ACTIVITIES OF THE WATER RESOURCES DIVISION CALIFORNIA DISTRICT, FISCAL YEAR 1993

Compiled by Myrna L. DeBortoli

U.S. GEOLOGICAL SURVEY

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MESSAGE FROM THE DISTRICT CHIEF

The U.S. Geological Survey has been describing the water resources of California for more than 100 years. The California District consists of 250 staff members at nine locations, all of whom have contributed in some way to the studies described in this report. To accomplish the mission of describing the water resources of the State, the Survey staff works with more than 130 cooperating local, State, and Federal agencies with common interests in this most valuable resource.

Climate extremes, such as the recent drought which is still fresh in people's minds, serve to focus our attention on the need for timely, high-quality water information. The flooding that occurred in southern California during the winter of 1992-93 is a reminder that climate extremes can change quickly.

The studies described in this report cover a wide range of water issues in California that are important to water managers and scientists. The complex water issues in the San Joaquin Valley are being addressed as part of the National Water Quality Assessment Program (NAWQA). National-, regional-, and local-scale studies are included in the NAWQA design because hydrologic issues usually cross political boundaries. Beginning in 1994, the Sacramento Valley also will be included in the NAWQA program. Important hydrodynamic and water-quality studies are continuing in the Sacramento-San Joaquin Delta and San Francisco Bay. In southern California, the Regional Aquifer System Analysis and associated projects are continuing to provide important information, including seawater intrusion along the coast and the complex hydrology of desert basins. In addition, evaluations of the effectiveness of water reclamation and recharge practices and assistance to water agencies in optimum management of water resources are primary focuses of studies in the southern part of the State. The statewide streamflow-measuring program provides information essential to water management. Details on these and other studies have been assembled in this report to provide the public with a summary of the water-resource activities of the U.S. Geological Survey in the State.

The California District staff is dedicated to accomplishing its mission to study and describe California's water resources. I welcome any comments or suggestions that you, the users of our information, might have to help us improve in this area. Please feel free to contact me directly at (916) 978-4633 or write to

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District Chief
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Sacramento, CA 95825

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U.S. GEOLOGICAL SURVEY ORIGIN

The U.S. Geological Survey (USGS) was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain." An integral part of that mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nations's energy, land, mineral, and water resources.

Since 1879, the research and factfinding role of the USGS has grown and been modified to meet the changing needs of the Nation. As part of that evolution, the USGS has become the Federal Government's most comprehensive earth-science research agency, the Nation's largest civilian mapmaking agency, the primary source of data on the Nation's surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs serve a diversity of needs and users. Programs include

- Assessing the energy and mineral potential of the Nation's land and offshore areas.
- Geological risk assessment, including issuing warnings of earthquakes, volcanic eruptions, landslides, and other geologic and hydrologic hazards.
- Conducting research on the tectonics of the Earth.
- Studying the geologic features, structure, processes, and history of the other planets of our solar system.
- Conducting topographic surveys and preparing topographic and thematic maps and related cartographic products.
- Developing and producing digital cartographic data bases and products.
- Collecting data on a routine basis to determine the quantity, quality, and use of surface and ground water.
- Conducting water-resource appraisals in order to describe the consequences of alternative plans for developing land and water resources.
- Conducting research in ground- and surface-water hydrology and hydraulics and coordinating water-data acquisition with other Federal agencies.
- Using remotely sensed data to develop new cartographic, geologic, and hydrologic research techniques for natural-resources planning and management.
- Providing earth-science information through an extensive publications program and a network of public-access points.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the USGS remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation--providing "Earth science in the public service."

WATER RESOURCES DIVISION BASIC MISSION AND PROGRAM

The mission of the Water Resources Division (WRD) is to provide the hydrologic information and understanding needed for the optimum use and management of the Nation's water resources. To accomplish this mission, the WRD, in cooperation with local, State, and Federal agencies, uses a wide variety of techniques to collect and interpret hydrologic information and to transfer that information to the water-user community. An integral part of that mission includes publishing and disseminating the earth-science information needed to understand, plan the use of, and manage the Nation's energy, land, mineral, and water resources.

This is accomplished, in large part, through cooperation with other Federal and non-Federal agencies, by

- Systematically collecting data needed for evaluating the quantity, quality, and use of the Nation's water resources.
- Conducting analytical and interpretive water-resources appraisals of the occurrence, availability, and physical, chemical, and biological characteristics of surface and ground water.
- Conducting basic and applied research in hydraulics, hydrology, and water chemistry, solute transport, and hydraulic modeling to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade.
- Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.
- Coordinating with other Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground water.
- Providing scientific and technical assistance in hydrology fields to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to International agencies on behalf of the Department of State.

CALIFORNIA DISTRICT ORGANIZATION

The headquarters for the California District is in Sacramento. Hydrologic investigations and data collection during fiscal year 1993 were done from 2 project offices (Sacramento and San Diego) and 8 field offices. These offices and supporting units are shown in the District organization chart (fig. 1). The location of each office is shown in figure 2. (At the end of fiscal year 1993, several field offices were closed and one was opened. These are noted to provide up-to-date information.)

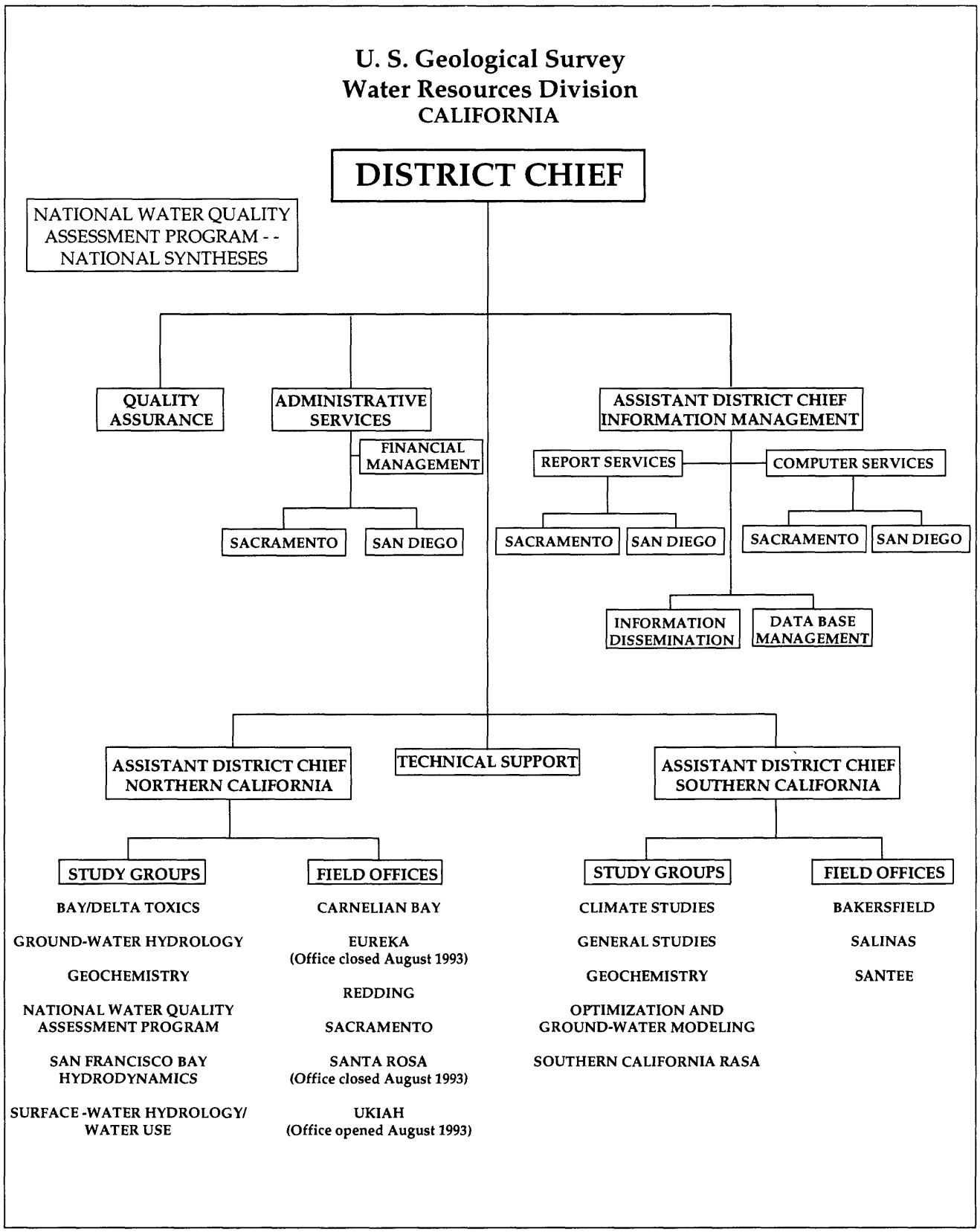


Figure 1. Organization chart for the California District, 1993.

Figure 2. Location of offices in the California District, 1993.

CALIFORNIA DISTRICT ADDRESSES

Inquiries regarding projects described in this report may be directed to the District Office. Addresses for the offices of the District Chief and Assistant District Chiefs and Field Office Chiefs are listed below. Locations of the offices are shown in figure 2.

DISTRICT CHIEF

Michael V. Shulters District Chief	(916) 978-4633	U.S. Geological Survey 2800 Cottage Way, Rm W-2233 Sacramento, CA 95825

ASSISTANT DISTRICT CHIEFS

Steven J. Deverel Assistant District Chief-Northern California	(916) 978-4648	2800 Cottage Way, Rm W-2233 Sacramento, CA 95825
Anthony Buono Assistant District Chief-Southern California	(619) 637-9005	5735 Kearny Villa Road Suite O San Diego, CA 92123
Frederick J. Heimes Assistant District Chief- Information Management	(916) 978-4640	2800 Cottage Way, Rm W-2233 Sacramento, CA 95825

FIELD OFFICE CHIEFS

Bakersfield Paul D. Hayes	(805) 861-4347	3131 Pegasus Drive Bakersfield, CA 93308
Carnelian Bay James R. Mullen	(916) 546-0187	5229 North Lake Boulevard P.O. Box 1360 Carnelian Bay, CA 96140
Eureka	Office closed August 1993	
Redding Michael F. Friebel	(916) 246-5282	11075 Black Marble Way Redding, CA 96003
Sacramento Steven W. Anderson	(916) 978-4660	3419-A Arden Way Sacramento, CA 95825
Salinas Larry F. Trujillo	(408) 754-6717	1636 East Alisal Street Salinas, CA 93905 P.O. Box 5027 Salinas, CA 93915
Santa Rosa	Office closed August 1993	
Santee Jeffrey Agajanian	(619) 557-5155	10130 Mission Gorge Road Santee, CA 92071
Ukiah Kenneth L. Markham	Office opened August 1993 (707) 462-2794	1240 Airport Park Boulevard Ukiah, CA 95482

CALIFORNIA DISTRICT FUNDING

Programs of the Water Resources Division in California are funded by (1) Federal appropriations to the Geological Survey by Congress; (2) Federal and State cooperation, in which the Water Resources Division represents national interest and the cooperating agencies represent State and local interest with the funding generally shared equally (the Federal share comes from direct Congressional appropriations); and (3) other Federal agencies (OFA). Total funds and sources of funding for fiscal year 1993 are shown in figure 3. [The fiscal year (FY) is from October 1 to September 30 and is designated by the calendar year in which it ends.]

Funding percentages for investigations for fiscal year 1993 in each of the broad categories of hydrologic-data collection, areal appraisals and interpretive studies, and research projects are shown in figure 4.

In fiscal year 1993, the following State, local, and Federal agencies contributed funds and services under cooperative programs with the California District:

State Agencies

California Department of Conservation
California Department of Boating and Waterways
California Department of Parks and Recreation
California Department of Transportation
California Department of Water Resources
California State Water Resources Control Board
California Regional Water Quality Control Board
Central Valley Region
San Francisco Bay Region
California Polytechnic State University-San Luis Obispo

Local Agencies

Adelanto, city of
Alameda County Flood Control and Water Conservation District
Alameda County Water District
Antelope Valley-East Kern Water Agency
Atherton, city of
Barstow, city of
Calaveras County Water District
Calleguas Municipal Water District
Carpenteria County Water District
Casitas Municipal Water District
Coachella Valley Water District
Contra Costa County Flood Control and Water Conservation District
Contra Costa Water District
Crestline-Lake Arrowhead Water Agency
Desert Water Agency
East Bay Municipal Utility District
Eastern Municipal Water District
Energy Growth Partnership
Five Bears Hydroelectric
Georgetown Divide Public Utility District
Highland Hydro Constructors

Local Agencies--*Continued*

Hopland Band of Pomo Indians
Humboldt Bay Municipal Water District
Imperial County Department of Public Works
Imperial Irrigation District
Independent Hydro Developers
Indian Wells Valley Water District
Lassen Station Hydroelectric
Los Angeles County Department of Public Works
Louisiana State University and A&M College
Madera Irrigation District
Malacha Power Project
Marin Municipal Water District
Mendocino County Water Agency
Merced, city of
Merced Irrigation District
Mojave Water Agency
Mono County
Montecito Water District
Monterey County Water Resources Agency
Monterey Peninsula Water Management District
Moronogo Band of Mission Indians
Nelson Creek Power Company
Nevada Irrigation District
Oakdale-South San Joaquin Irrigation District
Olcese Water District
Orange County Water District
Oroville-Wyandotte Irrigation District
Pacific Gas & Electric Company
PacificCorp
Palmdale, city of
Palo Alto, city of
Pechanga Indian Reservation
Placer County Water Agency
Riverside County Flood Control and Water Conservation District
Rock Creek Limited Partnership

Local Agencies--*Continued*

Sacramento Municipal Utility District
Sacramento County Regional Sanitation District
San Benito County Water District
San Bernardino County Flood Control District
San Bernardino Valley Municipal Water District
San Diego, city of
San Diego County Department of Public Works
San Francisco, city and county of,
Hetch Hetchy Water and Power
San Francisco Water Department
San Luis Obispo County Engineering Department
San Mateo County
Santa Barbara, city of
Santa Barbara County Flood Control and Water Conservation District
Santa Barbara County Water Agency
Santa Clara Valley Water district
Santa Cruz, city of
Santa Cruz County Flood Control and Water Conservation District
Santa Margarita River Watershed (watermaster)
Santa Maria Valley Water Conservation District
Santa Ynez River Water Conservation District
Scotts Valley Water District
Sonoma County Planning Department
Sonoma County Water Agency
South Sutter Water District
Southern California Edison Company
STS Hydropower Ltd.
Synergics, Inc.
Tulare County Flood Control District
Tuolumne County
Turlock Irrigation District
United Water Conservation District

Local Agencies--*Continued*

Ventura County Public Works Agency
Water Replenishment District of Southern California
Woodbridge Irrigation District
Yolo County Flood Control and Water Conservation District
Yuba County Water Agency

Federal Agencies

Department of the Air Force
- Edwards Air Force Base
- Vandenberg Air Force Base

Department of the Army
- Corps of Engineers
  - Los Angeles District
  - Sacramento District
  - San Francisco District
  - Mobile, Alabama District
- Fort Irwin

U.S. Department of the Interior
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Reclamation
- National Park Service

U.S. Environmental Protection Agency

Department of the Navy
- U.S. Navy
  - Naval Air Station, Point Mugu
  - Navy Southwest, San Diego
- U.S. Marine Corps
  - Marine Corps Air Ground Combat Center, Twentynine Palms
  - Marine Corps Base, Camp Pendleton
  - Marine Corps Logistics Base, Barstow

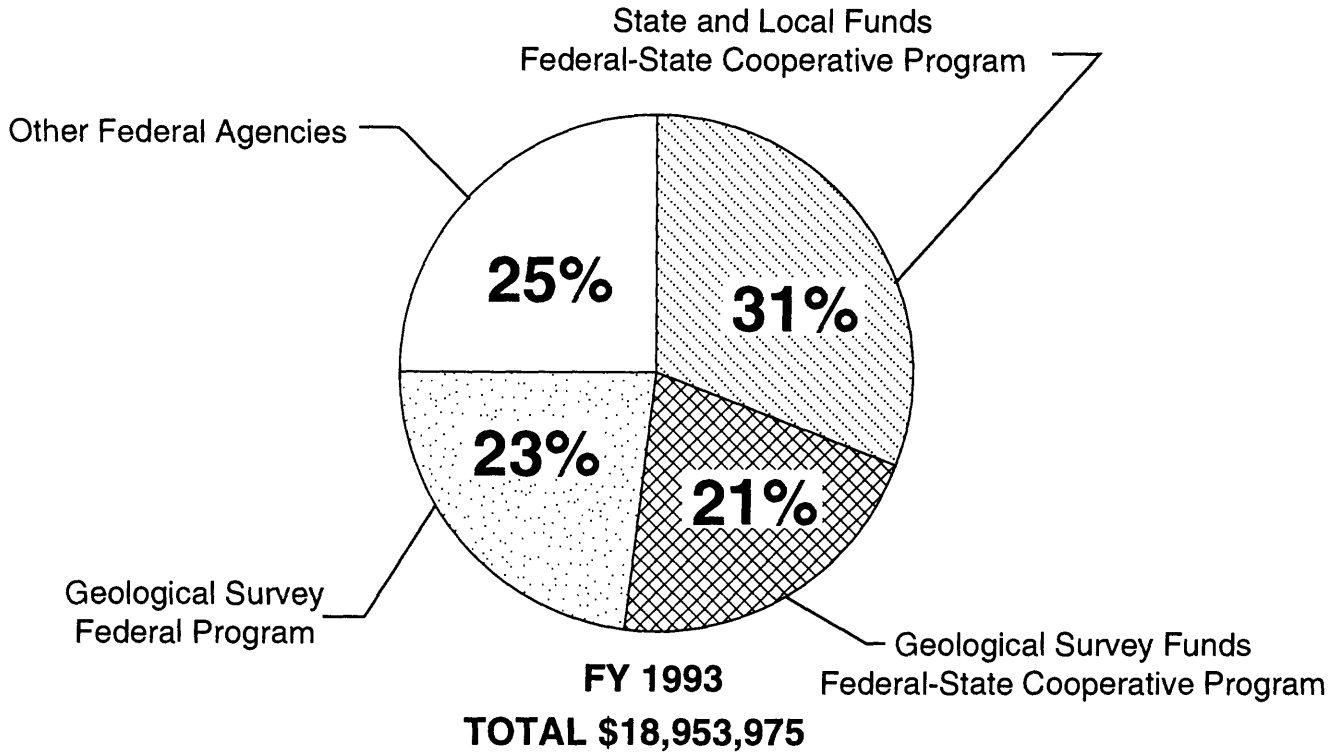


Figure 3. Sources of California District funds in fiscal year 1993.

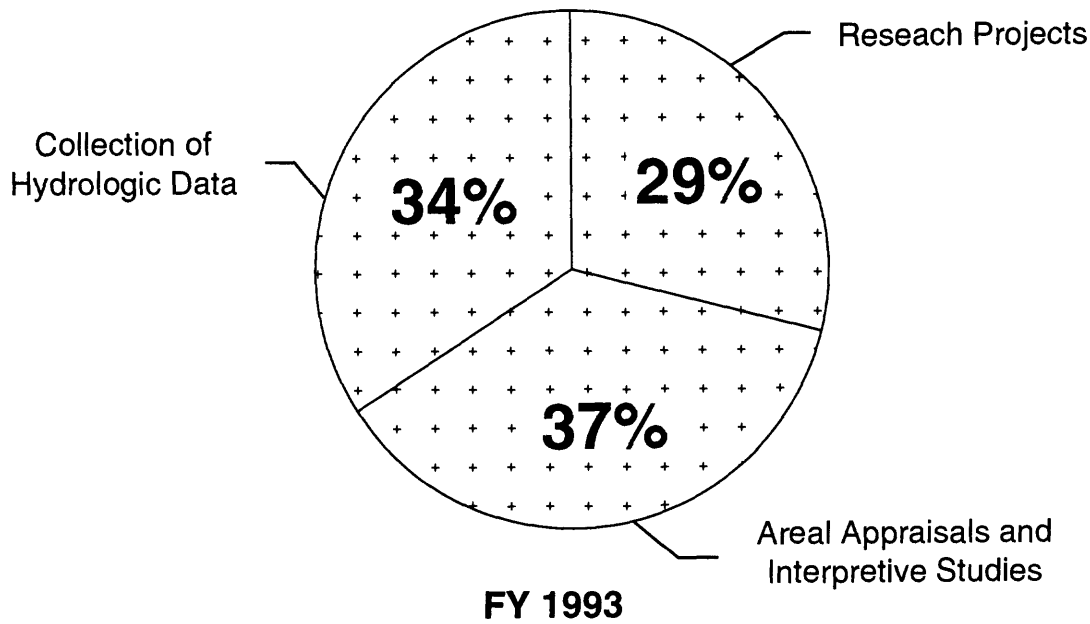


Figure 4. Categories of investigations in the California District, by funding, fiscal year 1993.

WATER CONDITIONS

The 1993 water year (October 1, 1992, to September 30, 1993) finally brought statewide relief from the 6 years of drought that beset California from 1987 to 1992. For the first time since 1986, precipitation exceeded average throughout the State (fig. 5). Statewide precipitation was 142 percent of the long-term average--the highest since 1983, a record-setting water year. Runoff was above average in all but the South Lahontan region (figs. 6 and 7). Statewide runoff was 125 percent of average. Runoff in the important Sacramento River basin, which typically provides about one-quarter of the water used by California's farms and cities, was 122 percent of average (figs. 6 and 8). Reservoir storage, severely depleted by the 6 years of drought, recovered and, by the end of the water year, was 106 percent of average for the date (fig. 9)--significantly improved from 56 percent of average for the date at the beginning of the water year.

The storms that brought relief from the drought also brought severe flooding to southern California. As shown in figure 7, runoff for 1993 for Arroyo Seco near Pasadena was the highest since 1969--the year of highest runoff on record. This was the second consecutive year of above-average precipitation and runoff in southern California, and it is safe to say that the drought there is over. The turnaround for the rest of the State was not so dramatic, however. As shown for all other stations in figure 7 and for the Sacramento basin in figure 8, runoff for 1993 was the highest since only 1986, the last nondrought year. Although the statewide drought was declared over by State officials as water-supply concerns were alleviated, the lingering effects of the drought and the persistence of its associated climatic patterns may require a wet year in 1994 before all agree with this declaration.

1993 WATER YEAR

The 1993 water year began with hope for a change from the persistent drought with October precipitation well above average in all regions of the State. However, October is not usually a very wet month and the above-average precipitation provided more hope than water. November, which typically marks the beginning of California's rainy season, returned to well below-average conditions statewide. Lake Tahoe (fig. 10), below its natural rim since September 1990, reached a record-low elevation of 6,220.26 feet on November 30, 1992. The previous record low was 6,221.74 feet in December 1934. Early December storms began the period of wet weather that persisted into spring and finally brought the State out of its drought. In spite of higher than average precipitation in December, however, streamflow runoff continued to lag and did not reach above-average runoff until January. At the end of December, reservoir storage was still only 58 percent of average for the date.

January precipitation was more than twice average for most of the State, with precipitation in the South Coastal region more than 4 1/2 times average. With drainage basins saturated, substantial runoff began with areas of flooding across the entire length of the State. January runoff was 150 percent of average statewide but was much greater in the south. Runoff in the Central Coast region was more than 4 times average and in the South Coast region more than 10 times average. Several rivers in southern California had record peak flow. Mudslides and floods caused death and destruction on several rivers. In northern California, rivers reached their highest levels since 1986. Smaller reservoirs began to fill or encroach on storage allocated for flood protection. The Sacramento River overflowed into the flood-control channels that protect the city of Sacramento, also for the first time since 1986. In January, the rapid accumulation of snow in the mountains caused the closures of major highways, structural damage to buildings, and propane-tank explosions caused by leaking gas.

As a result of the January storms, President Clinton ordered Federal disaster aid for 22 counties and 3 cities across California. Statewide, the storms caused at least 22 deaths and damaged more than 1,000 residences and commercial properties.

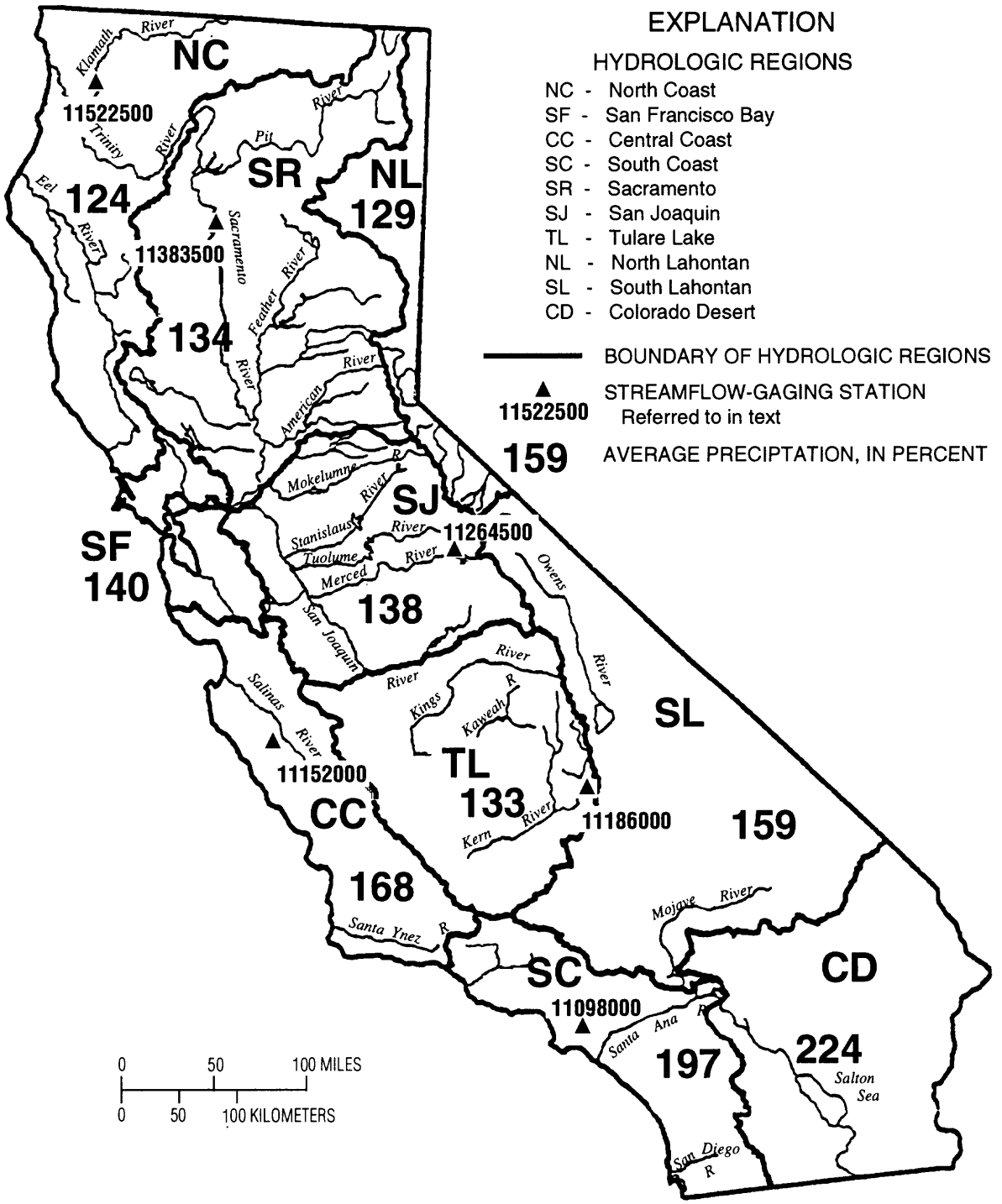


Figure 5. Precipitation for the 1993 water year, in percent, by hydrologic region relative to long-term average. Statewide precipitation was 142 percent. (Data compiled by California Department of Water Resources)

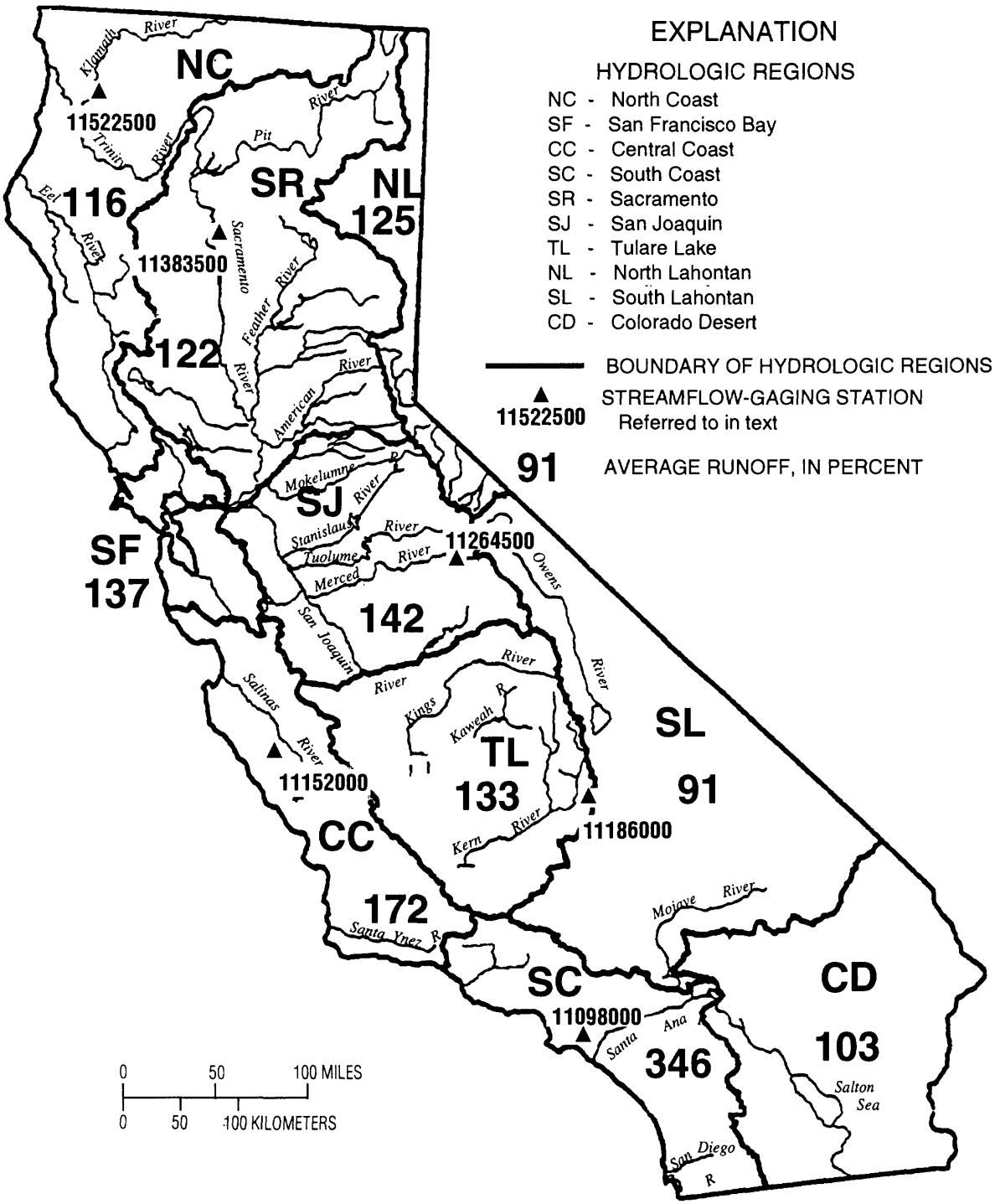


Figure 6. Runoff for the 1993 water year, in percent, by hydrologic region relative to long-term average. Statewide runoff was 125 percent. (Data compiled by California Department of Water Resources)

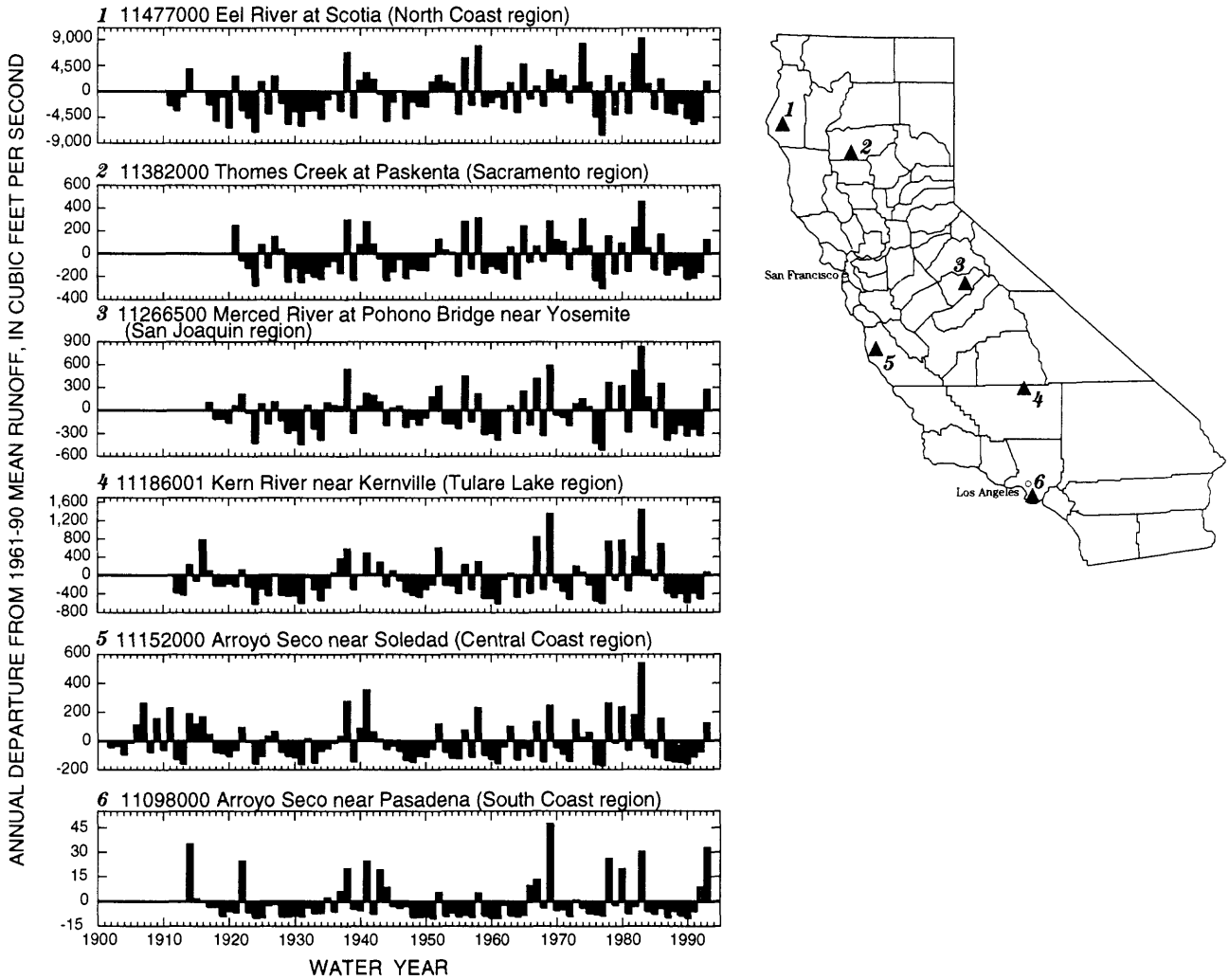


Figure 7. Annual departure from 1961-90 mean runoff at six unregulated streamflow-gaging stations through 1993 water year.

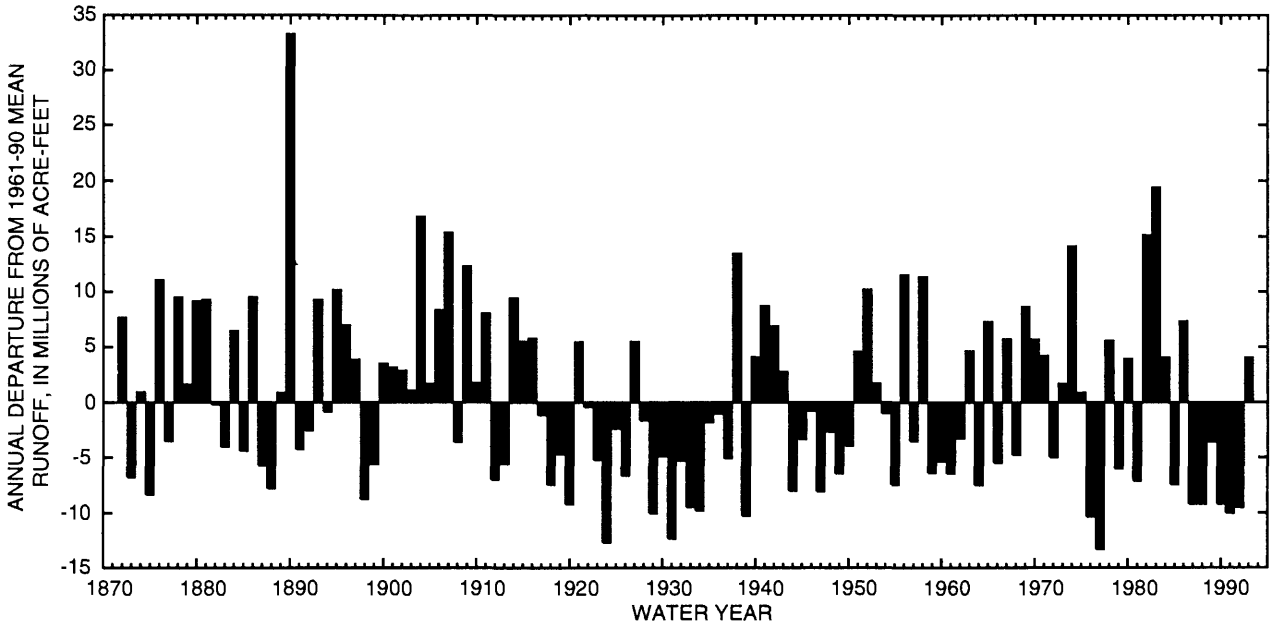


Figure 8. Annual departure from 1961-90 mean runoff in the Sacramento River basin for water years 1872-1993. The Sacramento River basin runoff is the combined flows from the upper Sacramento, Feather, Yuba, and American River basins, adjusted to represent unimpaired runoff. Flows for 1872 to 1905 were estimated from historical data. Flow for 1993 is from a February 1, 1993, forecast. (Data compiled from the California Department of Water Resources)

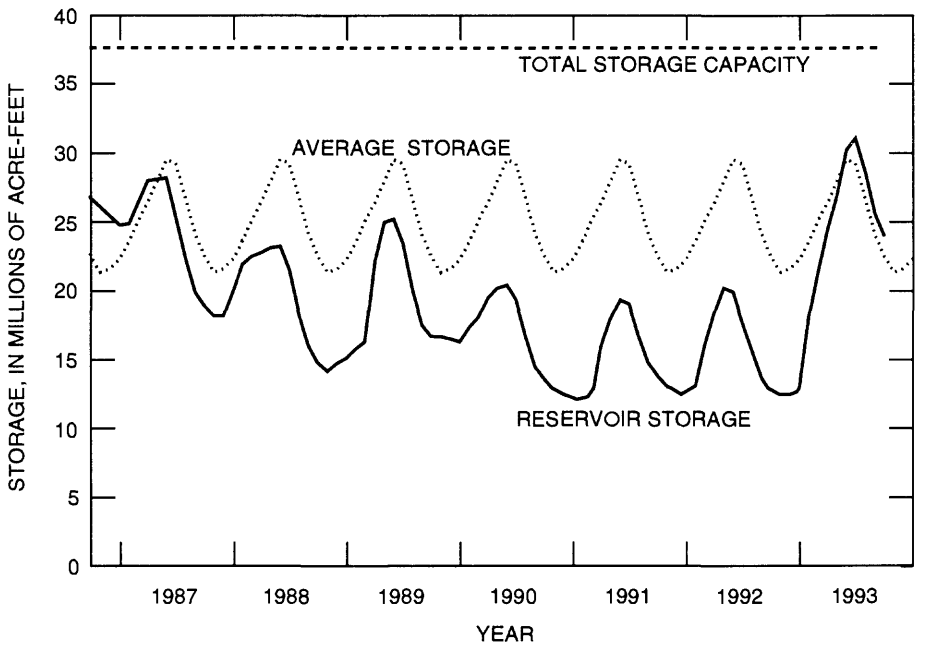


Figure 9. Statewide reservoir storage, 1986-93, for 155 major reservoirs. (Data compiled by California Department of Water Resources)

Above-average precipitation and runoff continued into February in most parts of the State. The precipitation distribution pattern that began in October continued, with the southern part of the State receiving proportionately more precipitation (relative to long-term averages) than the north. In fact, January and February precipitation in the South Coast region virtually matched, in absolute terms, that in the Sacramento region and exceeded that in the North Coast region which typically has relatively high precipitation. February runoff in the North Coast region actually fell below average for the month.

By early February, snowfall in the mountains already had reached or exceeded the average for April 1 when the snowpack typically reaches its maximum. The snowpack accumulated through the end of February at a rate nearly that of the winter of 1982-83, the maximum on record. Reservoir storage at the end of February reached 85 percent of average for the date. Increasing reservoir storage, a large snowpack, and forecasts of above-average runoff for the year resulted in declarations by water managers and the governor (February 24, 1993) that "the drought is over."

March ended the winter storm season with precipitation near average in the central part of the State and well below average in the northern and southern parts of the State. Runoff continued above average and, in March, snowmelt began to make significant contributions to runoff. Flood-control operations began for several major reservoirs in the Sacramento River basins. April precipitation was well below average except in the North Coast and northern Sacramento regions, reversing the distribution exhibited during the winter. No rain in San Diego during April set a record. The snowpack in the Sierra Nevada decreased slightly during March and April, unable to keep up with the record pace of the 1983 water year.

A series of storms in late May and early June provided the last significant precipitation for the year. In May, precipitation fell primarily in the northern part of the State, while in early June precipitation was statewide. The upper Sacramento River reached the flood-warning stage and overflowed into the flood bypass channel at the Tisdale Weir, which was the latest in the year for it to overflow since the height of the weir was raised in 1935. Snowmelt runoff peaked in late May and continued through June and into early July. Reservoir storage surpassed average for the date by the end of May.

July through September was exceptionally dry, even considering California's normally dry summer. Although storm systems in the north brought some showers to the higher mountains, there was a notable absence of the tropical moisture moving north out of Mexico, which commonly produces showers in the southern Sierra Nevada and southern deserts. Most observers in the Sierra Nevada reported little or no rain. In spite of the dry summer, runoff in many areas of the State continued above average through the end of the water year. Reservoir storage also remained above average.

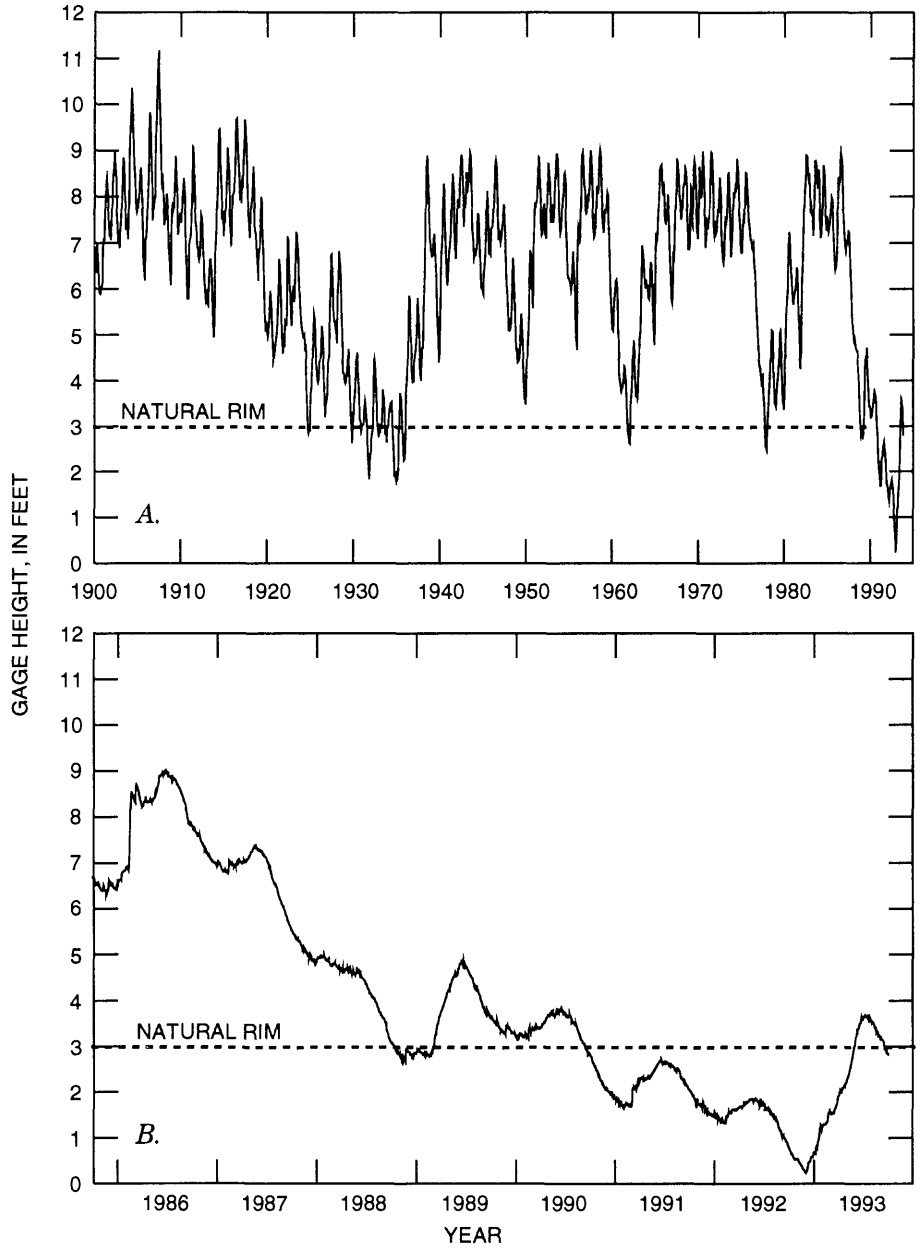


Figure 10. Water levels in Lake Tahoe. The natural rim is the level below which water cannot flow out of the lake. Add 6,220 feet to adjust gage heights to elevations above sea level. *A.* Month-end water levels for 1900-93. *B.* Daily water levels for October 1985 to September 1993.

FLOODING IN SOUTHERN CALIFORNIA, JANUARY-FEBRUARY 1993

From January 6 to February 28, 1993, a series of storms produced 20 to 40 inches of rain over much of the southern California coastal and mountain areas and more than 52 inches at some locations in the San Bernardino Mountains.

The first major runoff peak occurred January 6 and 7, as a result of heavy rainfall on a fairly substantial snowpack that had accumulated in December 1992 in the San Gabriel and San Bernardino Mountains. The recurrence intervals (average interval of time in which a given peak flow will be equaled or exceeded once) for these peak flows in the Mojave and Santa Ana River Basins were about 25 to 50 years. In the Victorville area, the Mojave River overtopped a levee, causing damage to a housing tract.

A second major runoff peak occurred late on January 16, with the most severe flooding in the Santa Margarita and San Luis Rey River basins. Rainfall data show the 6-hour precipitation frequency (similar to recurrence interval for streamflow) was more than 100 years. This intense precipitation fell on a drainage basin still saturated from the January 6-7 storm. Several peaks of record were recorded in the Santa Margarita River basin, some at streamflow-gaging stations with as much as 70 years of record. Peak flows exceeded a 100-year recurrence interval flood at several streamflow-gaging stations. The peak stage at the Murrieta Creek near Temecula streamflow-gaging station overtopped the gage shelter, exceeding the previous peak of record by more than 5 feet. Floodwaters caused damage in the city of Temecula. The Santa Margarita River near the Temecula streamflow-gaging station, just downstream from the Murrieta Creek gage, also had a peak stage exceeding the previous peak by more than 5 feet. The Santa Margarita River caused extensive flooding and damage at the U.S. Marine Corps' Camp Pendleton near the mouth of the river, where the debris-choked river washed out a bridge and deposited large quantities of sediment and debris as floodwaters spread over the broad, flat floodplain.

A nearly identical storm pattern as that in January developed in early February. Major storms and resultant runoff peaks occurred on February 8 and from February 18 to 19. The peak streamflows were in the 25- to 50-year recurrence interval range. Significant local flooding occurred because of the saturated conditions in the drainage basins owing to the January storms. Major bank failures occurred along the Mojave River in the Silver Lakes area as a result of sustained high flow in the normally dry channel.

CLIMATOLOGICAL PERSPECTIVES

The winters of water years 1992 and 1993 included periods of nearly continuous storms that caused severe flooding in southern California, especially during February 1992 and January-February 1993. The intensity of these winter storms may be the result of a very recent tendency for winter storms to focus on the southern part of the State, as well as on Arizona. This tendency may be associated with changes in the frequency and severity of El Nino since about 1965 but is more directly a result of broad changes in winter atmospheric circulations over the eastern North Pacific Ocean and North America. This change in winter-storm patterns also seems to be associated with certain long-term atmospheric trends that facilitated the recent drought in California.

The winter storms of both February 1992 and January-February 1993 were spun off from large regions of low pressure in the atmosphere off the coast of northern California and Oregon. For both winters, this low-pressure region was forced farther south than normal by a high-pressure area to its north, over Alaska and the Gulf of Alaska. The storms built strength as they approached southern California by interacting with subtropical jet streams that also were crossing the Baja California and southern California coasts carrying large amounts of moisture. In February 1992, the low-pressure system was held far enough offshore so that the Sierra Nevada received much less precipitation (relatively) than did the coastal ranges and southern California. In January and February 1993, the high-pressure systems were stronger to the north of the low-pressure system than to the east and the Sierra Nevada received a considerable share of the precipitation from the winter storms. However, in both years, southern California took the brunt of the storms that were spun off the broad low-pressure system.

The high-pressure ridge that held the low-pressure system offshore during the winters of 1992 and 1993 was located along generally the same axis as the ridge of high pressures that was common during the drought winters and that had decreased the likelihood of winter storms reaching California and the Pacific Northwest. The ridge of high pressures over the continent and especially over the Pacific Northwest has prevented storms from arriving in California--especially northern California, resulting in the recent (and possibly ongoing) California drought--especially in northern California.

Is the Drought Over?

Is the extended drought that began in 1987 really over? Hydrologic conditions for 1993 certainly indicate the end of the drought and, for most areas of the State, the water-supply problems associated with the drought also are over. However, it will take years to recover from the effects of the drought on the environment, ground-water storage, and some surface-water reservoirs. Three major reservoirs--Lake Tahoe, Lake Berryessa, and New Melones Reservoir--remain low because of their large storage capacity relative to drainage basin size.

Lake Tahoe (fig. 10), which has a gated dam at the outlet to provide controlled storage (usable storage capacity 732,000 acre-feet), had a fourth consecutive year with no usable storage at the end of the water year. However, the wet winter of 1993 did provide some improvement, and in late May 1993, the lake level rose above the natural rim, providing outflow into the Truckee River. The lake had been continuously below the rim since September 1990. However, the lake remained above the rim only until mid-September. It will require several years for the lake to recover to optimal levels.

From a broader perspective, a general consensus that the drought is indeed over may still depend on what happens during the 1994 water year. Because of the lingering adverse effects of 6 years of drought, as well as the possibility that dry conditions could recur, 1993 could be just a brief respite in a longer period of drought. A second wet year would certainly put such questions to rest.

In southern California, 1993 does mark the second consecutive year of above-average precipitation and runoff. From a local perspective, 1991 was the last year of an 8-year drought in southern California (fig. 7) (The drought in southern California actually began in 1984, 3 years earlier than in northern and central California.) The drought ended with the storms in February 1992. Southern California will maintain a continued interest in the hydrologic conditions to the north, however, because of their dependence on water supplied from the north.

- PAGE 19 FOLLOWS -

PROJECT DESCRIPTIONS

SURFACE-WATER STATIONS

Number: CA001

Location: Statewide (See accompanying map)

Project Chief: Kenneth W. Lee

Period of Project: Continuing

Problem: Surface-water information is needed for surveillance, planning, design, hazard warning, and operation and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. An appropriate data base is necessary to provide this information.

Objectives: Collect timely and high-quality surface-water data for (1) assessment of water resources; (2) operation of reservoirs or industries; (3) forecasting flow; (4) disposal of wastes and pollution controls; (5) discharge data to accompany water-quality measurement; (6) compact and legal requirements; and (7) research or special studies. Collect data necessary for analytical studies to define the statistical properties of, and trends in the occurrence of water in streams, lakes, and estuaries for use in planning and design.

Approach: Standard methods of data collection will be used as described in the series "Techniques of Water-Resources Investigations of the U.S. Geological Survey." Partial-record gaging is used instead of continuous-record gaging where it serves the required purpose.

Progress: Surface-water data for 790 continuous-record streamflow stations were collected, reviewed, and compiled for publication. Data were collected or reviewed from 147 reservoir stations. Data were collected and compiled for 93 partial-record stream and reservoir sites that provide peak flow, low flow, seasonal flow, limited range of discharge, or stage information. Installation of additional satellite data-collection platforms and telephone modems for real-time transmission of streamflow information from selected sites continued. Data for 1992 were published in four volumes of the annual data report series.

Plans for Fiscal Year 1994: Statewide data collection and review, as well as installation of additional satellite data-collection platforms and telephone modems, will continue. Streamflow data will be published in the annual data report for water year 1993.

Reports:

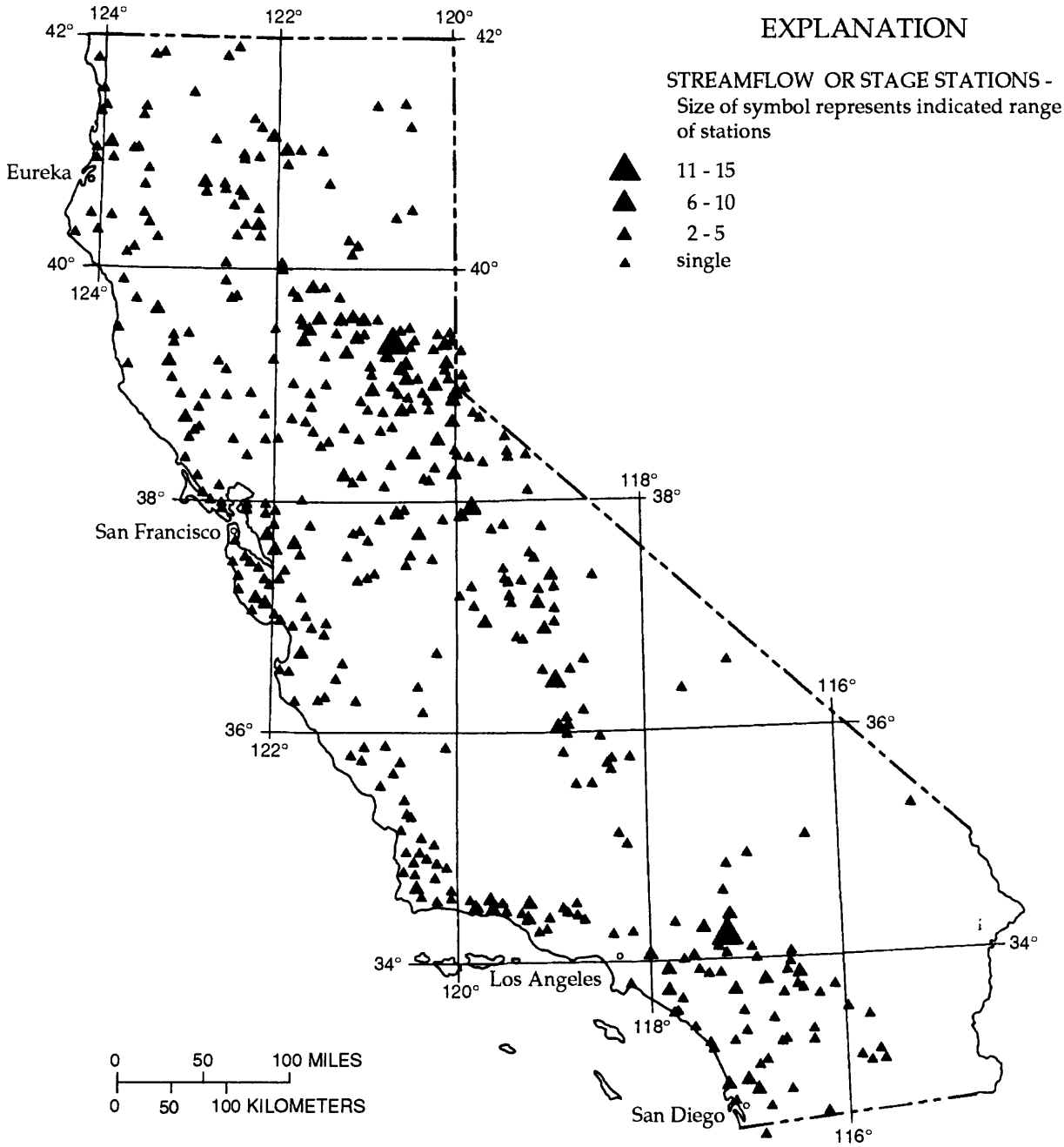
Anderson, S.W., Hunter, T.C., Hoffman, E.B., and Mullen, J.R., 1993, Water resources data--California, water year 1992. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-92-3, 529 p.

Anderson, S.W., Mullen, J.R., Friebel, M.F., and Markham, K.L., 1993, Water resources data--California, water year 1992. Volume 4. Northern Central Valley basins and the Great Basin from Honey Lake basin to Oregon State line: U.S. Geological Survey Water-Data Report CA-92-4, 439 p.

Bowers, J.C., 1993, Southern California storms and floods of January-February 1993: U.S. Geological Survey Open-File Report 93-411, 2 p. (Water Fact Sheet)

Hoffman, E.B., Bowers, J.C., Mullen, J.R., and Hayes, P.D., 1993, Water resources data--California, water year 1992. Volume 1. Southern Great Basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-92-1, 448 p.

Markham, K.L., Palmer, J.R., Friebel, M.F., and Trujillo, L.F., 1993, Water resources data--California, water year 1992. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-92-2, 405 p.



Location of streamflow-measuring stations.

GROUND-WATER STATIONS

Number: CA002

Location: Statewide (See accompanying map)

Project Chief: Charles E. Lamb

Period of Project: Continuing

Problem: Ground water accounts for 39 percent of freshwater withdrawals in California--more than 14 billion gallons per day. More than 10 million people are served by ground-water supplies. In addition, 12.5 billion gallons per day are withdrawn for irrigation. The distribution and quality of ground water is highly variable related to geology, natural, and manmade stresses. Monitoring of ground-water levels and chemistry is essential to the management and development of the resource.

Objectives: Collect ground-water-level and ground-water-quality data to assess the quantity, quality, and distribution of ground water. These data will serve as management tools for national and local water planning.

Approach: Water levels will be measured and recorded with varying frequencies: continuously, monthly, semiannually, and annually. Water samples will be collected for field and laboratory analysis. Standard methods of data collection will be used as described in the "National Handbook of Recommended Methods for Water-Data Acquisition" and other Water Resources Department memorandums.

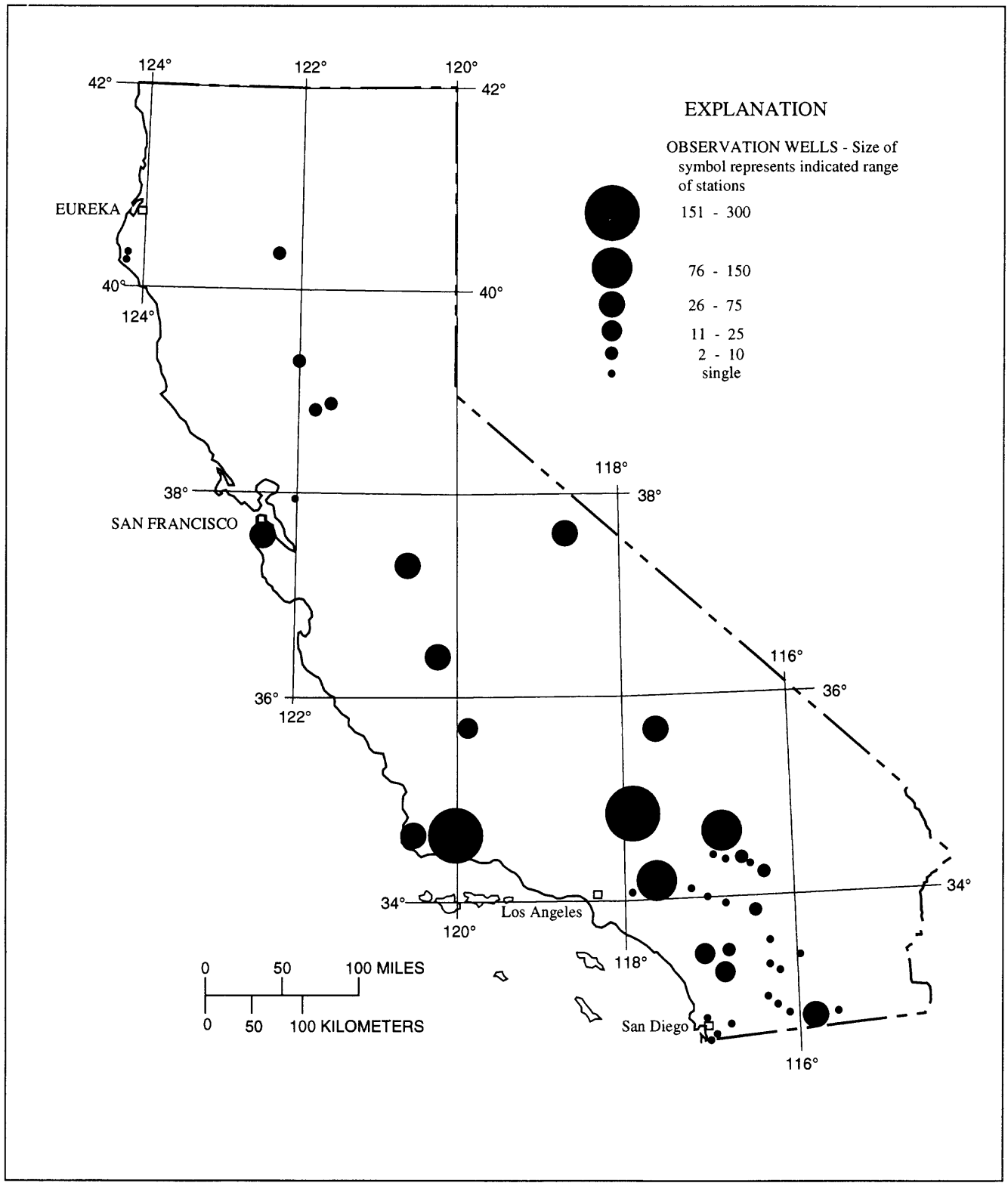
Progress: Collection and compilation of ground-water-level data continued at 1,056 long-term sites, 175 short-term sites, and 34 continuous recorder wells. Samples were collected and analyzed for chemical quality at 324 scheduled long-term sites and 65 short-term project sites. Data for water year 1992 were published in a separate volume of the annual data report series.

Plans for Fiscal Year 1994: Statewide data collection and record processing for ground-water levels and ground-water quality will continue. All data will be published in a separate volume of the annual data report series.

Reports:

Hamlin, S.N., 1993, Summary of ground-water data and evaluation of ground-water monitoring networks for eastern Merced County, California: U.S. Geological Survey Water-Resources Investigations Report 92-4153, 14 p.

Johnson, J.A., and Fong-Frydendal, L.J., 1993, Water resources data--California, water year 1992. U.S. Geological Survey Water-Data Report CA-92-5, 437 p.



Location of selected observation wells.

WATER-QUALITY STATIONS

Number: CA003

Location: Statewide (See accompanying map)

Project Chief: Rick T. Iwatsubo

Period of Project: Continuing

Problem: Water-resource planning and water-quality assessment require a nationwide base level of relatively standardized information. For informed planning and realistic assessment of the water resource, the chemical and physical quality of the rivers and streams must be defined and monitored.

Objectives: Provide a national bank of water-quality data for broad Federal planning and action programs and provide data for Federal management of interstate and international waters.

Approach: A network of water-quality stations will be operated to provide averages for chemical concentrations, loads, and time trends as required by planning and management agencies.

Progress: Water-quality data were collected periodically at many sites throughout California. Water-quality samples were collected bimonthly at 12 and quarterly at 6 NASQAN (National Stream Quality Accounting Network) stations, and quarterly at 3 Hydrologic Benchmark stations. Water temperature or specific conductance were measured continuously at 48 sites. Precipitation samples were collected weekly at the National Trends Network stations in the Los Padres National Forest and at Yreka. Water-quality data also were collected at 73 stream or reservoir sites. Water samples were analyzed from 389 observation wells. Data for 1992 were published in the annual data report series.

Plans for Fiscal Year 1994: Statewide data collection and processing of surface-water, ground-water, and precipitation samples will continue. All data will be published in the annual data report series.

Reports:

Anderson, S.W., Hunter, T.C., Hoffman, E.B., and Mullen, J.R., 1993, Water resources data--California, water year 1992. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-92-3, 529 p.

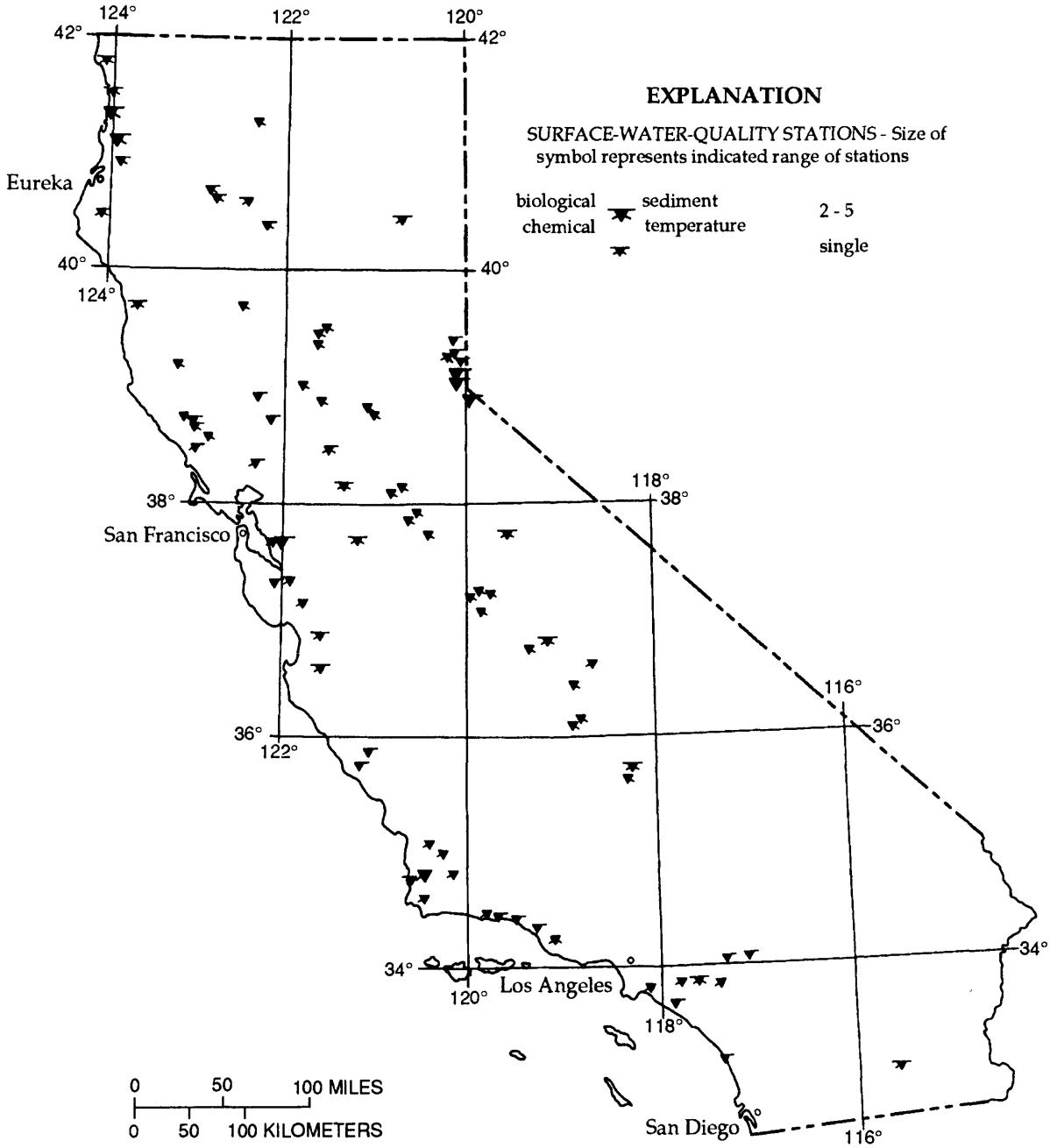
Anderson, S.W., Mullen, J.R., Friebel, M.F., and Markham, K.L., 1993, Water resources data--California, water year 1992. Volume 4. Northern Central Valley basins and the Great Basin from Honey Lake basin to Oregon State line: U.S. Geological Survey Water-Data Report CA-92-4, 439 p.

Hoffman, E.B., Bowers, J.C., Mullen, J.R., and Hayes, P.D., 1993, Water resources data--California, water year 1992. Volume 1. Southern Great Basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-92-1, 448 p.

Iwatsubo, R.T., and Woodward, Richard, 1993, California--Stream-water quality, *in* National Water Summary 1990-91--Hydrologic events and stream water quality: U.S. Geological Water-Supply Paper 2400, p 187-196.

Johnson, J.A., and Fong-Frydendal, L.J., 1993, Water resources data--California, water year 1992. U.S. Geological Survey Water-Data Report CA-92-5, 437 p.

Markham, K.L., Palmer, J.R., Friebel, M.F., and Trujillo, L.F., 1993, Water resources data--California, water year 1992. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-92-2, 405 p.



Location of surface-water-quality monitoring stations.

SEDIMENT STATIONS

Number: CA004

Location: Statewide (See accompanying map for water-quality stations, page 25)

Project Chief: James M. Knott

Period of Project: Continuing

Problem: The environmental effects of erosion, movement, and deposition of sediment can be devastating. Knowledge of sediment transport is essential in the development and management of water and land resources. The wide variation in drainage basin and precipitation characteristics in California results in significant differences in the quantity and quality of fluvial sediment; this variability requires that sediment be monitored frequently at several locations within the State for effective assessment of sediment transport.

Objectives: Provide sediment data that can be used to (1) develop land-management practices that will reduce erosion rates; (2) evaluate the effects of timber harvesting on fisheries; (3) determine the effects of debris basins and drop structures on sediment transport; (4) monitor reservoir capacity losses for flood control and water supply; (5) determine the relation of sediment to lake algae growth; (6) evaluate changes in coastal morphology caused by coastal river sediment transport; (7) determine the effects of urbanization on channel morphology; and (8) estimate channel change resulting from proposed dam sites.

Approach: Suspended-sediment and bed-material samples will be collected at specific streams within the State. Bed-load samples also will be collected at those sites that are total-load stations if the stream characteristics are suitable. Daily concentration and suspended-sediment discharge will be computed for all daily sediment stations. Monthly bed-load discharge will be estimated for all daily total-load stations. Selected suspended-sediment, bed-load, and bed-material samples will be analyzed for particle-size distribution.

Progress: Sediment data were collected at 12 daily, 25 periodic, 15 NASQAN (National Stream Quality Accounting Network), and 3 Hydrologic Benchmark stations. Data for 1992 were published in four volumes of the annual data report series.

Plans for Fiscal Year 1994: Statewide data collection and processing of sediment samples will continue. All data will be published in the annual data report series.

Reports:

Anderson, S.W., Hunter, T.C., Hoffman, E.B., and Mullen, J.R., 1993, Water resources data--California, water year 1992. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-92-3, 529 p.

Anderson, S.W., Mullen, J.R., Friebel, M.F., and Markham, K.L., 1993, Water resources data--California, water year 1992. Volume 4. Northern Central Valley basins and the Great Basin from Honey Lake basin to Oregon State line: U.S. Geological Survey Water-Data Report CA-92-4, 439 p.

Hoffman, E.B., Bowers, J.C., Mullen, J.R., and Hayes, P.D., 1993, Water resources data--California, water year 1992. Volume 1. Southern Great Basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-92-1, 448 p.

Markham, K.L., Palmer, J.R., Friebel, M.F., and Trujillo, L.F., 1993, Water resources data--California, water year 1992. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-92-2, 405 p.

NATIONAL TRENDS NETWORK FOR MONITORING ATMOSPHERIC DEPOSITION

Number: CA005

Location: Statewide (See accompanying map)

Project Chief: Kenneth W. Lee

Period of Project: Continuing

Problem: Some lakes in the United States are becoming more acidic causing fish populations to decrease.

Objectives: To determine the areal and temporal variation of wet-atmospheric deposition in the United States. Sites in California are part of a national program.

Approach: Sample and analyze wet-atmospheric deposition and determine the annual loading in areas of California. Atmospheric-deposition samplers are operated at Chuchupate Ranger Station in Los Padres National Forest, Ventura County, California, and at a station near Yreka, Siskiyou County. Other sites may be added as needed.

Progress: Precipitation data were collected at the Chuchupate Ranger Station in the Los Padres National Forest, Ventura County, with assistance from the U.S. Forest Service. Operations at the precipitation stations near Yreka, Siskiyou County, were reviewed.

Plans for Fiscal Year 1994: Collection and analysis of atmospheric-deposition samples will continue at the Chuchupate Ranger Station. Inspections of the Yreka site will continue annually.

Reports: None

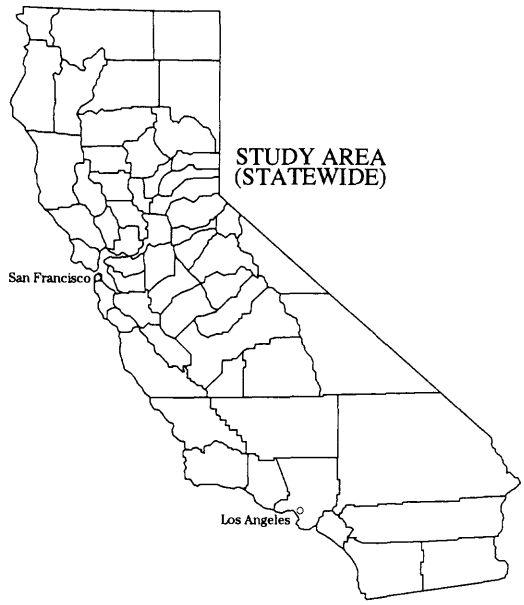
WATER-USE INFORMATION FOR CALIFORNIA

Number: CA007

Cooperating Agency: California Department of Water Resources

Project Chief: William E. Templin

Period of Project: Continuing



Problem: Water-use estimates are needed to manage the water resources of the Nation at three levels: national and state levels and within drainage basins. Water-use estimates must be consistently updated and reevaluated to assure the validity of the comparisons and conclusions of the estimates. California continually has the largest water-use volume of any state in the Nation; its multiagency water-management organizational structure and magnitude of water users create a complex water-use information environment. The challenge is to meet present and future water-use information needs within the limits of available resources.

Objectives: (1) Determine how much fresh and saline surface and ground water is withdrawn and for what purposes, how much of this water is consumed during use, and how much water is returned to surface and underground sources after use; (2) maintain and improve computerized systems to store and retrieve statewide and site-specific water-use information; (3) identify and evaluate methods commonly used to collect, analyze, and disseminate water-use information and then devise and apply new methods and techniques as necessary to improve these methods; and (4) and make available the values and applications of water-use information.

Approach: For fiscal year 1994, focus will be on water use in the Sacramento-San Joaquin Delta. All existing information and data collection activities will be coordinated to develop the best available set of water-use data for this area. Methods to improve the quantification of water diversions from and returns to the delta channels will be researched. Water-use information will continue to be coordinated with the work of other Federal, State, and local agencies through close involvement with the California Water-Use Coordination Committee and its subcommittees.

Progress: Water-Use Information Program personnel in coordination with personnel from the Project Section focused on developing estimates of water used in three areas of California: the Antelope Valley, the South San Francisco Bay area, and the Central Valley. A report on past, present, and future water uses in the Antelope Valley was written. Existing information on surface- and ground-water uses in the South San Francisco Bay area was compiled. Previously compiled data, collected for these areas as part of the statewide estimates of water use in 1990, were used in the Antelope Valley and the South San Francisco studies. These studies indicated that much more information was available locally than had been gathered for these areas during statewide collection efforts. These local studies provided land- and water-use information for other hydrologic studies done in these areas and improved our understanding of water uses in these areas, as well as the adequacy of our data bases.

The results of these studies will be used to help us expand information collection statewide. An article was published in coordination with researchers from the University of Wyoming on an application of the MWD_MAIN urban water-demand forecasting system. Four abstracts were published by the American Water Resources Association on the findings of these water-use studies: (1) water use in the Antelope Valley; (2) ground-water pumpage estimates using power-consumption data; (3) industrial water use in California; and (4) commercial water uses for golf courses, amusement parks, and ski areas. Data on power consumption in the Central Valley were aggregated by township and analyzed for its use in estimating agricultural water uses during 1985-90.

Plans for Fiscal Year 1994: The reports in progress will be completed. A program will be developed for water use in the delta area. Work on priority issues for the National Water-Use Program will be done throughout the year as the issues arise.

Reports:

Cherry, D.E., Templin, W.E., and Haltom, T.C., 1993, Industrial water use in California (abs.): American Water Resources Association, Annual Conference and Symposium, 29th, Proceedings, Tucson, Arizona, August 29-September 2, 1993.

Cherry, D.E., Wright, J.M., Templin, W.E., and Haltom, T.C., 1993, Water use at golf courses, amusement parks, and ski areas in California (abs.): American Water Resources Association, Annual Conference and Symposium, 29th, Proceedings, Tucson, Arizona, August 29-September 2, 1993.

Haltom, T.C., and Templin, W.E., 1993, Estimating agricultural ground-water pumpage in California (abs.): American Water Resources Association, Annual Conference and Symposium, 29th, Proceedings, Tucson, Arizona, August 29-September 2, 1993.

Templin, W.E., Haltom, T.C., and Cherry, D.E., 1993, Water supply and demand in the Antelope Valley, California (abs.): American Water Resources Association, Annual Conference and Symposium, 29th, Proceedings, Tucson, Arizona, August 29-September 2, 1993.

GROUND-WATER APPRAISAL, U.S. MARINE CORPS BASE, TWENTYNINE PALMS

Number: CA027

Cooperating Agency: U.S. Marine Corps, Air Ground Combat Center, Twentynine Palms

Project Chief: Peter Martin (advisor)

Period of Project: Continuing through September 1993

Problem: Most of the water supply for the Marine Corps Base at Twentynine Palms is obtained from wells in the Surprise Spring ground-water basin, which is about 10 miles northwest of base headquarters and housing. Pumping in the Surprise Spring basin has caused considerable decline in ground-water levels, and there is a continued need to monitor ground-water levels and quality. The Marine Corps would like to develop additional ground-water supplies near the base headquarters in the Mesquite Lake basin, but geohydrologic information is limited.

Objectives: Assist the Marine Corps with monitoring and development of its ground-water resources as needed.

Approach: Monitoring ground-water levels and quality will continue. If further assistance is required, additional hydrologic studies, including test drilling, will be completed.

Progress: Water levels were monitored semiannually in 19 wells in the Surprise Spring basin, in 2 wells in the Mesquite Lake basin, and in 2 wells in the Deadman basin. Three wells in the Surprise Spring basin and one well in the Mesquite Lake basin were sampled for chemical analyses of major dissolved ions, nitrate, and fluoride.

Plans for Fiscal Year 1994: Monitoring of ground-water levels and chemical quality will continue under Project 002. If requested, the U.S. Geological Survey will conduct additional hydrologic studies to assist the Marine Corps with development and management of their ground-water resources.

Reports: None

APPRAISAL OF GROUND-WATER RESOURCES, INDIAN WELLS VALLEY

Number: CA030

Cooperating Agencies: Indian Wells Valley Water District; and U.S. Navy, Naval Weapons Center, China Lake

Project Chief: Roy A. Schroeder

Period of Project: Continuing through September 1993

Problem: Water supply for the Naval Ordinance Test Station and other users in Indian Wells Valley is ground water pumped from wells. Other sources of water are not available; therefore, a dependable ground-water supply and knowledge of the characteristics of this ground-water supply is vital for long-range planning by the various users.

Objectives: Define current ground-water conditions in the valley using a water-level and water-quality monitoring network and develop a computer model that can be used to predict aquifer response to future ground-water development.

Approach: Water levels will be measured, ground-water pumpage will be estimated, and samples will be collected for chemical analyses. Previous model data will be reorganized and reevaluated to develop a steady-state and transient-state digital flow model of the basin. The flow model will be used to predict ground-water levels primarily in the current pumping centers of the basin under selected management alternatives. Current and historical chemical data will be used to show spatial variations and changes in ground-water quality. The solute-transport model, MODPATH, will be used to illustrate the movement of solutes in response to pumping.

Progress: A report describing variations in ground-water quality, processes affecting chemical quality, variations in oxygen- and hydrogen-isotope ratios, and computer simulations of solute transport in Indian Wells Valley has received Director's approval.

Plans for Fiscal Year 1994: Network monitoring will continue under Project 002 with biannual measuring of ground-water levels in 22 wells and annual sampling for ground-water quality in 10 wells in Indian Wells Valley.

Reports: None

FLOOD HYDROLOGY OF BUTTE BASIN, SACRAMENTO VALLEY

Number: CA271

Cooperating Agency: California Department of Water Resources

Project Chief: Jerry G. Harmon

Period of Project: Continuing

Problem: Flooding in the Sacramento River basin may cause changes in the magnitude and duration of overbank flows to Butte basin and increased amounts of lateral erosion. Continued lateral migration of the channel may cause the Sacramento River to change course and enter Butte basin or allow excessive flows down the main channel of the river, where the design channel capacity decreases in leveed reaches.

Objectives: (1) Define relations and document changes in the proportional division of floodflows between the Sacramento River and Butte basin; (2) show the results of channel scour, channel fill, and streambank erosion at monumented cross sections of the river; and (3) present water-surface profiles of floods to provide a base for documenting changes in channel-flow characteristics.

Approach: Flood data (part of the ongoing data-collection program) will be collected. Channel cross-section data at monumented sites will be collected annually. Flood data will include streamflow and surveyed or recorded stage measurements.

Progress: Annual cross-section surveys and streamflow-recording gage and crest-stage gage operations continued. Floodflow and flood-stage data were collected during and after the flood of January 1993. Elevations and descriptions of reference marks were documented for surveys of high-water marks along the Sacramento River and in Butte Basin, including the Goose Lake Flood-Relief structure. An open-file report was approved and is being prepared for transmittal to the printer, and a water-resources investigations report is being prepared to be submitted to the Director for approval for publication.

Plans for Fiscal Year 1994: Streamflow-recording gages and crest-stage gages will be in operation during the 1993-94 flood season. The data-collection network will include peak-stage data near the Goose Lake Flood-Relief structure. Elevations and descriptions of reference marks will be documented to relate to floodflow measurements and surveys of high-water marks along the Sacramento River and in Butte basin. Flows will be measured and recorded to document changes or stability in the characteristics of floodflows. Monumented cross sections of the river will be resurveyed annually and compared with data from previous surveys for each of the seven sites. A report is planned that will describe the channel morphology of the Sacramento River in a selected reach.

Reports: None

GROUND-WATER RESOURCES OF THE SANTA BARBARA AREA

Number: CA342

Cooperating Agency: Santa Barbara, city of

Project Chief: John R. Freckleton

Period of Project: July 1977 to September 1993

Problem: Reduced efficiency of surface reservoirs resulting from siltation will place increased demand on the ground-water supply in the Santa Barbara ground-water basin. Because of anticipated pumpage in the basin and the resultant possibility of seawater intrusion into the freshwater aquifer, it has become necessary to develop and implement a ground-water program capable of evaluating these effects on the ground-water basin.

Objectives: Design a comprehensive program to regularly monitor water levels and water quality in the ground-water basin in order to quantity the effects of increased pumping and the potential movement of seawater into the ground-water reservoir. Develop mathematical models to simulate basin operation under stress and changing water-quality conditions.

Approach: Previous investigations will be reviewed. Historical water-level and water-quality data and rainfall and streamflow records will be collected and analyzed. Additional hydraulic data, such as storage coefficient and transmissivity estimates, will be collected and input to mathematical simulation models.

Progress: Work on a report describing the geohydrology of Storage Unit III and on a combined Santa Barbara areawide flow model continued. The "Geohydrology" and "Water Quality" sections of the report were rewritten and the "Modeling" section of the report was expanded. The project is complete except for report.

Plans for Fiscal Year 1994: The report will be completed.

Reports:

Hsieh, P.A., and Freckleton, J.R., 1993, Documentation of a computer program to simulate horizontal-flow barriers using the U.S. Geological Survey's modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 92-477, 32 p.

ESTIMATING TIDAL AND RESIDUAL CIRCULATION IN SAN FRANCISCO BAY AND THE SACRAMENTO-SAN JOAQUIN DELTA

Number: CA419

Cooperating Agencies: California Department of Water Resources; California State Water Resources Control Board; U.S. Army Corps of Engineers; and Contra Costa Water District

Project Chief: Lawrence H. Smith

Period of Project: Continuing

Problem: California State and Federal water projects regulate the quantity of fresh water flowing into San Francisco Bay from the Sacramento-San Joaquin River Delta. These legislatively mandated changes have caused a decrease in the annual inflow of fresh water to the bay and has altered the time sequences of inflows during the year. The effect of decreased inflow may be altering the mixing characteristics of the bay and adversely affecting fish and invertebrate populations.

Objectives: To determine the magnitude and location of variations in hydrodynamics (water currents and salinity) within San Francisco Bay that result from changes in freshwater inflows from the Sacramento-San Joaquin River Delta. To measure tidal flows in the delta and to distinguish between natural variations of flow and variations of flow caused by State and Federal water projects.

Approach: Two- and three-dimensional mathematical models will be used to project the effect of variations in delta flows on water currents and salinity in the bay. Currents and salinity will be measured during a wide range of delta-flow conditions. A new prototype of a ship-mounted acoustic Doppler current profiling system will be tested and used to measure vertical profiles of currents. A high-resolution in situ, conductivity-temperature-depth system will be used to measure vertical salinity profiles. Field data will be used as appropriate to calibrate and validate mathematical models. Ultrasonic velocity meters will be used to measure flows continuously in delta channels.

Progress: Three ultrasonic velocity meters (UVM) in the Sacramento-San Joaquin Delta were installed, and calibrations were begun. Analysis of data from two other UVMs showed the sources, paths, and quantities of water that reach the State and Federal export pumps for various hydrologic and export conditions. A large hydrographic data set was collected in Suisun Bay during winter and spring runoff conditions. Preliminary analyses of these data showed a rapid seaward movement of the salt field in the main channel during runoff and a rapid, partial recovery afterward. Coding of a new three-dimensional model for all San Francisco Bay continued. Optical backscatter sensor (OBS) measurements, began as part of this project, were extended to include measurements in central San Francisco Bay and transferred to a new project, "Suspended-Sediment and Trace-Metal Transport Processes in South San Francisco Bay."

Plans for Fiscal Year 1994: Three to four additional UVMs will be installed in the delta, and calibrations will be achieved during the year for at least three sites using a broad-band acoustic Doppler current profiling system (ADCP) and the Survey's vessel-mounted acoustic Doppler discharge measurement system (ADDMS). Additional hydrographic and suspended-sediment time series will be collected in Suisun Bay to document the responses of circulation and mixing in the nontidal current null zone to changes in freshwater inflow. Emphasis will be placed on the recovery period after runoff subsides. Coding of a three-dimensional model of all San Francisco Bay will be completed, and calibration will begin. A study of low-frequency variations of salinity and water levels will continue.

Reports:

Burau, J.R., Simpson, M.R., and Cheng, R.T., 1993, Tidal and residual currents measured by an acoustic Doppler current profiler at the west end of Carquinez Strait, San Francisco, California, March to November 1988: U.S. Geological Survey Water-Resources Investigations Report 92-4064, 79 p.

Smith, P.E., and Larock, B.E., 1993, A finite-difference model for 3-D flow in bays and estuaries, *in* Shen, H.W., Su, S.T., and Wen, Feng, eds., Hydraulic engineering '93--Proceedings of the 1993 Conference, v. 2, San Francisco, July 25-30: New York, American Society of Civil Engineers, p. 2116-2122.

Smith, P.E., and Larock, B.E., 1993, An efficient finite-difference model for three-dimensional flow in bays and estuaries (abs): American Society of Civil Engineers, National Conference on Hydraulic Engineering and International Symposium on Engineering Hydrology, San Francisco, July 25-30, 1993, Program.

SOUTHERN CALIFORNIA REGIONAL AQUIFER-SYSTEM ANALYSIS

Number: CA424

Cooperating Agency: None. (U.S. Geological Survey Federal Program)

Project Chief: Peter Martin

Period of Project: October 1990 to September 1994 (reactivated)

Problem: To meet the needs for hydrologic information on a regional scale and to develop predictive capabilities to effectively manage the Nation's ground-water resources, the U.S. Geological Survey has initiated a series of hydrologic investigations in the Regional Aquifer-Systems Analysis (RASA) program. The RASA study of the southern California basins covers a 75,000-square-mile area. The area includes 89 drainage basins that can be grouped into coastal and desert basins according to common characteristics and relations.

Objectives: To analyze major problems and issues affecting ground-water use in southern California including (1) ground-water depletion, (2) ground-water contamination, (3) seawater intrusion, (4) quantity and distribution of recharge, (5) inter-aquifer flow, and (6) conjunctive use of ground and surface water. Because of the large size of the study area and the number of basins involved, it is impractical to study these problems and issues for each basin. Thus, at least one coastal basin and one desert basin will be selected for intensive study to determine the major geohydrologic processes and human activities that control or influence these problems.

Approach: The coastal basin selected for intensive study is the Santa Clara-Calleguas basin; the desert basin selected is the Mojave basin. The study will involve assembling available geohydrologic data into the Geographic Information System (GIS), defining the regional geohydrology and geochemistry, and developing ground-water flow and solute-transport models to help understand the ground-water-flow system. Information obtained from these intensive studies will aid in the effective management of the ground-water resources of these and other basins in southern California.

Progress: Santa Clara-Calleguas basin: Water-level and water-quality data were collected to monitor seawater intrusion. Flow-meter data from production wells were compiled and evaluated. Aquifer tests at selected production wells near RASA multiple-well monitoring sites were evaluated. These data were used to refine the preliminary ground-water-flow model previously developed for the basin. Pumpage and streamflow data were estimated for the transient-state flow model. A preliminary cross-sectional solute transport model was developed in conjunction with the cooperatively funded study of Oxnard Plain.

Mojave River basin: Twelve multiple-well monitoring sites were completed along the Mojave River to define aquifer or depth dependent ground-water flow and water-quality characteristics. Water levels were measured for more than 300 wells to determine the regional flow pattern. More than 100 wells were sampled and analyzed for major ions, nutrients, selected trace elements, and stable isotopes of oxygen and hydrogen. The geochemical data were used to define the source and age of recharge to the basin. Surface geophysical techniques (direct current resistivity and seismic refraction) were completed in areas of suspected faulting in an attempt to determine vertical displacement. GIS was developed for the Mojave area to analyze and display available geohydrologic information. A preliminary water-level map of the regional aquifer for winter 1993 was prepared to document water-level rises resulting from 1992 and 1993 major flows into the Mojave River. A preliminary ground-water-flow model was developed for the entire river basin.

Plans for Fiscal Year 1994: The preliminary draft of the professional paper describing the results of the Santa Clara-Calleguas basin study will be completed. The report will describe the geohydrologic and geochemical frameworks of the basin, discuss major problems/issues affecting water use in the basin, and describe the ground-water-flow model developed for the basin. Data collection and analysis will continue in the Mojave basin. Model development and calibration will be completed.

Reports: None

HYDROLOGIC STUDIES RELATED TO VOLCANIC ACTIVITY IN LONG VALLEY CALDERA

Number: CA431

Cooperating Agency: U.S. Geological Survey Federal Program; and Mono County

Project Chief: Christopher D. Farrar

Period of Project: Continuing

Problem: Long Valley caldera is a large volcanic depression located along the eastern Sierra Nevada Frontal fault system. Since 1978, earthquake activity increased in the caldera. This earthquake activity, as well as a total uplift of 0.6 meter, probably is a result of rising magma. On May 26, 1982, the U.S. Geological Survey issued a notice of potential volcanic hazard in the Long Valley area. Since then, the Survey has taken the lead in studies that include monitoring, assessment of potential hazards, and research for methods of prediction.

Objectives: Monitor ground water and surface water to detect changes in the hydrologic system caused by geologic processes and phenomena associated with vulcanism or with magma at depth in Long Valley caldera. Delineate type and magnitude of pressure response that would be expected in the ground-water system of Long Valley caldera prior to volcanic eruption. Revise the current conceptual model of the ground-water-flow system, including nonthermal and thermal aquifers, as new information becomes available. Measure land-surface deformation caused by geothermal fluid withdrawal and injection.

Approach: A network will be operated to monitor the levels, temperature, and quality of ground water; the quality of surface water; and the temperatures and composition of fumarole gas. Data will be assessed in relation to geologic events. A quantitative relation between change in ground-water pressure with strain in the aquifer matrix will be developed. Geologic and geophysical information obtained from other studies will be assimilated and used to revise the conceptual ground-water-flow model. Land-surface deformation will be measured annually by surveying bench marks in and near the geothermal well field at Casa Diablo.

Progress: A network of hydrologic monitoring sites was operated to provide data for assessing the response of the hydrologic system to geologic processes and resource developments. Ground-water, surface-water, and fumarole gas data were collected. A paper describing the changes in gas composition and helium isotope ratios was published in the Journal of Geophysical Research.

Geothermal development has produced pressure declines of about 4 feet in the production reservoir at a radial distance of at least 3 miles and pressure increases of about 8 feet in the injection reservoir to a distance of at least 2.5 miles. Reduced pressure in the production reservoir is causing steam to vent from fault zones. The steam is causing soil temperatures to rise (to as high as 90°C), enough to kill trees. Geothermal development also has caused land subsidence in the well field. Maximum subsidence of 0.4 foot was measured between 1988-93. An extended abstract describing the subsidence is in press.

Selected thermal infrared images of parts of Mammoth Mountain and Casa Diablo were produced from scanner data collected in September 1992. The images delineate the areal extent of two known thermal areas on Mammoth Mountain and show thermal anomalies associated with faults near Casa Diablo.

Plans for Fiscal Year 1994: Data collection will continue through 1994. A repeat aerial infrared survey will be done for selected areas if funding permits. The images will be used to identify geologic structures that are accentuated by increased ground temperatures. A paper describing land subsidence and the effects of geothermal development on thermal springs will be presented at the 15th annual Geothermal Workshop, Auckland, New Zealand, and published in the proceedings. Planned reports include a journal article describing the deformation of the Casa Diablo area and a report providing hydrologic data from the monitoring network for 1990-93.

Reports: None

EVALUATION OF GROUND-WATER CONTAMINATION FROM NONPOINT SOURCES USING SOLUTE-TRANSPORT TECHNIQUES

Number: CA466

Cooperating Agency: Santa Ynez River Water Conservation District

Project Chief: Daniel J. Bright

Period of Project: October 1986 to September 1993

Problem: Several studies have documented the deterioration of ground-water quality in the Lompoc area of the Santa Ynez River basin. These studies indicate that recharge of irrigation water probably is the principal cause of the observed deterioration. Ground water in the Lompoc area, especially in the Lompoc plain, is only marginally acceptable for most uses. Dissolved-solids concentrations currently exceed 2,000 milligrams per liter in several parts of the plain. If the ground-water quality continues to deteriorate, the ground water will be unusable for almost all uses without some treatment.

Objectives: Define the geohydrologic framework of the Lompoc area of the Santa Ynez River basin. Define quantitatively, where possible, the effects of irrigation on the quality of ground water. Evaluate ground-water flow and solute transport using numerical simulation.

Approach: Phase 1--Use existing hydrologic data to define the geohydrologic and geochemical framework of the study area; install observation wells and suction-cup lysimeters on four study plots that are typical of agricultural and geohydrologic conditions in the areas; and monitor water levels monthly and sample wells bimonthly. Phase 2--develop a three-dimensional finite-difference ground-water-flow model to simulate flow through the unconsolidated deposits that fill the basin; and simulate the movement of solutes in the main water-producing zone using a two-dimensional, finite-element solute-transport model.

Progress: The report on phase 1 of this study, "Ground-water hydrology and quality in the Lompoc area, Santa Barbara, California, 1987-88," was published as Water-Resources Investigations Report 91-4142. The report on phase 2 of this study, "Evaluation of ground-water flow and solute transport in the Lompoc area, Santa Barbara, California," was reviewed and is being prepared for Headquarter's review. The phase 2 report quantifies the hydrologic information presented in the phase 1 report of the study and demonstrates some potential long-term effects on water levels and water quality that may result from proposed ground-water-management alternatives. An analysis of the hydrology of the study area was done by developing and calibrating a ground-water-flow model to simulate hydraulic head in the aquifer system beneath the Lompoc plain, upland, and terrace, and a solute-transport model to simulate dissolved-solids concentration in the main water-producing zone beneath the Lompoc plain. The management-alternative simulations for the 32-year period, 1989-2020, include (1) doubling the average annual recharge from the Santa Ynez River, (2) simulating the effect of importing supplemental water, (3) changing the current location of the wastewater-treatment plant discharge point, and (4) reducing the average annual agricultural pumpage by 50 percent. Model results indicate that projected dissolved-solids concentrations for the main water-producing zone would decrease beneath the eastern and central plains in all management alternatives. Beneath the western plain, however, projected dissolved-solids concentration decreased only in simulation 4, which reduced agricultural pumpage. Collection of water-level and water-quality data from the monitoring network was done in fiscal year 1993 and results were reported in the annual data report.

Plans for Fiscal Year 1994: The phase 2 report will be submitted for approval. Collection of water-level and water-quality data from the monitoring-network wells will continue under Project 002.

Reports: None

OPTIMUM MANAGEMENT IN A BASIN WITH CHANGING WATER-SUPPLY AND WATER-QUALITY PROBLEMS

Number: CA467

Cooperating Agency: San Bernardino Valley Municipal Water District

Project Chief: Wesley R. Danskin

Period of Project: October 1987 to September 1994

Problem: Historically, water purveyors have applied various techniques to solve water-supply andwater-quality problems. Although most water purveyors rely on some form of conjunctive use of ground and surface waters, seldom is there optimum management of the entire water system. Improved management of complex hydrologic systems should be possible by developing and applying hydraulic- and economic-optimization techniques. But, to date, there has been little actual use of optimization techniques to solve real-world water-supply and water-quality problems.

Objectives: Develop and apply optimization techniques to demonstrate their usefulness in a real-world setting for conjunctive management of ground-water pumpage, ground-water levels, ground-water quality, and artificial ground-water recharge using surface water. Research will focus on developing new methodologies to incorporate system and parameter uncertainty in the optimization model.

Approach: Key aspects of the ground-water system will be verified to ensure accurate simulation with the existing ground-water-flow model. A surface-water distribution model will be designed and constructed. Critical water-quality problems and potential management options will be identified. A hydraulic/economic-optimization model will be developed that combines the surface- and ground-water models with the water-quality issues. New methods of water management will be evaluated.

Progress: The optimal water-management study of the San Bernardino area extended our understanding of how to use constrained optimization techniques to manage a complex, real-world setting. Results of the optimization model were used in combination with detailed field data from multiple-level piezometers to suggest improved water-management plans for coordination with the numerous water purveyors in the basin and use of results from a regional water-use model and a subregional ground-water-flow model, both developed by consultants.

Proposed changes in water management included (1) siting a new well field and major pipeline, (2) designing a pumping pattern to contain a contaminant plume of trichloroethylene, and (3) using water from a new reservoir. The optimization model aided in achieving difficult goals--lowering ground-water levels in an urbanized area subject to liquefaction during a major earthquake, providing sufficient water in outlying areas that are affected by a recent drought, and controlling migration of contaminants from an Environmental Protection Agency superfund site.

Work in fiscal year 1993 included drafting a comprehensive hydrologic and modeling report, training the cooperator staff in the use of the ground-water-flow model, and analyzing potential changes in water management of the basin.

Plans for Fiscal Year 1994: Most work in fiscal year 1994 will involve an initial investigation of the adjacent Yucaipa basin. This investigation will include a thorough literature review, aquisition of a Geographic Information System (GIS) for the area, and development of a preliminary ground-water-flow model. In addition, the two reports for the Bunker Hill basin will be completed, and training of the cooperator on the use of the ground-water-flow and optimization models will continue.

Reports: None

RAINFALL AND RUNOFF IN THE ANTELOPE VALLEY, MOJAVE DESERT

Number: CA469

Cooperating Agency: Los Angeles County Department of Public Works

Project Chief: James C. Blodgett

Period of Project: October 1987 to September 1994

Problem: Storm runoff in urbanized basins in Antelope Valley, California, is a major concern because increases in impervious areas in new developments cause increased runoff volumes and peak magnitude. Developing areas are on alluvial fans which commonly have high rates of infiltration. Reliable methods to estimate regional storm runoff are needed for land-use planning, land-development criteria, and design of drainage facilities. Several rainfall-runoff models are available for estimating runoff; however, there is a need to define the areal variation and relative significance of the input parameters to optimize the uses of these models.

Objectives: The primary objectives are to (1) apply a rainfall-runoff model appropriate for estimating design-storm characteristics in ungaged drainage basins in Antelope Valley, and (2) estimate the frequency of runoff developed by regional analyses of streamflow data and compare those values with values obtained by long-term simulation. Specific objectives include (1) instrumentation and measurement of rainfall and runoff in eight drainage basins in Antelope Valley and (2) testing and comparison of several rainfall-runoff models to simulate measured runoff.

Approach: Eight basins that represent urbanized and nonurbanized conditions will be selected for collection of continuous-flow and precipitation data. Using these data and suitable historical data, selected rainfall-runoff models will be calibrated and results evaluated. Basins will be selected to provide three types of hydrologic data: flow magnitude, duration, and frequency; precipitation-runoff model calibration; and flow attenuation in a downstream direction. Aerial photography and infiltration measurements will be obtained to determine the characteristics of the basins for model application.

Progress: Streamflow and precipitation data for the 1993 water year and historical rainfall-runoff data for all long-term precipitation stations are being processed. These data will be used to provide rainfall frequency and areal distribution data in Antelope Valley and to identify significant basin and precipitation characteristics. The DR3M model was used to evaluate various rainfall and runoff parameters. Model results indicate the need to accurately define the size of the basins. All basins were surveyed during the January through March 1992 storm period; boundaries of several basins previously defined were revised. An analysis of storm-precipitation intensity-duration data for six major storms during 1938-92 indicates that the duration of major storm activity ranges from 1 to 4 days. Significant valleywide storms were recorded in 1943 and 1983 with 1-day precipitation totals of as much as 5.0 inches; the recurrence interval for those storms ranged from 11 years to more than 100 years. The February 1992 storm at Palmdale had a 1-day precipitation total of 1.51 inches, with a recurrence interval of 3 years; the February 1993 storm had a 1-day precipitation total of 2.0 inches, with a recurrence interval of 8 years. The February 1992 and 1993 storms produced flooding in Palmdale and Lancaster. A paper discussing selected precipitation distributions in Antelope Valley was presented at the American Society of Civil Engineering Hydrology conference in 1993.

Plans for Fiscal Year 1994: Rainfall-runoff data collected during the 1990-93 water years will be applied to the rainfall-runoff models. The models will be calibrated using the more accurately defined discharge data and basin boundaries. The rainfall-runoff models will be extended to include historical data for selected precipitation stations to compare results with historical runoff data. Because of the 1987-92 drought and the resulting lack of floodflow, the project has been extended to 1994. A paper on the characteristics of precipitation (1913-92) in Antelope Valley was started in fiscal year 1993 and is nearly complete.

Reports:

Blodgett, J.C., and Nasseri, Iraj, 1993, Selected precipitation characteristics in Antelope Valley, Mojave Desert, California: American Society of Civil Engineers, Engineering Hydrology, Hydraulics Division Symposium, San Francisco, July 25-30, p. 7-12.

DETAILED STUDY AND ASSESSMENT OF IRRIGATION DRAINAGE IN THE SALTON SEA AREA, IMPERIAL VALLEY

Number: CA470

Cooperating Agency: U.S. Department of the Interior

Project Chief: Roy A. Schroeder

Period of Project: Continuing

Problem: Selenium concentrations exceeding criteria for the protection of aquatic life were detected in irrigation drainage throughout the Imperial Valley. Elevated levels of selenium and DDT metabolites also were detected in the fish and waterfowl at the National Wildlife Refuge (NWR). The elevated level of selenium has resulted in restrictions on human consumption of fish from the Salton Sea.

Objectives: Determine the source, transport, and fate of selenium and other potential toxins in the Imperial Valley.

Approach: Water-quality samples were collected from 100 farm drain sumps for comparison with results of sampling done in 1986. Results were used to prepare concentration maps and to establish the relative importance of various hydrogeochemical processes. Twenty-one sites were monitored monthly to determine temporal variability. Lysimeter and piezometer data were evaluated to discern the interaction between drainwater and regional ground water. A range of representative environments for chemical residues in biota were measured to identify the trophic levels at which bioaccumulation of toxins occur.

Progress: The final interpretive report for the 1988-90 detailed study received Director's approval and is now published. A companion data report was published. Phase 4 studies will continue under the direction of the U.S. Bureau of Reclamation.

Plans for Fiscal Year 1994: The U.S. Geological Survey will continue to serve in an advisory capacity to the U.S. Bureau of Reclamation, which is now the lead agency for ongoing monitoring and mitigation or remediation efforts.

Reports:

Schroeder, R.A., Rivera, Mick, and others, 1993, Physical, chemical, and biological data for detailed study of irrigation drainage in the Salton Sea area, California, 1988-90: U.S. Geological Survey Open-File Report 93-83, 179 p.

Setmire, J.G., Schroeder, R.A., Densmore, J.N., Goodbred, S.L., Audet, D.J., and Radke, W.R., 1993, Detailed study of water quality, bottom sediment, and biota associated with irrigation drainage in the Salton Sea area, California, 1988-90: U.S. Geological Survey Water-Resources Investigations Report 93-4014, 102 p.

CHANGES IN RUNOFF IN PERRIS VALLEY, RIVERSIDE COUNTY

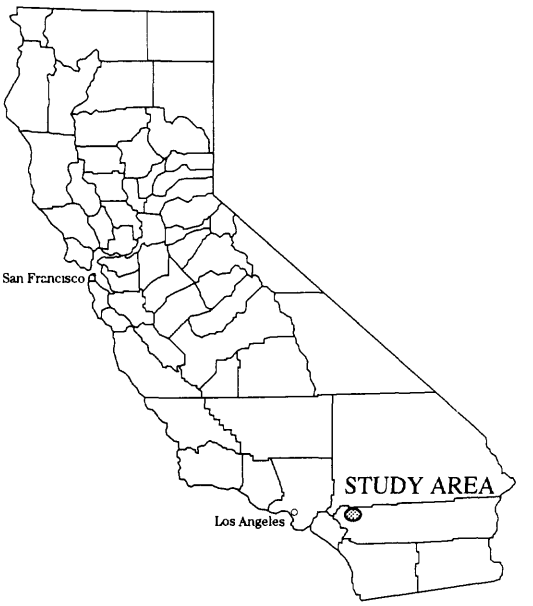
Number: CA472

Cooperating Agency: Riverside County Flood Control and Water Conservation District

Project Chief: Joel R. Guay

Period of Project: October 1988 to September 1994

Problem: Increased urbanization in Perris Valley since 1970 has caused appreciable changes in runoff characteristics. The additional impervious area has resulted in increased runoff volumes and peak discharges. Few studies have documented what effect urbanization has on runoff characteristics. Because rainfall-runoff data for Perris Valley prior to urbanization is available, a current study could determine how urbanization has affected runoff characteristics in Perris Valley.



Objectives: Compare current runoff characteristics in urbanized Perris Valley with runoff characteristics prior to urbanization.

Approach: Rainfall-runoff data collected from 1989 to 1993 will be used to calibrate and verify a rainfall-runoff model. A rainfall-runoff model also will be calibrated and verified using the 1970-75 rainfall-runoff data. The results of the two models will be compared to estimate the effects of urbanization on runoff characteristics.

Progress: Because of limited data owing to the 1987-92 drought, the study was extended another year to collect additional data. Rainfall and runoff data for 11 storms were collected in water year 1993. Data for 36 storms were used to calibrate and verify the urban model. Eleven of these 36 storms had a peak discharge greater than 1,000 cubic feet per second; the largest storm had a peak discharge of 4,400 cubic feet per second. Historical rainfall data (1948-93) were entered into the rainfall-runoff models to produce a long-term time series for storm runoff. Each model simulated more than 800 storms.

Plans for Fiscal Year 1994: A frequency analysis of the simulated runoff data will be used to determine storm-runoff characteristics for each period. The effects of urbanization will be determined by comparing the runoff characteristics of storms for preurban and urban hydrologic conditions.

Reports:

Guay, J.R., 1993, Simulation of changes in storm-runoff characteristics, Perris Valley, California, *in* Kuo, C.Y., ed., Engineering hydrology--Proceedings of the symposium, San Francisco, July 25-30, 1993: New York, American Society of Civil Engineers, p. 983-988.

GROUND-WATER HYDRAULICS IN WOLF VALLEY, RIVERSIDE COUNTY

Number: CA474

Cooperating Agency: Pechanga Indian Reservation/ Bureau of Indian Affairs

Project Chief: Charles A. Kaehler

Period of Project: October 1988 to September 1994

Problem: Both population and water use are increasing rapidly in the upper Santa Margarita River basin, Riverside County, California. In Wolf Valley, there is concern that future pumping will cause ground-water levels to decline and will deplete ground-water storage beneath the Pechanga Indian Reservation, especially beneath the Kelsey Tract of the reservation. Much of the water for the reservation is produced from a shallow alluvial aquifer, and most of the larger wells in the valley pump water from a deep aquifer that is separated from the shallow aquifer in some places by a confining bed.

Objectives: To develop a greater understanding of ground-water hydraulics in the multiple-aquifer system of Wolf Valley. To collect additional hydrologic data, conduct aquifer tests, and construct analytical solutions (distance/drawdown graphs) using the results of the aquifer tests. The effects of pumping on ground-water levels and storage beneath Kelsey Tract of the Pechanga Indian Reservation will be evaluated.

Approach: All available data on well construction, aquifer tests, subsurface geology, and historical water levels and pumpage for Wolf Valley will be compiled. The existing water-level monitoring program will continue. Water levels in all available wells will be measured each autumn and spring. Four or five test holes will be drilled and logged to supplement existing geologic data. Two or more nests of piezometers will be installed near a large-capacity production well and will be used during a long-term aquifer test to estimate the hydraulic properties of the deep and shallow aquifers, as well as the confining bed. Knowledge gained on the ground-water hydraulics of the valley will be used for construction of distance/drawdown graphs.

Progress: Preparations for the long-term aquifer test continued into fiscal year 1993; the test began in April after resolving problems concerning the test well and the water supply of the Reservation. Transducers and data loggers were operated in five piezometers to monitor pre-test water levels and to monitor drawdown during the pumping and recovery of the aquifer test. Water levels in other piezometers and wells near the test site were measured periodically. Barometric data were collected to determine expected barometric effects on water levels measured in observation wells during the aquifer test. The pumping phase of the aquifer test began April 28, 1993, and extended to August 23, 1993, a total of 117 days. The recovery phase of the test began August 23, 1993 and is continuing. Detailed water-level data were collected from the test well and monitoring wells, test-well discharge data were collected, and data reduction and graphing began in preparation for analysis of the data.

Plans for Fiscal Year 1994: Data analysis will be completed, and a final report for the study will be submitted for colleague review by the end of the second quarter of the fiscal year.

Reports: None

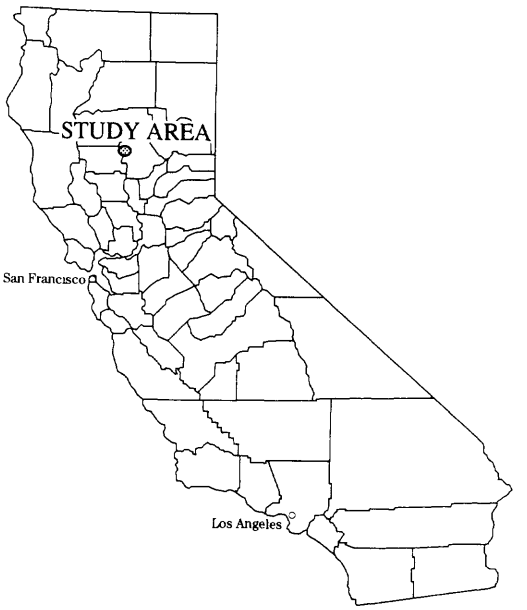
DEVELOPMENT OF SACRAMENTO RIVER BED-SCOUR RELATION AT THE SR-32 BRIDGE AT HAMILTON CITY

Number: CA476

Cooperating Agency: California Department of Transportation

Project Chief: James C. Blodgett

Period of Project: October 1988 to September 1995



Problem: Exposure or undermining of the bridge pier and abutment foundations from the erosive action of flowing water at the State Route 32 bridge at Hamilton City, California, can result in bridge failure or the need for expensive repairs. Bridge-scour data are difficult to obtain, partly because major scour usually occurs during flood conditions. As a result, actual measurements of scour that can be used to define significant bridge and channel characteristics in causing scour and comparison of scour data with laboratory derived relations are needed.

Objectives: Determine those hydraulic and bridge geometric factors that are important in the cause and extent of channel-bed scour. Develop equations to predict depth and lateral extent of scour at the old and new bridges and compare these equations with scour equations for other sites. Determine the rate of channel stabilization associated with constriction and local scour at the new bridge.

Approach: Channel-survey data obtained near the old bridge site will be used to relate bridge geometry and to indicate typical channel conditions. Scour and hydraulic data at the new bridge will be collected about four times per year and stored: once before the flood season, twice during the flood season, and once after the flood season. Geophysical soundings will be obtained annually to provide information on the maximum depth of scour below the surveyed channel bed. Data will be analyzed and separated into the components of channel bed, constriction, and local scour. Constriction and local scour will be related to bridge geometry.

Progress: Channel-geometry and bridge-scour data were collected in October 1992 and January and February 1993. Equipment, which provides data in the *x, y,* and *z* planes, was used to provide scour data at the SR-32 site. Flooding occurred during the 1993 water year, and thus data needed for analysis of scour conditions at the site now are available. Flow data and measurements of the channel geometry have been obtained at the site since 1979, before construction of the new bridge. Channel-bed (general) scour averaged 1.4 foot from 1979 to 1993 for the upstream reach unaffected by the bridge. During this period, the thalweg (the lowest point in channel cross section) migrated laterally more than 50 feet. Near the bridge, local scour related to flow contraction averages more than 2 feet. Local scour near the bridge piers was calculated using the highest surveyed bed elevation near the bridge piers as the reference elevation. Local scour depths of about 9 feet below the reference elevation were measured from 1988 to 1992. Channel changes occurred during flooding when flows were about 6 percent greater than average A paper describing the depths of scour and areal variation of scour near the bridge was prepared and presented at the American Society of Civil Engineering 1993 conference.

Plans for Fiscal Year 1994: Collection of scour depth and channel-geometry data will continue with emphasis on collecting scour data during several moderately high flows. If suitable floods occur, scour data also will be collected around the bridge piers. An evaluation of these scour data, as well as data collected in the reach unaffected by the bridge, and a review of existing scour formulas will be completed. A final report will be prepared in fiscal year 1995.

Reports:

Blodgett, J.C., and Harris, C.D., 1993, Measurement of bridge scour at the SR-32 crossing of the Sacramento River at Hamilton City, California, 1987-92, *in* Shen, H.W., Su, S.T., and Wen, Feng, eds., Hydraulic engineering '93--Proceedings of the 1993 Conference, v. 2, San Francisco, July 25-30: New York, American Society of Civil Engineers, p. 1860-1865.

GROUND-WATER RESOURCE INVESTIGATIONS, EDWARDS AIR FORCE BASE

Number: CA477

Cooperating Agency: U.S. Air Force, Edwards Air Force Base

Project Chief: Devin L. Galloway

Period of Project: Continuing

Problem: Declining water levels, an apparent degradation in water quality, and an antiquated water-distribution system have resulted in a water shortage at Edwards Air Force Base. In addition, there has been widespread land-surface subsidence in the southwest part of the base, and an extensive system of cracks, fissures, and potholes has developed on Rogers Lake (dry). This has generated concern about the condition of the runways on the lakebed.

Objectives: Define the boundaries and areal extent of the ground-water system. Quantify the distribution of hydrologic properties. Determine the ground-water-flow paths in relation to existing pumping centers and known areas of subsurface contamination. Define water types for different aquifers. Develop a long-term ground-water monitoring program. Identify sites for development of future well fields. Determine the influence of ground-water withdrawals and declining ground-water levels on the areal extent and amounts of land-surface subsidence and the extent and cause(s) of fissures, cracks, and potholes on the lakebed.

Approach: Surface geophysical methods will be used to identify the geologic structure and boundaries of the ground-water basin. Nested piezometers will be installed to establish a multilevel monitoring network. Ground-water levels will be measured and water-quality samples will be collected. Aquifer tests will be done. Land subsidence and surface deformation will be assessed by geodetic surveys, aerial photography of the lakebed, and monumentation of selected fissures. Extensometers will be installed to measure the amount and rate of subsidence. A ground-water-flow model will be developed.

Progress: Anticipated funding for the project was cut 50 percent because of severe reductions in military expenditures. This reduction resulted in the postponement of several planned activities including additional sampling for ground-water quality and completion of the land-surface elevation transects for Rogers Lake. Emphasis shifted toward the completion of three reports and the establishing, measuring, and monitoring of the ground-water-level network. Monitoring of the continuous-record (hourly) ground-water-level network continued. A 15th monitoring station was added to a test well on the north shore of Rogers Lake. A second overlapping network of larger areal extent was established and monthly ground-water-level measurements were made throughout the year. Aquifer-system compaction data were collected hourly from the Holly and fissure extensometer sites. The monument array established near the fissure site was resurveyed. The project hosted the second U.S. Geological Survey Subsidence Interest Group conference in November 1992 at Edwards Air Force Base. Seven extended abstracts were presented by the project staff to the conference proceedings, which was co-edited by the project staff. A report on hydrogeology and land-subsidence data and a report on the interpretation of this data were published. A third report defining hydrologic boundaries and potentiometric surfaces and profiles was submitted for colleague review. An invited presentation describing aquifer-system strain related to the Landers earthquake, which was measured by the automated network at Edwards Air Force Base, was given at a special tectonics session of the American Geophysical Union spring meeting.

Plans for Fiscal Year 1994: Monitoring of the ground-water-level and aquifer-system compaction networks will continue. The measurement of the land-surface elevation transects, postponed for fiscal year 1993, will resume. A ground-water-flow model will be developed for the Edwards Air Force Base.

Reports:

Galloway, D.L., 1993, Coseismic volume strain associated with the Landers earthquake: An analysis of aquifer fluid-pressure responses, Antelope Valley, California (abs.): Eos, Transactions of the American Geophysical Union, Abstracts, Spring Meeting Supplement, v. 74, no. 16, p. 317.

Londquist, C.J., Rewis, D.L., Galloway, D.L., and McCaffrey, W.F., 1993, Hydrogeology and land subsidence, Edwards Air Force Base, Antelope Valley, California, January 1989-December 1991: U.S. Geological Survey Water-Resources Investigations Report 93-4114, 71 p.

Rewis, D.L., 1993, Drilling, construction, and subsurface data for piezometers on Edwards Air Force Base, Antelope Valley, California, 1991-92: U.S. Geological Survey Open-File Report 93-148, 35 p.

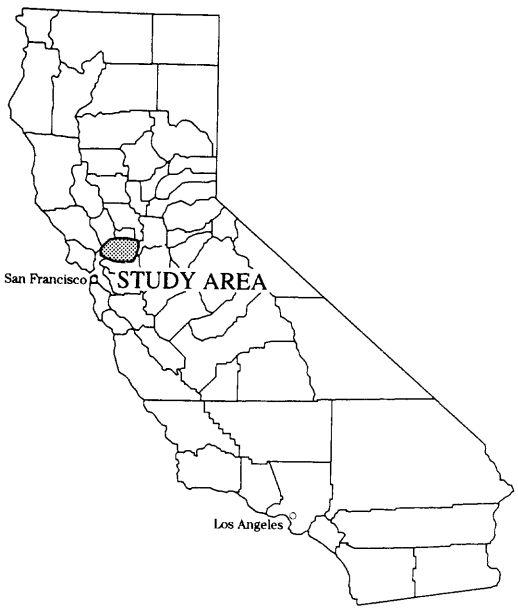
EVALUATION OF SUBSIDENCE RATES AND PROCESSES IN SURFICIAL PEAT, SACRAMENTO-SAN JOAQUIN DELTA

Number: CA479

Cooperating Agency: California Department of Water Resources

Project Chief: Steven J. Deverel

Period of Project: October 1989 to September 1994



Problem: The Sacramento-San Joaquin Delta islands and tracts have been subsiding because of oxidation of organic soils at a rate of 1 to 3 inches per year since the drainage of the islands and tracts began in the early part of this century. Continued subsidence threatens the integrity of the levee system and will increase the amount of energy required to maintain a low water table for crop production. Knowledge of the processes contributing to subsidence of these soils will provide a basis for water-and land-management strategies to mitigate subsidence.

Objectives: The overall goal of this study is to better understand the factors that affect organic soil loss in the Sacramento-San Joaquin Delta. Specifically, the objectives are to (1) quantify subsidence rates in organic soils at selected locations; (2) identify and quantitatively assess hydrologic and geochemical processes that affect carbon loss under different land- and water-management practices; and (3) assess the spatial and temporal variability of carbon loss.

Approach: An attempt will be made to quantify the processes contributing to carbon loss from the organic soils at several agricultural sites in the delta. Two of these processes are (1) respiration of organic carbon and (2) dissolution and mobilization of aqueous-dissolved and particulate organic carbon. These processes will be assessed in conjunction with subsidence measurements at each site. A carbon mass-balance approach will be taken at each site to reconcile subsidence with carbon loss.

Progress: Monitoring of land-surface elevation changes and carbon-dioxide fluxes continued. As was shown in previous years, carbon-dioxide evolution from the soil surface varies seasonally and is inversely dependent on soil temperature and soil moisture. Land-surface elevations were affected by water levels. A net decrease of about 0.5 inch per year caused by carbon loss was measured on all three islands during the study.

Plans for Fiscal Year 1994: Funding will decrease substantially in fiscal year 1994 and measurement of carbon fluxes will end. Collection of extensometer data will continue. A two-part journal article on the results of the data collection done through May 1992 was accepted by the Soil Science Society of America Journal and will be prepared for publication.

Reports:

Rojstaczer, Stuart, and Deverel, S.J., 1992, Time dependence in atmospheric carbon inputs from drainage of organic soils in the San Joaquin-Sacramento Delta (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement Abstracts, v. 73, no. 43, p. 109.

Rojstaczer, Stuart, and Deverel, S.J., 1993, Time dependence in atmospheric carbon inputs from drainage or organic soils: Geophysical Research Letters, v. 20, no. 13, p. 1383-1386.

NITRATE IN GROUND-WATER BASINS

Number: CA480

Cooperating Agency: Eastern Municipal Water District

Project Chief: Terry F. Rees

Period of Project: January 1990 to September 1993

Problem: Nitrate concentrations in ground water from many basins in southern California approach or exceed the maximum contaminant level of 10 milligrams per liter (as nitrogen). In order to manage the ground-water resources and to identify future mitigating measures the chemical, biological, and hydraulic processes that affect nitrogen speciation and concentration need to be determined for various representative land-use and hydrologic conditions.

Objectives: Define current ground-water conditions in the Hemet subbasin, including thickness and extent of water-bearing materials, direction of ground-water flow, and chemical composition of ground water. Determine the effects of chemical, biological, and hydraulic processes on nitrogen speciation and concentration in the unsaturated zone beneath various land-use and hydrologic conditions. Determine the quantity of nitrate reaching the water table at each site in the study area. Determine the degree of mixing and vertical distribution of nitrate in the saturated zone.

Approach: A detailed study has been done at seven sites that have hydrologic and land-use conditions representative of southern California basins: (1) a residential area; (2) a golf course using reclaimed water; (3) a citrus grove; (4) an irrigated agricultural area; (5) a poultry operation; and (6,7) two dairies. Instrumentation included neutron access tubes, suction-cup lysimeters, and soil-gas sampling tubes installed above the water table, and multiple-completion wells installed below the water table. Physical and hydrogeologic characteristics, common chemical concentrations, selected isotopes, and bacteria population have been studied.

Progress: Research on the project was completed at the end of December 1992. An interpretive report, "Hydrology, water quality, and nitrogen geochemistry in the saturated and unsaturated zones beneath various land uses, Riverside and San Bernardino Counties, California, 1991-93," was submitted for colleague review and the revised manuscript was submitted for processing for Director's approval. To date, two journal publications have been prepared and have received Director's approval.

The quantity of water stored in the Hemet basin in August 1992 is estimated to be 327,000 acre-feet. Dissolved-solids concentrations ranged from 380 to 700 milligrams per liter (mg/L), except in small areas where the concentration exceeded 1,000 mg/L. Nitrate concentrations exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) of 10 mg/L nitrate (as nitrogen) in the southeastern part of the basin, in the Domenigoni Valley area, and beneath a dairy in the Diamond Valley area.

Significant microbial denitrification in the unsaturated zone could be documented beneath residential, reclaimed water, and dairy land uses. Denitrification was less apparent beneath agricultural and citrus grove land uses.

Plans for Fiscal Year 1994: The project is complete except for release of the final report.

Reports: None

PROCESSES GOVERNING THE DISTRIBUTION AND MOBILITY OF SELENIUM AND ARSENIC IN SHALLOW GROUND WATER, TULARE BASIN

Number: CA481

Cooperating Agency: California Department of Water Resources

Project Chief: Roger Fujii

Period of Project: October 1989 to September 1994

Problem: Large parts of the Tulare basin are affected by shallow ground water, leading to a need for subsurface drainage for continued agricultural production. Disposal of agricultural drainwater in evaporation ponds and potential downward migration of contaminated, shallow ground water to regional aquifers have been a source of concern for migratory waterfowl and human health because of the high concentrations of arsenic and selenium in the drainwater. The diversity and contrast of depositional environments has contributed to the highly variable concentrations of arsenic and selenium in shallow ground water throughout the basin.

Objectives: Compare distribution of arsenic, selenium, and other selected elements in ground water and sediments at four locations in subareas of the Tulare basin. Identify geochemical, biological, and hydrologic processes controlling the solubility and mobility of arsenic and selenium at each location. Compare and contrast the potential influence of key processes among the subareas. Determine the necessary studies to comprehensively evaluate the geochemical, biological, and hydrologic processes governing solubility and mobility of arsenic and selenium for the subareas in this basin.

Approach: The distribution of arsenic and selenium in ground water and sediments will be evaluated at four locations in the basin. At each site, 20-, 50-, 100-, and 200-foot wells will be drilled and sampled. During drilling of the 100-foot well, a continuous core will be taken and porewater and sediment will be analyzed every 5 to 10 feet. Samples will be analyzed for arsenic, selenium, and other trace and major constituents. Water levels will be monitored. These data will help to define the key processes that affect the mobility of arsenic and selenium and to form the basis for further studies in the basin.

Progress: Results of analysis of porewater and well-water samples from three new study sites in the Alpaugh and Lost Hills areas are (1) at one site, specific conductance ranged from 3,650 to 16,430 microsiemens per centimeter (µS/cm), selenium (Se) ranged from 1 to 8 micrograms per liter (µg/L), and arsenic (As) ranged from 4 to 577 µg/L, (2) at a second site, specific conductance ranged from 15,300 to 66,000 µS/cm, Se ranged from less than 1 to 123 µg/L, and As ranged from 6 to 100 µg/L, and (3) at site 2R, specific conductance ranged from 4,110 to 35,700 µS/cm, Se ranged from less than 1 to 1,252 µg/L, and As ranged from less than 1 to 6 µg/L. Redox conditions were characterized in the Alpaugh and Lost Hills area by evaluating the Terminal Electron Accepting Processes (TEAPs). Oxygen/nitrate reduction, iron reduction, sulfate reduction, and methanogenisis were indicated as the predominant TEAPs. Selenium was found above the detection limit (1 µg/L) only in oxygen/nitrate reducing wells. Arsenic species at study sites (arsenate and arsenite) corresponded to TEAPs as follows: oxygen/nitrate reducing wells had 95 percent or more arsenate, predominantly iron reducing wells had 17 to 55 percent arsenite, and predominantly sulfate reducing wells had 81 to 90 percent arsenite. Solid-phase extractions (0.1M PO4, pH 8) indicate greater than 20 percent of arsenic is P-extractable, indicating As adsorption is an important control on As solubility.

Plans for Fiscal Year 1994: Selective extractions of selected sediment samples from three to four sites will be completed and analyzed. These data estimate solid-phase associations of Se and As and will be published in a report this year. Most of the effort in fiscal year 1994 will be related to data analysis and report writing (this is the last year of the project).

Reports:

Chalmers, A.T., and Fujii, Roger, 1993, Effects of redox conditions on the distribution and solubility of Se and As in ground water, Tulare Basin, California: II. Redox characterization and As (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 271.

Fujii, Roger, and Chalmers, A.T., 1993, Effects of redox conditions on the distribution and solubility of Se and As in ground water, Tulare Basin, California: I. Field methods and Se (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 271.

Swain, Walter C., and Duell, Lowell F.W., Jr., 1993, Water-quality data for shallow wells in the western and southern Tulare Basin, San Joaquin Valley, California, May to August 1989: U.S. Geological Survey Open-File Report 92-655, 30 p.

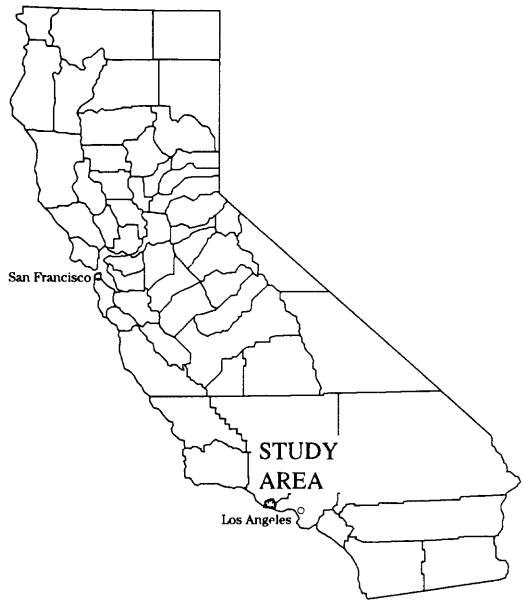
OPTIMUM CONTROL OF SEAWATER INTRUSION, OXNARD PLAIN, VENTURA COUNTY

Number: CA483

Cooperating Agencies: United Water Conservation District; and Calleguas Municipal Water District

Project Chief: Eric G. Reichard

Period of Project: October 1989 to September 1993



Problem: Seawater intrusion beneath the Oxnard Plain threatens the water supply in Ventura County. There is a need to improve the understanding of the processes of seawater intrusion in the multiaquifer system and to develop management plans for controlling intrusion.

Objectives: Apply and demonstrate the usefulness of solute-transport and hydraulic-optimization modeling techniques in evaluating various management options to control seawater intrusion in a multiaquifer system.

Approach: The study tasks are to drill and collect data from nested test wells in the Oxnard Plain, to analyze the data to develop a conceptual model of the three-dimensional geohydrologic system, to develop a density-dependent transport model of seawater intrusion, and to develop a set of simulation optimization models for evaluating alternative strategies for controlling seawater intrusion.

Progress: A cross-sectional solute-transport model of seawater intrusion through Hueneme was developed using SUTRA (a two-dimensional, density-dependent, solute-transport model developed by the U.S. Geological Survey). The simulation-optimization modeling was extended to considered uncertainty in surface-water supplies. A draft report describing simulation-optimization modeling was completed.

Plans for Fiscal Year 1994: A report describing simulation-optimization modeling will be submitted for Director's approval. A report describing the cross-sectional solute-transport modeling also will be completed and will be submitted for Director's approval.

Reports:

Cleveland, T.G., Nishikawa, Tracy, and Hanson, R.T., 1993, Vertical distribution of hydraulic conductivity estimated from flowmeter and drawdown data using gradient optimization (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 244.

Reichard, E.G., 1993, A Stochastic simulation-optimization model for ground-water/surface-water management (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 250.

SAN FRANCISCO BAY-ESTUARY TOXIC CONTAMINANTS STUDY

Number: CA484

Cooperating Agencies: U.S. Geological Survey Federal Program; U.S. Environmental Agency; and California Water Resources Control Board

Project Chief: Kathryn M. Kuivila

Period of Project: March 1990 to September 1995

Problem: Estuaries are among the most heavily used of the Nation's surface-water resources and are particularly susceptible to contamination by toxic substances. The San Francisco Bay estuary receives a broad range of organic contaminants that vary widely in their sources, seasonality, toxicity, and environmental behavior. Despite an increasing awareness of potential contamination issues, the effect of organic contaminants in the estuarine environment is not fully understood.

Objectives: Determine how organic contaminants from riverine and local sources are transported and react in the estuary under varying hydrologic conditions. Determine the ultimate fate of these organic contaminants within the estuary. Develop methods to detect and quantify ecological responses to the presence of organic contaminants in the estuary.

Approach: Present data on pesticide use and waste discharges will be synthesized to select specific organic contaminants for sampling and analysis. Various sampling techniques will be used, including fixed-site monitoring and synoptic studies to provide a consistent record of river-transported contaminants. Certain hypotheses on contaminant distribution during specific hydrologic and contaminant-loading conditions will be tested. Bottom sediment and biota will be collected and analyzed to define the distribution of these contaminants and their partitioning between water, sediment, and biota.

Progress: The focus of the project this year was the transport of dissolved pesticide pulses from the rivers, through the delta, and into San Francisco Bay following rainfall in January and February 1993. Three distinct pulses of diazinon were detected in the Sacramento River at Sacramento and were followed through the delta and Suisun Bay to Martinez. Similar pulses of diazinon (and other pesticides) were observed at Vernalis on the San Joaquin River and were detected at Stockton 2 days later. At central delta sites, distributions of diazinon showed a gradual increase over time rather than a pulse-like distribution. Results of the bioassays [done in collaboration by the Regional Water Quality Control Board (RWQCB)] indicated that the San Joaquin River at Vernalis was acutely toxic to *Ceriodaphnia dubia* for the 12 consecutive days (February 8-19) with the highest diazinon concentrations. The results of the pesticide sampling emphasize the highly temporal nature of pesticide inputs and the importance of high-flow conditions in pesticide transport to the bay. Daily sampling continued for dissolved pesticides at Vernalis (San Joaquin River) and three times a week at the Tower Bridge (Sacramento River). Suspended sediments were collected during high flow at Sacramento on the Sacramento River and at Vernalis on the San Joaquin River and will be analyzed later for pesticides. A method was developed using microcosms and radiolabelled carbofuran to estimate microbial degradation of carbofuran. Four presentations, as well as four papers, on the results of the project were presented at the Toxic Substances Hydrology Program Technical Meeting. A water-fact sheet was written and published.

Plans for Fiscal Year 1994: The emphasis for next year will be on sampling suspended sediments and sediment-bound pesticides in Suisun Bay. Journal articles will be written on the results of long-term pesticide monitoring at Sacramento and Vernalis and on pesticide sampling in January and February 1993.

Reports:

Crepeau, K.L., Kuivila, K.M., and Domagalski, J.L., 1993, Concentrations of dissolved rice pesticides in the Sacramento River, California, 1990-92 (abs.): Eos, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 134.

Kuivila, K.M., 1993, Diazinon concentrations in the Sacramento and San Joaquin Rivers and San Francisco Bay, California, February 1993: U.S. Geological Survey Open-File Report 93-440, 2 p. (Water-Fact Sheet)

Kuivila, K.M., Crepeau, K.L., Copeland, D.D., and Goelman, K., 1993, Input and transport of a dormant spray pesticide to the San Francisco Bay, California, February 1993 (abs.): Eos, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 134.

SAN JOAQUIN-TULARE BASINS NATIONAL WATER QUALITY ASSESSMENT PROGRAM

Number: CA485

Cooperating Agency: None. (U.S. Geological Survey Federal Program)

Project Chief: Neil M. Dubrovsky

Period of Project: Continuing

Problem: The quality of the Nation's water is being degraded by various human and natural processes. A large amount of water-quality data has been collected to assess the effect of point sources and compliance with regulations. In contrast, the effect of nonpoint sources is significant but rarely studied. Existing data generally are inadequate to assess the status and trends in water quality of large regions and the Nation. Additional data need to be collected to address questions about water quality and to determine the effect of regulatory practices and past water-quality management decisions.

Objectives: (1) Provide a description of current water-quality conditions consistent with the needs of the national level synthesis of the data; (2) define long-term trends (if any) in water-quality data; and (3) identify, describe, and explain to the extent possible the major human and natural factors that affect observed water-quality conditions and trends. Key factors of concern in the study unit are concentrations of pesticides, nutrients, and naturally occurring trace elements in surface and ground water; and surface-water salinity.

Approach: During the first phase an extensive retrospective analysis of the status and trends in water quality and aquatic ecology will be done using existing data. A reconnaissance will be done concurrently to collect data on aspects of water quality for which little or no data exists. These two activities will identify areas where there is insufficient data for water-quality assessment and will provide the basis for design of a 3-year intensive data-collection phase. A long-term network will consist of a carefully selected subset of the stations sampled in the intensive phase.

Progress: Retrospective analysis of available data is nearly complete. Samples of tissues and bed sediments were collected at 18 sites in October to determine the occurrence of trace elements and hydrophobic organic contaminants in these media. Sampling of the basic fixed-station network for surface-water quality began in January 1993. Ten stations on the lower San Joaquin River and its tributaries were sampled monthly for major ions and nutrients. The intensive fixed-station study of the seasonal variation in dissolved pesticides in surface water also began in January. Four sites were monitored: Orestimba Creek, Salt Slough, the Merced River, and the San Joaquin River at Vernalis. Two surface-water synoptics also were done to ascertain the distribution of the herbicide 2,4-D. During the summer, 20 ground-water samples were collected from vineyards for the first data set for the "Land-use Study," which will compare the effect of land use on the quality of shallow ground water. Data collection to assess the relation between aquatic ecology and water quality also was done at 14 sites during the summer; data on fishes, invertebrates, algae, and habitat were collected.

Plans for Fiscal Year 1994: Monitoring of surface-water quality will continue at the basic fixed stations. Monitoring for pesticides in surface water will continue but will focus on the effect of the winter orchard dormant spray on eastside tributaries: weekly sampling will be supplemented by collecting samples across a hydrograph during one major storm; samples during a period of high flow also will be collected to assess the transport of sediment bound pesticides in westside tributaries; samples will be collected for a land-use study of the quality of shallow ground water under almond orchards; and data will be collected

to investigate transport of agricultural chemicals in a vertical profile along a ground-water flowline underlying vineyards. An ecological synoptic will be done to obtain broader coverage of the eastern San Joaquin Valley and adjacent foothills.

Reports:

Domagalski, J.L., 1993, Pesticides detected in the San Joaquin River basin, California: Results of an intensive fixed-station sampling design developed for the National Water Quality Assessment Program (abs.): Eos, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 129.

Dubrovsky, N.M., and Domagalski, J.L., 1993, Pesticides detected in the San Joaquin River basin, California: Analysis of existing data and design of monitoring network (abs.): Eos, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 134-135.

APPRAISAL OF WATER RESOURCES IN THE WAWONA AREA OF YOSEMITE NATIONAL PARK WITH EMPHASIS ON THE AVAILABILITY OF GROUND WATER

Number: CA486

Cooperating Agency: National Park Service

Project Chief: James W. Borchers

Period of Project: October 1990 to September 1993

Problem: The 1980 General Management Plan for Yosemite National Park recommends relocating the park and concessioner headquarters and most employee housing out of Yosemite Valley. Most of the relocations have not taken place because of questions regarding water supplies of alternative sites, including Wawona. Currently, most water used in Wawona is from the south fork of the Merced River, but this source of water does not adequately meet present demands during low riverflows. Alternative water sources need to be determined. Minimal information exists on water supply from springs and ground water in the fractured granitic rocks underlying the Wawona area.

Objectives: Examine the potential for water-resources development in the Wawona area of Yosemite National Park. The investigation will focus on defining the hydrogeologic framework of the ground-water-flow system of the South Fork, Merced River valley, near Wawona. Development of an adequate water supply may require conjunctive use of surface and ground water and importation of water from outside the Wawona area. Evaluate existing data to determine the relation between streamflow and ground water in the Wawona area and the reliability of nearby springs as a source of supply.

Approach: A reconnaissance study will be done to (1) develop a conceptual model of the fracture-controlled flow system using existing data, (2) collect data to refine the model, and (3) use the model to evaluate the ground-water system as a source of supply. Refinement of the conceptual model will be based on ground-water levels, water chemistry, stream gains and losses, aquifer tests, surface and borehole geophysics, and test drilling. Analysis will include evaluation of conjunctive use of springs, wells, and surface-water sources of supply.

Progress: Sampling for inorganic, isotopic, and dissolved gas constituents was done at two test holes at Wawona, two domestic wells south of Wawona in Oakhurst, two springs near Ahwahnee, and a warm spring located between Wawona and Oakhurst. This sampling was done to help determine the source of saline ground water in two test holes drilled during the study at Wawona. A 2-inch pipe was grouted at 230 feet below land surface to the surface of test hole 2 and capped to control the flow of water from the test hole. Most of the year was spent analyzing data.

Plans for Fiscal Year 1994: In December 1993, a special session will convene at the fall meeting of the American Geophysical Union to present additional results of the Wawona study. The project is complete except for report.

Reports:

Borchers, J.W., Hickman, S., and Nimz, G.J., 1993, In-situ stress and ground-water flow in fractured granite at Wawona, Yosemite National Park, California: A model for the west-central Sierra Nevada (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 581.

Borchers, J.W., Morin, R.H., and Hickman, S., 1993, Characterization of fractures in granitic rocks at Wawona, Yosmite National Park, California: A comparison of borehole geophysical and downhole visualization tools (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 567.

Caffee, M.W., Finkel, R.C., Nimz, G.J., and Borchers, J., 1992 Isotopic composition of chlorine in groundwater from the Wawona Basin, Yosemite National Park: Eos, Transactions of the American Geophysical Union, Abstracts, v. 73, no. 43, p. 173.

Hudson, G.B., Davisson, M.L., Nimz, G.J., Böhlke, J.K., and Borchers, J.W., 1993, Isotopic segregation of ground water in the fractured granitic rock at Wawona, Yosemite National Park, California (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 582.

Hudson, G.B., Ruiz, B.V., and Borchers, J.W., 1992, The application of noble gases in groundwater studies: Eos, Transactions of the American Geophysical Union, Abstracts, v. 73, no. 43, p. 170.

Nimz, G.J., Caffee, M.W., and Borchers, J.W., 1993, Extremely low 36CL/CL values in deep ground water at Wawona, Yosemite National Park, California: Evidence of rapid upwelling of deep crustal waters (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 582.

Nimz, G.J., Smith, D.K., Caffee, M.W., Finkel, R.C., Hudson, G.B., Borchers, J.W., and Nimz, K.P., 1992, Isotopic characterization of hydrologic structure and chemical interaction between groundwater and granitic rock in the Wawona Basin, Yosemite National Park: Eos, Transactions of the American Geophysical Union, Abstracts, v. 73, no. 43, p. 170.

Snaman, D.K., Hunter, R.J., Wood, M.D., and Borchers, J.W., 1993. Tiltmeter mapping of fractures in grantitic rock at Wawona, Yosemite National Park, California (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 582.

ASSESSMENT OF THE EFFECTS OF POTENTIAL CLIMATE CHANGE ON THE WATER RESOURCES OF THE CARSON AND AMERICAN RIVER BASINS

Number: CA488

Cooperating Agency: None. (U.S. Geological Survey Federal Program)

Project Chief: Michael D. Dettinger

Period of Project: March 1990 to September 1994

Problem: Changes in current climatic patterns could have significant effects on the type, amount, and timing of precipitation and runoff in the Carson and American River basins. Significant changes could result in far-reaching effects on hydrologic processes, biota, water management, and water use. These same "effects" may tend to influence the forms that climate change (tendencies toward wetter, drier, warmer, or cooler seasons) could take.

Objectives: Define the effects of possible climate change on the water resources of the Carson and American River basins and develop analytical tools for analysis of the effects of climate change on water resources elsewhere. In fiscal year 1994, the scope of the study will be broadened to define the interactions and feedback between large-scale climate systems (continental) and regional-scale hydrology, especially in the midcontinent region of North America.

Approach: The study was a joint effort between the California and Nevada Districts to describe current climate, develop future climate scenarios, develop a data base to support watershed modeling, and develop a model of watershed processes for current and future scenarios. In fiscal year 1994, a conceptual land-air interaction model will be developed linking a land-surface hydrologic model with a planetary boundary-layer model. The overlying atmosphere will not be modeled but specified instead. Such a model should support the development of a theory for time and distance scales at which hydrologic systems and climatic systems can and do interact.

Progress: Several journal articles were drafted and are in either Survey or journal review. These articles describe (1) regression analyses of climate-change responses of nine rivers, (2) gamma-variate disaggregation, (3) watershed-model responses to daily climate-change scenarios, (4) synthesis of climate-change scenarios which is based on observed or modeled atmospheric-circulation patterns, (5) relations between circulation patterns in global climate models and simulated monthly precipitation rates, and (6) large-scale atmospheric forcing of interdecadal trends in the hydroclimatology of the Sierra Nevada. Several shorter contributions to conference proceedings also were approved.

Plans for Fiscal Year 1994: A simplified clear-sky model of the land planetary boundary layer (PBL) interactions will be developed initially to determine time and distance scales at which land-surface variations can be communicated to the overlying atmosphere. To check the simplifications, a complex PBL model from Oregon State University (OSU) will be modified to produce a parallel set of results. Then the more difficult task of incorporating cloudy to stormy conditions into the simple model will be undertaken (the OSU model is not structured to allow such an addition).

Reports:

Dettinger, M.D., 1993, Description of interdecadal trends in surface temperatures of the Sierra Nevada and Gunnison River areas using singular-spectrum analysis (abs.), *in* Kelmelis, J.A., and Snow, Mitchell, eds., Proceedings of the U.S. Geological Survey Global Change Research Forum, Herndon Virginia, March 18-20, 1991: U.S. Geological Survey Circular 1086, p. 80-81.

Guetter, A.K., Georgakakos, K.P., Dettinger, M.D., and Cayan, D.R., 1993, U.S. outflow variability and anomaly patterns (abs.): American Meteorological Society, Conference on Hydroclimatology, Anaheim, California, January 17-22, Program, p. 158-159.

Keppenne, C.L., Dettinger, M.D., and Ghil, Michael, 1993, Spatio-temporal analysis of interannual fluctuations in the United States surface-air temperature record (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 123.

IRRIGATION DRAINAGE DETAILED STUDY OF KLAMATH BASIN, CALIFORNIA AND OREGON

Number: CA489

Cooperating Agency: U.S. Department of the Interior

Project Chief: Peter D. Dileanis

Period of Project: October 1991 to September 1993

Problem: Results of a reconnaissance investigation done in 1988 indicate two major water-quality concerns that may effect aquatic environments within the Klamath Basin: (1) the effects of pesticide use and (2) excessive eutrophication of aquatic environments. This investigation also indicated a need for further study on the occurrence of arsenic and mercury in some biological tissues.

Objectives: Determine if use of pesticides on agricultural lands adjacent to the Klamath Basin Wildlife Refuge is harming aquatic environments. Determine the relation between excessive eutrophication in the waterways and existing agricultural practices and the effects of the eutrophic conditions on aquatic environments.

Approach: Effects of pesticides and eutrophication will be studied using various bioassays and chemical tests performed onsite or in a laboratory. Sampling stations will be located in and around the wildlife refuges and will represent end points for irrigation return flows, the most likely areas to contain detectable pesticides and to be effected by eutrophication. Static bioassays using Microtox (bacteria), algae, *Daphnia,* amphipods, frog embryo, and fish and in situ bioassays using *Daphnia,* amphipods, and fish will be done weekly. Water-quality measurements will be made with all bioassays. Water samples will be analyzed for organic pesticides.

Progress: An open-file data report was prepared, which presents all the data collected by U.S. Geological Survey and U.S. Fish and Wildlife Service personnel during 1990-92. Data analysis completed in 1993 indicates that the most significant water-quality problems are related to eutrophic conditions and high organic-carbon loads of water upstream of wildlife refuges. Aquatic habitat in the wildlife refuges and surrounding areas are characterized by low dissolved oxygen and potentially toxic ammonia concentrations, exacerbated by high pH. Concentrations of pesticides, with the exception of Acrolein, generally were low in the large drains feeding into Tule Lake. The project is complete except for report.

Plans for Fiscal Year 1994: The interpretive report will be completed.

Reports: None

NATIONAL WATER QUALITY ASSESSMENT PROGRAM--NATIONAL SYNTHESES

Number: CA491

Cooperating Agency: None. (U.S. Geological Survey Federal Program)

Project Chief: Robert J. Gilliom

Period of Project: Continuing

Problem: Protecting the quality of the Nation's ground- and surface-water resources is a high-priority national concern. The quality of these resources can affect public health and the economics of agriculture, industry, fish and shellfish, and recreation. At present, there is no unified and consistent program for national water-quality assessment. Without such a program, policy decisions must be made on the basis of extrapolations from knowledge of a few localized problems and in ignorance of other types of problems which may be unknown because no one has investigated them at the right times and places.

Objectives: Define the quality of the Nation's ground- and surface-water resources through a continuing assessment program at a nationwide scope that would (1) describe the status and temporal trends in water quality and (2) improve the understanding of the factors that influence water quality and thereby provide the basis to forecast change and evaluate the likely effect of various proposed remedial and protective actions on water quality.

Approach: The program is a national perennial program of water-quality data acquisition, interpretation, and assessment. Activity will be clustered into study units that are widely scattered around the Nation but which, in aggregate, account for a large percentage of the Nation's water use. A nationally consistent set of target water-quality variables will be studied. The work and reporting of results will be done at three scales: national, regional, and study unit.

Progress: National design guidelines for the study-unit investigations and initial documentation of plans for the national synthesis were completed. Existing data on pesticides at the national scale were compiled and reports are being prepared.

Plans for Fiscal Year 1994: Analyses of existing data on pesticides will be completed. In addition, a detailed design for the national synthesis data analysis will be completed. Analyses of new data from the National Water Quality Assessment Program study units will begin.

Reports:

Capel., P.D., 1993, Organic chemical concepts, Chapter 7 *in* Alley, W.M., ed., Regional ground-water quality: New York, Van Nostrand Reinhold, p. 155-179.

Dubrovsky, N.M., and Deverel, S.J., 1993, Multiscale approach to regional ground-water assessment: Case study of selenium in the San Joaquin Valley, Chapter 22 *in* Alley, W.M., ed., Regional ground-water quality: New York, Van Nostrand Reinhold, p. 537-562.

GROUND WATER, SOUTH SAN FRANCISCO BAY AREA

Number: CA493

Cooperating Agencies: The San Francisco Bay Area Water Users Association; San Francisco, city of; San Francisco Water Department; andAtherton, city of

Project Chief: John L. Fio

Period of Project: January 1991 to September 1994

Problem: The south San Francisco Bay and peninsula area is one of the largest urban and industrial centers in northern California. Its water supply is primarily surface water from local and distant drainage basins. Availability of water is strongly affected by annual precipitation, runoff, and reservoir storage in the Sierra Nevada. An alternative source of water is needed to augment surface-water deliveries during droughts or following disasters that might disrupt deliveries and reduce supplies. Ground-water in the underlying aquifer systems is a viable alternative, but the variability in aquifer characteristics and ground-water quality is poorly understood.

Objectives: The overall objective of the study is to assess the ground-water resources using existing data. The specific study objectives are to (1) identify regional geohydrologic boundaries, aquifer characteristics, storage volumes, and water budgets; (2) define regional chemical characteristics of ground water; (3) identify areas of potential subsidence, water logging, ground-water development or areas of potential ground-water development, or areas that may benefit by conjunctive use of surface, ground, and reclaimed water.

Approach: The study will assess, at a reconnaissance level, the hydraulic characteristics of the aquifer, spatial distribution of water quality, and problems associated with ground-water withdrawal or recharge. The study will use existing data, which are widely dispersed among participating agencies. Data from earlier reports, maps, existing well logs, as well as data on water use, land use, and water quality will be compiled in a geographic information system (GIS). The GIS data base then will be used to assess the spatial variability in ground-water characteristics on a regional basis.

Progress: The data base has been completed and was used to conduct a regional assessment of ground-water conditions in the study area. Maps showing the fraction of coarse-grained sediment at depth intervals of 0 to 15 meters, 35 to 60 meters, and greater than 60 meters have been constructed. Maps showing hydraulic-head contours for shallow (less than 45 meters below land surface) and deep (greater than 45 meters below land surface) zones have been constructed. Maps showing average concentrations of dissolved solids and nitrate have been constructed, and geochemical modeling to characterize ground-water supplies, land use, and consumptive use have been compiled for individual water districts in the study area. Two reports have been written. The first report has received colleague review; it describes a regional assessment of the geohydrology and water quality of the south San Francisco Bay area. A second report is undergoing editorial review; it documents the structure, contents, and limitations of the data base developed for the study.

Plans for Fiscal Year 1994: Water- and land-use data are being used to determine water-supply and consumptive-use patterns in the study area for 1990, and the results will be described in an interpretive report that is in preparation. This report is scheduled for transmittal to colleague review in July 1994. The report describing the regional geohydrology and water quality of the south San Francisco Bay area and the report documenting the structure, contents, and limitations of the data base are scheduled to be submitted to the Director for approval.

Reports: None

EFFECTS OF WATER BANKING ON GROUND-WATER FLOW AND QUALITY IN THE RIALTO-COLTON BASIN, SAN BERNARDINO

Number: CA494

Cooperating Agency: San Bernardino Valley Municipal Water District

Project Chief: Linda R. Woolfenden

Period of Project: October 1991 through September 1995

Problem: Water banking is a key factor for meeting future water-supply needs in southern California. Historically, ground-water extractions have exceeded natural recharge in southern California, resulting in declining water levels and, in some areas, water-quality degradation. Using ground-water basins for water banking during wet periods will help solve southern California's water-supply problems. The Rialto-Colton basin has the potential for water banking because of its historically good quality of water, the known large capacity for ground-water storage in the basin, and and the local availability of imported water.

Objectives: The objective of this study is to determine the effects of water banking on the local ground-water-flow system and on ground-water quality near an existing artificial-recharge site and basinwide. This will be accomplished by determining the movement and mixing of imported water at the existing artificial-recharge site within the Rialto-Colton basin, defining basinwide ground-water hydraulics and ground-water quality, and predicting the movement and mixing of artificially recharged imported water.

Approach: The study tasks are to drill and complete eight multiple-depth wells, measure water levels and collect samples for chemical analyses for these wells and selected existing wells, conduct aquifer tests, develop a water budget, and simulate basinwide ground-water flow using a mathematical model. Data collected from these tasks will contribute to the formulation of a conceptual model. The mathematical model will be used to verify the conceptual model and to assess the effects of artificially recharging imported water on basinwide ground-water flow and ground-water quality.

Progress: Work during the first 2 years of the study concentrated on drilling and constructing multiple-depth piezometers at 10 sites throughout the basin. These piezometers, as well as selected existing wells, were used to define the hydraulic characteristics of water-bearing materials and confining beds, to monitor water levels, and to collect samples for chemical analyses. In addition to analyses for major dissolved ions, hydrogen and oxygen isotopes were useful in determining the fate of artificially recharged imported water. Work on a ground-water-flow model was started.

Plans for Fiscal Year 1994: During fiscal year 1994 (the third year of the study), an additional test well will be drilled. Aquifer tests are planned for four sites to estimate the hydraulics properties of aquifer materials. Aerial photos, and possibly gravity measurements, will be used to more precisely define the San Jacinto fault and other unnamed faults that act as partial barriers to ground-water flow. Water from most wells installed for this project and two existing wells will be sampled for chemical analyses, including major dissolved ions, hydrogen and oxygen isotopes, and carbon-14. The carbon-14 analyses will be useful in determining the extent that the unnamed faults act as barriers to ground-water flow. Work on the mathematical model to simulate ground-water flow will continue.

Reports:

Woolfenden, L.R., 1993, Distribution of stable isotopes in ground water in the Rialto-Colton basin, California: American Society of Civil Engineers, Annual Conference, Management of irrigation and drainage systems, Park City, Utah, July 21-23, 1993, p. 271-278.

GROUND-WATER HYDROLOGY AND TRACE-ELEMENT TRANSPORT IN FRACTURED ROCKS AT THE PENN MINE AND CAMANCHE RESERVOIR, CALAVERAS COUNTY

Number: CA495

Cooperating Agencies: California State Water Resources Control Board; and East Bay Municipal Utility District

Project Chief: Charles N. Alpers

Period of Project: October 1991 to December 1995

Problem: Penn Mine is an abandoned copper-zinc mine in northwestern Calaveras County, California. Mining activity from the 1860's to 1950's left nearly 1 million ton of waste rock and tailings exposed in surface piles. In 1979, seven unlined waste-water ponds were built by the East Bay Municipal Utility District and California Regional Water Quality Control Board--Central Valley Region to capture contaminated runoff from the site. Parts of the largest pond likely recharge the underlying aquifer of fractured metavolcanic rock. Remediation of acid drainage will depend on achieving a better understanding of ground-water hydrology and trace-element transport.

Objectives: Determine ground-water-flow patterns near the Penn Mine site with emphasis on the fractured metavolcanic-rock aquifer and quantify interactions with Camanche Reservoir. Characterize the geochemistry of the ground-water system and determine important physical and biogeochemical processes controlling distributions of major constituents and trace elements. Determine residence time of dissolved sulfate in acidic ground water between Penn Mine and Camanche Reservoir and evaluate mixing of water from mine workings and waste-water ponds. Quantify transport of major constituents and trace elements along flow paths from the mine site to Camanche Reservoir.

Approach: Detailed hydrogeologic and geochemical investigations began between Penn Mine and Camanche Reservoir. Surface mapping and surface and downhole geophysics will be used to determine orientation, density, and location of fractures. Downhole flow-meter measurements will determine zones with flowing fractures; selected zones will be isolated using inflatable packers and sampled separately for water quality and hydraulic conductivity. Water-rock interactions will be assessed using mass-balance calculations and supplemented with speciation-saturation and mass-transfer calculations.

Progress: Eight additional wells were drilled near the waste-water impoundments at Penn Mine and Camanche Reservoir in November 1992. In addition, four wells were drilled into the underground mine workings. Water-quality samples were collected in December 1992. Recovery curves from pumpage during sampling were used to estimate transmissivity in the fractured-rock aquifers. Data loggers recorded hourly water-table elevation in several wells at multiple-depth intervals. Preliminary estimates were made of metal flux in Camanche Reservoir from the unlined waste-water impoundments.

Plans for Fiscal Year 1994: The following tasks are scheduled to be completed: (1) additional water-quality sampling in the area between the Penn Mine waste-water impoundments and Camanche Reservoir and into the underground mine workings, (2) determination of apparent ground-water age using dissolved chlorofluorocarbons and tritium in ground-water samples and analysis of stable isotopes: $^{18}O/^{16}O$ and $^{2}H/^{1}H$ in ground and surface waters and $^{34}S/^{32}S$ and $^{18}O/^{16}O$ in dissolved sulfate, (3) interpretation of water-quality data using geochemical modeling, (4) interpretation of water-level data, slug-test data, and apparent ground-water age using hydrologic modeling (MODFLOW and discrete fracture network approach), and (5) refinement of estimates of metal flux by ground-water transport into Camanche Reservoir from Penn Mine waste-water impoundments and underground mine workings.

Reports:

Alpers, C.N., and Hamlin, S.N., 1993, Geochemistry and hydrology of an acidic ground-water plume in fractured metamorphic rocks at Penn Mine, Calaveras County, California (abs.): Eos, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 326.

EVALUATION OF CARBON FLUXES IN FLOODED ORGANIC SOILS IN THE SACRAMENTO-SAN JOAQUIN DELTA

Number: CA496

Cooperating Agency: California Department of Water Resources

Project Chief: Bronwen Wang

Period of Project: October 1991 to September 1995

Problem: Much of the land surface in the Sacramento-San Joaquin Delta has subsided below sea level. This subsidence primarily is due to oxidation of the organic soils, which were drained in the early 1900's. To prevent further subsidence and possible levee failure, the California Department of Water Resources plans to inundate islands in the western delta. Understanding of island elevation changes and aqueous and gaseous carbon fluxes in these resubmerged organic soils will contribute to the development of water- and land-management practices that will be developed to minimize land subsidence.

Objectives: The overall objective is to determine the effects of different water- and land-management practices on land subsidence and on aqueous and gaseous carbon fluxes in organic soils. Specific objectives of the study are to (1) quantify aqueous and gaseous carbon fluxes under different water- and land-management regimes, (2) determine the biogeochemical processes controlling these carbon fluxes, (3) assess the effects of different water- and land-management practices on these biogeochemical processes, and (4) assess the effects of different water- and land-management practices on subsidence.

Approach: Island elevation changes and aqueous and gaseous carbon fluxes will be quantified, and predominant biogeochemical processes will be identified under different water- and land-management practices. Specific study elements include (1) island-elevation-change measurements using extensometers, (2) assessment of aqueous and gaseous carbon fluxes by IR-total organic carbon analysis and gas chromatography, and (3) assessment of the biogeochemical pathways from carbon, hydrogen, and oxygen isotope composition.

Progress: The results of the first manipulation of water management of the ponds showed that irrigation of the moist pond resulted in a short-term decrease in the CO_2 flux. The CO_2 flux returned to preirrigation levels within 72 hours; a peak flux was seen approximately 2 weeks after irrigation. Methane concentrations increased in the upper 2 feet of the soil profile after irrigation. Flooding may have caused a reduction in O_2 in the surface soil thereby decreasing the activity of the aerobic microorganisms responsible for methane oxidation and aerobic peat oxidation to CO_2. Carbon dioxide was emitted from the moist and seasonal ponds and the control site. Methane flux was not measured from any of these three sites, not even in the moist pond after irrigation. The gaseous carbon flux from the flooded pond consisted of methane; no measurable carbon dioxide flux was found. Analysis of variance showed that the mean carbon flux under flooded conditions was significantly lower than the mean carbon flux under moist, seasonal, and control conditions. No significant difference was found between the moist and seasonal ponds and the control site. Even though the difference was not significant, mean carbon flux from the seasonal pond was consistently lower than the moist pond and the control site. This may be due to a lower moisture content in the seasonal pond than in the moist pond and the control site.

Plans for Fiscal Year 1994: Monitoring will continue in the ponds to provide a long-term record of the effects of water management on the gaseous carbon flux. In addition, carbon inputs are being measured to provide a carbon budget to evaluate if accretion could occur under any of these water-management

strategies. Measurement of surface elevations will continue in order to evaluate the effects of the different water-management strategies on land-surface elevation. Laboratory experiments are planned to evaluate the effects of depth of flooding and frequency of wetting and drying cycles on the carbon flux.

Reports:

Wang, Bronwen, and Deverel, S.J., 1993, Evaluation of gaseous carbon fluxes from organic soils under drained, irrigated, and flooded conditions, Sacramento-San Joaquin Delta, California (abs.): Eos, Transactions of the American Geophysical Union, Fall Meeting Supplement, v. 74, no. 43, p. 120.

GROUND-WATER AND SURFACE-WATER RELATIONS ALONG THE MOJAVE RIVER

Number: CA497

Cooperating Agency: Mojave Water Agency

Project Chief: Gregory C. Lines

Period of Project: October 1991 to September 1995

Problem: Water supply for the Mojave River basin is derived mainly from ground-water pumpage, and most of the ground-water recharge in the basin is from the Mojave River. A thorough understanding of ground- and surface-water relations is essential for future management and use of local and imported water and to evaluate management options for artificial recharge along the river.

Objectives: Document the sources and quantities of historical ground-water recharge and discharge along the Mojave River. Define hydraulic conditions that control exchange of water between the river and the ground-water system. Identify reaches of the river suitable for artificial recharge.

Approach: Historical recharge from the Mojave River will be estimated using discharge records from gaging stations and water-level measurements from wells. Phreatophytes will be mapped using aerial photographs, and ground-water pumpage will be determined from reported values and from water requirements for agricultural and municipal use. Hydraulic conditions controlling exchange of water between the river and river deposits will be quantified by infiltrometer tests, observation-well and gaging-station data, and channel and flood-plain geometry.

Progress: Major work elements during fiscal year 1993, the second year of the study, included measuring water levels in wells along the river to document water-table changes owing to flooding during the winter of 1992-93. Specific yield of the floodplain aquifer was determined by microgravity measurements and was used to estimate ground-water recharge. Streamflow records at gaging stations were analyzed to determine streamflow losses, base flow, and changes in streamflow characteristics.

Plans for Fiscal Year 1994: Water-level monitoring and analysis of historical gaging-station records will continue; however, work will be concentrated on defining streamflow depletion owing to evapotranspiration and ground-water pumping.

Reports: None

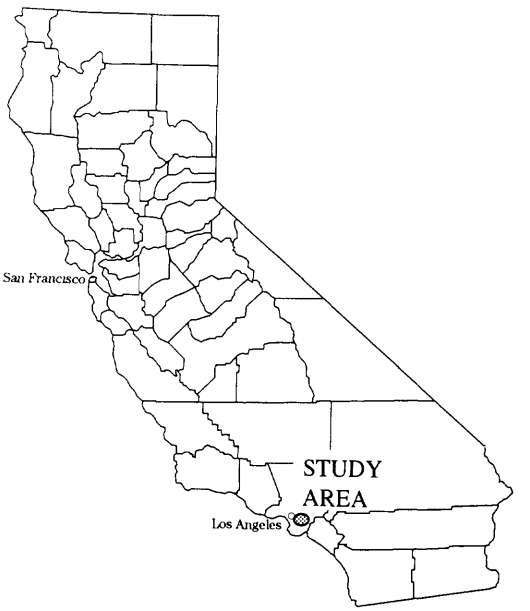
DENITRIFICATION, ATTENUATION OF ORGANIC COMPOUNDS, AND COLLOID TRANSPORT BENEATH A RECLAIMED-WATER ARTIFICIAL RECHARGE BASIN

Number: CA498

Cooperating Agency: Water Replenishment District of Southern California

Project Chief: Terry F. Rees

Period of Project: October 1992 through September 1996



Problem: A shortage of water for Los Angeles County has increased pressure to use reclaimed water to recharge ground-water basins. Reclaimed water frequently has increased concentrations of nitrogen compounds, total organic carbon, colloid organic carbon, colloid-associated metals, bacteria, viruses, and other colloids. Developing water-quality standards for recharge of reclaimed water requires knowledge of the degree to which these substances are removed as water percolates through the unsaturated zone and, assuming that they reach the water table, what geochemical and biological reactions and transport properties control their concentrations as they move through the aquifer to the point of withdrawal.

Objectives: Determine the distribution of nitrogen species, TOC, COC, CAM, and bacteria and viruses in the unsaturated zone beneath an artificial recharge basin using reclaimed water. Determine the amount of denitrification and colloid attenuation occurring in the unsaturated zone. Determine the physical and chemical fractionation of TOC, COC, CAM, and bacteria and viruses in water as they move through the unsaturated zone. To the degree funding allows, determine the chemical fractionation of these constituents as they move through the unsaturated zone.

Approach: A literature review will be done. Continuous cores will be collected at the start and finish of the project and will be analyzed for lithology, water content, porewater chemistry, and bacteria and viruses populations. At least one multiple-completion well in the saturated zone will be installed beneath the basin. Unsaturated zone instrumentation will include various types of lysimeters, gas sampling tubes, and a multilevel sampler. A neutron access tube will be installed to monitor water movement in the unsaturated zone. Upgradient and downgradient multiple-completion wells will be installed to monitor mixing in the saturated zone. Physical fractionation will be determined using centrifugation, ultrafiltration, and tangetial-flow filtration.

Progress: The research percolation pond was built and instrumented during November and December 1992. The 1-acre pond is about 8 feet deep and holds about 2-acre feet of water. Nine test-holes were installed in the bottom of the pond. One test hole was completed as an observation well with perforations at 50 feet below the pond bottom. A second hole also was completed as an observation well, but with perforations at 25 feet below the pond bottom. The third hole has a neutron-access tube with gas sampling tubes installed to monitor unsaturated zone pore moisture and unsaturated zone soil gases. The fourth hole has a radio-frequency moisture-probe tube installed. The remaining holes have as many as four suction-lysimeters installed at different depths. The types of lysimeters used include standard ceramic cup and stainless-steel cup and all Teflon.

Cores were collected during site installation and were used for determining lithology, particle-size distribution, unsaturated hydraulic characteristics, and bacterial populations. The bacteria enumerated included various enteric bacteria and nitrifying and denitrifying bacteria.

Two sets of samples were collected from the site. The first set was collected in May 1993, and the second set was collected in August 1993.

Plans for Fiscal Year 1994: Results from samples collected during May and August 1993 will be evaluated to adjust the experimental protocol at the site. Samples will be collected twice during fiscal year 1994 with an emphasis on microbial enumeration and carbon and nitrogen balance determinations.

Reports: None

SOUTH SAN FRANCISCO BAY SEDIMENT PROCESSES

Number: CA499

Cooperating Agency: San Francisco Bay Regional Water Quality Control Board

Project Chief: David H. Schoellhamer

Period of Project: October 1992 to September 1994

Problem: Estuaries are areas of accumulation of fine sediment particles that may include adsorbed trace metals and organic compounds. Concentrations of the trace metals and organic compounds in the accumulated estuarine sediments can reach levels that are toxic to benthic organisms. The cycle of sediment deposition, resuspension, transport, and redeposition leads to a long estuarine residence time for the fine sediment particles and adsorbed substances. Thus, the residence time of many toxic substances in estuaries, as well as organism exposure to these substances, is strongly related to the transport of fine sediment particles.

Objectives: The primary objective is to assess quantitatively the processes affecting the transport of suspended sediment and trace metals in South San Francisco Bay. Specific objectives are to (1) identify the processes that result in resuspension and transport of sediment in South San Francisco Bay, (2) quantify the effects of these processes on sediment residence times during low-inflow periods, and (3) determine if sediment resuspension affects dissolved concentrations of silver, cadmium, copper, and zinc.

Approach: Time-series data for suspended-solids concentrations will be collected at several sites and analyzed to identify sediment resuspension and transport processes in South Bay. A tidal hydrodynamic model with Lagrangian particle tracking will be used to assess the increase in summer residence times of adsorbed trace metals caused by sediment deposition and resuspension. The effect of sediment resuspension processes on dissolved-metals concentrations will be evaluated by analyzing dissolved concentrations of silver (a contaminant of special concern in South Bay), cadmium, copper, and zinc from water samples.

Progress: Sites at which suspended-solids concentrations are measured were established at Point San Pablo, San Francisco pier 24 (Bay Bridge), San Mateo Bridge, Dumbarton Bridge, and channel marker 17 south of the Dumbarton Bridge. Optical backscatterance sensors at mid-depth and near-bottom were used to measure suspended-solids concentrations every 15 minutes at the sites. Servicing trips were made weekly to monthly to clean sensors and to collect water samples used to calibrate the sensors. Construction of an additional site at the Golden Gate has begun. A submersible instrument for measuring water velocity, pressure, and suspended-solids concentration in shallow water was purchased and tested. The hydrodynamics of south San Francisco Bay were simulated to estimate water residence times.

Plans for Fiscal Year 1994: The monitoring sites will be maintained and shallow water instrumentation will be deployed. The residence time of sediment particles will be estimated with numerical simulations of the south bay. The effect of sediment resuspension processes on dissolved-metals concentrations will be evaluated by analyzing dissolved concentrations of several metals.

Reports: None

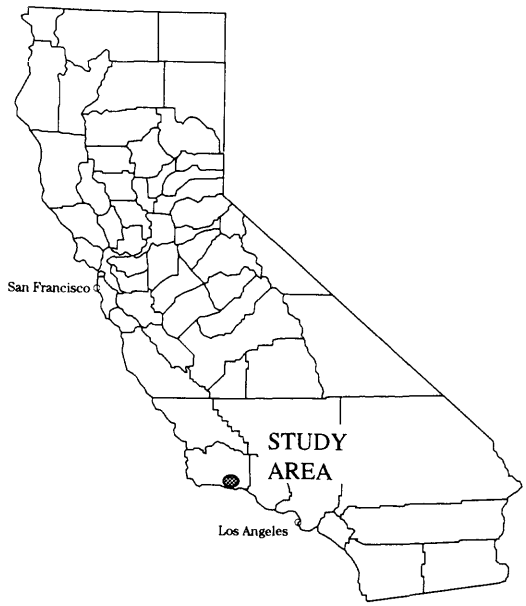
MULTIPLE-OBJECTIVE OPTIMIZATION APPLIED TO WATER-SUPPLY AND WATER-QUALITY PROBLEMS IN THE SANTA BARBARA AREA

Number: CA500

Cooperating Agency: Santa Barbara, city of

Project Chief: John R. Freckleton

Period of Project: April 1993 to March 1996



Problem: Santa Barbara relies chiefly on surface water to meet its water needs. However, reduced reservoir capacity owing to siltation and reduced surface-water supply during drought has necessitated increased ground-water extraction in the area. In addition, degradation of ground-water quality is occurring owing to seawater intrusion, upwelling of water high in dissolved solids into the freshwater aquifers, and migration of point-source pollutants into the ground-water system. Efficient water-management methods are needed to minimize the degradation of the water quality and to lessen the adverse economic effects.

Objectives: Demonstrate the use of multiple-objective optimization by addressing water-supply and water-quality problems in the Santa Barbara area. Develop methodology that allows water-management alternatives that entail multiple, and possibly conflicting objectives, to be investigated using flow and transport models coupled with multiple-objective optimization procedures. Extend, or develop, methods to link data, simulation models, and multiple-objective optimization.

Approach: Management goals and related legal and physical system constraints will be formulated mathematically as objective and constraint equations. Existing ground-water-flow and solute-transport models will be used directly, or as simplified in regression relations, to provide input data necessary for the optimization procedure. Multiple-objective optimizations problems will be solved by vector-maximization techniques. Acceptable solutions will be identified by a "filtering" process in which inferior solutions will be discarded. Sensitivity of solutions to changes in filtering parameters will be investigated.

Progress: Geographic Information System (GIS) data bases were established for the Santa Barbara and Goleta quadrangles, and ground-water-quality and site-inventory data for the study area were entered into these GIS data bases. The ground-water-flow and solute-transport models that will be used for this study were transferred from the California District Prime minicomputer to local Data General (DG) workstations located in San Diego, California. A work plan was formulated and presented to the city of Santa Barbara water managers. ADBASE (a multiple-objective linear programming package) was transferred from the Prime system to the DG system and tested with test problems. In these test problems, the maximum criterion vectors (solutions) generated by ADBASE conform to the solutions generated by the composite linear programming problem (an alternate way of addressing multiple-objective optimization problems) solved by a commercial linear programming package. MINOS and NPSOL (nonlinear optimization solvers developed at Stanford University), which may be used in this study, have been transferred to the DG system. MINOS was tested on the DG system with a small problem and generated the same solution as on the Prime. The NPSOL solver, which makes subroutine calls to MODFLOW--a U.S. Geological Survey ground-water-flow model--was successfully tested on the DG system with the current Santa Barbara area flow model.

Plans for Fiscal Year 1994: Operational and legal constraints of the water-supply system will be cataloged. A meeting will be held with the Santa Barbara water managers to assign priorities to water-management concerns. Multiple-objective management strategies will be tested using a small-scale,

two-objective problem. Development of links for the ground-water-flow and transport models and optimization procedures will begin.

Reports: None

GEOHYDROLOGY AND GROUND-WATER QUALITY OF THE WINCHESTER BASIN, RIVERSIDE COUNTY

Number: CA501

Cooperating Agency: Eastern Municipal Water District

Project Chief: Terry F. Rees

Period of Project: October 1992 to September 1995

Problem: Poor quality ground water is moving from the Winchester basin into the southwest part of the Hemet basin, degrading the better quality water present in that basin.

Geohydrologic information about the Winchester basin is needed to formulate and evaluate plans for water-resources management in the area. At present, few data on the quantity, chemical quality, or movement of ground water are available for the study area, and little is known about the thickness, extent, and hydraulic properties of the aquifer in the Winchester basin and the characteristics of the boundary between the Winchester and Hemet basins.

Objectives: Develop an understanding of the geohydrology of the Winchester basin, particularly in the area adjacent to the Hemet basin. Determine (1) the geohydrologic properties of the aquifer, (2) the quantity of ground water in storage, (3) the horizontal and vertical definition of ground-water quality, (4) the direction of ground-water flow, and (5) the quantity of water moving from the Winchester basin into the Hemet basin.

Approach: The objectives of the study will be accomplished by collecting water-level and water-quality data from several existing sites that are distributed aerially and vertically in the aquifer; by installing test holes to collect additional geologic and hydrologic data; and by determining hydraulic properties of the aquifer using aquifer tests. Depending on funding levels, a MODFLOW ground-water-flow model may be developed to test various management alternatives to control water movement between the Winchester and Hemet basins.

Progress: Four sites were identified for extensive instrumentation: one site near the Winchester-Perris basin boundary; one site near the center of the basin, 0.75 mile west of the town of Winchester; one site near the Winchester-Hemet basin boundary; and one site within the Hemet basin. The three Winchester sites are completed and the Hemet site should be completed before the end of the fiscal year. The well network has been established and the network data has been entered into the U.S. Geological Survey data base. Water-quality samples were collected once from the network.

Plans for Fiscal Year 1994: Instrumentation of the Hemet site will be completed. Water-quality samples and water-table altitudes will be collected during the winter of 1993 and the summer of 1994. Preliminary work will be done on the MODFLOW model.

Reports: None

CALIFORNIA ARMY STORMWATER PROJECT

Number: CA502

Cooperating Agency: U.S. Army

Project Chief: Alan Stroppini

Period of Project: February 1993 to January 1994

Problem: In November 1990, new regulations were adopted for acquiring National Pollution Discharge Elimmination System Stormwater Permits for municipalities and industrial facilities. The U.S. Army applied for a "group permit" through the U.S. Environmental Protection Agency to include all listed Army facilities throughout the Nation. California complied with the new regulations by issuing a General Industrial Stormwater Permit, which requires submittal of Stormwater Pollution Prevention Plans and Monitoring Plans. The Army requested the U.S. Geological Survey to assist them in the development of these plans.

Objectives: Assist the U.S. Army in the (1) determination of the need for regulatory exposure, (2) development of stormwater pollution prevention plans (SWP3) and monitoring plans (MP), (3) development of procedures for submitting Notice of Intent, and (4) acquisition of general permits for seven U.S. Army facilities and nine U.S. Army Reserve facilities.

Approach: Initially, sites will be visited on all facilities, and the need for regulatory exposure will be evaluated. For facilities requiring permits, SWP3s and MPs will be developed to provide information on potential sources of pollution to stormwater discharge, existing best-management practices, and recommendations for implementation of new best-management practices to improve the quality of the stormwater discharge. For facilities not requiring permits, the rationale will be documented. Assistance will be given for submitting a Notice of Intent. Additional sites will be visited, and SWP3 documents will be developed as needed.

Progress: To date eight facilities have submitted Notices of Intent and are covered under the General Industrial Stormwater Permit. Draft SWP3s were prepared for nine additional facilities. Discussions took place with the U.S. Environmental Protection Agency, California State Water Resources Control Board, and California Regional Water Quality Control Board representatives to resolve several issues related to what industrial activities on these Army bases need to be covered by the permits and how to permit these facilities. On the basis of these discussions and site visits at the California-based Army facilities, the Army's original list of 16 facilities may need minor revisions.

Plans for Fiscal Year 1994: Our current plan is to continue assisting those facilities with the largest regulatory exposure. Work beyond January 1994 is uncertain.

Reports: None

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Publications of the U.S. Geological Survey (USGS):--Professional Papers, Water-Supply Papers, Bulletins, Circulars, Water-Resources Investigations Reports, and Open-File Reports are sold by the U.S. Geological Survey, Books and Open-File Reports Section, Denver, Colorado. Hydrologic Investigations Atlases, Hydrologic Unit Maps, and other maps pertaining to California are sold by the U.S. Geological Survey, Map Distribution Section, which also is in Denver. See page 88 of this report for the addresses for ordering specific types of Survey publications.

U.S. Geological Survey Water-Resources Investigations Reports and Open-File Reports are available for inspection at the California District Office, U.S. Geological Survey, Federal Building, Room W-2233, 2800 Cottage Way, Sacramento, CA 95825, and U.S. Geological Survey, 5735 Kearny Villa Road, Suite O, San Diego, CA 92123. Information on their availability may be obtained from the District Chief at the above address.

New reports are announced monthly in "New Publications of the Geological Survey," subscriptions to which are available upon request from the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Water-Data Program:--Water-data stations at selected locations throughout the Nation are used by the Geological Survey to obtain records on stream discharge (flow) and stage (height), reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. These data provide a continuing record of the quantity and quality of the Nation's surface- and ground-water resources, and thus provide the hydrologic information needed by Federal, State, and local agencies and the private sector for the development and management of land and water resources. All data collected are stored in the Survey's National Water Data Storage and Retrieval System (WATSORE) and also are published by water year for each State in a publication series entitled "U.S. Geological Survey Water Resources Data." Information about the Water-Data Program can be obtained from the California District Chief.

NAWDEX:--The National Water Data Exchange was established to assist users of water data to identify, locate, and acquire needed data. It provides a nationwide service for indexing and describing the characteristics of data available from the entire spectrum of data-collection activities throughout the Federal and non-Federal water-data community.

NAWDEX maintains two data bases: (1) a Water-Data Sources Directory and (2) a Master Water-Data Index which identifies and describes available water data. NAWDEX sources can be obtained from the California District Chief. A leaflet explaining NAWDEX services is available from the NAWDEX Program Office, U.S. Geological Survey, 421 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092; phone: (703) 648-5677.

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