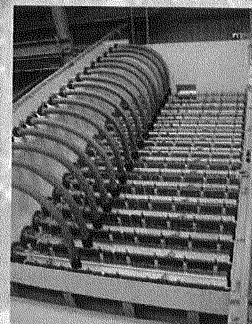
Orange County Water District



GROUNDWATER MANAGEMENT PLAN

March 2004

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Executive Summary

The Orange County Water District (OCWD, District) is the manager of the Orange County Groundwater Basin (Basin). Since the District was formed in 1933, the Basin has played a key role in meeting the water supply needs of north Orange County. The District's mission statement provides a concise description of OCWD's work:

> *It is the mission of the Orange County Water District to provide local water retailers with a reliable, adequate, high-quality local water supply at the lowest reasonable cost and in an environmentally responsible manner.*

This report presents the current update of the District's *Groundwater Management Plan* (Plan):

- Describes the background and purpose of the Plan.
- Describes the hydrogeology of the Basin.
- Discusses the range of District activities and management programs, including groundwater monitoring, production management, recharge water supply, and groundwater quality management and improvement projects.
- Describes historical and future water demands and integrated demand/supply management strategies.
- Summarizes financial management programs.
- Develops recommendations for continued proactive Basin management.

ES-1 BACKGROUND AND PURPOSE

The District's most recent *Groundwater Management Plan* was prepared in 1994. Earlier versions were prepared in 1989 and 1990. These early plans served as the model for groundwater management plans authorized under Assembly Bill 3030, signed into law in 1992.

Since 1994, significant changes in the Basin have occurred, including (1) annual groundwater pumping increases, (2) development of a new water source for groundwater recharge and groundwater injection, (3) increases in the base flow to the Santa Ana River (SAR), (4) additional restrictions on imported water supplies available to the District to supplement local recharge, and (5) new water quality issues driven by changes in water quality regulations.

The Plan presented in this report addresses changes in the Basin in a structured framework by identifying the key Basin issues and potential management strategies and by describing factors for the District's Board to consider in making decisions regarding how much pumping the Basin can sustain.

Another purpose of the Plan is to offer an opportunity for public participation through publicly noticed meetings and to provide a structured report for the public to gain further understanding of the District's comprehensive programs.

The Plan also addresses the requirements of Senate Bill 1938, passed in 2002, which includes a list of issues to be addressed to ensure compliance of groundwater management plans with the California Water Code.

Any specific projects that may be developed as a result of recommendations in the Plan would be reviewed and approved by the District's Board of Directors and processed for environmental review prior to project implementation. The Plan does not commit the District to a particular program or level of Basin production, but describes the factors to consider and key issues as the Board makes Basin management decisions on a regular basis each year.

Potential projects that are conceptually described in the Plan are described in greater detail in the *Long-Term Facilities Plan*.

Two major objectives drive the Plan: protecting and enhancing groundwater quality and cost-effectively protecting and increasing the Basin's sustainable yield. Several goals are associated with meeting these objectives, as presented in Table ES-1. These goals are achieved through the implementation of the programs, policies, and other activities described in this report.

Table ES-1

GROUNDWATER MANAGEMENT OBJECTIVES

Protect and Enhance Groundwater Quality	Cost Effectively Protect and Increase the Basin's Sustainable Yield
• Prevent seawater intrusion • Protect recharge water quality • Address existing groundwater contamination • Prevent future groundwater contamination • Conduct monitoring to assess water quality	• Protect and increase supply of recharge water • Increase recharge capacity • Maximize Basin's flexibility to respond to and recover from drought • Minimize drawdown impacts in sensitive areas • Explore opportunities for conjunctive use • Control groundwater losses • Increase supply of water extracted from colored water zone and shallow aquifer • Manage natural resources • Conduct monitoring to provide information to manage the Basin

ES-2 BASIN HYDROLOGY

The Basin covers an area of approximately 350 square miles underlying the north half of Orange County beneath broad lowlands known as the Tustin and Downey plains (Figure ES-1).

Figure ES-1

MAP OF THE ORANGE COUNTY GROUNDWATER BASIN

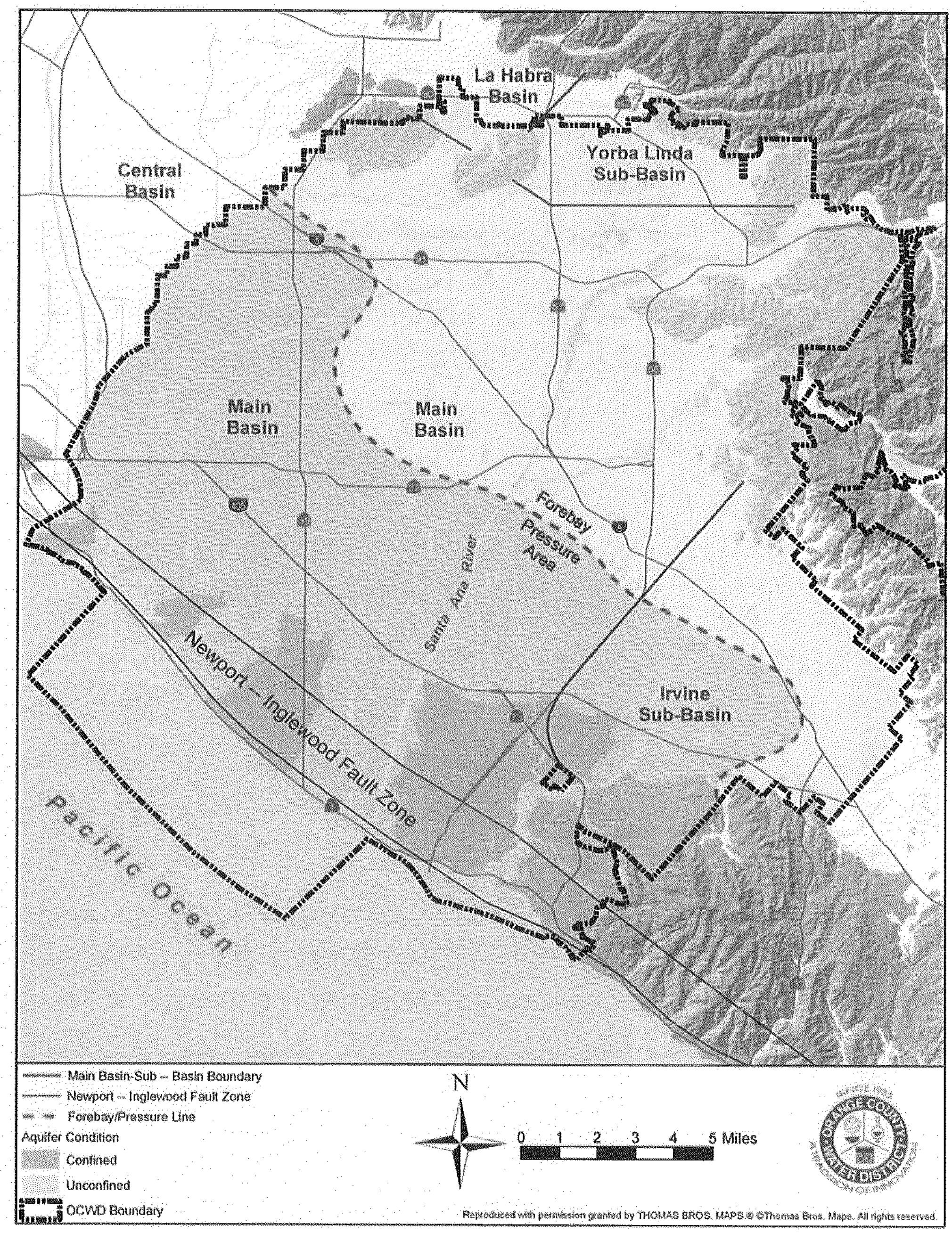
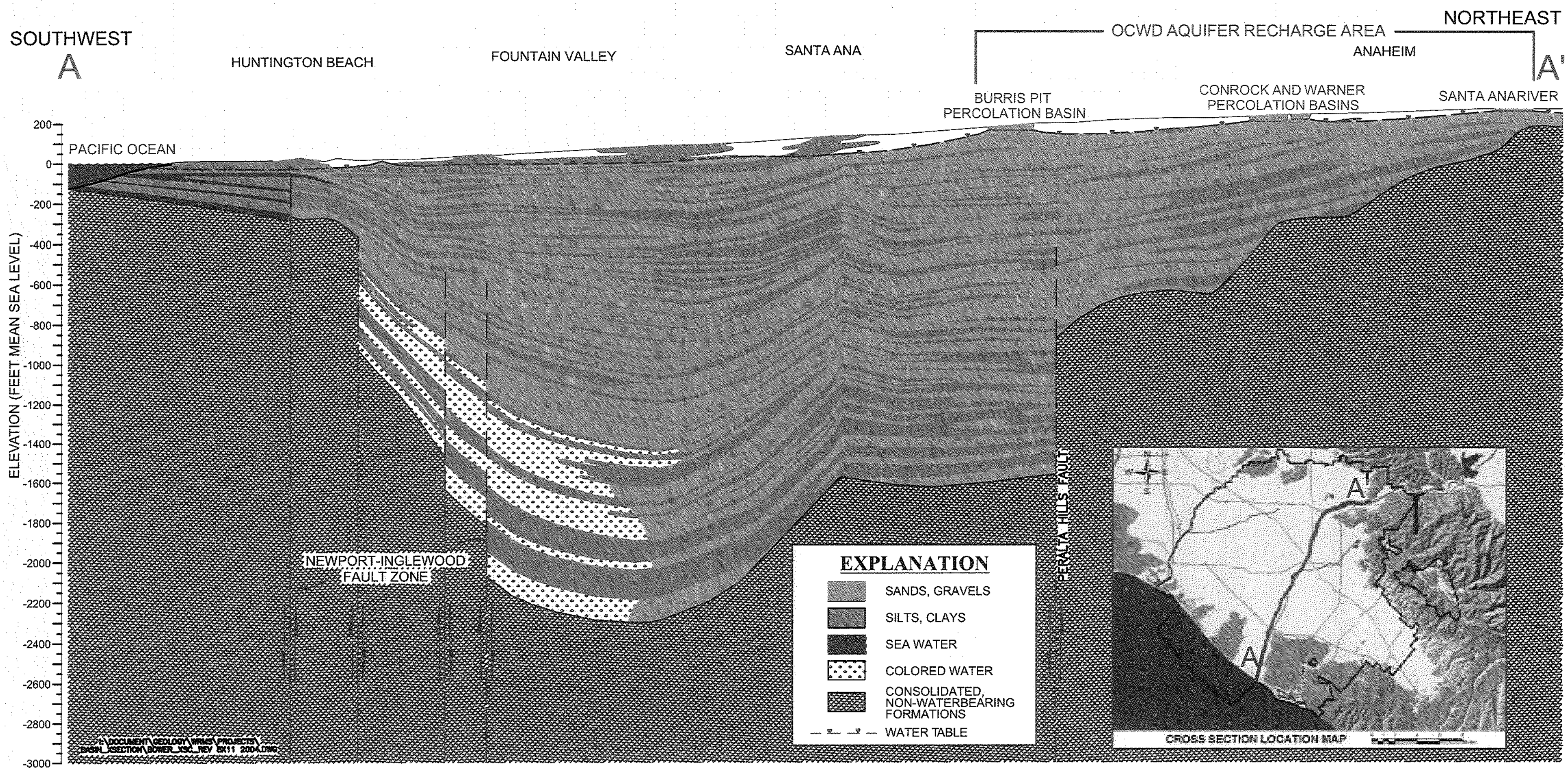


FIGURE ES-2
GEOLOGIC CROSS SECTION THROUGH ORANGE COUNTY GROUNDWATER BASIN



The aquifers comprising the Basin extend over 2,000 feet deep and form a complex series of interconnected sand and gravel deposits

OCWD's extensive groundwater monitoring well network provides data on aquifers to depths of 2,000 feet in many areas of the Basin. Data from these wells were used to delineate the depth of the "principal" aquifer system, within which most of the groundwater production occurs. Shallower aquifers exist above the principal aquifer system, the most prolific being known as the Talbert aquifer. With the exception of a few large-system municipal wells in the cities of Garden Grove, Anaheim, and Tustin, wells producing from the shallow aquifer system predominantly have industrial and agricultural uses. Production from the shallow aquifer system is typically about five percent of total Basin production. Deeper aquifers exist below the principal aquifer system, but these zones have been found to contain colored water or have been too deep to economically construct production wells. With the exception of four colored water production wells constructed by Mesa Consolidated Water District (MCWD) and Irvine Ranch Water District (IRWD), few wells penetrate the deep aquifer system. Figure ES-2 presents a geologic cross-section through the Basin along the SAR.

The California Department of Water Resources (DWR) divided the Basin into two primary hydrologic divisions: the Forebay and Pressure areas. The Forebay refers to the area of intake or recharge where the majority of recharge to the Basin occurs, primarily by direct percolation of SAR water, and is characterized by highly permeable sands and gravels with relatively few and discontinuous clay and silt deposits. The Pressure Area is generally defined as the area in the Basin where surface water and near-surface groundwater are impeded from percolating in large quantities into the major producible aquifers by clay and silt layers at shallow depths (upper 50 feet).

OCWD staff developed a hydrologic budget (inflows and outflows) for the purpose of constructing the groundwater flow model and for evaluating Basin production capacity and recharge requirements. The key components of the budget include measured and unmeasured (estimated) recharge, groundwater production, and subsurface flows along the coast and across the Los Angeles/Orange County line. Because the Basin is not operated on an annual safe-yield basis, the net change in storage in any given year may be positive or negative; however, over the long term (several years), the Basin must be maintained in an approximate balance to ensure the long-term viability of Basin supplies. Table ES-2 presents the components of a representative balanced Basin water budget (no annual change in storage) and does not represent data for any given year.

Table ES-2

REPRESENTATIVE BASIN WATER BUDGET

FLOW COMPONENT	Acre-feet
INFLOW	
Measured Recharge	
1. Forebay spreading facilities, current maximum including imported water	250,000
2. Talbert Barrier injection, current maximum	12,000
3. Alamitos Barrier injection, Orange County only	2,500
Subtotal:	**264,500**
Unmeasured Recharge (average precipitation)	
1. Inflow from La Habra Basin	3,000
2. Santa Ana Mountain recharge into Irvine subbasin	13,500
3. San Joaquin Hills recharge into Irvine subbasin	500
4. Areal recharge from rainfall/irrigation (Forebay area)	13,000
5. Areal recharge from rainfall/irrigation (Pressure area)	4,500
6. Chino Hills recharge into Yorba Linda subbasin	6,000
7. Subsurface inflow at Imperial Highway beneath SAR	4,000
8. SAR recharge between Imperial Highway and Rubber Dam	4,000
9. Subsurface inflow beneath Santiago Creek	10,000
10. Peralta Hills recharge into Anaheim/Orange	4,000
11. Tustin Hills recharge into City of Tustin	6,000
12. Seawater inflow through coastal gaps	2,000
Subtotal:	**70,500**
TOTAL INFLOW:	**335,000**
OUTFLOW	
1. Groundwater Production	327,000
2. Flow across Orange/Los Angeles County line, est. at 400,000 af accumulated overdraft	8,000
TOTAL OUTFLOW:	**335,000**
CHANGE IN STORAGE:	**0**

Note: the representative water budget has equal (balanced) total inflow and total outflow and does not represent data for any given year.

Overdraft of the Basin is defined based on the overdraft being zero when the Basin was full in 1969. If groundwater storage is less than the 1969 level, the difference in storage is defined as the accumulated overdraft. In general, lower groundwater levels correspond to a lower storage level and a greater accumulated overdraft.

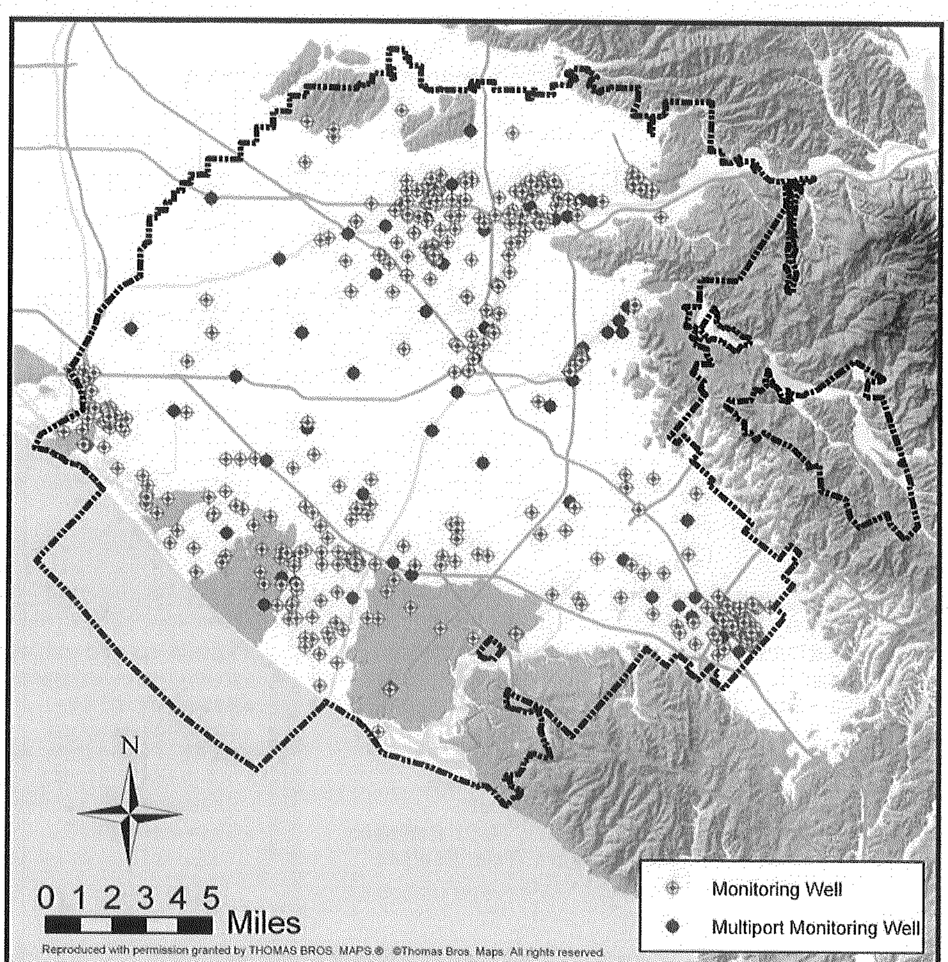
The District also has developed a comprehensive computer-based groundwater flow model (Basin Model), which encompasses the entire Basin and extends five miles into the Central Basin in Los Angeles County. The development and calibration of OCWD's Basin Model was regularly presented to and reviewed by a Model Advisory Panel. The model has substantially improved the District's overall understanding of processes and conditions that determine how and why the Basin reacts to pumping and recharge. The model's ability to simulate known and projected future conditions will evolve and improve as new data become available and updated simulations are completed.

ES-3 GROUNDWATER MONITORING

For its size and complexity, the Basin is one of the world's most extensively monitored basins. The District has implemented and continues to augment a comprehensive, proactive monitoring program to track dynamic conditions including groundwater production, storage, elevations, and quality. A vast network of production and monitoring wells is used to collect data at frequencies necessary for short- and long-term trend analyses. The spatial distribution of the wells has been tailored toward basinwide analysis and, where appropriate, focused on local or sub-regional investigations. Because of the Basin's multiple-aquifer configuration, emphasis has been placed on installing multi-depth monitoring wells that provide depth-specific water level and quality data. Figure ES-3 depicts the District's monitoring well network.

Figure ES-3

OCWD MONITORING WELL NETWORK



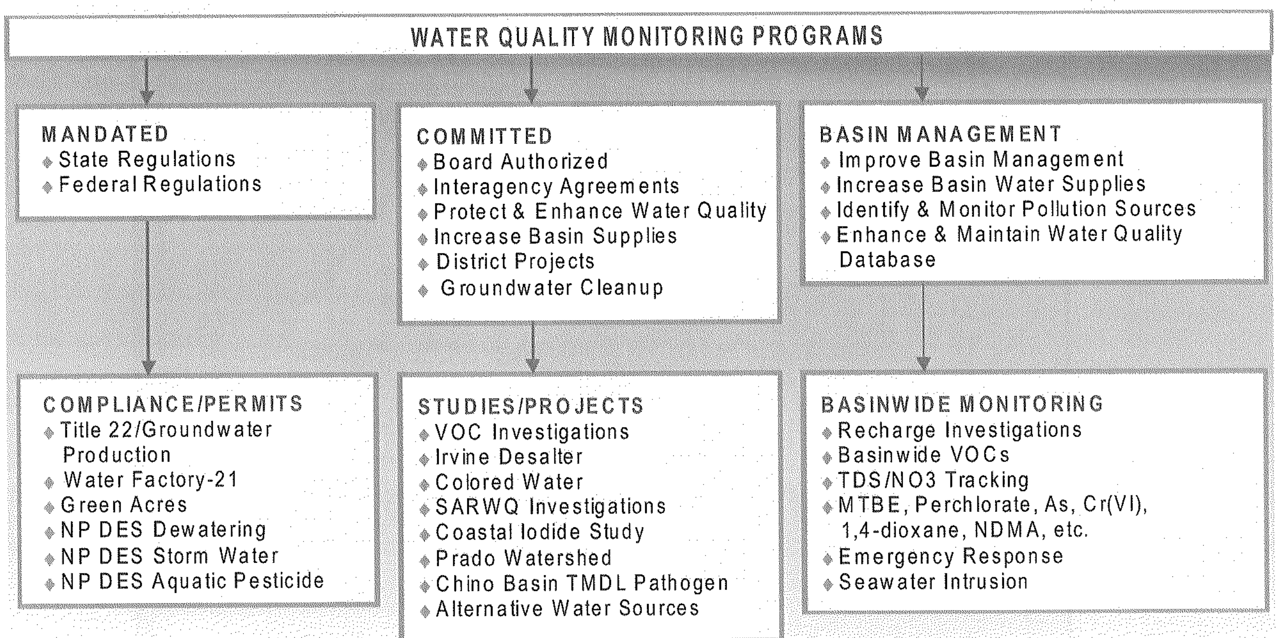
Groundwater extraction occurs from nearly 500 production wells in the Basin, with approximately 200 large-capacity municipal supply wells accounting for 97 percent of this extraction. Since 1990, at the District's request, large-capacity well owners have reported their groundwater production on a monthly basis for each of their wells, even though they are billed for their production on a semi-annual basis. The monthly production data for individual wells are entered and stored in OCWD's Water Resources Management System (WRMS) database. These data were essential input for the calibration of the District's Basin Model and are often used to evaluate the causes of seasonal groundwater level fluctuations.

In addition to monitoring groundwater extraction, the District measures groundwater elevation (or level) data at nearly every production and monitoring well in the Basin at least once per year. The majority of the large-capacity production and monitoring wells, comprising a total of over 1,000 individual measurement points, are monitored for water levels on a monthly or bi-monthly basis to evaluate short-term effects of pumping or recharge operations. More frequent water level measurements are collected at selected monitoring wells in the vicinity of OCWD's recharge facilities, seawater barriers, and areas of special investigation involving drawdown, water quality impacts, or contaminant remediation.

The District also administers a comprehensive water quality monitoring program to protect and evaluate groundwater resources for potable supply. The water quality monitoring programs are broadly classified into three categories: (1) regulatory or compliance with permits, environmental, and groundwater drinking water regulations, (2) committed OCWD and research projects, and (3) Basin management, i.e., evaluating and protecting Basin water quality. Examples of water quality monitoring activities within the regulatory, committed, and Basin management categories are illustrated in Figure ES-4.

Figure ES-4

WATER QUALITY MONITORING ACTIVITIES WITHIN THE REGULATORY, COMMITTED, AND BASIN MANAGEMENT CATEGORIES



Another important component of the District's monitoring program focuses on prevention of seawater intrusion. The coastal area of the Basin is vulnerable to seawater intrusion due to geologic features and increased pumping from inland municipal wells to meet consumer demands. The susceptible locations in the Basin are the Talbert, Bolsa, Sunset, and Alamitos Gaps. A coastal seawater program monitors the effectiveness of the Talbert Gap Seawater Intrusion Barrier (Talbert Barrier) to retard seawater intrusion through the Talbert Gap and to track salinity levels in the Bolsa and Sunset Gaps. Over 425 monitoring and production wells are sampled semi-annually to assess water quality conditions during periods of lowest production (winter) and peak demands (summer).

In addition to administering a comprehensive groundwater monitoring program, the District conducts routine monitoring of the SAR and major creeks and surface water bodies in the upper watershed that are tributary to the river. Since the quality of the river may affect groundwater quality and the SAR is the primary source of recharge water, a routine monitoring program is maintained to continually assess ambient river water quality. Characterizing the quality of the SAR and its impact on the Basin is necessary to verify the sustainability of continued use of river water for recharge and to safeguard a high-quality drinking water supply for Orange County.

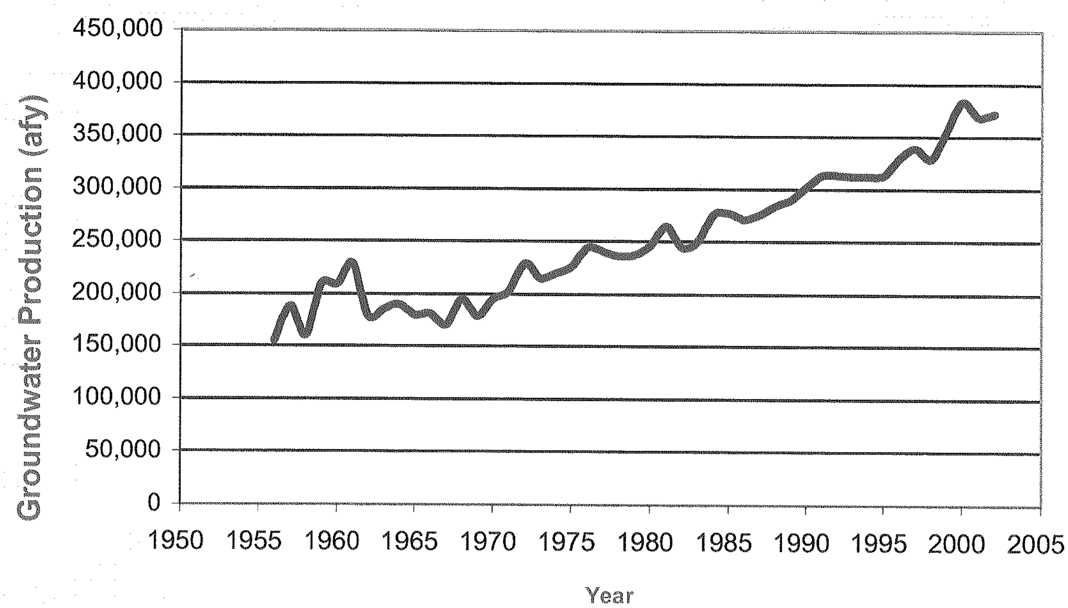
ES-4 GROUNDWATER PRODUCTION MANAGEMENT

For the past 50 years, the District has implemented a general management policy to provide for uniformity of cost and access to Basin supplies without respect to how long an entity has been producing from the Basin. This policy enabled a very successful transition from an agricultural economy to an urban economy and the accommodation of significant population growth from 300,000 in 1954 to about 2.3 million today.

As shown in Figure ES-5, total groundwater production has approximately doubled since 1954. Every OCWD groundwater producer (Producer) that is a city or water district has increased groundwater production over this period.

Figure ES-5

GROUNDWATER PRODUCTION

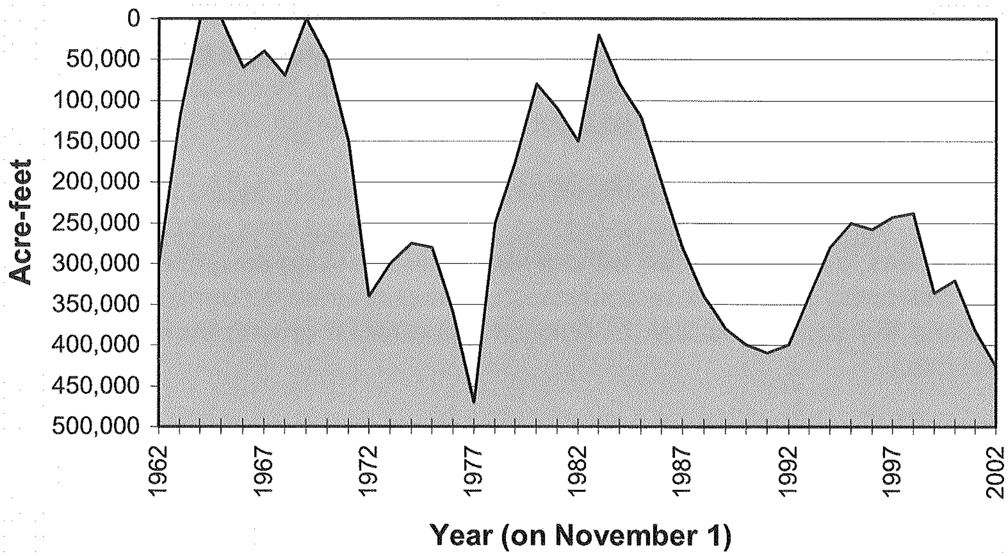


Note: Includes in-lieu (see Section 5)

Historically, the District has also managed the Basin based upon seeking to increase supply rather than restricting demand. No pumping restrictions exist. The management program takes advantage of the Basin's value as a low-cost, natural water storage and distribution facility. Figure ES-6 illustrates the Basin's available storage and accumulated overdraft since 1962.

Figure ES-6

AVAILABLE BASIN STORAGE SINCE 1962



The District manages the amount of production through financial incentives. The framework for the financial incentives is based on establishing the Basin Production Percentage (BPP). The BPP is the ratio of groundwater production to total water demands, expressed as a percentage. Pumping below the BPP is charged a fee on a per acre-feet basis. This fee is called the Replenishment Assessment (RA). Groundwater production above the BPP is charged the RA and the Basin Equity Assessment (BEA), which is typically set so that the cost of groundwater production above the BPP is similar to the cost of purchasing alternative supplies.

Increasing accumulated overdraft of the Basin since the late-1990s has prompted increased evaluation of the Basin's yield and how the yield can be optimized through projects and programs. As a response to various factors, including a series of years with below average precipitation and the increased accumulated overdraft, in 2003 the District reduced the BPP to decrease pumping from the Basin. This was the first BPP reduction since 1993. The Plan describes an updated management approach to manage the amount of water supply provided by the Basin.

The management program has enabled the Basin to avoid an adjudication process of determining groundwater rights, which is beneficial since adjudications of other groundwater basins have been lengthy, costly, and divisive. A key component of the management program is to reach consensus with the Producers regarding Basin management issues. The consensus-based approach, coupled with management of Basin production through the BPP and increasing the recharge of water into the Basin, has enabled increased Basin production to meet growing water needs.

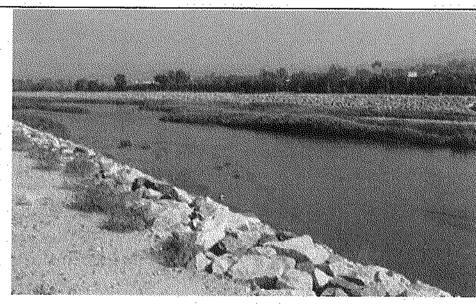
ES-5 RECHARGE WATER SUPPLY MANAGEMENT

Refilling or replenishing the Basin to balance the removal of pumped groundwater is a core activity for OCWD. The District maintains several programs to enhance recharge. As shown in Table ES-3, OCWD currently owns and operates more than 1,000 acres of recharge facilities in and adjacent to the SAR and Santiago Creek. The recharge facilities, also called spreading or percolation facilities, consist of 17 major facilities grouped in the four main components shown in the table. Table ES-3 also shows how percolation rates tend to decrease with time as the spreading basins develop a thin clogging layer from fine-grained sediment deposition and from biological growth.

Table ES-3

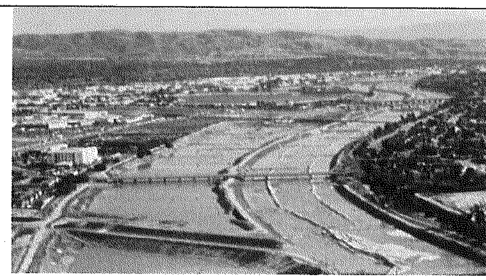
ESTIMATED STORAGE AND PERCOLATION CAPABILITIES

MAIN RIVER SYSTEM
(Imperial Highway to Ball Road)
Area: 245 acres
Storage capacity: 480 af
Percolation Rate:
Clean 115 cfs
Clogged 87 cfs



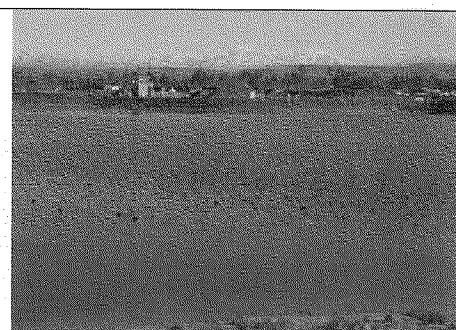
North View of SAR Near Imperial Highway

OFF-RIVER SYSTEM
Weir Ponds
1, 2, 3, and 4
Off-River between Weir Pond 4 and Carbon Creek Diversion Channel
Area: 126 acres
Storage capacity: 394 af
Percolation Rate:
Clean 40 cfs
Clogged 15 cfs



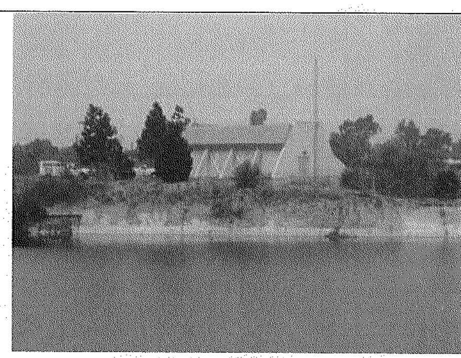
Off-River (on left side of main river channel)

DEEP BASIN SYSTEM
Huckleberry Basin
Conrock Basin
Warner Basin
Little Warner Basin
Anaheim Lake
Mini Anaheim
Miller Basin
Kraemer Basin
Placentia Basin
Raymond Basin
Area: 280 acres
Storage Capacity: 8,484 af
Percolation Rate:
Clean 300 cfs
Clogged 89 cfs



Kraemer Basin

BURRIS PIT/SANTIAGO BASIN SYSTEM
Five Coves Basins
Lincoln Basin
Burris Pit
Ball Road Basin
Blue Diamond Pit
Bond Pit
Smith Pit
Area: 373 acres
Storage Capacity: 17,500 af
Percolation Rate:
Clean 210 cfs
Clogged 106 cfs



Burris Pit Station

In addition to operating the percolation system, the District also operates the Talbert Barrier in Fountain Valley and Huntington Beach and participates in financing operation of the Alamitos Barrier in Seal Beach and Long Beach. These barriers inject water into aquifers near the coast to create a hydraulic barrier against seawater that would otherwise migrate into the aquifers where groundwater is produced inland. The barriers help prevent seawater intrusion and also help refill the Basin. Sources of recharge water include SAR base flow and storm flow, Santiago Creek flows, imported supplies purchased from the Metropolitan Water District of Southern California (Metropolitan), and purified water from the Groundwater Replenishment (GWR) System (starting in 2007). The SAR is the largest single source of recharge water.

The occurrence of wet and dry periods significantly impacts the availability of recharge water supplies. Rainfall data from San Bernardino, which is in the upper SAR watershed, are available since 1934. Since 1934, six droughts of four years or longer have occurred. During the worst drought, from 1958 to 1964, the average annual rainfall deficit from the average San Bernardino precipitation of 16.7 inches was approximately six inches. This represents a rainfall deficit of 35 percent per year. Based on review of historical data, local recharge water supplies can be reduced from 40,000 to 55,000 acre-feet per year (afy) or more during a dry year, not including potential imported water reductions. On the other hand, in a very wet year, recharge water supplies can increase up to 100,000 afy. Such very wet years have occurred roughly one out of every ten years since 1934 and never have occurred back-to-back.

ES-6 GROUNDWATER QUALITY MANAGEMENT

OCWD's extensive groundwater quality management program protects consumers and allows the District to monitor the Producers' water quality, address current water quality issues, and develop strategies to anticipate and resolve future issues. The District's multi-faceted water quality management program areas include:

- Nitrate management
- Total dissolved solids (TDS) management
- Groundwater contaminant cleanup
- Leaking underground fuel tanks, including the gasoline additive methyl tertiary-butyl ether (MTBE)
- Emerging contaminants, such as endocrine disrupting compounds (EDCs), and pharmaceuticals and personal care products (PPCPs)
- Colored groundwater management
- Close coordination with regulatory agencies
- Drinking water source protection activities
- Land use and development
- Well construction and abandonment programs
- Other related water quality activities

ES-7 GROUNDWATER QUALITY IMPROVEMENT PROJECTS

The Producers and the District implement a number of cooperative, innovative projects to improve water quality. For these projects, the District provides financial incentives, in the form of BEA exemptions, for specific cases where groundwater that does not meet drinking water standards is pumped and purified for municipal use. When authorizing a BEA exemption, the District must provide the replenishment water for the additional production.

Cooperative projects include desalters, nitrate removal, removal of volatile organic compounds (VOCs), colored water treatment, iron and manganese removal, and removal of n-nitrosodimethylamine (NDMA). These projects are summarized in Table ES-4.

Table ES-4

SUMMARY OF WATER QUALITY IMPROVEMENT PROJECTS

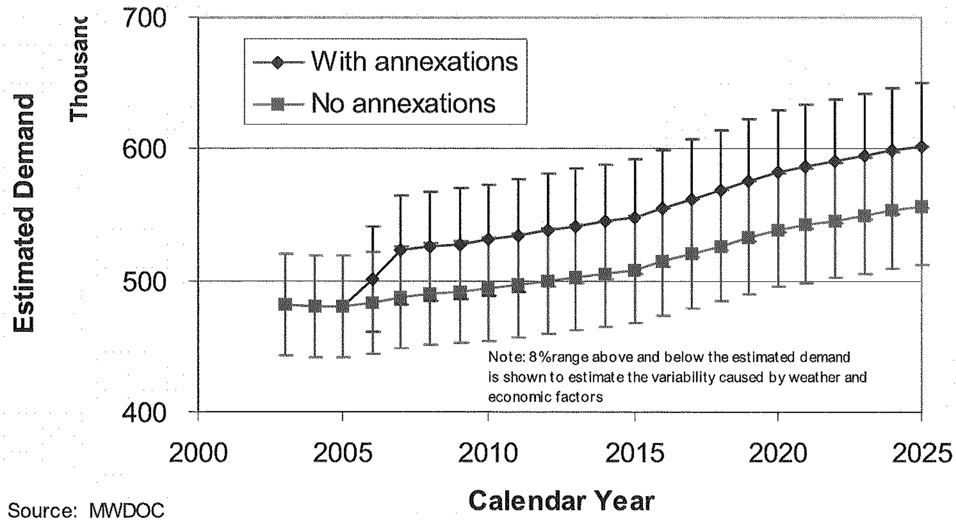
Project Name	Project Description	Board Approval of BEA Exemption	Recent Annual Groundwater Production Above the BPP (af)	OCWD Subsidy
Irvine Desalter	Removal of nitrate and TDS for potable water use and removal of TDS and VOC for industrial and irrigation use	2001	0	BEA Exemption
Tustin Desalter	Nitrate and TDS removals from wells on 17th Street using RO membranes	1998	1,773	BEA Exemption
Garden Grove Nitrate	Blending two Garden Grove wells to meet nitrate MCL	1998	1,500	BEA Exemption
Tustin Nitrate	Nitrate removal from wells on Main Street using RO membranes and ion exchange	1998	1,076	BEA Exemption
River View Golf Club VOC	VOC extraction from well in RVGC	1998	350	$50/af Reduction in BEA
MCWD Colored Water	Color removal from wells 6 and 11 using ozone oxidation	2000	4,224	BEA Exemption
IRWD DATS	Color removal from wells C8 and C9 using NF membranes	1999	6,500	BEA Exemption
Fullerton Iron / Manganese	Wellhead treatment process for iron and manganese from Fullerton Coyote well	1999	700	BEA Exemption
MCWD NDMA	Removal of NDMA from well 5 using UV	2000	3,581	Direct Contribution for design and construction of treatment system and operations and maintenance
Total	-	-	**19,704**	-

ES-8 HISTORICAL AND FUTURE WATER DEMANDS

This Plan reviews the District's current water demands and provides an estimate of future water demands – both within OCWD's existing boundary and within possible annexation areas. Figure ES-7 presents estimated future water demands with and without possible annexations. Total water demands within the District's boundary were approximately 483,000 acre-feet (af) for fiscal year 2002-03. As shown in Figure ES-7, the numbers are projected to increase to approximately 557,000 afy by 2025. With possible future annexations, the total could increase to 602,000 afy.

Figure ES-7

ESTIMATED FUTURE WATER DEMANDS



Source: MWDOC

ES-9 INTEGRATED DEMAND AND SUPPLY MANAGEMENT

The District's mechanisms for managing groundwater production include the BPP and the BEA, which are set each year. Basin production limitations are an additional tool to manage pumping for selected portions of the Basin.

Managing the amount of water the Basin can supply is fundamental to operating the Basin on a sustainable, long-term basis. In December 2002, the District updated its Basin management approach by linking the amount of production to the amount of recharge water available and the desired amount of Basin refill. The District carefully monitors the availability of recharge water supplies because the availability of sufficient amounts of recharge water is key to recharging the Basin. When setting the BPP, the District evaluates several factors, including the amount of recharge water estimated to be available for the upcoming year and the accumulated overdraft level. Several basin management factors are related to the overdraft level. These factors are considered on an annual basis as the BPP for the upcoming year is determined.

Tables ES-5 and ES-6 illustrate, respectively, the impacts of low and high accumulated overdraft levels and the management opportunities associated with these levels. Table ES-5 shows that low accumulated overdraft levels help control seawater intrusion, lower pumping energy costs, and reduce vertical migration of poor quality water. High accumulated overdraft levels decrease groundwater losses and minimize high groundwater elevation problems. Table ES-6 shows that, by and large, more management opportunities and flexibility are available when accumulated overdraft levels are low.

Table ES-5

IMPACTS OF LOW AND HIGH ACCUMULATED OVERDRAFT

Impact	Accumulated Overdraft Level	
	Low	High
Helps control seawater intrusion	Yes	No
Lowers pumping energy cost for producers	Yes	No
Reduces vertical migration of poor quality water	Yes	No
Decreases groundwater losses	No	Yes
Minimizes high groundwater elevation problems	No	Yes

Table ES-6

MANAGEMENT OPPORTUNITIES AT LOW AND HIGH ACCUMULATED OVERDRAFT

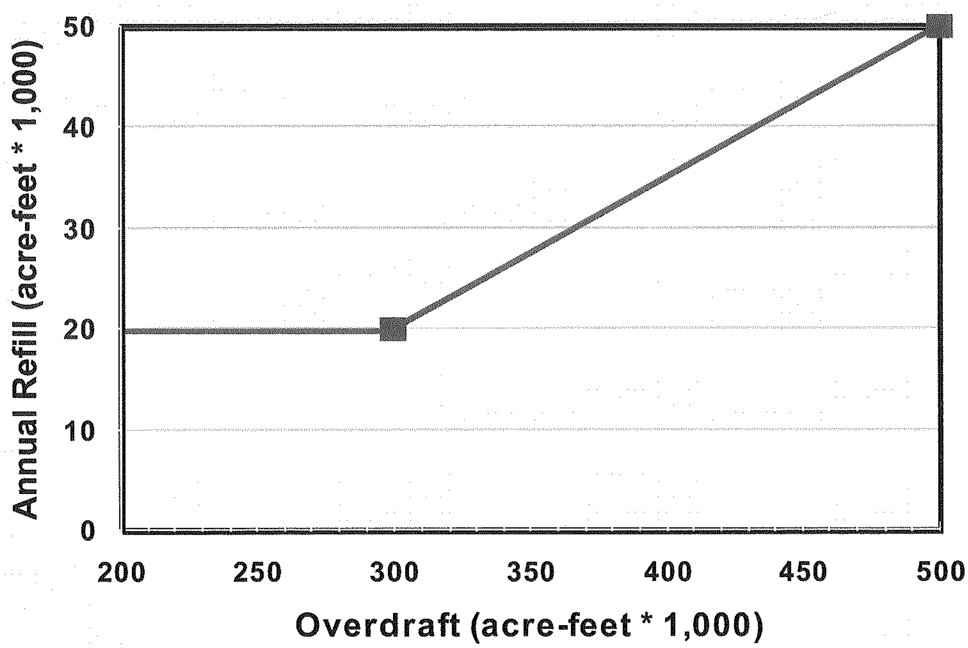
Opportunity	Accumulated Overdraft Level	
	Low	High
Minimizes need for coastal pumping reductions	Probable	Unlikely
Decreases funds needed to buy water to reduce overdraft	Probable	Unlikely
Enhances ability to maintain stable BPP	Probable	Unlikely
Allows potential to temporarily increase BPP	Probable	Unlikely
Makes stored water available during shortage condition	Probable	Unlikely
Provides storage space to recharge large amounts of low-cost water when available	Unlikely	Probable

A key feature of the hydrologic cycle is that the drought years are typically consecutive, such as the 1958-64 drought, which had seven straight years of below-average rainfall; but the very wet years typically do not occur back-to-back. This feature is important in determining the appropriate amount of water to keep in storage in the Basin.

The District has historically used a general target of 200,000 af as the recommended accumulated overdraft level. Through a cooperative project with Metropolitan, Metropolitan can store 63,000 af of water in the basin. The availability of recharge water, the existing accumulated overdraft, the storage program with Metropolitan, and the factors listed in Tables ES-5 and ES-6 are considered to determine how much water should be planned for refilling the Basin. The Plan presents a recommended refill rate, as shown in Figure ES-8, which may be modified on an annual basis due to various factors such as the availability of recharge water.

Figure ES-8

RECOMMENDED BASIN REFILL RATE



ES-10 FINANCIAL MANAGEMENT

The District has an excellent revenue base and a strong "AA+" financial rating. The District also has the ability to issue additional long-term debt, if necessary, to develop projects to increase the Basin's yield and protect water quality. This Plan presents background financial information, budgeted operating expenses for 2003-04, and expected operating revenues for 2003-04. OCWD's reserve policies are also described.

ES-11 RECOMMENDATIONS

The District has a proactive, effective program for managing water quality issues. Due to the changing nature of water quality regulation and advancements in water quality testing, the water quality management program should continue to evolve.

The District's programs to protect and increase the Basin's sustainable yield in a cost effective manner continue to evolve due to increasing water demands and changes in the availability of recharge water supplies. Below average rainfall in the period from 1998-99 to 2001-02 and restricted availability of recharge water from Metropolitan are important factors that affected Basin conditions. The occurrence of wet and dry periods, the future availability and cost of Metropolitan recharge water, operation of GWR System Phase 1, and changing water management practices of agencies in the watershed will continue to affect the District's operation of the Basin and the management approaches utilized by the District. Many of the recommendations are continuations of the District's existing programs.

The Plan contains recommendations for the District to continue its proactive management of the Basin. These recommendations are summarized in Table ES-7. The table organizes these recommendations by general program area and also links the recommendations to the two management objectives of protecting and enhancing water quality and protecting and increasing the Basin's sustainable yield.

Table ES-7

RECOMMENDATIONS

Program/Activity	Protect/Enhance Water Quality	Protect/Increase Sustainable Yield
Monitoring		
•Monitor quality of recharge water sources	Yes	Yes
•Monitor groundwater quality using District's wells and selected wells owned by others	Yes	
•Monitor water management and recycling plans in watershed for impact on SAR flow rates and SAR quality	Yes	Yes
•Conduct groundwater level and hydrogeologic evaluations to provide information to manage the Basin	Yes	Yes
Recharge Supply Management		
•Protect District's interest in management of flow in SAR		Yes
•Monitor water management and recycling plans in the watershed for their potential impact upon future SAR flows		Yes
•Evaluate feasibility of new recharge water supplies (such as water transfers)		Yes
•Evaluate feasibility of additional conjunctive use or storage projects		Yes
•Evaluate projects to increase the District's capacity to recharge water		Yes
•Evaluate projects to maintain the recharge rate in the SAR riverbed		Yes
•Locate future recharge projects to maximize benefits to the Basin and address areas of low groundwater levels to the extent feasible	Yes	Yes
•Manage natural resources in the watershed to sustain natural resources and a secure water supply	Yes	Yes
Groundwater Quality Management		
•Prevent seawater intrusion	Yes	Yes
•Evaluate emerging contaminants	Yes	Yes
•Prevent future contamination through coordinated efforts with regulatory agencies and watershed stakeholders	Yes	
•Evaluate projects to control vertical movement of poor quality water	Yes	Yes
Groundwater Improvement Projects		
•Evaluate and pursue projects to address existing areas of contamination	Yes	
Integrated Demand And Supply Management		
•Evaluate projects to maximize Basin's ability to respond to and recover from droughts		Yes
•Evaluate projects to control groundwater losses		Yes
•Evaluate projects to reduce water demand through conservation and water use efficiency		Yes

Any specific projects that would be developed as a result of these recommendations would be reviewed and approved by the District's Board of Directors and processed for environmental review prior to project implementation.

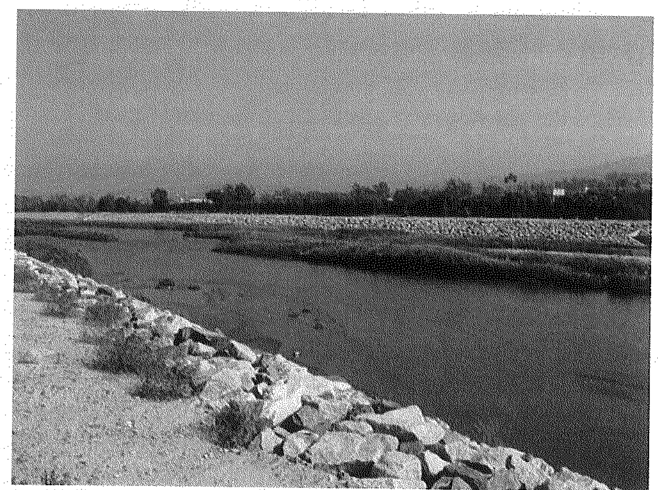
In the District 2003-2006 Strategic Plan, the District established quantifiable goals or Key Performance Indicators to measure progress toward meeting the two major objectives. These Key Performance Indicators are listed in Table ES-8. The table also lists the Plan section that provides supporting information.

Table ES-8

KEY PERFORMANCE INDICATORS

Key Performance Indicator	Reference	Protects/Enhances Water Quality	Protect/Increase Sustainable Yield
Cease landward migration of 250 milligram per liter chloride contour by 2006	Section 3	Yes	Yes
Increase Prado water conservation pool elevation by four feet by 2005	Section 5	Yes	Yes
Increase recharge capacity by 10,000 afy	Section 5	---	Yes
All water recharged into the Basin through District facilities meets or is better than DHS MCLs and Action Levels	Section 6	Yes	---
Reduce Basin overdraft by 20,000 afy	Section 9	Yes	Yes

section 1 Introduction



The OCWD is the manager of the Basin in coastal Southern California, which extends from the Los Angeles/Orange County line east to Anaheim and southeast to Irvine. Groundwater pumped from the Basin provides the majority of water demands in the Basin.

This section provides background information on the District and sets the framework for the Plan. The subsections below:

- Discuss the District's formation, mission, and operating authorities.
- Trace changing conditions in the Basin that are important to development of the Plan.
- Describe the public participation component of the Plan.
- Discuss the Plan's compliance with the California Water Code.
- Present objectives that guide the District's management of the Basin.

1.1 HISTORY OF OCWD

The District was formed by a special act of the California Legislature in 1933 for the purpose of protecting the Basin. Since then, the District has achieved world-renowned status for its innovative approach to groundwater recharge, water quality protection, and groundwater resource management. The District's projects have helped to provide groundwater that meets approximately two-thirds of the water supply demand for a population of over 2.3 million. Because the Basin is locally controlled and non-local supplies are subject to potential future shortages, the Basin is a critical water supply source for northern Orange County. The District's mission statement provides a concise description of the District's work:

> *It is the mission of the Orange County Water District to provide local water retailers with a reliable, adequate, high-quality local water supply at the lowest reasonable cost and in an environmentally responsible manner.*

The District was originally formed as the result of a lawsuit filed by The Irvine Company (TIC) against upstream SAR water users due to reduced groundwater levels and decreasing river flows. As the scope of the litigation and the number of defendants grew, the potential cost to be incurred by TIC grew, as did the potential benefit to other Orange County water users. In April 1931, the Orange County Farm Bureau sent a letter to the county's state senator and state assemblyman requesting their help to form an organization to represent Orange County's interest in the lawsuit. On June 4, 1933, the Orange County Water District Act was passed in Sacramento.

The primary source of water for groundwater recharge in Orange County is SAR water. The SAR Watershed is shown in Figure 1-1. River water is diverted into spreading basins located in the Cities of Anaheim and Orange for percolation into the Basin. As far back as 1933, the District recognized the importance of water rights to SAR flow. By 1969, OCWD had secured water rights to approximately 42,000 afy of SAR baseflows and all stormflows reaching Prado Basin. To date, the District has captured approximately 4.5 million acre-feet (maf) of river water for recharge of the Basin. In addition, approximately 3.0 maf of imported water has also been recharged using the District's spreading basins. The District has continued to expand its spreading basin facilities. Approximately 1,000 acres of riverbed and off-stream basins are currently used for groundwater recharge.

In 1933, the District was comprised of 162,676 acres. The District is currently 229,000 acres in size and covers most of the northern half of Orange County (see Figure 1-2). This expansion occurred as the result of 46 annexations.

Figure 1-1

SANTA ANA RIVER WATERSHED

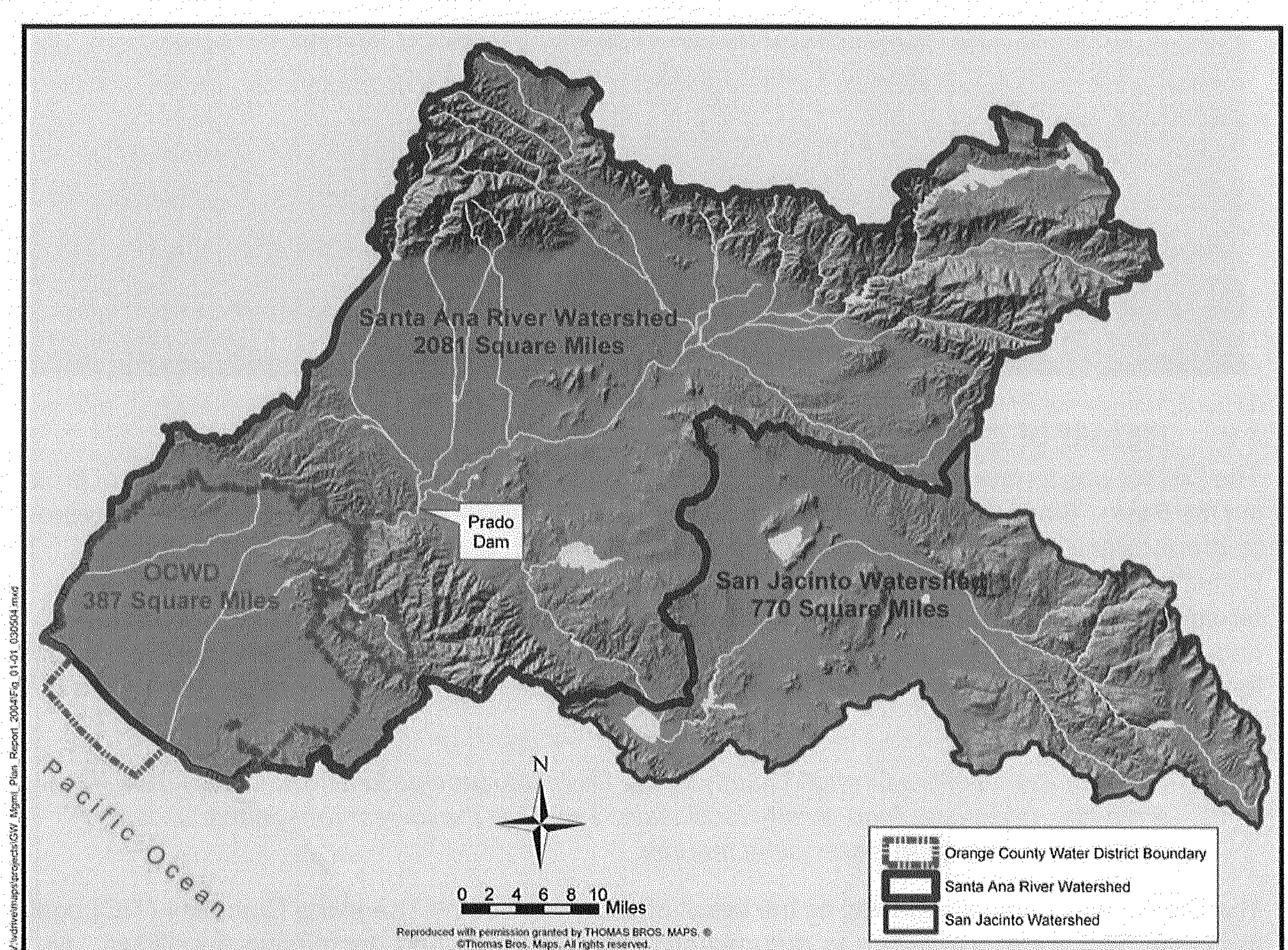
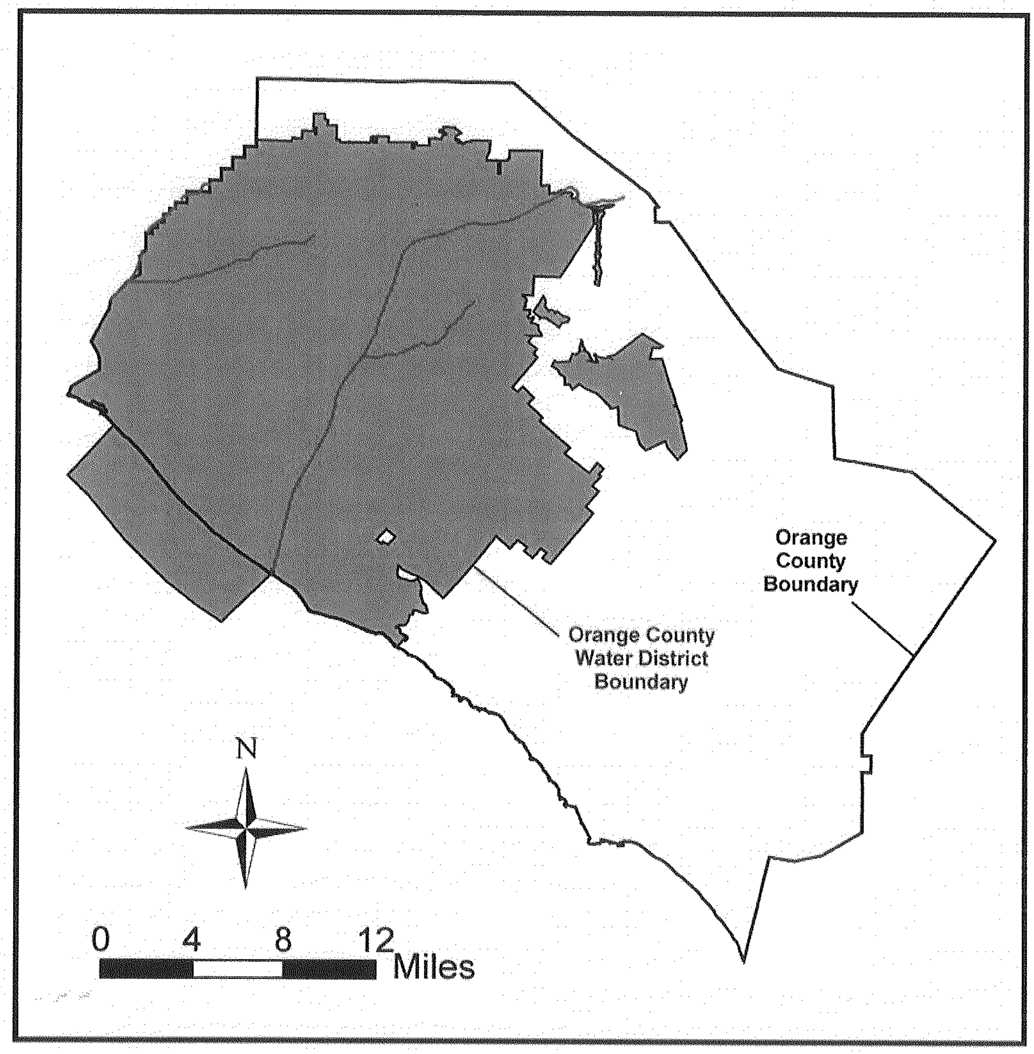


Figure 1-2

ORANGE COUNTY WATER DISTRICT BOUNDARY



Protection of coastal groundwater quality led to the implementation of Water Factory 21 (WF-21), which injects a blend of purified water and groundwater to protect coastal groundwater supplies from seawater intrusion in the Talbert Gap. For over 20 years, WF-21 and the Talbert Barrier have successfully managed seawater intrusion while defining the standards for groundwater injection with purified water. A second project, the Alamitos Barrier, has used imported water for over 30 years to inject and create a seawater barrier along the Los Angeles/Orange County line near Seal Beach. The District's hydrogeologists continue to assess how these seawater intrusion projects may be operated, not only to reduce seawater intrusion, but also to increase the availability of coastal groundwater supplies.

The District Act of 1933 provides for local financing through *ad valorem* taxes. Due to increased groundwater pumping through the 1930s to early 1950s, groundwater pumping exceeded the rate of water recharge into the basin. As groundwater withdrawal from the Basin continued to exceed recharge over a period of many years, groundwater levels continued to decline. This condition is referred to as "overdraft."

In 1954, a major revision of the District Act gave OCWD rights to the SAR and the authority to assess a pump tax now known as the RA. The District levies and collects the RA on groundwater extracted from the Basin. These funds are used to construct, operate, and maintain facilities to protect and increase groundwater supplies.

The 1954 District Act change was one of the most significant modifications to the original District Act. The principal limitation faced by OCWD at the time was a lack of an adequate, dependable funding base for purchasing large amounts of Basin replenishment water from Metropolitan. Purchase of imported replenishment water was needed to begin to refill the overdrafted Basin. Groundwater levels had fallen an average of 15 feet below sea level. The amounts purchased with property tax revenues in water years 1949-50 to 1952-53 averaged about 28,000 afy, far too little to cover annual overdrafts of 100,000 afy. In addition, there was some concern about the use of property taxes to fund replenishment activities. Property owners in most of the District were already annexed to Metropolitan and paying property taxes to Metropolitan for the acquisition and transportation of Colorado River water. Also, property owners in areas overlying the Basin but not annexed to Metropolitan or not within the OCWD service area were benefiting from the replenishment program without paying for it. Furthermore, the property tax subsidized Producers because non-pumping property owners paid for replenishment activities that primarily benefited Producers. The ultimate solution is described by author William Blomquist in his book "Dividing the Waters" (Blomquist, 1992).

> *The area's water management problems were discussed at a joint meeting in 1952 of the Water Problems Committee of the Orange County Farm Bureau, the Water Committee of the Associated Chambers of Commerce, and the Board of Directors of the Orange County Water District. The twelve-man Orange County Water Basin Conservation Committee (the Committee of 12) was formed to study the issues further and develop recommendations. The Committee of 12 maintained the area's basic commitment to increasing supply rather than restricting demand. They considered and rejected centralized control over water consumption and distribution by an agency empowered to enforce conservation, or adjudication and limitation of water rights using the court-reference procedure. They supported instead a proposal to fund replenishment by taxing pumping. This approach held the promise of raising the necessary funds, relating producers' taxation to their benefits received, and relieving nonproducers from paying for replenishment except to the extent that they purchased water from producers. Furthermore, at least theoretically, a tax on pumping would build in conservation incentives without mandating conservation.*

OCWD was not authorized to tax pumping, so the Orange County Water District Act would have to be amended. The Committee of 12 assembled a package of amendments that amounted to a substantial redesign of the district. To be fair, a pump tax would have to be implemented basin-wide, so the Committee proposed enlarging the district's territory to include Anaheim, Fullerton, and Santa Ana, plus areas owned by the Anaheim Union Water Company and the Santa Ana Valley Irrigation Company near the canyon. A pump tax would make it necessary to measure and record water production from the thousands of wells within the district, so an amendment was proposed requiring every producer therein to register wells with OCWD and to record and submit production data to the District twice per year. The Committee also proposed that an annual District Engineer's Report on basin conditions and groundwater production be submitted to the District and water users, to allow them to monitor the effects of the replenishment program and to provide a shared picture on a regular basis of basin conditions, including the extent of seawater intrusion and the level of the water table.

The Committee's recommendations also included a limited property tax provision to help offset some of the overhead or administrative expenses involved in starting up the pump tax program. In addition, the ad valorem tax would be used to purchase up to 375,000 acre-feet of replenishment water, an amount equivalent to 1953 estimates of the accumulated overdraft of the basin. The general assessment was lowered from 15 cents to 8 cents per $100 of assessed valuation.

These amendments to the Orange County Water District Act were passed by the state legislature in 1953. The amendments, including the pump tax provisions, were upheld in a validation suit in Orange County Superior Court, and the OCWD Board of Directors voted the first "replenishment assessment" (as the pump tax was known) on June 9, 1954.

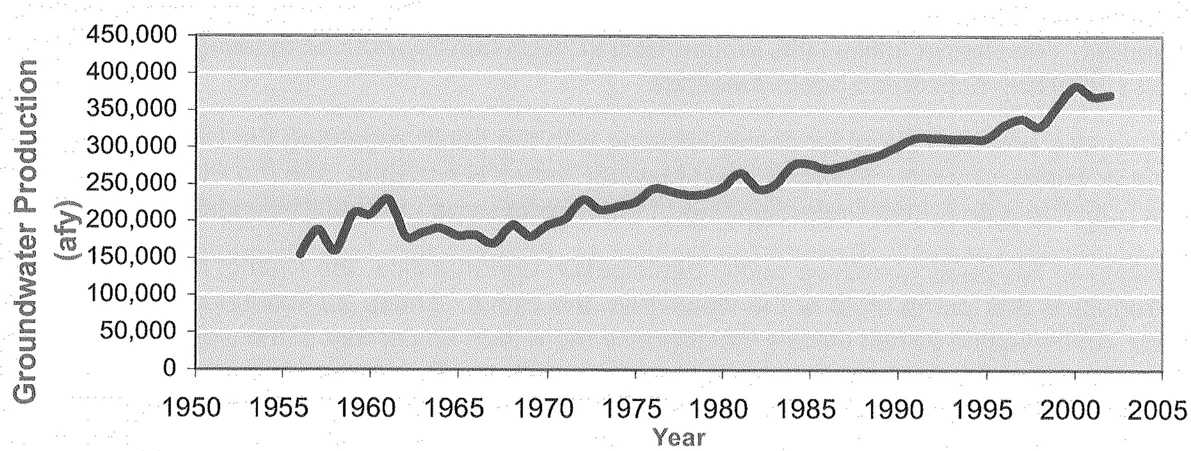
With the RA in place, the District can purchase adequate amounts of imported water for additional groundwater recharge. Funds are also used to monitor water quality and Basin conditions, improve spreading facilities, conduct research, and for administrative purposes.

The District has successfully employed groundwater management techniques to increase the annual yield from the Basin as shown in Figure 1-3. Annual production has more than doubled from approximately 150,000 afy in the mid-1950s to present day levels of approximately 320,000 to 380,000 afy. These efforts have provided a more reliable and lower cost water supply to Orange County. Additional efforts that the District may pursue to maximize use of the Basin are presented in this Plan.

The District is governed by a 10-member Board of Directors. Seven of the directors are directly elected by the voters in seven districts that are approximately equal in population. The directors from Anaheim, Fullerton, and Santa Ana are appointed by the cities respective city councils.

Figure 1-3

GROUNDWATER PRODUCTION



The District also conducts innovative research. Examples include researching and developing methods to increase percolation efficiency of the spreading basins using innovative basin cleaning techniques and a range of water quality and water recycling improvements.

1.2 NEED FOR GROUNDWATER WATER MANAGEMENT PLAN

The District's most recent *Groundwater Management Plan* was prepared in 1994. Earlier versions were prepared in 1989 and 1990. These early plans served as the model for groundwater management plans authorized under Assembly Bill 3030, signed into law in 1992.

Since 1994, conditions in the Basin have changed. These changes include:

- Maximum annual pumping from the Basin increased from approximately 311,000 af to 380,000 af, an increase of approximately 22 percent.
- The District is constructing Phase 1 of the GWR System, which will provide 72,000 afy of new water for the Talbert Barrier and groundwater recharge.
- Baseflow (non-stormflow) in the SAR has also increased.
- Imported water supplies available to the District to supplement local recharge sources have become more restricted.
- Potential new water quality issues have arisen due to changes in water quality regulations.

The Plan addresses these changes in a structured framework by identifying the key Basin issues and potential management strategies. The Plan also describes factors for the District's Board to consider in making decisions regarding how much pumping the Basin can sustain.

Any specific projects that may be developed as a result of recommendations in the Plan would be reviewed and approved by the District's Board of Directors and processed for environmental review prior to project implementation. The Plan does not commit the District to a particular program or level of Basin production, but describes the factors to consider and key issues as the Board makes Basin management decisions on a regular basis each year.

Potential projects that are conceptually described in the Plan are described in greater detail in the *Long-Term Facilities Plan.*

1.3 PUBLIC PARTICIPATION

The California Water Code requires the development of the Plan to include a public participation component. The District fulfilled this requirement through publicly-noticed meetings held as part of the District's regularly-scheduled board meetings.

The Plan also provides a tool for communicating with the public regarding the District's water supply and water quality projects. Public interest in water issues is common, and the Plan provides a report for the public to gain further understanding of the District's comprehensive programs.

In addition to the publicly-noticed public participation opportunities, the District held workshops with the Producers that pump most of the water from the Basin. These 22 Producers are cities, special districts, and investor-owned utilities that produce more than 90 percent of the water pumped from the Basin. The District holds regular monthly meetings with the Producers to discuss a variety of water supply and water quality issues. The content of the Plan was developed with input and review from the Producers through holding workshops and providing the Producers with preliminary drafts of the Plan prior to its finalization.

As part of its overall outreach program, the District informs and engages the public in groundwater discussions through an active speakers bureau, media releases, and the water education class "Orange County Water 101."

1.4 COMPLIANCE WITH CALIFORNIA WATER CODE

In addition to the public participation components described in Section 1.3, the California Water Code includes a list of issues to be addressed in a groundwater management plan. Although all of these items are not mandatory, the District has sought to address each of these components, which include the following:

1. Establishment of management objectives
2. Adoption of monitoring protocols
3. Control of seawater intrusion
4. Management of wellhead protection areas and recharge areas
5. Regulation of the mitigation of contaminated groundwater
6. Well abandonment and well destruction plan
7. Mitigation of conditions of overdraft
8. Replenishment of groundwater extracted by Producers
9. Monitoring of groundwater levels/storage monitoring
10. Facilitation of conjunctive use operations
11. Well construction policies
12. Activities of local agencies related to the Basin
13. Development of regulatory relationships
14. Review of land use plans
15. Prevention of groundwater quality degradation
16. Inelastic land surface subsidence
17. Changes in surface flow and quality

1.5 GROUNDWATER MANAGEMENT OBJECTIVES

The District's management of the Basin is guided by two primary objectives: protecting water quality and cost effectively increasing the Basin's sustainable yield. These two objectives and activities associated with each objective are listed in Table 1-1.

Table 1-1

GROUNDWATER MANAGEMENT OBJECTIVES

Protect and Enhance Groundwater Quality	Cost Effectively Protect and Increase the Basin's Sustainable Yield
• Prevent seawater intrusion • Protect recharge water quality • Address existing groundwater contamination • Prevent future groundwater contamination • Conduct monitoring to assess water quality	• Protect and increase supply of recharge water • Increase recharge capacity • Maximize Basin's flexibility to respond to and recover from drought • Minimize drawdown impacts in sensitive areas • Explore opportunities for conjunctive use • Control groundwater losses • Increase supply of water extracted from colored water zone and shallow aquifer • Manage natural resources • Conduct monitoring to provide information to manage the Basin

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Over the long term (several years), the Basin must be maintained in an approximate balance (inflow and outflows are approximately equal) to ensure the long-term viability of Basin supplies. Because of the Basin's size and complexity, a good understanding of Basin hydrogeology is critical to wise water management. This section:

- Describes the hydrogeologic characteristics of the Basin, including aquifer systems, Basin boundaries, and physiographic features.
- Describes the major components of inflows and outflows that compromise the Basin water budget.
- Presents groundwater storage and elevation trends.
- Trace the history, development, and operation of the District's Basin Model.

2.1 DESCRIPTION OF BASIN HYDROGEOLOGY

The Basin underlies the north half of Orange County beneath broad lowlands known as the Tustin and Downey plains. The Basin covers an area of approximately 350 square miles, bordered by the Coyote and Chino hills to the north, the Santa Ana Mountains to the northeast, the Pacific Ocean to the southwest, and terminates at the Orange County line to the northwest, where its aquifer systems continue into the Central Basin of Los Angeles County (see Figure 2-1). Groundwater flow is unrestricted across the county line. The Newport-Inglewood fault zone forms the southwestern boundary of all but the shallow aquifers in the Basin.

The aquifers comprising the Basin extend over 2,000 feet deep and form a complex series of interconnected sand and gravel deposits (DWR, 1967). In coastal and central portions of the Basin, these deposits are more separated by extensive lower-permeability clay and silt deposits, known as aquitards. In the inland area, generally northeast of Interstate 5, the clay and silt deposits become thinner and more discontinuous, allowing larger quantities of groundwater to flow more easily between shallow and deeper aquifers. Figure 2-2 presents a geologic cross section through the Basin along the SAR.

OCWD's extensive groundwater monitoring well network provides data on the Basin's aquifers to depths of 2,000 feet in many areas of the Basin. The monitoring wells provide detailed, depth-specific water level and water quality data from individual aquifer zones. Data from these wells were used to delineate the depth of the "principal" aquifer system, within which most of the groundwater production occurs. Shallower aquifers exist above the principal aquifer system, the most prolific being known as the Talbert aquifer. With the exception of a few large-system municipal wells in the cities of Garden Grove, Anaheim, and Tustin, wells producing from the shallow aquifer system predominantly have small-system industrial and agricultural uses. Production from the shallow aquifer system is typically about five percent of total Basin production. Deeper aquifers exist below the principal aquifer system, but these zones have been found to contain colored water or have been too deep to economically construct production wells. With the exception of four colored water production wells constructed by MCWD and IRWD, few wells penetrate the deep aquifer system.

Figure 2-1

MAP OF THE ORANGE COUNTY GROUNDWATER BASIN

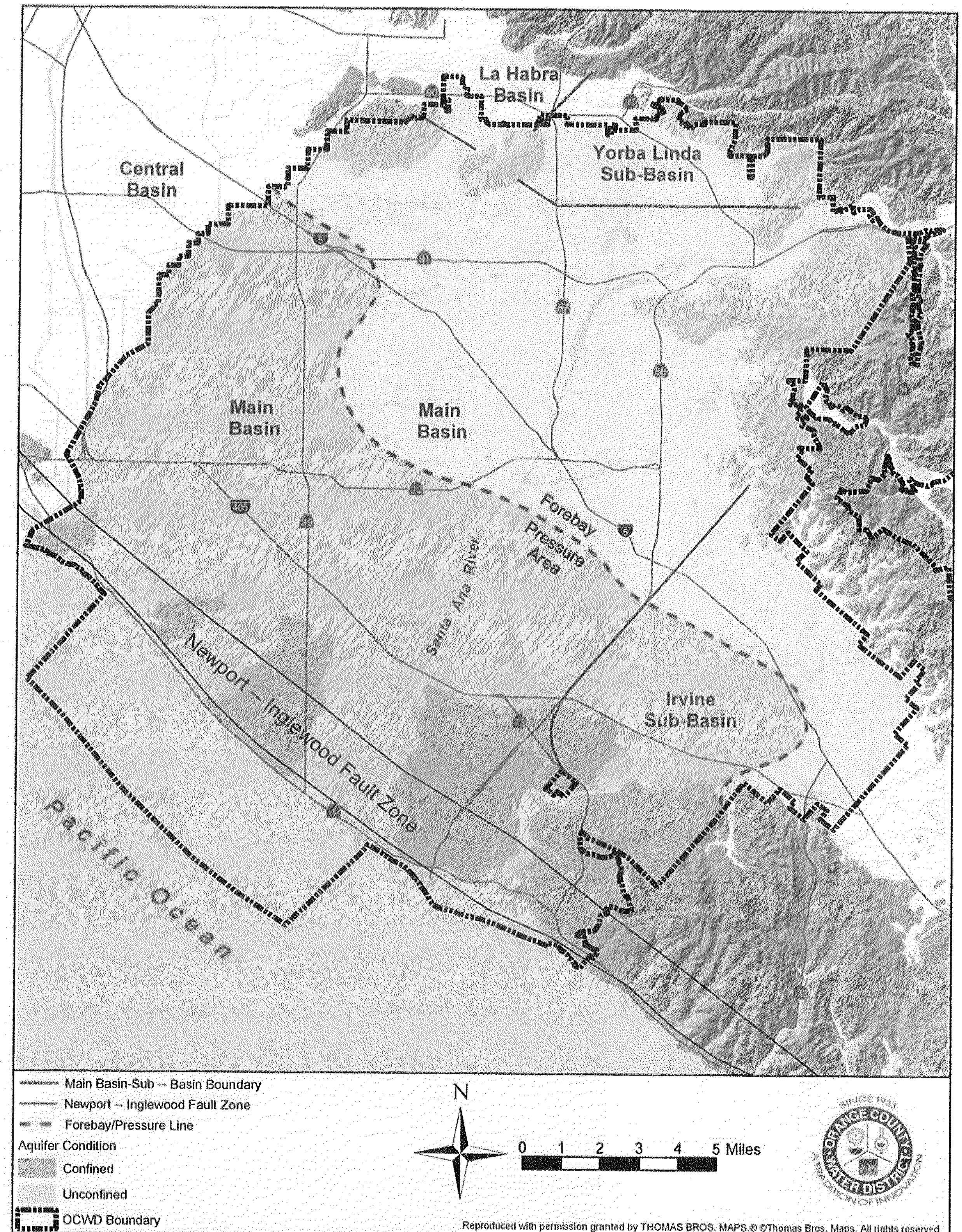
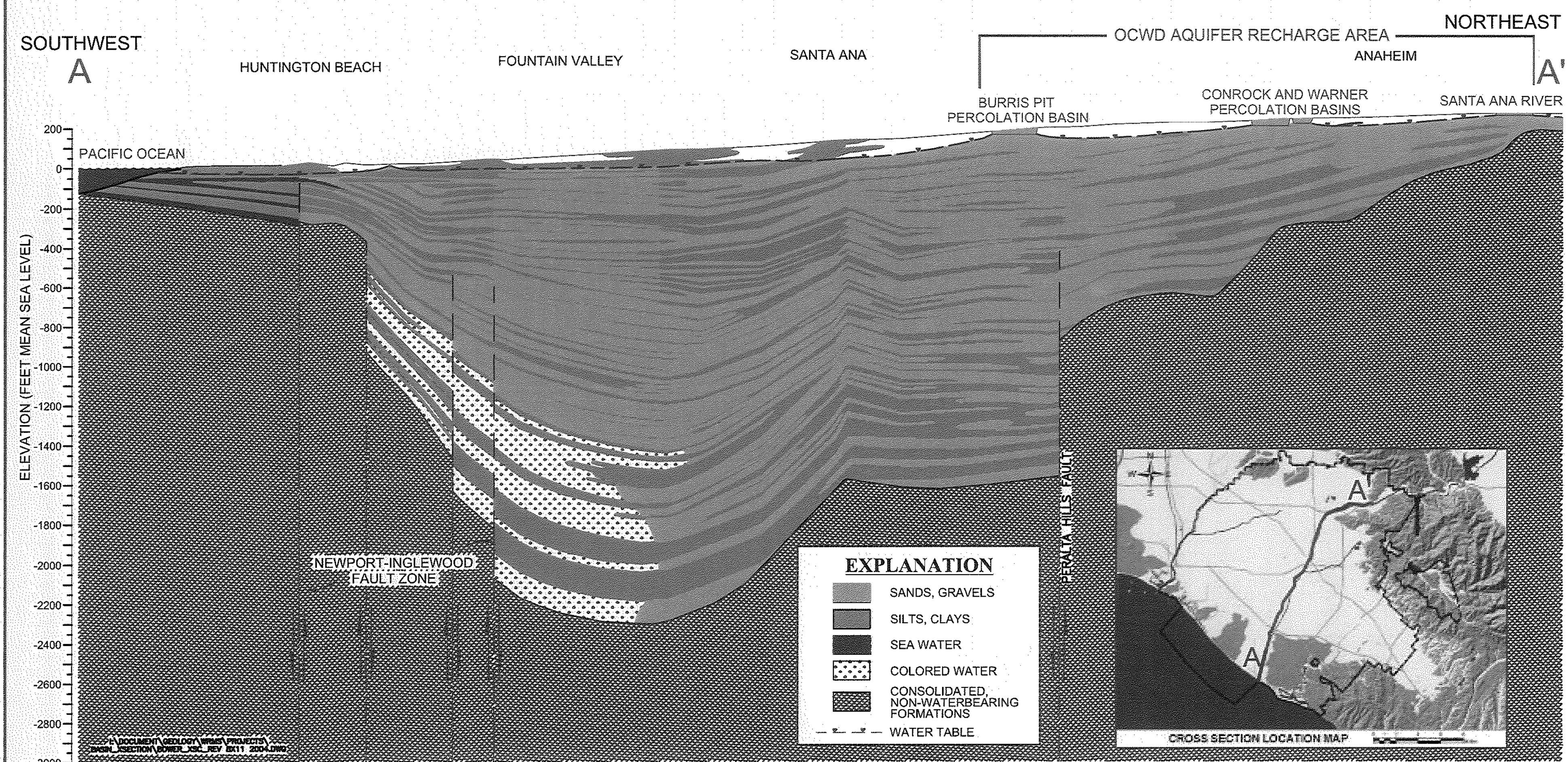


FIGURE 2-2
GEOLOGIC CROSS SECTION THROUGH ORANGE COUNTY GROUNDWATER BASIN



2.1.1 FOREBAY AND PRESSURE AREAS

The DWR, formerly the Division of Water Resources (DWR, 1934), divided the Basin into two primary hydrologic divisions, the Forebay and Pressure areas, as shown in Figure 2-1. The Forebay/Pressure area boundary generally delineates the areas where surface water or shallow groundwater can/cannot move downward to the first producible aquifer in quantities significant from a water-supply perspective. From a water-quality perspective, the amount of vertical flow to deeper aquifers from surface water or shallow groundwater may be significant in terms of impacts of past agricultural or industrial land uses (e.g., fertilizer application and leaky underground storage tanks).

The Forebay refers to the area of intake or recharge where the majority of recharge to the Basin occurs primarily by direct percolation of SAR water. The Forebay Area, encompassing most of the cities of Anaheim, Fullerton, and Villa Park and portions of the cities of Orange and Yorba Linda, is characterized by highly-permeable sands and gravels with relatively few and discontinuous clay and silt deposits.

The Pressure Area, in a general sense, is defined as the area in the Basin where surface water and near-surface groundwater are impeded from percolating in large quantities into the major producible aquifers by clay and silt layers at shallow depths (upper 50 feet). Most of the central and coastal portions of the Basin fall within the Pressure Area. Because the principal and deeper aquifers within the Pressure Area are under "confined" conditions (under hydrostatic pressure), the water levels in wells penetrating these aquifers exhibit large seasonal variations in response to pumping.

2.1.2 GROUNDWATER SUBBASINS, MESAS AND GAPS

The Irvine subbasin, bounded by the Santa Ana Mountains and the San Joaquin Hills, forms the southern-most portion of the Basin (see Figure 2-1). The Costa Mesa Freeway and Newport Boulevard approximate the subbasin's boundary with the Main Basin. The freeway and Newport Boulevard approximate where the principal aquifer rapidly deepens and thickens to the west. Irvine-area aquifers are thinner and contain more clay and silt deposits than aquifers in the main portion of the Basin. The base of the aquifer system in the Irvine subbasin ranges from approximately 1,000 feet deep beneath the former Marine Corps Air Station (MCAS) Tustin to less than 200 feet deep at the eastern boundary of the former MCAS El Toro. East of former MCAS El Toro, the aquifer further thins and transitions into lower-permeability sandstones and other semi-consolidated sediments, which have minor water-producing capacity. Groundwater production within the Irvine subbasin is primarily conducted by TIC for agricultural irrigation. Groundwater typically flows out of the Irvine subbasin westerly into the main Basin since the amount of natural recharge in the area (predominantly from the Santa Ana Mountains) is typically greater than the approximately 6,000 afy of pumping (Singer, 1973; Banks, 1984). With the future operation of the Irvine Desalter Project, currently in design, groundwater production in the Irvine subbasin may exceed the natural replenishment from the adjacent hills and mountains, in which case groundwater would be drawn into the Irvine subbasin from the Main Basin.

The Yorba Linda subbasin is located north of the Anaheim Forebay recharge area, within the cities of Yorba Linda and Placentia. It is part of the Basin, but currently has little groundwater pumping due to its low transmissivity and high TDS concentrations (Mills, 1987). Groundwater from the Yorba Linda subbasin flows southward into the Main Basin since the limited groundwater production is less than the natural replenishment from the adjacent Chino Hills.

The La Habra Basin is located north of the Basin within the Cities of La Habra and Brea. It comprises a shallow alluvial depression between the Coyote Hills and the Puente Hills. Similar to the Yorba Linda subbasin, little groundwater production occurs in the La Habra Basin due to low transmissivity and poor water quality (high TDS). Hydrogeologic studies have indicated that 2,200 to 5,500 afy of groundwater flows out of the La Habra Basin in two areas: (1) southerly into the Main Basin along the Brea Creek drainage between the East and West Coyote hills and (2) westerly into the Central Basin in Los Angeles County (James M. Montgomery, 1977; Ramsey, 1980; OCWD, 1994).

Four relatively flat elevated areas, known as mesas, occur along the coastal boundary of the Basin. The mesas were formed by ground surface uplift along the Newport Inglewood Fault Zone. Ancient meandering of the SAR carved notches through the uplifted area and left behind sand- and gravel-filled deposits beneath the lowland aquifers within the mesas, known as gaps (Poland et al., 1956). Groundwater in the shallow aquifers within the gaps is susceptible to seawater intrusion, which resulted in the construction of two seawater intrusion barriers in the Talbert and Alamitos gaps (see Figure 2-1). Except for areas seaward of the main branches of the Newport Inglewood Fault, the mesas are also underlain by aquifers that are part of the Basin.

2.2 WATER BUDGET

OCWD staff developed a hydrologic budget (inflows and outflows) for the purpose of constructing the Basin Model and for evaluating Basin production capacity and recharge requirements. The key components of the budget include measured and unmeasured (estimated) recharge, groundwater production, and subsurface flows along the coast and across the Orange/Los Angeles County line. Because the Basin is not operated on an annual safe-yield basis, the net change in storage in any given year may be positive or negative; however, over the long term (several years), the Basin must be maintained in an approximate balance. Table 2-1 presents the components of a balanced Basin water budget (no annual change in storage) and does not represent data for any given year. The budget presented is based on the following assumptions: (1) average precipitation, (2) accumulated overdraft approximating current conditions (400,000 acre-feet [af] from full), (3) recharge at the Forebay facilities held to the current maximum capacity of 250,000 afy, and (4) adjusted groundwater production so that total Basin inflows and outflows are equal. The major components of the water budget are described in the following sections.

Table 2-1

REPRESENTATIVE BASIN WATER BUDGET

FLOW COMPONENT	Acre-feet
INFLOW	
Measured Recharge	
1. Forebay spreading facilities, current maximum including imported water	250,000
2. Talbert Barrier injection, current maximum	12,000
3. Alamitos Barrier injection, Orange County only	2,500
Subtotal:	**264,500**
Unmeasured Recharge (average precipitation)	
1. Inflow from La Habra Basin	3,000
2. Santa Ana Mountain recharge into Irvine subbasin	13,500
3. San Joaquin Hills recharge into Irvine subbasin	500
4. Areal recharge from rainfall/irrigation (Forebay area)	13,000
5. Areal recharge from rainfall/irrigation (Pressure area)	4,500
6. Chino Hills recharge into Yorba Linda subbasin	6,000
7. Subsurface inflow at Imperial Highway beneath SAR	4,000
8. SAR recharge between Imperial Highway and Rubber Dam	4,000
9. Subsurface inflow beneath Santiago Creek	10,000
10. Peralta Hills recharge into Anaheim/Orange	4,000
11. Tustin Hills recharge into City of Tustin	6,000
12. Seawater inflow through coastal gaps	2,000
Subtotal:	**70,500**
TOTAL INFLOW:	**335,000**
OUTFLOW	
1. Groundwater Production	327,000
2. Flow across Orange/Los Angeles County line, est. at 400,000 af accumulated overdraft	8,000
TOTAL OUTFLOW:	**335,000**
CHANGE IN STORAGE:	**0**

Note: the representative water budget has equal (balanced) total inflow and total outflow and does not represent data for any given year.

2.2.1 MEASURED RECHARGE

Measured recharge consists of all water artificially recharged at OCWD's Forebay spreading facilities and water injected at the Talbert Barrier and on the Orange County side of the Alamitos Barrier. SAR storm and baseflows serve as the primary source of recharge in the Forebay. Average annual captured river baseflow and stormflow account for approximately 155,000 and 60,000 af of recharge, respectively. These flows can be augmented by up to 35,000 af of imported replenishment water to fully utilize the current 250,000 afy capacity of the Forebay facilities. Monthly recharge rates for each spreading facility have been documented since 1988.

OCWD's Talbert Barrier is composed of a series of injection wells that span the 2.5-mile wide Talbert Gap, between the Newport and Huntington Beach mesas. The Talbert Barrier injects water into four aquifers that are used for municipal supply. Over 95 percent of the water injected flows inland and, therefore, constitutes a portion of the Basin's replenishment supply. The current blend of the 12 million gallons per day (mgd) of injection water is composed of generally equal percentages of WF-21 recycled water, deep well water, and water purchased from the City of Fountain Valley (a blend of imported water and groundwater).

The Alamitos Barrier is composed of a series of injection wells that span the Alamitos Gap at the Los Angeles/Orange County line and is operated by the Los Angeles County Department of Public Works (LACDPW) in cooperation with OCWD and the Water Replenishment District of Southern California (WRD). Imported water is the current supply source, but WRD has constructed a recycled water treatment facility that will eventually meet 50 percent of the barrier supply needs. From inspection of groundwater contour maps, it appears that nearly half (approximately 2,500 afy) of the Alamitos Barrier injection remains within or flows into Orange County. Similar to the Talbert Barrier, the Alamitos Barrier injects into four aquifer zones, and essentially all of the injection flows inland as a component of Basin replenishment.

2.2.2 UNMEASURED RECHARGE

Unmeasured recharge, also referred to as "incidental recharge," occurs naturally and accounts for a significant amount of the Basin's producible yield. Based on past estimates of annual changes in groundwater storage by comparing groundwater elevation changes, OCWD staff estimates that roughly 60,000 afy of unmeasured recharge occur on average within the Basin after subtracting losses to LA County. Net incidental recharge is used to refer to the amount of incidental recharge after accounting for groundwater losses, such as outflow to LA County. This average recharge was substantiated during calibration of the Basin Model and is also consistent with the estimate of 58,000 afy reported by Hardt and Cordes (1971) as part of a U.S. Geological Survey (USGS) electric analog modeling study of the Basin.

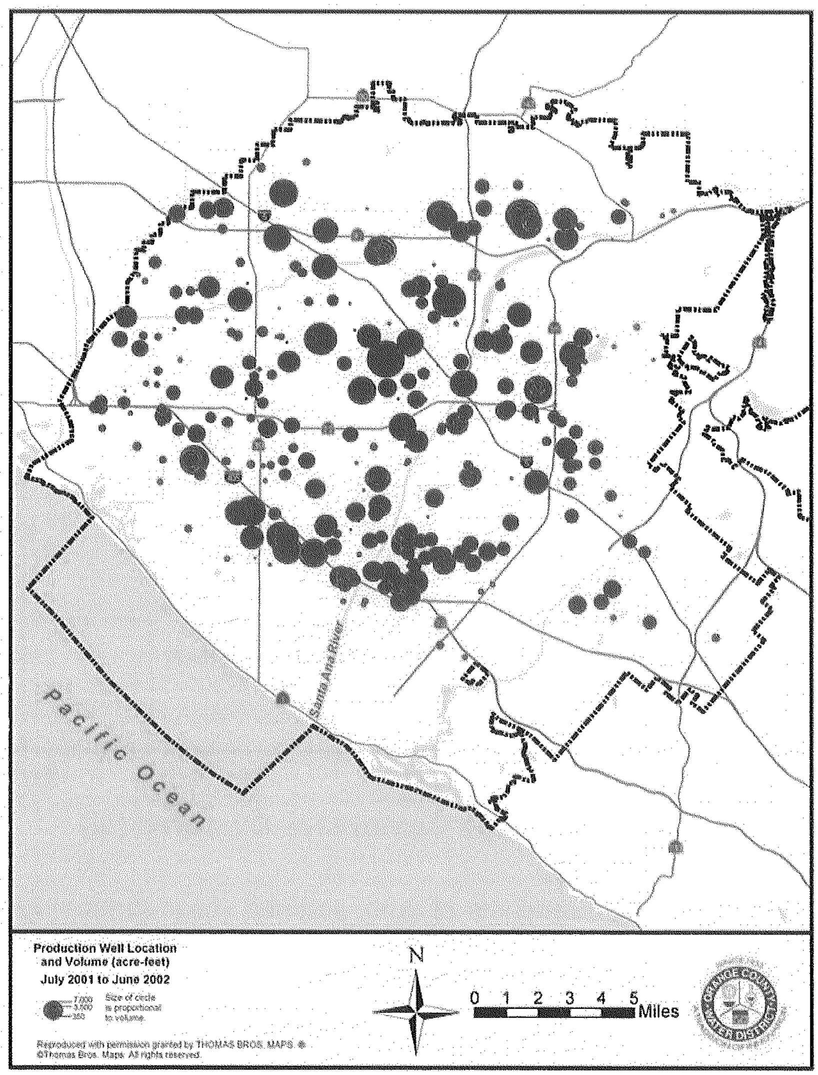
Unmeasured recharge consists of precipitation-derived recharge at the Basin margin along the Chino, Coyote, and San Joaquin Hills and the Santa Ana Mountains; underflow beneath the SAR and Santiago Creek; SAR recharge between Imperial Highway and the OCWD rubber diversion dam; and areal recharge from precipitation, irrigation return flows, and urban runoff. Underflow is groundwater that enters the Basin at the mouth of Santa Ana Canyon, the Santiago Creek drainage below Villa Park Dam, and seawater inflow through the gaps. Because unmeasured recharge is one of the least understood components of the Basin's water budget, the error margin of staff's estimate for any given year is probably in the range of 20,000 af. Since the unmeasured recharge is well distributed throughout the Basin, the physical significance (e.g., water level drawdown or mounding in any given area) of over- or underestimating the total recharge volume within this error margin is considered to be minor.

2.2.3 GROUNDWATER PRODUCTION

Groundwater production from the Basin totaled approximately 350,000 af in 2001-02 and has steadily increased since 1954 (see Figure 1-3). Production occurs from approximately 500 active wells within the District, approximately 300 of which produce less than 25 afy. Groundwater production from approximately 200 large-capacity or large-system wells operated by the 21 largest water retail agencies accounted for an estimated 97 percent of the total production in 2001-02. Large-capacity wells are all metered, and monthly individual well production has been documented since 1988. Prior to 1988, per-well production data were recorded semi-annually.

Groundwater production is distributed uniformly throughout the majority of the Basin with the exceptions of the Irvine and Yorba Linda subbasins, the immediate coastal areas, and the foothill margins of the Basin, where little to no production occurs (see Figure 2-3). Increases in coastal production would lead to increased stress on the Talbert and Alamitos Barriers, requiring additional barrier capacity. Inasmuch as it is technically and economically feasible, future increases in coastal groundwater demand should be addressed by wells constructed inland in areas of lower well density and higher aquifer transmissivity.

Figure 2-3
DISTRIBUTION OF GROUNDWATER PRODUCTION

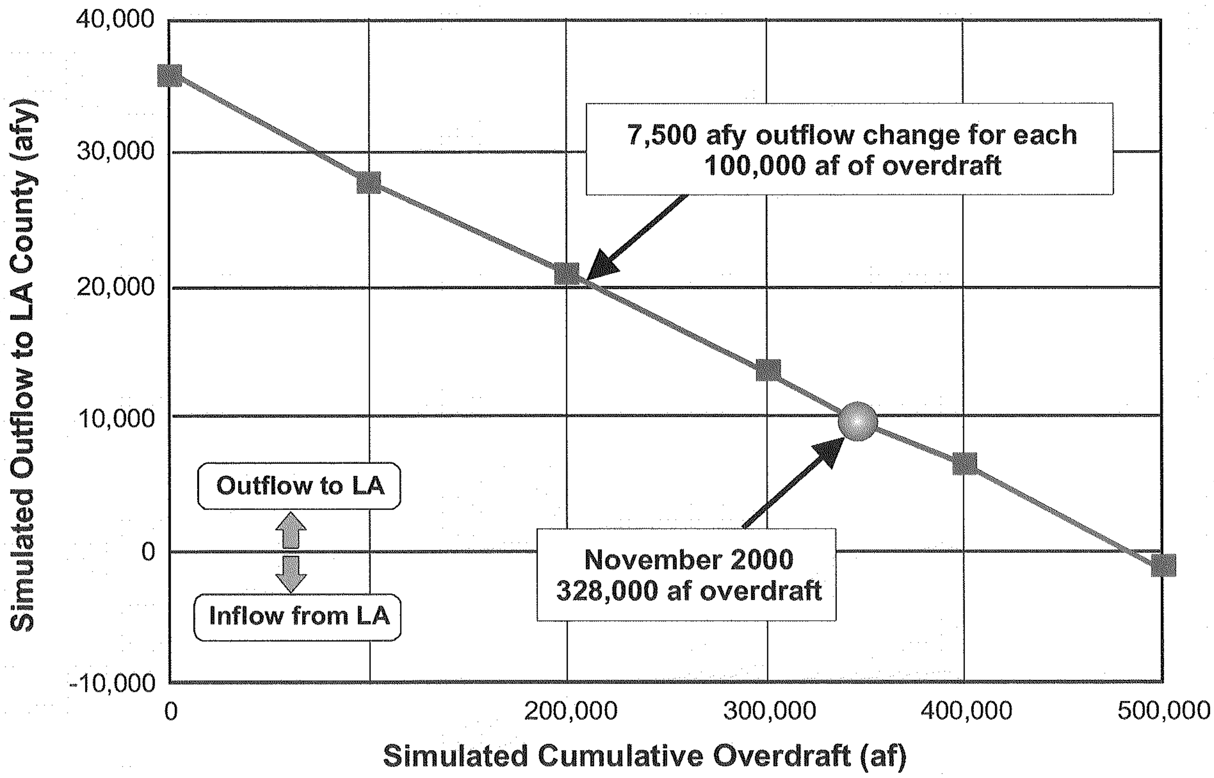


The distribution of existing wells and the siting of future wells depend on many different factors, including logistics, property boundaries, hydrogeology, and regulatory guidelines. Logistical considerations include property availability, city and other political boundaries, and proximity to other water facilities. Proximity to existing water transmission pipelines can be extremely important, given the cost of new reaches of pipeline. Hydrogeologic considerations for siting a well may include: thickness of permeable aquifer units, groundwater quality, drawdown interference from nearby wells, seasonal water level fluctuations, and potential impacts to the Basin such as seawater intrusion.

2.2.4 SUBSURFACE OUTFLOW

Groundwater outflow from the Basin across the Los Angeles/Orange County line has been estimated to range from approximately 1,000 to 14,000 afy based on groundwater elevation gradients and aquifer transmissivity (DWR, 1967; McGillicuddy, 1989). WRD indicated underflow from Orange County to Los Angeles County within the aforementioned range. Underflow varies annually and seasonally depending upon hydrologic conditions on either side of the county line. Modeling by OCWD indicated that, assuming groundwater elevations in the Central Basin remain constant, underflow to Los Angeles County increases approximately 7,500 afy for every 100,000 af of increased groundwater in storage in Orange County (see Figure 2-4).

Figure 2-4
RELATIONSHIP BETWEEN BASIN STORAGE AND ESTIMATED OUTFLOW



With the exception of unknown amounts of semi-perched (near-surface) groundwater being intercepted and drained by unlined flood control channels along coastal portions of the Basin, no other significant Basin outflows are known to presently occur.

2.3 GROUNDWATER STORAGE AND ELEVATION TRENDS

A vast amount of fresh water is stored within the Basin, although only a fraction of this amount can practically be removed without causing physical damage such as seawater intrusion or increasing the potential for land subsidence. Nonetheless, it is important to note the total volume of groundwater that is within the active flow system, e.g., within the influence of pumping and recharge operations. The following paragraph describes the methodology used to estimate total volume of groundwater within the Basin.

OCWD used its geographic information system and the aquifer system boundaries described in Section 2.4 to calculate the total volume of each of the three major aquifer systems as well as the intervening aquitards. The area and thickness of each hydrogeologic unit were multiplied to obtain a total volume. Because groundwater fills the pore spaces that represent typically between 20 and 30 percent of the total volume, the total volume was multiplied by this porosity percentage to arrive at a total groundwater volume. Assuming the Basin is completely full (using 1969 water levels as the benchmark), the total estimate of fresh groundwater stored in the Basin is approximately 66 maf, as broken down by hydrogeologic unit in Table 2-2.

Table 2-2
ESTIMATED BASIN GROUNDWATER STORAGE BY HYDROGEOLOGIC UNIT

Hydrogeologic Unit	Pressure Area	Forebay	Total
Shallow Aquifer System	3,800,000	1,200,000	5,000,000
Aquitard	900,000	200,000	1,100,000
Principal Aquifer System	24,300,000	8,600,000	32,900,000
Aquitard	1,600,000	300,000	1,900,000
Deep Aquifer System	18,800,000	6,300,000	25,100,000
Total	**49,400,000**	**16,600,000**	**66,000,000**

Notes:
1. Volumes calculated using the 3-layer basin model surfaces with ArcInfo Workstation GRID.
2. A porosity of 0.25 was assumed for aquifer systems.
3. A porosity of 0.30 was assumed for aquitards.

For comparison, DWR (1967) estimated that about 38 maf of fresh water are stored in the groundwater basin when full, but DWR used a factor known as the specific yield to calculate this volume. The specific yield (typically between 10 and 20 percent) is the amount of water that can be drained by gravity from a certain volume of aquifer and reflects the soil's ability to retain and hold a significant volume of water due to capillary effects. Thus, DWR's drainable groundwater volume, although technically correct, is roughly half of OCWD's estimate of total groundwater volume in the Basin.

OCWD estimates that the Basin can be operated on a short-term emergency basis with a maximum accumulated overdraft (storage reduction from full condition) of approximately 500,000 af without causing irreversible seawater intrusion and land subsidence. The estimated maximum historical accumulated Basin overdraft of 500,000 to 700,000 af occurred in 1956-57 (DWR, 1967; OCWD, 2003). Water level elevations in November 1969 are used as the baseline to represent near-full conditions. The net decrease in storage from 1969 conditions represents the accumulated overdraft. In November 2002, the accumulated overdraft was estimated to be approximately 426,000 af (OCWD, 2003). Figure 2-5 illustrates the Basin accumulated overdraft since 1962.

Figure 2-5
AVAILABLE BASIN STORAGE SINCE 1962

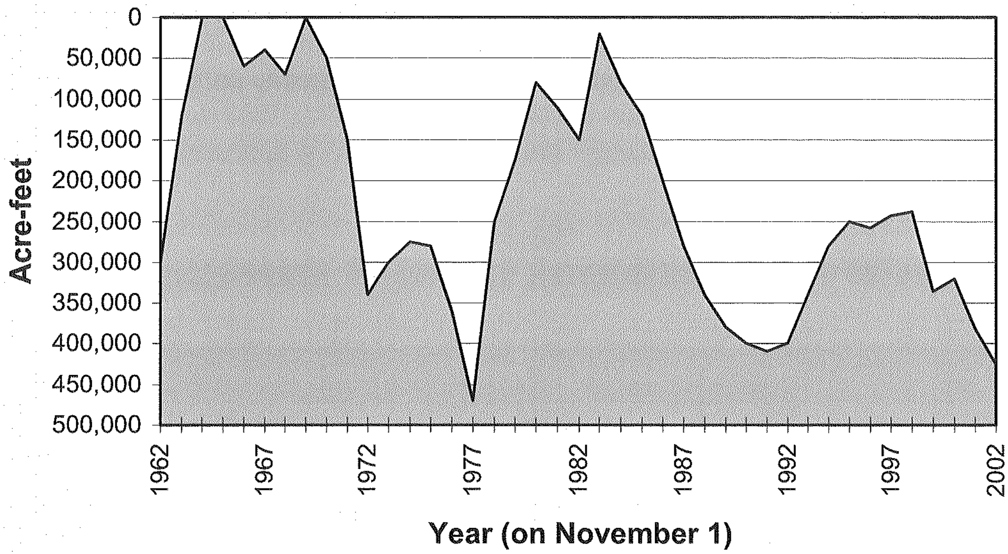


Figure 2-6 presents groundwater level profiles generally following the SAR, from Costa Mesa to the Anaheim Forebay area. The water level profiles represent November 1 of the selected years shown (1969, 1983, and 2002). In 1969 and 1983, the Basin was considered full and near full, respectively. For both of these years, the water level difference between coastal and Forebay endpoints was approximately 170 feet. In 2002, with increased Basin production and accumulated overdraft of 426,000 af, the water level difference for these same endpoints increased to approximately 260 feet. This steepening directly translates into a steeper hydraulic gradient enabling greater flow to occur from the Forebay to the coastal areas. However, the lowering of coastal water levels also increases seawater intrusion potential.

Figure 2-6
HISTORICAL GROUNDWATER ELEVATION PROFILES

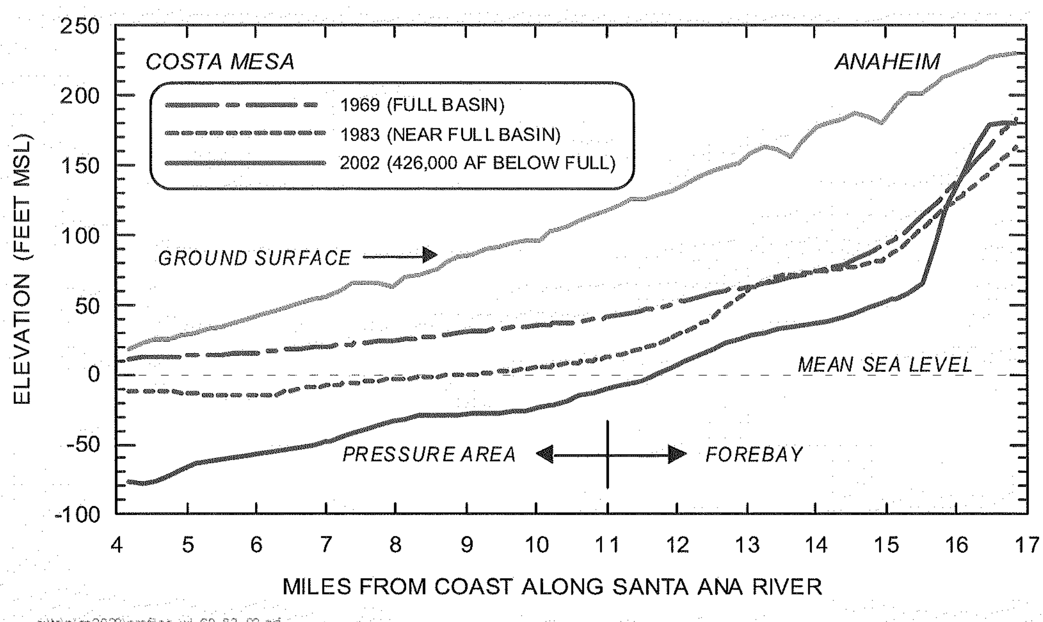
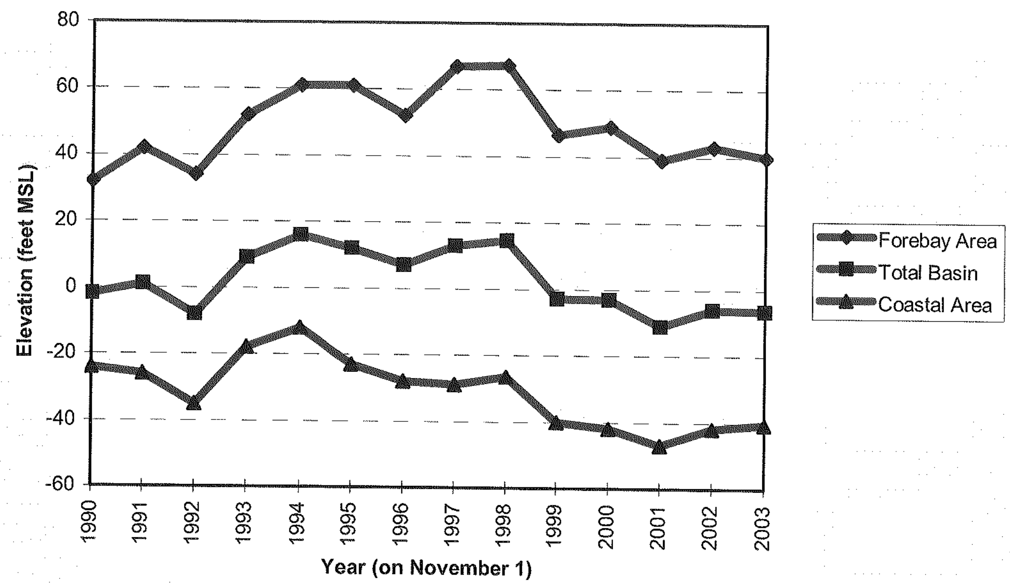


Figure 2-7 presents average groundwater levels in the Forebay and coastal areas and the total Basin. Average values were calculated using a 1,000 foot square grid and the groundwater elevation contour map prepared each year using data collected around November 1. With a 1,000 foot square grid, groundwater elevations were estimated at each grid point using the groundwater elevation contours, and the average values were calculated for each of the three areas.

Figure 2-7

AVERAGE FOREBAY, TOTAL BASIN, AND COASTAL AREA GROUNDWATER ELEVATIONS



Comparison of the groundwater level trends in Figure 2-7 to the changes in accumulated overdraft in Figure 2-5 provides insights into the Basin's response during refill. From November 1992 to November 1994, the Basin's accumulated overdraft reduced 120,000 af. During 1992-93, precipitation was greater than normal and increased SAR stormflow was recharged in the Forebay (see Section 5). Incidental recharge was also greater due to increased rainfall. During this period of refill, groundwater levels in the coastal area increased approximately 20 feet, about the same amount as groundwater levels in the Forebay. These data indicate that, in the period from 1992 to 1994, the coastal area groundwater levels recovered a similar amount as groundwater levels in the Forebay, where most of the recharge occurred. Such a similarity is expected if other factors, such as the distribution of pumping, remain unchanged during the period. This response occurs because groundwater in the deep portions of the Forebay Area and in the Pressure Area occurs under confined conditions, and changes in groundwater elevations are transmitted rapidly through the aquifers.

From 1999 to 2000, the Basin refilled approximately 15,000 af. Groundwater levels rose about three feet in the Forebay, but declined about two feet in the Pressure Area. This response, where groundwater levels increased in the Forebay but declined in the Pressure Area, may be the result of a shift in distribution of pumping and is also near the error margin in the calculations.

Figure 2-8 shows the locations of four wells, A-27, SA-21, SAR-1, and OCWD-CTG1, with long-term groundwater level data. Figure 2-9 presents water level hydrographs and locations of wells A-27 and SA-21, representing historical conditions in the Forebay and Pressure area, respectively. The hydrograph data for well A-27 near Anaheim Lake date back to 1932 and indicate that the historic low water level in this area occurred in 1951-52. The subsequent replenishment of Colorado River water essentially refilled the Basin by 1965. Water levels in this well reached an historic high in 1994 and have decreased in the last few years as groundwater production has exceeded recharge. The hydrograph for well SA-21 indicates that water levels in this area have decreased since 1970. In addition, the magnitude of the seasonal water level fluctuations has approximately doubled from pre-1990 to the present. The increased water level fluctuations are due to a combination seasonal water demand-driven pumping and participation in the Metropolitan Short-Term Seasonal Storage Program by local Producers (Boyle Engineering and OCWD, 1997).

Figure 2-8

LOCATION MAP FOR LONG-TERM GROUNDWATER ELEVATION HYDROGRAPHS

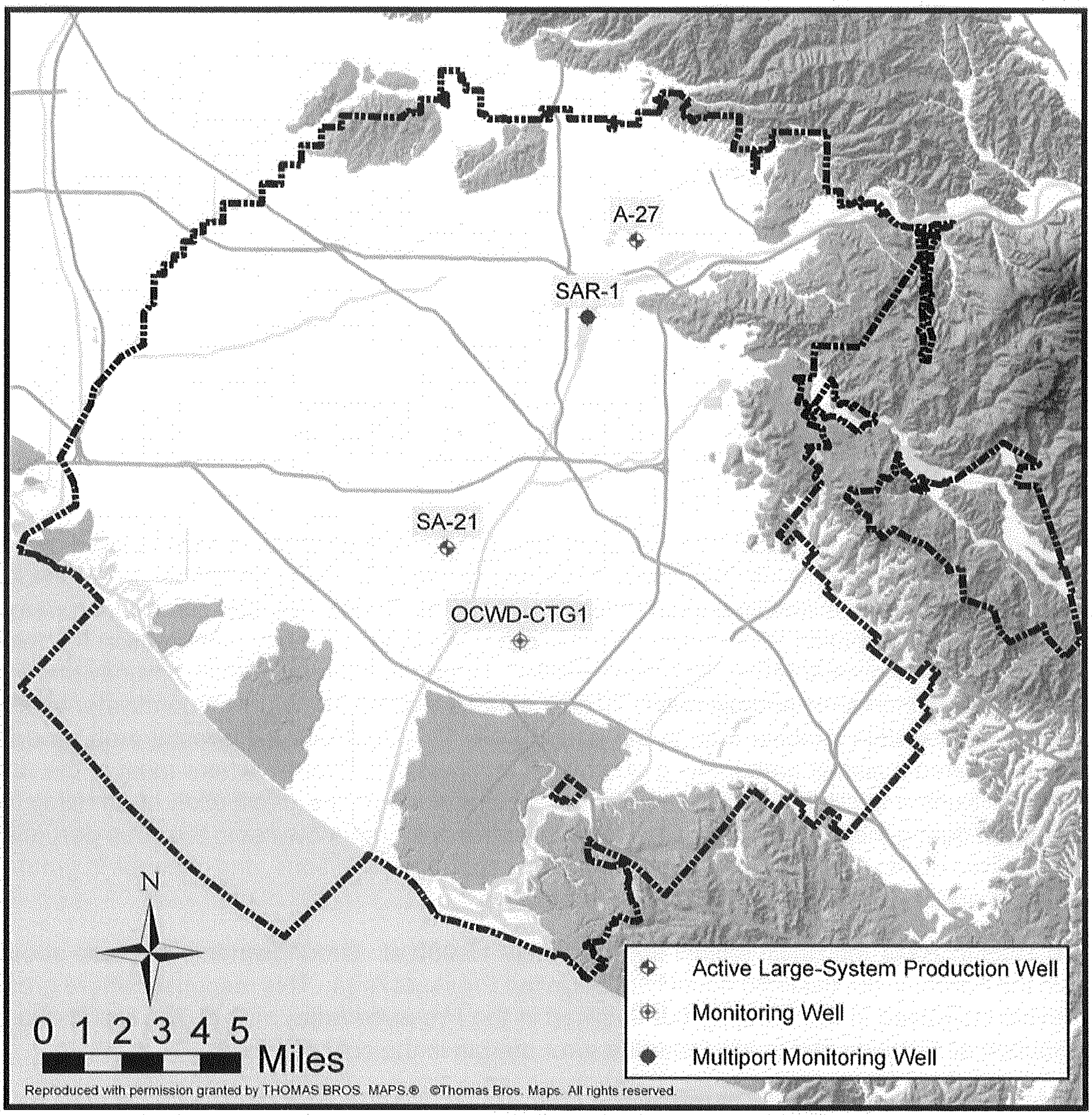
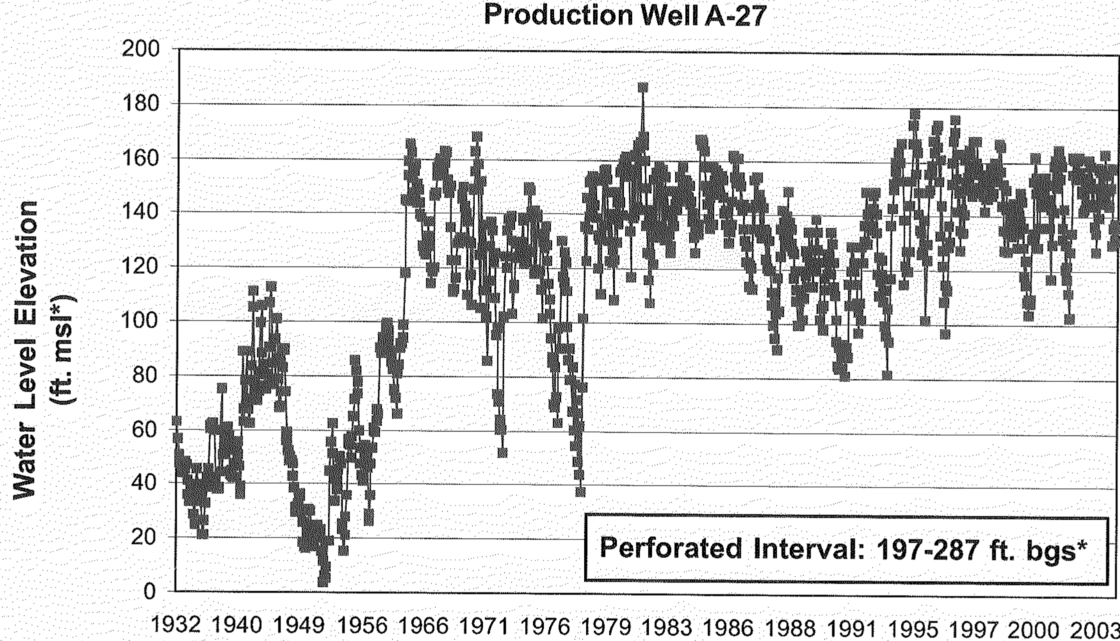
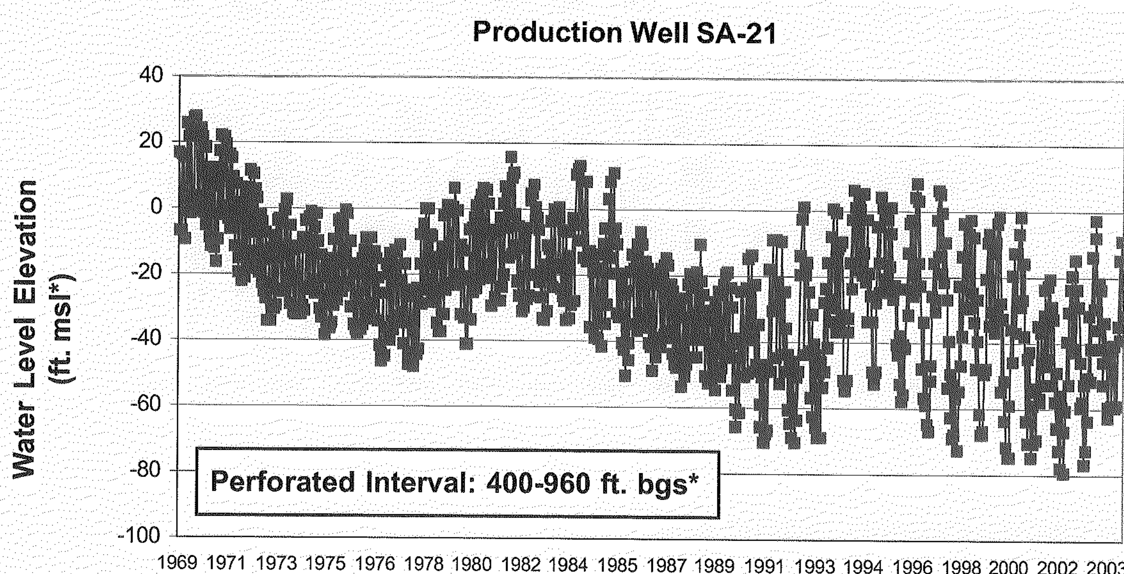


Figure 2-9

WATER LEVEL HYDROGRAPHS OF WELLS A-27 AND SA-21



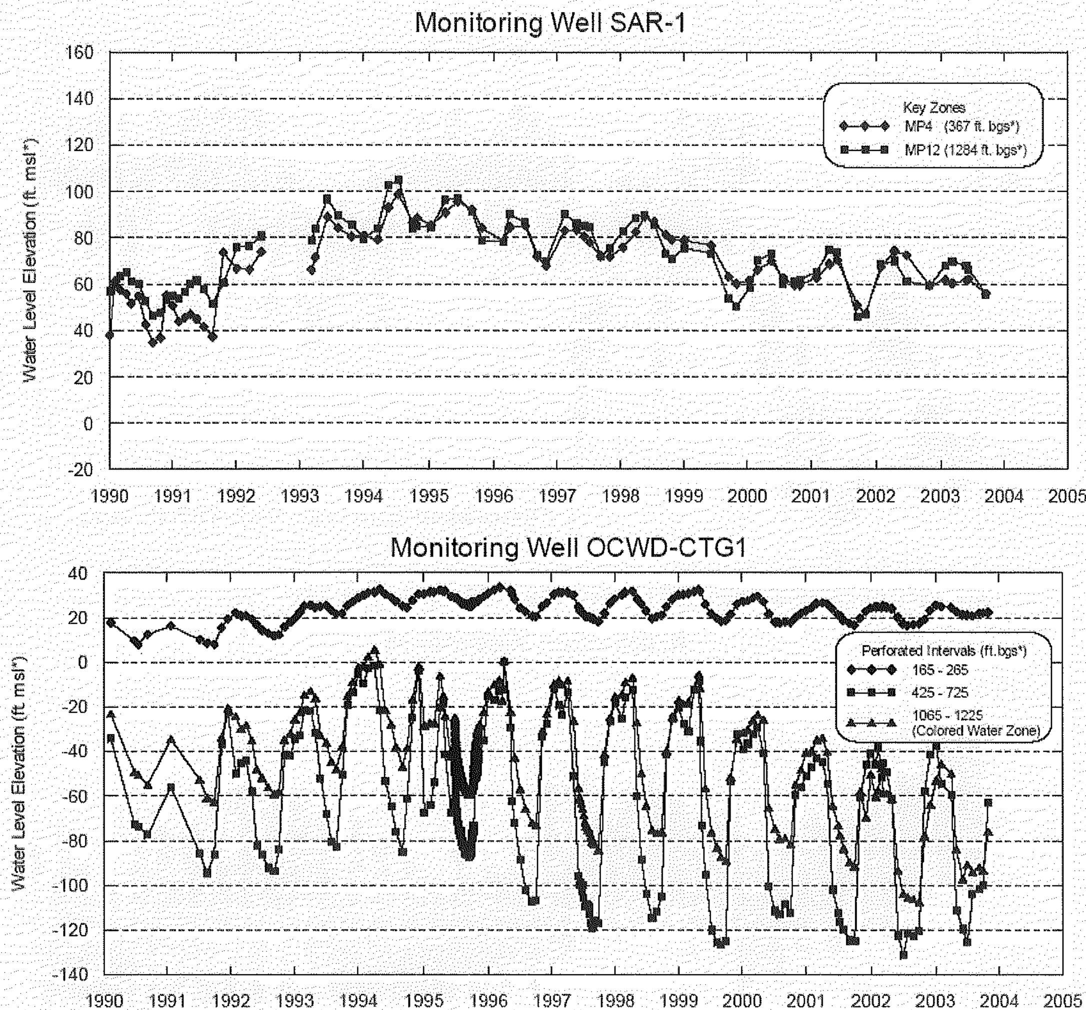


* msl=mean sea level *bgs=below ground surface

Figure 2-10 presents water level hydrographs and locations of two OCWD multi-depth monitoring wells, SAR-1 and OCWD-CTG1, showing the relationship between water level elevations in aquifer zones at different depths. The hydrograph of well SAR-1 in the Forebay exhibits a similarity in water levels between shallow and deep aquifers, which indicates the high degree of hydraulic interconnection between aquifers characteristic of much of the Forebay. The hydrograph of well OCWD-CTG1 is typical of the Pressure Area in that a large water level distinction is observed between shallow and deep aquifers, indicating the effects of a clay/silt layer that restricts vertical groundwater flow. Water levels in the deepest aquifer zone at well OCWD-CTG1 have higher elevations than overlying aquifers, in part, because few wells directly produce water from these zones, primarily due to their associated colored water.

Figure 2-10

WATER LEVEL HYDROGRAPHS OF WELLS SAR-1 AND OCWD-CTG1



2.4 GROUNDWATER MODEL DESCRIPTION

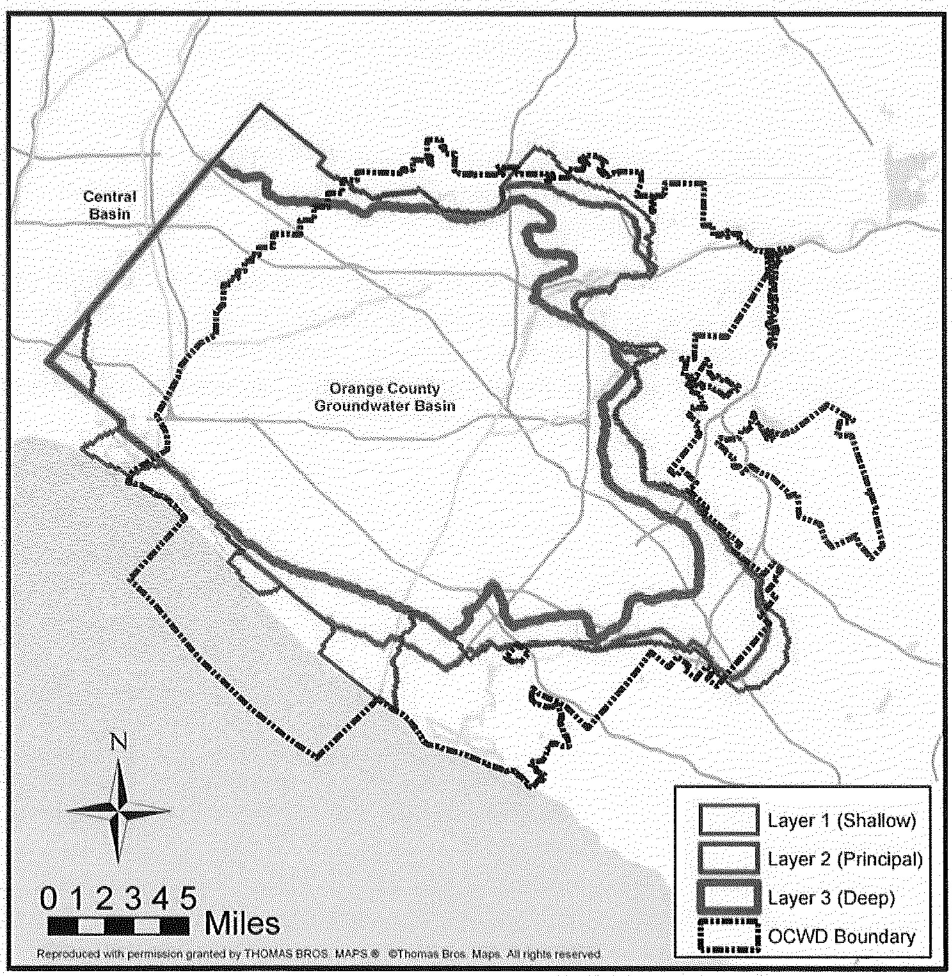
In general, a groundwater flow model contains two major components: the mathematical model and the conceptual model. The mathematical model is the computer program used to solve the complex system of equations that govern the flow of groundwater. The conceptual model is the hydrogeologic framework of the area being modeled, obtained by gathering, analyzing, interpreting, and finally integrating all the geologic and hydrologic data for a given area into a conceptual understanding of how the flow system looks and behaves.

For a properly-constructed model, the mathematical model needs to be appropriate for the level of detail inherent in the conceptual model. The modeled area must be divided into a mesh of grid cells – the smaller the grid cells, generally the more accurate the computations – assuming the hydrogeology can be reasonably-defined at the grid cell level of detail. Based on all the input data, the model calculates a water level elevation for each and every grid cell of the modeled area at a given point in time. It should be noted that very simple groundwater flow problems, for which exact mathematical solutions exist, can be solved by hand, thus validating the actual flow equations built into the computer programs.

OCWD's Basin model encompasses the entire Basin and extends approximately five miles into the Central Basin in Los Angeles County to provide for more accurate model results than if the model boundary stopped at the county line (see Figure 2-11). As noted previously in this chapter, the county line is not a hydrogeologic boundary, i.e., groundwater freely flows through aquifers that have been correlated across the county line.

Coverage of the modeled area is accomplished with grid cells having horizontal dimensions of 500 feet by 500 feet (approximately 5.7 acres) and vertical dimensions ranging from approximately 50 to 1,800 feet, depending on the thickness of each model layer at that grid cell location. Basin aquifers and aquitards were grouped into three composite model layers thought sufficient to describe the three distinguishable flow systems referred to as the shallow, principal, and deep aquifer systems. The three model layers comprise a network of over 90,000 grid cells.

Figure 2- 11
BASIN MODEL EXTENT



The widely-accepted computer program, "MODFLOW," developed by the USGS, was used as the base modeling code for the mathematical model (McDonald and Harbaugh, 1988). Analogous to an off-the-shelf spreadsheet program needing data to be functional, MODFLOW requires vast amounts of input data to define the hydrogeologic conditions in the conceptual model. The types of information that must be input in digital format (data files) for each grid cell in each model layer include the following:

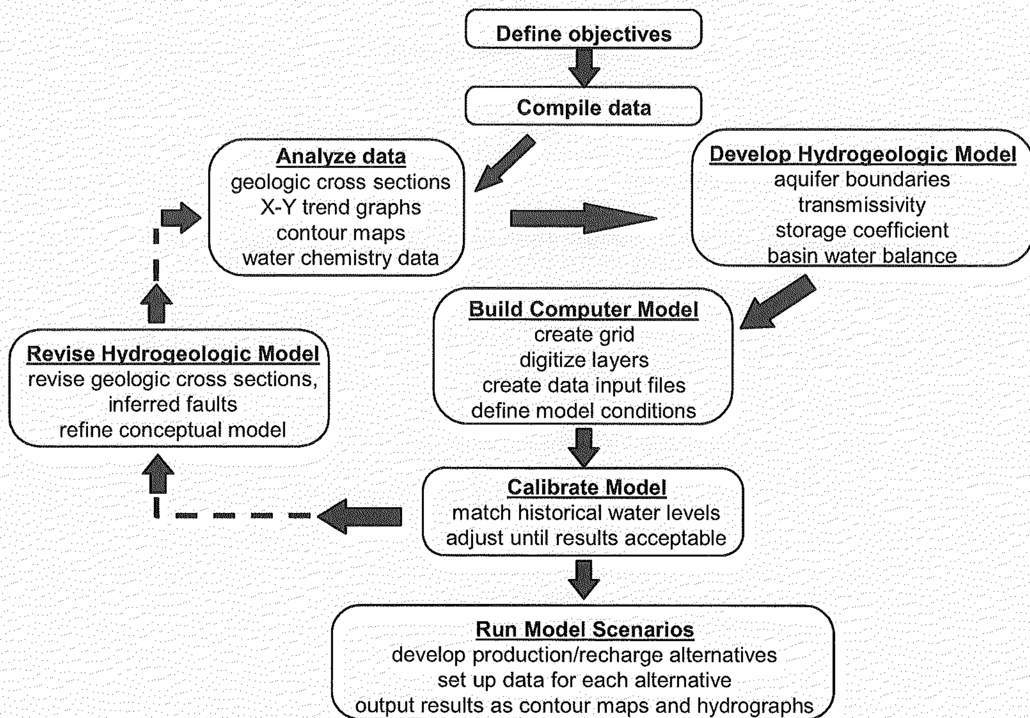
- Aquifer top and bottom elevations
- Aquifer lateral boundary conditions (ocean, faults, mountains)
- Aquifer hydraulic conductivity and storage coefficient/specific yield
- Initial groundwater surface elevation contours
- Natural and artificial recharge rates (runoff, precipitation, percolation, injection)
- Groundwater production rates for approximately 200 large system and 300 small system wells

These data originate from hand-drawn contour maps, spreadsheets, and the WRMS historical database. Because MODFLOW requires the input data files in a specific format, staff developed a customized database and geographic information system (GIS) program to automate data compilation and formatting functions. These data pre-processing tasks form one of the key activities in the model development process.

Before a groundwater model can be reliably used as a predictive tool for simulating future conditions, the model must be calibrated to reach an acceptable match between simulated and actual observed conditions. The Basin model was first calibrated to steady-state conditions to numerically stabilize the simulations, to make rough adjustments to the water budget terms, and to generally match regional groundwater flow patterns. Also, the steady-state calibration helped to determine the sensitivity of simulated groundwater levels to changes in incidental recharge and aquifer parameters such as hydraulic conductivity. Steady-state calibration of the Basin model is documented in more detail in the OCWD Master Plan Report (OCWD, 1999).

Typical transient model output consists of water level elevations at each grid cell that can be plotted as a contour map for one point in time or as a time-series graph at a single location. Post-processing of model results into usable graphics is performed using a combination of semi-automated GIS and database program applications. Figure 2-12 presents a simplified schematic of the modeling process.

Figure 2-12
MODEL DEVELOPMENT FLOWCHART



Model construction, calibration, and operation were built upon 12 years of effort by OCWD staff to collect, compile, digitize, and interpret hundreds of borehole geologic and geophysical logs, water level hydrographs, and water quality analyses. The process was composed of ten main tasks comprising over 120 subtasks. The major tasks are summarized below:

1. Finalize conceptual hydrogeologic model layers and program GIS/database applications to create properly formatted MODFLOW input data files. Over 40 geologic cross sections were used to form the basis of the vertical and lateral aquifer boundaries.

2. Define model layer boundaries. The top and bottom elevations of the three aquifer system layers and intervening aquitards were hand-contoured, digitized, and overlain on the model grid to populate the model input arrays with a top and bottom elevation for each layer at every grid cell location. Model layer thickness values were then calculated by using the GIS.

3. Develop model layer hydraulic conductivity (K) grids. Estimates of K for each layer were based on (in order of importance): available aquifer test data, well specific capacity data, and lithologic data. In the absence of reliable aquifer test or specific capacity data for areas in Layers 1 and 3, lithology-based K estimates were calculated by assigning literature values of K to each lithology type (e.g., sand, gravel, clay) within a model layer and then calculating an effective K value for the entire layer at that well location. Layer 2 had the most available aquifer test and specific capacity data. Therefore, a Layer 2 transmissivity contour map was prepared and digitized, and the GIS was then used to calculate a K surface by dividing the transmissivity grid by the aquifer thickness grid. Initial values of K were adjusted during model calibration to achieve a better match of model results with known groundwater elevations.

4. Develop layer production factors for active production wells simulated in the model. Many production wells had long screened intervals that spanned at least two of the three model layers. Therefore, groundwater production for each of these wells had to be divided among each layer screened by use of layer production factors. These factors were calculated

using both the relative length of screen within each model layer and the hydraulic conductivity of each layer. Well production was then multiplied by the layer factors for each individual well. For example, if a well had a screened interval equally divided across Layers 1 and 2, but the hydraulic conductivity of Layer 1 was twice that of Layer 2, then the calculated Layer 1 and 2 production factors for that well would have been one-third and two-thirds, respectively, such that when multiplied by the total production for this well, the production assigned to Layer 1 would have been twice that of Layer 2. For the current three-layer model, approximately 25 percent of the production wells in the model were screened across more than one model layer. In this context, further vertical refinement of the model (more model layers) may better represent the aquifer architecture in certain areas but may also increase the uncertainty and potential error involved in the amount of production assigned to each model layer.

5. Develop Basin model water budget input parameters, including groundwater production, artificial recharge, and unmeasured recharge. Groundwater production and artificial recharge volumes were applied to grid cells in which production wells or recharge facilities were located. The most uncertain component of the water budget – unmeasured or incidental recharge (described in Section 2.2.2) – was applied to the model as an average monthly volume based on estimates calculated annually for the OCWD Engineer's Report. Unmeasured recharge was distributed to cells throughout the model, but was mostly applied to cells along margins of the Basin at the base of the hills and mountains. The underflow component of the incidental recharge represents the amount of groundwater flowing into and out of the model along open boundaries. Prescribed groundwater elevations were assigned to open boundaries along the northwest model boundary in Los Angeles County; the ocean at the Alamitos, Bolsa, and Talbert Gaps; the mouth of the Santa Ana Canyon; and the mouth of Santiago Creek Canyon. Groundwater elevations for the boundaries other than the ocean boundaries were based on historical groundwater elevation data from nearby wells. The model automatically calculated the dynamic flow across these open boundaries as part of the overall water budget.

6. Develop model layer storage coefficients. Storage coefficient values for portions of model layers representing confined aquifer conditions were prepared based on available aquifer test data and were adjusted within reasonable limits based on calibration results.

7. Develop vertical leakance parameters between model layers. Vertical groundwater flow between aquifer systems in the Basin is generally not directly measured, yet it is one of the critically-important factors in the model's ability to represent actual Basin hydraulic processes. Using geologic cross sections and depth-specific water level and water quality data from the OCWD multi-depth monitoring well network, staff identified areas where vertical groundwater flow between the modeled aquifer systems is either likely to occur or be significantly impeded, depending on the relative abundance and continuity of lower-permeability aquitards between model layers. During model calibration, the initial parameter estimates for vertical leakance were adjusted to achieve closer matches to known vertical groundwater gradients.

8. Develop groundwater contour maps for each model layer to be used for starting conditions and for visual comparison of water level patterns during calibration. Staff used observed water level data from multi-depth and other wells to prepare contour maps of each layer for November 1990 as a starting point for the calibration period. Care was taken to use wells screened within the appropriate vertical interval representing each model layer. The hand-drawn contour maps were then digitized and used as model input to represent starting conditions.

9. Perform transient calibration runs. The nine-year period of November 1990 to November 1999 was selected for transient calibration, as it represented the period set of groundwater elevation, production, and recharge data. The transient calibration process and results are described in Section 2.4.1.

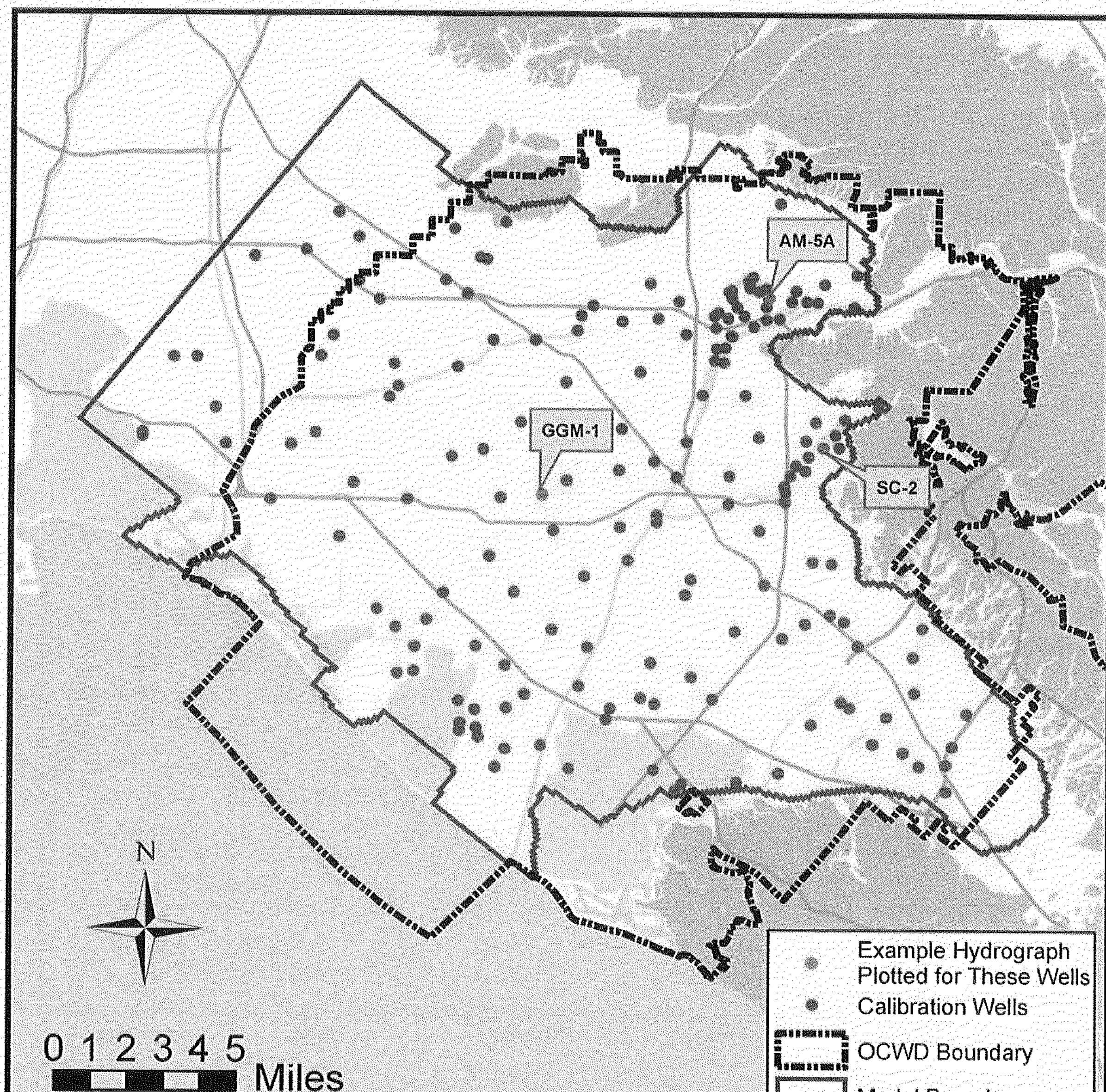
10. Perform various Basin production and recharge scenarios using the calibrated model. Criteria for pumping and recharge, including facility locations and quantities, were developed for each scenario and input for each model run.

2.4.1 MODEL CALIBRATION

Calibration of the transient Basin model involved a series of model runs of the period 1990 to 1999, using monthly flow and water level data. The time period selected for calibration represents a period during which basic data required for monthly transient calibration were essentially complete (compared to pre-1990 historical records). The calibration period spans at least one "wet/dry" rainfall cycle. Monthly water level data from almost 250 target locations were used to determine if the simulated water levels adequately matched observed water levels. As shown in Figure 2-13, the calibration target points were densely distributed throughout the Basin and also covered all three model layers.

Figure 2-13

BASIN MODEL CALIBRATION WELLS



After each model run, a hydrograph of observed versus simulated water levels was created and reviewed for each calibration target point. In addition, a groundwater elevation contour map for each layer was also generated from the simulated data. The simulated groundwater contours for all three layers were compared to interpreted contours of observed data (November 1997) to assess closeness of fit and to qualitatively evaluate whether the simulated gradients and overall flow patterns were consistent with the conceptual hydrogeologic model. November 1997 was chosen for the observed versus simulated contour map comparison since these hand-drawn contour maps had already been created for the prior steady state calibration step. Although November 1997 observed data were contoured for all three layers, the contour maps for Layers 1 and 3 were somewhat more generalized than for Layer 2 due to a lower density of data points (wells) in these two layers.

Depending on the results of each calibration run, model input parameters were adjusted, including hydraulic conductivity, storage coefficient, boundary conditions, and recharge distribution. Time-varying head boundaries along the Orange/Los Angeles County line were found to be extremely useful in obtaining a close fit with observed historical water levels in the northwestern portion of the model. Fifty calibration runs were required to reach an acceptable level of calibration in which model-generated water levels were within reasonable limits of observed water level elevations during the calibration period. Figures 2-14 through 2-16 show examples of hydrographs of observed versus simulated water levels for three wells used as calibration targets.

Figure 2-14

CALIBRATION HYDROGRAPH FOR MONITORING WELL AM-5A

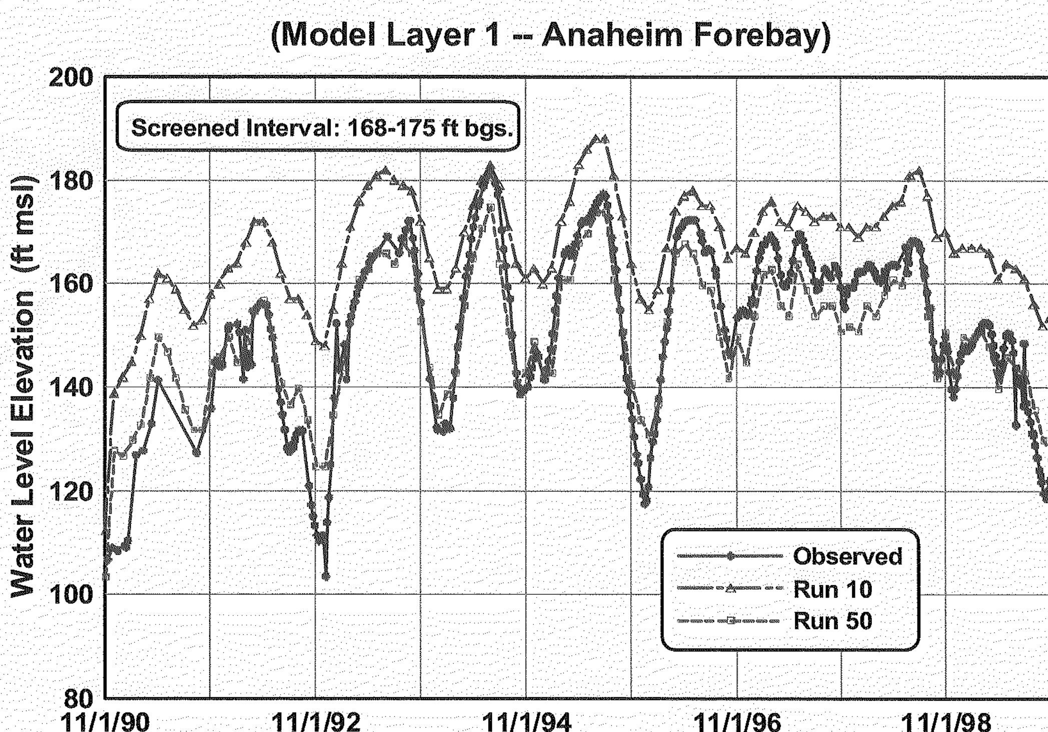


Figure 2-15

CALIBRATION HYDROGRAPH FOR MONITORING WELL SC-2

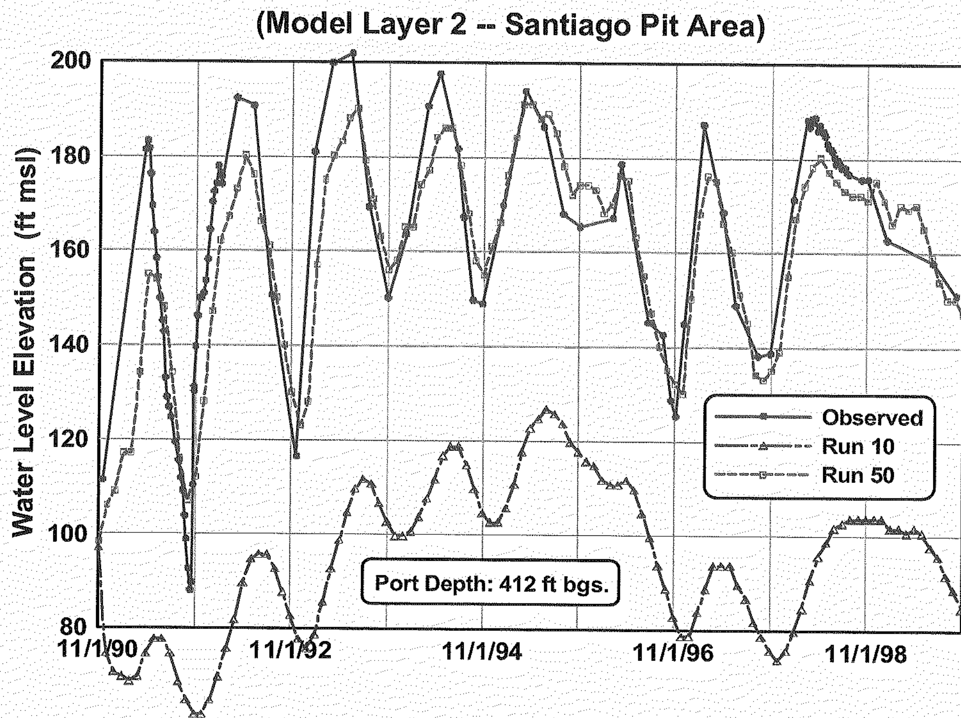
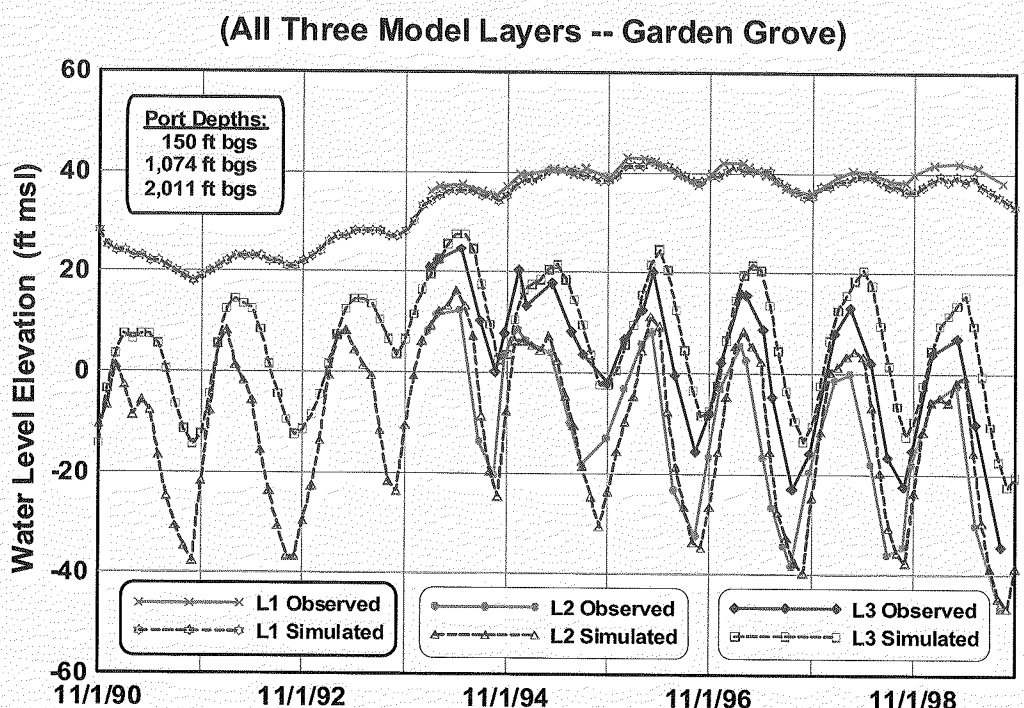


Figure 2-16

CALIBRATION HYDROGRAPH FOR MONITORING WELL GGM-1



Noteworthy findings of the model calibration process are summarized below:

- The model was less sensitive to changes in storage coefficient, requiring order-of-magnitude changes in this parameter to cause significant changes in simulated water levels, primarily affecting the amplitude of seasonal water level variations.
- The vast amount of observed historical water level data made it readily evident when the model was closely matching observed conditions.
- Incidental (unmeasured) recharge averaging approximately 70,000 afy during the 1990-1999 period appeared to be reasonable, as the model was fairly sensitive to variations in this recharge amount.
- Groundwater outflow to Los Angeles County was estimated to range between 5,000 and 12,000 afy between 1990 and 1999, most of this occurring in Layers 1 and 3.
- Groundwater flow at the Talbert Gap was inland during the entire model calibration period, indicating moderate seawater intrusion conditions. Model-derived seawater inflow ranged from 500 to 2,700 afy in the Talbert Gap and is consistent with chloride concentration trends over the last ten years that have indicated inland movement of saline groundwater in these areas.
- Model-derived groundwater inflow from the ocean at Bolsa Gap was only 100-200 afy due to the Newport-Inglewood Fault zone, which offsets the Bolsa aquifer and significantly restricts the inland migration of saline water across the fault.
- Model adjustments (mainly hydraulic conductivity and recharge) in the Santiago Pits area in Orange significantly affected simulated water levels in the coastal areas.
- Model reductions to the hydraulic conductivity of Layer 2 (Principal aquifer system) along the Peralta Hills Fault in Anaheim/Orange had the desired effect of steepening the gradient and restricting groundwater flow across the fault into the Orange area. These simulation results were consistent with observed hydrogeologic data indicating that the Peralta Hills Fault acts as a partial groundwater barrier.
- Potential unmapped faults immediately downgradient from the Santiago Pits appear to restrict groundwater flow in the Principal aquifer system, as evidenced by observed steep gradients in that area, which were reproduced by the model. As with the Peralta Hills Fault, an approximate order-of-magnitude reduction in hydraulic conductivity along these suspected faults achieved the desired effect of reproducing observed water levels with the model.

2.4.2 MODEL ADVISORY PANEL

The model development and calibration process was regularly presented to and reviewed by a Model Advisory Panel. This technical panel consisted of four groundwater modeling experts who were familiar with the Basin and highly qualified to provide insight and guidance during the model construction and calibration process. Twelve panel meetings were held between 1999 and 2002. The panel was tasked with providing written independent assessments of the strengths, weaknesses, and overall validity and usefulness of the model in evaluating various Basin management alternatives. Two memoranda were prepared: one at the completion of the steady-state model calibration and steady-state scenarios that supported the 1999 Master Plan Report (Harley et al., 1999) and one at the completion of the transient model calibration and initial transient Basin operational scenarios (Harley et al., 2001). Key conclusions and findings of the panel regarding the transient model are summarized below.

- Transient modeling has substantially improved the overall understanding of processes and conditions that determine how and why the Basin reacts to pumping and recharge. This improved understanding, coupled with the model's ability to simulate existing and possible future facilities and alternative operations, significantly improves the District's potential ability to enhance and actively manage Basin water resources.
- Modeling has helped verify major elements of the Basin conceptual model and has been instrumental in clarifying:
  - Variations in the annual water balance
  - Hydrostratigraphy of the Basin
  - Horizontal flow between Basin subareas
  - The potential degree of interconnection and magnitude of vertical flow between major aquifers
  - The potential hydraulic significance of the Peralta Hills Fault in the Anaheim Forebay
  - Variations in aquifer hydraulic properties

The relative significance of engineered versus natural recharge and groundwater outflow within the Basin

Numerous other issues and conditions.

- The ability of the model to simulate known and projected future conditions will evolve and improve as new data become available and updated calibration runs are completed.
- Parameters used to set up the model appear to be within limits justified by known, estimated, and assumed subsurface conditions based upon available historic data.
- Initial transient calibration completed using a nine-year calibration period (1990-1999) is considered adequate to confirm the initial validity of the model for use in evaluating a variety of potential future projects and conditions.
- Areas of the Basin that could benefit from future exploration, testing, monitoring, analysis and/or additional model calibration were identified.
- The model is not considered appropriate for assessing detailed local impacts related to new recharge facilities or well fields. These impacts should be assessed using more detailed local submodels and by conducting detailed field studies.
- The model does not, nor is it intended to, address water supply availability, cost, water quality, or land subsidence.

Recommendations of the panel included suggestions that thorough documentation be prepared on model configuration and calibration and that the model calibration period be extended as new data become available.

2.4.3 TALBERT GAP MODEL

Between 1999 and 2000, OCWD contracted with Camp Dresser & McKee Inc. to develop a detailed groundwater flow model of the Talbert Gap and surrounding area for the purpose of evaluating and estimating the amount and location of fresh water injection wells needed to control seawater intrusion under current and projected future Basin conditions. The Talbert Gap modeling effort was undertaken as part of the design scope of work for Phase 1 of the GWR System, which included expansion of the existing Talbert Barrier. The configuration and initial calibration of the Talbert Gap Model and further model refinement and calibration were documented by Camp Dresser & McKee Inc. (2000, 2003).

Consistent with the Basin Model Advisory Panel's findings, OCWD determined that a more detailed model of the Talbert Gap was necessary to evaluate the local water level changes associated with various potential injection barrier alignments and flow rates. The Talbert model comprises an area of 85 square miles, 13 Layers (seven aquifers and six aquitards), and 509,000 grid cells (250 feet x 250 feet horizontal dimensions). Figures 2-15 and 2-16 show the model area and layering schematic, respectively.

Figure 2-17
TALBERT GAP MODEL AND BASIN MODEL BOUNDARY MAP

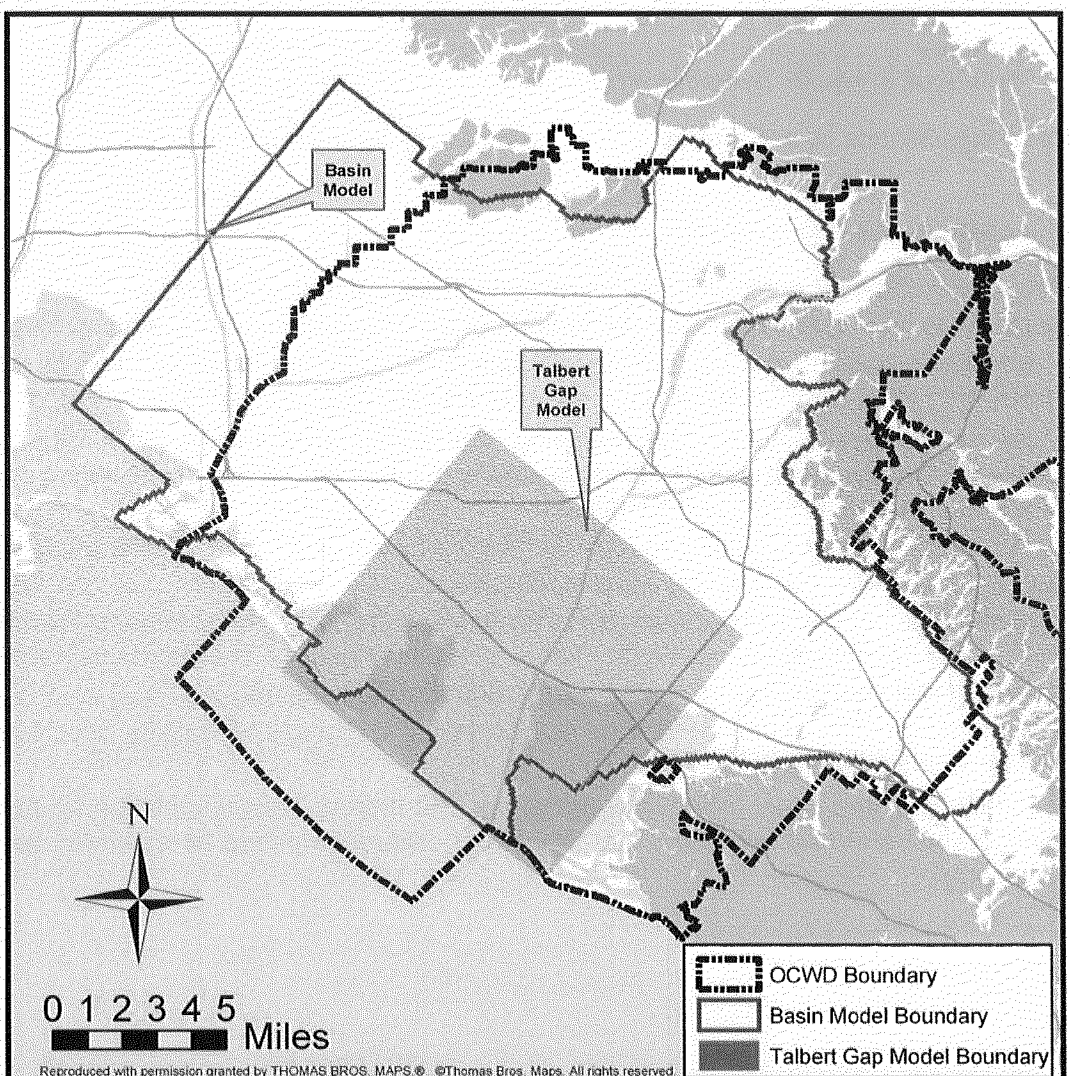
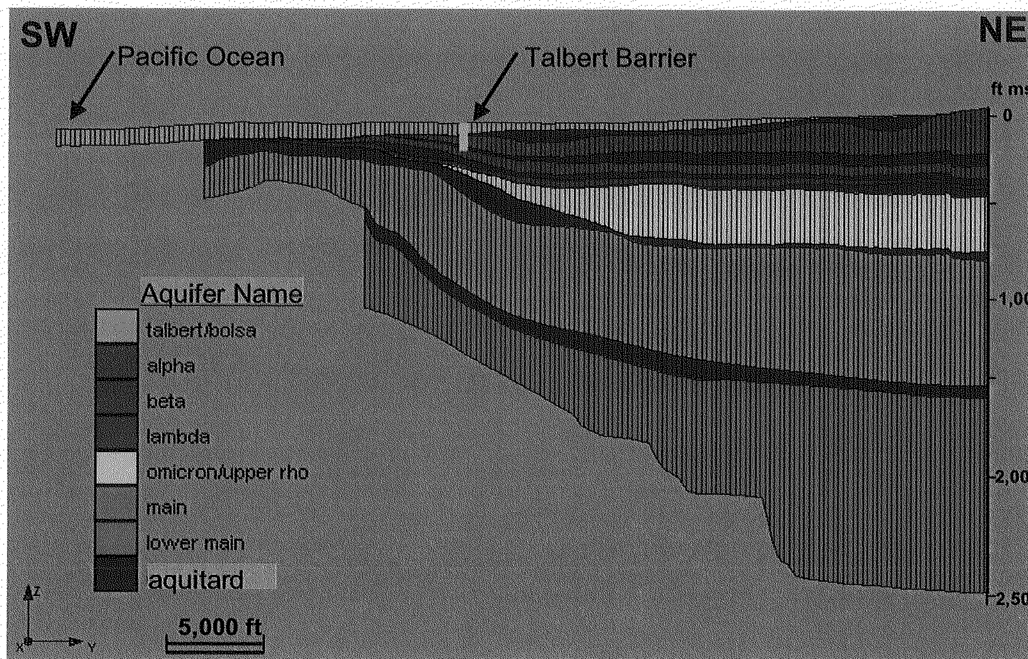


Figure 2-18
TALBERT GAP MODEL AQUIFER LAYERING SCHEMATIC



Key findings of the Talbert Gap model are summarized below.

- Depending on the amount of Basin production, particularly near the Talbert Barrier, 30 mgd (approximately 34,000 afy) of injection will substantially raise water levels, yet may not be sufficient to fully prevent seawater intrusion in the Talbert Gap. Additional injection wells beyond those planned for Phase 1 of the GWR System may be required.
- Under projected 2020 conditions, the future Talbert Barrier may require an annual average injection rate of up to 45 mgd based on the results of existing analyses. This estimated future injection requirement will be further evaluated as additional data are collected.
- The Talbert model inland boundaries do not coincide with hydrologic or geologic features, e.g., recharge area, faults. Therefore, simulated water levels are highly influenced by the time-varying water levels specified along the boundaries. For future Talbert model predictive runs, the Basin model should be used to generate water levels that can then be specified along the inland Talbert model boundaries.
- The Talbert model was less sensitive to adjustment hydraulic conductivity and storage coefficient than the Basin model, primarily because of the stronger influence of the specified-head boundaries in the Talbert model.

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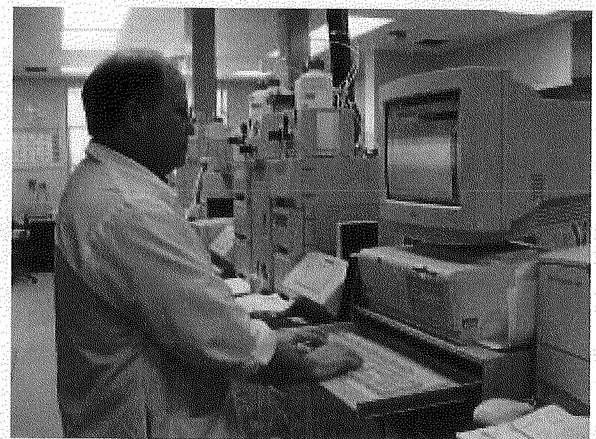
section 3 Groundwater Monitoring



For its size and complexity, the Basin is one of the world's most extensively monitored. The District has implemented and continues to augment a comprehensive monitoring program to track dynamic Basin conditions including groundwater production, storage, elevations, and quality. A vast network of production and monitoring wells is used to collect data at frequencies necessary for short- and long-term trend analyses. The spatial distribution of the wells has been tailored toward Basinwide analysis and, where appropriate, has focused on local or sub-regional investigations. Because of the Basin's multiple-aquifer configuration, emphasis has been placed on installing multi-depth monitoring wells that provide depth-specific water level and quality data.

This section:

- Provides an overview of groundwater extraction in the Basin.
- Presents methods used to assess groundwater elevations and Basin storage.
- Discusses groundwater monitoring efforts, including specialized programs for Title 22 Drinking Water Standards.
- Describes seawater intrusion monitoring and prevention measures.
- Discusses land subsidence.

3.1 GROUNDWATER EXTRACTION

As discussed in Section 2.2.3, groundwater extraction (also called pumping or production) occurs from nearly 500 production wells in the Basin, with approximately 200 large-capacity municipal supply wells accounting for 97 percent of this extraction. As required by the District Act, all wells with discharge outlets greater than two inches in diameter are to be equipped with a water production totalizing meter. Owners of wells with smaller diameter discharge outlets and which serve an area of one acre or less are assessed a fixed annual charge (currently the equivalent of the replenishment assessment for one acre-foot).

Since 1990, at the request of OCWD, large-capacity well owners have reported their groundwater production on a monthly basis for each of their wells, even though they are billed for their production on a semi-annual basis. The monthly production data for individual wells are entered and stored in the District's WRMS database. These data were essential input data for the calibration of the Basin model described in Section 2.4 and are often used to evaluate the causes of seasonal groundwater level fluctuations. OCWD staff also uses groundwater production data, along with other gains and losses, to estimate changes in Basin storage throughout the year. Figure 3-1 illustrates examples of seasonal groundwater production trends in three municipal wells.

3.2 GROUNDWATER ELEVATION AND BASIN STORAGE

Groundwater elevation (or level) data are measured at nearly every production and monitoring well in the Basin at least once per year. The majority of the large-capacity production and monitoring wells, comprising a total of over 1,000 individual measurement points, are monitored for water levels on a monthly or bi-monthly basis to evaluate short-term effects of pumping or recharge operations. More frequent water level measurements are collected at selected monitoring wells in the vicinity of OCWD's recharge facilities, seawater barriers, and areas of special investigation involving drawdown, water quality impacts, or contaminant remediation. Examples of water level hydrographs are shown in Figures 2-7 and 2-8. Figure 3-2 presents a map of OCWD's monitoring well network.

Figure 3-1

EXAMPLES OF SEASONAL WELL PUMPING PATTERNS

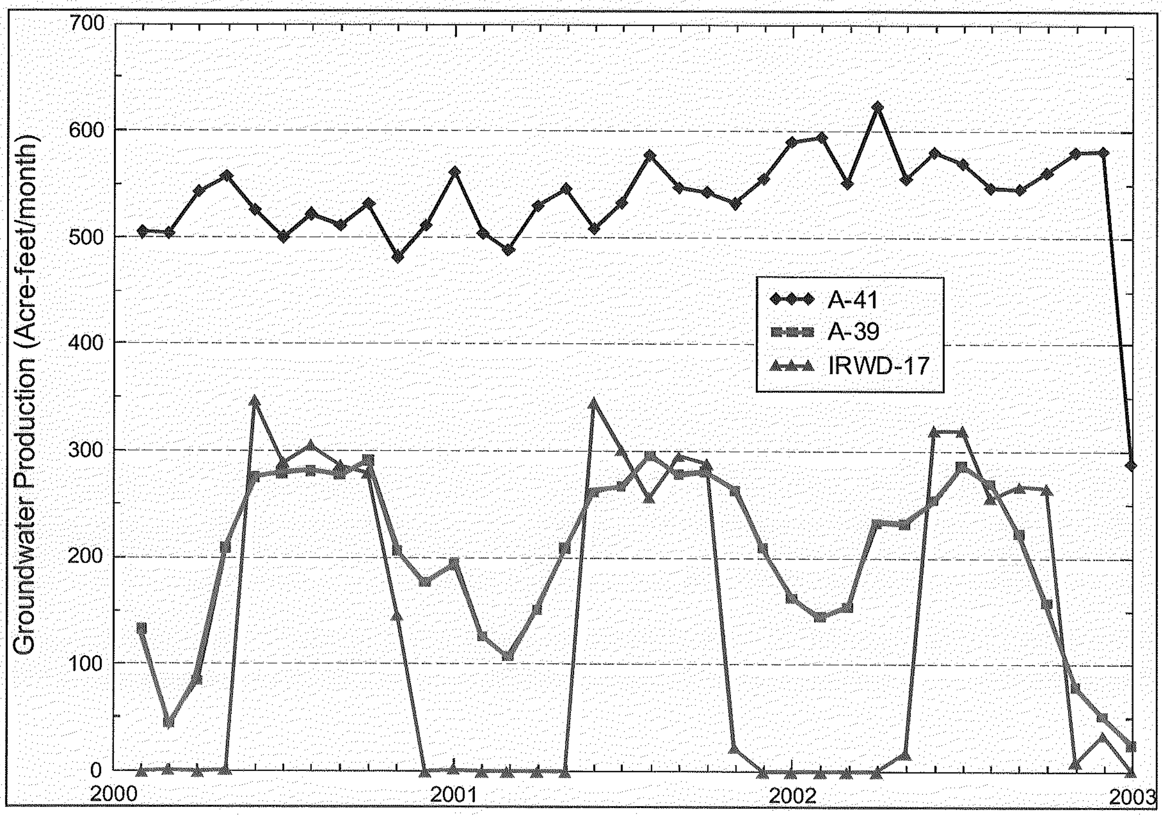
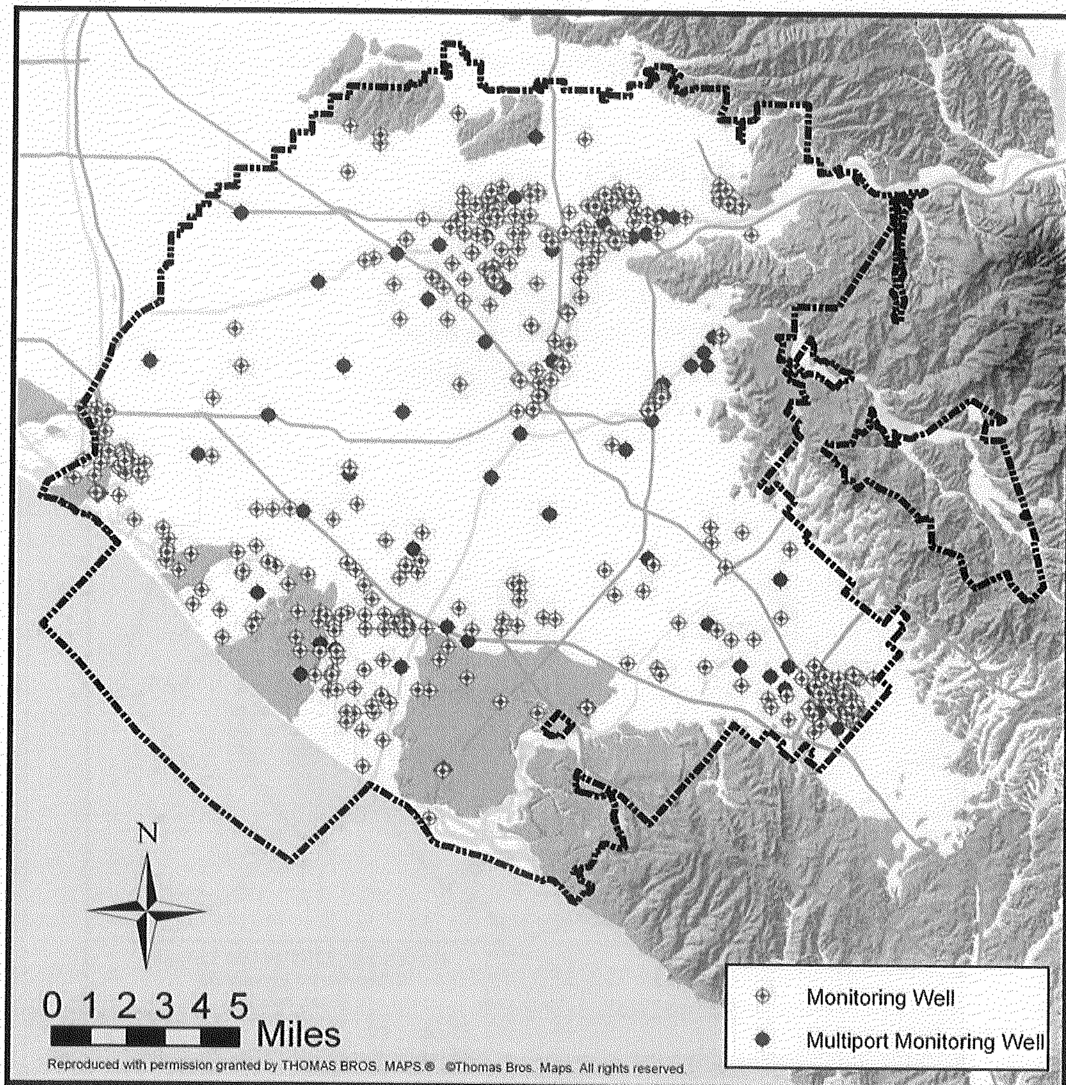


Figure 3-2

MONITORING WELL NETWORK



OCWD uses two methods to estimate annual changes in the amount of groundwater stored in the Basin: (1) groundwater elevation changes times the aquifer storage coefficient and (2) water budget summation of all Basin inflows and outflows. Each method has inherent uncertainties that may be amplified or reduced depending on the hydrologic conditions in a given year. Thus, a fair amount of judgment is involved in comparing and evaluating the estimated storage change for each method before developing a final storage estimate.

The first method involves the measurement of water levels in wells throughout the Basin on or about November 1 each year. Water level measurements from wells screened within the Principal aquifer are plotted, and interpreted elevation contours are drawn and digitized, as shown in Figure 3-3. The District's GIS is then used to overlay and subtract the most recent contours with those of the prior year to generate a water level change contour map (Figure 3-4). The GIS is then used to multiply these water level changes by a grid of aquifer storage coefficients representative of varying hydrogeologic conditions throughout the Basin. This results in a storage volume change calculation for each grid cell, which is totaled to provide a net storage volume change for the year ending November 1.

The water budget method involves totaling up all measured or estimated Basin inflows (+) and outflows (-) to obtain a net storage volume change for the year. The inflows and outflows are described in detail in Section 2.2.

Figure 3-3

NOVEMBER 2002 WATER LEVELS

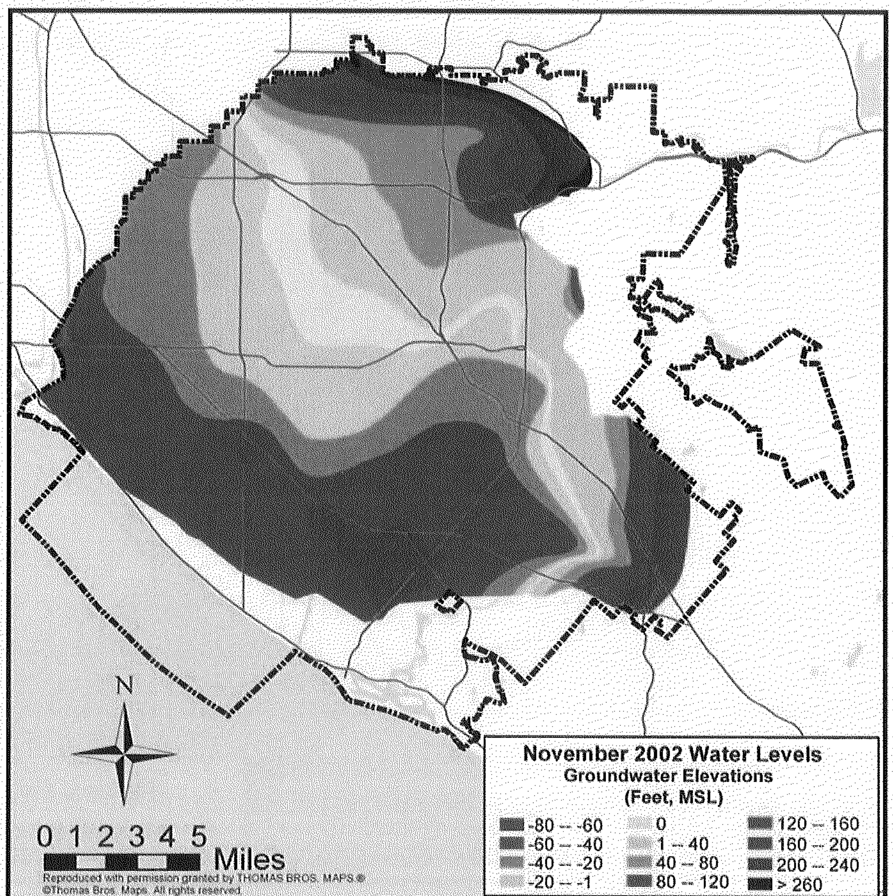
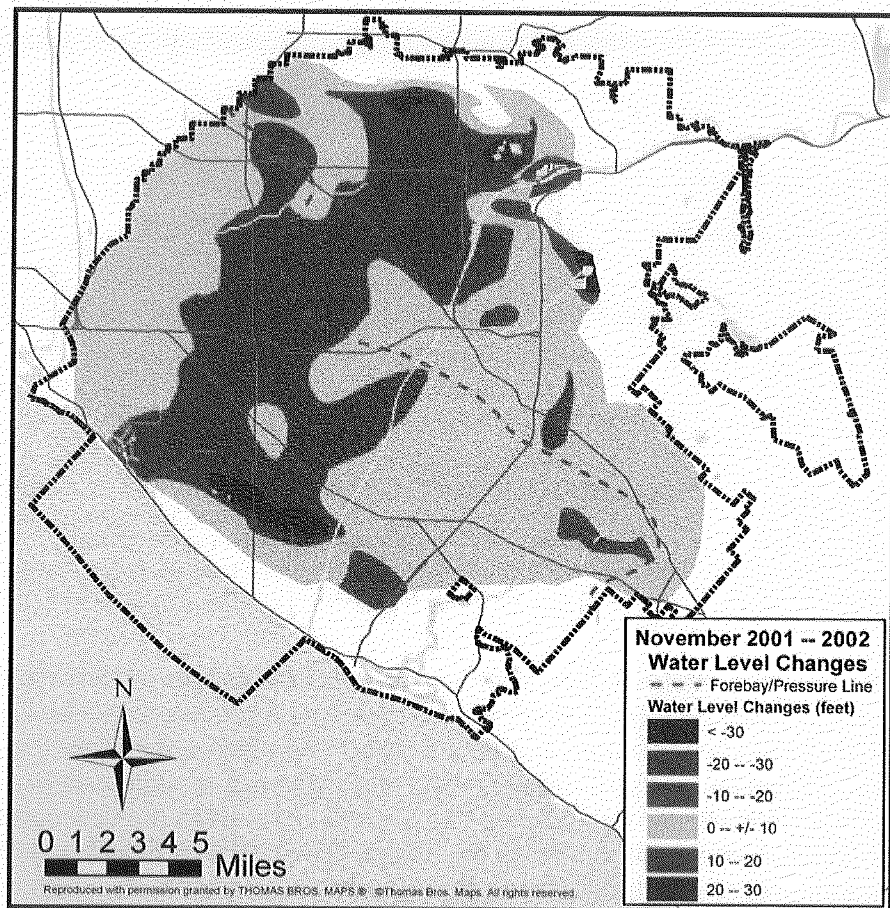


Figure 3-4

NOVEMBER 2001-2002 WATER LEVEL CHANGES



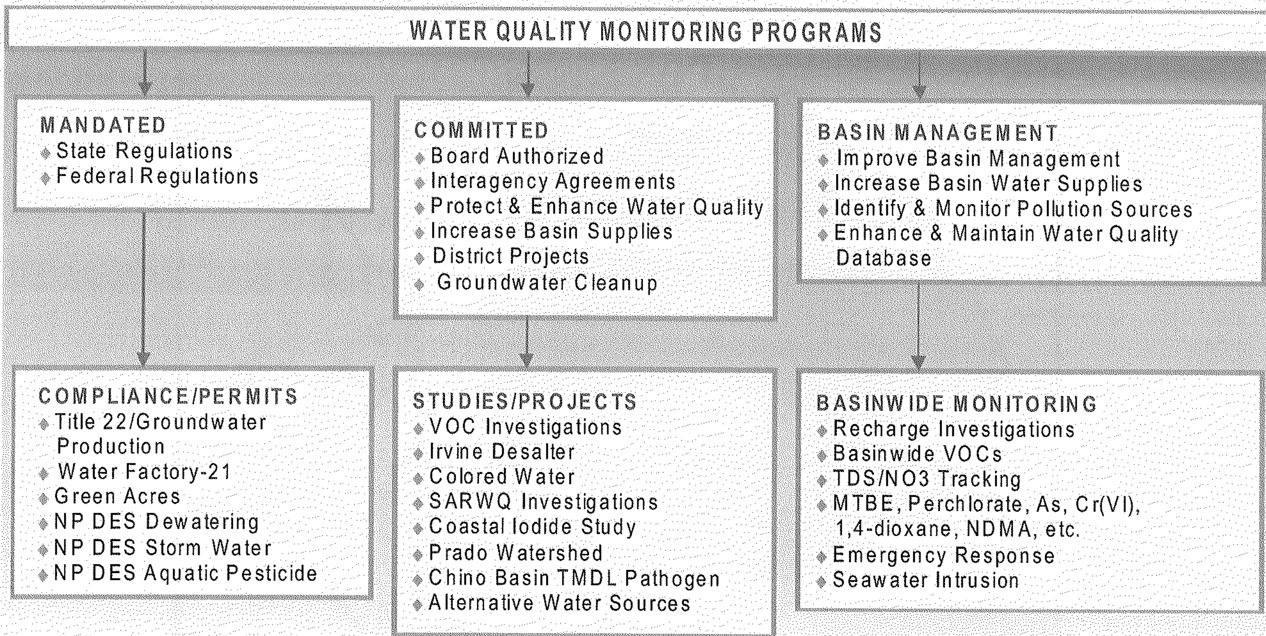
3.3 GROUNDWATER QUALITY

Administering a comprehensive water quality monitoring program is a core District function. Water quality data are continuously collected to assess ambient conditions of the Basin. Information is used to monitor the effects of Basin extraction, the effectiveness of the seawater intrusion barriers, impacts from historic and current land use and also to serve as a sentinel or early warning of emerging contaminants of concern. Analysis of water chemistries across the Basin aid in better understanding of groundwater hydrogeology (i.e., flow and transport in the underlying aquifers, travel time, etc.) and provide valuable information for Basin management and regulatory programs.

The water quality monitoring programs are broadly classified into three categories: (1) regulatory or compliance with permits and environmental and groundwater drinking water regulations, (2) committed OCWD and research projects, and (3) Basin management, i.e., or evaluating and protecting Basin water quality. Examples of water quality monitoring activities within the regulatory, committed, and Basin management categories are illustrated in Figure 3-5.

Figure 3-5

WATER QUALITY MONITORING ACTIVITIES



Collection of water quality samples follows approved federal and state procedures and industry-recognized quality assurance and quality control protocols to ensure that sampled water is representative of ambient groundwater (or surface water) conditions. Water samples are collected in method-specific containers, stored in coolers at approximately 4°C, and delivered to state-certified laboratories, researchers, or contract laboratories for analysis. The majority of samples are delivered to the laboratory on the day of sample collection; the remaining are shipped overnight for next-day delivery. Site conditions, field measurements of selected water quality parameters (temperature, pH, electrical conductivity, and dissolved oxygen), and other relevant sample observations are recorded into field notebooks at each sampling location, and a chain-of-custody is completed for each sample collected per site. Sampling occurs in a variety of terrains, in inclement weather, and after hours. Figure 3-6 shows representative sample containers used to collect water quality samples for a variety of chemical analyses.

Figure 3-6

REPRESENTATIVE SAMPLE CONTAINERS

The District's groundwater monitoring network consists of over 800 wells representing a diverse cross-section of well types and broad range of well depths and screened intervals. These include active drinking water, private domestic, irrigation, and industrial wells; single and multi-point monitoring wells; and inactive wells as shown in Figure 3-7. The distribution of OCWD-constructed monitoring wells and drinking water wells constructed by others is shown in Figures 3-2 and 3-7.

Production wells that provide water for drinking water, irrigation/agriculture, and industrial uses generally have well screens located in the permeable, water-bearing zones that may tap multiple aquifers. Therefore, water quality samples collected from these wells may represent water from one or more aquifers; some permeable zones may provide greater contribution of the groundwater than others to the overall water sample. In contrast, monitoring wells are designed and constructed with well screens placed at a specific depth and length to provide water quality at desired zones within an aquifer. OCWD constructs monitoring wells in the Basin to supplement water quality data from production wells and to fill data gaps. Figure 3-8 illustrates the three monitoring well designs used for Basinwide water quality monitoring activities: multi-point, "nested," and cluster.

Figure 3-7

BASIN WELL LOCATIONS

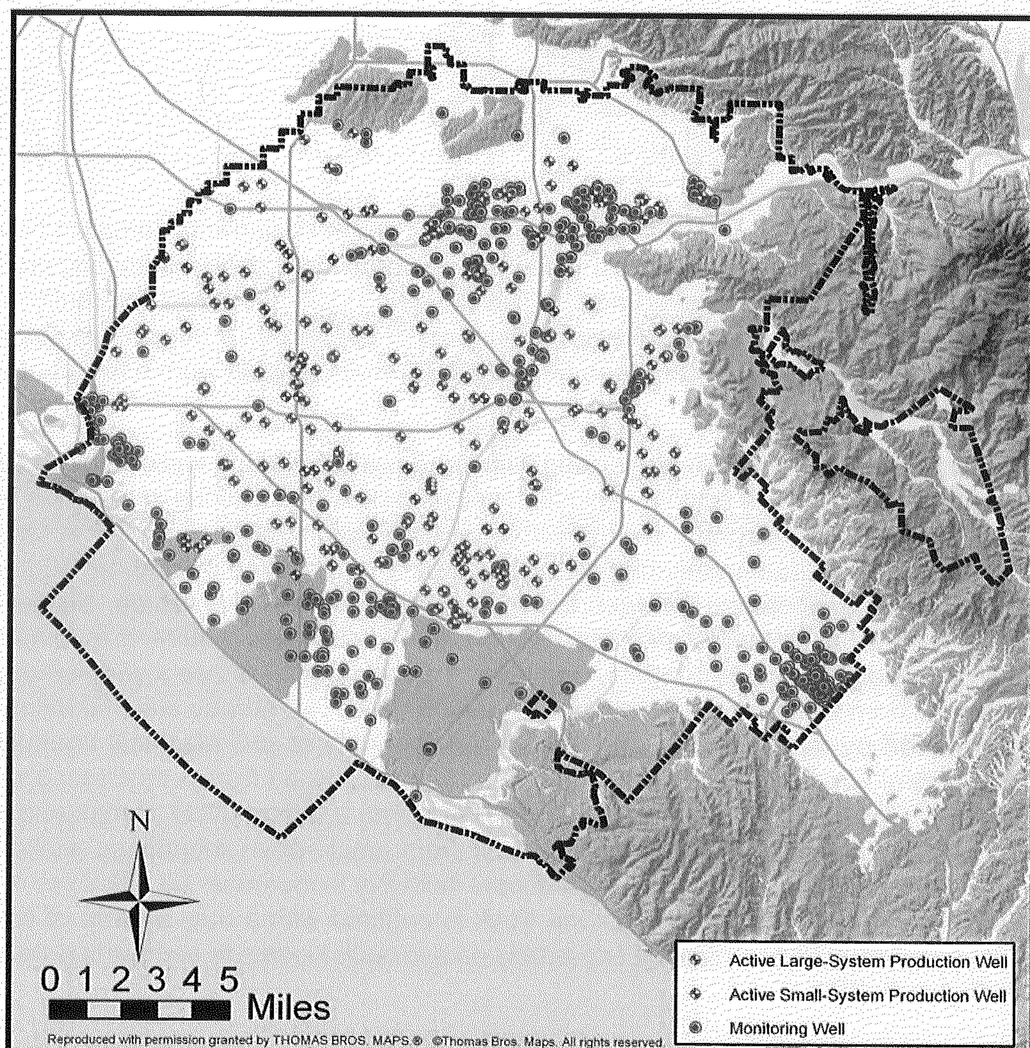
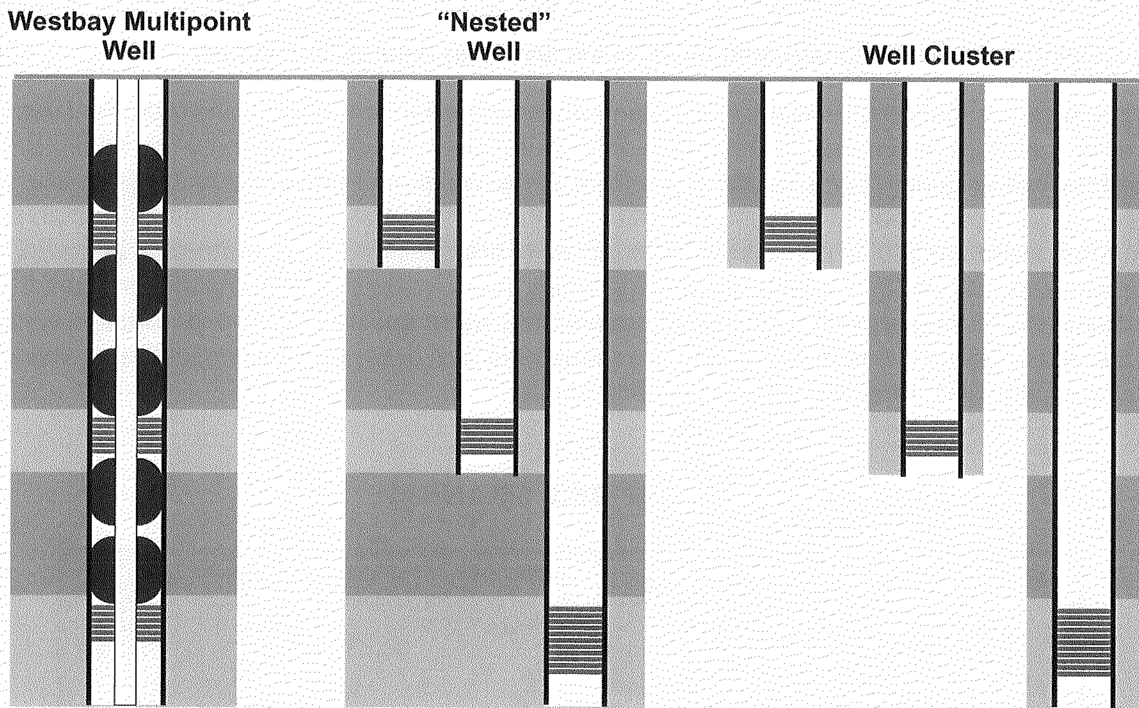


Figure 3-8

THREE COMMON MONITORING WELL DESIGNS



The multi-point well is a Westbay well design that contains a single casing with sampling ports located at specific depths in the underlying aquifers (Figure 3-9). A computer-assisted sampling probe is used to collect a water sample at the desired depth. The sampling port has direct hydraulic connection between the port value and the aquifer, allowing groundwater to flow into a detachable stainless steel sample container. The District has more than 50 multi-point wells ranging from a few hundred feet to over 2,000 feet in depth.

A "nested" well design consists of primary casing with individual monitoring wells screened at specific depths and completed in a single casing. A cluster is represented by individual monitoring wells completed with single casings at targeted depths within close proximity of each other. A "single point" monitoring well is one individual monitoring well that typically is screened over about 10 to 30 feet of sediments. The primary difference between the multi-point wells and the nested, cluster or single-point monitoring wells is the method of sample collection. Multi-point wells require no purging of groundwater prior to sample collection. In contrast, single point monitoring wells use a submersible pump to purge groundwater from the surrounding formation until "ambient" or steady state conditions are obtained as determined by steady, continuous field measurements of pH, electrical conductivity, and temperature. Several hundred gallons of groundwater may be purged from a monitoring well prior to sample collection. Generally, a truck equipped with one or more submersible pumps and a portable generator is used to purge and sample groundwater from single-point monitoring wells. Portable submersible pump and reel systems provide additional flexibility to increase the efficiency of sampling monitoring wells without dedicated pumps. One truck is outfitted with a dual system of submersible pumps and environmental hoses installed separately on hydraulic booms to sample two wells simultaneously (see Figure 3-10).

Figure 3-9

MULTIPORT WELL DESIGN DETAIL

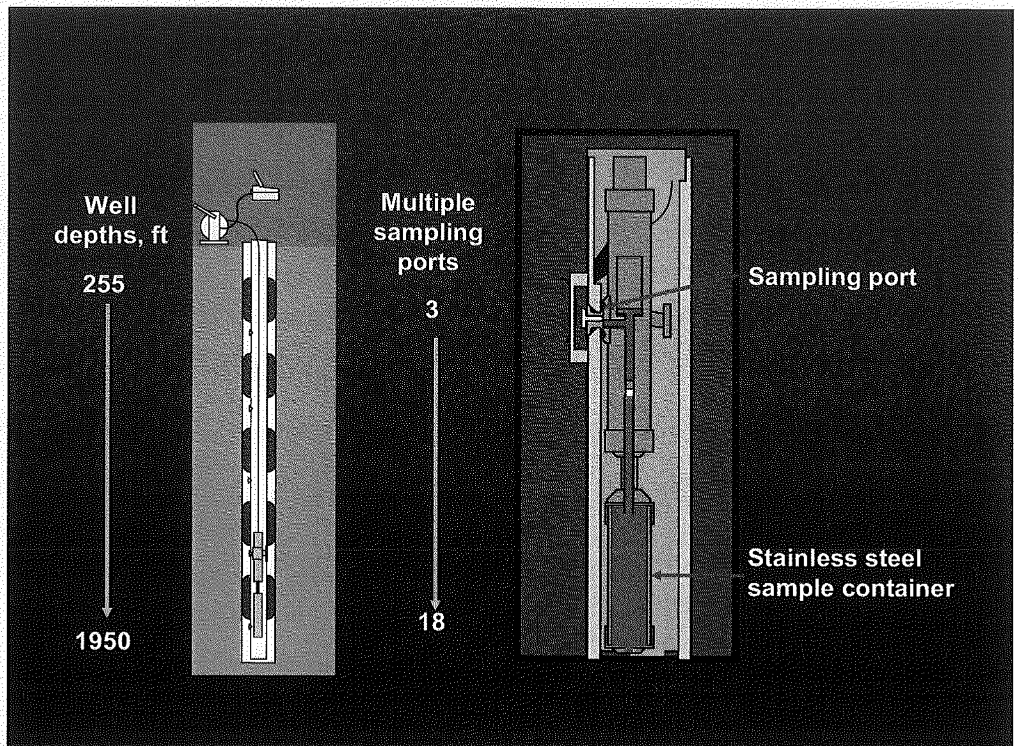
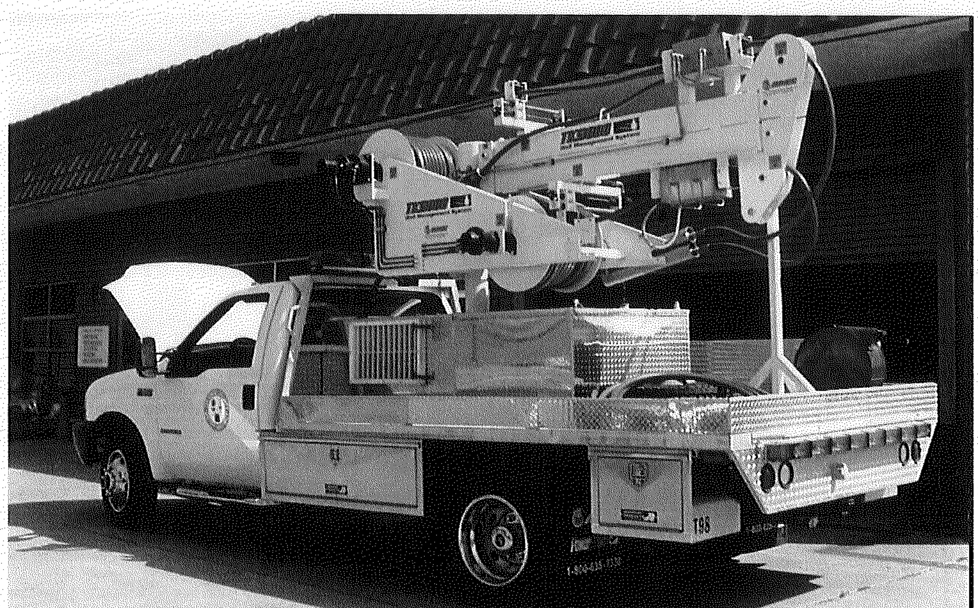


Figure 3-10

DUAL BOOM WATER QUALITY SAMPLING VEHICLE



Approximately 13,500 groundwater samples are collected annually for compliance and non-compliance programs from over 800 wells containing around 1,400 sampling points. A summary of the well types, number of wells, and number of sample points is presented in Table 3-1. The numbers are estimated because, in any given year, the number of wells may vary slightly depending on well maintenance, abandonment, new well construction, and related factors. The number of water quality samples has increased since the 1990s to meet regulatory requirements and to gain a better understanding of the Basin. Activities have included developing a monitoring program to define the hydrogeology, assessing the groundwater quality of the Basin, addressing poor water quality areas, and conducting the Santa Ana River Water Quality and Health (SARWQH) Study to verify the safety of continued use of the river for groundwater replenishment water. Figure 3-11 shows the approximate 76 percent increase in the number of groundwater and surface water samples collected in recent years. The monthly distribution of samples is dynamic and ranges from 600 to 1700 samples in any given month.

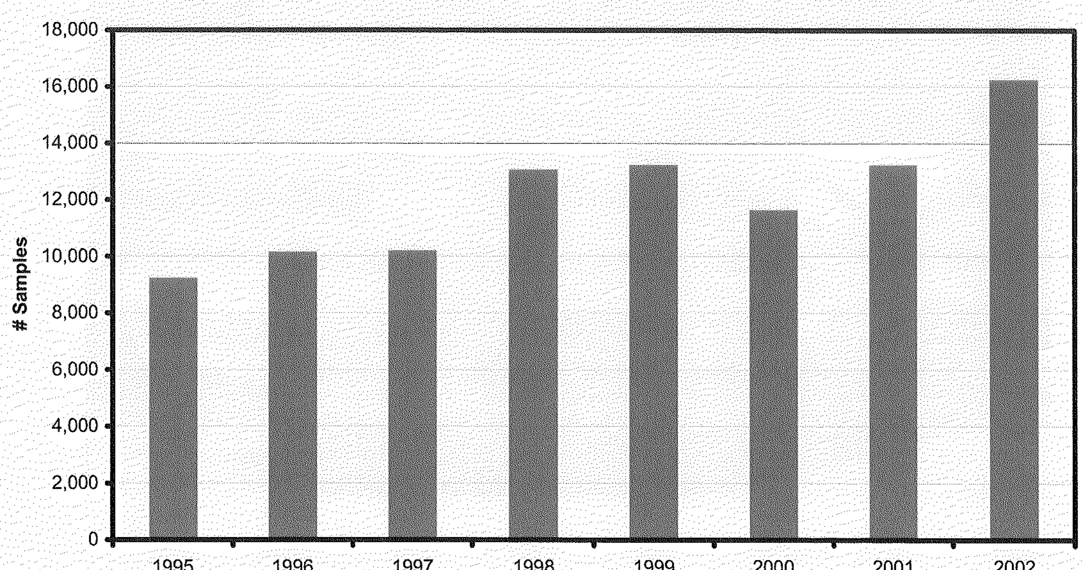
Table 3-1

DISTRIBUTION OF WELLS IN BASINWIDE MONITORING PROGRAM

Well Type	No. of Wells	No. of Sample Points
Drinking Water (potable)	225	225
Basinwide (mostly non-OCWD, non-potable production wells)	200	200
Monitoring (mostly OCWD owned)	110	110
Westbay (multipoint; OCWD owned)	56	561
Monitoring for seawater intrusion (Talbert Gap/Coastal Area)	72	367
Total	**663**	**1463**

Figure 3- 11

NUMBER OF WATER SAMPLES COLLECTED 1995-2002



3.3.1 TITLE 22 DRINKING WATER STANDARDS

In 1974, the District proposed a Basinwide groundwater quality monitoring program, on behalf of Basin Producers, to satisfy the drinking water testing requirements specified in the federal Safe Drinking Water Act (SDWA). The SDWA and subsequent amendments authorize the Environmental Protection Agency (EPA) to set health-based standards (maximum contaminant levels or MCLs) for drinking water to protect public health against both naturally-occurring and man-made contaminants. EPA administers the SDWA at the federal level and establishes MCLs for bacteriological, inorganic, organic, and radiological constituents (United States Code Title 42, and Code of Federal Regulations Title 40). California administers and enforces the drinking water program and has adopted its own SDWA, which incorporates the federal SDWA requirements including some requirements specific only to California (California Health and Safety Code, Section 116350 and related sections).

In 1975, the California Department of Health Services (DHS) approved of OCWD's Basinwide key well monitoring program to comply with the groundwater monitoring requirements for potable supply wells. Twenty-five wells, named key wells, were strategically located throughout the Basin to satisfy the DHS monitoring requirements. In 1989-90, the key well program was expanded to include testing of all drinking water wells. As shown in Figure 3-7, the drinking water wells are located throughout the Basin except in the Irvine subbasin, which historically has been primarily agricultural. The wells are generally constructed with well screens ranging from approximately 100 to 1000 feet or more below ground surface (bgs) and provide water quality information related to the primary producing aquifers. Over 225 drinking water wells are routinely monitored to assess the ambient water quality and provide real-time data of ambient conditions.

OCWD's laboratory is state-certified to perform bacteriological, inorganic, and organic analyses. A state-certified contactor laboratory analyzes radiological samples. DHS- or EPA-approved analytical methods are used for analyzing water quality samples for the drinking water compliance program. As new chemicals are regulated, the laboratory develops the analytical capability and becomes certified in the approved method to process compliance samples (see Figure 3-12).

Figure 3-12

OCWD'S STATE CERTIFIED LABORATORY

Since the 1970s, the number of regulated chemicals in groundwater drinking water sources has increased more than four-fold. Presently, more than 100 regulated and unregulated chemicals are monitored at a specified monitoring frequency established by regulation and listed in Table 3-2. Following an initial testing program over four consecutive quarters, DHS reviews volatile and synthetic organic chemical data and conducts a vulnerability assessment to determine if reduced monitoring or a waiver is warranted.

Table 3-2

MONITORING OF REGULATED AND UNREGULATED CHEMICALS

DHS Title 22 Drinking Water Monitoring Frequency -- Regulated Chemicals		
Chemical Class	**Frequency**	**Monitoring Period**
Inorganic - general minerals	Once every 3 years	
Inorganic - trace metals	Once every 3 years	
Nitrate and nitrite	Annually	New wells sampled quarterly for 1st year
Detected at ≥ 50% MCL	Quarterly	
Volatile organic chemicals (VOC)	Annually	New wells sampled quarterly for 1st year
Detected VOC	Quarterly	
Synthetic organic chemicals	Quarterly	New wells sampled quarterly for 1st year; DHS may revise frequency based on initial results and vulnerability assessment
Radiological	Once every 4 years	New wells sampled quarterly for 1st year; DHS may revise frequency to every 3 years to be consistent with other chemical classes
EPA and DHS Unregulated Chemical Monitoring		
Chemical Class	**Frequency**	**Monitoring Period**
DHS - 9 Inorganic and Organic Chemicals	2 Samples: (1) Vulnerable period: May-Jun-Jul-Aug-Sep (2) 5 to 7 months before or after the sample collected in vulnerable period	Monitoring to be completed between January 2001 and December 2003
EPA List 1 - Inorganic and Organic Chemicals		
EPA List 2 - Organic Chemicals		Same sample period as above but for only EPA selected water utility systems

The Basin is continuously monitored for the regulated chemical classes listed in Table 3-2. Typically, about one-third of the drinking water wells are sampled every year for general minerals, trace metals, and secondary MCL constituents (color, odor, TDS, sodium, chloride, alkalinity, etc.) VOCs and nitrates are sampled annually at every well. As noted in Table 3-2, the monitoring frequency is increased if VOCs and nitrates are detected. Quarterly monitoring is required for wells having detectable levels of VOCs or if nitrate concentrations exceed 50 percent of the MCL. In addition, OCWD will monitor wells routinely for selected chemicals on the unregulated lists, chemicals with Action Levels (ALs), or new chemicals of concern.

Analyses for synthetic organic chemicals (SOCs) include testing for herbicides, pesticides, plasticizers, and other semi-volatile organics and require use of 12 or more EPA methods to analyze for the regulated chemicals. Initial testing has been completed at all drinking water wells, which are currently on a reduced monitoring frequency. Newly-constructed wells are monitored for SOCs for four consecutive quarters to provide seasonal data for DHS to assess the long-term monitoring frequency in their vulnerability assessment.

In addition to the regulated chemicals, both EPA and DHS require monitoring for unregulated chemicals. Unregulated chemicals do not have an established drinking water standard, but are new priority chemicals of concern. For example, MTBE, the gasoline constituent that has affected groundwater water basins nationwide, is an EPA unregulated chemical. Perchlorate, an oxidizer used as a solid rocket propellant that affects the thyroid producing hormones, is on both the federal and state unregulated monitoring list. Monitoring provides occurrence and levels detected in drinking water supply wells as the first assessment step to determine if the establishment of a standard (MCL) is necessary. Wells must be sampled twice to comply with the unregulated chemical monitoring rules.

3.3.2 VOLATILE ORGANIC COMPOUNDS

OCWD has taken a proactive role to monitor the Basin for VOCs since 1986. Assembly Bill 1803, passed in the mid-1980s, required a one-time survey of drinking water groundwater resources to determine if solvents and other organics are chemicals of concern in California. The District expanded the monitoring program to include testing of agricultural, industrial, private, and domestic wells. This aggressive monitoring effort led to the discovery of the El Toro MCAS solvent plume. After years of extensive hydrogeologic investigation, the areal extent of the trichloroethylene (TCE) plume was defined, along with a groundwater cleanup plan, which includes the Irvine Desalter.

The aggressive VOC monitoring program detected solvents and degreasing chemicals, such as perchloroethylene (perc or PCE) and TCE, in the Forebay area of the Basin. Several drinking water wells were taken out of service when TCE and PCE exceeded the MCL of five parts per billion (ppb). One water utility is blending to reduce VOC levels to below the MCL, while another water utility uses wells that have very low concentrations only during periods of high demand. All drinking water wells are monitored at least annually for VOCs, and wells with detectable levels are on a quarterly monitoring frequency.

In response to the detection of VOCs in the Forebay area and findings in five water systems, OCWD initiated a groundwater investigation to identify potential responsible parties (PRP). The District solicited the Regional Water Quality Control Board (RWQCB) to prioritize its pollutant site investigations group to focus on the Forebay area groundwater contamination. Over 100 monitoring wells, many in cluster well configuration, were drilled, constructed, and completed in the Forebay area to provide a broad range of monitoring points to define the areal extent of VOC contamination. Monitoring wells are sampled as frequently as quarterly in areas of localized high concentrations of solvents and annually at other locations. The monitoring wells have been generally screened in the upper 350 feet and provide water quality of the upper level of the aquifer system. As new chemicals of concern arise, these chemicals are added to the VOC monitoring program to screen for their occurrence. For example, perchlorate, 1,4-dioxane, fuel oxygenates, and tertiary butyl alcohol are included in the Forebay VOC monitoring program.

3.3.2.1 VOLATILE ORGANIC COMPOUNDS – IRVINE SUBBASIN

The Basinwide VOC monitoring detected TCE in agricultural wells in the Irvine subbasin. Similar to the groundwater investigations initiated in the Forebay, OCWD constructed single-point and multi-point monitoring wells to supplement data collected from other production wells (active and inactive) to aid in defining the source and areal extent of the TCE. Results of the extensive monitoring activities identified the El Toro MCAS as the source of VOC contamination. Subsequent comprehensive groundwater investigation by the Navy confirmed that solvents originating from the base were contaminating the groundwater and migrating off-site. As noted previously, the Irvine Desalter project addresses the long-term cleanup of the polluted groundwater. Because the Irvine area does not have drinking water wells that would be routinely monitored for the regulated or unregulated chemicals, the data gaps are filled through OCWD's non-potable well monitoring program. The monitoring wells and accessible agricultural wells are sampled for volatile organics, general minerals, and selected chemicals of concern (i.e., perchlorate, 1,4-dioxane, etc.) to provide water quality information in this area of the Basin. The District will be participating in a shallow water isotopic tracer study to assess the inter-relationship of the near-shallow water with deeper, underlying aquifers. Tracer information will be valuable to understanding groundwater flow paths and average water ages.

3.3.2.2 BASINWIDE WATER QUALITY MONITORING ACTIVITIES

Approximately 200 non-municipal production wells located throughout the Basin are routinely sampled for VOCs and general minerals. The wells produce groundwater for multiple uses: drinking water (private, domestic), industrial processes, ponds (golf courses, residential and commercial complexes, recreational, etc.), and irrigation/agricultural. The monitoring frequency and constituents to be monitored are determined by the location of the well in the Basin, proximity to documented PRP release sites (i.e., well may be monitored semi-annually/quarterly as part of the Forebay VOC investigation), and periods of operation. In general, VOCs are sampled annually with general minerals analyzed between one to three years. Water quality data augment information collected at Title 22 drinking water wells and other monitoring programs or special studies.

3.3.3 SURFACE WATER QUALITY

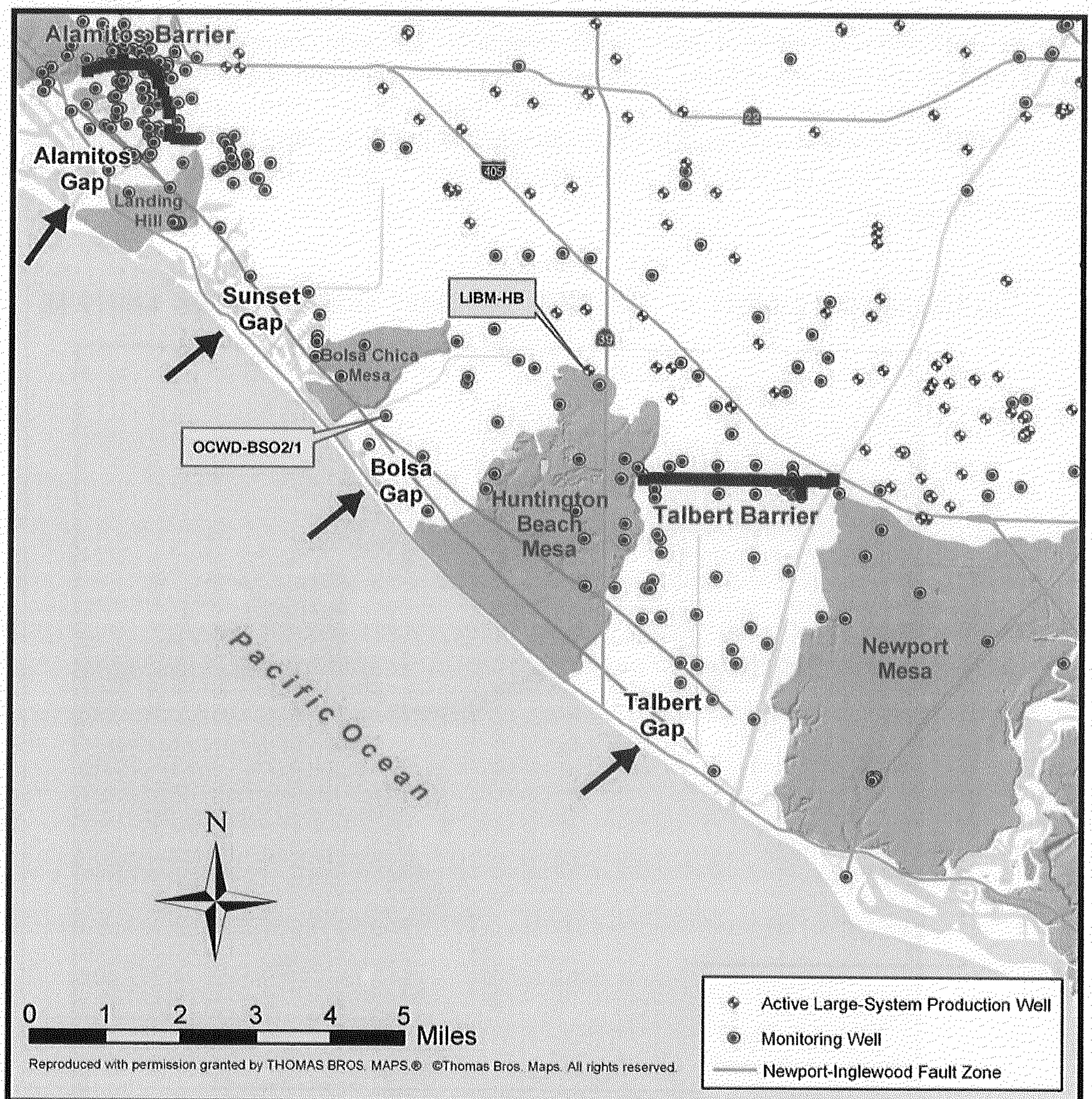
In addition to administering a comprehensive groundwater monitoring program, the District conducts routine monitoring of the SAR and major creeks and surface water bodies in the upper watershed that are tributary to the river. Since the quality of the river may affect groundwater quality, a routine monitoring program is maintained to continually assess ambient river water quality conditions. Characterizing the quality of the SAR and its impact on the Basin is necessary to verify the sustainability of continued use of river water for recharge and to safeguard a high-quality drinking water supply for Orange County. This is the overall goal of the SARWQH study. Monitoring the SAR and applicable tributaries will continue beyond the conclusion of the SARWQH study to evaluate the safety of the recharge of river water to replenish the Basin.

3.4 SEAWATER INTRUSION MONITORING AND PREVENTION

Since the early 1900s, monitoring and preventing the encroachment of seawater into fresh groundwater zones along coastal Orange County has posed a major Basin management challenge. Seawater encroachment also represents a key factor in determining the Basin operating range in terms of maximum accumulated overdraft. Besides seawater intrusion, other identified sources of coastal groundwater salinity include connate water (water trapped in the pores of the sediment at the time the sediments were deposited) and brines disposed at the ground surface from past oil production (Poland et al., 1956; DWR, 1961; DWR, 1968, J.M. Montgomery, 1974). The primary avenues for seawater intrusion are permeable sediments underlying topographic lowlands or "gaps" between the erosional remnants or "mesas" of the Newport-Inglewood Uplift, as shown in Figure 3-13. The susceptible locations are the Talbert, Bolsa, Sunset, and Alamitos Gaps. Most previous seawater intrusion investigations focused on the gaps rather than the mesas.

Figure 3-13

COASTAL PHYSIOGRAPHIC FEATURES AND SEAWATER BARRIER LOCATIONS



A coastal seawater monitoring program assesses the effectiveness of the Talbert Barrier to retard seawater intrusion through the Talbert Gap and to track salinity levels in the Bolsa and Sunset Gaps. Over 425 monitoring and production wells are sampled semi-annually to assess water quality conditions during periods of lowest production (winter) and peak demands (summer). Monthly water levels are measured in the coastal wells to evaluate seasonal effects of pumping and replenishment by the injection barrier.

The key groundwater monitoring parameters that OCWD uses to monitor seawater intrusion and the effectiveness of the Talbert and Alamitos Barriers include water level elevations, chloride, TDS, electrical conductivity, and bromide. Groundwater elevation contours for the aquifers most susceptible to seawater intrusion are prepared to evaluate the mound developed by the barrier injection wells and determine whether this mound is sufficient to prevent the inland movement of saline water. Chloride, a major ion indicative of groundwater salinity, is measured at OCWD's monitoring wells and used to track the extent and movement of saline water over time. Chloride concentration contours shown in Figure 3-14 illustrate how groundwater salinity has progressed inland since 1993 beneath the Newport and Huntington Beach mesas. In addition to contour maps, OCWD staff prepares and reviews chloride concentration trends at individual wells to identify and evaluate intrusion in specific aquifer zones (Figure 3-15). To combat this intrusion, future injection wells may be considered for construction on or adjacent to these mesas.

Figure 3-14

LANDWARD MOVEMENT OF 250 MG/L CHLORIDE CONCENTRATION CONTOUR

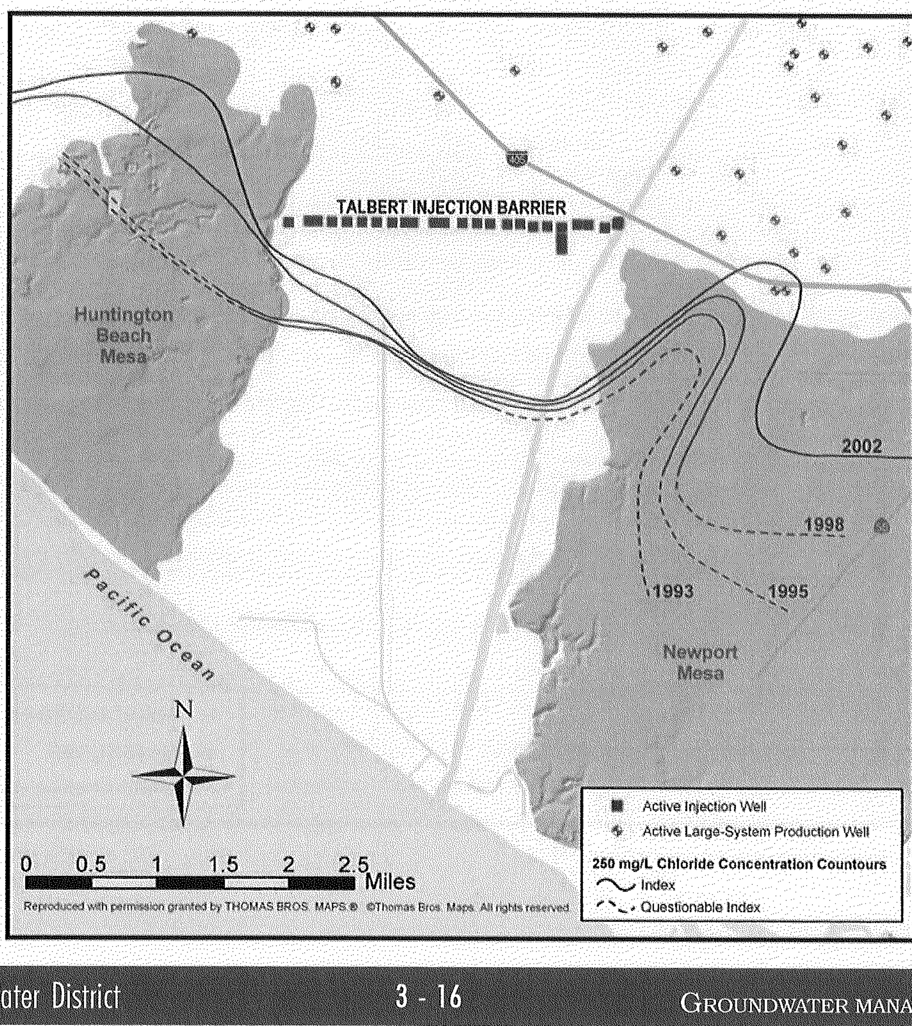
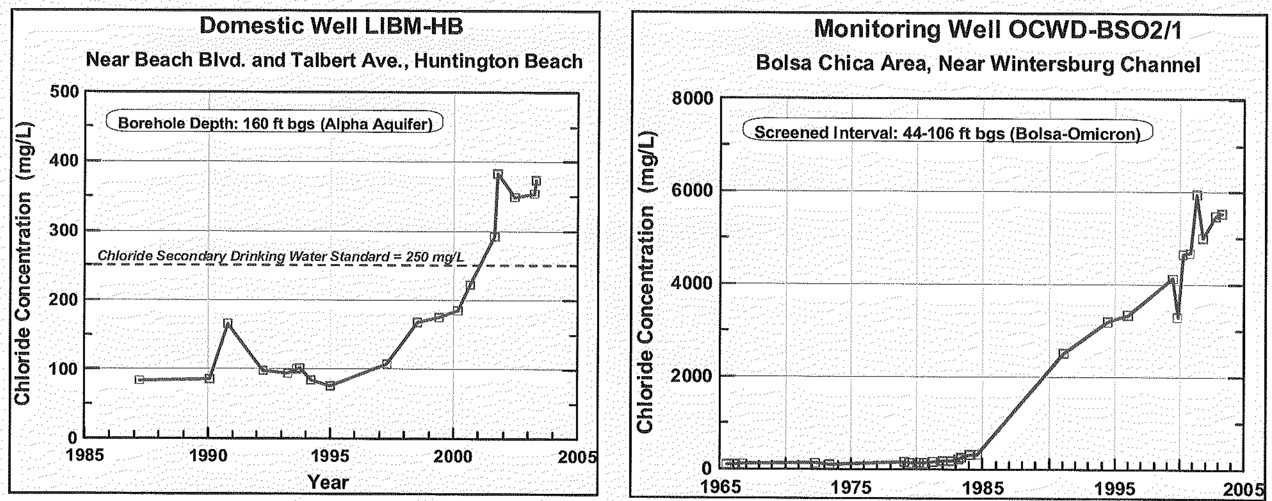


Figure 3-15

EXAMPLE CHLORIDE CONCENTRATION TREND CHARTS

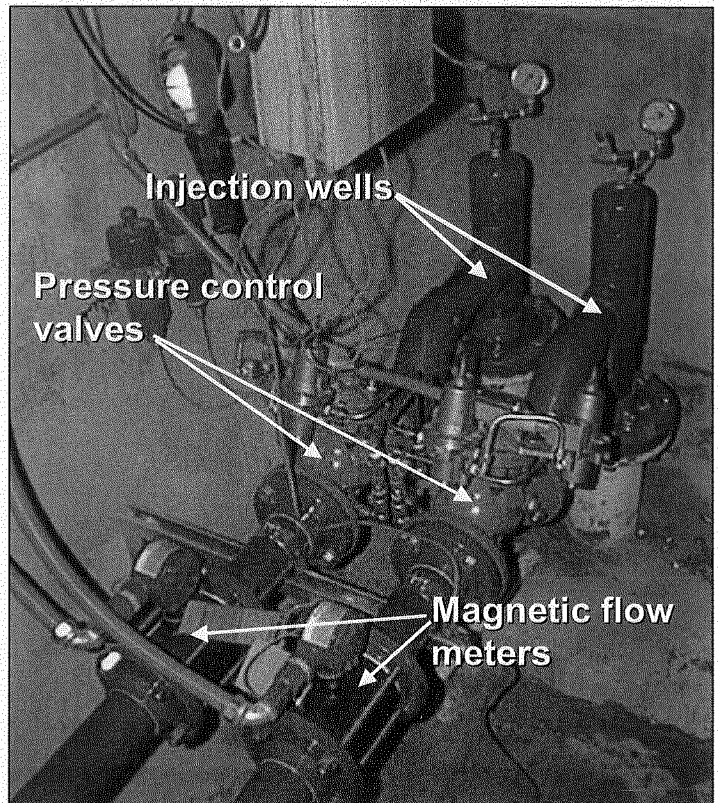


Investigations by OCWD in the last five years, including construction of several new monitoring wells, have focused on suspected salinity sources and intrusion pathways beneath the mesas themselves. Recent findings of these investigations were based on ratios of chloride, bromide, and iodine and corroborated previous DWR and USGS studies that indicated that connate water and past oilfield brine disposal represent key sources of salinity in addition to seawater intrusion.

Monitoring and operations of the Alamitos and Talbert injection wells are performed by LACDPW and OCWD, respectively. The Alamitos Barrier has operated since 1965 under a joint management and funding agreement between OCWD and LACDPW. A joint management committee comprised of OCWD, LACDPW, and other interested parties meet a minimum of twice per year to review operational data (flows, elevations, chlorides) and to evaluate the barrier's effectiveness and potential needs for improvement. Since going on line in 1975, the Talbert Barrier injection wells have been operated by OCWD. These wells are operated based on flow and pressure readings with the overall goal of maximizing total injection without over pressurizing the wells. Figure 3-16 shows a photo of automated pressure control valves and magnetic flow meters recently installed at a Talbert Barrier injection well. Plans are being prepared to upgrade the injection well flow/pressure/level monitoring and control systems at both barriers.

Figure 3-16

AUTOMATED FLOW/PRESSURE CONTROL VALVE AND MAGNETIC METERS



3.5 LAND SUBSIDENCE

Subsidence of the ground surface has been associated with groundwater withdrawal in many regions of the world. In the case of thick sedimentary groundwater basins comprised of alternating "confined" or "pressure" aquifers (permeable sands and gravels) and aquitards (less permeable silts and clays), such as in the central and coastal portions of the Basin, the extraction of groundwater reduces the fluid pressure of the saturated pore spaces within the buried sediments. The pressure reduction in the deeper sediments allows the weight of the overlying sediments to compact the deeper sediments, particularly the clays and silts. If groundwater withdrawals cause water level drawdowns to be sustained for several years or more, the incremental amount of sediment compaction can eventually manifest itself in a measurable lowering of the land surface (USGS, 1999).

OCWD commissioned a study by the DWR (1980) to evaluate the potential for land subsidence in the Basin. Because the study was limited in scope, its findings were deemed preliminary pending further investigation. Nevertheless, the study cited survey data from the Orange County Surveyor that indicated that the land surface in the City of Santa Ana declined a maximum of 0.84 inch/year from 1956 to 1961. Surveys during the period 1970 to 1976 indicated maximum land surface declines of 0.24 inch/year in Santa Ana. Key findings of the study included the following:

- Subsidence in the City of Santa Ana is apparently related to the removal of groundwater. However, it is not possible to directly correlate observed subsidence and historic water-level declines.
- Subsidence in the vicinity of the City of Huntington Beach can be attributed to the removal of oil.
- Most of the compaction takes place in the fine-grained sediments.
- Water squeezed out of the compacted fine-grained sediments, known as "water of compaction," is permanently mined from the Basin.

Land surface changes (rising and lowering) of similar magnitude to those noted by DWR were reported by Bawden (Bawden et al, 2001) while reviewing satellite radar images for a seismic assessment of Southern California. Bawden reported seasonal land surface changes of up to 4.3 inches (total seasonal amplitude from high to low) in the Los Angeles-Orange County area and a net decline of approximately 0.5 inch/year near Santa Ana over the period 1993 to 1999, which coincides with a period of net withdrawal of groundwater from the Basin. Despite the indications of land subsidence to some degree in portions of Orange County, there has been no indication that the suggested land surface changes have caused, or are likely to cause, any structural damage in the area. By maintaining groundwater levels and Basin storage within its historical operating range, the potential for problematic land subsidence will be reduced.

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section 4 Groundwater Production Management

Since its formation, the District has managed the Basin to increase supply rather than restrict demand – taking advantage of the Basin's value as a low-cost, natural water storage and distribution facility. The District's consensus-based program has enabled the Basin to avoid a lengthy, costly adjudication. This section:

- Describes the District's general management approach.
- Discusses the role of the BPP in managing pumping.
- Defines the Basin Production Limitation provision in the District Act
- Discusses the RA and BEA.

4.1 GENERAL MANAGEMENT APPROACH

As a general management policy, the District strives for uniformity of cost and access to Basin supplies without respect to how long an entity has been producing from the Basin. The District has operated under this management program since initiation of the RA in 1954. During that period, the District has witnessed an enormous growth in municipal and industrial water usage. Groundwater consumption for these users has increased from 50,000 afy to a maximum of 384,000 afy (including in-lieu supplies in 1999-2000). This reflects a very successful transition from an agricultural economy to an urban economy. In 1954, agricultural water uses were 100,000 afy and now are only 10,000 afy. Additionally, the population of the District in 1954 was 300,000 and now is about 2.3 million.

The uniformity in cost concept accommodated the tremendous growth of the cities in the District. Total groundwater production has approximately doubled since 1954. Every OCWD producer that is a city or a water district has increased its groundwater production over this period. The District's equitable management program has provided for the avoidance of a costly and divisive adjudication process of determining groundwater rights.

Historically, the District has also managed the Basin based upon seeking to increase supply rather than restricting demand. No pumping restrictions exist. Producers can obtain 100 percent of their water needs from the Basin, which greatly enhances their water reliability. The management program takes advantage of the Basin's value as a natural low-cost water storage and distribution resource.

Increased accumulated overdraft of the Basin since the late-1990s has prompted further evaluation of the Basin's yield and how the yield can be optimized through projects and programs. As a response to various factors, including the increased accumulated overdraft, in 2003 the District reduced the BPP, further described below, to reduce pumping from the Basin, the first reduction in overall pumping since 1993. This Plan describes an updated approach to manage the amount of water supply provided by the Basin. This approach is based on the methodology approved by the District's Board in 2002 that estimates the amount of groundwater production the Basin can annually sustain utilizing recharge water supplies the District can count on receiving.

Examples of the District's policies and management approach include:

- Increasing groundwater production sustainability by investing in facilities to capture greater amounts of SAR flows and to prevent seawater intrusion.
- Constructing Phase 1 of the GWR System to provide additional replenishment water and enhance the Talbert Barrier.
- Assisting Producers in reaching and maintaining the BPP.

- Establishing an individual BEA for each producer that provides for uniformity in cost for production above the BPP.
- Spreading the cost of items such as the coastal seawater barrier program, producer groundwater remediation projects, and the cost of Metropolitan replenishment water purchases among all users.
- Monitoring the Basin water quality for all Producers.
- Protecting the water rights and quality of the SAR flows.

The District is internationally known for its unique, proactive, supply-side management approach. The District, operating under these management philosophies, has been able to develop one of the most advanced and progressive modern groundwater management systems in the world. This has occurred while nearly every other major groundwater basin in Southern California has experienced a costly and time-consuming adjudication.

4.2 BASIN PRODUCTION PERCENTAGE

Section 31.5 of the District Act empowers the Board to annually establish the BPP, which is defined as "the ratio that all water to be produced from groundwater supplies within the District bears to all water to be produced by persons and operators within the District from supplemental sources as well as from groundwater within the District." The BPP is set uniformly for all Producers. The retail water agencies that produce the majority of the groundwater from the Basin are shown in Figure 4-1. Groundwater production below the BPP is assessed the RA. In addition, pumping limitations or requirements can be established for selected Producers. In-lieu water, which is described in Section 5, is regarded as groundwater production when calculating a producer's BPP.

It has been the District's general goal to maintain and/or raise the BPP as high as possible to allow Producers to pump as much groundwater as is possible, thereby lowering their overall water supply cost. Maintaining a constant BPP also allows for increased production out of the Basin since total water demands continue to increase.

Figure 4-2 shows the history of the BPP along with the actual BPP that was achieved by the Producers. Until recently, the actual BPP has sometimes been approximately five percent lower than the allowable BPP. This is primarily due to the IRWD, the Yorba Linda Water District (YLWD), and the City of Buena Park, which have been unable to pump up to the BPP.

Figure 4-1

RETAIL WATER AGENCIES IN ORANGE COUNTY

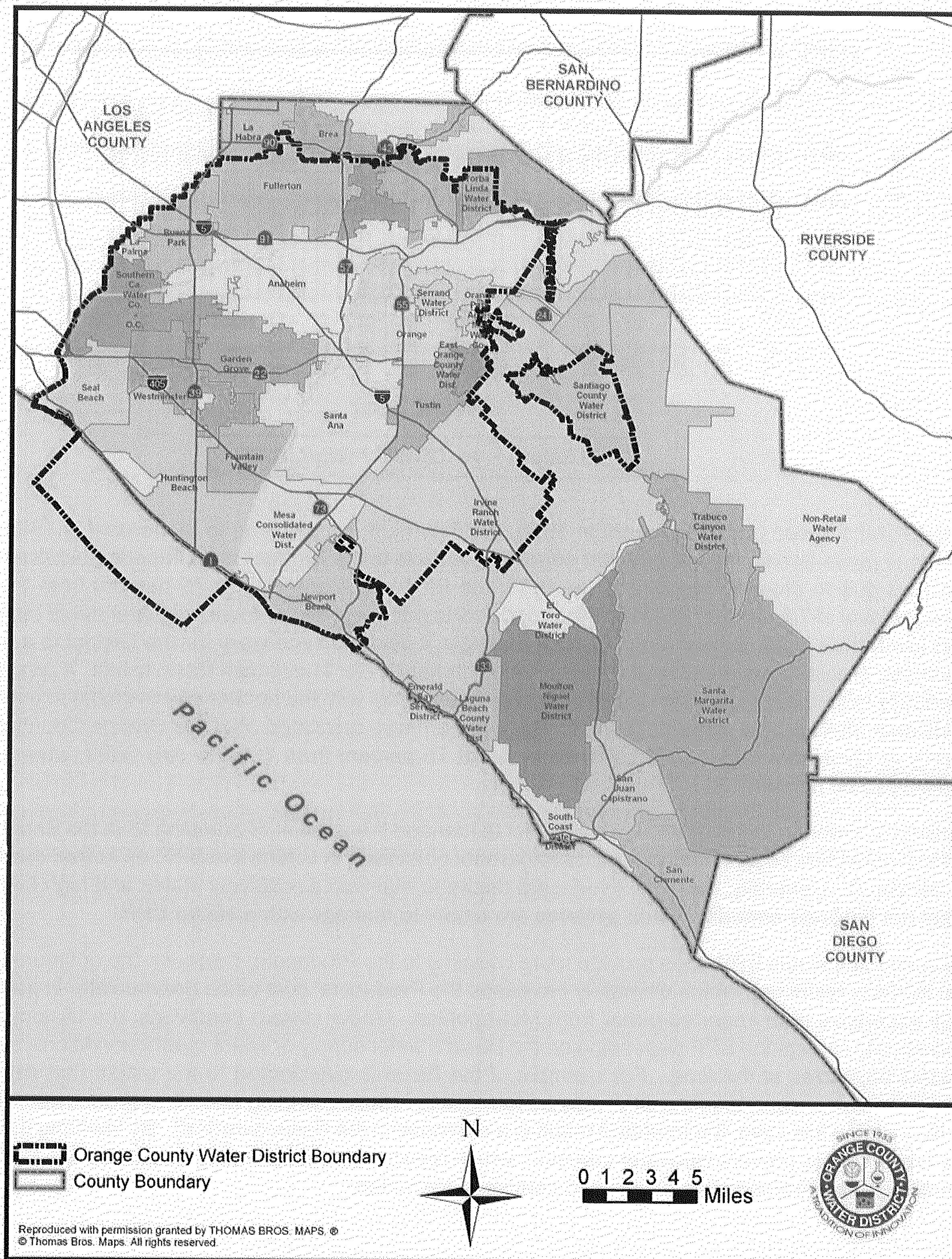
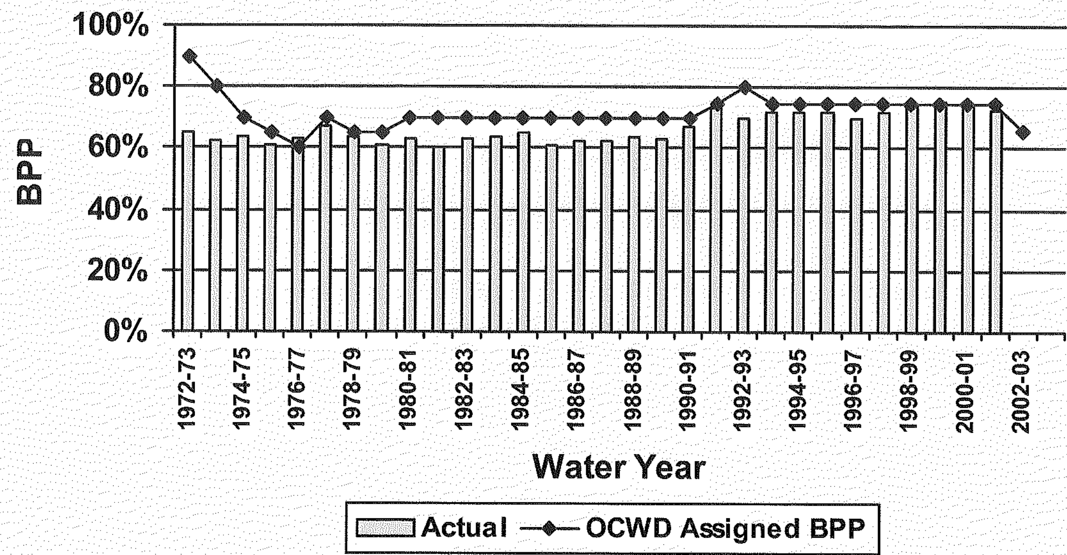


Figure 4-2

BASIN PRODUCTION PERCENTAGE HISTORY



The BPP increased from 70 percent in 1990, to 75 percent in 1991, and to 80 percent in 1992. This increase made additional groundwater supplies available to the Producers as imported supplies were reduced due to drought conditions. In 1993, the BPP was increased to 75 percent from the pre-drought level of 70 percent, allowing the Producers to pump greater amounts of water out of the Basin and lower their water supply cost. Correspondingly, it became necessary for the District to annually purchase greater amounts of Metropolitan replenishment water to maintain Basin levels. A program to gradually raise the RA was developed to provide the District with the necessary revenues to purchase additional Metropolitan water each year. This program was rescinded after the Orange County bankruptcy in December 1994. The BPP remained at 75 percent from 1993 to July 2003, when it was reduced to 66 percent.

Raising or lowering the BPP allows the District to manage the amount of pumping from the Basin. The District considers several factors and management objectives in setting the BPP, as further described in Section 9. Generally, the retail Producers desire to maintain a relatively stable and high BPP that does not fluctuate annually. Their systems are easier to manage with a stable BPP.

Maintaining a stable BPP does provide more certainty to the Producers; however, the optimum use of the Basin is restricted, which ultimately increases the Producers' cost since groundwater is generally less expensive than imported water from Metropolitan. Under certain conditions, the District would periodically change the BPP depending on the Basin's water supply or water quality conditions, and the District objectives at the time. For example, if the Basin is overdrafted to the extent that seawater intrusion is a concern, then the BPP may be lowered to reduce pumping and allow groundwater levels to recover. In this case, the intended result is a decrease in the Basin overdraft. By lowering the BPP, the District helps prevent seawater intrusion, which results in lower operating costs over the long term since expensive remediation of intruded seawater is avoided.

Changes in the BPP also affect the District's revenue, since the District's primary source of revenue is from collection of the RA. Decreasing the BPP results in less pumping on which the RA is collected, causing the District's revenue to decrease. Increasing the BPP correspondingly increases the District's revenue, assuming all other factors are equal.

4.3 BASIN PRODUCTION LIMITATION

Section 31.5 of the District Act allows the District to set a Basin Production Limitation for persons or operators. Section 31.5(g)(7) says "Production requirements or limitations and the surcharge for production in excess of the Basin production limitations on persons and operators within the district shall be applicable during the ensuing water year."

Previously, the District placed some Producers who could not pump up to the BPP on Pumping Limitations (for pumping below the BPP). Under a limitation, the District pays the producer the BEA. However, this program was later discontinued primarily in favor of the Conjunctive Use Well program, which provided financial incentives to assist Producers with the construction of additional wells. With the additional wells, several Producers were then able to pump up to the BPP.

Basin Production Limitations provide the District with a tool to manage pumping from selected portions of the Basin. Basin Production Limitations are currently being utilized with some coastal Producers as part of the Temporary Coastal Pumping Transfer Program, which shifts approximately 20,000 afy pumping from the coastal area to inland to minimize seawater intrusion.

4.4 REPLENISHMENT AND BASIN EQUITY ASSESSMENTS

The RA is paid by the Producers for all groundwater production within the BPP and is $149 per af for 2003-04. The RA was first implemented in 1954 and is established by the OCWD Board each April for the ensuing water year beginning July 1. The RA currently provides the District with approximately two-thirds of its operating revenue.

Increasing the RA directly impacts the cost of water supplies to the producer and ultimately the water consumer. Figure 4-3 presents the estimated impact of RA changes on the monthly bill of a residential home. As shown, a $10 increase to the RA increases the monthly consumers water bill by $0.27/month. Therefore, for every one-dollar increase to the RA, the monthly consumer's water bill increases by approximately $0.03/month.

In addition to the RA, groundwater production above the BPP is charged an assessment called the BEA, which is calculated for each producer and is currently around $315/af. The BEA is calculated so that the cost of groundwater production above the BPP is financially equivalent to purchasing supplies from Metropolitan.

Figure 4-3

REPLENISHMENT ASSESSMENT VS CONSUMER MONTHLY WATER BILL

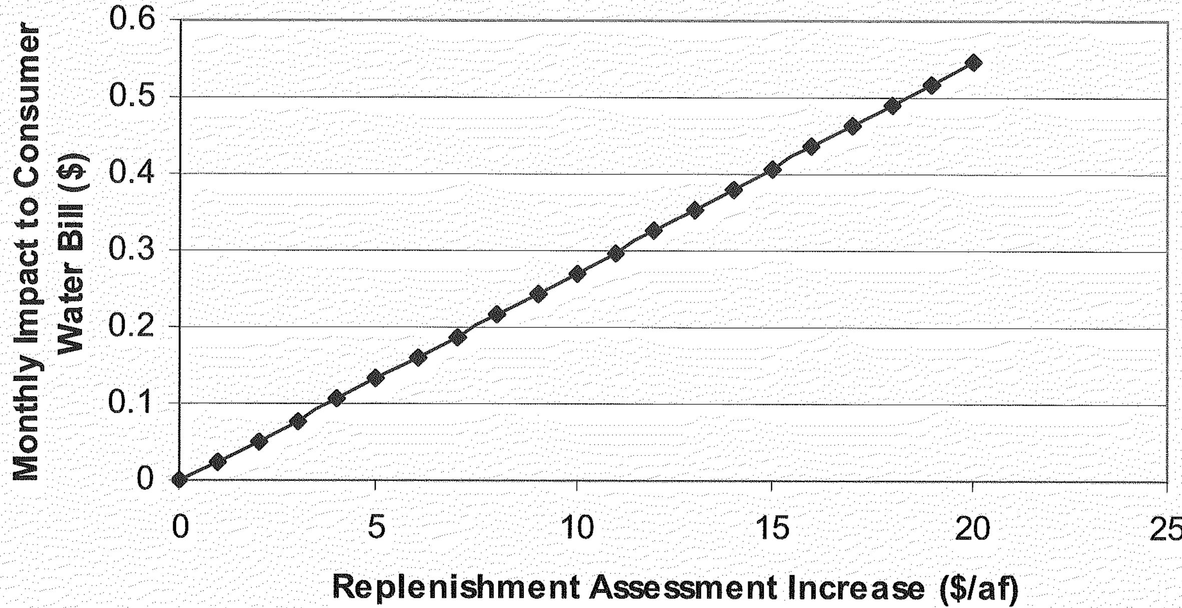


FIGURE 4-3 ASSUMPTIONS:

- A family of four uses 0.5 afy of water
- BPP of 66 percent for groundwater, remaining 34% from Metropolitan imported water supplies
- RA of $149/af
- Energy cost of $54/af to pump groundwater
- Production well operation and maintenance (O&M) cost of $68/af (energy cost and operation and maintenance cost are based on surveys of the Producers reported in the annual OCWD Engineer's Report)
- Metropolitan imported water cost of $470/af including Readiness-to-Serve charge and MWDOC surcharge

section 5 Recharge Water Supply Management

Groundwater pumping in the Basin removes groundwater from the aquifers. Removal of pumped groundwater needs to be balanced with refilling the Basin so that the amount of water is sufficient to meet future pumping needs. In addition to natural replenishment processes that refill the Basin, the District maintains programs to enhance recharge. The Basin's primary source of water for groundwater recharge ('recharge water') is the SAR. River flows are diverted into spreading basins located in the cities of Anaheim and Orange for percolation into the Basin. The District also operates the Talbert Barrier in Fountain Valley and Huntington Beach and participates in the Alamitos Barrier in Seal Beach and Long Beach. In addition to helping to prevent seawater intrusion, the barriers also help refill the Basin.

This section:

- Provides an overview of the 17 major facilities in the District's four groundwater spreading systems.
- Describes OCWD's seawater intrusion barriers.
- Discusses sources of recharge water, including the SAR (baseflow and stormflow), Santiago Creek flows, and imported supplies.
- Outlines the District's program to monitor the quality of recharge water.

5.1 RECHARGE FACILITIES

The Basin is recharged (refilled or replenished) by multiple sources. These include artificial, i.e., by man-made systems, and incidental or natural recharge. Artificial recharge within the Basin occurs in the Forebay through percolation spreading facilities and also via injection through the Talbert and Alamitos Barriers. Spreading facilities in the Forebay recharge water from the SAR and Santiago Creek and supplemental water purchased from Metropolitan.

OCWD currently owns and operates approximately 1,000 acres of recharge spreading facilities located in and adjacent to the SAR and Santiago Creek. Recharge activities date back to 1949, when the District first began purchasing imported supplies from the Colorado River. In 1953, OCWD began improvements in the SAR bed, including deepening of river channels and construction of off-channel spreading basins. Subsequently, OCWD has built a recharge system that provides the majority of water supplied by the District.

The 17 major facilities in the Anaheim/Orange area are grouped into four major components: the Main River System, the Off-River System, the Deep Basin System, and the Burris Pit/Santiago System. Each system has a series of percolation spreading basins, either shallow or deep, whose sidewalls and bottoms allow for percolation into the underlying aquifer.

For the most part, water enters these facilities from the SAR downstream of Prado Dam. Flows in the SAR at Imperial Highway are controlled at the District's main control facility, the Imperial Highway Inflatable Dam and Bypass Structure. From there, water flows by gravity or pumps between the various recharge basins, either by pipelines, overflow weirs, or open channels.

The primary function of the facilities is to recharge the aquifer or Basin. The rate at which water enters from the surface into the ground is called the percolation rate (or recharge or infiltration rate) and is the main factor in determining the effectiveness of the recharge facilities. Percolation rates tend to decrease with time as the percolation spreading basins develop a thin clogging layer from fine grain sediment deposition and from biological growth. Percolation rates are restored by mechanical removal of the clogging layer from the basins. The higher percolation rates allow a greater quantity of water to be put into the Basin in less time.

Table 5-1 presents an overview of each system, including the basins included in each system and their hydraulic characteristics. The facilities are depicted graphically in Figure 5-1.

Table 5-1

OVERVIEW OF GROUNDWATER RECHARGE SYSTEMS

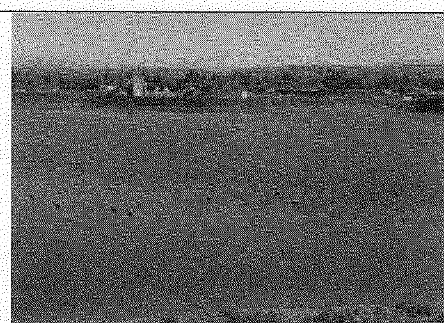
MAIN RIVER SYSTEM
(Imperial Highway to Ball Road)
Area: 245 acres
Storage capacity: 480 af
Percolation Rate:
Clean 115 cfs
Clogged 87 cfs

North View of SAR Near Imperial Highway

OFF-RIVER SYSTEM
Weir Ponds
1, 2, 3, and 4
Off-River between Weir Pond 4 and Carbon Creek Diversion Channel
Area: 126 acres
Storage capacity: 394 af
Percolation Rate:
Clean 40 cfs
Clogged 15 cfs

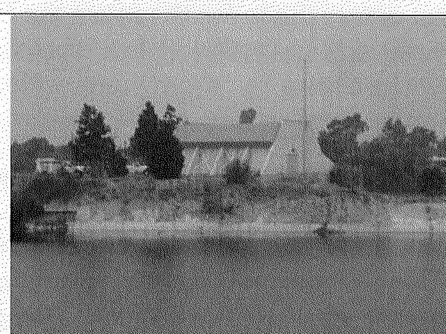
Off-River (on left side of main river channel)

DEEP BASIN SYSTEM
Huckleberry Basin
Conrock Basin
Warner Basin
Little Warner Basin
Anaheim Lake
Mini Anaheim
Miller Basin
Kraemer Basin
Placentia Basin
Raymond Basin
Area: 280 acres
Storage Capacity: 8,484 af
Percolation Rate:
Clean 300 cfs
Clogged 89 cfs



Kraemer Basin

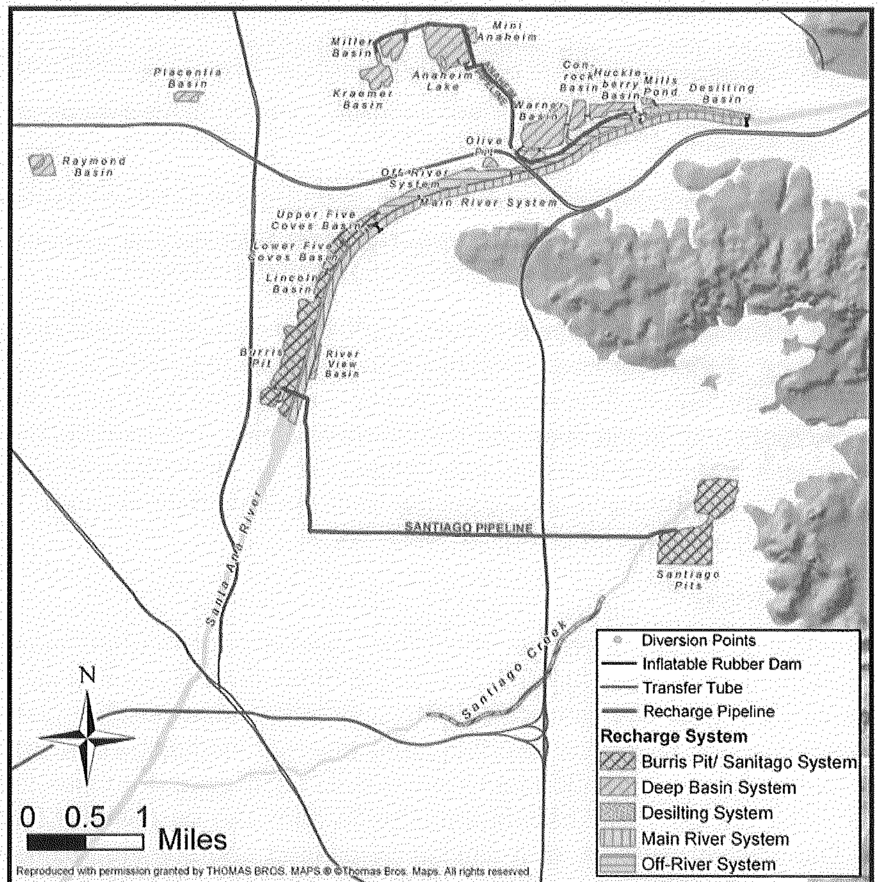
BURRIS PIT/SANTIAGO BASIN SYSTEM
Five Coves Basins
Lincoln Basin
Burris Pit
Ball Road Basin
Blue Diamond Pit
Bond Pit
Smith Pit
Area: 373 acres
Storage Capacity: 17,500 af
Percolation Rate:
Clean 210 cfs
Clogged 106 cfs



Burris Pit Station

Figure 5-1

ORANGE COUNTY WATER DISTRICT RECHARGE FACILITIES



5.1.1 MAIN RIVER SYSTEM

The Main River System consists of the SAR Channel, just west of Imperial Highway to Ball Road. In the area generally south of Ball Road, the Basin is separated from the ground surface by a low-permeability clay layer. This reduces the ability to recharge river water south of Ball Road. The river's unlined channel bottom consists of very sandy permeable material and upstream of Ball Road is directly connected to alluvial materials that allow water to percolate down into the underlying aquifers. The SAR reach hydraulically connected to the underlying aquifers is approximately six miles long and 300-400 feet wide and extends from Imperial Highway to Ball Road.

The District maximizes recharge by constructing a series of sand levees in the river using bulldozers. The sand levees increase the residence time and spread the wetted areas within the permeable sections of the river, thus increasing percolation. Typically, water flows at a velocity sufficient to prevent the fine sediment and biological growth from accumulating. When sediment and growth do accumulate, the system is cleaned with heavy equipment to restore the high percolation rate. The riverbed is also cleaned naturally, when stormflows in the river each winter and spring wash out the levees and scour the riverbed.

The capacity to transfer water through this system is equal to the capacity of the SAR as a flood protection channel. Currently, the U.S. Army Corps of Engineers (ACOE) regulates the flow out of Prado Dam to a maximum of approximately 7,000 cubic feet per second (cfs). Upon completion of its

SAR Mainstem Project, the ACOE will have the capability to discharge significantly larger flows, mainly when flood conditions exist. The District's Headgates facilities (i.e., the Imperial Highway Inflatable Dam and Bypass Structure) can control river flows up to 2,000 cfs; however, the sand levees only remain intact during flows up to 350 cfs. Above 350 cfs, the sand levees erode away, and water flows from bank to bank in the riverbed. Although high percolation rates are believed to take place during these conditions, these rates are difficult to measure when river flows are high. When river flows are above 2,000 cfs, the rubber dams are deflated, and only minimal water can be diverted for recharge into the Deep Basin System described in Section 5.1.3.

SAR flows change throughout the rainy season, with extremely high flows possible during the winter months. SAR flows are extremely variable, depending on upstream precipitation conditions. The diversion capacities and capabilities allow different operational strategies.

The SAR river bed percolation rate has declined approximately one percent per year for the last 20 years due to armoring of the river bed. This has occurred due to sand being trapped behind Prado Dam. Sand that would naturally flow down the river is trapped behind Prado Dam, which over time reduces the amount of sand in the river bed below Prado Dam. The river bed sediments have thus gradually become less conducive to percolation, particularly in the area closest to Imperial Highway. This problem, which is commonly reported in river bed sediments downstream of dams, is further discussed in the District's Recharge Study (OCWD, 2003).

5.1.2 OFF-RIVER SYSTEM

The Off-River System consists of a shallow sheet-flow channel separated from the Main River System by a levee. The Off-River System runs parallel to the Main River System beginning at the Imperial Highway Inflatable Dam (just downstream from the diversion structure at Imperial Headgates) and ends at the Carbon Canyon Diversion Channel. The Imperial Inflatable Dam, which was installed in 1993, is seven feet in diameter and 300 feet long and is constructed of rubberized fabric that can be inflated with air. The pooled water behind the inflated dam can be diverted through the headgate facilities to the Deep Basin System, or it can be by-passed and continue to flow down river. The Headgate facilities consist of gated conduits within the river levee. Racks to screen out trash are located upstream of the gates to prevent debris from entering the Off-River System.

A desilting system precedes the Off-River System, allowing sand and silt to settle out. It is composed of four weir settling ponds with a surface storage of approximately 200 acre-feet and has been in operation since 1974. The remainder of the Off-River System parallels the SAR channel from Weir 4 to Carbon Canyon Diversion Channel. It is approximately 2.3 miles long and 200 feet wide and has been in operation since 1988. Water transfer facilities at the beginning and end of the Off-River System have hydraulic capacity of 500 cfs; however, because of geologic conditions in this area, only a maximum percolation rate of 40 cfs can be attained. Therefore, hydraulic flows of approximately 100 cfs or less are usually maintained in this system. Flows that reach the end of the Off-River System are routed to the Burris Pit/Santiago System, described in Section 5.1.4.

5.1.3 DEEP BASIN SYSTEM

The Deep Basin System consists of the Warner Basin Sub-system (which includes Huckleberry Pond, Conrock Basin, Warner Basin, and Little Warner Basin), along with Anaheim Lake, Mini Anaheim, Miller Basin, Kraemer Basin, Placentia Basin, and Raymond Basin. These recharge basins range in depth from 10 feet to 60 feet. Portions of their side-walls and bottoms are composed of natural sandy pervious materials that allow water to percolate into the aquifer. Due to the size and depths of the basins, percolation velocities may be slow, allowing for the majority of the fine-grained sediment particles to settle out. The basins can be drained and cleaned using equipment to remove the clogging layer, thereby restoring percolation rates and increasing recharge efficiency.

Up to 400 cfs of the flow in the desilting system can be diverted to the Warner Sub-system, with the remaining flow moving to downstream facilities. When the Warner Sub-system is full, flows must be reduced to approximately 250 cfs in order to match the percolation of the Warner System and the transmission capacity of the pipeline servicing the other downstream basins (Anaheim Lake, Miller, Kraemer, Placentia, and Raymond). As diversions to Warner are reduced to match percolation, flows will increase in the Off-River System and/or the SAR. Flow in the river percolates at a rate of approximately 100 cfs from Imperial Highway to Ball Road. Excess flows beyond 100 cfs and less than 500 cfs can be diverted at the Five Coves Rubber Dam into Five Coves, Lincoln, and Burris Pit Basins. During storm events, flows over 500 cfs are lost to the ocean beyond this dam. Five Coves Rubber Dam, constructed in 1994, is essentially the same size and construction as Imperial Rubber Dam.

Placentia and Raymond basins are owned by the Orange County Public Facilities and Resources Department (PF&RD) and can only be used during the non-flood season. Water is conveyed to these basins using the Carbon Creek Channel.

5.1.4 BURRIS PIT/SANTIAGO SYSTEM

The Burris Pit/Santiago System consists of Five Coves Basin, Lincoln Basin, Burris Pit and Ball Road Basin along the SAR, and the Santiago Pits (Blue Diamond Pit, Bond Pit, Smith Pit) and Santiago Creek five miles east of the river. The system begins at the confluence of the SAR and the Carbon Canyon Diversion Channel and ends at the Santiago Basins in Orange.

Of these basins, only Five Coves Basin can be currently cleaned in the same manner as the previously-described systems. Efforts are in progress to improve the recharge capabilities of some of the other basins.

A water transfer capacity of 500 cfs exists at the beginning of the Burris Pit/Santiago System via the Five Coves Inflatable Rubber Dam, through Lincoln Basin, and into Burris Pit. From Burris Pit, water can be pumped at a rate of up to 235 cfs through the Burris Pit Pump Station and conveyed by the 66-inch Santiago Pipeline to the Santiago Pits. Flows of 500 cfs can be maintained for several days while Burris Pit is filling; however, once Burris Pit and the Santiago Pits are full, the flow must be reduced to match the minimum percolation rate of Santiago Pits (approximately 100 cfs).

Santiago Creek is the primary drainage for the Santa Ana Mountains. Santiago Reservoir (Irvine Lake) is used by the Serrano Water District, IRWD, and TIC to retain Santiago Creek flows. Releases from Santiago Reservoir flow downstream to Villa Park Reservoir, a county-owned flood control basin behind Villa Park Dam. At this point, Serrano Water District captures and treats approximately 3,000 afy from Santiago Creek, which adds to the overall local supply. These flows have been relatively constant over recent years. OCWD's Santiago basins are located downstream of Villa Park Dam, where Santiago Creek reaches the Basin. Except for extremely wet years, Santiago Creek flows below Villa Park Dam are generally less than 10 cfs.

In 2000, the District completed the Santiago Creek Recharge Project, consisting of a metered turnout from the existing Santiago Pipeline into Santiago Creek, immediately downstream of the Santiago Pits. Using the 42-inch turnout pipeline, an average of 10 cfs can be fed into the creek at times when the

Burris Pit Pump Station is discharging water to the Santiago Pits. The flow to the creek is recharged to the Basin as the water travels down the sandy and rocky creek bed. Typically, all of the 10 cfs flow is percolated into the ground before reaching Hart Park in the City of Orange.

In 2003, the Santiago Pits Pump Station was completed in the bottom of Bond Pit. The purpose of the pump station is to pump water out of the Santiago Pits, into Santiago Creek or back down into the Santiago Pipeline. From the pipeline, the water can be discharged to the River View Recharge Basin (completed in fall 2003) or back to Burris Pit. Pumping the water to these recharge points increases the quantity of percolation to the Basin and creates capacity in the Santiago Pits for storage of water from winter storms. Draining down the pits also allows the walls of the pits to dry out, which acts to increase the percolation rate the following year.

5.15 IMPROVEMENTS TO RECHARGE FACILITIES

The District regularly evaluates potential projects to improve the existing recharge facilities and build new facilities. Improvements to the existing facilities may include:

- Improvements in the ability to transfer water from one recharge basin to another.
- Improvements in the ability to remove the clogging layer that forms on the bottom of the recharge basins.
- Improvements to the shape or configuration of the basin to increase the infiltration rate or ability to clean the basin.
- Converting an existing underperforming recharge basin to a new type of recharge facility.

The District also regularly evaluates building new facilities. This effort includes:

- Evaluating potential sites for purchase and subsequent construction of a recharge facility.
- Evaluating potential dual-use sites, where a subsurface recharge system could be built and remain compatible with the existing use. An example is building a subsurface in filtration gallery under a parking lot.

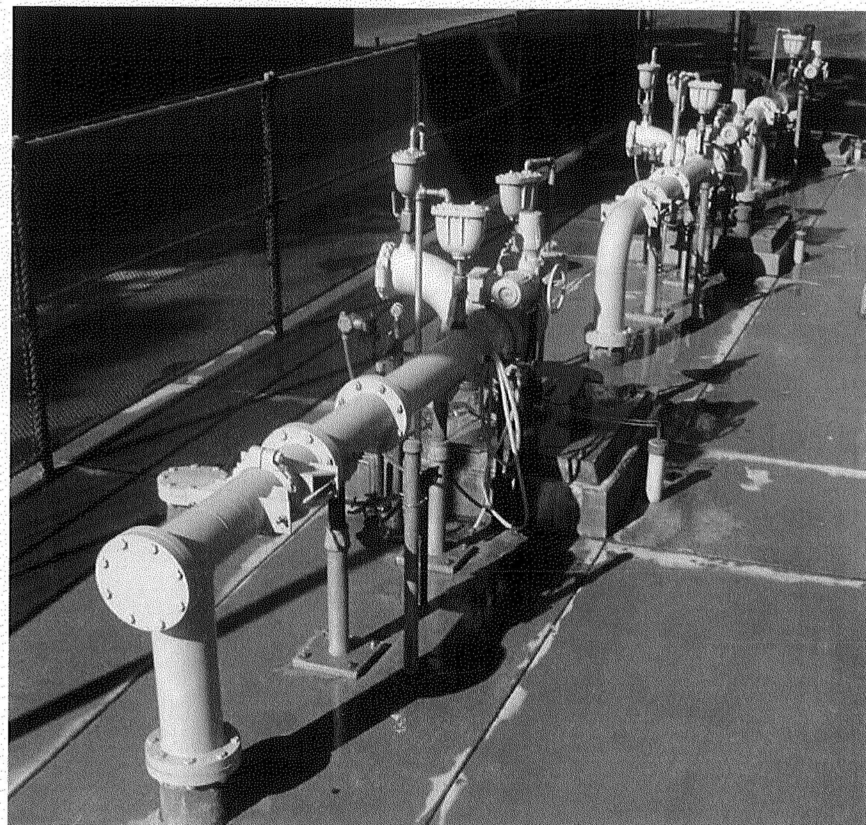
The primary goal of these potential projects is to increase the District's recharge capacity. The District's Recharge Study (OCWD, 2003) contains more details on these efforts.

5.2 SEAWATER INTRUSION BARRIERS

OCWD's Talbert Barrier is composed of a series of 26 injection wells that span the 2.5-mile-wide Talbert Gap between the Newport and Huntington mesas. In 2003, the injection water blend was comprised of purified water from OCWD's WF-21, deep well water, and imported potable water. This blend has changed throughout the years since WF-21 was commissioned in 1975. The Talbert Barrier wells inject an average of 12 mgd of water into four aquifer zones. Injecting water through the wells forms a hydraulic barrier to seawater that would otherwise migrate inland toward areas of groundwater production. Figure 5-2 shows one of the Talbert Barrier injection wells.

Figure 5-2

TALBERT BARRIER INJECTION WELL



WF-21 was decommissioned in 2004 and is being replaced with the GWR System, which will include 12 new wells and allow injection of up to 35 mgd of purified water into the expanded injection barrier and 35 mgd forebay recharge. The GWR System, which will be constructed by 2007, will better control seawater intrusion as well as replenish the coastal aquifers. Additional details on the GWR System are provided in Section 5.3.5.2.

The Alamitos seawater intrusion barrier is composed of a series of injection wells that span the Los Angeles/Orange County line in the Seal Beach-Long Beach area. It is operated by the LACDPW in cooperation with OCWD and the WRD. The source of this water is currently potable supplies from Metropolitan, but in the future will be split evenly (50/50 blend) between purified water from WRD and potable supplies from Metropolitan. Also, the Alamitos Barrier System includes four extraction wells located seaward of the injection barrier to create a pumping trough to remove the degraded brackish groundwater.

5.3 SOURCES OF RECHARGE WATER

Sources of recharge water include SAR baseflow and stormflow, Santiago Creek flows, imported supplies purchased from Metropolitan, supplemental supplies from the upper SAR Watershed (e.g., the Arlington Desalter), and purified water from WF-21 and the GWR System (future).

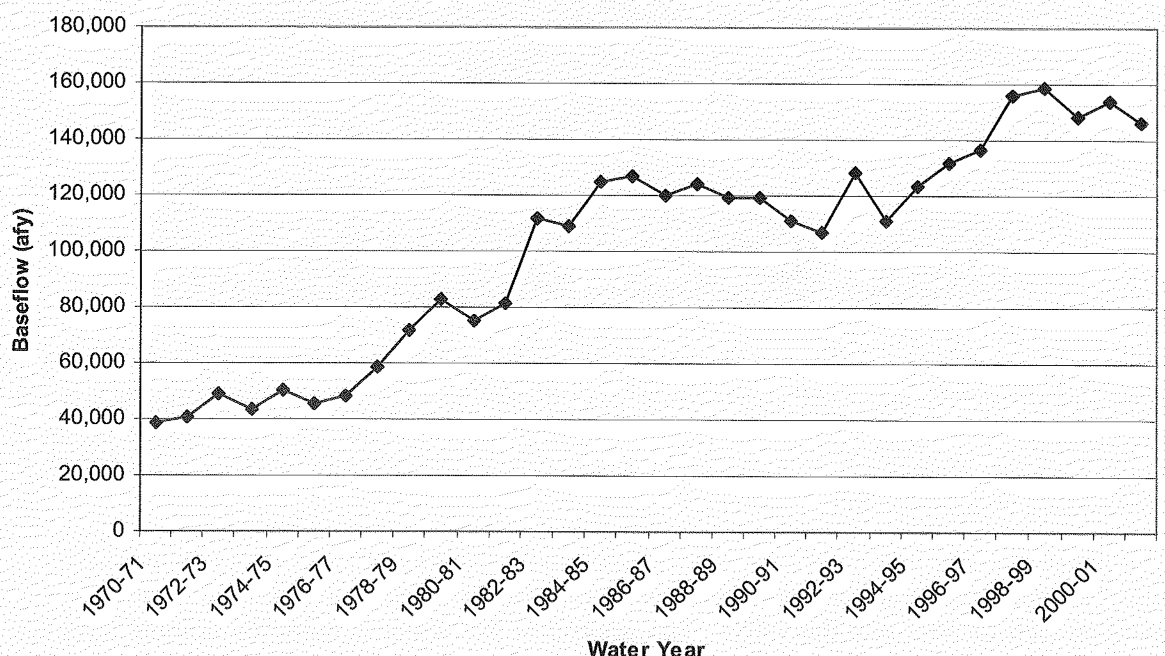
5.3.1 SANTA ANA RIVER BASEFLOW

The primary source of replenishment for the Basin is SAR flows. SAR flows below Prado Dam consist of a perennial baseflow component and a seasonal stormflow component. The majority of baseflow, especially in the summer months, is composed of tertiary-treated wastewater discharges from wastewater treatment facilities upstream of Prado Dam. Future estimated increases in population in the upper SAR watershed will result in baseflow increases. Since the 1970s, SAR baseflow has increased with additional runoff and treated wastewater discharges from the establishment of upstream residential communities. Baseflow increases are a replenishment source to the Basin. Figure 5-3 illustrates historic baseflow in the SAR at Prado Dam for the period of 1970-2002. Currently, the District is able to capture and percolate all of the SAR baseflow during non-storm events.

OCWD is allotted by court decision a minimum SAR baseflow of 42,000 afy. Wastewater discharges showed an increase from approximately 47,000 afy in 1970 to approximately 170,000 afy in 2002 (SAR Watermaster, 2003). For the same period, baseflow increased from 38,000 to 146,000 afy. The total increases in treated wastewater discharge and baseflow over the historic period are related.

Figure 5- 3

BASEFLOW IN THE SANTA ANA RIVER AT PRADO DAM



The year-to-year fluctuations in the baseflow reflect the influence of stormwater and groundwater interactions, as indicated by sharp increases during the wet years of 1983 and 1993 and the declining trend of the drought years 1986-1992. Wastewater discharges are normally slightly greater than measured SAR baseflow except during periods of high rainfall.

Over the long term, baseflow into Prado Dam and treated wastewater discharges into the SAR upstream of Prado Dam have a direct correlation. Releases to the SAR and baseflow show a historical correlation of almost one-to-one, i.e., a given increase in wastewater discharged into the SAR in the upper watershed caused an equivalent increase in baseflow at Prado Dam.

Reclamation programs, water conservation, and regulatory requirements could affect the amount of wastewater discharged into the SAR. While current baseflow exceeds the minimum amount required at Prado Dam, reclamation programs in the upper SAR watershed could reduce SAR baseflows and impact the amount of water captured and spread in Orange County. Based on projections by the Santa Ana Watershed Project Authority (SAWPA), wastewater discharges to the SAR are expected to range from 200,000 afy to over 240,000 afy in 2025, depending on the amount of water reclamation.

5.3.2 SANTA ANA RIVER STORMFLOW

The volume of groundwater replenished from SAR stormflows is a function of precipitation intensity, duration, impervious area, and distribution over a given year. Although stormflows average approximately 33 percent of the total SAR flows, they average a lower percentage of the total water recharged at OCWD's spreading facilities. This is primarily because the magnitude of stormflow releases from Prado Dam often greatly exceeds the percolation capacity of the spreading basins. For example, an SAR stormflow of 3,000 cfs is roughly six times the estimated maximum percolation capacity of the spreading basins at 500 cfs. The volume of water lost to the ocean in this case amounts to approximately 5,000 af/day. On average, the District captures and percolates approximately 50,000 afy of stormflows. Figure 5-4 illustrates the amount of SAR stormflow at Prado Dam (measured at the gauging station below Prado Dam).

Figure 5-4

SANTA ANA RIVER STORMFLOW AT PRADO DAM

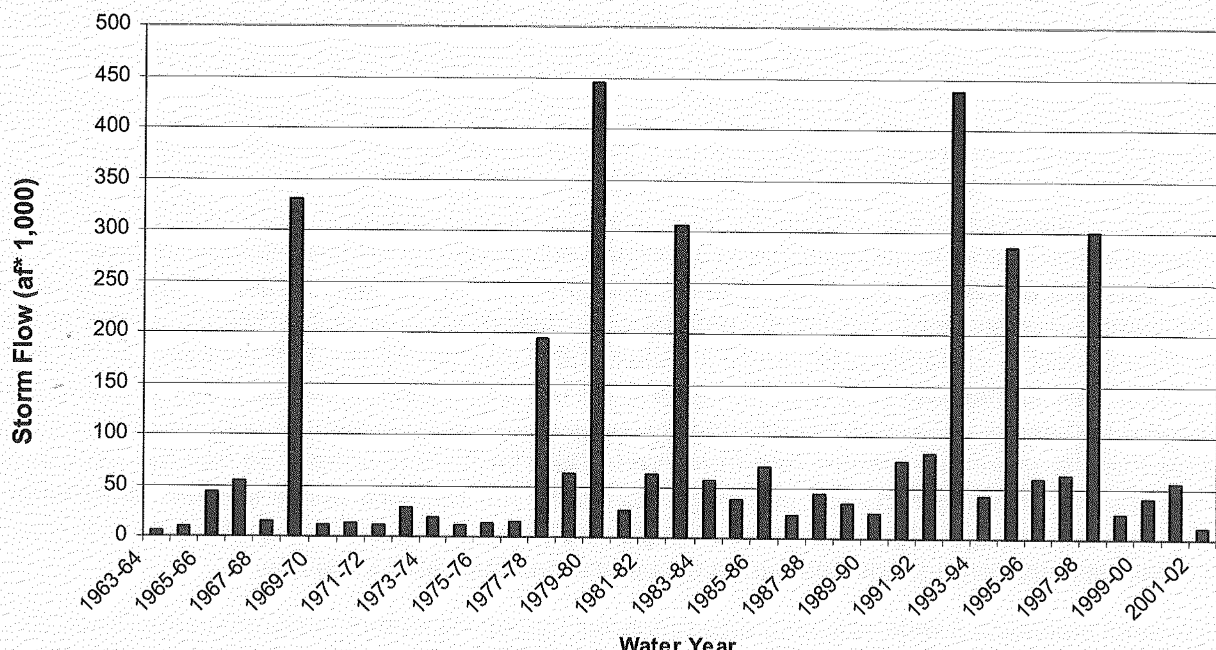
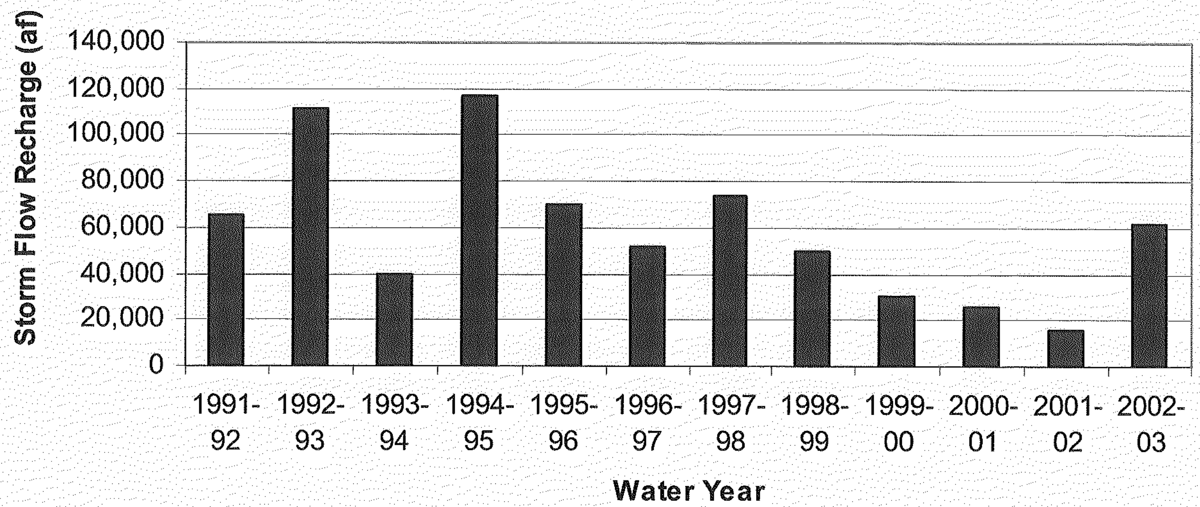


Figure 5-5 shows the amount of SAR stormflow recharged by the District. The maximum annual amount of stormflow recharge between 1991-92 and 2002-03 was 117,000 af, and the minimum was 16,000 af. Based on the data in Figure 5-5, the District estimates that on average, 50,000 afy of storm flow will be captured and recharged.

It is common to have some loss of stormwater to the ocean during normal years, when the flow rate is elevated rapidly over a short period of time. During water year 1997-98, the District lost approximately 270,000 af of SAR stormflows to the ocean. It is important to note that in very wet years such as 1992-93, the amount of increased stormflow above the average amount is approximately 60,000 afy.

Figure 5-5

SANTA ANA RIVER STORMFLOW RECHARGED IN FOREBAY



Two additional key factors related to the volume of stormflow recharged are the distribution of rainfall and whether the precipitation occurs as rain or snow in the local mountains. More stormflows can be conserved behind Prado Dam if storm events are separated by time, allowing for the gradual release of water from the dam between storms. Also, if snow accumulates in the mountains, a steady baseflow over time results from the snow melting slowly in the upper watershed.

Since 1938, when Congress authorized Prado Dam construction for flood protection, water conservation has been a secondary purpose for OCWD. Today, water can be retained in a pool behind Prado Dam up to an elevation of 494, during the flood season, and 505 feet mean sea level (msl), during the non-flood season, so as to maintain flood control and not impact endangered species habitat. OCWD began pursuing an official water conservation pool program in the early 1990s. Figure 5-6 shows Prado Dam and water stored behind the dam for subsequent recharge in the District's recharge facilities. The District is currently planning to increase the maximum winter pool elevation in the Prado Basin from 494 to 498 feet as shown in Figure 5-7. The additional conserved water is estimated to average 4,000 afy as a result of this four-foot increase in the maximum winter pool elevation. OCWD desires that the maximum release rate from Prado Dam be 500 cfs or less, so that the release rate corresponds to OCWD's recharge capacity. Increasing the District's ability to store stormwater at Prado Dam for subsequent groundwater recharge also benefits groundwater quality since stormwater has lower total dissolved solids and nitrate concentrations than SAR baseflow.

The District maintains a wide-reaching environmental habitat restoration program in the Prado Basin. This cooperative program with the U.S. Fish and Wildlife Service has expanded the population of the threatened Least Bells Vireo, a small song bird. The District also works to remove arundo, a non-native plant that consumes large amounts of water and out-competes native plants that are beneficial to wildlife. These and other environmental projects maintained by the District provide benefits to the environment and are also beneficial to the District's water conservation programs. It is estimated that by 2025, an annual minimum of 36,000 acre-feet of additional water will be available in the Santa Ana River as a result of removing Arundo. This estimate is based on a minimum of 3.6 acre-feet of additional water per acre of Arundo removed. Where no native growth replaces the Arundo, the water savings is estimated to be about six acre-feet of water per acre of Arundo removed.

Figure 5-6

PRADO DAM AND STORED WATER

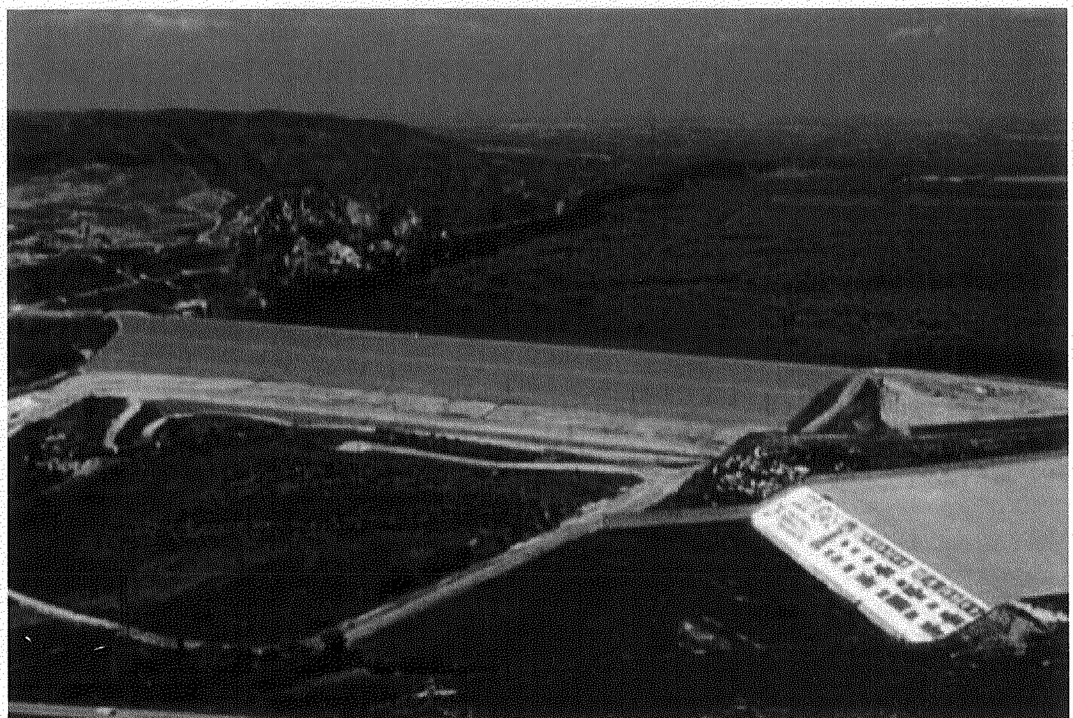
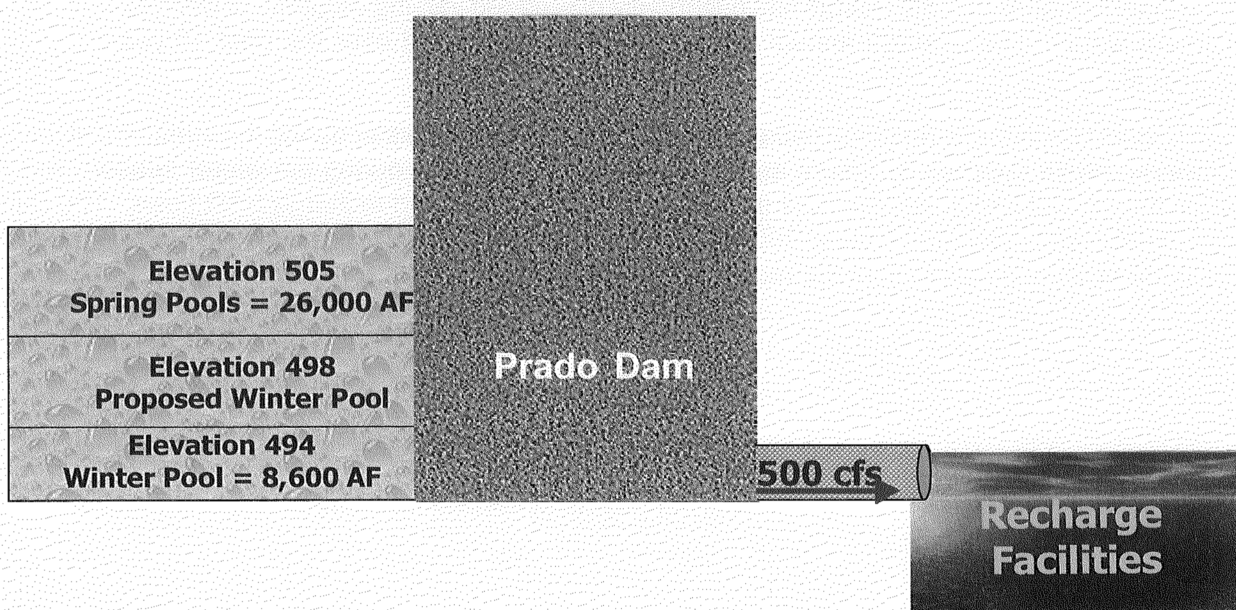


Figure 5-7

PRADO DAM SEASONAL CONSERVATION POOLS



5.3.3 SUPPLEMENTAL IMPORTED WATER

Imported water purchased from Metropolitan is used to supplement the recharge of the Basin. From the District's viewpoint, the imported water is termed "supplemental" in that it allows more recharge than would be possible solely with SAR flows.

5.3.3.1 REPLENISHMENT WATER

Metropolitan provides groundwater replenishment water to the District when excess water supplies are available. Metropolitan's system allows for its delivery to Orange County, and the District has recharge capacity available to receive the water. Direct replenishment water is received at the District's recharge facilities in the cities of Anaheim and Orange and is physically recharged into the Basin through percolation. The District receives direct replenishment water in four locations:

OC-59 – Located in Claremont. Supplies travel down San Antonio Wash to Chino Creek, through the Prado Basin, and then down the SAR through Santa Ana Canyon. The source of this water is the State Water Project (SWP).

OC-28 – Located adjacent to Anaheim Lake. Supplies empty directly into Anaheim Lake. The source of this water is the Colorado River. Future modifications to the Metropolitan Diemer treatment plant will allow the District to receive a blend of SWP and Colorado River water.

OC-13 – Located adjacent to Irvine Lake. Supplies empty into Irvine Lake and travel down to the pipeline or through the Santiago Pits through Santiago Creek. The source of this water is primarily Colorado River water from Metropolitan, blended with Irvine Lake water.

OC-11/11a/12 - Located in Yorba Linda. Supplies empty into the SAR just above the District's spreading facilities. The source of this water is the Colorado River.

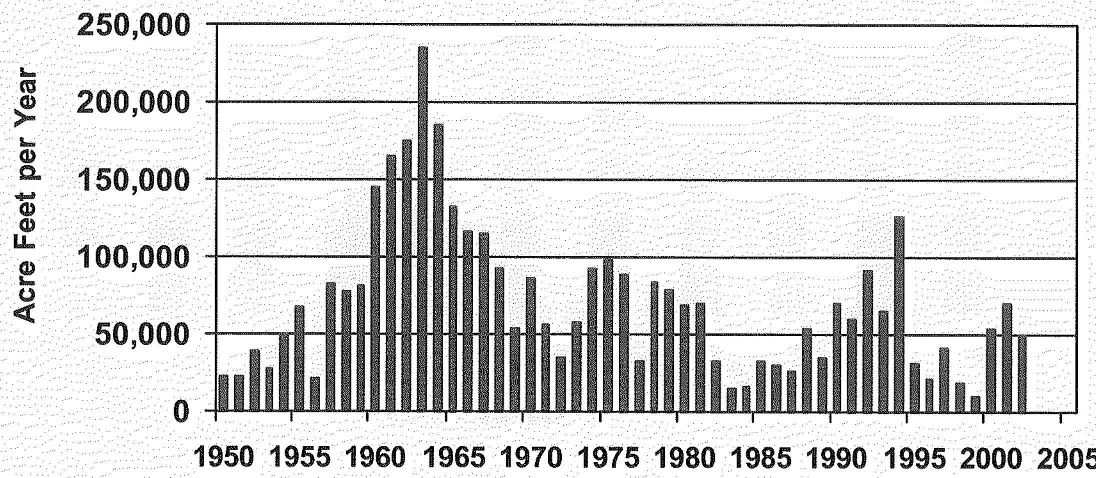
OCWD utilizes the OC-28 connection most frequently because it directly enters the recharge basins in Anaheim. Other connections are susceptible to evaporation or water quality impacts because of their distance from the point of percolation.

As shown in Figure 5-8, the District has historically purchased varying amounts of Metropolitan replenishment water. The average annual amount of water purchased over the past 10 years has been 60,000 af.

The District typically has recharge capacity available to receive this water during the summer/fall months. However, these supplies by nature are more frequently available during the winter season, which is when the District's recharge facilities are being used to capture and recharge SAR flows. The District can usually take between 50 cfs to 200 cfs (100 - 400 af/day) of direct replenishment water depending upon the operating condition of the recharge facilities.

Figure 5-8

HISTORIC IMPORTED METROPOLITAN REPLENISHMENT WATER PURCHASES



5.3.3.2 IN-LIEU DELIVERIES

In-lieu replenishment water is provided to the District when excess supplies and treatment capacity are available from Metropolitan. In-lieu supplies are physically recharged into the Basin when participating Producers turn off their wells and receive excess Metropolitan water in-lieu of pumping groundwater. This reduces the amount of water taken from the Basin. The in-lieu program is an energy-efficient method of recharging the Basin and can target definitive areas. In addition, the program allows the District's recharge capacity to be preserved for SAR flows. This program is cost neutral to the Producers. Recent administrative changes to the in-lieu program allow for any Producer to participate in the program during any month(s) that water is available from Metropolitan.

5.3.3.3 INJECTION WATER

Potable water purchased from Metropolitan has been injected in the Talbert Barrier since 2002. It is anticipated that potable Metropolitan water will be used to make up a portion of the injection water at the Talbert Barrier until about 2009, when the second year of operation of the GWR System is complete. After this time, the GWR System should provide all of the water injected in the Talbert Barrier.

5.3.4 INCIDENTAL RECHARGE

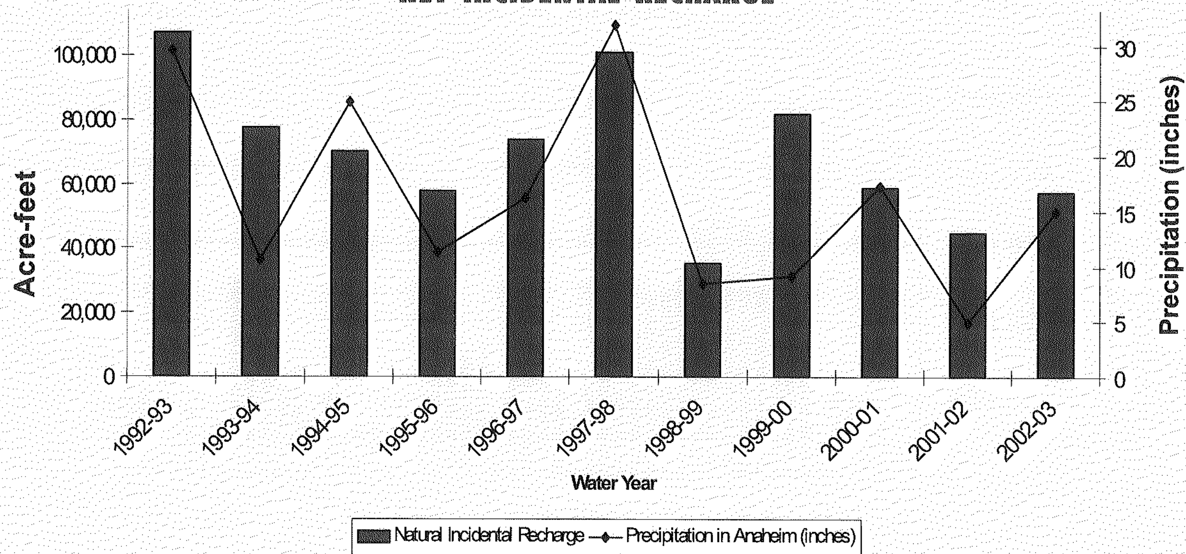
Incidental or natural recharge to the Basin occurs from local mountain-front recharge, precipitation and irrigation water infiltration, and groundwater underflow to/from Los Angeles County and the ocean. Except for the groundwater underflow components, natural incidental recharge occurs outside the District's control.

Net incidental recharge refers to the net amount of incidental recharge that occurs after accounting for subsurface outflow to Los Angeles County. As described in Section 2, when the accumulated overdraft in the Basin is 400,000 af, the estimated amount of outflow to Los Angeles County is 8,000 afy.

Estimated net incidental recharge and precipitation in Anaheim is shown in Figure 5-9. On average, approximately 60,000 af of net incidental recharge occurs each year. In very wet years such as 1992-93 and 1997-98, the increased amount of incidental recharge above the average amount is approximately 40,000 afy.

Figure 5- 9

NET INCIDENTAL RECHARGE



5.3.5 PURIFIED WATER

Until early 2004, purified water was put into the Basin through injection wells using water from WF-21. WF-21 purified treated wastewater to provide a source for the Talbert Barrier. In 2007, the GWR System will begin operation and provide water for groundwater recharge in Anaheim as well as for the seawater intrusion barrier.

5.3.5.1 WATER FACTORY 21

WF-21 operated until 2004 and purified approximately 4 mgd of clarified secondary wastewater effluent using lime clarification pretreatment, multi-media filtration, reverse osmosis (RO), and recently ultraviolet light (UV) treatment. The plant, which was built in 1975, reached the end of its useful life and is being replaced with the GWR System. From 2004 to 2007, the Interim Microfiltration Facility is providing 5 mgd of purified water for the injection wells using the same treatment processes as the GWR System.

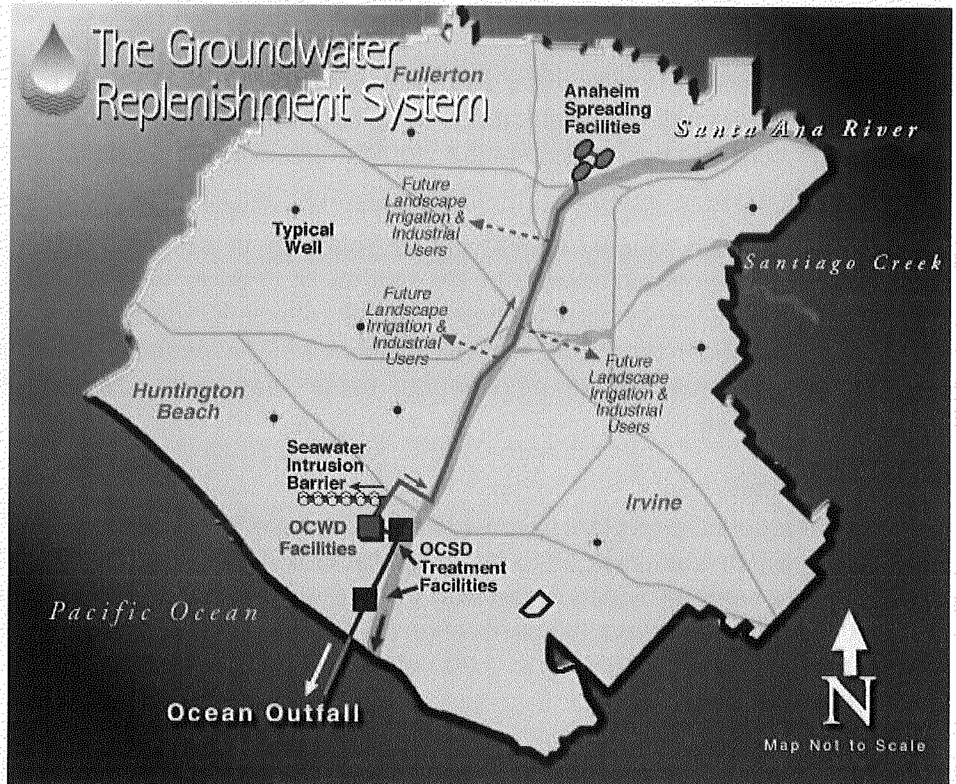
5.3.5.2 GROUNDWATER REPLENISHMENT SYSTEM

The GWR System is jointly sponsored by OCWD and the Orange County Sanitation District (OCSD). The first phase of the GWR System will increase the reliability and sustainability of local groundwater supplies through the creation of a new source of water, producing a total of 72,000 afy for groundwater recharge. The GWR System will be operational in mid-2007.

The GWR System will augment existing groundwater supplies through indirect potable reuse, providing a reliable, high-quality source of recharge water for the Basin. Additionally, direct injection of project water into the Talbert Barrier will protect the coastal aquifer from further degradation due to seawater intrusion. Located in central Orange County, as shown in Figure 5-10, the GWR System consists of three major components: (1) Advanced Water Treatment (AWT) facilities and pumping stations, (2) a pipeline connection from the treatment facilities to existing recharge basins, and (3) expansion of the Talbert Barrier.

Figure 5-10

GROUNDWATER REPLENISHMENT SYSTEM MAP



The heart of the GWR System is the advanced water purification plant, which purifies the water with microfiltration (MF), RO, and advanced oxidation processes (AOP), which consist of UV and hydrogen peroxide (H_2O_2).

Following filter screening, OCSD-clarified secondary effluent, normally disposed to the ocean, receives MF membrane treatment. MF is a low-pressure membrane process that removes suspended matter from water. MF specifically will be used to separate suspended and colloidal solids including bacteria and protozoa from the OCSD secondary effluent. Sodium hypochlorite will be added to the MF feedwater to minimize MF membrane fouling. WF-21 type conventional facilities were evaluated for the GWR System RO pretreatment, but due to space limitations and increased costs for WF-21 retrofitting, MF was chosen to replace WF-21's conventional purification processes. MF filtrate will be fed to RO, and MF reject streams will be returned to OCSD's Plant No. 1 for disposal. Based on a design recovery of approximately 90 percent, 86 mgd of filtrate will be produced by MF.

MF filtrate will be sent to the RO treatment process. The feed water will essentially pass through polypropylene-wound cartridge filters prior to RO treatment. The RO process will reject dissolved contaminants and minerals. Particularly, RO treatment will reduce dissolved organics, pesticides, TDS, silica, and viruses from MF filtrate. The RO concentrate will be discharged into the ocean via the existing OCSD ocean outfall. Based on a design recovery of approximately 85 percent, the projected production rate of RO is 70 mgd. The plant has the capability to be upsized in the future to deliver 130 mgd of product water.

Following RO, the water will undergo UV along with H_2O_2 treatment. UV treatment involves the use of UV light to penetrate cell walls of microorganisms, preventing replication and inducing cell death. UV thus provides additional barrier of protection against bacterial and viral inactivation and, combined with RO treatment, increases removal efficiency. More importantly, UV with H_2O_2 oxidizes many organic compounds for ultimate removal from water. UV and H_2O_2 treatment will be used for NDMA and other low molecular weight organic removal. After RO treatment, the product water is so low in mineral content that it has a corrosive nature, which can be mitigated with the addition of lime. If lime addition did not take place, the concrete transmission pipe would corrode in the presence of the unstabilized water.

The GWR System will provide roughly 42,000 afy for recharge in Kraemer Basin. When Kraemer Basin requires cleaning, Miller Basin, owned by the County of Orange, will be used. Due to its high quality, GWR System water is expected to recharge at high rates in Kraemer and Miller Basins. Additional water may be recharged in those basins depending on water availability and storage availability. Kraemer may be ultimately equipped with a continuous basin cleaning device (BCD) that would allow high sustained recharge rates.

5.3.5.3 ALAMITOS BARRIER

WRD has constructed a purification plant to provide purified water for injection at the Alamitos Barrier. The purification plant, which is anticipated to begin operation in 2004, uses an MF-RO-UV treatment system, with the source water provided by tertiary treated wastewater from the Long Beach Water Reclamation Plant. Purified water from the purification plant will replace a portion of the treated potable water that was injected into the barrier. Up to 3,000 afy of purified water will be used.

5.3.6 GREEN ACRES PROJECT

The Green Acres Project is a non-potable water supply project that utilizes a dedicated set of pipelines to deliver irrigation and industrial water to users. Most of the water is irrigation water used on golf courses, greenbelts, cemeteries, and nurseries. Operation of the Green Acres Project reduces demands on the Basin by providing non-potable water to non-potable uses, and thereby avoiding potable water delivery to non-potable water users. The project has been in operation since 1991 and produces approximately 7-mgd of irrigation and industrial water by receiving clarified secondary wastewater effluent from the OCSD and providing additional treatment using filtration and chlorine disinfection.

5.3.7 OTHER SOURCES OF RECHARGE WATER

Recharge water is also provided by projects upstream of Prado Dam. Water from these projects flows to the District's recharge facilities through the SAR. Since 1990, the main sources of recharge water in this category has been water from:

- The Arlington Desalter. When potable consumption does not match the potential output of the Arlington Desalter in Riverside, the District has frequently purchased the excess water for groundwater recharge. Since the potable demands that can be met with Arlington De salter flows are increasing and will reach nearly 100 percent of the desalter's capacity, minimal flows will likely be available for recharge water after 2004.
- The Bunker Hill Basin groundwater pumpout project in San Bernardino, a cooperative project with the San Bernardino Valley Municipal Water District. In the late 1990s, this project provided up to 10,000 afy of recharge water. The groundwater pumpout project was implemented in the Bunker Hill Basin in San Bernardino to mitigate the negative impacts of high groundwater levels. It is uncertain if this project will provide recharge water in the future.

- Western Municipal Water District projects, including the emergency drought exchange, Western/Metropolitan demonstration storage, and Western – Elsinore transfer projects. Historically, these projects provided up to approximately 7,000 afy of recharge water. It is uncertain if these projects will be able to provide recharge water in the future.

In addition to wastewater discharges to the SAR from the Chino Basin, Riverside, and San Bernardino areas, wastewater discharges to Temescal Creek by the Eastern Municipal Water District (Eastern) may also be available. This projected increase in discharge by Eastern to Temescal Creek, a tributary to the SAR near Corona, is due to the production of recycled water in the Eastern service area increasing such that, in the winter months, Eastern's recycled water production exceeds its demands. It is estimated that the discharge to Temescal Creek will range from six and 43 mgd for up to two months in the winter each year.

5.4 MONITORING QUALITY OF RECHARGE WATER

The District conducts an extensive program to monitor the quality of the water recharged into the groundwater basin. This includes monitoring of the SAR, replenishment water from Metropolitan, WF-21, and GWR System supplies.

5.4.1 SANTA ANA RIVER

Since the SAR is the District's primary source of recharge water, the District maintains a comprehensive monitoring program for the river. The program is important because baseflow in the river is primarily from wastewater treatment plants upstream of Prado Dam, and stormflow in the river is impacted by urban and occasionally agricultural runoff.

From 1994 to 2003, the District conducted the SARWQH Study to comprehensively characterize the quality of river flows and the groundwater in the area near the recharge facilities. The multidisciplinary study design included an examination of hydrogeology, microbiology, water chemistry, toxicology and public health. An integral component of the SARWQH Study was independent review of the research design and study findings by the Scientific Advisory Panel, established by the National Water Research Institute (NWRI) to provide expert guidance for the study. The results of this study helped to confirm that current recharge practices using SAR water are protective of public health.

On-going monthly monitoring of the river is conducted at Imperial Highway (near the diversion of the river to the off-river recharge basins), at below Prado Dam, and at several points on the river and key tributaries to the river above Prado Dam. General minerals, nutrients, and selected other constituents are monitored monthly, and radioactivity constituents, metals, volatile organics, and semi-volatile organics (e.g., pesticides and herbicides) are monitored quarterly.

In addition to these surface water monitoring sites, the District monitors groundwater quality at selected monitoring wells where known travel times of recharge water to the wells are less than six months. These wells provide an indication of groundwater quality after six months or less groundwater flow. Recharge water samples are collected in coordination with these targetted groundwater samples so that the changes in water quality after recharge can be estimated. This allows for evaluations of changes in water quality for parameters such as nitrate as the water is infiltrated and subsequently flows in the subsurface.

The District is also investigating the use of fish biomonitoring as a supplement to chemical testing of recharge water. The first phase of the Biomonitoring Development Project was completed in 2001 and demonstrated the rudimentary feasibility of operating a fish biomonitoring system with SAR water after the water has infiltrated and traveled a short distance underground. The Phase 2 project began in 2003 and is planned to help assess the practical value of fish biomonitoring systems for groundwater recharge projects. Biomonitoring would be a new tool to supplement chemical testing to assure the safety of SAR recharge. The combination of chemical testing and biomonitoring systems would provide the best tools to address concerns about the future sustainability of river water recharge as the quality of future river flow is altered by upstream development.

5.4.2 REPLENISHMENT WATER FROM METROPOLITAN

Replenishment water from Metropolitan delivered to the District through outlet OC-28 at Anaheim Lake is monitored as part of the District's routine monthly monitoring program. General minerals, nutrients, and other selected constituents are monitored monthly. Radioactivity constituents, metals, volatile organics, and semi-volatile organics (e.g., pesticides and herbicides) are monitored quarterly.

5.4.3 WATER FACTORY 21 AND GROUNDWATER REPLENISHMENT SYSTEM

WF-21 has over 25 years of extensive monitoring, consisting of routine monthly and quarterly monitoring for general minerals, metals, organics, and microbiological constituents. Injection water and groundwater near the injection wells were monitored. In addition, focused research-type testing has been conducted on organic water quality and virus testing. The testing has consistently demonstrated that the purified water produced by WF-21 has been safe for injection into the groundwater basin.

The GWR System will have a similar but more geographically-extensive monitoring program. Previously, WF-21 only injected water in the Talbert Barrier. The GWR System will inject water in the Talbert Barrier and infiltrate water in Kraemer Basin.

section 6 Groundwater Quality Management

Water quality protection is a basic tenant of OCWD. An extensive groundwater quality management program allows the District to address current issues and develop strategies to anticipate and resolve future issues. This section discusses the many facets of OCWD's groundwater quality management program. The following subsections:

- Trace the evolution of nitrate and TDS concentrations in the Basin and outline management strategies.
- Discuss groundwater contamination cleanup policies and goals and selected projects being implemented to remove contaminants from the Basin.
- Present a case study of water quality management for MTBE contamination.
- Describe District programs to identify and address emerging contaminants, manage colored groundwater, coordinate with regulatory agencies, and implement other related activities to protect water quality.

6.1 NITRATE MANAGEMENT

Nitrate is the most prevalent form of the major inorganic nitrogen compounds in the Basin, but the nitrate concentration exceeds the MCL in only a small number of areas. The District works to address these areas and to address future sources of nitrate.

6.1.1 SOURCES OF NITRATE

Nitrogen is naturally occurring and exists in the environment in many forms and changes as it moves through the nitrogen cycle. Nitrate is a nitrogen-oxygen ion (NO_3^-) that is highly leachable (does not bind to soil), very soluble, and mobile in water. It is essential for plant growth and routinely added as a nutrient (fertilizer) to soil to improve plant growth and productivity (cropland, parks, golf courses, lawns, etc.). Other sources of nitrate in groundwater include biological nitrogen fixation in the soil, rainfall (airborne nitrogen transformed to nitrate in precipitation), animal feedlots, and wastewater disposal systems. Water, moving through the soil by irrigation or rainfall, carries dissolved nitrate downward and laterally to the groundwater.

Historically, Orange County was a thriving agricultural community with abundant water supplies from the SAR and the Basin. Land uses included pastures, livestock, cropland, vineyards, and orchards. The rich farmland was irrigated by shallow groundwater wells in the Forebay and near the foothills whereas artesian springs flowed across peat lands in the coastal area. Eventually, groundwater became a key source of water for the growing demands of the county. These past agricultural land uses in the Basin are the primary sources of high concentrations of nitrates currently detected in groundwater.

6.1.2 NITRATE REGULATION AND POTENTIAL HEALTH EFFECTS

The protective health level of 10 milligrams per liter (mg/L) for nitrate-nitrogen has been in place since 1962 as set by the U.S. Public Health Service. Subsequent reviews of this standard have not resulted in any changes. Nitrite, not nitrate, is the nitrogen form of health concern. Both nitrate, which can be converted to nitrite in the body, and nitrite are federal and state regulated constituents in drinking water with three distinct MCLs as listed in Table 6-1.

Table 6-1

DRINKING WATER STANDARDS FOR NITRATE AND NITRITE

Constituent	MCL, Mg/L
Nitrate as Nitrogen	10
Nitrite as Nitrogen	1
Nitrate as Nitrogen + Nitrite as Nitrogen	10

MCL = maximum contaminant level
mg/L = milligrams per liter (or ppm)

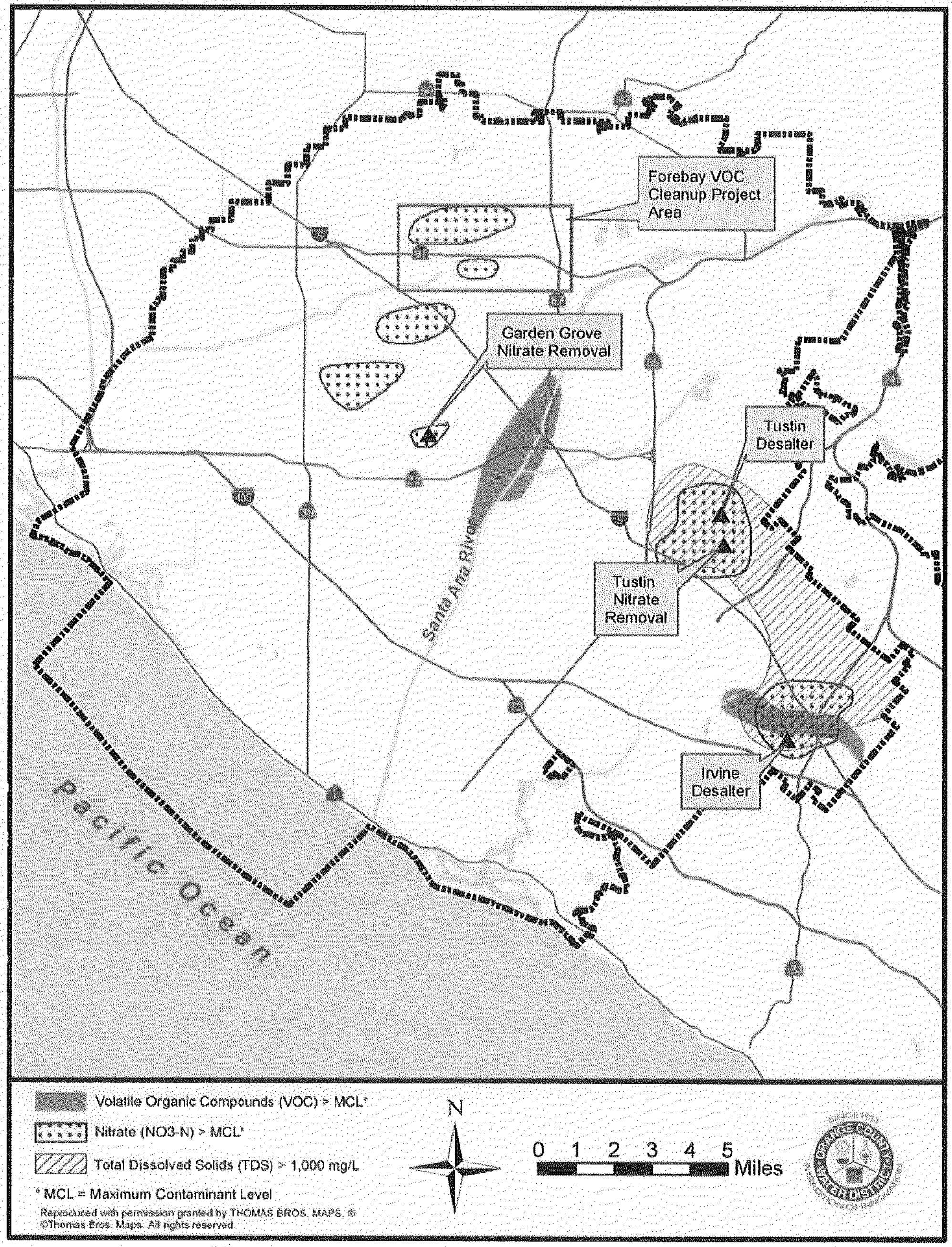
The nitrate and nitrite MCLs were set to be protective of infants who may experience methemoglobinemia at higher concentrations. Infants under the age of six months are more susceptible to nitrate toxicity than older children and adults. Bacteria in the digestive system in young infants converts nitrate to nitrite (NO_2^-). Nitrite oxidizes iron in the hemoglobin of red blood cells to form methemoglobin. Methemoglobin cannot carry oxygen in the blood causing the infant to suffer oxygen deficiency. This condition is known as methemoglobinemia or commonly called "blue baby syndrome" (the most noticeable symptom of nitrate poisoning is a bluish skin coloring).

6.1.3 NITRATE OCCURRENCE AND DISTRIBUTION IN THE GROUNDWATER BASIN

Wells impacted by nitrates are usually shallow and draw from groundwater that may have been impacted by years of agriculture fertilizer application or incidental run-off from the Irvine or Tustin foothills. The Forebay area is susceptible to shallow groundwater migration downward to the first producible aquifers as described in Section 2. The Drinking Water Source Assessment and Protection Programs (DWSAP) also identified multiple wells in the basins as being vulnerable to nitrate contamination from historic agricultural land uses. Figure 6-1 shows areas in the Basin impacted by nitrates, salts and volatile organic compounds (VOCs).

Figure 6-1

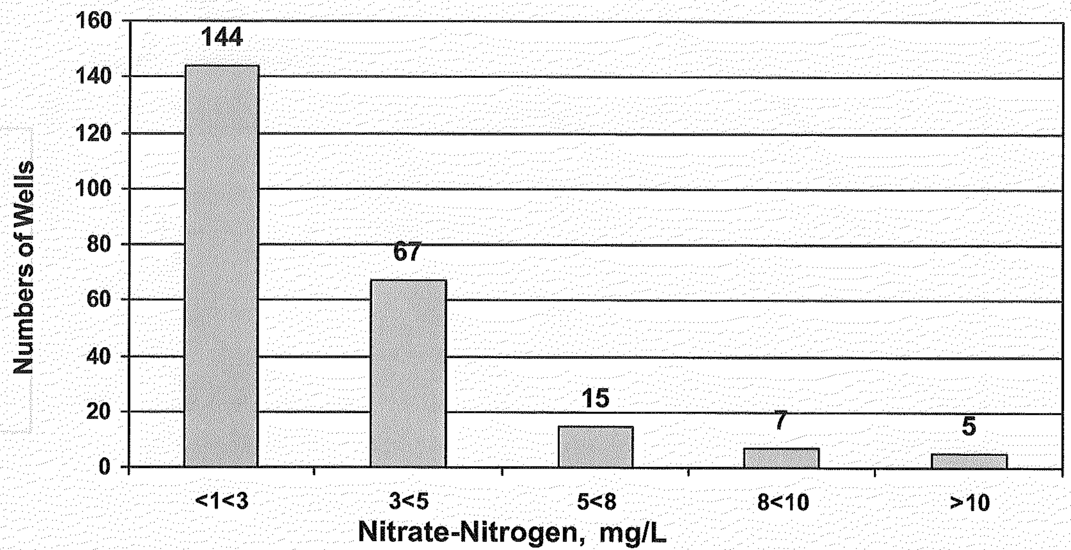
AREAS IMPACTED BY NITRATES, SALTS, AND VOCS



Nitrate-nitrogen generally ranges from four to 7 mg/L in the Forebay area and from 1 to 4 mg/L in the Pressure area. The distribution of average nitrate-nitrogen in municipal supply wells is shown in Figure 6-2. Approximately 89 percent of the drinking water wells have average nitrate-nitrogen less than 50 percent of the MCL or less than 5 mg/L.

Figure 6-2

AVERAGE NITRATE-NITROGEN CONCENTRATION IN POTABLE SUPPLY WELLS



6.1.4 NITRATE MANAGEMENT STRATEGIES

The Basin does not have assimilative capacity for nitrate. Therefore, groundwater quality management strategies should address sources of nitrates (and other pollutants) in applied water to minimize nitrates entering the Basin and to protect water quality from further degradation. Nitrate management goals include remediating nitrate-laden groundwater, a product of past land use legacies, and striving to attain the RWQCB's groundwater subbasin nitrate-nitrogen water quality objectives of 3 mg/L in the Forebay and Pressure areas. In the Irvine area, the water quality objective for nitrate-nitrogen ranges from 6 to 8 mg/L.

Drinking water sources containing nitrate-nitrogen concentrations exceeding 10 mg/L must be reduced by blending with other sources or treatment before delivery into the potable supply system. Because of the potential acute health effects, nitrate-nitrogen is monitored quarterly at wells having concentrations equal to or greater than 50 percent of the MCL. At a minimum, production wells are tested annually for nitrate.

Orange County has transformed to a highly urbanized community replacing the agricultural land uses. Concurrent with the land use transition is the significant mass reduction of land application of nitrate fertilizers, which are sources of potential contamination of underlying aquifers. A primary nitrate management strategy is remediation of degraded areas of the Basin that are impacted by high nitrates.

As described in Section 7, several groundwater treatment projects are in operation or in the planning stage to reduce nitrates in source waters.

6.2 TOTAL DISSOLVED SOLIDS MANAGEMENT

Increasing salinity is a significant water quality problem in many parts of the southwestern United States and Southern California, including the Basin. The United States Bureau of Reclamation (USBR) and Metropolitan conducted a two-year technical study of the impacts of TDS (salinity) on the region's water supplies. The 1998 USBR/Metropolitan Salinity Management Study confirms the widespread impact of salinity in water supplies. Increasing salinity reduces the availability of local groundwater supplies and is a significant constraint to implementation of water recycling projects. The economic impacts include additional costs for replacement of plumbing, appliances, and water treatment by residential, industrial, commercial users and water utilities.

There is a salt imbalance in the Basin. Basin management requires reduction of salt input by using low TDS water for groundwater replenishment and focusing on long-term planning for future desalters. Increasing salinity in water is directly related to increasing consumer costs in Orange County.

Avoiding the potential loss of water supplies due to increasing salinity and the developing projects to reduce water salinity are District priorities and require a broad watershed management approach. Constructed water quality projects to reduce salinity include WF-21, the GWR System, several local and regional groundwater desalters, utilization of the SAR Interceptor (SARI) industrial brine line, Prado Dam Water Conservation, and coordination with the RWQCB on salt management issues. This Plan focuses on TDS management strategies in the Basin. However, long-term salinity management issues require participation and cooperation with upper Santa Ana watershed stakeholders and import water agencies, as these are key sources of water used to replenishment the Basin.

6.2.1 SALINITY OVERVIEW AND REGULATORY STATUS

Salinity (salts or TDS) is a measure of the dissolved minerals in water. TDS is composed of positively charged cations and negatively charged anions. The principal cations are sodium, calcium, potassium, and magnesium. Key anions are chloride, sulfate, carbonate, and bicarbonate. TDS is measured in the laboratory by evaporating a known volume of water to dryness and measuring the remaining salts.

The concentration of salts and the hardness of water may limit the beneficial uses for domestic, industrial, and agricultural applications. Hardness of the water is measured by the amount of divalent metallic cations, principally calcium and magnesium. Water supplies containing high concentrations of calcium and magnesium are undesirable for domestic and many industrial uses. Hard water causes (1) scale formation in boilers, pipes, and heat-exchange equipment and (2) soap scum and an increase in detergent use. Some industrial processes, such as computer microchip manufacturers, must have low TDS in the process water and often must treat the municipal supply prior to use.

High salinity source water affects the agricultural community. TDS may impact plant growth, crop yield, and drainage and cause potential clogging of drip irrigation lines. Salt tolerance in plants depends on the salinity of the soil and applied water. Boron is an essential nutrient for normal plant growth, but in large concentrations boron may become toxic. Soil permeability is affected by the concentration of sodium in the irrigation water sources and is routinely measured by agricultural growers.

The SDWA requires EPA to establish MCLs or treatment techniques for drinking water constituents to be protective of public health (primary MCLs) and for aesthetic quality (secondary MCLs). TDS is regulated by EPA and DHS as a constituent that affects the aesthetic quality of water – notably, taste. The recommended secondary MCLs for key constituents comprising TDS are listed below in Table 6-2.

Table 6-2

SECONDARY DRINKING WATER STANDARDS FOR SELECTED CONSTITUENTS

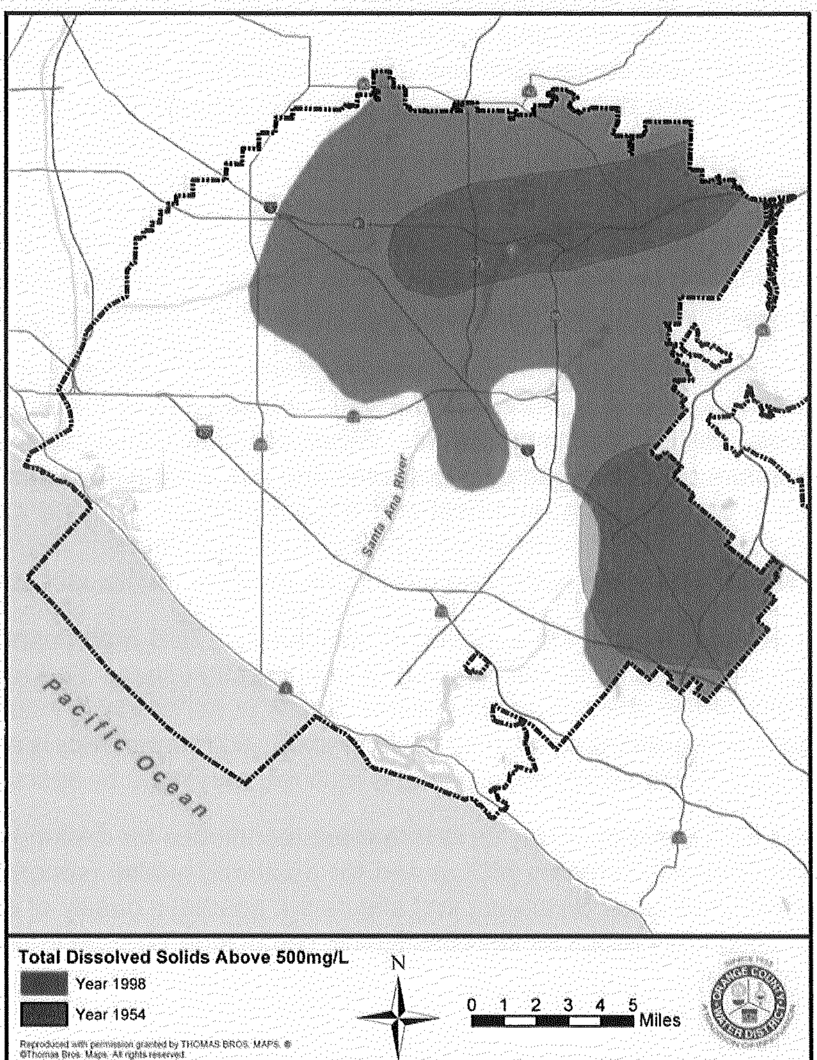
Constituent	Recommended Secondary MCL, mg/L
Total Dissolved Solids (salts)	500
Chloride	250
Sulfate	250

6.2.2 INCREASING SALINITY IN THE BASIN

Increases in groundwater TDS concentrations are a function of the recharge water salinity, including SAR stormflows and baseflows, imported replenishment water, and local incidental recharge from irrigation return flows and precipitation. They may also be attributed in part to deep percolation of high-TDS, near-surface groundwater that has been impacted by past agricultural and land uses. Figure 6-3 illustrates the increase in TDS exceeding 500 mg/L in the Basin in 1954 compared to 1998.

Figure 6-3

AREAS IN THE BASIN CONTAINING TDS ABOVE 500 MG/L



A salt imbalance has existed in the Basin for several decades, where the average TDS concentrations of the recharge water exceed the average TDS of the groundwater extracted. Table 6-3 presents a salt balance for the Basin using average recharge volumes and SAR flows and 1996-97 groundwater production. Imported water recharge volumes were increased approximately 10,000 afy to balance inflows and outflows. Water year 1996-97 was selected for the salt balance calculation because, from a flow perspective, total inflow was nearly equal to total outflow. TDS concentrations for the listed inflows were based on USGS and OCWD SAR flow and quality measurements, reported and measured TDS concentrations for imported water and the WF-21 Talbert Barrier injection water, and estimated TDS of local incidental recharge. The average TDS of groundwater produced was reported in the *1996-97 OCWD Engineer's Report*.

Table 6-3

OCWD BASIN SALT BALANCE

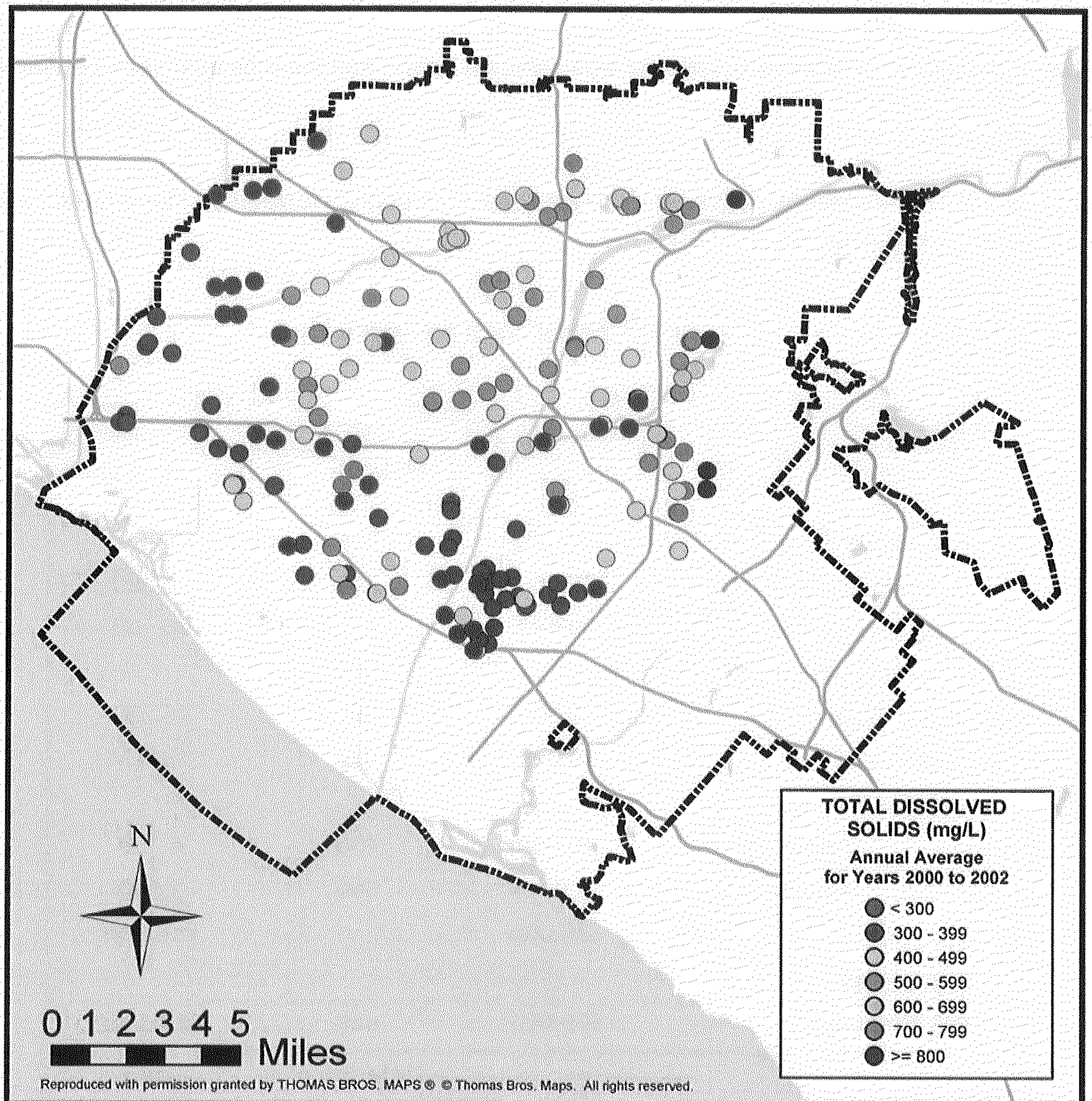
	Flow (afy)	TDS (mg/L)	Salt (tons/year)
INFLOW			
Recharged Baseflow	123,000	625	104,500
Recharged Storm Flow	75,000	400	40,800
Incidental Recharge	70,000	800	76,100
Import Water			
State Water Project	30,000	400	16,300
Colorado River	20,000	680	18,500
Injection Barrier			
Talbert	10,000	450	6,100
Alamitos	2,000	550	1,500
Total:	330,000		263,800
OUTFLOW			
GW Production	330,000	450	201,800
		Difference:	**62,000**
		=	**14 mg/L/year**

Note: (Using 1996-97 Groundwater Production)

Table 6-3 indicates that approximately 62,000 tons of salts are added to the Basin annually, or an average TDS increase of 14 mg/L per year, due to the difference in TDS of the recharge water and produced groundwater. The primary reason for this imbalance is that significant coastal and central portions of the Basin contain older groundwater with TDS concentrations of less than 400 mg/L, as shown in Figure 6-4. Over time, the extracted low-TDS groundwater will be replaced with recharge water with higher TDS.

Figure 6-4

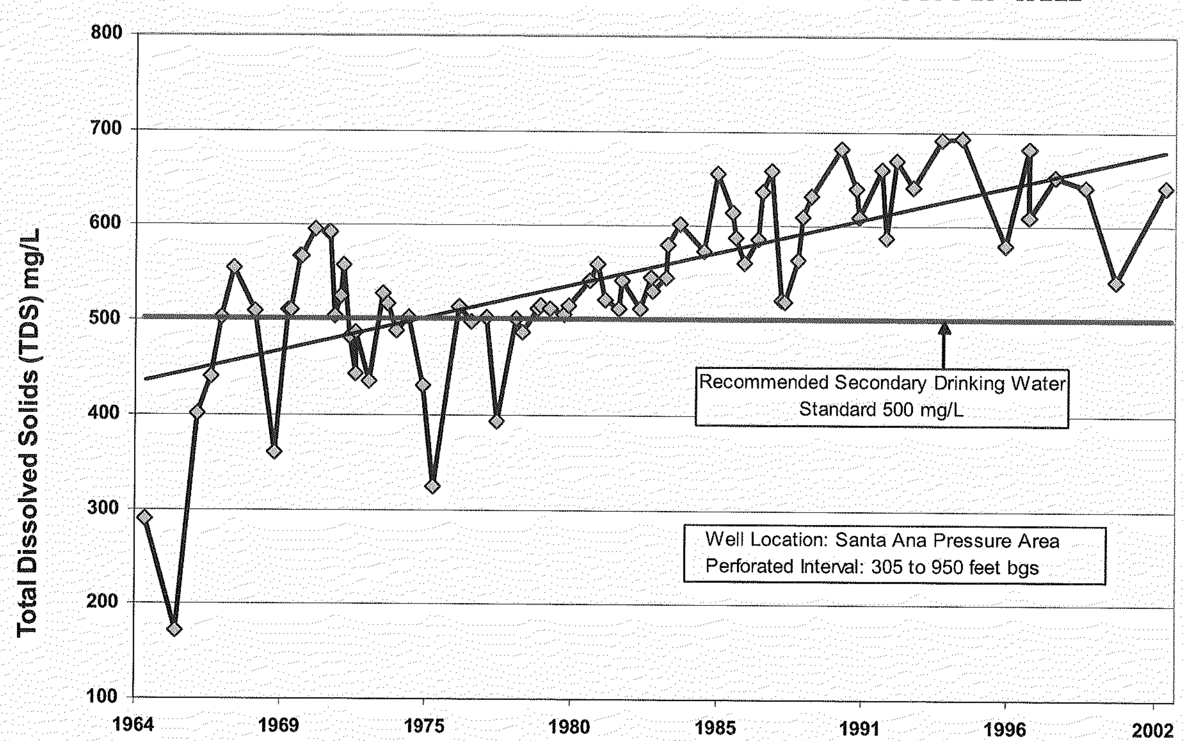
TDS AND GROUNDWATER PRODUCTION FOR 2000-2002



The impact of increasing salt concentrations in groundwater is shown in Figure 6-5. A yearly increase of more than 8 mg/L of TDS has been documented for this drinking water well tapping the principal aquifer in the Pressure area. Similar trends have been observed in many of the wells in the Basin. Groundwater salinity in the Yorba Linda and Irvine subbasins, and in parts of Anaheim and Tustin has increased to levels that exceed the RWQCB's water quality objectives. Water quality objectives set for Orange County's main Basin range from 500 mg/L for the Pressure area to 600 mg/L for the Forebay.

Figure 6-5

INCREASING TOTAL DISSOLVED SOLIDS IN A POTABLE SUPPLY WELL



Groundwater desalter projects, such as the Tustin Desalter and future Irvine Desalter, will help to remove groundwater with high salt levels. These projects are described in Section 7. Modifications to the Metropolitan system to provide lower TDS recharge water at Anaheim Lake and Kraemer Basin are also in the planning stage. The GWR System will also provide a new source of low TDS recharge water. Implementation of these projects is important in reversing the salt imbalance in the Basin.

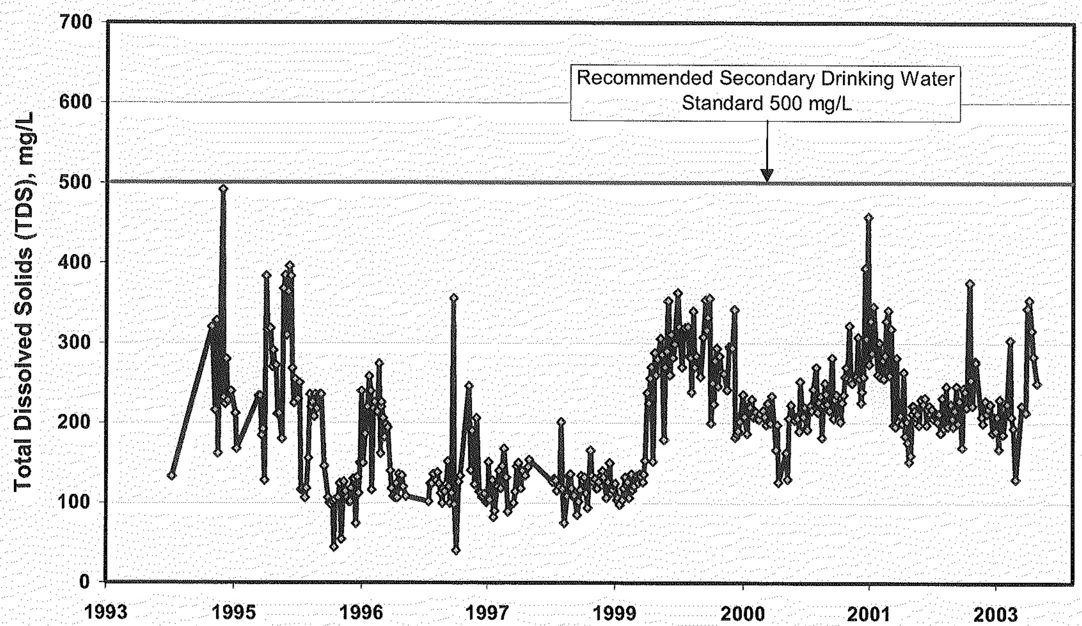
6.2.3 BARRIER RECHARGE WATER QUALITY

Unlike other sources of water for recharge, the District is able to reliably control the salinity of recharge water used to maintain seawater intrusions barriers. For over 25 years, WF-21 has prevented loss of coastal groundwater supplies to seawater intrusion by injecting low TDS purified water to create a freshwater mound or barrier to seawater intrusion. WF-21 has been highly effective since the District has been able to reliably control the TDS of injection water via RO treatment. Figure 6-6 shows that the TDS of barrier injection water over the past nine years is well below the recommended secondary drinking water standard of 500 mg/L. The future GWR System will replace the WF-21 treatment system and will also provide low TDS injection water (approximately 100 mg/L).

The District is working with the WRD to switch from imported water supplies to a blend of imported water and purified water at the Alamitos Barrier, thus allowing for a reliable low TDS injection water supply.

Figure 6-6

WF-21 INJECTION BARRIER WATER – TOTAL DISSOLVED SOLIDS



6.2.4 IMPACT OF SALINITY ON CONSUMER COSTS

Increasing salinity of water supplies directly impacts consumer costs as shown in the 1998 USBR/ Metropolitan Salinity Management Study. The report developed a salinity model to assess economic impacts if salinity increases were experienced in Colorado River water and SWP water. The model was developed to account for regional differences in water deliveries, demographics, TDS concentrations, and average water use per household or by agriculture or industry. The annual economic impact of a 100 mg/L increase in imported water supply TDS was estimated at $95 million. Conversely, a 100 mg/L decrease in TDS would reduce consumer costs by $95 million as shown in Figure 6-7. Approximately $18 million would be realized in cost savings for groundwater supplies. Residential cost savings were estimated at $35 million. Figure 6-8 shows $64 million of benefits if most local groundwater (about 90 percent) and wastewater (about 80 percent) were to experience a 100 mg/L decrease in salinity.

Figure 6-7

ANNUAL ECONOMIC BENEFITS OF 100 MG/L SALINITY DECREASE – IMPORTED WATER SUPPLIES

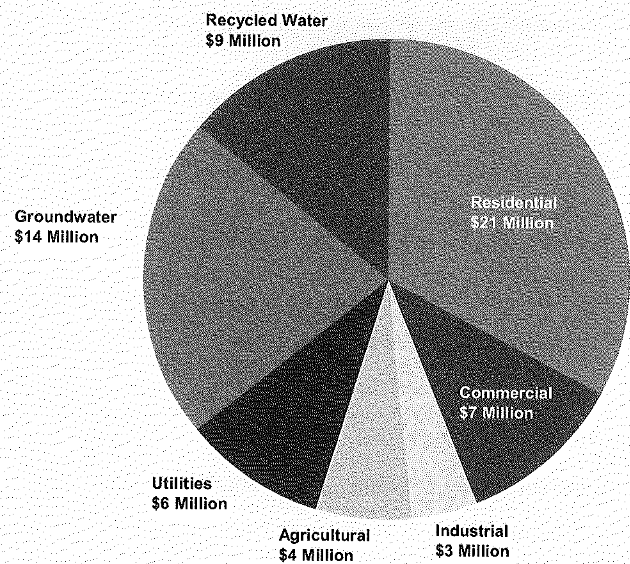


Figure 6-8

ANNUAL ECONOMIC BENEFITS OF 100 MG/L SALINITY DECREASE – GROUNDWATER AND WASTEWATER

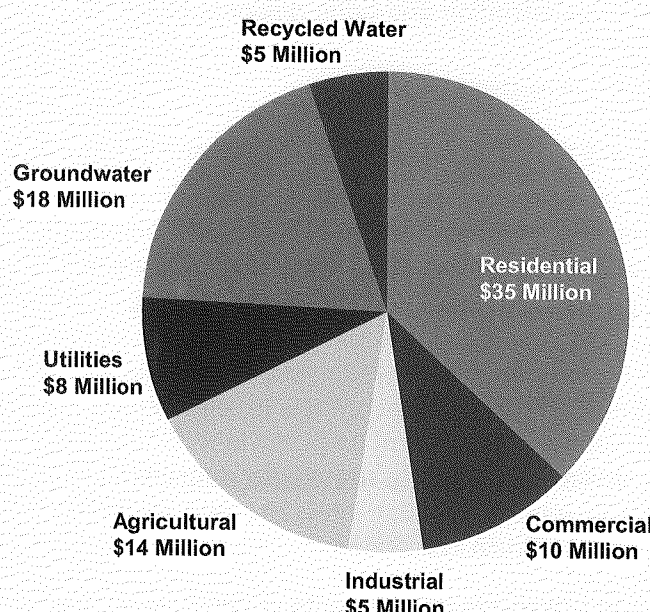


Table 6-4 summarizes the economic benefits to water users from salinity reduction. Cost savings include less need to construct desalting facilities to lower TDS in groundwater supplies and greater compliance of wastewater discharges with permit requirements. Residential consumer cost savings would be realized in longer lifespan for appliances and plumbing as well as need for water softening devices. If no action is taken to reduce salinity, then consumer costs may be expected to continue to increase.

Table 6-4

SUMMARY OF ECONOMIC BENEFITS OF REDUCED SALINITY

User	Economic Benefit
Residential	Increased life of plumbing system and appliances
	Reduced use of bottled water and water softeners
Commercial	Decreased cost of water softening
	Decreased use of water for cooling
	Increased equipment service life
Industrial	Decreased cost of water treatment
	Decreased water usage
	Decreased sewer fees
Agricultural	Increased crop yield
	Decreased water usage for leaching purposes
Utilities	Increased life of treatment facilities and pipelines
Groundwater	Improved wastewater discharge requirements' permit compliance
	Decreased desalination and brine disposal costs
Recycled Water	Decreased of imported water for leaching usage
	Desalination and brine disposal costs

USBR/MWD 1988 Salinity Management Study

6.2.5 MANAGING ORANGE COUNTY'S GROUNDWATER SALT IMBALANCE

Long-term management of increasing salinity in groundwater supplies is critical to maintaining viable local supplies and minimizing consumer costs. Salts reduction programs are needed in order to (1) prevent loss of Basin use due to high salinity water and (2) minimize financial impact to consumers for replacement of plumbing and appliances. The economic long-term impacts from loss of the use of the Basin may be estimated by the current cost for imported water as an alternative water supply. However, loss of Basin use equates to loss of water resources reliability and further dependence on imported water supplies. Several management options to reduce salts input include obtaining lower TDS source water for groundwater replenishment (import water, SAR water, and new sources of low salinity water), constructing desalter facilities to remediate degraded groundwater resources, expanding barrier injection facilities to retard seawater intrusion, and maintaining an aggressive water quality monitoring program to assess Basin conditions.

Management strategies to obtain greater amounts of SWP water help reduce salt input, since SWP has a lower TDS than the SAR and the Colorado River. A bypass of Metropolitan's Diemer treatment facility is planned for the near future to provide a blend of SWP and Colorado River water that has a lower TDS than the current supply of Metropolitan water available for replenishment at Anaheim Lake. Since the SAR is the primary source of recharge water for the Basin, management strategies to reduce salts in river discharges are important. Desalters, extension of the SARI brine line, and control of salt impacts from agricultural activities are important tools for mitigating salt impacts. Other non-reclaimable waste lines in the upper watershed, such as the Non-reclaimable Waste Line in the Chino Basin that segregates high TDS industrial wastewater, are valuable tools for managing salt impacts.

From a salts management standpoint, the GWR System will provide a reliable source of low TDS water to the Basin. Use of RO provides control over product water TDS. Unlike imported water supplies, the GWR System will provide a source of recharge water, whose quantity and quality is not impacted by future drought conditions.

The GWR System is estimated to reduce the Basin salt imbalance by approximately 47,000 tons/year, based on the difference between recharging 72,000 afy of GWR System water at 70 mg/L and an equal amount of imported blended Colorado River and SWP water at 550 mg/L. Operation of the GWR System will also help prevent seawater intrusion, which is another possible source of salt input into the Basin.

6.3 GROUNDWATER CONTAMINANT CLEANUP

Protecting the quality of the groundwater supply and providing maximum use of the resource are priority responsibilities of OCWD as manager of the Basin. This section describes the various components of the District's groundwater contaminant cleanup program.

6.3.1 GROUNDWATER PROTECTION POLICY

The District's Groundwater Quality Protection Policy was adopted in May 1987 to establish a program to safeguard the quality of the Basin. The policy was developed with the support of the Producers and is based on the statutory authority granted under Section 2 of the District Act. A key component of the policy describes circumstances under which the District will undertake contamination cleanup activities at District expense. This type of action may be needed in a situation where the party responsible for the contamination cannot be identified, is unable to cleanup the contamination, or is unwilling to cleanup the contamination, and the level of contamination poses a significant threat to the Basin. The policy establishes objectives to guide the District necessary to:

- Maintain a suitable groundwater supply for all existing and potential beneficial uses
- Prevent degradation of the quality of the groundwater supply
- Assist responsible regulatory agencies in identifying sources of pollution to assure cleanup by the responsible party(s)
- Maintain or increase the Basin's usable storage capacity
- Inform the general public of water quality problems as they are encountered, as well as the overall condition of the groundwater supply, through appropriate regulatory agencies and Producers

The policy establishes eight specific programs designed to achieve these objectives:

- Water quality monitoring of surface and groundwaters
- Identification, interim containment and cleanup
- Coordinated operation with regulatory agencies
- Toxic residuals
- Hazardous waste management planning
- Technical information
- Public disclosure
- Groundwater protection and evaluation

6.3.2 GUIDELINE POLICY ENCOURAGING PRODUCTION AND BENEFICIAL USE OF GROUNDWATER NOT MEETING DRINKING WATER STANDARDS

The District has authority to adjust the BEA for the exemption of poor quality groundwater produced by wells to offset additional treatment, including blending, and distribution costs necessary to beneficially use the groundwater. Exemptions must be sufficient to offset additional treatment and distribution costs and to provide a financial incentive to encourage production. Costs and incentives are determined on a case-by-case basis.

6.3.3 WATER QUALITY TREATMENT GOALS FOR GROUNDWATER PROGRAMS

In June 1984, the Board adopted treatment goals to encourage groundwater quality cleanup that maximize beneficial use of contaminated water in areas of the Basin where water quality problems exist with high concentrations of TDS, nitrates, selenium, color, and organic constituents exceeding drinking water standards.

- Groundwater cleanup projects involving treatment shall meet state primary and secondary drinking water standards when water is used for potable supplies.
- Groundwater cleanup projects involving treatment for irrigation purposes shall meet criteria necessary for the intended beneficial use.
- Groundwater cleanup projects requiring treatment beyond levels to meet the California primary and secondary drinking water standards may be considered in cases where a regulatory or government agency has a water quality requirement or other requirement related to treatment which must be met.
- The District shall pursue payment or reimbursement of cleanup costs from the responsible party for groundwater cleanup projects involving treatment of contaminants from a known source
- Groundwater cleanup projects involving water quality treatment to levels which are more stringent than the California primary and secondary drinking water standards will require that the water purveyor or agency receiving the water pay the additional costs of the added treatment, if provided at the request of or for the benefit of the requesting agency.

6.3.4 SANITARY LANDFILL PROGRAM

In June 1984, the District adopted a program committed to the protection of groundwater quality to participate as necessary with all public and private institutions involved in solid waste disposal management to assure that the vital protection of water quality is assured. A new effort under this program is to work with the regulatory agencies and other stakeholders to develop appropriate tools to manage the disposal of unused pharmaceutical wastes. The intent of this effort is to ensure that unused pharmaceutical wastes are not disposed in such a way that groundwater quality is impacted.

6.3.5 LEAKING UNDERGROUND FUEL TANKS

Leaking underground fuel tanks (LUFT) and fuel releases are a nationwide concern. Gasoline hydrocarbons with low drinking water standards include benzene, toluene, ethylbenzene, and xylenes (collectively known as BTEX chemicals). These nonpolar gasoline constituents have relatively low water solubilities and were the primary constituents driving groundwater plume delineations and developing groundwater remedial activities since the 1980s. The BTEX compounds are biodegraded by naturally-occurring microbes, which led to the natural attenuation or passive bioremediation approach to cleaning up hydrocarbon releases. The mandates of the federal and state Clean Air Acts (CAA) to use oxygenated fuels to improve air quality have resulted in groundwater contamination of shallow aquifers throughout California including Orange County. However, the detection of the gasoline additive MTBE at LUFT and pipeline leak sites, its environmental fate and transport in groundwater, and recent drinking water well closures have heightened the awareness on the continued use of MTBE as a fuel oxygenate and the need to responsibly revise cleanup strategies. MTBE, unlike the BTEX hydrocarbons, does not biodegrade readily and sorbs weakly to soil. Natural attenuation, bioremediation, and groundwater monitoring are not effective approaches to address MTBE releases or cleanup, and other alternatives must be pursued. MTBE is discussed in more detail in Section 6.4.

6.3.6 RESTORING DEGRADED GROUNDWATER – SELECTED PROJECTS

In 1985, portions of the groundwater basin beneath the former El Toro Marine Corps Air Station and the central area of Irvine were found to contain VOCs. Numerous monitoring wells installed by the U.S. Navy and OCWD show there is a one-mile wide by three-mile long VOC plume, comprised primarily of TCE, that extends off the base (see Figure 6-1). Beneath the base, VOC contamination is primarily found in the shallow groundwater up to 150 feet below the ground surface. Off-base, to the northwest, the VOC plume is found in deeper aquifers from 300 to 1,000 feet deep.

To address the VOC plume and high TDS concentrations in the groundwater, OCWD and IRWD are implementing the Irvine Desalter Project. Groundwater contaminated with VOCs will be treated using air-stripping and reverse osmosis and used for irrigation and other non-drinking water uses. Groundwater that does not contain VOCs but has high dissolved solids concentrations will be treated using reverse osmosis before being used for potable uses. Section 7 describes this part of the Irvine Desalter Project in more detail.

OCWD also has an aggressive VOC monitoring program in the Forebay in areas where VOC contamination of the groundwater was known or suspected at concentrations above the drinking water standard. Since 1989, over 40 monitoring wells have been installed to determine the areal extent of the VOC-impacted groundwater plume. Based on monitoring data, the VOC plume included the primarily industrial area north of the Riverside Freeway (Highway 91) and west of the Orange Freeway (Highway 57). Within this area are facilities that have a history of using chlorinated solvents (i.e., TCE and PCE) and/or have documented release of VOCs that have impacted groundwater.

The VOC plume is primarily confined to the shallowmost aquifer, which is generally less than 200 feet deep; however, hydrogeologic data indicate a potential for VOC-impacted groundwater to move down into deeper aquifers tapped by existing production wells. In fact, within the past several years, two City of Fullerton production wells were removed from service and eventually destroyed because of increasing PCE concentrations. Figure 6-9 shows the PCE concentration at one of these production wells before it was removed from service. To minimize the spread of VOC contamination, which may put additional production wells at risk, OCWD is implementing the Forebay VOC Cleanup Project. The primary objective of the proposed Forebay VOC Cleanup project is to prevent further spread of groundwater contaminated by VOCs.

As currently envisioned, the Forebay VOC Cleanup Project would include four extraction wells to capture and pump groundwater having elevated levels of VOCs. The extent of the VOC plume in the shallow groundwater and the proposed locations of the four extractions wells (EW-1 to EW-4) are shown in Figure 6-10. Extracted shallow groundwater would be conveyed to a central treatment facility to reduce VOC concentrations to below drinking water standards by air stripping or other applicable VOC treatment method. The treated groundwater will be discharged to a nearby flood retention basin for percolation back to the shallow aquifer. High nitrate groundwater in the vicinity of one extraction well would be blended with low nitrate groundwater from the other three extraction wells to reduce nitrate levels to near or below the drinking water standard.

Figure 6-9

PCE CONCENTRATION AT FULLERTON PRODUCTION WELL

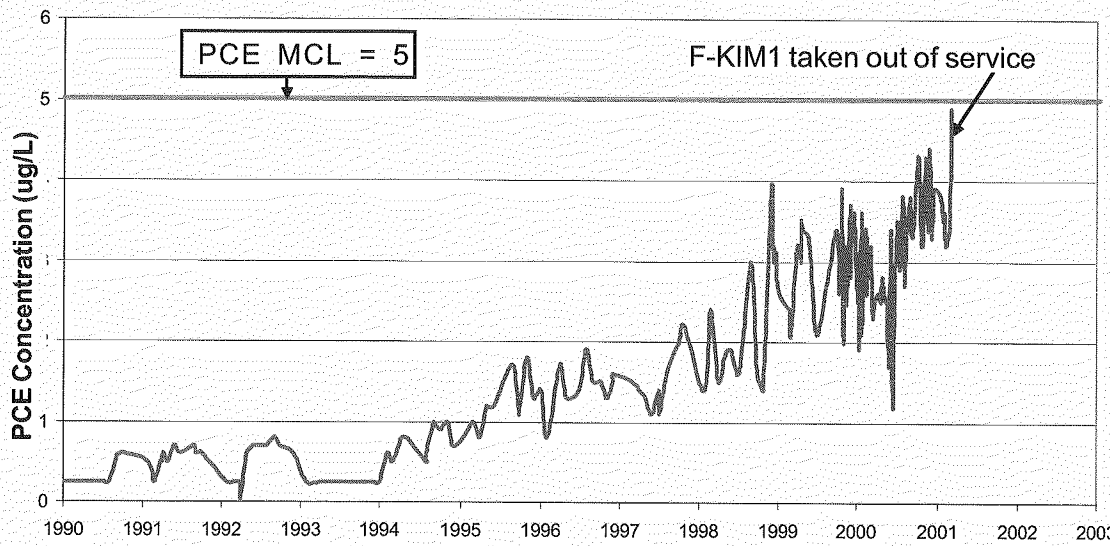
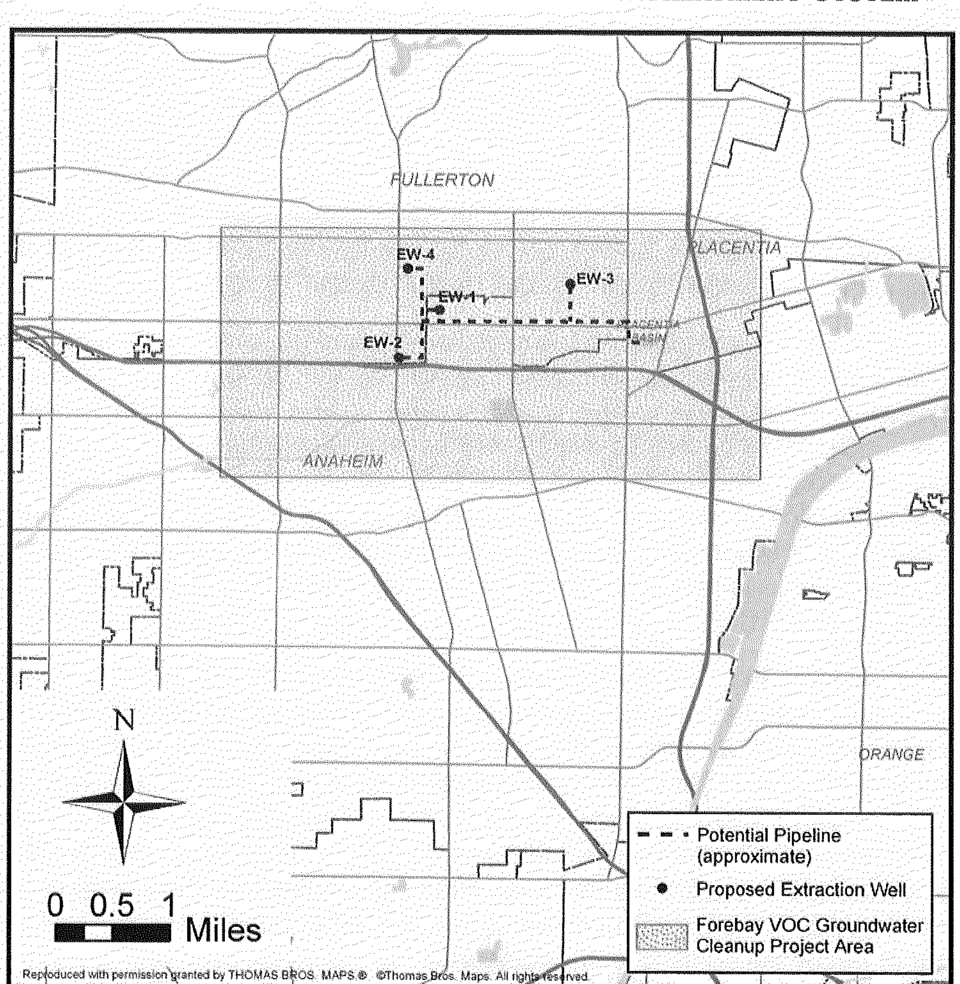


Figure 6-10

CONCEPTUAL LAYOUT OF THE GROUNDWATER TREATMENT SYSTEM



In 2001, increasing concentrations of PCE, TCE, and perchlorate were detected in IRWD well No. 3, which is located in Santa Ana. This is significant because the well is the first well located within the Pressure Area of the Basin found to be impacted by the downward migration of contaminants from the ground surface. This indicates that, although the aquitard between the shallow and deeper aquifers in the pressure area inhibits the downward migration of shallow groundwater into the deeper aquifer, it does not completely prevent it. OCWD is currently working with IRWD on various options to require aggressive cleanup actions at several nearby sites that are suspected of being sources of the contamination.

The District is conducting preliminary evaluations of a project to pump shallow groundwater impacted by TDS, nitrates, and/or other constituents, provide treatment to remove the constituents of concern, and subsequently provide the water for industrial and irrigation uses. For the shallowest groundwater, pumping rates from wells will likely be low because of the small thickness of the sediments and relatively low permeability of some shallow sediments. Due to the relatively low pumping rates at individual wells, it is possible that the project would require a large number of wells. If the water is used for industrial and irrigation uses, a separate distribution system would be required. One of the project's benefits is that it would remove degraded groundwater and provide the water for a beneficial use. Staff plan to evaluate this project further in the Long-Term Facilities Plan.

6.4 MTBE: A CASE STUDY

MTBE is not naturally occurring in the environment. MTBE is a synthetic, organic chemical used as a gasoline additive (up to 7 percent) beginning in the late 1970s to increase octane ratings during the phase-out of lead in gasoline. In the mid-1990s, MTBE increased as an oxygenate additive (11 percent to 15 percent by volume) to meet the 1990 federal CAA Amendments to use oxygenated gasoline, or reformulated gasoline (RFG), to reduce air emissions. Oxygenated fuels promote greater combustion of gasoline hydrocarbons, thereby reducing carbon monoxide and ozone levels in air. Other oxygenates include ethyl tert-butyl ether (ETBE), tert-amyl methyl ether (TAME), di-isopropyl ether (DIPE), and ethanol. California adopted similar but a more stringent reformulated gasoline program to comply with the CAA to improve air quality. The federal and state RFG regulations require the use of oxygenated fuels, and MTBE has been the oxygenate of choice by gasoline manufacturers. Although studies have shown an improvement in air quality, MTBE has become a significant threat to groundwater resources primarily from LUFT releases and due to its physiochemical characteristics. MTBE does not biodegrade readily and sorbs weakly to soil.

This subsection presents MTBE issues as a "case study" illustrating OCWD's approach to groundwater quality protection.

6.4.1 REGULATORY STATUS OF MTBE

The EPA considers MTBE as a possible human carcinogen and established an advisory level of 20-40 ppb in drinking water. EPA has not set a primary or secondary drinking water standard for MTBE; however, the agency appointed a Blue Ribbon Panel to investigate oxygenates in gasoline, the air quality benefits, and impacts to water quality. The September 1999 "Report of the Blue Ribbon Panel on Oxygenates in Gasoline" noted that between 5 and 10 percent of community drinking water sources in high MTBE-use areas have detectable levels of MTBE and that the major source of groundwater contamination appears to be releases from underground storage tanks. To obtain nationwide occurrence data, EPA included MTBE in its unregulated chemical monitoring rule (UCMR) requiring municipal well testing between January 2001 and December 2003. EPA will consider the results of the MTBE nationwide testing to evaluate if MTBE should be considered for future standard setting.

In California, the DHS established a secondary maximum contaminant level for MTBE at 5 ppb in 1999 based on the aesthetics of its low odor threshold. OCWD's laboratory conducted extensive research on the threshold odor concentrations for MTBE, and data were considered in the regulatory process in setting the secondary MCL for MTBE. Several months later, the Cal/EPA's Office of Environmental Health Hazard Assessment (OEHHA) adopted a Public Health Goal (PHG) of 13 ppb for MTBE based on the carcinogenic effects observed in experimental animals. In May 2000, DHS established the primary MCL for MTBE at 13 ppb based on the health risks as determined by the PHG and considered exposure, analytical method of detection, and costs of treatment.

In 1998, California's governor announced a phase-out of MTBE as a gasoline oxygenate based on the Lawrence Livermore National Laboratories (LLNL) finding that MTBE posed an environmental hazard and requested a waiver from the federal CAA's oxygenate requirement (Happell, et al, 1988). In 1999 and 2002, the governor released two Executive Orders (D-5-99 and D-52-02) that ordered removal of MTBE from gasoline fuel by December 31, 2003. In 2001, EPA denied the California oxygenate waiver, a lawsuit was filed, and the Ninth Circuit Court of Appeals ordered EPA to reconsider the oxygenate waiver for California (July 2003). Water associations, including OCWD, have supported the ban on MTBE and are in favor of an oxygenate waiver as an initial step to prevent continued groundwater contamination.

6.4.2 MTBE RESPONSE PROGRAMS

Drinking water wells in the Basin are tested for MTBE at least annually and approximately 50 wells quarterly. Since 1995, over 17,350 MTBE samples have been analyzed from approximately 1,300 wells. Figure 6-11 shows MTBE concentrations at two drinking water wells in the Basin that were removed from service.

OCWD is concerned with the high levels of MTBE in the shallow groundwater documented at release sites ranging up to 1,000,000 ppb. The majority of tank owners and responsible parties do not have a groundwater cleanup program in place to remove the MTBE. The District continues to work with local water agencies to monitor for MTBE and other fuel-related contaminants to identify areas that may have potential underground storage tank problems and releases resulting in groundwater contamination.

OCWD strongly supports measures that would result in the use appropriate fuel oxygenates (with consideration of the potential impact to groundwater from a LUFT release). In 1998, OCWD developed an MTBE Action Kit to inform officials within the District's service area about this issue. The District continues to work closely with other water agencies and regulatory agencies so that MTBE does not become a problem in Orange County.

In 2003, OCWD filed suit against numerous oil and petroleum-related companies that produce, refine, distribute, market, and sell MTBE and other oxygenates. The suit seeks funding from these responsible parties to pay for the investigation, monitoring, and removal of oxygenates from the Basin. As shown on Figure 6-12, the Basin has hundreds of documented LUFT sites. The majority of the release sites have not implemented groundwater cleanup to remove MTBE from the underlying contaminated shallow groundwater.

Figure 6-11

MTBE CONTAMINATION AT TWO DRINKING WATER WELLS

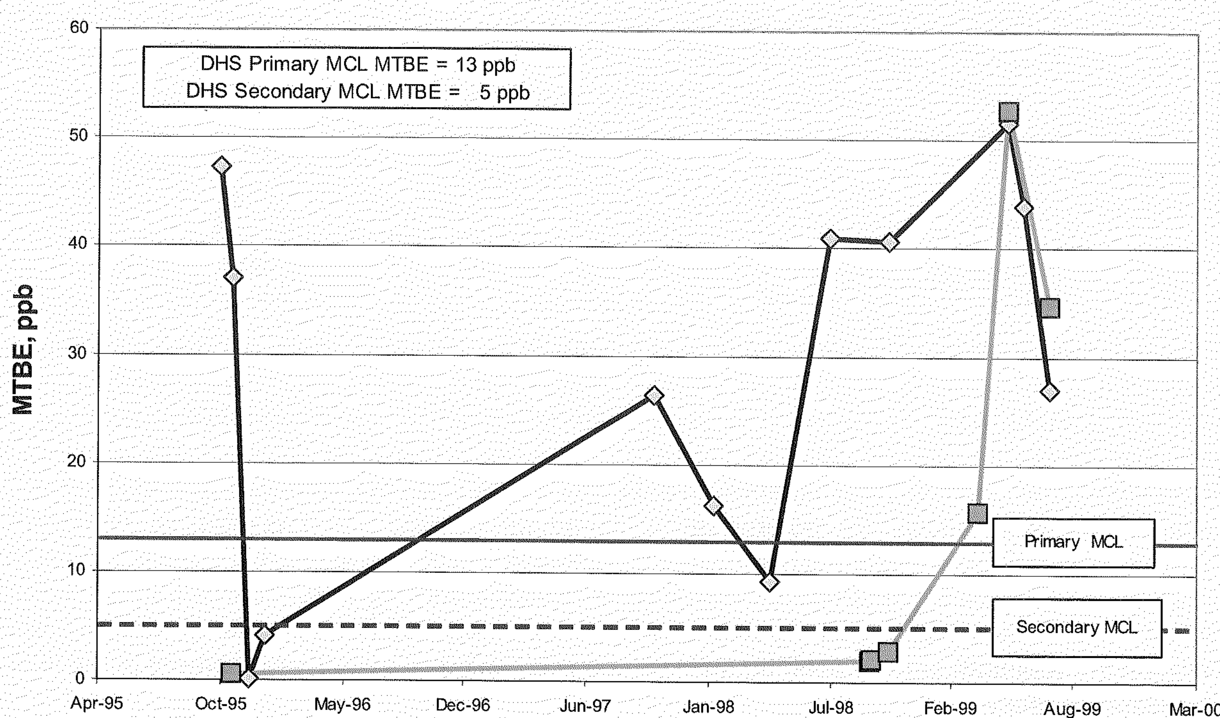
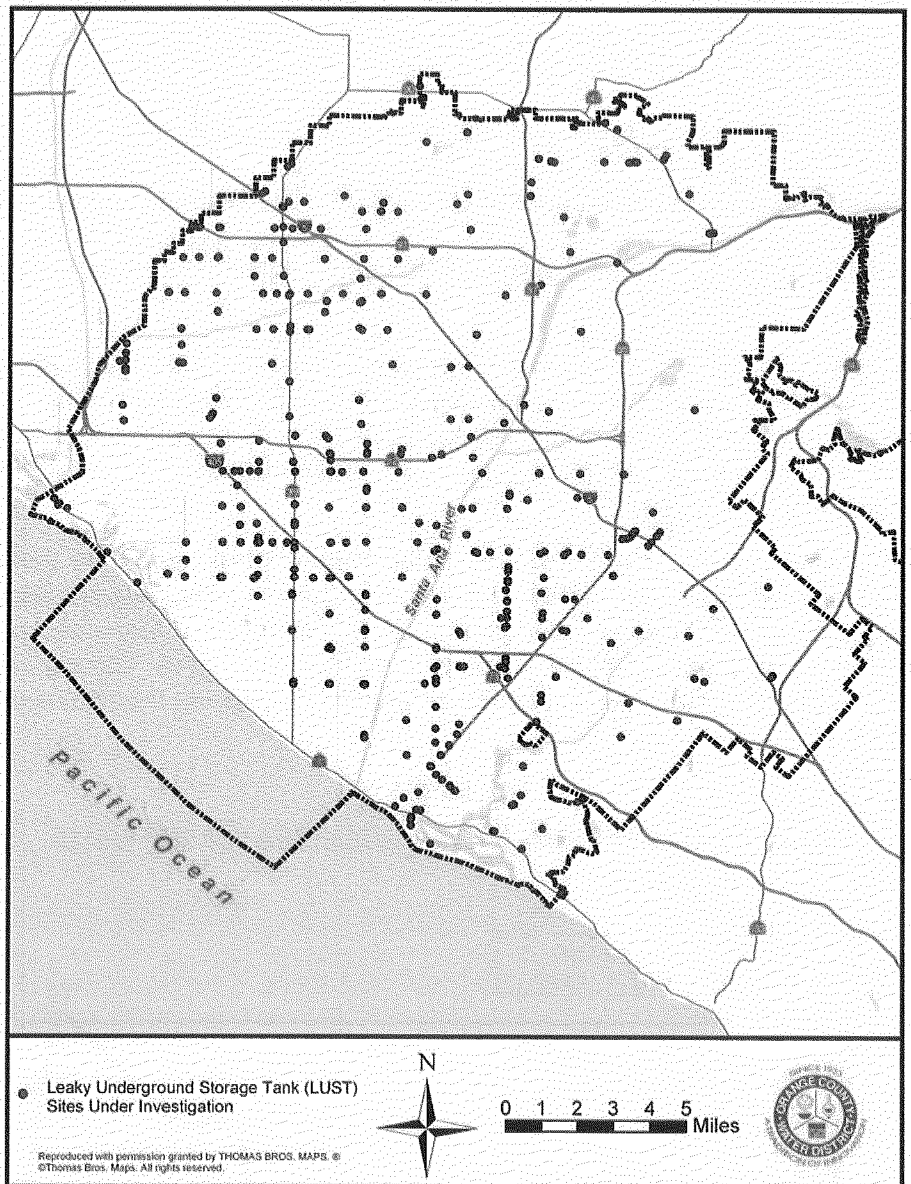


Figure 6-12

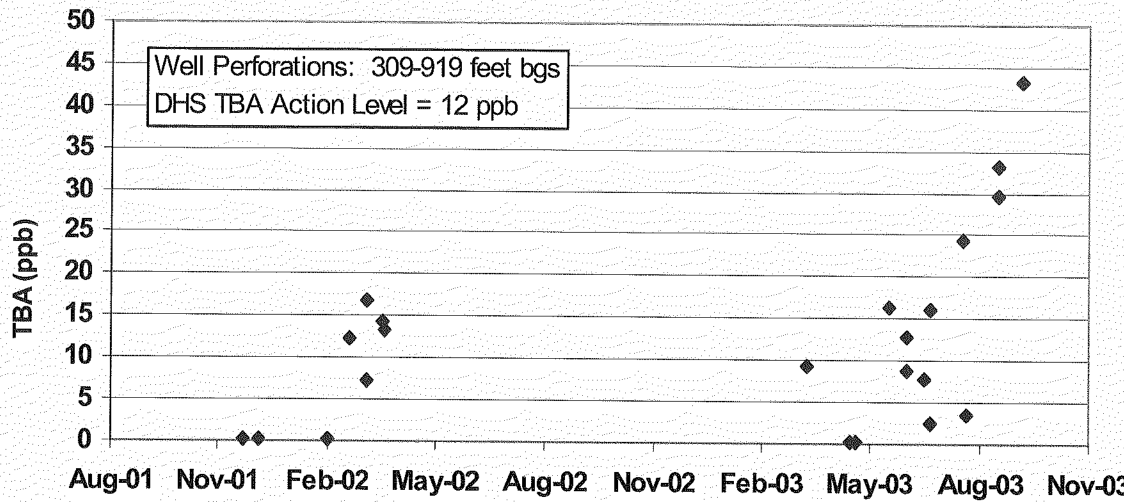
LEAKY UNDERGROUND STORAGE TANK SITES



In the summer of 1998, OCWD began testing for the other alkyl ether compounds, including ETBE, TAME, and DIPE as part of the routine volatile organics analysis. To date, these constituents have been non-detect in all groundwater samples analyzed from drinking and non-drinking water sources. Tertiary butyl alcohol (TBA) is also an octane enhancer and may be a co-contaminant with MTBE. OCWD developed the analytical capability to analyze for TBA and began monitoring in May 1999. DHS included TBA as an analyte for required testing as an unregulated chemical effective January 2001. Only one drinking water well in the basin has detectable levels of TBA at levels exceeding the state AL of 12 ppb (see Figure 6-13). DHS recommends removing a drinking water source from service if the levels of TBA exceed 1,200 ppb (100 times the AL for carcinogens); however, the water utility recently removed the well from service pending discussions with DHS and overall assessment of the well and production capacity.

Figure 6-13

TERTIARY BUTYL ALCOHOL DETECTED IN DRINKING WATER WELL



6.4.3 MTBE GROUNDWATER CLEANUP AND PROTECTION STRATEGIES

In early 1997, the City of Santa Monica approached several other water agencies and the Association of California Water Agencies (ACWA), to discuss the establishment of a statewide research effort to evaluate the impact of MTBE contamination in drinking water sources. In October 1997, an MTBE Research Partnership was formed to address these needs. The Research Partnership consists of representatives from water agencies (through ACWA and the City of Santa Monica), and a petroleum and petrochemical companies (through the Western States Petroleum Association [WSPA], and the Oxygenated Fuels Association [OFA]). The Research Partnership has created two technical work groups: Source Water Protection and Treatability. These work groups have generated and are continuing to develop valuable information about MTBE groundwater cleanup and protection strategies.

Treatment technologies evaluated by the MTBE Partnership include air stripping, advanced oxidation, and adsorption (National Water Research Institute, 2000). The MTBE Partnership may consider other treatment technologies at a later date (e.g., membranes, biological treatment).

In general, air stripping, advanced oxidation, and adsorption can be used to remove MTBE from drinking water. As the required removal efficiency increases, the unit costs for each technology also increase. Depending upon site-specific requirements, a treatment train of two or more technologies in series may be appropriate (i.e., use one technology to remove the bulk of MTBE and a follow-up technology to polish the effluent water stream). If other contaminants (e.g., excessive nitrates or TDS) are also found in groundwater with MTBE, additional treatment processes (ion exchange [IX], membranes) would also need to be included in the process train.

6.5 EMERGING CONTAMINANTS

Water quality is a critical issue to the District, the producers, and the public. Water quality criteria will continue to be a moving target in the future. Emerging contaminants, new compounds of regulatory concern, and the ongoing trend of more sensitive regulatory levels place a significant challenge on the District. If new chemicals are detected with more sensitive laboratory methods, the potential human health effects of the detection at low concentrations are typically not known; however, regulatory agencies and the public are aware of these chemicals and seek information and occurrence data. Communicating appropriate, scientific-based health information on new emerging contaminants is a challenge for water utilities and health officials.

6.5.1 PHARMACEUTICALS, PERSONAL CARE PRODUCTS, AND ENDOCRINE DISRUPTORS

The "past" emerging chemicals of concern – MTBE, chromium-6 (CrVI), perchlorate, 1,4-dioxane, NDMA – are being replaced by a new wave of emerging environmental contaminants. This broad class of thousands of chemicals is composed of consumer and health related products used daily and includes drugs (prescription and over-the-counter), food supplements, fragrances, sun-screen agents, deodorants, flavoring agents, insect repellants, and inert ingredients. This diverse group of chemicals is commonly referred to as pharmaceuticals and personal care products (PPCPs). Important classes of high use prescription drugs include antibiotics, hormones, beta-blockers (blood pressure medicine), analgesics (pain-killers), steroids, antiepileptic, sedatives, and lipid regulators.

Another class of emerging chemicals of concern include compounds that may affect the endocrine system. These compounds, commonly referred to as Endocrine Disrupting Compounds (EDCs), may originate from the wide range of cover-the-counter pharmaceuticals (cold remedies, diet supplements, etc.), pesticides, or other industrial compounds.

Water quality concerns arise from the widespread use of PPCPs and EDCs. In most cases, the human health significance of the occurrence of these compounds at low concentrations is not known. European studies in the 1990s confirmed the presence of these chemicals in the less than one microgram per liter range (ppb) in surface waters and groundwaters and at low concentrations in wastewater treatment plant effluents.

Research investigations have documented that EDCs interfere with the normal function of hormones that affect growth and reproduction in animals and humans. Findings of secondary sex changes, poor hatching, decreased fertility, and altered behavior are observed in fish following exposure to EDCs. A recent report by the USGS also found detectable concentrations of hormones and PPCPs in many vulnerable waterways throughout the United States (Kolpin 2002). Due to the potential impact of EDCs on future water reclamation projects, it is imperative that the District prioritizes tracking and awareness of these chemicals with regulatory agencies. Monitoring activities will be tailored, with guidance by DHS, to meet the informational needs required for future reclamation projects.

6.5.2 ANALYTICAL CHALLENGES

Detection of new chemicals at groundwater contaminated sites, which may pose a risk to public health or the environment, prompts regulatory agencies to require the responsible party to test at lower detection levels. Frequently, new analytical methods must be developed to analyze at orders of magnitude lower than existing methods. As new analytical methods are developed to test for these emerging chemicals, regulatory agencies are requiring testing and occurrence data for these newer chemicals at nearby drinking water sources to ensure protection of public health.

The District's state-certified laboratory develops analytical capabilities to analyze for new compounds identified as critical for overall District management of the Basin and reclamation activities. Past target compounds include MTBE (1995), CrVI (2001), perchlorate (1998), NDMA (2000), and 1,4-dioxane (2001). OCWD's laboratory is one of the few in the state that develops analytical capability, at low detection levels, upon awareness of the potential for future regulation or monitoring requirements (MCL, unregulated chemical monitoring, or component of groundwater recharge project permit, etc.). DHS has limited resources to focus on methods development and has required project permittees to test for new compounds, either through contract labs or developing the analytical capability in-house.

Source control programs and the development of analytical techniques and methods to monitor for these future targets will be required of the District. OCWD is committed to continually (1) track new compounds of concern, (2) research chemical occurrence and treatment, (3) communicate closely with DHS on prioritizing investigation and guidance, (4) coordinate closely with OCSD and regulatory agencies to identify sources and reduce contaminant releases, (5) inform the Producers on emerging issues, and (6) implement a Basinwide monitoring program as a key sentinel approach to groundwater protection.

6.6 COLORED GROUNDWATER MANAGEMENT

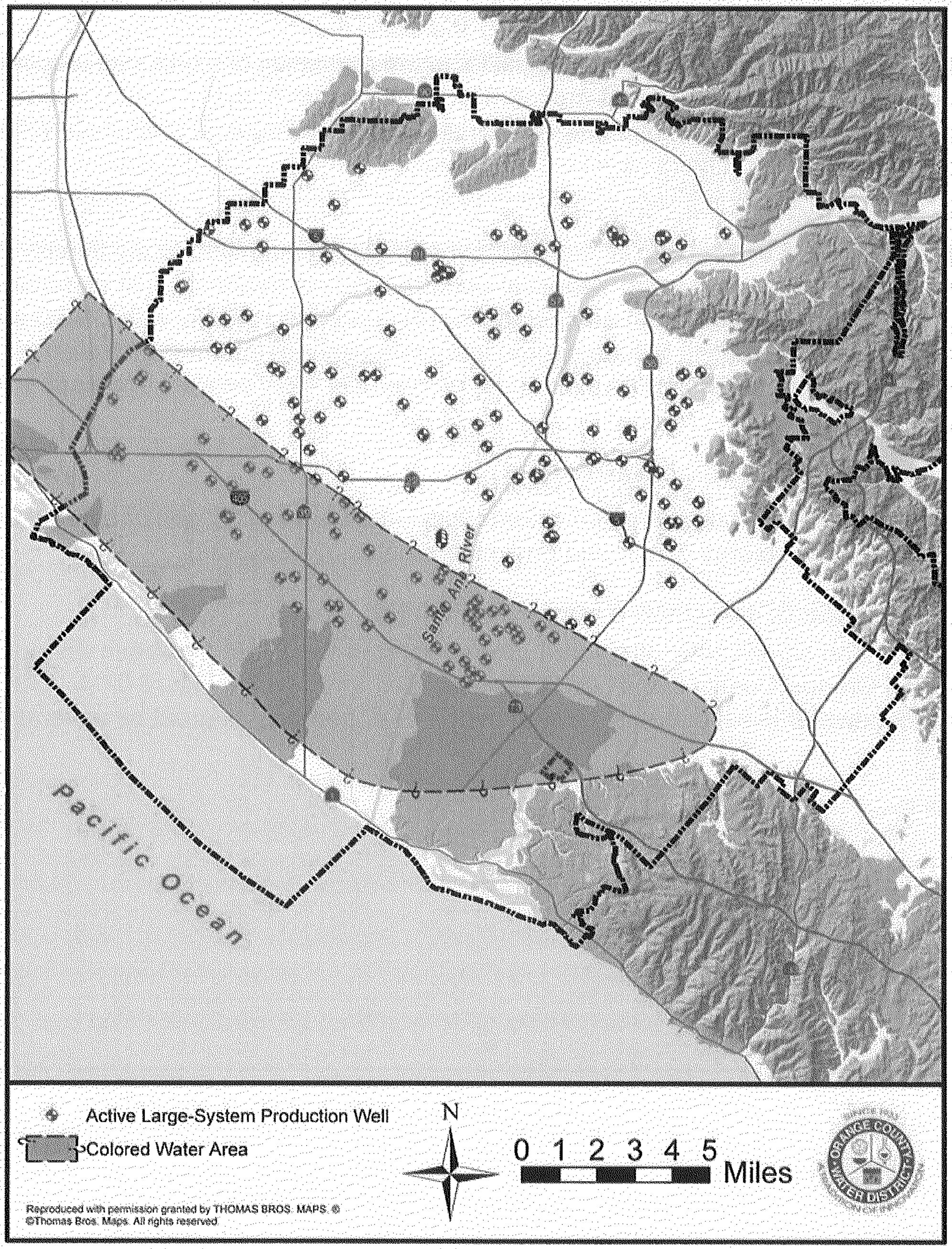
This section discusses the occurrence of colored groundwater, implications of colored water production processes to treat colored water, and preliminary costs of treatment.

6.6.1 OCCURRENCE OF COLORED WATER IN THE BASIN

The occurrence and significance of colored groundwater in the Basin has been encountered over a broad region of Orange County in the Lower Main aquifer, as shown in Figure 6-14. The total amount of colored groundwater is estimated to be well over 1 maf, perhaps as great as several million.

Figure 6-14

EXTENT OF COLORED WATER



Three facilities currently treat colored groundwater in Orange County. MCWD has operated an ozone oxidation treatment facility since 1985 at its Well No. 4 site and has operated the Colored Water Treatment Facility using ozone oxidation and biologically active filters since 2001. IRWD has successfully operated the Deep Aquifer Treatment System (DATS), a membrane treatment facility treating colored groundwater since 2002. In cooperation with OCWD, MCWD, and IRWD, considerable research has been completed to learn more about the effectiveness of various treatment technologies.

6.6.2 IMPLICATIONS OF COLORED GROUNDWATER PRODUCTION

The production and treatment of colored groundwater in the coastal areas has four principal benefits:

1. A "new" source of water is potentially available at nearly any location in the coastal area where a deep well can be constructed.
2. Production from the color zone may reduce or revere the piezometric head differential between the color and clear zones, thereby reducing the potential for upwelling of colored water into clear zones.
3. The water is of very high quality, with the exception of color and odor – an aesthetic negative.
4. Tapping the colored groundwater zone essentially activates or more fully utilizes the transmissive capability of the deeper formations to convey water to the coastal areas from the Anaheim Forebay.

The cost to treat colored groundwater varies depending on the water quality (color and other parameters) and the necessary treatment facilities. The production of significant quantities of colored groundwater may impact water levels in the clear zone. The OCWD monitoring wells reveal a correlation of clear/colored zone water level fluctuations, even with no appreciable colored groundwater extractions, indicating a fairly strong hydrologic connection between the two zones. Additional analysis needs to be conducted to define this interface issue and other colored groundwater zone recharge requirements.

In general, colored groundwater production in the coastal area has merit and should be considered as a viable option in combination with other measures.

The quality of water in the colored groundwater zone varies throughout the area. Color levels range form a low of 25 color units (cu) to a high of 180 cu. Water quality characteristics at various wells in the colored zone is shown in Table 6-5.

Table 6-5

COLORED GROUNDWATER QUALITY CHARACTERISTICS

Agency	Well No	Water Quality Characteristics					
		Color (cu)	TOC (mg/L)	TDS (mg/L)	AOC (µg c/L)	UVA	Temperature (°C)
MCWD	4	65-120	3.6	--	175	.173	--
MCWD	6[d]	105-120	4.3	254	185[e]	0.35	23
IRWD	7[a]	180	11	320	346	0.65	28-32
IRWD	51	30	--	212	--	--	--
Huntington Beach	8	25	2.1	265	251	--	23
LBCWD	[b]	70	5.6	240	--	--	--
OCWD	D1[c]	55-100	2.6	231	--	--	--
OCWD	D2-D5[c]	26-65	1.97[f]	212[f]	--	--	26-28
Cape Hatteras, NC	[g]	120-230	2-10	85	--	--	14

(a) Dyer Road Wellfield
(b) Holtz well located in Huntington Beach
(c) Talbert Barrier blending wells
(d) May-July 1997 average
(e) July 1997 average
(f) January 1995
(g) Buxton WTF feedwater

Documentation of previous investigations on several colored groundwater development projects has been reviewed, and is summarized in the following paragraphs.

MCWD Treatment Projects - MCWD has a long history of colored water development. MCWD installed ozone oxidation treatment for color and odor and started operating at its Well No. 5 site in 1983. It continued to operate the color removal system until the color disappeared in the late 1980s. MCWD installed ozone oxidation treatment for color at its Well No. 4 site in 1984 and has operated the color removal system since 1985. MCWD pilot tested ozone oxidation followed by biologically active filtration (OBAF) using water from Well No. 6 at its Well No. 4 site from 1996 to 1999. MCWD completed construction and began operation of the Colored Water Treatment Facility (CWTF) in 2001. MCWD completed additional treatment for bromate control in late 2003. Additional information regarding this project is provided in Section 7.

IRWD Deep Aquifer Treatment System (DATS) - IRWD has undertaken and completed an extensive pilot testing program on color and organic removal of deep groundwater from the Dyer Road Well Field (DRWF). The pilot research project was conducted from fall 1992 to spring 1994 using Well No. 7 (180 cu). Several alternative processes were tested: conventional ozonation, in-line ozonation, nanofiltration (NF), MF, GAC adsorption, biologically-active filtration (BAF), conventional clarification/ filtration, dissolved air flotation (DAF), and other combinations. The preferred process is color-selective NF membranes treatment, which has been utilized and is currently operating at the DATS. IRWD has operated the DATS since 2002. Additional information regarding this project is provided in Section 7.

6.6.3 TREATMENT PROCESSES

Although several treatment processes have the capability of reducing excessive levels of color and other organics in the colored groundwater zone, three processes appear to be the most effective: (1) NF membranes, followed by chemical oxidation for H_2S removal (NFCO), if required, (2) OBAF, and (3) IX resins.

The conventional coagulation/clarification/filtration process also effectively removes color. However, the process has significantly greater land requirements and therefore is not feasible in most portions of the coastal area. No single process can be considered as preferred for all color removal projects in Orange County. Several factors must be considered before determining the optimum process for a particular treatment project and are listed below:

- Color and organic water quality concentration
- Color molecular weight fractionation
- Other water quality levels (H_2S, iron, manganese, arsenic, bromide)
- Well and treatment plant capacity
- Treatment plant location, aesthetics, site constraints, and neighborhood constraints
- Residuals management requirements (NF concentrate, residual ozone destruction, BAF backwash wastes, sludge removal)
- Public safety issues and perceptions
- Full-scale operations/pilot testing data

6.6.4 POTENTIAL FOR ADDITIONAL COLORED GROUNDWATER DEVELOPMENT

Additional colored groundwater utilization facilities could be developed at the various sites in the coastal area:

- MCWD Well No. 6 Plant Expansion
- IRWD Wells Nos. 51/52 Plant
- New site(s) in west Orange County area
- New site(s) in Fountain Valley

MCWD is planning on expanding the colored groundwater treatment plant at its Well No. 6 facility into a regional facility, utilizing colored groundwater from another well on the site area to meet the needs of other purveyors.

IRWD continues to plan one or more colored groundwater treatment facilities for the future. The implementation schedule is contingent on the outcome of the ongoing IRWD water resources management study update.

Colored water treatment in the west Orange County area may be a viable supply of water for a future seawater barrier that may be needed in the Sunset Gap/Alamitos Gap area. If purified water from the GWR System or the City of Long Beach are not available in the Sunset Gap/Alamitos Gap area, the most feasible source of injection water could be treated colored water from new deep groundwater wells in the west Orange County area. This potential project is being evaluated further in the District's Long Term Facilities Plan.

To determine the viability of further developing and treating the colored groundwater zone, the following issues need to be considered.

1. Evaluate the transmissivity and production potential of the aquifers
2. Evaluate the degree of localized hydraulic connection between the Main aquifer and the colored groundwater zone, to assess the ability to control colored water upwelling potential
3. Define recharge requirements for the colored groundwater zone
4. Refine the viability and cost-effectiveness of the presently utilized and alternative treatment process
5. Determine the additional potential yield from colored groundwater development

6.6.5 COST ESTIMATES

Several cost estimates have been prepared over the last few years to depict the economic feasibility of developing and treating the colored groundwater zone. The various cost estimates prepared for the NF, NFCO, and OBAF processes, assuming a capital recovery interest rate of between 6.5 and 8.0 percent, are in the range of approximately $250 to $380 per af.

6.7 REGULATORY INVOLVEMENT

OCWD does not have regulatory authority to require responsible parties or potential responsible parties to address pollutant releases that have impacted groundwater. Therefore, close coordination and routine communication are on-going with regulatory oversight agencies having responsibility to investigate sources of contamination that may have impacted groundwater and assess the potential threat that the contamination poses to public health and the environment. Lead agencies includes the Department of Toxic Substances Control (Resource Conservation and Recovery Act (RCRA) sites), the County of Orange, Health Care Agency (leaking underground fuel tanks), RWQCB (significant groundwater contamination sites from all sources), Environmental Protection Agency (for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or RCRA sites), and the Orange County District Attorney.

As an agency with responsibility to manage and protect the groundwater resources, OCWD is actively involved on technical advisory committees or as a stakeholder to review on-going groundwater cleanup site investigations and commenting on the findings, conclusions, technical merits of progress reports, and recommendations for future planned activities. The District's comprehensive understanding of Basin hydrogeology, aquifer systems, and extensive water quality database brings valuable knowledge and expertise in assessing the areal extent of a contaminated site and evaluating the merits of proposed remedial activities. OCWD routinely provides well information, hydrogeologic data and water quality data to regulatory agencies to assist in their investigations of groundwater contaminated sites.

OCWD detected 1,4-dioxane, a solvent stabilizer, in groundwater samples collected at PRP sites that have documented solvent spills and releases. 1,4-dioxane, similar to MTBE, is very persistent and does not degrade easily in the environment. There is no state or federal drinking water standard; however, DHS has established an AL of 3 ppb in drinking water. With the finding of 1,4-dioxane at some PRP sites, the RWQCB is requiring additional groundwater delineation and deferring site closure pending results of new studies.

The District conducts third party groundwater split samples at contaminated sites to assist regulatory agencies in evaluating progress of groundwater cleanup and/or providing confirmation data of the areal extent of contamination. Results of Basinwide monitoring activities are shared with regulatory agencies to assist in their management decisions on site investigations and prioritizing sites for further investigation or cleanup.

6.8 DRINKING WATER SOURCE ASSESSMENT AND PROTECTION

Protecting and preventing pollution at the source is a national priority in protecting public health by ensuring a clean, safe drinking water supply. Source water, used in this context, is untreated water from rivers, lakes, streams, and groundwater aquifers used for drinking water supply. The 1986 and 1996 SDWA Amendments, established wellhead protection and source water assessment (SWA) programs, respectively. These programs are the foundation of protecting drinking water resources from contamination and avoid costly treatment to remove pollutants. In California, the DWSAP program fulfills these federal mandates.

DHS is the primary lead agency for developing and implementing the DWSAP program and responsible for performing the assessments of existing groundwater sources. OCWD was a contributing, working member of the technical advisory committee convened to assist DHS with development of the DWSAP, which was submitted and approved by EPA in 1999. With over 16,000 active drinking water sources in California requiring source water assessments to be completed by May 2003, DHS solicited and encouraged large water utilities to perform their own assessments.

Several discussions occurred with Basin producers in response to DHS inquiries encouraging water utilities to prepare their own system drinking water source assessments. Basin producers believed that assuming responsibility for preparation of the DWSAP reports would provide greater detail and better reflect existing conditions than could be developed by DHS due to their time and resource constraints. OCWD in partnership with Basin producers accepted responsibility to complete the SWAs. The SWA elements require significant data collection elements in addition of two distinct field data collections activities.

The eight major components of the DWSAP program are summarized in Table 6-6. OCWD assumed the lead to prepare and complete the DWSAP data forms using information in the WRMS database. Well specific information listed on driller's logs is a major source of facility information stored in WRMS. Producers provided additional well specific information specific for DSWAP data forms. Information on the drinking water source and its site characteristics are used to determine the effectiveness of the source's physical barriers in preventing contaminants from reaching the source.

Table 6-6

COMPONENTS OF THE DWSAP PROGRAM

Number	DWSAP Component	Description	Primary Responsible Agency
1	Location of drinking water well	Latitude and longitude determined by global positioning system (GPS) with accuracy of 5 meters and with correction. Actual survey data were used where available.	OCWD
2	Delineation of source area and groundwater protection zones	Modified calculated fixed radius method	OCWD
3	Drinking water physical barrier effectiveness	Evaluation of the well construction and site characteristics (geology and hydrogeologic considerations) of the effectiveness to prevent contaminants from reaching the groundwater aquifer	OCWD: Information from WRMS database with producer input as needed on site specific issues
4	Inventory of possible contaminating activities (PCA)	Identification of types of PCA's in the three protection zones	Groundwater Producers performed PCA inventory for each well
5	Vulnerability ranking	Evaluation of each PCA in terms of risk ranking, zone of location, and the physical barrier effectiveness of the source; prioritization of PCA's to identify those to which the source is most vulnerable.	OCWD
6	Assessment/capture zone map	Map of the system containing the well location with the three protection zones	OCWD
7	Complete assessment	Preparation of vulnerability assessment summary	OCWD in consultation with Groundwater Producer on potential contaminating activities and wells containing detectable regulated contaminants (DHS priority list of chemicals)
8	Public notification	Specific information on the assessment is included in the water system's annual consumer confidence report.	Groundwater Producers in annual Consumer Confidence Report

OCWD used the modified calculated fixed radius method to delineate the wellhead source water protection area for two-, five- and ten-year time-of-travel zones (required by DWSAP program). The specified zone is the surface area overlying the aquifer that contributes water to the well within the time-of-travel period. Table 6-7 and Figure 6-15 illustrate the components of the delineation areas (time of travel zones) and sizes of "capture" zones (time of travel capture zone maps).

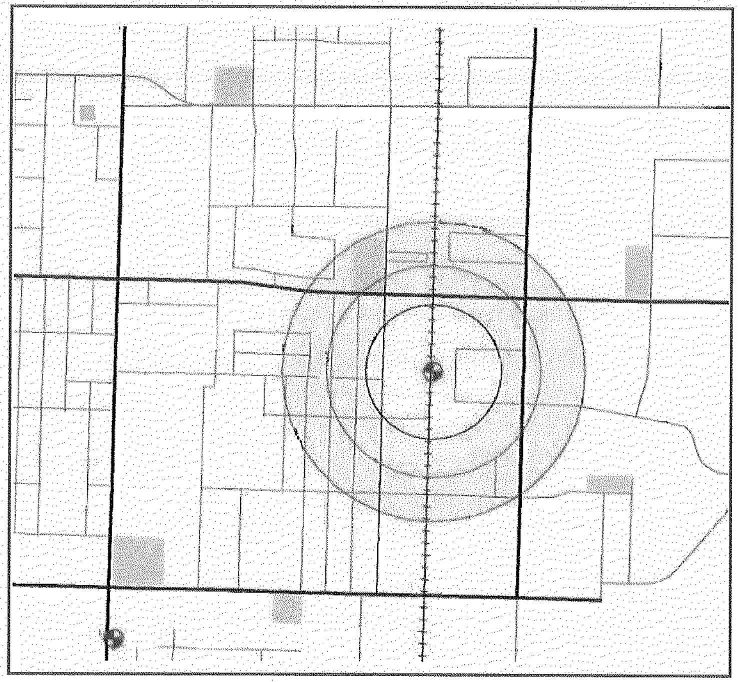
Table 6-7

DESCRIPTION OF DELINEATION OF TIME OF TRAVEL PROTECTION

Zone	Travel Time	Description
A	2 year	Protect drinking water sources from viral, microbial, and direct chemical contamination; limited time to respond to significant microbial contamination or chemical spills.
B5	2 to 5 years	Prevent chemical contamination of aquifer and protect source for a long period; provides for more response time for chemical spills than Zone A.
B10	5 to 10 years	Allows for some attenuation or remediation of contaminated sites, planning and obtaining alternate sources of water supply; encourages long-term planning of drinking water sources.

Figure 6-15

DELINEATION OF TIME OF TRAVEL PROTECTION



For new wells constructed since 2000, the well owner/water utility, not DHS, is responsible for completing a DWSAP report. The DWSAP report is a component of the drinking water well permitting process and must be submitted and approved prior to approval to use the source in the potable supply system. OCWD will continue to assist producers in preparation of the DWSAP report as new wells are constructed.

The goal of the SWA is to provide public information and increase public awareness on the vulnerability of wells to potential contamination and to encourage voluntary, local source water protection activities. Developing management strategies to prevent, reduce, or eliminate risks to groundwater sources from pollution from possible contaminating activities is one component of the multiple barrier protection of source water. Contingency planning is an essential component of a complete DWSAP and includes developing alternate water supplies for unexpected loss of each drinking water source, by man-made or catastrophic events.

6.9 LAND USE AND DEVELOPMENT

Protecting groundwater sources from contamination protects public health and prevents loss of valuable groundwater resources to meet increasing water needs. The SWA includes several wellhead protection elements: (1) delineates the time-of-travel aquifer capture zone of the source and identifies land area to be protected, (2) identifies and locates potential sources of contamination to the well, and (3) encourages management strategies to protect and prevent contamination of the groundwater. Managing land use and planning for future development are key management activities essential for protecting, preventing, and reducing contaminant risks to future drinking water supplies.

OCWD closely monitors, reviews, and comments on environmental documents (i.e., Environmental Impact Reports (EIR), Notice of Preparations, proposed zoning changes, land use projects, etc.), including draft NPDES and waste discharge permits issued by the RWQCB, with focus on water quality protection. The proposed projects/programs may have elements that cause short and/or long-term water quality impacts to source water used for groundwater replenishment or have the potential to degrade groundwater resources. Monitoring and reviewing waste discharge permits provides the District with insight on projects in the watershed that require establishment of effluent limits at points of discharge. The monitoring and review also identifies polluted sites in the Basin undergoing groundwater investigation and provides opportunity to comment on issues of concern pertaining to protecting the Basin and implementing timely remedial cleanup plans. OCWD actively participates in the Basin planning activities of the Santa Ana RWQCB as part of its responsibility for overall management and protection of the Basin.

Other measures addressing land use and development include compliance with the federal mandated storm water program. The District monitors the development and implementation of the County's Municipal Stormwater Water Quality Management Plan to protect groundwater replenishment water. At the local level, the storm water program requires implementation of structural and non-structural best management practices (BMPs) to control storm water and urban runoff at new developments to protect water quality and prevent degradation. The BMPs or measures must reduce/eliminate the discharge of pollutants from new and significant developments.

The majority of the Basin's land area is located in a highly urbanized setting and will require tailored strategies unique for an urban setting to protect existing water supply sources. Stakeholder education across all sectors of the community, the public, planners, developers, and businesses is a management strategy to raise the awareness of the need to protect drinking water sources. Developing and implementing source water protection measures will require evaluation of benefits and costs, as not all protection measures will be cost-effective. Consideration must be given to the cost of cleanup to remove a pollutant from a water supply source or complete loss of supply due to the extent of contamination and cost to treat.

Future land use and development, even in a highly urban setting, provide opportunities at the planning and permitting stage to consider potential impacts to water system's sources and to require pollution prevention in land use permit conditions, zoning, subdivision design, and related development components. These may include coordinating with local agencies having oversight responsibilities on the handling, use, storage of hazardous materials; underground tank permitting; well abandonment programs; septic tank upgrades; and drainage issues.

The stormwater permits adopted by the RWQCB for the portions of Orange, Riverside, and San Bernardino Counties that are within the Santa Ana River watershed are important regulatory components. These permits are fostering increased awareness and management of water quality issues as they relate to new development and significant redevelopment. For example, each of the permits requires the permit holders (the counties and their co-permitees) to implement a public outreach program related to water quality. The permit also requires adoption of specific approaches to minimize the impact of new development and significant redevelopment on water quality.

6.10 PUBLIC OUTREACH FOR POLLUTION PREVENTION

A successful public education outreach program that benefits groundwater is the Groundwater Guardian Team (Figure 6-16). The Team was awarded designation as Groundwater Guardian Community since 1996 for implementing groundwater-related activities to support of protecting the Basin, including:

- Co-sponsoring a two-day Children's Water Education Festival, which features hands-on activities designed to teach third- and fourth-grade students about the interdependence of water, soil, plants, trees, animals and humans
- Developing of a yearlong interactive presentation at the Discovery Science

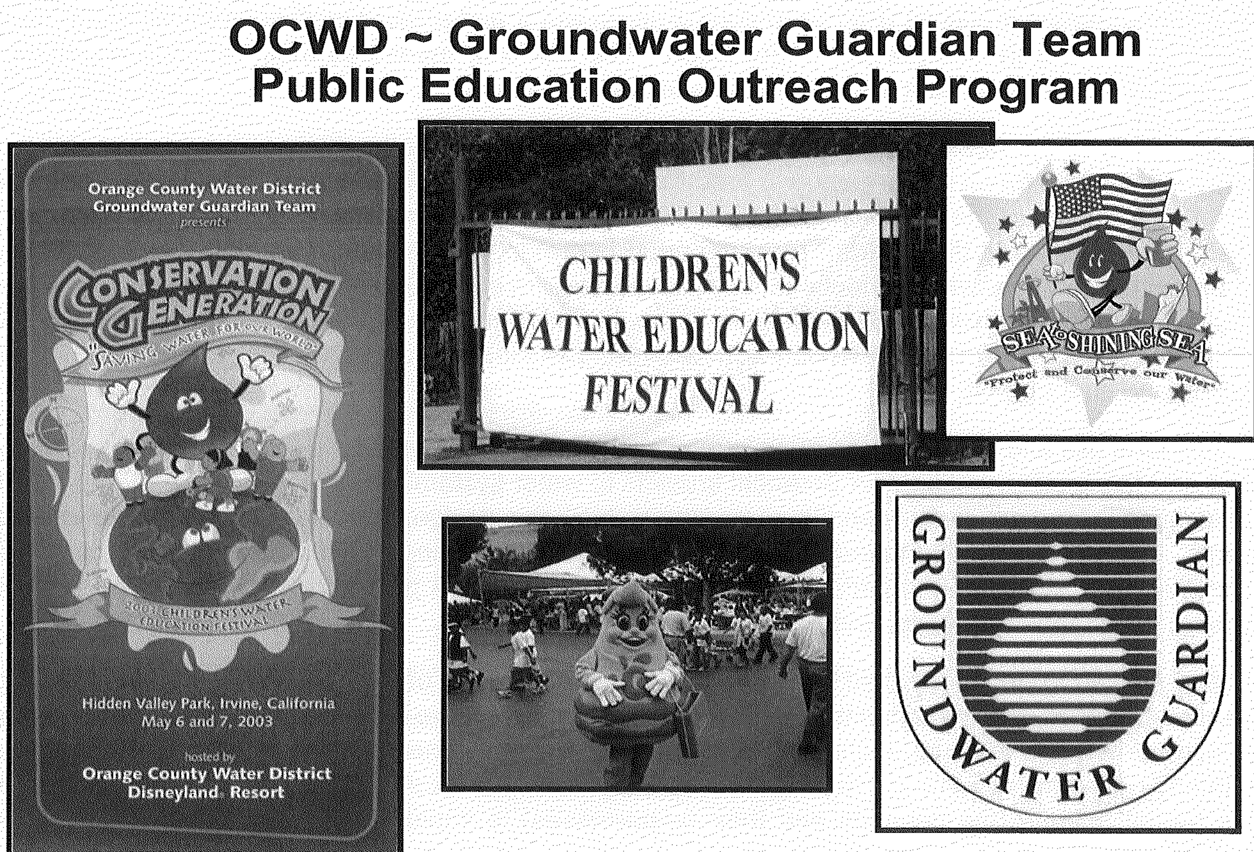
Center in Santa Ana, CA, educating visitors about water and oil, and recycling used motor oil to avoid water contamination.

- Establishing an MTBE committee to initiate public outreach about the gasoline additive that is contaminating groundwater supplies in Southern California.
- Providing information and education on groundwater protection and water conservation at community events throughout the County.

The Groundwater Guardian program encourages communities to begin groundwater awareness and protection activities and serves as a model of developing source water protection as recommended by the DWSAP program.

Figure 6-16

GROUNDWATER GUARDIAN TEAM PUBLIC OUTREACH PROGRAM



6.11 WELL CONSTRUCTION POLICIES

Monitoring wells constructed by the District are constructed to prevent the migration of surface contamination into the subsurface. This is achieved through the placement of annular well seals and surface seals during construction. Also, seals are placed within the borehole annulus between aquifers to minimize the potential for flow between aquifers.

Well construction ordinances adopted and implemented by the OCHCA and municipalities follow state well construction standards established to protect water quality under California Water Code Section 231. To provide guidance and policy recommendations on these ordinances, the County of Orange established the Well Standards Advisory Board in the early 1970s. The five-member appointed Board includes the District's Hydrogeologist. Recommendations of the Board are used by the OCHCA and municipalities to enforce well construction ordinances within their jurisdictions.

6.12 WELL CLOSURE PROGRAM FOR ABANDONED WELLS

An abandoned well is a well that the owner has permanently discontinued from use or is in a state of disrepair such that it can no longer be used for its intended purpose. In some cases, abandoned wells have been forgotten about by the owner, were not discolosed at the time of property sale or transfer to a new owner, or are located on property of which the owner is unknown or unclear. Based on eight years of records research and field reconnaissance, performed by in-house staff and Groundwater Guardian program volunteers, OCWD staff estimated that there may be 1,400 abandoned wells which have not been properly closed. Many of these wells may not be able to be located due to overlying structures, landscaping, or pavement and, therefore, are not feasible for proper closure. The remaining wells that can be identified and accessed would be considered as candidates for closure. The Orange County Health Care Agency, municipalities, and water purveyors support OCWD's efforts to prioritize closure of wells that pose the greatest threat to water quality; those wells located in known areas of contamination, those with inter-aquifer screened intervals, and/or those without proper sanitary seals.

The District is evaluating the development and implementation of an abandoned production well closure program to protect groundwater underlying the highly urbanized northern half of Orange County. Properly closing abandoned wells can be time consuming and costly. This program will especially target the closure of abandoned wells that have no owner on record. Concurrently, local well standards enforcement agencies will encourage identifiable well owners to close abandoned wells that are not in compliance with mandated well standards.

The need for development of a multi-agency abandoned well closure program stems from several factors. The estimated 1,400 wells considered to be abandoned or of an unknown status pose a threat to water quality because abandoned wells are potential conduits for contamination transport as well as physical hazards to humans and/or animals. Because OCWD's District Act provides statutory authority to protect groundwater within its service area and the OCHCA and the four non-participating municipalities have the authority to enforce State well closure requirements, a multi-agency approach is needed.

The program would target eventual destruction of all accessible abandoned wells within the Basin. In addition to its own list of wells, OCWD would request assistance from the local water purveyors and municipalities to provide lists of abandoned wells that they would like to see destroyed. Once these lists of wells are gathered, OCWD would ask the applicable well standards enforcement agencies to enforce their ordinances. The well standards enforcement agencies would notify the well owners that the wells must be properly destroyed within an appropriate timeframe or the owners will be held accountable for failure to comply. Well owners that are unwilling or unable to comply with well destruction ordinances may be subject to property liens or eligible for low-interest loans or grants to help fund the destruction costs.

A ranking process would determine the order in which this program seeks ordinance enforcement as well as the order in which wells are properly destroyed using OCWD funds. Wells that pose a physical threat to human life would be immediately altered so as to prohibit injury. Wells that have a close proximity to an active water production well, wells with a perforated interval that extends through several aquifers, wells with unknown perforated intervals, and wells which have a poor or no sanitary seal would be ranked as a higher priority for well destruction. Each well would be considered on an individual basis.

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section 7 Groundwater Quality Improvement Projects

The preceding section of this Plan describes the wide range of groundwater quality issues the District is addressing through proactive programs. This section describes specific projects that improve groundwater quality by removing TDS, nitrate, VOCs and other constituents.

7.1 BEA EXEMPTION FOR IMPROVEMENT PROJECTS

Production from wells that produce from "a zone replenished by the Santa Ana River or its tributaries," is subject to payment of the RA and BEA, according to the OCWD Act. Section 38.1 of the Act provides specific criteria for exemption of the BEA:

> *"If the board of directors finds and determines that the water produced from the facility or facilities or any of them has or will have a beneficial effect upon the quality of the water supplies of the district, the board of directors may make an order that water produced from the water-producing facility or facilities shall be exempted from either or both of the following:*
>
> (A) The payment of all or any portion of the basin equity assessment ...
>
> (B) The production requirements and limitations as provided in this act."

Under this provision, the District has previously exempted all or a portion of the BEA in specific cases where groundwater does not meet drinking water standards and is pumped and treated for municipal use. In these instances, the benefits to the Basin included: (1) removal and beneficial use of poor-quality groundwater and (2) lessening or preventing the spread of poor-quality groundwater into non-degraded aquifer zones. The purpose and amount of the BEA exemption were based on reimbursing the Producer for necessary water treatment costs. Only groundwater unsuitable for potable use is eligible for the BEA exemption.

OCWD's policy has been to use a partial or total exemption of the BEA as a means of compensating the qualified participating agency or Producer for its costs for treating poor-quality groundwater. These costs typically include capital, interest, and O&M costs for the treatment facilities.

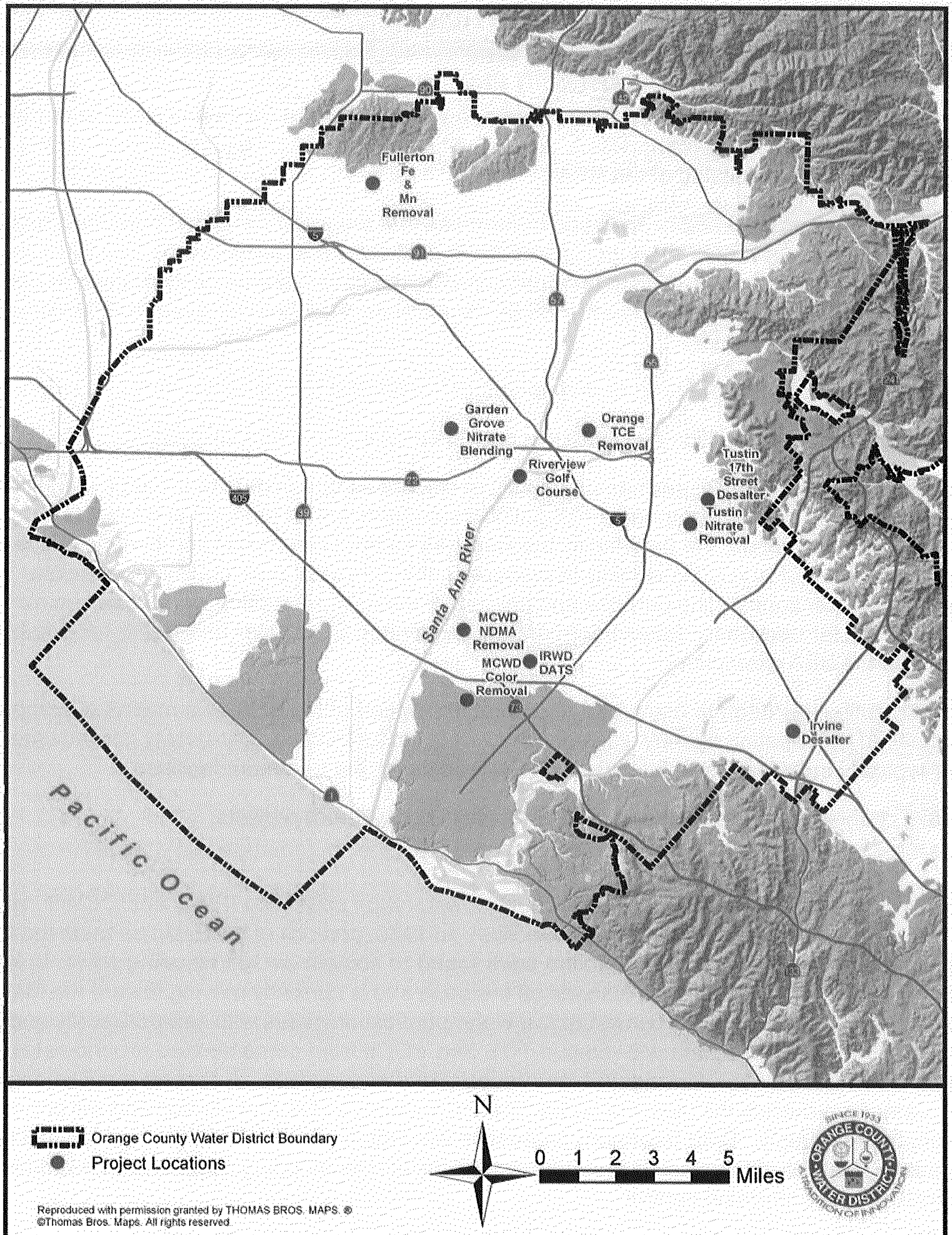
Figure 7-1 shows the locations of the water quality improvement projects.

7.2 DESALTER PROJECTS

The Irvine Desalter is a joint groundwater quality restoration project by IRWD and OCWD, with financial participation by the US Navy and Metropolitan. In 1985, portions of the Basin beneath the former El Toro MCAS and the central area of Irvine were found to contain aircraft cleaning solvents known as VOCs. A plume of contamination extends off the base and is currently moving toward the Main Basin. The Irvine Desalter project will consist of two water purification plants with separate wells and pipeline systems. One treatment plant will remove TDS and VOCs from contaminated groundwater, and the treated water will be used for irrigation and recycled water purposes. A second purification plant will treat water from outside the plume of contamination to remove TDS and nitrates and will provide a new drinking water supply. Both treatment processes will employ RO membranes and disinfection. The process to treat the contaminated groundwater will include air stripping coupled with activated carbon adsorption for air emission control.

Figure 7-1

WATER QUALITY IMPROVEMENT PROJECTS



The Tustin Seventeenth Street Desalter has been in operation since 1996 and reduces high nitrate and TDS concentration from the groundwater produced by Tustin's Seventeenth Street Wells Nos. 2 and 4 and Tustin's Newport well. The desalter utilizes two RO membrane trains to treat the groundwater. The treatment capacity of each RO train is 1 mgd. Approximately 1 mgd is bypassed and blended with the RO product water to produce up to 3 mgd or 3,000 afy. During fiscal year 2001-02, 354,000 pounds of nitrate per year were removed at this treatment facility.

7.3 NITRATE REMOVAL PROJECTS

The Garden Grove Nitrate Removal Project is a blending project utilizing two wells in order to meet the MCL for nitrate. Garden Grove Well No. 28 containing high nitrate concentration is blended with Garden Grove Well No. 23 containing low nitrate concentration. The typical average flow rates of Garden Grove Well Nos. 28 and 23 are 1,200 and 1,855 gpm. The blended water meets the MCL for nitrate and is disinfected with chlorine prior to delivery into the potable water distribution system. Operation of this project removes nitrate from the Basin since, without the blending project, the high nitrate well would not be operable unless treatment is provided.

Tustin's Main Street Treatment Plant has been in operation since 1989 and reduces nitrate levels from the groundwater produced by Tustin's Main Street Wells Nos. 3 and 4. The untreated groundwater can undergo either RO or IX treatment. The RO membranes and IX unit operate in a parallel treatment train. Approximately 1 mgd is bypassed and blended with the treatment plant product water to produce up to 2 mgd or 2,000 afy. During fiscal year 2001-02, 120,000 pounds of nitrate were removed at this treatment plant.

7.4 VOC REMOVAL PROJECTS

The River View Golf Course (RVGC), located in the City of Santa Ana, petitioned for exemption from the BEA on the basis that its well quality is impacted by VOC contamination that resulted from an upgradient source. The well is currently used solely for golf course irrigation, but had been used for potable supply prior to the VOC degradation. The District's Board approved a partial BEA exemption in the amount of $50/af for treatment costs necessary for the groundwater unsuitable for potable use. The RVGC well capacity is approximately 350 afy. Continued operation of the RVGC well helps to remove VOC contamination from the Basin.

7.5 COLORED WATER TREATMENT

The MCWD colored groundwater treatment plant utilizes ozone oxidation for color removal. Untreated colored groundwater from Wells Nos. 6 and 11 is pumped to ozone contactors for color removal. Among the ozone by-products is the assimiable organic carbon (AOC), which increases the microbiological regrowth potential within the distribution system. Pressurized biologically-active filtration is employed immediately after ozone oxidation in order to remove AOC and produce a microbiologically stable water. In order to meet the stringent disinfection by-products MCLs, chloramination (a combination of chlorine and ammonia) is used as the disinfectant of product water prior to delivery to distribution system. The Phase 1 target water production goal is 5,000 afy.

IRWD's DATS is a project to remove color from deep aquifer groundwater. A total of 8 mgd of colored groundwater is pumped from two wells (IRWD C8 and C9) to the DATS plant. NF membranes are the main treatment of the DATS. The facility has three NF trains, each producing 2.44 mgd at a recovery rate of 92 percent. The high quality NF product water is degasified and disinfected prior to entering the drinking water system. The highly colored NF concentrate is sent to disposal in the sanitary sewer. The DATS membrane process removes color and other organics to produce 7.4 mgd of drinking water, which is pumped into the DRWF pipeline.

The colored water treatment projects operated by MCWD and IRWD provide an important benefit in addition to the water supply they produce. Groundwater levels in the colored aquifer are typically higher than in the clear water aquifers. The aquifers with colored water are generally deeper than the primary clear water production zones, and upward vertical migration of the colored water into the clear water aquifers has been observed. Upward migration of colored water into the clear water zones has the potential to impair water quality in the clear water zones. The large groundwater level difference between the colored water aquifer and clear water aquifers exacerbates this situation. By pumping from the colored water aquifer, the MCWD and IRWD colored water treatment projects reduce the groundwater level in the colored water aquifer, thus reducing the vertical migration of colored water into the clear water aquifers.

7.6 IRON AND MANGANESE REMOVAL

The City of Fullerton iron and manganese removal project is located at the City's Coyote well site. The groundwater extracted from this well is unsuitable for domestic or agricultural purposes due to excessive iron and manganese concentrations. The well capacity is approximately 500 gpm or 700 afy at an operational factor of 90 percent. The District provides a BEA exemption to cover Fullerton's treatment costs. Treatment of the water to lower the iron and manganese concentrations is necessary for potable use of the water.

7.7 NDMA REMOVAL

MCWD's NDMA project provides wellhead treatment for potable water production well MCWD-5, with the objective to remove low levels of NDMA to meet the current NDMA Action Level of 10 nanograms per liter (ng/L) established by DHS. It is important to note that no MCL has been established for NDMA. The treatment process consists of UV oxidation, and the UV lamps are contained in quartz sleeves. This project, which has a maximum treatment capacity of 5 mgd, has been in operation since July 2001. Continued operation of MCWD-5 helps to remove NDMA from the Basin and minimizes downgradient migration of NDMA.

7.8 SUMMARY OF IMPROVEMENT PROJECTS AND REPLENISHMENT OBLIGATIONS

Table 7-1 summarizes the water quality improvement projects that provide a benefit to the basin by removing salts, nitrate, VOC, or other constituents of concern. When the District authorizes a BEA exemption for such a project, the District is obligated to provide the replenishment water for the production above the BPP, but the District does not receive the BEA revenue that would otherwise be provided by the producer. As shown in Table 7-1, the District's total replenishment obligation (annual groundwater production allowed by BEA exemption) for projects that have received a BEA exemption is 33,750 afy.

Table 7-1

SUMMARY OF WATER QUALITY IMPROVEMENT PROJECTS AND REPLENISHMENT OBLIGATION

Summary of Water Quality Improvement Projects				
Project Name	Project Description	Board Approval of BEA Exemption	Recent Annual Groundwater Production Above the BPP (af)	OCWD Subsidy
Irvine Desalter	Removal of nitrate and TDS for potable water use and removal of TDS and VOC for industrial and irrigation use	2001	0	BEA Exemption
Tustin Desalter	Nitrate and TDS removals from wells on 17th Street using RO membranes	1998	1,773	BEA Exemption
Garden Grove Nitrate	Blending two Garden Grove wells to meet nitrate MCL	1998	1,500	BEA Exemption
Tustin Nitrate	Nitrate removal from wells on Main Street using RO membranes and ion exchange	1998	1,076	BEA Exemption
River View Golf Club VOC	VOC extraction from well in RVGC	1998	350	$50/af Reduction in BEA
MCWD Colored Water	Color removal from wells 6 and 11 using ozone oxidation	2000	4,224	BEA Exemption
IRWD DATS	Color removal from wells C8 and C9 using NF membranes	1999	6,500	BEA Exemption
Fullerton Iron / Manganese	Wellhead treatment process for iron and manganese from Fullerton Coyote well	1999	700	BEA Exemption
MCWD NDMA	Removal of NDMA from well 5 using UV	2000	3,581	Direct Contribution for design and construction of treatment system and operations and maintenance
Total	-	-	**19,704**	-

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section 8 Historical and Future Water Demands

Estimating total water demands is important because the amount of future total demands helps determine the range of demands that may be placed on the Basin. This section:

- **Discusses past and current total demand.**
- **Estimates future demands, both within OCWD's existing boundary and with possible annexations.**
- **Describes the District's activities in water conservation.**

8.1 TOTAL WATER DEMANDS

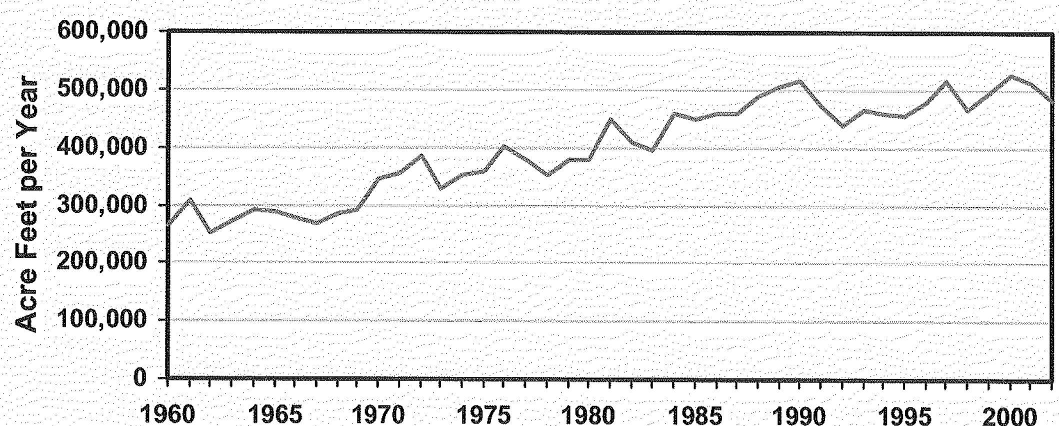
Numerous factors impact future demands such as population growth, economic conditions, conservation programs, and hydrologic conditions. Estimates of future demands are therefore subject to some uncertainty and should be updated on a periodic basis. Projections were obtained from the individual retail water Producers within the existing District boundaries and from model projections from Metropolitan. Projections were also obtained for areas outside the District that have the potential to annex into the District.

8.1.1 CURRENT WATER DEMANDS

Total water demands within the District's boundary for fiscal year 2002-03 were approximately 485,000 af. Figure 8-1 provides historical water demands in the District (excluding replenishment), which were obtained from the District's annual Engineer's Report. Total demands have increased about 250,000 afy since 1962.

Figure 8-1

HISTORIC TOTAL DISTRICT WATER DEMANDS



8.1.2 FUTURE WATER DEMANDS

Estimating water demands is necessary for the planning of future water supply projects and programs. OCWD must strive to provide a reliable and economical source of water to its customers in the future, while protecting the groundwater basin. The magnitude of estimated demands must be quantified as accurately as possible because the amount of water needed will help determine future courses of action.

Future water demands from possible annexation areas have been estimated in addition to demands within existing boundaries.

Future water demands within OCWD's boundary are related to estimated population increases, which are summarized in Table 8-1.

Table 8-1

ESTIMATED POPULATION WITHIN ORANGE COUNTY WATER DISTRICT BOUNDARY

	2000	2005	2010	2015	2020	2025
Without Annexations	2,184,652	2,268,691	2,326,973	2,360,612	2,408,245	2,548,263
With Annexations	2,184,652	2,268,691	2,471,588	2,518,640	2,577,430	2,727,285

Source: MWDOC and Center for Demographics Research

The total population within the Santa Ana River Watershed is also estimated to increase, as shown in Table 8-2.

Table 8-2

ESTIMATED POPULATION WITHIN SANTA ANA RIVER WATERSHED

2000	2005	2010	2015	2020	2025
5,125,068	5,516,902	5,835,946	6,232,207	6,666,743	7,192,720

Source: SAWPA (2002)

8.1.2.1 DEMANDS WITHIN EXISTING DISTRICT BOUNDARIES

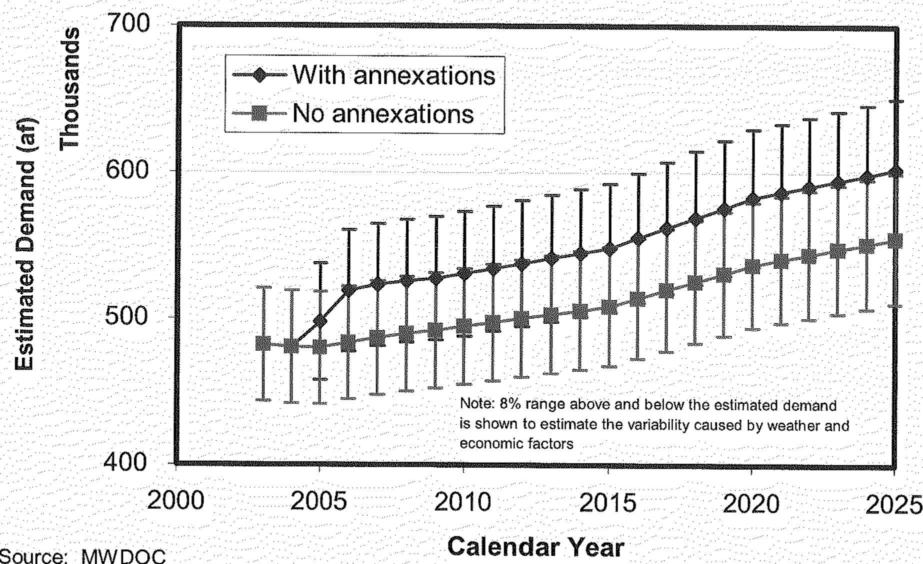
Projected water demands by the individual retail producers within the District were originally obtained from MWDOC, which annually requests the Producers to project future water demands. These figures were compiled and redistributed to the Producers for their review.

Water demand projections are also available from the water demand modeling conducted by Metropolitan. As part of its Integrated Resources Plan, Metropolitan developed a detailed model of water demands that accounts for population growth, economic factors, water conservation, and other important water demand considerations. The model is particularly useful because it can evaluate the sensitivity of future water demands to changing conditions, such as drought and population changes. Upon request, Metropolitan staff ran a version of this model using specific demographic and census data for Orange County.

Future water demand projections are provided in Figure 8-2 based on the Metropolitan model. Demands are projected to increase to approximately 557,000 afy in the year 2025, assuming no annexation occurs. For comparison purposes, the estimates provided by the Producers to the MWDOC are that 2025 demands in the basin area will be 559,000 afy assuming no annexation occurs.

Figure 8-2

ESTIMATED FUTURE WATER DEMANDS



Source: MWDOC

The estimated increase in demand from 482,000 af in calendar year 2003 to 557,000 af in 2025 is an annual growth rate of approximately seven-tenths of one percent (0.7 percent) without potential annexations, assuming the increased demand occurs at a uniform annual rate.

Future annual water demands will fluctuate, primarily due to factors such as weather and economic conditions. It should be expected that annual demands might potentially increase or decrease as much as eight percent annually above or below the estimated demand, as shown by the bars indicated in Figure 8-2.

8.1.2.2 DEMANDS WITHIN POSSIBLE ANNEXATION AREAS

The District's current boundaries encompass an area of approximately 229,000 acres. The District has a history of annexing in new lands. In 1933, when the District was formed, its size was 162,676 acres, which is 40 percent smaller than today's size.

In 2003, the City of Anaheim, IRWD, and YLWD requested that the District annex additional lands to the District. Total demands, including the estimated demands from the three potential annexation areas, are shown in Figure 8-2.

The estimated increase in demand from 482,000 af in calendar year 2003 to 602,000 af in 2025 is an annual growth rate of approximately 1.1 percent with potential annexations, assuming the increased demand occurs at a uniform annual rate.

The estimated increased demand in 2025 for the three potential annexing agencies is listed in Table 8-3, based on the Metropolitan demand model.

Table 8-3

ESTIMATED 2025 DEMANDS FOR THREE POTENTIAL ANNEXING AGENCIES

Agency	Estimated Annual Demand in 2025 (af)	Estimated Annexation Demand in 2025 (af)
City of Anaheim – without annexation	92,000	-
City of Anaheim – with annexation	95,000	3,000
IRWD – without annexation	71,000	-
IRWD – with annexation	109,000	38,000
YLWD – without annexation	19,000	-
YLWD – with annexation	24,000	5,000
Total	-	46,000
Note: values are rounded to the nearest thousand Source: MWDOC		

8.1.3 WATER DEMAND PROJECTION REVIEW

Future demand projects provided by the MWDOC model and by the agencies should continue to be reviewed on a regular basis. This will ensure that the most up-to-date information is used and that any changes in estimated future demands are accounted for in future planning efforts.

8.2 WATER CONSERVATION PROGRAMS

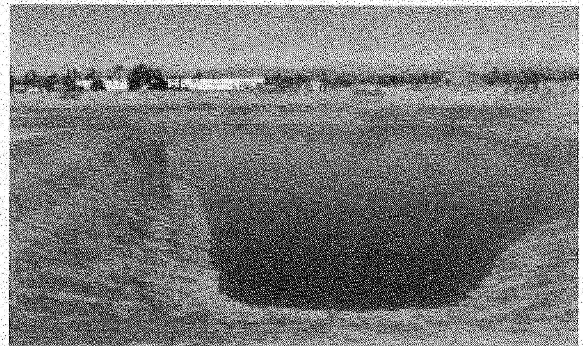
Water conservation, which can also be referred to as demand side management or water use efficiency, will play an important role in helping to meet future water demands. By implementing conservation programs, future water demand projections can be reduced, and less imported water will be necessary to meet the area's water requirements. The OCWD service area currently imports over 200,000 afy of supplemental water to meet water demands.

The impact of conservation on future water demands is difficult to estimate at this time. OCWD, MWDOC, OCSD, and interested retail water agencies have been meeting to help determine the exact role conservation will play in the future. There are many conservation programs at varying cost and impacts. Factors to consider include which programs to implement, how to fund them, the size of the programs, and which agency should administer them.

The District participated with MWDOC, OCSD, and other agencies in a low-flush toilet program that subsidized the replacement of old high-volume toilets with modern low-flow toilets. The District also participates with the MWDOC and Metropolitan in a Hotel/Motel Water Conservation Program to save water through minimizing water use at hotels. The water conservation program offers free laminated towel rack hangers or bed cards which ask hotel and motel guests who spend more than one night to consider using their towels and bed linens more than once during their stay. The program is currently active in over 30,000 hotel/motel guest rooms.

OCWD also participates with the MWDOC and other local agencies in a restaurant water conservation program. The program, designed specifically for restaurants, offers free laminated cards for the restaurants to place on their tables. The cards explain to guests that the restaurant is interested in helping conserve water for Orange County and will only serve water upon request. This program allows the guests and the restaurant to be environmentally aware while reducing water use, lowering costs, and saving energy.

section 9 Integrated Demand and Supply Management



OCWD utilizes a supply side management approach to achieve long-term sustainable yield from the Basin. On a regular basis, the amount of water that the Basin can supply is determined, and the District modifies the BPP and related management tools so that the amount of actual pumping corresponds to the amount of water that the Basin can supply. These activities are guided by the District's management objective of cost effectively protecting and increasing the Basin's sustainable yield. This section:

- Discusses the Basin's operating range (upper and lower levels of groundwater storage) and describes the impacts and opportunities associated with low and high accumulated overdraft.
- Evaluates impacts of droughts.
- Describes management strategies, including recharge water supply management and the methodology for setting the BPP.

9.1 BASIN OPERATING RANGE

The Basin operating range refers to the upper and lower levels of groundwater storage that the Basin fluctuates between. When groundwater levels are high and there is minimal or no overdraft, this represents the upper (higher) end of the range. Lower groundwater levels and increased overdraft represent the lower end of the range, as schematically shown in Figure 9-1.

Because of the variety of factors that affect management of the Basin, the District has not set a defined "safe" operating range. The District's approach outlines the range of factors that should be considered at different levels of overdraft. Consideration of these factors is used to determine the amount of Basin recharge that is needed and to specify the amount of pumping in light of the recent local hydrology, condition of the Basin and seawater intrusion barriers, and the availability of supplemental replenishment water. These factors are described in Table 9-1 and Figure 9-1.

Overdraft levels are defined based on the accumulated overdraft. The reference point for overdraft is that the basin storage condition measured in November 1969 is defined as a "full" condition. Accumulated overdraft is estimated each year based on conditions in November and is reported in the District's Engineer's Report (OCWD Engineer's Report, 2003). Accumulated overdraft represents the estimated amount of available storage below the "full" condition.

In general, it would be difficult to operate the Basin at less than 100,000 af of accumulated overdraft because of the high groundwater levels that would occur at this low level of overdraft. At less than 100,000 af of overdraft, the negative aspects listed in Table 9-1 would be greatly exacerbated.

Prior to completion of the GWR System Phase 1 in 2007, the temporary maximum level of overdraft should be 400,000 af or less to minimize the risk of seawater intrusion. A level of 400,000 af overdraft should be a temporary condition only and is not favorable for controlling seawater intrusion. When GWR System Phase 1 is operating after 2007 and increased amounts of Talbert Barrier injection are occurring, seawater intrusion may be controlled in the Talbert Gap at up to 500,000 af of overdraft based on modeling studies. Groundwater monitoring results will be carefully evaluated to determine if the increased injection is protective with increased overdraft. Monitoring results from the Bolsa, Sunset, and Alamitos Gaps will also be evaluated carefully at high levels of overdraft. Talbert Barrier improvements may allow greater levels of overdraft from the standpoint of preventing seawater intrusion in the Talbert Gap, but the susceptibility of seawater intrusion in the other Gaps is still being evaluated and may dictate that lower levels of overdraft are needed to prevent seawater intrusion.

Approximately 40,000,000 af of water are estimated to be in storage when the overdraft is 200,000 af. On a percentage basis, when the overdraft is 200,000 af, the Basin is 99.5 percent full. If the Basin overdraft increases from 200,000 to 400,000 af, the Basin changes from 99.5 to 99 percent full. This illustrates that from a classical reservoir perspective, the Basin is almost always nearly "full". The relatively narrow range of storage within which the Basin can safely operate is largely dictated by water quality issues, in particular, the risk of seawater intrusion. If this risk could be mitigated at higher levels of overdraft, then the flexibility to overdraft the Basin during droughts would be increased. Additional issues that would need to be evaluated prior to increasing the amount of overdraft, assuming an effective seawater barrier was operating, would include the risk of land subsidence, inflow of colored water or poor quality groundwater from outside the Basin, and the number of shallow production wells that would become inoperable due to lower groundwater levels.

The District previously set a target accumulated overdraft of 200,000 af. This Plan reaffirms the target of 200,000 af accumulated overdraft, with the additional factor that the 63,000 af of storage for the Metropolitan Conjunctive Use Program is accounted for. The benefit of the existing target of 200,000 af overdraft is that it provides up to 200,000 af of water in storage. Having up to 200,000 af of water in storage is valuable to the District and the Producers, particularly during drought conditions as described in Section 9.2.1.

The Metropolitan Conjunctive Use Program provides 63,000 af of excess Metropolitan surface water to be delivered via existing connections and stored in the Basin when available during normal and wet years. In exchange for this storage, Metropolitan contributed to basin improvements, including new injection well facilities and production wells. Accounting for the 63,000 af of Metropolitan storage, the target accumulated overdraft level is 137,000 af.

If future monitoring demonstrates that the Basin can be sustainably operated at 400,000 af overdraft, then there would be 200,000 af of water in storage for the District to utilize if the Basin is at the target accumulated overdraft of 137,000 af (accounting for 63,000 af of Metropolitan storage). To place the 200,000 af of water in storage in perspective, at the 2003-04 estimated pumping of 324,000 af, 200,000 af of storage is approximately 7 months of pumping.

If the Basin is at the target of 137,000 af, then up to 137,000 af of storage capacity is available if a wet period occurs when additional free SAR stormwater is available. As discussed in Section 5, the increased amount of stormflow that has historically occurred in very wet El Nino years is 60,000 af. Net incidental recharge has also increased up to 40,000 af in very wet years. Increased SAR base flow can also occur in response to very wet years, but a portion of the increased base flow is typically observed in the year after the wet year due to increase groundwater discharge to the SAR upstream of Prado Dam. Up to 100,000 af of increased recharge water is therefore estimated in very wet years. Since these very wet years (30 inches per year of more precipitation) have not occurred in back-to-back years in the rainfall history summarized in Figure 9-2, having a target overdraft level of 137,000 af provides sufficient storage capacity to recharge additional stormwater for one very wet year, with little likelihood that a second consecutive wet year would occur. If two consecutive wet years were to occur, the District can increase pumping through adjusting the BPP to create more storage capacity. At the high levels of groundwater storage represented by 137,000 af of overdraft, outflow of groundwater to LA County becomes more of an issue, and projects to address the outflow become more important.

Figure 9-1

SCHEMATIC ILLUSTRATION OF IMPACTS OF CHANGING THE AMOUNT OF GROUNDWATER IN STORAGE

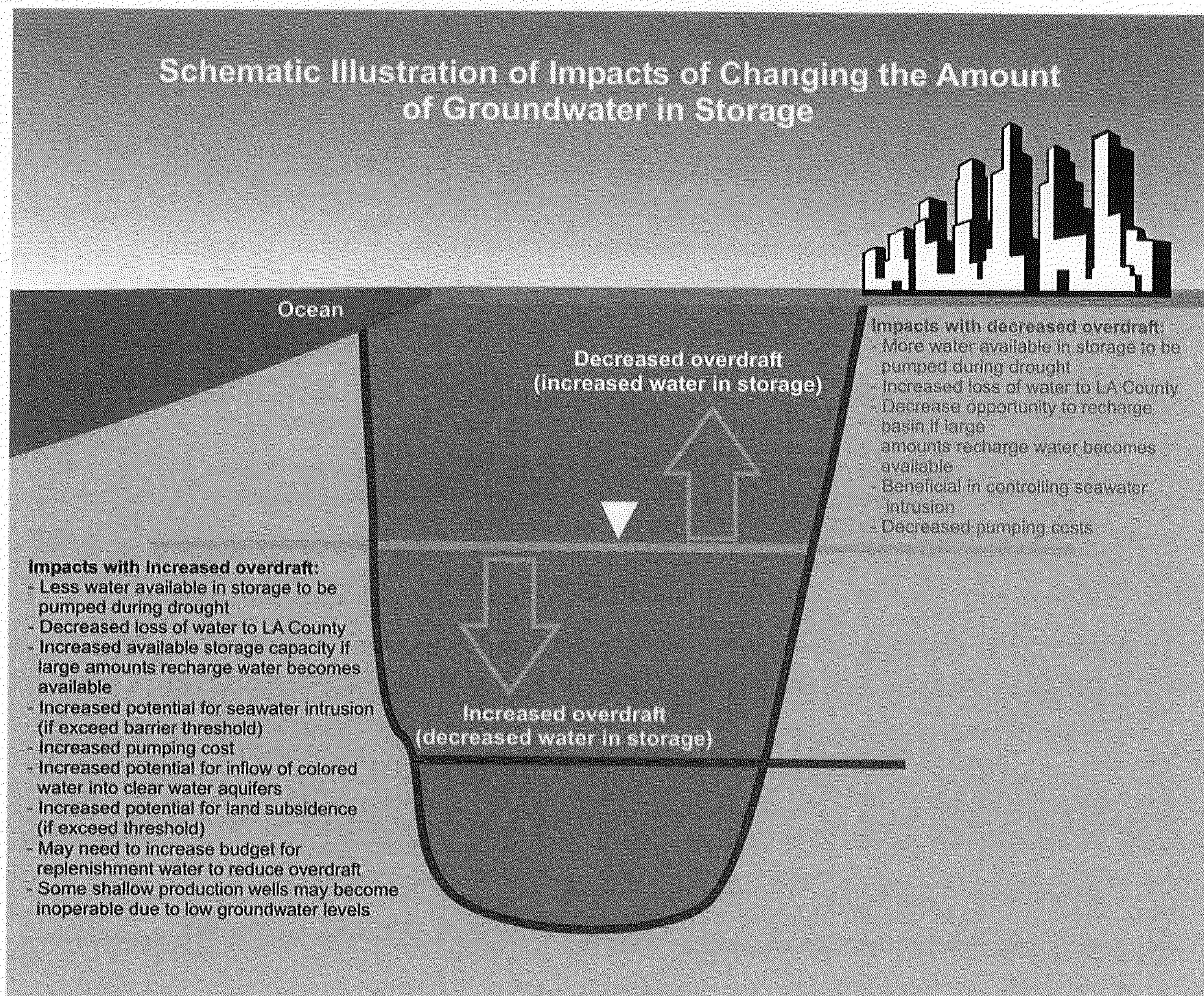


Table 9-1

BENEFITS AND DETRIMENTS OF DIFFERENT OVERDRAFT LEVELS

Accumulated Overdraft (af)	Benefits	Detriments	Annual Refill Target (af)
Less than 200,000	• Beneficial to controlling seawater intrusion • Lower pumping energy costs for producers • Easier to maintain stable BPP • Water available to be pumped from storage in shortage condition • Potential to temporarily increase BPP • Decreased potential for vertical migration of poor quality water • Opportunity to operate Basin to build reserves	• Increased loss of groundwater to Los Angeles County • Possible localized high groundwater levels and seepage at groundsurface if near full condition • Decreased opportunity to recharge Basin if large amount of free recharge water becomes available • Possible decrease in recharge capacity due to high groundwater levels (not observed at current recharge rates, but may be an issue with higher rates in future)	0
200,000 to 350,000	• Minimal to no problems with high groundwater levels • Increased available storage capacity if large amount of recharge water becomes available • Decreased groundwater outflow to Los Angeles County	• Limited amount of water in storage that can be pumped during drought or other shortage condition • Risk of seawater intrusion increases as overdraft increases from 200,000 to 350,000 af • Option for Metropolitan to call 20,000 afy from storage for 3 years would further increase overdraft	0 to 28,000
350,000 to 500,000	• Minimal to no problems with high groundwater levels • Increased available storage capacity if large amount of recharge water becomes available • Further decrease in groundwater outflow to Los Angeles County	• Little to no water in storage that can be pumped during drought or other shortage condition • Increased pumping energy costs • Further increased risk of seawater intrusion • Coastal pumping reductions potentially needed • Option for Metropolitan to call 20,000 afy from storage for 3 years further worsens overdraft • Increased number of production wells inoperable due to low groundwater levels below 400,000 af overdraft • Potential risk of increased land subsidence • Potential increased risk of vertical migration of poor quality water. • Need to increase budget for replenishment water to reduce overdraft • More difficult to maintain stable BPP	28,000 to 50,000

9.2 DROUGHT SCENARIOS

Drought is an extended period of below-average precipitation. There is no single, official definition of the time period associated with a drought. Depending on the extent of the deviation from average precipitation, the areal extent of the below-average precipitation, and other factors, a drought could correspond to a three-year period, or a longer or shorter period.

During a drought in the SAR Watershed, the District is affected in the following ways:

- The flow in the SAR declines, decreasing the amount of water available to recharge the Basin.
- The TDS of the river flows generally increase.

During a drought in the central California/Sierra Nevada area or the Colorado River watershed, the District is affected by:

- The availability of supplemental replenishment water from Metropolitan is greatly reduced (typically not available, or available in limited amounts).
- Imported water supplies from Metropolitan may be restricted, resulting in potential increased demands on the Basin.
- The TDS of the supplemental replenishment water from Metropolitan delivered through the SWP increases for a drought in the central California/Sierra Nevada area. The TDS of the Colorado River replenishment increases for a drought in the Colorado River watershed.

During a drought, it may be important to have the flexibility to increase pumping from the Basin if imported supplies from Metropolitan are restricted. To the extent that the Basin has water in storage that can be pumped out during a drought, the Basin provides a valuable water supply asset during drought conditions.

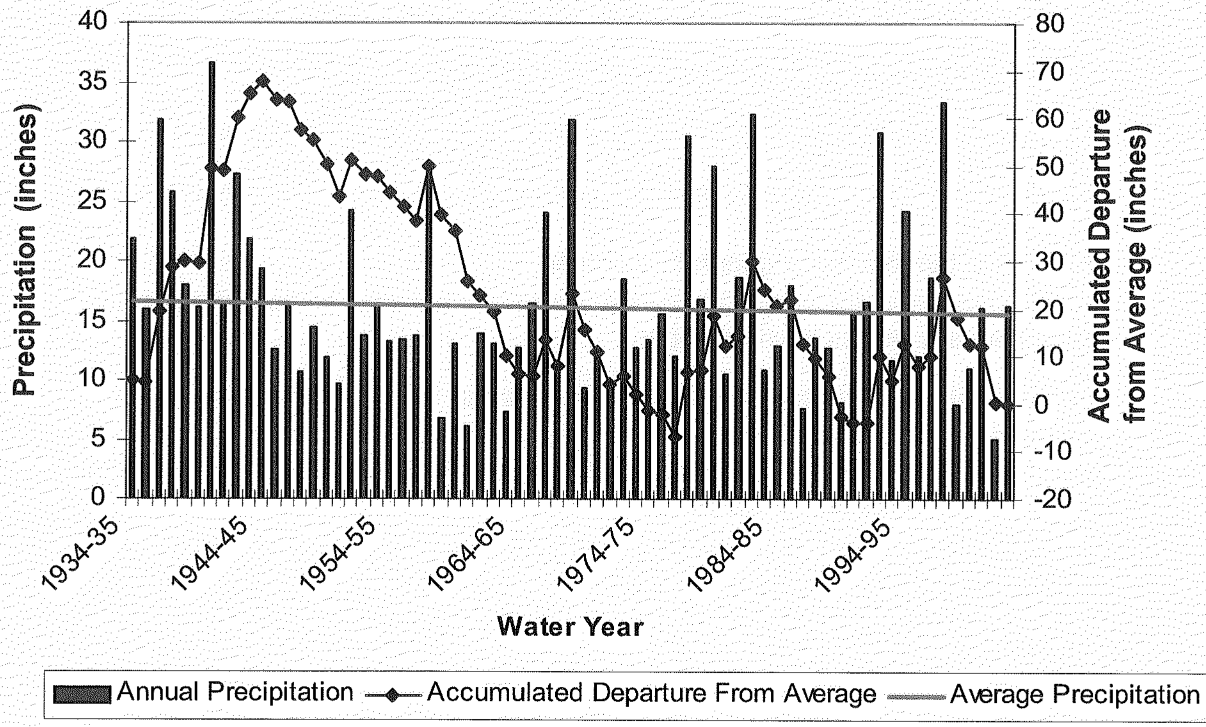
Ensuring that the Basin can provide a buffer against drought conditions requires:

- Maintaining sufficient water in storage that can be pumped out in time of need;
- Operating the Basin at the lower water level during the drawdown in a safe manner;
- Possessing a plan to refill the Basin.

To evaluate the extent of droughts in the SAR watershed, precipitation at San Bernardino is shown in Figure 9-2. The San Bernardino precipitation station is selected because it has a relatively long period of record and is the station used in the Santa Ana River Watermaster reports (Santa Ana River Watermaster Report, 2003). Average precipitation was 16.7 inches from 1934-35 to 2001-02. Figure 9-2 shows the annual precipitation, average precipitation, and the accumulated departure from average precipitation from 1934-35 to 2001-02. The accumulated departure from average precipitation is calculated by subtracting the historical average precipitation from the actual annual precipitation and adding the difference up for each year. On Figure 9-2, increasing values of accumulated departure from average represent a relatively wet period and decreasing values represent a relatively dry period.

Figure 9-2

PRECIPITATION AT SAN BERNARDINO



Using the San Bernardino precipitation, droughts in the SAR watershed are listed in Table 9-2. From the standpoint of the longest duration and the greatest total rainfall deficit, the worst drought since 1934 was the 1958-59 to 1964-65 drought. This drought consisted of 7 consecutive years of below average rainfall, with a total rainfall deficit of 43.6 inches.

One of the primary impacts of droughts is to reduce the District's supply of recharge water. Based on the historical recharge water information in Section 5, the potential decline in recharge water availability was estimated. For SAR base flow, SAR storm flow and net incidental recharge, the estimated decline in recharge water availability is summarized in Table 9-3. Not accounting for potential declines in the availability in Metropolitan replenishment water, the local supply of SAR recharge water and net incidental recharge water can decline up to 55,000 afy or more during drought years.

Table 9-2

DROUGHTS IN THE SANTA ANA RIVER WATERSHED

Drought Period (Water Year)	Length of Drought (years)	Number of Years with Above Average Rainfall During Drought	Rainfall Deficit [1] (inches)	Average Rainfall Deficit per Year (inches/year)
1945-46 to 1950-51	6	0	24.4	4.1
1952-53 to 1956-57	5	0	12.7	2.5
1958-59 to 1964-65	7	0	43.6	6.2
1969-70 to 1976-77	8	1	30.0	3.7
1986-87 to 1989-90	4	1	24.5	6.1
1998-99 to 2001-02	4	0	26.3	6.6

[1] Rainfall deficit calculated as the decline in the accumulated departure from average precipitation (16.7 inches per year in San Bernardino)

Table 9-3

IMPACT OF DROUGHTS ON RECHARGE WATER SUPPLIES

Recharge Water Supply	Estimated Decrease in Supply Due to Drought (af/yr)
SAR Base Flow	Up to 15,000
SAR Storm Flow	Up to 20,000 or more
Net Incidental Recharge	Up to 20,000
Total	Up to 55,000 or more

Note: does not include potential decline in Metropolitan replenishment supplies

9.2.1 MAINTAINING WATER IN STORAGE FOR DROUGHT CONDITIONS

For the Basin to serve as a safe, reliable buffer during drought conditions, sufficient groundwater must be in storage before the drought occurs. For example, if at the beginning of a drought the Basin accumulated overdraft is at 137,000 af and the Basin can be drawn down to 400,000 af overdraft without seawater intrusion, then 200,000 af is available in storage (plus 63,000 af of Metropolitan storage). In a hypothetical four-year drought, recharge water supplies can decrease up to 55,000 afy during drought years as summarized in Table 9-3. If pumping remains constant and all other sources of inflow and outflow remain the same except for the decline in recharge water supplies shown in Table 9-3, the 200,000 af of storage can be used to offset the decline in recharge water supplies over a roughly four-year drought. In this example, the basin storage that exists at the beginning of the drought is critical and is needed to maintain pumping while the recharge supplies dwindle. Another feature of this example is that there is little if any water available to increase the BPP if Metropolitan supplies are restricted due to drought conditions.

9.2.2 BASIN OPERATION DURING DROUGHT

If the Basin overdraft is intentionally increased, such a drawdown of the Basin should be conducted under specific constraints. For example, if stored water in the Basin is used as a buffer during drought conditions by allowing stored water to be withdrawn to offset dwindling recharge water supplies, the Basin must be operated in a safe manner during the drawdown. The primary issues that must be addressed are seawater intrusion in the Talbert, Bolsa, Sunset and Alamitos Gaps; whether sufficient excess recharge capacity is available to eventually refill the Basin; land subsidence; loss of production from shallow production wells that experience low groundwater levels; and increased inflow of colored water into clear water aquifers, as summarized in Table 9-1.

During the drawdown period, the District should:

- Collect a financial reserve to fund the programs to refill the Basin.
- Evaluate the need for increased monitoring to verify that the over-pumping is not harming the Basin.

9.2.3 REFILLING THE BASIN AFTER A DROUGHT

The District should have a plan to refill the Basin before allowing over-pumping of the Basin during a drought. The plan needs to include the physical means to refill the Basin and the financial resources to fund the refill. Refilling is critical to allow the Basin to serve as a buffer against the next potential drought. Approaches for refilling the Basin are described in Table 9-4.

9.3 BASIN PRODUCTION MANAGEMENT STRATEGIES

As described in Section 4, the District's primary mechanism for managing production from the Basin is the BPP. Groundwater production within the BPP is charged the RA, while production above the BPP is charged the RA plus the BEA. This approach serves to discourage, but not eliminate, production above the BPP.

If a producer desires to pump above the BPP, the District does not have the authority to prohibit such pumping. The BEA is intended to discourage this and provide the money to the District to purchase extra replenishment water to offset the extra pumping. Such "extra" pumping could however have a negative impact on the Basin if it continued for a sufficiently long period of time. In this hypothetical situation, the District's tools for protecting the Basin would be to consider lowering the BPP and increasing the RA to discourage increased production and fund projects and programs to protect the Basin from seawater intrusion or other negative impacts that were occurring as a result of the extra pumping.

Table 9-4

APPROACHES TO REFILL THE BASIN

Approach	Discussion
Decrease Total Water Demands	• Increase water conservation measures (note this does not result in a 1:1 decrease in groundwater pumping because some of the increased conservation reduces Metropolitan demands
Decrease BPP	• Allows groundwater levels to recover rapidly • Decreases revenue to the District • Increases water cost for producers • Does not require additional recharge facilities • Dependent upon other sources of water (e.g., Metropolitan) being available to substitute for reduced groundwater pumping
Increase Recharge	• Dependent on increased supply of recharge water • Water transfers and exchanges could be utilized to provide the increased supply of recharge water • Dependent on building and maintaining excess recharge capacity (which would be under-utilized in non-drought years)
Combination of the Above	• A combination of the approaches provides flexibility and a range of options for refilling the basin

9.4 SUPPLY MANAGEMENT STRATEGIES

The District's supply management strategies center around attaining maximum flexibility in the sources of recharge water for the Basin. Secondly, the District works with MWDOC to maintain overall supply flexibility, including evaluations of ocean water desalination, water transfers and exchanges, conservation, and expanded storage and conjunctive use programs.

9.4.1 RECHARGE WATER SUPPLY MANAGEMENT

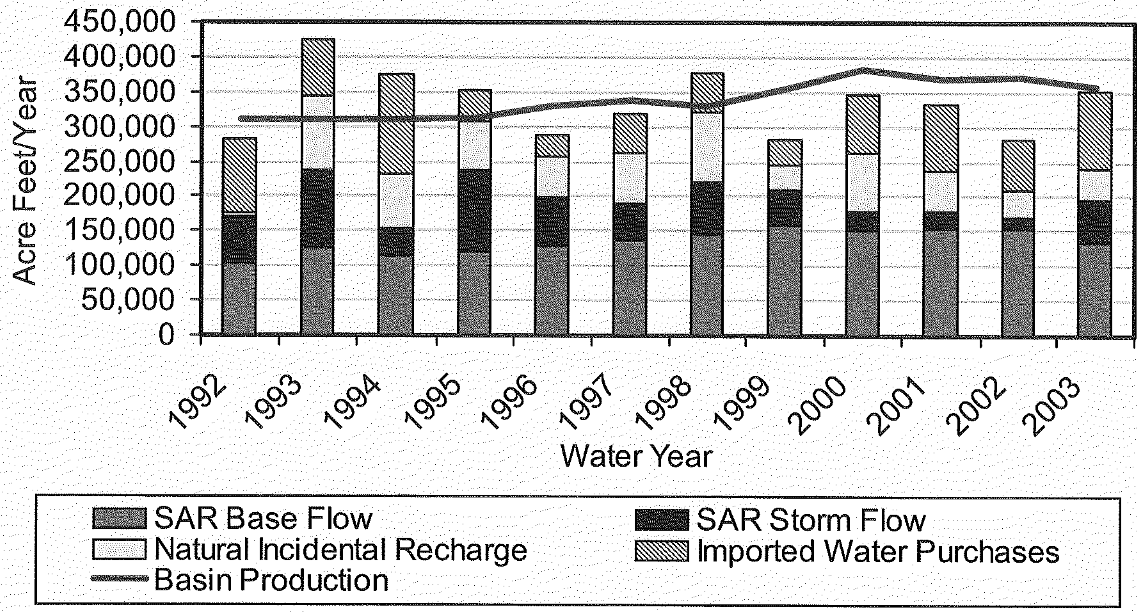
The primary sources of recharge water supplies are:

- SAR base flows
- Captured SAR storm flows
- Net natural incidental recharge
- Talbert Seawater Barrier Injection
- GWR System water recharge in the Forebay (starting in 2007)
- Alamitos Seawater Barrier Injection
- Arlington Desalter water
- Other upstream supplies discharged to the SAR (e.g., San Bernardino high groundwater pumpout)
- Metropolitan replenishment water

Figure 9-3 shows the relationship of annual pumping to the amount of recharge from these supplies for the last 12 years. From 1992-93 through 1997-98, recharge exceeded production due to above average precipitation. From 1998-99 to 2002-03, recharge was significantly less than production, which resulted in the accumulated overdraft increasing by about 190,000 af (Figure 2-5). Balancing pumping and recharge such that the Basin is not significantly overdrafted is critical to achieving the objective of managing the basin on a sustainable basis.

Figure 9-3

1992 TO 2003 BASIN PRODUCTION AND RECHARGE SOURCES



The current methodology for estimating the amount of water from each source is summarized in Table 9-5.

Table 9-5

SOURCES OF RECHARGE WATER SUPPLIES

Source	Methodology for Estimating [1]
SAR Base Flows	3-year moving average
Captured SAR Storm Flows	10-year moving average
Natural Net Incidental Recharge (Incidental recharge minus Los Angeles County outflow)	5-year moving average, with adjustment to account for storage level in basin
Talbert Seawater Barrier Injection	Annual review and estimate
GWR System Phase 1 water pumped to Kraemer Basin (beginning in 2007)	Annual review and estimate
Alamitos Seawater Barrier Injection	Annual review and estimate
Arlington Desalter Supplies	Annual review and estimate
Other upstream supplies discharged to the SAR	Annual review and estimate
Metropolitan replenishment water	Annual review and estimate
Notes: [1] Estimated amount of water from each source to be reviewed annually at a minimum (more frequent analysis as conditions warrant)	

To increase flexibility in the supply of recharge water, the District engages in activities to increase opportunities for storing recharge water, increasing the supply of recharge water, and adding new options to the supply mix. These activities include:

- Increasing the storage level behind Prado Dam.
- Increasing the removal of non-native invasive species, such as Arundo Donax, that consume excessive amounts of water compared to native species.
- Evaluating the feasibility of future phases of the GWR System.
- Evaluating storage opportunities in the groundwater basins upstream of Prado Dam.

9.4.2 JOINT PLANNING WITH MWDOC FOR OVERALL WATER SUPPLY FLEXIBILITY

OCWD and MWDOC jointly plan for the maximum flexibility in the overall water supply, including groundwater, imported water, recycled water, conservation, and ocean water desalination.

The activities include:

- Coordinating mutual water resources planning, supply availability, and water use efficiency (conservation) programs for the benefit of the Basin area in Orange County.
- Conducting and developing an Orange County Water Reliability Program to improve the overall water and emergency supply to Orange County.
- Evaluating ocean water desalination, water recycling, and other means to increase the supply and system reliability for the Basin area.
- Evaluating water transfers and exchanges that would make surplus supplies from other areas available to the District.

9.5 MANAGEMENT OPPORTUNITIES AT LOW AND HIGH OVERDRAFT

The potential physical impacts of low and high accumulated overdraft are described in Figure 9-1. At low and high accumulated overdraft levels, there are also management opportunities potentially available to the District. When accumulated overdraft is low, these potential management opportunities include:

- Minimizing the need to reduce coastal pumping.
- Decreasing funds needed to buy water to reduce the overdraft.
- Increasing ability to keep the BPP stable.
- Temporarily increasing the BPP.
- Stored water being available if shortage conditions occur.

When accumulated overdraft is high, there is an opportunity to recharge large amounts of low-cost water if available.

These potential management opportunities are summarized in Table 9-6.

Table 9-6

MANAGEMENT OPPORTUNITIES AT LOW AND HIGH OVERDRAFT

Opportunity	Accumulated Overdraft Level	
	Low	High
Minimizes need for coastal pumping reductions	Probable	Unlikely
Decreases funds needed to buy water to reduce overdraft	Probable	Unlikely
Enhances ability to maintain stable BPP	Probable	Unlikely
Allows potential to temporarily increase BPP	Probable	Unlikely
Makes stored water available during shortage condition	Probable	Unlikely
Provides storage space to recharge large amounts of low-cost water when available	Unlikely	Probable

9.6 METHODOLOGY FOR SETTING THE BASIN PRODUCTION PERCENTAGE

The Basin management approach approved by the District in December 2002 is based upon developing a base amount of groundwater production the Basin can annually sustain utilizing dependable water supplies the District can count on receiving given average conditions. The base amount of dependable replenishment water is derived from the sources described in Table 9-5.

For the 2003-04 water year, the estimated dependable supply of recharge water is summarized in Table 9-7 based on agreed upon amount after reviewing historical figures.

Table 9-7

RECHARGE WATER SUPPLIES ESTIMATED FOR 2003-04

Source	Amount (afy)
SAR Base Flows	155,000
Captured SAR Storm Flows	50,000
Natural Net Incidental Recharge	60,000
Talbert Seawater Barrier Injection	12,000
Alamitos Seawater Barrier Injection	2,000
Arlington Desalter Supplies	5,000
Metropolitan replenishment water (65,000 af purchased; 40,000 af would be used to increase the BPP. 25,000 af would be used to help fill the groundwater basin)	40,000
Totals	324,000

The amount of recharge shown in Table 9-7 is dependent upon Metropolitan being able to deliver 65,000 af of replenishment water. Of this 65,000 af, 25,000 af would be used to help refill the Basin.

The remaining 40,000 af would help increase the BPP. Recharging the Basin with 324,000 af of base sources in 2003-04 would support a BPP of 66 percent, assuming total demands are 491,000 af. Without 40,000 af of Metropolitan replenishment water as shown in Table 9-7, the BPP would have to be lowered from 66 percent to 58 percent.

Operation of the GWR System starting in 2007 will provide 72,000 afy of recharge water. Assuming that 12,000 afy of water is injected in the Talbert Barrier in the years prior to the GWR System becoming operational, the GWR System will provide a net increase of 60,000 afy to the Basin as shown in Table 9-8.

Table 9-8

RECHARGE WATER SUPPLIES WITH GWR SYSTEM PHASE 1

Source	Amount (afy)
SAR Base Flows	155,000
Captured SAR Storm Flows	50,000
Natural Net Incidental Recharge	60,000
Talbert Seawater Barrier Injection	30,000
GWR System Additional (Forebay recharge)	42,000
Alamitos Seawater Barrier Injection	2,000
Arlington Desalter Supplies	2,000
Metropolitan replenishment water (60,000 purchased; 40,000 af would be used to increase the BPP. 20,000 af would be used to help fill the groundwater basin)	40,000
Totals	381,000

The BPP should be established using the following principles:

- Set a base production amount at a level utilizing an average amount of replenishment water that can be secured from all sources (see Table 9-5).
- Account for water quality improvement project pumping that is above the BPP.
- Adjust the BPP annually based upon the previous year's performance relative to the Average Hydrology/Normal Replenishment (AH/NR) condition and current overdraft situation. This approach would allow adjustments for short-term variables and account for long-term trend changes.
- Adjust the AH/NR condition using a 3-10 year rolling average (as shown in Table 9-5).
- To mitigate financial impacts on producers, make all efforts not to reduce the BPP more than five percent in any one year, unless health and safety issues or other emergency circumstances prevail.
- In the event of a drought or curtailment of imported water supplies, the District's Board may authorize changes to the BPP as necessary to address the circumstances.
- Ensure that the accumulated overdraft is reduced by a minimum of 20,000 af each year until the accumulated overdraft is 250,000 af or less. The recommended Basin refill rate is shown in Figure 9-4, which would refill the basin from 400,000 to 200,000 af of overdraft in nine years.

Figure 9-4

RECOMMENDED BASIN REFILL RATE

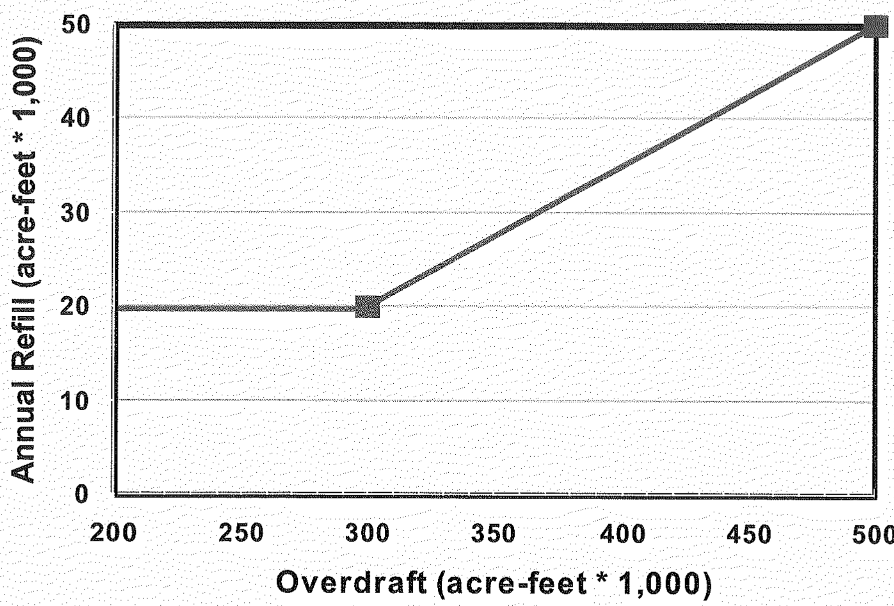


Table 9-9

EXAMPLE BPP CALCULATION

Replenishment/Demands	Amount (af)
Replenishment	
Replenishment water Into Basin	336,000
Replenishment water dedicated to Basin refill	20,000
Water quality improvement project pumping above the BPP	13,000
Net replenishment (after subtract refill amount and water quality improvement project pumping above BPP)	303,000
Demands	
Previous calendar year total water demands	478,000
Local/reclaimed water supplies	16,000
Net demands (after subtract local/reclaimed)	462,000
BPP = net replenishment / net demands	
BPP = 303,000 / 462,000 BPP = 0.66 BPP = 66%	

Note: Based on estimated conditions for 2004-05

9.7 FUTURE PROJECTS

The BPP could also be increased by implementing new water supply projects to increase the amount of dependable water supplies listed in Table 9-5.

9.7.1 GROUNDWATER REPLENISHMENT SYSTEM PHASE 2

The GWR System Phase 2 project is a potential future project that involves expansion of the Advanced Water Treatment Facility (AWTF) to produce additional water supplies for groundwater recharge and injection. This expansion would increase the capacity of the AWTF from 70 MGD to approximately 100 MGD. The current GWR layout has been designed for a future maximum build out to produce 130 MGD of purified water for groundwater recharge and injection. The additional water produced in Phase 2 would likely be used primarily for mid-basin injection wells located in the vicinity of Santa Ana (see Section 9.6.3). It would be conveyed to the injection wells through the GWR pipeline. The pipeline has been sized to accommodate these future flows. It is estimated that the Phase 2 expansion could be online between approximately 2012 and 2015.

9.7.2 CONJUNCTIVE USE AND WATER TRANSFERS

The existing Metropolitan storage program provides for Metropolitan to store 63,000 af of water in the Basin. This water can be withdrawn over a three-year time period. Metropolitan obtained this opportunity by contributing to improvements in Basin management facilities.

The District reviews opportunities for additional conjunctive use projects that would store water in the Basin and could potentially store water in other groundwater basins. Additionally, the District reviews opportunities for water transfers that could provide additional sources of recharge water. Such projects are evaluated carefully with respect to their impact on available storage and their reliability and cost effectiveness.

9.7.3 RECHARGE ENHANCEMENTS

The District has an ongoing program to assess enhancements in the existing recharge facilities, evaluate new recharge methods, and analyze potential new recharge facilities. This program is described in detail in the District's Recharge Study (OCWD, 2003).

As the GWR System is expanded, increased water availability will exist in the Forebay. In order to get water to the basin, mid-basin injection can be employed. This would involve using high quality GWR System water (Phase 2) for direct injection into the Principal aquifer in the central and eastern portions of the Basin. By directly injecting water into the Principal aquifer where most of the pumping occurs, pumping depressions can be more effectively mitigated. Also, mid-basin injection would reduce the recharge requirement at the Forebay spreading grounds, thus reducing the future potential for groundwater mounding in that area.

Currently, the estimated yield is 30,000 afy with new wells along the SAR and "Red Car" right-of-way (ROW). Injection wells would convey water into the Basin. Mid-basin injection would include development of facilities along three routes: SAR, Red Car ROW and Edinger Avenue to the east. The objective is to avoid losing more water to Los Angeles County, but still mitigate pumping depressions in the Basin.

The basin model was used to evaluate two different mid-basin injection alignments, both with 30,000 afy of direct injection into the Principal aquifer. Option 1 included injection wells along the SAR and then branching to the northwest along the Red Car ROW, whereas Option 2 consisted of injection wells along the SAR and branching eastward along Edinger Avenue. The modeling evaluation showed that although both mid-basin options improved overall groundwater conditions, the more easterly alignment (Option 2) was more effective at raising low water levels in the most heavily pumped areas in Santa Ana and Costa Mesa. Also, Option 2 resulted in less groundwater underflow to Los Angeles County compared to Option 1.

Since injection well site acquisition and construction could potentially be more difficult and expensive along Edinger Avenue than the Red Car ROW, an alternate alignment could include a hybrid of the two options discussed above, that is, along the SAR and shorter reaches of both the Red Car ROW to the west and Edinger Avenue to the east. This will be developed further in the Long-Term Facilities Plan.

section 10 Financial Management

The District has an excellent revenue base, a strong "AA+" financial rating, and the ability to issue additional long-term debt in the future, if necessary, to maintain the Basin's yield and protect water quality. This section:

- **Summarizes the District's financial condition.**
- **Presents the District's budget (operating expenses and revenues).**
- **Describes the District's cash reserve policies.**

10.1 BACKGROUND FINANCIAL INFORMATION

The District's fiscal year (FY) begins on July 1 and ends on June 30. The annual operating budget in 2003-04 was approximately $71 million and is comprised of three primary accounts: the general fund, water purchases, and annual debt service. District revenues are expected to be approximately $72 million in 2003-04.

10.2 OPERATING EXPENSES

The District's budgeted operating expenses for 2003-04 are summarized in Table 10-1 and described below.

10.2.1 GENERAL FUND

The District's general fund account primarily allows the District to operate the spreading facilities in the Cities of Anaheim and Orange, WF-21, the Talbert and Alamitos Injection Barriers, the Green Acres Project, and the Prado Wetlands. In addition, the District's Water Quality Laboratory, groundwater-monitoring programs, watershed management, planning, and other miscellaneous activities are funded by this account.

Table 10-1

2003-04 BUDGETED OPERATING EXPENSES

EXPENSES	AMOUNT (in millions)
General Fund	$23.5
Total Debt Service	18.3
Water Purchases (excluding $15.5 million for Metropolitan replenishment water previously received)	24.3
Replacement and Refurbishment Fund Transfer	4.7
Small Capital Equipment Items	0.4
Total	**$71.2**

10.2.2 WATER PURCHASES

The District Act provides general direction regarding the amount of water that should be purchased each year for supplemental groundwater recharge. As described in Section 5, replenishment water is primarily purchased from Metropolitan, either as direct replenishment or in-lieu replenishment. Section 27.b of the District Act provides that the District should purchase sufficient water to replenish the average annual overdraft for the immediate past five years plus an additional amount of water sufficient to eliminate the accumulated overdraft over a period of not less than 10 years nor more than 20 years.

The District can also elect to purchase additional water to refill the Basin faster and take advantage of surplus Metropolitan replenishment water if available. In the fall of 2002, the District began extensive discussions with the Producers to develop a new Basin management approach. This approach is developed further in Section 9. For 2003-04, 65,000 af of replenishment water purchases were budgeted, at an estimated cost of approximately $39.8 million (including $15.5 million of Metropolitan replenishment water previously received).

10.2.3 DEBT SERVICE

The debt service budget provides for repayment of the District's existing debt service from previous bond issues. The District has a comprehensive long-range debt program, which provides for the funding of projects necessary to increase basin production and protect water quality, while providing predictable impacts to the RA. The annual project-related debt expense is approximately $18.3 million.

The District is the only water agency in California to hold an AA+ credit rating from Standard & Poor's and Fitch, along with an aa2 rating from Moody's. The ratings assigned by these agencies have a direct impact on the District's borrowing cost and, therefore, on the District's ratepayers. Because of the District's excellent credit rating, it is able to borrow money at a substantially reduced cost.

10.2.4 REPLACEMENT AND REFURBISHMENT FUND

The District has approximately $323 million in existing plant and fixed assets. These facilities were constructed to provide a safe and reliable water supply. This fund was established to ensure that sufficient funds are available to repair and replace existing District infrastructure after it reached the end of its useful life. The Replacement and Refurbishment Fund is planned to replace facilities such as pumps, heavy equipment, wells, water recycling facilities, and other assets that help fulfill the District's mission.

In 1998, the OCWD Board established the Replacement and Refurbishment Fund of approximately $35 million, in addition to annually transferring approximately $4.5 million from the operating budget. The annual transfer for 2003-04 is budgeted as $4.7 million.

10.2.5 SMALL CAPITAL ITEMS

This category includes small equipment items such as vehicles, fax machines, tools, computers, and software. These items are expensed and funded using current revenues.

10.3 OPERATING REVENUES

Expected operating revenues for 2003-04 are shown in Table 10-2 and described below.

Table 10-2

2003-04 OPERATING REVENUES

REVENUES	AMOUNT (in millions)
Assessments (RA & BEA)	$50.8
Ad Valorem Income	12.2
Interest	1.2
Miscellaneous (water sales, rents etc...)	7.5
Total	**$71.7**

10.3.1 ASSESSMENTS

An RA is paid for all water pumped out of the Basin. The District semi-annually invoices Producers for their production in July and January. The amount of revenue generated by the RA is directly related to the amount of groundwater production. The RA is anticipated to generate $48.3 million in revenue for 2003-04 based on 324,000 af of estimated production at $149/af.

The BEA is assessed annually for all groundwater production above the BPP. The BEA rate is calculated for each agency and is currently approximately $280/af. The BEA generates around $2.5 million annually and is used to purchase replenishment water.

10.3.2 AD VALOREM TAXES

The District receives a small percentage of the property taxes collected in the service area. For 2003-04, the District expects to receive approximately $8.8 million from property taxes. The County of Orange assesses and collects the property taxes and transmits them to the District at various times during the year. This revenue source has been dedicated to the District's annual debt service expense.

10.3.3 INTEREST REVENUES

Cash reserves generate interest revenues. The majority of cash reserves are invested in short-term securities. Yields on cash reserves are anticipated to be low and have been estimated at two percent for 2003-04, for anticipated revenue of $1.2 million. However, $800,000 of this amount is within the Capital Fund and another $800,000 is transferred to the Replacement and Refurbishment Fund.

10.3.4 MISCELLANEOUS REVENUES

Miscellaneous revenues are primarily comprised of water sales from the Green Acres Project and loan repayments. The loan repayments originate from the Conjunctive Use Well Program in which the District loaned Producers money at low interest rates for construction of new production wells and related facilities. In addition, numerous small items such as rents, subsidies, and minor fees are grouped in this account. Approximately $7.5 million is expected to be received in 2003-04.

10.4 RESERVES

The District maintains cash reserves to ensure its financial integrity so that the Basin can be successfully managed and protected. The District's primary source of revenue is from the RA, which is collected twice per year. The reserves provide the financial resources to meet the District's obligations in the six-month period between RA collections.

10.4.1 RESERVE POLICIES

The District has reserve policies, which establish reserves in the following categories:

- 15 percent of the annual operating budget
- The Replacement and Refurbishment Program
- The Toxic Cleanup Reserve
- Contingencies required by the District Act
- Bond reserve covenants

10.4.1.1 FIFTEEN PERCENT OF THE ANNUAL OPERATING BUDGET

This reserve category helps the District maintain sufficient cash funds for cash flow purposes and for unexpected events. Maintaining reserves in this category also helps sustain the District's excellent credit rating. This category is particularly important because the District's principal source of revenue, the RA, is only collected twice a year. Payments for significant activities, such as replenishment water purchases, are typically required on a monthly basis. The reserve provides the financial "bridge" to meet the District's financial obligations on a monthly basis. In FY 2003-04, 15 percent of the annual operating budget is approximately $13 million.

10.4.1.2 REPLACEMENT AND REFURBISHMENT PROGRAM

As described in Section 10.2.4, the District maintains a Replacement and Refurbishment Fund to provide the financial resources for replacement and/or repair of the District capital assets. These assets include treatment facilities, monitoring and injection wells, and treatment facilities. At the beginning of FY 2003-04, the fund balance was approximately $38 million.

10.4.1.3 TOXIC CLEANUP RESERVE

Funds are reserved in this account to be available if and when a portion of the Basin becomes threatened by contamination. Over two million residents in the District rely on the Basin as their primary source of water. If the Basin were ever to become in danger of being polluted and unusable, the effects on District customers could be enormous, depending on the type and extent of the contamination. Four million dollars is maintained in this account to allow the District to immediately remediate contamination scenarios to restore the use of the Basin.

10.4.1.4 CONTINGENCIES REQUIRED BY THE DISTRICT ACT

Section 17.1 of the District Act requires the allocation of funds to cover annual expenditures that have not been provided for or that have been insufficiently provided for and for unappropriated requirements. This reserve amount is $3 million.

10.4.2 DEBT SERVICE ACCOUNT

Restricted funds in this account have been set aside by the bonding institutions as a requirement to ensure financial solvency and to help guarantee repayment of any debt issuances. These funds cannot be used for any other purpose. The requirement varies from year to year depending on the District's debt issuance and outstanding state loans. The account currently has approximately $5.5 million.

This section provides recommendations for the District to consider as part of ongoing management of the Basin and key performance indicators to track progress towards improving Basin conditions.

11.1 RECOMMENDATIONS

The District's programs to protect and increase the Basin's sustainable yield in a cost-effective manner continue to evolve due to increasing water demands and changes in the availability of recharge water supplies. Below average rainfall in the period from 1998-99 to 2001-02 and restricted availability of recharge water from Metropolitan are important factors that affected Basin conditions. The occurrence of wet and dry periods, the future availability and cost of Metropolitan recharge water, operation of GWR System Phase 1, and changing water management practices of agencies in the watershed will continue to affect the District's operation of the Basin and the management approaches utilized by the District. Many of the recommendations are continuations of the District's existing programs.

The Plan contains recommendations for the District to continue its proactive management of the Basin. These recommendations are summarized in Table 11-1. The table organizes these recommendations by general program area and also links the recommendations to the two management objectives of protecting and enhancing water quality and protecting and increasing the Basin's sustainable yield.

Specific projects that may be developed as a result of these recommendations would be reviewed and approved by the District's Board of Directors and processed for environmental review prior to project implementation.

Table 11-1

RECOMMENDATIONS

Program/Activity	Protect/Enhance Water Quality	Protect/Increase Sustainable Yield
Monitoring		
• Monitor quality of recharge water sources	Yes	Yes
• Monitor groundwater quality using District's wells and selected wells owned by others	Yes	
• Monitor water management and recycling plans in watershed for impact on SAR flow rates and SAR quality	Yes	Yes
• Conduct groundwater level and hydrogeologic evaluations to provide information to manage the Basin	Yes	Yes

Program/Activity	Protect/Enhance Water Quality	Protect/Increase Sustainable Yield
Recharge Supply Management		
• Protect District's interest in management of flow in SAR		Yes
• Monitor water management and recycling plans in the watershed for their potential impact upon future SAR flows		Yes
• Evaluate feasibility of new recharge water supplies (such as water transfers)		Yes
• Evaluate feasibility of additional conjunctive use or storage projects		Yes
• Evaluate projects to increase the District's capacity to recharge water		Yes
• Evaluate projects to maintain the recharge rate in the SAR riverbed		Yes
• Locate future recharge projects to maximize benefits to the Basin and address areas of low groundwater levels to the extent feasible	Yes	Yes
• Manage natural resources in the watershed to sustain natural resources and a secure water supply	Yes	Yes

Program/Activity	Protect/Enhance Water Quality	Protect/Increase Sustainable Yield
Groundwater Quality Management		
• Prevent seawater intrusion	Yes	Yes
• Evaluate emerging contaminants	Yes	Yes
• Prevent future contamination through coordinated efforts with regulatory agencies and watershed stakeholders	Yes	
• Evaluate projects to control vertical movement of poor quality water	Yes	Yes
Groundwater Improvement Projects		
• Evaluate and pursue projects to address existing areas of contamination	Yes	
Integrated Demand and Supply Management		
• Evaluate projects to maximize Basin's ability to respond to and recover from droughts		Yes
• Evaluate projects to control groundwater losses		Yes
• Evaluate projects to reduce water demand through conservation and water use efficiency		Yes

11.2 KEY PERFORMANCE INDICATORS

In the District's 2003-2006 Strategic Plan, the District established quantifiable goals or Key Performance Indicators to measure progress toward meeting the two major objectives. These Key Performance Indicators are listed in Table 11-2. The table also lists the Plan section that provides supporting information.

Table 11-2

KEY PERFORMANCE INDICATORS

Key Performance Indicator	Reference	Protects/Enhances Water Quality	Protect/Increase Sustainable Yield
Cease landward migration of 250 milligram per liter chloride contour by 2006	Section 3	Yes	Yes
Increase Prado water conservation pool elevation by four feet by 2005	Section 5	Yes	Yes
Increase recharge capacity by 10,000 afy	Section 5	---	Yes
All water recharged into the Basin through District facilities meets or is better than DHS MCLs and Action Levels	Section 6	Yes	---
Reduce Basin overdraft by 20,000 afy	Section 9	Yes	Yes

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Abbreviations & Acronyms

The following abbreviations and acronyms are used in this report:

ACOE	U.S. Army Corps of Engineers
ACWA	Association of California Water Agencies
af	acre-feet
af/day	acre-feet per day
afy	acre-feet per year
AH/NR	Average Hydrology/Normal Replenishment
ALs	Action Levels
AOC	assimiable organic carbon
AOP	advanced oxidation processes
AWT	Advanced Water Treatment
BAF	biologically active filtration
Basin	Orange County groundwater basin
Basin Model	OCWD groundwater model
B/C	benefit/cost
BCD	Basin Cleaning Device
Bgs	below ground surface
BEA	Basin Equity Assessment
BMPs	best management practices
BPP	Basin Production Percentage
BTEX	benzene, toluene, ethylbenzene and the xylenes
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
CrVI	chromium-6
crf	capital recovery fund
cu	color units
DAF	dissolved air flotation
DATS	Deep Aquifer Treatment System
DBPs	disinfection by-products
DGW	deep groundwater
DIPE	di-isopropyl ether
DOC	dissolved organic carbon
DHS	California Department of Health Services
District	Orange County Water District
DRWF	Dyer Road Wellfield
DWSAP	Drinking Water Source Assessment and Protection
DWR	California Department of Water Resources
Eastern	Eastern Municipal Water District
EDCs	endocrine disrupting compounds
EIR	Environmental Impact Reports
EPA	United States Environmental Protection Agency
ETBE	ethyl tert-butyl ether
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute
GIS	geographic information system

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OLAC	Orange and Los Angeles Counties
O_3	ozone
Panel	Scientific Advisory Panel
PCA	possible contaminants activities
PCE	perchloroethylene
pCi/L	picoucuries per liter
PF&RD	Orange County Public Facilities & Resources Department
PhACs	pharmaceutically active compounds
PHG	Public Health Goal
Plan	Groundwater Management Plan
ppb	parts per billion
ppt	parts per trillion
PPCPs	pharmaceuticals and personal care products
PRP	potential responsible party
Producers	Orange County groundwater producers
RA	replenishment assessment
RCRA	Resource Conservation and Recovery Act
RFG	reformulated gasoline
RO	reverse osmosis
ROW	right-of-way
RSU	Roto Strip Units
RVGC	River view Golf Course
RWQCB	Regional Water Quality Control Board
SAR	Santa Ana River
SARI	Santa Ana River Interceptor
SARWQH	Santa Ana Regional Water Quality and Health
SAWPA	Santa Ana Watershed Project Authority
SCADA	Supervisory Control and Data Acquisition
SDS	simulated distribution system
SDWA	Safe Drinking Water Act
SOCs	synthetic organic chemicals
SWA	source water assessment
SWP	State Water Project
SWRCB	State Water Resource Control Board
Talbert Barrier	Talbert Gap Seawater Intrusion Barrier
TAME	tert-amyl methyl ether
TBA	tertiary butyl alcohol
TCE	trichloroethylene
TDS	total dissolved solids
THM	trihalomethane
TIC	The Irvine Company
TiO_2	titanium dioxide
UCMR	unregulated chemical monitoring rule
USBR	United States Bureau of Reclamation
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey

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UV	ultraviolet light
VOCs	volatile organic compounds
WDR	waste discharge requirements
WF-21	Water Factory 21
WRD	Water Replenishment District of Southern California
WRMS	Water Resources Management System
WY	Water Year
YLWD	Yorba Linda Water District

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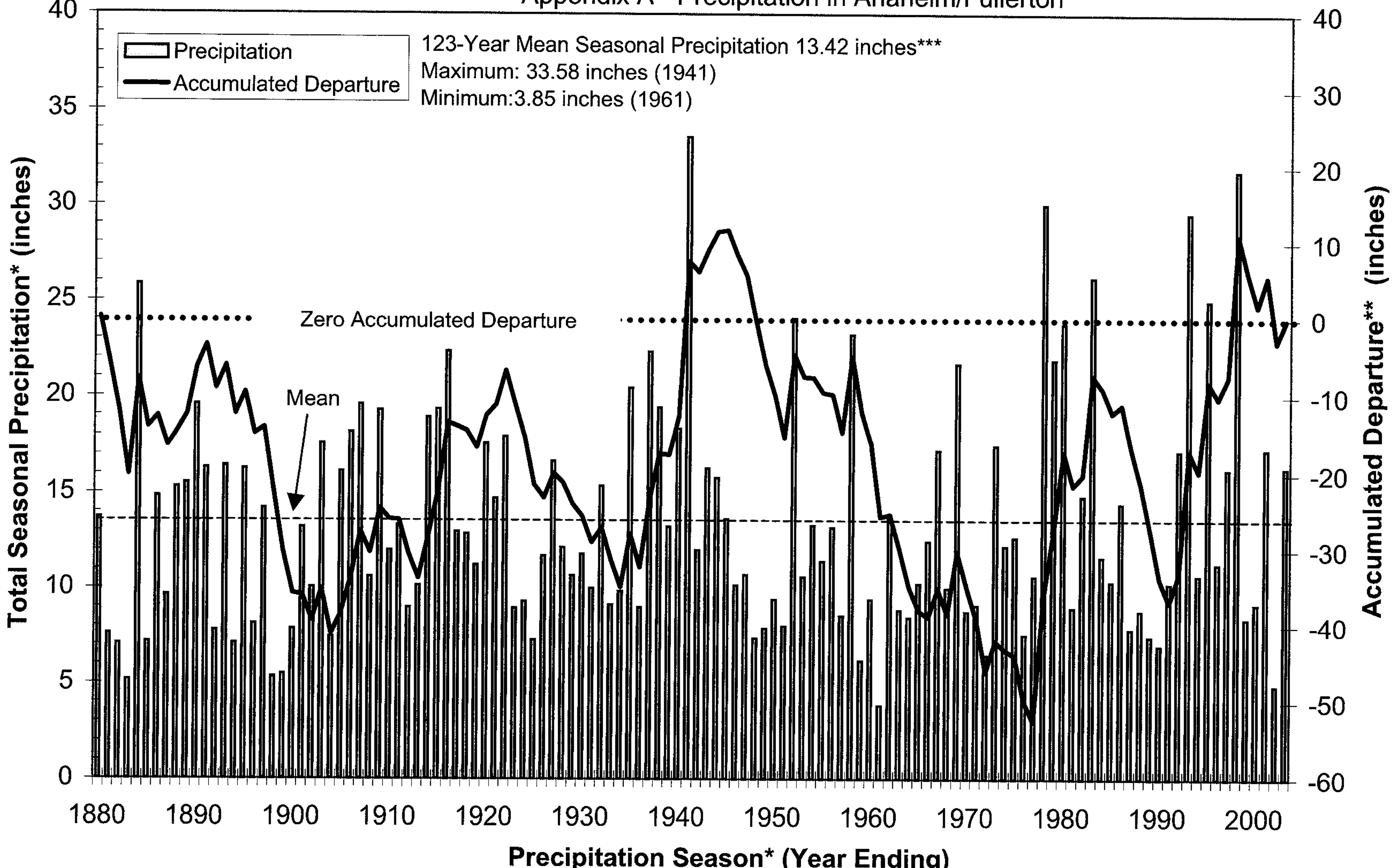
APPENDICES

Appendix A - Precipitation in Anaheim/Fullerton



*Precipitation Season extends from July 1st to June 30th of following year.
**Accumulated departure from 124-year mean of 13.42 inches.
***Anaheim City Hall (Sta. 31&33): 1880-1992; Fullerton Hillcrest Reservoir (Sta. 96): 1993-2003
Source: Orange County Public Facilities and Resource Department

Precipitation and Accumulated Departure
at Anaheim City Hall (1880-1992)
and Fullerton Hillcrest Reservoir (1993-2002)

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
ABS-2	SINGLE CASING	1	175	155	165
ALBM4-A	SINGLE CASING	1	187	147	177
ALBM4-I	SINGLE CASING	1	245	215	235
ALBM5-A	SINGLE CASING	1	95	65	85
ALBM5-I	SINGLE CASING	1	135	125	135
AM-1	SINGLE CASING	1	137	97	115
AM-2	SINGLE CASING	1	156	87	100
AM-3	SINGLE CASING	1	112	91	107
AM-4	SINGLE CASING	1	296	187	205
AM-5	SINGLE CASING	1	247	230	245
AM-5A	SINGLE CASING	1	180	168	175
AM-6	SINGLE CASING	1	296	232	250
AM-7	SINGLE CASING	1	297	210	225
AM-8	SINGLE CASING	1	297	268	285
AM-9	SINGLE CASING	1	317	285	303
AM-10	SINGLE CASING	1	298	217	235
AM-11	SINGLE CASING	1	276	218	240
AM-12	SINGLE CASING	1	294	210	225
AM-13	SINGLE CASING	1	275	252	270
AM-14	SINGLE CASING	1	317	297	315
AM-15	SINGLE CASING	1	318	300	317
AM-15A	SINGLE CASING	1	231	214	220
AM-16	SINGLE CASING	1	320	300	315
AM-16A	SINGLE CASING	1	227	215	222
AM-17	SINGLE CASING	1	318	290	308
AM-18	SINGLE CASING	1	316	291	309
AM-18A	SINGLE CASING	1	234	208	215
AM-19	SINGLE CASING	1	237	217	225
AM-19A	SINGLE CASING	1	126	115	123
AM-20	SINGLE CASING	1	397	361	379
AM-20A	SINGLE CASING	1	268	250	258
AM-21	SINGLE CASING	1	269	250	258
AM-21A	SINGLE CASING	1	179	157	165
AM-22	SINGLE CASING	1	356	339	353
AM-22A	SINGLE CASING	1	239	216	224
AM-23	SINGLE CASING	1	351	330	347
AM-24	SINGLE CASING	1	378	335	350
AM-24A	SINGLE CASING	1	306	279	294
AM-25	SINGLE CASING	1	362	340	358
AM-25A	SINGLE CASING	1	219	188	195
AM-26	SINGLE CASING	1	388	377	383
AM-27	SINGLE CASING	1	336	287	305
AM-28	SINGLE CASING	1	398	358	376
AM-29	SINGLE CASING	1	367	340	358
AM-29A	SINGLE CASING	1	95	75	95
AM-30	SINGLE CASING	1	375	349	367

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
AM-30A	SINGLE CASING	1	398	152	159
AM-31	SINGLE CASING	1	358	335	353
AM-31A	SINGLE CASING	1	360	162	170
AM-32	SINGLE CASING	1	398	335	353
AM-33	SINGLE CASING	1	378	354	372
AM-33A	SINGLE CASING	1	238	206	221
AM-34	SINGLE CASING	1	354	317	335
AM-34A	SINGLE CASING	1	271	252	260
AM-35	SINGLE CASING	1	400	332	350
AM-36	SINGLE CASING	1	398	369	387
AM-37	SINGLE CASING	1	378	349	367
AM-38	SINGLE CASING	1	358	316	334
AM-39	SINGLE CASING	1	188	168	188
AM-39A	SINGLE CASING	1	135	115	135
AM-40	SINGLE CASING	1	191	175	190
AM-40A	SINGLE CASING	1	166	145	165
AM-41	SINGLE CASING	1	200	190	200
AM-41A	SINGLE CASING	1	166	156	166
AM-42	SINGLE CASING	1	190	180	190
AM-42A	SINGLE CASING	1	130	115	130
AM-43	SINGLE CASING	1	100	80	100
AM-44	SINGLE CASING	1	160	140	160
AM-44A	SINGLE CASING	1	88	78	88
AM-45	SINGLE CASING	1	132	102	132
AM-46	SINGLE CASING	1	124	94	124
AMD-9	CASINGS	1	230	200	220
AMD-9	CASINGS	2	480	450	470
AMD-9	CASINGS	3	610	580	600
AMD-9	CASINGS	4	926	896	916
AMD-10	CASINGS	1	322	292	312
AMD-10	CASINGS	2	470	440	460
AMD-10	CASINGS	3	580	550	570
AMD-10	CASINGS	4	804	774	794
AMD-10	CASINGS	5	964	934	954
AMD-11	CASINGS	1	328	298	318
AMD-11	CASINGS	2	426	396	416
AMD-11	CASINGS	3	630	600	620
AMD-11	CASINGS	4	716	686	706
AMD-11	CASINGS	5	936	906	926
FM-1	SINGLE CASING	1	359	348	356
FM-1A	SINGLE CASING	1	197	164	172
FM-2	SINGLE CASING	1	352	320	338
FM-2A	SINGLE CASING	1	237	226	234
FM-3	SINGLE CASING	1	298	257	263
FM-4	SINGLE CASING	1	355	327	345
FM-4A	SINGLE CASING	1	170	142	160

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
FM-5	SINGLE CASING	1	141	121	141
FM-6	SINGLE CASING	1	320	150	310
FM-7	SINGLE CASING	1	197	187	197
FM-7A	SINGLE CASING	1	170	160	170
FM-8	SINGLE CASING	1	139	114	134
FM-9	SINGLE CASING	1	245	220	240
FM-10	SINGLE CASING	1	240	215	235
FM-10A	SINGLE CASING	1	176	151	171
FM-11	SINGLE CASING	1	261	236	256
FM-11A	SINGLE CASING	1	159	134	154
FM-12	SINGLE CASING	1	231	206	226
FM-12A	SINGLE CASING	1	160	135	155
FM-13	SINGLE CASING	1	235	210	230
FM-13A	SINGLE CASING	1	165	140	160
FM-14	SINGLE CASING	1	259	234	254
FM-14A	SINGLE CASING	1	172	147	167
FM-15	SINGLE CASING	1	243	218	238
FM-15A	SINGLE CASING	1	145	120	140
FM-16	SINGLE CASING	1	273	248	268
FM-16A	SINGLE CASING	1	150	125	145
FM-9A	SINGLE CASING	1	191	166	186
HB-DYKE	SINGLE CASING	1	206	170	190
IDM-3	CASINGS	1	214	174	194
IDM-3	CASINGS	2	330	290	310
IDM-3	CASINGS	3	682	652	672
IDP-1	SINGLE CASING	1	701	121	681
IDP-2	SINGLE CASING	1	680	120	660
IDP-3	SINGLE CASING	1	525	125	505
IDP-4	SINGLE CASING	1	430	125	410
KBS-1	SINGLE CASING	1	230	209	219
KBS-3	SINGLE CASING	1	90	80	90
KBS-4	SINGLE CASING	1	158	138	158
KBS-4A	SINGLE CASING	1	90	80	90
MCAS-4	SINGLE CASING	1	275	181	238
MCAS-5A	SINGLE CASING	1	133	120	130
MCAS-6	SINGLE CASING	1	285	167	222
MCAS-8	SINGLE CASING	1	435	392	410
MCAS-9	SINGLE CASING	1	450	372	445
MCAS-10	SINGLE CASING	1	389	347	377
MSP-10P	SINGLE CASING	1	50	40	50
MSP-10T	SINGLE CASING	1	140	70	140
OCWD-1AI	CASINGS	1	356	300	350
OCWD-1AI	CASINGS	2	470	410	465
OCWD-2AI	CASINGS	1	NA	329	366
OCWD-2AI	CASINGS	2	NA	424	464
OCWD-3AI	CASINGS	1	313	235	307

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-3AI	CASINGS	2	422	387	417
OCWD-4CBAI	CASINGS	1	180	149	174
OCWD-4CBAI	CASINGS	2	240	224	234
OCWD-4CBAI	CASINGS	3	325	279	319
OCWD-4CBAI	CASINGS	4	389	359	384
OCWD-5CBAI	CASINGS	1	191	165	185
OCWD-5CBAI	CASINGS	2	266	225	260
OCWD-5CBAI	CASINGS	3	371	311	365
OCWD-5CBAI	CASINGS	4	455	405	450
OCWD-6CBAI	CASINGS	1	231	215	225
OCWD-6CBAI	CASINGS	2	291	270	285
OCWD-6CBAI	CASINGS	3	346	315	340
OCWD-6CBAI	CASINGS	4	465	420	460
OCWD-7	SINGLE CASING	1	48	28	48
OCWD-7BAI	CASINGS	1	350	290	345
OCWD-7BAI	CASINGS	2	255	175	250
OCWD-7BAI	CASINGS	3	155	130	150
OCWD-8RAI	CASINGS	1	90	55	85
OCWD-8RAI	CASINGS	2	200	110	195
OCWD-8RAI	CASINGS	3	305	225	300
OCWD-10RAI	CASINGS	1	225	200	220
OCWD-10RAI	CASINGS	2	163	125	158
OCWD-10RAI	CASINGS	3	82	44	77
OCWD-11RI	CASINGS	1	112	92	107
OCWD-11RI	CASINGS	2	80	60	75
OCWD-12RI	CASINGS	1	90	80	85
OCWD-12RI	CASINGS	2	80	39	79
OCWD-13R	SINGLE CASING	1	78	34	70
OCWD-34H5	CASINGS	1	360	300	340
OCWD-34H5	CASINGS	2	475	405	455
OCWD-35J1	CASINGS	1	260	190	240
OCWD-35J1	CASINGS	2	190	130	170
OCWD-35K1	CASINGS	1	263	193	243
OCWD-35K1	CASINGS	2	190	130	170
OCWD-A1	CASINGS	1	85	36	71
OCWD-AIR1	CASINGS	1	255	200	250
OCWD-AIR1	CASINGS	2	515	410	510
OCWD-AIR1	CASINGS	3	855	675	850
OCWD-AIR1	CASINGS	4	1485	1375	1460
OCWD-AN1	SINGLE CASING	1	115	35	115
OCWD-AN2	SINGLE CASING	1	115	35	115
OCWD-BGO10	SINGLE CASING	1	100	80	90
OCWD-BP1	SINGLE CASING	1	40	20	40
OCWD-BP2	SINGLE CASING	1	70	50	70
OCWD-BP3	SINGLE CASING	1	205	185	205
OCWD-BP4	SINGLE CASING	1	180	140	180

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-BS103	CASINGS	1	88	43	78
OCWD-BS103	CASINGS	2	145	98	135
OCWD-BS103	CASINGS	3	215	184	205
OCWD-BS105	CASINGS	1	95	69	85
OCWD-BS105	CASINGS	2	133	105	123
OCWD-BS105	CASINGS	3	207	150	197
OCWD-BS106	CASINGS	1	102	50	92
OCWD-BS106	CASINGS	2	163	111	153
OCWD-BS106	CASINGS	3	265	213	255
OCWD-BS107	CASINGS	1	202	117	192
OCWD-BS107	CASINGS	2	316	254	306
OCWD-BS107	CASINGS	3	451	398	441
OCWD-BS111	CASINGS	1	170	128	160
OCWD-BS111	CASINGS	2	215	184	205
OCWD-BSO1A	CASINGS	1	30	10	26
OCWD-BSO1A	CASINGS	2	55	31	50
OCWD-BSO1A	CASINGS	3	357	245	335
OCWD-BSO1B	SINGLE CASING	1	115	80	104
OCWD-BSO2	SINGLE CASING	1	116	44	106
OCWD-BSO4	SINGLE CASING	1	498	268	498
OCWD-BSO6A	CASINGS	1	38	21	38
OCWD-BSO6A	CASINGS	2	150	85	135
OCWD-BSO6B	CASINGS	1	220	160	215
OCWD-BSO6B	CASINGS	2	305	235	295
OCWD-BSO8	CASINGS	1	41	21	41
OCWD-BSO8	CASINGS	2	81	61	81
OCWD-BSO8	CASINGS	3	156	81	151
OCWD-BSO8	CASINGS	4	209	174	209
OCWD-BSO8	CASINGS	5	289	249	281
OCWD-BSO9A	CASINGS	1	24	10	24
OCWD-BSO9A	CASINGS	2	169	115	162
OCWD-BSO9A	CASINGS	3	285	195	285
OCWD-BSO9B	CASINGS	1	101	56	101
OCWD-BSO9B	CASINGS	2	620	520	615
OCWD-BSO9C	SINGLE CASING	1	445	340	435
OCWD-CTG1	CASINGS	1	265	160	260
OCWD-CTG1	CASINGS	2	725	420	720
OCWD-CTG1	CASINGS	3	1025	800	1025
OCWD-CTG1	CASINGS	4	1225	1060	1220
OCWD-CTG5	CASINGS	1	620	420	620
OCWD-CTG5	CASINGS	2	1000	880	1000
OCWD-CTG5	CASINGS	3	1120	1040	1120
OCWD-CTK1	CASINGS	1	660	410	655
OCWD-CTK1	CASINGS	2	1020	780	1015
OCWD-CTK1	CASINGS	3	1320	1260	1315
OCWD-FC1	SINGLE CASING	1	185	165	185

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-FC2	SINGLE CASING	1	115	95	115
OCWD-FH1	SINGLE CASING	1	140	120	140
OCWD-GA1	SINGLE CASING	1	40	30	40
OCWD-GA2	SINGLE CASING	1	40	30	40
OCWD-GA3	SINGLE CASING	1	40	30	40
OCWD-GA4	SINGLE CASING	1	40	30	40
OCWD-GA5	SINGLE CASING	1	40	30	40
OCWD-GA6	SINGLE CASING	1	40	30	40
OCWD-GA7	SINGLE CASING	1	40	30	40
OCWD-GA9	SINGLE CASING	1	29	19	29
OCWD-HH2	CASINGS	1	47	32	42
OCWD-HH2	CASINGS	2	100	85	95
OCWD-HH2	CASINGS	3	147	130	140
OCWD-HH3	CASINGS	1	46	35	40
OCWD-HH3	CASINGS	2	90	75	85
OCWD-HH3	CASINGS	3	148	133	143
OCWD-HH4	CASINGS	1	37	25	30
OCWD-HH4	CASINGS	2	56	45	50
OCWD-HH4	CASINGS	3	96	80	90
OCWD-HH4	CASINGS	4	145	130	140
OCWD-HH5	CASINGS	1	22	14	19
OCWD-HH5	CASINGS	2	42	32	38
OCWD-HH5	CASINGS	3	77	63	73
OCWD-HH5	CASINGS	4	117	102	112
OCWD-HH6	CASINGS	1	55	40	50
OCWD-HH6	CASINGS	2	110	90	100
OCWD-HH6	CASINGS	3	190	170	180
OCWD-I27M1	SINGLE CASING	1	22	17	22
OCWD-I28M1	SINGLE CASING	1	24	19	24
OCWD-KB1	SINGLE CASING	1	200	180	200
OCWD-KR2	SINGLE CASING	1	394	NA	NA
OCWD-LV1	SINGLE CASING	1	155	135	155
OCWD-M1	SINGLE CASING	1	115	75	110
OCWD-M2	SINGLE CASING	1	155	85	150
OCWD-M4	CASINGS	1	125	80	120
OCWD-M4	CASINGS	2	180	145	175
OCWD-M4	CASINGS	3	275	235	270
OCWD-M4	CASINGS	4	335	295	330
OCWD-M5	CASINGS	1	100	65	95
OCWD-M5	CASINGS	2	165	115	160
OCWD-M5	CASINGS	3	265	215	260
OCWD-M5	CASINGS	4	310	285	305
OCWD-M6A	CASINGS	1	130	65	125
OCWD-M6A	CASINGS	2	170	150	165
OCWD-M6A	CASINGS	3	290	260	285
OCWD-M6B	SINGLE CASING	1	240	185	235

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-M7A	CASINGS	1	140	70	135
OCWD-M7A	CASINGS	2	175	155	170
OCWD-M7A	CASINGS	3	225	190	220
OCWD-M7B	SINGLE CASING	1	265	240	260
OCWD-M8	CASINGS	1	155	50	150
OCWD-M8	CASINGS	2	210	185	205
OCWD-M8	CASINGS	3	255	225	250
OCWD-M8	CASINGS	4	315	275	310
OCWD-M9	CASINGS	1	120	90	115
OCWD-M9	CASINGS	2	160	135	155
OCWD-M9	CASINGS	3	230	185	225
OCWD-M9	CASINGS	4	300	250	295
OCWD-M10	CASINGS	1	165	80	160
OCWD-M10	CASINGS	2	200	175	195
OCWD-M10	CASINGS	3	245	215	240
OCWD-M10	CASINGS	4	310	280	305
OCWD-M11	CASINGS	1	110	70	105
OCWD-M11	CASINGS	2	155	125	150
OCWD-M11	CASINGS	3	230	170	225
OCWD-M11	CASINGS	4	295	260	290
OCWD-M12	CASINGS	1	115	70	110
OCWD-M12	CASINGS	2	225	130	220
OCWD-M12	CASINGS	3	265	240	260
OCWD-M12	CASINGS	4	355	330	350
OCWD-M13	CASINGS	1	100	65	95
OCWD-M13	CASINGS	2	205	140	200
OCWD-M13	CASINGS	3	300	230	295
OCWD-M13	CASINGS	4	400	360	395
OCWD-M14A	CASINGS	1	95	60	90
OCWD-M14A	CASINGS	2	185	120	180
OCWD-M14A	CASINGS	3	305	200	300
OCWD-M14B	SINGLE CASING	1	345	320	340
OCWD-M15A	CASINGS	1	90	60	85
OCWD-M15A	CASINGS	2	180	115	175
OCWD-M15A	CASINGS	3	295	195	290
OCWD-M15B	SINGLE CASING	1	340	310	335
OCWD-M16	CASINGS	1	95	65	90
OCWD-M16	CASINGS	2	165	115	160
OCWD-M16	CASINGS	3	275	180	270
OCWD-M16	CASINGS	4	320	295	315
OCWD-M17A	CASINGS	1	100	60	95
OCWD-M17A	CASINGS	2	190	130	185
OCWD-M17A	CASINGS	3	350	330	345
OCWD-M17B	SINGLE CASING	1	310	210	305
OCWD-M18	CASINGS	1	95	65	90
OCWD-M18	CASINGS	2	180	110	175

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-M18	CASINGS	3	295	195	290
OCWD-M18	CASINGS	4	340	310	335
OCWD-M19	CASINGS	1	115	60	110
OCWD-M19	CASINGS	2	200	130	195
OCWD-M19	CASINGS	3	270	215	265
OCWD-M20	CASINGS	1	110	60	105
OCWD-M20	CASINGS	2	200	170	195
OCWD-M20	CASINGS	3	275	255	270
OCWD-M21	CASINGS	1	105	65	100
OCWD-M21	CASINGS	2	190	150	185
OCWD-M21	CASINGS	3	265	205	260
OCWD-M21	CASINGS	4	345	320	340
OCWD-M22	CASINGS	1	110	70	105
OCWD-M22	CASINGS	2	215	140	210
OCWD-M22	CASINGS	3	275	230	270
OCWD-M23A	CASINGS	1	95	65	90
OCWD-M23A	CASINGS	2	170	110	165
OCWD-M23A	CASINGS	3	265	190	260
OCWD-M23B	SINGLE CASING	1	325	295	320
OCWD-M24	CASINGS	1	100	70	95
OCWD-M24	CASINGS	2	170	115	165
OCWD-M24	CASINGS	3	235	185	230
OCWD-M24	CASINGS	4	315	290	310
OCWD-M25	SINGLE CASING	1	195	65	185
OCWD-M26	SINGLE CASING	1	145	70	135
OCWD-M27	SINGLE CASING	1	120	60	110
OCWD-M28	SINGLE CASING	1	155	80	145
OCWD-M30	SINGLE CASING	1	120	90	110
OCWD-M31	SINGLE CASING	1	172	82	162
OCWD-M36	CASINGS	1	95	80	90
OCWD-M36	CASINGS	2	180	165	175
OCWD-M36	CASINGS	3	255	240	250
OCWD-M36	CASINGS	4	305	290	300
OCWD-M37	CASINGS	1	135	120	130
OCWD-M37	CASINGS	2	195	180	190
OCWD-M37	CASINGS	3	245	230	240
OCWD-M37	CASINGS	4	312	297	307
OCWD-M37	CASINGS	5	353	338	348
OCWD-M38	CASINGS	1	114	94	104
OCWD-M38	CASINGS	2	176	156	166
OCWD-M38	CASINGS	3	254	234	244
OCWD-M38	CASINGS	4	356	336	346
OCWD-M38	CASINGS	5	536	516	526
OCWD-M39	CASINGS	1	90	70	80
OCWD-M39	CASINGS	2	130	100	120
OCWD-M39	CASINGS	3	180	150	170

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-M39	CASINGS	4	220	200	210
OCWD-M39	CASINGS	5	280	250	270
OCWD-M40	CASINGS	1	115	85	105
OCWD-M40	CASINGS	2	190	160	180
OCWD-M40	CASINGS	3	235	205	225
OCWD-M40	CASINGS	4	530	330	520
OCWD-M41	CASINGS	1	86	66	76
OCWD-M41	CASINGS	2	115	95	105
OCWD-M41	CASINGS	3	220	200	210
OCWD-M41	CASINGS	4	256	236	246
OCWD-M41	CASINGS	5	400	370	390
OCWD-M42	CASINGS	1	130	100	120
OCWD-M42	CASINGS	2	157	137	147
OCWD-M42	CASINGS	3	230	210	220
OCWD-M42	CASINGS	4	290	260	280
OCWD-M42	CASINGS	5	530	500	520
OCWD-M42	CASINGS	6	638	608	628
OCWD-M43	CASINGS	1	156	136	146
OCWD-M43	CASINGS	2	320	290	310
OCWD-M43	CASINGS	3	360	340	350
OCWD-M43	CASINGS	4	410	380	400
OCWD-M43	CASINGS	5	550	520	540
OCWD-M48	CASINGS	1	110	80	100
OCWD-M48	CASINGS	2	205	175	195
OCWD-M48	CASINGS	3	490	470	480
OCWD-MOOR	SINGLE CASING	1	470	NA	NA
OCWD-OVP1	CASINGS	1	10	7	10
OCWD-OVP1	CASINGS	2	21	15	21
OCWD-OVP1	CASINGS	3	40	26	40
OCWD-OVP2	CASINGS	1	10	7	10
OCWD-OVP2	CASINGS	2	28	15	28
OCWD-OVP2	CASINGS	3	40	33	40
OCWD-OVP3	CASINGS	1	10	7	10
OCWD-OVP3	CASINGS	2	27	15	27
OCWD-OVP3	CASINGS	3	40	32	40
OCWD-OVP5	CASINGS	1	10	7	10
OCWD-OVP5	CASINGS	2	26	15	26
OCWD-OVP5	CASINGS	3	40	32	40
OCWD-OVP7	CASINGS	1	10	7	10
OCWD-OVP7	CASINGS	2	27	15	27
OCWD-OVP7	CASINGS	3	40	32	40
OCWD-OVP9	CASINGS	1	10	7	10
OCWD-OVP9	CASINGS	2	20	15	20
OCWD-OVP9	CASINGS	3	40	25	40
OCWD-OVP10	CASINGS	1	10	7	10
OCWD-OVP10	CASINGS	2	25	15	25

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OCWD-OVP10	CASINGS	3	40	30	40
OCWD-OVP11	CASINGS	1	10	7	10
OCWD-OVP11	CASINGS	2	28	15	28
OCWD-OVP11	CASINGS	3	40	33	40
OCWD-OVP12	CASINGS	1	10	7	10
OCWD-OVP12	CASINGS	2	20	15	20
OCWD-OVP12	CASINGS	3	40	25	40
OCWD-OVP13	CASINGS	1	13	8	13
OCWD-OVP13	CASINGS	2	23	19	23
OCWD-OVP13	CASINGS	3	40	28	40
OCWD-PD1	SINGLE CASING	1	13	7	13
OCWD-PD3A	SINGLE CASING	1	9	4	9
OCWD-PD3B	SINGLE CASING	1	20	15	20
OCWD-PD4A	SINGLE CASING	1	7	2	7
OCWD-PD4B	SINGLE CASING	1	20	15	20
OCWD-PD5A	SINGLE CASING	1	7	2	7
OCWD-PD5B	SINGLE CASING	1	20	15	20
OCWD-PD6A	SINGLE CASING	1	8	3	8
OCWD-PD6B	SINGLE CASING	1	20	15	20
OCWD-PD7A	SINGLE CASING	1	7	2	7
OCWD-PD7B	SINGLE CASING	1	20	15	20
OCWD-RVW1	SINGLE CASING	1	78	67	77
OCWD-RVW1A	SINGLE CASING	1	49	39	49
OCWD-SA3	SINGLE CASING	1	165	100	160
OCWD-SA5	CASINGS	1	146	112	132
OCWD-SA5	CASINGS	2	327	273	312
OCWD-SA10	CASINGS	1	129	90	120
OCWD-SA10	CASINGS	2	262	225	255
OCWD-SA10	CASINGS	3	345	300	330
OCWD-SA12	CASINGS	1	132	86	126
OCWD-SA12	CASINGS	2	261	236	256
OCWD-SA12	CASINGS	3	336	305	325
OCWD-SA22	CASINGS	1	135	109	130
OCWD-SA22	CASINGS	2	181	155	176
OCWD-SA22	CASINGS	3	367	300	332
OCWD-T2	CASINGS	1	33	20	30
OCWD-T2	CASINGS	2	180	70	170
OCWD-T2	CASINGS	3	370	300	360
OCWD-T3	CASINGS	1	95	65	85
OCWD-T3	CASINGS	2	180	110	170
OCWD-T4	SINGLE CASING	1	176	68	168
OCWD-T5	CASINGS	1	200	110	190
OCWD-T5	CASINGS	2	305	285	295
OCWD-W1	SINGLE CASING	1	398	NA	NA
OM-1	SINGLE CASING	1	245	217	235
OM-2	SINGLE CASING	1	250	211	219

NA: Not Available

APPENDIX B - OCWD GROUNDWATER MONITORING WELLS
(EXCLUDING WESTBAY MULTIPORT WELLS)

Well Name	Well Type	Casing Sequence No.	Cased Depth (ft)	Top Perforation (ft.)	Bottom Perforation (ft.)
OM-2A	SINGLE CASING	1	130	118	125
OM-3	SINGLE CASING	1	245	191	245
OM-3A	SINGLE CASING	1	117	90	110
OM-4	SINGLE CASING	1	237	221	230
OM-4A	SINGLE CASING	1	119	112	117
OM-6	SINGLE CASING	1	249	196	204
OM-7	SINGLE CASING	1	234	181	207
OM-8	SINGLE CASING	1	319	285	293
OM-8A	SINGLE CASING	1	178	156	164
SCS-3	SINGLE CASING	1	42	31	42
SCS-4	SINGLE CASING	1	32	21	32
SCS-5	SINGLE CASING	1	43	22	43
SCS-6	CASINGS	1	29	23	29
SCS-6	CASINGS	2	153	147	153
SCS-7	CASINGS	1	36	20	36
SCS-7	CASINGS	2	141	125	141
SCS-8	SINGLE CASING	1	129	108	129
SCS-9	SINGLE CASING	1	178	153	173
SCS-10	SINGLE CASING	1	221	206	216
SCS-B1	CASINGS	1	43	18	43
SCS-B2	CASINGS	1	10	5	10
SCS-B2	CASINGS	2	29	19	29
SCS-B3	CASINGS	1	10	5	10
SCS-B3	CASINGS	2	25	16	26
TIC-67	SINGLE CASING	1	902	245	900
W-14659	SINGLE CASING	1	27	12	27
W-15061	SINGLE CASING	1	NA	NA	NA
W-15534	SINGLE CASING	1	212	175	212

NA: Not Available

Appendix C - OCWD MULTIPORT SYSTEM MONITORING WELLS

WELL I.D.	STATE WELL NO.	Date Installed	Date Retrofit	G.S. Elev. (ft msl)	Top of MP to G.S.	Top of MP Elev.(ft msl	MEASUREMENT PORT DEPTH (Feet Below Top of MP Casing) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ABS-1	3S/9W-32F2	3/90		*229.02	1.81	230.83	27	77	257															
AMD-1[1]	4S/9W-06H2	7/90		*217.68	-0.22	217.46	105	135	180	245	329	383	523	762	1037	1392								
AMD-2	4S/10W-12B3	10/90		*191.99	0.15	192.14	157	262	387	512	659	824	1014	1154	1294	1444								
AMD-3[1]	4S/10W-03R3	5/91		*163.06	-0.69	162.37	65	135	210	360	480	569	823	923	1173	1283								
AMD-4	4S/10W-09B5	11/91		*137.37	-0.23	137.14	206	296	381	561	702	794	939	1059	1124	1269	1409							
AMD-5[1]	4S/10W-14F1	1/92		*163.24	-0.70	162.54	101	201	301	415	497	642	754	924	1029	1214	1324	1424						
AMD-6[1]	4S/10W-22J1	4/92		*137.52	-0.85	136.67	112	152	222	277	372	497	622	714	794	904	1094	1264	1409					
AMD-7	4S/10W-16M4	12/92		*122.70	-0.71	121.99	121	221	271	311	371	471	580	694	809	934	1074	1169	1299	1424				
AMD-8[1]	4S/11W-13C4	9/93		*78.825	-0.68	78.15	80	180	315	525	662	764	859	1004	1164	1289	1454	1569	1764	1949	2014			
BPM-1[1]	4S/11W-3E01	2/94		*57.39	-0.70	56.69	129	249	458	613	780	890	1040	1267	1392	1502	1687	1804	1934	2109				
BPM-2[1]	4S/11W-15Q02	3/94		*56.46	-0.70	55.76	181	336	496	581	778	903	1028	1243	1367	1494	1614	1764	1931	2073	2173			
CB-1[1]	4S/10W-08F3	9/89	12/92	*119.44	0.00	119.44	78	143	443	663	873	1053	1193	1333	1463									
COSM-1[1]	5S/10W-34P1	9/91		*28.44	-0.50	27.94	92	154	271	351	451	541	621	723	853	983	1103	1215	1435	1599	1764			
COSM-2	5S/10W-33K1	10/02		*26.83	-0.38	26.45	60	115	202	309	409	541	651	763	890	1055								
CSF-1	3S/10W-25D1	05/03		*251.04	-0.49	250.55	132	212	332	454	609	718												
FFS#1[1]	3S/10W-35K2	8/88	2/96	*179.72	-0.24	179.48	181	361	530	820	1060	1160	1300	1420										
FVM-1[1]	5S/10W-20H4	1/90	5/99	*40.49	-0.96	39.53	134	171	221	358	448	498	558	630	812	894	1001	1121	1176	1231	1321	1495	1585	1835
GGM-1[1]	4S/10W-32K1	1/94		*85.57	-0.72	84.85	150	300	465	552	744	829	954	1074	1264	1519	1654	1771	2011					
GGM-2[1]	4S/11W-35N2	1/93		*43.25	-0.70	42.55	213	295	462	719	954	1049	1149	1254	1489	1629	1744	1904	1994					
GGM-3[1]	4S/11W-25J4	10/92		*76.23	-0.71	75.52	197	312	547	642	842	1007	1107	1279	1544	1684	1784	1954						
HBM-1[1]	5S/11W-14G2	9/92		*27.14	-0.65	26.49	91	191	321	483	562	702	924	1038	1130	1352	1464	1544	1644	1934				
HBM-2[1]	6S/11W-01G1	12/91		*12.73	-0.75	11.98	112	162	247	307	362	447	522	572	677	739	849	929						
HBM-3	6S/11W-02Q3	5/92		*37.00	-0.71	36.29	152	217	289	349	425	510	570	680	809	924	1069	1169	1279	1419				
HBM-4[1]	6S/11W-01D4	3/93		*57.27	-0.70	56.57	75	120	179	231	296	351	416	551	691									
HBM-5[2]	6S/10W-05L1	10/93		*13.68	-0.71	12.97	71	76	86	126	171	216	248	273										
HBM-6	5S/11W-27K04	1/98		*-0.46	-0.62	-1.08	53	85	110	215	264	296	508	578										
IDM-1[1]	5S/9W-25B1	11/89	Mar-03	*163.27	-0.75	162.52	86	271	336	436	631	703	763	878	993	1053								
IDM-2[1]	5S/9W-21M1	12/93		*77.30	-0.72	76.58	129	236	286	353	493	613	713	890	1055	1182	1259	1404						
KBS-2	3S/9W-31Q01	6/94		*224.02	0.99	225.01	99	214																
LAM-1[1]	4S/11W-30H?	4/95		*20.34	-0.71	19.63	72	222	272	472	572	834	996	1073	1153	1253	1498	1613						
MCAS-1	6S/9W-01L2	12/88	10/90	*144.66	-0.81	143.85	65	155	215	275	335	455	545											
MCAS-2	6S/9W-12A1	10/88	10/90	*162.84	-0.53	163.40	45	135	205	375	425	495	555	625										
MCAS-3	6S/8W-07B1	11/88	10/90	*217.54	2.24	219.78	91	166	226	346	426	496												
MCAS-7[1]	6S/9W-02G1	9/88	12/94	*102.94	-0.13	102.81	92	192	352	442	512	802	912	982	1082									
SAR-1	4S/9W-07N1	6/88	2/93	*207.69	2.40	210.09	162	297	327	367	519	584	829	894	914	1014	1114	1284	1374	1446				
SAR-2	4S/10W-13R1	8/88	5/95	*184.82	-0.62	184.20	141	271	311	471	611	741	881	981	1021	1101	1231	1351						
SAR-3[1]	4S/10W-25G1	8/88	5/93	*149.84	2.06	151.90	164	234	414	514	644	774	954	1074	1199	1269	1393							
SAR-4	4S/10W-36C3	8/88	8/96	*138.27	2.69	140.96	123	328	478	598	738	868	978	1068	1168	1398								
SAR-5[1]	5S/10W-02G2	11/89	3/93	*112.05	-1.98	110.07	80	170	360	617	764	944	1084	1193	1293	1543	1733	1823						
SAR-6	4S/9W-07B2	8/89	4/94	*221.99	1.74	223.73	206	366	476	581	706	786	1086	1186	1276	1501								
SAR-7	4S/9W-05K2	1/90		*234.91	0.89	235.80	111	171	311	441	606	741	861	1193	1353									
SAR-8	4S/9W-05Q2	11/90		*232.67	2.22	234.89	44	94	159															
SAR-9[1]	5S/10W-10H2	8/93		*92.117	-0.65	91.47	150	239	409	491	606	730	877	1072	1262	1477	1572	1724	1821	1893				
SBM-1[1]	5S/11W-08A1	7/93		*17.07	2.00	19.07	79	149	244	374	514	706	916	1256										
SC-1	4S/9W-22H1	3/89		*302.56	1.96	304.52	48	93	153	197	299	394												
SC-2	4S/9W-27C2	4/89	3/02	*300.17	2.02	302.19	49	96	148	192	251	303												
SC-3[1]	4S/9W-33N1	10/89	1/93	*221.33	-2.11	219.22	227	412	577	712	1022	1154	1234	1374	1459									
SC-4[1]	4S/9W-28Q1	3/91		*258.81	-1.17	257.64	102	201	271	393	483	573	660	830	1082									
SC-5[1]	5S/9W-05L1	6/91		*177.59	-0.57	177.02	124	196	291	470	670	807	937	1024	1238	1430								
SC-6[1]	5S/10W-13L1	10/93		*83.55	-0.90	82.65	92	202	302	542	789	964	1124	1329	1464	1544	1684	1894	2029	2119				
SCS-1	4S/9W-27B1	1/93		*318.36	1.94	320.30	29	94	146	183	223	298												
SCS-2	4S/9W-22Q2	5/94		*322.40	1.40	323.80	139	179	218	265	330													
WBS-2A	4S/9W-4C02	7/94		*248.15	1.04	249.19	54	94	139															
WBS-3	4S/9W-4A01	6/94		*256.96	0.99	257.95	79	219																
WBS-4	4S/9W-04M3	11/90		*241.40	-0.06	241.34	67	122	212															
WMM-1[1]	5S/10W-07E5	2/90		*49.75	-0.67	49.08	114	364	484	604	744	814	894	984	1064	1214	1314	1369	1434	1569	1624	1744	1804	1944

*Indicate surveyed well elevations, all other values approximated from USGS TOPO maps

2. HBM-5 MP1, MP2, & MP3 are all in Zone 1.

s:\gs\mpdepths.xls

Zones which are intermittently dry

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