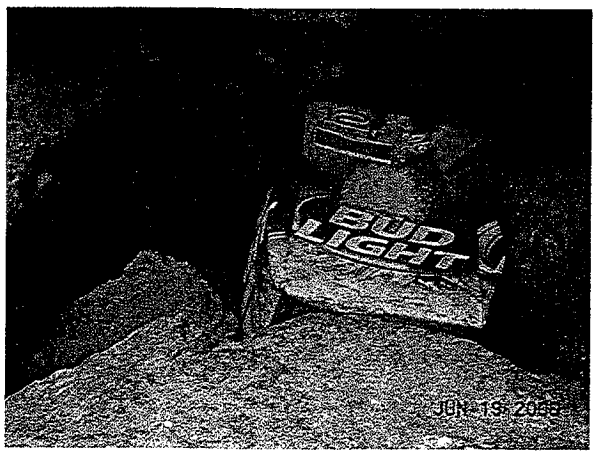
A015039

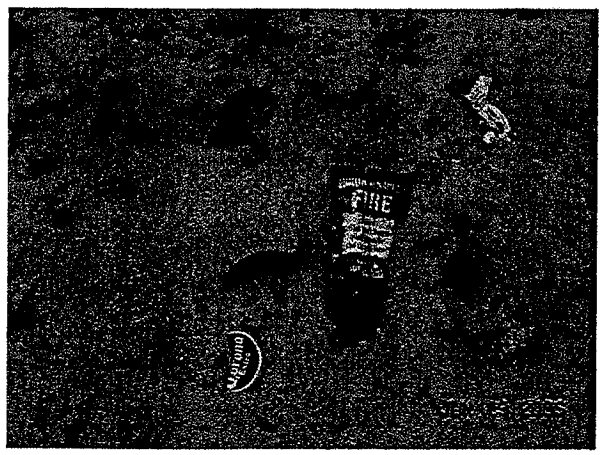
Trash & Debris Photos from Hueneme Beach Park
City of Port Hueneme
June 19, 2006 (Monday)





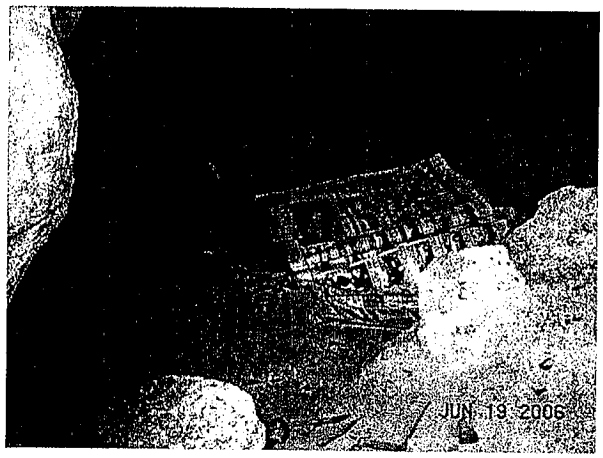


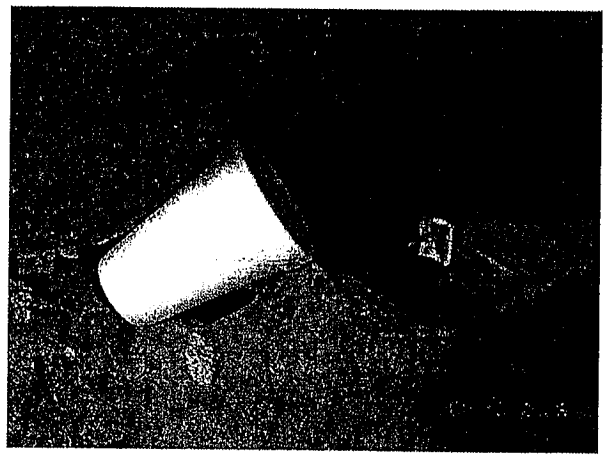


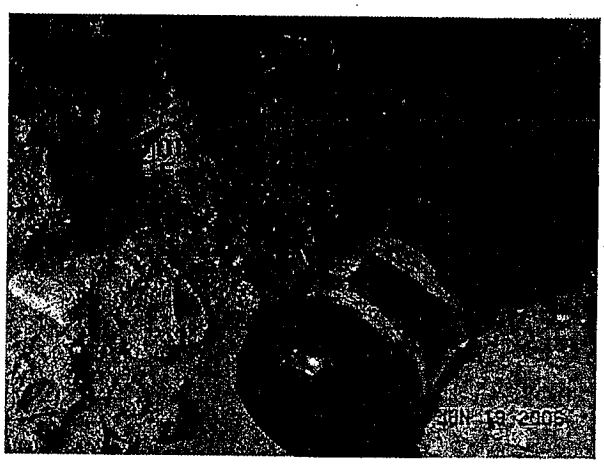


A015040

Trash & Debris Photos from Hueneme Beach Park
City of Port Hueneme
June 19, 2006 (Monday)

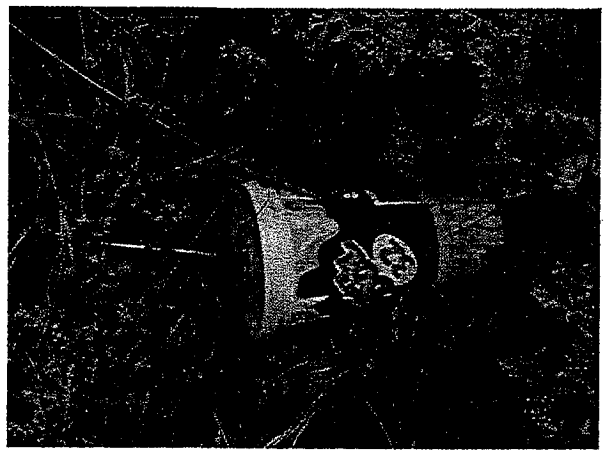


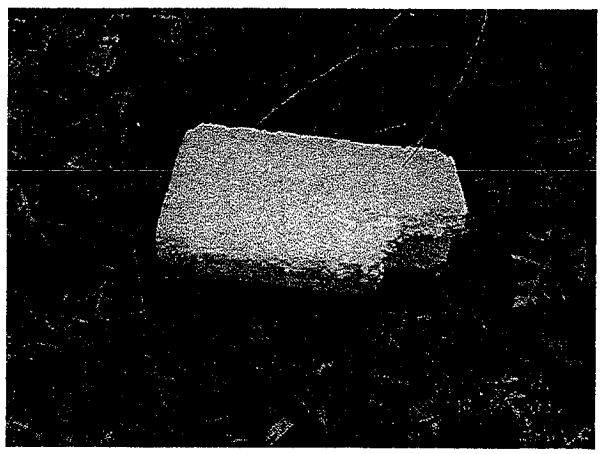


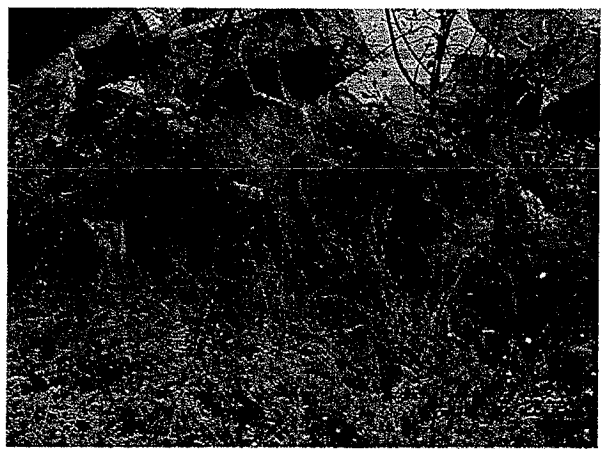


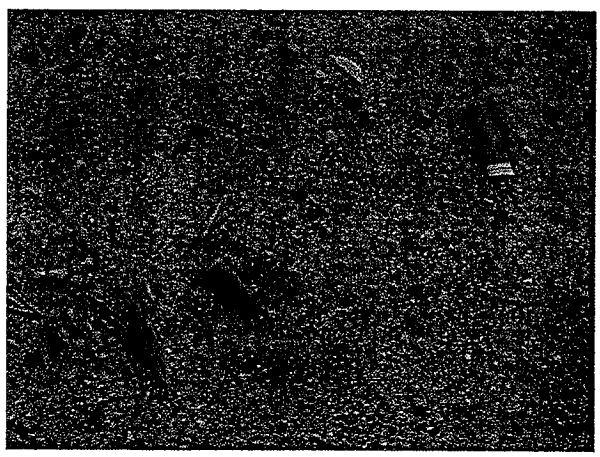
A015041

Trash & Debris Photos from Hueneme Beach Park
City of Port Hueneme
June 19, 2006 (Monday)



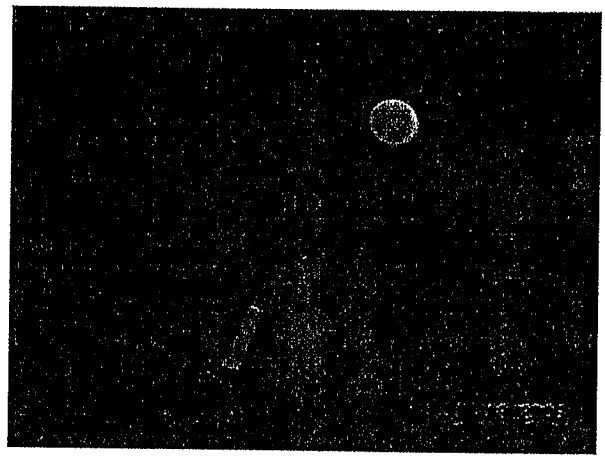


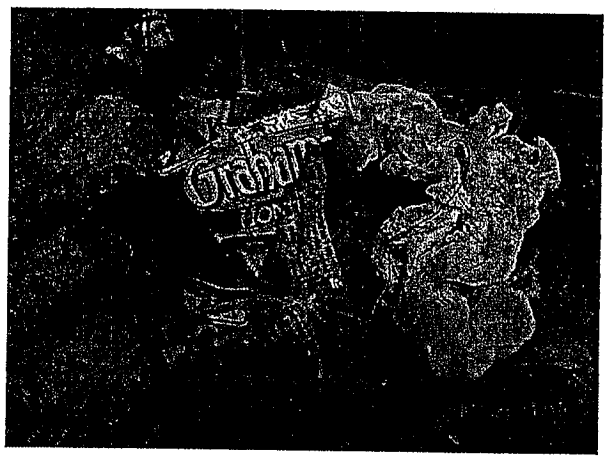


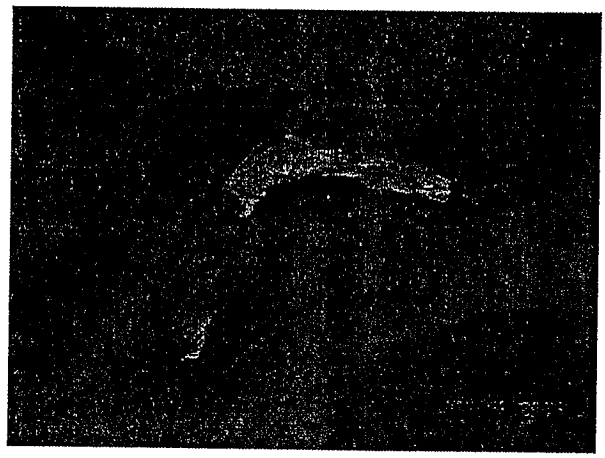


A015042

Trash & Debris Photos from Hueneme Beach Park
City of Port Hueneme
June 19, 2006 (Monday)

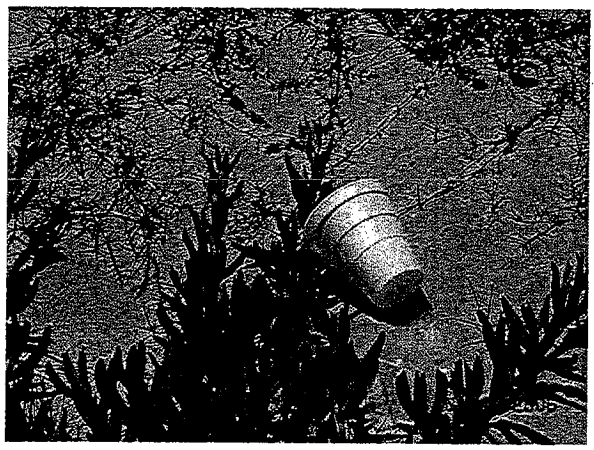






A015043

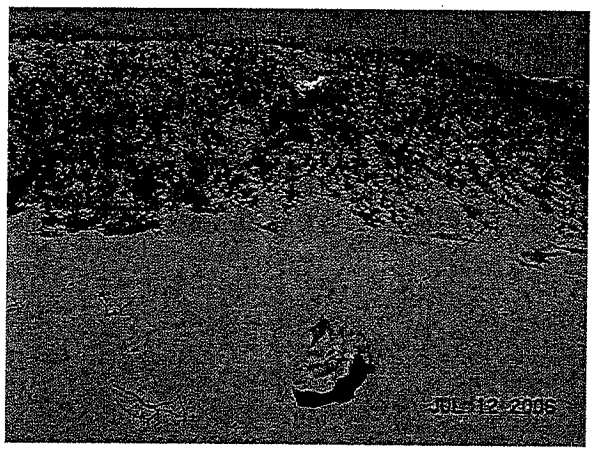
Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)

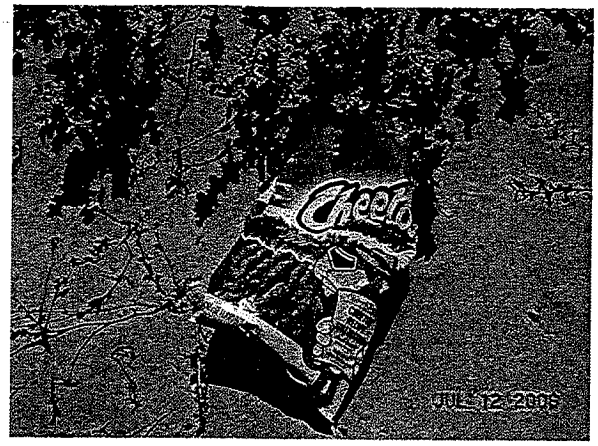


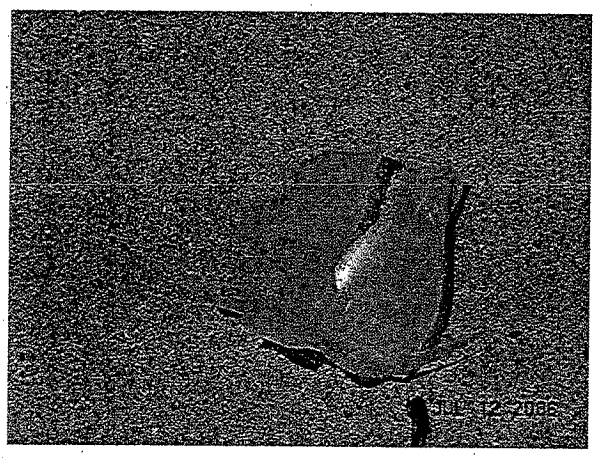
A015044

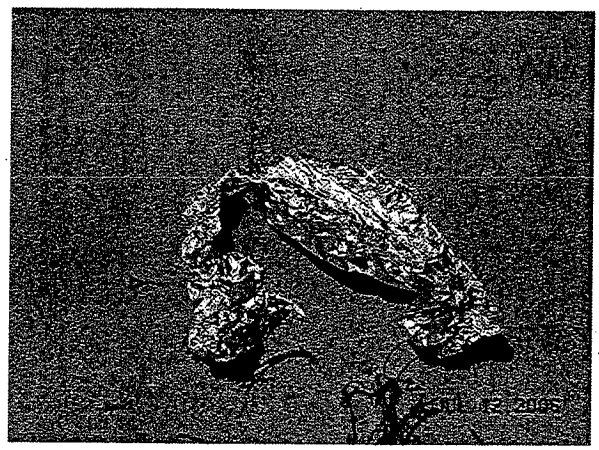
Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)

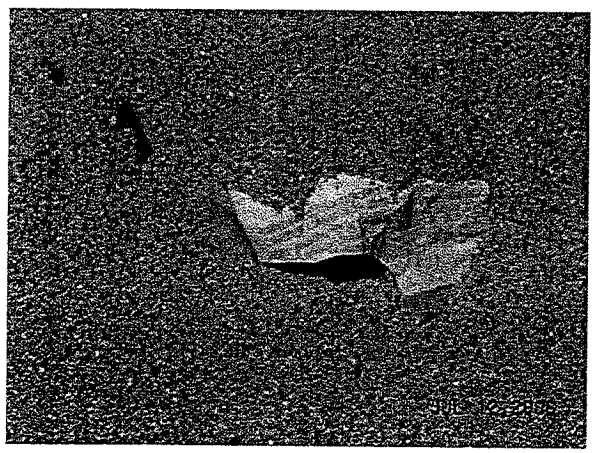
Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)

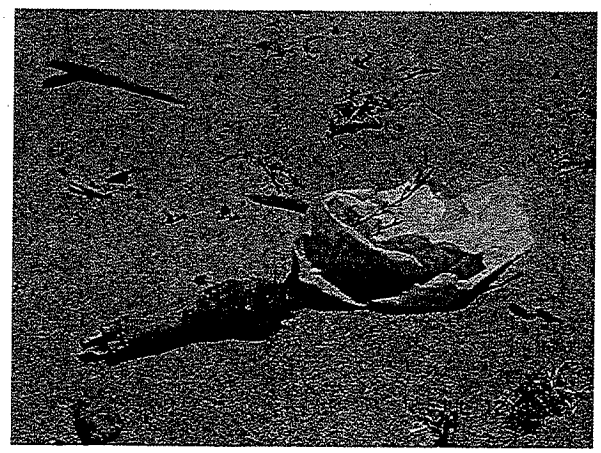






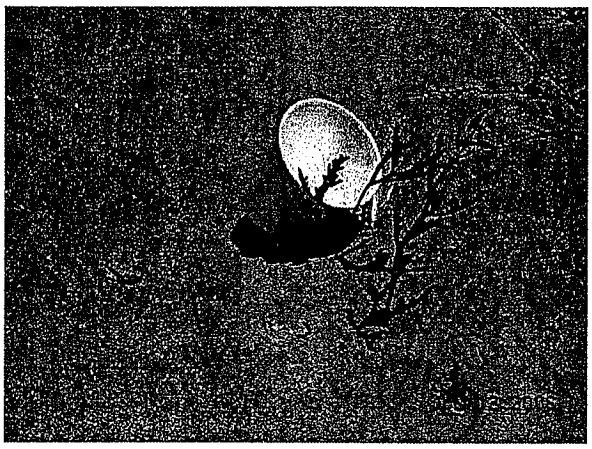


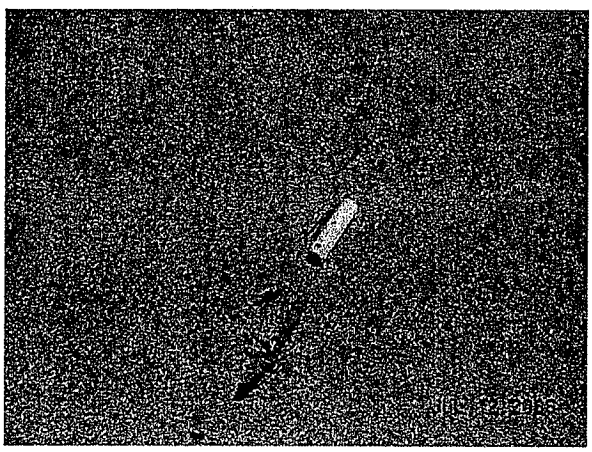


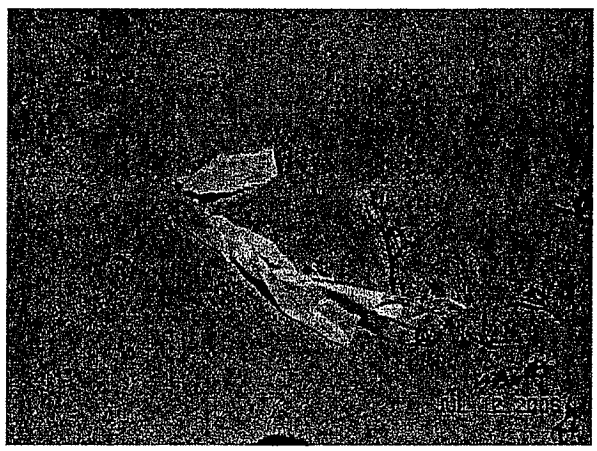


A015046

Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)

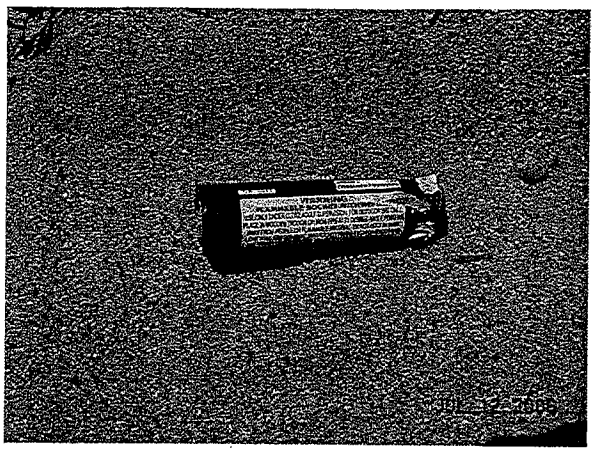


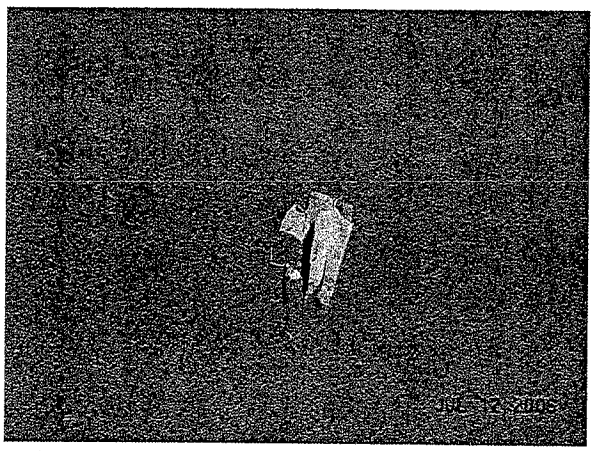


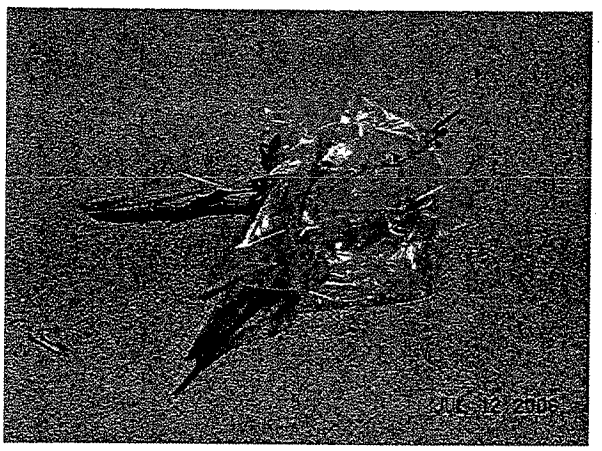


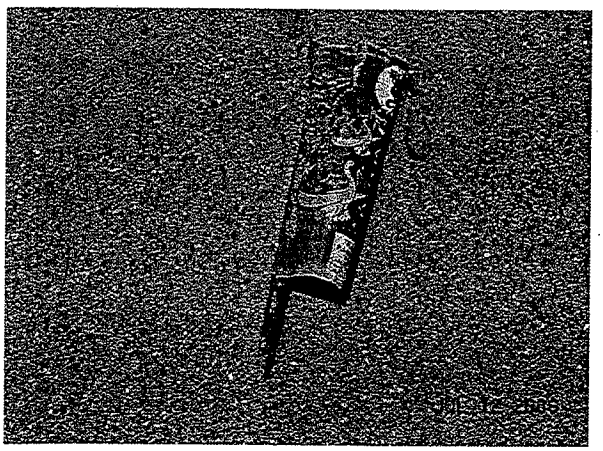
A015047

Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)



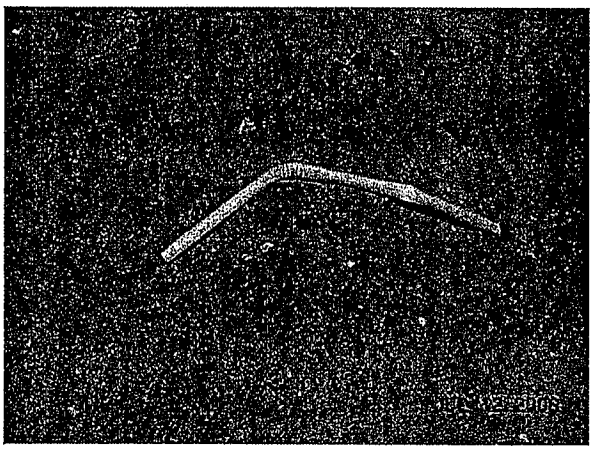


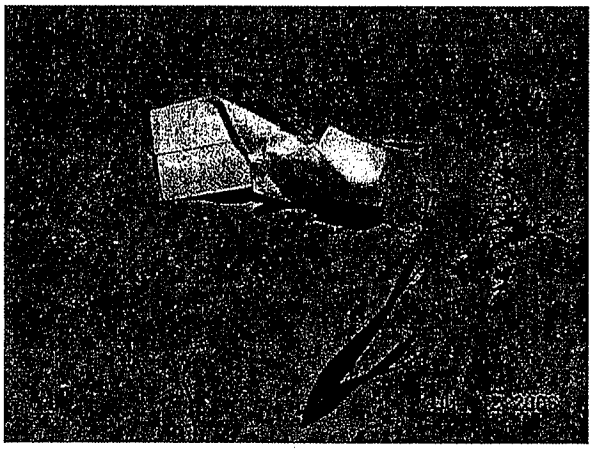


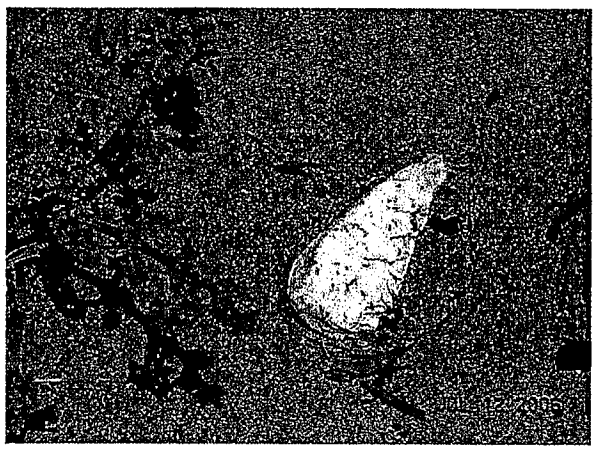


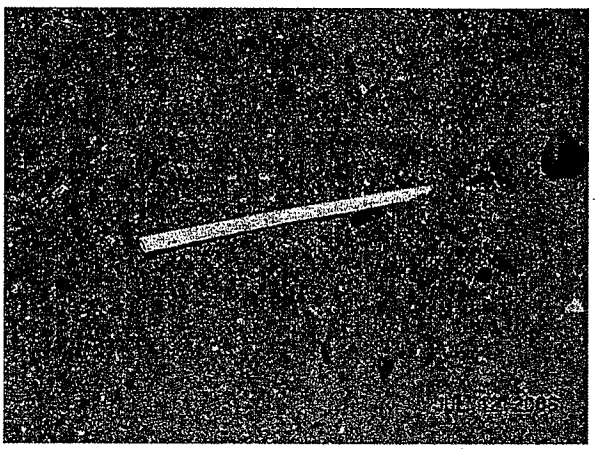
A015048

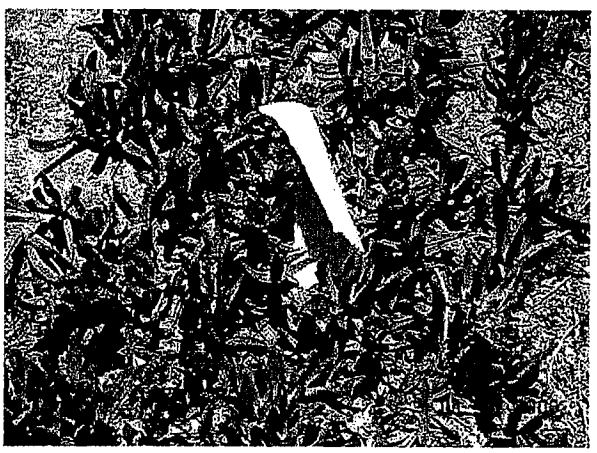
Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)





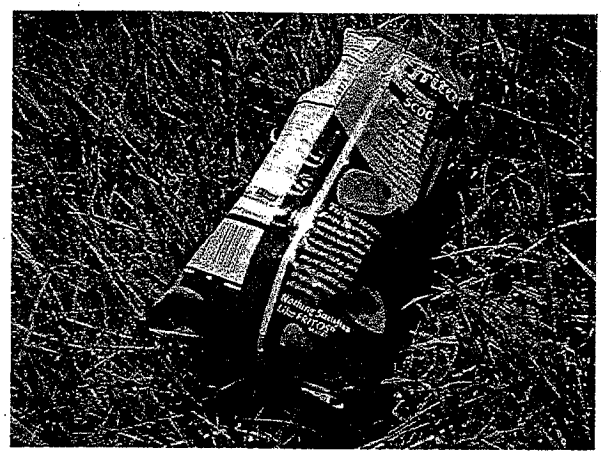






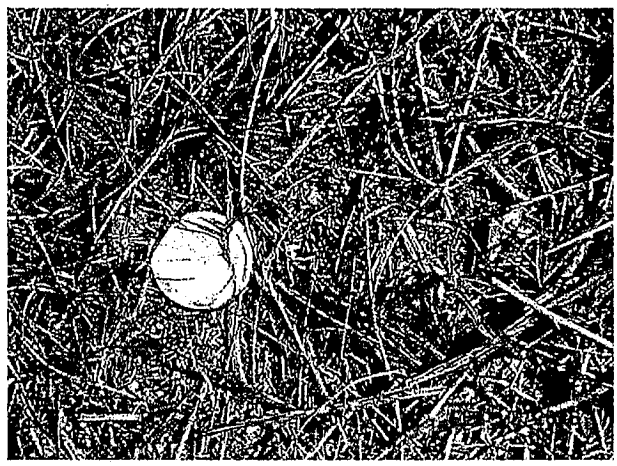
A015049

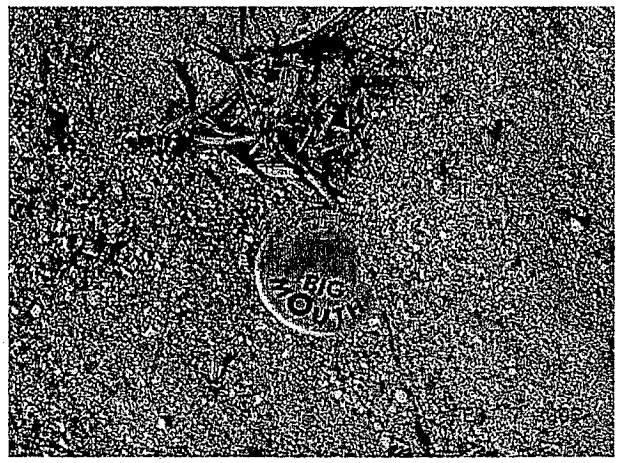
Trash & Debris Photos from Ormond Beach
City of Oxnard
July 12, 2006 (Wednesday)

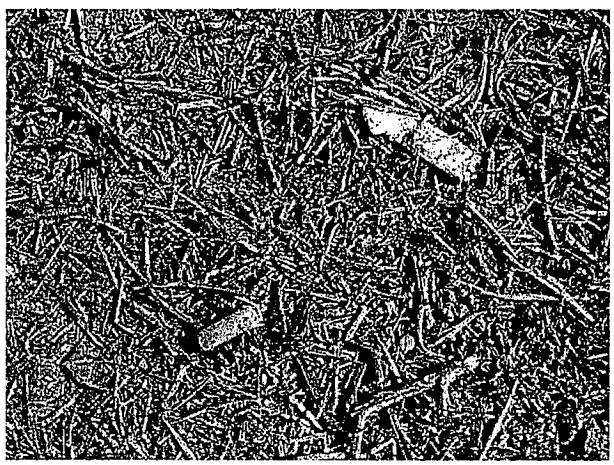


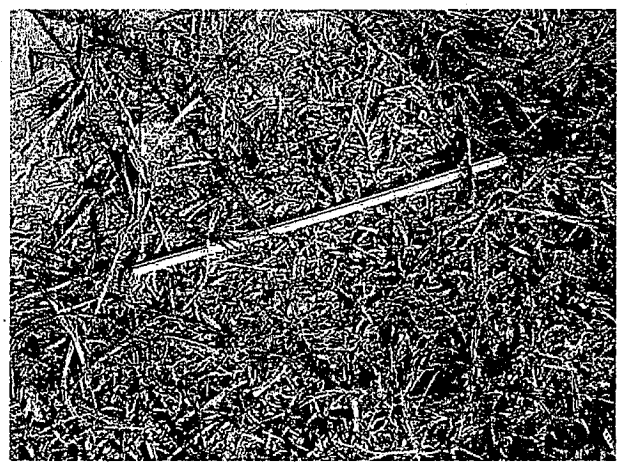
A015050

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
February 7, 2006 (Tuesday)



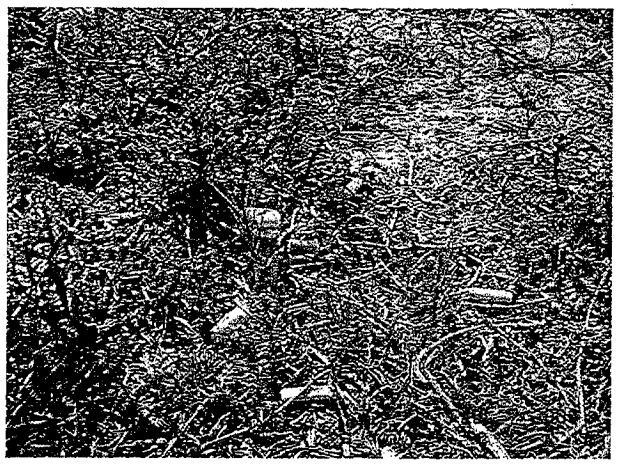


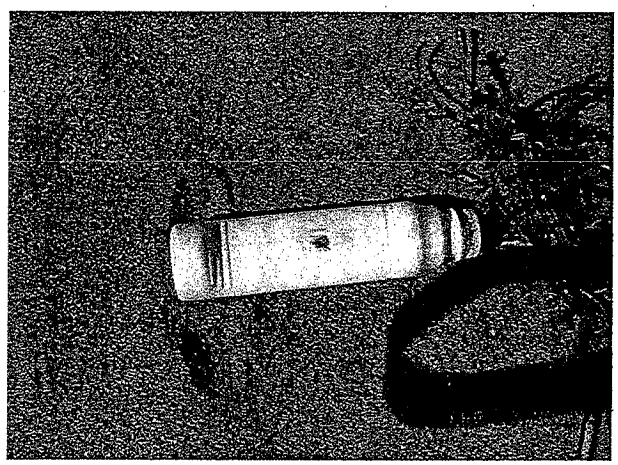




A015051

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
February 7, 2006 (Tuesday)

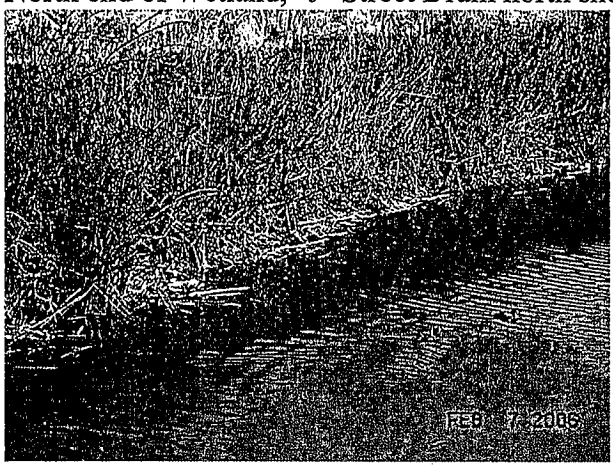




North end of Wetland, "J" Street Drain north shore. Drain empties into Ormond Lagoon.

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
February 7, 2006 (Tuesday)

North end of Wetland, "J" Street Drain north shore.

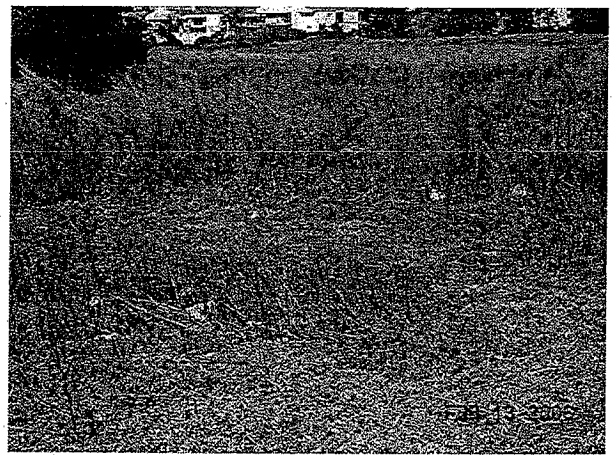


Northeast corner of Wetland, intersection of "J" Street Drain & Ormond Lagoon,

West Side of Wetland, Ormond Lagoon shore - "J" Street Drain & OID empty into lagoon.

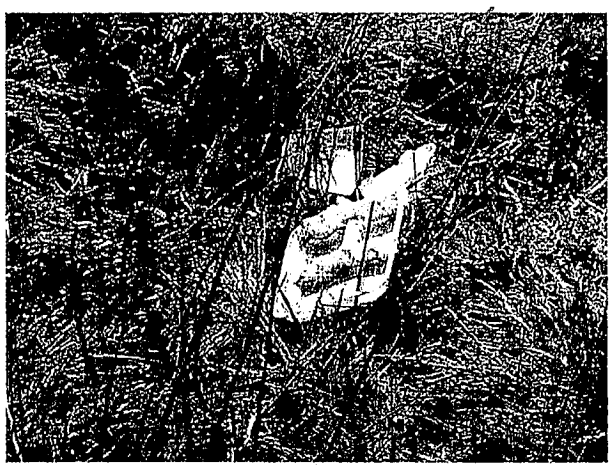
A015053

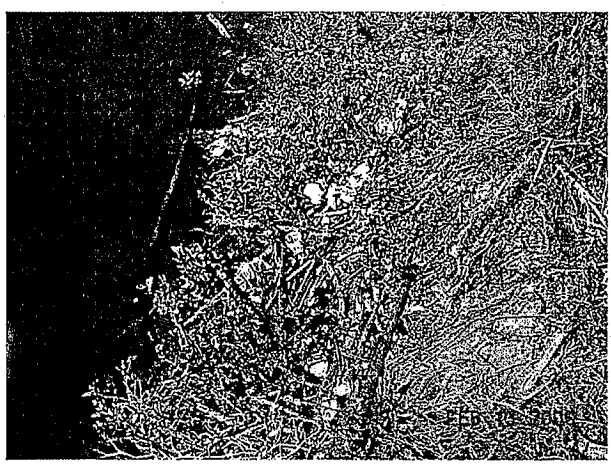
Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)

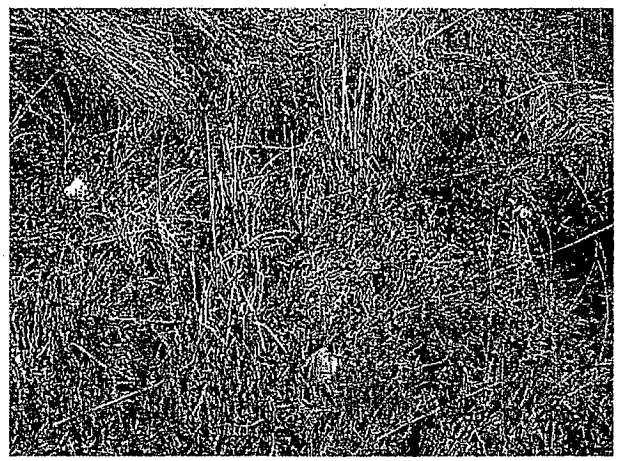


 A015054

Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)

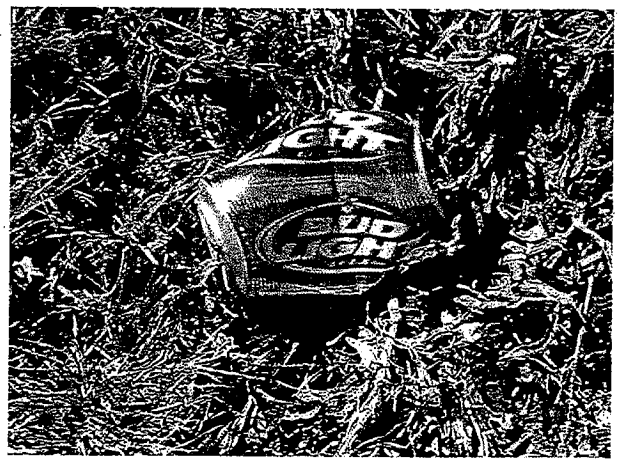






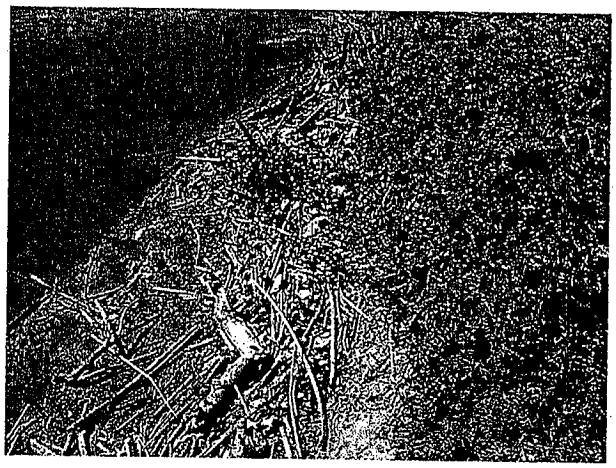
A015055

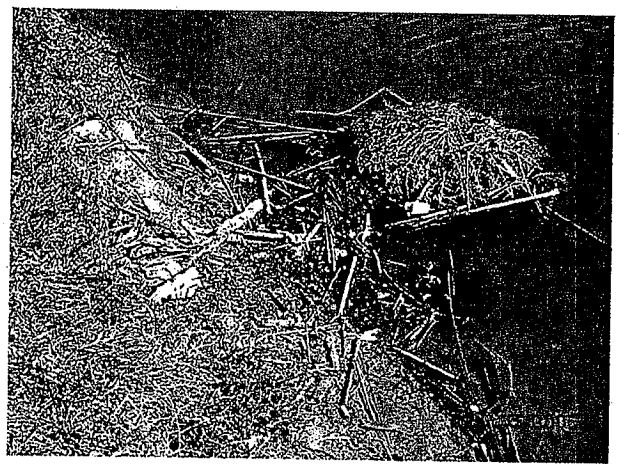
Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)

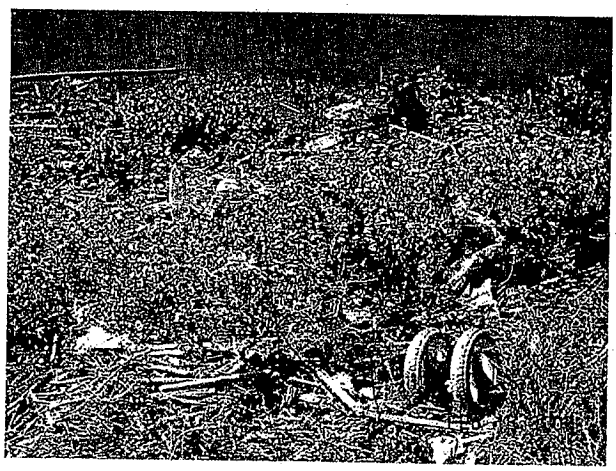


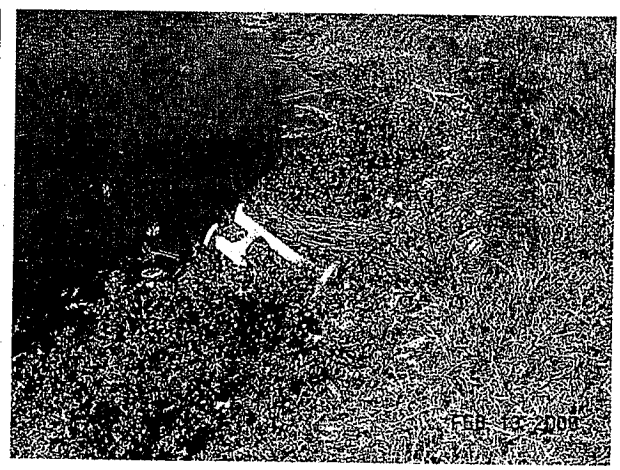
 A015056

Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)



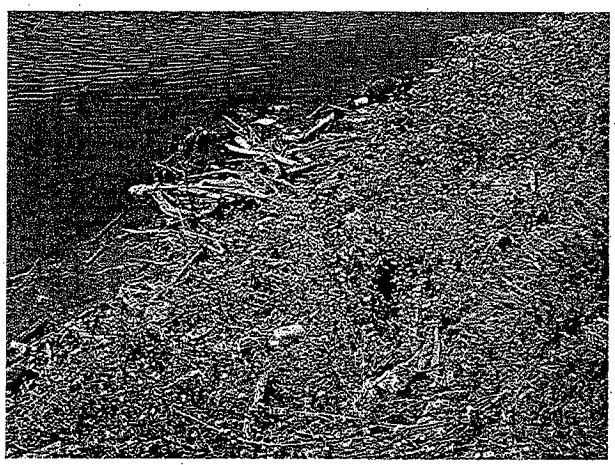


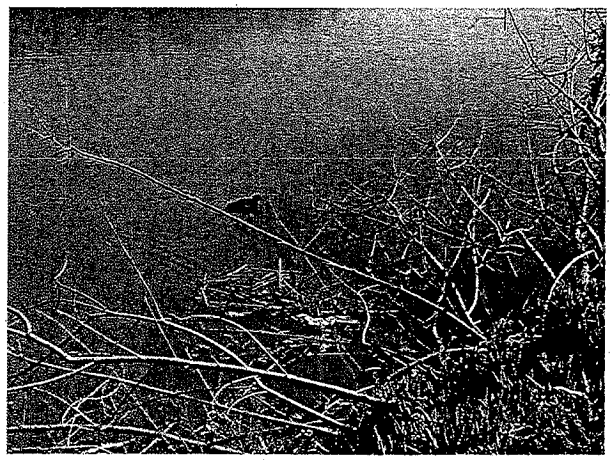




 A015057

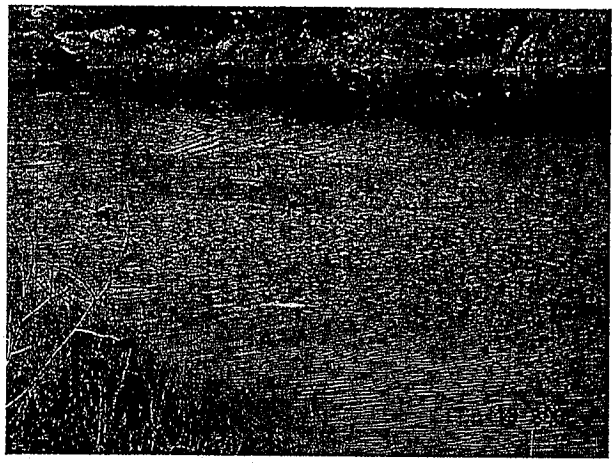
Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)

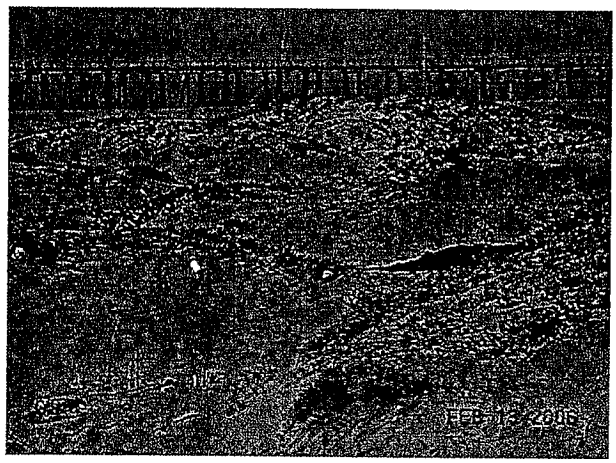


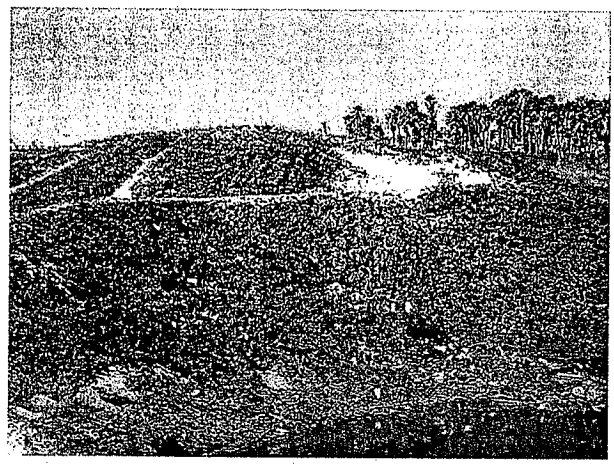


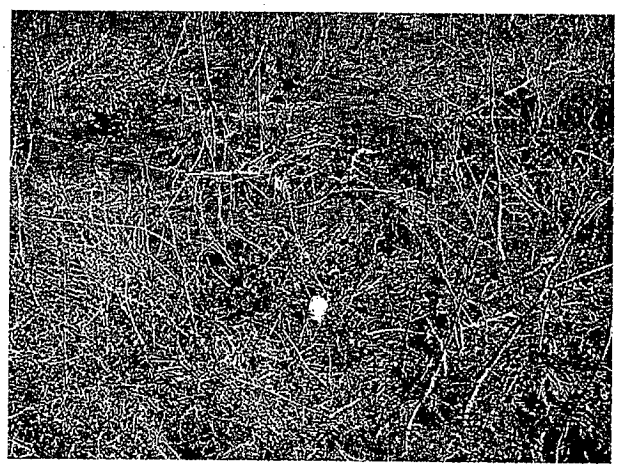
 A015058

Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)



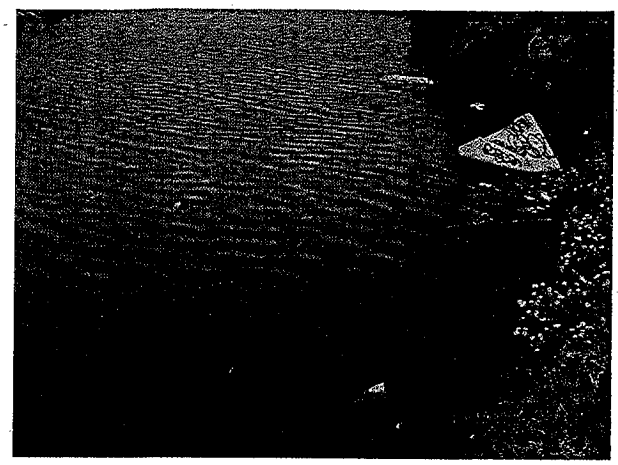


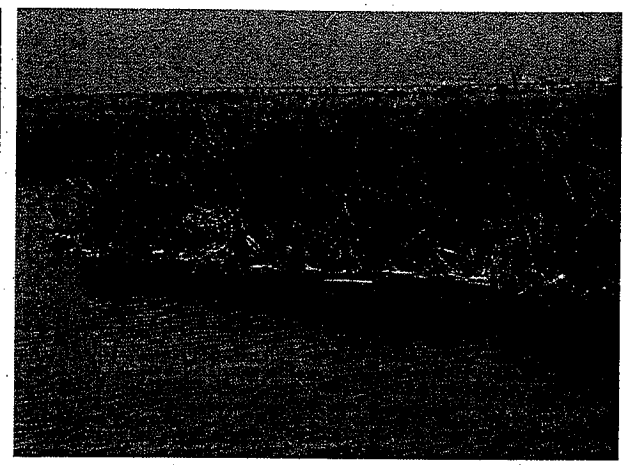




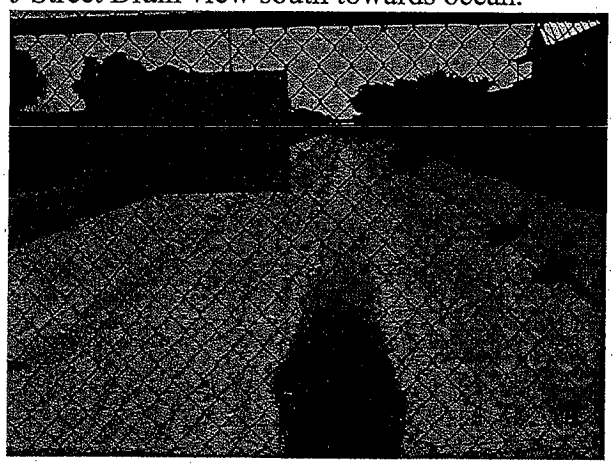
 A015059

Trash & Debris Photos from Westside of Ormond Wetlands/Beach/Lagoon & "J" Street Drain, City of Oxnard
February 13, 2006 (Monday)





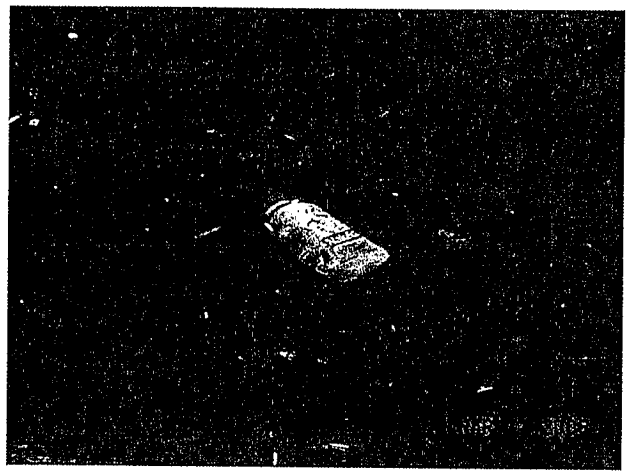
J Street Drain view south towards ocean.

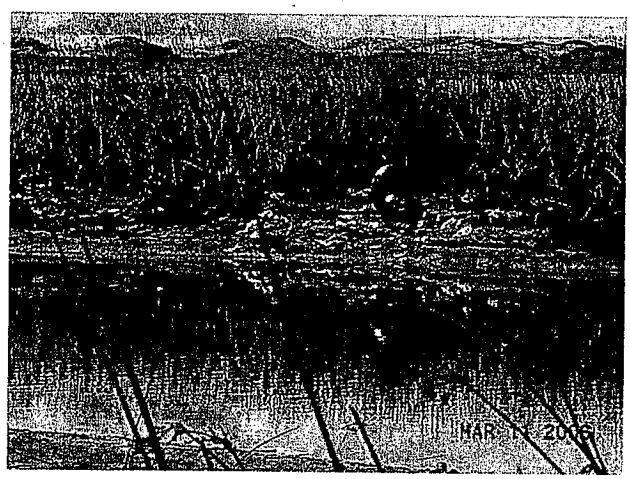


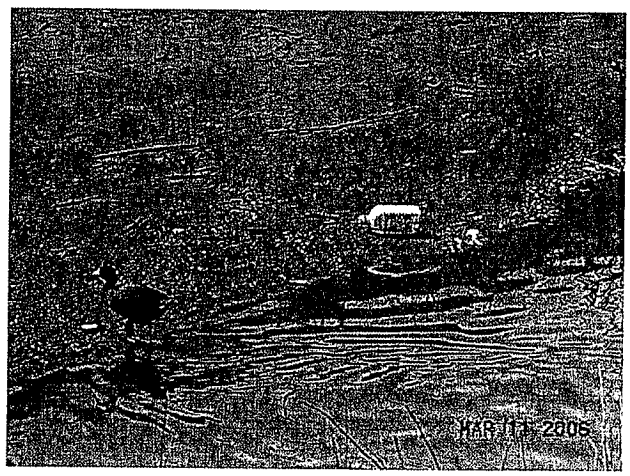
J Street Drain view north.

 A015060

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)

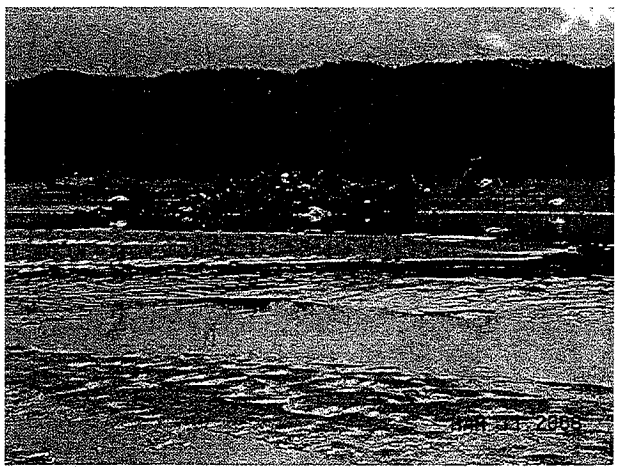






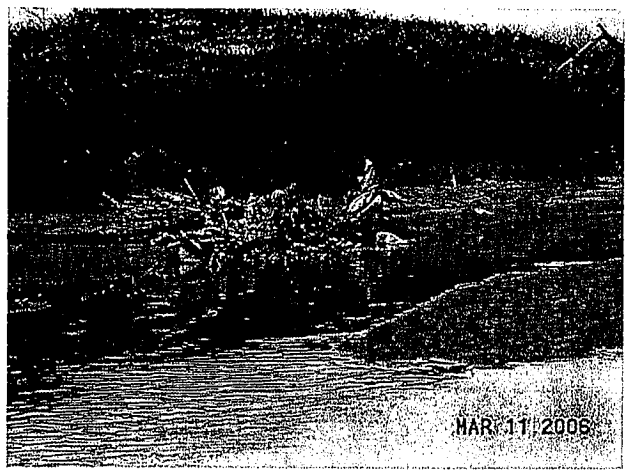
A015061

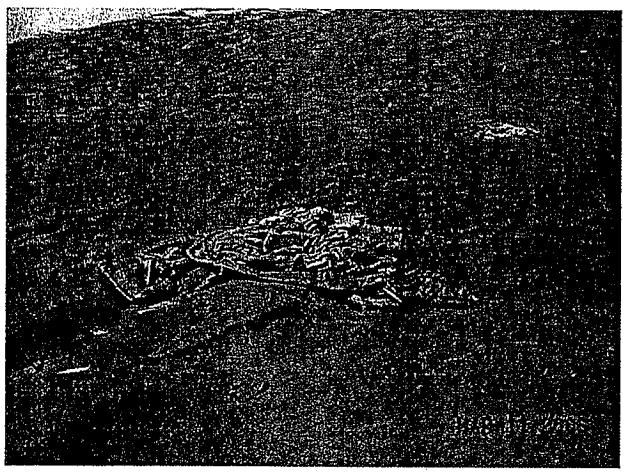
Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)

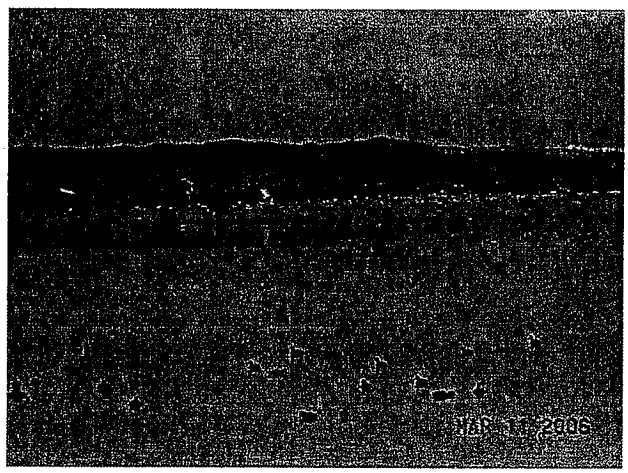


A015062

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)

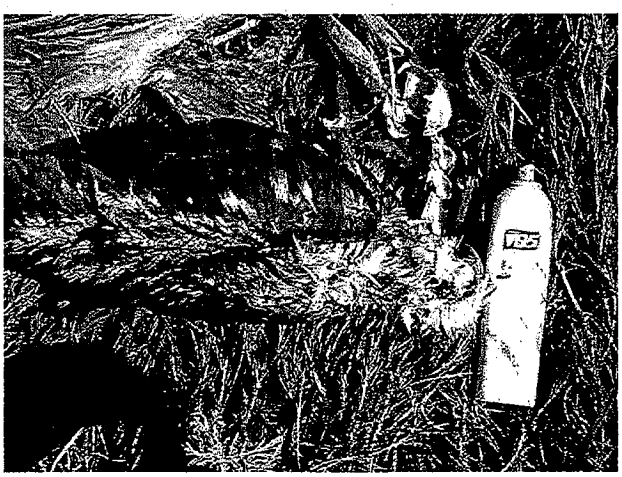


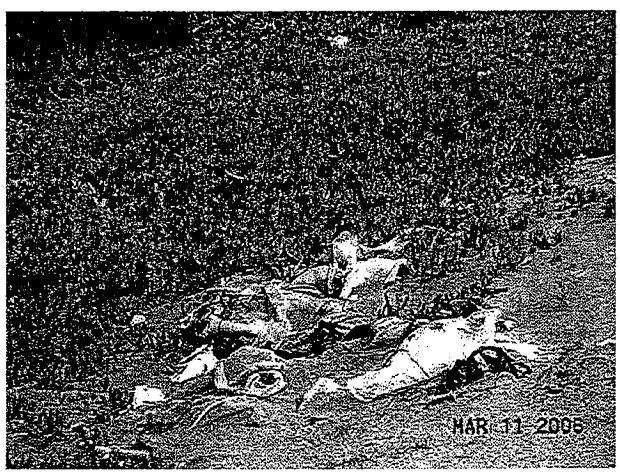




A015063

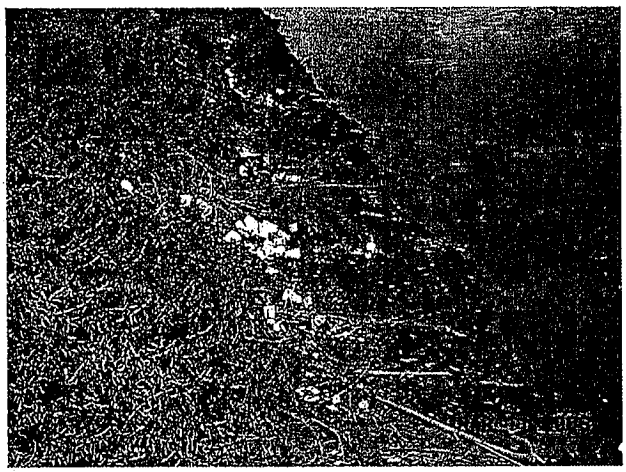
Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)

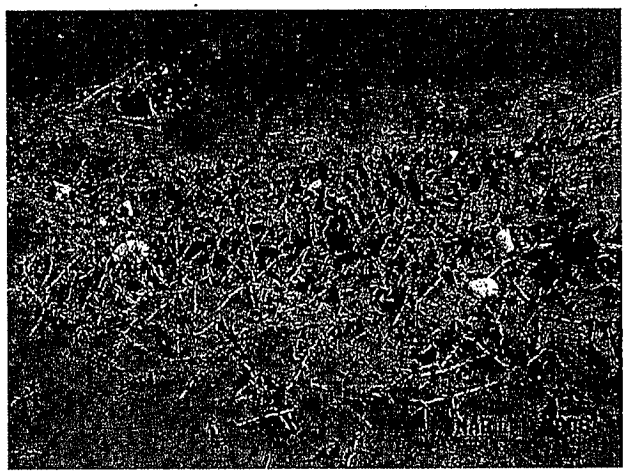


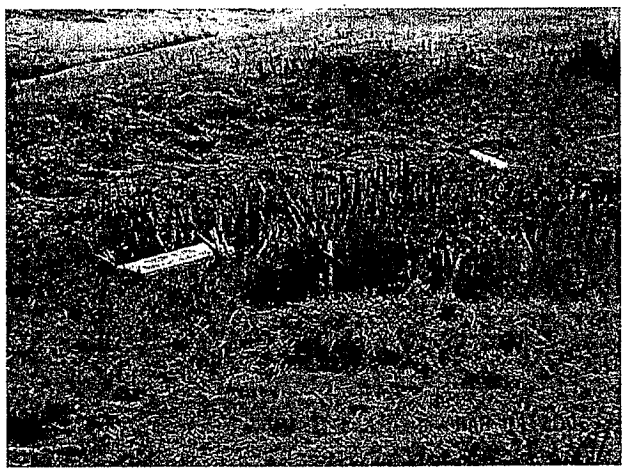


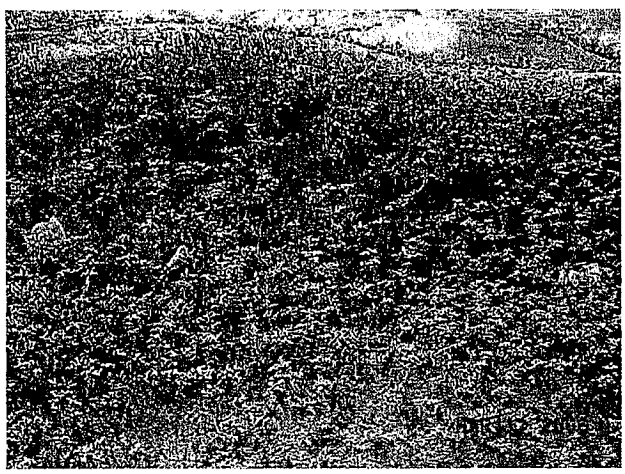
A015064

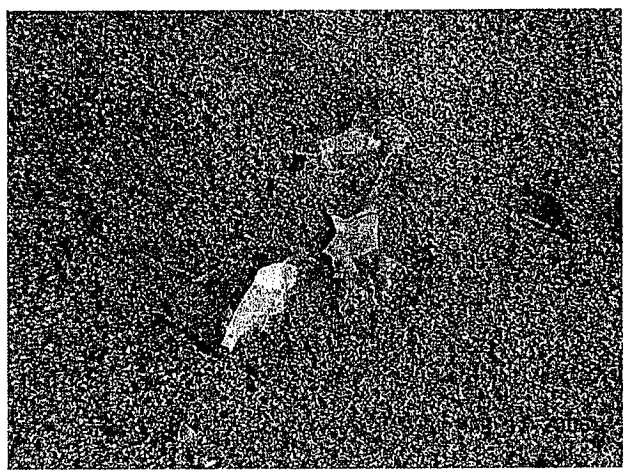
Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)





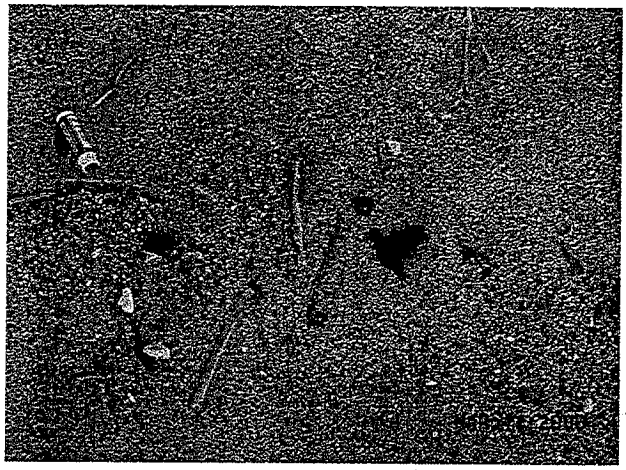


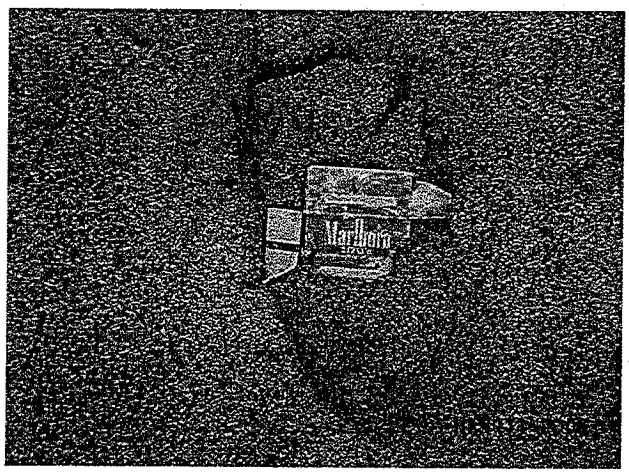


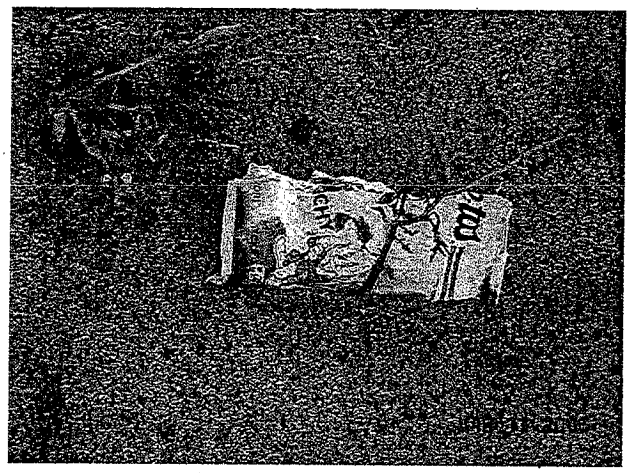


A015065

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain,
City of Oxnard
March 11, 2006 (Saturday)

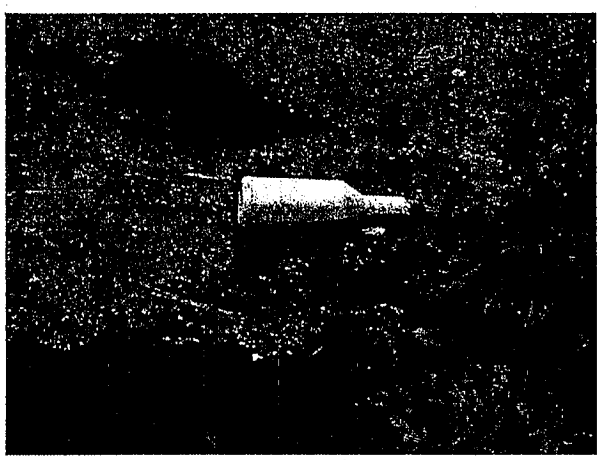


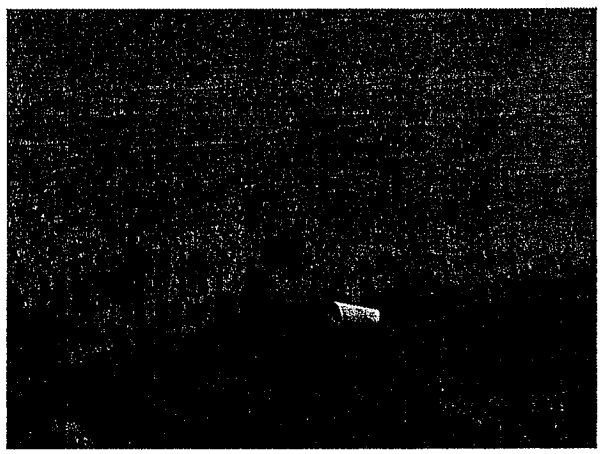


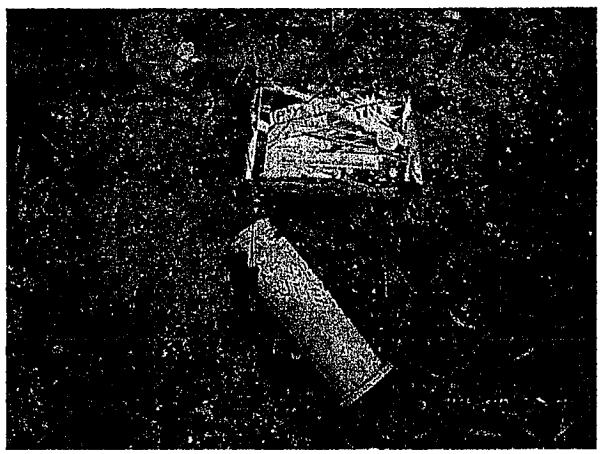


A015066

Trash & Debris Photos from Ormond Wetlands-Lagoon
City of Oxnard
June 19, 2006 (Monday)

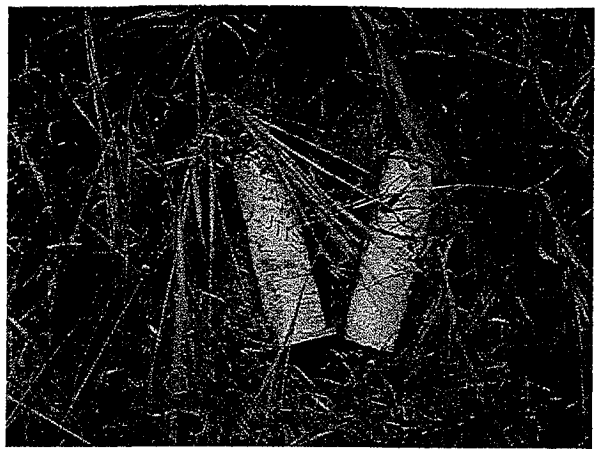


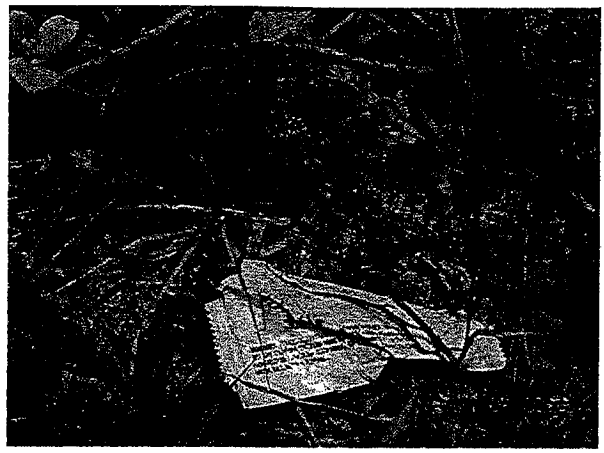


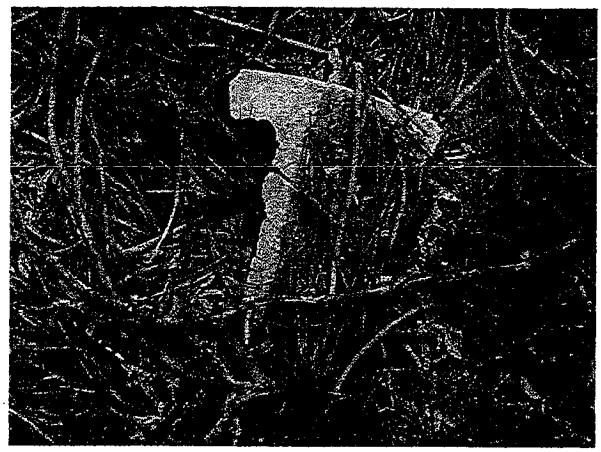


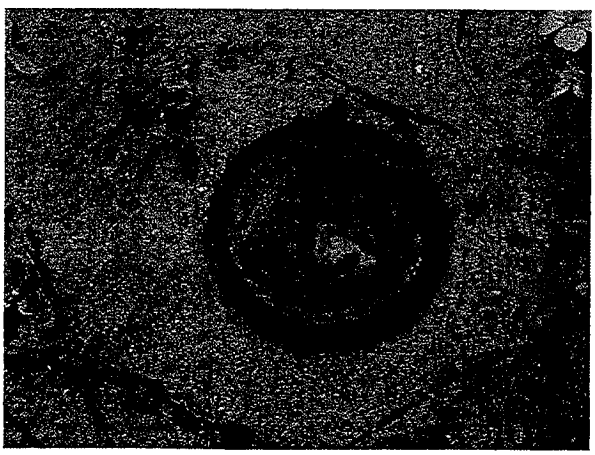
A015067

Trash & Debris Photos from Ormond Wetlands-Lagoon
City of Oxnard
June 19, 2006 (Monday)



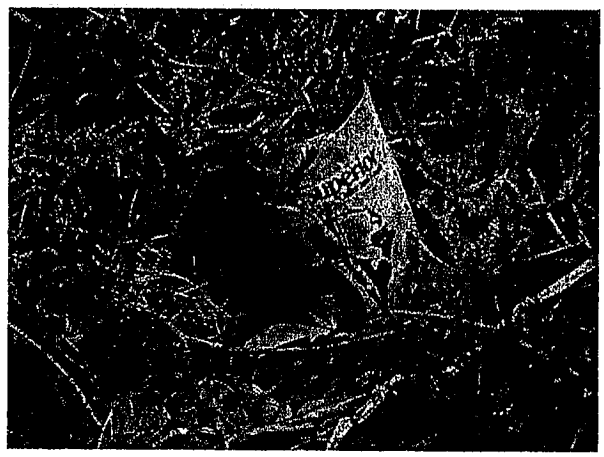


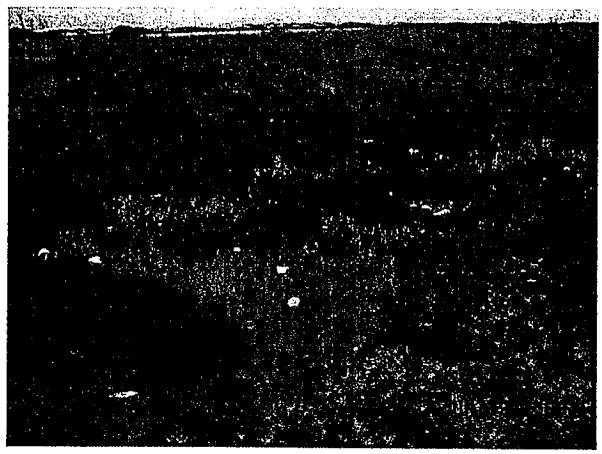


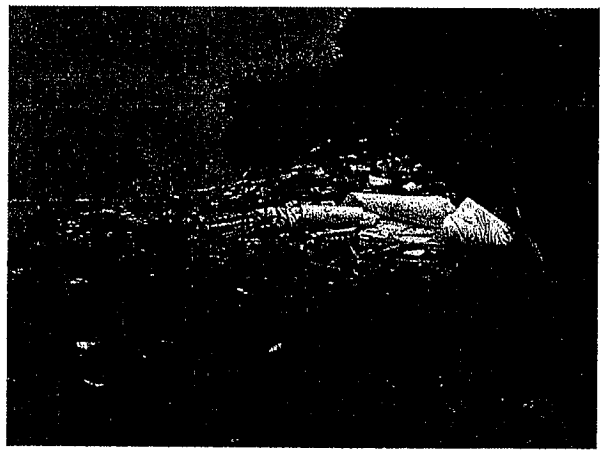


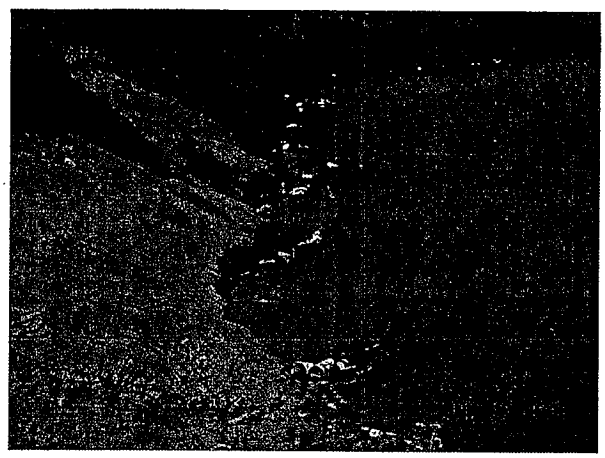
A015068

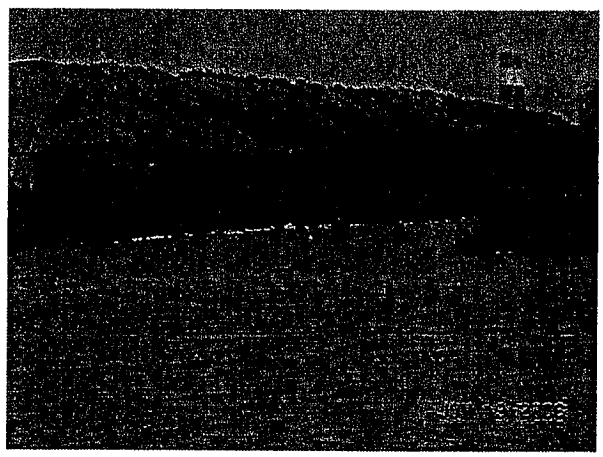
Trash & Debris Photos from Ormond Wetlands-Lagoon
City of Oxnard
June 19, 2006 (Monday)





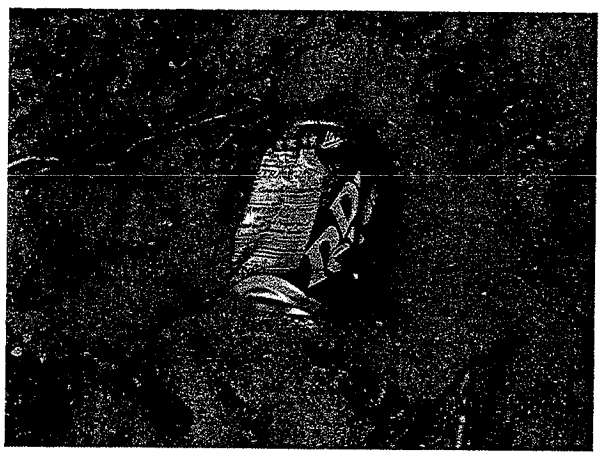


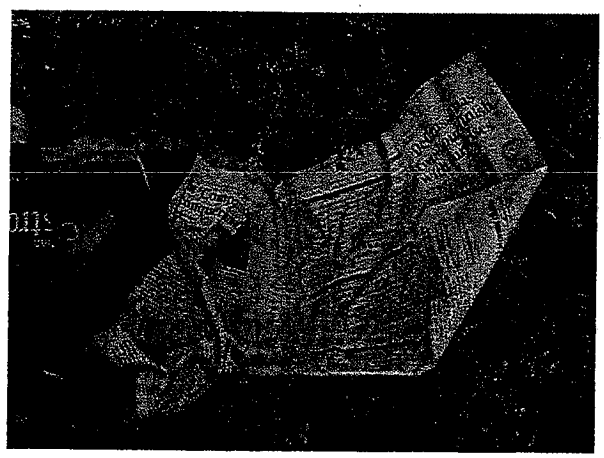


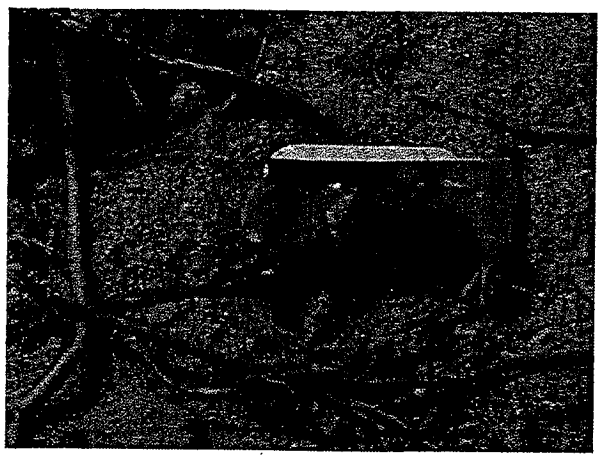


A015069

Trash & Debris Photos from Ormond Wetlands-Lagoon
City of Oxnard
June 19, 2006 (Monday)

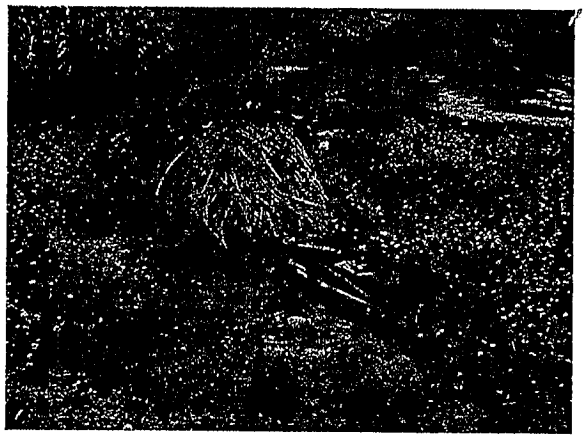


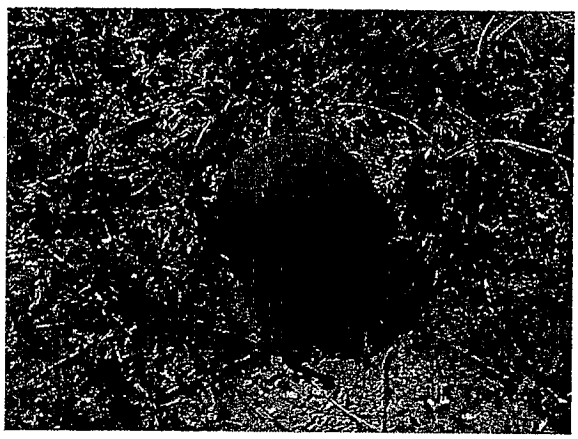


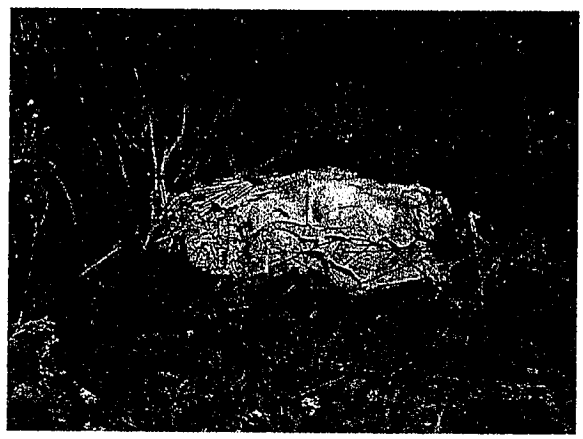


A015070

Trash & Debris Photos from Ormond Wetlands-Lagoon
City of Oxnard
June 19, 2006 (Monday)



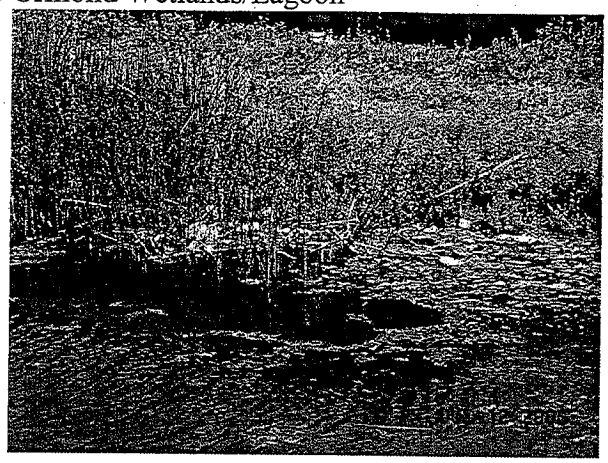


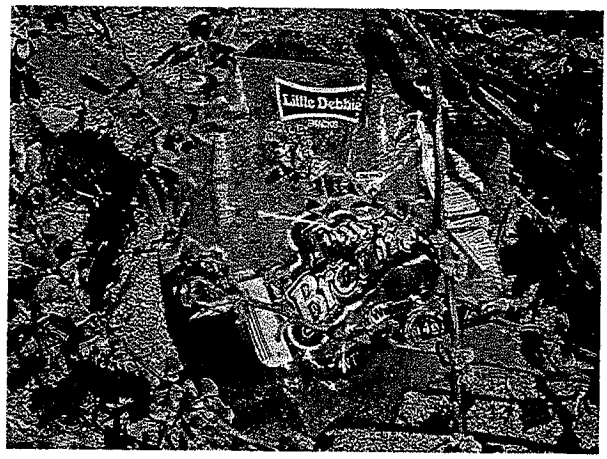


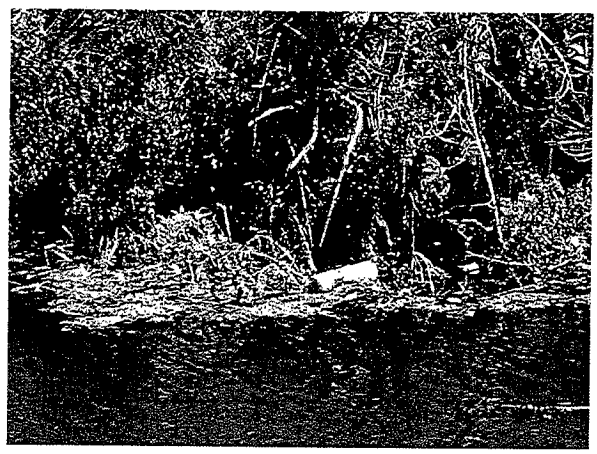
A015071

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)

Ormond Wetlands/Lagoon



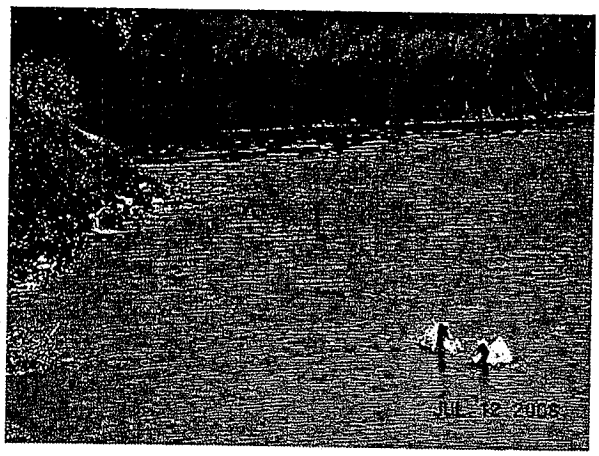


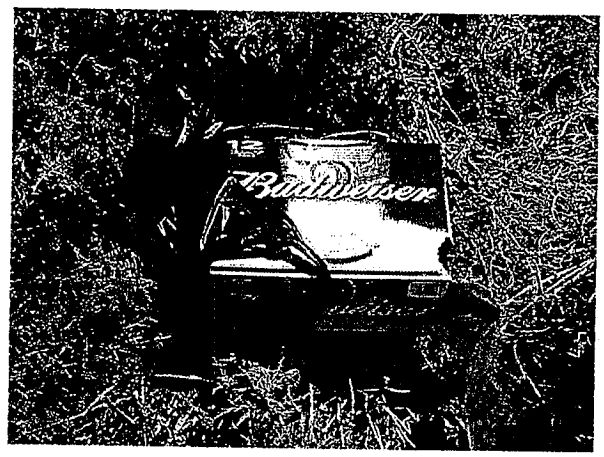


A015072

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)

Ormond Wetlands/Lagoon

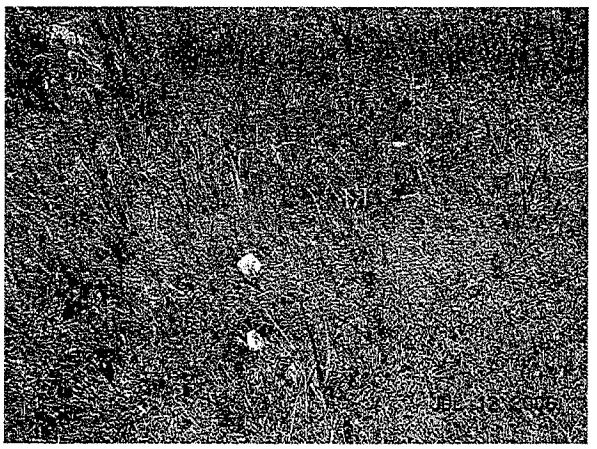


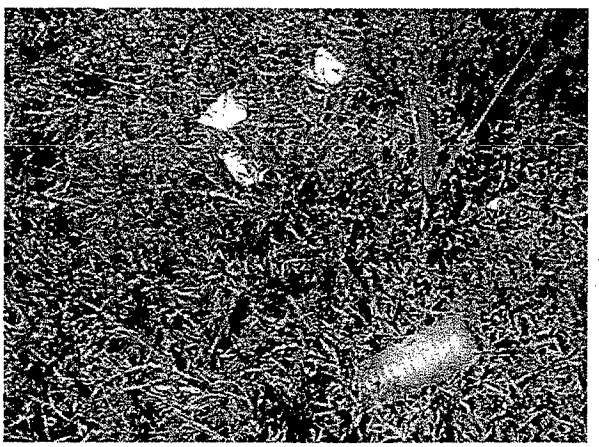


A015073

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)

Ormond Wetlands/Lagoon

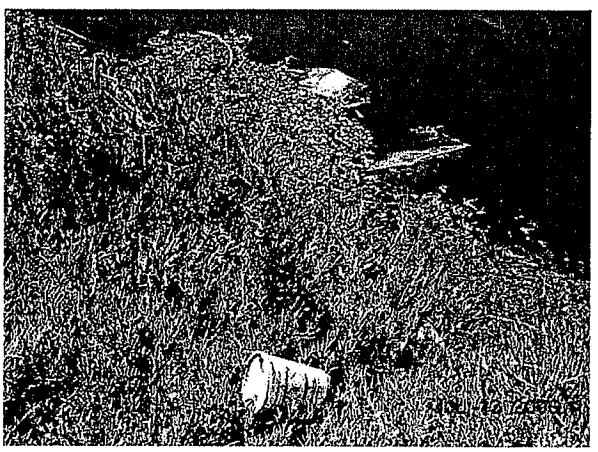




A015074

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)

Ormond Wetlands/Lagoon

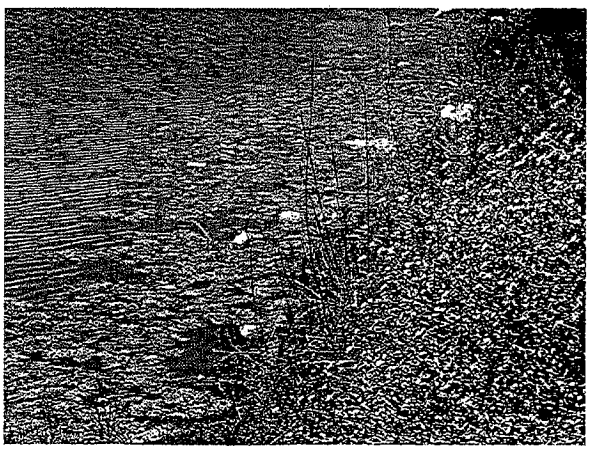


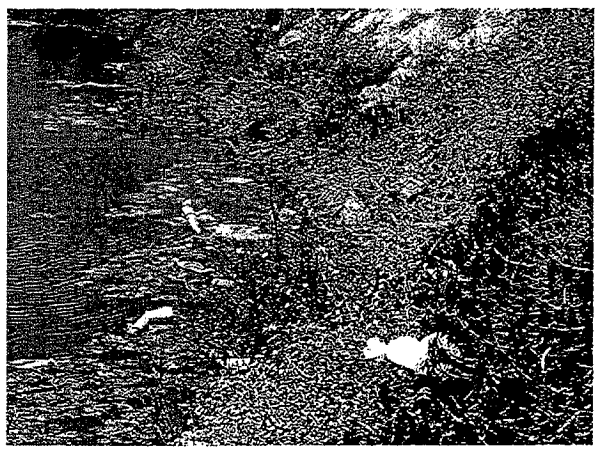
A015075

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)

J Street Drain

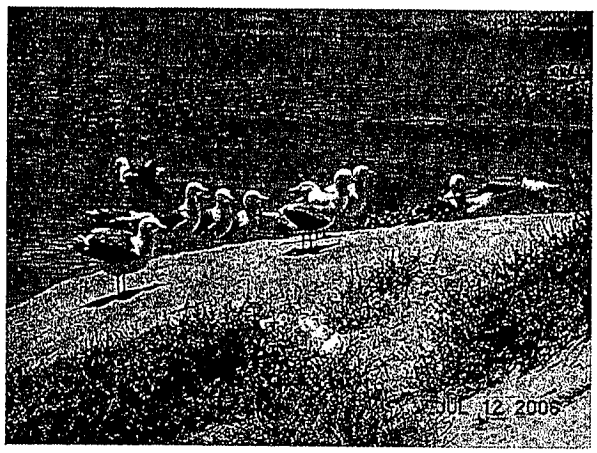
J Street Drain flows into Ormond Wetlands/Lagoon

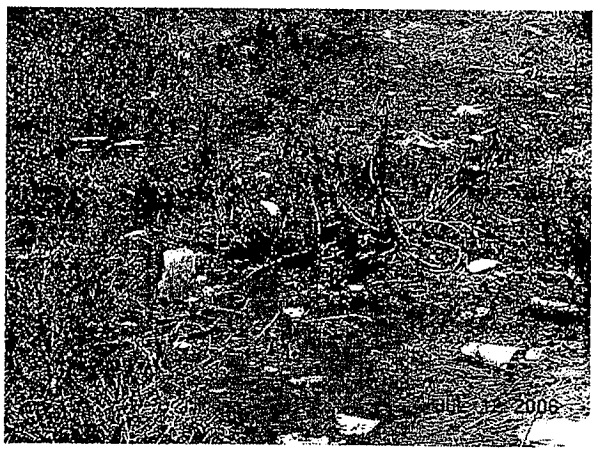


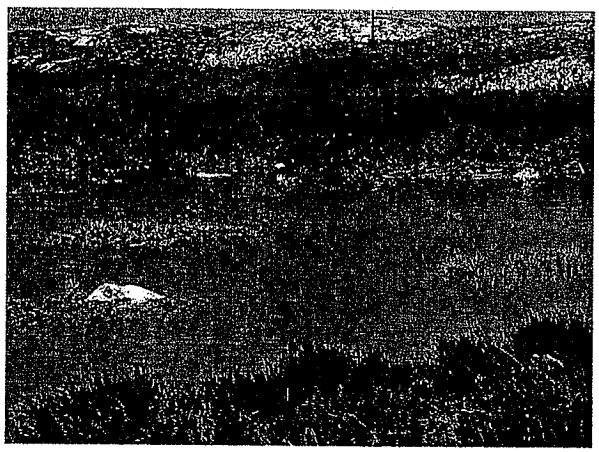


A015076

Trash & Debris Photos from Westside of Ormond Wetlands/Lagoon & J Street Drain
City of Oxnard
July 12, 2006 (Wednesday)



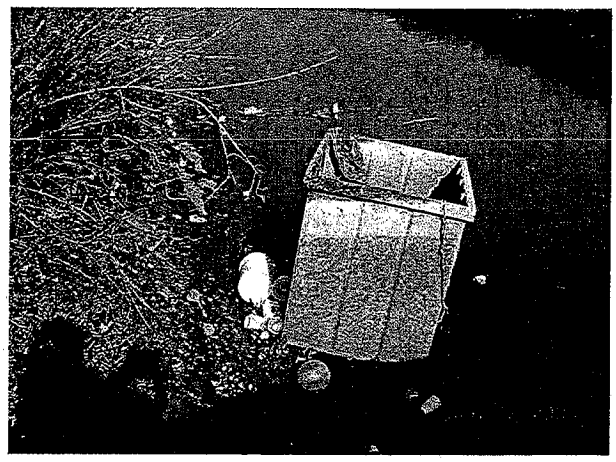


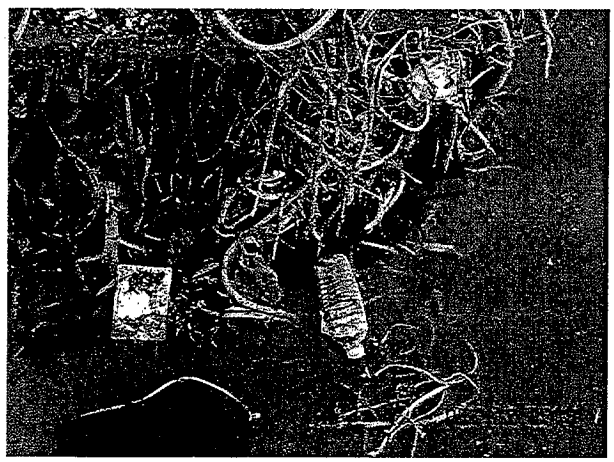


A015077

Trash & Debris Photos from Oxnard Industrial Drain (OID)
City of Oxnard
December 12, 2006 (Tuesday)

OID - Taken from Halaco's bridge.





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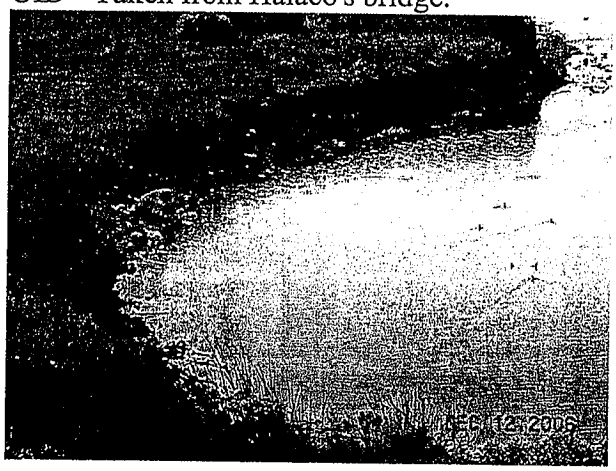
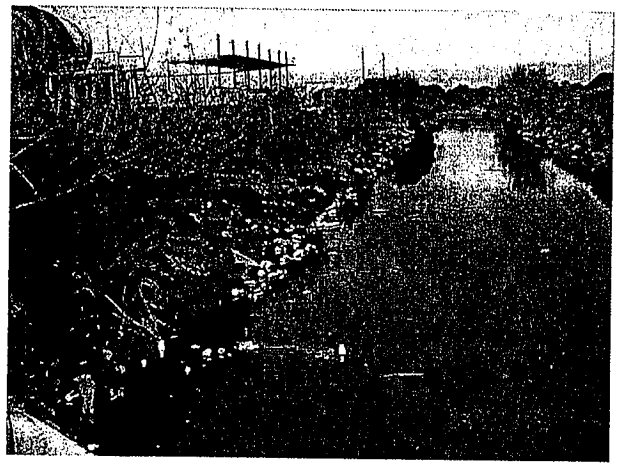
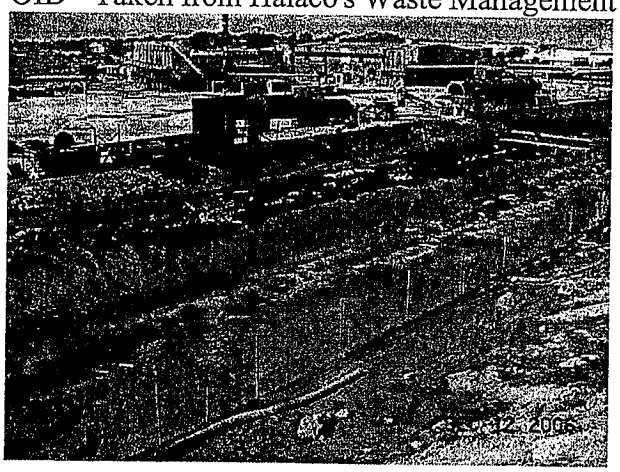
Trash & Debris Photos from Oxnard Industrial Drain (OID)
City of Oxnard
December 12, 2006 (Tuesday)

OID - Taken from Halaco's bridge.





OID - Taken from Halaco's Waste Management Unit



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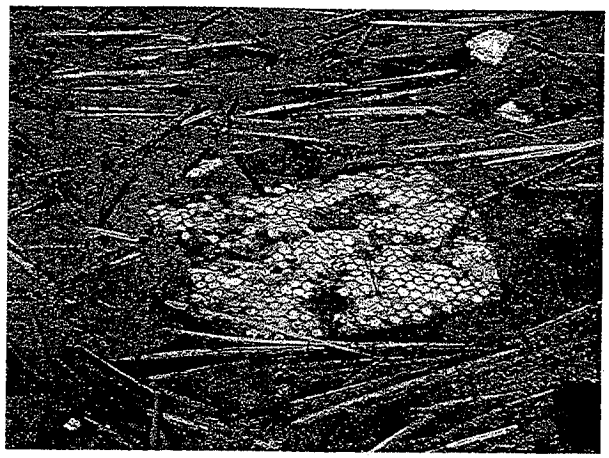
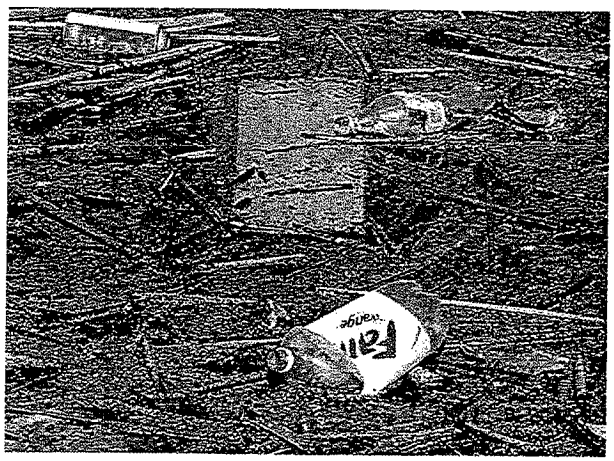
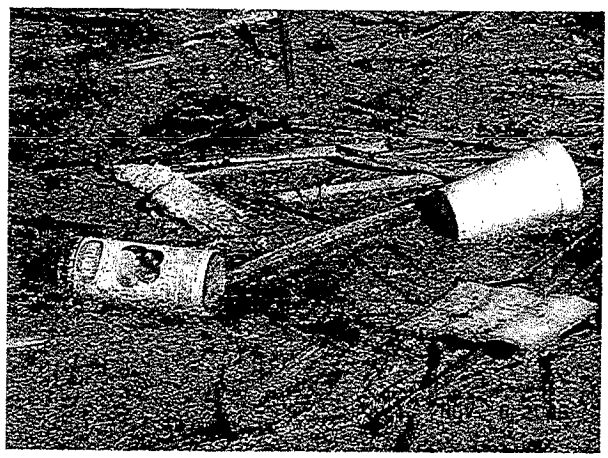
City of Oxnard
December 8, 2006 (Wednesday)

OID - Taken from Halaco's bridge.







Composition and distribution of beach debris in Orange County, California

Shelly L. Moore, Dominic Gregorio[1], Michael Carreon[2], Stephen B. Weisberg, and Molly K. Leecaster[3]

ABSTRACT

Many studies have quantified the amount of debris collected along beach shoreline areas in various locations around the world. Only a few of those studies have been conducted in the United States, and they are largely limited to semi-quantitative efforts performed as part of volunteer clean-up activities. In this study, we quantified the distribution and types of beach debris by sampling 43 stratified random sites from Seal Beach to San Clemente on the Orange County, California, coast from August to September, 1998. An area of shoreline was delineated for each site that was 25 yards in length and extended from the water's edge to the first pavement or rocky cliff. All trash was collected by at least three people walking systematically along transects. In addition, a five-gallon bucket was used to sieve one bucket of sand at each site to collect and quantify the small items that were undetectable by visual examination. Based upon the survey data results, it was estimated that more than 106 million items, weighing approximately 13 tons, occur on Orange County shorelines. The most abundant items were pre-production plastic pellets, followed by foamed plastics and hard plastics. Debris density on the remote rocky shoreline was greater than that on high-use sandy beaches for most debris items. This finding partially reflects the periodic cleanup of high-use beaches by local municipalities, and also indicates that a high percentage of the observed debris was transported to the site from waterborne sources. The amount of Orange County beach debris estimated by this study is 50 times that (excluding pre-production plastic pellets) collected in the California Coastal Cleanup Day. The difference appears to be attributable to Cleanup Day's focus on large, visible debris at a subset of high-use beaches that are periodically cleaned by mechanical combers.

INTRODUCTION

Beaches along the southern California coast are used extensively for a variety of recreational purposes, attracting almost 150 million visitors annually (Schiff *et al.* 1999). Recreational uses such as boating, swimming, surfing, sunbathing, and picnicking generate debris along the shoreline including food bags and wrappers, cups and utensils, trash bags, fast-food and other product containers, toys, fishing lures and floats, and plastic. In addition, southern California has the highest coastal population density of any area in the country (Culliton *et al.* 1988), providing an additional source of debris via urban runoff and maritime disposal (including accidental spills). Debris is one of the most highly visible expressions of human impact on the marine environment, which is one of

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Debris from an Orange County beach.

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the factors that has led to the popularity of public cleanup efforts along the shoreline (Ribic *et al.* 1997). More than an aesthetic issue, debris can threaten marine mammals, birds, and turtles through ingestion and entanglement (Bjorndal *et al.* 1994, Fowler 1987, Robards 1993, Ryan 1987). Marine debris is also becoming a regulatory focal point. The Los Angeles Regional Water Quality Control Board recently implemented legal limitations, through the total maximum daily load (TMDL) process, on the amount of trash that local governments can allow to enter the ocean through storm drains.

Many studies have enumerated the types and amount of marine debris on beaches (Corbin and Singh 1993, Garrity and Levings 1993, Golik 1997, Golik and Gertner 1992, Lucas 1992, Ross *et al.* 1991, Ribic *et al.* 1997, Walker *et al.* 1997, Willoughby 1986), and a few studies have quantified subsurface nearshore debris (June 1990, Moore and Allen 2000). Most of the debris data for beaches outside of the United States have been collected through systematic, scientifically rigorous studies, while most of the information within the United States has been derived from volunteer beach cleaning efforts. Although cleaning efforts are valuable for removing debris from beaches, they provide only semi-quantitative estimates of debris. Here we present the first study to quantitatively assess the types and amount of debris on the California coast, with a secondary objective of describing how debris differs among shoreline types.

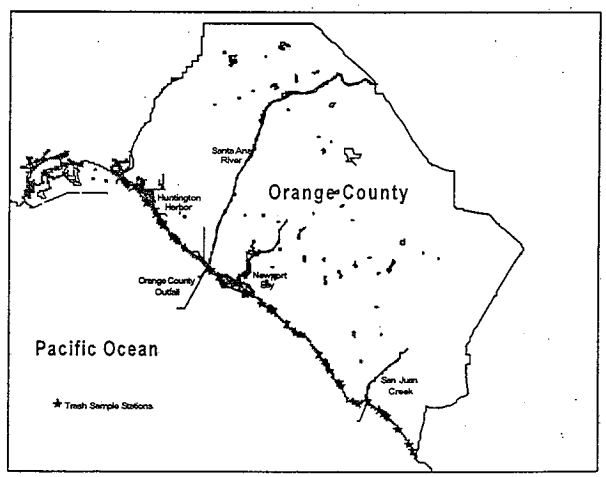
METHODS

Beach debris was surveyed and collected at 43 sites from Seal Beach to San Clemente on the Orange County, California, coast between August 2 and September 18, 1998 (Figure 1). Sites were selected using a stratified random design, stratified by shoreline type (rocky shoreline and sandy beach). Sample sites were selected randomly within the strata and a systematic component was overlayed to minimize clustering, following the sampling design used in the National Stream Survey (Overton 1987). Each stratum was subdivided into a series of sections (each identified by a count variable) of like-strata joined together into a stratum line. A partition was created for each stratum line, with the number of intervals in the partition equal to the sample size. The partition was placed over this stratum line by selecting a random starting point for the beginning of the first interval. Based upon this starting point, the intervals were defined as consecutive equal-width lengths. A simple random sample of one point was then chosen from within each interval. Each point was translated back to the shoreline using the section count variable. The partition structure ensures systematic separation of the sampling, while the random selection of sites within partitions ensures an unbiased estimate of beach debris.

Each sample site was delineated as an area 25 yards in length that extends from the water's edge to the first pavement or rocky cliff. All trash at the site was collected by at least three people walking systematically along transects to ensure that all areas within the sample site were examined. All debris was bagged and transported to the laboratory for identification and quantification. In addition, a five-gallon bucket was used to sieve one bucket of sand at each site to quantify the small items that were undetectable by visual examination. In the laboratory, debris was sorted into the broad categories used by the Center for Marine Conservation during their Coastal Cleanup days (i.e., glass, metal, plastics, foamed plastics, rubber, paper, wood, and cloth). From each broad category, debris was further sorted into more specific subcategories (e.g., cups, plates, etc.), enumerated, and weighed. Within the specific categories, brand names were recorded, when possible, to establish cross-brand trends.

The total amount of debris along the Orange County coast was estimated by calculating a mean amount of trash for a 25-yard segment within each strata and then weighting those means by the relative amount of shoreline distance in each strata. Estimates for smaller debris collected by sieving were calculated using a similar methodology, after estimating the number of yards from the water's edge to the first pavement or rocky cliff for each site then extrapolating the abundance for each sample site area.

FIGURE 1. Sample sites for the Orange County beach debris study, August to September 1998.



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RESULTS

More than 106 million items, weighing approximately 13 tons, were estimated to occur along the Orange County shoreline (Table 1). Three categories of plastics (pre-production plastic pellets, foamed plastics, and hard plastics) accounted for 99% of the total abundance and 51% of the total weight. Cigarette butts were fourth in abundance and accounted for less than 1% of the total abundance and weight. Cigarettes, candy, fast–food products, beer, and other beverages were the most identified brand-related debris (Table 2). Marlboro®, Starburst®, Jack in the Box®, Budweiser Light®, and Coca Cola® all led in their respective categories.

Most of the plastics encountered were in the form of small pieces of plastic (Table 3). Foamed plastic pieces accounted for 88% of the total foamed plastics and hard plastic pieces accounted for 50% of the total hard plastics. Of the whole plastic items, food and beverage items were the most abundant.

The distribution of debris differed among shoreline types. Sandy beaches are eight times more abundant than rocky shoreline in Orange County, but most debris did not reflect this ratio (Table 4). Foamed and hard plastics, glass, rubber, and animal droppings all occurred at higher proportions on rocky beaches. Pre-production plastic pellets, paper, wood, and cloth all occurred at higher proportions on sandy beaches. Cigarette butts and metal were found at approximately equal ratios between beach types.

DISCUSSION

The most abundant item found on southern California beaches was pre-production plastic pellets, which are probably lost in transport from the raw materials producers to the processors who mold the pellets into plastic products. The pellets, collected primarily through sieving the surface layers of sand, come in a variety of shapes (ovoid, cylindrical, etc.) and are typically less than 5 mm in diameter. Approximately one quadrillion of these pellets, representing 60 billion pounds of resin, are manufactured annually in the United States alone (U.S. EPA 1992). The presence of these pellets is not unique to U.S. beaches; Gregory (1977, 1978) estimated that approximately 1,000 tons of these pellets occur on New Zealand beaches.

The relative distribution of brand-name products in the debris we collected largely reflects the product's relative market share. For example, we collected 10 times more Marlboro cigarette butts than any other brand, consistent with Marlboro's 32% market share. Similarly, Budweiser and Budweiser Light dominated the beer debris category, as they do in sales. One exception to the high correlation between brand-related debris quantity and market share was in the fast-food container category. Industry leader McDonalds constituted less than 10% of the total debris measured, while Jack in the Box accounted for nearly three times that level. Perhaps the geographic distribution of fast-food restaurants in relation to Orange County beaches was responsible for the

TABLE 1. Estimated total abundance and weight of trash on Orange County beaches, August to September, 1998.

Debris Type	Abundance	Weight (lbs)
Pre-production plastic pellets	105,161,101	4,780
Foamed plastics	742,296	1,526
Hard plastics	642,020	7,910
Cigarette butts	139,447	344
Paper	67,582	870
Wood	27,919	4,554
Metal	23,500	3,015
Glass	22,195	1,944
Rubber	10,742	817
Pet and bird droppings	9,388	17
Cloth	5,949	1,432
Other	10,363	401

TABLE 2. Percent of total of top three brands in main brand categories collected on Orange County beaches, August to September, 1998.

Brand Name	Percent of Total	Percent of Market Share
Cigarette Products		
Marlboro	62	32.3
Camel	7	4.6
Benson & Hedges	7	<2.4
Candy Products		
Starburst	16	na
Snickers	13	na
Blow Pop	9	na
Fast-Food Products		
Jack in the Box	27	3.6
Carls Jr.	19	1.9
KFC	12	<0.9
Beer Products		
Budweiser Light	27	12.9
Budweiser	16	18.3
Corona	7	2.0
Drink Products		
Coca Cola	16	20.6
Pepsi	15	14.2
Capri Sun	8	<1.2

na = Not available

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TABLE 3. Estimated total abundance of plastics on Orange County beaches, August to September, 1998.

Trash Type	Abundance
Foamed Plastics	
Foamed plastic pieces	652,639
Fast food containers	43,167
Other foamed plastics	25,415
Cups	10,595
Packaging material	9,940
Plates	270
Meat trays	180
Buoys	90
Total:	742,296
Plastics	
Plastic pieces	318,790
Caps and lids	88,548
Straws	84,990
Food bags and wrappers	58,394
Other plastic	48,799
Cups and utensils	9,641
Other plastic bags	7,164
Cigarette lighters	5,810
Beverage bottles	4,550
Trash bags	3,729
Toys	2,159
Buckets	1,973
Rope	1,848
Other bottles	1,563
Milk and water bottles	1,182
Diapers	1,003
Strapping bands	449
6-pack holders	321
Fishing line	321
Tampon applicators	301
Fishing lures and floats	281
Oil and lube bottles	114
Light sticks	90
Total:	642,020
Total Plastics	1,384,316

discrepancy in the amount of fast-food product debris collected compared to the brand's respective market share.

Four major sources have been identified as pathways in the transport of debris to the Orange County shoreline: (1) littering by beachgoers, (2) wind currents from upland sources, (3) runoff from land-based activities, and (4) overboard disposal from boating activities (including accidental spills). Each of these sources requires a different management action to effect a reduction in beach debris. Although our study was not designed to differentiate sources, our data suggest that water- based sources (runoff and overboard disposal) were more important than direct littering or wind. One line of evidence for this is that plastic pellets were found in abundance on all shoreline areas and are unlikely to originate from littering or wind. The second line of evidence is the greater density of most debris items found on less-frequented rocky shoreline compared to the sandy beaches (Table 4). While this pattern was true for most debris, an exception was the greater amount of paper products, such as food wrappers, found on sandy beaches, suggesting that they were left by beachgoers.

The only previous quantification of debris on the Orange County shoreline was from data collected by volunteers during the annual California Coastal Cleanup Day. Their 1998 cleanup event occurred the week after the present survey was completed and their estimate of the amount of debris was 50 times lower than our data (Table 5). Moreover, our estimate for Orange County debris exceeded the California Coastal Cleanup Day estimate for the entire state.

The estimates provided by the two surveys differ for several reasons. First, the California Coastal Cleanup Day is conducted by volunteers whose purpose it is to clean the beach rather than to quantify debris. As a result, it is likely that the some of the debris collected during this event was not recorded. Second, the volunteers focus their cleaning efforts on a subset of the coastline, which excludes the rocky shoreline where 10% of the debris was encountered in the present study. Third, the California Coastal Cleanup Day event focuses on many of the popular, easily accessible beaches that are regularly cleaned by mechanical combers. Moreover, the cleanup events usually cover only an area 1/4 to 1/2 of a mile from their starting locations (Mark Patrick, County of Orange, Harbors, Beaches, and Parks, personal communication), rather than the whole beach.

TABLE 4. Estimated total abundance of trash by beach type on Orange County beaches, August to September, 1998.

Debris Type	Beach Type: Sandy	Beach Type: Rocky	S:R Ratio
Percent of Shoreline	89	11	8:1
Pre-production plastic pellets	96,211,029	8,950,072	11:1
Foamed plastics	557,319	184,977	3:1
Hard plastics	424,257	217,763	2:1
Cigarette butts	124,422	15,025	8:1
Paper	64,729	2,853	23:1
Wood	25,611	2,308	11:1
Metal	20,468	3,032	7:1
Glass	4,055	18,140	1:4
Rubber	9,039	1,703	5:1
Pet and bird droppings	7,217	2,171	3:1
Cloth	5,529	420	13:1
Other	10,300	63	163:1
Total	97,463,975	9,398,527	10:1

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TABLE 5. Comparison of abundance for the Orange County summer trash survey and Center for Marine Conservation 1998 California Coastal Cleanup Day.

Debris Type	Bight'98	Coastal Cleanup Day	
	Orange County	Orange County	California
Pre-production Plastic Pellets	105,161,101	-	-
Foamed Plastics	742,296	8,170	211,406
Hard Plastics	642,020	10,860	382,380
Cigarette Butts	139,447	6,717	309,910
Paper	67,582	2,504	133,335
Wood	27,919	720	27,136
Metal	23,500	1,456	110,201
Glass	22,195	1,033	94,333
Rubber	10,742	643	25,666
Pet and Bird Droppings	9,388	-	-
Cloth	5,949	317	10,620
Other	10,363	-	-
Total with pellets	106,862,502	32,420	1,304,987
Total without pellets	1,701,401	32,420	1,304,987

Another variable that could partially account for the discrepancy in the two survey results is that volunteers traditionally focus on larger, more visible debris to the exclusion of small, undetectable debris. To assess the impact of this variable, two beach sites (Salt Creek Beach and Sunset Beach) were sampled using le same methods as the present study. Sampling occurred immediately after the September 18, 1999, California Coastal Cleanup Day. While more than 8,000 pieces of debris were collected from these beaches as part of the cleanup effort, we estimated 67,795 pieces remaining (Table 6). Most of the remaining items were small; the majority of large items, such as glass bottles, were effectively removed by the California Coastal Cleanup Day volunteers.

TABLE 6. Comparison of beach debris amounts between Coastal Cleanup Day volunteers and the Orange County beach debris follow-up study.

	Total abundance of beach debris			
	Sunset Beach		Salt Creek	
Trash Type	CCD	OC*	CCD	OC*
No. of Volunteers	56	8	197	5
Total Weight (lbs)	137	106	405	35
Foamed plastics	313	19,219	1,057	6,336
Hard plastics	1,419	13,658	1,775	5,667
Cigarette butts	222	9,293	1,646	2,464
Paper	139	3,133	711	1,338
Wood	28	387	121	246
Metal	26	1,126	244	2,534
Glass	15	950	257	-
Rubber	67	282	157	387
Cloth	5	634	48	141
Total	2,234	46,682	6,016	19,113

CCD = Coastal Cleanup Day.
OC = Orange County beach debris follow-up study.
* Orange County beach debris follow-up study abundences are estimates of trash found in 1/2 mile based on a 25 yard sample.

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Composition and Distribution of Beach Debris in Orange County, California

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‡*Southern California Marine Institute, 820 South Seaside Avenue, Terminal Island CA 90731, USA*
§*Divers Involved Voluntarily in Environmental Rehabilitation and Safety, P.O. Box 4241, Fullerton CA 92834, USA*

Many studies have quantified debris collected on beaches around the world. Only a few of those studies have been conducted in the United States, and they are largely limited to semi-quantitative efforts performed as part of volunteer clean-up activities. This study quantifies the distribution and composition of beach debris by sampling 43 stratified random sites on the Orange County, California coast, from August to September 1998. We estimated that approximately 106 million items, weighing 12 metric tons, occur on Orange County beaches. The most abundant items were pre-production plastic pellets, foamed plastics, and hard plastics. Debris density on the remote rocky shoreline was greater than that on high-use sandy beaches for most debris items. This finding partially reflects the periodic clean-up of high-use beaches by local municipalities, and also indicates that a high percentage of the observed debris was transported to the site from waterborne sources. **© 2001 Elsevier Science Ltd. All rights reserved.**

Keywords: beaches; debris; plastics; pellets; southern California; pollution monitoring.

Beaches along the southern California coast are used extensively for a variety of recreational purposes, attracting almost 150 million visitors annually (Schiff *et al.*, 1999). Recreational uses such as boating, swimming, surfing, sunbathing, and picnicking generate debris along the shoreline including food bags and wrappers, cups and utensils, trash bags, fast-food and other product containers, toys, fishing lures and floats, and plastic. In addition, southern California has the highest coastal population density of any area in the country (Culliton *et al.*, 1988), providing an additional source of debris via urban runoff and maritime disposal (including accidental spills).

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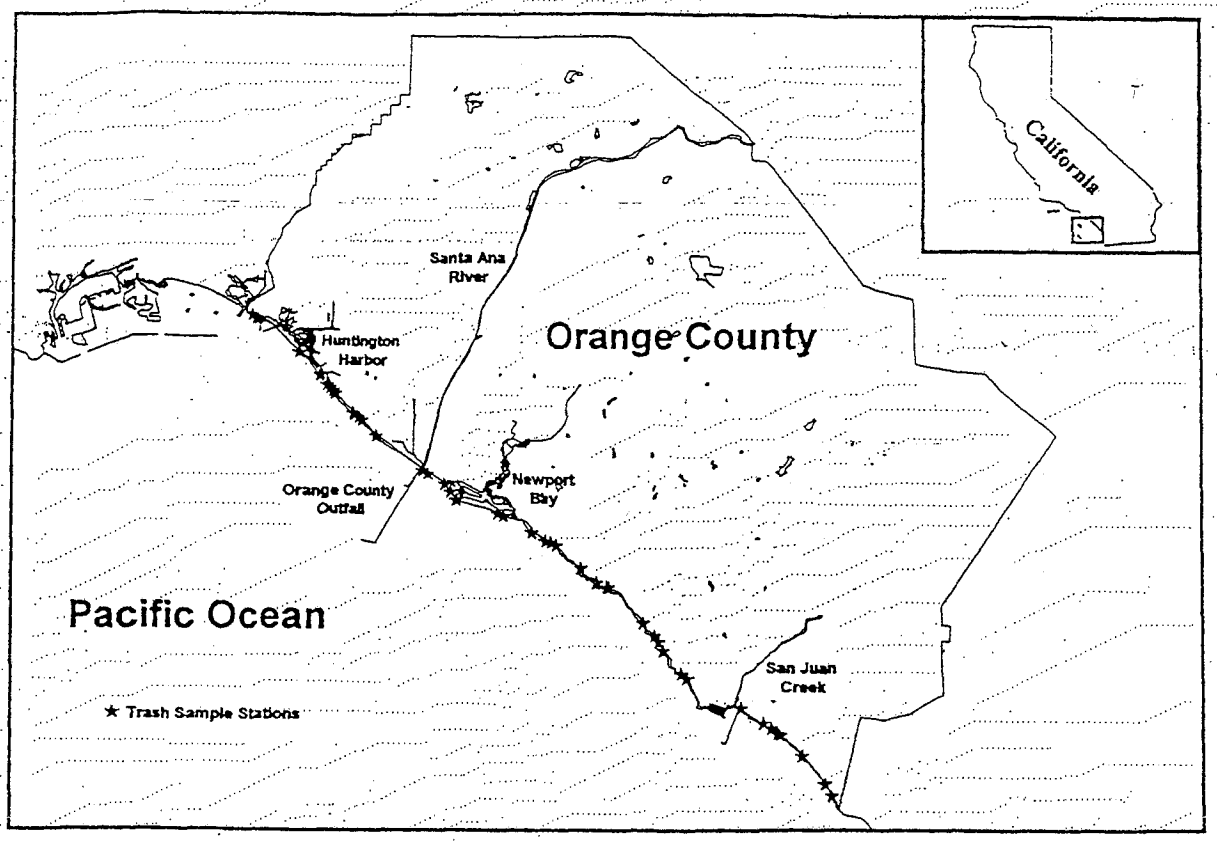

Fig. 1 Sample sites for the Orange County beach debris study, August 1998–September 1998.

was created for each stratum line, with the number of intervals in the partition equal to the sample size. The partition was placed over this stratum line by selecting a random starting point for the beginning of the first interval. Based on this starting point, the intervals were defined as consecutive equal-width lengths. A simple random sample of one point was then chosen from within each interval. Each point was translated back to the shoreline using the section count variable. The partition structure ensures systematic separation of the sampling, while the random selection of sites within partitions ensures an unbiased estimate of beach debris.

Each sample site was delineated as an area 22.9 m in length that extends from the water's edge to the first pavement or rocky cliff. All trash at the site was collected by at least three people walking systematically along transects to ensure that all areas within the sample site were examined. All debris was bagged and transported to the laboratory for identification and quantification. In addition, an 18.9 l bucket was used to sieve one bucket of sand at each site to quantify the small items that were undetectable by visual examination. In the laboratory, debris was sorted into the broad categories used by the Center for Marine Conservation during their Coastal Clean-up days (i.e., glass, metal, plastics, foamed plastics, rubber, paper, wood, and cloth). From each broad category, debris was further sorted into more specific subcategories (e.g., cups, plates, etc.), enumerated, and weighed. Within the specific categories, brand names were recorded, when possible, to establish cross-brand trends.

The total amount of debris along the Orange County coast was estimated by calculating a mean amount of trash for a 22.9 m segment within each strata and then weighting those means by the relative amount of shoreline distance in each strata. Estimates for smaller debris collected by sieving were calculated using a similar methodology, after estimating the number of meters from the water's edge to the first pavement or rocky cliff for each site then extrapolating the abundance for each sample site area.

Results

More than 106 million items, weighing approximately 12 metric tons, were estimated to occur along the Orange County shoreline (Table 1). Three categories of plastics (pre-production plastic pellets, foamed plastics, and hard plastics), accounted for 99% of the total abundance and 51% of the total weight. Cigarette butts were fourth in abundance and accounted for less than 1% of the total abundance and weight. Cigarettes, candy, fast-food products, beer, and other beverages were the most identified brand-related debris (Table 2). Marlboro®,

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TABLE 1

Estimated total abundance and weight of trash on Orange County beaches, August 1998–September 1998.

Debris type	Estimated totals for Orange County	
	Abundance	Weight (kg)
Pre-production plastic pellets	105 161 101	2168
Foamed plastics	742 296	692
Hard plastics	642 020	3588
Cigarette butts	139 447	156
Paper	67 582	394
Wood	27 919	2066
Metal	23 500	1368
Glass	22 195	882
Rubber	10 742	371
Pet and bird droppings	9388	8
Cloth	5949	650
Other	10 363	182
Total	106 862 502	12 525

TABLE 2

Percent of total of top three brands in main brand categories collected on Orange County beaches, August 1998–September, 1998.

Brand name	Percent of total	Percent market share
Cigarette products		
Marlboro	62	32.3
Camel	7	4.6
Benson and Hedges	7	<2.4
Candy products		
Starburst	16	na[a]
Snickers	13	na
Blow Pop	9	na
Fast food products		
Jack in the box	27	3.6
Carls Jr	19	1.9
KFC	12	<0.9
Beer products		
Budweiser light	27	12.9
Budweiser	16	18.3
Corona	7	2.0
Drink products		
Coca Cola	16	20.6
Pepsi	15	14.2
Capri Sun	8	<1.2

[a] na – not available.

Starburst®, Jack in the Box®, Budweiser Light®, and Coca Cola® all led in their respective categories.

Most of the plastics encountered were in the form of small pieces of plastic (Table 3). Foamed plastic pieces accounted for 88% of the total foamed plastics and hard plastic pieces accounted for 50% of the total hard plastics. Of the whole plastic items, food and beverage items were the most abundant.

The distribution of debris differed among shoreline types. Sandy beaches are eight times more abundant than rocky shoreline in Orange County, but most debris did not reflect this ratio (Table 4). Foamed and hard plastics, glass, rubber, and animal droppings all occurred at higher proportions on rocky beaches. Pre-production plastic pellets, paper, wood, and cloth all occurred at higher proportions on sandy beaches. Cigarette butts and metal were found at approximately equal ratios between beach types.

TABLE 3

Estimated total abundance of plastics on Orange County beaches, August 1998–September 1998.

Trash type	Abundance
Foamed plastics	
Foamed plastic pieces	652 639
Fast food containers	43 167
Other foamed plastics	25 415
Cups	10 595
Packaging material	9940
Plates	270
Meat trays	180
Buoys	90
Total	742 296
Plastics	
Plastic pieces	318 790
Caps and lids	88 548
Straws	84 990
Food bags and wrappers	58 394
Other plastic	48 799
Cups and utensils	9641
Other plastic bags	7164
Cigarette lighters	5810
Beverage bottles	4550
Trash bags	3729
Toys	2159
Buckets	1973
Rope	1848
Other bottles	1563
Milk and water bottles	1182
Diapers	1003
Strapping bands	449
6-pack holders	321
Fishing line	321
Tampon applicators	301
Fishing lures and floats	281
Oil and lube bottles	114
Light sticks	90
Total	642 020
Total plastics	1 384 316

Discussion

The most abundant item found on southern California beaches was pre-production plastic pellets, which are probably lost in transport from the raw material producers to the processors who mold the pellets into plastic products. The pellets, collected primarily through sieving the surface layers of sand, come in a variety of shapes (ovoid, cylindrical, etc.) and are typically less than 5 mm in diameter. Approximately one quadrillion of these pellets, representing 60 billion pounds of resin, are manufactured annually in the United States alone (USEPA, 1992). The presence of these pellets is not unique to US beaches (Gregory, 1977, 1978, 1983; Shiber, 1979, 1982). Gregory (1977, 1978) estimated that the number of these pellets on New Zealand beaches could possibly exceed 1000 t.

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TABLE 4

Estimated total abundance of trash by beach type on Orange County beaches. August 1998–September 1998.

Debris type	Beach type		
	Sandy	Rocky	Sandy:Rocky ratio
Percent of shoreline	89	11	8:1
Pre-production plastic pellets	96 211 029	8 950 072	11:1
Foamed plastics	557 319	184 977	3:1
Hard plastics	424 257	217 763	2:1
Cigarette butts	124 422	15 025	8:1
Paper	64 729	2853	23:1
Wood	25 611	2308	11:1
Metal	20 468	3032	7:1
Glass	4055	18 140	1:4
Rubber	9039	1703	5:1
Pet and bird droppings	7217	2171	3:1
Cloth	5529	420	13:1
Other	10 300	63	163:1
Total	97 463 975	9 398 527	10:1

The relative distribution of brand-name products in the debris we collected largely reflects the product's relative market share. For example, we collected 10 times more Marlboro cigarette butts than any other brand, consistent with Marlboro's 32% market share. Similarly, Budweiser and Budweiser Light dominated the beer debris category, as they do in sales. One exception to the high correlation between brand-related debris quantity and market share was in the fast-food container category. Industry leader McDonalds constituted less than 10% of the total debris measured, while Jack in the Box accounted for nearly three times that level. Perhaps the geographic distribution of fast-food restaurants in relation to Orange County beaches was responsible for the discrepancy in the amount of fast-food product debris collected compared to the brand's respective market share.

Four major sources have been identified as pathways in the transport of debris to the Orange County shoreline: (1) littering by beachgoers, (2) wind currents from upland sources, (3) runoff from land-based activities, and (4) overboard disposal from boating activities (including accidental spills). Each of these sources requires a different management action to effect a reduction in beach debris. Although our study was not designed to differentiate sources, our data suggest that water-based sources (runoff and overboard disposal) were more important than direct littering or wind. One line of evidence for this is that plastic pellets were found in abundance on all shoreline areas and are unlikely to originate from littering or wind. The second line of evidence is the greater density of most debris items found on less-frequented rocky shoreline compared to the sandy beaches (Table 4). While this pattern was true for most debris, an exception was the greater amount of paper products, such as food wrappers, found on sandy beaches, suggesting that they were left by beachgoers.

The only previous quantification of debris on the Orange County shoreline was from data collected by volunteers during the annual California Coastal Clean-up Day. Their 1998 clean-up event occurred the week after the present survey was completed and their estimate of the amount of debris was 50 times lower than our data (Table 5). Moreover, our estimate for Orange County debris exceeded the California Coastal Clean-up Day estimate for the entire state.

The estimates provided by the two surveys differ for several reasons. First, the California Coastal Clean-up Day is conducted by volunteers whose purpose it is to clean the beach rather than to quantify debris. As a result, it is likely that the some of the debris collected during this event was not recorded. Second, the volunteers focus their cleaning efforts on a subset of the coastline, which excludes the rocky shoreline where 10% of the debris was encountered in the present study. Third, the California Coastal Clean-up Day event

TABLE 5

Comparison of abundance for the Orange County summer trash survey and Center for Marine Conservation 1998 California Coastal Clean-up Day.

Debris type	Summer Survey	Coastal Clean-up Day	
	Orange County	Orange County	California
Pre-production plastic pellets	105 161 101	–	–
Foamed plastics	742 296	8170	211 406
Hard plastics	642 020	10 860	382 380
Cigarette butts	139 447	6717	309 910
Paper	67 582	2504	133 335
Wood	27 919	720	27 136
Metal	23 500	1456	110 201
Glass	22 195	1033	94 333
Rubber	10 742	643	25 666
Pet and bird droppings	9388	–	–
Cloth	5949	317	10 620
Other	10 363	–	–
Total with pellets	106 862 502	32 420	1 304 987
Total without pellets	1 701 401	32 420	1 304 987

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TABLE 6

Comparison of beach debris amounts between Coastal Clean-up Day volunteers and the Orange County beach debris follow-up study.

Trash type	Total abundance of beach debris			
	Sunset Beach		Salt Creek	
	CCD[a]	OC[b]	CCD	OC[b]
No. of volunteers	56	8	197	5
Total weight (kg)	62	48	184	16
Foamed plastics	313	19 219	1057	6336
Hard plastics	1419	13 658	1775	5667
Cigarette butts	222	9293	1646	2464
Paper	139	3133	711	1338
Wood	28	387	121	246
Metal	26	1126	244	2534
Glass	15	950	257	–
Rubber	67	282	157	387
Cloth	5	634	48	141
Total	2234	48 682	6016	19 113

[a] CCD – Coastal Clean-up Day.
[b] Orange County beach debris follow-up study abundances are estimates of trash found in 0.8 km based on a 22.9 m sample.

focuses on many of the popular, easily accessible beaches that are regularly cleaned by mechanical combers. Moreover, the clean-up events usually only cover an area 0.4–0.8 of a kilometer from their starting locations (Mark Patrick, County of Orange, Harbors, Beaches, and Parks, pers. comm.), rather than the whole beach.

Another variable that could partially account for the discrepancy in the two survey results is that volunteers traditionally focus on larger, more visible debris to the exclusion of small, undetectable debris. To assess the impact of this variable, two beach sites (Salt Creek Beach and Sunset Beach) were sampled using the same methods as the present study. Sampling occurred immediately after the 18 September 1999, California Coastal Clean-up Day. While more than 8000 pieces of debris were collected from these beaches as part of the clean-up effort, we estimated 67 795 pieces remaining (Table 6). Most of the remaining items were small: the majority of large items, such as glass bottles, were effectively removed by the California Coastal Clean-up Day volunteers.

The authors wish to thank the following organizations and their volunteers/employees for assistance with this project: Divers Involved Voluntarily in Environmental Rehabilitation and Safety, Southern California Marine Institute, Southern California Coastal Water Research Project, Cabrillo Marine Aquarium, and the Long Beach Conservation Corps. We would also like to thank Mark Patrick for his assistance in the comparison with the 1999 Coastal Clean-up Day activities.

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A015091

Guidance for Developing TMDLs in California

EPA Region 9

January 7, 2000

A015092

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Disclaimer

This document provides guidance to the State of California concerning its responsibility under section 303(d) of the Clean Water Act concerning the development of TMDLs for water quality-limited segments listed under section 303(d). It also provides guidance to the public and the regulated community on how EPA intends to exercise its discretion in implementing section 303(d) and its regulations regarding TMDLs. The guidance is designed to implement national regulations and policies on these issues. The document does not, however, substitute for section 303(d) of the Clean Water Act or EPA's regulations; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, the State of California, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate and consistent with the requirements of section 303(d) and EPA's regulations. EPA may change this guidance in the future.

1. What does this guidance address?

Clean Water Act Section 303(d) establishes a water quality assessment and planning process through which states, territories, and authorized tribes are required to identify polluted waterbodies, set priorities for addressing these polluted waters, and write pollutant control plans called Total Maximum Daily Loads (TMDLs) in order to attain state water quality standards, including water quality standards promulgated by EPA for California. This process, known generally as the TMDL process, provides an effective mechanism for determining the causes of waterbody impairment and allocating responsibility among different pollutant discharge sources for reducing pollutant emissions to achieve water quality standards. The TMDL process affords the public the opportunity to participate in decisions about these pollutant control plans. States are generally responsible for developing TMDLs, and EPA reviews and approves TMDLs. If EPA disapproves a TMDL, EPA is responsible for establishing the TMDL for the State. In some cases, EPA may also establish TMDLs when the State has not yet adopted and submitted a required TMDL. TMDLs are implemented through existing regulatory and non-regulatory programs to control pollutant discharges from point sources (e.g. discharges from wastewater treatment plants) and nonpoint sources (e.g. polluted runoff from agricultural lands).

The goal of a Total Maximum Daily Load (TMDL) is to attain state water quality standards including water quality standards promulgated by EPA for California. A TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It identifies one or more numeric targets based on applicable water quality standards, specifies the maximum amount of a pollutant that can be discharged (or the amount of a pollutant that needs to be reduced) to meet water quality standards, allocates pollutant loads among sources in the watershed, and provides a basis for taking actions needed to meet the numeric target(s) and implement water quality standards.

This guidance describes the minimum federal requirements for developing TMDLs as well as additional requirements for establishing TMDLs in California which must be met in order to comply with State legal and administrative procedures.[1] It is important that TMDLs include all the required elements and comply with federal and state procedural requirements in order to ensure that the TMDLs include information needed to implement effective pollutant controls, provide meaningful opportunities for public input, and are legally and technically defensible. More than 500 waterbodies or segments have been identified as needing TMDLs in California, many for multiple pollutants. Therefore, a great deal of work needs to be done by the State, EPA, and interested stakeholders to develop and implement TMDLs. This guidance, which is tailored to California's unique legal and administrative process, should assist in completing this work in a timely manner.

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[1] This guidance reports EPA's understanding of requirements which stem from State statutes, regulations, or policies, based on information furnished by the State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCBs). Interested parties should contact the SWRCB or RWQCBs to obtain definitive guidance concerning State-related requirements.

This guidance is based on existing federal and state requirements in effect in January, 2000. The guidance does not address proposed changes in federal TMDL requirements or possible changes in California's TMDL program being considered in the State legislature. The guidance also does not address the process for identifying waterbodies that do not meet Water Quality Standards after application of technology-based and other required controls (the Section 303(d) list). The guidance does not discuss TMDL implementation requirements in detail since TMDL implementation plans are currently governed by regulatory provisions which are separate from TMDL development requirements. Finally, the guidance focuses upon legal and procedural requirements and does not provide technical guidance concerning scientific methodologies for developing TMDLs.

In August 1999, EPA published proposed revisions to the TMDL regulations and national TMDL guidance. This California guidance will remain in effect unless EPA determines that it is superceded by new regulations and/or guidance.

2. Minimum Required Elements of TMDLs

2.1 Federal Requirements

State TMDL SUBMITTAL and TMDLs established by EPA **must** contain the following elements indicated in bold type in order to be approvable under the Clean Water Act (CWA) and associated federal regulations[2]:

1. Submittal Letter

A letter must be submitted by the State providing notification that the final TMDL(s) for specific water(s)/pollutant(s) were adopted by the State and submitted to EPA for approval under Section 303(d) of the CWA [40 CFR 130.7(d)].

2. Water Quality Standards Attainment

The TMDL and associated waste load and load allocations must be set at levels necessary to result in attainment of all applicable water quality standards, including designated beneficial uses, narrative water quality objectives[3], numeric water quality objectives, and State anti-degradation policies [40 CFR 130.7(c)(1)].

3. Numeric Target(s)

The TMDL document describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative objectives, and antidegradation

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[2]In this document, the term "must" is used to describe a federal requirement. The terms "may" or "should" are used to describe recommended program actions or elements.

[3] In California, the term "water quality objective" is equivalent to the federal "water quality criteria".

policies. Numeric water quality target(s) for TMDL must be identified, and an adequate basis for target(s) as interpretation of water quality standards must be specifically documented in the submittal. [40 CFR 130.7(c)(1)] TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.

These targets identify the specific instream (and potentially hillslope) goals or endpoints for the TMDL which equate to attainment of the water quality standard. In some cases, multiple indicators and associated numeric target values may be needed to interpret an individual water quality standard (e.g. multiple fish habitat indicators to interpret acceptable sediment levels). In addition, some TMDLs may incorporate multiple numeric targets to account for seasonal differences in acceptable pollutant levels in a particular water body.

In many cases where applicable standards are expressed in numeric terms, it is appropriate to set the numeric target equal to the numeric water quality standard. However, it may be desirable to interpret a numeric standard in terms other than the method through which the standard is expressed as long as the target(s) can be shown to relate back to achieving the water quality standard(s). For some pollutants (e.g., bioaccumulative toxins or salts) or receiving water settings (e.g. lakes or poorly mixed waters), it makes more sense from the standpoint of source control and impact assessment to focus the TMDL on reductions of pollutant mass loads than solely on avoidance of exceedences of concentration-based standards.

In situations where applicable water quality standards are expressed in narrative terms or where 303(d) listings were prompted primarily by beneficial use or antidegradation concerns, it is necessary to develop a quantitative interpretation of narrative standards. Since a TMDL is an inherently quantitative analysis, it is necessary to determine appropriate quantitative indicators of the water quality problem of concern in order to calculate a TMDL. It is sometimes possible to supplement instream indicators and targets with hillslope targets-- measures of conditions within the watershed which are directly associated with waterbodies meeting their water quality standards for the pollutant(s) of concern.

The numeric targets section generally includes the following elements:

- identification of one or more instream indicators (and possibly hillslope indicators) and the basis for using the indicator(s) to interpret or apply applicable water quality standards
- identification of target levels for each indicator and the technical basis for the targets
- comparison of historical or existing conditions and target conditions for the indicators selected for the TMDL.

If it is determined that water quality standards are now being met throughout the year taking into account seasonal variations and other critical conditions, and are not expected to be exceeded by the next listing cycle, then the TMDL is not required (although it can be developed to support permit issuance or for informational purposes pursuant to Clean Water Act Section 303(d)(3)). If the State determines a TMDL is not necessary after the TMDL development process has begun, the State would normally stop work on the TMDL and identify the waterbody as a candidate for removal from the 303(d) list at the time of the next listing cycle. EPA

encourages the State to notify interested members of the public of this finding and potentially provide an opportunity for public review of the State's analysis. For TMDLs required under consent decrees, the State should notify EPA immediately of any finding that the TMDL is not necessary in order for EPA to ensure that consent decree requirements are met.

4. Source Analysis

Point, nonpoint, and background sources of pollutants of concern must be described, including the magnitude and location of sources. The TMDL document demonstrates all sources have been considered [40 CFR 130.2(i) and 40 CFR 130.7(c)(1)].

An understanding of pollutant loading sources and the amounts and timing of pollutant discharges is vital to the development of effective TMDLs. The TMDL document must provide estimates of the amounts of pollutants entering the receiving water of concern or, in some cases, the amount of pollutant that is bioavailable based on historic loadings stored in the aquatic environment. These pollutant sources or causes of the problem need to be documented based on studies, literature reviews or other sources of information. Because the source analysis provides the key basis for determining the levels of pollutant reductions needed to meet water quality standards, and the allowable assimilative capacity, TMDL, wasteload allocations, and load allocations, quantified source analyses are required. Sources can be categorized in many ways, including but not limited to discharge source, land use category, ownership, pollutant production process (e.g. sedimentation processes), and/or tributary watershed areas. The source analysis must discuss in detail the data and methods used to estimate source contributions.

5. Link Between Numeric Target(s) and Pollutant(s) of Concern

The TMDL document must describe the relationship between numeric target(s) and identified pollutant sources, and estimate total assimilative capacity (loading capacity) of the waterbody for the pollutant of concern [40 CFR 130.7(d) and 40 CFR 130.2 (i) and (f)].

The loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL. Thus, a maximum allowable pollutant load must be estimated to address the site-specific nature of the impairment. The loading capacity reflects the maximum amount of a pollutant that may be delivered to the waterbody and still achieve water quality standards. A number of different loading capacity approaches have been approved as part of TMDLs.

The loading capacity section must discuss the methods and data used to estimate loading capacity. A range of methods can be used from predictive water quality models to inferred linkages based on comparison of local reference conditions with existing conditions in the watershed of concern. In some cases, loading capacity may vary within the watershed of concern (e.g., toxics loading capacity may be higher in areas with high water mixing rates than in backwater areas with poor water exchange), and in different time periods (e.g. nutrient loading capacity may be lowest during high temperature summer low flow periods). The basis for spatial and temporal variations in loading capacity estimates should be discussed in detail.

6. TMDLs and Individual Load and Wasteload Allocations

The document must identify the TMDL (total allowed pollutant amount) and its components: appropriate wasteload allocations for point sources and load allocations for nonpoint sources and natural background. If no point sources are present or anticipated, wasteload allocations are zero. If no nonpoint sources are present or anticipated, load allocations are zero. TMDLs and associated wasteload and load allocations must be expressed in quantitative terms [40 CFR 130.2 (e-i) and 40 CFR 130.7(c)].

The method of TMDL calculations must be discussed in detail. In some cases it will be appropriate to reserve (i.e., not allocate) a portion of the allowable loading capacity as part of the TMDL and its associated allocations. Such reserves may address the margin of safety requirement, account for sources which do not receive specific allocations, and/or to provide for future sources (although EPA advises providing for future sources through establishment of load allocations for future loading sources where feasible).

Separate wasteload and load allocations are needed for point and nonpoint sources, respectively. In cases where it is feasible, individual wasteload allocations should be established for each existing or anticipated future point source discharge, including NPDES-permitted stormwater discharges. However, circumstances may arise in which it is appropriate to set wasteload allocations that cover more than one discharge (e.g., discharges covered by a general permit). The State should coordinate with EPA prior to proposing a wasteload allocation which addresses more than one discharge, and clearly explain how the group wasteload allocation would be implemented.

Load allocations for nonpoint sources may be expressed as specific allocations for specific dischargers or as "gross allotments" to nonpoint source discharger categories. Separate nonpoint source allocations should be established for background loadings. Allocations may be based on a variety of technical, economic, and political factors. The methodology used to set allocations should be discussed in detail. It is advisable to include some assessment of the feasibility of the allocations in order to increase the likelihood that the TMDL can actually be attained through implementation actions and, accordingly, is sufficient to be approved by EPA.

TMDLs (and thus, load allocations and wasteload allocations) can be expressed as *"mass per time, toxicity, or other appropriate measure"*, depending on the type of waterbody and the sources that contribute to impairment. When using allocations in some *"other appropriate measure"* a discussion of why the *"other appropriate measure"* was used is necessary. *"Other appropriate measures"* may include an estimate of the percent reduction in discharge of the pollutant of concern which is needed to attain water quality standards. Where the percent reduction approach is used, the specific pollutant loading baseline against which the reductions are to be measured must be specified. For example, if the water quality impairment is due to excessive sedimentation from upland conditions, then the allocations may relate to the decrease in amount of erosion from uplands. If the problem is sedimentation related to channel conditions, then the allocations may relate to the decrease in the amount of bank erosion or the increase in stream stability.

Load allocations can be expressed in many ways. It is important to express load allocations in ways that can be implemented and monitored effectively. Where feasible, load allocations should be expressed in terms of:

- individual discharge location,
- individual land ownership, or
- individual land area subject to management jurisdiction by a single entity.

Where it is infeasible to set load allocations in these terms, load allocations may be expressed in the following ways:

- by pollutant discharge process (e.g. landslides),
- by land use type (e.g., rangeland),
- by land characteristics (e.g., geologic type)
- by discharger group (e.g. construction sites),
- by tributary subbasin area,
- by waterbody segment, or
- other discreet source description method approved by EPA.

In some TMDLs, it will be appropriate to express load allocations in terms of multiple classifications. Examples may include:

- lands managed for timber harvest with slopes greater than X% or less than X%,
- row crop lands located within 1000 feet of perennial streams or outside that zone, or
- unpaved roads within the A, B, and C subbasins of a larger watershed.

Federal regulations do not establish specific criteria which must be considered in dividing and allocating any available loading capacity between contributing sources. The State may consider a mix of the following allocation criteria (see Technical Support Document for Water Quality Based Permit Decisions (EPA, 1991) for more information):

- technical and engineering feasibility,
- cost or relative cost,
- economic impacts/benefits,
- cost effectiveness,
- fairness/equity,
- ability to monitor implementation and effectiveness,
- assurance and timeliness of attainment of the TMDL and water quality standards,
- relative source contributions, and/or
- other appropriate criteria.

7. Margin of Safety

The TMDL document must describe an explicit and/or implicit margin of safety for each pollutant [40 CFR 130.7(c)].

An explicit margin of safety can be provided by reserving (not allocating) a portion of the loading capacity identified for the waterbody for the pollutant of concern. An implicit margin of safety can be provided by making and documenting conservative assumptions used in the TMDL analysis. The TMDL submittal must provide a detailed explanation of the basis for margin of safety which shows why it is adequate to account for uncertainty in the TMDL. Where an implicit margin of safety is provided, the submittal should include a specific discussion of sources of uncertainty in the analysis and how individual analytical assumptions or other provisions adequately account for these specific sources of uncertainty.

Different analysis steps in TMDL development will involve different levels of uncertainty in the accuracy of results. TMDL developers should consider and document the types of uncertainty involved in each step of the analysis. Because TMDLs must account for uncertainties in the analysis, the different sources of uncertainty should be summarized. A margin of safety is required in the TMDL to account for uncertainty in the understanding of the relationship between pollutant discharges and water quality impacts. In any case, assumptions must be stated and the basis behind the margin of safety must be documented. The margin of safety is not meant to compensate for a failure to consider known sources.

8. Seasonal Variations and Critical Conditions

The TMDL document must describe the method used to account for seasonal variations and critical conditions (e.g., stream flows, pollutant loadings, and other water quality parameters) in the TMDL(s) [40 CFR 130.7(c)].

Pollutant discharges and associated effects on beneficial uses may vary in different years and at different times of the year. The TMDL developer should evaluate how seasonal or interannual variations in loadings, flows, pollutant fate and transport, pollutant effects, ecological conditions or other factors affect the waterbody of concern in TMDL. TMDLs are required to demonstrate how seasonal variations and critical conditions were accounted for in the TMDL analysis in order to ensure that the TMDL results in attainment of water quality standards throughout the year. The TMDL document must show how the TMDL accounts for seasonal variations and critical conditions concerning receiving water flow (e.g. low flow during drought periods), receiving water conditions (e.g. temperature), beneficial use impacts (e.g., key aquatic life stages), pollutant loadings (e.g., high flow nonpoint source runoff), and other environmental factors which affect the relationship between pollutant loading and water quality impacts. This element is required in order to ensure that the TMDL will protect the receiving water during the periods in which it is most sensitive to the impacts associated with the pollutant(s) of concern.

9. Public Participation

The TMDL package must document the provision of public notice and public comment opportunity concerning TMDL calculations; and explains how public comments were considered in the final TMDL(s) [40 CFR 130.7(c)(1)].

Minimum requirements for public participation for state adopted and EPA established TMDLs are discussed in the following section. However, there are additional ways of providing for public participation in TMDL development beyond the minimum. Table 1 on the following page summarizes three models of stakeholder participation and discusses some advantages and disadvantages of each model. These examples do not cover all approaches to providing for public participation but are intended to illustrate a range of viable public participation models. Although the State can address minimum federal requirements concerning public participation by providing a 30 day notice and comment period and preparing a comment responsiveness summary, EPA encourages that, where feasible, the State communicate with the public earlier in the process of developing a particular TMDL to discuss the TMDL approach and stakeholder involvement opportunities.

10. Technical Analysis

The TMDL document must provide an appropriate level of technical analysis supporting all TMDL elements [40 CFR 130.2(i) and 40 CFR 130.7(c)].

The State may include needed technical analysis in the TMDL document, submit copies of supporting documentation providing technical analysis supporting the TMDL, or cite documents in the State's administrative record which discuss the supporting technical analysis in detail. If the State cites documents as the basis for technical findings in the TMDL which are not submitted with the TMDL package, the TMDL document must clearly summarize the technical analysis supporting the findings concerning individual TMDL elements. In addition, the State should maintain these documents in its administrative record for review by EPA on request.

Table 1: Public Participation Models

Model	Characteristics	Advantages	Disadvantages
Public Notice and Comment	- provides formal opportunity to review proposed TMDL, may include public hearings - responses are provided to public comments in final TMDL or in a responsiveness summary - State or EPA explain how comments were considered in the final decision	- less time and resource intensive - satisfies minimum public participation requirements - avoids repetition of effort where TMDL based on previous, uncontroversial decisions	- interested parties will not hear about TMDL - reduces chance of local support and buy-in - developing comment responses can be time consuming and difficult - may be dissatisfying to stakeholders who want more involvement
Stakeholder Consultation Plus Public Comment Period	- developer meets several times with stakeholders during TMDL development - developer informs group of progress and draft analysis, seeks input	- involved stakeholders not taken by surprise - increases chances for local support/buy in - earlier identification of tough or contentious issues	- moderately time/resource intensive - may be dissatisfying to stakeholders who want more involvement - difficult to manage expectations
Extensive Stakeholder Collaboration Plus Public Comment Period	- stakeholders involved from outset in different TMDL elements - stakeholders may do substantial analysis, not just review state work - stakeholders may attempt to seek agreement on TMDL content	- best chances for local support/buy in - improves ability to identify and evaluate implementation measures - may reduce resources needed for analysis since other parties do some analysis	- very time/resource intensive - may be unrealistic to get consensus or agreement on TMDL content - problematic for TMDLs with tight, inflexible deadlines - may be unsatisfying to interested stakeholders--- extensive time commitments required may be infeasible for many interested groups

Requirements For The Phased Approach To TMDLs

EPA has described an approach to TMDL development in situations where data and information needed to determine the TMDL and associated allocations are limited. This "phased approach" to TMDLs enables States to adopt TMDLs and begin implementation while collecting additional information needed to review and, if necessary, revise TMDL elements based on new information (see Guidance for Water Quality Based Decisions-- The TMDL Process (EPA, 1991) for more information). For TMDLs developed under the "phased approach", the following additional element must be included in the TMDL submittal:

11. Monitoring and Review Plan

TMDLs developed under phased approach must identify specific implementation actions, monitoring plans and a schedule for considering revisions to the TMDLs.

EPA also recommends that any TMDL include a monitoring and review process whether it is developed pursuant to the phased approach or not.

Requirement Concerning Point/Nonpoint Source Allocation Practicability

For waters affected by both point source and nonpoint source discharges, TMDL documents must address the following additional requirement. Note that EPA has also established national policies concerning reasonable assurances as part of TMDL implementation plans, which are discussed in the implementation section of this guidance.

12. Showing of Practicability of Nonpoint Source Load Allocations

Where point source(s) receive less stringent wasteload allocations because nonpoint source reductions are expected and reflected in load allocations, the TMDL must include a demonstration that nonpoint source loading reductions needed to implement load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

This means that the load allocations are technically feasible and reasonably assured of being implemented in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate but must include an actual demonstration that the measures identified will actually obtain the predicted reductions and that the State is able to assure this result.

2.2 Other EPA Guidance Concerning TMDL Content

In addition to these minimum required elements, EPA recommends that all TMDLs should contain the following elements in order to facilitate public and EPA review of the TMDL:

Problem Statement

The process of problem definition identifies the context for TMDL development and describes the water quality standards issue(s) which prompted development of the TMDL. The problem statement should identify:

- name(s) and location(s) of waterbody segments for which the TMDL is being developed,
- the pollutant(s) for which the TMDL is being developed and information about why the pollutant(s) are being addressed,
- the specific applicable water quality standard(s) for those pollutants,
- a description of the water quality impairment or threat which necessitated TMDL development, and
- adequate background information about the watershed setting for the TMDL to help the reader understand the key water quality, pollutant discharge, land use, and resource protection issues in the watershed.

Administrative Record Keeping

An administrative record that supports development and approval of the TMDL should also be prepared. Components of the administrative record should include all materials used to develop the TMDL and make decisions, including any data or references that were used, records of any correspondence, and other background materials. Such a record is needed in order to ensure that the public has the opportunity to review documents which formed the basis for the TMDL. In addition, EPA may request access to documents upon which the State relied in developing a TMDL if necessary to determine whether a TMDL submittal complies with federal requirements. As discussed above under Technical Analysis, the State should maintain in its administrative record copies of technical documents which serve as the basis for one or more findings contained in the TMDL submittal to EPA.

2.3 Federal Requirements and Guidance Concerning TMDL Implementation

States are not currently required to include implementation plans as part of the TMDL submittal. However, federal regulations require States to incorporate TMDLs in the State Water Quality Management Plan along with adequate implementation measures to implement all aspects of the plan (including the TMDLs) [40 CFR 130.6]. Therefore, TMDL implementation measures must be identified by the State and submitted for EPA's review, either concurrent with the TMDL or afterward. EPA suggests that the implementation plan should be prepared and submitted concurrent with the TMDL. If the State plans to prepare the implementation plan after the TMDL, the State's TMDL submittal should provide a schedule for developing the implementation plan.[4] Federal regulations do not currently provide that EPA will establish an implementation plan for TMDLs established by EPA. However, EPA may make implementation recommendations as part of TMDLs it establishes. States should consider EPA's implementation recommendations at the time the State develops its implementation measures for the TMDL and should adopt these measures into the Basin Plan unless the State identifies alternative measures which are sufficient to implement the TMDL.

The State's TMDL implementation plan submittal should describe planned implementation actions or, where appropriate, specific process(es) and schedule(s) for determining future implementation actions. The implementation plan needs to be sufficient to implement all wasteload and load allocations in a reasonable period of time. TMDL(s) and implementation measures are formally incorporated into the water quality management plan through the state's established process for amending that plan. Water quality management plan revisions must be consistent with other existing provisions of the water quality management plan [40 CFR 130.6].

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[4] As discussed in Section 2.4 below, the State of California's position is that State law usually requires the Regional Boards to adopt implementation provisions concurrent with TMDLs in order to meet State Basin Planning requirements for TMDL adoption.

Reasonable Assurances Concerning Implementation

EPA's national policy is that all TMDLs are expected to provide reasonable assurances that they can and will be implemented in a manner that results in attainment of water quality standards (EPA, 1997). This means that the wasteload and load allocations are technically feasible and reasonably assured of being implemented in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate.

TMDLs and NPDES Permits

Discharge permits issued under Clean Water Act Section 402 (the NPDES program) contain effluent limitations for individual pollutants. These effluent limitations must be consistent with any wasteload allocations developed as part of TMDLs approved or established by EPA. This provision applies to all types of NPDES permits (including stormwater and general permits). If these procedures are not addressed in the TMDL, the NPDES permit writer determines the specific method of assuring that a new or revised permit is consistent with its wasteload allocation at the time the permit is scheduled for issuance.

To avoid permitting problems, EPA recommends that the State evaluate how waste load allocations will be translated into NPDES permit limits as part of developing the TMDL implementation plan. EPA believes it is useful to do this concurrent with TMDL development. Consideration of permitting issues will also assist in evaluating the practicability of WLAs during the allocation step of TMDL development. Permitting issues which the State should consider in establishing WLAs include:

- whether WLAs and effluent limits will be expressed on a concentration and/or mass basis,
- whether pollutant trading is contemplated as part of the TMDL and WLAs,
- appropriate permit averaging periods,
- whether mixing zones are appropriate, and, if so, how they would be delineated, and
- ambient monitoring provisions.

TMDLs and Nonpoint Sources

There are few specific federal requirements concerning implementation of nonpoint source controls pursuant to load allocations. As discussed above, the State must demonstrate reasonable assurances that the load allocations will be (1) set at sufficient levels to attain Water Quality Standards and (2) implemented, if wasteload allocations were relaxed based on the expectation of nonpoint source reductions. EPA's national policy is that all implementation plans for all TMDLs will provide reasonable assurances that all wasteload and load allocations will be implemented in a timely manner. EPA recommends evaluating at a specific level how load allocations will be implemented as part of the TMDL implementation plan, and believes it is useful to do this concurrent with TMDL development. Consideration of potential nonpoint source management approaches and the effectiveness of available management practices will

assist in evaluating the practicability of load allocations and assessing whether there is reasonable assurance that the TMDL will be implemented and result in attainment of water quality standards.

2.4 State of California-Related Requirements

In addition to federal requirements, the Regional Water Quality Control Boards and State Water Resources Control Board are required to comply with various additional requirements under State law in order to develop, adopt, and submit a TMDL and associated implementation measures to EPA. These State-related requirements are summarized below in table 2, based on material provided to EPA by the State. The process through which the State develops these required materials is discussed in the following section. In addition, Appendix A to this guidance provides a legal opinion from the Office of Chief Counsel, State Water Resources Control Board, which describes economic considerations in TMDL development and basin planning which stem from State law.

EPA does not review TMDL submittals for compliance with State-related requirements, and they are listed here for information purposes only. Interested parties should contact the State or Regional Board TMDL contacts for more definitive guidance concerning State-related requirements.

Table 2: State Basin Planning Required Elements

Requirements For Basin Plan Amendment	Summary
Administrative Record	Record of information used to make the staff decision and only admissible evidence during legal challenge
Notification	Provide State Board staff of draft amendment for review of state board and Office of Administrative Law (OAL) requirements, State Board and EPA review of TMDL staff report draft
Index	List of contents, and number pages
Public Process	Evidence of meetings, sign in sheets, mailing lists
Public Comment	Comment letters from 45 days between Public draft presentation and Board presentation
Records cited	List of records on which amendment is based
Peer Review and report	Route through Division of Water Quality (DWQ) coordinator, allow time for technical peer review
TMDL introduction	Confirm that supporting material in chapter introduction is sufficient and diagrams and basin plan material are updated
CEQA check list	Documents no environmental impact assumption
Amendment	Copy as presented for Regional Board consideration (may be the same as required for printing and distribution below)
Transcript	Of regional board meeting where amendment was approved

Requirements For Basin Plan Amendment	Summary
Exhibit	Copies of those exhibits presented at hearing by staff and public
Late Public Comments	Summary of verbal responses to comments made at hearing and to those received after formal comment period
Economic Cost Analysis	Analysis of costs of agricultural controls, performance standards, and/or treatment requirements mandated by amendment (see Appendix A for details.)
Staff Report/TMDL	Rationale for amendment
Adopted Amendment	Adopted amendment and signed resolution
Printing and Distribution	Basin Plan update inserts mailed to current holders and updated 'record of amendments' page for insertion
Required Approvals and Concurrences	
Regional Water Board	approves TMDL and basin plan amendment
State Water Board	approves TMDL and basin plan amendment following Regional Board action
Office of Administrative Law	concurs that basin plan amendment meets State Administrative Procedures Act requirements
U.S. EPA	approves state submitted TMDL and basin plan amendment

3. Steps in TMDL Development and Approval

There are likely to be three approaches through which TMDLs are completed in California– (1) State adoption, (2) EPA establishment, and (3) State adoption following extensive 3rd party assistance in developing TMDL component parts. This section describes the procedural steps in completing TMDLs through these 3 approaches.

3.1 State-Adopted TMDLs

This approach entails preparation of a TMDL by Regional Board staff, approval by the Regional Board, approval by State Board, approval by Office of Administrative Law, and approval by U.S. EPA. The steps in this process are summarized in table 3 below.

Table 3: Steps in Developing and Adopting State-Adopted TMDLs

Step	Timing	Responsible Party
Develop draft TMDL/ Basin Plan Amendment(BPA) - usually involves detailed workplan and may involve significant stakeholder involvement	varies	Regional Board staff (often with substantial assistance from other parties)
Provide TMDL/BPA and record for peer review	varies	Regional Board staff
Peer review completed	within 60 days	Peer reviewer(s)
Respond to peer review	varies	Regional Board staff
Provide draft TMDL/BPA to EPA for review	varies	Regional Board and EPA staff
Open public comment period	45 days	Regional Board staff
Hold public hearing	varies	Regional Board
Adopt TMDL, considering public comments	varies	Regional Board
Transmit BPA/TMDL and record to State Board	varies	Regional Board staff
Prepare approval package for State Board	varies	State Board staff
Open comment period	30 days	State Board staff
Hold meeting to hear public comments	varies	State Board
Approve TMDL considering public comments	varies	State Board
Transmit BPA/TMDL and supporting record to Office of Administrative Law	varies	State Board Staff
Review BPA/TMDL for consistency with State Administrative Procedures Act	within 60 days	OAL staff
Transmit concurrence/comments to State Board	within 60 days	OAL staff
(If needed) Resolve OAL comments	varies	State and Regional Board staff
(If needed) obtain OAL concurrence	varies	State Board staff, OAL staff
Transmit final TMDL/BPA and record to EPA	varies	State Board staff
Approve or disapprove TMDL	30 days	EPA
If disapprove, establish TMDL	within 30 days after disapproval	EPA
Open comment period	30 days min.	EPA
Transmit final TMDL to State for inclusion in Basin Plan after considering public comments and making changes if needed	within 30 days after comment period	EPA

3.2 EPA-Established TMDLs

EPA's process for establishing a TMDL is more straightforward than the State's process and is summarized in table 4.

Table 4: EPA's Process for Establishing TMDLs

Step	Timeline	Responsible Party
Develop draft TMDL	varies	EPA staff, often with help from State or other parties
Public notice draft TMDL	30 day minimum	EPA staff
Hold public hearing if warranted	varies	EPA staff
Develop final TMDL, considering public comment	varies	EPA staff
Establish and transmit final TMDL to State for inclusion in Basin Plan with implementation measures	immediately upon establishment	EPA Division Director

3.3 Process Steps for Third Party Involvement in TMDL Development

Several TMDLs have been developed in California for which third parties (e.g., dischargers, land managers, or citizen groups) have prepared significant portions of the TMDL analysis or provided support for TMDL development. Third parties can assist in TMDL development in several capacities. They may include:

- developing significant work products with State and/or EPA oversight,
- administering stakeholder meetings and organizations,
- providing technical support for individual components of the TMDL,
- providing specific funding assistance for individual TMDL analysis elements, and
- providing expert review of specified components of TMDLs.

Table 5 suggests steps for more intensive involvement of third parties in TMDL development. EPA strongly recommends that these steps be followed in order to ensure that intensive third party involvement in TMDL development is productive. Only the State water quality agency or EPA are authorized to actually adopt or establish TMDLs, but third parties can assist a great deal in TMDL work in a well-managed process. Where a particular stakeholder group or discharger plays an enhanced role in TMDL development, the TMDL development process should provide specific opportunities for the Regional Board and other interested stakeholders to participate in the selection and application of the methods used to develop TMDL components. These extra opportunities for involvement in review of 3rd party efforts are needed to ensure that the selected approaches are valid and balanced.

Table 5: Steps for Involving Third Parties in TMDL Analysis

Step	Timeframe	Responsible Party
Contact Regional Board to discuss potential TMDL-related work (also contact EPA if consent decree TMDL involved)	as soon as possible	Third party organization with work conducted as part of a public process
Regional Board and Third Party establish written agreement specifying resource commitments, work to be done by third party, technical workplan,	as soon as possible	Regional Board and Third Party (and EPA if consent decree TMDLs involved)

Step	Timeframe	Responsible Party
milestones, interim deliverables, schedules, public involvement provisions, and project dependencies.		
Designate State staff contact who will work with Third Party throughout project to ensure work products are consistent with all TMDL requirements	as soon as possible	Regional Board staff
Neutral peer reviewers review technical approach	as soon as possible (can be done earlier)	peer reviewers identified and overseen by Regional Board, (also EPA if consent decree involved), third party funds
Adjust approach as needed to address peer review comments	varies	Third Party, with Regional Board oversight
Perform activities/analysis per workplan	per schedule	Third party with Regional Board staff oversight
Deliver interim/final products to Regional Board (and EPA if consent decree TMDLs involved)	per schedule	Third party with Regional Board oversight
Public review/adoption process as described above	see above	see above

3.4 How Does EPA Review and Establish TMDLs?

EPA Region 9 staff usually review draft TMDLs and provide comments to the State before the State adopts the TMDLs, in order to help ensure that the TMDLs include all federally-required elements.

The Clean Water Act and EPA regulations require EPA to review State-adopted TMDLs and either approve or disapprove the TMDLs within 30 days of final submission. EPA reviews TMDL submissions to ensure that:

- all TMDL elements required by the Clean Water Act and EPA regulations are present,
- adequate explanations and documentation are provided for each element, and
- the TMDL will result in attainment of applicable State water quality standards.

EPA Region 9 generally uses a checklist prepared by Region 9 to document its review of the TMDL submission (see Appendix B). The checklist identifies each TMDL element required by the Clean Water Act or EPA's regulations, briefly describes the element, and provides a brief explanation of EPA's analysis indicating that the element is or is not consistent with federal requirements. The checklist also addresses TMDL implementation elements in order to assist in review of State TMDL submissions which include implementation measures.

If EPA finds that all required elements are present and are adequately documented, and that the TMDL is therefore expected to result in attainment of water quality standards, EPA approves the TMDL. If any required element is missing or insufficiently documented, EPA attempts to clarify the submission during the 30 day review period. If the State does not provide

the missing TMDL element(s) or does not clarify or document the basis for its findings, EPA disapproves the TMDL.[5] If EPA disapproves the TMDL, it has 30 days to establish a TMDL which meets federal requirements.

EPA is not required to provide for public review and comment on its decision to approve or disapprove a State-established TMDL because the State provides the public with the opportunity to review and comment on the TMDL prior to State adoption of the TMDL. If EPA establishes a TMDL, EPA provides the public with an opportunity to review and comment on the TMDL, considers public comments concerning the EPA-established TMDL, and makes changes to the TMDL if warranted based on comments received from the public.

After EPA completes its review of the final TMDL submittal, staff complete a staff report, checklist, and decision letter. The Water Division Director is the official who actually makes the final decisions concerning TMDL submissions. The decision letter signed by the Water Division Director is transmitted along with the staff report and checklist to the Executive Director of the State Water Resources Control Board with a copy to the Executive Officer of the appropriate Regional Water Quality Control Board.

EPA sometimes establishes TMDLs without having disapproved a State TMDL submission (e.g., to meet court-ordered schedules or at the request of the State). EPA-established TMDLs must contain the minimum federally required elements mandated by the Clean Water Act and EPA regulations, and result in attainment of water quality standards. When EPA establishes a TMDL, it provides an opportunity for public review and comment on the TMDL, prepares a public comment responsiveness summary, and makes changes in the TMDL if needed based on comments received. The TMDL is established through the action of the Water Division Director. The final TMDL is transmitted to the Executive Director of the State Water Resources Control Board with a copy to the Executive Officer of the appropriate Regional Water Quality Control Board for inclusion in the Basin Plan by the State.

4. Additional Guidance for TMDL Development

4.1 Water Quality Standards and TMDLs

Under the Clean Water Act and EPA's regulations, the TMDL process is designed to implement existing water quality standards in waters where water quality is not good enough to meet those standards. In most situations, existing water quality standards will need to be applied in developing TMDLs. For many TMDLs, the State will need to interpret narrative objectives,

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[5] If the State provides insufficient opportunities for public participation or does not describe how public comments were considered in the final TMDL, EPA may open a comment period and make its final decision following the close of the comment period, after considering comments received from the public.

use nonattainment, or (possibly) antidegradation policies quantitatively to develop TMDL numeric targets if no numeric standards are in effect or numeric standards are not designed to address the impairment of concern. Federal regulations do not require the state to adopt TMDL numeric targets as state water quality standards. To assist in interpreting narrative objectives, beneficial use designations, and/or antidegradation policies, TMDL writers should consult applicable California implementation procedures for water quality standards.

In some cases, it may be appropriate to reevaluate the appropriateness of water quality standards for the targeted waters. Separate federal regulations provide for modifying water quality standards for individual water bodies when specified showings can be made. Additional guidance documents concerning modification of water quality standards are listed in the references. As early in the process as possible, parties who are interested in seeking revisions of water quality standards on a site-specific basis should consult with Water Quality Standards program staff at EPA Region 9, the State Water Resources Control Board, and the appropriate Regional Water Quality Control Board to discuss the suitability of standards modifications in particular situations.

4.2 TMDL Planning and Project Management

Each TMDL project is different. Planning and managing a complex TMDL project can be difficult. The following checklist summarizes factors TMDL analysts should consider in initiating a TMDL project:

- How long to you have to complete the TMDL?
- Do you face resource constraints? What staff, contractor, or stakeholder resources are available? Are resources assured for future years?
- Can other agencies, stakeholders, or programs help you do the TMDL?
- How complex are the watershed setting and pollutant issues of concern?
- What information, data, and prior efforts are available regarding the watershed setting and pollutant of concern?
- What is the scope of the TMDL? What area and what pollutants are to be addressed?

EPA strongly encourages the State to develop detailed workplans to guide the technical analysis and stakeholder participation aspects of the TMDL before starting the TMDL. The State should distribute workplans to stakeholders for input if time and resources allow. The workplans should include specific information on technical methods, interim milestones in TMDL development, responsible parties, schedules, interim deliverables, and project dependencies. It is often useful to plan a TMDL timeline by working backwards from an existing decision deadline to determine how much time is actually available to develop the TMDL. In addition, the workplans should:

- include estimated resources/costs of the project and the specific method of funding to be used, including provisions for contract assistance where needed,
- factor in time for review of the draft TMDL by EPA and interested stakeholders,

- provide some flexibility to account for unforeseen events, and
- provide for each step prescribed in the State and federal administrative processes.

TMDL planners should assess whether it is feasible to coordinate with related program decisions/activities to reduce the amount of work done solely to support the TMDL decision. Examples of coordination opportunities include:

- standards revisions already planned or underway,
- discharge permitting decisions,
- rotating basin management approaches or other watershed management planning (if any),
- development of environmental impact statements or reports for planned projects, and
- other activity in watershed (e.g., hydropower licenses issued by Federal Energy Regulatory Commission, habitat conservation plans developed pursuant to Federal Endangered Species Act, Section 319 nonpoint source management projects).

In many locations in California, there is considerable interest in developing TMDLs through a "watershed approach". The State should consider the following factors which, in EPA's experience, are key to effectively melding TMDL development and locally focused watershed management planning:

- Regional Boards should clarify that TMDL (and perhaps other regulatory) decisions that will need to be made and establish timeframes (if any) for making these decisions.
- These efforts should start several years before a TMDL is scheduled for adoption because this approach generally takes substantial time to complete.
- The State should obtain agreement to ground rules by all participants, including ground rules with respect to regulatory deadlines.
- The State should secure firm commitments from stakeholders concerning participation, funding support, etc.
- The State should use existing stakeholder groups where feasible, if those groups are interested in working on TMDL issues.
- The group should develop a detailed schedule which contemplates key decisions and dependencies related to the minimum TMDL requirements and how they are completed.
- State water quality staff should participate fully as stakeholders and have the time and resources available which are necessary to do so.

5. Sources of Additional Information and Guidance

Further information concerning TMDL development can be obtained from EPA Region 9 by visiting the Region 9 web site at www.epa.gov/region09/water/tmdl or by calling the Region 9 Water Division office at (415) 744-2012. In addition, information concerning the national TMDL program and national reference documents can be obtained by visiting the EPA Headquarters web site at www.epa.gov/OWOW/tmdl. Several cited references which provide useful guidance concerning TMDLs and related programs are listed below, and can be obtained or will soon be available through the EPA Headquarters web site.

EPA, 1990. *Technical Support Document for Water Quality-Based Toxics Control.* EPA 505-2-90-001.

EPA, 1991. *Guidance for Water Quality-Based Decisions: The TMDL Process.* EPA 440/4-91-001.

EPA, 1996. *Catalog of Publications: Office of Science and Technology.* EPA-820-R-96-001. (Wasteload Allocation Guidance Series).

EPA, 1997. New Policies for Establishing and Implementing Total Maximum Daily Loads (TMDLs). Memorandum from Robert Perciasepe to Regional Administrators, August 8, 1997.

EPA, 1999. *Protocol for Developing Sediment TMDLs.* EPA 841-B-99-004, October, 1999.

EPA, 1999. *Protocol for Developing Nutrient TMDLs.* EPA 841-B-99-007, November, 1999.

Documents which should assist in considering modifications of water quality standards on a site specific basis include:

EPA 1983-84. *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses* Vol. 1, EPA 440/4-86-037, 1983; Vol. 2 Estuarine Systems, EPA 440/4-86-038, 1984; Vol. 3: Lake Systems, EPA 440/4-86-039, 1984.

EPA Region 9, 1992. Guidance for Modifying Water Quality Standards and Protecting Effluent-Dependent Ecosystems. Interim Final, June 1992.

EPA, 1993. *Water Quality Standards Handbook.* 2nd Edition. EPA 823-B-93-002, September 1993.

EPA, 1994. *Interim Guidance on Determination and Use of Water Effect Ratios for Metals.* EPA 823-B-94-001, February 1994.

EPA, 1995. *Interim Economic Guidance for Water Quality Standards: Workbook.* EPA 823/B-95-002.

Appendix A: "Economic Considerations in TMDL Development and Basin Planning"-- An Opinion From Office of the Chief Counsel, California State Water Resources Control Board

TMDL analysts with the State and Regional Water Boards and other interested stakeholders have requested clarification concerning economic analysis considerations in the TMDL process. Neither the federal Clean Water Act nor EPA regulations require that any particular form of economic analysis must be conducted to meet federal requirements for TMDL adoption. The Office of Chief Counsel, State Water Resources Control Board, issued the following memorandum addressing economic analysis requirements under State law. The Office of Chief Counsel is solely responsible for the content of the memorandum. EPA had no role in its preparation, and we are including it with the guidance solely to convey the State's legal analysis of State requirements.

Winston H. Hickox
Secretary for Environmental Protection

State Water Resources Control Board

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Gray Davis
Governor

TO: Stefan Lorenzato
TMDL Coordinator
Division of Water Quality

FROM: Sheila K. Vassey
Senior Staff Counsel
OFFICE OF CHIEF COUNSEL

DATE:

SUBJECT: ECONOMIC CONSIDERATIONS IN TMDL DEVELOPMENT AND BASIN PLANNING

ISSUE

When are the Regional Water Quality Control Boards (Regional Water Boards or Boards) legally required to consider economics in Total Maximum Daily Load (TMDL)[1] development and water quality control planning (basin planning)?[2]

CONCLUSION

The Regional Water Boards, in general, adopt TMDLs as basin plan amendments. Under state law, there are three triggers for Regional Water Board consideration of economics or costs in basin planning. These are:

- The Regional Water Boards must estimate costs and identify potential financing sources in the basin plan before implementing any agricultural water quality control program.
- The Boards must consider economics in establishing water quality objectives that ensure the reasonable protection of beneficial uses.

[1] See 33 U.S.C. § 1313(d); 40 C.F.R. § 130.7.

[2] See Wat. Code §§ 13240-13247.

- The Boards must comply with the California Environmental Quality Control Act (CEQA)[3] when they amend their basin plans. CEQA requires that the Boards analyze the reasonably foreseeable methods of compliance with proposed performance standards and treatment requirements. This analysis must include economic factors.

Economic factors come into play under federal law when the Regional Water Boards designate uses. Specifically, the Boards can decide not to designate, dedesignate, or establish a subcategory of, a potential use where achieving the use would cause substantial and widespread economic and social impact.

DISCUSSION

I. STATE LAW

Under federal and state law, the Regional Water Boards are required to include TMDLs in their basin plans.[4] There are three statutory triggers for an economic or cost analysis in basin planning. These triggers are:

- adoption of an agricultural water quality control program;
- adoption of water quality objectives; and
- adoption of a treatment requirement or performance standard (CEQA).

Each category is briefly discussed below.

A. Agricultural Water Quality Control Program

Agricultural activities are significant sources of nonpoint source pollution. Many waterbodies in the state are impaired due to one or more agricultural operations. As a result, the Regional Water Boards will be faced with developing programs to control agricultural activities, as part of TMDL development.

Under the Porter-Cologne Water Quality Control Act (Porter-Cologne),[5] before a Regional Water Board implements an agricultural water quality control program, the Board must identify

[3] Pub. Resources Code § 21000 et seq.

[4] See 33 U.S.C. § 1313(d); 40 C.F.R. § 130.7(d)(2) (TMDLs must be incorporated into the state's water quality management plan. In California the basin plans are part of the state's water quality management plan.); Wat. Code §§ 13050(j), 13242.

[5] Wat. Code § 13000 et seq.

the total cost of the program and potential sources of financing.[6] This information must be included in the basin plan.

The statute does not define "agricultural" programs. The Legislature has, however, defined agricultural activities elsewhere to mean activities that generate "horticultural, viticultural, forestry, dairy, livestock, poultry, bee, or farm product[s]."[7] Because "agricultural" programs under Porter-Cologne are not restricted to particular activities, presumably, the Legislature intended that the term be interpreted broadly. Thus, the Regional Water Boards should identify costs and financing sources for agricultural water quality control programs" covering not only typical farming activities but also silviculture, horticulture, dairy, and the other listed activities.

The statute focuses only on costs and financing sources. The statute does not require the Regional Water Boards to do, for example, a cost-benefit analysis or an economic analysis.

B. Water Quality Objectives

Porter-Cologne requires that the Regional Water Boards take "economic considerations", among other factors, into account when they establish water quality objectives.[8] The objectives must ensure the reasonable protection of beneficial uses and the prevention of nuisance.[9]

Attached to this memorandum is a 1994 memorandum containing guidance on the consideration of economics in the adoption of water quality objectives.[10] The key points of this guidance are:

- The Boards have an affirmative duty to consider economics when adopting water quality objectives.
- At a minimum, the Boards must analyze: (1) whether a proposed objective is currently being attained; (2) if not, what methods are available to achieve compliance with the objective; and (3) the costs of those methods.

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[6] *Id.* § 13141.

[7] Food & Agr. Code §§ 564(a), 54004.

[8] Wat. Code § 13241. The other factors include the past, present, and probable future beneficial uses of water; environmental characteristics of the hydrographic unit under consideration; water quality conditions that could reasonably be achieved through the coordinated control of all factors affecting water quality in the area, the need for developing housing, and the need to develop and use recycled water.

[9] *Ibid.*

[10] Memorandum, dated January 4, 1994, from William R. Attwater, Chief Counsel, to Regional Water Board Executive Officers and Attorneys, entitled "Guidance on Consideration of Economics in the Adoption of Water Quality Objectives".

- If the economic consequences of adoption of a proposed objective are potentially significant, the Boards must state on the record why adoption of the objective is necessary to ensure the reasonable protection of beneficial uses or the prevention of nuisance.
- The Regional Water Boards can adopt objectives despite significant economic consequences.
- The Boards are not required to do a formal cost-benefit analysis.

C. CEQA

The Regional Water Boards must comply with CEQA when they amend their basin plans.[11] The State Resources Agency has certified the basin-planning program as exempt from the requirement to prepare environmental documents under CEQA.[12] In lieu of preparing an environmental impact report or negative declaration, the Boards must comply with the State Water Resources Control Board's regulations on exempt regulatory programs when they amend their basin plans.[13] These regulations require the Boards to prepare a written report that analyzes the environmental impacts of proposed basin plan amendments.[14] In general, CEQA requires the Regional Water Boards to consider economic factors only in relation to physical changes in the environment.[15]

CEQA also has specific provisions governing the Regional Water Boards' adoption of regulations, such as the regulatory provisions of basin plans that establish performance standards or treatment requirements. The Boards must do an environmental analysis of the reasonably foreseeable methods of compliance with those standards or requirements.[16] They must consider economic factors in this analysis.

CEQA does not define "performance standard"; however, the term is defined in the rulemaking provisions of the Administrative Procedure Act.[17] A "performance standard" is a regulation that describes an objective with the criteria stated for achieving the objective.[18]

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[11] See Pub. Resources Code § 21080.

[12] See Cal. Code Regs., tit. 14, § 15251(g).

[13] See Cal. Code Regs., tit. 23, §§ 3775-3782.

[14] *Id.* § 3777.

[15] See Cal. Code Regs., tit. 14, § 15064(e).

[16] Pub. Resources Code § 21159.

[17] Gov. Code §§ 11340-11359.

[18] *Id.* § 11342(d).

TMDLs will typically include performance standards. TMDLs normally contain a quantifiable target that interprets the applicable water quality standard. They also include wasteload[19] allocations for point sources, and load allocations[20] for nonpoint sources and natural background to achieve the target.[21] The quantifiable target together with the allocations may be considered a performance standard. Thus, the Regional Water Board must identify the reasonably foreseeable methods of compliance with the wasteload and load allocations and consider economic factors for those methods. This economic analysis is similar to the analysis for water quality objectives discussed above. That is, the Regional Water Board should determine: (1) whether the allocations are being attained; (2) if not, what methods of compliance are reasonably foreseeable to attain the allocations; and (3) what are the costs of these methods.

II. FEDERAL LAW

Under federal law, economics can be considered in designating potential beneficial uses. Specifically, the federal water quality standards regulations allow a state to dedesignate, to decide not to designate, or to establish a subcategory of a potential beneficial use on economic grounds. To rely on this basis, the state must demonstrate that attaining the use is infeasible because the controls necessary to attain the use "would result in substantial and widespread economic and social impact."[22]

The states can take this action only for potential uses. These are uses that do not meet the definition of an "existing use". Existing uses are those uses actually attained in the water body on or after November 28, 1975.[23]

Attachment

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[19] See 40 C.F.R. § 130.2(g). A wasteload allocation is the portion of the receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution.

[20] See *id.* § 130.2(g). A load allocation is the portion of the receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources.

[21] See *id.* § 130.2(i). A TMDL is the sum of the individual wasteload and load allocations.

[22] See *id.* § 131.10(g)(6).

[23] *Id.* § 131.3(e).

Appendix B: EPA Region 9 TMDL Review Checklist

EPA Region 9 uses this checklist to review TMDLs submitted for EPA Region 9 approval to ensure that the TMDLs meet all the requirements of the Clean Water Act and EPA's regulations concerning TMDL content. Because many TMDL submissions from California and other states also include TMDL implementation measures pursuant to EPA's regulatory requirements at 40 CFR 130.6, the checklist also includes review criteria for TMDL implementation measures. EPA regulations do not require the submission of implementation measures at the same time as TMDLs are submitted.

State: **Waterbodies:**
Pollutant(s): **Date of State Submission:**
Date Received By EPA: **EPA Reviewer:**

TMDL Review Criteria (per Clean Water Act Section 303(d) and 40 CFR 130.2 and 130.7)	**Approved**	**Comments**
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).		
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.		
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.		
4. Source Analysis: Point, nonpoint, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant sources have been considered.		
5. Allocations: Submittal identifies appropriate wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, wasteload allocations are zero. If no nonpoint sources are present, load allocations are zero.		
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of wasteload allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).		
7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.		

8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)		
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).		
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.		
Note: **The following criteria do not apply to all TMDLs, but must be applied in the situations noted.**		
11. Monitoring Plan for TMDLs Under Phased Approach (where phased approach is used): TMDLs developed under phased approach identify implementation actions, monitoring plan and schedule for considering revisions to TMDL.		
12. Reasonable Assurances (for waters affected by both point and nonpoint sources): Where point source(s) receive less stringent wasteload allocations because nonpoint source reductions are expected and reflected in load allocations, implementation plan provides reasonable assurances that nonpoint implementation actions are sufficient to result in attainment of load allocations in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate.		
Implementation Plan Review Criteria (per Clean Water Act Section 303(e) and 40 CFR 130.6)		
13. Clear Implementation Plan: Submittal describes planned implementation actions or, where appropriate, specific process and schedule for determining future implementation actions . Plan is sufficient to implement all wasteload and load allocations in reasonable period of time. TMDL(s) and implementation measures are incorporated into the water quality management plan. Water quality management plan revisions are consistent with other existing provisions of the water quality management plan.		

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	C	Abalone Cove Beach	40511000				
				DDT (sediment)		1.1 Miles	2019
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		1.1 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	B	Alamitos Bay	40512000				
				Indicator bacteria		328 Acres	2019
				This listing was made by USEPA for 2006. The listing includes the area of Alamitos Bay at Shorefloat, 1st St. and Bayshore, 2nd St. Bridge and Bayshore, 56th Place - bayside.			
					Source Unknown		
4	R	Aliso Canyon Wash	40521000				
				Copper		10 Miles	2019
					Source Unknown		
				Fecal Coliform		10 Miles	2019
					Source Unknown		
4	C	Amarillo Beach	40431000				
				DDT		0.64 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		0.64 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	R	Arroyo Seco Reach 1 (LA River to West Holly Ave.)	40515010				
				Coliform Bacteria		5.2 Miles	2009
					Nonpoint Source		
				Trash		5.2 Miles	2007
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	R	Arroyo Seco Reach 2 (Figueroa St. to Riverside Dr.)	40515010				
				Coliform Bacteria		4.4 Miles	2009
					Nonpoint Source		
				Trash		4.4 Miles	2007
					Nonpoint Source		
4	C	Avalon Beach	40511000				
				Indicator bacteria		0.67 Miles	2019
				Area affected is between Pier and BB restaurant (2/3), between Pier and BB restaurant (1/3), between storm drain and Pier (1/3). and between BB restaurant and the Tuna Club.			
					Nonpoint/Point Source		
4	R	Ballona Creek	40513000				
				Cadmium (sediment)		6.5 Miles	2005
					Nonpoint/Point Source		
				Cyanide		6.5 Miles	2019
					Source Unknown		
				Silver (sediment)		6.5 Miles	2005
					Nonpoint Source		
4	R	Ballona Creek Estuary	40513000				
				Shellfish Harvesting Advisory		2.3 Miles	2006
					Nonpoint/Point Source		
4	T	Ballona Creek Wetlands	40517000				
				Exotic Vegetation		289 Acres	2019
					Nonpoint Source		
				Habitat alterations		289 Acres	2019
					Nonpoint Source		
				Hydromodification		289 Acres	2019
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Reduced Tidal Flushing	Nonpoint Source	289 Acres	2019
4	R	Bell Creek	40521000				
				Coliform Bacteria	Nonpoint/Point Source	8.9 Miles	2009
4	C	Big Rock Beach	40431000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	0.74 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	0.74 Miles	2019
4	C	Bluff Cove Beach	40511000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	0.55 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	0.55 Miles	2019
4	R	Brown Barranca/Long Canyon	40321000				
				Nitrate and Nitrite	Nonpoint Source	2.6 Miles	2003
4	R	Burbank Western Channel	40521000				
				Cyanide	Source Unknown	13 Miles	2019
				Trash	Nonpoint/Point Source	13 Miles	2002
4	C	Cabrillo Beach (Outer)	40512000				
				DDT *Fish consumption advisory for DDT.*	Nonpoint Source	0.58 Miles	2019

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls)		0.58 Miles	2019
				Fish consumption advisory for PCBs.			
					Nonpoint Source		
4	E	Calleguas Creek Reach 1 (was Mugu Lagoon on 1998 303(d) list)	40311000				
				Endosulfan (tissue)		344 Acres	2005
					Nonpoint Source		
4	R	Calleguas Creek Reach 2 (estuary to Potrero Rd- was Calleguas Creek Reaches 1 and 2 on 1998 303d list)	40312000				
				ChemA (tissue)		4.3 Miles	2005
				Historical use of pesticides and lubricants.			
					Nonpoint Source		
				Endosulfan (tissue)		4.3 Miles	2005
					Nonpoint Source		
				Fecal Coliform		4.3 Miles	2006
				Area affected is at the mouth of the creek.			
					Nonpoint/Point Source		
				Sedimentation/Siltation		4.3 Miles	2005
					Agriculture		
					Natural Sources		
4	R	Calleguas Creek Reach 3 (Potrero Road upstream to confluence with Conejo Creek on 1998 303d list)	40312000				
				Chloride		3.5 Miles	2002
					Nonpoint/Point Source		
				Sedimentation/Siltation		3.5 Miles	2005
					Agriculture		
					Natural Sources		
				Total Dissolved Solids		3.5 Miles	2019
					Nonpoint/Point Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	R	Calleguas Creek Reach 4 (was Revolon Slough Main Branch: Mugu Lagoon to Central Avenue on 1998 303d list)	40311000				
				Boron		7.2 Miles	2019
				This listing was made by USEPA.			
					Nonpoint Source		
				ChemA (tissue)		7.2 Miles	2005
				Historical use of pesticides and lubricants.			
					Nonpoint Source		
				Endosulfan (tissue & sediment)		7.2 Miles	2005
					Nonpoint Source		
				Fecal Coliform		7.2 Miles	2006
					Nonpoint/Point Source		
				Sedimentation/Siltation		7.2 Miles	2005
					Agriculture		
					Natural Sources		
				Sulfates		7.2 Miles	2019
				This listing was made by USEPA.			
					Nonpoint Source		
				Total Dissolved Solids		7.2 Miles	2019
				This listing was made by USEPA.			
					Nonpoint Source		
				Trash		7.2 Miles	2019
					Nonpoint Source		
4	R	Calleguas Creek Reach 5 (was Beardsley Channel on 1998 303d list)	40311000				
				ChemA (tissue)		4.3 Miles	2005
					Nonpoint Source		
				Dacthal (sediment)		4.3 Miles	2005
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Endosulfan (tissue & sediment)		4.3 Miles	2005
					Nonpoint Source		
				Sedimentation/Siltation		4.3 Miles	2005
					Agriculture		
					Natural Sources		
				Trash		4.3 Miles	2019
					Nonpoint Source		
4	R	Calleguas Creek Reach 6 (was Arroyo Las Posas Reaches 1 and 2 on 1998 303d list)	40362000				
				Chloride		15 Miles	2002
					Nonpoint/Point Source		
				Fecal Coliform		15 Miles	2006
					Nonpoint/Point Source		
				Sedimentation/Siltation		15 Miles	2005
					Agriculture		
					Natural Sources		
				Sulfates		15 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		15 Miles	2019
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 7 (was Arroyo Simi Reaches 1 and 2 on 1998 303d list)	40367000				
				Boron		14 Miles	2019
					Nonpoint Source		
				Chloride		14 Miles	2002
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Fecal Coliform		14 Miles	2006
					Nonpoint Source		
				Sedimentation/Siltation		14 Miles	2005
					Agriculture		
					Natural Sources		
				Sulfates		14 Miles	2019
					Nonpoint Source		
				Total Dissolved Solids		14 Miles	2019
					Nonpoint Source		
4	R	Calleguas Creek Reach 8 (was Tapo Canyon Reach 1)	40366000				
				Boron		7.2 Miles	2019
					Nonpoint/Point Source		
				Chloride		7.2 Miles	2002
					Nonpoint/Point Source		
				Sedimentation/Siltation		7.2 Miles	2005
					Nonpoint Source		
				Sulfates		7.2 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		7.2 Miles	2019
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 9A (was lower part of Conejo Creek Reach 1 on 1998 303d list)	40312000				
				ChemA (tissue)		1.7 Miles	2005
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Endosulfan (tissue)	Nonpoint Source	1.7 Miles	2005
				Fecal Coliform	Nonpoint/Point Source	1.7 Miles	2006
				Lindane/Hexachlorocyclohexane/HCH (tissue) *Historical use of pesticides and lubricants.*	Nonpoint Source	1.7 Miles	2005
				Sulfates	Nonpoint/Point Source	1.7 Miles	2019
				Total Dissolved Solids	Nonpoint/Point Source	1.7 Miles	2019
4	R	Calleguas Creek Reach 9B (was part of Conejo Creek Reaches 1 and 2 on 1998 303d list)	40363000				
				ChemA (tissue)	Nonpoint Source	6.2 Miles	2005
				Chloride	Nonpoint/Point Source	6.2 Miles	2002
				Endosulfan (tissue)	Nonpoint Source	6.2 Miles	2005
				Fecal Coliform	Nonpoint/Point Source	6.2 Miles	2006
				Sulfates	Nonpoint/Point Source	6.2 Miles	2019
				Total Dissolved Solids	Nonpoint/Point Source	6.2 Miles	2019

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	R	Calleguas Creek Reach 10 (Conejo Creek (Hill Canyon)-was part of Conejo Crk Reaches 2 & 3, and lower Conejo Crk/Arroyo Conejo N Fk on 1998 303d list)	40364000				
				ChemA (tissue)		3 Miles	2005
					Nonpoint Source		
				Chloride		3 Miles	2019
					Nonpoint/Point Source		
				Endosulfan (tissue)		3 Miles	2005
					Nonpoint Source		
				Fecal Coliform		3 Miles	2006
					Nonpoint Source		
				Sulfates		3 Miles	2019
					Nonpoint Source		
				Total Dissolved Solids		3 Miles	2019
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 11 (Arroyo Santa Rosa, was part of Conejo Creek Reach 3 on 1998 303d list)	40365000				
				ChemA (tissue)		8.7 Miles	2005
					Nonpoint Source		
				Endosulfan (tissue)		8.7 Miles	2005
					Nonpoint Source		
				Fecal Coliform		8.7 Miles	2006
					Nonpoint/Point Source		
				Sedimentation/Siltation		8.7 Miles	2005
					Agriculture		
					Natural Sources		

A015131

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Sulfates		8.7 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		8.7 Miles	2019
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 12 (was Conejo Creek/Arroyo Conejo North Fork on 1998 303d list)	40364000				
				Sulfates		5.5 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		5.5 Miles	2019
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 13 (Conejo Creek South Fork, was Conejo Cr Reach 4 and part of Reach 3 on 1998 303d list)	40368000				
				ChemA (tissue)		17 Miles	2005
					Nonpoint Source		
				Chloride		17 Miles	2002
					Nonpoint/Point Source		
				Endosulfan (tissue)		17 Miles	2005
					Nonpoint Source		
				Sulfates		17 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		17 Miles	2019
					Nonpoint/Point Source		
4	R	Canada Larga (Ventura River Watershed)	40210010				
				Fecal Coliform		8 Miles	2019
				Horse stables, land use, cattle, and wildlife may be sources.			
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Low Dissolved Oxygen	Nonpoint Source	8 Miles	2019
4	C	Carbon Beach	40416000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.5 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.5 Miles	2019
4	C	Castlerock Beach	40513000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	0.21 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	0.21 Miles	2019
4	B	Channel Islands Harbor	40311000				
				Lead (sediment)	Nonpoint Source	209 Acres	2019
				Zinc (sediment)	Nonpoint Source	209 Acres	2019
4	C	Channel Islands Harbor Beach	40311000				
				Indicator bacteria	Nonpoint/Point Source	0.08 Miles	2019
4	T	Colorado Lagoon	40512000				
				Chlordane (tissue & sediment)	Nonpoint Source	13 Acres	2019
				DDT (tissue)	Nonpoint Source	13 Acres	2019
				Dieldrin (tissue)	Nonpoint Source	13 Acres	2019

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Indicator bacteria		13 Acres	2019
				This listing was made by USEPA for 2006. This listing includes the north, center, and south areas of the lagoon.			
					Source Unknown		
				Lead (sediment)		13 Acres	2019
					Nonpoint Source		
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)		13 Acres	2019
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (tissue)		13 Acres	2019
					Nonpoint Source		
				Sediment Toxicity		13 Acres	2019
					Nonpoint Source		
				Zinc (sediment)		13 Acres	2019
					Nonpoint Source		
4	R	Compton Creek	40515010				
				Coliform Bacteria		8.5 Miles	2009
					Nonpoint/Point Source		
				Trash		8.5 Miles	2019
					Source Unknown		
4	R	Coyote Creek	40515010				
				Coliform Bacteria		13 Miles	2019
					Nonpoint/Point Source		
				Copper, Dissolved		13 Miles	2006
					Nonpoint Source		
				Diazinon		13 Miles	2019
					Source Unknown		

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Lead *This listing was made by USEPA for 2006.*	Source Unknown	13 Miles	2007
				pH	Source Unknown	13 Miles	2019
				Toxicity *This listing was made by USEPA for 2002.*	Point Source	13 Miles	2008
				Zinc *This listing was made by USEPA for 2006.*	Source Unknown	13 Miles	2007
4	L	Crystal Lake	40543000				
				Organic Enrichment/Low Dissolved Oxygen	Nonpoint Source	3.7 Acres	2019
4	R	Dominguez Channel (lined portion above Vermont Ave)	40351000				
				Ammonia	Nonpoint/Point Source	6.7 Miles	2019
				Copper	Nonpoint/Point Source	6.7 Miles	2019
				Dieldrin (tissue)	Nonpoint/Point Source	6.7 Miles	2019
				Indicator bacteria	Nonpoint/Point Source	6.7 Miles	2007
				Lead (tissue)	Nonpoint/Point Source	6.7 Miles	2019
				Sediment Toxicity	Source Unknown	6.7 Miles	2019

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Zinc (sediment)		6.7 Miles	2019
					Nonpoint/Point Source		
4	E	Dominguez Channel Estuary (unlined portion below Vermont Ave)	40512000				
				Ammonia		140 Acres	2019
					Nonpoint/Point Source		
				Benthic Community Effects		140 Acres	2019
					Nonpoint/Point Source		
				Benzo(a)pyrene (PAHs)		140 Acres	2019
					Source Unknown		
				Benzo[a]anthracene		140 Acres	2019
					Source Unknown		
				Chlordane (tissue)		140 Acres	2019
					Nonpoint/Point Source		
				Chrysene (C1-C4)		140 Acres	2019
					Source Unknown		
				Coliform Bacteria		140 Acres	2007
					Nonpoint/Point Source		
				DDT (tissue & sediment)		140 Acres	2019
					Nonpoint/Point Source		
				Dieldrin (tissue)		140 Acres	2019
					Nonpoint/Point Source		
				Lead (tissue)		140 Acres	2019
					Nonpoint/Point Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls)		140 Acres	2019
					Source Unknown		
				Phenanthrene		140 Acres	2019
					Source Unknown		
				Pyrene		140 Acres	2019
					Source Unknown		
				Zinc (sediment)		140 Acres	2019
					Nonpoint/Point Source		
4	R	Dry Canyon Creek	40521000				
				Fecal Coliform		3.9 Miles	2009
					Urban Runoff/Storm Sewers		
					Natural Sources		
4	L	Echo Park Lake	40515010				
				Algae		13 Acres	2019
					Nonpoint Source		
				Ammonia		13 Acres	2019
					Nonpoint Source		
				Copper		13 Acres	2019
					Nonpoint Source		
				Eutrophic		13 Acres	2019
					Nonpoint Source		
				Lead		13 Acres	2019
					Nonpoint Source		
				Odor		13 Acres	2019
					Nonpoint Source		

A015137

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (tissue)		13 Acres	2019
					Nonpoint Source		
				pH		13 Acres	2019
					Nonpoint Source		
				Trash		13 Acres	2007
					Source Unknown		
4	L	El Dorado Lakes	40515010				
				Algae		35 Acres	2019
					Nonpoint Source		
				Ammonia		35 Acres	2019
					Nonpoint Source		
				Copper		35 Acres	2019
					Nonpoint Source		
				Eutrophic		35 Acres	2019
					Nonpoint Source		
				Lead		35 Acres	2019
					Nonpoint Source		
				Mercury (tissue)		35 Acres	2019
					Nonpoint Source		
				pH		35 Acres	2019
					Nonpoint Source		
4	L	Elizabeth Lake	40351000				
				Eutrophic		123 Acres	2019
					Nonpoint Source		
				Organic Enrichment/Low Dissolved Oxygen		123 Acres	2019
					Nonpoint Source		
				pH		123 Acres	2019
					Nonpoint Source		
				Trash		123 Acres	2019
					Nonpoint Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	C	Escondido Beach	40434000				
				DDT		1.2 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		1.2 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	C	Flat Rock Point Beach Area	40511000				
				DDT		0.11 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		0.11 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	R	Fox Barranca (tributary to Calleguas Creek Reach 6)	40362000				
				Boron		6.7 Miles	2019
					Nonpoint Source		
				Sulfates		6.7 Miles	2019
					Nonpoint Source		
				Total Dissolved Solids		6.7 Miles	2019
					Nonpoint Source		
4	C	Hobie Beach (Channel Islands Harbor)	40311000				
				Indicator bacteria		0.06 Miles	2019
					Nonpoint/Point Source		
4	R	Hopper Creek	40341000				
				Sulfates		13 Miles	2019
					Nonpoint/Point Source		
				Total Dissolved Solids		13 Miles	2019
					Nonpoint/Point Source		

A015139

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
4	C	Inspiration Point Beach	40511000					
				DDT		0.14	Miles	2019
				Fish Consumption Advisory for DDT.				
					Nonpoint Source			
				PCBs (Polychlorinated biphenyls)		0.14	Miles	2019
				Fish Consumption Advisroy for PCBs.				
					Nonpoint Source			
4	C	La Costa Beach	40416000					
				DDT		0.74	Miles	2019
				Fish Consumption Advisory for DDT.				
					Nonpoint Source			
				PCBs (Polychlorinated biphenyls)		0.74	Miles	2019
				Fish Consumption Advisory for PCBs.				
					Nonpoint Source			
4	L	Lake Calabasas	40521000					
				Ammonia		18	Acres	2006
					Nonpoint Source			
				DDT (tissue)		18	Acres	2019
					Nonpoint Source			
				Eutrophic		18	Acres	2019
					Nonpoint Source			
				Odor		18	Acres	2019
					Nonpoint Source			
				Organic Enrichment/Low Dissolved Oxygen		18	Acres	2019
					Nonpoint Source			
				pH		18	Acres	2019
					Nonpoint Source			
4	L	Lake Hughes	40351000					
				Algae		21	Acres	2019
					Nonpoint Source			
				Eutrophic		21	Acres	2019
					Nonpoint Source			
				Fish Kills		21	Acres	2019
					Nonpoint Source			

A91519

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Odor	Nonpoint Source	21 Acres	2019
				Trash	Nonpoint Source	21 Acres	2019
4	L	Lake Lindero	40423000				
				Algae	Nonpoint Source	15 Acres	2006
				Chloride	Nonpoint Source	15 Acres	2019
				Eutrophic	Nonpoint Source	15 Acres	2006
				Odor	Nonpoint Source	15 Acres	2006
				Selenium	Source Unknown	15 Acres	2019
				Specific Conductivity	Nonpoint Source	15 Acres	2019
				Trash	Nonpoint Source	15 Acres	2019
4	L	Lake Sherwood	40426000				
				Algae	Nonpoint Source	135 Acres	2006
				Ammonia	Nonpoint Source	135 Acres	2006
				Eutrophic	Nonpoint Source	135 Acres	2006
				Mercury (tissue)	Nonpoint Source	135 Acres	2019

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Organic Enrichment/Low Dissolved Oxygen	Nonpoint Source	135 Acres	2006
4	C	Las Flores Beach	40415000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.1 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.1 Miles	2019
4	C	Las Tunas Beach	40412000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.2 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.2 Miles	2019
4	R	Las Virgenes Creek	40422010				
				Nutrients (Algae)	Nonpoint Source	12 Miles	2006
				Organic Enrichment/Low Dissolved Oxygen	Nonpoint Source	12 Miles	2006
				Scum/Foam-unnatural	Nonpoint Source	12 Miles	2006
				Sedimentation/Siltation	Source Unknown	12 Miles	2019
				Selenium	Nonpoint Source	12 Miles	2019
				Trash	Nonpoint Source	12 Miles	2019

A051512

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	L	Legg Lake	40531000				
				Ammonia		25 Acres	2019
					Nonpoint Source		
				Copper		25 Acres	2019
					Nonpoint Source		
				Lead		25 Acres	2019
					Nonpoint Source		
				Odor		25 Acres	2019
					Nonpoint Source		
				pH		25 Acres	2019
					Nonpoint Source		
				Trash		25 Acres	2019
					Nonpoint Source		
4	L	Lincoln Park Lake	40515010				
				Ammonia		3.8 Acres	2019
					Nonpoint Source		
				Eutrophic		3.8 Acres	2019
					Nonpoint Source		
				Lead		3.8 Acres	2019
					Nonpoint Source		
				Odor		3.8 Acres	2019
					Nonpoint Source		
				Organic Enrichment/Low Dissolved Oxygen		3.8 Acres	2019
					Nonpoint Source		
				Trash		3.8 Acres	2007
					Source Unknown		

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	R	Lindero Creek Reach 1	40423000				
				Algae		3 Miles	2006
					Nonpoint Source		
				Scum/Foam-unnatural		3 Miles	2006
					Nonpoint Source		
				Selenium		3 Miles	2019
					Nonpoint Source		
				Trash		3 Miles	2019
					Nonpoint Source		
4	R	Lindero Creek Reach 2 (Above Lake)	40425000				
				Algae		4.5 Miles	2006
					Nonpoint Source		
				Scum/Foam-unnatural		4.5 Miles	2006
					Nonpoint Source		
				Selenium		4.5 Miles	2019
					Nonpoint Source		
				Trash		4.5 Miles	2019
					Nonpoint Source		
4	C	Long Beach City Beach	40512000				
				Indicator bacteria		4.7 Miles	2019
				This listing was made by USEPA for 2006. This listing includes the beach area at 3rd Place, 5th, 10th, 16th, 36th, 54th, 55th, 62nd, and 72nd Streets, Coronado Ave., Granada Ave., Molina Ave., and Prospect Ave..			
					Source Unknown		
4	C	Long Point Beach	40511000				
				DDT		0.7 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		

A015144

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls)		0.7 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	B	Los Angeles Harbor - Cabrillo Marina	40512000				
				DDT		77 Acres	2019
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		77 Acres	2019
					Source Unknown		
4	B	Los Angeles Harbor - Consolidated Slip	40512000				
				2-Methylnaphthalene		36 Acres	2008
				This listing was made by USEPA for 2006.			
					Source Unknown		
				Benthic Community Effects		36 Acres	2019
					Nonpoint Source		
				Benzo(a)pyrene (PAHs)		36 Acres	2008
				This listing was made by USEPA for 2006.			
					Source Unknown		
				Benzo[a]anthracene		36 Acres	2008
				This listing was made by USEPA for 2006.			
					Source Unknown		
				Cadmium (sediment)		36 Acres	2019
				Historical use of pesticides and lubricants, stormwater runoff, aerial deposition, and historical discharges for metals.			
					Nonpoint Source		
				Chlordane (tissue & sediment)		36 Acres	2019
					Nonpoint Source		
				Chromium (sediment)		36 Acres	2019
					Nonpoint Source		
				Chrysene (C1-C4)		36 Acres	2008
				This listing was made by USEPA for 2006.			
					Source Unknown		

A015115

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Copper (sediment)	Nonpoint Source	36 Acres	2019
				DDT (tissue & sediment) *Fish Consumption Advisory for DDT.*	Nonpoint Source	36 Acres	2019
				Dieldrin	Nonpoint Source	36 Acres	2008
				Lead (sediment)	Nonpoint Source	36 Acres	2019
				Mercury (sediment) *Historical use of pesticides and lubricants, stormwater runoff, aerial deposition, and historical discharges for metals.*	Nonpoint Source	36 Acres	2019
				PCBs (Polychlorinated biphenyls) (tissue & sediment) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	36 Acres	2019
				Phenanthrene *This listing was made by USEPA for 2006.*	Source Unknown	36 Acres	2008
				Pyrene *This listing was made by USEPA for 2006.*	Source Unknown	36 Acres	2008
				Sediment Toxicity	Nonpoint Source	36 Acres	2019
				Toxaphene (tissue)	Nonpoint Source	36 Acres	2019
				Zinc (sediment) *Historical use of pesticides and lubricants, stormwater runoff, aerial deposition, and historical discharges for metals.*	Nonpoint Source	36 Acres	2019
4	B	Los Angeles Harbor - Fish Harbor	40518000				
				Benzo(a)pyrene (PAHs) *This listing was made by USEPA for 2006.*	Source Unknown	91 Acres	2008

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Benzo[a]anthracene	Source Unknown	91 Acres	2019
				Chlordane	Source Unknown	91 Acres	2019
				Chrysene (C1-C4)	Source Unknown	91 Acres	2019
				Copper	Source Unknown	91 Acres	2019
				DDT	Nonpoint Source	91 Acres	2019
				Dibenz[a,h]anthracene	Source Unknown	91 Acres	2019
				Lead	Source Unknown	91 Acres	2019
				Mercury	Source Unknown	91 Acres	2019
				PAHs (Polycyclic Aromatic Hydrocarbons)	Nonpoint Source	91 Acres	2019
				PCBs (Polychlorinated biphenyls)	Nonpoint Source	91 Acres	2019
				Phenanthrene	Source Unknown	91 Acres	2019
				Pyrene	Source Unknown	91 Acres	2019

A015117

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Sediment Toxicity		91 Acres	2019
					Source Unknown		
				Zinc		91 Acres	2019
					Source Unknown		
4	B	Los Angeles Harbor - Inner Cabrillo Beach Area	40512000				
				Copper		82 Acres	2019
					Source Unknown		
				DDT *Fish Consumption Advisory for DDT.*		82 Acres	2019
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*		82 Acres	2019
					Nonpoint Source		
4	E	Los Angeles River Estuary (Queensway Bay)	40512000				
				Chlordane (sediment) *Historical use of pesticides and lubricants.*		207 Acres	2019
					Nonpoint Source		
				DDT (sediment) *Historical use of pesticides and lubricants.*		207 Acres	2019
					Nonpoint Source		
				Lead (sediment) *Historical use of pesticides and lubricants.*		207 Acres	2019
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (sediment) *Historical use of pesticides and lubricants.*		207 Acres	2019
					Nonpoint Source		
				Sediment Toxicity		207 Acres	2019
					Source Unknown		
				Trash		207 Acres	2007
					Source Unknown		

A015148

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Zinc (sediment)		207 Acres	2019
				Historical use of pesticides and lubricants.			
					Nonpoint Source		
4	R	Los Angeles River Reach 1 (Estuary to Carson Street)	40512000				
				Coliform Bacteria		3.4 Miles	2009
					Nonpoint/Point Source		
				Cyanide		3.4 Miles	2019
					Source Unknown		
				Diazinon		3.4 Miles	2019
					Source Unknown		
				Trash		3.4 Miles	2007
					Nonpoint/Point Source		
4	R	Los Angeles River Reach 2 (Carson to Figueroa Street)	40515010				
				Coliform Bacteria		19 Miles	2009
					Nonpoint/Point Source		
				Oil		19 Miles	2019
					Nonpoint Source		
				Trash		19 Miles	2007
					Nonpoint/Point Source		
4	R	Los Angeles River Reach 3 (Figueroa St. to Riverside Dr.)	40521000				
				Trash		7.9 Miles	2007
					Source Unknown		

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED		PROPOSED TMDL COMPLETION
4	R	Los Angeles River Reach 4 (Sepulveda Dr. to Sepulveda Dam)	40521000					
				Coliform Bacteria		11	Miles	2009
					Nonpoint/Point Source			
				Trash		11	Miles	2007
					Source Unknown			
4	R	Los Angeles River Reach 5 (within Sepulveda Basin)	40521000					
				Oil		1.9	Miles	2019
					Nonpoint/Point Source			
				Trash		1.9	Miles	2007
					Nonpoint/Point Source			
4	R	Los Angeles River Reach 6 (Above Sepulveda Flood Control Basin)	40521000					
				1,1-Dichloroethane (1,1-DCE)/Vinylidene chloride		7	Miles	2019
					Nonpoint Source			
				Coliform Bacteria		7	Miles	2009
					Nonpoint Source			
				Tetrachloroethylene/PCE		7	Miles	2019
					Nonpoint Source			
				Trichloroethylene/TCE		7	Miles	2019
					Nonpoint Source			
4	B	Los Angeles/Long Beach Inner Harbor	40518000					
				Beach Closures		3003	Acres	2004
					Nonpoint/Point Source			
				Benthic Community Effects		3003	Acres	2019
					Nonpoint Source			

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Copper *This listing was made by USEPA for 2006.*	Source Unknown	3003 Acres	2008
				DDT	Nonpoint/Point Source	3003 Acres	2019
				PCBs (Polychlorinated biphenyls)	Nonpoint/Point Source	3003 Acres	2019
				Sediment Toxicity	Nonpoint/Point Source	3003 Acres	2019
				Zinc *This listing was made by USEPA for 2006.*	Source Unknown	3003 Acres	2008
4	B	Los Angeles/Long Beach Outer Harbor (inside breakwater)	40512000				
				DDT	Nonpoint Source	4042 Acres	2019
				PCBs (Polychlorinated biphenyls)	Nonpoint Source	4042 Acres	2019
				Sediment Toxicity *This listing was made by USEPA for 2006.*	Source Unknown	4042 Acres	2008
4	T	Los Cerritos Channel	40515010				
				Ammonia	Nonpoint Source	31 Acres	2019
				Bis(2ethylhexyl)phthalate/DEHP	Source Unknown	31 Acres	2019
				Chlordane (sediment)	Source Unknown	31 Acres	2019
				Coliform Bacteria	Nonpoint Source	31 Acres	2019

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Copper	Nonpoint Source	31 Acres	2019
				Lead	Nonpoint Source	31 Acres	2019
				Trash	Source Unknown	31 Acres	2019
				Zinc	Nonpoint Source	31 Acres	2019
4	L	Machado Lake (Harbor Park Lake)	40512000	Algae	Nonpoint Source	45 Acres	2019
				Ammonia	Nonpoint Source	45 Acres	2019
				ChemA (tissue) *Historical use of pesticides and lubricants.*	Nonpoint Source	45 Acres	2019
				Chlordane (tissue) *Fish Consumption Advisory.*	Nonpoint Source	45 Acres	2019
				DDT (tissue) *Fish Consumption Advisory.*	Nonpoint Source	45 Acres	2019
				Dieldrin (tissue)	Nonpoint Source	45 Acres	2019
				Eutrophic	Nonpoint Source	45 Acres	2019
				Odor	Nonpoint Source	45 Acres	2019
				PCBs (Polychlorinated biphenyls) (tissue)	Nonpoint Source	45 Acres	2019

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Trash		45 Acres	2019
					Nonpoint Source		
4	C	Malaga Cove Beach	40511000				
				DDT		0.39 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		0.39 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	L	Malibou Lake	40424000				
				Algae		40 Acres	2006
					Nonpoint Source		
				Eutrophic		40 Acres	2006
					Nonpoint Source		
				Organic Enrichment/Low Dissolved Oxygen		40 Acres	2006
					Nonpoint Source		
4	C	Malibu Beach	40421000				
				DDT		0.77 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
4	R	Malibu Creek	40421000				
				Fish Barriers (Fish Passage)		11 Miles	2019
					Dam Construction		
				Nutrients (Algae)		11 Miles	2006
					Nonpoint/Point Source		
				Scum/Foam-unnatural		11 Miles	2006
					Nonpoint/Point Source		
				Sedimentation/Siltation		11 Miles	2019
					Source Unknown		

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Selenium		11 Miles	2019
					Source Unknown		
				Sulfates		11 Miles	2019
					Source Unknown		
				Trash		11 Miles	2019
					Nonpoint Source		
4	E	Malibu Lagoon	40421000				
				Benthic Community Effects		15 Acres	2019
					Nonpoint/Point Source		
				Eutrophic		15 Acres	2006
					Nonpoint/Point Source		
				pH		15 Acres	2006
				Possible sources might be septic systems, storm drains, and birds.			
					Source Unknown		
				Shellfish Harvesting Advisory		15 Acres	2005
					Nonpoint/Point Source		
				Swimming Restrictions		15 Acres	2005
					Nonpoint/Point Source		
				Viruses (enteric)		15 Acres	2005
					Nonpoint/Point Source		
4	C	Malibu Lagoon Beach (Surfrider)	40421000				
				DDT		1 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		1 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	B	Marina del Rey Harbor - Back Basins	40517000				
				DDT (tissue)		391 Acres	2005
					Nonpoint Source		
				Dieldrin (tissue)		391 Acres	2005
					Nonpoint Source		
4	R	Matilija Creek Reach 1 (Jct. With N. Fork to Reservoir)	40220012				
				Fish Barriers (Fish Passage)		0.63 Miles	2019
					Dam Construction		
4	R	Matilija Creek Reach 2 (Above Reservoir)	40220010				
				Fish Barriers (Fish Passage)		15 Miles	2019
					Dam Construction		
4	L	Matilija Reservoir	40220012				
				Fish Barriers (Fish Passage)		121 Acres	2019
					Dam Construction		
4	R	McCoy Canyon Creek	40521000				
				Fecal Coliform		4 Miles	2009
					Nonpoint Source		
				Nitrate		4 Miles	2019
					Nonpoint Source		
				Nitrogen, Nitrate		4 Miles	2019
					Urban Runoff/Storm Sewers		
					Natural Sources		
4	L	McGrath Lake	40311000				
				Chlordane (sediment)		20 Acres	2019
					Nonpoint Source		
				DDT (sediment)		20 Acres	2019
					Nonpoint Source		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Dieldrin (sediment)		20 Acres	2019
				Historical use of pesticides and lubricants, storm water runoff/aerial deposition from agricultural fields.			
					Nonpoint Source		
				Fecal Coliform		20 Acres	2019
					Agriculture		
					Landfills		
					Natural Sources		
				PCBs (Polychlorinated biphenyls) (sediment)		20 Acres	2019
				Historical use of pesticides and lubricants, storm water runoff/aerial deposition from agricultural fields.			
					Nonpoint Source		
				Sediment Toxicity		20 Acres	2019
					Nonpoint Source		
4	R	Medea Creek Reach 1 (Lake to Confl. with Lindero)	40424000				
				Algae		2.6 Miles	2006
					Nonpoint Source		
				Sedimentation/Siltation		2.6 Miles	2019
					Source Unknown		
				Selenium		2.6 Miles	2019
					Nonpoint Source		
				Trash		2.6 Miles	2019
					Nonpoint Source		
4	R	Medea Creek Reach 2 (Abv Confl. with Lindero)	40423000				
				Algae		5.4 Miles	2006
					Nonpoint Source		
				Sedimentation/Siltation		5.4 Miles	2019
					Source Unknown		
				Selenium		5.4 Miles	2019
					Nonpoint Source		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Trash		5.4 Miles	2019
					Nonpoint Source		
4	R	Mint Canyon Creek Reach 1 (Confl to Rowler Cyn)	40351000				
				Nitrate and Nitrite		8.1 Miles	2004
					Nonpoint Source		
4	L	Munz Lake	40351000				
				Eutrophic		6.6 Acres	2019
					Nonpoint Source		
				Trash		6.6 Acres	2019
					Nonpoint Source		
4	C	Nicholas Canyon Beach	40444000				
				DDT		1.7 Miles	2019
				Fish Consumption Advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		1.7 Miles	2019
				Fish Consumption Advisory for PCBs.			
					Nonpoint Source		
4	C	Ormond Beach	40311000				
				Indicator bacteria		1.6 Miles	2008
				This listing was made by USEPA for 2006. This listing includes the area of Ormond Beach at J St., Oxnard Drain, and Arnold Rd.			
					Source Unknown		
4	C	Palo Verde Shoreline Park Beach	40511000				
				Pesticides		0.24 Miles	2019
					Source Unknown		
4	C	Paradise Cove Beach	40435000				
				DDT		1.7 Miles	2019
				Fish consumption advisory for DDT.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls)		1.7 Miles	2019
				Fish consumption advisory for PCBs.			
					Nonpoint Source		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	L	Peck Road Park Lake	40531000				
				Chlordane (tissue)		103 Acres	2019
					Nonpoint Source		
				DDT (tissue)		103 Acres	2019
					Nonpoint Source		
				Lead		103 Acres	2019
					Nonpoint Source		
				Odor		103 Acres	2019
					Nonpoint Source		
				Organic Enrichment/Low Dissolved Oxygen		103 Acres	2019
					Nonpoint Source		
				Trash		103 Acres	2007
					Nonpoint Source		
4	C	Peninsula Beach	40311000				
				Indicator bacteria		0.2 Miles	2003
				Area affected is beach area north of South Jetty.			
					Nonpoint/Point Source		
4	R	Piru Creek (from gaging station below Santa Felicia Dam to headwaters)	40342000				
				Chloride		67 Miles	2019
					Source Unknown		
				pH		67 Miles	2019
					Nonpoint Source		
					Conservation Discharge Releases		
4	C	Point Dume Beach	40435000				
				DDT		2.5 Miles	2019
				Fish consumption advisory for DDT.			
					Nonpoint Source		

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) *Fish consumtiion advisory for PCBs.*	Nonpoint Source	2.5 Miles	2019
4	C	Point Fermin Park Beach	40512000				
				DDT *Fish consumption advisory for DDT.*	Nonpoint Source	1.6 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish consumption advisory for PCBs.*	Nonpoint Source	1.6 Miles	2019
4	R	Pole Creek (trib to Santa Clara River Reach 3)	40331000				
				Sulfates	Nonpoint Source	9 Miles	2019
				Total Dissolved Solids	Nonpoint Source	9 Miles	2019
4	B	Port Hueneme Harbor (Back Basins)	40311000				
				DDT (tissue)	Nonpoint Source	65 Acres	2019
				PCBs (Polychlorinated biphenyls) (tissue)	Nonpoint Source	65 Acres	2019
4	C	Port Hueneme Pier	40311000				
				PCBs (Polychlorinated biphenyls)	Source Unknown	0.33 Miles	2019
4	C	Portuguese Bend Beach	40511000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.4 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCB.*	Nonpoint Source	1.4 Miles	2019
4	L	Puddingstone Reservoir	40552000				
				Chlordane (tissue)	Nonpoint Source	243 Acres	2019

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				DDT (tissue)	Nonpoint Source	243 Acres	2019
				Mercury (tissue)	Nonpoint Source	243 Acres	2019
				Organic Enrichment/Low Dissolved Oxygen	Nonpoint Source	243 Acres	2019
				PCBs (Polychlorinated biphenyls) (tissue)	Nonpoint Source	243 Acres	2019
4	C	Puerco Beach	40431000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	0.5 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	0.5 Miles	2019
4	C	Redondo Beach	40512000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.5 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.5 Miles	2019
4	C	Rincon Beach	40100010				
				Indicator bacteria *Area affected is 50 and 150 yards south of mouth of Rincon Creek, and at the end of the footpath.*	Nonpoint/Point Source	0.09 Miles	2003
4	R	Rio De Santa Clara/Oxnard Drain No. 3	40311000				
				ChemA (tissue)	Nonpoint Source	1.9 Miles	2019
				Chlordane (tissue)	Nonpoint Source	1.9 Miles	2019
				DDT (tissue)	Nonpoint Source	1.9 Miles	2019

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Nitrogen	Nonpoint Source	1.9 Miles	2019
				PCBs (Polychlorinated biphenyls) (tissue)	Nonpoint Source	1.9 Miles	2019
				Sediment Toxicity	Nonpoint Source	1.9 Miles	2019
				Toxaphene (tissue)	Nonpoint Source	1.9 Miles	2019
4	R	Rio Hondo Reach 1 (Confl. LA River to Snt Ana Fwy)	40515010				
				Coliform Bacteria	Nonpoint/Point Source	4.6 Miles	2009
				Trash	Nonpoint/Point Source	4.6 Miles	2007
4	R	Rio Hondo Reach 2 (At Spreading Grounds)	40515010				
				Coliform Bacteria	Nonpoint/Point Source	4.9 Miles	2009
4	C	Robert H. Meyer Memorial Beach	40441000				
				Beach Closures	Nonpoint Source	1.2 Miles	2019
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.2 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.2 Miles	2019
4	C	Royal Palms Beach	40511000				
				DDT *Fish consumption advisory for DDT.*	Nonpoint Source	1.1 Miles	2019

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls)		1.1 Miles	2019
				Fish consumption advisory for PCBs.			
					Nonpoint Source		
4	R	San Antonio Creek (Tributary to Ventura River Reach 4)	40220023				
				Nitrogen		9.8 Miles	2019
					Nonpoint Source		
4	C	San Buenaventura Beach	40210000				
				Indicator bacteria		1.8 Miles	2008
				This listing was made by USEPA for 2006. This listing includes the area of San Buenaventura Beach at Kalorama, San Jon Rd, Dover Lane, and Weymouth drains.			
					Source Unknown		
4	R	San Gabriel River Estuary	40516000				
				Copper		3.4 Miles	2007
				This listing was made by USEPA for 2006.			
					Source Unknown		
4	R	San Gabriel River Reach 1 (Estuary to Firestone)	40515010				
				Coliform Bacteria		6.4 Miles	2019
					Nonpoint/Point Source		
				pH		6.4 Miles	2019
					Source Unknown		
4	R	San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam	40515010				
				Coliform Bacteria		12 Miles	2019
					Nonpoint/Point Source		
				Lead		12 Miles	2019
					Nonpoint/Point Source		
4	R	San Jose Creek Reach 1 (SG Confluence to Temple St.)	40531000				
				Coliform Bacteria		2.7 Miles	2019
					Nonpoint/Point Source		

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Selenium *This listing was made by USEPA for 2006.*	Source Unknown	2.7 Miles	2007
				Toxicity *This listing was made by USEPA for 2006.*	Source Unknown	2.7 Miles	2007
4	R	San Jose Creek Reach 2 (Temple to I-10 at White Ave.)	40531000				
				Coliform Bacteria	Nonpoint/Point Source	17 Miles	2019
4	B	San Pedro Bay Near/Off Shore Zones	40512000				
				Chlordane	Source Unknown	8173 Acres	2019
				Chromium (sediment)	Nonpoint/Point Source	8173 Acres	2019
				Copper (sediment)	Nonpoint/Point Source	8173 Acres	2019
				DDT (tissue & sediment) *Fish Consumption Advisory for DDT.*	Nonpoint/Point Source	8173 Acres	2019
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)	Nonpoint/Point Source	8173 Acres	2019
				PCBs (Polychlorinated biphenyls) *Fish consumption advisory for PCBs.*	Nonpoint/Point Source	8173 Acres	2019
				Sediment Toxicity	Nonpoint/Point Source	8173 Acres	2019
				Zinc (sediment)	Nonpoint/Point Source	8173 Acres	2019

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	E	Santa Clara River Estuary	40311000				
				ChemA		49 Acres	2019
					Source Unknown		
				Coliform Bacteria		49 Acres	2019
					Nonpoint Source		
				Toxaphene		49 Acres	2019
					Nonpoint Source		
4	R	Santa Clara River Reach 1 (Estuary to Hwy 101 Bridge)	40311000				
				Toxicity		10 Miles	2019
					Source Unknown		
4	R	Santa Clara River Reach 3 (Freeman Diversion to A Street)	40331000				
				Total Dissolved Solids		31 Miles	2019
					Nonpoint/Point Source		
4	R	Santa Clara River Reach 5 (Blue Cut gaging station to West Pier Hwy 99 Bridge) (was named Santa Clara River Reach 7 on 2002 303(d) list)	40351000				
				Coliform Bacteria		9.4 Miles	2019
					Nonpoint/Point Source		
4	R	Santa Clara River Reach 6 (W Pier Hwy 99 to Bouquet Cyn Rd) (was named Santa Clara River Reach 8 on 2002 303(d) list)	40351000				
				Chlorpyrifos		5.2 Miles	2019
					Source Unknown		
				Coliform Bacteria		5.2 Miles	2019
					Nonpoint/Point Source		
				Diazinon		5.2 Miles	2019
					Source Unknown		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

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REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Toxicity		5.2 Miles	2019
					Source Unknown		
4	R	Santa Clara River Reach 7 (Bouquet Canyon Rd to above Lang Gaging Station) (was named Santa Clara River Reach 9 on 2002 303(d) list)	40351000				
				Coliform Bacteria		21 Miles	2019
					Nonpoint/Point Source		
4	R	Santa Clara River Reach 11 (Piru Creek, from confluence with Santa Clara River Reach 4 to gaging station below Santa Felicia Dam)	40341000				
				Boron		6.2 Miles	2019
					Source Unknown		
				Sulfates		6.2 Miles	2019
					Source Unknown		
4	L	Santa Fe Dam Park Lake	40531000				
				Copper		20 Acres	2019
					Nonpoint Source		
				Lead		20 Acres	2019
					Nonpoint Source		
				pH		20 Acres	2019
					Nonpoint Source		
4	B	Santa Monica Bay Offshore/Nearshore	40513000				
				DDT (tissue & sediment) *Centered on Palos Verdes Shelf.*		146645 Acres	2019
					Nonpoint/Point Source		
				Debris		146645 Acres	2019
					Nonpoint/Point Source		
				Fish Consumption Advisory		146645 Acres	2019
					Nonpoint/Point Source		

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LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				PCBs (Polychlorinated biphenyls) (tissue & sediment)	Nonpoint/Point Source	146645 Acres	2019
				Sediment Toxicity	Nonpoint/Point Source	146645 Acres	2019
4	R	Santa Monica Canyon	40513000				
				Lead	Nonpoint Source	2.7 Miles	2019
4	R	Sawpit Creek	40531000				
				Bis(2ethylhexyl)phthalate/DEHP	Source Unknown	3.9 Miles	2019
				Fecal Coliform	Source Unknown	3.9 Miles	2019
4	C	Sea Level Beach	40441000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	0.21 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	0.21 Miles	2019
4	R	Sepulveda Canyon	405.13				
				Ammonia	Nonpoint Source	0.83 Miles	2019
4	R	Sespe Creek (from 500 ft below confluence with Little Sespe Cr to headwaters)	40332020				
				Chloride	Nonpoint Source	54 Miles	2019
				pH	Nonpoint Source	54 Miles	2019

A215166

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	C	Topanga Beach	40413000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	2.5 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	2.5 Miles	2019
4	R	Topanga Canyon Creek	40411000				
				Lead	Nonpoint Source	8.6 Miles	2019
4	R	Torrance Carson Channel	40512000				
				Coliform Bacteria	Nonpoint Source	3.4 Miles	2007
				Copper	Nonpoint Source	3.4 Miles	2019
				Lead	Nonpoint Source	3.4 Miles	2019
4	C	Trancas Beach (Broad Beach)	40437000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.7 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.7 Miles	2019
4	R	Triunfo Canyon Creek Reach 1	40424000				
				Lead	Nonpoint Source	2.5 Miles	2019
				Mercury	Nonpoint Source	2.5 Miles	2019
				Sedimentation/Siltation	Source Unknown	2.5 Miles	2019
4	R	Triunfo Canyon Creek Reach 2	40424000				
				Lead	Nonpoint Source	3.3 Miles	2019

A015167

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
				Mercury		3.3 Miles	2019
					Nonpoint Source		
				Sedimentation/Siltation		3.3 Miles	2019
					Source Unknown		
4	R	Tujunga Wash (LA River to Hansen Dam)	40521000				
				Coliform Bacteria		9.7 Miles	2009
					Nonpoint Source		
				Trash		9.7 Miles	2007
					Nonpoint Source		
4	B	Ventura Harbor: Ventura Keys	40311000				
				Coliform Bacteria		179 Acres	2019
					Nonpoint Source		
4	C	Ventura Marina Jetties	40311000				
				DDT		0.69 Miles	2019
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		0.69 Miles	2019
					Source Unknown		
4	R	Ventura River Estuary	40210011				
				Algae		0.2 Miles	2019
					Nonpoint/Point Source		
				Eutrophic		0.2 Miles	2019
					Nonpoint/Point Source		
				Total Coliform *Stables and horse property may be the sources.*		0.2 Miles	2019
					Nonpoint Source		
				Trash		0.2 Miles	2019
					Nonpoint/Point Source		
4	R	Ventura River Reach 1 and 2 (Estuary to Weldon Canyon)	40210011				
				Algae		4.5 Miles	2019
					Nonpoint/Point Source		

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	R	Ventura River Reach 3 (Weldon Canyon to Confl. w/ Coyote Cr)	40210011				
				Pumping	Nonpoint Source	2.8 Miles	2019
				Water Diversion	Nonpoint Source	2.8 Miles	2019
4	R	Ventura River Reach 4 (Coyote Creek to Camino Cielo Rd)	40220021				
				Pumping	Nonpoint Source	19 Miles	2019
				Water Diversion	Nonpoint Source	19 Miles	2019
4	R	Verdugo Wash Reach 1 (LA River to Verdugo Rd.)	40521000				
				Coliform Bacteria	Nonpoint Source	2 Miles	2009
				Trash	Nonpoint Source	2 Miles	2007
4	R	Verdugo Wash Reach 2 (Above Verdugo Road)	40524000				
				Coliform Bacteria	Nonpoint Source	7.6 Miles	2009
				Trash	Nonpoint Source	7.6 Miles	2007
4	R	Walnut Creek Wash (Drains from Puddingstone Res)	40531000				
				pH	Nonpoint/Point Source	12 Miles	2007
				Toxicity *USEPA deferred action on this listing until 2008.*	Nonpoint/Point Source	12 Miles	2007

A015159

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	L	Westlake Lake	40425000				
				Algae	Nonpoint Source	119 Acres	2006
				Ammonia	Nonpoint Source	119 Acres	2006
				Eutrophic	Nonpoint Source	119 Acres	2006
				Lead	Nonpoint Source	119 Acres	2019
				Organic Enrichment/Low Dissolved Oxygen	Nonpoint Source	119 Acres	2006
4	R	Wheeler Canyon/Todd Barranca	40321000				
				Sulfates	Nonpoint Source	10 Miles	2019
				Total Dissolved Solids	Nonpoint Source	10 Miles	2019
4	C	Whites Point Beach	40511000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.1 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.1 Miles	2019
4	R	Wilmington Drain	40342000				
				Ammonia	Nonpoint Source	0.56 Miles	2019
				Coliform Bacteria	Nonpoint Source	0.56 Miles	2007
				Copper	Nonpoint Source	0.56 Miles	2019
				Lead	Nonpoint Source	0.56 Miles	2019

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	PROPOSED TMDL COMPLETION
4	C	Zuma Beach (Westward Beach)	40436000				
				DDT *Fish Consumption Advisory for DDT.*	Nonpoint Source	1.6 Miles	2019
				PCBs (Polychlorinated biphenyls) *Fish Consumption Advisory for PCBs.*	Nonpoint Source	1.6 Miles	2019

ABBREVIATIONS

REGIONAL WATER QUALITY CONTROL BOARDS

1 North Coast
2 San Francisco Bay
3 Central Coast
4 Los Angeles
5 Central Valley
6 Lahontan
7 Colorado River Basin
8 Santa Ana
9 San Diego

WATER BODY TYPE

B = Bays and Harbors
C = Coastal Shorelines/Beaches
E = Estuaries
L = Lakes/Reserviors
R = Rivers and Streams
S = Saline Lakes
T = Wetlands, Tidal
W= Wetlands, Freshwater

CALWATER WATERSHED

"Calwater Watershed" is the State Water Resources Control Board hydrological subunit area or an even smaller area delineation.

GROUP A PESTICIDES OR CHEM A

aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan, and toxaphene

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Sedimentation/Siltation		1.6 Miles	2003
					Construction/Land Development		
					Nonpoint Source		
3	R	Warden Creek	31023010				
				Fecal Coliform		6 Miles	2004
					Source Unknown		
4	C	Abalone Cove Beach	40511000				
				Indicator bacteria		1.1 Miles	2003
					Source Unknown		
4	R	Aliso Canyon Wash	40521000				
				Selenium		10 Miles	2005
					Nonpoint Source		
4	R	Ballona Creek	40513000				
				Coliform Bacteria		6.5 Miles	2007
				For 2006, coliform bacteria was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint/Point Source		
				Copper, Dissolved		6.5 Miles	2005
					Nonpoint Source		
				Lead		6.5 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Pathogens		6.5 Miles	2007
				For 2006, pathogens was added by USEPA to the List of Water Quality Limited Segments Being Addressed By USEPA Approved TMDLs.			
					Source Unknown		
				Selenium		6.5 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Shellfish Harvesting Advisory		6.5 Miles	2006
					Nonpoint/Point Source		

A015172

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Toxicity	Nonpoint/Point Source	6.5 Miles	2005
				Trash	Source Unknown	6.5 Miles	2001
				Viruses (enteric)	Nonpoint/Point Source	6.5 Miles	2007
				For 2006, viruses (enteric) was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
				Zinc	Source Unknown	6.5 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
4	R	Ballona Creek Estuary	40513000	Cadmium	Source Unknown	2.3 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Chlordane (tissue & sediment)	Nonpoint/Point Source	2.3 Miles	2005
				Coliform Bacteria	Nonpoint/Point Source	2.3 Miles	2007
				For 2006, coliform bacteria was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
				Copper	Source Unknown	2.3 Miles	2005
				DDT (sediment)	Nonpoint/Point Source	2.3 Miles	2005
				Lead (sediment)	Nonpoint/Point Source	2.3 Miles	2005
				PAHs (Polycyclic Aromatic Hydrocarbons) (sediment)	Nonpoint/Point Source	2.3 Miles	2005

A015173

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				PCBs (Polychlorinated biphenyls) (tissue & sediment)	Nonpoint/Point Source	2.3 Miles	2005
				Sediment Toxicity	Nonpoint/Point Source	2.3 Miles	2005
				Silver	Source Unknown	2.3 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Zinc (sediment)	Nonpoint/Point Source	2.3 Miles	2005
4	T	Ballona Creek Wetlands	40517000	Trash	Nonpoint Source	289 Acres	2019
4	C	Big Rock Beach	40431000	Coliform Bacteria	Nonpoint Source	0.74 Miles	2003
4	C	Bluff Cove Beach	40511000	Indicator bacteria	Nonpoint Source	0.55 Miles	2003
4	R	Burbank Western Channel	40521000	Ammonia	Source Unknown	13 Miles	2004
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Copper	Source Unknown	13 Miles	2005
				Lead	Source Unknown	13 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			

A051574

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Cabrillo Beach (Outer)	40512000				
				Indicator bacteria		0.58 Miles	2003
					Nonpoint Source		
4	E	Calleguas Creek Reach 1 (was Mugu Lagoon on 1998 303(d) list)	40311000				
				Chlordane (tissue)		344 Acres	2005
					Nonpoint Source		
				Copper		344 Acres	2007
				For 2006, copper was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint/Point Source		
				DDT (tissue & sediment)		344 Acres	2005
					Nonpoint Source		
				Dieldrin		344 Acres	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Mercury		344 Acres	2007
				For 2006, mercury was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint/Point Source		
				Nickel		344 Acres	2007
				For 2006, nickel was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint/Point Source		
				Nitrogen		344 Acres	2003
					Nonpoint/Point Source		
				PCBs (Polychlorinated biphenyls) (tissue)		344 Acres	2005
					Nonpoint/Point Source		
				Sediment Toxicity		344 Acres	2005
					Nonpoint/Point Source		

A015175

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Sedimentation/Siltation		344 Acres	2006
				For 2006, sedimentation/siltation was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Agriculture Natural Sources		
				Toxaphene		344 Acres	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Zinc		344 Acres	2007
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
4	R	Calleguas Creek Reach 2 (estuary to Potrero Rd- was Calleguas Creek Reaches 1 and 2 on 1998 303d list)	40312000				
				Ammonia		4.3 Miles	2003
					Nonpoint/Point Source		
				Chlordane (tissue)		4.3 Miles	2005
					Nonpoint Source		
				Copper, Dissolved		4.3 Miles	2007
				For 2006, copper, dissolved was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint Source		
				DDT		4.3 Miles	2005
					Nonpoint Source		
				DDT (tissue & sediment)		4.3 Miles	2005
					Nonpoint Source		
				Dieldrin		4.3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Nitrogen		4.3 Miles	2003
					Nonpoint/Point Source		
				PCBs (Polychlorinated biphenyls) (tissue)		4.3 Miles	2005
					Nonpoint/Point Source		

A015176

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Sediment Toxicity	Nonpoint/Point Source	4.3 Miles	2005
				Toxaphene (tissue & sediment)	Nonpoint Source	4.3 Miles	2005
4	R	Calleguas Creek Reach 3 (Potrero Road upstream to confluence with Conejo Creek on 1998 303d list)	40312000				
				Ammonia	Source Unknown	3.5 Miles	2003
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Chlordane	Source Unknown	3.5 Miles	2006
				For 2006, chlordane was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
				DDT	Source Unknown	3.5 Miles	2019
				Dieldrin	Source Unknown	3.5 Miles	2019
				Nitrate and Nitrite	Nonpoint/Point Source	3.5 Miles	2003
				PCBs (Polychlorinated biphenyls)	Source Unknown	3.5 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Toxaphene	Source Unknown	3.5 Miles	2019
4	R	Calleguas Creek Reach 4 (was Revolon Slough Main Branch: Mugu Lagoon to Central Avenue on 1998 303d list)	40311000				
				Chlordane (tissue & sediment)	Nonpoint Source	7.2 Miles	2005

A051517

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Chlorpyrifos (tissue)	Nonpoint Source	7.2 Miles	2005
				DDT (tissue & sediment)	Nonpoint Source	7.2 Miles	2005
				Diazinon *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	Source Unknown	7.2 Miles	2006
				Dieldrin (tissue)	Nonpoint Source	7.2 Miles	2005
				Nitrate as Nitrate (NO3)	Nonpoint/Point Source	7.2 Miles	2003
				Nitrogen *The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.*	Nonpoint Source	7.2 Miles	2004
				PCBs (Polychlorinated biphenyls) (tissue)	Nonpoint Source	7.2 Miles	2005
				Selenium *For 2006, selenium was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.*	Nonpoint Source	7.2 Miles	2007
				Toxaphene (tissue & sediment)	Nonpoint Source	7.2 Miles	2005
				Toxicity	Nonpoint Source	7.2 Miles	2005
4	R	Calleguas Creek Reach 5 (was Beardsley Channel on 1998 303d list)	40311000				
				Chlordane (tissue & sediment)	Nonpoint Source	4.3 Miles	2005

A015178

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Chlorpyrifos (tissue)		4.3 Miles	2005
					Nonpoint Source		
				DDT (tissue & sediment)		4.3 Miles	2005
					Nonpoint Source		
				Diazinon		4.3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Dieldrin (tissue)		4.3 Miles	2005
					Nonpoint Source		
				Nitrogen		4.3 Miles	2004
				The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.			
					Nonpoint Source		
				PCBs (Polychlorinated biphenyls) (tissue)		4.3 Miles	2005
					Nonpoint Source		
				Toxaphene (tissue & sediment)		4.3 Miles	2005
					Nonpoint Source		
				Toxicity		4.3 Miles	2005
					Nonpoint Source		
4	R	Calleguas Creek Reach 6 (was Arroyo Las Posas Reaches 1 and 2 on 1998 303d list)	40362000				
				Ammonia		15 Miles	2003
					Nonpoint/Point Source		
				Chlordane		15 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Chlorpyrifos		15 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		

A015179

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				DDT (sediment)		15 Miles	2005
					Nonpoint Source		
				Diazinon		15 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Dieldrin		15 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Nitrate and Nitrite		15 Miles	2003
					Nonpoint/Point Source		
				Nitrate as Nitrate (NO3)		15 Miles	2003
					Nonpoint/Point Source		
				Toxicity		15 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
4	R	Calleguas Creek Reach 7 (was Arroyo Simi Reaches 1 and 2 on 1998 303d list)	40367000				
				Ammonia		14 Miles	2003
					Nonpoint/Point Source		
				Chlorpyrifos		14 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Diazinon		14 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Organophosphorus Pesticides		14 Miles	2005
					Municipal Point Sources Agriculture		
				Toxicity		14 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		

A015186

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Calleguas Creek Reach 8 (was Tapo Canyon Reach 1)	40366000				
				Chlordane		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Chlorpyrifos		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				DDT		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Diazinon		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Dieldrin		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				PCBs (Polychlorinated biphenyls)		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Toxaphene		7.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
4	R	Calleguas Creek Reach 9A (was lower part of Conejo Creek Reach 1 on 1998 303d list)	40312000				
				Chlordane (tissue)		1.7 Miles	2005
				Historical use of pesticides and lubricants.	Nonpoint Source		
				Chlorpyrifos		1.7 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				DDT (tissue)		1.7 Miles	2005
					Nonpoint Source		
				Diazinon		1.7 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		

A015181

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Dieldrin (tissue) *Historical use of pesticides and lubricants.*	**Nonpoint Source**	**1.7 Miles**	**2005**
				Nitrate as Nitrate (NO3)	**Nonpoint/Point Source**	**1.7 Miles**	**2003**
				Nitrogen, Nitrate *The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.*	**Nonpoint/Point Source**	**1.7 Miles**	**2004**
				PCBs (Polychlorinated biphenyls) (tissue) *Historical use of pesticides and lubricants.*	**Nonpoint Source**	**1.7 Miles**	**2005**
				Toxaphene (tissue & sediment)	**Nonpoint Source**	**1.7 Miles**	**2005**
				Toxicity *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	**Source Unknown**	**1.7 Miles**	**2006**
4	**R**	**Calleguas Creek Reach 9B (was part of Conejo Creek Reaches 1 and 2 on 1998 303d list)**	**40363000**				
				Ammonia *The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.*	**Nonpoint/Point Source**	**6.2 Miles**	**2004**
				Chlordane *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	**Source Unknown**	**6.2 Miles**	**2006**
				Chlorpyrifos *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	**Source Unknown**	**6.2 Miles**	**2006**
				DDT (tissue)	**Nonpoint Source**	**6.2 Miles**	**2005**
				Diazinon *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	**Source Unknown**	**6.2 Miles**	**2006**

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Dieldrin		6.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				PCBs (Polychlorinated biphenyls)		6.2 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Toxaphene (tissue & sediment)		6.2 Miles	2005
					Nonpoint Source		
				Toxicity		6.2 Miles	2006
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 10 (Conejo Creek (Hill Canyon)-was part of Conejo Crk Reaches 2 & 3, and lower Conejo Crk/Arroyo Conejo N Fk on 1998 303d list)	40364000				
				Ammonia		3 Miles	2002
					Nonpoint/Point Source		
				Chlordane		3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Chlorpyrifos		3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				DDT (tissue)		3 Miles	2005
					Nonpoint Source		
				Diazinon		3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Dieldrin		3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Nitrogen, Nitrite		3 Miles	2003
					Nonpoint/Point Source		

A015183

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				PCBs (Polychlorinated biphenyls)		3 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Toxaphene (tissue & sediment)		3 Miles	2005
					Nonpoint Source		
				Toxicity		3 Miles	2005
					Nonpoint/Point Source		
4	R	Calleguas Creek Reach 11 (Arroyo Santa Rosa, was part of Conejo Creek Reach 3 on 1998 303d list)	40365000				
				Ammonia		8.7 Miles	2004
				The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.			
					Nonpoint/Point Source		
				Chlordane		8.7 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				DDT (tissue)		8.7 Miles	2005
					Nonpoint Source		
				Dieldrin		8.7 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				PCBs (Polychlorinated biphenyls)		8.7 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Toxaphene (tissue & sediment)		8.7 Miles	2005
					Nonpoint/Point Source		
				Toxicity		8.7 Miles	2005
					Nonpoint/Point Source		

A015181

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Calleguas Creek Reach 12 (was Conejo Creek/Arroyo Conejo North Fork on 1998 303d list)	40364000				
				Ammonia	Nonpoint/Point Source	5.5 Miles	2003
				Chlordane (tissue)	Nonpoint Source	5.5 Miles	2005
				DDT (tissue)	Nonpoint Source	5.5 Miles	2005
				Dieldrin	Source Unknown	5.5 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				PCBs (Polychlorinated biphenyls)	Source Unknown	5.5 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				Toxaphene	Source Unknown	5.5 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
4	R	Calleguas Creek Reach 13 (Conejo Creek South Fork, was Conejo Cr Reach 4 and part of Reach 3 on 1998 303d list)	40368000				
				Ammonia	Nonpoint/Point Source	17 Miles	2004
				The USEPA approved Calleguas Creek Nitrogen and Related Effects TMDL also addresses the impacts of algae on this water quality limited segment.			
				Chlordane	Source Unknown	17 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
				DDT (tissue)	Nonpoint Source	17 Miles	2005
				Dieldrin	Source Unknown	17 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			

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2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				PCBs (Polychlorinated biphenyls)		17 Miles	2006
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Toxaphene (tissue & sediment)		17 Miles	2005
					Nonpoint Source		
				Toxicity		17 Miles	2005
					Nonpoint/Point Source		
4	C	Carbon Beach	40416000				
				Indicator bacteria		1.5 Miles	2003
					Source Unknown		
4	C	Castlerock Beach	40513000				
				Indicator bacteria		0.21 Miles	2003
					Nonpoint/Point Source		
4	R	Compton Creek	40515010				
				Copper		8.5 Miles	2005
					Nonpoint/Point Source		
				Lead		8.5 Miles	2005
					Nonpoint/Point Source		
				pH		8.5 Miles	2004
					Nonpoint/Point Source		
4	C	Dan Blocker Memorial (Coral) Beach	40431000				
				Coliform Bacteria		2.1 Miles	2002
				(This listing includes the area of the beach at Latigo Beach and Solstice Canyon.)			
					Nonpoint Source		
4	C	Dockweiler Beach	40512000				
				Indicator bacteria		4.6 Miles	2003
					Nonpoint Source		

A015185

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Dry Canyon Creek	40521000	Selenium, Total	Nonpoint Source	3.9 Miles	2005
4	R	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2	40311000	ChemA (tissue)	Nonpoint Source	12 Miles	2005
				Chlordane (tissue)	Nonpoint Source	12 Miles	2005
				DDT (tissue & sediment)	Nonpoint Source	12 Miles	2005
				Nitrogen	Nonpoint Source	12 Miles	2003
				Sediment Toxicity	Nonpoint Source	12 Miles	2005
				Toxaphene (tissue)	Nonpoint Source	12 Miles	2005
				Toxicity	Nonpoint Source	12 Miles	2005
4	C	Escondido Beach	40434000	Indicator bacteria	Nonpoint Source	1.2 Miles	2003
4	C	Flat Rock Point Beach Area	40511000	Indicator bacteria	Nonpoint Source	0.11 Miles	2003

A015187

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Fox Barranca (tributary to Calleguas Creek Reach 6)	40362000	Nitrate and Nitrite	Nonpoint Source	6.7 Miles	2003
4	C	Hermosa Beach	40512000	Indicator bacteria	Nonpoint Source	2 Miles	2003
4	C	Inspiration Point Beach	40511000	Indicator bacteria	Nonpoint Source	0.14 Miles	2003
4	C	La Costa Beach	40416000	Indicator bacteria	Nonpoint Source	0.74 Miles	2003
4	C	Las Flores Beach	40415000	Coliform Bacteria	Nonpoint Source	1.1 Miles	2003
4	C	Las Tunas Beach	40412000	Indicator bacteria	Nonpoint Source	1.2 Miles	2003
4	R	Las Virgenes Creek	40422010	Coliform Bacteria	Nonpoint Source	12 Miles	2005
4	C	Leo Carillo Beach (South of County Line)	40444000	Coliform Bacteria	Nonpoint Source	1.8 Miles	2003

AR151188

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Lindero Creek Reach 1	40423000	Coliform Bacteria	Nonpoint Source	3 Miles	2005
4	R	Lindero Creek Reach 2 (Above Lake)	40425000	Coliform Bacteria	Nonpoint Source	4.5 Miles	2005
4	C	Long Point Beach	40511000	Coliform Bacteria	Nonpoint Source	0.7 Miles	2003
4	B	Los Angeles Harbor - Inner Cabrillo Beach Area	40512000	Indicator bacteria	Source Unknown	82 Acres	2004
4	R	Los Angeles River Reach 1 (Estuary to Carson Street)	40512000	Ammonia	Nonpoint/Point Source	3.4 Miles	2004
				Cadmium	Source Unknown	3.4 Miles	2005
				Copper, Dissolved	Nonpoint/Point Source	3.4 Miles	2005
				Lead	Nonpoint/Point Source	3.4 Miles	2005
				Nutrients (Algae)	Nonpoint/Point Source	3.4 Miles	2004
				pH	Nonpoint/Point Source	3.4 Miles	2003

For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.

A015189

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	R	Los Angeles River Reach 2 (Carson to Figueroa Street)	40515010	Zinc, Dissolved	Nonpoint/Point Source	3.4 Miles	2005
				Ammonia	Nonpoint/Point Source	19 Miles	2004
				Copper *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	Source Unknown	19 Miles	2005
				Lead	Nonpoint/Point Source	19 Miles	2005
				Nutrients (Algae)	Nonpoint/Point Source	19 Miles	2004
4	R	Los Angeles River Reach 3 (Figueroa St. to Riverside Dr.)	40521000	Ammonia	Nonpoint/Point Source	7.9 Miles	2004
				Copper *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	Source Unknown	7.9 Miles	2005
				Lead *For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.*	Source Unknown	7.9 Miles	2005
				Nutrients (Algae)	Nonpoint/Point Source	7.9 Miles	2004
4	R	Los Angeles River Reach 4 (Sepulveda Dr. to Sepulveda Dam)	40521000	Ammonia	Nonpoint/Point Source	11 Miles	2004

A015199

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				Copper		11 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Lead		11 Miles	2005
				Nutrients (Algae)	Nonpoint/Point Source	11 Miles	2004
4	R	Los Angeles River Reach 5 (within Sepulveda Basin)	40521000		Nonpoint/Point Source		
				Ammonia		1.9 Miles	2004
				Copper	Nonpoint/Point Source	1.9 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Lead		1.9 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
				Nutrients (Algae)		1.9 Miles	2004
4	R	Los Angeles River Reach 6 (Above Sepulveda Flood Control Basin)	40521000		Nonpoint/Point Source		
				Selenium		7 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.	Source Unknown		
4	C	Lunada Bay Beach	40511000				
				Indicator bacteria		0.63 Miles	2002
					Nonpoint Source		
4	C	Malaga Cove Beach	40511000				
				Indicator bacteria		0.39 Miles	2002
					Nonpoint Source		

A015191

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Malibu Beach	40421000	Indicator bacteria	Nonpoint Source	0.77 Miles	2002
4	R	Malibu Creek	40421000	Coliform Bacteria	Nonpoint/Point Source	11 Miles	2002
4	E	Malibu Lagoon	40421000	Coliform Bacteria	Nonpoint/Point Source	15 Acres	2005
4	C	Malibu Lagoon Beach (Surfrider)	40421000	Coliform Bacteria	Nonpoint Source	1 Miles	2003
4	C	Manhattan Beach	40512000	Indicator bacteria	Nonpoint Source	2 Miles	2002
4	B	Marina del Rey Harbor - Back Basins	40517000	Chlordane (tissue & sediment)	Nonpoint Source	391 Acres	2005
				Copper (sediment)	Nonpoint Source	391 Acres	2005
				Fish Consumption Advisory	Nonpoint Source	391 Acres	2005
				Indicator bacteria	Nonpoint Source	391 Acres	2004
				Lead (sediment)	Nonpoint Source	391 Acres	2005

A015192

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
				PCBs (Polychlorinated biphenyls) (tissue & sediment) *Historical use of pesticides, storm water runoff/aerial deposition from urban areas. Shellfish harvesting advisory for PCBs in tissue.*	Nonpoint Source	391 Acres	2005
				Sediment Toxicity	Nonpoint Source	391 Acres	2005
				Zinc (sediment)	Nonpoint Source	391 Acres	2005
4	C	Marina del Rey Harbor Beach	40517000	Indicator bacteria	Nonpoint Source	0.29 Miles	2004
4	R	McCoy Canyon Creek	40521000	Selenium, Total	Urban Runoff/Storm Sewers Natural Sources	4 Miles	2005
4	C	McGrath Beach	40311000	Coliform Bacteria	Nonpoint Source	1.5 Miles	2003
4	R	Medea Creek Reach 1 (Lake to Confl. with Lindero)	40424000	Coliform Bacteria	Nonpoint Source	2.6 Miles	2005
4	R	Medea Creek Reach 2 (Abv Confl. with Lindero)	40423000	Coliform Bacteria	Nonpoint Source	5.4 Miles	2005
4	R	Monrovia Canyon Creek	40531000	Lead	Nonpoint Source	3.4 Miles	2005

A015193

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Nicholas Canyon Beach	40444000	Indicator bacteria	Nonpoint Source	1.7 Miles	2002
4	R	Palo Comado Creek	40423000	Coliform Bacteria	Nonpoint Source	6.8 Miles	2005
4	C	Palo Verde Shoreline Park Beach	40511000	Pathogens	Nonpoint Source	0.24 Miles	2003
4	C	Paradise Cove Beach	40435000	Fecal Coliform	Nonpoint Source	1.7 Miles	2003
4	C	Point Dume Beach	40435000	Indicator bacteria	Nonpoint Source	2.5 Miles	2002
4	C	Point Fermin Park Beach	40512000	Total Coliform	Nonpoint Source	1.6 Miles	2002
4	C	Point Vicente Beach	40511000	Indicator bacteria	Nonpoint Source	0.63 Miles	2002
4	C	Portuguese Bend Beach	40511000	Indicator bacteria	Nonpoint Source	1.4 Miles	2002

A615191

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Promenade Park Beach	40210000				
				Indicator bacteria		0.37 Miles	2003
				Area affected is at Oak Street , Redwood Apartments, and south of drain at California Street.			
					Nonpoint/Point Source		
4	C	Puerco Beach	40431000				
				Indicator bacteria		0.5 Miles	2002
					Nonpoint Source		
4	C	Redondo Beach	40512000				
				Coliform Bacteria		1.5 Miles	2003
					Nonpoint Source		
4	C	Resort Point Beach	40511000				
				Indicator bacteria		0.15 Miles	2002
					Nonpoint Source		
4	R	Rio Hondo Reach 1 (Confl. LA River to Snt Ana Fwy)	40515010				
				Copper		4.6 Miles	2005
					Nonpoint/Point Source		
				Lead		4.6 Miles	2005
					Nonpoint/Point Source		
				pH		4.6 Miles	2004
					Nonpoint/Point Source		
				Zinc		4.6 Miles	2005
					Nonpoint/Point Source		
4	R	Rio Hondo Reach 2 (At Spreading Grounds)	40515010				
				Ammonia		4.9 Miles	2004
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		

4015195

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Royal Palms Beach	40511000				
				Indicator bacteria		1.1 Miles	2002
					Nonpoint Source		
4	R	San Gabriel River, East Fork	40543000				
				Trash		5.9 Miles	1999
					Nonpoint Source		
4	R	Santa Clara River Reach 3 (Freeman Diversion to A Street)	40331000				
				Ammonia		31 Miles	2004
					Nonpoint/Point Source		
				Chloride		31 Miles	2002
					Nonpoint/Point Source		
4	R	Santa Clara River Reach 5 (Blue Cut gaging station to West Pier Hwy 99 Bridge) (was named Santa Clara River Reach 7 on 2002 303(d) list)	40351000				
				Ammonia		9.4 Miles	2004
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Chloride		9.4 Miles	2005
				Chloride was relisted by USEPA in 2002.			
					Nonpoint/Point Source		
				Nitrate and Nitrite		9.4 Miles	2004
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
4	R	Santa Clara River Reach 6 (W Pier Hwy 99 to Bouquet Cyn Rd) (was named Santa Clara River Reach 8 on 2002 303(d) list)	40351000				
				Ammonia		5.2 Miles	2004
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Chloride		5.2 Miles	2005
				Chloride was relisted by USEPA in 2002.			
					Nonpoint/Point Source		

A015195

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Santa Monica Beach	40513000				
				Indicator bacteria		3 Miles	2002
					Nonpoint Source		
4	R	Santa Monica Canyon	40513000				
				Indicator bacteria		2.7 Miles	2002
					Nonpoint Source		
4	C	Sea Level Beach	40441000				
				Indicator bacteria		0.21 Miles	2002
					Nonpoint Source		
4	R	Sepulveda Canyon	405.13				
				Copper		0.83 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Indicator bacteria		0.83 Miles	2007
				For 2006, indicator bacteria was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint Source		
				Lead		0.83 Miles	2005
				For 2006, lead was moved by USEPA from the 303(d) list to this being addressed list because of a completed USEPA approved TMDL.			
					Nonpoint Source		
				Selenium		0.83 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
				Zinc		0.83 Miles	2005
				For 2006, this listing was added by USEPA to this being addressed list because of a completed USEPA approved TMDL.			
					Source Unknown		
4	R	Stokes Creek	40422020				
				Coliform Bacteria		4.7 Miles	2005
					Nonpoint Source		

A015197

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Surfers Point at Seaside	40210000				
				Indicator bacteria		0.53 Miles	2003
				Area affected is the end of the access path via a wooden gate.			
					Nonpoint/Point Source		
4	C	Topanga Beach	40413000				
				Coliform Bacteria		2.5 Miles	2002
					Nonpoint Source		
4	C	Torrance Beach	40512000				
				Coliform Bacteria		1.1 Miles	2002
					Nonpoint Source		
4	R	Torrey Canyon Creek	40341000				
				Nitrate and Nitrite		1.7 Miles	2004
					Nonpoint Source		
4	C	Trancas Beach (Broad Beach)	40437000				
				Fecal Coliform		1.7 Miles	2002
					Nonpoint Source		
4	R	Tujunga Wash (LA River to Hansen Dam)	40521000				
				Ammonia		9.7 Miles	2004
					Nonpoint Source		
				Copper		9.7 Miles	2005
					Nonpoint Source		
4	C	Venice Beach	40513000				
				Indicator bacteria		2.5 Miles	2002
					Nonpoint Source		
4	R	Wheeler Canyon/Todd Barranca	40321000				
				Nitrate and Nitrite		10 Miles	2004
					Nonpoint Source		

A215198

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY USEPA APPROVED TMDLS

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED	USEPA APPROVED TMDL
4	C	Whites Point Beach	40511000				
				Indicator bacteria		1.1 Miles	2002
					Nonpoint Source		
4	C	Will Rogers Beach	40513000				
				Indicator bacteria		3 Miles	2002
					Nonpoint Source		
4	C	Zuma Beach (Westward Beach)	40436000				
				Indicator bacteria		1.6 Miles	2002
					Nonpoint Source		
5	R	Arcade Creek	51921000				
				Chlorpyrifos		9.9 Miles	2004
					Urban Runoff/Storm Sewers		
				Diazinon		9.9 Miles	2004
				The agricultural source of diazinon for these waterbodies is from aerial deposition.			
					Agriculture		
					Urban Runoff/Storm Sewers		
5	R	Bear Creek	51320023				
				Mercury		15 Miles	2007
					Resource Extraction		
5	R	Cache Creek, Lower (Clear Lake Dam to Cache Creek Settling Basin near Yolo Bypass)	51120000				
				Mercury		96 Miles	2007
				All resource extraction sources are abandoned mines.			
					Resource Extraction		
5	R	Chicken Ranch Slough	51921000				
				Chlorpyrifos		8 Miles	2004
					Urban Runoff/Storm Sewers		

A015199

2006 CWA SECTION 303(d) LIST OF WATER QUALITY LIMITED SEGMENTS BEING ADDRESSED BY ACTIONS OTHER THAN TMDLs

USEPA APPROVAL DATE: JUNE 28, 2007

REGION	TYPE	NAME	CALWATER WATERSHED	POLLUTANT/STRESSOR	POTENTIAL SOURCES	ESTIMATED SIZE AFFECTED
2	E	Stege Marsh	20330011			
				Chlordane		29 Acres
					Source Unknown	
				Copper		29 Acres
					Source Unknown	
				Dacthal		29 Acres
					Source Unknown	
				Dieldrin		29 Acres
					Source Unknown	
				Mercury		29 Acres
					Source Unknown	
				PCBs (Polychlorinated biphenyls)		29 Acres
					Source Unknown	
				Zinc		29 Acres
					Source Unknown	
4	R	Coyote Creek	40515010			
				Ammonia		13 Miles
					Point Source	
4	R	San Jose Creek Reach 1 (SG Confluence to Temple St.)	40531000			
				Ammonia		2.7 Miles
					Nonpoint/Point Source	

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		(b) Excerpt of RWQCB-LA Basin Plan	1-19 to 1-46
		(c) Letter from US Forest Service on Stickleback habitat	1-47 to 1-86
		(d) Letter from RWQCB-LA to steering committee	1-87 to 1-90
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07/03/03		Steering Committee Meeting on Santa Clara River Characterization Study on July 3, 2003:	
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04/24/03		Letter from Samuel Unger (RWQCB) to Gerald Bowes (State Water Resources Control Board (SWRCB)) requesting arrangement of External Peer Review for Santa Clara River	2-1

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07/16/03		Email from Gerald W. Bowes (SWRCB) to Sam Unger (RWQCB) in response to his request for peer reviewers.	2-14
07/16/03		Email from Elizabeth Erickson (RWQCB) to Professor Thomas Meixner (UC Riverside).	2-15 to 2-16
07/16/03		Email from Thomas Meixner (UC Riverside) to Elizabeth Erickson (RWQCB) to confirm that he has no personal or financial conflicts involved in the development of the development of the Santa Clara TMDL	2-17 to 2-18
07/21/03		Email from Elizabeth Erickson (RWQCB) to John Melack (UC Santa Barbara).	2-19 to 2-20
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08/01/03		Email from John Melack (UC Santa Barbara) to Elizabeth Erickson (RWQCB) to confirm that he has no personal or financial conflicts involved in the development of the development of the Santa Clara TMDL	2-29 to 2-30
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	5	**Draft Package to RWQCB Members**	
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	7	**References**	
		1) Ambrose, Richard F., Steven F. Lee, Sean P. Bergquist, Environmental Monitoring and Bioassessment of Coastal Watersheds in Ventura and Los Angeles Counties, Department of Environmental Health Sciences and Environmental Science of Engineering Program, University of California, Los Angeles, February 2003.	7-1 to 7-268
		2) CH2MHILL, Memorandum, "Santa Rosa Animal Waste Control Demonstration Project Annual Report," April 6, 1992.	7-269 to 7-270
		3) Department of Water Resources, Investigation of Water Quality and Beneficial Uses Upper Santa Clara River	7-271

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		Hydrologic Area, Final Project Report, 1993.	
		4) Hanson, R.T., Peter Martin, K.M. Koczot, Simulation of Ground-Water/Surface-Water Flow in the Santa Clara-Calleguas Basin, Ventura County, California, U.S. Geological Survey, Sacramento, California, 2003.	7-272
		5) Keller, Arturo A., Yi Zheng, Determination of the Critical Water Quality Conditions for the Impaired Reaches of the Santa Clara River Watershed, Bren School of Environmental Science & Management, University of California, Santa Barbara.	7-273 to 7-292
		6) Keller, Arturo A., Yi Zheng, Analysis of pH Variation in the Impaired Reaches of the Santa Clara River, Bren School of Environmental Science & Management, University of California, Santa Barbara.	7-293 to 7-296
		7) Keller, Arturo, Analysis of Potential Nutrient Load Allocation for the Reaches of the Santa Clara River Considered in the 1998 303(d) List, Bren School of Environmental Science & Management, University of California, Santa Barbara.	7-297 to 7-306
		8) Los Angeles Regional Water Quality Control Board, Final Additional Analysis to Newhall Ranch Specific Plan Final EIR, March 2003.	7-307 to 7-308
		9) Montgomery Watson Harza, Prepared for County Sanitation Districts of Los Angeles County, Nitrogen	7-309 to 7-400

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		Removal Evaluation for the Saugus and Valencia Water Reclamation Plants, Final Report, December 2002.	
		10) Reinhart, Jill, "Community Effort Succeeds: Removing a Michigan Creek From Impaired Waters List", Partners: Conservation Technology Information Center, January/February 2003, Vol. 21 No.1, pg. 8-9.	7-401 to 7-402
		11) Systech Engineering, Inc., Final Task 1 Report for Santa Clara River Nutrient TMDL Analysis: Source Identification and Characterization, July 15, 2002. (Final Task 2 Report for Santa Clara River Nutrient TMDL Analysis of Hydrology and Water Quality September 1, 2002, contained in its entirety in this record from 3-297 to 3-484)	7-403 to 7-488
		12) Technical Reports to the Steering Committee. a. WARMF model calibration refinement for nitrogen compounds. b. Expected Performance of Upgraded WWTP's c. Stream Health Studies	 7-489 to 7-504 7-505 to 7-524 7-525 to 7-596
		13) United States Environmental Protection Agency, Protocol for Developing Nutrient TMDL's, First Edition, Office of Water, November 1999.	7-597 to 7-598

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		14) United States Department of the Interior, Fish and Wildlife Service, "Biological Opinion for the Valencia Company's Clean Water Act Section 404 Authorization for Portions of the Santa Clara River, Los Angeles County, California," Letter, November 27, 1998.	7-599 to 7-642
		15) United States Department of the Interior, Fish and Wildlife Service, "Biological Opinion for the Valencia Company's Clean Water Act Section 404 Authorization for Portions of the Santa Clara River, Los Angeles County, California," Letter, November 15, 2002.	7-643 to 7-684
		16) Zedler, Joy B., "Wetlands at Your Service: Reducing Impacts of Agriculture at the Watershed Scale," The Ecological Society of America, University of Wisconsin, Botany Department and Arboretum, 2003.	7-685 to 7-686

State of California
California Regional Water Quality Control Board, Los Angeles Region

RESOLUTION NO. 03-011
August 7, 2003

Amendment to the Water Quality Control Plan for the Los Angeles Region to include a TMDL for Nitrogen Compounds in the Santa Clara River

WHEREAS, the California Regional Water Quality Control Board, Los Angeles Region, finds that:

1. The federal Clean Water Act (CWA) requires the California Regional Water Quality Control Board (Regional Board) to develop water quality standards which include beneficial use designations and criteria to protect beneficial uses for each water body found within its region.

2. The Regional Board carries out its CWA responsibilities through California's Porter-Cologne Water Quality Control Act and establishes water quality objectives designed to protect beneficial uses contained in the Water Quality Control Plan for the Los Angeles Region (Basin Plan).

3. Regional Board Resolution No. 2002-011 amended the Basin Plan on April 25, 2002 to update the ammonia objectives for inland surface waters, including the Santa Clara River. The revised ammonia objectives are based on 1991 U.S. Environmental Protection Agency (USEPA) guidance documents.

4. Section 303(d) of the CWA requires states to identify and to prepare a list of water bodies that do not meet water quality standards. The Santa Clara River was listed on California's 202 section 303(d) list, due to impairment for nitrogen compounds.

5. A consent decree between the U.S. Environmental Protection Agency (USEPA), Heal the Bay, Inc., and BayKeeper, Inc. was approved on March 22, 1999. The court order directs the USEPA to complete TMDLs for all the Los Angeles Region's impaired waters within 13 years.

6. The elements of a TMDL are described in 40 CFR sections 130.2 and 130.7 and section 303(d) of the CWA, as well as in USEPA guidance documents (e.g., USEPA, 1991). A TMDL is defined as "the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background." (40 CFR § 130.2.) Regulations further stipulate that TMDLs must be set at "levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." (40 CFR § 130.7(c)(1).) The regulations in 40 CFR section 130.7 also state

that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.

7. Upon establishment of TMDLs by the State or USEPA, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality Management Plan. (40 CFR §§ 130.6(c)(1), 130.7.) The Basin Plan, and applicable statewide plans serve as the State Water Quality Management Plans governing the watersheds under the jurisdiction of the Regional Board.

8. The Santa Clara River is located in Los Angeles and Ventura Counties and is the largest river system in the Los Angeles Region that remains in a relatively natural state. It drains from the east beginning in the Transverse Ranges below Soledad Pass through the Santa Clara River and its major tributaries, Castaic, Piru, Hopper, Sespe and Santa Paula Creeks to Pacific Ocean. The proposed TMDL addresses documented water quality impairments by nitrogen compounds.

9. The Regional Board's goal in establishing the above-mentioned TMDL is to maintain the warm freshwaterand wildlife habitats (WARM, WILD), groundwater recharge (GWR) and others beneficial uses of Santa Clara River as established in the Basin Plan. Additionally, ammonia is known to cause toxicity to aquatic organisms.

10. Interested persons and the public have had reasonable opportunity to participate in review of the amendment to the Basin Plan. Efforts to solicit public review and comment include more than eighteen public workshops held between February 11, 2002 and June 12, 2003; public notification 45 days preceding the Board hearing; and responses from the Regional Board staff to oral and written comments received from the public.

11. The amendment is consistent with the State Antidegradation Policy (State Board Resolution No. 68-16), in that the changes to water quality objectives (i) consider maximum benefits to the people of the state, (ii) will not unreasonably affect present and anticipated beneficial use of waters, and (iii) will not result in water quality less than that prescribed in policies. Likewise, the amendment is consistent with the federal Antidegradation Policy. (See 40 CFR § 131.12.)

12. The basin planning process has been certified as functionally equivalent to the California Environmental Quality Act requirements for preparing environmental documents and is, therefore, exempt from those requirements (Public Resources Code, Section 21000 et seq.), and the required environmental documentation and CEQA environmental checklist have been prepared.

13. The Regional Board staff conducted a CEQA scoping meeting on June 12, 2003, to allow interested persons to comment on the environmental issues that should be addressed when considering the Basin Plan amendment.

14. In developing the Basin Plan amendment, staff considered alternatives to the Basin Plan amendment considered by the Regional Board. Among the alternatives

considered were (1) a no action alternative, (2) an implementation program that would be shorter than that prescribed by the Basin Plan amendment, and (3) an implementation program that would be longer than that prescribed by the Basin Plan amendment. Staff also considered alternatives proposed by interested persons. These alternatives are set forth in the administrative record, staff proposal, and the response to comments.

15. The expression of the wasteload allocations as concentrations does not limit the Regional Board's discretion in translating the wasteload allocations into NPDES permit effluent limitations.

16. The proposed amendment results in no potential for adverse effect (de minimis finding), either individually or cumulatively, on wildlife.

17. The regulatory action meets the "Necessity" standard of the Administrative Procedures Act, Government Code, section 11353, subdivision (b).

18. The Basin Plan amendment incorporating a TMDL for nitrogen compounds for the Santa Clara River must be submitted for review and approval by the State Water Resources Control Board (State Board), the State Office of Administrative Law (OAL), and the US Environmental Protection Agency (USEPA). The Basin Plan amendment will become effective upon approval by OAL and USEPA. A Notice of Decision will be filed.

THEREFORE, be it resolved that pursuant to Section 13240 and 13242 of the Water Code, the Regional Board hereby amends the Basin Plan as follows:

1. Pursuant to sections 13240 and 13242 of the California Water Code, the Regional Board, after considering the entire record, including oral testimony at the hearing, hereby adopts the amendment to Chapter 7 the Water Quality Control Plan for the Los Angeles Region to incorporate the elements of the Santa Clara River Nitrogen Compounds TMDL as set forth in Attachment A hereto.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the State Board in accordance with the requirements of section 13245 of the California Water Code.

3. The Regional Board requests that the State Board approve the Basin Plan amendment in accordance with the requirements of sections 13245 and 13246 of the California Water Code and forward it to OAL and the USEPA.

4. If during its approval process the SWRCB or OAL determines that minor, non-substantive corrections to the language of the amendment are needed for clarity or consistency, the Executive Officer may make such changes, and shall inform the Board of any such changes.

5. The Executive Officer is authorized to sign a Certificate of Fee Exemption.

August 7, 2003

6. Amend the text in the Basin Plan, Plans and Policies (Chapter 5) to add:

   "Resolution No. 03-011. Adopted August 7, 2003.
   'Amendment to include a TMDL for Nitrogen Compounds for Santa Clara River'
   The resolution proposes a TMDL for nitrogen compounds in the Santa Clara River."

I, Dennis A. Dickerson, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Los Angeles Region, on August 7, 2003.

Original Signed By

Dennis A. Dickerson
Executive Officer

August 7, 2003

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