Groundwater Quality

A Regional Survey of Groundwater Quality in the Metropolitan Water District Service Area

Report Number 991

May 1994

MWD

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

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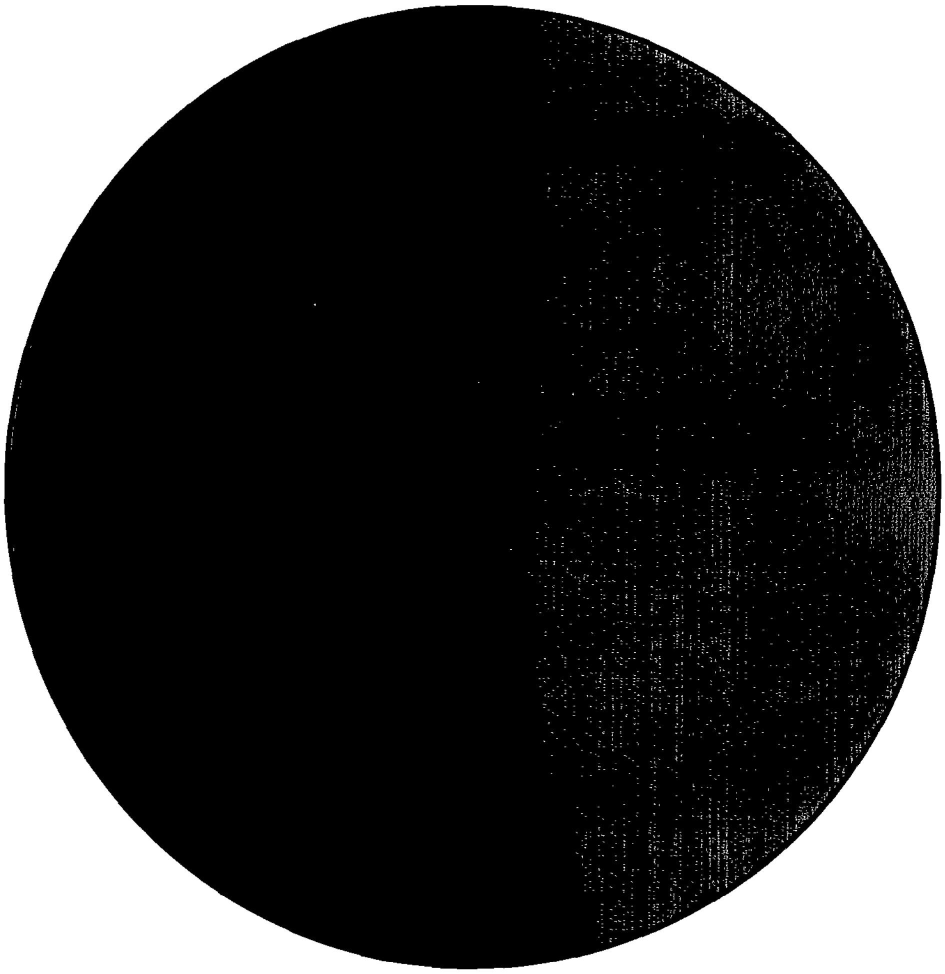
SUMMARY FIGURE 1

Overall Impacts



Summary

The groundwater quality in 15 major groundwater basins in Southern California was evaluated in this regional report. The concentrations of over 200 water quality constituents and production information for 3,500 municipal water supply wells are contained in an extensive computer database. Using a 14-year analysis period, regional groundwater conditions were assessed by the number of wells chemically impacted and the production volumes associated with those wells.

Major Impacts

In general, groundwater impacts are due to decades-long disposal of waste and wastewater, seawater intrusion, and salt and nitrogen loading. Based on the criteria that at least one primary or secondary chemical Maximum Contaminant Level (MCL) established by State and federal agencies for drinking water was exceeded during the analysis period, overall results indicate that:

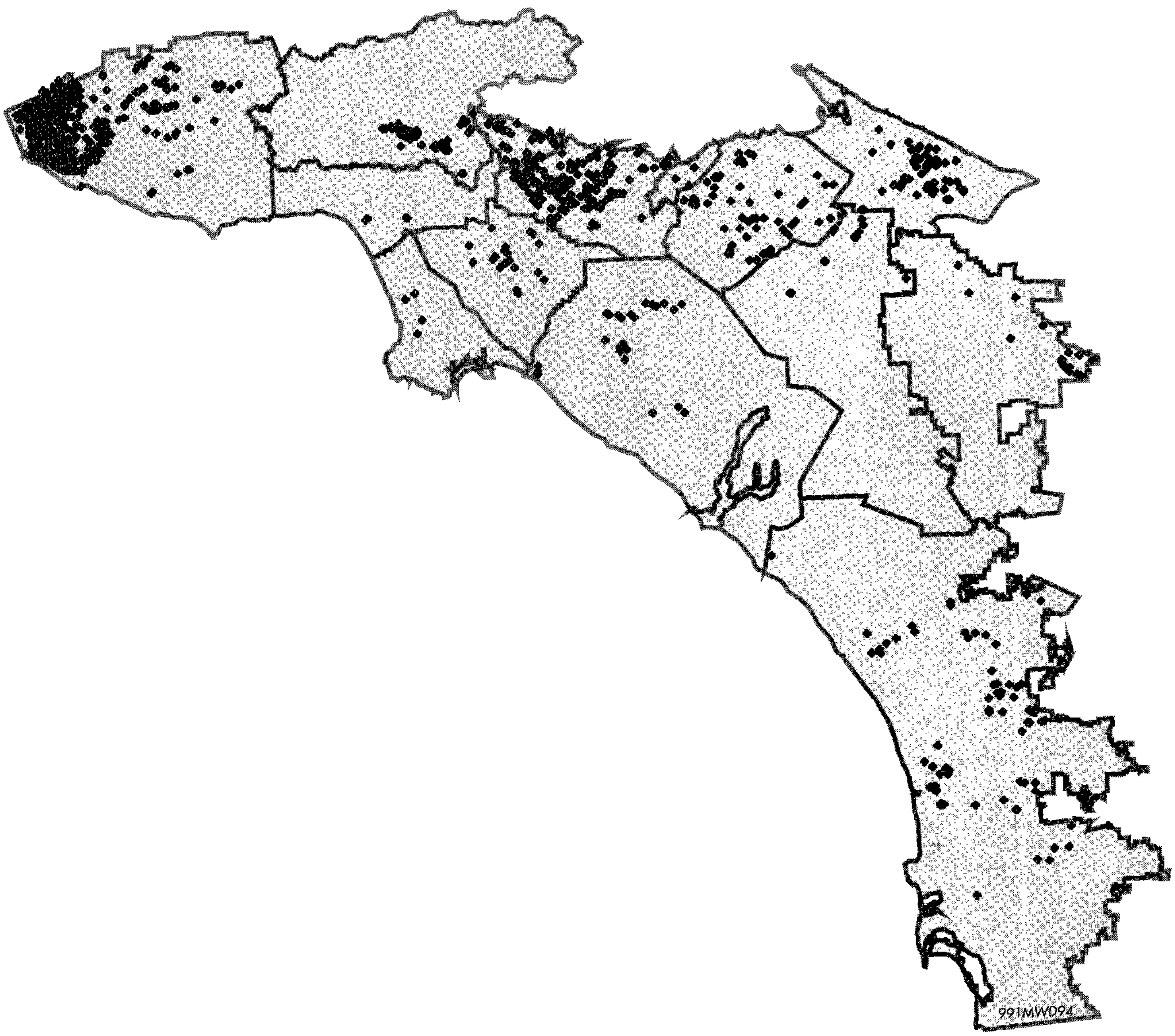
- 46 percent of the wells were impacted (Summary Figures 1 and 2), and, coincidentally;
- 46 percent of the production was impacted.

The major regional groundwater problems, with impacts on all basins, were:

- Nitrogen, impacting 14 percent of wells;
- Volatile Organic Compounds (VOCs), impacting 11 percent of wells;
- Minerals, including some secondary standards, impacting 23 percent of wells; and
- Total Dissolved Solids (TDS), a secondary standard, impacting 17 percent of wells.

SUMMARY FIGURE 2

Impacted Wells



Sources of Contamination

Release of chemicals and of wastes of any kind on the land, past and present, continues to threaten the groundwater supply. Of particular concern in Metropolitan's service area are: 200 Superfund (National Priority List) sites and CERCLA (Comprehensive Environmental Response, Compensation and Liability Act) sites; more than 1,000 landfills; more than 3,000 known leaking underground storage tank sites; irrigated agriculture, dairy and livestock wastes; sanitary wastes; large existing plumes of nitrate, other salts, and solvents; and manufacturing wastes.

Groundwater Treatment

Blending and treatment methods are used to make impacted groundwater potable. Metropolitan has several programs in place to improve the groundwater supply, and has most recently adopted its Groundwater Recovery Program to help make treatment options cost-competitive with imported supplies. Numerous groundwater treatment plants are already planned or on-line, a trend that is expected to continue.

Groundwater Protection

Various State and federal laws and various local management strategies have been adopted to protect the quality of groundwater. However, the task is of enormous scale and is difficult to accomplish. Both State and local groundwater protection actions are evolving.

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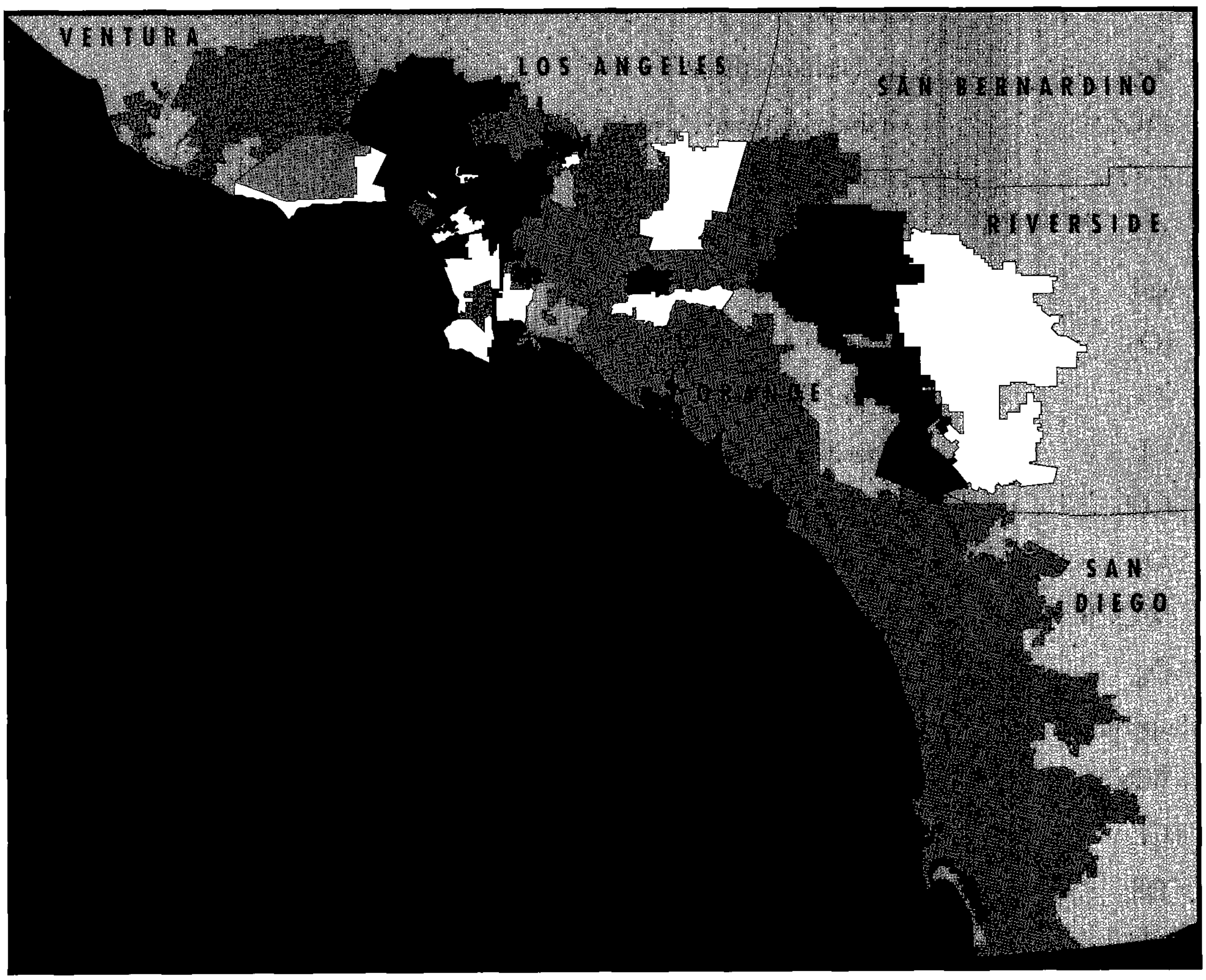
Abbreviations

AFY	Acre-feet per year
CCl_4	Carbon Tetrachloride
CDHS	California Department of Health Services
CERCLA	Federal Comprehensive Environmental Response, Compensation and Liability Act
CIWMB	California Integrated Waste Management Board
Cl	Chloride
DCA	1,2-Dichloroethane
GAC	Granular Activated Carbon
LUST	Leaking Underground Storage Tanks
MCL	Maximum Contaminant Levels
mg/L	Milligrams Per Liter
NO_2	Nitrite
NO_3	Nitrate
PCE	Tetrachloroethylene
pCi/L	PicoCuries Per Liter
RO	Reverse Osmosis
RWQCB	Regional Water Quality Control Board
SO_4	Sulfate
Superfund	CERCLA common name
SWRCB	State Water Resources Control Board
TCE	Trichloroethylene
TDS	Total Dissolved Solids
ug/L	Micrograms Per Liter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOCs	Volatile Organic Compounds

FIGURE 1.1

The Metropolitan Water District of Southern California

Service Area and Member Agencies



1. Introduction

1.1 Metropolitan Water District of Southern California

The Metropolitan Water District of Southern California (Metropolitan) is a regional public agency responsible for developing, storing, treating and distributing supplemental water supply at wholesale rates to 27 member agencies for domestic and municipal uses, and provides surplus water for agriculture (Figure 1.1). As of July 1993, Metropolitan served a population of more than 15.7 million Southern Californians in a 5,200 square-mile service area.

With new sources of water more expensive and subject to legal, technical, financial, environmental, and regulatory issues, any additional loss of groundwater due to contamination puts more pressure on Metropolitan's limited supplies. Therefore, it is important to Metropolitan to assess the conditions of the local groundwater supply.

1.2 Sources of Water

Currently, annual water use in Metropolitan's service area is about 3.5 million acre-feet (MAF), and Metropolitan provides about 60 percent of that demand. In fiscal year 1992-93, Metropolitan received 1.20 MAF of water from the Colorado River Aqueduct and 0.72 MAF of water through the State Water Project facilities. Metropolitan's member agencies provided the remainder, with local groundwater and surface diversions, reclaimed water and imported water via the Los Angeles Aqueduct. Groundwater used by local agencies amounted to about 1.33 MAF. This production is sustained through average annual replenishment of 1.19 MAF of local precipitation, return flow and reclaimed water, and 0.14 MAF of Metropolitan's imported water.

1.3 Eliminating Shortages

Growth in Metropolitan's service area has recently averaged 280,000 people per year. Regional planning agencies are projecting the population to increase from 15.7 million to 20 million by the year 2010. Metropolitan's dependable supply from the Colorado River may be reduced with the commencement of operation of the Central Arizona Project. The State Water Project, as it now exists, is incomplete, and with existing facilities the State cannot reliably fulfill all of its contractual obligations without additional water resource development.

In California, it is not a question of whether there will be droughts but rather when. Shortages created by nature are normal for this area. A shortage of imported supply caused by a drought forces agencies to rely more on groundwater, especially lower-quality water that previously would not have been used. In 1991, Metropolitan experienced the sixth year of a severe drought and fell short of meeting demand by about 800,000 acre-feet (AF) of water. With Metropolitan's existing facilities and sources, the chance of a repeat of that shortage condition is projected to be one in three in the year 2000, increasing to two in five by the year 2010.

Drought has another impact, which is less water for natural replenishment of basins. Between 1987-1991, Southern California precipitation was only 75 percent of normal, while basins continued to be drawn down. The result was a drop of about 1.6 million AF in the cumulative storage of Southern California's major groundwater basins.

To help meet demands, respond to new stricter water quality regulations, increase reliability, and better manage its water, Metropolitan has begun a major capital improvement program to expand its distribution and water storage system and to update and enhance its water treatment facilities. Metropolitan's facility program is designed to support and facilitate artificial recharge of imported water into groundwater basins. Additionally, Metropolitan is investing in innovative water resource management programs, such as: groundwater treatment; wastewater reclamation; conservation; exchanges and transfers; and conjunctive use of groundwater storage with imported supplies.

Metropolitan and its member agencies are currently developing an Integrated Resource Plan, which will further clarify the future role of groundwater in Southern California.

1.4 Groundwater Use

Groundwater supplies account for 90 percent of the local water produced in Metropolitan's service area. Fifteen major groundwater basin groups, with more than 90 separate sub-basins, and covering an area of 2,600 square miles, serve Southern California.

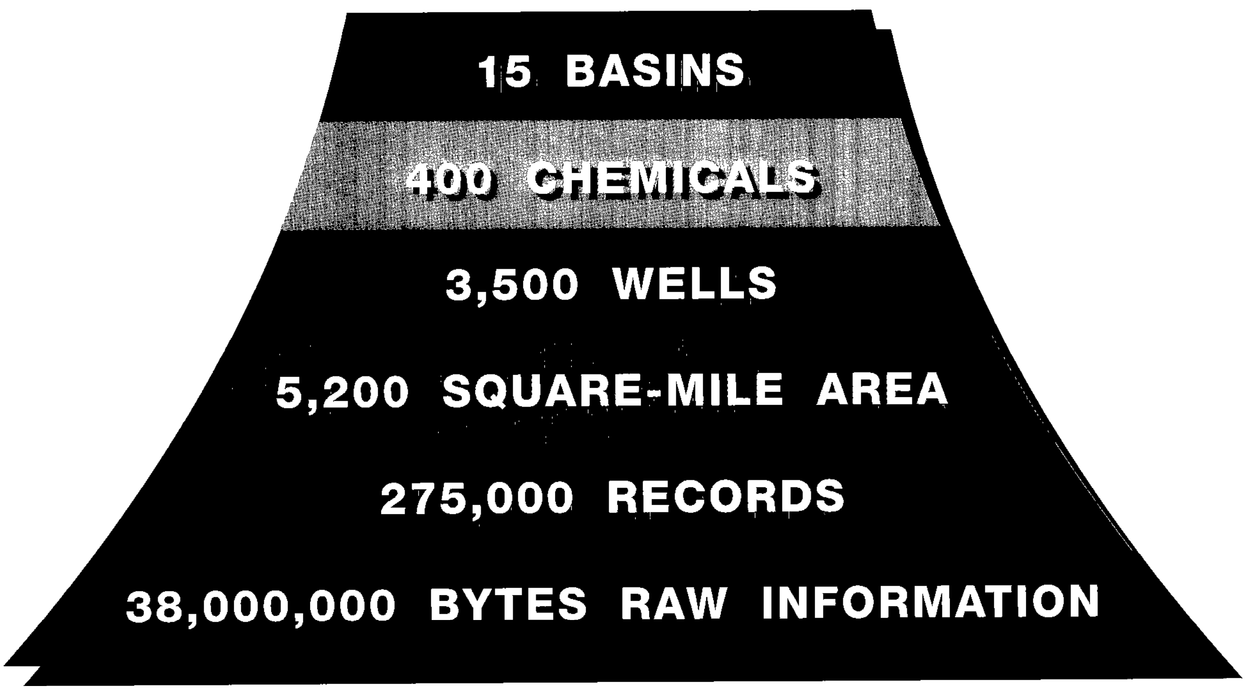
Most of the groundwater used in Metropolitan's service area is replenished by rainfall, runoff and return of surface applications percolating into groundwater basins. Basins are also recharged with imported and reclaimed supplies, which are approximately 140,000 AFY and 180,000 AFY, respectively (Figure 1.2). Surplus imported supplies are thus stored in groundwater basins for later use, especially during droughts and peak demand periods.

Groundwater Replenishment	Figure 1.2
Groundwater Replenishment Source	**Supply (Million AFY)**
Precipitation, Return Flow, Reclaimed	1.19
Imported	0.14
Total Groundwater Use	1.33

FIGURE 2.1

Scope of MWD

Groundwater Quality Database



2. Groundwater Impacts

2.1 Objective

A comprehensive assessment of groundwater quality conditions in Metropolitan's service area was made. A groundwater database was established consisting of existing municipal water supply well data collected from Metropolitan's member agencies and other public agencies (Figure 2.1).

This assessment is being used to determine the reliability of groundwater and opportunities to expand its usage. In addition, the database can be used to:

- Evaluate quality
- Assess the extent of impacts
- Improve basin management
- Project quality standards impacts
- Determine research and development needs
- Develop basin protection strategies

2.2 Database Development

2.2.1 Data Collection and Analyses

The database incorporates both groundwater quality and production data. The incoming data were organized into a compatible format, and through a review and screening process, were reduced from approximately one million to about 275,000 records.

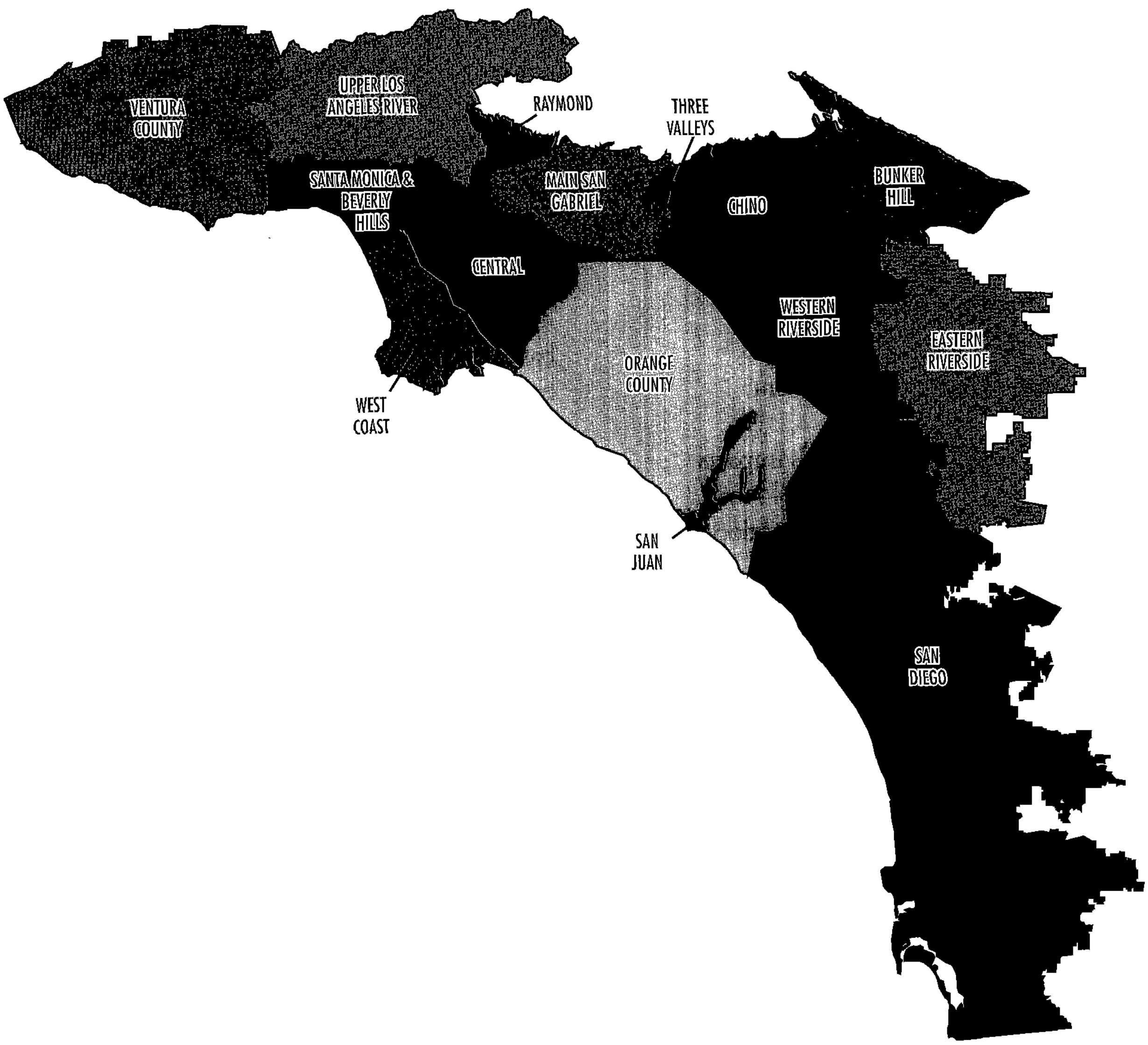
Individual well information other than quality data were also gathered when available, including: member and submember agency; well owner; State well identification number; geographic coordinates; county and basin locations; local well name; and well completion zones and depth. Five-year average gross production values were calculated from the most recent production histories, excluding years with zero production. In certain areas where production data were not available, a value of 250 AFY per well was used.

The service area was divided into 15 major groundwater basin groups based on hydrogeological information (Figure 2.2). Each basin group is typically comprised of several basins and sub-basins, called hydrogeologic subunits. The Bunker Hill Basin, although outside Metropolitan's service area, was included because it is a source of groundwater for Metropolitan subagencies.

Data contributors included 46 agencies, listed in Figure 2.3. Metropolitan worked with contributors to resolve questions, including standardized chemical names and units for groundwater quality data. For each of the several hundred chemical names in the database, the Chemical Abstract Service number was used to eliminate duplication. To ensure that scarce, important data were retained, such as for radon and arsenic, all duplicate sample data were examined individually.

FIGURE 2.2

Groundwater Basin Groups in Regional Study



Agencies Contributing Data — Figure 2.3

MEMBER AGENCIES

- Anaheim
- Beverly Hills
- Burbank
- Calleguas Municipal Water District
- Central Basin Municipal Water District
- Chino Basin Municipal Water District
- Coastal Municipal Water District
- Compton
- Eastern Municipal Water District
- Foothill Municipal Water District
- Fullerton
- Glendale
- Las Virgenes Municipal Water District
- Long Beach
- Los Angeles
- Municipal Water District of Orange County
- Pasadena
- San Diego County Water Authority
- San Fernando
- San Marino
- Santa Ana
- Santa Monica
- Three Valleys Municipal Water District
- Torrance
- Upper San Gabriel Valley MWD
- West Basin Municipal Water District
- Western MWD of Riverside County

SUBAGENCIES

- Capistrano Valley Water District
- Elsinore Valley Municipal Water District
- Orange County Water District
- Pomona
- Rancho California Water District
- Riverside

OTHER LOCAL AGENCIES

- Chino Basin Watermaster
- Los Angeles County Department of Public Works
- Main San Gabriel Basin Watermaster
- San Juan Basin Authority
- Santa Ana Watershed Protection Authority
- United Water Conservation District
- Upper Los Angeles River Area Watermaster
- Ventura County Flood Control District

STATE AGENCIES

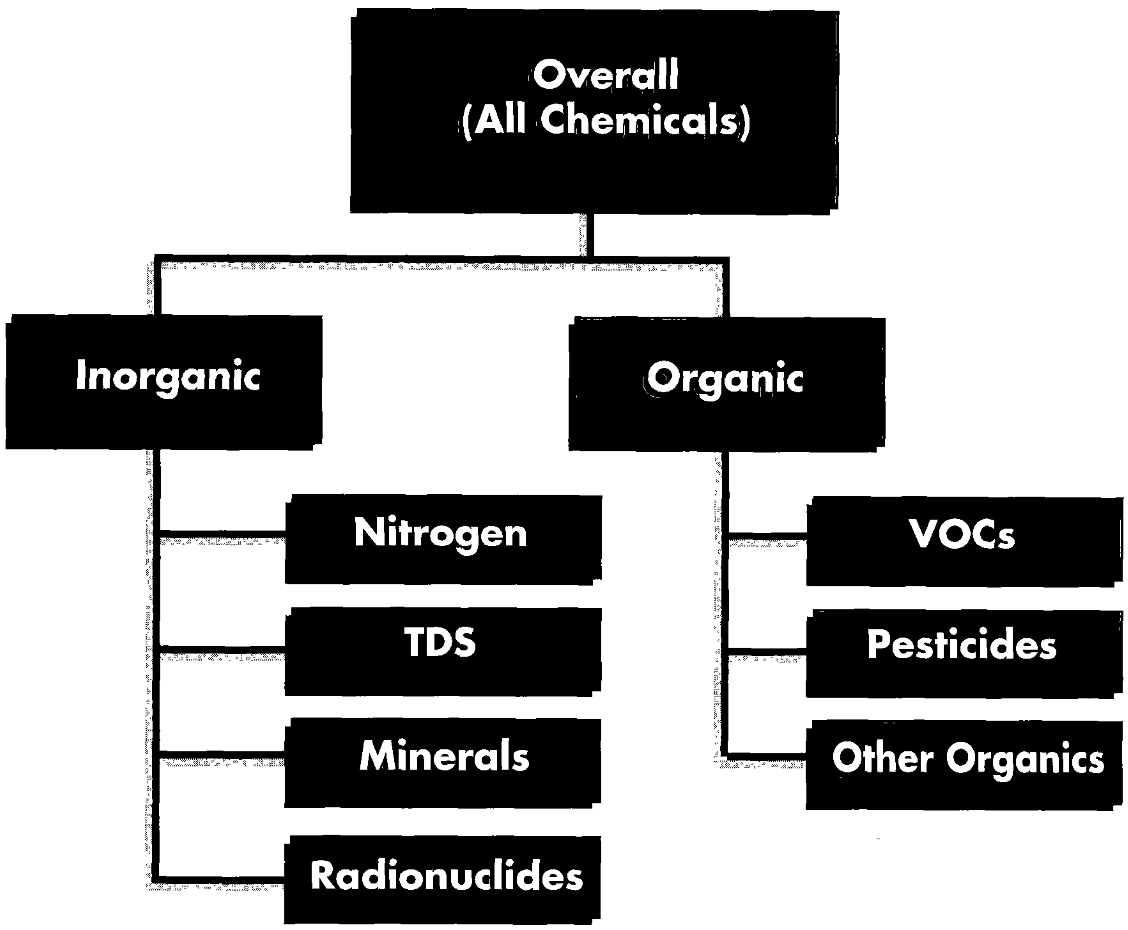
- California Integrated Waste Management Board
- State Department of Health Services
- State Water Resources Control Board

FEDERAL AGENCIES

- U.S. Environmental Protection Agency
- U.S. Geological Survey

FIGURE 2.4

Chemical Groups Used in Database Analyses



To interpret the data, chemicals were divided into groups related to their common physical and reactive properties, and the concentrations found in well samples were compared to drinking water standards. First, the impacts on wells and corresponding production were determined for all chemicals grouped together, denoted as overall impacts. Next, chemicals were divided into organic and inorganic types, and then into groups for each type (Figure 2.4).

The four Inorganic Groups consist of: Nitrogen; Total Dissolved Solids (TDS); Minerals; and Radionuclides. The Minerals Group and the TDS Group have some similarity as both include dissolved minerals. However, the Minerals Group evaluated the impact of individual minerals based on their corresponding MCLs, while the TDS Group examined the sum of all minerals dissolved in water against a single MCL. The three Organic Groups are: Volatile Organic Compounds (VOCs); Pesticides; and Other Organics. Finally, the impacts of important individual chemicals were also evaluated.

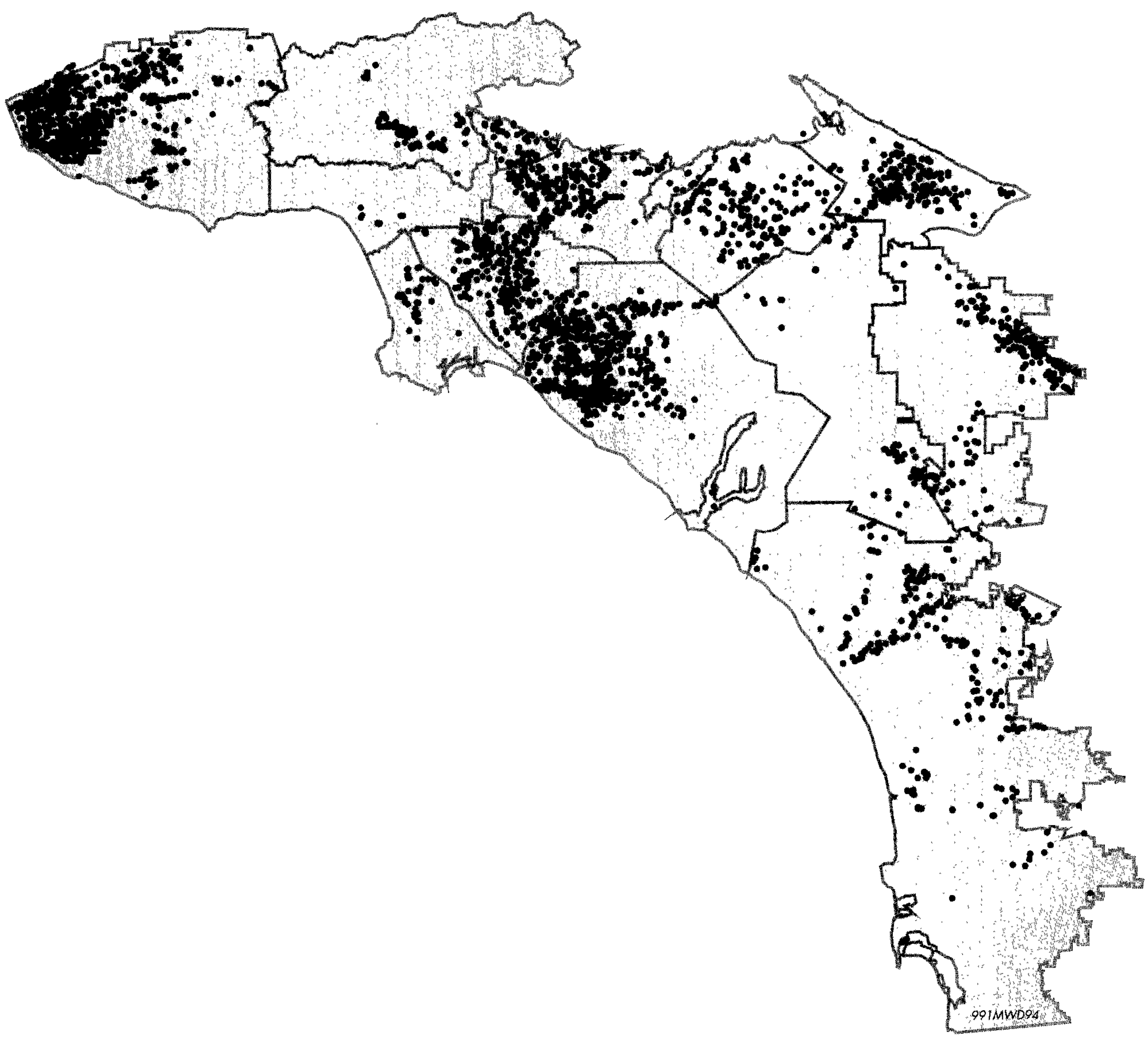
Results presented in this report are an examination of data from 1976 to 1989, a 14-year period where data exist for approximately 3,500 wells, shown in Figure 2.5, accounting for a production of about 1.4 million acre-feet per year (MAFY). A linear extrapolation was made from available data to project the impacts for the entire service area. Production has declined recently from the 1.4 MAFY, but this still represents the broader picture of groundwater conditions.

2.2.2 Database Limitations

Database results are limited to a two-dimensional perspective, because current sampling techniques examine mixed groundwater coming from different depths in any particular well. Further, testing is performed on individual wells, which represent only a point, whereas plumes of contamination extend over areas. Because of these limitations, database illustrations show impacts for individual wells.

FIGURE 2.5

3500 Municipal Groundwater Production Wells in Regional Study



The results of this survey may underestimate the extent of contamination in several ways. First, the vadose (or unsaturated) zone contains contamination that has not yet worked its way into the groundwater below, and subsequently to a well where it can be detected. This process may take decades.

Second, because severely impacted wells are typically taken out of service and then not sampled, current data were not likely to be available regarding the contamination. Therefore, a 14-year evaluation period was chosen to provide a more complete picture of contamination. Third, the available well data may not reflect the impacts of all contaminants, as sampling regulations have evolved over time to include additional chemicals and increasingly stringent MCLs.

Upcoming regulations for arsenic and radon were evaluated. However, data available for these two elements are limited and agencies will need to perform additional sampling and analyses using recently developed methodologies to achieve a clear regional picture.

2.3 Drinking Water Standards

The U.S. and California drinking water standards for chemicals which were used to determine the acceptability of groundwater from a particular well are listed in Figures 2.6 and 2.7. In addition to primary standards, the State secondary MCLs for TDS, chloride, sulfate, iron, manganese, and zinc were also used as criteria in evaluating groundwater impacts. All are important indices of groundwater quality and usability, as high levels impair aesthetic and practical uses of a municipal supply. Appendix A lists State and federal drinking water standards.

A well and its production were considered impacted by a specific chemical if it exceeded the MCL for that chemical one or more times during the 14-year period. It is important to note that if an impacted well was producing water equal to or exceeding an MCL, it does not imply that the water purveyor was serving unsafe water. Groundwater can be blended or treated to meet drinking water standards.

It was assumed that sampling and laboratory analyses conducted by participating agencies included adequate quality control. Impacted wells which were previously taken out of service before the start of the analysis period (1976) are not included in this report.

Inorganic Drinking Water Standards Used as Criteria in Report — Figure 2.6

Inorganic	MCL *
Nitrogen, mg/L #	
Nitrate	10
Nitrate plus Nitrite	10 c
Nitrate	1
TDS, mg/L	
TDS	1,000 +a
Minerals, mg/L	
Aluminum	1
Arsenic	0.05
Barium	1
Cadmium	0.005
Chloride	500 +a
Chromium	0.05
Copper	1.0 +
Fluoride	1.4
Iron	0.3 +
Lead	0.05
Manganese	0.05 +
Mercury	0.002
Selenium	0.01
Silver	0.05
Sulfate	500 +a
Zinc	5.0 +
Radionuclides, pCi/L	
Gross Alpha	15
Gross Beta	50
Radium-226	5 b
Radium-228	5 b
Strontium-90	8
Tritium	20,000
Uranium	20

\# as nitrogen
* Maximum Contaminant Level
\+ secondary drinking water standard
a upper limit of secondary drinking water standard
b standards are for Radium-226 and Radium-228 combined
c total amount of nitrate and nitrite

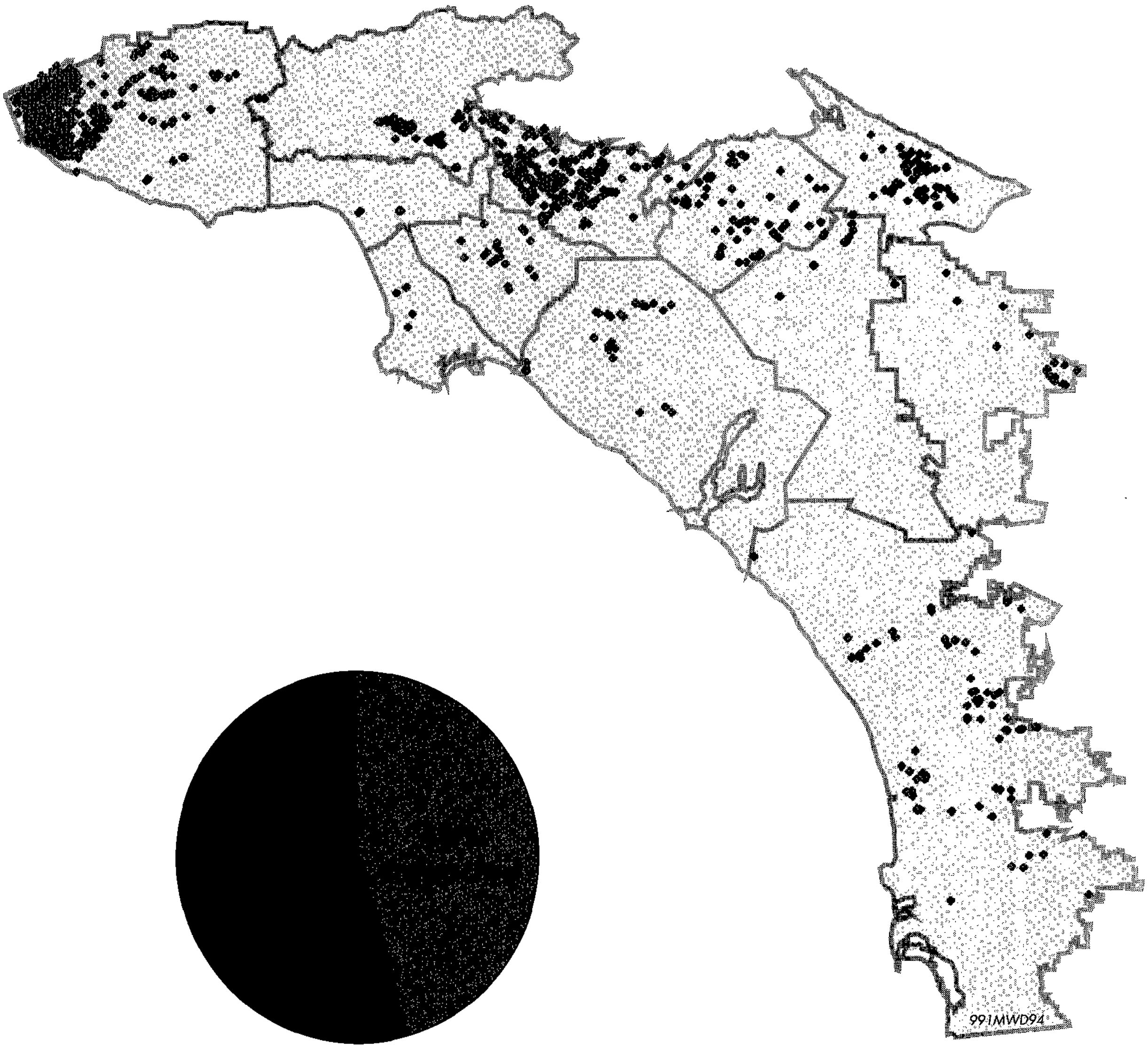
Organic Drinking Water Standards Used as Criteria in Report — Figure 2.7

Organic, mg/L

VOCs	MCL
Benzene	0.001
Carbon Tetrachloride	0.0005
1,2-Dichlorobenzene	0.6
1,4-Dichlorobenzene	0.005
1,1-Dichloroethane	0.005
1,2-Dichloroethane	0.0005
1,1-Dichloroethene	0.006
cis-1,2-Dichloroethene	0.006
trans-1,2-Dichloroethene	0.01
1,2-Dichloropropane	0.005
1,3-Dichloropropene	0.0005
Ethylbenzene	0.680
Freon 11	0.15
Freon 113	1.2
Monochlorobenzene	0.030
Styrene	0.1
1,1,2,2-Tetrachlorethane	0.001
Tetrachloroethene	0.005
Total Trihalomethanes	0.10
1,1,1-Trichlorethane	0.200
1,1,2-Trichlorethane	0.032
Trichlorethene	0.005
Vinyl Chloride	0.0005
Xylenes	1.750
Pesticides	
Atrazine	0.003
Bentazon	0.018
Carbofuran	0.018
Chlordane	0.0001
2,4-D	0.07
Dibromochloropropane	0.0002
Endrin	0.0002
Ethylene Dibromide	0.00002
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor Epoxide	0.00001
Lindane	0.0002
Methoxychlor	0.04
Molinate	0.02
Simazine	0.010
Thiobencarb	0.07
Toxaphene	0.003
2,4,5-TP (Silvex)	0.01
Other Organics	
Di (2-ethylhexyl) phthalate	0.004

FIGURE 2.8

Overall Impacts



PRODUCTION

2.4 Overall Impacts

Approximately 1,573 wells (or 46 percent) were equal to or exceeded at least one of the MCLs during the 14-year evaluation period (Figure 2.8). These overall impacted wells accounted for approximately 642,000 AFY (or 46 percent) of the production. Each of the 15 groundwater basin groups were impacted.

The following chemical groups represent the important regional groundwater quality problems accounting for the majority of the impacts:

- Nitrogen
- Volatile Organic Compounds (VOCs)
- Minerals
- Total Dissolved Solids (TDS)

In general, groundwater impacts seem to be increasing, because of decades-long disposal of waste and wastewater, seawater intrusion, and salt loading.

2.5 Inorganic and Organic Impacts

The overall impacted wells were divided into three types: (1) 1,286 wells that were equal to or exceeded only inorganic MCLs; and (2) 418 wells that were equal to or exceeded only organic MCLs; of which (3) 131 of those wells that were equal to or exceeded both inorganic and organic MCLs (Figure 2.9). Percentages are calculated based on the fraction of all database wells. The locations of the three types of wells are shown in Figure 2.10.

Areas with major impacts by both inorganic and organic chemicals are generally indicative of a history of multiple land uses and waste disposal practices, generally including both agricultural and industrial activities. The highest density of

Overall, Inorganic, and Organic Impacts — **Figure 2.9**

Impact Category	Wells		Production	
	Number	%	AFY	%
Overall	**1,573**	46	**642,000**	46
Inorganic	1,286	38	459,000	33
Organic	418	12	273,000	20
Both Organic and Inorganic	131	4	90,000	7

FIGURE 2.10

Wells with Organic and Inorganic Impacts

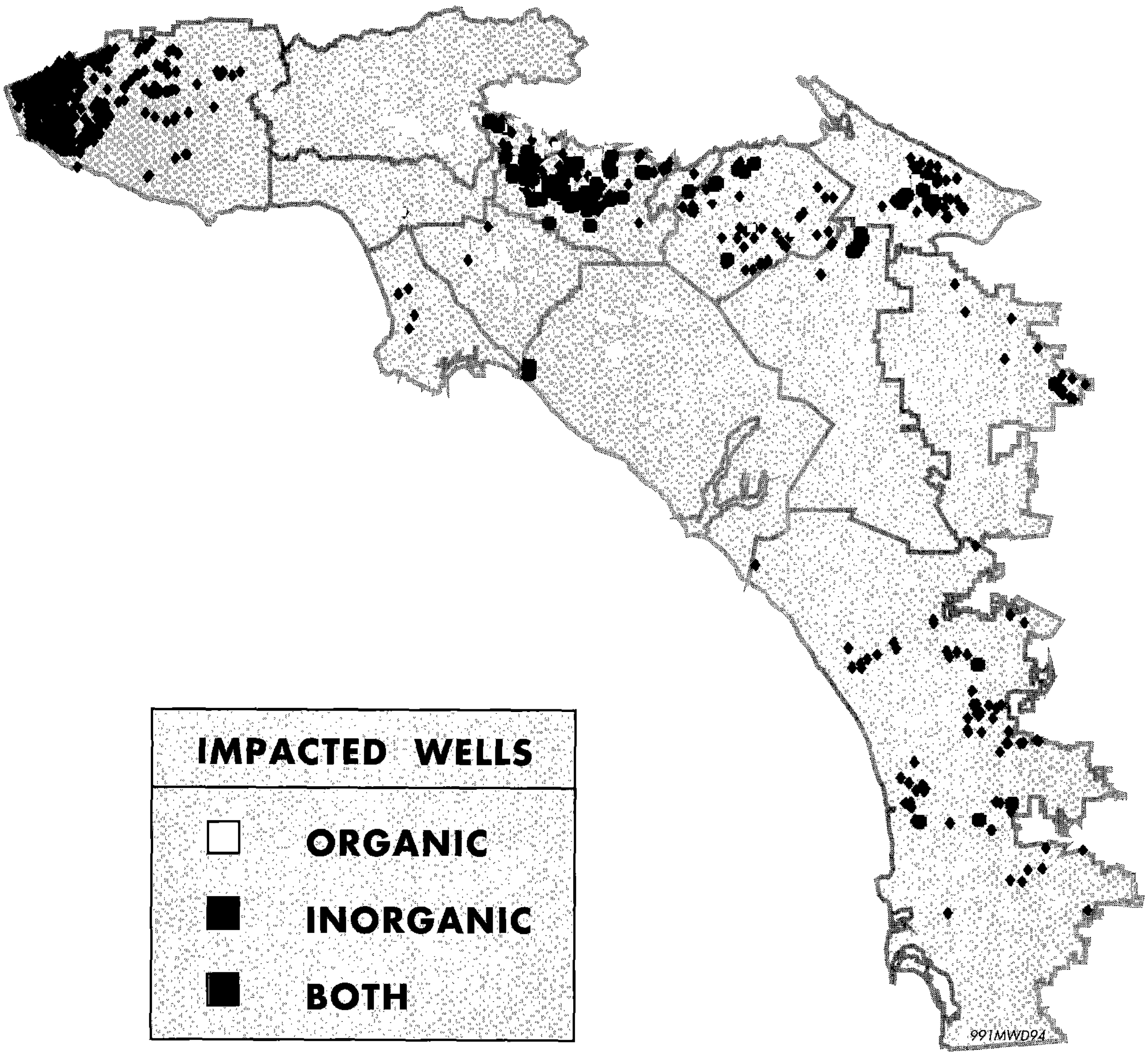
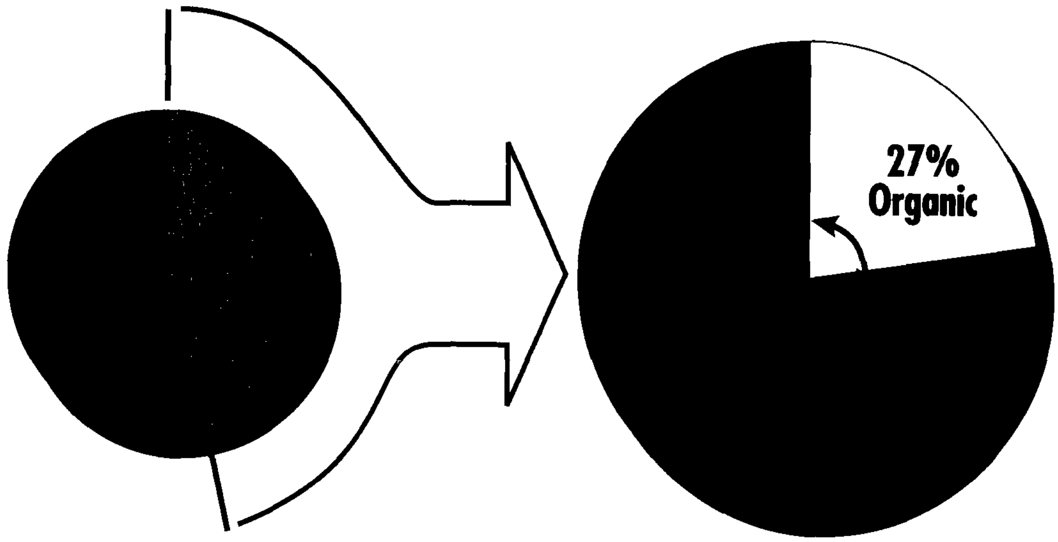
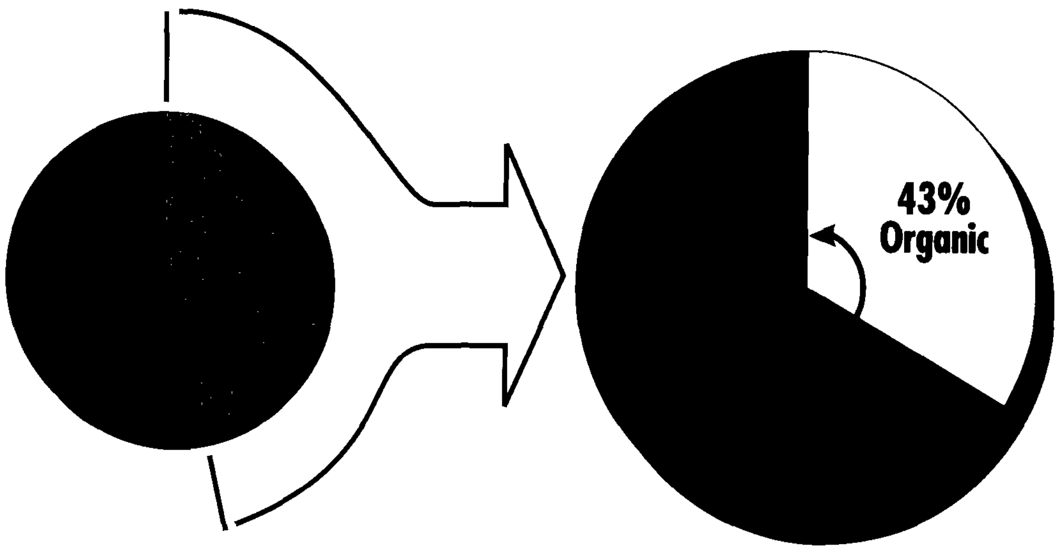


FIGURE 2.11

Impacted Wells and Production



Impacted Wells



Impacted Production

these wells was in the Main San Gabriel Basin, in part, due to an extensive database resulting from the intensive cleanup and management plans proposed by State, federal, and local water agencies including Metropolitan.

Percentages calculated based on the fraction of impacted wells alone, showed that inorganic problems dominated organic. Inorganics accounted for 82 percent of the well impacts, and organics account for 27 percent, including an overlap of nine percent of the impacted wells that were equal to or exceeded both organic and inorganic MCLs. A comparison of these calculations showing both number of impacted wells and corresponding production impacts is presented in Figure 2.11. Organics had a proportionally larger impact on production than on the number of wells, impacting 43 percent and 27 percent, respectively.

2.6 Inorganic Groups

For the 1,286 wells (or 38 percent) impacted by Inorganics, the Nitrogen, TDS, and Minerals Groups were the leading quality problems. The fourth group, Radionuclides, had much less impact, perhaps because of limited sampling.

2.6.1 Nitrogen Group

2.6.1a Nitrogen Sources and Regulations

Nitrogen is a constituent of all proteins, and as such is widely distributed in plants and animals. Major sources of nitrogen include: irrigated agriculture; dairy and livestock wastes; sanitary wastes (septic tanks in unsewered areas and wastewater treatment plant discharges); landfill leachate; and some manufacturing wastes which are disposed of in waste pits.

The three MCLs in the Nitrogen Group are for nitrate, nitrite, and a standard for total nitrogen existing in the forms of nitrate and nitrite. Nitrate (NO_3), with an MCL of 10 mg/L as nitrogen (as N), has long been regulated because of its acute human health effects impairing the ability of blood to carry oxygen.

The monitoring cycle for the latter two MCLs took effect in January 1993. Nitrite (NO_2) is limited to 1 mg/L as N, and the total combined nitrogen from nitrate and nitrite is limited to 10 mg/L as N. Thus, a well could meet the individual nitrate and nitrite MCLs and still exceed the combined MCL.

2.6.1b Nitrogen Impacts

Nitrogen is a major problem, with approximately 469 wells and 233,000 AFY of production impacted (Figure 2.12).

Nitrogen Impacts — **Figure 2.12**

Impact Type*	Wells		Production	
	Number	%	AFY	%
Nitrogen Group	**469**	**14**	**233,000**	17
Nitrate	421	12	215,000	15
Nitrate + Nitrite	51	1	20,000	1
Nitrite	12	<1	10,000	<1

* There are overlaps between the impact types, as they are not unique.

As shown in Figure 2.14, most groundwater basins have nitrogen impacts.

Nitrate accounted for the majority of the impacts in the Nitrogen Group (Figure 2.12). Nitrite is readily oxidized to nitrate, so it is usually found only in small amounts in groundwater. Few data were available for the two MCLs involving nitrite, as they are relatively new standards.

Nitrogen was also measured in a considerable number of wells at concentrations less than MCLs but greater than zero, being detected in an additional 1,180 wells and 442,000 AFY of production (Figure 2.13).

2.6.2 Total Dissolved Solids (TDS) Group

2.6.2a TDS Sources and Regulations

The predominant dissolved matter in municipal water supplies are Inorganics (minerals). These minerals constitute the Total Dissolved Solids, or TDS, and commonly include: sodium; calcium; magnesium; bicarbonate; sulfate; chloride; and silica.

There is no primary MCL for TDS, however, there are three individual secondary MCLs as it is an important index of groundwater quality and usability, since high levels impair aesthetics and impair practical uses of a municipal supply. For example, elevated calcium and magnesium components in water inhibit soap from lathering. Therefore, the TDS Group uses the upper secondary MCL of 1,000 mg/L, as shown in Figure 2.6 and Appendix A, as the criterion to evaluate TDS impacts.

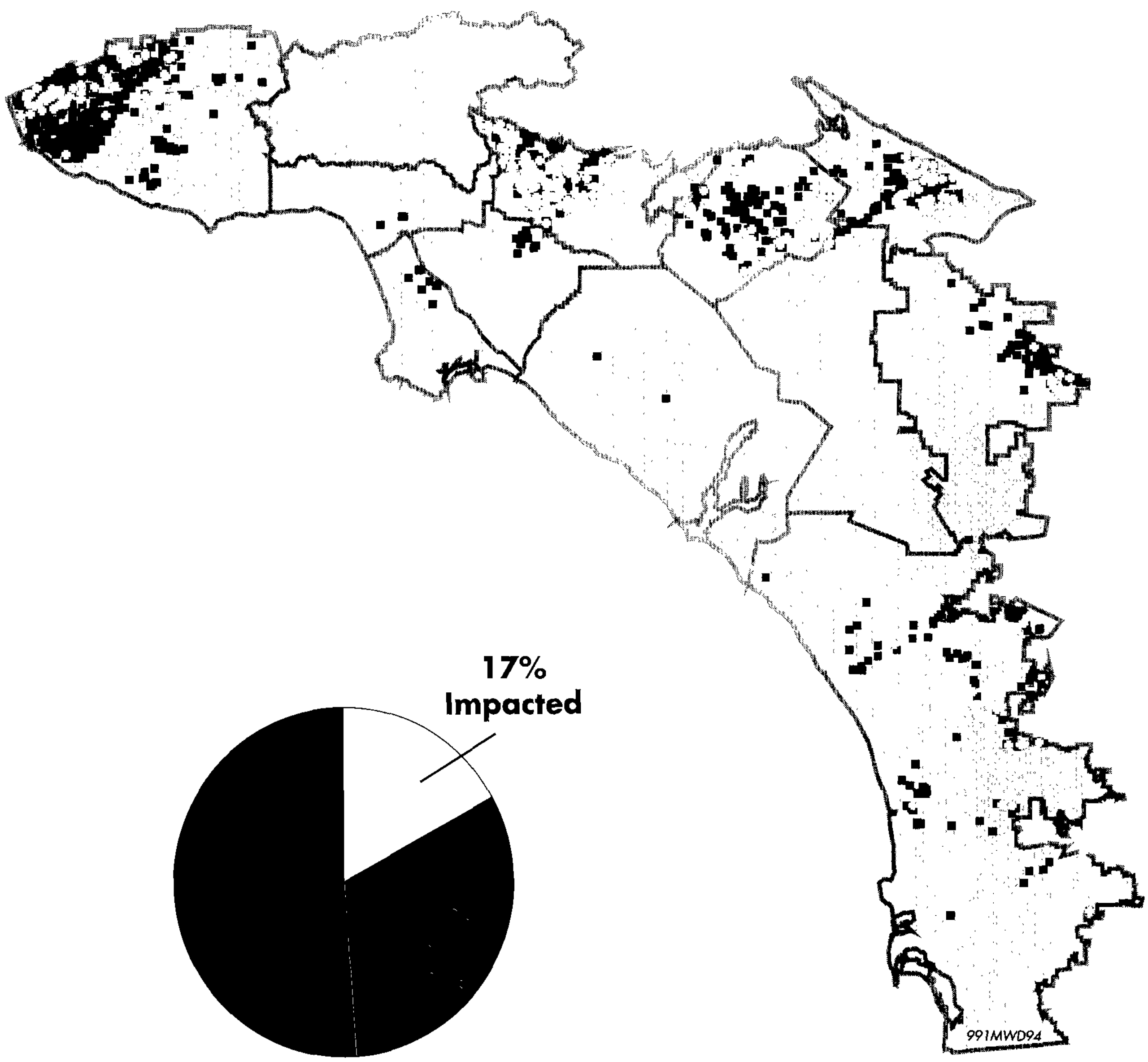
Additional Nitrogen Impacts — **Figure 2.13**

Impact Type+	Wells		Production	
	Number	%	AFY	%
Nitrogen Group: Equal to or Exceeding MCLs	**469**	**14**	233,000	17
Nitrogen Detected: Less than MCLs, but Greater than Zero	**1,180**	**34**	442,000	32

+ Numbers are unique; there are no overlaps between impact types.

FIGURE 2.14

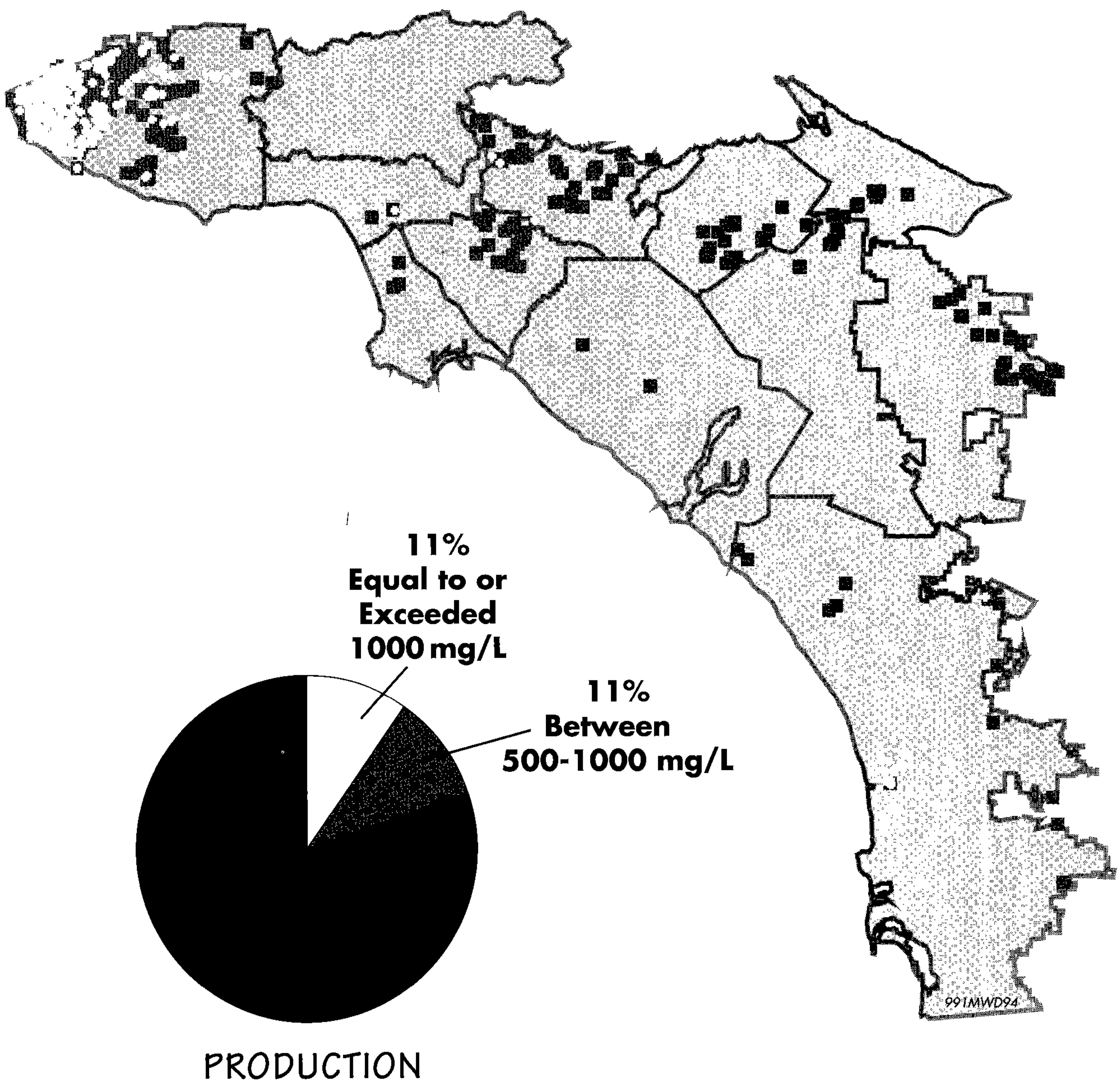
Nitrogen Impacts



PRODUCTION

FIGURE 2.15

TDS Impacts



High TDS levels can occur in coastal areas due to seawater intrusion, often resulting from overdraft of groundwater basins adjacent to the coastline. Salts in groundwater come from the application of water and disposal of wastes to land, and especially from: irrigated agriculture, dairy and livestock activities; septic tanks in unsewered areas; wastewater treatment plant discharges; manufacturing and processing; and landfill leachates. It is interesting to note that the general paths of some rivers in Southern California can be traced using impacted well locations, probably as a result of nitrogen-containing wastewater treatment plant discharges to the rivers that recharge nearby groundwater basins.

2.6.2b TDS Impacts

TDS is a widespread groundwater quality issue, and impacted all basin groups (Figure 2.15). The basins with significant impacts included: the Oxnard Plain area of Ventura County Basins, due to irrigated agriculture and seawater intrusion; Chino Basin with dairy activities and irrigated agriculture; and coastal areas including West Coast Basin, Long Beach and Orange County, due to seawater intrusion (all of which have lines of freshwater-injection barrier wells to prevent further intrusion).

A comparison between the location of TDS impacts (Figure 2.15) and Nitrogen Group impacts (Figure 2.14) shows that they were commonly found together at inland locations, because both occur in sewage and wastewater treatment plant effluents and in waters percolating from dairy activities and irrigated agriculture.

A total of 152,000 AFY was impacted by TDS, accounting for 11 percent of all production (Figure 2.16).

There are three secondary drinking water standards for TDS (Appendix A), in recognition that it is an important index of the practical usability of groundwater. Therefore, impacts for the recommended secondary MCL of 500 mg/L were also determined, in addition to those for the upper secondary MCL standard of 1,000 mg/L as previously described.

An additional 498 wells and 149,000 AFY of production were impacted by TDS, equal to or exceeding the recommended secondary MCL of 500 mg/L but less than the upper secondary MCL of 1,000 mg/L (Figure 2.17). These are unique categories, and a well with TDS equal to or exceeding 1,000 mg/L is only counted once.

TDS Impacts **Figure 2.16**

Impact Type	Wells		Production	
	Number	%	AFY	%
TDS+	577	17	152,000	11

+ For TDS greater than or equal to the upper secondary MCL of 1,000 mg/L.

Additional TDS Impacts			Figure 2.17	
Impact Type+	**Wells**		**Production**	
	Number	**%**	**AFY**	**%**
TDS Group: TDS $\geq$ 1,000 mg/L	**577**	**17**	152,000	11
TDS $\geq$ 500 mg/L and TDS < 1,000 mg/L*	**498**	**14**	149,000	11

+ Numbers are unique; there are no overlaps between impact types.

* Includes additional impacts for the recommended secondary MCL, where TDS is greater than or equal to 500 mg/L, but less than 1,000 mg/L.

2.6.3 Minerals Group

Minerals are inorganic elements and compounds that occur naturally in the earth's crust and dissolve into water. The Minerals Group includes both major minerals and trace elements, all of which may reach elevated concentrations in groundwater through human activities.

2.6.3a Mineral Sources and Regulations

Major minerals, such as sulfate and chloride, dissolve readily in water and become concentrated in agricultural runoff and wastewater treatment plant discharges, and through evaporation in seawater and freshwater bodies. Sulfate and chloride are regulated with secondary standards because of aesthetic considerations, due to the cathartic effect on humans, and the salty taste imparted to water, respectively. Fluoride is regulated because too high a level may cause mottled teeth enamel and osteosclerosis.

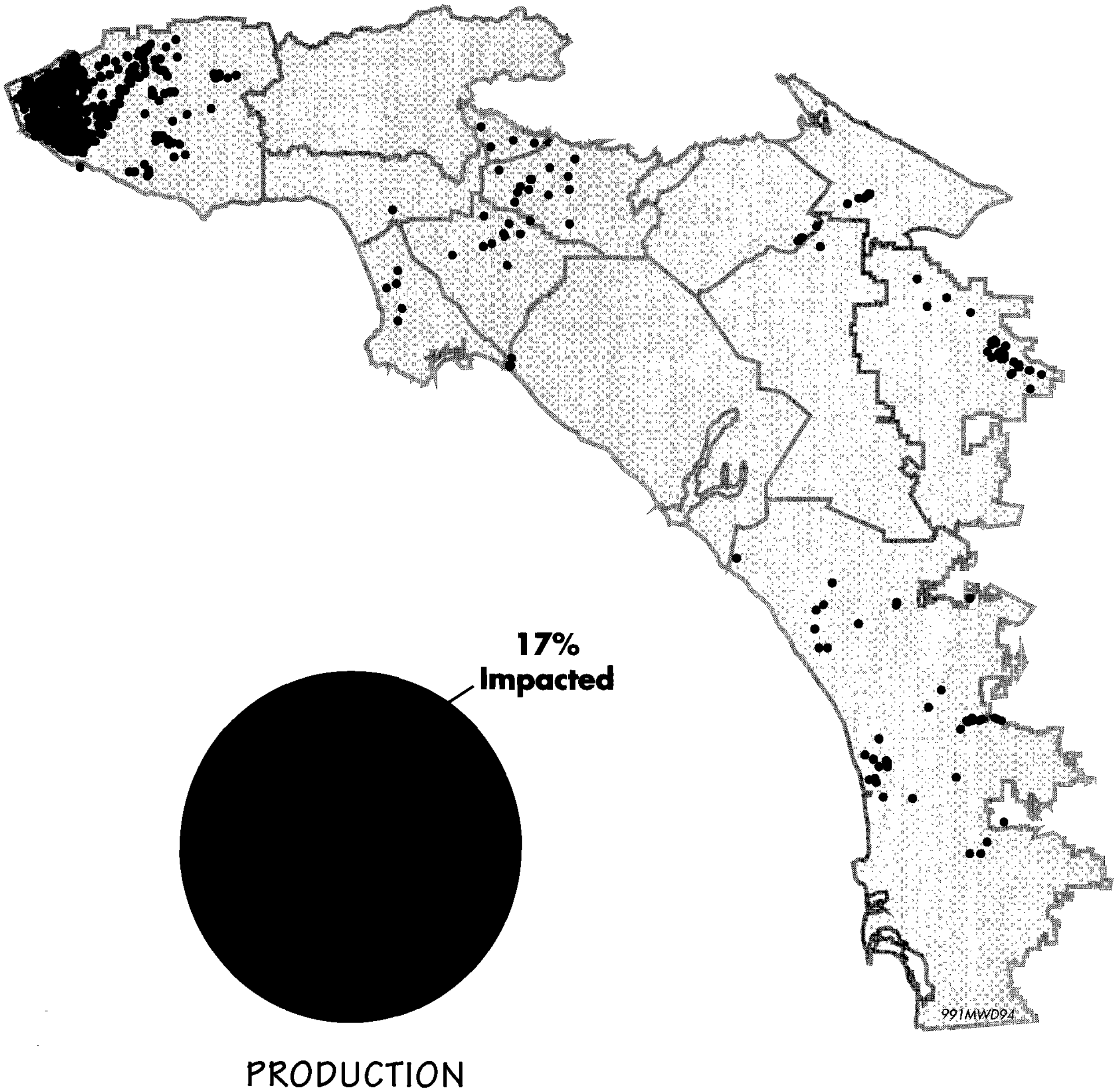
Trace elements in the Minerals Group include silver, mercury, arsenic, and selenium. Trace elements can damage living organisms at low concentrations and tend to accumulate in the food chain. In addition to being toxic, some like chromium and arsenic, are also known carcinogens. Trace elements have a wide variety of uses, including mercury in paints and batteries, cadmium in electroplating, and chromium in steel manufacturing.

Minerals Group, Major Minerals, and Trace Element Impacts Figure 2.18				
Impact Type*	**Wells**		**Production**	
	Number	**%**	**AFY**	**%**
Minerals Group	**805**	**23**	237,000	17
Major Minerals				
Manganese	**493**	**14**	129,000	9
Sulfate	**330**	**10**	92,000	7
Iron	**311**	**9**	89,000	6
Chloride	**92**	**3**	23,000	2
Fluoride	**40**	**1**	24,000	2
Trace Elements				
Cadmium	**6**	**<1**	2,000	<1
Lead	**6**	**<1**	1,000	<1
Selenium	**4**	**<1**	1,000	<1
Mercury	**2**	**<1**	1,000	<1
Barium	**1**	**<1**	1,000	<1
Aluminum	**1**	**<1**	1,000	<1
Silver	**1**	**<1**	<1,000	<1

* There are overlaps between the impact types, as they are not unique.

FIGURE 2.19

Mineral Impacts



Selenium, although an essential trace element in animal diets at approximately 0.1 mg/L, is toxic to them at higher concentrations. Selenium has received attention in recent years due to the Kesterson Wildlife Refuge in Central California, where naturally-occurring selenium leached out in agricultural drainage water at concentrations toxic to migratory bird populations. Across the valley from the area, however, livestock receive selenium supplements, as their diet is selenium-deficient.

2.6.3b Mineral Impacts

The Minerals Group is a major water quality problem, and impacted approximately 237,000 AFY of production, including both major and trace element constituents (Figure 2.18). The major mineral contributors were manganese, sulfate, iron, chloride, and fluoride. Manganese, a naturally widely distributed element, was the most important, impacting 493 wells and 129,000 AFY of production. Seven trace elements impacted only a few wells, with cadmium leading with six wells and 2,000 AFY of production (Figure 2.18). No wells produced groundwater that was equal to or exceeded the chromium, zinc, or arsenic MCLs. Section 2.8 presents a discussion on arsenic and the upcoming USEPA revision to the current MCL of 50 ug/L.

As shown in Figure 2.19, the Minerals Group impacts were widely distributed in a pattern similar to that of the TDS Group. The TDS and Minerals Groups are related, as each evaluates some of the same chemicals but in a different context. The TDS Group examines the total concentration of all dissolved minerals, whereas the Minerals Group examines specific minerals against their individual MCLs. The Minerals Group predominated, with 805 wells and 237,000 AFY impacted, as compared to 577 wells and 152,000 AFY impacted by the TDS Group.

2.6.4 Radionuclides Group

A radionuclide is an element which spontaneously undergoes radioactive decay and releases energy in the process. Radionuclides include both man-made and naturally-occurring isotopes.

2.6.4a Radionuclide Sources and Regulations

Strontium-90 is a man-made radioactive isotope derived from fission products of nuclear reactor fuels, and present in fallout from nuclear bombs. It has a variety of uses including: industrial

Radionuclide Impacts				Figure 2.20
Impact Type*	**Wells**		**Production**	
	Number	**%**	**AFY**	**%**
Radionuclides Group	**32**	**<1**	**9,000**	**<1**
Strontium-90	**19**	**<1**	5,000	<1
Gross Beta	**8**	**<1**	4,000	<1
Gross Alpha	**8**	**<1**	1,000	<1
Uranium	**1**	**<1**	<1,000	<1

* There are overlaps between the impact types, as they are not unique.

thickness gauges; static charge elimination; eye disease treatment; and cigarette density control. Uranium is a naturally-occurring radioactive element, which is used in nuclear reactors and in the production of nuclear weapons.

Gross alpha measures total radioactivity due to emissions of alpha particles (two protons and two neutrons), generally due to naturally-occurring radionuclides. Gross beta measures total radioactivity due to emission of beta particles (one electron), and is generally due to man-made radionuclides.

Radionuclides are believed to have potentially mutagenic (genetic damage) effects on the human body, and are regulated in terms of picoCuries per liter (pCi/L), which is a measure of radioactivity. Radon, for which the MCL has not yet been finalized, is discussed in Section 2.8.

2.6.4b Radionuclide Impacts

Radionuclides rank lowest of the four Inorganic Groups in terms of impacts. Thirty-two wells and 9,000 AFY of production were equal to or exceeded MCLs, with each impacting less than one percent of wells and production (Figure 2.20). The four radionuclide impacts were: strontium-90; gross alpha; gross beta; and uranium.

2.7 Organic Groups

For the 418 wells affected by organics, the problems were:

- Volatile Organic Compounds (VOCs)
- Pesticides
- Other Organics

The VOCs Group is the dominant organic problem and is also a major groundwater quality problem. The Pesticides and Other Organics Groups had much less impact than VOCs.

2.7.1 Volatile Organic Compounds (VOCs) Group

2.7.1a VOC Sources and Regulations

VOCs have had widespread commercial and industrial use over the past 30 years, due to many diverse applications. Industrial parts cleaning and dry cleaning operations are the top two users of VOCs, followed by manufacturers of chemical intermediates, electronic products, pharmaceuticals and textiles.[1] Facilities using VOCs range in size from small dry cleaning to major aerospace/defense complexes. Common

[1] *Potential for Source Reduction and Recycling of Halogenated Solvents (1992), Source Reduction Research Partnership for the Metropolitan Water District and the Environmental Defense Fund.*

VOC Impacts — Figure 2.21

Impact Type*	Wells		Production	
	Number	%	AFY	%
VOC Group	**375**	**11**	**238,000**	17
Trichloroethylene (TCE)	**251**	7	173,000	12
Tetrachloroethylene (PCE)	**158**	**5**	94,000	7
Carbon Tetrachloride (CCl_4)	**116**	**3**	88,000	6
1,2-Dichloroethane (DCA)	**51**	**1**	29,000	2
1,1,2,2-Tetrachloroethane	**53**	**2**	18,000	1

* There are overlaps between the impact types, as they are not unique.

sources of VOC releases include drains, pipelines and discharges diverted to soil or aquifers, and leaking underground storage tanks. VOC disposal and subsequent movement through landfills can increase the mobility of other toxic chemicals, all of which are ultimately reflected in the leachate contamination of groundwater.

Common solvent usage has included: trichloroethylene (TCE) for industrial parts cleaning; tetrachloroethylene (PCE) for dry cleaning; carbon tetrachloride (CCl_4), formerly used for dry cleaning and fire extinguishers; 1,2-dichloroethane (DCA) in soaps and organic synthesis; and 1,1,2,2-tetrachloroethane for paint removers and in bleach manufacturing. The physical properties and unreactive nature of VOCs that make them so useful also helps make them persistent and mobile in groundwater. Their general toxicity to living organisms makes them resistant to biodegradation in the subsurface and a health issue for municipal water supplies.

As regulations regarding the storage, use and disposal of VOCs have become more restrictive and more sophisticated, there have been advancements in the prevention of environmental releases of VOCs. Accidents and errors, however, can still result in spills that affect groundwater quality.

2.7.1b VOC Impacts

The VOCs Group impacted 238,000 AFY of production and 375 wells (Figure 2.21). Impacted wells were located generally in areas of heavy population and/or industrial activity, notably: Bunker Hill; Central; Chino; Main San Gabriel; Orange County; and Upper Los Angeles River (San Fernando) Basins (Figure 2.23).

The five most commonly occurring VOCs were: TCE; PCE; CCl_4; DCA; and 1,1,2,2-tetrachloroethane (Figure 2.21). VOCs were also detected at concentrations less than MCLs but greater than zero, in an additional 485 wells and 294,000 AFY of production (Figure 2.22).

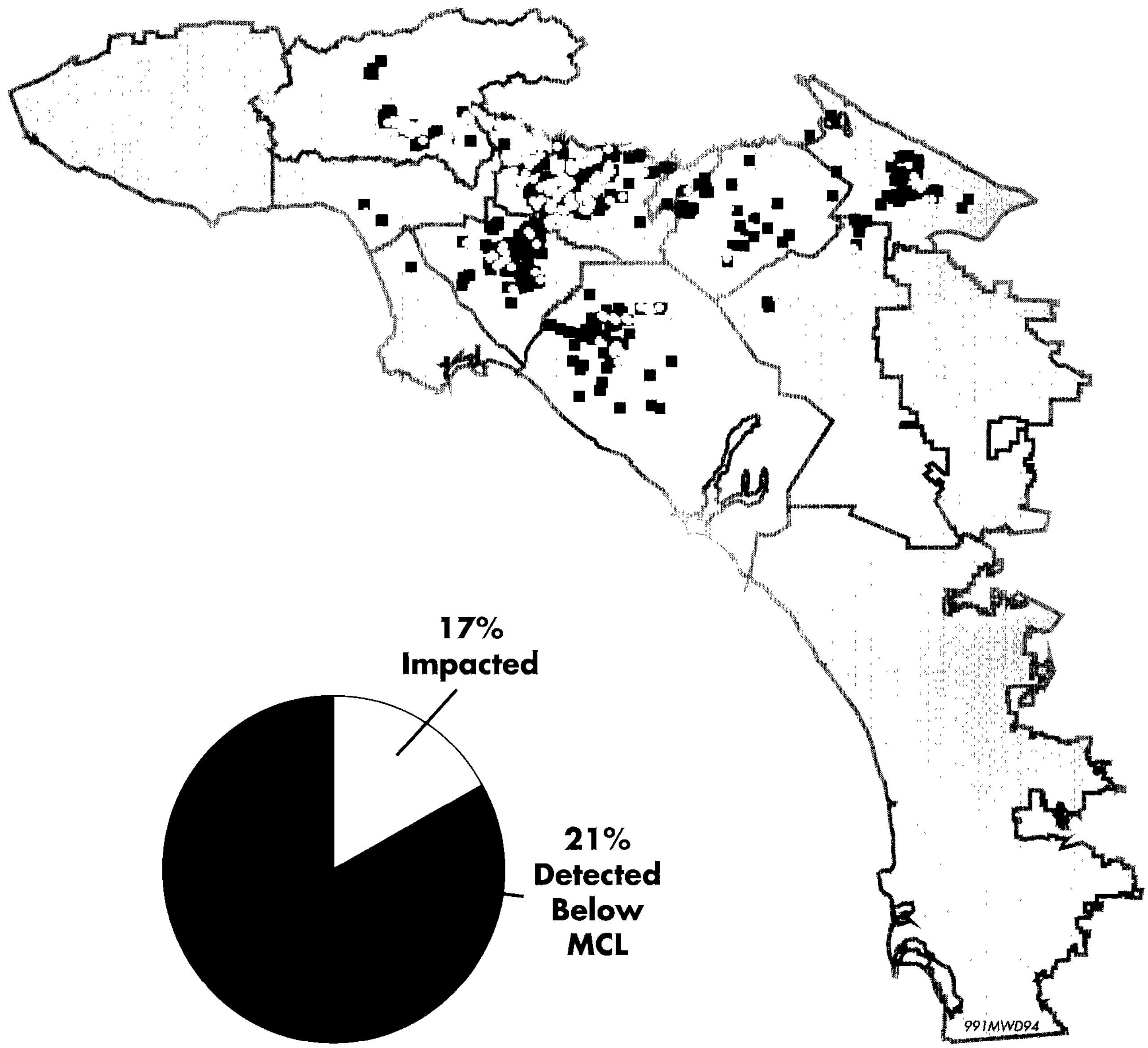
Additional VOC Impacts **Figure 2.22**

Impact Type+	Wells		Production	
	Number	%	AFY	%
VOCs Group: Equal to or Exceeding MCLs	**375**	**11**	238,000	17
VOCs Detected: Less than MCLs, but Greater than Zero	**485**	**16**	294,000	21

+ Numbers are unique; there are no overlaps between impact types.

FIGURE 2.23

VOC Impacts



PRODUCTION

2.7.2 Pesticides Group

2.7.2a Pesticide Sources and Regulations

A pesticide is any substance used to destroy or inhibit the action of plant or animal pests, and includes: insecticides; herbicides; rodenticides; and nematocides. They are associated with irrigated agriculture, dairy, and livestock activities. Virtually all are toxic to humans to some degree and they vary in biodegradability.

2.7.2b Pesticide Impacts

As organic contaminants, the Pesticides Group impacts ranked well behind VOCs, affecting 42 wells and 35,000 AFY of production (Figure 2.24). The five pesticides that impacted wells at levels equal to or exceeding their respective MCLs were: Dibromochloropropane (DBCP); Chlordane; Heptachlor; Heptachlor Epoxide; and Bentazon. DBCP was the most significant pesticide impacting groundwater in Metropolitan's service area. A total of 13 regulated pesticides were detected in groundwater (at concentrations greater than zero), representing widely different uses, from fumigants used to kill insects to spray defoliants for killing weeds (Figure 2.25).

Pesticide Impacts **Figure 2.24**

Impact Type*	Wells		Production	
	Number	%	AFY	%
Pesticide Group	**42**	**1**	**35,000**	2
DBCP	**36**	**1**	32,000	2
Chlordane	**5**	**<1**	1,000	<1
Heptachlor	**5**	**<1**	1,000	<1
Heptachlor Epoxide	**5**	**<1**	1,000	<1
Bentazon	**1**	**<1**	1,000	<1

* There are overlaps between the impact types, as they are not unique.

Regulated Pesticides Detected in Groundwater		Figure 2.25
Pesticide**	**Type**	**Additional Uses/Comments**
Atrazine	Herbicide	Plant growth regulator; Used by Caltrans
Bentazon	Herbicide	Food crops
Chlordane	Insecticide	Fumigant
2,4-D	Herbicide	Defoliant: Agriculture and pasture weed killer; Fruit drop control
DBCP	Nematocide	Soil fumigant
Endrin	Insecticide	Banned US use and manufacture
Heptachlor	Insecticide	Banned except for termite control
Heptachlor Epoxide	Insecticide	Heptachlor & Chlordane degradation product
Lindane	Pesticide	Insecticide: Livestock, Crops, Lumber
Methoxychlor	Insecticide	Acaricide: Livestock, Dairy farms, Food crop
Simazine	Herbicide	Algaecide: Agriculture, Aquatic sites
Silvex	Herbicide	Plant growth regulator; Banned
Toxaphene	Insecticide	Not recommended for dairy activities

** Pesticides detected in groundwater at concentrations greater than zero.

2.7.3 Other Organics Group

The Other Organics Group included regulated organics in the database that did not fit into either the VOCs or Pesticides Groups. Only one chemical, di(2-ethylhexyl) phthalate, fit this description.

2.7.3a Other Organic Sources and Regulations

Di(2-ethylhexyl) phthalate is used as a plasticizer and in vacuum pumps, and is of concern because of its persistence, toxicity and potential for exposure to organisms. The current State primary MCL is 0.004 mg/L, and a corresponding federal MCL of 0.006 mg/L became effective in January, 1994.

2.7.3b Other Organic Impacts

There was a minor impact on groundwater resources by di(2-ethylhexyl) phthalate, which impacted nine wells with a corresponding 3,000 AFY of production.

2.8 Upcoming Drinking Water Standards

The U.S. Environmental Protection Agency (USEPA) will be establishing a new primary MCL for radon, and is revising the existing 50 ug/L primary MCL for arsenic.

2.8.1 Radon

2.8.1a Radon Sources and Regulations

Radon-222 (radon) is a radioactive element generated naturally as a gas in the earth, which dissolves into groundwater. It volatilizes during showers, bathing, and other activities, such as washing clothes. Radon spontaneously decays to radioactive daughter products, and in the process changes from a gas to an ultrafine solid. It can be inhaled as well as ingested, and both routes of exposure are of concern. Several studies have found a direct link between radon and human lung cancer.

The USEPA has proposed a new MCL for radon at 300 picoCuries per liter (pCi/L). There is also some discussion of setting it at 200 pCi/L, but this is considered less likely.

2.8.1b Radon Impacts

Of the 449 wells for which radon data were available, 164 (37 percent) would equal or exceed the proposed standard of 300 pCi/L. However, if the MCL were set at 200 pCi/L, 299 wells (67 percent) would equal or exceed the MCL (Figure 2.26). Radon was detected in each of the wells that were sampled, ranging from 1.0 to 2,018 pCi/L. Note that no projection is made for the entire database. Figure 2.27 shows impacted wells for a potential MCL of 300 pCi/L.

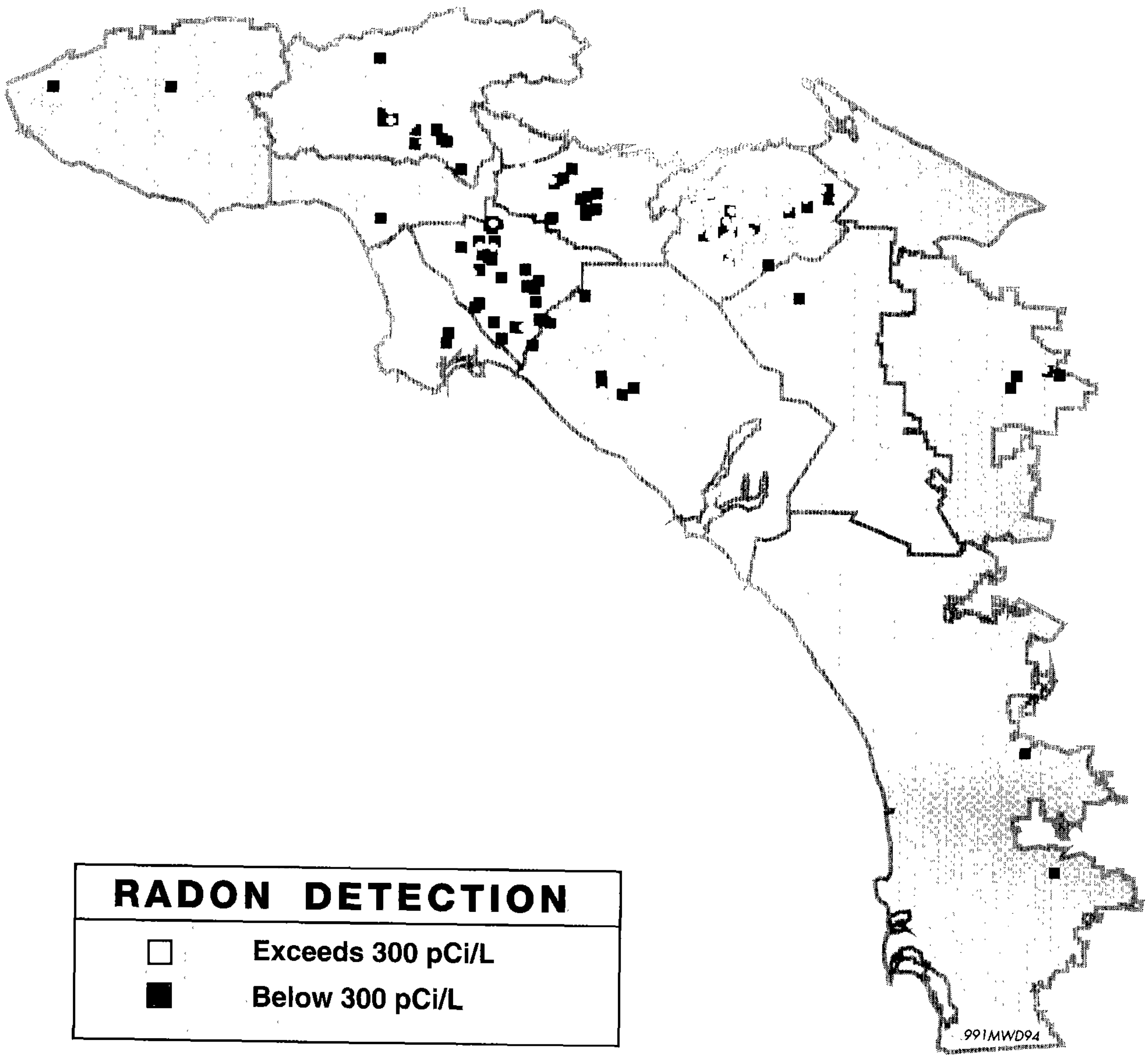
Projected Radon Impacts — Figure 2.26

Projected Impact Type+	Wells		Production	
	Number	**% of sample***	**AFY**	**% of sample***
If Radon MCL is set at 300 pCi/L	**164**	**37**	103,000	38
If Radon MCL is set at 200 pCi/L	**299**	**67**	189,000	70

+ Numbers are not unique; there are overlaps between impact types.
* Percent of sampled wells and their associated production only.

FIGURE 2.27

Projected Radon Impacts



2.8.2 Arsenic

2.8.2a Arsenic Sources and Regulations

Arsenic is a naturally-occurring element which leaches from geological formations. It can additionally be introduced through the use of arsenical pesticides in agriculture and with livestock. Arsenic exists in treated wastewater, which recharges some groundwater basins, and ranges from 1 ug/L (microgram per liter) to 10 ug/L. It is also found in seawater, at 3 to 24 ug/L, and may impact coastal regions through seawater intrusion induced by groundwater overdraft. Arsenic occurs in imported surface supplies at 2 to 6 ug/L in Colorado River Aqueduct water, and at 2 to 5 ug/L in State Project water. The Los Angeles Department of Water and Power's Owens Valley source averages approximately 22 ug/L, due to geothermal sources in the Hot Creek area of Lake Crowley.

Arsenic causes non-carcinogenic as well as carcinogenic effects in humans, and the 1986 Safe Drinking Water Act Amendments mandated that the arsenic standard be revised. It is anticipated that the MCL will be reduced from the current 50 ug/L down to a concentration between 0.5 and 20 ug/L. Recent information from the USEPA indicates that the MCL is expected to be proposed in September, 1994, finalized two years later in September, 1996, and would become effective in March, 1998.

Analytical methodology is a concern. Analytical methods are not available in typical water quality laboratories that can measure arsenic below 0.5 ug/L. The current detection limit is generally between 1 and 5 ug/L. The detection limit for reporting has recently been revised downward by CDHS from 10 ug/L to 5 ug/L. Prior to the spring of 1993, most groundwater analyses used a detection level of 10 ug/L.

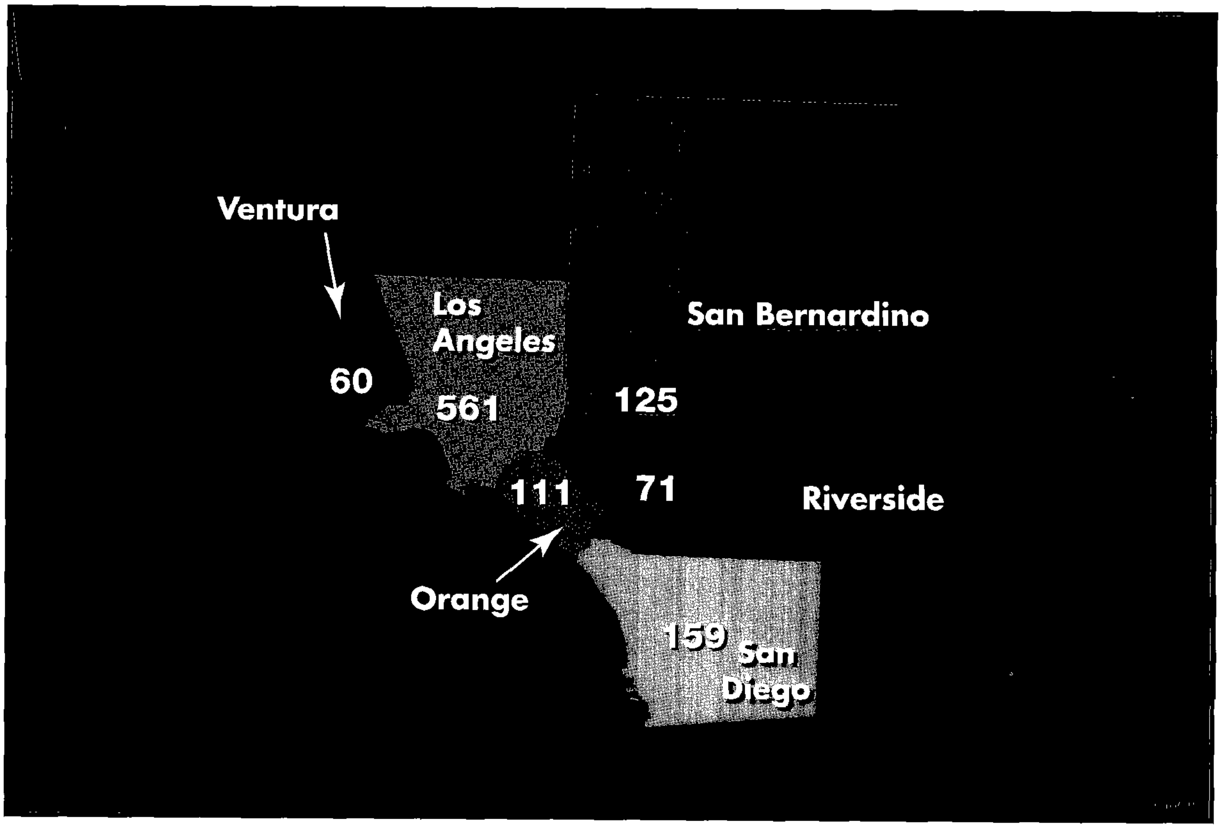
2.8.2b Arsenic Impacts

With data for 115 wells, no wells were equal to or exceeded the current standard of 50 ug/L, and arsenic was detected above zero in 33 (29 percent) of those sampled. A projection of impacts for a revised MCL potentially in the low ug/L range is limited because the data had a reporting detection limit of 10 ug/L.

Metropolitan has formed an arsenic task force to carry out a variety of studies in order to provide input to the USEPA by March, 1994, six months before the expected rule proposal. Treatment studies will include bench scale, pilot, and full-scale treatment plant tests, and computer modeling of some adsorption phenomena.

FIGURE 3.2

Landfills in Six-County Area



3. Threats to Groundwater Quality

3.1 Major Contamination Sources

Major point sources and non-point sources of groundwater contamination are shown in Figure 3.1. Many have involved the handling of wastes via land dispersal, burial, and underground injection, and the use, storage, and disposal practices associated with chemicals, such as leaking underground storage tanks (LUST). Also, some groundwater quality problems have been indirectly induced, such as seawater intrusion resulting from the overuse of an aquifer. Most contamination occurs over decades of activities, and in many instances poses large challenges to clean-up efforts.

3.2 Landfills

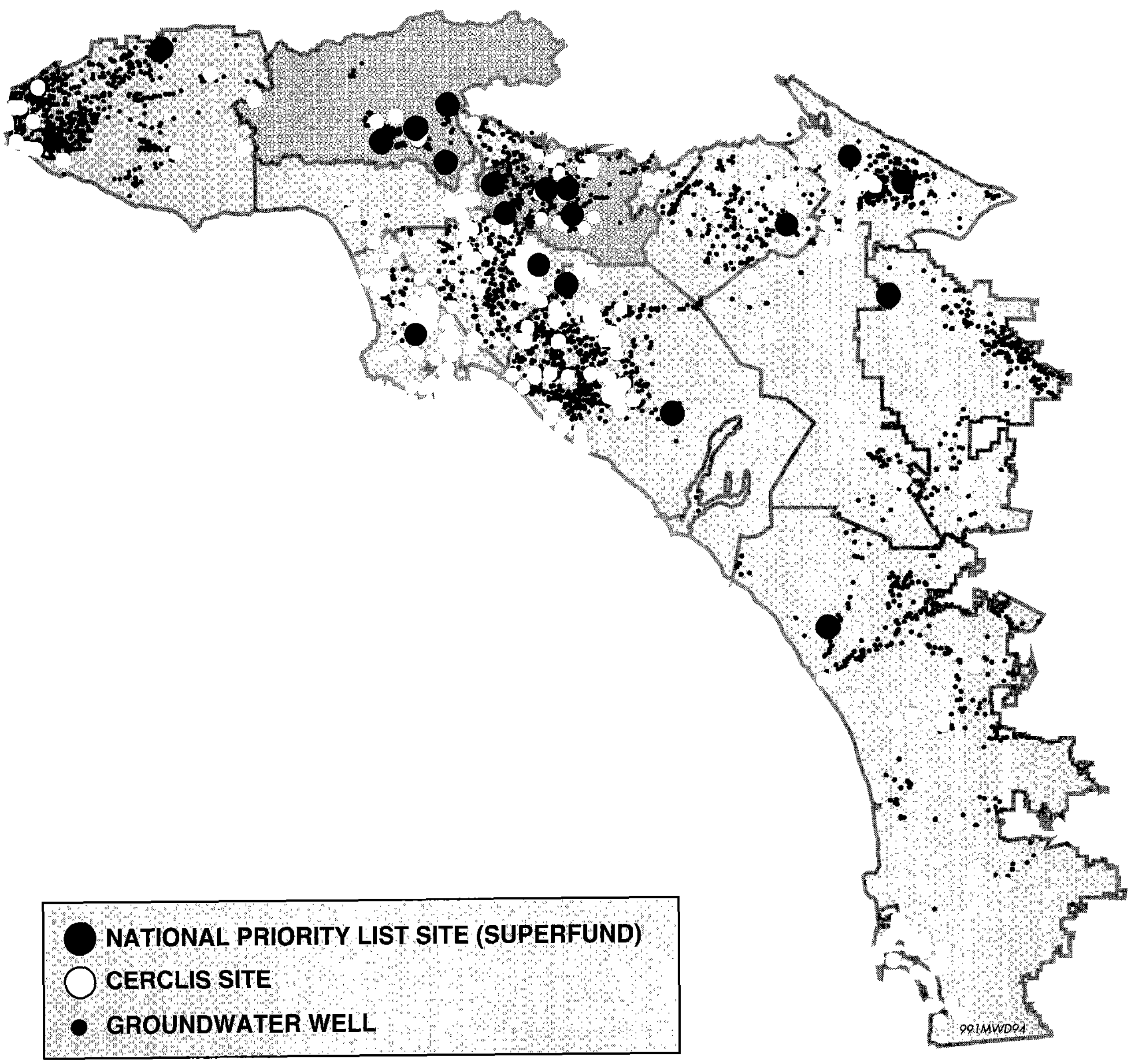
There are more than 1,000 landfills in the six-county region in Southern California (Figure 3.2). Los Angeles County leads with 561 landfills, followed by San Diego County with 159. The numbers were generated by compiling information from the State Water Resources Control Board and the California Integrated Waste Management Board. They represent a full range of sites including active and closed, municipal and industrial, as well as public and private facilities. The locations of historic landfills are difficult to identify as urban sprawl has altered or removed landmarks and roads used to describe the sites.

Major Sources of Groundwater Contamination — Figure 3.1

Point Sources	Non-Point Sources
Landfills	Agriculture
Superfund-type Sites	Dairies
LUST	Seawater Intrusion
Oil Production & Refining Facilities	Urban Runoff
Industrial & Manufacturing Facilities	Sewer, Oil, and Other Pipeline Networks
Septic Tanks	
Spills & Accidents	

FIGURE 3.3

Superfund and CERCLIS Sites Shown with Municipal Water Wells



Leaking Underground Storage Tanks					Figure 3.4
County	Open Cases to Date#	Open Cases by Type			
		Not Defined+	Soil Only	Groundwater	Drinking Water *
Los Angeles	2893	1178	738	968	9
Orange	1058	38	443	577	0
San Diego	1059	454	316	286	3
Ventura	867	525	118	224	0
Riverside	315	43	133	139	0
San Bernardino	294	52	169	70	3
Total 6-County	6486	2290	1917	2264	15

From State Water Resources Control Board, Report of Releases of Hazardous Substances from Underground Storage Tanks, (1992).

+ Includes cases being worked on and cases with limited information.

* Includes only those at which one or more domestic or municipal supply wells have been impacted.

All landfills generate liquid leachate, and although some of the more modern landfills are lined, it is a matter of when, not if, they will leak, thus requiring permanent monitoring and effective contingency plans for remediation. Canyon sites are seen as less risky alternatives to sand and gravel mining pits, as these pits are typically located over highly permeable alluvium overlying Southern California groundwater basins.

3.3 Superfund

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund, is the 1980 federal program that identifies sites which may release or have released hazardous substances into the environment, and ensures their cleanup. Provisions for hazardous releases from uncontrolled or abandoned waste sites, and for

LUST, were added to the program in 1986, along with several other modifications.

The highest priority problem sites are commonly called Superfund sites, and are placed on the National Priority List (NPL) for action. Nationwide, 73 percent of the 1,200 sites currently on the NPL have documented groundwater contamination. Those sites not sufficiently hazardous to warrant listing on the NPL and those currently under investigation are listed in CERCLIS (CERCLA Information System).

There are approximately 200 CERCLIS and 20 Superfund sites in Metropolitan's service area (Figure 3.3; sites are not to scale). Two groundwater basins which are highlighted in Figure 3.3, the Main San Gabriel and Upper Los Angeles River Basins (San Fernando Valley), have such extensive groundwater contamination that they are considered to be megasites. In these cases, cleanup addresses the management of the entire basin. The close proximity of municipal supply wells with Superfund and CERCLIS sites underscores the need for protection of groundwater quality.

3.4 Leaking Underground Storage Tanks (LUST)

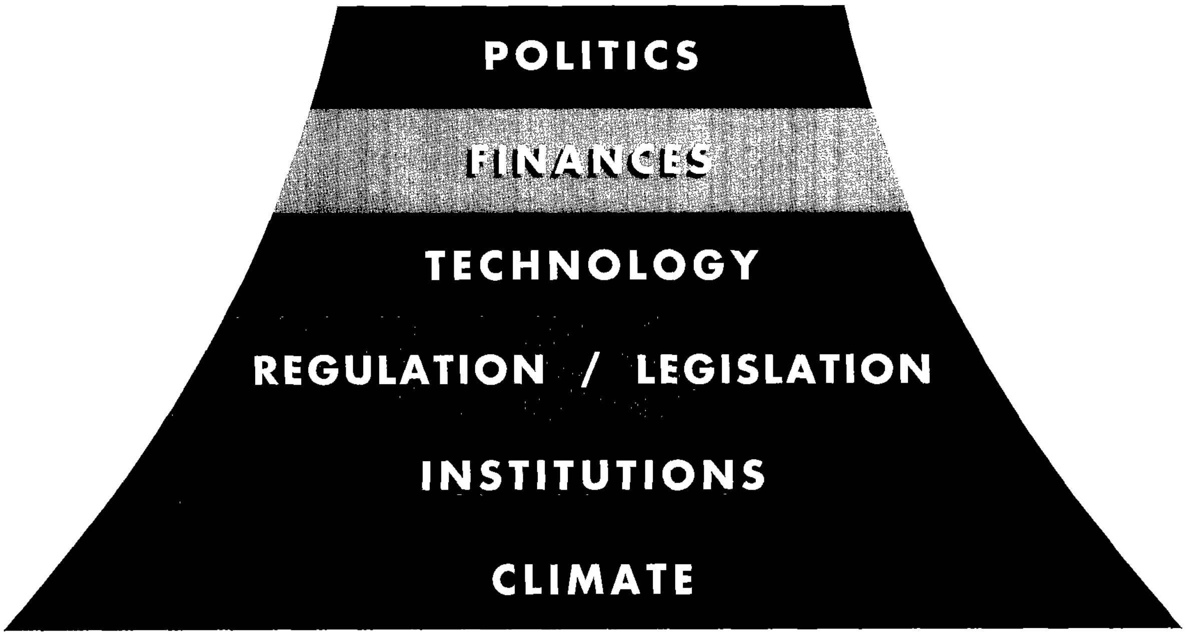
According to 1992 data from the State Water Resources Control Board (SWRCB), there were 6,486 LUST identified in a six-county wide area in Southern California, with about a quarter of them threatening groundwater (Figure 3.4). This is an increase of 71 percent over the 3,779 open cases reported by the SWRCB in 1990.

Particularly widespread is the escape of petroleum hydrocarbons from leaking underground storage tanks at gasoline stations, and from refinery and oilfield production facilities. Most refineries in Southern California have petroleum hydrocarbons floating several feet thick on top of the water table beneath the sites.

Although there has been considerable petroleum hydrocarbon leakage, benzene, a common component, has not been frequently detected in drinking water wells. Factors that may have contributed to this include that: (1) municipal water wells are not sited on these properties; (2) contaminated wells may have already been shut down; (3) local hydrogeology may slow or prevent migration to drinking water wells; (4) local basin management practices, such as injection wells used to prevent seawater intrusion, may also drive contamination away from wells located inland; and (5) physical, chemical and biological factors, including adsorption, vaporization and microbiological degradation, may decrease benzene levels.

FIGURE 4.1

Groundwater Management Framework



4. Management Strategies and Treatment Technologies

4.1 Management Strategies for Contaminated Groundwater

Groundwater management is a complex arena, with increasing quality regulations, legislation, and institutional constraints (Figure 4.1). In general, groundwater basins are managed by local agencies or, when they are adjudicated, by a court-appointed Watermaster. The water pumped from basins for municipal supply is subject to federal and State water quality regulations, as are Metropolitan's imported supplies.

Groundwater is constantly moving from one area to another, sometimes bringing contamination with it. This complicates groundwater management, requiring intricate strategies sometimes involving more than one basin. Although basin management has traditionally focused on overdraft protection, the emphasis is shifting to include protection and restoration of groundwater quality.

Institutional barriers themselves offer a formidable challenge to optimizing the management of groundwater resources. Any particular groundwater basin may be adjudicated, and may have numerous entities involved in its management. The creation of agreements to alter the management and improve protection of a groundwater basin requires determined negotiation and a regional outlook by each participant.

Groundwater contamination is likely to become more pervasive as decades of man's activities, including waste discharges and agricultural practices, are gradually taking their toll on groundwater basins. Simultaneously, drinking water regulations are both increasing in number and becoming more stringent. In 1950, there were about a dozen constituents for which there were water quality regulations. Today, there are more than 60, and by the year 2000, it is projected that there may be as many as 200 regulated constituents. Thus, a groundwater source or a treatment plant that meets current standards may be out of compliance in the future.

There are a variety of management strategies employed to ensure that the water served to the community is potable (Figure 4.2).

Contaminated Groundwater Management Strategies — Figure 4.2
Blend
Pump and Treat
Non-Potable Use
Relocate Well
Abandon

4.1.1 Blend

The most predominant strategy, blending involves mixing impacted groundwater with a higher quality supply, such as other groundwater or imported supplies, to meet drinking water standards.

4.1.2 Pump and Treat

In the pump-and-treat strategy, groundwater is extracted from a basin and treated to remove contaminants. In some cases, impacted groundwater is highly treated, and then blended with untreated impacted groundwater to produce a cost-effective, potable supply.

Treatment is more expensive than blending and, on occasion, infeasible due to technological limitations in meeting drinking water requirements. However, as the cost of imported supplies increases, and their availability diminishes, the treatment of lower quality groundwater becomes more attractive.

4.1.3 Nonpotable Uses

Impacted groundwater is sometimes used for nonpotable purposes other than drinking water, such as for industrial use or more commonly for agricultural irrigation. As agricultural land converts to urban, the use is no longer suitable and the well may be subject to treatment or abandonment.

4.1.4 Relocate Well

A new well may be drilled in an unimpacted area of the basin when the old well is abandoned. This strategy may cause contamination to spread toward the new pumping site, while the contamination problem remains unaddressed.

4.1.5 Abandon

The use of an impacted groundwater basin may be abandoned, and replaced with imported supplies. This approach, once common practice, is no longer viable because of the constraints on expanding imported supplies.

4.1.6 Serve As Is

In an emergency, impacted groundwater is temporarily distributed to customers, but only with appropriate public notice. This option is rarely used, invokes strongly negative public reaction, and is only approved by CDHS when there is no immediate alternative supply.

4.2 Treatment Technologies

4.2.1 Treatment Technology Selection

Treatment of groundwater for drinking water purposes is required primarily to provide a water that is chemically, radiologically, and bacteriologically safe for human consumption. Generally, treatment processes are employed that remove compounds hazardous to human health or to alter aesthetically undesirable qualities such as taste and odor problems.

When evaluating what treatment processes to use, consideration must be given to the groundwater sources and the variations in quality of different sources. Lower quality waters with higher contaminant concentrations require increasingly sophisticated treatment techniques.

In Metropolitan's service area, the chemical groups that may typically require treatment are:

- Nitrogen (Nitrate)
- Volatile Organic Compounds (VOCs)
- Total Dissolved Solids (TDS)
- Minerals (Trace Metal Elements)
- Pesticides

A number of treatment methods are available for removing these contaminant classes from groundwater (Figure 4.3). Note that radon, a radioactive gas for which an MCL has not yet

Treatment Technologies for Classes of Contaminants Figure 4.3

Treatment	VOCs	Nitrate	Pesticides	TDS	Metals
Air Stripping	•		✓		
Carbon Adsorption	✓		•	✓	✓
Ion Exchange	✓	•	✓		✓
Membranes	✓	✓	✓	•	✓
Precipitation		✓	✓	✓	•
Biological Treatment	✓	✓	✓		✓
Chemical Oxidation	✓		✓		✓

• Typically most effective treatment technology for a particular contaminant class.

✓ Treatment technology capable of contaminant removal.

Cost of Groundwater Treatment Projects — Figure 4.4

No.	Project	Contaminant#	Type of Treatment#	Annual Production (AFY)	Start Date	Unit Cost+ ($/AF)
1	Santa Monica GW Treatment Project *	VOC	Off-gas/ GAC	1,800	1993	373
2	Oceanside Desalter *	TDS	RO	2,000	1993	700
3	Burbank Lake Street Plant *	VOC	GAC	2,750	1992	385 [a]
4	West Basin Desalter *	TDS	RO	1,500	1993	632 [a]
5	Rowland GW Treatment Project*	VOC	RO/GAC	600	1996	787
6	Irvine Desalter *	TDS, VOC, NO_3	RO	6,700	1995	820 [a]
7	Tustin Desalter *	TDS	RO	3,200	1995	561 [a]
8	Menifee Basin Desalter *	TDS	EDR	3,360	1996	864
9	Arlington Desalter	TDS	RO	6,100	1990	456
10	Glenwood Nitrate Removal Plant	NO_3	IX	1,600	1989	280
11	El Toro TCE Pump-out Project	VOC	Rotary Air Stripping	1,100	1990	270 [a]
12	Orange TCE Removal Project	VOC	Rotary Air Stripping	1,100	1993	150 [a]
13	South Gate Wellhead Treatment Unit	VOC	GAC	1,279	1991	255 [a]
14	DWP/AOP Plant	VOC	AOP	5,800	1991	250
15	DWP/North Hollywood Unit	VOC	Air Stripping, GAC	3,000	1989	300
16	Devil's Gate VOC GW Treatment Plant	VOC	Air Stripping, GAC	10,200	1990	135
17	Newmark/San Bernardino	VOC	Air Stripping, Off-Gas GAC	6,000	1986	125
18	Waterman/San Bernardino	VOC	Air Stripping, Off-Gas GAC	7,200	1988	125
19	Pomona Plant	NO_3	IX	16,800	1993	150

* MWD's Groundwater Recovery Program Projects.
[a] Unit cost includes replenishment assessment.
+ All unit costs include pumping, capital and O&M estimated in 1994 dollars.

\# Legend
- AOP: Advanced Oxidation Process
- EDR: Electrodialysis Reversal
- GAC: Granular Activated Carbon
- IX: Ion Exchange
- RO: Reverse Osmosis
- TDS: Total Dissolved Solids
- VOC: Volatile Organic Compounds
- GW: Groundwater
- NO_3: Nitrate

been finalized, is most efficiently treated by air stripping, and is also capable of being removed by carbon adsorption. The following sections are brief overviews of these typical treatment technologies. Appendix B presents cost estimates, cites references indicated in the text, and presents more detailed information on the treatment options. For comparison, actual treatment costs for groundwater treatment projects in Southern California are shown in Figure 4.4. Treatment for VOCs, TDS, and nitrate predominates.

Pre-treatment and/or post-treatment facilities for many applications may be required at additional cost. Furthermore, waste streams produced by most technologies will require disposal or treatment, again at additional cost.

4.2.2 Air Stripping

Air stripping is most effective in removing VOCs. Two configurations frequently used are packed-tower air stripping and diffused air stripping.

Off-gases from the strippers may need treatment to prevent emission of the groundwater contaminants into the air above regulated levels. Pre-treatment is needed to prevent scaling or fouling of the tower packing. Finally, non-volatile organics that cannot be removed by air stripping may require use of another treatment technology in series with air stripping.

4.2.2a Packed-Tower Air Stripping

In the packed-tower configuration, impacted water flows down through packing while clean air flows upward (counter-current flow) and exhausts through the top of the stripper. VOCs transfer from the water to the air vapor. These systems are used for concentrations ranging from less than 1 mg/L to hundreds of mg/L. Inorganic constituents, such as iron or hardness, may result in fouling of the air stripper and require pre-treatment for removal prior to the stripper.

4.2.2b Diffused Air Stripping

In a diffused air stripper, volatile compounds are transferred from liquid to vapor and removed from the system. Metals, such as iron and manganese, may need to be removed following treatment.

4.2.3 Carbon Adsorption

Granular activated carbon (GAC) is effective for removing slightly water-soluble organic and inorganic constituents over a broad concentration range. Because of the high costs of operating and monitoring the process, it is generally used for contaminant concentrations less than 1 mg/L. It is also effective in removing pesticides.

The process consists of pumping water through fixed-bed carbon contactors where the contaminants are adsorbed. Adsorption can be a physical or a chemical process. In physical adsorption, contaminants are transferred to the carbon and settle in its pores. In chemical adsorption, contaminants are transferred to the carbon and a chemical interaction between the carbon and the contaminant occurs. Inorganic constituents, such as iron, may decrease the efficiency of the GAC system.

Carbon is regenerated after its adsorptive capacity has been reached, involving the removal of organic matter from the carbon, either by oxidation or steam heating. A major concern is premature plugging of the carbon system due to chemical or biological fouling, and pre-treatment may be required. Spent carbon is generally transported by the supplying vendor to an off-site facility for regeneration when carbon usage is less than 500,000 pounds per year. In cases when carbon usage is higher, on-site regeneration may be considered.

Advantages of a carbon system are that it is generally simple to operate and little operator attention is required. Major system costs are associated with carbon usage, but this system is most cost effective when organics are less than 1 mg/L.

4.2.4 Ion Exchange

This process removes unwanted ions, such as nitrate, in any concentration by transferring them to an ion exchange resin. The resin has a limited capacity, becomes saturated with ions and must be periodically regenerated.

Ion exchange units generally are steel or fiberglass vessels containing a bed of resin. The units are operated in the downflow mode with a cyclic sequence of operation, backwash, and regeneration.

The major concerns are scaling and/or plugging of ion exchange media. Pre-treatment for removal of potential scaling materials and removal of scale/foulant from vessels may be expensive. The process transfers nitrate from the water supply and concentrates it in a brine solution. Disposal of the spent brine regenerant, or washing solution can be a high cost item. The system lends itself to automation and does not require a great deal of operation attention.

4.2.5 Membranes

Membrane separation techniques are used for removing total dissolved solids, specific ions such as nitrate, and concentrating contaminants. Reverse osmosis (RO) and electrodialysis reversal (EDR) are commonly used membrane systems.

In reverse osmosis, pressurized water is passed through a membrane, which is a salt barrier, mounted on a support structure contained in a water-transporting vessel. Vessel configurations are spiral-wound, hollow-fine-fiber, tubular, and plate-and-frame. They may be in either parallel or series depending on the effluent quantity and quality desired. Other pressurized membrane systems, such as nanofiltration, are being developed that utilize lower driving pressures and are thus less costly (Figure 4.5).

Electrodialysis reversal is a process where ions are selectively transported through membranes, resulting in a dilute water stream. Ions are attracted into brine streams by an induced electric current resulting from placing an anode and a cathode on opposite sides of several water streams separated by alternating anion- and cation-specific membranes. This type of configuration is called an electrodialysis stack. The reversal term comes from the interchanging of the anode and the cathode several times during every hour of operation. This is done to reduce the fouling of the ion-specific membranes caused by a buildup of salts on one side of the membrane.

Pressurized Membrane Filtration				Figure 4.5
Characteristic	**Reverse Osmosis**	**Nanofiltration**	**Ultrafiltration**	**Microfiltration**
Primary Removal	Dissolved Ions	Natural Organics	High MW # Organics	Large Particles, >0.5 um Diameter
Pore Size, um	<0.001	0.001	0.01	0.1
Molecular Weight Cutoff, AMU+	- - -	>300	1,000 to 500,000	>500,000
Driving Pressure Range, psi	250-1200	70-150	10-100	10-50

Molecular Weight

+ Atomic Mass Units

Pre-treatment requirements can increase operating costs substantially. The membranes are sensitive to particulates, chemical deposition, and in some cases certain oxidants, such as chlorine. Adjustment of pH is almost always required before and after treatment.

Where metals are being removed, brine disposal could be costly if the brine becomes a hazardous waste. Brine disposal can be a high cost in any regard.

Reverse osmosis, which involves low capital costs and high operation and management (O & M), and wastewater costs, is the preferred method of TDS reduction. However, EDR, which involves high capital costs and low O & M costs, is gaining popularity. These technologies are commonly used when raw water sources exceed several thousand parts per million of TDS.

Membrane processes can be automated but operation and maintenance personnel will still be required. The pre-treatment requirements mentioned can increase operating costs substantially.

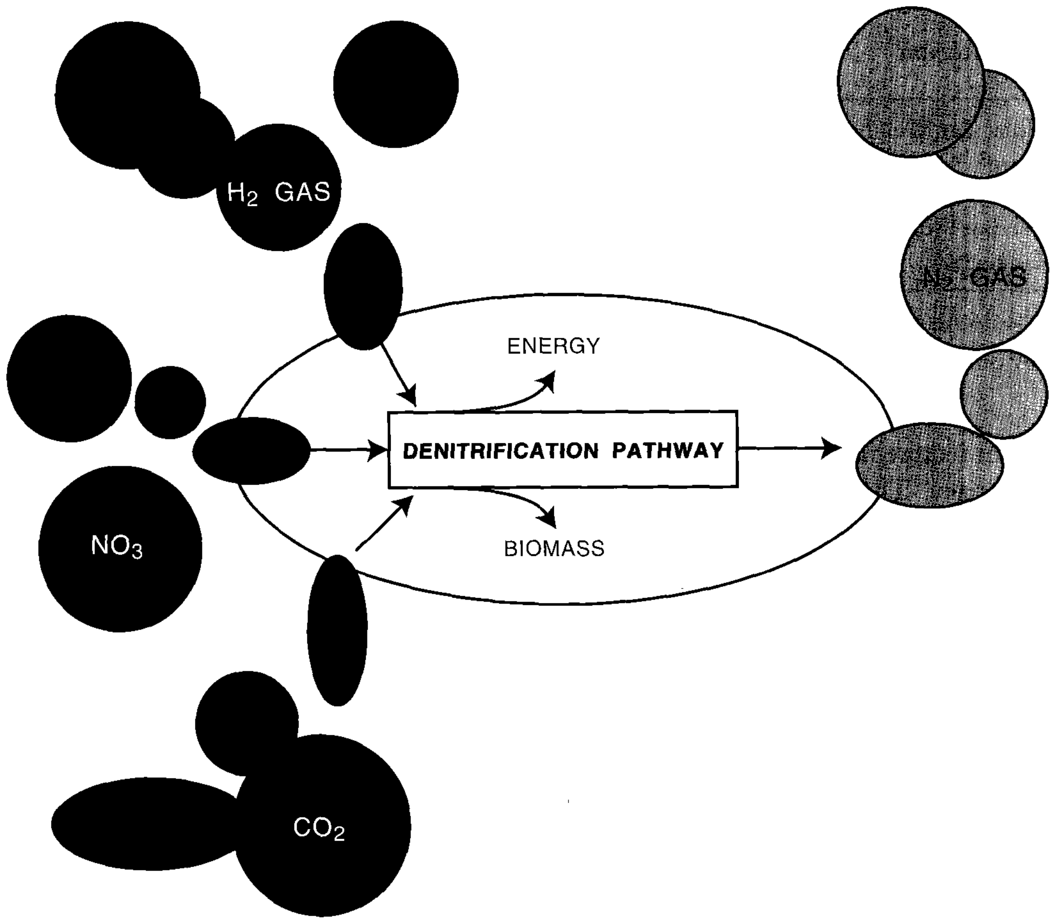
4.2.6 Chemical Precipitation

Precipitation is often used to remove particulates, certain dissolved substances, and metals such as arsenic. For metals, it is the most cost-effective technology.

Chemicals are added to promote precipitation, followed by clarification. Chemicals include: oxidizing agents (oxygen, ozone, or chlorine); coagulants (aluminum salts, iron salts, lime, and synthetic polymers); and pH adjusting chemicals (acids and caustics). The chemicals cause the metals to form an insoluble precipitate large enough to settle. A rapid-mixing tank, where the

FIGURE 4.6

Autotrophic Denitrification



In autotrophic denitrification, bacteria such as Paracoccus denitrificans convert nitrate (NO_3) from contaminated groundwater into nitrogen gas (N_2). Bacteria use carbon dioxide (CO_2) in this metabolic pathway, and gain from the production of energy and biomass.

chemicals are added, may aid chemical distribution and enhance precipitation. A clarification process, including either settling or filtration or both, would follow.

The major uncertainty is the disposal costs for the precipitation products (sludge). If the concentrations of metals removed are high enough, the sludge may be a hazardous waste, making disposal expensive.

4.2.7 Chemical Oxidation

Chemical oxidation is effective in removing organic contaminants over a broad concentration range. Oxidation can be promoted in the liquid phase to decompose organic compounds into carbon dioxide, water, and residual inorganic compounds.

One typical mechanism uses ultraviolet (UV) light and either hydrogen peroxide or ozone to promote rapid oxidation. There are no wastes or by-products if the reactions are allowed to be completed.

Oxidation treatment of organic compounds has been researched on the pilot- and full-scale levels. Package treatment systems are available from a number of suppliers. Cost estimates for 99 percent VOC removal by a batch UV-catalyzed hydrogen peroxide/ozone system may be as much as $9.10 per 1,000 gallons of water treated (Chan et al., 1987). This system can be more cost competitive when both volatile and nonvolatile organics are present, since both can be removed by this process.

Pre-treatment may be required to prevent precipitation of metals in the process and fouling in the oxidation units. Changes in water feed characteristics can affect pre-treatment requirements greatly.

4.2.8 Biological Treatment

Biological treatment processes for municipal water supply currently are not in use in the United States. However, they are used for nitrate removal in several European countries. The process is also used in at least one country in Europe for iron and manganese removal.

Cooperative research being done by Metropolitan and submember agency Orange County Water District on biological denitrification shows that it can be more cost-effective at removing nitrates than reverse osmosis, electrodialysis or ion exchange. The joint research project is further described in Section 5.5.1.

Biological treatment features degradation of organic material in an aqueous waste stream by microbial action (Figure 4.6). Note that biological denitrification transforms nitrate into harmless nitrogen gas. Ion exchange, by comparison, concentrates the nitrate in a waste brine requiring disposal.

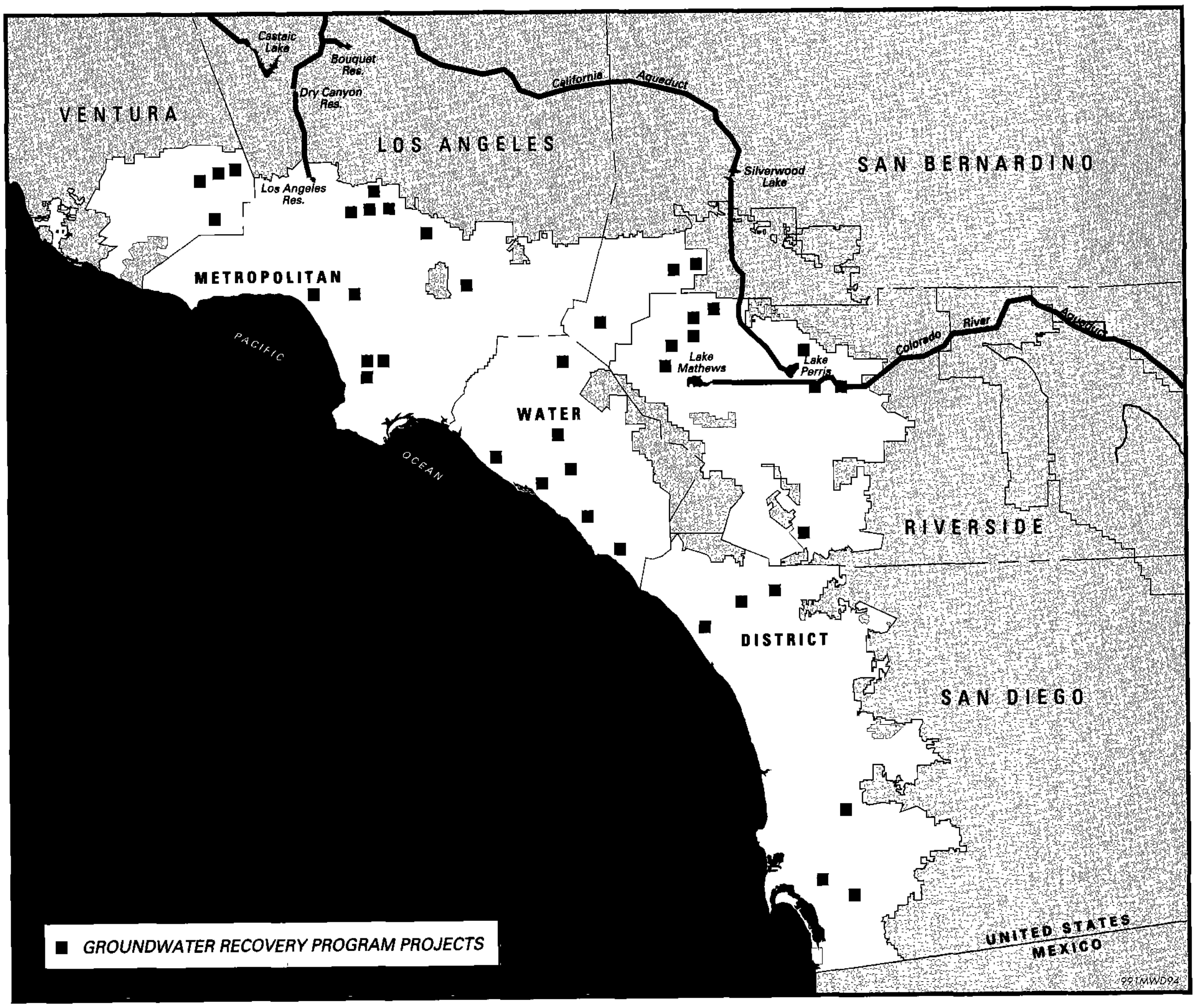
There are two categories of biological treatment processes, suspended growth systems and attached growth systems. Both may be applied under either aerobic or anaerobic conditions, although aerobic reactors are more widely used.

In suspended growth reactors, microorganisms are suspended within the waste stream in growth reactors to mix with and metabolize constituents. In attached growth reactors, microorganisms are cultivated as a biofilm attached to an inert medium that comes into direct contact with the waste stream. The process is more efficient with high nitrate concentrations. Use of a biological system will probably be most effective when nitrate levels are greater than 20 milligrams per liter (mg/L) nitrate as nitrogen (as N).

The cost of nitrate reduction from 34 mg/L as N to 6 mg/L as N by biological treatment was estimated to be $0.16 per 1,000 gallons of water treated (Montgomery, 1987). This estimate is based on the assumption that 88 percent of the influent water was biologically treated and blended with the remaining untreated influent. With a 95 percent removal efficiency by the biological system, an effluent concentration of 6 mg/L as N could be achieved when the feed water concentration is 34 mg/L as N.

FIGURE 5.1

Planned and Potential Groundwater Recovery Program Projects



5. Metropolitan Groundwater Management Programs

Metropolitan's groundwater programs seek to improve supply and focus on these objectives:

- Increase importation of surplus water through conjunctive use of groundwater storage
- Increase groundwater production capacity
- Protect and improve groundwater quality
- Reduce peaking demands on Metropolitan
- Recover groundwater lost to contamination

Metropolitan is not specifically responsible for any groundwater basins, but under a number of programs, has cooperative agreements with local and member agencies that are charged with the responsibility. Programs include: financial incentives through the Groundwater Recovery Program; the Local Projects Program; Seasonal Storage Service; conjunctive-use programs; and legislative and regulatory support.

5.1 *Groundwater Recovery Program*

Under the Groundwater Recovery Program (GRP), started in 1991, Metropolitan provides financial assistance to local agencies to treat impacted groundwater to be used for municipal purposes. Through a yield-purchase arrangement, Metropolitan provides up to $250 per acre-foot (AF) of the treated groundwater, thereby increasing dependable supplies from a previously unusable source. Planned and potential GRP projects are shown in Figure 5.1.

It has been estimated that there are approximately 16 million AF of groundwater in Southern California that is brackish and therefore has too high of a mineral content to be acceptable for use as a drinking water source. Desalting brackish water, though less expensive than seawater desalination, is still costly and the water produced costs more than if agencies purchase imported supplies from Metropolitan. Thus, Metropolitan's Board of Directors (Board) adopted the Groundwater Recovery Program to increase local supplies by making groundwater recovery financially feasible and economically competitive with purchasing imported water.

To date, Metropolitan's Board has approved eight projects which will recover almost 22,000 AF of impacted groundwater a year (shown previously in Figure 4.4). The projects primarily treat and remove high concentrations of TDS and VOCs. Over forty projects are expected to be on-line by the year 2000, and the goal of 200,000 AF of recovered groundwater per year should be achieved by 2004.

Other groundwater treatment facilities have been in operation for a number of years. Most of these were on-line prior to the initiation of the GRP. In other instances, projects did not qualify for financial assistance under the GRP because the cost of the project did not exceed Metropolitan's water rate. These facilities developed nearly 106,000 acre-feet per year (AFY) in Metropolitan's service area.

5.2 Local Projects Program

To help its member agencies develop reclamation and other local water supply projects, Metropolitan implemented the Local Projects Program (LPP) in 1981. The program provides financing for projects that help agencies reduce their demands on Metropolitan.

For example, through member agency Western MWD of Riverside County, Metropolitan supported the Santa Ana Watershed Project Authority's Arlington Desalter Plant, located in the Western Riverside Basin Group. The plant has a capacity of 6,700 AFY, and is removing TDS and nitrate from groundwater. In a second instance, the Glenwood Nitrate Reclamation Project, located in the Upper Los Angeles River Basin Group, removes excess nitrate from groundwater using ion exchange treatment. Under the project, 1,600 AFY of recovered groundwater will be used for direct potable purposes.

The LPP is also used for groundwater recharge and seawater barrier injection water. For example, in the West Coast Barrier Project, approximately 70,000 AFY of tertiary-treated reclaimed water from the Hyperion Wastewater Treatment Plant will be used for landscape irrigation, industrial and commercial processes, and seawater intrusion barrier injection.

Now that the GRP has been established to encourage the treatment of contaminated groundwater, the LPP only accepts projects that reuse reclaimed water.

5.3 Pricing Incentives and Seasonal Storage Service Program

Since the 1950s, Metropolitan has supported conjunctive management of groundwater basins with its replenishment rates. Discounted water rates may be used for groundwater recharge and recovery through direct and in-lieu operations. In-lieu recharge is accomplished when agencies take imported water instead of pumping, and leave the groundwater in storage.

Using discounted/reduced water rates is the basis of the Seasonal Storage Service Program (SSS), initiated in 1989, in which Metropolitan provides financial incentives to stimulate conjunctive use of groundwater basins to store imported water. Under the program, member agencies can buy surplus imported water at a discounted rate between October 1 and April 30, or at other times at the General Manager's discretion.

To receive the discount, agencies must either produce the stored water during the high-demand summer months or hold it in long-term storage (stored for more than one year). The discount provides the money the agencies need to build and operate groundwater facilities and improve basin management strategies, such as producing water in the summer and storing Metropolitan's water in the winter. The discount may also be used to finance groundwater treatment facilities.

5.4 Conjunctive-Use Programs

Under the conjunctive-use concept, Metropolitan's imported water is stored in groundwater basins when supplies are sufficient, for later use during peak demands or droughts.

The 1993 Demonstration Local Storage Program was created to take advantage of the excess available imported water supply resulting from the abundant precipitation during the year. Metropolitan, under two agreements, sold 11,000 AF of imported water to be placed into storage during that calendar year at discounted rates less than those for SSS. Unlike SSS, participating agencies would agree to store equivalent, usable amounts of water for up to ten years and to produce that stored water at Metropolitan's call in four equal increments, each lasting three months.

Under the Cyclic Storage Program, Metropolitan delivers water to the member agency for storage in a groundwater basin. This water is owned by Metropolitan until such a time as the member agency purchases the water. This predelivered replenishment water is sold at SSS rates.

Currently, Metropolitan has cyclic storage agreements with three member agencies: Chino Basin MWD; Three Valleys MWD; and Upper San Gabriel Valley MWD.

Metropolitan also recently entered into a Cooperative Storage agreement with Calleguas MWD. Cooperative Storage functions are much like Cyclic, except with expanded member agency supply reliability benefits.

Chino Basin storage accounts include a 100,000 AF cyclic storage program. A 5,000 AF pilot program where stored groundwater is recovered by injection into Metropolitan's pipeline recently became operational. The experience Metropolitan has gained in groundwater storage and recovery has led to a separate 50,000 AF conjunctive-use program which is currently in an advanced stage of facility planning.

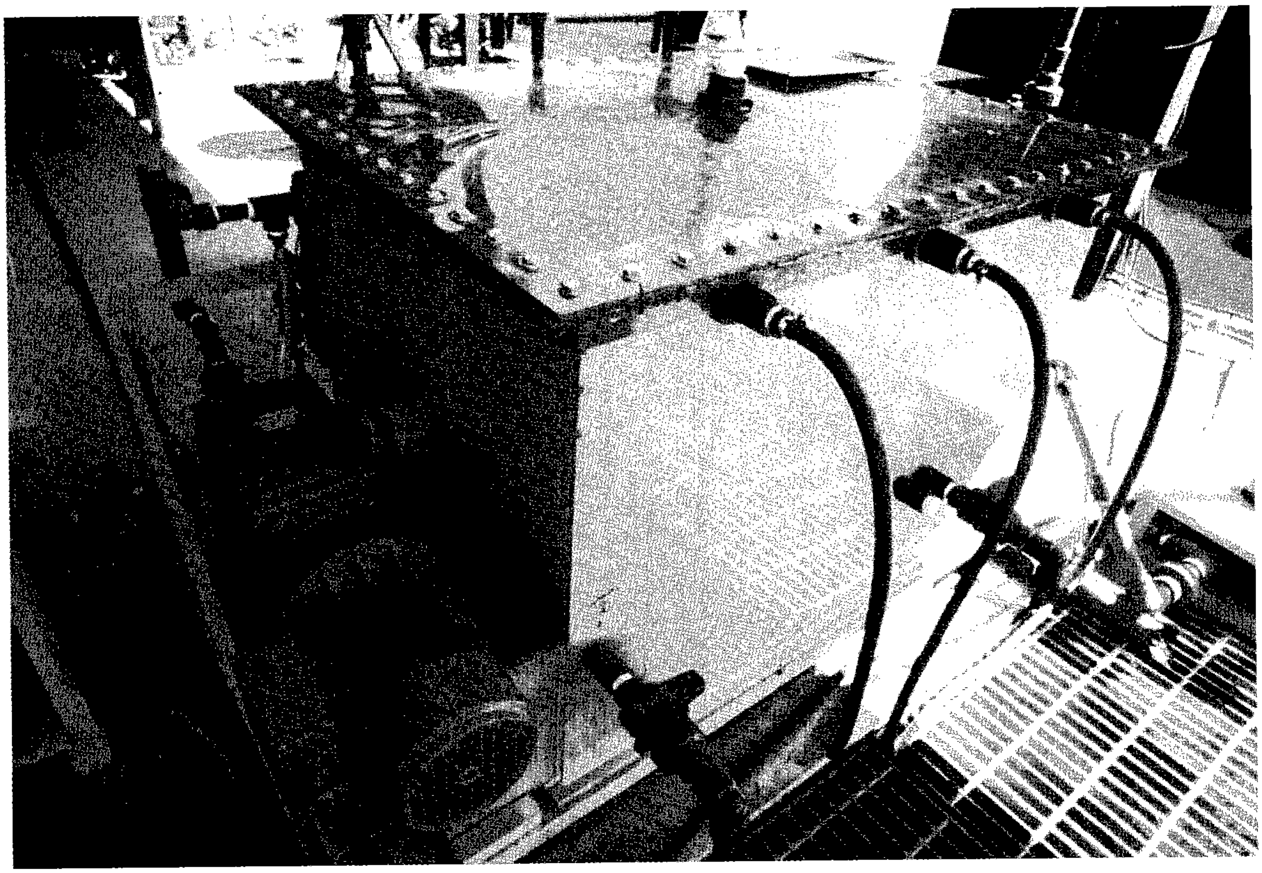
Metropolitan has two contracts with the Main San Gabriel Basin Watermaster for cyclic storage of up to 167,000 AF of water. Additionally, Metropolitan is negotiating development of a conjunctive-use project, a wellfield, and a groundwater treatment plant in the Baldwin Park area. The first phase of the project would produce about 30,000 AFY and store 150,000 AF.

Under a conjunctive-use pilot demonstration project with Eastern MWD, Metropolitan stored about 2,000 AF of water in the San Jacinto Basin in 1990. Metropolitan is also assisting Eastern MWD in several ongoing technical studies aimed at optimizing the use of San Jacinto and Hemet Basins, which are both located in the Eastern Riverside Basin Group.

In late 1991, Metropolitan entered into a drought storage agreement with the City of Pasadena. As of December 1993, 20,000 AF had been stored in the Raymond Basin.

Figure 5.2

Biological Denitrification Research Project



Picture shows small-scale reactor that tested the biological denitrification process for removing nitrate from groundwater, conducted by Orange County Water District in the Phase I of the joint research and development project with Metropolitan.

5.5 Research and Development

Metropolitan participates with member agencies, and local and national agencies in cooperative studies seeking approaches to maximize groundwater use, develop innovative treatment technologies and groundwater protection measures, assess basin contamination, and optimize basin management.

Examples include:

- Research in biological nitrate removal treatment technology;
- Projects demonstrating innovative injection and recovery of imported water in groundwater basins;
- Development of optimal groundwater basin data collection strategies;
- Research regarding contaminant transport in groundwater and reduction of hazardous substances through development of waste minimization technology;
- Assessment of health issues and operational criteria for groundwater recharge with reclaimed water; and
- Research regarding treatment of colored water to remove natural organic matter which is aesthetically unacceptable.

5.5.1 Nitrate Removal Research

Since 1988, Metropolitan and submember agency Orange County Water District (OCWD) have been conducting research on biological denitrification, using bacteria to remove nitrates from impacted groundwater.

In Phase I, laboratory and small-scale tests established the viability of the process (Figure 5.2). In a Phase II, pilot test currently under design, the process will be tested on a well with high nitrate levels in the City of Garden Grove, and will examine operational requirements and financial feasibility.

5.5.2 Nitrate Fate and Transport Study

Metropolitan, in cooperation with member agency Eastern Municipal Water District of Riverside County and OCWD, is participating in a four-year USGS study investigating the effects of chemical, microbial, and hydraulic processes on different forms of nitrogen in saturated and unsaturated groundwater zones. The study seeks to advance the knowledge regarding the fate and transport of nitrate, as there is inadequate scientific understanding.

5.5.3 Source Reduction Research Partnership Study

Up to 58 percent of the most commonly used industrial solvents in the U.S. could be readily eliminated within the decade, if industry could be encouraged to stop using them, according to the Source Reduction Research Partnership study released by Metropolitan in cooperation with the Environmental Defense Fund.[1] The study assessed the use of five solvents, including TCE, and made recommendations on more than 150 techniques for cutting back on their use.

5.6 Legislative and Regulatory Advocacy

Metropolitan has taken an active leadership role in organizing and assisting member agencies with State and federal legislation and regulatory practices.

For example, Metropolitan joined with other agencies to form the Azusa Task Force to oppose expansion of the Azusa Landfill, located in a gravel and sand pit, overlying the Main San Gabriel Basin recharge area. Those efforts have resulted in the State Water Resources Control Board (SWRCB) cancellation of the landfill expansion permit. The landfill operator lost a court appeal in February, 1993, but is continuing to litigate that cancellation.

The Task Force is also working with the Regional Water Quality Control Board, Los Angeles Region, to ban the use of sand and gravel pits for new and expanded landfills throughout the Los Angeles Region.

A Metropolitan staff member was recently appointed by Governor Pete Wilson to the External Program Review, State Water Resources Control Board Groundwater Protection Task Force. A report to the Governor will recommend changes to activities carried out by the SWRCB and the nine Regional Water Quality Control Boards regarding improving groundwater protection.

Metropolitan is, in addition, active in several groundwater management and quality committees on the local and national levels of the American Water Works Association (AWWA). This includes the development of a federal groundwater protection legislation package by the AWWA Groundwater Technical Advisory Workgroup.

1 *Potential for Source Reduction and Recycling of Halogenated Solvents (1992), Source Reduction Research Partnership for the Metropolitan Water District and the Environmental Defense Fund.*

FIGURE 6.1

Regional Water Quality Control Boards in Southern California

Central Coast (3); Los Angeles (4); Central Valley (5); Lahontan (6); Colorado River Basin (7); Santa Ana (8); and San Diego (9).

6. Groundwater Protection

Groundwater is one of Southern California's most important and fragile natural resources. Yet this resource is threatened by numerous sources of contamination. Figures 6.2 through 6.7, which were developed by other agencies, illustrate groundwater quality conditions in localized basins. Various levels of government are pursuing a wide array of actions to protect the quality of our irreplaceable groundwater resources.

California's nine Regional Water Quality Control Boards (RWQCBs) and its State Water Resources Control Board (SWRCB) provide California's most important defense against pollution (Figure 6.1). Based on authority provided in the Porter-Cologne Water Quality Act of 1969, the RWQCBs establish surface and groundwater quality objectives in basin plans and issue permits prescribing waste discharge requirements. Each board consists of nine members appointed by the Governor, representing a diverse mix of interests including agriculture, local government, industry, and the environment.

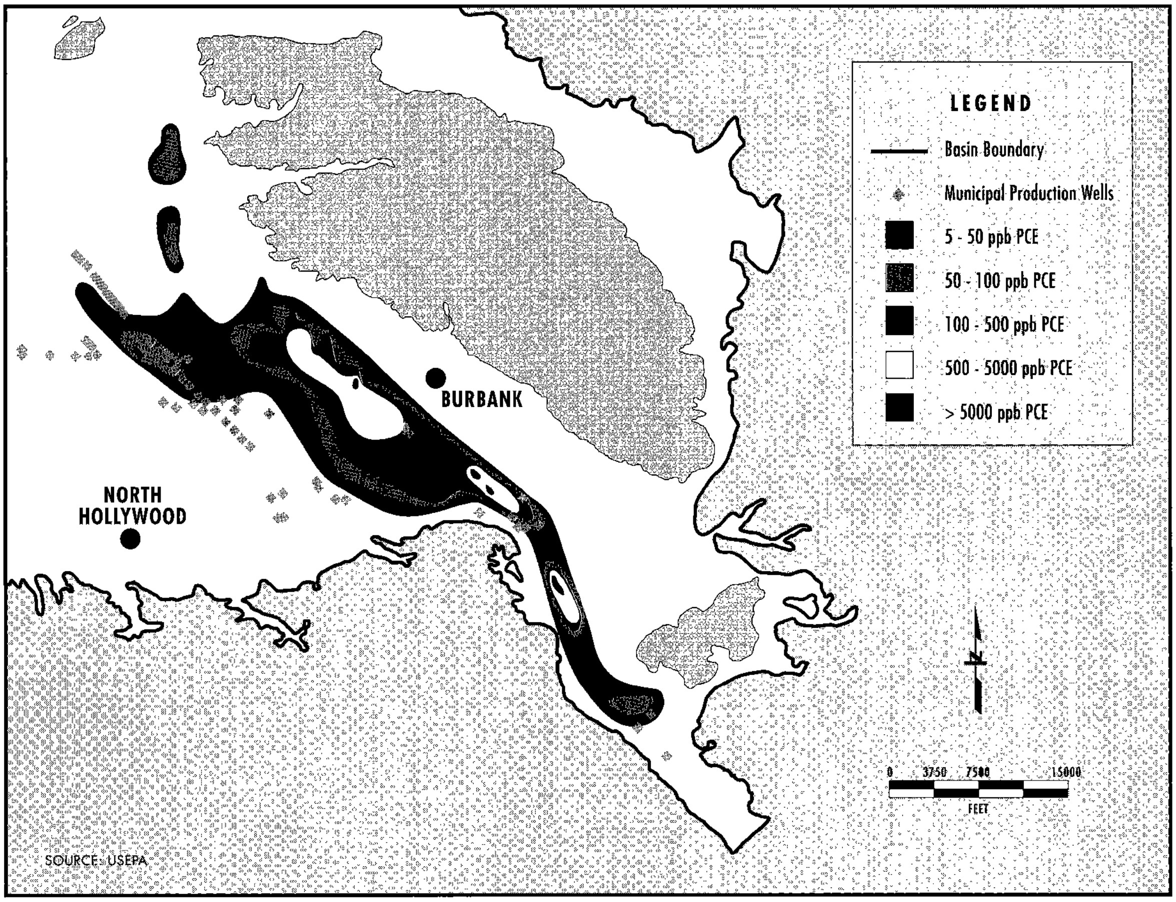
The Federal Water Pollution Control Act of 1972 and Clean Water Act of 1987 set goals of restoring and maintaining the chemical, physical and biological integrity of the nation's waters. Point and non-point source discharges of pollutants are regulated through the National Pollution Discharge Elimination System (NPDES). In California, permits are issued by the RWQCBs under authority granted by the United States Environmental Protection Agency (USEPA). NPDES permits are widely used to regulate municipal wastewater treatment plants, industrial discharges and, more recently, to regulate pollutants in urban and agricultural storm runoff.

In 1976, Congress passed the Resource Conservation and Recovery Act (RCRA) which regulates hazardous waste. The nine RWQCBs apply RCRA to help protect water resources from contamination caused by municipal and hazardous waste landfills. Furthermore, California's Integrated Waste Management Act of 1989 requires development of county waste management plans, sets deadlines for waste diversion and requires source reduction and recycling plans. The California Integrated Waste Management Board was established with authority for comprehensive statewide permitting, inspection, and enforcement regarding groundwater quality and other waste disposal issues.

California's Department of Toxic Substances Control implements the State's site clean-up laws and participates in the federal Superfund program. The federal Superfund program obtains money from a tax on chemical and petroleum industries and from lawsuits or negotiations with parties potentially responsible for contamination (commonly called Potentially Responsible Parties or PRPs). Superfund is authorized under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA). USEPA has adopted a three-goal strategy for all Superfund sites: (1) Protect human health; (2) contain the contamination and prevent further spreading; and (3) develop a plan of achieving long-term cleanup. Major federal Superfund activities are underway to clean up the Upper Los Angeles

FIGURE 6.2

Upper Los Angeles River Basin (San Fernando) PCE Impacts



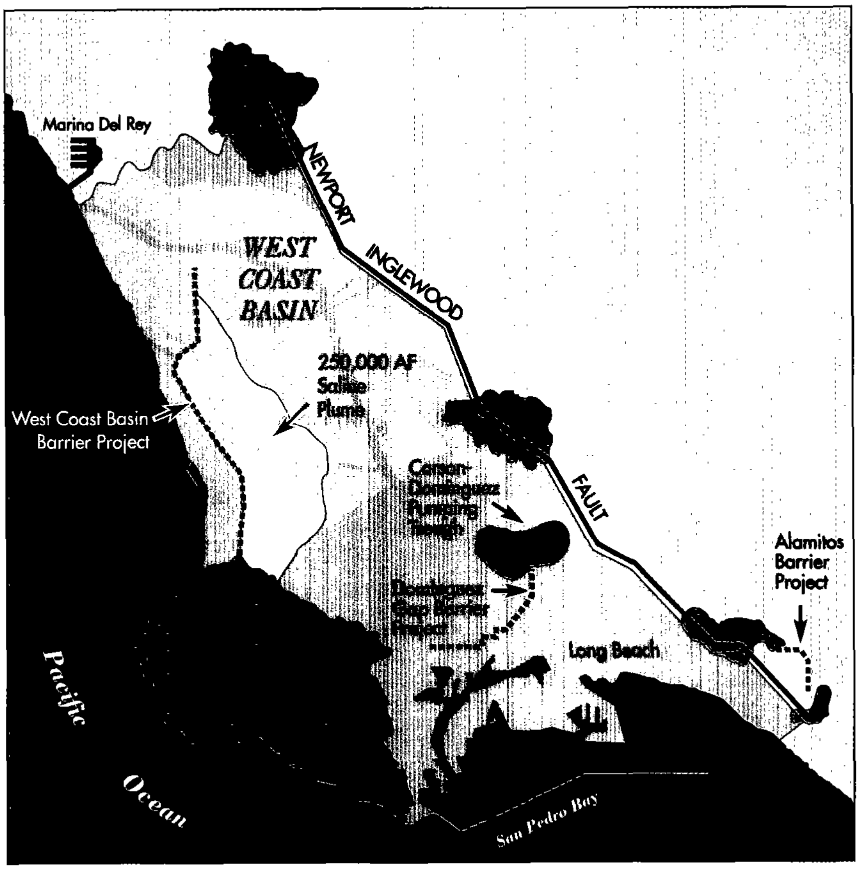
River (San Fernando) Basin and the Main San Gabriel Basin.

In California, the Department of Food and Agriculture and the county agricultural commissioners have responsibility for avoiding water pollution through a pesticide regulation and permit process. In addition to State laws, pesticide use is restricted by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) by USEPA.

Appendix C summarizes State and federal programs and controls concerning groundwater.

FIGURE 6.3

Saline Groundwater Plume from Historic Seawater Intrusion in West Coast Basin

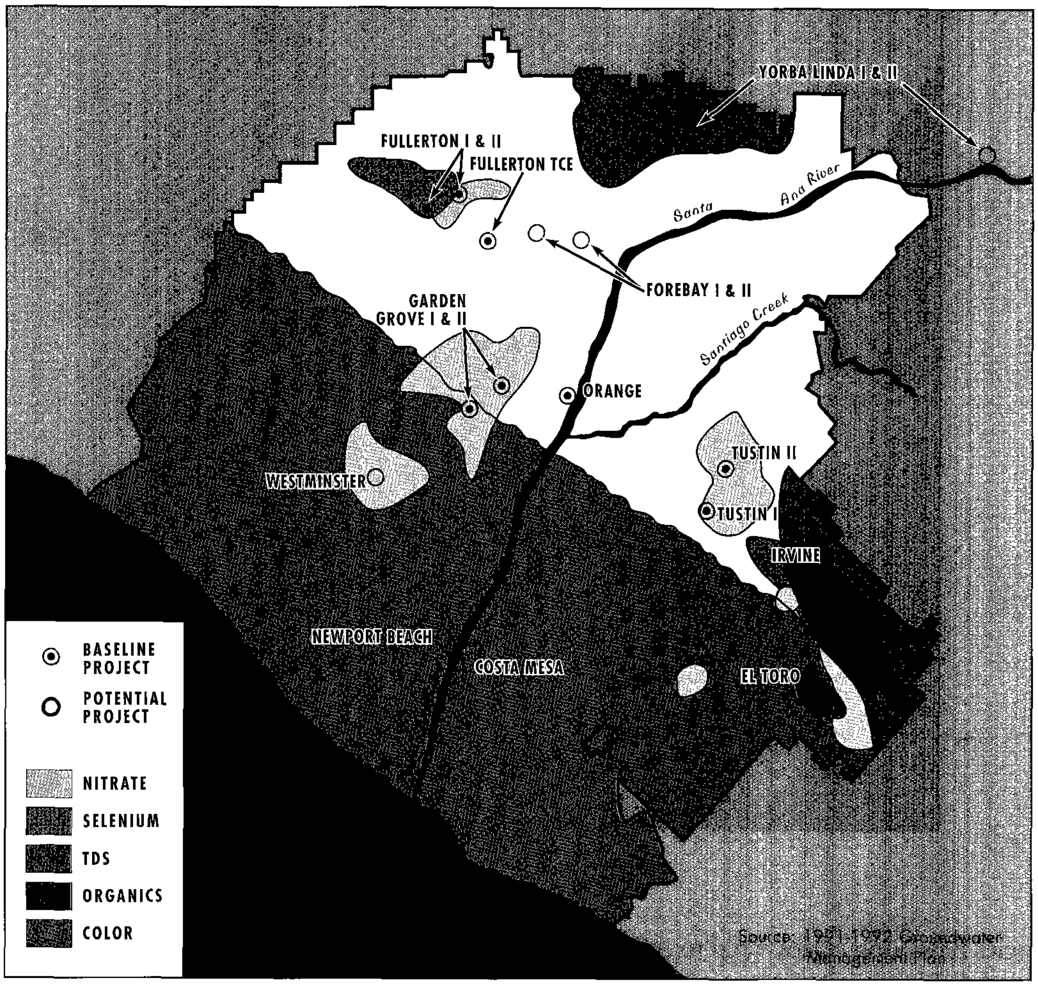


Local agencies have long endeavored to protect groundwater quality, especially through the development and operation of barriers used to prevent seawater intrusion into overdrafted groundwater basins. Barriers consisting of carefully placed injection and extraction wells help protect the West Coast, Central and Orange County Basins from elevated concentrations of chlorides, bromides and other salts.

The Santa Ana Watershed Project Authority (SAWPA) is a joint powers authority comprised of five regional water agencies located in the watershed. SAWPA's program in water quality management is integrated with those of other

FIGURE 6.4

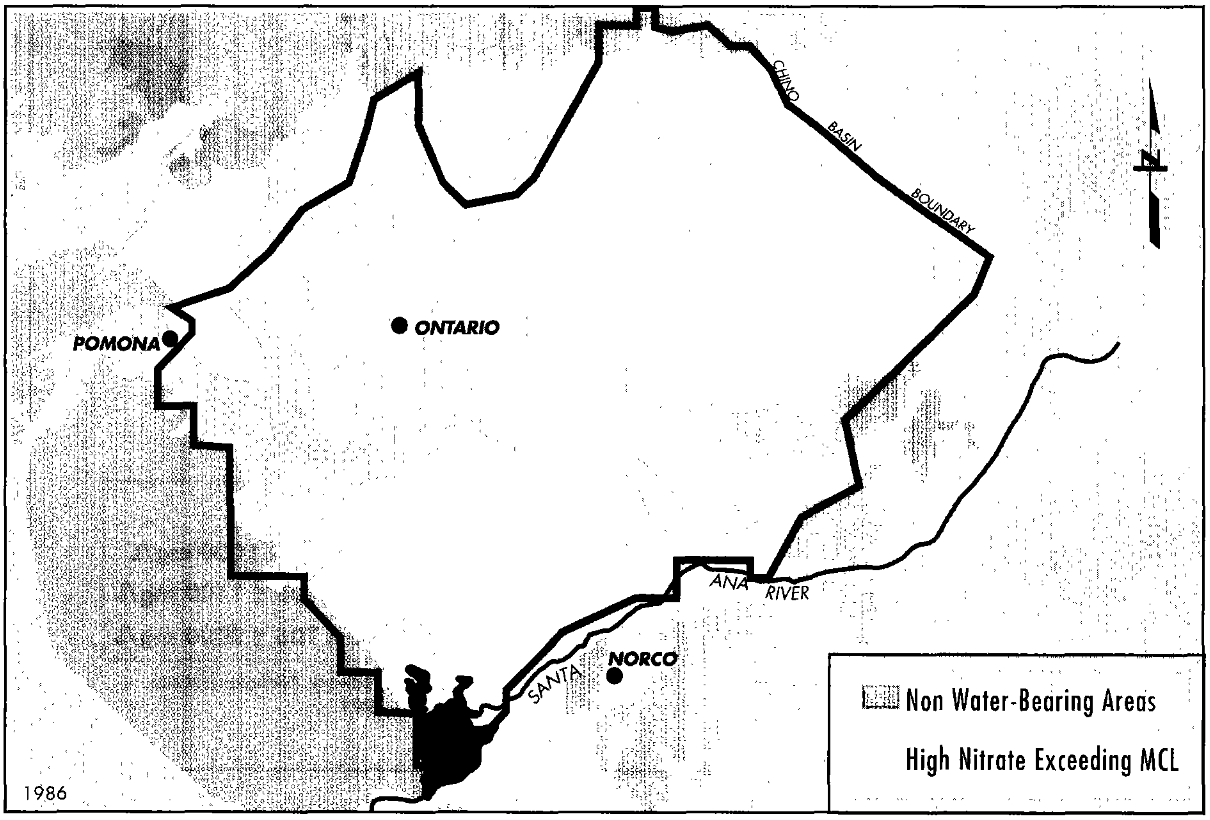
Groundwater Contamination and Potential Treatment Projects in OCWD



agencies to accomplish a common objective: assuring that limited water resources will be used and reused efficiently. SAWPA's program includes development of groundwater treatment plants, and improved management and waste discharge strategies for controlling and protecting water quality.

In order to improve groundwater quality conditions in the Chino Basin, local agencies,

FIGURE 6.5
Chino Basin Nitrate Plumes

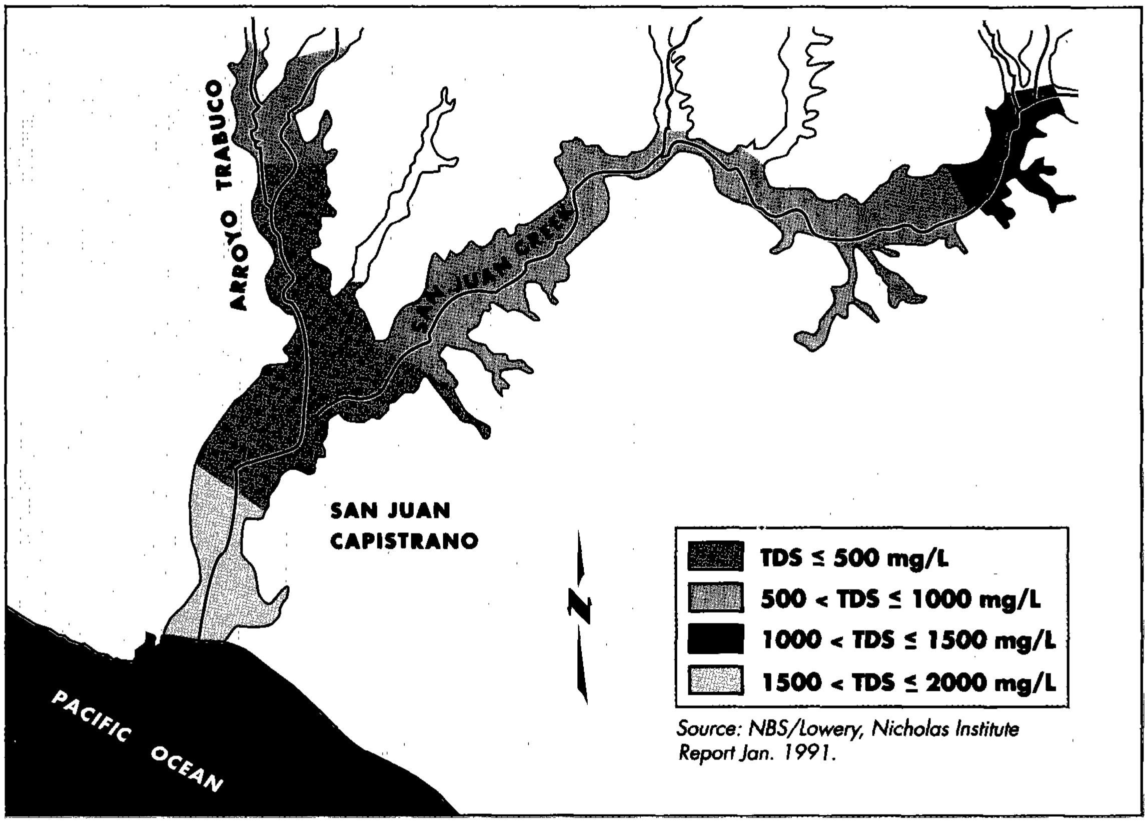


with the assistance of Metropolitan, have formed a task force which is developing a basin water management plan with an emphasis of protecting groundwater quality. Throughout Southern California, other agencies are also developing plans to manage and protect groundwater resources in the Hemet, San Jacinto, San Juan, Santa Monica, Charnock, Central Basins and numerous other groundwater basins.

The Azusa Landfill Task Force, as previously described in Section 5.6, was created jointly by local agencies and Metropolitan in order to protect the Main San Gabriel Basin from further contamination posed by the expansion of the

FIGURE 6.6

TDS in the San Juan Basin



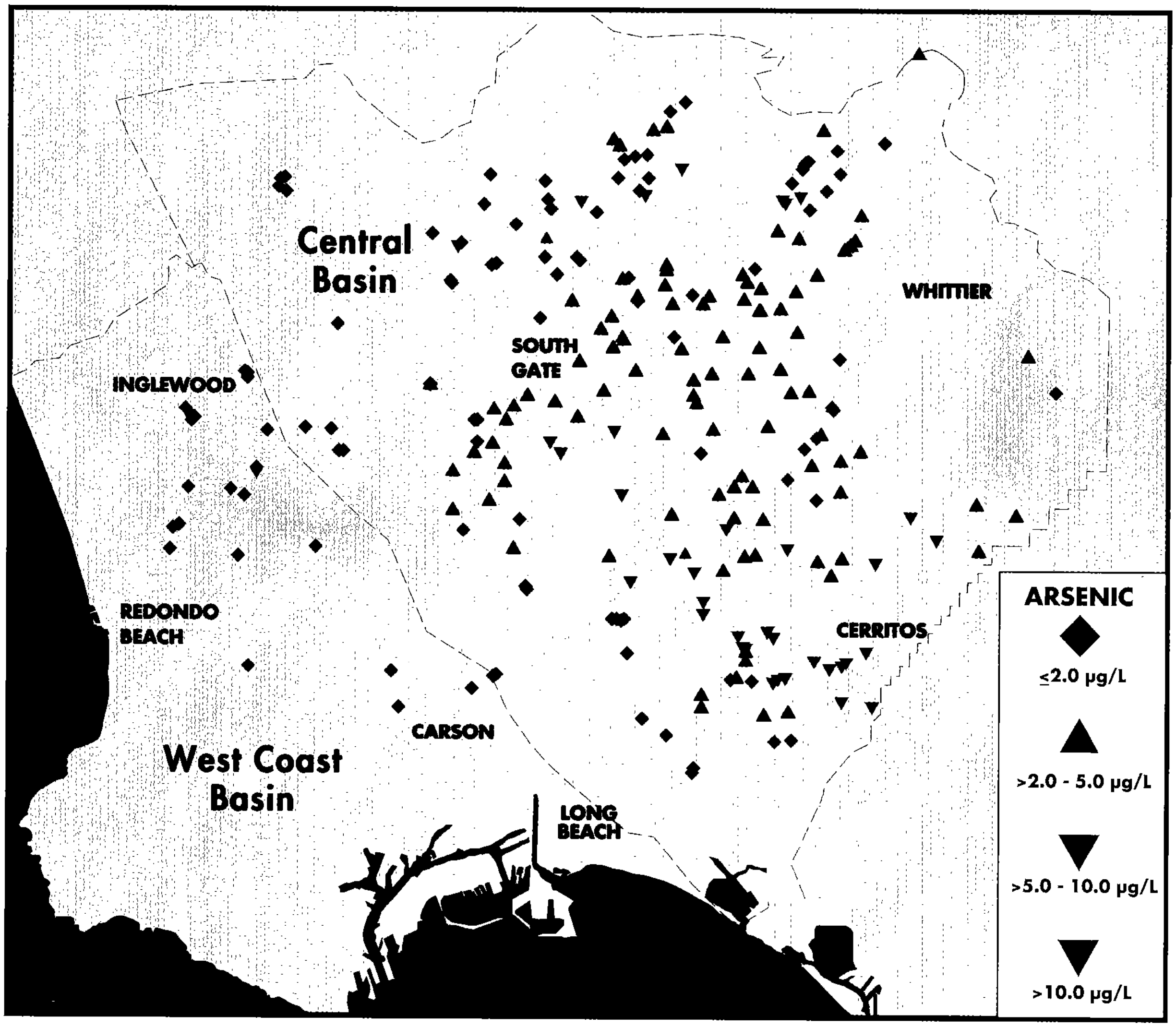
Azusa Landfill. Assembly Bill 3030, signed into law in 1992, provides authority for local agencies to adopt and implement groundwater management plans which may clean up and regulate contamination.

The Orange County Water District (OCWD), long known for innovation, has adopted a comprehensive groundwater management plan that will protect and enhance water quality in the Orange County Basin. OCWD is building treatment plants, some with financial contributions from Metropolitan's Groundwater Recovery Program, to remove contaminants and provide drinking water.

Central Basin Municipal Water District recently adopted a plan to protect the vulnerable Whittier Narrows groundwater recharge area by developing

FIGURE 6.7

Arsenic Survey in Central and West Coast Basins



portable treatment plants that remove VOCs and provide drinking water.

While the list of groundwater protection activities may be impressive, achieving the goal is difficult. Numerous land use activities can adversely affect groundwater quality. Regulators are overwhelmed with work and constrained by tight budgets. The cost of cleaning up existing contamination and preventing it from spreading is great.

APPENDICES

Appendix A

Drinking Water Quality Standards

Appendix B

Supplemental Treatment Technology Information

Appendix C

State and Federal Programs and Controls Concerning Groundwater

Appendix A

FIGURE A-1

Drinking Water Quality Standards
as of January 1993

Primary Standards – Mandatory Health Related Standards

ORGANIC CHEMICALS (mg/L)

Parameter	*Federal MCL*	*State MCL*
Atrazine	0.003	0.003
Bentazon	NS	0.018
Benzene	0.005	0.001
Carbofuran	0.04	0.018
Carbon Tetrachloride	0.005	0.0005
Chlordane	0.002	0.0001
2,4-D	0.07	0.1
Dibromochloropropane	0.0002	0.0002
1,2-Dichlorobenzene	0.6	NS
1,4-Dichlorobenzene	0.075	0.005
1,1-Dichloroethane	NS	0.005
1,2-Dichloroethane	0.005	0.0005
1,1-Dichloroethene	0.007	0.006
cis-1,2-Dichloroethene	0.07	0.006
trans-1,2-Dichloroethene	0.1	0.01
1,2-Dichloropropane	0.005	0.005
1,3-Dichloropropene	NS	0.0005
Di(2-ethylhexyl)phthalate	0.006*	0.004
Endrin	0.0002(.002*)	0.0002
Ethylbenzene	0.7	0.680
Ethylene Dibromide	0.00005	0.00002
Glyphosate	0.7*	0.7
Heptachlor	0.0004	0.00001
Heptachlor Epoxide	0.0002	0.00001
Lindane	0.0002	0.004
Methoxychlor	0.04	0.1

(continued on following page)

ORGANIC CHEMICALS (mg/L)
(continued)

Parameter	Federal MCL	State MCL
Molinate	NS	0.02
Monochlorobenzene	0.1	0.030
Simazine	0.004*	0.010
Styrene	0.1	NS
1,1,2,2-Tetrachloroethane	NS	0.001
Tetrachloroethene	0.005	0.005
Thiobencarb	NS	0.07
Total Trihalomethanes	0.10	0.10
Toxaphene	0.003	0.005
2,4,5-TP (Silvex)	0.05	0.01
1,1,1-Trichlorethane	0.20	0.200
1,1,2-Trichlorethane	0.005*	0.032
Trichlorethene	0.005	0.005
Trichlorofluoromethane (Freon 11)	NS	0.15
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	NS	1.2
Vinyl Chloride	0.002	0.0005
Xylenes	10	1.750

Primary Standards — Mandatory Health Related Standards, continued

INORGANIC CHEMICALS (mg/L)

Parameter	*Federal MCL*	*State MCL*
Aluminum	0.05-0.2 #	1
Arsenic	0.05	0.05
Asbestos	7 x	NS
Barium	1 (##2)	1
Cadmium	0.005	0.010
Chromium	0.1	0.05
Copper	xx	1.0 #
Fluoride	4.0	1.4-2.4
Lead	xx	0.05
Mercury	0.002	0.002
Nitrate (as N) (a)	10	10
Nitrite (as N)	1	NS
Nitrate plus Nitrite (as N)	10	NS
Selenium	0.05	0.01
Silver	0.1 #	0.05

RADIONUCLIDES (pCi/L)

Gross Alpha	15	15
Gross Beta	50 **	50
Radium-226 (b)	5. *	5
Radium-228 (b)	5. *	5
Radon-222	300 **	NS
Strontium-90	8	8
Tritium	20,000	20,000
Uranium	30 **	20

CLARITY (NTU)

Filter Effluent Turbidity	1.0	0.5
Plant Effluent Turbidity	1.0	0.5

MICROBIOLOGICAL

Coliform-State Standard (CFU/100 mL)	—	1
Coliform-Federal Standard	5.0 %	—
Fecal Coliform-Federal Standard	(c)	(c)

Secondary Standards — Aesthetic Standards

CHEMICAL PARAMETERS

Parameter	Federal MCL	State MCL+		
		Recommended@	Upper$	Short Term$$
Chloride, mg/L	250	250	500	600
Sulfate, mg/L	250	250	500	600
Total Dissolved Solids, mg/L	500	500	1000	1500
Specific Conductance, umho/cm	NS	900	1600	2200

Parameter	Federal MCL	State MCL++
Color, units	15	15
Foaming Agents-MBAS, mg/L	0.5	0.5
Iron, mg/L	0.3	0.3
Manganese, mg/L	0.05	0.05
Odor Threshold, units	3	3
pH, units	6.5-8.5	NS
Thiobencarb, ug/L	NS	1.0
Zinc, mg/L	5	5.0

Key to Abbreviations

MCL	Maximum Contaminant Level.
NS	No standard.
mg/L	Milligrams per liter.
pCi/L	picoCuries per liter.
*	Monitoring cycle began January 17, 1993.
**	Proposed standard.
#	Secondary standard.
##	Monitoring cycle began January 1, 1993.
x	Measured in million fibers per liter (longer than 10 microns).
xx	The Federal MCL for lead has been replaced with a treatment technique requiring agencies to optimize corrosion control treatment. There is a similar treatment technique for copper.
(a)	Nitrate (NO3) is reported as NO3 or as nitrogen (N). To convert data from N to NO3, multiply by 4.43.
(b)	Standards are for Radium-226 and Radium-228 combined.
(c)	State MCLs: Coliforms shall not exceed 1 CFU/100 mL as the arithmetic mean of all monthly samples and also shall not exceed 4 CFU/100 mL in more than 5% of all monthly samples. Federal MCLs: No more than 5.0% for the monthly samples may be total coliform-positive. Federal fecal coliform MCLs: The occurrence of two consecutive total coliform-positive samples, one which contains fecal coliform/E. coli, constitutes an acute MCL violation.
+	For parameters with no fixed consumer acceptance contaminant limits.
++	For parameters with fixed consumer acceptance limits.
@	Recommended levels are desirable for a higher degree of consumer acceptance.
$	Upper levels are acceptable if it is neither reasonable nor feasible to provide more suitable waters.
$$	Short Term levels are acceptable only for existing systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.
CFU/100 mL	Colony-forming units per 100 milliliters.
CFU/mL	Colony-forming units per milliliter.

Appendix B

Supplemental Treatment Technology Information

The cost estimates given in Appendix B are approximations that represent capital, operation and maintenance, and engineering and administrative costs associated with implementing that technology. Three plant sizes (0.1, 1.0, and 10 mgd), contaminant levels, and other assumptions used in calculating the estimated treatment costs further qualify the direct applicability of these numbers. Pre-treatment and/or post-treatment facilities for many applications may be required at additional cost.

Furthermore, waste streams produced by most technologies will require disposal or treatment, again at additional cost. Estimates are provided for a range of flow capacities and water qualities when possible. Although the data available regarding the technologies are not recent, they can be useful in comparing costs between different technologies. References used in the generation of the cost data are also included.

FIGURE B-1

Cost Estimates For Packed Tower Aeration (PTA)

			System Cost ($ per 1,000 Gallons)					
			0.1 mgd		1.0 mgd		10 mgd	
Compound	Percent Removal	A:W Ratio	PTA	With Emission Control	PTA	With Emission Control	PTA	With Emission Control
1,2-Dichloroethane	95	80	0.49	1.08	0.21	0.48	0.14	0.34
	99	100	0.57	1.22	0.27	0.60	0.19	0.43
p-Dichlorobenzene	95	50	0.45	0.92	0.18	0.34	0.12	0.23
	99	60	0.51	1.02	0.23	0.42	0.15	0.29
Benzene	95	35	0.42	0.84	0.15	0.28	0.10	0.18
	99	40	0.84	0.92	0.20	0.34	0.12	0.22
Trichloroethylene	95	30	0.39	0.79	0.13	0.25	0.08	0.16
	99	30	0.44	0.84	0.17	0.28	0.10	0.18
1,1,1-Trichloroethane	95	25	0.38	0.77	0.12	0.23	0.07	0.14
	99	25	0.43	0.81	0.15	0.26	0.09	0.16
Carbon Tetrachloride	95	20	0.37	0.74	0.12	0.21	0.07	0.13
	99	20	0.42	0.78	0.15	0.24	0.09	0.14
1,2-Dichloroethane	95	80	0.49	1.08	0.21	0.48	0.14	0.34
	99	100	0.57	1.22	0.27	0.60	0.19	0.43
Vinyl Chloride	95	5	0.35	2.39	0.10	1.88	0.06	1.80
	99	5	0.38	2.41	0.12	1.89	0.07	1.80
Range	95-99	5-100	0.35-0.57	0.74-2.41	0.10-0.27	0.21-1.89	0.08-0.19	0.13-1.80

mgd Millions of gallons per day.
A:W Air to water.

Assumptions listed in Figure B-2.
Cost estimates after Adams and Clark (1989).

FIGURE B-2

Assumptions for Cost Estimates for Packed Tower Aeration (PTA)

(after Adams and Clark 1989)

- PTA system operated at 70% of design capacity.
- Maximum tower diameter is 16 feet.
- Maximum liquid loading is 30 gallons per minute square foot.
- Minimum air gradient is 50 newtons per square meter per meter.
- Influent water temperature is 12° C.
- Tower packing material is 2-inch plastic saddles.
- Net efficiency of blower/motor is 35%.
- Net efficiency of pump/motor is 80%.
- Tower off-gas velocity is 50 feet per minute.
- Post-heater gas-phase temperature is 24° C.
- Gas-phase BPL granular activated carbon (GAC) price is $2.00 pound at 20,000 pounds.
- Gas-phase GAC adsorber bed depth is 0.5 feet except for vinyl chloride which is 4 feet.
- On-site steam regeneration is 50 kilograms steam per kilograms spent GAC; replace GAC every 5 years.
- GAC regeneration and handling losses are 12%.
- Amortization of capital at 10% interest over 20 years.
- Labor and fringe rate is $15 per hour.
- Electric rate is $0.08 per kilowatt hour.
- Contractor profit factor for construction cost is 7%.
- Special construction site-work factor is 5%.
- Construction engineering fees factor is 12%.
- ENR Construction Cost Index (June 1988) is 421.
- Producers Price Index (May 1988) is 299.

FIGURE B-3

Cost Estimates for Granular Activated Carbon Adsorption

Flow (mgd)	Capital Cost: Total ($)	Capital Cost: Amortized ($)	Capital Cost: Unit ($ per 1,000 gallons)	Contaminant Concentration (ppb)	O & M Cost: Total ($)	O & M Cost: Unit ($ per 1,000 gallons)	Total Cost ($ per 1,000 gallons)
0.1	68,900-137,800	8,100-16,200	0.22-0.44	200	6,400-12,800	0.18-0.36	0.40-0.80
				70	5,800-11,600	0.16-0.32	0.38-0.76
1.0	502,300-1,004,600	59,000-118,000	0.16-0.32	200	46,100-92,200	0.13-0.26	0.29-0.58
				70	43,400-86,800	0.12-0.24	0.28-0.56
10.0	2,500,000-5,000,000	292,600-585,200	0.08-0.16	200	128,800-257,600	0.04-0.08	0.12-0.24
				70	102,000-204,000	0.03-0.06	0.11-0.22

O&M Operation and maintenance.
mgd Millions of gallons per day.
ppb Parts per billion.

Assumptions:
- Pressurized contactors.
- 10-foot bed depth.
- 10% carbon usage (10 pounds *contaminant/100 pounds carbon*).
- ENR Construction Cost Index is 421.
- Amortization of capital at 10% interest over 20 years.
- 30% engineering and administration costs on capital.
- 5 gallons per minute per square foot application rate.
- Empty bed contact time of 15 minutes.
- Off-site carbon regeneration.
- Contactor housing included.

Cost estimates after Gumerman (1979) and Hansen (1979).

FIGURE B-4

Cost Estimates for Ion Exchange

Flow	Capital Cost			O & M Cost		Total Cost
	Total	Amortized	Unit	Total	Unit	
(mgd)	($)	($)	($ per 1,000 gallons)	($)	($ per 1,000 gallons)	($ per 1,000 gallons)
0.1	146,500	17,200	0.47	22,500	0.62	1.09
1.0	627,900	73,800	0.20	80,500	0.22	0.42
10.0	4,395,300	516,300	0.14	450,800	0.12	0.26

O&M Operation and maintenance.
mgd Millions of gallons per day.
mg/L Milligrams per liter.

Assumptions:

Water anion concentrations are as follows: 80 mg/L sulfate
100 mg/L nitrate
120 mg/L other anions.
Strongly basic anion exchange resin operated in chloride form.
Nitrate exchange capacity of 7 kilograins nitrate per cubic foot.
Sodium chloride regenerant, 15 pounds per cubic foot resin.
6-foot bed depth.
100 psi operating pressure.
Costs do not include brine disposal.
Amortization of capital at 10% interest over 20 years.
30% engineering and administration costs on capital.
ENR Construction Cost Index is 421.

Cost estimates after Gumerman (1979) and Hansen (1979).

FIGURE B-5

Cost Estimates for Reverse Osmosis

Flow	Capital Cost		O & M Cost			Total Cost
	Total	Amortized	Unit	Total	Unit	
(mgd)	($)	($)	($ per 1,000 gallons)	($)	($ per 1,000 gallons)	($ per 1,000 gallons)
0.1	260,000	30,500	0.83	48,000	1.32	2.15
1.0	1,560,000	183,200	.50	340,000	0.93	1.43
10.0	10,920,000	1,282,700	0.35	2,700,000	0.74	1.09

O & M Operation and Maintenance.
mgd Millions of gallons per day.

Assumptions:
- The range for TDS is 5,000 to 10,000 parts per million.
- Single pass, high pressure system.
- 70% water recovery.
- Costs do not include brine disposal.
- Amortization of capital at 10% interest over 20 years.
- 30% engineering and administration costs on capital.
- ENR Construction Cost Index is 421.

Cost estimates after Gumerman (1979) and Hansen (1979).

FIGURE B-6

Cost Estimates for Precipitation

Basin	Flow	Capital Cost			O & M Cost		Total
		Total	Amortized	Unit	Total	Unit	
	(mgd)	($)	($)	($ per 1,000 gallons)	($)	($ per 1,000 gallons)	($ per 1,000 gallons)
Rapid Mix	0.1	20,900	2,500	0.07	7,200	0.20	0.27
	1.0	31,400	3,700	0.01	7,200	0.20	0.21
	10.0	48,100	5,700	0.002	12,200	0.003	0.005
Flocculation	0.1	83,700	9,800	0.27	2,600	0.07	0.34
	1.0	146,500	17,200	0.05	4,200	0.01	0.06
	10.0	439,500	51,600	0.014	10,000	0.003	0.02
Clarification	0.1	75,300	8,900	0.24	4,500	0.12	0.36
	1.0	167,400	19,700	0.05	6,400	0.02	0.07
	10.0	711,600	83,600	0.023	14,800	0.004	0.03

O&M Operation and Maintenance.
mgd Millions of gallons per day.
Assumptions:
- One rapid mix tank, 1 minute detention time, G is 600 sec^{-1}.
- Two horizontal paddle flocculators, 30 minute detention time, G is 50 sec^{-1}.
- Two rectangular clarifiers, 60 minute detention time, 12-foot side wall depth, sludge collection system.
- Costs do not include chemical addition and related facilities.
- Costs do not include sludge treatment or disposal.
- Amortization of capital at 10% interest over 20 years.
- 30% engineering and administration costs on capital.
- ENR Construction Cost Index is 421.

Cost estimates after Gumerman (1979).

FIGURE B-7

Cost Estimates for Biological Treatment

Flow	Influent Nitrate Concentration	Product Water Nitrate Concentration	Capital Cost			O & M Cost		Total Cost
			Total	Amortized	Unit	Total	Unit	
(mgd)	(mg/L)	(mg/L)	($)	($)	($ per 1,000 gallons)	($)	($ per 1,000 gallons)	($ per 1,000 gallons)
4	70	25-45	1,800,000	211,000	0.15	88,000	0.06	0.21
4	150	25-45	2,000,000	235,000	0.16	248,000	0.17	0.33

O&M Operation and Maintenance.
mgd Millions of gallons per day.
mg/L Milligrams per liter.

Assumptions:

- Product water is a blend of treated and untreated water.
- Preliminary cost estimate made before pilot studies completed.
- Based on attached growth reactors.
- Post-treatment costs for flotation, filtration, and chlorination included as well as methanol used as biological food source.
- Groundwater does not require pretreatment for iron, manganese, or organics, and is low in turbidity.
- Amortization of capital at 10% interest over 20 years.

Cost estimates after Montgomery (1987).

FIGURE B-8

References for Treatment Technologies

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Appendix C

State and Federal Programs and Controls Concerning Groundwater

State

Agricultural Drainage Water Management Loan Program (Proposition 44) (1986-87)

Administered by the State Water Resources Control Board (SWRCB), this state program provides loans to remediate damage done by agriculture.

California Pesticide Management Plan for Ground Water Protection (1985)

The State Department of Food and Agriculture is the lead agency for pesticide regulations and has developed this plan to provide management of pesticides in the State. The plan is required by the USEPA in compliance with that agency's Agricultural Chemicals in Ground Water: Pesticide Strategy. Under this plan, the department collects data on pesticides that are registered for use in California. It can take action to ensure that pesticide use does not harm groundwater supplies.

Clean Water and Water Reclamation Bond (Proposition 83) (1988)

Approved by California voters in 1988, it is administered by the SWRCB and provides low-interest loans and grants for wastewater cleanup. The SWRCB classifies groundwater as being eligible for financial assistance when the contamination is due to human activities.

Clean Water Bond Act (1984)

Administered by the SWRCB, this program provides loans to municipalities for water reclamation projects.

Hazardous Substance Cleanup Bond Act (1984)

This is the State's Superfund program, providing money for site-specific clean-up projects not included in the Federal Superfund list. After expenditure of funds, new legislation (Senate Bill 475-Torres and Assembly Bill 41-Wright) was enacted to provide an expanding funding base effective July 1, 1989. It includes the underground tank program. The State Department of Health Services is the lead agency.

Hazardous Waste Management Planning and Facility Siting (1986)

Also known as the Tanner Act (SB 2948), this establishes land use criteria for the siting of hazardous waste facilities. It requires Regional and County Hazardous Waste Management Plans, local permitting of hazardous waste management facilities, and a State facilities siting appeals process. The plans must cover all hazardous waste generated in the county from 1986 to the year 2000. The county plans must be approved by cities and the State Department of Toxic Substances Control, which is the lead agency responsible for implementation.

Hazardous Waste Source Reduction Act (SB 14) (1988)

This act is intended to promote reduction of hazardous waste at its source and to promote recycling. It requires generators of hazardous waste to prepare source reduction plans and hazardous waste management performance reports. The State Department of Toxic Substances Control is the statewide agency responsible; local environmental health departments are responsible at the local level.

Integrated Solid Waste Management Act (AB 939) (1989)

This State act, under California Public Resources Code 40000, repealed and recast California's waste management laws and programs. It requires countywide integrated waste management plans with city source reduction and recycling elements; the plans must include waste characterization, composting, household hazardous waste, funding, and public information and education. The implementing agency is the California Integrated Waste Management Board (CIWMB), with local enforcement.

Monitoring of Large Public Water Systems (1983)

This State act is also known as AB 1803. It requires the State Department of Health Services to monitor public water systems for contaminants and for the nine Regional Water Quality Control Boards (RWQCBs) to review data and identify dischargers which have affected the public drinking water wells. It was amended to include smaller drinking water systems.

Pesticide Contamination Prevention Act (1985)

This is the first and most complex State laws to deal with pesticides and contamination of groundwater. It authorized the State Department of Food and Agriculture to develop a comprehensive management plan, to collect data on use, and develop a detection response plan.

Porter-Cologne Water Quality Control Act (1969)

This State Act established the SWRCB and the nine RWQCBs as the principal state agencies with primary responsibility for the coordination and control of water quality. It established a permitting system for control of waste discharges to land and water.

Safe Drinking Water and Toxics Enforcement Act (1986)

This is Proposition 65, approved by voters to protect drinking water sources from toxic contamination and provide warnings to consumers about toxic exposures. The State Department of Health and Welfare is the lead agency, with county supervisorial boards and county health officers responsible for local implementation. Notices and bans apply to the listed carcinogens and reproductive toxins. Public water and sewer systems were exempted from compliance.

State Regulation of Hazardous Waste Disposal (1987)

This is known as the Calderon Bill AB 3525/3374 (Water Code 13273) and the Eastin Bill AB 2448. The Calderon Bill requires air emissions and leachate testing from all existing/former solid waste sites, with priority ranking of sites for water and air quality assessments. The Eastin Bill creates a new solid waste Superfund, and the California Integrated Waste Management Board (CIWMB) administers $100 million in a new solid waste cleanup account. The SWRCB is the agency which is responsible for Solid Waste Water Quality Assessment (SWAT), a onetime air-quality, groundwater and vadose monitoring to see if hazardous wastes are leaking from the landfill. The nine RWQCBs have local responsibility.

Toxic Pits Cleanup Act (1984)

This State act required the identification and regulation of pits, ponds, and lagoons used to store or treat hazardous waste. It prohibits discharge of hazardous wastes within 1/2 mile upgradient of a potential drinking water source.

Underground Tank Law (1983)

The SWRCB is the implementing agency. It regulates underground tank installation, monitoring and cleanup and requires secondary containment for new tanks.

Water Conservation Bond Law (Proposition 82) (1988)

Administered by the State Department of Water Resources, this State program provides low-interest loans for groundwater recharge and conservation. It was Proposition 82, approved by voters in 1988, and it renews a program established in 1984 and updated in 1986.

Federal

Clean Water Act (1972)

This Federal law focuses on controlling pollution discharge into surface waters. Because of the relation between groundwater and surface water quality, the act is also important for groundwater protection. It provides for the National Pollutant Discharge Elimination System (NPDES), which establishes permits and limits the amount of gross pollution that factories and municipal sewage treatment plants can release.

It also provides grants to states for nonpoint source control implementation funding through USEPA's Office of Water Regulations and Standards.

Originally enacted in 1972 as the Federal Water Pollution Control Act, it was amended in 1977 and renamed the Clean Water Act. It was reauthorized in 1991.

Comprehensive Environmental Response and Liability Act (CERCLA or Superfund) (1980)

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which is commonly known as Superfund, identifies sites which may or have released hazardous substances into the environment, and ensures their cleanup. Provisions for Hazardous releases from uncontrolled or abandoned hazardous waste sites, and LUST were added to the program in 1986.

The highest priority problem sites are commonly called Superfund sites and are placed on the National Priority List (NPL) for action. Those sites not sufficiently hazardous to be on the NPL, or are currently under investigation, are listed in the CERLIS (CERCLA Information System).

Nationwide, 73% of the 1,189 hazardous-waste sites currently on the Superfund Priorities List have documented groundwater contamination and would benefit from groundwater remediation.

Emergency Planning and Community Right-to-Know Act (EPCRA) (1986) (also called Title III of the Superfund Amendments and Reauthorization Act of 1986)

This act, implemented by USEPA, establishes requirements for Federal, State and local governments and industry in the development of emergency planning, release notification, and reporting of inventories of toxic and hazardous chemicals. Through community Right-to-Know reporting requirements, the public has access to information regarding the presence of these hazardous chemicals.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (1972)

USEPA is the implementing agency. The act requires manufacturers to register pesticides with the agency so it can assess its effect on humans; it can restrict or prohibit use.

Pollution Prevention Act (1990)

This Federal act mandates source reduction and waste management of all toxic and hazardous substances. Beginning in 1991, the amounts treated, disposed, recycled, recovered, or released must be reported to the USEPA in this effort to reduce and prevent pollution.

Resource Conservation and Recovery Act (RCRA) (1976)

This Federal act regulates hazardous and nonhazardous solid wastes. Under Subtitle C, it requires USEPA to regulate hazardous waste from cradle to grave, and includes provisions to protect groundwater.

Control of solid waste, under Subtitle D, is primarily in the hands of the states.

As amended in 1984, the act also covers the siting, construction and monitoring of approximately 2 million underground storage tanks.

Safe Drinking Water Act (SDWA)(1976)

This is the primary Federal legislation protecting drinking water supplied by public water systems (those serving more than 25 people). The USEPA is lead agency and is mandated to set standards for drinking water.

As amended in 1986, the USEPA is required to set maximum contaminant levels (MCLs) for 83 contaminants deemed harmful to humans (with specific deadlines). It also has authority over groundwater. Water agencies are required to monitor water to ensure it meets standards.

Two programs of the act directly affect groundwater resources. The Wellhead Protection Program requires states to devise protection programs for areas around public water supply wells to prevent contamination from entering.

The Sole Source Aquifer Program gives added protection to aquifers designated by USEPA to be sole or principal sources of drinking water to the community. It prohibits Federal funds for any project that would be harmful to a sole source.

Pending SDWA Regulations

Arsenic (Proposed rule expected 1994)

The proposed MCL is expected to be between 2 and 20 ppb (most probably around 5 ppb). Current detection limit is usually 10 ppb; the impact will be significant.

Contaminants from USEPA's Priority List (Expected 1995)

This will establish standards for 25 contaminants. Every three years after, 25 more are to be revised or finalized. The priority list was published in 1988, republished 1991.

Disinfectants and Disinfection By-products (Proposed rule expected 1994)

This will set standards and treatment requirements for disinfection by-products and groundwater disinfection. A change of philosophy was proposed in 1990 to give balance between known microbial health risks and the theoretical health risks of disinfectant by-products.

Groundwater Disinfection Rule (Proposed rule expected 1994)

The proposed rule was issued July 31, 1992, and it is expected to become final in mid-1996.

Radionuclides Regulation (Rule expected 1993, but delayed)

USEPA has proposed an MCL of 300 pCi/L for radon. For the first time, the USEPA is considering cost in developing this standard.

Surface Mining Control and Reclamation Act (SMCRA) (1977)

This Federal act regulates coal mining to prevent contaminants from entering groundwater. It requires coal operations to receive a permit from the U.S. Department of the Interior; the activity must protect groundwater from toxic mine drainage.

Toxic Substances Control Act (TSCA) (1976)

USEPA is the implementing agency under this Federal act and has control over production, use, distribution and disposal of hazardous substances. Manufacturers of new chemicals have to advise USEPA of their existence, and the agency must assess them for their impact on human health or the environment.