ACTIVITIES OF THE WATER RESOURCES DIVISION CALIFORNIA DISTRICT, FISCAL YEAR 1992

Compiled by Myrna L. DeBortoli

U.S. GEOLOGICAL SURVEY

Open-File Report 93-145

1006-09

Sacramento, California
1993

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
DALLAS L. PECK, Director

For sale by the
U.S.Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

For additional information write to:
District Chief
U.S. Geological Survey
Federal Building, Room W-2233
2800 Cottage Way
Sacramento, CA 95825

MESSAGE FROM THE DISTRICT CHIEF

As 1993 announced its arrival with abnormally high precipitation throughout the State, the 6-year drought appears to have ended in California. Nevertheless, the drought stands as testimony to the temporal limitation of the State's water resource. Water managers and private citizens alike should now be very cognizant of the complexity of sharing a limited resource, such as water, and the resultant environmental effect of exploiting this resource in order to satisfy many thirsty competitors. The California District of the U.S. Geological Survey has been active in water resources data collection, interpretation, and research in California for almost a century. More than 2,400 water-resource related reports demonstrate the District's strong commitment to collect the prerequisite hydrologic data to conduct systematic and scientific investigations that provide useful information to water managers, especially during periods of hydrologic extremes such as this last drought. This report summarizes ongoing data-collection activities, investigations, and research, all of which build on the previous reports and continue to evolve the hydrologic information base. Additionally, the large number of published reports attests to our agency's belief in communication of the data collected and the results of the investigations and research.

Our objective is to provide hydrologic information and an understanding of the hydrologic environment of the State in support of the best management of California's water resources. In order to improve our ability to meet this objective, the District has begun one of several nationwide pilot programs coordinated by the National Water Information Clearinghouse to provide wide access to hydrologic information. The District intends to actively investigate and encourage computer system links among existing water-information sources in various water agencies in the State. The pilot program is intended not to establish a centralized repository for the data, but rather to design and develop an intergovernmental and interagency water-information system. In addition, activities of the California District hopefully will continue to improve awareness of, and access to, existing sources of information and to provide referral services for information on water data, investigations, and research.

This publication is one such attempt at the information transfer process. The narratives contained herein will, in some cases, lead to detailed questions or the desire to learn more about a particular study or area. Inquiries to our offices are welcomed and encouraged.

John M. Klein
District Chief, 1992
U.S. Geological Survey
Sacramento, California

CONTENTS

FIGURES

TABLE

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 1992 were conducted from 2 project offices and 8 field offices. These offices and supporting units of the District are shown in the organization chart (fig. 1). (Following the end of fiscal year 1992, several field offices were closed and one was opened. These are noted to provide up-to-date information.)

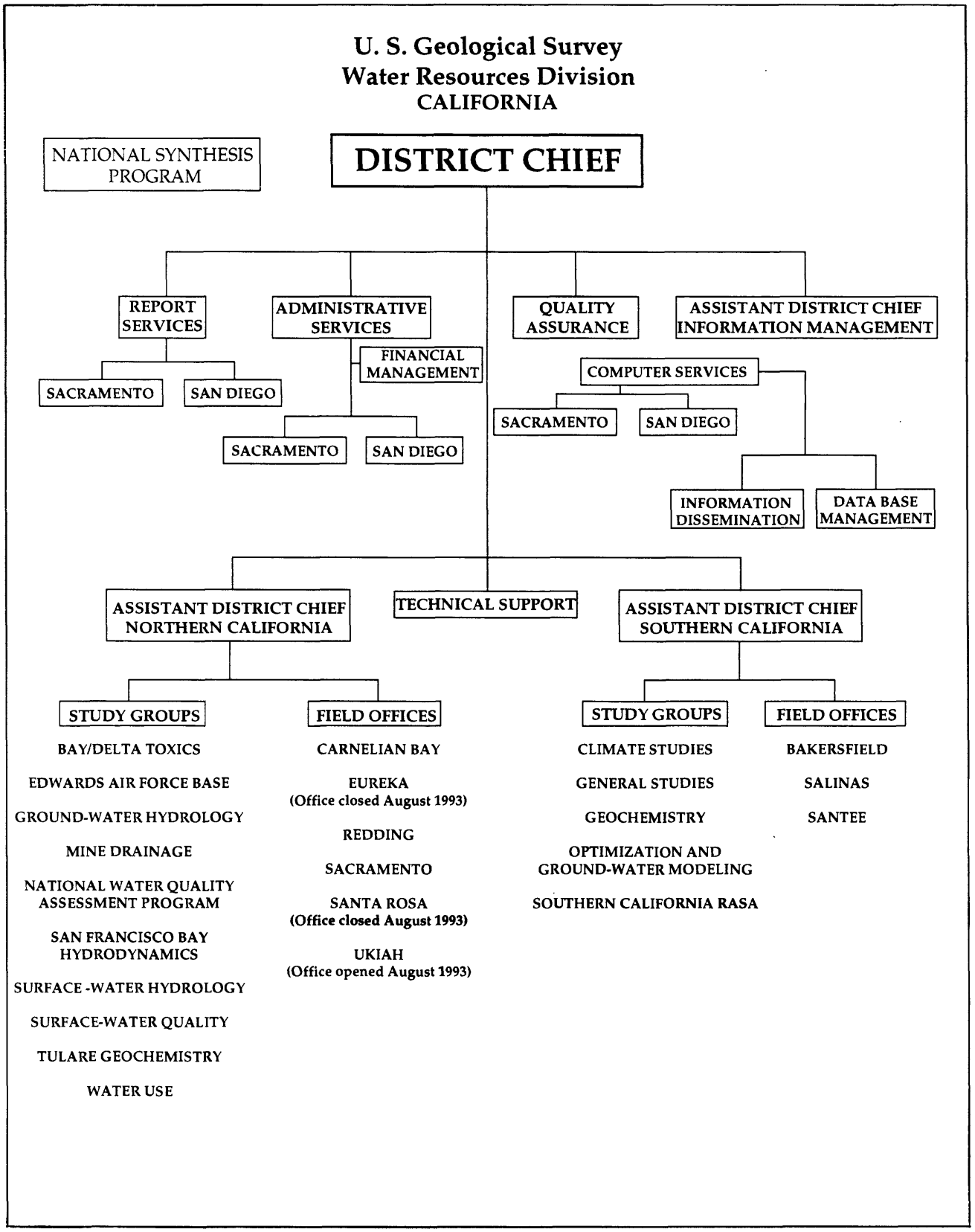


Figure 1. Organization chart for the California District, 1992.

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. Location of offices are shown in figure 2.

DISTRICT CHIEF (effective June 1993)

Michael V. Shulters District Chief, 1993	(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
F.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) 978-4658	3419-A Arden Way Sacramento, CA 95825
Salinas Larry F. Trujillo	(408) 754-6717	1636 East Alisal Street P.O. Box 5027 Salinas, CA 93915
Santa Rosa	Office closed August 1993	
Santee Jeffrey Agajanian	(619) 557-5155	10130 Mission Gorge Road P.O. Box 710881 Santee, CA 92071
Ukiah Kenneth L. Markham, Acting	Office opened August 1993 (707) 462-2794	1240 Airport Park Boulevard Ukiah, CA 95482

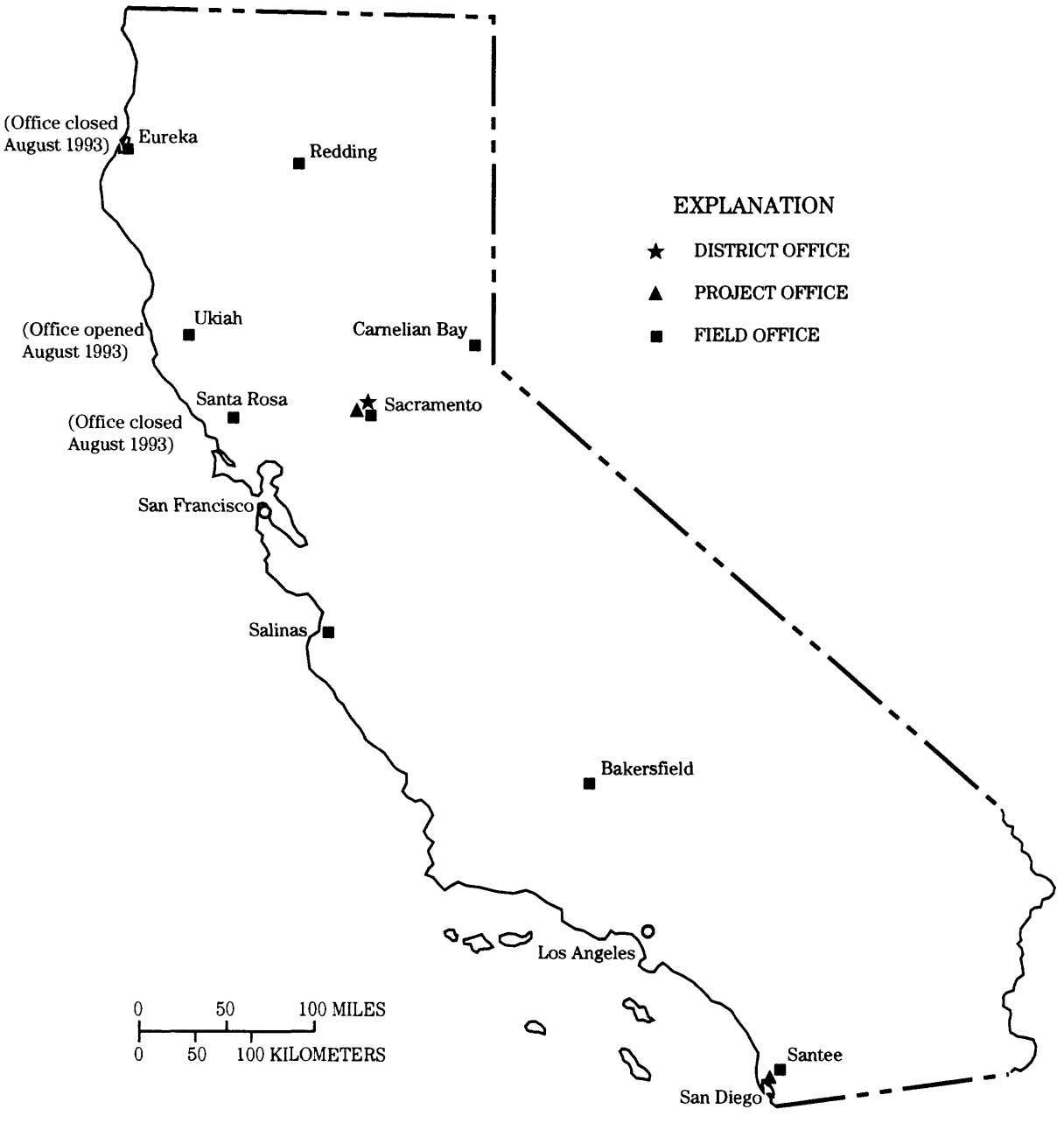


Figure 2. Location of offices in the California District, 1992.

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 1992 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 1992 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 1992, State, local, and Federal agencies that contributed funds and services under cooperative programs with the California District are

State Agencies

California Department of Boating and Waterways
California Department of Fish and Game
California Department of Parks and Recreation
California Department of Pesticide Regulation
California Department of Transportation
California Department of Water Resources
California State Water Resources Control Board
California Regional Water Quality Control Board
Central Valley Region
Colorado River Basin Region
Lahontan Region
San Francisco Bay Region

Local Agencies

Adelanto, city of
Alameda County Flood Control and Water Conservation District
Alameda County Water District
Antelope Valley-East Kern Water Agency
Calaveras County Water District
Calleguas Municipal Water District
Carpenteria County Water District
Casitas Municipal Water District
Channel Islands Beach Community Services District
Coachella Valley Water District
Contra Costa County Flood Control and Water Conservation District
Crestline-Lake Arrowhead Water Agency
Desert Water Agency
East Bay Municipal Utility District
Eastern Municipal Water District
Five Bears Hydroelectric
Georgetown Divide Public Utility District

Local Agencies--*Continued*

Humboldt Bay Municipal Water District
Imperial County Department of Public Works
Imperial Irrigation District
Independent Hydro Developers
Indian Wells Valley Water District
Los Angeles County Department of Public Works
Louisiana State University and A&M College
Madera Irrigation District
Marin Municipal Water District
Mendocino County Water Agency
Merced, city of
Merced Irrigation District
Metropolitan Water District
Mojave Water Agency
Mono County
Montecito Water District
Monterey County Water Resources Agency
Monterey Peninsula Water Management District
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
Pala Band of Mission Indians
Palmdale, city of
Palo Alto, city of
Perchanga Indian Reservation
Placer County Water Agency
Riverside County Flood Control and Water Conservation District
Rock Creek Limited Partnership
Sacramento Municipal Utility District

Local Agencies--*Continued*

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.
Tahoe Regional Planning Agency
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

U.S. Department of Agriculture
- Forest Service

U.S. Department of the Air Force
- Edwards Air Force Base
- Vandenberg Air Force Base

U.S. Department of the Army
- Corps of Engineers
  - Los Angeles District
  - Sacramento District
  - San Francisco District

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

U.S. Environmental Protection Agency

U.S. 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

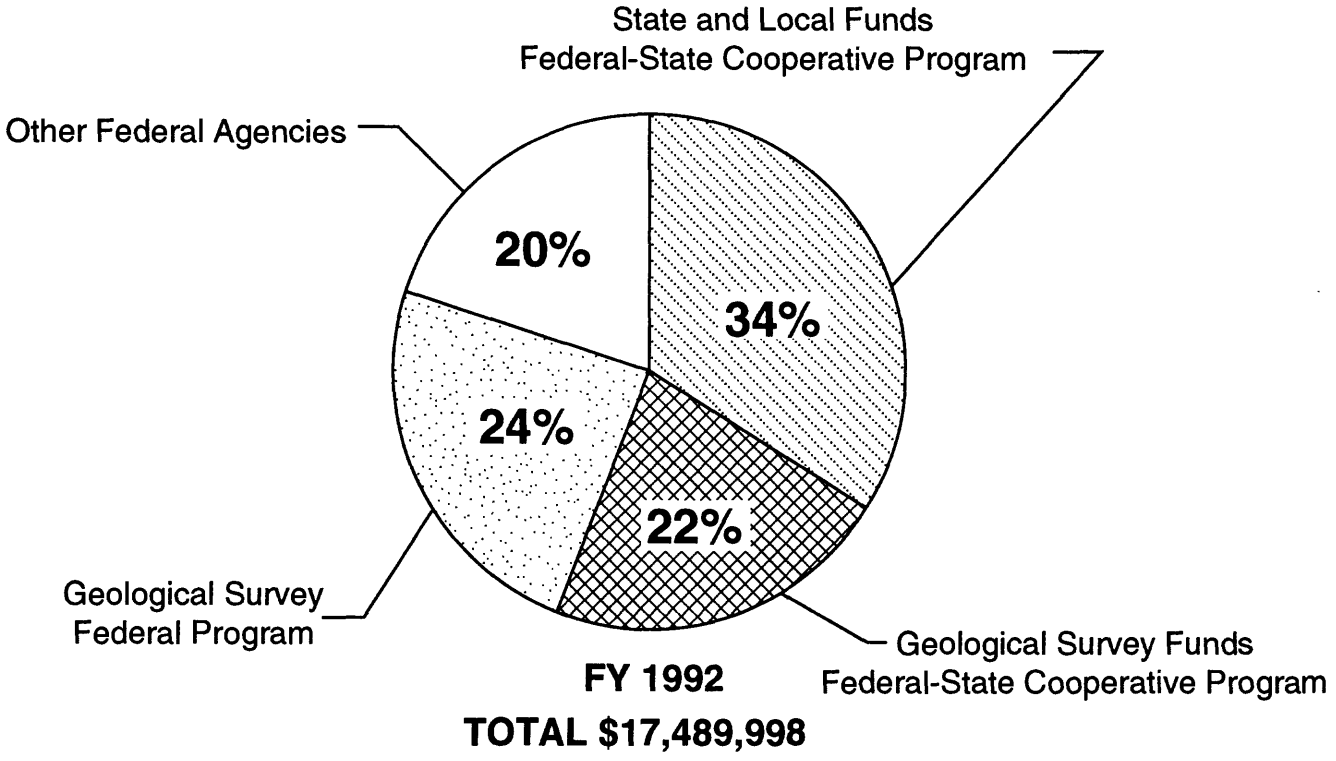


Figure 3. Sources of California District funds in fiscal year 1992.

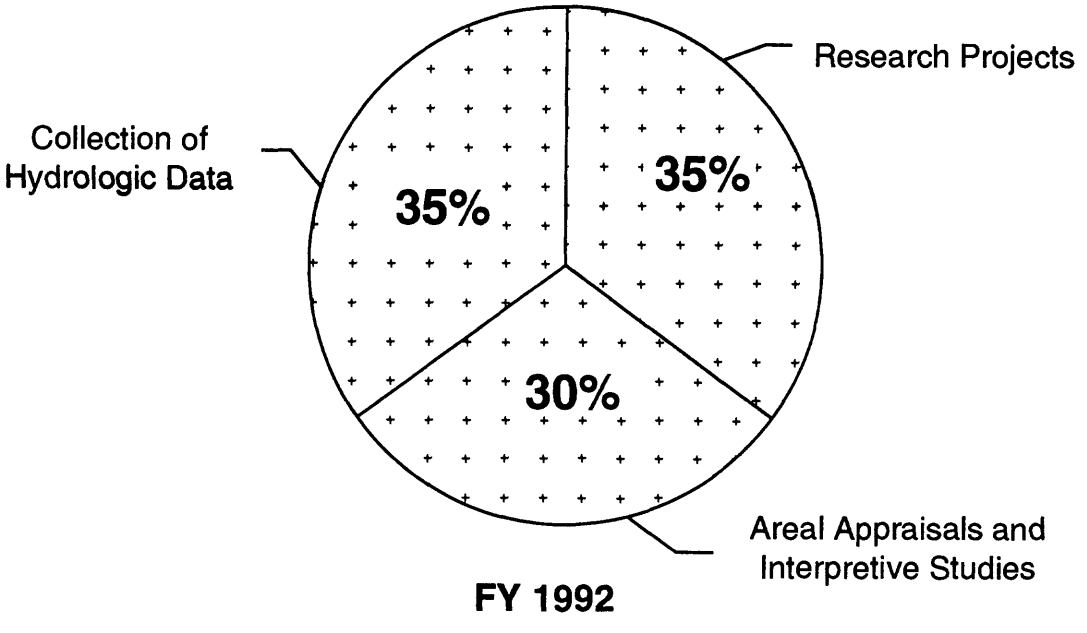


Figure 4. Categories of investigations in the California District, by funding, fiscal year 1992.

WATER CONDITIONS

The drought, now in its sixth consecutive year, continued to affect water resources in California during the 1992 water year (October 1, 1991, to September 30, 1992). Statewide, with precipitation for the 1992 water year averaging 86 percent of normal (fig. 5), runoff was 43 percent of average (table 1), and end-of-year reservoir storage was 56 percent of average (fig. 6), the lowest since 1977. These severe conditions resulted in major cutbacks in water deliveries and caused ground-water levels to continue to decline in many areas.

The 1992 water year brought relief from the drought in California with February rain and snow throughout the State. The February storms, followed by storms in late March, resulted in above average runoff in February and March in the Central Coast region and above average runoff throughout the summer in the South Coast region. Precipitation totals for the 1992 water year were above average in the Central and South Coast regions and the South Lahontan and Colorado Desert regions, but annual runoff totals were above average only in the South Coast region.

The February 1992 storms, welcomed as a "drought breaker" in southern California, also brought death and destruction. Torrential rains, totaling more than a foot and exceeding rates of 1-inch per hour in places, caused flooding and mudslides in the steep terrain of the Transverse Range, primarily in Ventura and Los Angeles Counties. At least seven people were killed and damages were estimated at almost $23 million. With most of the runoff moving quickly out to sea, more than 100 miles of beaches were fouled by debris and sewage from overloaded treatment systems, and local officials restricted access to ocean waters from Ventura County to San Diego County.

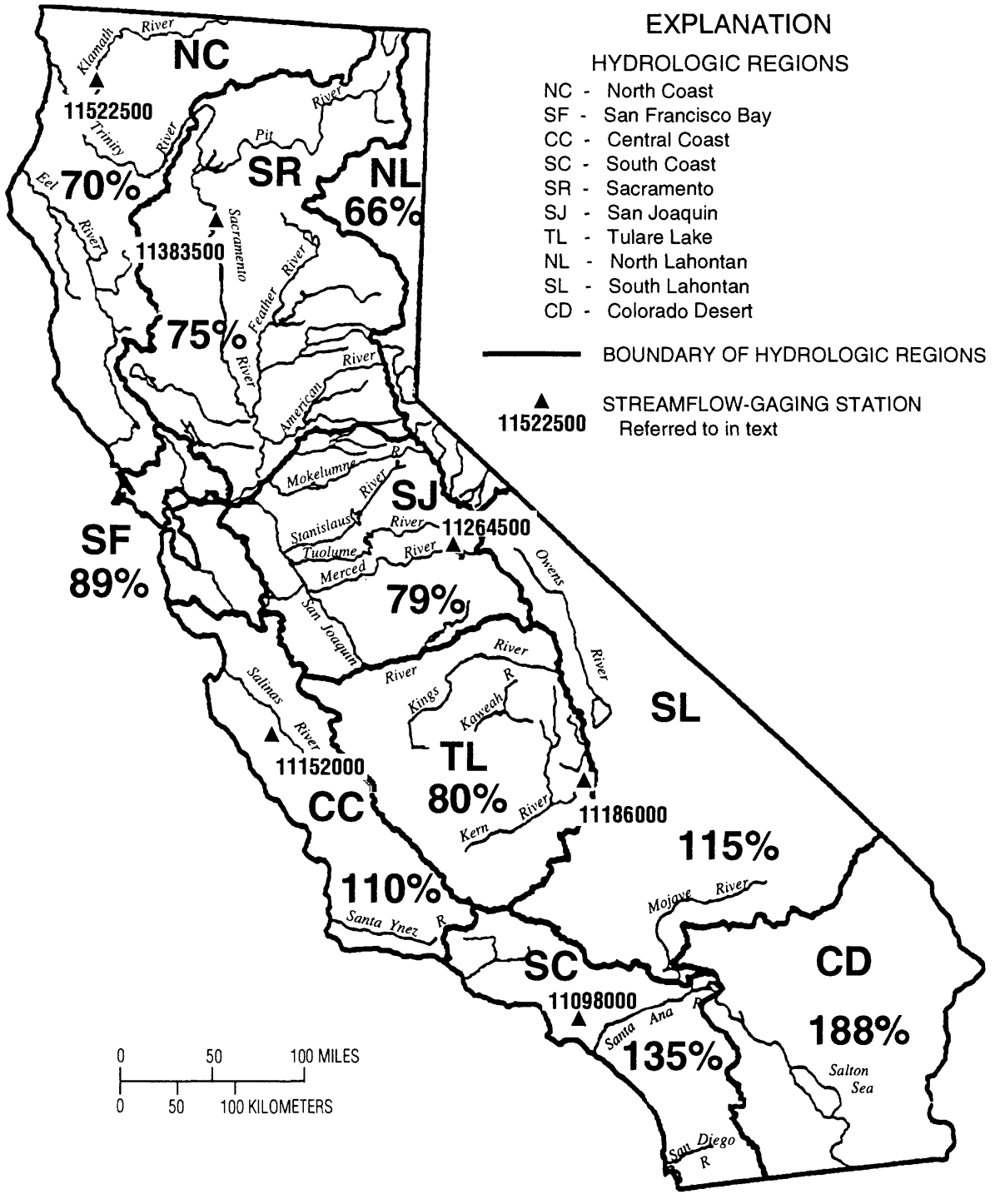


Figure 5. Average precipitation, in percent, for 1992 water year by hydrologic region. Percentages are preliminary estimates and may change when final data are avialable.

Table 1. Summary of water conditions in California for drought of 1987-92

[From the California Department of Water Resources]

Hydrologic region	Percentage of average						
	Runoff (water year)						Reservoir storage Oct 1, 1992
	1987	1988	1989	1990	1991	1992	
North Coast	56	52	76	46	35	40	56
San Francisco Bay	25	26	45	23	48	35	89
Central Coast	19	20	19	9	43	53	52
South Coast	32	40	28	16	58	112	118
Sacramento Basin	49	49	78	49	45	47	60
San Joaquin Basin	33	38	60	40	50	41	43
Tulare Lake Basin	45	42	50	34	56	37	28
North Lahontan	40	33	78	45	45	35	15
South Lahontan	70	62	64	54	49	47	75
Colorado River[1]	115	70	53	46	62	51	--
STATEWIDE	48	48	70	45	43	43	56

[1]Inflow to Lake Powell

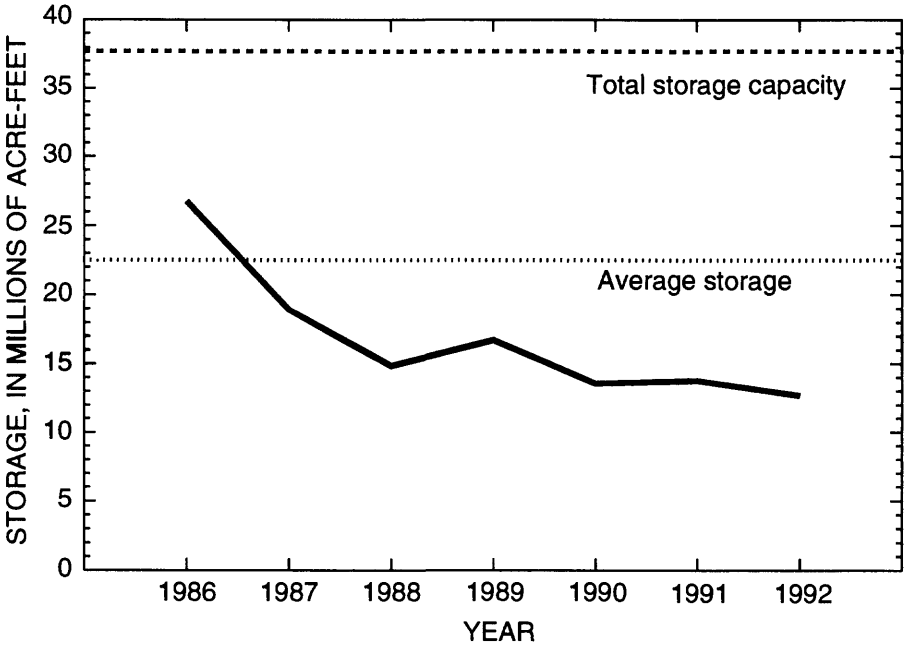


Figure 6. Statewide reservoir storage on September 30, 1986-92 (California Department of Water Resources, 1992, Water supply outlook, October 6, 1992: California Department of Water Resources, Division of Flood Management, Flood Operation, and Hydrology Branches, 4 p.).

THE DROUGHT IN PERSPECTIVE

The 1992 water year was the second driest year of the current drought in the Sacramento River basin (fig. 7), which is a major contributor to the State's water supply, and is the ninth driest year on record. The California Department of Water Resources classified 1992 as "critically dry" and added it to the category of critically dry water years for the current drought. Although the 1989 water year also was below average, it was not included in the critically dry category because of the heavy March rains in the northern one-half of the State. The drought of 1987-92 is the second driest (lowest accumulated runoff) 6-year period on record in the basin, only slightly less severe than the period of 1929-34, which is within the longer drought of 1928-37 (fig. 8). The runoff total for 1929-34 was 58.7 million acre-feet compared with 59.7 million acre-feet for 1987-92--a difference of only 1.7 percent. The 120 years of historical record for precipitation in the Sacramento River basin indicate a recurrence interval of 60 years for a 6-year drought. The current drought is unprecedented in the historical record for runoff in the Sacramento River basin. Three consecutive critically dry years (1990-92) have never occurred before, and five critically dry years have never before occurred in any 6-year drought period. The previous extreme was 4 critically dry years out of 6 years from 1929 to 1934.

Long-term average runoff in the Sacramento River basin is 18.7 million acre-feet. The driest year on record is the 1977 water year, with runoff of 5.1 million acre-feet. The driest water year of the current drought is 1991, which is the seventh driest water year on record, with runoff of 8.4 million acre-feet. The driest 2-year drought on record remains the 1976-77 drought, followed by the driest 2-year period of the current drought (water years 1991-92), which is second among all 2-year droughts with 31 percent more runoff. The driest 7-year drought on record occurred from 1929 to 1935. To exceed the severity of that drought, runoff for 1993 would need to be less than 15.6 million acre-feet, only slightly less than the long-term average. The longest drought on record was from 1928 to 1937. To match those 10 consecutive years of less-than-normal runoff, the current drought would have to continue into 1996 with annual runoff for 1993 through 1996 averaging less than 15.8 million acre-feet per year.

Records from six long-term unregulated streamflow stations were selected to show the areal extent and variation of the current drought (fig. 9). Stations in the North Coast region (11522500) and Sacramento region (11383500) show a drought severity similar to the record of runoff from the Sacramento River basin. In those regions, the current drought is second in severity behind a 6-year period during the drought of 1928-37. Because of limited record lengths (about 70 years), the records for these stations indicate a recurrence interval of about 35 years for the current 6-year drought. In the San Joaquin (11264500), Tulare Lake (11186000), and Central Coast (11152000) regions, the drought has been more severe, outranking any equivalent period of drought duration throughout historical record. On the basis of limited length of record for those stations, the recurrence interval for the San Joaquin, Tulare Lake, and Central Coast regions ranges from 70-90 years. In the South Coast region (11098000), the drought began in December and ended with the storms of February 1992 and was the longest and most severe drought in this station's 80 years of record.

The diverse distribution of precipitation and runoff that characterizes California was apparent in 1992 and in earlier years of the drought (figs. 5 and 9). The storms of 1992 ended the drought in most of the southern part of the State and eased the severity of the drought in the Central Coast region, with more moderate precipitation and runoff that first brought relief in March 1991 continuing. Runoff at Arroyo Seco near Soledad in the central part of the State was higher during the 1992 water year than in any previous year of the drought; runoff at the Salmon River at Somes Bar at the northern end of the State was lowest in 1992 than in any year of the drought. In contrast, a wet March in 1989 provided temporary relief from the drought in the north with the Salmon River reaching almost normal runoff during 1989 although the southern part of the State continued to experience severe drought conditions.

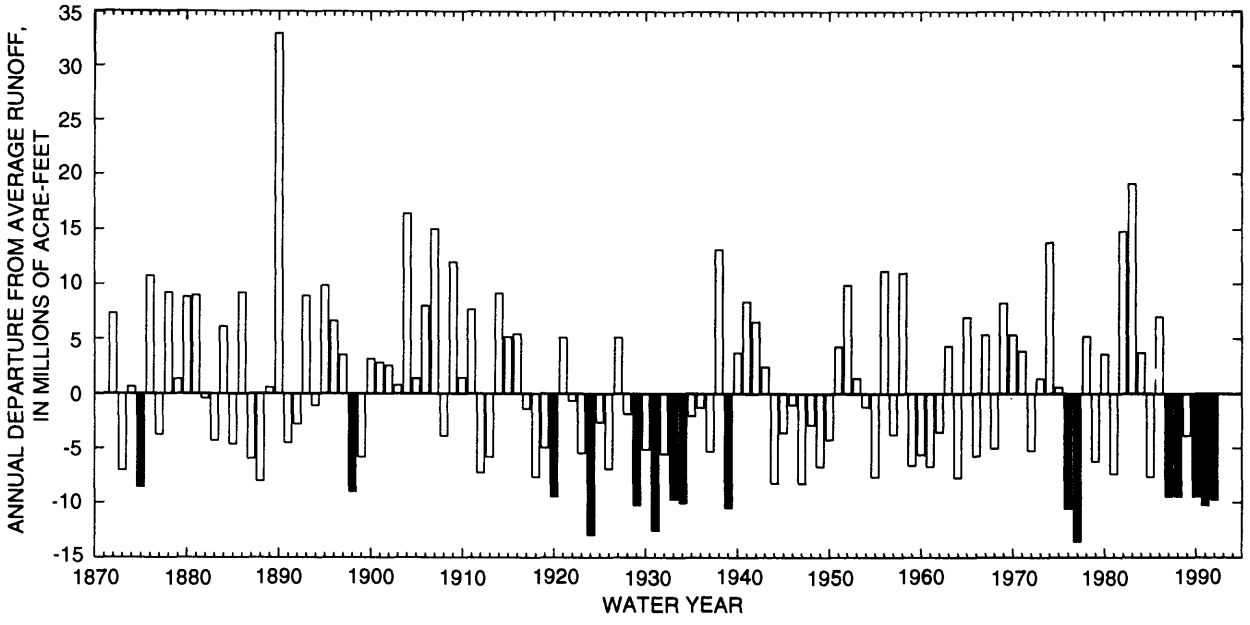


Figure 7. Annual departure from average runoff in the Sacramento River basin for water years 1872-1992. Shaded years are classified as "critically dry" by the California Department of Water Resources. The Sacramento River basin runoff is the combined flows from the upper Sacramento, Feather, Yuba, and American River basins, adjusted to represent unimpaired runoff. Flows for 1872 to 1905 are estimated from historical data. (Data from the California Department of Water Resources).

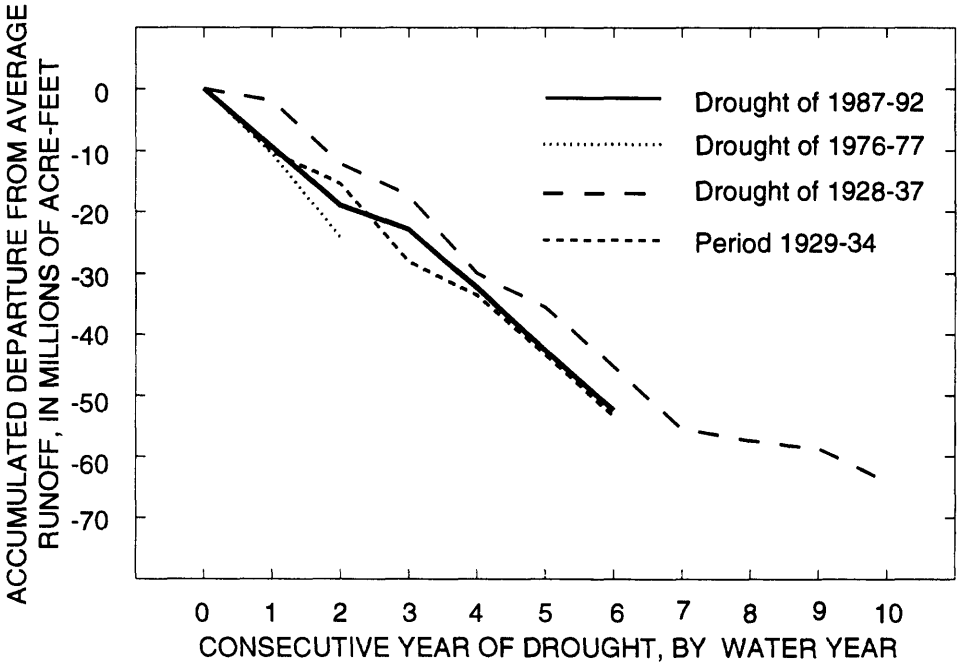


Figure 8. Accumulated departures from average annual runoff for selected drought periods in the Sacramento River basin. The period 1929-34, within the longer 1928-37 drought period, is the most severe 6-year drought period on record.

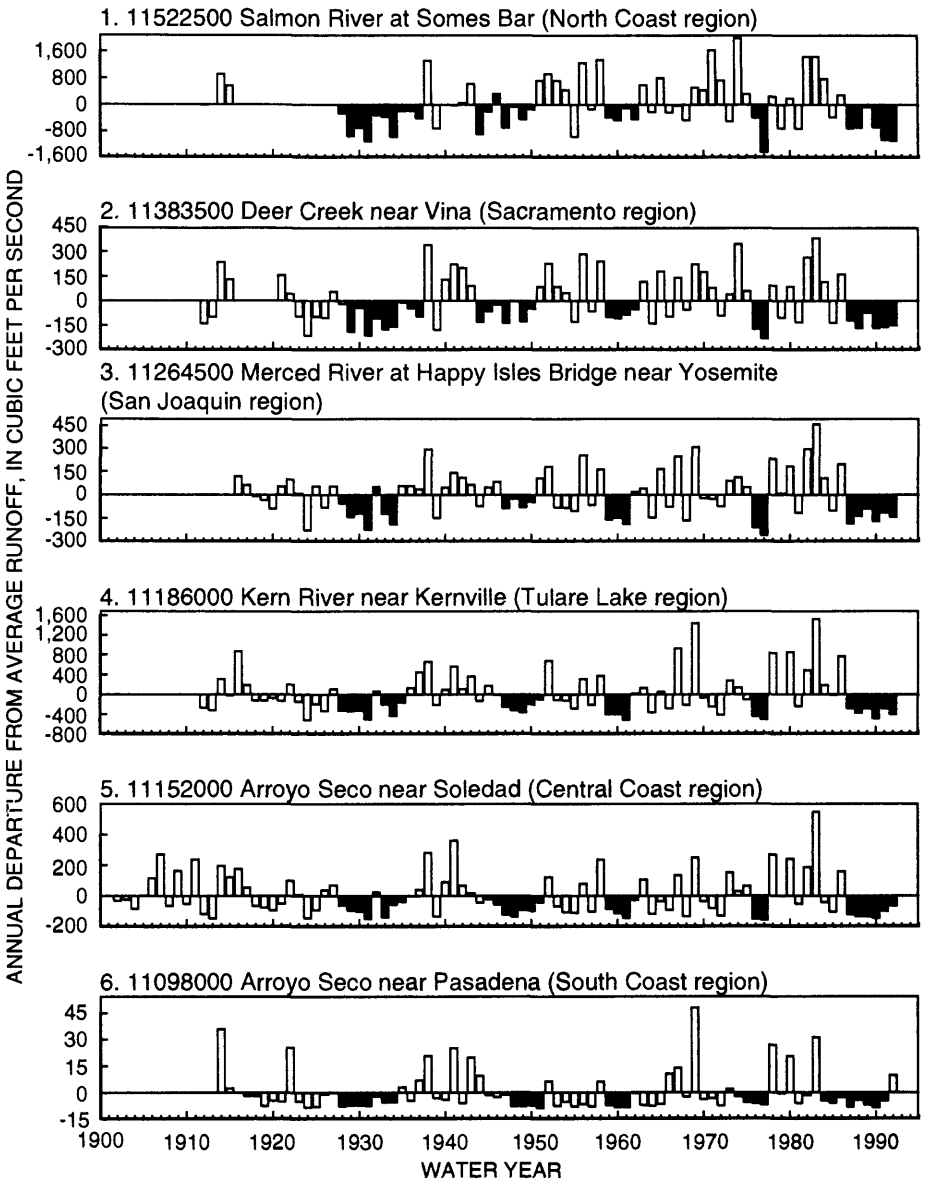


Figure 9. Annual departure from average runoff at six unregulated long-term streamflow-gaging stations through the 1992 water year. Major drought periods are shaded. Location of stations in figure 5.

The long-term record of water levels for Lake Tahoe (fig. 10) is another indicator of the drought's severity. A dam at the outlet of the lake provides controlled storage above the natural rim of the lake to a maximum permissible elevation of 6,229.1 feet. Lake elevations rarely decline below the natural rim but has done so twice during the current drought, first in 1988 and again in 1990. Lake elevation has remained below the rim since September 1990, and on September 30, 1992, reached a new record low elevation of 6,220.80 feet and still is declining. The previous record low was 6,221.74 feet set in December 1934.

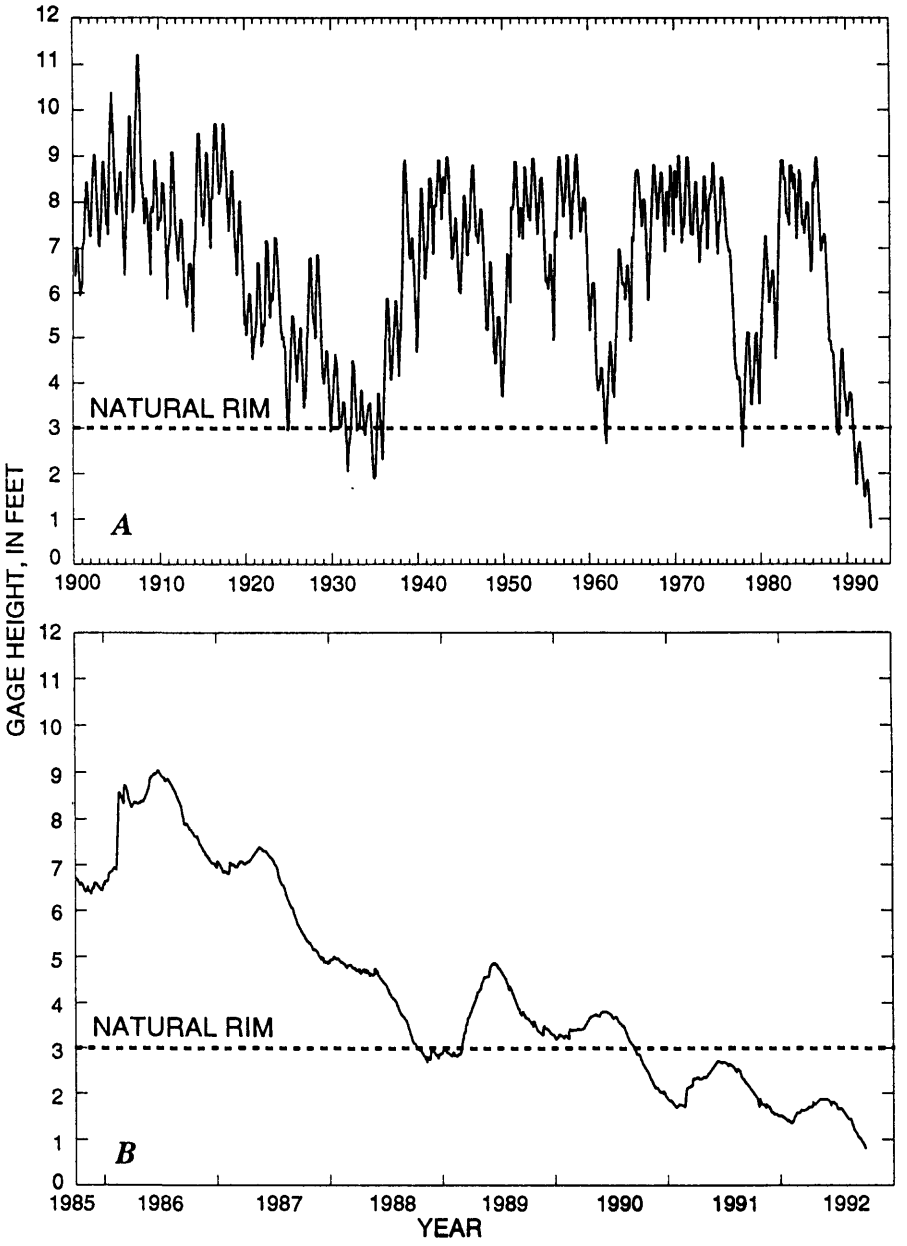


Figure 10. Water levels in Lake Tahoe. The natural rim is the level below which water cannot flow out of the lake. Add 6,220 feet to adjust gage heights sea level. *A,* Year-end water levels for 1900-92. *B,* Water levels for October 1985 to September 1992.

EFFECTS OF THE DROUGHT

Although 1987 marks the beginning of the current drought, water-supply problems in 1987 were minimal because of surface water in storage from 1986 (fig. 6), with the most serious effects on wildlands and nonirrigated agriculture. During 1988 and half of 1989, water shortages affected about one-third of California's population and more than 40 percent of the State's irrigated agriculture. Rainfall in many areas was insufficient for dry-farmed crops and grazing. Many urban areas instituted mandatory or voluntary water-conservation measures. Where available, ground water was used to compensate for deficiencies in surface-water supplies. In general, ground-water supplies were considered adequate. However, shortages were a problem in areas where ground-water reservoirs are small (upland and coastal areas) and in localized areas of excessive drawdown.

In 1989, the State's two major water projects, the State Water Project and the Federal Central Valley Project, announced anticipated reductions in water deliveries of as much as 50 percent. However, the wet weather in March 1989 ("March miracle") brought relief to many water users, allowing full delivery of agricultural water supplies and the eventual lifting of drought restrictions in most areas of the State. Water restrictions continued along the Central Coast region, which did not benefit from the March 1989 rains and is not supplied by the State's major water projects.

In 1990, spring rains brought no relief from the drought. Deliveries from State and Federal water projects were reduced as much as 50 percent for agricultural customers, with lesser reductions to some municipal and industrial contractors. This was only the second time in the history of the water projects that such reductions in water deliveries were necessary--the first reduction was 1977. Surface-water supplies from other sources were greatly curtailed as well. Most urban areas of the State again instituted drought restrictions. Areas in the central part of the State continued to be the hardest hit by the drought, especially those areas without access to large-scale developed surface-water supplies or major ground-water basins.

In 1991, reductions in water supply were even more severe in spite of a second "March miracle" that brought heavy precipitation throughout the State. The March storms, which brought three times the normal precipitation for the month and a fivefold increase in the statewide snowpack, succeeded only in eliminating the worst-case scenarios that were causing near panic in the water-management community. Water-conservation measures and severe reductions in water deliveries that had been planned prior to the March storms were for the most part left in effect. The State Water Project stopped most agricultural water deliveries and reduced municipal and industrial deliveries to 30 percent of contractor's entitlement requests. The Central Valley Project reduced overall deliveries to 50 percent of normal with reductions ranging from 25 to 75 percent. Urban areas implemented local conservation plans, though no statewide mandates were imposed. The State created a special water bank to aid in the transfer of water to areas of need. In a turn-around from previous years, the Central Coast region experienced dramatically improved conditions because of the March storms. The greatest shortages were to agricultural customers dependent on water supplies from the large water projects that had depleted their reserves.

In 1992, for the third consecutive year, water supplies were again severely restricted. However, deliveries by the two large water projects were greater overall than in 1991 and considerably better than had been projected prior to the storms in February. The State Water Project delivered about twice as much water as it delivered in 1991--45 percent of requested entitlements for all contractors. The State Water Project resumed deliveries to agricultural customers, whose water deliveries were stopped in 1991. The Federal Central Valley Project delivered about the same water supply as it delivered in 1991, averaging about 50 percent of normal with amounts ranging from 25 percent to agricultural contractors to 75 percent to water-rights and urban contractors. The State continued to coordinate a water-bank program to help those with the greatest need. Repeating the pattern of 1991, February storms greatly relieved drought problems in the Central Coast region, refilling small surface-water reservoirs and bolstering ground-water supplies to the area. In the South Coast region, where the drought had ended, the Metropolitan Water District of southern California lifted water rationing in April. However, agricultural customers dependent on water supplies from the large water projects continued to experience severe water-supply problems.

Ground-water reserves continued to be tapped causing localized problems from excessive drawdown, including water-quality deterioration, seawater intrusion, and the potential for land subsidence and associated permanent reduction in storage owing to compaction. Some of these problems were amplified by the steady growth in annual well construction during the drought. However, the ability of many agricultural areas use ground-water supplies prevented severe reduction in the State's agriculture production, though increasingly land is being taken out of production in some of the most drought-effected areas. Because of the diversity of ground-water basins, trends in water levels and water storage are not uniform throughout the State. However, ground-water storage has reached record lows in some areas.

Fish and wildlife, water quality, hydroelectric power, and recreation all have been adversely affected by the drought, and water managers continue to try to balance their often conflicting needs. The effect of the drought on wildland resources, fish, and wildlife has been unprecedented. Populations of some important commercially fished species, such as salmon and striped bass, have declined dramatically. In 1990, winter-run salmon in the Sacramento River was listed as a threatened species by California and as an endangered species by the Federal Government, prompting special measures by the State and Federal water projects. In 1992, the count of winter-run salmon at the Red Bluff diversion dam was 1,180, up from 191 in 1991. Fall-run salmon, which numbered 140,000 as recently as 1988, are projected to number only 20,000 in the 1992 fall run.

The drought and associated insect damage and disease caused a loss of 18 billion board feet of merchantable timber by 1991, and the toll will continue even after the drought ends. The buildup of fuels from dead trees and brush has led to many large forest fires and continues to create a hazard of wildfire. Hydroelectric power generation in the Sierra Nevada by the Sacramento Municipal Utility District and Pacific Gas and Electric Company was about one-half of normal in 1992. A congressional report last year estimated that the drought has cost ratepayers about $3 billion in lost hydroelectric production.

PROJECT DESCRIPTIONS

19

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.

Objective: 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 780 continuous streamflow stations were collected, compiled, and reviewed for publication. Data were collected or reviewed from 149 reservoir stations. Data were collected and compiled for 102 partial-record stream and reservoir sites that provide peak flow, low flow, seasonal flow, limited range of discharge, or stage information. Data for 1991 were published in four volumes of the annual data report series.

Plans for Fiscal Year 1993: Statewide data collection and review will continue. Installation of additional satellite data-collection platforms and telephone modems is planned for real-time transmission of streamflow information from selected sites. Streamflow data will be published in the annual data report for water year 1992.

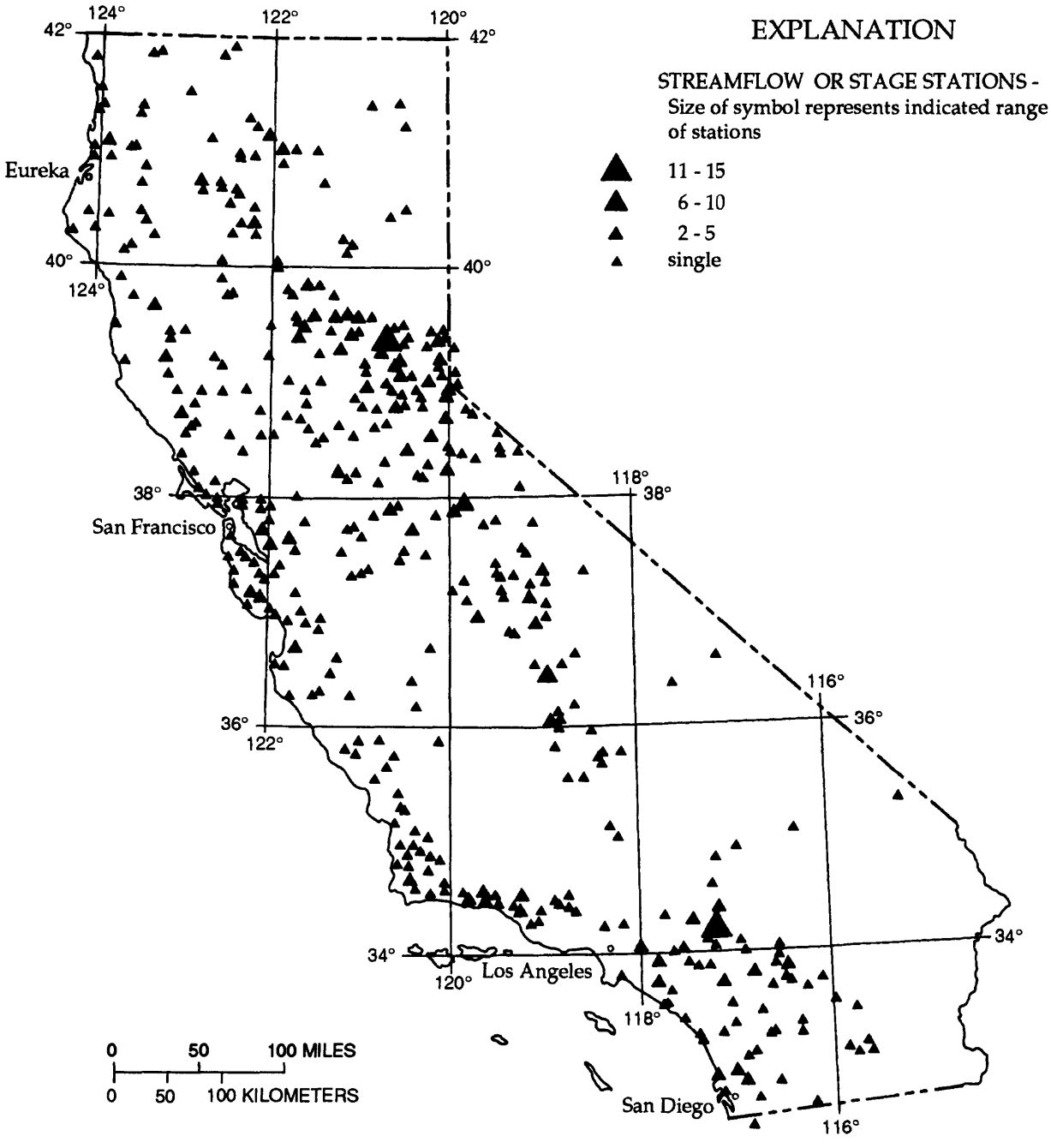
Reports:

Jensen, R.M., Hoffman, E.B., Bowers, J.C., and Mullen, J.R., 1992, Water resources data--California, water year 1991. 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-91-1, 312 p.

Markham, K.L., Anderson, S.W., Mullen, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. 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-91-4, 319 p.

Mullen, J.R., Anderson, S.W., Hunter, T.C., and Hoffman, E.B., 1992, Water resources data--California, water year 1991. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-91-3, 373 p.

Trujillo, L.F., Markham, K.L., Palmer, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-91-2, 315 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.

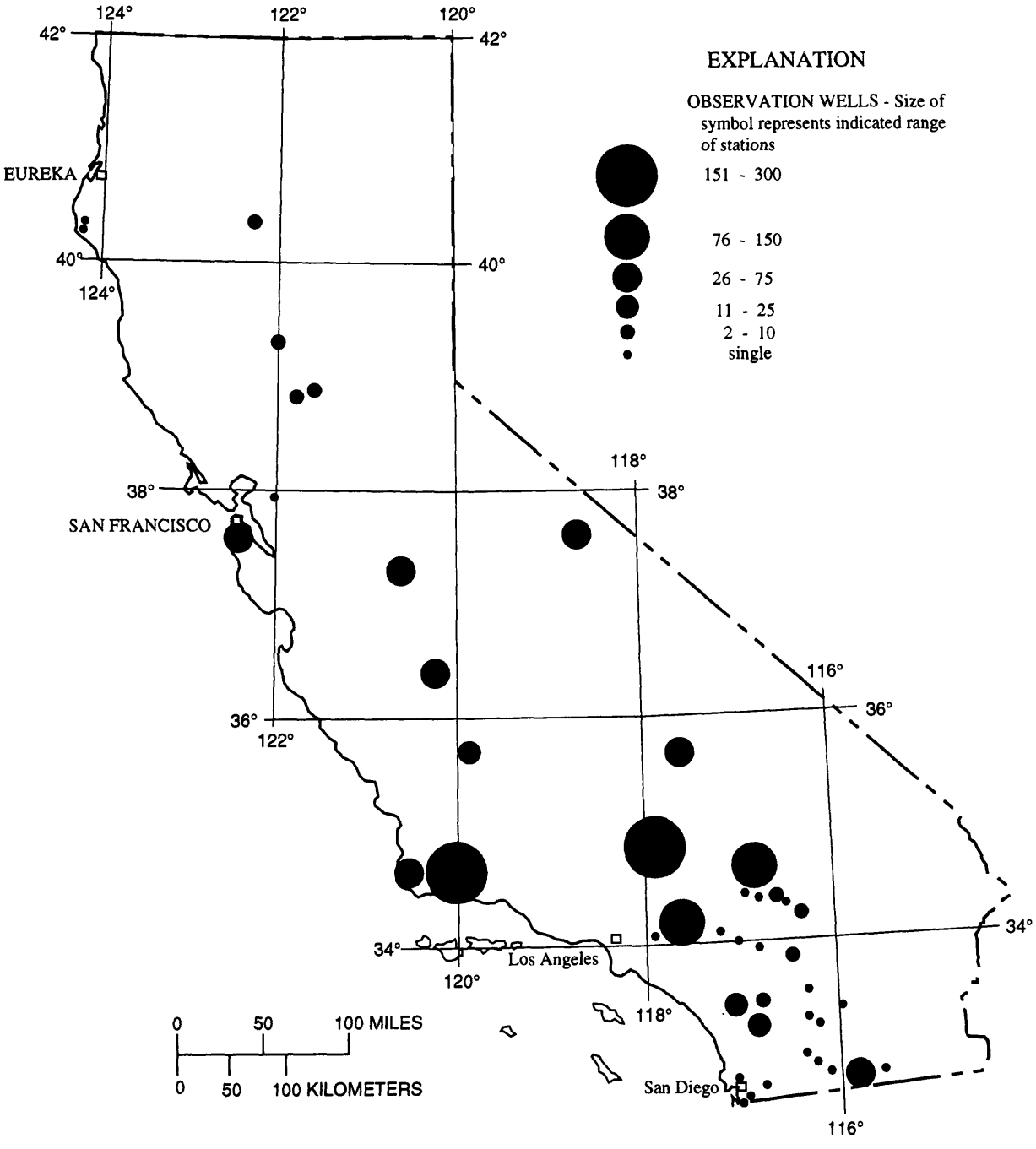
Approach: Water-levels will be measured and recorded with varying frequencies: continuous, monthly, semiannual, and annual. Water samples will be collected for field and laboratory analysis. Standard methods of data collection will be used as described in the "National Handbook of Recommended Methods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

Progress: Collection and compilation of ground-water-level data continued at 1,007 long-term sites, 223 short-term sites, and 33 continuous-recorder wells. Samples were collected and analyzed for chemical quality at 315 scheduled long-term sites and 57 short-term sites. Data for water year 1991 were published in a separate volume of the annual data-report series.

Plans for Fiscal Year 1993: Statewide data collection and record processing for ground-water levels and quality will continue. All data will be published in a separate volume of the annual data-report series.

Reports:

Johnson, J.A., Fong-Frydendal, L.J., and Baker, J.B., 1992, Water resources data--California, water year 1991. Volume 5. Ground water data: U.S. Geological Survey Water-Data Report CA-91-5, 427 p.



Location of selected observation wells.

WATER-QUALITY STATIONS

Number: CA003

Location: Statewide (See accompanying map. Also see map of selected observation wells, page 23)

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 intelligent 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 21 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 64 stream or reservoir sites. Water samples were analyzed from 372 observation wells. Data for water year 1991 were published in the annual data-report series.

Plans for Fiscal Year 1993: Statewide data collection will continue. All data will be published in the annual data report for water year 1992.

Reports:

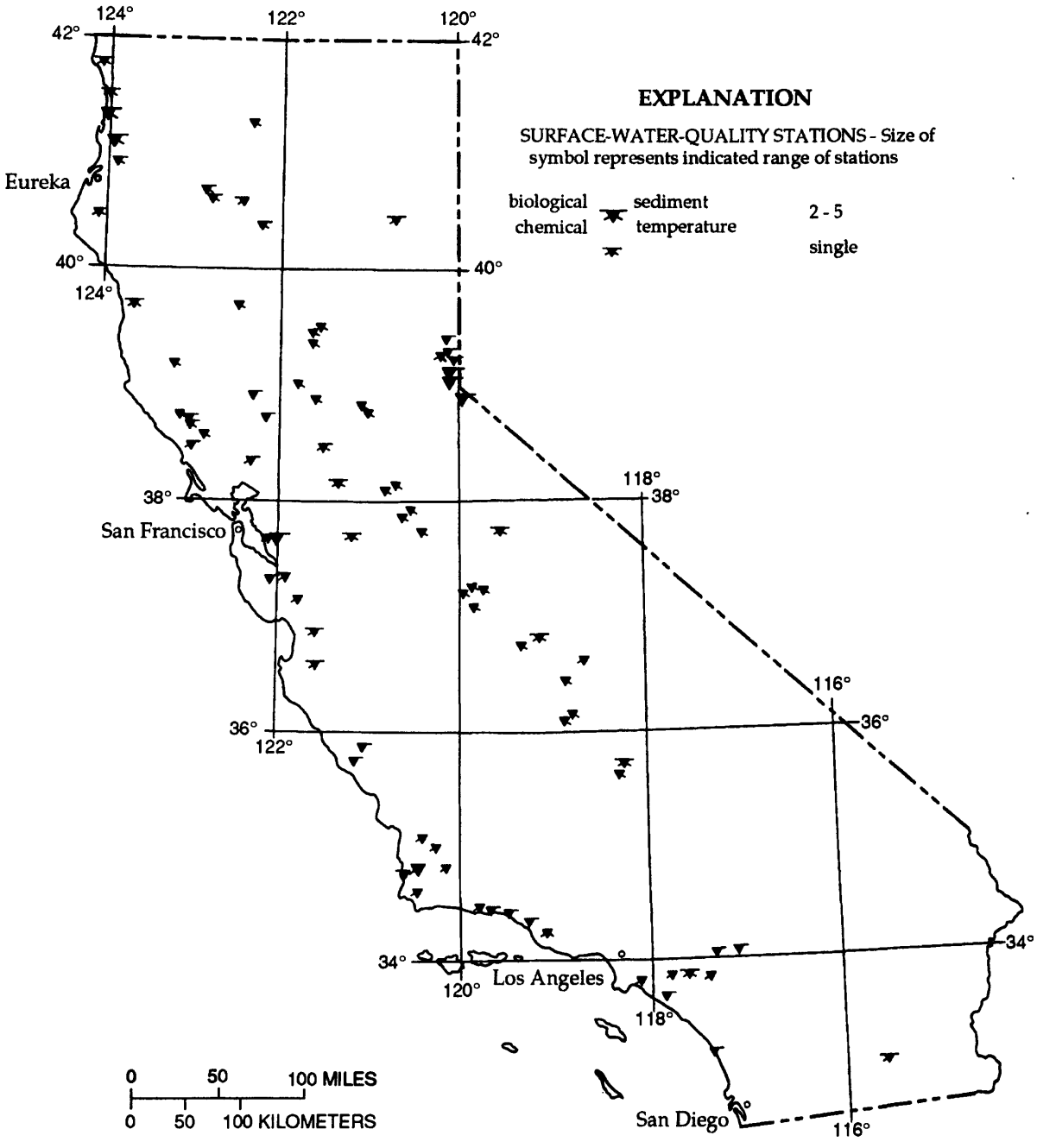
Jensen, R.M., Hoffman, E.B., Bowers, J.C., and Mullen, J.R., 1992, Water resources data--California, water year 1991. Volume 1. Southern Great Basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-91-1, 312 p.

Johnson, J.A., Fong-Frydendal, L.J., and Baker, J.B., 1992, Water resources data--California, water year 1991. Volume 5. Ground water data: U.S. Geological Survey Water-Data Report CA-91-5, 427 p.

Markham, K.L., Anderson, S.W., Mullen, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. 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-91-4, 319 p.

Mullen, J.R., Anderson, S.W., Hunter, T.C., and Hoffman, E.B., 1992, Water resources data--California, water year 1991. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-91-3, 373 p.

Trujillo, L.F., Markham, K.L., Palmer, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-91-2, 315 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 effects of erosion, movement, and deposition of sediment on our environment can be devastating. Knowledge of sediment transported by streams 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 closely monitored at several locations within the State for proper management of the water and land resources.

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; (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, bed-material samples will be analyzed for particle-size distribution.

Progress: Sediment data were collected at 15 daily, 21 periodic, 18 NASQAN (National Stream Quality Accounting Network), and 3 Hydrologic Benchmark stations. Sediment data for water year 1991 were published in the annual data-report series.

Plans for Fiscal Year 1993: Statewide data collection will continue. Sediment data will be published in the annual data report for water year 1992.

Reports:

Jensen, R.M., Hoffman, E.B., Bowers, J.C., and Mullen, J.R., 1992, Water resources data--California, water year 1991. 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-91-1, 312 p.

Markham, K.L., Anderson, S.W., Mullen, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. 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-91-4, 319 p.

Mullen, J.R., Anderson, S.W., Hunter, T.C., and Hoffman, E.B., 1992, Water resources data--California, water year 1991. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-91-3, 373 p.

Trujillo, L.F., Markham, K.L., Palmer, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-91-2, 315 p.

NATIONAL TRENDS NETWORK FOR MONITORING ATMOSPHERIC DEPOSITION

Number: CA005

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

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 station near Yreka, Siskiyou County, were reviewed.

Plans for Fiscal Year 1993: 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: Nationwide, statewide, and site-specific estimates of water use are needed to establish water-resources policies and to conduct hydrologic investigations; water-use estimates must be consistent in water-use categories and methods of determination to allow valid comparisons of statewide totals. 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 problem is to meet present and future water-use information needs in the most efficient and cost-effective manner.

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 refine computerized systems to store and retrieve statewide and site-specific water-use information; (3) devise and apply new methods and techniques to improve the collection, analysis, and dissemination of water-use information; and (4) explain the values and applications of water-use information and make this information available.

Approach: Information will be developed for 14 National Water Use categories: irrigation; industrial; commercial; domestic; water supply; sewage treatment; mining; livestock specialties; animal specialties; reservoir evaporation (beginning in 1990); hydroelectric power; and 3 thermoelectric power sources: nuclear, fossil fuel, and geothermal. Site-specific information will be input into a Water Use Data System. Statewide information will be entered into an aggregated Water Use Data System. Methods and techniques for collection, storage, and dissemination of water-use information will be improved.

Progress: The Water-Use Information Program focused on developing estimates of the water used throughout California as part of the nationwide report on "Estimated Use of Water in the United States, 1990." Substantial improvements were made in our understanding of water uses throughout California. Less ground water was used in 1990 than was expected because of larger deliveries from water-storage reservoirs than anticipated, apparent shifts to crops with lower water demands, and the continued lack of adequate knowledge of actual ground-water pumpage. A report comparing 1985 and 1990 water uses is in process. The statewide water-use-coordination committee continues to meet about every 6 months and is developing into a good forum for information transfer. Experience was gained in the application of a water-demand forecasting model in cooperation with Monterey County Water Resources Agency in the Salinas Valley. This experience benefited from additional assistance coordinated through the University of Wyoming as part of a set of case studies funded by the National Water Use Program. An article on this experience is in process. A new study was developed and completed on industrial water use, primarily in the Central Valley, and a report is being drafted. An open-file report containing water-delivery and crop information for the west side of the San Joaquin Valley went to colleague review. A revised edition of the National Handbook of Recommended Methods for Data Acquisition, Chapter 11,

"Water Use," which was submitted to the U.S. Geological Survey's Office of Water Data Coordination, is being revised. Coordination continued with the subsidence study in Antelope Valley and the ground-water study in the south San Francisco Bay area. Water-use studies were postponed until 1992.

Plans for Next Year: The reports in process will be completed. Reports will be written on water uses that affect subsidence in the Antelope Valley and water uses affecting ground-water recharge in the San Francisco Bay area.

Reports: None

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: Greg C. Lines

Period of Project: Continuing

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 two wells in the Mesquite Lake basin, and in two wells in the Deadman basin. Four wells in the Surprise Spring basin were sampled for chemical analyses of major dissolved ions, nitrate, and fluoride. Two wells were drilled, constructed, and tested near base headquarters.

Plans for Fiscal Year 1993: Monitoring of ground-water levels and chemical quality will continue. 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 Air Weapons Station, China Lake

Project Chief: Roy A. Schroeder

Period of Project: Continuing

Problem: Indian Wells Valley is undergoing rapid population growth and is faced with the problem of managing its water resources in order to best meet future needs.

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 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 concentrations, and computer simulations of solute transport in Indian Wells Valley has been submitted for Director's approval.

Plans for Fiscal Year 1993: It is expected that the water-quality report will be approved and published in the Water-Resources Investigations series in early 1993. A condensed version will be prepared for publication in a journal if time permits. A network for monitoring of ground-water levels biannually in 22 wells and ground-water quality annually in 10 wells in Indian Wells Valley will be continued.

Reports: None

CHARACTERISTICS OF FLOODING AND CHANNEL CHANGES OF THE SACRAMENTO RIVER BETWEEN HAMILTON CITY AND BUTTE CITY

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: Progress was limited to preparation of reports, annual cross-section surveys, and streamflow-recording gage and crest-stage gage operations until the next flood.

Plans for Fiscal Year 1993: Streamflow-recording gages and crest-stage gages will be in operation during the 1992-93 flood season. The data-collection network will include peak-stage data near Parrott Weir, which was constructed in 1988. 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 characteristics of floodflows. Monumented cross sections of the river will be resurveyed annually and compared with data from previous surveys for each of seven sites. A report will be written after the next flood to document changes in floodflow characteristics following an extended drought period.

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 1992

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 quantify 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: A report describing the computer code that was used to provide a means of linking Storage Units III and I and the Foothill basin into an areawide model has been completed and approved for publication as U.S. Geological Survey Open-File Report 92-477. Water levels measured in Storage Unit III wells drilled in June 1991 presently are rising. The recovery is thought to be a result of decreased pumping in Storage Unit III. The lessening, last year, of the recent California drought has decreased the demand on the local ground-water supplies. Analyses of water from test wells for major anion and cation constituents indicate that poor-quality (high dissolved-solids concentration) water is present in the Sespe Formation(?) shale underlying the storage unit. Good-quality water also is present, but poor well-construction practices could allow the poor-quality water to migrate to water-supply wells. A report that describes the geohydrology of Storage Unit III and a combined Santa Barbara areawide flow model is in review.

Plans for Fiscal Year 1993: Geologic, hydrologic, and water-supply distribution-system data will be input to a GIS (geographic information system) data base to facilitate development of a multiple-objective optimization model for the Santa Barbara area ground-water basins.

Reports: None

ESTIMATING TIDAL AND RESIDUAL CIRCULATION IN SAN FRANCISCO BAY

Number: CA419

Cooperating Agency: California Department of Water Resources; and California State Water Resources Control Board

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. This regulation has 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 shrimp populations.

Objectives: To determine the magnitude and location of variations in the hydrodynamics (water currents and salinity) within San Francisco Bay that result from changes in freshwater inflows from the Sacramento-San Joaquin River Delta.

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. In addition, currents and salinity will be measured during a wide range of delta-flow conditions. A new prototype of a vessel-mounted acoustic Doppler current profiling (ADCP) 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.

Progress: Preliminary analyses of water-level and salinity monitoring data showed a pronounced annual variation in the spring-neap tidal cycle. Vertical salinity stratification results from runoff events, and subsequently the degree of stratification, varies with the spring-neap cycle. Permits for five UVMs (ultrasonic velocity meters) in the Sacramento-San Joaquin Delta were obtained and necessary equipment fabricated. A prototype of a new broadband ADCP (acoustic Doppler current profiler) was tested, and a workshop was hosted to discuss the tests and to communicate needed modifications to the manufacturer. Coding of a new three-dimensional model for all San Francisco Bay began, and a workstation-based package of graphics programs was completed that permits exploration of multidimensional model simulations of flow and salt transport. Optical backscatter sensor (OBS) measurements were collected and calibrated with total suspended solids samples at two sites in South San Francisco Bay.

Plans for Fiscal Year 1993: Delta UVMs will be installed early in the water year, and calibrations will be achieved during the year for at least three sites using a broadband ADCP and ADDMS, the Survey's vessel-mounted acoustic Doppler discharge measurement system. Hydrographic time series will be collected in Suisun Bay to document the responses of circulation and mixing in the non-tidal current null zone to changes in freshwater inflow. Potential collaboration with scientists from the University of Washington may extend this effort to include the dynamics of the particle entrapment zone. Coding of a three-dimensional model of all of San Francisco Bay will be completed, and calibration will begin. The study of low-frequency variations of salinity and water levels will continue. The OBS measurements,

which began as a part of this project, will be extended to include measurements in central San Francisco Bay and transferred to a new merit project, "Suspended Sediment and Trace-Metal Transport Processes in South San Francisco Bay."

Reports:

Smith, P.E., Oltmann, R.N., and Simpson, M.R., 1992, Data set for verification of 3-D free-surface hydrodynamic models, Carquinez Strait, California: American Society of Civil Engineers, Hydraulic Engineering Sessions Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 430-435.

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 1995 (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 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 overdraft, (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 a 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: Data collection was completed for the Santa Clara-Calleguas basin--the coastal basin selected for intensive study. Available geologic, hydrologic, and geographic information was input into a computerized Geographic Information System (GIS). The GIS has been used to supply input data sets for the ground-water-flow model being developed for the basin. Water-quality data collected from 40 wells installed as part of this study and results of direct-current resistivity soundings show that the area affected by seawater intrusion is less than previously reported. Leakage of saline water from a shallow "perched" aquifer through failed or corroded well casings was found to be the source of increasing chloride concentration in some areas. Carbon-14 age data indicate that the lower aquifer system is not effectively recharged by surface spreading of water diverted from the Santa Clara River. Data collection was started in the Mojave basin--the desert basin selected for intensive study. Twelve multiple-well monitoring sites were constructed along the Mojave River to monitor surface- and ground-water relations. Available geologic, hydrologic, and geographic information was input into a GIS. Input data from a previously documented USGS analog ground-water-flow model were used to develop a preliminary MODFLOW model for the basin.

Plans for Fiscal Year 1993: Development and calibration of ground-water-flow models will be completed for both basins. Reports describing the geohydrology and geochemistry of the Santa Clara-Calleguas basin will be prepared. The GIS developed for the Santa Clara-Calleguas basin will be documented so that other agencies can utilize the data base. Geochemical data will be collected in the Mojave basin to define the source and age of recharge to the basin. Geophysical techniques will be used to define the areal and vertical extent of the Mojave River deposits and the underlying older alluvium.

Reports:

Densmore, J.N., Middleton, G.K., and Izbicki, J.A., 1992, Surface-water releases for ground-water recharge, Santa Clara River, Ventura County, California, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 407-416.

Gleason, J.D., Veronda, Guida, Smith, G.I., Friedman, Irving, and Martin, Peter, 1992, Deuterium content of water from wells and perennial springs, southeastern California: U.S. Geological Survey Open-File Report 91-470, 22 p.

Hanson, R.T., and Nishikawa, T., 1992, Flow-meter data: An important addition to aquifer-test analysis for modeling layered aquifer systems: Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 165.

Izbicki, J.A., 1992, Sources of chloride in ground water of the Oxnard Plain, California, *in* Prince, K.R., and Johnson, A.I., eds., Regional aquifer systems of the United States: Aquifers of the far west, AWRA Monograph Series 16: Bethesda, Maryland, American Water Resources Association, p. 5-14.

Izbicki, J.A., Martin, Peter, and Michel, R.L., 1992, Use of tritium to evaluate the rate of seawater intrusion in a coastal aquifer system (abs.): Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 189

Izbicki, J.A., Michel, R.L., and Martin, Peter, 1992, ^{3}H and ^{14}C as tracers of ground-water recharge: American Society of Civil Engineers, Irrigation and Drainage Session Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 122-127.

Nishikawa, T., and Rojstaczer, S., 1992, Ocean loading and fluid flow induced tidal response of a coastal aquifer, Ventura County, California (abs.): Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 188.

Predmore, S.K., 1992, Use of Geographic Information System in visualizing spatial data (abs.): National Computer Technology Meeting, 6th, Norfolk, Virginia, May 17-22, Program.

Stamos, C.L., Predmore, S.K., and Zohdy, A.A.R., 1992, Use of D-C resistivity to map saline ground water: American Society of Civil Engineers, Irrigation and Drainage Session Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 80-85.

HYDROLOGIC STUDIES RELATED TO VOLCANIC ACTIVITY IN LONG VALLEY

Number: CA431

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

Project Chief: Christopher D. Farrar

Period of Project: Continuing

Problem: Long Valley along the eastern Sierra Nevada frontal fault is part of a large volcanic depression called the Long Valley caldera. Since 1978, earthquake activity has increased in the caldera. This earthquake activity and a total uplift of 31 centimeters probably are 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. In response to this notice, the Survey has taken the lead in studies that include monitoring, assessment of potential hazards, and research for methods of prediction.

Objectives: The project is divided into three phases with the following objectives: Phase 1--monitor ground water and surface water to detect changes in the hydrologic system caused by geologic processes and phenomena associated with volcanism or with magma at depth in Long Valley caldera. Phase 2--determine the flood discharge at selected locations, depth of flow, extent of inundation, and time of travel of flood wave following projected failure of Long Valley Dam (Lake Crowley) on Owens River. Phase 3--delineate type and magnitude of changes that would be expected in the ground-water system of Long Valley caldera prior to volcanic eruption.

Approach: Phase 1--operate a network to monitor ground-water levels, water temperature and water quality, and surface-water quality. Relate data to geologic events. Phase 2--apply General Purpose Dam-Break Flood Simulation Model (K-634) for a projected dam failure. Application of other models or development of a new diffusion model will be considered. Phase 3--develop quantitative models capable of analyzing the interactions that take place between water-saturated rock and magmatic intrusions.

Progress: A network of hydrologic monitoring sites was operated to provide data for assessing the response of the hydrologic system to magmatic or volcanic processes, seismic activity, geothermal developments, and water-supply developments. Data collection included measurements of ground-water levels, atmospheric pressure, water temperatures, discharge of springs and streams, precipitation, gas temperatures of fumaroles, and chemical and isotopic composition of water and gas samples. During the monitoring period between 1982-1992, the greatest change in the hydrologic system occurred during the 6 years of below mean precipitation (1987-92). The changes included declines in ground-water levels and reductions in spring and stream discharge. Geothermal development has produced pressure declines in the production reservoir to a radial distance of at least 3 miles and pressure increases in the injection reservoir to a distance of at least 2.5 miles. Geothermal development also has caused land subsidence in the well field. Pumping of potable water from supply wells has caused as much as 50 feet of drawdown locally. A magnitude 7.5 earthquake on June 28, 1992, in southern California caused dynamic ground-water-level changes of as much as 6 feet in Long Valley wells. A high resolution aerial infrared survey was done for parts of Mammoth Mountain and the Casa Diablo area to locate faults and fracture zones associated with high heat flow. The results of fumarole monitoring are described in a paper to be published in the Journal of Geophysical Research.

Plans for Fiscal Year 1993: Data collection from the monitoring network will continue through 1993. Ground-water levels will be recorded in six new monitoring wells if county funding is approved. Infrared images will be produced from the 1992 survey and will be used to direct ground surveys of thermal zones. An annual leveling survey will be done in the geothermal well field. Leveling data will be used with pumpage and injection data to identify the process causing deformation. A report describing the response of the ground-water system to the Landers earthquake is planned.

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: Existing hydrologic data will be used to define the geohydrologic and geochemical framework of the study area. Observation wells and suction-cup lysimeters will be installed on four study plots that are typical of agricultural and geohydrologic conditions in the areas. Water levels will be monitored monthly, and wells will be sampled bimonthly. A three-dimensional finite-difference ground-water-flow model will be developed to simulate flow through the unconsolidated deposits that fill the basin. The movement of solutes in the main water-producing zone will be simulated 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 submitted for review. This report (1) quantifies the hydrologic information presented in the first phase of the study and (2) demonstrates some general long-term effects on water levels and water quality likely to occur as a result of proposed ground-water management alternatives. The hydrologic analysis included the development and calibration of 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. Preliminary 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, in which agricultural pumpage is reduced.

Plans for Fiscal Year 1993: The phase 2 report will be submitted for approval. Collection of water-level and water-quality data from the monitoring-network wells will continue.

Reports:

Bright, D.J., Stamos, C.L., Martin, Peter, and Nash, D.B., 1992, Ground-water hydrology and quality in the Lompoc area, Santa Barbara County, California, 1987-88: U.S. Geological Survey Water-Resources Investigations Report 91-4172, 77 p.

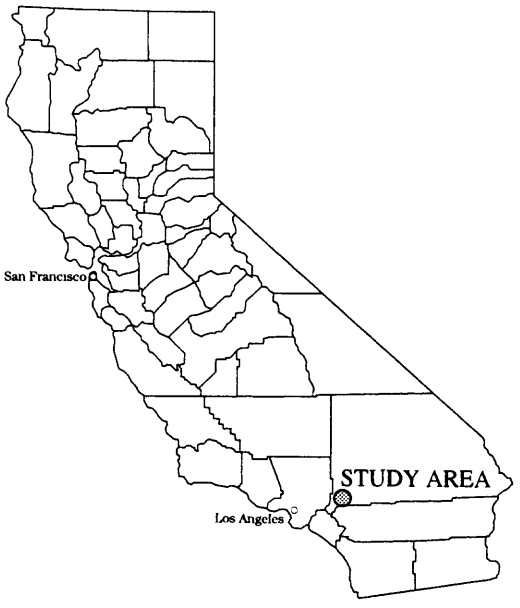
OPTIMUM MANAGEMENT IN A BASIN WITH CHANGING WATER-SUPPLY AND WATER-QUALITY PROBLEMS

Number: CA467

Cooperating Agency: San Bernardino Valley Municipal Water District

Project Chief: Wesley R. Danskin

Period of Project: October 1987 to September 1993



Problem: Historically, water purveyors have applied various techniques to solve their water-supply and water-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, the actual use of optimization techniques to solve real-world water-supply and water-quality problems has been slight.

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, quality of ground water, and artificial recharge of 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 constrained optimization techniques can be applied to the management of a complex, real-world system. Results of the optimization model were used in combination with detailed field data from multilevel piezometers to design improved water-management plans for the basin. Successful use of the optimization results required close 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 include construction of a new well field and major pipeline, use of a pumping pattern designed to contain a contaminant plume of trichloroethylene, and distribution of water from a new reservoir to optimal recharge locations. 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 EPA superfund site.

Plans for Fiscal Year 1993: Most work in fiscal year 1993 will involve completion of two reports: one documenting the ground-water-flow and optimization models and another describing the overall results. Additional work will include analysis of ground-water-level data from multilevel piezometers, transfer of model codes to the cooperating agency, training of the agency's staff in the use of the model codes, and continued coordination with local water purveyors to design and install a comprehensive management/monitoring network.

Reports:

Woolfenden, L.R., and Danskin, W.R., 1992, Application of optimization techniques to water-supply problems: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Abstracts, p. 74.

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 1992

Problem: Storm runoff in drainage basins being urbanized in Antelope Valley, California, is a major concern because increases in effective impervious areas in new developments cause increases in storm runoff volumes and peak magnitude. Reliable methods to estimate regional storm runoff are needed for land-use planning, establishing land-development criteria, and designing drainage facilities. Because numerous rainfall-runoff models are available, local development regulatory agencies are confronted with the problem of selecting the correct model for their region.

Objectives: The primary objectives are to (1) derive runoff frequencies for long-term simulation and (2) select a rainfall-runoff model appropriate for estimating design storm characteristics in ungaged drainage basins in Antelope Valley. Specific objectives include (1) instrumentation and measurement of rainfall and runoff in nine drainage basins in Antelope Valley and (2) testing and comparison of various rainfall-runoff models to simulate measured runoff.

Approach: Nine 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, various rainfall-runoff models will be calibrated and results evaluated. Basins will be selected to provide four types of hydrologic data: flood magnitude and frequency and precipitation-runoff model calibration; flow duration and frequency; and flow attenuation in a downstream direction. Aerial photography and infiltration measurements will be obtained to evaluate characteristics of the basins and flow for model application.

Progress: Streamflow and precipitation data for the 1992 water year are being processed; several storms occurred during January through March 1992. The recurrence interval of these storms is 3 years or less. Efforts to assemble and analyze historical rainfall data for all long-term precipitation stations continued. These data will be used to provide rainfall frequency and areal distribution data in Antelope Valley. An evaluation of historical rainfall-runoff data was used to identify significant basin and precipitation characteristics. The DR3M computer model was used to evaluate various rainfall and runoff parameters. Calibration of other rainfall-runoff models was not attempted because streamflow data from the basins were insufficient. Model results based on the size of several basins appeared to be questionable. Several basin boundaries determined from aerial photographs were in error. In addition, the size of the basins determined using topographic maps is in error because of urban development in the basins. All basins were surveyed during the January-March 1992 storm period, and runoff boundaries previously defined were revised. A study of precipitation characteristics in the valley indicated that winter storms of multiday duration could be of greater significance in causing floods than the magnitude of precipitation during a 24-hour period. Such was the case during the February 1992 floods.

Plans for Fiscal Year 1993: Rainfall-runoff data will be collected on a continuing basis and applied to the DR3M rainfall-runoff model. The model will be calibrated using recent precipitation data and the newly defined basin boundaries. The rainfall-runoff model will be extended to include historical data for selected precipitation stations to compare results with historical runoff data. Because of the drought, the project has been extended for 2 years. A paper on precipitation characteristics (1913-92) in Antelope Valley is planned for publication.

Reports: None

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: October 1987 to September 1992

Problem: A reconnaissance study during 1986-88 found high selenium concentrations in irrigation drainage and biota from the Salton Sea area. Selenium and other potential toxins in agricultural drainage are a source of concern for aquatic wildlife throughout the Imperial Valley and has resulted in restrictions on the 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 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: In response to the mortality of 150,000 eared grebes last winter, water samples were collected from rivers, surface drainage ditches, and the Salton Sea for analysis of pesticides. Runoff from four fields during flood irrigation also was analyzed for pesticides. A broad array of pesticides, primarily insecticides, was detected in numerous samples; several of the pesticides were present at concentrations that approach or exceed criteria for protection of aquatic wildlife.

Plans for Fiscal Year 1993: The final interpretive report for the 1988-90 detailed study has received colleague review and is currently being prepared for submittal for Director's approval. The companion data report generally is complete pending minor revisions to tables by the U.S. Fish and Wildlife Service. It is expected that the data report will be released and approved for publication in late 1992. Planning and monitoring for phase 4 studies under the direction of the U.S. Bureau of Reclamation will continue.

Reports: None

CHANGES IN RUNOFF IN PERRIS VALLEY, RIVERSIDE COUNTY

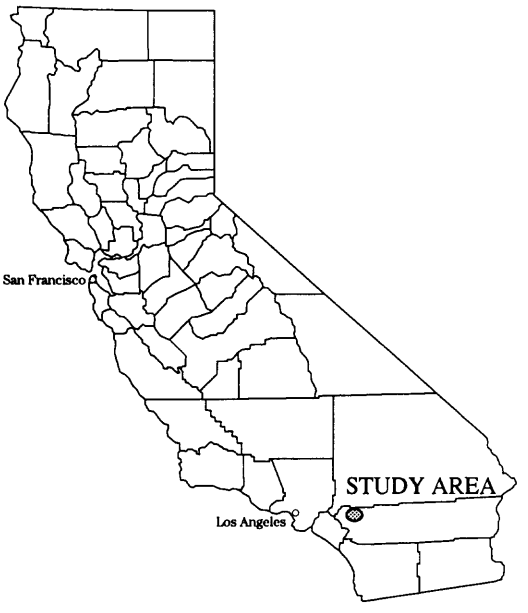
Number: CA472

Cooperating Agency: Riverside County Flood Control and Water Conservation District

Project Chief: Joel R. Guay

Period of Project: October 1988 to September 1993

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 1992 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: The preurbanization rainfall-runoff model was successfully calibrated, and work continued on completion of the posturbanization rainfall-runoff model that will simulate current urban hydrologic conditions. Rainfall and runoff data for 10 storms were collected in water year 1992. Data for 25 storms are currently available to calibrate and verify the rainfall-runoff models. Six of these 25 storms had a peak discharge greater than 1,000 cubic feet per second; the largest was 4,400 cubic feet per second.

Plans for Fiscal Year 1993: Rainfall and runoff data will be collected at four sites to supplement available data. A long-term time series of simulated storm runoff will be developed using the preurbanization and posturbanization rainfall-runoff models and historical data. The effects of urbanization will be determined by comparing the storm-runoff characteristics of preurban and urban hydrologic conditions.

Reports: None

WATER RESOURCES AND GEOHYDROLOGY OF THE CITY AND COUNTY OF SAN FRANCISCO

Number: CA473

Cooperating Agency: San Francisco Water Department

Project Chief: Steven P. Phillips

Period of Project: October 1988 to September 1992

Problem: The San Francisco Water Department currently meets public supply demands by importing water from the Tuolumne River and Hetch Hetchy Reservoir in the Sierra Nevada. Expanded development of local water resources, primarily for nonpotable use, could reduce the dependency on imported water. However, better definition of the local water resources and geohydrology will be needed for future development.

Objectives: Phase 1--Define the water resources and geohydrology of the city and county of San Francisco, and assess water use and ground-water conditions in Golden Gate Park, Fleishhacker Zoo, and Lake Merced. Phase 2--Develop a model to estimate recharge, and determine the potential for ground-water development in San Francisco on the basis of hydrologic and water-water quality constraints.

Approach: Data from previous studies and new geohydrologic data will be reviewed and analyzed to delineate the later and vertical boundaries of the ground-water basins. Water levels and quality will be measured in about 50 existing and newly installed wells. A hydraulic routing model will be developed to estimate recharge. The model will be calibrated against measured evapotranspiration, water use, and sewer flows. The potential for ground-water development will be determined on the basis of the results of the other study components and on potential conjunctive use, subsidence, and seawater intrusion.

Progress: The hydrologic routing algorithm developed for this study was refined and calibrated to sewer flows on a monthly and individual storm basis. This algorithm simulates an urban water system and allows estimation of ground-water recharge. Quantification of ground-water recharge in San Francisco is important because the city plans to increase development of ground water. A draft report describing geohydrology, water quality, and estimation of ground-water recharge in San Francisco was completed in March and sent to the cooperator to meet their immediate needs.

Plans for Fiscal Year 1993: The report will be submitted for Director's approval.

Reports: None

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 1993

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 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. 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 production well to measure the hydraulic properties of the deep and shallow zones 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 in fiscal year 1992. Transducers and data loggers were operated in five piezometers to monitor pre-test water levels on an hourly basis. 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. In September, the cooperator installed a discharge pipeline extending from the test well to Pechanga Creek. Assistance was given in the planning, design, and logistical support for installation of a new well on the main part of the reservation. USGS assisted in the collecting and logging of drill cuttings, interpreted geophysical logs, oversaw well completion, and conducted a short-term aquifer test. Hydrogeologic data collected during drilling and testing of the well will add to the understanding of the ground-water system in Wolf Valley. An annotated outline of the project report was reviewed, and work on the first draft continued.

Plans for Fiscal Year 1993: The remainder of the study will consist of a long-term aquifer test using the Pechanga well and USGS piezometers; analysis of data; construction of analytical solutions (distance drawdown graphs), using knowledge of the aquifer system and data from the aquifer tests to evaluate possible future effects on water levels on the Kelsey Tract from large-scale pumping in Wolf Valley; and completion of the report.

Reports: None

EFFECTS OF NONPOINT SOURCE RUNOFF FROM ALAMEDA COUNTY ON SOUTH SAN FRANCISCO BAY

Number: CA475

Cooperating Agency: Alameda County Flood Control and Water Conservation District

Project Chief: Peter D. Dileanis

Period of Project: October 1988 to September 1992

Problem: Population growth in the San Francisco Bay area has caused concern about water quality in all areas of the bay. Runoff from urbanized areas adjacent to San Francisco Bay may be contributing to water-quality degradation of the bay waters. The California Regional Water Quality Control Board--San Francisco Bay Region has directed Alameda County to document contaminant loading from nonpoint sources to the bay, originating from drainage basins in the county. This project will evaluate the effects of these contaminants in the bay water and sediments in conjunction with Alameda County's study of contaminant discharges from nonpoint sources.

Objectives: Define spatial and temporal characteristics of freshwater plumes and associated suspended sediment resulting from storm flows in the three largest Alameda County tributaries to south San Francisco Bay. Determine the rate and area of dispersion of contaminants that are transported to the south bay by urban runoff from Alameda County.

Approach: Fresh water from storms discharged from San Lorenzo Creek will be monitored as it enters the bay and disperses. This will be done with automatic conductivity sensors in shallow waters and by boat-mounted sensors in deeper water. Chemical and biological constituents, such as trace metals, organic compounds, and viruses characteristic of nonpoint-source runoff will be sampled at the stream outflow and at various points in the bay to determine the dispersion of these contaminants in the bay waters and sediments.

Progress: Methods for production of a bacteriophage tracer were refined and production efficiency was increased. More than 400 liters of bacteriophage stock solution with a concentration of more than 10 billion bacteriophage per milliliter were produced. Using the bacteriophage, the movement of stormwater runoff was traced from Alameda Creek, San Lorenzo Creek, and San Leandro Creek a total of five times. About 200 water samples were collected during a 10- to 20-day period for each of the five monitoring events. An area of about 30 to 40 square miles around the mouth of each creek was included in the sampling area. Bacteriophage were detected as much as 5 miles from the source creeks along the inshore parts of the Bay but not more than about 1.5 miles into the bay. Bacteriophage were not detected more than 12 days from release. Surficial sediment samples were collected every 6 weeks between December and May at six sites offshore of San Lorenzo Creek to monitor seasonal variation of urban pollutants. Five cores were collected at 1-meter depths near San Lorenzo Creek and in San Leandro Bay. Decreasing concentrations of lead with depth in two cores from San Leandro Bay indicate a suitable depositional environment exists for dating sediments and for evaluating changes in pollutant levels during increasing urbanization of the basin.

Plans for Fiscal Year 1993: Additional sediment cores will be collected and analyzed for trace elements and dated using radioisotope concentrations. Statistical analysis and graphical presentations of the data will be completed and a report prepared.

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 1992

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 1991 and May 1992. New equipment that provides data in the *x*, *y*, and *z* planes has been used to provide scour data at the SR-32 site. Flooding did not occur during the 1992 water year, so adequate data needed for analysis of scour conditions at the site are not 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 0.8 foot from 1979 to 1981 for the upstream reach unaffected by the bridge. During this period, the thalweg (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 more than 8 feet below the reference elevation were measured from 1988 to 1992. Channel changes of these magnitudes occurred during the period of drought (1987 to present) when annual maximum floodflows averaged about 30 percent of predrought flow conditions.

Plans for Fiscal Year 1993: Collection of scour depth and channel-geometry data will continue with emphasis on collecting scour data during several moderately high-flow events. If suitable floods occur, scour data also will be collected around the bridge piers. An evaluation of this scour data, as well as data collected in the reach unaffected by the bridge, will be completed and an interim report prepared.

Reports: None

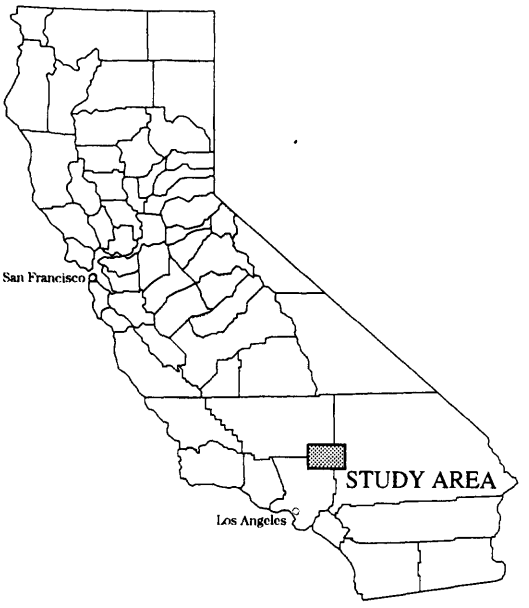
GROUND-WATER RESOURCE INVESTIGATIONS, EDWARDS AIR FORCE BASE

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 decrease 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 runways on the lakebed.

Objectives: Define the boundaries and areal extent of the ground-water system. Quantify the distribution of hydrologic properties. Determine ground-water recharge and discharge. 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 boundary conditions of the ground-water basin. Exploratory drilling will be done. Piezometers will be installed at various levels to establish a multilevel monitoring network. Ground-water levels will be measured and water-quality samples will be collected. Aquifer tests will be done. Evidence of land subsidence and surface deformation will be obtained 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 at selected locations.

Progress: Exploratory test drilling was done at four sites, and a total of 10 piezometers were installed at these sites to monitor water-level responses to pumping in the South Track well field and to document head differences across the inferred Antelope Valley fault. A water-level monitoring network consisting of 91 wells was established for the base and currently is being monitored monthly. A total of 14 transducers were installed in selected wells to obtain hourly water-level records to supplement the monthly measurements. An extensometer was installed near the large fissure on Rogers Lake (dry) to monitor compaction above the water table. Operation of the deep extensometer south of Rogers Lake continued, and data from the extensometer indicate that land subsidence is continuing in this area. A seismic survey was done on Rogers Lake in the area of the assumed ground-water divide between the Lancaster and North Muroc ground-water subbasins and also in the area where the inferred Antelope Valley fault is projected to pass under the lakebed. A GPS survey was completed at selected bench marks on the base to determine changes in land-surface elevation since the last survey in 1989. Fieldwork for the geologic mapping of the base was completed.

Plans for Fiscal Year 1993: Water-level and subsidence monitoring will continue. A monument array established near the lakebed fissure will be monitored to measure horizontal deformation of the lakebed. Surface transects of Rogers Lake will be surveyed and profiles of the lakebed surface will be prepared. Water samples from selected wells in the Buckhorn area and near the Antelope Valley fault will be collected for water-quality analysis. Pressure transients, measured in monitoring wells near the South Track and Graham Ranch well fields, will be analyzed for estimates of the hydraulic properties of the aquifer.

Reports:

Blodgett, J.C., and Williams, J.S., 1992, Land subsidence and problems affecting land use at Edwards Air Force Base and vicinity, California, 1990: U.S. Geological Survey Water-Resources Investigations Report 92-4035, 25 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 1993

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 which 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 which 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. Abnormally large carbon-dioxide flux values were measured on Sherman and Orwood Islands during the winter months. These large fluxes are believed to be the result of dry conditions and soil cracking. Cracks in the soil allow soil gas with high carbon-dioxide concentrations to escape during flux measurements. Dissolved organic-carbon fluxes were measured in the drainage outlets for all three islands.

The nature of dissolved organic carbon in the drainwater was examined by determining the concentrations of hydrophilic and hydrophobic acids and bases in samples. Low pH and high concentrations of hydrophilic acids were measured in samples collected on Jersey Island where the water table is higher than the other two islands and ground water is in direct contact with well-decomposed organic matter near land surface. Because of the deeper water table on the other two islands, the ground water is in contact with less decomposed organic matter and has lower concentrations of hydrophilic acids and higher pH values. Land-surface elevation changes primarily are influenced by fluctuations in ground-water levels. Permanent subsidence continued at about 1 centimeter per year on all three islands. Permanent subsidence measured at the extensometers compared well with decreases calculated from carbon-dioxide evolution from organic-matter oxidation. Estimates of land-surface elevation decreases

from the aqueous dissolved organic carbon flux are less than 1 percent of the total measured elevation decreases.

Plans for Fiscal Year 1993: Funding will decrease substantially in fiscal year 1993 and measurement of carbon fluxes will decrease by one-half. Collection of extensometer data will continue. A two-part journal article was written on the results of the data collection done through May 1992 and has been submitted to Soil Science Society of America Journal.

Reports:

Wang, B., and Deverel, S., 1992, Factors affecting carbon fluxes in the organic soils of the Sacramento-San Joaquin Delta, California: American Society of Agronomy, Annual Meeting, 84th, Minneapolis, Minnesota, November 1-6, 1992, Agronomy Abstracts, p. 62-63.

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: Extensive field data were collected during fiscal year 1992. All wells and lysimeters at the seven sites in the study area, as well as other wells in the 25-well network for monitoring water quality, were sampled for water-quality analyses during December 1991, March 1992, June 1992, and September 1992. Samples for analysis of nitrogen isotopic composition were collected during early summer and autumn 1992. Soil-gas samples also were collected during the autumn sampling campaign. Unsaturated-zone pore-moisture contents were measured monthly and water-table altitudes were measured quarterly in the 70-well network for monitoring water levels. Cooperator Information Meetings were held December 2-3, 1991; July 1, 1992; and September 27, 1992. Preliminary results indicate that unsaturated-zone pore-water nitrate concentrations tend to be highest in the top 1 meter of the soil column, and rapidly decrease with increasing depth. Beneath about 7 meters, nitrate concentrations stabilize at about 30 mg/L (milligrams per liter) (as N) until the capillary fringe is reached. There, additional nitrogen removal occurs. Nitrate concentrations exceeding 7,000 mg/L were observed in the top 10 centimeters of the soil column beneath a dairy. Before the water reached a depth of 7 meters, this concentration had been reduced to 35 mg/L. The concentration then remained relatively constant until the water reached the capillary fringe. Concentrations in the capillary fringe were generally less than 5 mg/L. Nitrogen isotopic measurements indicate that microbial denitrification occurred in the unsaturated zone.

Plans for Fiscal Year 1993: Results for the project will be prepared for publication. A report in theWater-Resources Investigations series will be prepared describing the entire project. Several journal publications describing specific aspects of the study are planned.

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 1993

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 between 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 sediments 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 samples from two new study sites in the Alpaugh area showed: (1) at site 31D, specific conductance ranged from 970 to 29,800 microsiemens per centimeter (µS/cm), selenium (Se) ranged from 1 to 390 micrograms per liter (µg/L) (Se and specific conductance are highly correlated, $r2 = 0.89$), and arsenic (As) ranged from 58 to 13,450 µg/L and (2) at site 16J, specific conductance ranged from 1,340 to 58,500 µS/cm, Se ranged from less than 1 to 10 µg/L, and As ranged from 6 to 560 µg/L. Evaluation of the redox status of wells in the Alpaugh area has shown that soluble Se was present mainly under oxidizing conditions as selenate [Se(VI)] (greater than 90 percent), whereas the soluble As species were distributed between arsenate [As(V)] and aresnite [As(III)] and corresponded qualitatively to redox conditions. Quantitative evaluation of the redox status of these wells showed that platinum-electrode measured redox potential (Eh) and calculated redox potentials from several redox couples varied more than several hundred millivolts for a given well indicating redox disequilibrium and the necessity to measure redox-sensitive species. Three new cluster sites were installed: two near Lost Hills and one in the Alpaugh area.

Plans for Fiscal Year 1993: Analyses of porewater and observation well samples and sediment from the three new cluster sites will be completed. Selected sediment samples will be extracted to estimate solid-phase associations of Se and As and analyzed to determine the solubility of Se and As species under controlled Eh and pH conditions. Well analyses from five of the cluster sites will be published in a data report. Two new cluster sites may be installed in the Wheeler Ridge study area. Sampling of porewater and sediment at selected study sites will continue.

Reports:

Chalmers, A.T., and Fujii, R., 1992, Geochemical processes affecting the solubility of Se and As in ground water, Tulare Basin, California: American Society of Agronomy, Annual Meeting, 84th, Minneapolis, Minnesota, November 1-6, Agronomy Abstracts, p. 235.

INTERACTION OF GROUND-WATER FLOW AT REGIONAL, SUBREGIONAL, AND FARM SCALES, AND IMPLICATIONS FOR DRAINWATER FLOW AND QUALITY, WESTERN SAN JOAQUIN VALLEY

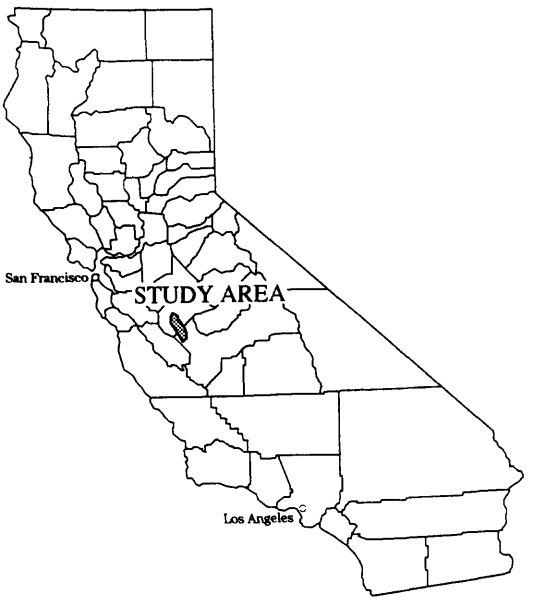
Number: CA482

Cooperating Agencies: Panoche Water and Drainage District; and California Department of Water Resources

Project Chief: John L. Fio

Period of Project: October 1989 to September 1992

Problem: In the western San Joaquin Valley, more than 250,000 acres of irrigated farmland require drainage because of soil salinity and a shallow water table. Shallow ground water and drainwater in these areas have toxic levels of boron, molybdenum, and selenium associated with high concentrations of dissolved solids. Preliminary data indicate that ground-water flow to drainage systems in the valley and resultant contaminant loads are affected by local, subregional, and regional hydrologic response to stresses. Management strategies designed to control drainwater flow and quality must address the interrelations at all three scales.



Objectives: Develop and verify a subregional-scale ground-water-flow model that simulates steady-state drainflow and drainwater chemistry. Quantitatively assess the interactions among the regional, subregional, and local ground-water-flow systems in response to irrigation and drainage. Evaluate the effects of potential local and larger-scale management actions on drainwater flow and quality. Assess implications for development of a field and modeling approach for the quantitative assessment of ground-water flow and contaminant movement in other irrigated and drained agricultural areas in which local- and regional-scale interactions must be evaluated.

Approach: A three-dimensional, finite-difference ground-water-flow model will be developed for the subregional flow system within the Panoche Water District in the western valley. Geohydrologic data from observation wells will be used to develop and calibrate the subregional model. Qualitative verification of simulated ground-water flow to the drainage systems will be made using geochemical data from ground-water and drainwater samples. Comparison of results from the subregional model and the Survey's regional-flow model of the western valley will assist the interactions between the two scales.

Progress: A quantitative assessment of ground-water flow in the study area was completed using a three-dimensional ground-water-flow model. The results are discussed in two reports describing geohydrologic and geochemical conditions in the study area. The reports were written and have undergone colleague review. Author response for both reports will be completed before November 30, 1992.

Plans for Fiscal Year 1993: Preparation of reports will be completed.

Reports: None

OPTIMUM CONTROL OF SEAWATER INTRUSION, OXNARD PLAIN, VENTURA COUNTY

Number: CA483

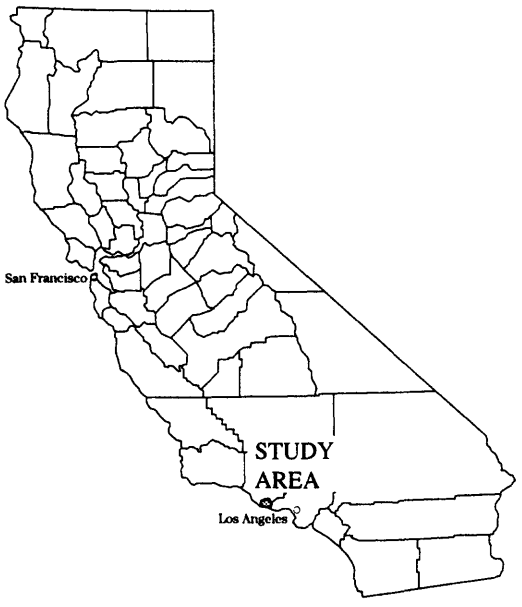
Cooperating Agency: United Water Conservation District

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: Water-level and water-quality data collection continued at all 20 USGS nested-well monitoring sites (a total of 85 wells) in Ventura County. Additional water-quality sampling was completed at existing wells within the basin. Five aquifer tests were conducted at production wells in the basin and slug tests were completed at all USGS wells. The preliminary simulation-optimization model was completed. Efficient pumping, artificial-recharge, and surface-water-delivery strategies for controlling seawater intrusion were identified, using the model. Work also continued on using HST3D, a three-dimensional, density-dependent solute-transport model, to simulate the movement of seawater and other regional contaminant sources. All tasks for this study have been carried out in close cooperation with Southern California RASA.

Plans for Next Year: Both the solute-transport model and final simulation-optimization model will be completed and described in reports.

Reports: None

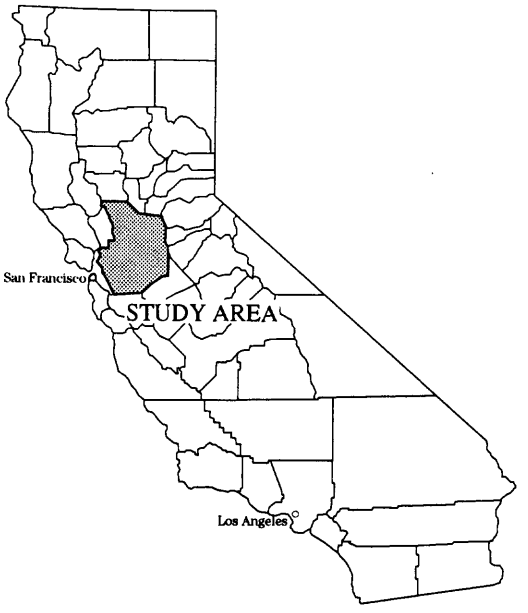
SAN FRANCISCO BAY-ESTUARY TOXIC CONTAMINANT STUDY

Number: CA484

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

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: Sampling for dissolved pesticides was done daily at Vernalis (San Joaquin River) and three times a week at the Tower bridge (Sacramento River). This sampling provides an invaluable record of the riverine pesticide inputs to the delta during an annual cycle. The results of this monitoring emphasizes the highly seasonal and temporal nature of the pesticide inputs. Following rainfall in February, suspended sediments were sampled three different times at Vernalis and once on the Sacramento River for later analyses of adsorbed pesticides. Fixed sites within the delta were again sampled during March and April for dissolved alfalfa pesticides. Low concentrations of carbofuran at these sites in 1992 compared with 1991 suggest a strong dependence on the timing of rainfall following application of the pesticide to the fields. From late April through June, samples were collected twice a week for rice pesticides and for toxicity tests at the Colusa Basin drain (major rice drainage canal). The concentrations of rice pesticides in the Colusa Basin drain were about one-third the concentrations measured last year, probably because of the longer total holding time of water on the fields. Results were presented as a talk and a poster at the Estuarine Research Federation meeting, a talk at the American Society of Limnology and Oceanography meeting, and a talk at the Interagency Ecological Study Program meeting. An article was written on partitioning of organic contaminants for the journal Estuaries.

Plans for Fiscal Year 1993: The above studies will continue with more emphasis on sampling after rainfall events and on the delta. An areal reconnaissance will be made of bed sediments and adsorbed pesticides within the delta. Articles or open-file reports will be written on (1) the results of pesticide monitoring at the Tower bridge and at Vernalis, (2) on the distribution of alfalfa pesticides, and (3) on the quality assurance of the laboratory procedures.

Reports:

Kuivila, K.M., Crepeau, K.L., and Domagalski, J.L., 1992, Input and transport of pesticides applied to alfalfa in the Sacramento-San Joaquin Delta: American Society of Limnology and Oceanography, 1992 Aquatic Sciences Meeting, Santa Fe, New Mexico, February 9-14, Program and Abstracts, 1 p.

Kuivila, K.M., Crepeau, K.L., and Domagalski, J.L., 1992, Input and transport of select alfalfa pesticides to San Francisco Bay, California: Society of Environmental Toxicology and Chemistry, Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Abstracts, p. 33.

Meyers, William, and Kuivila, K.M., and Scow, K.M., 1992, Microbial degration of carbofuran in the Sacramento-San Joaquin Delta, California: Society of Environmental Toxicology and Chemistry, Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Abstracts, p. 103.

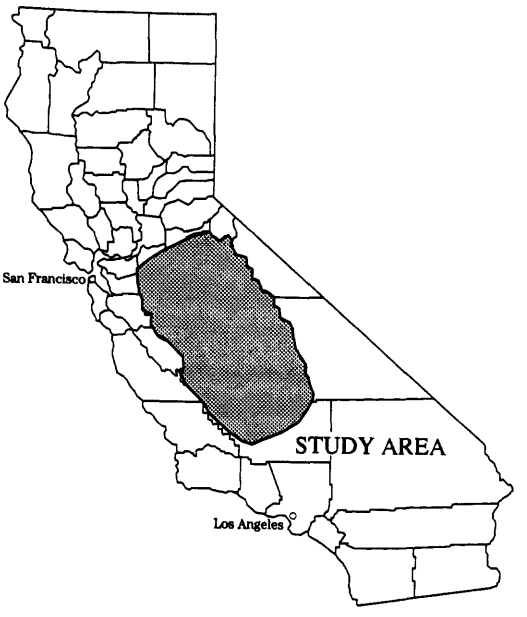
SAN JOAQUIN-TULARE BASINS NATIONAL WATER QUALITY ASSESSMENT PROGRAM

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 impact of point sources and compliance with regulations. In contrast, the impact 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 be a carefully selected subset of the stations sampled in the intensive phase.

Progress: The primary activity scheduled for fiscal year 1992 was acquisition and evaluation of existing data. Significant progress was made on reports describing existing data on nutrients in ground water, nutrients and sediment in surface water, pesticides in surface and ground water, and the aquatic ecology in the study unit. Two field components of the program were completed: (1) reconnaissance of potential sites for surface water and ecological assessments and (2) on-site assessment of suitability of surface-water sites for collection of bed-sediment and tissue samples to determine the occurrence of hydrophobic organic compounds and trace elements. Two pilot field activities also were conducted: measurement of extremely low concentrations of hydrogen gas in ground-water samples to determine the dominant microbially mediated redox reaction and a pilot sampling design for assessing seasonal variability in pesticide concentrations in surface water. Data from the latter item will be used with data from similar pilots for three other NAWQA study units to design a seasonal pesticide sampling approach for the NAWQA program. At the end of fiscal year 1992, two work groups convened to facilitate local input on two technical issues from members of the study unit liaison committee. One group considered the design of ground-water investigations; the second group reviewed current knowledge of and possible approaches to the study of distribution of pesticides in surface water.

Plans for Fiscal Year 1993: Activities have been planned but may be modified after completion of a national review of the scope of the study unit investigations. Planned activities include (1) completion of the reports that were prepared using existing data, (2) collection of bed-sediment and tissue samples for evaluation of the occurrence of hydrophobic organic compounds and trace elements, (3) collection of surface-water-quality data at a network of sites, (4) areal sampling of ground-water quality and drilling of observation wells, and (5) assessment of aquatic ecology.

Reports:

Brown, L.R., 1992, Biological and data management aspects of the National Water Quality Assessment Program in the San Joaquin-Tulare basins, California: California-Nevada Chapter of the American Fisheries Society, Annual Conference, 27th, Redding, California, February 6-8, Program, p. 15-16.

Ross, Lisa, and Domagalski, Joseph, 1992, Temporal and spatial distribution of pesticides in the San Joaquin River, California (abs): Environmental Toxicology and Chemistry Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Program.

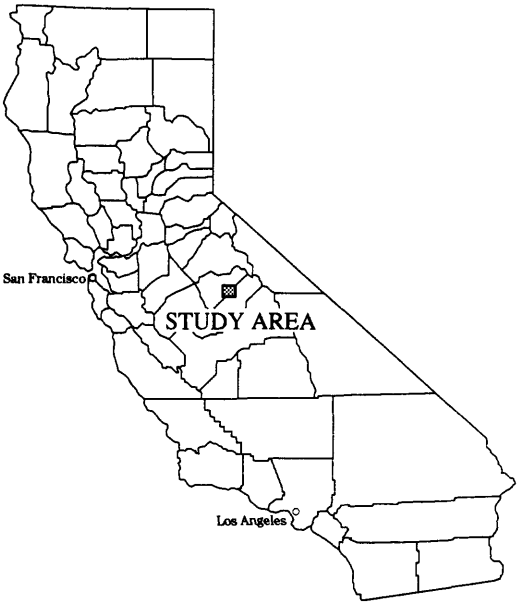
APPRAISAL OF WATER RESOURCES IN THE WAWONA AREA OF YOSEMITE NATIONAL PARK WITH EMPHASIS ON THE AVAILABILITY OF GROUND WATER

Number: CA486

Cooperating Agency: National Park Service

Project Chief: James W. Borchers

Period of Project: October 1990 to March 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 at El Portal and 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 ground water and springs in the fractured granitic rocks underlying the Wawona area.

Objectives: Examine 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: Two test holes were drilled to determine the relation between the state of stress and the orientation and permeability of fractures in the granitic rocks underlying the Wawona area, Yosemite National Park. Borehole seismometers were installed in four observation wells with 80-foot depths. Microearthquakes were recorded during the stress measurements in test hole 1. Correlation of microearthquakes and induced hydrofractures will indicate the direction of minimum and maximum stress in the rocks. Both test holes encountered pressurized, water-bearing fractures that allowed ground water to flow from test holes 1 and 2 at 20 and 90 gallons per minute, respectively. Both wells were sampled for standard inorganic, trace-element and isotopic constituents. Well cuttings will be used for later analysis of chemical constituents in fluid inclusions within the rocks and for isotopic analysis of rock minerals. Twelve single-well and two multiple-well aquifer tests were done. Published geologic maps were field checked. Six wells and three springs were sampled for dissolved gases. A ground-water-level monitoring network consisting of 44 wells was established. Three seepage runs were done on the South Fork Merced River and on Rainier Creek.

Plans for Fiscal Year 1993: Most of fiscal year 1993 will be spent in data analyses and report writing. Collection of ground-water level data from wells in the monitoring network will continue. Collection of hydraulic head data from two spring pools will begin. The two test wells will be sampled for dissolved gases. Flow in the South Fork Merced River at Wawona will be measured regularly during the year so that a new relation between flow and stream stage can be developed.

Reports: None

WATER RESOURCES OF INDIAN RESERVATIONS IN CALIFORNIA

Number: CA487

Cooperating Agency: Pala Band of Mission Indians

Project Chief: James C. Blodgett

Period of Project: July 1990 to September 1993

Problem: About 40 small Indian reservations in California occasionally request assistance in assessing their reservation's water resources. The ability for the U.S. Geological Survey to respond to these requests is dependent on availability of qualified personnel. Commonly, this will involve a reconnaissance study to determine the potential of surface or ground water for development or simply to suggest sites where small supplies of good quality water can be found.

Objectives: Provide water-resource appraisals of Indian reservations in California. Because the reservations generally are small (some having only tens of people), the work to be done on each reservation will be limited to reconnaissance level, qualitative hydrology, and well-site selection. Where present or future potential water needs are large, areas beyond the reservation may be evaluated.

Approach: As necessary, wells will be inventoried, streams will be measured, water quality will be determined, and favorable sites for development will be located. Limited geologic mapping will be done if not already available. When warranted, shallow augering will be done, and if necessary, test holes may be drilled. Preliminary hydrologic models may be developed to assist in data analyses and interpretation.

Progress: During fiscal year 1992, work was done on the Pala Indian Reservation. Rainfall and runoff data were collected at Bubble-Up Creek near Pala, California, and Keys Creek Tributary at Valley Center, California. The data are being used to calibrate and verify a rainfall-runoff model of the Bubble-Up Creek drainage basin. The model will be used with historical rainfall data to determine the frequency of volumes and peaks in the basin.

During water year 1992, 11.60 and 3.57 inches of rainfall were recorded at Bubble-Up Creek and Keys Creek Tributary gages, respectively. A stage-discharge rating for each station is being prepared. Preliminary work on the rainfall-runoff model began, using rainfall and runoff data from water year 1991. Because of the drought, measurements from only four storms were available to calibrate the rainfall-runoff model. These storms had peak discharges of 130, 24, 18, and 66 cubic feet per second. The project was suspended on May 13, 1992 as a result of budgets cuts experienced by the cooperator.

Plans for Fiscal Year 1993: The cooperator indicated that funds probably will be available for fiscal year 1993. If funds are available, rainfall and runoff data will be collected for another year at Bubble-Up Creek and Keys Creek Tributary. These data will be used with data from the previous 2 years of the study to calibrate the rainfall-runoff model.

Reports: None

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 1993

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.

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.

Approach: The study will be a joint effort between the California and Nevada Districts. The general approach is to describe current climate and develop future climate scenarios, develop a data base to support watershed modeling and to develop a model of watershed processes for current and future scenarios. Specifically, project personnel in the California District will (1) link historical data for unregulated streamflow for the basins to climate data through stochastic analysis; (2) analyze historical data for climate variability and develop plausible climate-change scenarios; and (3) analyze modeled streamflow responses to the scenarios.

Progress: Papers and poster sessions describing results of characterizations of historical temperature variations, streamflow regression models, and watershed-model simulations were presented at the 1991 National Oceanic and Atmospheric Administration (NOAA) Climate Diagnostics Workshop and at the 1992 Pacific Climatology Workshop. American Water Resources Association (AWRA) symposium papers describing (1) synthesis of climate-change scenarios based on atmospheric-circulation patterns and (2) multiple-regression models of climate-change effects on streamflow will be published by the AWRA during the autumn of 1992. Further regression analyses were completed and demonstrate differences in climate-change responses among the American and Carson Rivers and the nearby Truckee River. These "observed" differences are in general agreement with responses simulated by detailed watershed models of parts of the American and Carson Rivers. Journal articles describing (1) the further regression analyses, (2) gamma-variate disaggregation, and (3) watershed-model responses to daily climate-change scenarios were drafted and are in review.

Plans for Fiscal Year 1993: The three draft articles will be submitted for approval and to journals. Results will be presented at the 1992 AWRA Annual Symposium in November and at the American Geophysical Union Fall Meeting in December. Analyses of historical trends in winter atmospheric-circulation patterns over the North Pacific will be completed and documented in a journal article. An expanded version of the AWRA paper describing scenarios synthesized on the basis of atmospheric-circulation patterns will be prepared and submitted for approval. A journal article documenting analyses of the role of simulated circulation patterns in determining simulated precipitation rates in general-circulation models of the atmosphere is being drafted.

Reports:

Dettinger, M.D., and Cayan, D.R., 1992, Climate-change scenarios for the Sierra Nevada, California, based on winter atmospheric- circulation patterns, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 681-690.

Dettinger, M.D., Cayan, D.R., and Aguado, Edward, 1992, Winter-to-winter variations in atmospheric circulation patterns associated with Sierra Nevada storm and interstorm conditions (abs.): American Geophysical Union, 1992 Fall Meeting, San Francisco, December 7-11, p. 236. [Supplement to Eos, Transactions of the American Geophysical Union, October 27, 1992, v. 73, no. 43]

Dettinger, M.D., and Ghil, Michael, 1992, Interannual and interdecadal variability of surface-air temperatures in the United States *in* Proceedings of the Sixteenth Annual Climate Diagnostics Workshop: National Oceanic and Atmospheric Administration, Los Angeles, California, October 28-November 1, 1991, p. 209-214

Dettinger, M.D., and Jeton, A.E., 1992, Simulated streamflow responses to climate change in the American and Carson Rivers of the Sierra Nevada, California and Nevada: Pacific Climate (PACLIM) Conference, Annual PACLIM Workshop, 9th, Pacific Grove, California, April 21-24, Abstracts, 1 p.

Duell, L.W.F., Jr., 1992, Use of regression models to estimate effects of climate change on seasonal streamflow in the American and Carson River basins, California-Nevada, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 731-740.

Duell, L.F.W., Jr., 1992, Use of regression analysis to estimate effects of climate change on monthly streamflow in the American and Carson River basins, California-Nevada: Pacific Climate (PACLIM), Conference, Annual PACLIM Workshop, 9th, Pacific Grove, California, April 21-24, Abstracts, 1 p.

IRRIGATION DRAINAGE DETAILED STUDY OF KLAMATH BASIN, CALIFORNIA AND OREGON

Number: CA489

Cooperating Agency: U.S. Department of the Interior

Project Chief: Vacant

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: Weekly monitoring of the aquatic environment at 10 sites continued from June 1 to August 30. Weekly monitoring included bioassays, pesticides, dissolved oxygen, pH, conductivity, and temperature. Bioassays were done in the field using fathead minnows and aquatic invertebrates (*Daphnia* and *Hyallela* sp.), and water samples were collected for laboratory toxicity tests on frog embryos. Pesticide sampling was done using a solid-phase extraction technique. Sixty-four pesticide samples were chosen for analysis, based on a combination of random selection and observed biotoxicity. Water-quality characteristics were measured during each site visit using portable meters. Four recording multiparameter water-quality meters were rotated among the sites to collect continuous data throughout the 72-hour bioassay tests. Fifty-four water samples were collected and analyzed for nutrients, major ions, and organic carbon. One hundred fifty-five determinations of ammonia were made throughout the study area. In July, the fate and short-term effects of the herbicide, acrolein, were evaluated using chemical analysis and bioassays. Monitoring was done in a selected canal (J-7) after an acrolein application. Monitoring of offsite movement and the effects of aerial applications of methamidiphos and dysiston were completed in July and August. Paper cards were used to collect any pesticide drifting from the fields. Bioassays and water-quality measurements were done for canals adjacent to fields that were scheduled to be sprayed. Aquatic communities at core sites were evaluated using EPA rapid bioassay methods, and fish health surveys were done twice during the summer. Sediment bioassays using chironomid larvae were done periodically on Tule Lake sediments. Grebe eggs were collected for pesticide analysis.

Plans for Fiscal Year 1993: Analyses of data will be completed. A water-resources investigations report will be written and submitted for Director's approval.

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 of 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 began. Initial documentation of plans for the national synthesis also began. Existing data on pesticides at the national scale were compiled.

Plans for Fiscal Year 1993: Analyses of existing data on pesticides will be completed. In addition, a detailed design for the national synthesis data analysis will be completed.

Reports: None

GROUND WATER, SOUTH SAN FRANCISCO BAY AREA

Number: CA493

Cooperating Agency: The San Francisco Bay Area Water Users Association and the City of San Francisco

Project Chief: John L. Fio

Period of Project: January 1991 to September 1994

Problem: The south San Francisco Bay and peninsula area is part of the largest urban and industrial centers in northern California. Its water 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 is 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 first year of study entailed an extensive search for all available reports, maps, and related information describing historical and current ground-water, water-use, and land-use conditions in the study area. The well data base currently contains about 760 data points consisting of geologic, water-level, and water-quality data (total dissolved solids, specific conductance, major ions, alkalinity, pH, boron, bromide, and nitrate). Lithologic information for about 590 wells has been digitized in 1-foot intervals to characterize the vertical distribution of fine- and coarse-grained sediment in the study area. Water-level data for 190 wells and water-quality data for 280 wells have been entered into the well data base, and water-level and water-quality data for many of the wells consist of both historical and recent data (1990). All data is being entered into an ARC-INFO Geographic Information System (GIS) in order to conduct an assessment of regional hydrologic and geochemical conditions. The GIS will be used to evaluate the spatial relation between geologic, hydrologic, and water-quality data. To date, map coverages in the GIS include political boundaries, transportation networks, hydrography, land-surface elevation, surficial geology, depth to basement rocks, probable well yields, land use (1976-77), land subsidence (1934-67), depth to the saturated zone (1973), potentiometric heads under early-development conditions (1916), and total dissolved solids (1945-70).

Plans for Fiscal Year 1993: The data base will be completed and used to conduct a regional assessment of ground-water conditions in the study area. This will be done by constructing maps of the distribution of sediment texture (fraction of coarse-grained sediment), elevation of the free-water surface, potentiometric surface of underlying depth interval(s), and water-quality analyses. Representative geohydrologic cross sections will be identified for detailed geohydrologic assessment. Water- and land-use data will be compiled and used to estimate the distribution of pumpage and recharge within individual water districts.

Reports: None

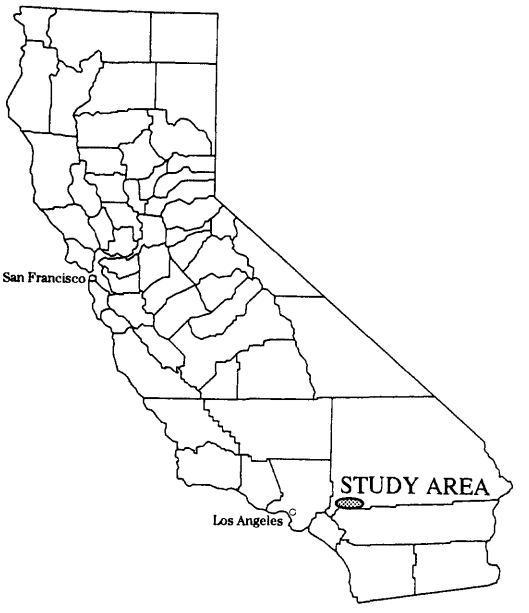
EFFECTS OF WATER BANKING ON GROUND-WATER FLOW AND QUALITY IN THE RIALTO-COLTON BASIN, SAN BERNARDINO

Number: CA494

Cooperating Agency: San Bernardino Valley Municipal Water District

Project Chief: Linda R. Woolfenden

Period of Project: October 1992 to 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 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: Activities for fiscal year 1992 focused on data collection and analysis. Water-level data and well logs were obtained from local water districts. Thirty production wells were canvassed. Water levels were measured in and samples collected from selected wells. Four multiple-depth well sites were completed for this project, and water levels were measured and samples were collected for chemical analysis. Water from wells drilled for this project and selected existing wells was analyzed for major ions; nutrients; strontium, bromide, and iodide; stable isotopes; and tritium. Water from selected shallow wells completed for this project was also sampled for priority pollutants.

Plans for Fiscal Year 1993: Data collection and analysis will continue. Four more multiple-depth well sites will be completed. Water levels will be measured in and water samples will be collected from all wells completed for this project. Aquifer tests will be conducted at three or four sites. Work will begin on the mathematical model.

Reports: None

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

Number: CA495

Cooperating Agency: California State Water Resources Control Board; and East Bay Municipal Utilities District

Project Chief: Charles N. Alpers

Period of Project: October 1991 to September 1994

Problem: Penn Mine is an abandoned copper-zinc mine in northwestern Calaveras County, California. Mining activity from the 1860's to the 1950's has left several million tons of waste rock and tailings exposed in surface piles. In 1979, seven wastewater ponds were built by the East Bay Municipal Utility District and the 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 wastewater 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 verified with speciation-saturation and mass-transfer calculations.

Progress: Eight monitoring wells were drilled between wastewater impoundments at Penn Mine and Camanche Reservoir during November 1991. The following downhole geophysical logs were collected: acoustic televiewer, gamma, fluid temperature, and fluid resistivity. Downhole flow-meter tests identified the contact zone between meta-volcanic and slate units to be the most permeable. Inflatable packers were installed in three wells to separate discrete fracture intervals and rock types. Water-quality samples were collected twice. Recovery curves from pumpage during sampling were used to estimate transmissivity in the fractured-rock aquifers. Data loggers connected either to transducers or to shaft encoders with float systems were installed to record hourly water-table elevation in four wells at eight depth intervals. Stable isotope ratios of $^{2}H/^{1}H$ and $^{18}O/^{16}O$ in ground water exhibit an evaporative signature likely related to processes in surface impoundments prior to recharge. Excellent correlations were demonstrated between $^{2}H/^{1}H$ and $^{18}O/^{16}O$ stable isotope ratios and water-quality constituents such as pH and dissolved sulfate, indicating that acid mine drainage recharged the ground water by infiltration from unlined surface impoundments.

Plans for Fiscal Year 1993: The following tasks are scheduled to be completed: (1) additional drilling and water-quality sampling in the area between the Penn Mine waste impoundments and Camanche Reservoir and into the underground mine workings, (2) 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 and slug-test data using hydrologic modeling (MODFLOW and discrete fracture network approach), and (5) computation of metal flux by ground-water transport into Camanche Reservoir from Penn Mine wasterwater impoundments and underground mine workings.

Reports: None

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: September 1992 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 minimize land subsidence and carbon flux.

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 biogeochemcial 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, respectively, and (3) assessment of the biogeochemical pathways from carbon, hydrogen, and oxygen isotope composition.

Progress: A field site for monitoring of aqueous and gaseous carbon flux in resubmerged organic soils was established. Three wooden enclosures 32 × 32 feet were constructed. These enclosures will serve as water impoundments during the studies and will be used to simulate permanently flooded, seasonally flooded, and moist environments. A water-supply system was constructed to maintain a constant water level within the enclosures. An extensometer was installed to continually monitor land-surface elevation changes under present moisture conditions. Two bench marks were installed for monthly spirit level measurements between the bench marks and leveling points within the flooded enclosures. A leveling survey between the Three Mile Slough bridge and the bench marks was run and the elevations of the bench marks were calculated. Core samples are being analyzed for dissolved organic carbon. In addition, laboratory studies were begun to investigate the influence of environmental factors on dissolved organic carbon under controlled conditions.

Plans for Fiscal Year 1993: Field monitoring of aqueous and gaseous carbon fluxes and land-surface elevation response under the three water-management regimes will begin. Laboratory studies evaluating the effect of individual environmental factors on gaseous carbon flux will begin.

Reports: None

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

Number: CA497

Cooperating Agency: Mojave Water Agency

Project Chief: Greg 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: Water levels were monitored in about 150 wells along the Mojave River to document ground-water recharge during two major runoff events during the winter and spring of 1991-92. Microgravity measurements were made at 27 sites along the river to compute specific yield of the flood-plain aquifer. Uncertainty of gaging-station records was determined to allow computation of estimated ground-water recharge from the river during 1931-92. Infiltration rates were measured at 11 sites on the flood-plain using a double-ring infiltrometer to document areal and temporal differences. Eight multiple-well monitoring sites were installed to determine lithologic, hydraulic-head, and water-quality differences with depth.

Plans for Fiscal Year 1993: Major work elements during the second year of the study include continuation of water-level monitoring in wells along the river, microgravity measurements, sampling of selected wells for analyses of hydrogen and oxygen isotopes, estimating yearly ground-water recharge from streamflow infiltration, documenting historical changes in phreatophyte growth along the river, and documenting changes in streamflow characteristics owing to 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 to 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 to what degree these are removed as water percolates through the unsaturated zone and, assuming 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 nitrogen species distribution, TOC distribution, COC distribution, CAM distribution, and bacteria and viruses distributions 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 saturated zone multiple-completion well 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: Fiscal year 1992 was the inaugural year for this project. Site selection for the research percolation pond was completed, and necessary permits and licenses were obtained. The design for the pond was completed, and necessary environmental clearances were obtained. Supplies for instrumenting the pond have been obtained and stockpiled for site installation in early fiscal year 1993. Analytical instrumentation necessary for the project has been obtained.

Plans for Fiscal Year 1993: Construction of the research percolation pond is scheduled for early November 1992. After construction of the berm for the pond, the site will be instrumented with lysimeters, multiple-completion wells, multilevel samplers, neutron access tubes, and radio-frequency attenuation probe tubes. Site installation should be completed by January 1, 1993. Intensive data collection will begin after completion of site installation. Microbial-enumeration procedures will be developed and evaluated.

Reports: None

BIBLIOGRAPHY

REPORTS FOR CALIFORNIA PUBLISHED IN 1992

Alpers, C.N., Nordstrom, D.K., and Burchard, J.M., 1992, Compilation and interpretation of water quality and discharge data for acidic mine waters at Iron Mountain, Shasta County, California, 1940-91: U.S. Geological Survey Water-Resources Investigations Report 91-4160, 173 p.

Alpers, C.N., Nordstrom, D.K., Thompson, J.M., and Lund, Michelle, 1992, Cyclic precipitation of dissolution of Zn-Cu-bearing melanterite controlling the composition of acid mine drainage from Iron Mountain (abs.): American Chemical Society National Meeting, Washington, D.C., August 24, Program.

Belitz, Kenneth, and Phillips, S.P., 1992, Simulation of water-table response to management alternatives, central part of the western San Joaquin Valley, California: U.S. Geological Survey Water-Resources Investigations Report 91-4193, 41 p.

Belitz, Kenneth, Phillips, S.P., and Gronberg, J.M., 1992, Numerical simulation of ground-water flow in the central part of the western San Joaquin Valley, California: U.S. Geological Survey Open-File Report 91-535, 71 p.

Bertoldi, G.L., 1992, Subsidence and consolidation in alluvial aquifer systems *in* Changing practices in ground water management--the pros and cons of regulation. Eighteenth Biennial Conference on Ground Water, Proceedings: Sacramento, California, California State Printing Office, Report No. 77, p. 63-74.

_____1992, Overview of phase I regional aquifer-system analysis, Central Valley, California, *in* Prince, K.R., and Johnson, A.I., eds., Regional aquifer systems of the United States: Aquifers of the far west, AWRA Monograph Series 16: Bethesda, Maryland, American Water Resources Association, p. 15-28.

Blodgett, J.C., Walters, J.R., and Borchers, J.W., 1992, Streamflow gains and losses and selected flow characteristics of Cottonwood Creek, north-central California, 1982-85: U.S. Geological Survey Water-Resources Investigations Report 92-4009, 19 p.

Blodgett, J.C., and Williams, J.S., 1992, Land subsidence and problems affecting land use at Edwards Air Force Base and vicinity, California, 1990: U.S. Geological Survey Water-Resources Investigations Report 92-4035, 25 p.

Bright, D.J., Stamos, C.L., Martin, Peter, and Nash, D.B., 1992, Ground-water hydrology and quality in the Lompoc area, Santa Barbara County, California, 1987-88: U.S. Geological Survey Water-Resources Investigations Report 91-4172, 77 p.

Brown, L.R., 1992, Biological and data management aspects of the National Water Quality Assessment Program in the San Joaquin-Tulare basins, California: California-Nevada Chapter of the American Fisheries Society, Annual Conference, 27th, Redding, California, February 6-8, Program, p. 15-16.

Chalmers, A.T., and Fujii, R., 1992, Geochemical processes affecting the solubility of Se and As in ground water, Tulare Basin, California: American Society of Agronomy, Annual Meeting, 84th, Minneapolis, Minnesota, November 1-6, Agronomy Abstracts, p. 235.

Danskin, W.R., Farrar, C.D., and Dreiss, S.J., 1991, Ground-water basins along the eastern Sierra Nevada: Tectonics, water, and politics, *in* Walawender, M.J., and Hanan, B.B., eds., Geological excursions in southern California and Mexico: Geological Society of America, Annual Meeting, San Diego, California, 1991, Guidebook, p. 447-473.

DeBortoli, M.L., and Grillo, D.A., compilers, 1992, Activities of the Water Resources Division, California District, fiscal year 1991: U.S. Geological Survey Open-File Report 92-151, 74 p. (Published annually with various authorship and pagination.)

Densmore, J.N., Middleton, G.K., and Izbicki, J.A., 1992, Surface-water releases for ground-water recharge, Santa Clara River, Ventura County, California, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 407-416.

Dettinger, M.D., and Cayan, D.R., 1992, Climate-change scenarios for the Sierra Nevada, California, based on winter atmospheric-circulation patterns, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 681-690.

Dettinger, M.D., Cayan, D.R., and Aguado, Edward, 1992, Winter-to-winter variations in atmospheric circulation patterns associated with Sierra Nevada storm and interstorm conditions (abs.): Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 236.

Dettinger, M.D., and Ghil, Michael, 1992, Interannual and interdecadal variability of surface-air temperatures in the United States *in* Proceedings of the Sixteenth Annual Climate Diagnostics Workshop: National Oceanic and Atmospheric Administration, Los Angeles, California, October 28-November 1, 1991, p. 209-214.

Dettinger, M.D., and Jeton, A.E., 1992, Simulated streamflow responses to climate change in the American and Carson Rivers of the Sierra Nevada, California and Nevada: Pacific Climate (PACLIM) Conference, Annual PACLIM Workshop, 9th, Pacific Grove, California, April 21-24, Abstracts, 1 p.

Dileanis, P.D., Sorenson, S.K., Schwarzbach, S.E., and Maurer, T.C., 1992, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Sacramento National Wildlife Refuges Complex, California, 1988-89: U.S. Geological Survey Water-Resources Investigations Report 92-4036, 79 p.

Domagalski, J.L., and Dubrovsky, N.M., 1992, Pesticide residues in the regional aquifer of the San Joaquin Valley, California, *in* Prince, K.R., and Johnson, A.I., eds., Regional aquifer systems of the United States: Aquifers of the far west, AWRA Monograph Series 16: Bethesda, Maryland, American Water Resources Association, p. 29-41.

Domagalski, J.L., and Dubrovsky, N.M., 1992, Pesticide residues in ground water of the San Joaquin Valley, California: Journal of Hydrology, v. 130, p. 299-338.

Duell, L.W.F., Jr., 1992, Use of regression models to estimate effects of climate change on seasonal streamflow in the American and Carson River basins, California-Nevada, *in* Herrmann, Raymond, ed., Managing water resources during global change: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Proceedings, p. 731-740.

_____1992, Use of regression analysis to estimate effects of climate change on monthly streamflow in the American and Carson River basins, California-Nevada: Pacific Climate (PACLIM), Conference, Annual PACLIM Workshop, 9th, Pacific Grove, California, April 21-24, Abstracts, 1 p.

Essaid, H.I., 1992, Simulation of freshwater and saltwater flow in the coastal aquifer system of the Purisima Formation in the Soquel-Aptos Basin, Santa Cruz County, California: U.S. Geological Survey Water-Resources Investigations Report 91-4148, 35 p.

Galloway, D.L., Ervin, E.M., Chornack, M.P., and Riggs, A.C., compilers, 1991, Hydrogeologic overview and field trip of the regional ground-water flow system in relation to Yucca Mountain, Nevada, *in* Walawender, M.J., and Hanan, B.B., eds., Geological excursions in southern California and Mexico: Geological Society of America, Annual Meeting, San Diego, California, 1991, Guidebook, p. 474-515.

Gleason, J.D., Veronda, Guida, Smith, G.I., Friedman, Irving, and Martin, Peter, 1992, Deuterium content of water from wells and perennial springs, southeastern California: U.S. Geological Survey Open-File Report 91-470, 22 p.

Gronberg, J.M., and Belitz, Kenneth, 1992, Estimation of a water budget for the central part of the western San Joaquin Valley, California: U.S. Geological Survey Water-Resources Investigations Report 91-4192, 22 p.

Hanson, R.T., and Nishikawa, T., 1992, Flow-meter data: An important addition to aquifer-test analysis for modeling layered aquifer systems: Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 165.

Hollett, K.J., Danskin, W.R., McCaffrey, W.F., and Walti, C.L., 1991, Geology and water resources of Owens Valley, California: U.S. Geological Survey Water-Supply Paper 2370-B, 77 p.

Izbicki, J.A., 1992, Sources of chloride in ground water of the Oxnard Plain, California, *in* Prince, K.R., and Johnson, A.I., eds., Regional aquifer systems of the United States: Aquifers of the far west, AWRA Monograph Series 16: Bethesda, Maryland, American Water Resources Association, p. 5-14.

Izbicki, J.A., Martin, Peter, and Michel, R.L., 1992, Use of tritium to evaluate the rate of seawater intrusion in a coastal aquifer system (abs.): Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 189.

Izbicki, J.A., Michel, R.L., and Martin, Peter, 1992, ^{3}H and ^{14}C as tracers of ground-water recharge: American Society of Civil Engineers, Irrigation and Drainage Session Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 122-127.

Jensen, R.M., Hoffman, E.B., Bowers, J.C., and Mullen, J.R., 1992, Water resources data--California, water year 1991. 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-91-1, 312 p.

Johnson, J.A., Fong-Frydendal, L.J., and Baker, J.B., 1992, Water resources data--California, water year 1991. Volume 5. Ground water data: U.S. Geological Survey Water-Data Report CA-91-5, 427 p.

Kuivila, K.M., Crepeau, K.L., and Domagalski, J.L., 1992, Input and transport of pesticides applied to alfalfa in the Sacramento-San Joaquin Delta: American Society of Limnology and Oceanography, 1992 Aquatic Sciences Meeting, Santa Fe, New Mexico, February 9-14, Program and Abstracts, 1 p.

_____1992, Input and transport of select alfalfa pesticides to San Francisco Bay, California: Society of Environmental Toxicology and Chemistry, Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Abstracts, p. 33.

Leighton, D.A., Deverel, S.J., and Macdonald, J.K., 1992, Spacial distribution of selenium and other inorganic constituents in ground water underlying a drained agricultural field, western San Joaquin Valley, California: U.S. Geological Survey Water-Resources Investigations Report 91-4119, 73 p.

Makita, S.N., and Fujii, Roger, 1992, Quality assurance practices of the U.S. Geological Survey laboratory in Sacramento, California: U.S. Geological Survey Open-File Report 91-522, 23 p.

Markham, K.L., Anderson, S.W., Mullen, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. 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-91-4, 319 p.

Meyers, William, and Kuivila, K.M., and Scow, K.M., 1992, Microbial degration of carbofuran in the Sacramento-San Joaquin Delta, California: Society of Environmental Toxicology and Chemistry, Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Abstracts, p. 103.

Mitten, H.T., and Borchers, J.W., 1992, Lithologic texture, Mather Air Force Base, California: Environmental Systems Research Institute, 12th Annual Meeting, Palm Springs, California, June 8-12, Poster.

Mullen, J.R., Anderson, S.W., Hunter, T.C., and Hoffman, E.B., 1992, Water resources data--California, water year 1991. Volume 3. Southern Central Valley basins and the Great Basin from Walker River to Truckee River: U.S. Geological Survey Water-Data Report CA-91-3, 373 p.

Nishikawa, T., and Rojstaczer, S., 1992, Ocean loading and fluid flow induced tidal response of a coastal aquifer, Ventura County, California (abs.): Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 188.

Predmore, S.K., 1992, Use of Geographic Information System in visualizing spatial data (abs.): National Computer Technology Meeting, 6th, Norfolk, Virginia, May 17-22, Program.

Reichard, E.G., 1992, Book review *of* "Ground water models: Scientific and regulatory applications," by the National Research Council, 1990 (Washington DC, National Academy Press): Hydrological Sciences Journal, v. 37, no. 1, p. 80.

Reichard, E.G., 1992, Book review *of* "Ground water and soil contamination remediation: Toward compatible science, policy, and public perception," by the National Research Council, 1990 (Washington DC, National Academy Press): Hydrological Sciences Journal, v. 37, no. 4, p. 403-404.

Reichard, E.G., and Meadows, J.K., 1992, Evaluation of a ground-water flow and transport model of the upper Coachella Valley, California: U.S. Geological Survey Water-Resources Investigations Report 91-4142, 101 p.

Ross, Lisa, and Domagalski, Joseph, 1992, Temporal and spatial distribution of pesticides in the San Joaquin River, California (abs): Environmental Toxicology and Chemistry Annual Meeting, 13th, Cincinnati, Ohio, November 8-12, Program.

Schroeder, R.A., 1991, Delineation of a hydrocarbon (weathered gasoline) plume in shallow deposits at the U.S. Naval Weapons Station, Seal Beach, California: U.S. Geological Survey Water-Resources Investigations Report 89-4203, 29 p.

Schroeder, R.A., and Martin, Peter, 1992, Nitrogen attenuation during transport of domestic wastewater through a thick unsaturated zone in the Mojave Desert: Eos, Transactions of the American Geophysical Union, Supplement, v. 73, no. 43, p. 209.

Simpson, M.R., 1992, Evaluation of a broad-band acoustic Doppler current profiler and its use as a dishcarge measurement system (abs.): International Hydrologists Conference, Portland, Oregon, October 17-22, Program.

Simpson, M.R., and Oltmann, R.N., 1992, Discharge-measurement system using an acoustic Doppler current profiler with applications to large rivers and estuaries: U.S. Geological Survey Open-File Report 91-487, 49 p.

Smith, P.E., Oltmann, R.N., and Simpson, M.R., 1992, Data set for verification of 3-D free-surface hydrodynamic models, Carquinez Strait, California: American Society of Civil Engineers, Hydraulic Engineering Sessions Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 430-435.

Stamos, C.L., Predmore, S.K., and Zohdy, A.A.R., 1992, Use of D-C resistivity to map saline ground water: American Society of Civil Engineers, Irrigation and Drainage Session Water Forum '92, Baltimore, Maryland, August 2-6, Proceedings, p. 80-85.

Trujillo, L.F., Markham, K.L., Palmer, J.R., and Friebel, M.F., 1992, Water resources data--California, water year 1991. Volume 2. Pacific Slope basins from Arroyo Grande to Oregon State line except Central Valley: U.S. Geological Survey Water-Data Report CA-91-2, 315 p.

Wang, B., and Deverel, S., 1992, Factors affecting carbon fluxes in the organic soils of the Sacramento-San Joaquin Delta, California: American Society of Agronomy, Annual Meeting, 84th, Minneapolis, Minnesota, November 1-6, 1992, Agronomy Abstracts, p. 62-63.

Wienke, S.M., Cole, B.E., Alpine, A.E., and Cloern, J.E., 1991, Plankton studies in San Francisco Bay, XIII. Chlorophyll distributions and hydrographic properties of San Francisco Bay, 1990: U.S. Geological Survey Open-File Report 91-476, 85 p.

Wilson, D.H., Reginato, R.J., and Hollett, K.J., eds., 1992, Evapotranspiration measurements of native vegetation, Owens Valley, California, June 1986: U.S. Geological Survey Water-Resources Investigations Report 91-4159, 83 p.

Woolfenden, L.R., and Danskin, W.R., 1992, Application of optimization techniques to water-supply problems: American Water Resources Association, Annual Conference and Symposium, 28th, Reno, Nevada, November 1-5, Abstracts, p. 74.

SOURCES OF WRD PUBLICATIONS AND INFORMATION

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, Federal Center, Box 25425, Denver, CO 80225. Hydrologic Investigations Atlases, Hydrologic Unit Maps, and other maps pertaining to California are sold by the U.S. Geological Survey, Map Distribution Section, Federal Center, Box 25286, Denver, CO 80225.

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.

WHERE TO OBTAIN ADDITIONAL INFORMATION ON U.S. GEOLOGICAL SURVEY PROGRAMS

WATER

California District
U.S. Geological Survey
2800 Cottage Way
Room W-2233, Federal Building
Sacramento, CA 95825
Phone: (916) 978-4643

GEOLOGY

Assistant Chief Geologist
U.S. Geological Survey
345 Middlefield Road, MS 919
Menlo Park, CA 94025
Phone: (415) 329-5101

WHERE TO OBTAIN ADDITIONAL INFORMATION ON U.S. GEOLOGICAL SURVEY REPORTS

Earth Science Information Center
U.S. Geological Survey
345 Middlefield Road, MS 532
Menlo Park, Ca 94025
Phone: (415) 329-4390 (to purchase publications)
Phone: (415) 329-4309 (to obtain historical information)

FOR MAIL ORDERS

BOOKS--To order U.S. Geological Survey Professional Papers, Water-Supply Papers, and Circulars.

USGS Map Distribution
Box 25286, MS 306
Denver Federal Center
Denver, CO 80225

OPEN-FILE REPORTS--To order U.S. Geological Survey Open-File Reports and Water Resources Investigations Reports.

USGS ESIC-Open File Report Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225-0046

MAPS--To order any U.S. Geological Survey Map.

USGS Map Distribution
Box 25286, Building 810
Denver Federal Center
Denver, CO 80225
Phone: 1-800-USA-MAPS