EVALUATION OF GROUND-WATER QUALITY IN THE SANTA MARIA VALLEY CALIFORNIA

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U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-128

Prepared in cooperation with the
California State Water Resources Control Board and the
California Regional Water Quality Control Board,
Central Coast Region

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle
EVALUATION OF GROUND-WATER QUALITY IN THE SANTA MARIA VALLEY, CALIFORNIA

5. Report Date
July 1977

6.

7. Author(s)
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8. Performing Organization Rept. No. USGS/WRI 76-128

9. Performing Organization Name and Address
U.S. Geological Survey, Water Resources Division
345 Middlefield Road
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10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U.S. Geological Survey, Water Resources Division
345 Middlefield Road
Menlo Park, California 94025

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes
Prepared in cooperation with the California State Water Resources Control Board and the California Regional Water Quality Control Board, Central Coast Region

16. Abstracts The quality and quantity of recharge to the Santa Maria Valley ground-water basin from natural sources, point sources, and agriculture are expressed in terms of a hydrologic budget, a solute balance, and maps showing the distribution of select chemical constituents. Point sources include a sugar-beet refinery, oil refineries, stockyards, golf courses, poultry farms, solid-waste landfills, and municipal and industrial wastewater-treatment facilities. Pumpage has exceeded recharge by about 10,000 acre-feet per year (12.3 cubic hectometers per year). The result is a declining potentiometric surface with an accumulation of solutes and an increase in nitrogen in ground water. Nitrogen concentrations in ground water have reached as much as 50 milligrams per liter. In comparison to the solutes from irrigation return, natural recharge, and rain, discharge of wastewater from municipal and industrial wastewater-treatment facilities contributes less than 10 percent. The quality of treated wastewater is often lower in select chemical constituents than the receiving water.

17. Key Words and Document Analysis. 17a. Descriptors

*Degradation, *Groundwater, *Hydrologic budget, *Industrial wastes, *Irrigation water, *Sewage treatment, *Solutes. California, Groundwater movement, Nitrogen

17b. Identifiers/Open-Ended Terms

Nonpoint-source discharge, Point-source discharge, Santa Maria Valley

17c. COSATI Field/Group

18. Availability Statement No restriction on distribution	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 78
	20. Security Class (This Page UNCLASSIFIED	22. Price

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4010-06

July 1977

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CONVERSION FACTORS

Factors for converting English units to metric units are shown to four significant figures. In the text, however, the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
acre	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometers)
acre-ft/mi (acre-feet per mile)	7.663×10^{-4}	hm^3/km (cubic hectometers per kilometer)
acre-ft/yr (acre-feet per year)	1.233×10^{-3}	hm^3/yr (cubic hectometers per year)
ft (feet)	3.048×10^{-1}	m (meters)
ft/mi (feet per mile)	1.890×10^{-1}	m/km (meters per kilometer)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic meters per second)
in (inches)	2.540×10	mm (millimeters)
in/yr (inches per year)	2.540×10	mm/yr (millimeters per year)
Mgal/d (million gallons per day)	3.785×10^3	m^3/d (cubic meters per day)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
tons	9.072×10^2	kg (kilograms)
tons/yr (tons per year)	9.072×10^2	kg/yr (kilograms per year)

EVALUATION OF GROUND-WATER QUALITY IN THE SANTA MARIA VALLEY, CALIFORNIA

By Jerry L. Hughes

ABSTRACT

The quality and quantity of recharge to the Santa Maria Valley ground-water basin from natural sources, point sources, and agriculture were evaluated. The results are expressed in terms of a hydrologic budget, a solute balance, and maps showing the distribution of selected chemical constituents in ground water. Point sources of waste discharge that could cause ground-water degradation were investigated including a sugar-beet refinery, oil refineries and oil-field wastewater, stockyards, golf courses, poultry farms, solid-waste landfills, and municipal and industrial wastewater-treatment facilities.

Measurements of specific conductance of ground water and water levels in nearly 400 wells and the analyses of about 100 water samples for most major anions and cations plus detergents, dissolved organic carbon, and trace metals permitted preparation of maps showing the potentiometric surface and the distribution of dissolved solids, chloride, sulfate, calcium plus magnesium, and nitrogen in ground water.

Pumpage of ground water for agricultural, municipal, and industrial uses has exceeded recharge by about 10,000 acre-feet per year (12.3 cubic hectometers per year). Most of the ground water pumped in the Santa Maria Valley is for agriculture. The result of pumping in excess of recharge is a declining potentiometric surface, an accumulation of solutes, and an increase in nitrogen in ground water. At present (1976), the area of confined water is most severely affected by this degradation. Nitrogen concentrations in ground water have reached as much as 50 milligrams per liter in isolated areas, with concentrations in excess of 10 milligrams per liter occurring through most of the area of confined water. Continued pumping in excess of recharge may also lower the potentiometric surface sufficiently to permit intrusion of seawater into the fresh-water zones.

Discharge of wastewater from municipal and industrial wastewater-treatment facilities is also contributing solutes to the ground-water system. In comparison to the influences of irrigation return water on ground-water quality, the contribution from point sources is less than 10 percent of the total solutes. In some areas of the valley, the concentration of dissolved solids and some chemical constituents in water discharging from municipal and industrial wastewater-treatment facilities is lower than in the receiving ground water.

INTRODUCTION

The water supply of the Santa Maria Valley is derived from the ground-water reservoir. Almost all wastes from point and nonpoint sources in the valley are discharged to land or to stream channels and ultimately percolate to the ground-water system. Ground-water quality has deteriorated significantly in some areas of the Santa Maria Valley during the past two decades. Protection of ground-water quality is essential if this source of water is to continue to be used beneficially in the future. An evaluation of the significance of individual waste discharges and methods of disposal and a better understanding of the areal and time-related variability of ground-water quality will aid in planning the management of wastewater in the valley. Available data and ongoing data-collection programs are not adequate to delineate water-quality degradation or to evaluate the effects of waste discharge on existing or future ground-water quality in the valley.

The purpose of this study was (1) to develop information on the present (1976) status of ground-water quality, (2) to evaluate point sources of waste discharge and their influence on the deterioration of ground-water quality, and (3) to suggest a water-quality-sampling network that would monitor areas of ground-water degradation and those sources determined by this study as affecting ground-water quality.

Point sources of waste discharge that could cause ground-water degradation in the Santa Maria Valley include: (1) Wastewater discharged from and associated with sugar and oil refineries, (2) percolation of effluent from wastewater-treatment facilities, (3) disposal of solid waste to landfill sites, (4) golf courses, and (5) stockyards, poultry farms, and feed lots.

Although the emphasis of this investigation was on point sources, the influence of nonpoint sources on ground-water quality was significant and widespread and was therefore given equal consideration. To achieve the objectives of this study, it was necessary to understand the hydrology and overall quality of ground water in the basin so the net effects of individual point sources could be identified. Nonpoint sources of ground-water degradation are by definition more general and include: (1) Natural, (2) agricultural, and (3) industrial activities such as oil-field production.

All ground-water quality and water-level data collected during this study plus similar data collected by earlier investigators and local water agencies have been tabulated in Hughes and Freckleton (1976). That data report should be referred to for basic data not contained herein.

Location and General Features of Study Area

Santa Maria Valley is along the Pacific Coast about 130 mi (209 km) north of Los Angeles, Calif. (fig. 1). It occupies the northwestern part of Santa Barbara County and the extreme southwestern part of San Luis Obispo County. The valley is characterized by a broad alluvial plain near the ocean that tapers gradually inland. The alluvial plain is further defined by upland or mesa areas, foothills, and mountain complexes.

The Santa Maria River traverses the valley from east to west, emptying into the Pacific Ocean just west of the town of Guadalupe. The Santa Maria River is formed by the convergence of the Cuyama and the Sisquoc Rivers at Fugler Point near Garey. Both the Cuyama and the Sisquoc Rivers have large drainage areas. For the purpose of this report, however, the study area is confined to the alluvial plain and mesa areas of the Santa Maria River plain, hereafter referred to as the ground-water basin.

Most of the population and related activities are on the alluvial plain. The principal activity in the valley is agriculture with some light industry in the more densely populated areas. The principal city in the study area is Santa Maria with a population of about 35,000 (Carollo, 1975, pl. III-3). The combined population of the smaller towns of Orcutt, Guadalupe, and local farm communities is probably 30,000 (Toups, 1970, p. 19).

Acknowledgments

This study was made in cooperation with the California State Water Resources Control Board and the California Regional Water Quality Control Board, Central Coast Region. The author thanks the many ranchers, drillers, well owners, and officials of the cities of Santa Maria, Orcutt, and Guadalupe for their cooperation and willingness to make available data necessary to this report.

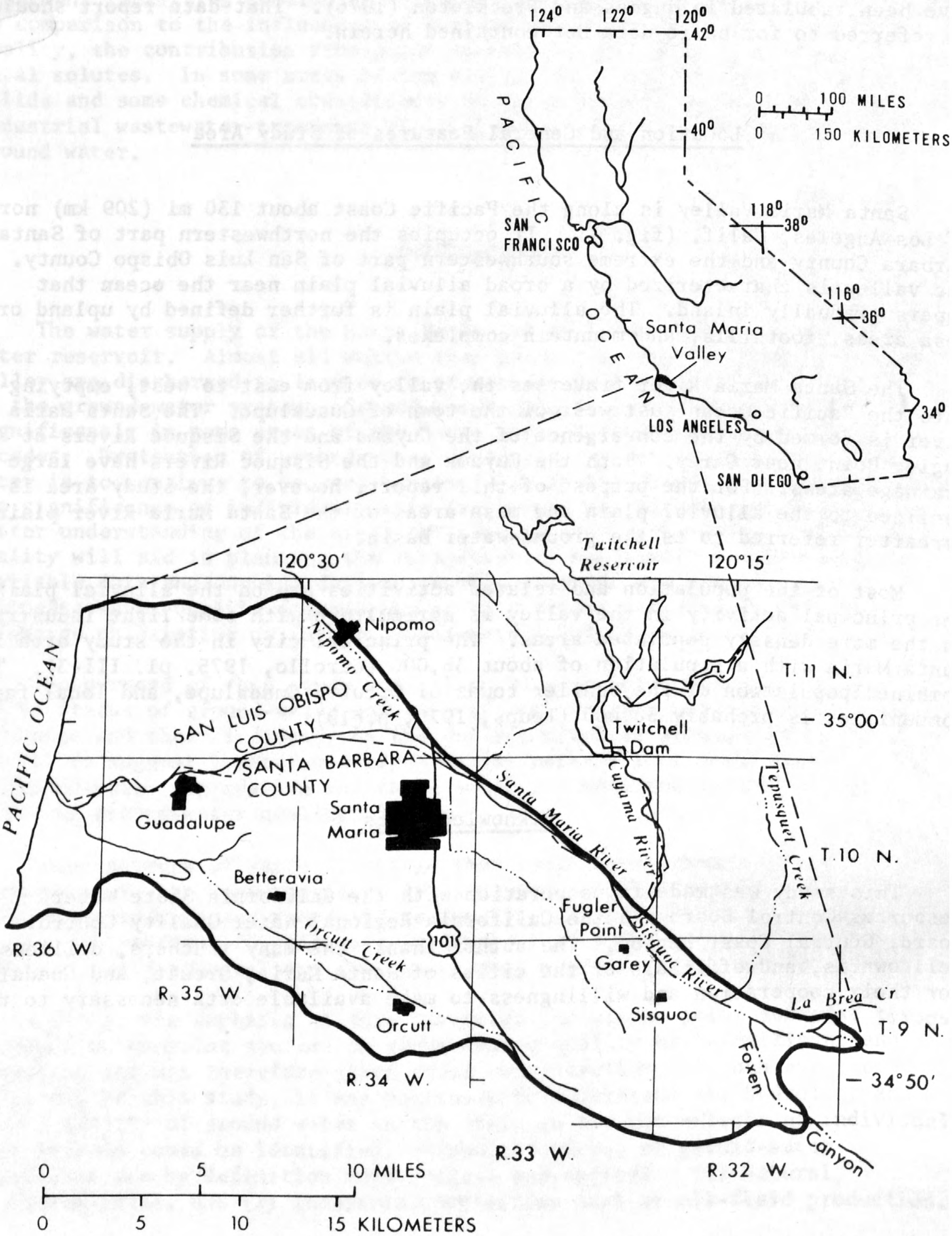
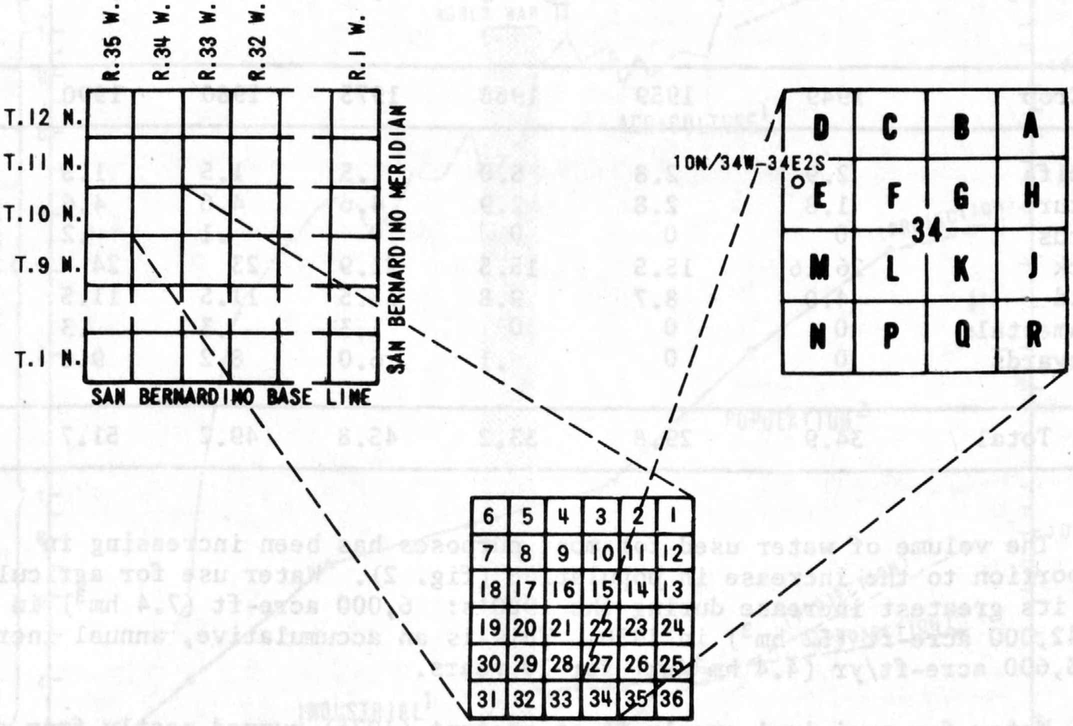


FIGURE 1.--Location of Santa Maria Valley area.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well number 10N/34W-34E2S the first two segments designate the township (T. 10 N.) and the range (R. 34 W.); the third number gives the section (sec. 34); and the letter indicates the 40-acre (16-ha) subdivision of the section, as shown in the accompanying diagram. The final digit is a serial number for wells in each 40-acre (16-ha) subdivision. The letter (S) indicates the San Bernardino base line and meridian.



WATER USE AND WASTEWATER DISPOSAL

Water supply in the Santa Maria Valley is derived totally from wells. Most of the Santa Maria River system is dry except during periods of heavy rain, and flow occurs only for short periods. Flow in the Cuyama River is controlled by Twitchell Dam, completed in 1959.

Agriculture is the largest single user of ground water. In 1958 water pumped for agriculture exceeded 100,000 acre-ft (123 hm^3); water pumped for both municipal and industrial purposes was less than 10,000 acre-ft (12.3 hm^3) (Miller and Evenson, 1966, p. 15 and 17). Farm products consist mostly of lettuce, broccoli, artichokes, and sugar beets. Some alfalfa is grown on the mesas. In recent years, however, the mesa areas are being converted from feed and hay to vineyards. This trend toward grapes and the historic and projected irrigated acreage for other crops grown are shown in table 1.

TABLE 1.--*Santa Maria Valley historic and projected irrigated agricultural acreage*

(in thousand acres)

[Brown and Caldwell, Consulting Engineers, written commun., 1975]

Crop	1949	1959	1968	1973	1980	1990	2000
Alfalfa	2.9	2.8	5.0	1.5	1.5	1.5	1.5
Pasture	1.8	2.8	2.9	4.6	4.6	4.6	4.6
Citrus	0	0	0	0	.1	.2	.2
Truck	26.16	15.5	15.5	21.9	23	24	24
Field	4.0	8.7	9.8	11.5	11.5	11.5	11.5
Ornamentals	0	0	0	.3	.3	.3	.3
Vineyards	0	0	.1	6.0	8.2	9.6	10
Total	34.9	29.8	33.2	45.8	49.2	51.7	52.1

The volume of water used for most purposes has been increasing in proportion to the increase in population (fig. 2). Water use for agriculture had its greatest increase during the 1920's: 6,000 acre-ft (7.4 hm^3) in 1920 to 42,000 acre-ft (52 hm^3) in 1930. This is an accumulative, annual increase of 3,600 acre-ft/yr (4.4 hm^3/yr) for 10 years.

Water for municipal supply is at present (1976) pumped mostly from areas around the Santa Maria airport (fig. 3). Subsequent to use for municipal and industrial purposes, water is sent to one of four wastewater-treatment facilities. These facilities are shown in figure 3 and are referred to as (1) City of Santa Maria Wastewater-Treatment Facility, serving the city of Santa Maria; (2) Laguna Sanitation District, serving the Orcutt community; (3) Santa Maria Airport Wastewater-Treatment Facility--adjacent to the west side of the Santa Maria airport--processing wastewater mostly from nearby light industry; and (4) Guadalupe Wastewater-Treatment Facility, serving the

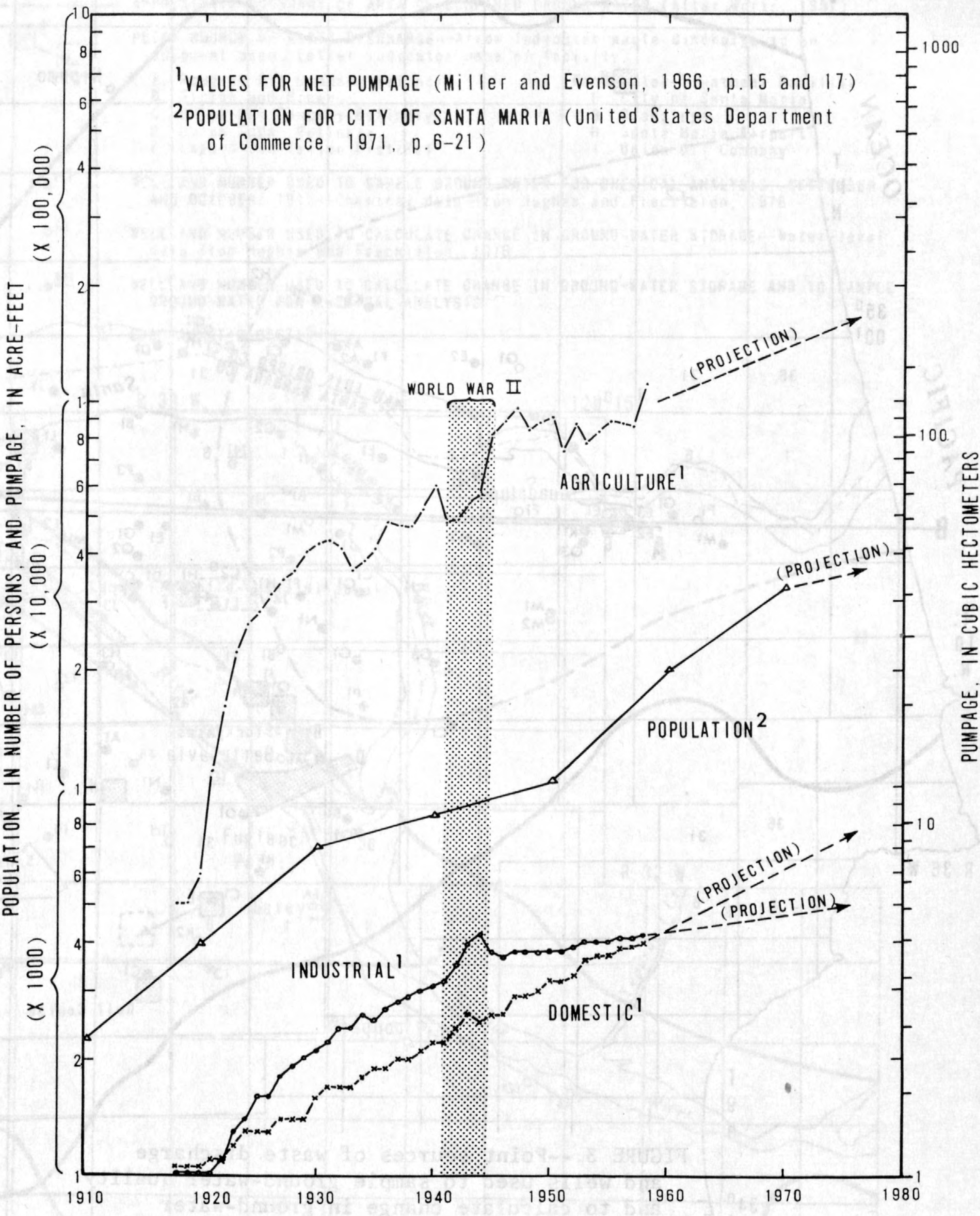


FIGURE 2.--Trends in water use and population.

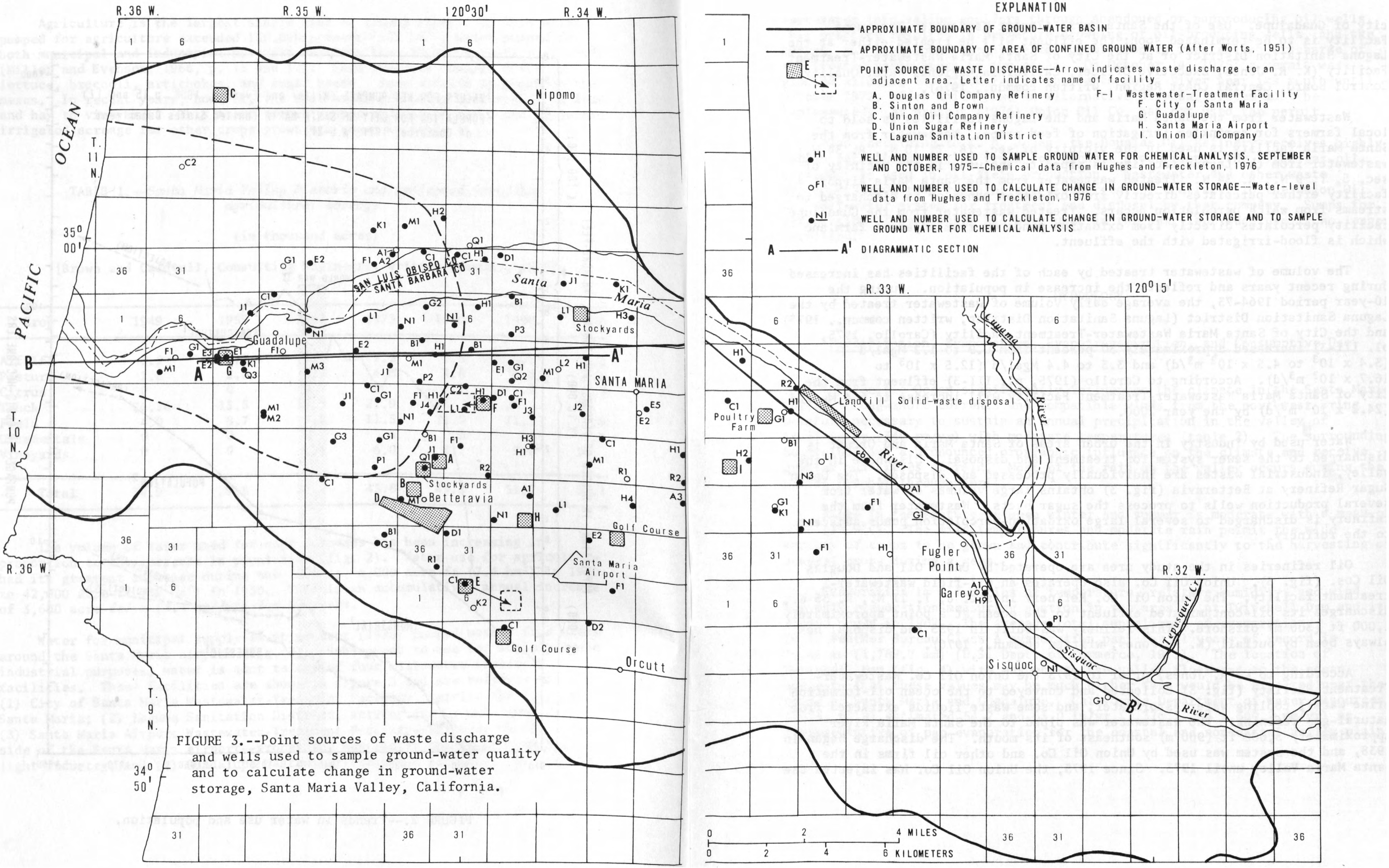


FIGURE 3.--Point sources of waste discharge and wells used to sample ground-water quality and to calculate change in ground-water storage, Santa Maria Valley, California.

city of Guadalupe. Use of the Santa Maria Airport Wastewater-Treatment Facility is to be terminated soon; the effluent will be treated either at the Laguna Sanitation District or at the City of Santa Maria Wastewater-Treatment Facility (K. R. Jones, Executive Officer, California Regional Water Quality Control Board, Central Coast Region, written commun., 1976).

Wastewater from the Santa Maria and the Laguna facilities is sold to local farmers for sprinkler irrigation of feed crops. Wastewater from the Santa Maria facility is used in the vicinity of sec. 18, T. 10 N., R. 34 W.; wastewater from the Laguna facility is piped to and used in the vicinity of sec. 5, T. 9 N., R. 34 W. Treated wastewater from the Santa Maria Airport facility either percolates directly from oxidation ponds or is discharged to streams from which percolation occurs. Treated wastewater from the Guadalupe facility percolates directly from oxidation ponds or from adjacent farmland which is flood-irrigated with the effluent.

The volume of wastewater treated by each of the facilities has increased during recent years and reflects the increase in population. During the 10-year period 1964-73, the average daily volume of wastewater treated by the Laguna Sanitation District (Laguna Sanitation District, written commun., 1975) and the City of Santa Maria Wastewater-Treatment Facility (Carollo, 1975, pl. III-3) increased approximately 30 percent from 0.9 to 1.2 Mgal/d (3.4×10^3 to 4.5×10^3 m^3/d) and 3.3 to 4.4 Mgal/d (12.5×10^3 to 16.7×10^3 m^3/d). According to Carollo (1975, pl. III-3) effluent from the City of Santa Maria Wastewater-Treatment Facility will increase to 6.4 Mgal/d (24.2×10^3 m^3/d) by the year 2000.

Water used by industry in the urban areas of Santa Maria and Orcutt is discharged to the sewer system for treatment and disposal. Elsewhere in the valley, industrial wastes are individually processed and disposed. The Union Sugar Refinery at Betteravia (fig. 3) obtains large volumes of water from several production wells to process the sugar beets. Wastewater from the refinery is discharged to several large oxidation-percolation ponds adjacent to the refinery.

Oil refineries in the study area are operated by Union Oil and Douglas Oil Cos. (fig. 3). Union Oil Co. also operates an oil-field wastewater-treatment facility. The Union Oil Co. Refinery in sec. 8, T. 11 N., R. 35 W., discharges its oil-contaminated effluent to the ocean at a point approximately 1,000 ft (300 m) offshore. This refinery was built in 1955 and disposal has always been by outfall (K. R. Jones, written commun., 1976).

According to K. R. Jones, prior to 1973 the Union Oil Co. Wastewater-Treatment Facility (fig. 3) collected and conveyed to the ocean oil-formation brine water, cooling water, stormwater, and some waste liquids extracted from natural-gas refining. The wastewater was piped to the Santa Maria River approximately 3,000 ft (900 m) southeast of its mouth. The discharge began in 1938, and the system was used by Union Oil Co. and other oil firms in the Santa Maria Valley until 1973. Since 1973, the Union Oil Co. has injected the wastewater into saline aquifers through abandoned or nonproducing oil wells. This practice resulted in premature drowning of oil-producing wells, and the company has petitioned the State for permission to reestablish discharge of the treated wastewaters to the ocean. On October 14, 1975, a permit was granted allowing the discharge to the Santa Maria River near its mouth until October 1977, after which time an alternative disposal system must be implemented. At present (1976) Union Oil Co. has not used the permit.

Also, according to K. R. Jones, the Douglas Oil Refinery receives highly concentrated crude oil by truck for asphalt production. The light gas-oil byproduct is used in oil-field production. Wastewater and other waste byproducts from this refining are discharged, by contract, to the Union Oil Co. wastewater system for treatment and disposal by that company. Sumps for percolation of wastewater had been used in the past, but such use is no longer permitted.

HYDROLOGY

Precipitation, Evaporation, Evapotranspiration, and Consumptive Use

The Pacific Ocean significantly influences the climate in the Santa Maria Valley. Long-shore currents and compatible winds from the northwest bring moisture necessary to sustain an annual precipitation in the valley of 13.37 in/yr (340 mm/yr) with moderate temperatures (table 2). The surrounding mountains have a pronounced orographic influence on the climate and receive greater quantities of rain. Most of the rain on the valley occurs during the period October through April.

Range in temperature between winter and summer is moderate with a mean of 57°F (13.9°C). The mild temperatures and moderate rain permit the wide variety of crops to be grown and contribute significantly to the harvesting of several crops during a year.

Evaporation is a function of temperature, relative humidity, and wind. The only evaporation-measuring station in the area is at Twitchell Dam and its record began in 1962. The average total annual rate of evaporation (U.S. Weather Bureau Class A evaporation pan) for 11 years of record is 70.46 in (1,789.7 mm) (U.S. Dept. of Commerce, 1973). The location of Twitchell Dam (fig. 4) with respect to the valley floor and to the ocean suggests that these values may be much higher than would be expected near the towns of Santa Maria and Guadalupe. California Department of Water Resources (1975, p. 9) estimated 54.2 and 63.0 in/yr (1,376.7 and 1,600.2 mm/yr) as representative of pan evaporation for the coastal and noncoastal valley plain.

TABLE 2.--*Climatological data*

[U.S. Department of Commerce, 1973]

	Santa Maria Airport Weather Station 1942-73				Twitchell Dam 1962-73
	Temperature, °F			Precipitation	Evaporation
	Maximum	Mean	Minimum	inches	inches
January	62.3	50.2	38.1	2.84	3.14
February	63.1	51.8	40.4	2.50	3.82
March	64.6	53.3	41.9	2.06	4.94
April	66.4	55.6	44.7	1.17	5.73
May	68.1	57.6	47.1	.22	6.54
June	69.5	59.6	49.7	.14	7.62
July	71.6	62.2	52.8	.03	9.05
August	71.9	62.4	52.9	.03	9.01
September	74.1	62.8	51.5	.16	7.18
October	73.3	60.4	47.5	.60	6.62
November	70.4	56.1	41.8	1.02	3.84
December	65.0	52.4	39.8	2.58	2.97
Mean annual	68.4	57.0	45.7	--	--
Total annual	--	--	--	13.37	70.46

Evapotranspiration is the loss of water from plants and soils to the atmosphere. The California Department of Water Resources (1975, p. 33 and 34) estimated evapotranspiration losses for pasture and alfalfa in the coastal and valley areas as follows: coastal pasture, 33.7 in/yr (856.0 mm/yr); coastal alfalfa, 32.8 in/yr (833.1 mm/yr); valley pasture, 40.8 in/yr (1,036.3 mm/yr); and valley alfalfa, 39.4 in/yr (1,000.8 mm/yr).

Consumptive use is a term that applies to water used or consumed by all processes that remove water permanently from the system and includes evapotranspiration, evaporation, and human consumption. Miller and Evenson (1966, p. 15) estimated a consumptive use for agriculture of 80 percent. Toups (1970, p. 13) estimated a 70-percent consumptive use. This indicates that for every 100,000 acre-ft/yr (123 hm^3/yr) pumped from wells for use in agriculture and for other purposes, 70,000 to 80,000 acre-ft/yr (86 to 99 hm^3/yr) is consumed.

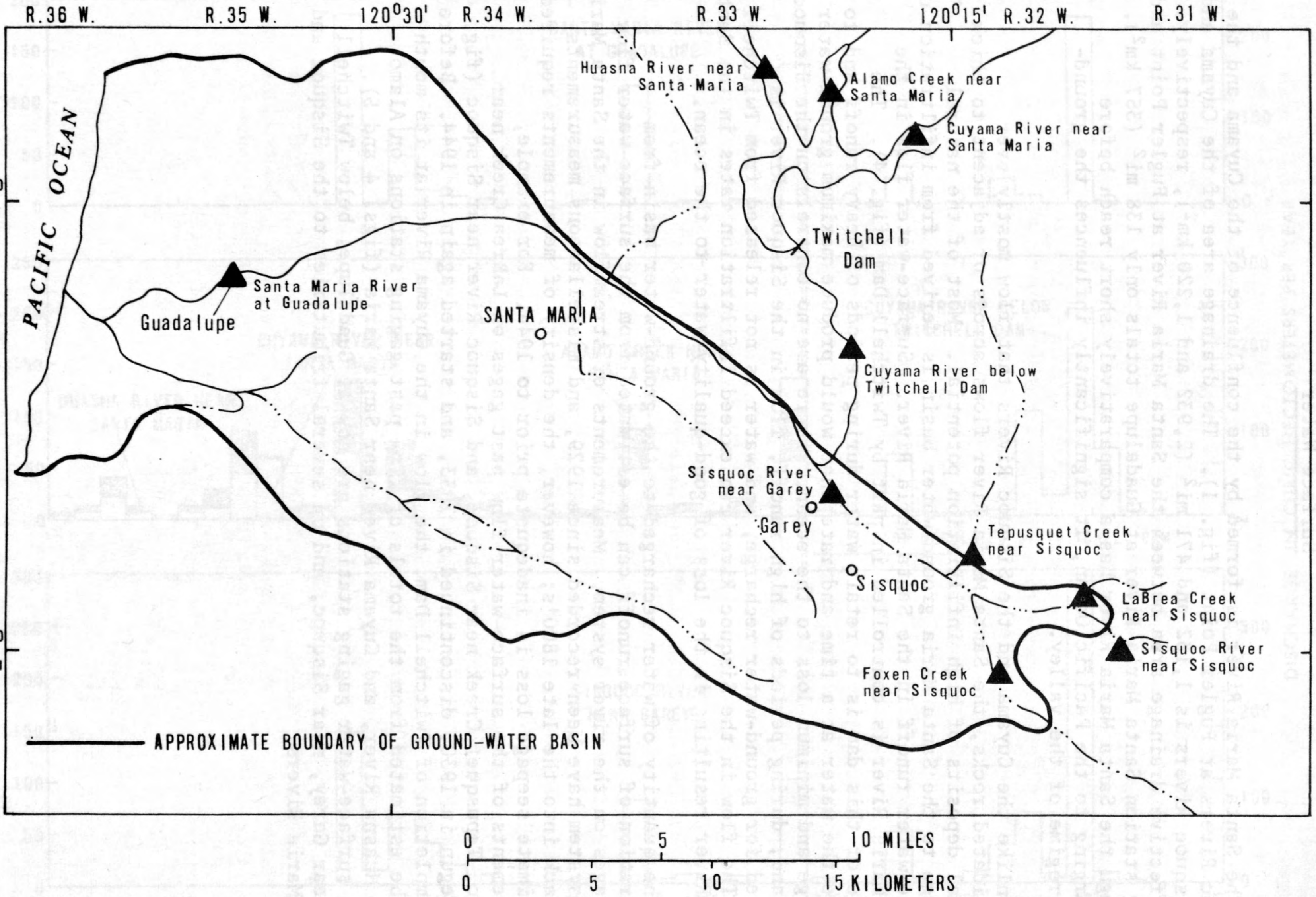


FIGURE 4.--Location of surface-water gaging stations.

Surface Water

The Santa Maria River is formed by the confluence of the Cuyama and the Sisquoc Rivers at Fugler Point (fig. 1). The drainage area of the Cuyama and the Sisquoc Rivers is 1,132 and 471 mi^2 (2,932 and 1,220 km^2), respectively. The effective drainage area between the Santa Maria River at Fugler Point and gaging station Santa Maria River at Guadalupe totals only 138 mi^2 (357 km^2). Although the Santa Maria River has a comparatively short reach before discharging to the Pacific Ocean, it significantly influences the ground-water regime of the valley.

Unlike the Cuyama and the Sisquoc Rivers that flow mostly over consolidated rocks, the Santa Maria River flows across or adjacent to thick alluvial deposits of high infiltration potential. Most of the natural recharge to the Santa Maria ground-water basin is derived from infiltration of surface-water runoff in the Santa Maria River. Surface-water flow in the Santa Maria River is controlled in part by Twitchell Dam (fig. 4). The purpose of this dam is to retain water during periods of heavy runoff and to release the water at a time and rate that would produce maximum ground-water recharge and minimum loss to the ocean. There are no controls on the Sisquoc River and, during periods of high runoff, flow in the Sisquoc River is utilized for ground-water recharge, and water is not released from Twitchell Dam. The flow in the Sisquoc River can exceed infiltration rates in the Santa Maria River resulting in the loss of good-quality water to the ocean.

The quantity of water recharged to the ground-water basin from infiltration of surface runoff can be estimated from the surface-water flow past gages on the river system. Measurements of streamflow in the Santa Maria River system have been recorded since 1929, and miscellaneous measurements date back into the late 1800's; however, the density of measurements required to estimate seepage loss is inadequate prior to 1944. For example, measurements of the surface-water flow past gages on LaBrea Creek near Sisquoc, Tepusquet Creek near Sisquoc, and Sisquoc River near Sisquoc (fig. 4) were begun in 1930, discontinued in 1933, and started again in 1944. Before the completion of Twitchell Dam, the flow in the Cuyama River at its mouth could be estimated from the totals of flow past gaging stations on Alamo Creek, Huasna River, and Cuyama River near Santa Maria (figs. 4 and 5). Active surface-water gaging stations are now at Guadalupe, below Twitchell Dam, near Garey, near Sisquoc, and on several tributaries to the Sisquoc and Santa Maria Rivers.

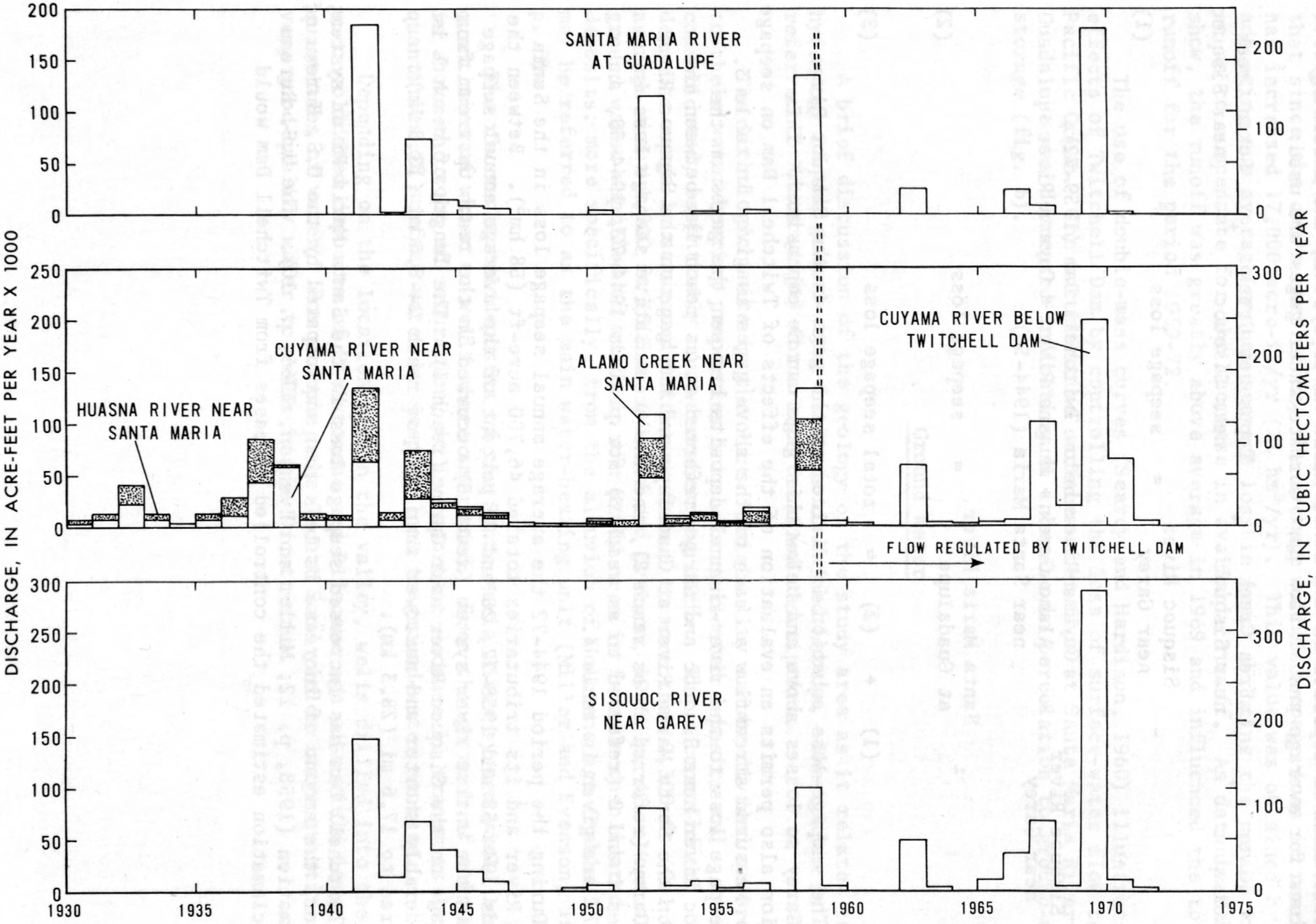


FIGURE 5.--Surface-water flow in Santa Maria River system since 1930.

To estimate the quantity of surface-water flow lost to infiltration to the river-channel deposits in the Santa Maria River system, the following equations for average annual flow past surface-water gages are used:

$$\begin{array}{c}\text{Sisquoc River}\\ \text{near Sisquoc}\end{array} + \begin{array}{c}\text{LaBrea Creek}\\ \text{near Sisquoc}\end{array} + \begin{array}{c}\text{Tepusquet Creek}\\ \text{near Sisquoc}\end{array} + \begin{array}{c}\text{Foxen Creek}\\ \text{near Sisquoc}\end{array} - \begin{array}{c}\text{Sisquoc River}\\ \text{near Garey}\end{array} = \text{seepage loss} \tag{1}$$

$$\begin{array}{c}\text{Sisquoc River}\\ \text{near Garey}\end{array} + \begin{array}{c}\text{Cuyama River below Twitchell Dam (1959-72);}\\ \text{Alamo Creek + Huasna River + Cuyama River}\\ \text{near Santa Maria (1944-58)}\end{array} - \begin{array}{c}\text{Santa Maria River}\\ \text{at Guadalupe}\end{array} = \text{seepage loss} \tag{2}$$

$$(1) + (2) = \text{total seepage loss} \tag{3}$$

The seepage-loss equation is divided at the gage on the Sisquoc River near Garey so losses above and below this gage can be emphasized. This division also permits an evaluation of the effects of Twitchell Dam on seepage loss. Measured streamflow at each of the above gages is given in table 3. The seepage loss to the river-channel deposits between the gages on the Sisquoc River near Sisquoc and Garey (referred to as reach 1), between the gage on the Santa Maria River at Guadalupe and the gage on the Sisquoc River near Garey (referred to as reach 2), and the accumulative seepage loss in reaches 1 and 2 (referred to as reach 3) for periods 1944-72, 1944-58, and 1959-72 are given in table 4.

During the period 1944-72 the average annual seepage loss in the Santa Maria River and its tributaries totaled 46,700 acre-ft (58 hm^3). Between the periods 1944-58 and 1958-72, 28 and 20 percent of the average annual seepage loss in the entire river system (reach 3) occurred in the reach upstream from the gage on the Sisquoc River near Garey (reach 1). The length of reach 1 is considerably shorter and narrower than that of reach 2--8.6 mi (13.8 km) compared to 17.6 mi (28.3 km).

Twitchell Dam has increased seepage loss in the Santa Maria River system; however, the amount of increase is less than anticipated by the U.S. Bureau of Reclamation (1958, p. 12; Miller and Evenson, 1966, p. 10). The U.S. Bureau of Reclamation estimated the controlled releases from Twitchell Dam would increase downstream seepage loss and recharge to ground-water storage by an average of 21,200 acre-ft/yr (26 hm^3/yr). Calculations by the author indicate that since the dam's completion, the average annual seepage loss in reach 2 has increased 17,000 acre-ft/yr (21 hm^3/yr). This value was obtained by adjusting the average annual seepage loss in reach 2 during the period 1959-72 so as to compensate for the increase in available runoff. As data in table 3 show, the runoff was greatly above average in 1969 and influenced the total runoff for the period 1959-72.

The use of double-mass curves (Searcy and Hardison, 1960) illustrates the effects of Twitchell Dam by controlling the loss of surface-water flow to the Pacific Ocean. The accumulative surface-water flow at Santa Maria River at Guadalupe was decreased indicating an increase in percolation to ground-water storage (fig. 6).

Ground Water

A brief discussion of the geology of the study area as it relates to the hydrology of the ground-water basin is contained herein. The reader is referred to Worts (1951) for a more detailed description.

The lithologic units in the Santa Maria Valley can be divided according to their water-bearing properties into unconsolidated deposits and consolidated, essentially non-water-bearing rocks. The unconsolidated deposits range in saturated thickness from 0 to more than 2,300 ft (701 m) but average about 1,000 ft (305 m) (Miller and Evenson, 1966, p. 4). Most of the ground water supplied to wells in the study area is from unconsolidated deposits; more specifically, from the alluvium of Holocene age (table 5) which may be referred to as the main water-bearing unit (Miller and Evenson, 1966, p. 5).

The river-channel deposits of the Santa Maria River system yield large quantities of water to wells where saturated. Even though much of this unit is above the zone of saturation, it is important because it transmits large quantities of surface water by seepage loss to ground-water storage.

Depending on the location within the valley, wells drilled into the unconsolidated deposits of Pleistocene and Pliocene age also yield large quantities of water. For example, the Orcutt Sand yields large quantities of very good-quality water to wells in the Orcutt area.

TABLE 3.--*Streamflow at*

Calendar year	Sisquoc River near Sisquoc	LaBrea Creek near Sisquoc	Tepusquet Creek near Sisquoc	Foxen Creek near Sisquoc	Sisquoc River near Garey
				Annual streamflow	
1944	42,010	6,860	1,470		38,160
1945	24,730	2,960	843		17,780
1946	19,510	141	349		9,590
1947	3,260	0	203		0
1948	767	0	141		0
1949	3,750	0	225		89
1950	7,010	107	247		1,200
1951	1,470	0	272		417
1952	79,090	20,730	2,810		74,780
1953	8,790	1,190	719		3,730
1954	13,780	2,050	881		9,880
1955	6,640	573	605		1,850
1956	12,610	2,040	1,070		7,200
1957	4,190	0	187		191
1958	110,100	19,200	4,570		99,040
1959	9,610	13	115		2,430
1960	2,980	0	162		30
1961	1,010	0	35		0
1962	48,640	8,120	2,480		46,570
1963	5,630	0	267		275
1964	2,420	0	114		0
1965	24,780	1,010	277	0	9,670
1966	46,680	11,800	1,600	48	34,620
1967	78,370	15,480	1,980	133	65,200
1968	7,300	475	208	67	2,270
1969	262,500	48,620	8,160	152	287,800
1970	21,550	1,180	791	286	8,100
1971	14,090	0	270	121	2,030
1972	3,510	4	212	86	221

surface-water gaging stations

Cuyama River near Santa Maria (1)	Huasna River near Santa Maria (2)	Alamo Creek near Santa Maria (3)	Total flow (1)+(2)+(3)	Cuyama River below Twitchell Dam	Santa Maria River at Guadalupe
in acre-feet					
19,350	7,730	4,380	31,460		13,540
10,630	6,840	2,800	20,270		6,960
7,780	2,940	1,220	11,940		5,430
2,530	627	689	3,846		15
1,870	437	438	2,745		0
2,060	377	161	2,598		0
2,030	3,810	1,300	7,140		2,460
932	4,210	853	5,995		0
46,610	38,890	21,030	106,530		112,800
3,550	4,350	2,290	10,190		352
5,080	4,480	2,020	11,580		1,270
1,350	2,080	1,100	4,530		3
3,610	9,760	3,410	16,780		4,200
827	594	804	2,225		0
51,510	49,160	28,900	129,570		133,500
Twitchell Dam influences flow					
				4,160	0
				1,060	0
				22	0
				58,560	24,280
				2,430	0
				1,670	0
				3,870	0
				4,490	23,880
				100,100	8,160
				19,180	97
				197,800	179,700
				64,030	131
				4,390	0
				4	0

TABLE 4.--*Summary of estimated seepage loss from streams*

Period	Reach 1	Reach 2	Reach 3
1944-72			
Total acre-feet	318,000	1,036,000	1,354,000
Acre-feet per year	10,980	35,700	46,700
Acre-feet per mile	[1]1,300	[2]2,000	[3]1,800
1944-58			
Total acre-feet	136,000	351,000	487,000
Acre-feet per year	9,000	23,400	32,500
Acre-feet per mile	[1]1,100	[2]1,300	[3]1,200
1959-72			
Total acre-feet	174,000	685,000	859,000
Acre-feet per year	12,400	48,900	61,300
Acre-feet per mile	[1]1,500	[2]2,800	[3]2,300

[1] Seepage loss per mile based on reach 1 of 8.6 miles.
[2] Seepage loss per mile based on reach 2 of 17.6 miles.
[3] Seepage loss per mile based on reach 3 of 26.2 miles.

Consolidated rocks define both the areal and vertical limits of the ground-water basin. The vertical limit coincides with the base of the deposits of Pleistocene and Pliocene age. Areally, the southern limit of the unconsolidated aquifer system approximates the topographic divide. The eastern and northern limits are marked by a consolidated rock and alluvial contact except in the Nipomo area. There the ground-water divide is poorly defined and arbitrarily drawn.

The general direction of ground-water flow is from east to west with ground-water discharge to the Pacific Ocean (fig. 7). The ground-water gradient is moderate in the area east of Santa Maria but flattens markedly west of State Highway 101. The ground-water gradient along an approximate east-west line from the mouth of the Cuyama River through the general vicinity of Guadalupe to the ocean during the nonpumping season (December-April) shows a gradient of 35 ft/mi (6.6 m/km) east of U.S. Highway 101 and 4.5 to 5.0 ft/mi (0.85 to 0.95 m/km) west of this highway.

According to Miller and Evenson (1966, p. 5), "The freedom of ground-water movement within the aquifer system decreases from east to west across the valley and also probably decreases with depth. Aquifers in the deposits of Pliocene and Pleistocene age are mostly confined, as is the main water-bearing zone, in the western part of the alluvial plain. Minor bodies of perched ground water lie above the confining beds in the areas beneath the western part of the plain, beneath the Nipomo Mesa, and locally beneath the Orcutt Upland." The approximate area of confined water is shown in figure 3.

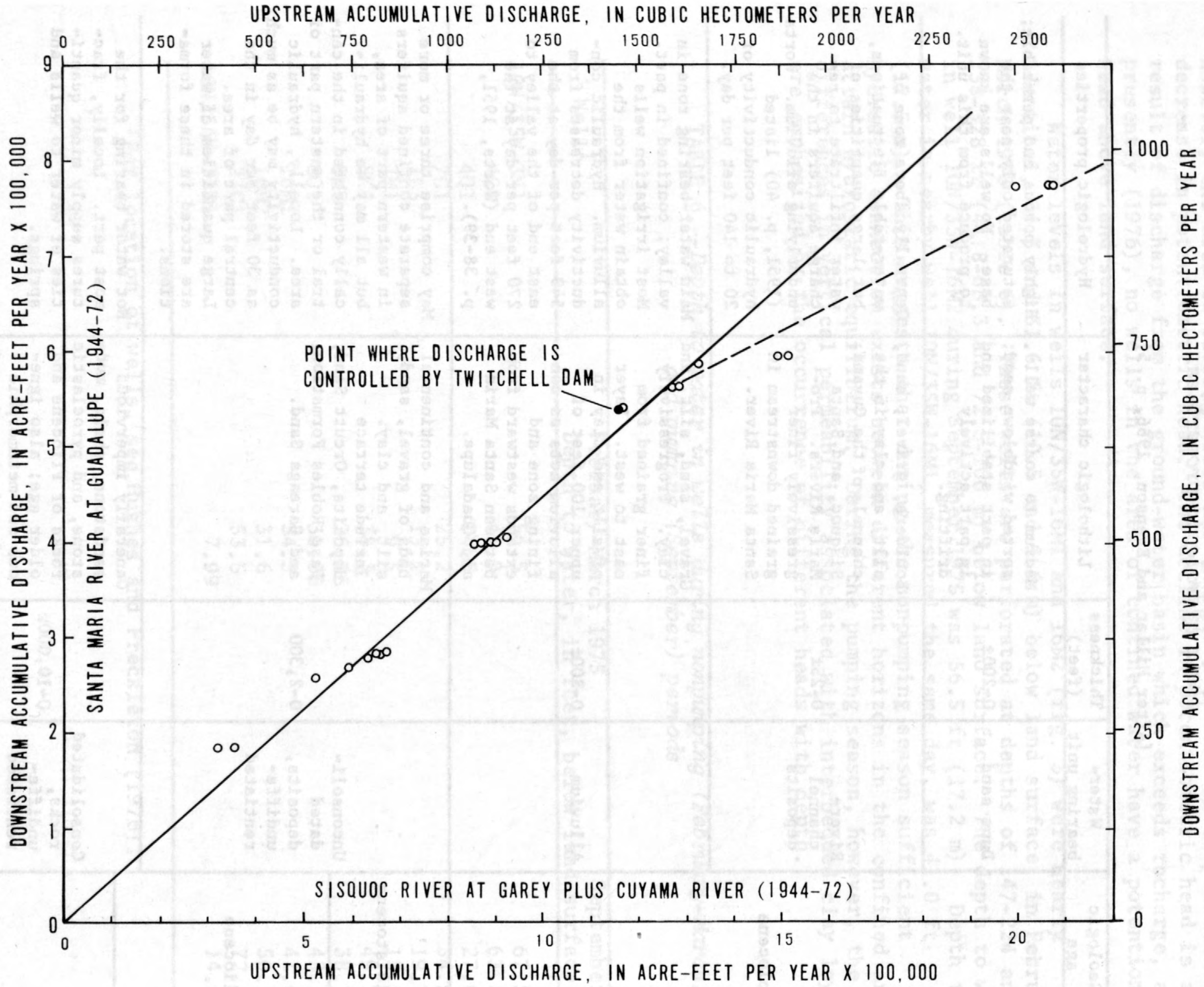


FIGURE 6.--Double-mass curve showing effect of Twitchell Dam on accumulative discharge in Santa Maria River system.

TABLE 5.--*Lithologic units in the Santa Maria ground-water basin and their hydrologic properties*

[After Miller and Evenson, 1966, p. 5]

	Geologic age	Water-bearing unit	Thickness (feet)	Lithologic character	Hydrologic properties
Quaternary	Holocene	Dune sand	0-200±	Medium to coarse well-sorted windblown sand; in part stabilized and in part actively drifting.	Highly porous and permeable; saturated only near the base. No wells are known to produce from this unit.
		River-channel deposits	0-25±	Boulders, gravel, sand, silt, and clay in the channels of the Cuyama, Sisquoc, and Santa Maria Rivers. Progressively finer grained downstream in Santa Maria River.	Generally above zone of water-table fluctuations, but large quantities of water infiltrate to recharge aquifers in the underlying alluvium. Worts (1951, p. 40) listed hydraulic conductivity of 20 to 140 feet per day.
		Alluvium	0-200±	Gravel, sand, silt, and clay. Progressively finer grained from east to west. Layer of silt and clay in upper 100 feet of alluvium acts as confining zone and extends westward from between Santa Maria and Guadalupe.	Main water-bearing zone in valley; confined in part. Most irrigation wells obtain water from the alluvium. Hydraulic conductivity decreases from 540 feet per day at the east end of the valley to 270 feet per day at the west end (Worts, 1951, p. 38-39).
	Pleistocene	Unconsolidated deposits, undifferentiated	0-2,300	Marine and continental beds of gravel, sand, silt, and clay. Include terrace deposits, Orcutt Sand, Paso Robles Formation, and Careaga Sand.	May comprise three or more separate confined aquifers in western part of area, but all may be hydraulically connected in the central or the eastern part of area. Locally, hydraulic conductivity may be as much as 30 feet per day in the central part of area. Large quantities of water are stored in these formations.
Tertiary	Pliocene				
Jurassic and Cretaceous		Consolidated rocks, undifferentiated	0-10,000±	Generally impervious sandstone, shale, mudstone, and pyroclastic rocks of Pliocene and older age; also igneous and metamorphic rocks of Jurassic and Cretaceous age.	Not water bearing for the most part. Locally, fractures supply minor quantities of water to wells and springs.

In the area of confined water, surface discharge of ground water from selected wells penetrating artesian zones was noted by Worts (1951, pl. 5); however, the area of flowing wells has changed with time in response to a decrease in potentiometric head. The decline in potentiometric head is a result of discharge from the ground-water basin which exceeds recharge, and, presently (1976), no wells in the area of confined water have a potentiometric head above land surface.

Water levels in wells 10N/35W-16M1 and 16M2 (fig. 3) were nearly identical, 34.3 and 31.6 ft (10.5 and 9.6 m) below land surface, in February-March 1975 (table 6). These wells are perforated at depths of 147-224 and 238-328 ft (44.8-68.3 and 72.5-100 m) below land surface. The depth to water in well 10N/35W-16M2 during September 1975 was 56.5 ft (17.2 m). Depth to water in nearby well 10N/35W-16M1, measured the same day, was 41.0 ft (12.5 m). This suggests that during the nonpumping season sufficient hydraulic connection exists between different horizons in the confined area to attain hydrostatic equilibrium. During the pumping season, however, the differences in vertical permeability associated with interbedded clay layers are emphasized by the occurrence of different heads with depth.

TABLE 6.--*Depth to water in wells during nonpumping (February-March) and pumping (September) periods*

Well[1]	February-March 1975	September 1975
	Depth to water, in feet, below land-surface datum	
10N/35W-3N1	56.5	67.5
4C1	41.9	63.5
4Q1	24.5	27.0
7G1	25.2	34.9
7L3	13.2	19.7
7M1	9.5	18.5
8K1	38.3	49.7
8M2	26.35	38.5
8Q1	36.65	48.1
16M1	34.3	41.0
16M2	31.6	56.5
27C1	53.5	72.2
10N/36W-12R1	7.99	14.5

[1] For location of wells, see Hughes and Freckleton (1976).

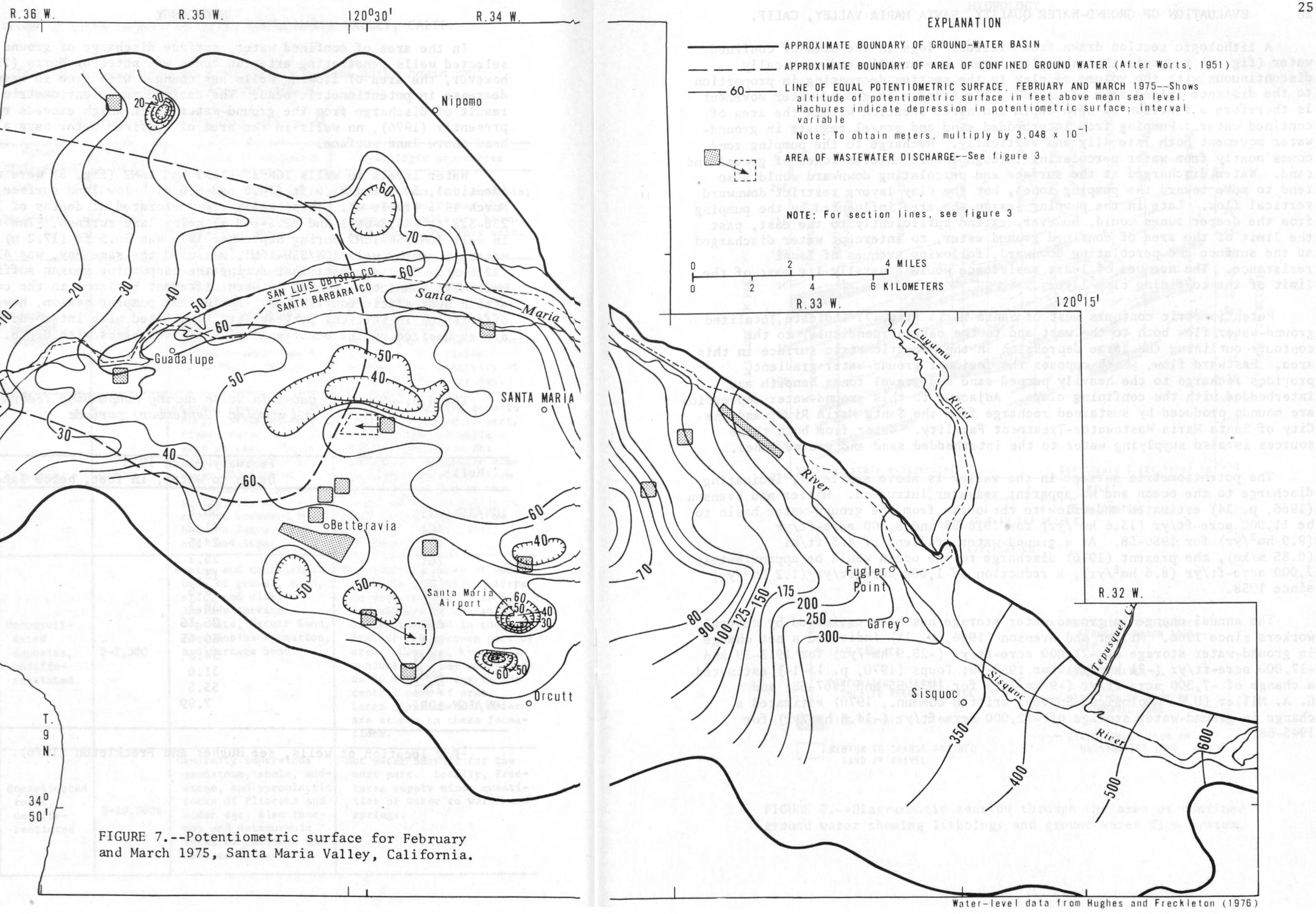


FIGURE 7.--Potentiometric surface for February and March 1975, Santa Maria Valley, California.

Water-level data from Hughes and Freckleton (1976)

A lithologic section drawn from drillers' logs in the area of confined water (fig. 8) suggests that the clay layers are areally and vertically discontinuous with the volume of clay in the section decreasing in proportion to the distance inland from the ocean. The freedom of ground-water movement is therefore a function of both depth and areal location within the area of confined water. Pumping from interbedded sand and gravel results in ground-water movement both laterally and vertically. Recharge to the pumping zone comes mostly from water percolating through interconnected zones of gravel and sand. Water discharged at the surface and percolating downward would also tend to move toward the pumping zones, but the clay layers restrict downward vertical flow. Late in the pumping season the area influenced by the pumping from the deeper zones would, however, extend sufficiently to the east, past the limit of the area of confined ground water, to intercept water discharged at the surface and percolating downward, following avenues of least resistance. The avenues of least resistance would generally lie east of the limit of the confining clay layers.

Potentiometric contours west of Santa Maria (fig. 7) indicate localized ground-water flow both to the west and to the east perpendicular to the contours outlining the large depression in the potentiometric surface in this area. Eastward flow, which opposes the regional ground-water gradient, provides recharge to the heavily pumped sand and gravel zones beneath and interbedded with the confining clays. Adjacent to this ground-water depression are mounds produced by sustained recharge from the Santa Maria River and the City of Santa Maria Wastewater-Treatment Facility. Water from both these sources is also supplying water to the interbedded sand and gravel zones.

The potentiometric surface in the valley is above sea level, indicating discharge to the ocean and no apparent seawater intrusion. Miller and Evenson (1966, p. 14) estimated underflow to the ocean from the ground-water basin to be 11,000 acre-ft/yr (13.6 hm^3/yr) for 1918-58 and 8,000 acre-ft/yr (9.9 hm^3/yr) for 1950-58. At a ground-water gradient of 4.5 ft/mi (0.85 m/km), the present (1976) discharge to the ocean would be approximately 7,000 acre-ft/yr (8.6 hm^3/yr), a reduction of 1,000 acre-ft/yr (1.2 hm^3/yr) since 1958.

The annual change in ground-water storage has been estimated by several workers since 1966. Miller and Evenson (1966, p. 18) indicated a net change in ground-water storage of -21,000 acre-ft/yr (-25.9 hm^3/yr) for 1918-59 and -17,000 acre-ft/yr (-21 hm^3/yr) for 1950-59; Toups (1970, p. 13-14) estimated a change of -7,300 acre-ft/yr (-9 hm^3/yr) for 1934-35 and 1967-68; and G. A. Miller (U.S. Geological Survey, written commun., 1970) estimated a change in ground-water storage of -12,000 acre-ft/yr (-14.8 hm^3/yr) for 1945-68.

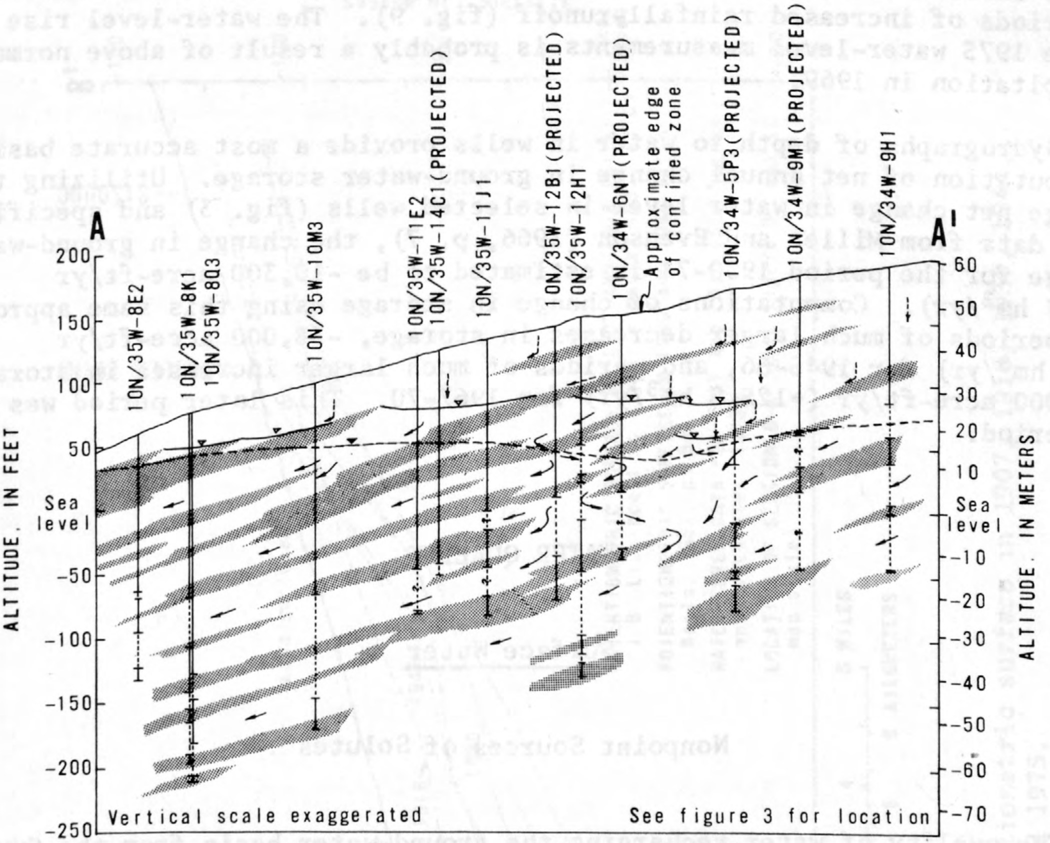


FIGURE 8.--Diagrammatic section through the area of confined ground water showing lithology and ground-water flow system.

Periodic monitoring of water levels in wells in the valley since the late 1920's shows a net decline with only temporary rises. These rises correspond to periods of increased rainfall-runoff (fig. 9). The water-level rise shown by the 1975 water-level measurements is probably a result of above normal precipitation in 1969.

Hydrographs of depth to water in wells provide a most accurate basis for a computation of net annual change in ground-water storage. Utilizing the average net change in water level in selected wells (fig. 3) and specific-yield data from Miller and Evenson (1966, p. 7), the change in ground-water storage for the period 1930-74 is estimated to be -10,300 acre-ft/yr (-12.7 hm^3/yr). Computations of change in storage using this same approach show periods of much larger decreases in storage, -38,000 acre-ft/yr (46.9 hm^3/yr) for 1945-66, and periods of much larger increases in storage, +102,000 acre-ft/yr (+125.8 hm^3/yr) for 1967-70. This later period was a very wet period.

WATER QUALITY

Surface Water

Nonpoint Sources of Solutes

The quality of water recharging the ground-water basin from the Cuyama and Sisquoc Rivers reflects both base flow and runoff from rain. The inverse relation between discharge and dissolved solids, sulfate, and chloride concentrations for the Cuyama River is shown in figure 10. The completion of Twitchell Dam in 1959 resulted in the retention of water low in dissolved-solids concentration during periods of increased runoff for release when maximum infiltration in the Santa Maria River could be realized. The retention of good-quality runoff has resulted in a dilution of the poorer quality base flow and probably some improvement in the average quality of recharge from the river.

The quality of base flow in the Cuyama River improved during the years 1906 to 1941 (fig. 10). During this undocumented period, concentrations of chloride and sulfate in base flows show a decrease of about 50 percent. These changes in the quality of the base flow may indicate both a change to more refined laboratory analytical methods and (or) agricultural development of the Cuyama Valley. Since 1941, significant changes in water chemistry of the base flows have not been noted. Singer and Swarzenski (1970, p. 40) indicated the ground water in the Cuyama Valley contained high concentrations of sulfate. They also indicated development in the Cuyama Valley seriously depleted available ground-water supplies, thus depleting ground-water outflow (Singer and Swarzenski, 1970, p. 16 and 18). The present base flow in the Cuyama River probably reflects only tributary inflow.

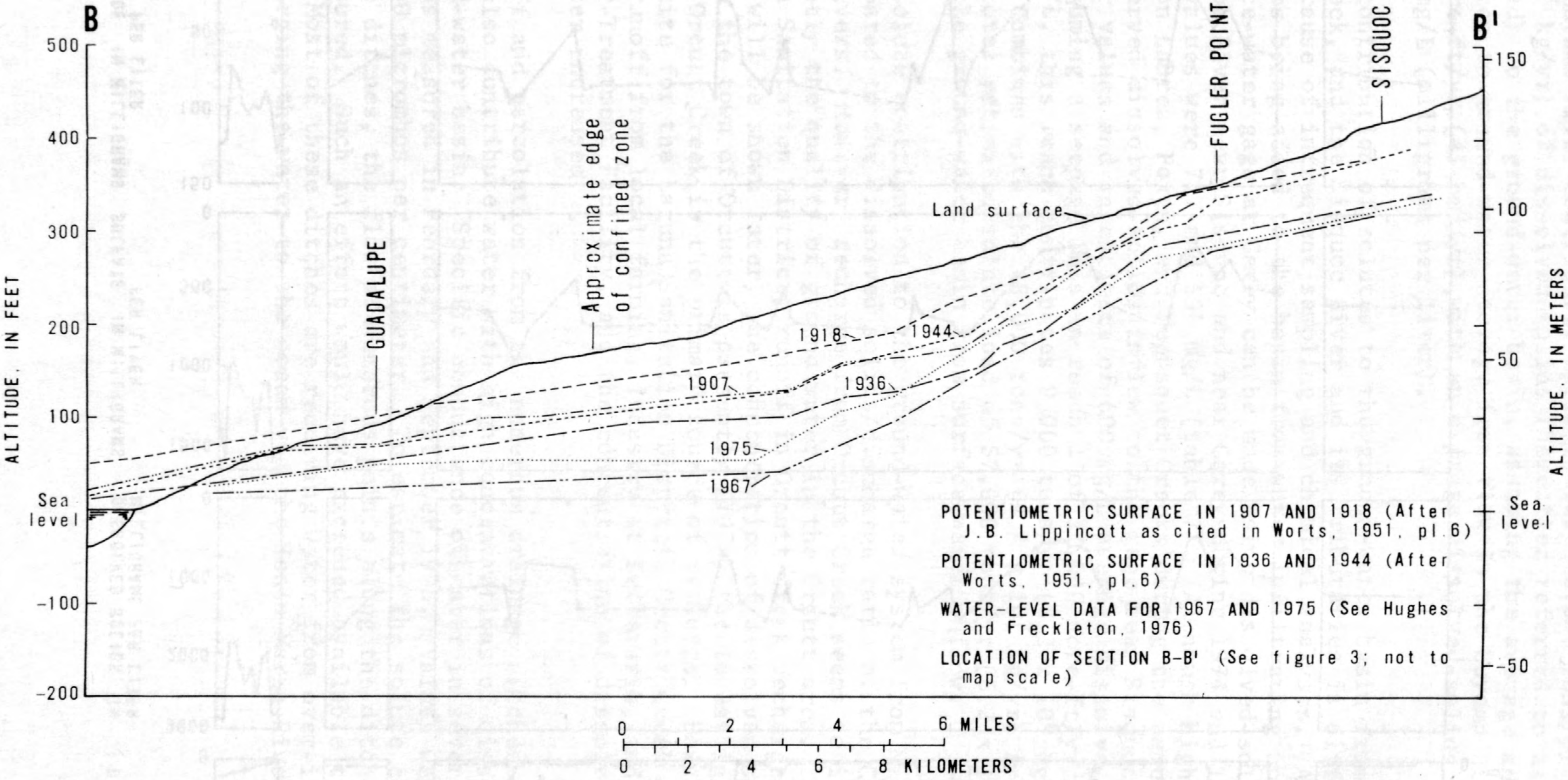


FIGURE 9.--Diagrammatic section showing potentiometric surface in 1907, 1918, 1936, 1944, 1967, and 1975.

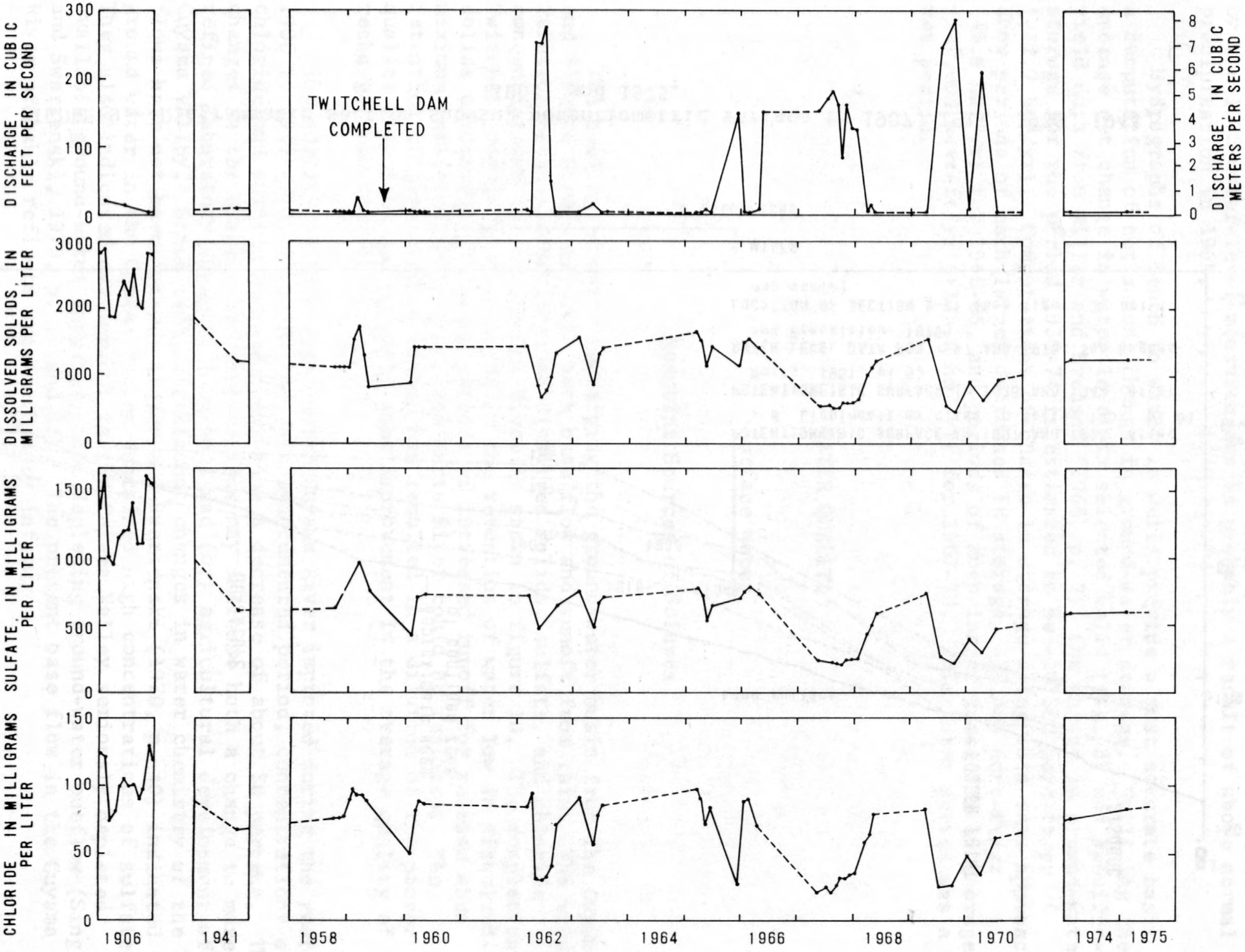


FIGURE 10.--Comparison of discharge and concentration of select chemical constituents in the Cuyama River.

The Cuyama River contributes approximately 48,000 tons/yr (4.4×10^7 kg/yr) of dissolved solids (hereafter referred to as solutes or solute load) to the ground-water basin, assuming the average annual contribution to ground-water storage from flow in the Cuyama River is 35,000 acre-ft/yr (43 hm^3/yr) with an average dissolved-solids concentration of 1,000 mg/L (milligrams per liter).

The contribution of solutes to the ground-water basin from Orcutt Creek, Nipomo Creek, and the Sisquoc River and its tributaries is difficult to assess because of infrequent sampling and chemical analyses. An estimate of the solutes being added to the basin from water infiltrating upstream from the surface-water gage at Garey can be made using dissolved-solids data for the Sisquoc River near Sisquoc and near Garey during 1974 and 1975. The observed values were 717 and 598 mg/L (table 7). Although higher values were measured on LaBrea, Foxen, and Tepusquet Creeks during the same period, the lower observed dissolved-solids inflow to the gage near Sisquoc has diluted the higher values and an estimate of 600 mg/L average dissolved solids was used. Assuming a seepage loss in reach 1 of 11,000 acre-ft/yr (13.6 hm^3/yr) at 600 mg/L, this reach contributes 9,000 tons/yr (8.2×10^6 kg/yr) of solutes. Combined with the 48,000 tons/yr (4.4×10^7 kg/yr) from the Cuyama River, a total estimated solute load of 57,000 tons/yr (5.2×10^7 kg/yr) is added to the ground-water basin from surface-water inflow.

The solute contribution to the ground-water system from Nipomo Creek is minor compared to the dissolved solids/discharge ratio of the Cuyama and the Sisquoc Rivers. However, recharge from Orcutt Creek seems to influence significantly the quality of ground water in the Orcutt area. Upstream from the Laguna Sanitation District, runoff in Orcutt Creek recharges the Orcutt Sand. As will be shown later, the concentration of dissolved solids in ground water near the town of Orcutt is presently (1976) the lowest in the study area, and Orcutt Creek is the primary source of recharge. Downstream from the disposal site for the Laguna Sanitation District, Orcutt Creek drainage receives runoff from local farming, industry at Betteravia, and the Airport Wastewater-Treatment Facility, and the concentration of dissolved solids in ground water increases.

Runoff and percolation from the numerous drainage ditches in the study area may also contribute water with high concentrations of dissolved solids to the ground-water basin. Specific conductance of water in several of these ditches was measured in February and September 1975. Values were generally 2,000-3,000 micromhos per centimeter. To estimate the solute contribution from these ditches, the flow at numerous points along the ditches would have to be measured. Such an effort would have exceeded available time and funding. Most of these ditches are receiving water from over-irrigated fields and discharging the water to the ocean via the Santa Maria River and Orcutt Creek.

TABLE 7.--*Chemical analyses of surface-*

[Constituents in milligrams per liter, except iron and boron
specific conductance in micromhos

CUYAMA RIVER BELOW

(Includes station names: Santa Maria River near Santa Maria, Cuyama River near Santa Maria,
and Cuyama River below Twitchell Dam; each of these station names

Date	Discharge (cubic feet per second)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Total alkalinity as calcium carbonate ($CaCO_3$)	Sulfate (SO_4)
Jan. 10, 1906	--	22	--	340	160	250	6.1	230	--	--	1,600
Jan. 20, 1906	--	24	--	290	150	280	8.3	200	--	--	1,500
Jan. 31, 1906	--	68	--	310	160	--	--	240	--	--	910
Feb. 9, 1906	--	20	--	460	160	350	12	430	--	--	1,700
Feb. 19, 1906	--	18	--	410	150	170	6.7	240	--	--	1,600
Feb. 25, 1906	18	30	--	320	140	230	6.3	250	--	--	1,500
Mar. 8, 1906	--	20	--	350	160	180	7.2	230	--	--	1,600
Mar. 21, 1906	--	19	--	250	69	86	4.5	190	--	--	770
Mar. 31, 1906	--	18	--	190	60	78	4.5	220	--	--	560
Apr. 10, 1906	--	20	--	210	82	83	3.5	280	--	--	700
Apr. 20, 1906	--	22	--	280	110	160	8.5	270	--	--	980
Apr. 28, 1906	--	20	--	260	120	190	7.2	260	--	--	1,100
May 9, 1906	--	17	--	260	120	200	11	250	--	--	1,100
May 20, 1906	--	--	--	270	130	180	5.6	260	--	--	1,200
May 30, 1906	--	22	--	270	120	120	4.7	250	--	--	1,100
June 10, 1906	12	26	--	270	130	160	5.4	240	--	--	1,200
June 20, 1906	--	27	--	270	150	130	8.2	230	--	--	1,300
June 30, 1906	--	30	--	350	150	140	4.6	220	--	--	1,300
July 10, 1906	--	27	100	230	120	230		210	4	--	1,200
July 19, 1906	--	20	100	170	93	150		300	--	--	730
July 30, 1906	--	24	200	310	160	200		290	--	--	1,600
Aug. 10, 1906	--	30	300	320	140	220		240	4	--	1,400
Aug. 20, 1906	--	22	100	320	150	190		220	--	--	1,400
Aug. 30, 1906	--	20	200	360	140	220		230	--	--	1,400
Sept. 10, 1906	--	17	100	290	140	220		220	--	--	1,300
Sept. 20, 1906	--	19	200	260	120	160		230	5	--	1,100
Sept. 30, 1906	--	20	200	230	110	200		290	--	--	960
Oct. 10, 1906	--	26	50	200	93	190		320	--	--	770
Oct. 20, 1906	--	24	100	270	120	240		290	--	--	1,100
Oct. 30, 1906	--	22	100	300	140	280		260	--	--	1,400
Nov. 10, 1906	4.9	26	300	330	160	100		220	7	--	1,500
Nov. 20, 1906	--	35	150	330	160	290		250	--	--	1,600
Nov. 30, 1906	--	26	100	370	170	300		280	--	--	1,700
Dec. 10, 1906	--	20	20	340	150	--	--	240	--	--	1,500
Dec. 20, 1906	--	18	100	460	150	260		280	--	--	1,600

water flow in the Santa Maria Valley

in micrograms per liter; water temperature in degrees Celsius;
per centimeter at 25°C; and pH]

Chloride (Cl)	Fluoride (F)	Nitrate plus nitrite as nitrogen (NO_2+NO_3)	Phosphate (PO_4)	Dissolved solids	Hardness as calcium carbonate ($CaCO_3$)	Hardness as noncarbonate	Specific conductance	pH	Water temperature	Dissolved oxygen (DO)	Boron (B)
TWITCHELL DAM											
Cuyama River below Buckhorn Canyon, Cuyama River above Sisquoc River, Cuyama River near Garey, describe flow in the Cuyama River at approximately the same location)											
130	--	--	--	--	--	--	--	--	--	--	--
130	--	--	--	2,780	--	--	--	--	--	--	--
120	--	--	--	2,990	--	--	--	--	--	--	--
140	--	--	--	3,250	--	--	--	--	--	--	--
120	--	--	--	2,950	--	--	--	--	--	--	--
120	--	--	--	2,540	--	--	--	--	--	--	--
120	--	--	--	3,000	--	--	--	--	--	--	--
50	--	--	--	1,520	--	--	--	--	--	--	--
48	--	--	--	1,200	--	--	--	--	--	--	--
67	--	--	--	1,510	--	--	--	--	--	--	--
87	--	--	--	1,930	--	--	--	--	--	--	--
100	--	--	--	2,270	--	--	--	--	--	--	--
100	--	--	--	2,150	--	--	--	--	--	--	--
120	--	--	--	2,370	--	--	--	--	--	--	--
87	--	--	--	2,130	--	--	--	--	--	--	--
100	--	--	--	2,330	--	--	--	--	--	--	--
110	--	--	--	2,510	--	--	--	--	--	--	--
110	--	--	--	2,480	--	--	--	--	--	--	--
94	--	--	--	2,220	--	--	--	--	--	--	--
84	--	--	--	1,560	--	--	--	--	--	--	--
130	--	--	--	2,910	--	--	--	--	--	--	--
100	--	--	--	2,620	--	--	--	--	--	--	--
100	--	--	--	2,650	--	--	--	--	--	--	--
100	--	--	--	2,530	--	--	--	--	--	--	--
100	--	--	--	2,390	--	--	--	--	--	--	--
91	--	--	--	2,080	--	--	--	--	--	--	--
81	--	--	--	1,880	--	--	--	--	--	--	--
75	--	--	--	1,640	--	--	--	--	--	--	--
97	--	--	--	2,180	--	--	--	--	--	--	--
120	--	--	--	2,590	--	--	--	--	--	--	--
130	--	--	--	2,820	--	--	--	--	--	--	--
130	--	--	--	2,830	--	--	--	--	--	--	--
140	--	--	--	3,010	--	--	--	--	--	--	--
130	--	--	--	2,970	--	--	--	--	--	--	--
130	--	--	--	2,950	--	--	--	--	--	--	--

TABLE 7.--*Chemical analyses of surface-water*

Date	Discharge (cubic feet per second)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Total alkalinity as calcium carbonate ($CaCO_3$)	Sulfate (SO_4)
CUYAMA RIVER BELOW											
Dec. 30, 1906	--	21	20	410	130	230		210	--	--	1,500
Oct. 22, 1941	10	21	--	160	77	110	8.8	300	--	--	590
Oct. 17, 1958	2.0	15	--	130	83	120	3.7	220	--	--	600
Nov. 13, 1958	2.0	--	--	--	--	--	--	250	--	--	--
Dec. 11, 1958	2.0	--	--	--	--	--	--	250	--	--	--
Jan. 15, 1959	2.0	--	--	--	--	--	--	330	--	--	--
Feb. 5, 1959	1.5	--	--	--	--	160	--	290	--	--	--
Mar. 12, 1959	25	20	--	230	100	140	6.6	230	--	--	950
Apr. 9, 1959	7.0	--	--	--	--	140	--	210	--	--	--
May 6, 1959	2.0	20	--	160	96	140	5.1	260	--	--	740
Feb. 4, 1960	5.0	20	--	130	46	73	5.7	230	--	--	400
Mar. 10, 1960	2.0	30	--	160	87	130	5.3	250	--	--	700
Apr. 7, 1960	1.0	--	--	--	--	140	--	240	--	--	--
May 5, 1960	1.0	15	--	140	100	140	5.0	260	--	--	710
1961	No flow	--	--	--	--	--	--	--	--	--	--
Mar. 5, 1962	5.0	14	--	150	91	120	5.2	210	--	--	700
Apr. 4, 1962	.50	--	--	--	--	140	--	220	--	--	--
May 1, 1962	250	20	--	130	44	62	4.3	140	7	--	450
June 7, 1962	250	--	--	--	--	55	--	170	--	--	--
July 10, 1962	275	--	--	--	--	63	--	200	--	--	--
Aug. 7, 1962	49	--	--	--	--	70	--	230	--	--	--
Sept. 11, 1962	.50	23	--	180	85	120	4.7	350	--	--	620
Feb. 5, 1963	1.0	24	--	190	91	140	5.8	330	--	--	740
May 6, 1963	[1]15	10	70	120	56	91	4.8	230	--	--	470
June 3, 1963	1.0	8.0	--	150	87	120	4.8	250	--	--	650
July 1, 1963	1.0	9.0	--	170	91	130	4.7	290	--	--	680
1964	No flow	--	--	--	--	--	--	--	--	--	--
Mar. 1, 1965	.50	--	--	210	100	140	5.0	360	--	--	770
Apr. 5, 1965	1.0	--	--	200	98	130	5.0	370	--	--	700
May 3, 1965	4.0	--	--	150	73	110	4.0	330	--	--	510
June 1, 1965	.50	--	--	170	90	130	4.0	350	--	--	630
Dec. 1, 1965	150	--	--	220	44	56	6.0	120	--	--	690
Jan. 4, 1966	1.3	--	--	210	88	130	6.0	340	--	--	730
Feb. 1, 1966	.70	--	--	200	95	130	5.0	310	--	--	760
Apr. 4, 1966	6.0	--	--	200	81	120	7.0	300	--	--	720
May 30, 1967	150	--	--	81	31	44	3.0	200	--	--	220
July 9, 1967	170	--	--	81	29	41	3.0	190	--	--	210
Aug. 7, 1967	180	--	--	79	30	40	3.0	180	--	--	200
Aug. 29, 1967	160	--	--	77	29	41	3.0	200	--	--	190
Oct. 4, 1967	82	--	--	87	33	53	4.0	230	--	--	230

See footnote at end of table.

flow in the Santa Maria Valley--Continued

Chloride (Cl)	Fluoride (F)	Nitrate plus nitrite as nitrogen (NO_2+NO_3)	Phosphate (PO_4)	Dissolved solids	Hardness as calcium carbonate ($CaCO_3$)	Hardness as noncarbonate	Specific conductance	pH	Water temperature	Dissolved oxygen (DO)	Boron (B)
TWITCHELL DAM--Continued											
100	--	--	--	2,660	--	--	--	--	--	--	--
69	1.3	--	--	1,280	710	--	--	--	16.7	--	--
77	.6	--	--	1,170	650	--	1,570	8.2	22.2	9.8	420
77	--	--	--	--	640	--	1,470	8.2	18.3	7.0	280
78	--	--	--	--	610	--	1,460	8.4	18.9	14.2	430
90	--	--	--	--	780	--	1,760	8.1	12.2	13.0	260
99	--	--	--	--	950	--	1,980	8.4	16.7	9.8	260
94	.6	--	--	1,760	990	--	2,190	8.3	16.7	10.4	420
94	--	--	--	--	730	--	1,790	8.4	22.8	11.0	370
95	.7	--	0.00	1,520	790	--	1,880	8.0	23.3	9.5	350
51	.5	1.4	--	--	520	--	1,220	8.2	9.4	10.0	160
83	1.0	--	--	--	760	--	1,800	8.4	20.0	12.0	380
90	--	--	--	--	770	--	1,850	8.4	26.7	11.2	300
89	--	--	.10	1,440	760	--	1,810	8.4	23.3	10.6	400
--	--	--	--	--	--	--	--	--	--	--	--
85	.9	3.0	--	1,450	780	--	1,780	7.9	16.7	13.2	300
95	--	--	--	--	820	--	1,890	8.4	23.3	14.0	320
32	.7	1.3	.20	875	510	--	1,170	8.0	20.0	12.8	230
32	--	--	--	--	450	--	1,050	7.9	22.2	11.2	210
34	--	--	--	--	480	--	1,120	8.1	23.3	10.0	210
42	--	--	--	--	580	--	1,360	8.0	26.7	10.8	300
73	1.0	.40	.05	1,360	790	--	1,750	7.3	17.8	5.2	340
92	1.0	--	--	1,590	850	--	2,030	7.9	11.1	8.0	330
57	.8	1.2	.00	989	540	--	1,330	7.8	14.4	8.8	300
79	.9	.50	--	1,320	720	--	1,700	7.9	27.2	9.0	320
86	1.0	.40	--	1,410	800	--	1,820	7.8	26.7	11.0	330
--	--	--	--	--	--	--	--	--	--	--	--
98	1.4	1.0	--	1,680	940	--	2,060	7.4	19.4	10.6	300
91	1.1	--	--	1,560	890	--	1,960	7.4	15.0	11.4	290
72	.1	1.0	--	1,140	670	--	1,570	7.4	21.1	10.0	380
85	1.0	--	--	1,460	780	--	1,810	7.4	20.0	8.8	270
26	1.2	2.0	--	1,180	630	--	1,390	7.4	11.7	9.2	220
87	1.1	2.0	--	1,500	600	--	1,930	7.9	7.2	11.8	280
90	1.2	--	--	1,540	640	--	1,940	8.1	11.7	14.0	320
72	.9	--	--	1,420	590	--	1,800	8.0	20.0	10.0	380
24	.7	1.0	--	550	330	--	787	8.3	13.9	12.8	190
25	.7	2.0	--	558	320	--	741	8.2	13.9	13.4	160
24	.6	1.5	--	530	320	--	745	8.3	17.8	12.0	200
25	.5	2.0	--	536	310	--	759	7.7	18.9	10.2	200
33	.6	6.5	--	600	350	--	803	7.3	17.8	10.0	220

TABLE 7.--*Chemical analyses of surface-water*

Date	Discharge (cubic feet per second)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Total alkalinity as calcium carbonate ($CaCO_3$)	Sulfate (SO_4)
CUYAMA RIVER BELOW											
Nov. 7, 1967	163	--	--	81	31	48	5.0	210	--	--	220
Dec. 11, 1967	127	--	--	89	34	50	5.0	220	--	--	240
Jan. 11, 1968	125	--	--	95	36	50	5.0	230	--	--	240
Mar. 15, 1968	2.7	--	--	130	62	88	4.0	280	--	--	440
Apr. 5, 1968	14	--	--	140	68	99	5.0	300	--	--	490
May 3, 1968	1.9	--	--	150	74	120	6.0	290	10	--	570
Apr. 21, 1969	4.9	--	--	200	95	140	6.0	360	--	--	740
July 25, 1969	245	--	--	94	31	43	3.0	180	--	--	260
Oct. 21, 1969	288	--	--	83	28	40	3.0	190	--	--	200
Jan. 19, 1970	7.5	--	--	130	54	78	4.0	290	--	--	390
Apr. 15, 1970	210	--	--	100	38	55	5.0	220	--	--	280
July 21, 1970	3.5	--	--	120	62	95	5.0	220	--	--	460
Feb. 19, 1974	2.1	19	30	180	83	120	4.8	360	--	290	590
Feb. 5, 1975	[2]3.4	18	30	180	78	120	5.7	330	--	270	590
ALAMO CREEK ABOVE											
Feb. 18, 1943	--	--	--	81	33	42	.8	260	--	--	160
Feb. 12, 1975	1.5	25	20	91	34	45	2.0	300	--	250	160
CUYAMA RIVER ABOVE											
Mar. 5, 1943	--	--	--	520	120	150	5.7	130	--	--	1,800
Feb. 12, 1975	2.0	10	20	140	76	110	4.1	280	--	230	530
HUASNA RIVER ABOVE											
Feb. 18, 1943	--	--	--	76	24	44	1.2	260	--	--	120
Feb. 12, 1975	.8	27	10	110	35	54	2.3	340	--	280	180
LABREA CREEK ABOVE											
Feb. 18, 1943	--	--	--	100	71	94	1.9	340	6	--	380
Feb. 19, 1974	1.5	14	60	130	83	120	3.2	260	--	210	450
TEPUSQUET CREEK											
Feb. 19, 1974	1.7	26	40	130	91	41	2.3	440	--	360	340
FOXEN CREEK											
Feb. 19, 1974	<.1	43	50	190	120	160	4.6	540	--	440	600
SISQUOC RIVER BELOW											
Mar. 5, 1943	--	--	--	58	29	26	3.2	180	--	--	150

See footnote at end of table.

flow in the Santa Maria Valley--Continued

Chloride (Cl)	Fluoride (F)	Nitrate plus nitrite as nitrogen (NO_2+NO_3)	Phosphate (PO_4)	Dissolved solids	Hardness as calcium carbonate ($CaCO_3$)	Hardness as noncarbonate	Specific conductance	pH	Water temperature	Dissolved oxygen (DO)	Boron (B)
TWITCHELL DAM--Continued											
33	0.6	2.5	--	600	330	--	824	7.5	17.8	10.1	220
34	.6	1.5	--	600	360	--	886	8.2	13.9	10.5	200
34	.6	2.5	--	629	380	--	914	7.6	8.9	11.8	190
59	.7	.50	--	1,010	580	--	1,360	7.7	15.6	15.7	120
64	.7	.60	--	1,100	640	--	1,520	7.7	21.1	8.6	270
77	.6	.40	--	1,230	680	--	1,680	7.5	14.4	8.9	300
83	.8	.80	--	1,530	900	--	1,910	8.0	25.0	8.1	310
25	.6	1.5	--	572	210	--	830	7.9	13.3	10.0	190
26	.5	4.4	--	470	320	--	726	7.5	17.2	7.8	170
49	.7	1.5	--	909	540	--	1,260	7.6	17.2	9.9	190
35	.6	.70	--	648	410	--	972	8.1	17.8	11.2	190
63	.8	--	--	977	540	--	1,300	8.2	30.6	5.7	300
76	.9	.20	--	1,250	790	500	1,770	8.0	10.5	--	290
82	.6	.20	--	1,240	770	500	1,720	6.9	14.5	--	240
CUYAMA RIVER											
31	--	.70	--	530	340	--	--	--	--	--	--
36	.4	.10	--	542	370	120	825	6.5	13.0	--	170
ALAMO CREEK											
45	--	.40	--	3,200	1,800	--	--	--	--	--	--
78	.4	.10	--	1,090	660	430	1,550	6.5	11.0	--	370
CUYAMA RIVER											
36	--	.40	--	480	290	--	--	--	--	--	--
53	.5	.10	--	627	420	140	950	6.7	13.5	--	200
SISQUOC RIVER											
44	--	--	--	1,000	540	--	--	--	--	--	--
60	1.0	.10	--	989	670	450	1,410	8.2	9.5	--	290
NEAR SISQUOC											
47	.8	.50	--	897	700	340	1,300	7.9	9.5	--	80
NEAR SISQUOC											
150	.4	1.2	--	1,540	970	530	2,180	8.2	10.0	--	510
TEPUSQUET CREEK											
8.8	--	--	--	420	260	--	--	--	--	--	--

TABLE 7.--*Chemical analyses of surface-water*

Date	Discharge (cubic feet per second)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Total alkalinity as calcium carbonate ($CaCO_3$)	Sulfate (SO_4)
											SISQUOC RIVER
Apr. 15, 1942	30	15	100	64	35	28	2.5	180	--	--	200
											SISQUOC RIVER
June 3, 1943	--	--	--	87	58	51	1.6	230	2	--	340
Feb. 19, 1974	28	15	70	100	60	54	2.2	260	--	210	340
											SISQUOC RIVER
Feb. 5, 1975	[3]75	15	40	87	48	39	2.1	250	--	200	270
											NIPOMO CREEK AT
Feb. 12, 1975	.5	32	20	100	54	84	3.9	350	--	290	170
											SANTA MARIA RIVER
Feb. 18, 1943	--	--	--	230	87	120	5.3	420	--	--	680
Feb. 5, 1975	2.0	19	80	47	28	43	7.3	140	--	110	100

[1] Molybdenum, total, 20 micrograms per liter; detergents (MBAS) 0.03 milligrams per liter.

[2] Cobalt, total, 50 micrograms per liter; lead, total, 100 micrograms per liter; lithium, total, 30 micrograms per liter.

Point Sources of Solutes

In addition to the solutes brought in by rivers and streams within the study area, discharge of solutes from several point sources exists. These represent in part the addition of new solutes, but also a part of the solutes already in the system but which have been concentrated by consumption of a part of the water in which they were dissolved. These point sources include (1) Douglas and Union Oil Cos., (2) Union Sugar Refinery, and (3) four domestic wastewater-treatment facilities. The potential effects on ground-water quality of irrigation, stockyards, oil fields, and solid-waste landfills will be evaluated indirectly by observation of changes in ground-water chemistry.

flow in the Santa Maria Valley--Continued

Chloride (Cl)	Fluoride (F)	Nitrate plus nitrite as nitrogen (NO_2+NO_3)	Phosphate (PO_4)	Dissolved solids	Hardness as calcium carbonate ($CaCO_3$)	Hardness as noncarbonate	Specific conductance	pH	Water temperature	Dissolved oxygen (DO)	Boron (B)
ABOVE LABREA CREEK											
9.0	0.4	0.10	--	473	300	--	--	--	13.9	--	--
NEAR SISQUOC											
16	--	.10	--	770	460	--	--	--	--	--	--
16	.7	.10	--	717	500	280	1,060	8.1	13.5	--	140
NEAR GAREY											
13	.3	.20	--	598	420	210	875	7.1	13.5	--	230
HIGHWAY 101 BRIDGE											
150	.4	1.7	--	774	470	190	1,275	6.6	12.5	--	90
AT GUADALUPE											
86	--	--	--	1,600	930	--	--	--	--	--	--
62	.3	6.5	--	402	230	120	650	7.2	10.5	--	70

[3] Cobalt, total, 50 micrograms per liter; lead, total, 100 micrograms per liter; lithium, total, 20 micrograms per liter.

Wastewater from oil refining has been discharged (1) into the ocean, (2) underground by deep-well injection, and (3) into sumps. Compared to methods 1 and 2, the volume of wastes disposed to sumps has been minor. Discharge of wastes from oil refining to the ocean, via pipelines to the Santa Maria River at its mouth or directly to the ocean, offers little or no threat to the fresh-water aquifers in the valley, provided the pipelines do not leak or break. Degradation of ground-water quality near an oil refinery should therefore result only from leakage and general spills in the refinery area, since sump disposal to the ground is no longer permitted.

Oil production in Cat, Santa Maria, Bradley, and Guadalupe oil fields (Oil Field Map Books, 1955) may contribute to degradation of ground water from casing leaks, spills, well blowouts, percolation of water used in drilling and repair, and from the runoff of rain falling on or flowing through the oil fields. The anomalous concentrations of sodium, chloride, bicarbonate, boron, sulfate-sulfide, organic acids, and ammonia near oil production or refinement often suggest ground-water degradation from this activity.

Wastewater from the plants of the Union Sugar Co. is discharged to several evaporation-percolation ponds (fig. 3). The volume of water discharged to the ponds averages 9.5 Mgal/d (3.6×10^4 m^3/d) (California Department of Water Resources, 1969, p. 13), of which 1.2 Mgal/d (4.5×10^3 m^3/d) is lost to evaporation from ponds and from nearby irrigated fields and 4.0 Mgal/d (1.5×10^4 m^3/d) percolates to ground water (Brown and Caldwell, Consulting Engineers, written commun., 1975). The amount of ground water pumped for use in the refinery is, however, 3.5 Mgal/d (1.3×10^4 m^3/d) (California Department of Water Resources, 1969, p. 13). It must therefore be assumed that water from the ponds is recycled to sustain the 9.5 Mgal/d (3.6×10^4 m^3/d) wastewater discharge. Since the water in the ponds is not as high in quality as that required to manufacture beet sugar (California Water Resources Control Board, 1963, p. 105), it seems likely that it was found necessary to pump additional ground water for the process. The recycled wastewater may be used in less sensitive processes such as washing the dirt and peels from the beet and the pulp from the plant and for cooling. Pulp and other solid wastes from the sugar-beet refinery are sold to Sinton and Brown (fig. 3) for use as cattle feed.

The recharge mound (fig. 7) beneath the sugar refinery is small, which suggests that most of the inflow to the plant is consumed in the sugar-beet processing, and only a small part of the discharge percolates to the water table. The quality of ground water near the ponds does not suggest a large volume of percolating water of different quality. Also, water samples taken from the ponds could not be pressure-filtered either in the field or in the laboratory because of suspended solids and microorganisms. This suggests that the ponds may be sufficiently clogged by settling solids and bacteria to reduce percolation to a minimum.

Table 8 indicates approximately 17,000 tons (1.5×10^7 kg) of solutes are discharged to the ponds annually. This amount is misleading because a large part of the discharge used to calculate the tonnage does not percolate but is recycled as mentioned previously. The potentiometric surface near the ponds indicates that some percolation does occur but is much less than the 4.0 Mgal/d (1.5×10^4 m^3/d) estimated by Brown and Caldwell, Consulting Engineers (written commun., 1975).

The average quality and quantity of water discharged from the valley's four wastewater-treatment facilities are given in table 8. Effluent from each of these facilities is discharged to streams and to evaporation-percolation ponds or is sold to nearby farmers for application on feed crops. Regardless of the method, part of the wastewater percolates to and influences the quality of ground water in the area of discharge. The average solutes available for percolation from the four wastewater-treatment facilities amount to about 13,000 tons/yr (1.2 x 10^7 kg/yr) (table 8) based on a maximum time interval of 16 years (1959-74). Most of the solutes in these wastewaters were, however, in the ground water pumped for use by the cities and industries represented. They do not, therefore, represent a source of new solutes, except for those added by the users of the water. Several constituents are likely to be influenced by this effect, notably chloride, nitrogen, and boron in municipal wastewater (table 8). Nitrogen is also present in rather large concentrations in the industrial effluents represented in table 8. The anomalous changes in the above-mentioned constituents aid in determining the effect of these discharges on ground-water quality.

Monthly reports to the California Regional Water Quality Control Board, Central Coast Region, by the city of Santa Maria show that in November 1974 the dissolved solids of the water supply for the city averaged 900 mg/L (R. N. Riddiough, Jr., Director of Public Works, written commun., 1975). Since November 1974 the average dissolved solids of the water supply for the city of Santa Maria has been approximately 770 mg/L. Chemical analyses of water from the city's supply wells show that the wells in secs. 27, 28, and 34, T. 10 N., R. 34 W., and sec. 3, T. 9 N., R. 34 W., have a dissolved-solids concentration of approximately 700 mg/L. City wells located in sec. 14, T. 10 N., R. 34 W., have an average dissolved-solids concentration of 950 mg/L. Probably when the dissolved-solids content of water from wells in section 14 increased, the city concentrated its pumping from wells to the south, using the higher dissolved-solids water from section 14 as a blended supplement during periods of high demand. The chemical quality of effluent from the wastewater-treatment facilities did not change significantly during this transition, suggesting the increase in population may have brought about changes in water use that offset the reduced dissolved solids in the supply source.

The quality of effluent from each of the wastewater-treatment facilities is proportional to the quality of the source pumped for city use. The dissolved-solids concentration of the effluent from the City of Guadalupe Wastewater-Treatment Facility averages about 2,000 mg/L compared to 1,480, 1,090, and 1,245 mg/L for the other wastewater-treatment facilities in the study area (table 8). The dissolved-solids concentration of water pumped for use by the city of Guadalupe, the city of Santa Maria, the Santa Maria Airport, and the Laguna Sanitation District (Orcutt community) averages 1,200, 770, 770, and 620 mg/L. The higher dissolved-solids concentrations in ground water in the Guadalupe area is a product of long-term accumulation of solutes from irrigation, wastewater discharge, and other sources.

TABLE 8.--*Summary of municipal and*

	City of Santa Maria		Santa Maria Airport	
	Period	Average	Period	Average
Discharge, million gallons per day	1960-74	4.20	1959-74	0.30
Calcium, milligrams per liter	1960-67	149	1960-74	66
Magnesium, milligrams per liter	1960-67	69	1960-74	51
Sodium, milligrams per liter	1960-74	246	1960-74	185
Potassium, milligrams per liter	1960-67	25	1960-74	14
Bicarbonate, milligrams per liter	1960-67	404	1960-74	278
Sulfate, milligrams per liter	1960-74	442	1960-74	261
Chloride, milligrams per liter	1960-74	271	1960-74	210
Fluoride, milligrams per liter	1960-67	1.4	1960-74	1.7
Nitrogen, milligrams per liter	1960-74	12.3	1960-74	14.2
Dissolved solids, milligrams per liter	1960-74	1,480	1960-74	1,090
Specific conductance, micromhos at 25°C	1960-67	2,239	1960-74	1,550
pH	1960-67	7.4	1960-74	7.6
Boron, micrograms per liter	1960-67	520	1960-74	743
Solute load, tons per year	1960-74	9,400	1959-74	500

[1] Brown and Caldwell, Consulting Engineers (written commun., 1975).

[2] California Dept. of Water Resources (1969, p. B-3); results given for a single year, not an average.

The average dissolved-solids concentration of effluents from each of the facilities will probably continue to increase with time as the source water deteriorates and the population increases. Carollo (1975, table IV-4, p. IV-34) estimated the volume of discharge from the Santa Maria Wastewater-Treatment Facility will increase from an average 4.5 Mgal/d (1.7 x 10^4 m^3/d) in 1975 to 6.4 Mgal/d (2.4 x 10^4 m^3/d) in the year 2000.

Ground Water

In February and March 1975 depth to water and specific conductance of ground water were measured in approximately 400 wells. The interpretation of ground-water flow shown in figure 7 is based on these measurements. The specific-conductance measurement indicates the dissolved-solids concentration in the water and thus provides a basis for an overall evaluation of the variations in ground-water quality in the study area, and it was a guide for selecting water samples to be used for chemical analyses.

industrial wastewater discharge

Laguna Sanitation District		City of Guadalupe		Sinton and Brown		Union Sugar	
Period	Average	Period	Average	Period	Average	Period	Average
1960-75	0.96	1960-74	0.37	--	[1]0.69	1968-74	[1]9.60
1961-74	69	1960-74	230	1969	[2]10	1970-74	[1]112
1961-74	41	1960-74	103	1969	[2]49	1970-74	[1]35
1961-75	258	1960-74	228	1969	[2]122	--	--
1961-74	16	1960-74	12	1969	[2]100	--	--
1961-71	346	1960-74	476	1969	[2]490	1975	[3]996
1961-75	249	1960-74	796	1969	[2]51	1970-75	[1]18
1961-75	289	1960-74	248	1969	[2]120	1970-75	[1]139
1961-70	1.2	1960-74	1.3	1969	1.4	1975	[3].1
1961-75	14.8	1960-74	28.0	--	--	1975	[3]27.4
1961-75	1,245	1960-74	2,023	--	[1]2,100	1970-75	[1]1,200
1961-71	1,783	1960-74	2,611	--	--	1975	[3]2,000
1961-71	7.3	1960-74	7.4	1969	[2]4.6	1970-75	[1]8.0
1961-70	610	1960-74	453	1969	[2]320	--	--
1960-75	1,800	1960-74	1,100	--	2,200	1968-74	[1]17,000

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[3] Single analysis of water from lower pond, performed by U.S. Geol. Survey; results given not an average.

During September and October 1975 water from approximately 100 wells was sampled for chemical analysis (fig. 3). The analyses included determinations for most of the major dissolved anions and cations plus nitrite and nitrate as nitrogen, ammonia, dissolved organic carbon (DOC), detergents (as MBAS, methylene-blue active substances), and trace elements at selected locations (Hughes and Freckleton, 1976). In addition to the initial interpretations provided by the field specific-conductance values, wells used to sample ground water were selected for their location with respect to a point source of wastewater discharge, depth of well or depth of perforated interval, areal distribution, and accessibility. The types of chemical constituents analyzed in each water sample were related to the potential source influencing the ground-water quality. For example, water samples collected near solid-waste landfills were analyzed for trace elements; water samples in areas possibly affected by municipal and industrial wastewater discharge were analyzed for detergents and DOC.

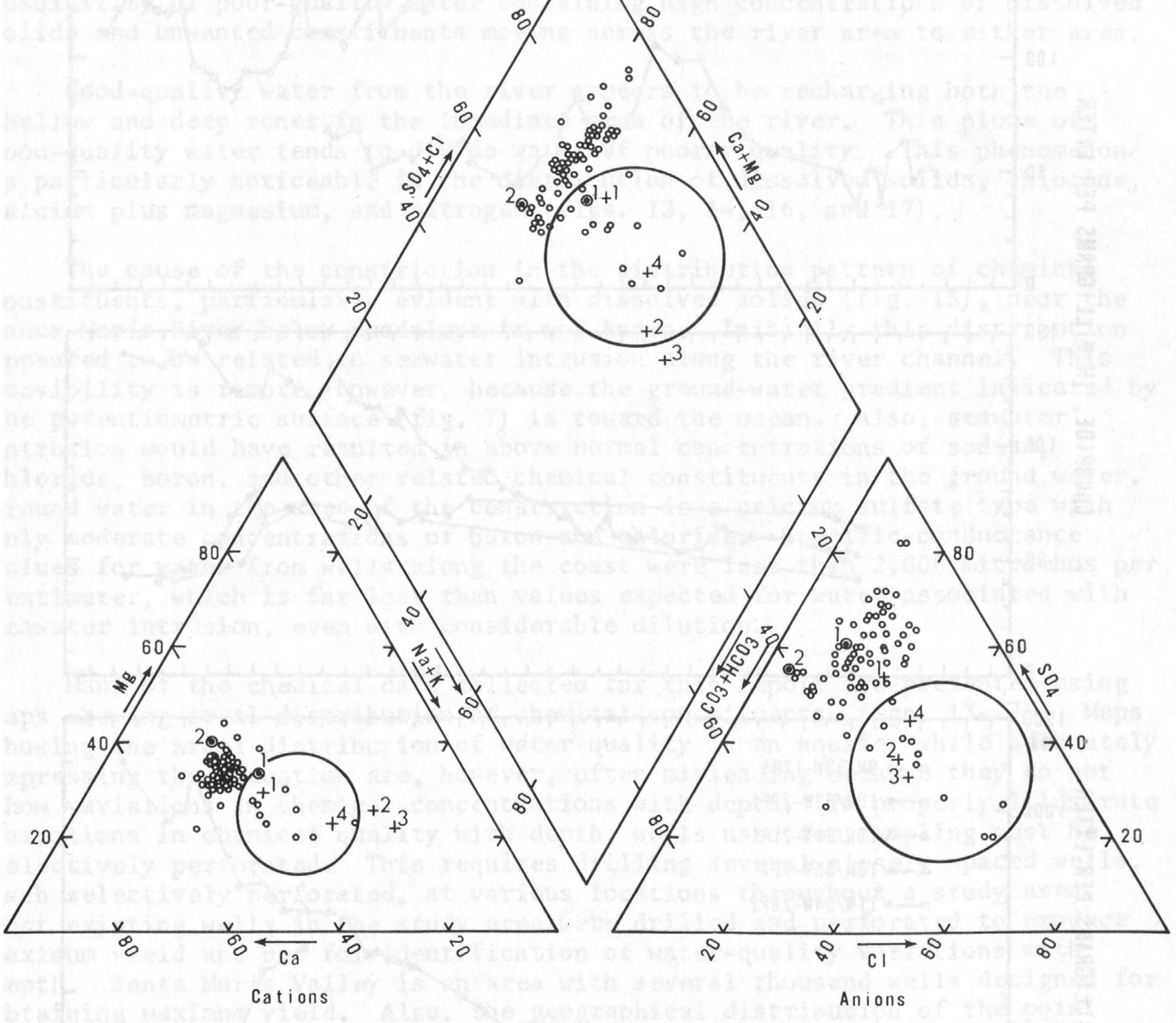
Most of the ground water in the study area may be classified as a calcium magnesium sulfate type (fig. 11). This water type is compatible with the quality of runoff in the Cuyama and the Sisquoc Rivers (table 7), the principal sources of ground-water recharge to the valley. Singer and Swarzenski (1970, p. 20) noted high calcium magnesium sulfate concentrations in some ground water in the Cuyama Valley, probably derived from or strongly influenced by Tertiary and pre-Tertiary marine deposits containing gypsum.

The percentage of reacting anion concentrating values tends toward a chloride predominance in the aquifer in the southern areas of the Santa Maria Valley (fig. 11). Water from wells near the town of Orcutt and along Orcutt Creek drainage is a calcium magnesium chloride type with sodium replacing calcium in a few samples.

A comparison of historic and current chemical data (fig. 12) indicates that ground-water degradation has occurred mostly in the area of confined ground water. Within this area, the degradation is most pronounced in the shallower perforated wells. Well 10N/35W-7F1 is in the area of confined water and is perforated from 140 to 243 ft (42.7 to 74.1 m). The concentration of chloride and sulfate in the water from this well has increased significantly since 1953. Elsewhere in the valley, the change in concentration of chloride and sulfate has been less pronounced, and a decrease in concentration of chloride and sulfate was noted in water from wells 10N/33W-20F1 and 11N/34W-29P2. These wells are in areas influenced by recharge from the Santa Maria River. The improvement in water quality in the Santa Maria River since the completion of Twitchell Dam (table 7, fig. 10) may be responsible for the improvement in the quality of water from these wells. The quality of water from wells 9N/33W-12R1 and 10N/34W-21R1 has been more constant suggesting that water percolating downward from point sources of wastewater or from irrigation is mixing with recharge from the river systems or with better quality water in ground water in storage.

The distribution of chemical substances in ground water, based on analyses of water collected during September and October 1975, indicates that the chemical quality varies both areally and vertically, but there are substantial patterns of occurrence (figs. 13 to 17) which reflect the nature of use and reuse of water.

Areally, the quality of ground water deteriorates from east to west, laterally from the Santa Maria River, and northward from the south edge of the ground-water basin. This pattern of distribution is compatible with directions of ground-water flow and suggests that the degradation near the area of confined water is related to an accumulation of water high in dissolved solutes. These solutes are produced by the use and reuse of water for irrigation and are displaced westward by recharge.



EXPLANATION

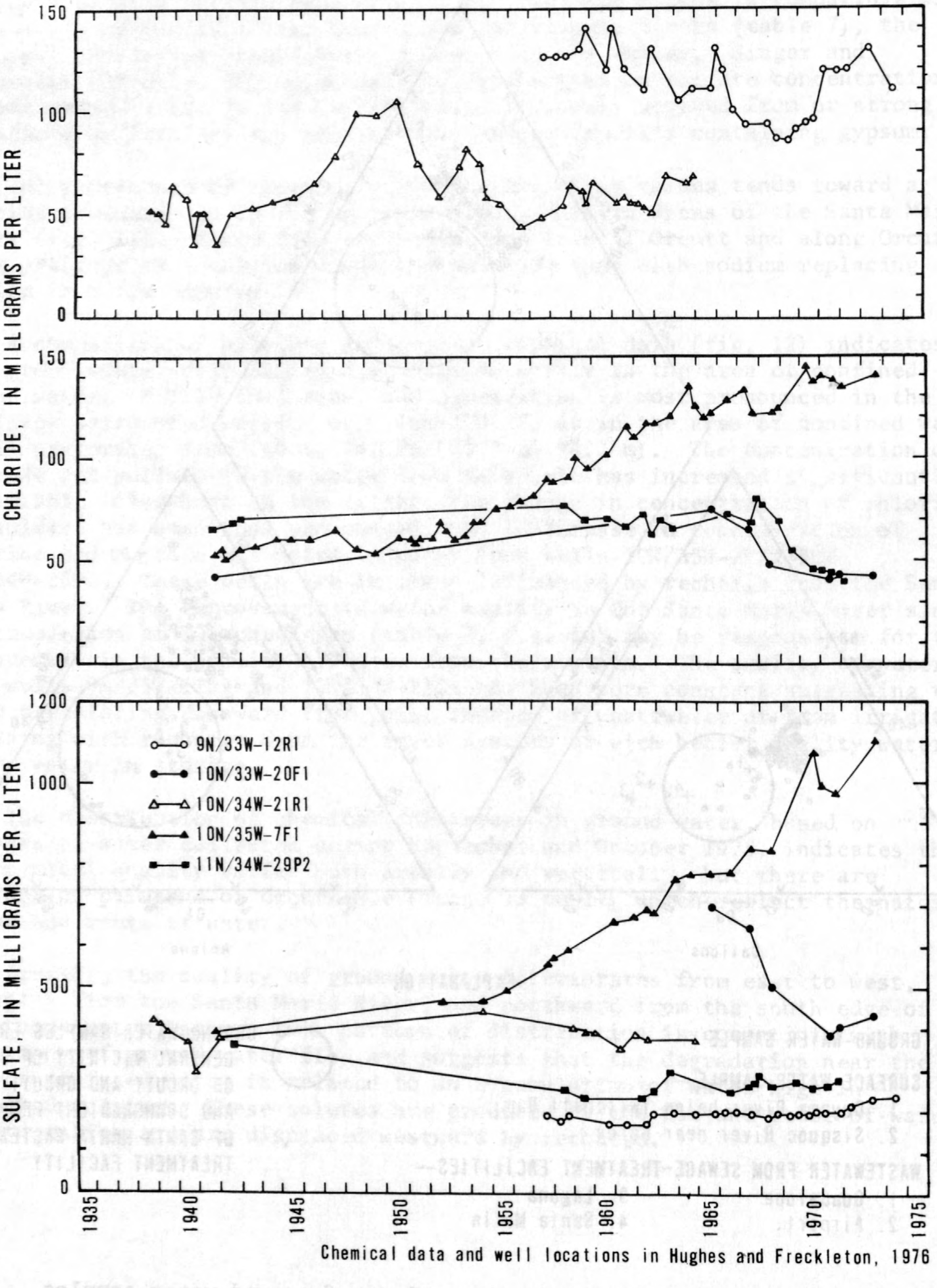
○ GROUND-WATER SAMPLE

●^{1} SURFACE-WATER SAMPLE--
1. Cuyama River below Twitchell Dam
2. Sisquoc River near Garey

+^{1} WASTEWATER FROM SEWAGE-TREATMENT FACILITIES--
1. Guadalupe
2. Airport
3. Laguna
4. Santa Maria

○ GROUND-WATER SAMPLES FROM GENERAL VICINITY OF CITY OF ORCUTT AND ORCUTT CREEK AND DOWNGRADIENT FROM CITY OF SANTA MARIA WASTEWATER-TREATMENT FACILITY

FIGURE 11.--Percentage reacting values of ground-water samples collected in September and October 1975.



Chemical data and well locations in Hughes and Freckleton, 1976

FIGURE 12.--Change in concentration of selected chemical constituents in ground water, 1938-74.

The recharge mound near the Santa Maria River (fig. 7) inhibits movement of ground water from the Nipomo area into the area south of the river. The reverse is also true; this hydraulic boundary serves to decrease the possibility of poor-quality water containing high concentrations of dissolved solids and unwanted constituents moving across the river area to either area.

Good-quality water from the river appears to be recharging both the shallow and deep zones in the immediate area of the river. This plume of good-quality water tends to divide water of poorer quality. This phenomenon is particularly noticeable in the distribution of dissolved solids, chloride, calcium plus magnesium, and nitrogen (figs. 13, 14, 16, and 17).

The cause of the constriction in the distribution pattern of chemical constituents, particularly evident with dissolved solids (fig. 13), near the Santa Maria River below Guadalupe is not known. Initially this distribution appeared to be related to seawater intrusion along the river channel. This possibility is remote, however, because the ground-water gradient indicated by the potentiometric surface (fig. 7) is toward the ocean. Also, seawater intrusion would have resulted in above normal concentrations of sodium, chloride, boron, and other related chemical constituents in the ground water. Ground water in the area of the constriction is a calcium sulfate type with only moderate concentrations of boron and chloride. Specific-conductance values for water from wells along the coast were less than 2,000 micromhos per centimeter, which is far less than values expected for water associated with seawater intrusion, even with considerable dilution.

Many of the chemical data collected for this report are presented using maps showing areal distribution of chemical constituents (figs. 13-17). Maps showing the areal distribution of water quality in an aquifer while adequately expressing the situation are, however, often misleading because they do not show variations in chemical concentrations with depth. To properly illustrate variations in chemical quality with depth, wells used for sampling must be selectively perforated. This requires drilling several closely spaced wells, each selectively perforated, at various locations throughout a study area. Most existing wells in the study area were drilled and perforated to produce maximum yield and not for identification of water-quality variations with depth. Santa Maria Valley is an area with several thousand wells designed for obtaining maximum yield. Also, the geographical distribution of the point sources of wastewater, coupled with the large size of the valley, eliminated the possibility of drilling the observation wells required to properly observe quality variations with depth. Wherever possible, existing wells were used to indicate variations in quality with depth by selecting wells with limited perforated intervals for sampling.

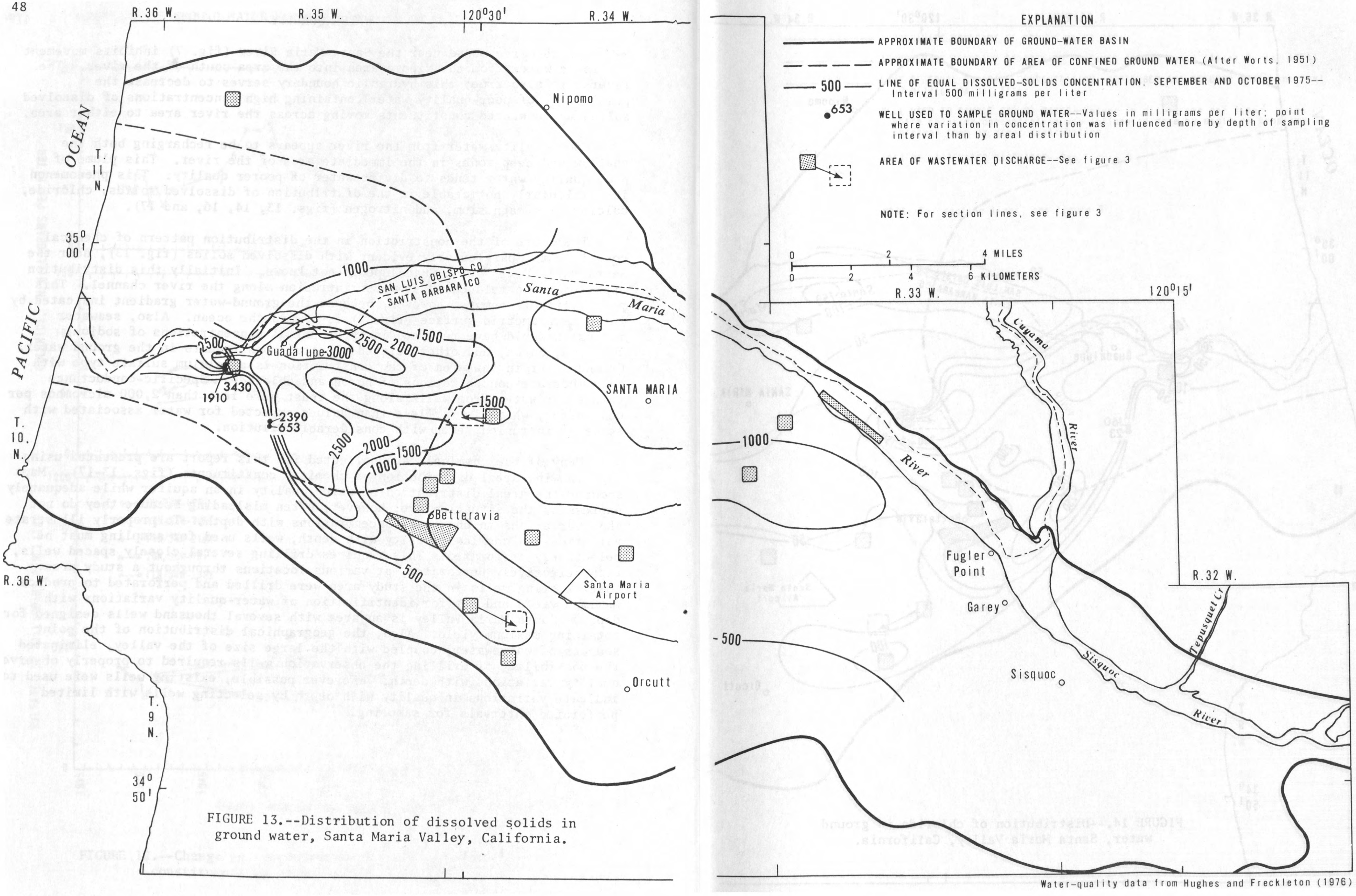


FIGURE 13.--Distribution of dissolved solids in ground water, Santa Maria Valley, California.

Water-quality data from Hughes and Freckleton (1976)

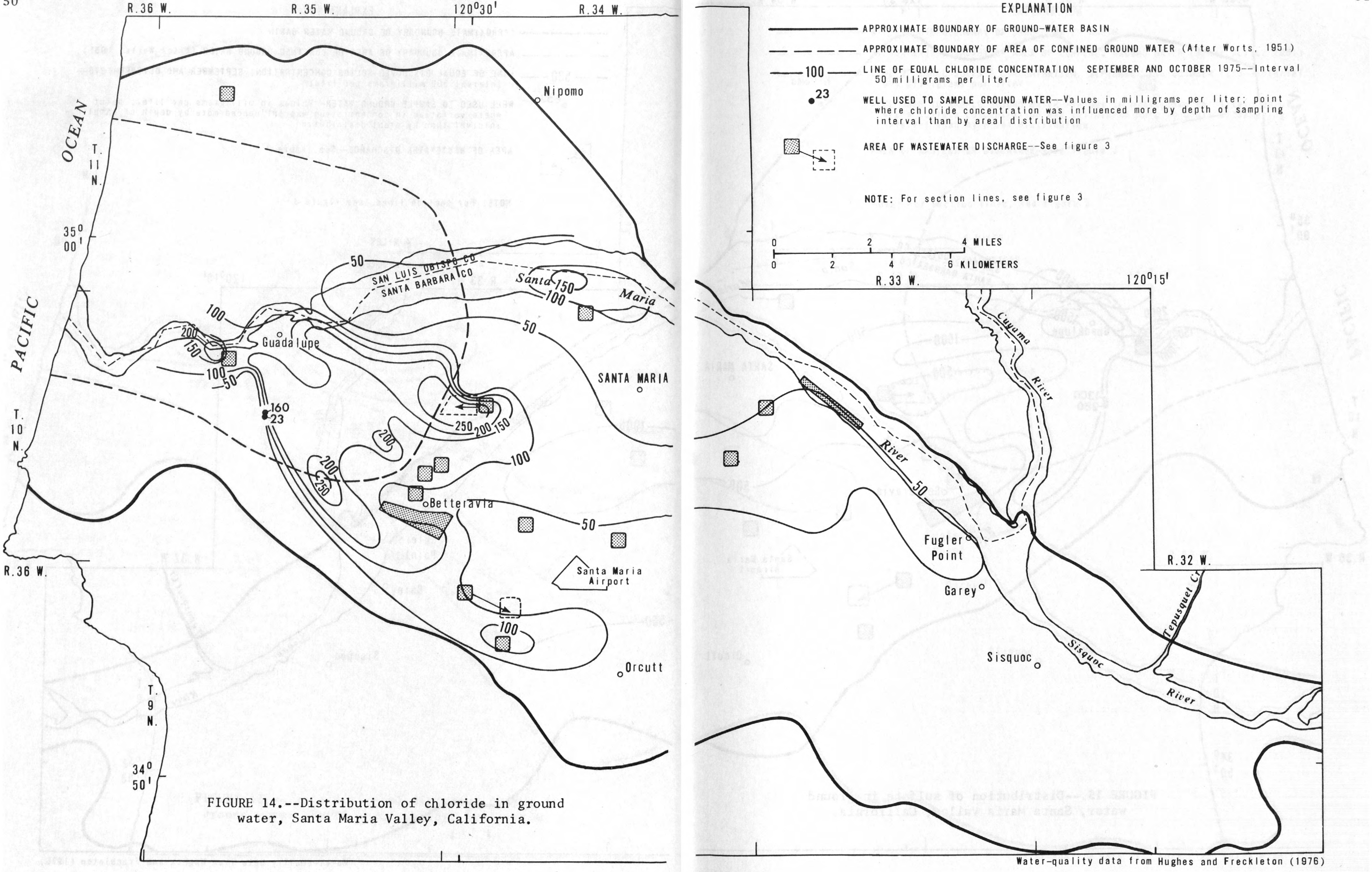


FIGURE 14.--Distribution of chloride in ground water, Santa Maria Valley, California.

Water-quality data from Hughes and Freckleton (1976)

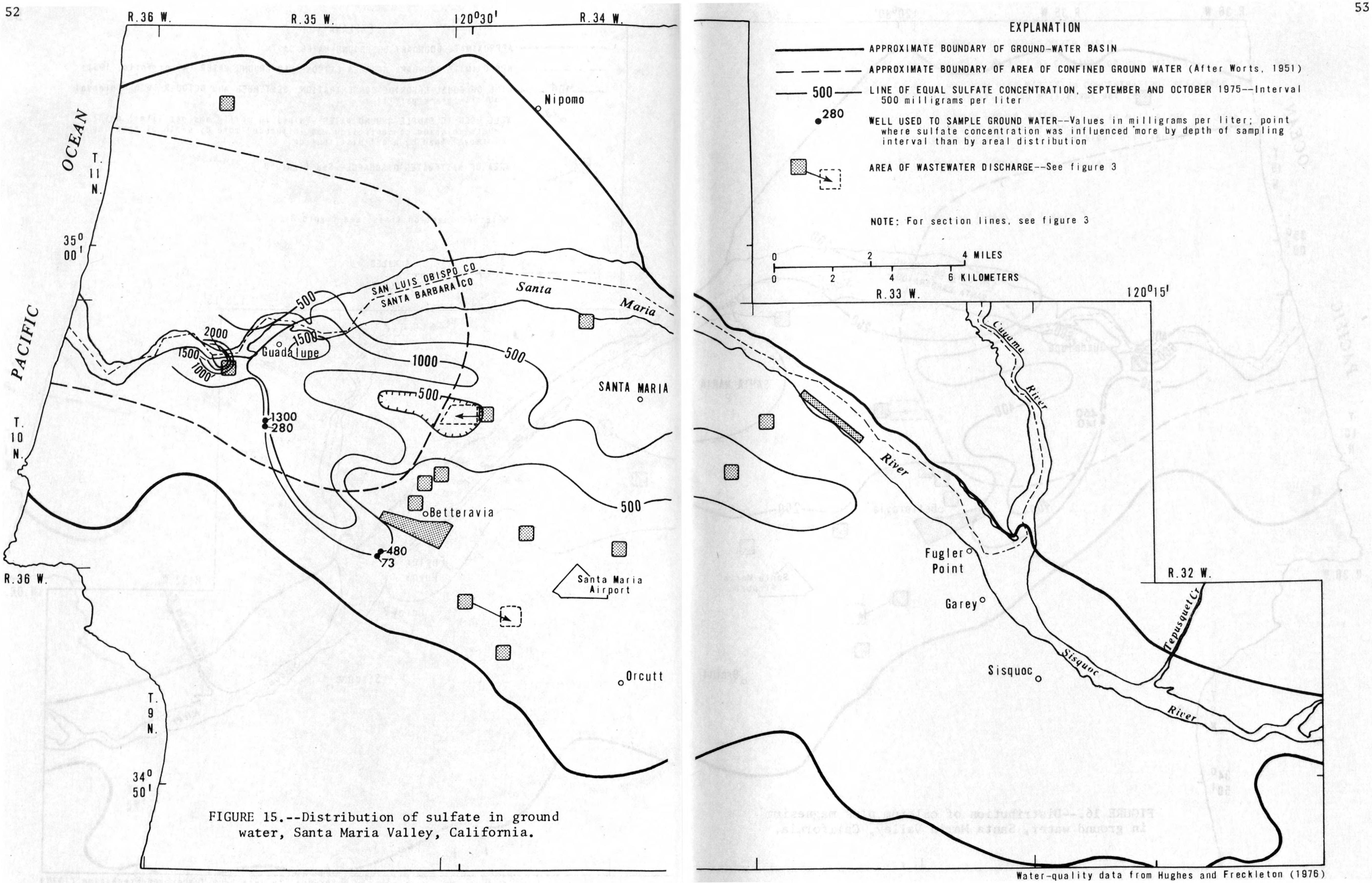


FIGURE 15.--Distribution of sulfate in ground water, Santa Maria Valley, California.

Water-quality data from Hughes and Freckleton (1976)

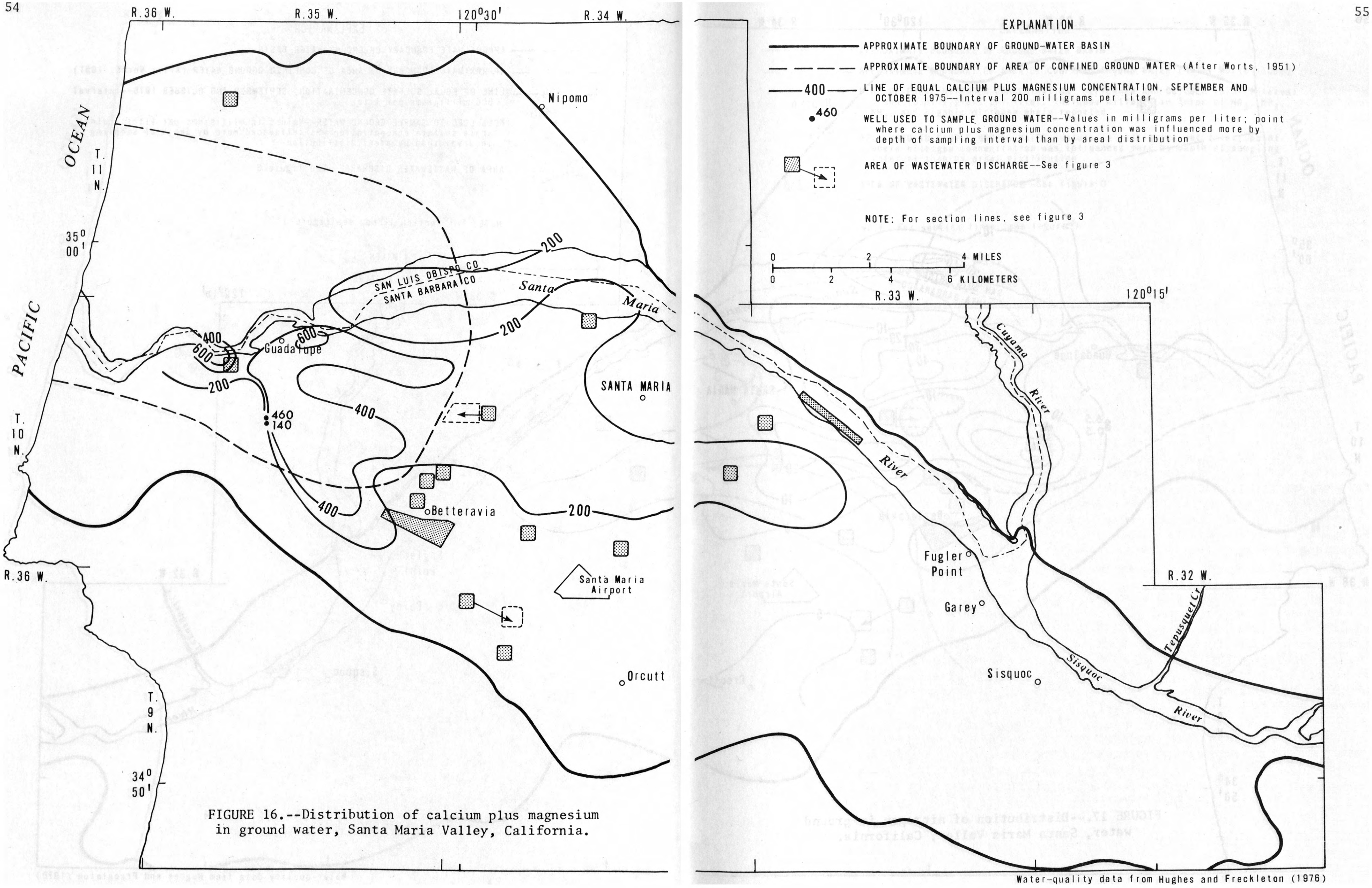


FIGURE 16.--Distribution of calcium plus magnesium in ground water, Santa Maria Valley, California.

Water-quality data from Hughes and Freckleton (1976)

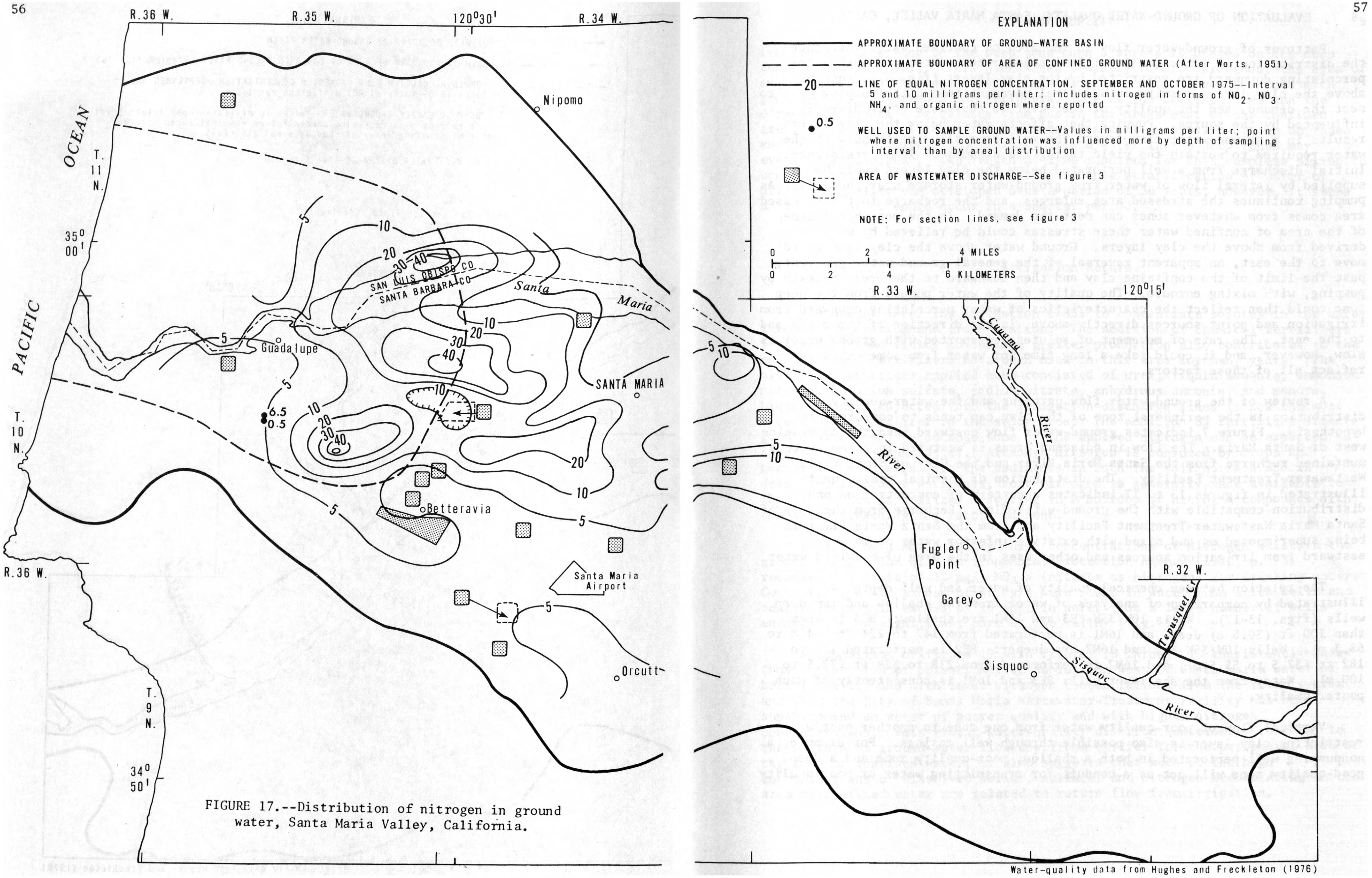


FIGURE 17.--Distribution of nitrogen in ground water, Santa Maria Valley, California.

Water-quality data from Hughes and Freckleton (1976)

Patterns of ground-water flow in the area of confined water influence the distribution of water quality. Irrigation return water and wastewater percolating downward are restricted by the clay layers (fig. 8). Pumping above the clay layers results in a lateral movement toward the pumping well to meet the demand, and the quality of the water is therefore often directly influenced by the source. Pumping that affects water below the clay layers results in a ground-water flow toward the well from all directions with the water required to sustain the yield taking the avenues of least resistance. Initial discharge from a well perforated below the clay layers would be supplied by lateral flow of water from ground-water storage near the well. As pumping continues the stressed area enlarges, and the recharge to the stressed area comes from whatever zones can meet the demand. In the peripheral zones of the area of confined water these stresses could be relieved by water derived from above the clay layers. Ground water above the clay thus could move to the east, an apparent reversal of the general ground-water gradient, past the limit of the confining clay and then downward to the area stressed by pumping, with mixing enroute. The quality of the water pumped from the deep zone could then reflect the characteristics of water percolating downward from irrigation and point sources directly above, in the direction of the ocean and to the east. The rate of movement of solutes transported with ground water is slow, however, and it could take a long time for water from some wells to reflect all of these factors.

A review of the ground-water flow patterns and the water-quality distribution in the peripheral zone of the clay cap tends to confirm this hypothesis. Figure 7 indicates ground-water flow eastward into the depression west of Santa Maria. The flow in adjacent areas is westward in response to a sustained recharge from the Santa Maria River and the City of Santa Maria Wastewater-Treatment Facility. The distribution of chemical constituents illustrated in figures 13 to 17 indicates a pattern of concentration and distribution compatible with the ground-water flow. Recharge from the City of Santa Maria Wastewater-Treatment Facility and from the Santa Maria River is being superimposed on and mixed with existing inferior water or moving eastward from irrigation sources and other uses in the area of confined water.

The relation between chemical quality of water and well depth is illustrated by comparison of analyses of water from two shallow and two deep wells (figs. 13-17). Wells 10N/35W-8E3 and 16M1 are shallow: 8E3 is less than 100 ft (30.5 m) deep, and 16M1 is perforated from 147 to 224 ft (44.8 to 68.3 m). Wells 10N/35W-8E2 and 16M2 are deeper: 8E2 is perforated 123 to 182 ft (37.5 to 55.5 m), and 16M2 is perforated from 238 to 328 ft (72.5 to 100 m). Water from the shallower wells 8E3 and 16M1 is consistently of much poorer quality.

Vertical flow of poor-quality water from one zone to another past a restricting clay layer is also possible through well casings. For example, a nonpumping well perforated in both a shallow, poor-quality zone and a deep, good-quality zone will act as a conduit for transmitting water of poor quality from the shallow zone to the deep zone when a stress is placed on the deep zone by a nearby well. This phenomenon probably occurs throughout the area of confined water as hydraulic potentials fluctuate with time. Combined with ground-water flow around the peripheral zone of the confined area and the direct contribution of solutes from use in the areas east of the confined area, the total section in the confined area will eventually become degraded and zones of relatively good-quality ground water in the deep zones may eventually disappear. The length of time required for this complete mixing to occur cannot be predicted accurately. Because stratification of water of different quality has developed over a period of 30 years, however, it seems unlikely that it could occur in a shorter period.

Irrigation Return

The use of water for irrigation tends to concentrate solutes in the water through evaporation and transpiration. The addition of chemical fertilizers to the water and fields to sustain greater production also contributes to the solute load. Fertilizers have been used in this area for many years. The nitrogen fertilizers applied have consisted of urea, liquid ammonia, ammonium nitrate, ammonium sulfate, sodium nitrate, anhydrous ammonia, and manure. Liquid ammonia injected into the irrigation-discharge lines is now the most widely used fertilizer in the study area. The addition of fertilizer affects ground-water quality because some of the applied nitrogen can be expected to appear in the ground water. Although nitrogen is consumed by crops and bacteria and adsorbs onto the sediments in both the soil horizon and in deeper, unsaturated materials, more nitrogen is generally made available to the crops than is utilized resulting in a buildup of nitrogen compounds with the excess reaching the saturated zone.

In the Santa Maria Valley, high concentrations of nitrogen exist in the ground water. The U.S. Environmental Protection Agency (1972, p. 73) recommends a limit of 10 mg/L NO_3-N (nitrate as nitrogen) for drinking water. Concentrations in excess of 40 mg/L were found in water from a few wells and concentrations in excess of 10 mg/L in water from a large number of wells encompassing a significant part of the valley (fig. 17).

A comparison of figure 17 with figures 13 through 16 consistently shows that in the area of potentiometric depression west of Santa Maria water of better quality and with lower nitrogen concentrations from the river system and from the City of Santa Maria Wastewater-Treatment Facility has been superimposed on water of poorer quality and with higher nitrogen concentrations. This ground-water-quality distribution closely conforms to the pattern of ground-water flow described earlier for the peripheral area of the zone of confined water; it also suggests that much of the high concentrations of dissolved solids, sulfate, and nitrogen accumulating in the area of confined water are related to return flow from irrigation.

Point Sources of Solutes

Point sources of wastewater discharge are contributing to the degradation of ground water within the valley. Water use for most purposes concentrates solutes and usually contributes to the degradation of a ground-water supply, provided percolation of the effluent occurs. The concentration of chemical constituents in areas either downgradient of or near point sources has produced mounds of recharge and a water quality compatible with the source. The quality of the source water, however, may be better than the receiving ground water with respect to some constituents. The effects and distribution of discharge of wastewater of poorer or significantly better quality are readily identifiable. The effect of wastewater on ground water of compatible quality with the receiving ground water is almost impossible to describe unless (1) a recharge mound is produced by the discharge or (2) an ion unique to the discharge can be identified and traced.

Wastewater is discharged from four domestic sewage-treatment facilities in the study area (fig. 3). The discharge and percolation of wastewater from the city of Santa Maria facility have resulted in both a pronounced recharge mound and an area of ground water with noticeably different chemical quality. With the exception of chloride (fig. 14), the quality of the wastewater is about the same as (figs. 13 and 16) or better than (figs. 15 and 17) the receiving water as defined by those chemical constituents mapped. For example, recharge of wastewater containing less than 10 mg/L nitrogen from the Santa Maria facility (table 8) to ground water with nitrogen concentrations greater than 10 mg/L has improved the quality of ground water with respect to this constituent (fig. 17). The lower nitrogen concentrations in the city's wastewater are mostly a result of the city's water-supply source being in an area where the ground water contains concentrations of nitrogen less than 10 mg/L. As noted earlier, the city of Santa Maria uses wells 9N/34W-3F1 and 10N/34W-34E2 (fig. 3), in the Orcutt-Santa Maria Airport area, for most of its needs. This water is lower in dissolved solids, calcium, magnesium, sulfate, and nitrogen, but it is higher in chloride than the ground water near the treatment-plant discharge.

A review of the percentage-reacting values (fig. 11) shows that water from wells in the Orcutt area has a different character from the water produced by most of the wells sampled in the basin. Water from wells west of the treatment facility and wastewater from the facility are similar in chemical characteristics. This suggests that the identity of the supply source is largely retained despite use by the city residents. Further evidence of this retention of identity is illustrated by a comparison of the ratio of calcium to sodium (fig. 18). Most wells in the valley have a calcium-to-sodium ratio of 2:1. This ratio is compatible with surface flow recharging the valley ground-water system from the Santa Maria River system. The calcium-to-sodium ratio of water from wells near the city of Orcutt, along Orcutt Creek, and near the Santa Maria Airport is 1:1. The calcium-to-sodium ratio of water from wells downgradient from the City of Santa Maria Wastewater-Treatment Facility is also 1:1.

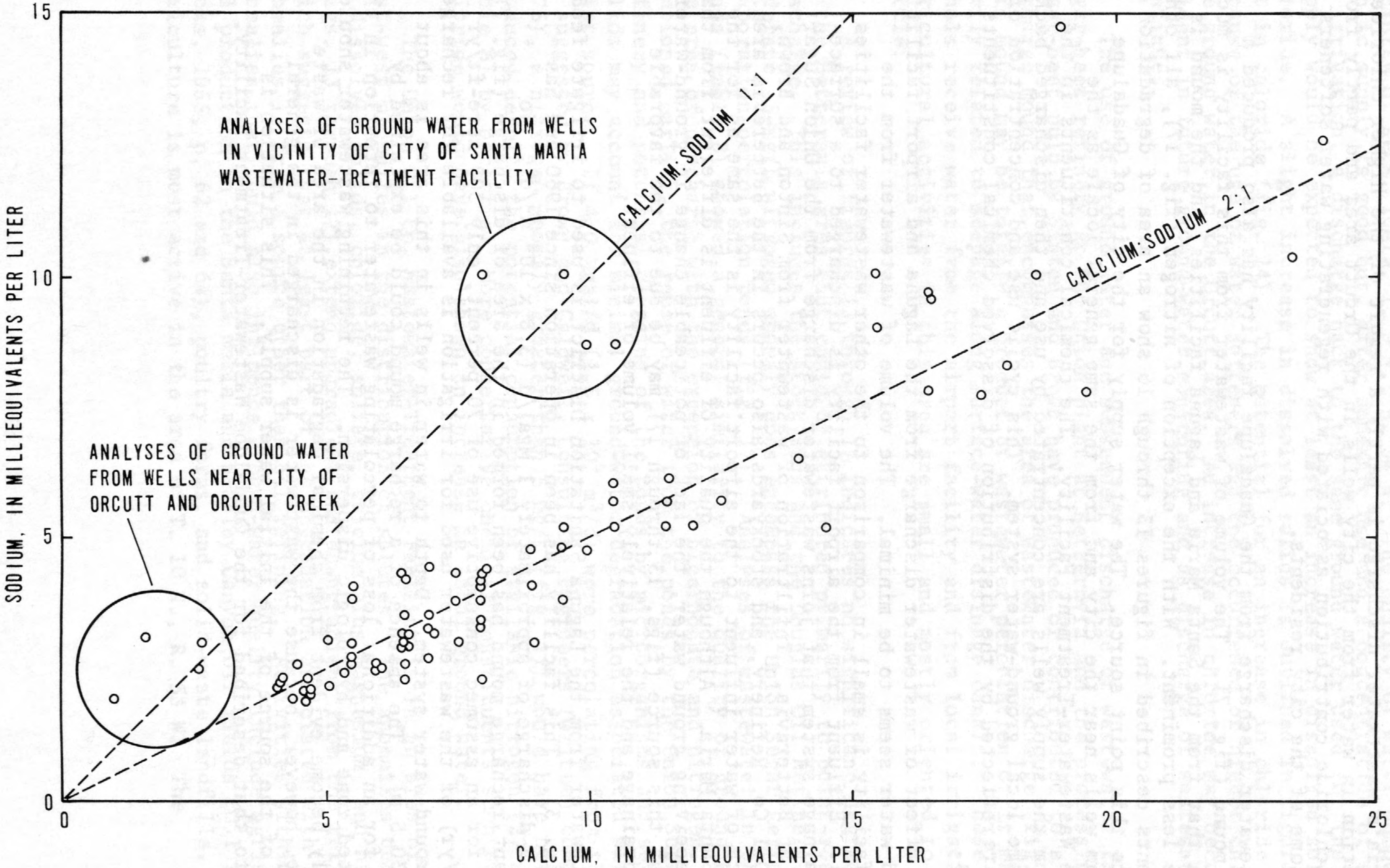


FIGURE 18.--Ratio of calcium to sodium in ground-water samples.

The increase in chloride concentration in ground water in the area of Santa Maria's wastewater discharge is partly a result of the higher chloride concentration in water from the city wells in the Orcutt area and partly from a sodium chloride contribution associated with regenerating water softeners used by some of the city residents.

Wastewater discharge from the Guadalupe facility has also produced a recharge mound (fig. 7). The volume of wastewater from this facility is much less than that from the Santa Maria and Laguna facilities, and the mound is therefore less prominent. With the exception of nitrogen (fig. 17), all other constituents described in figures 13 through 16 show an area of degradation related to this point source. The water supply for the city of Guadalupe comes from wells near the city and from the same general locale as the Guadalupe Wastewater-Treatment Facility. The chemical constituents in the water from the supply wells are concentrated by use and then discharged back to the same local ground-water system. This cyclic use and concentration of solutes are reflected by the distribution of dissolved chemical constituents in this area.

The effect of wastewater discharge from the Laguna and airport facilities on ground water seems to be minimal. The volume of wastewater from the airport facility is small in comparison to the other wastewater facilities (table 8). Effluent from the airport facility is discharged to a surface-water drainage system that joins wastewater discharge from the Union Sugar Refinery at Betteravia. Infiltration of wastewater from Sinton and Brown, Douglas Oil Co. Refinery, and stockyards also occurs in the Betteravia area. The source of water influent to the airport facility is the same as for the city of Santa Maria. Although the quality of effluent is different from that of the receiving ground water, the lack of noticeable change in ground-water quality at this source (figs. 13 through 17) may be due to the favorable surface drainage and the relatively small volume of effluent.

Wastewater from the Laguna Sanitation District is used to irrigate feed crops (fig. 3). This facility has been in operation since 1960 and has averaged a discharge of approximately 1 Mgal/d (3.8×10^3 m^3/d). No significant recharge mound has been formed in the area of discharge (fig. 7). Allowing for an assumed consumptive use of 70 percent, only 300 acre-ft/yr (0.4 hm^3/yr) of the wastewater used for irrigation is available for recharge to the ground-water system. Depth to water in wells in this area is about 100 ft (30.5 m). The absence of a recharge mound could be explained by allowing for an additional loss of percolating wastewater to retention in the unsaturated zone and hydrologic dispersion. The returning wastewater should eventually become evident from chemical degradation in the area of waste discharge, however, because the wastewater is discharged in the general location of the source of the initial water supply. This situation is similar to that described for the Guadalupe Wastewater-Treatment Facility.

Water supply for the Orcutt community is from wells in the general vicinity of secs. 10-15, T. 9 N., R. 34 W. The quality of water pumped for public supply is good but, after domestic use and a concentration of solutes by irrigation, a discharge back to the same ground water used for the initial supply would be expected to show at least an increase in dissolved solids and chloride. A slight increase in dissolved solids is outlined in figure 13 but not in chloride (fig. 14). The potential for an increase in chloride exists because of the use of water softeners and the occurrence of higher chloride in the ground water in the Orcutt area. An increase in chloride may become more evident in future ground-water monitoring and as discharge of wastewater continues.

The use of ground water and subsequent discharge of wastewater from the sugar-beet refinery at the Union plant at Betteravia and the processing of sugar-beet pulp by Sinton and Brown have produced or contributed to a definite recharge mound that encompasses the area of wastewater discharge (fig. 7). This mound may be totally a product of wastewater percolation or it may be partly related to seepage along surface-water drainage canals. These drainage canals receive water from the airport facility and from local irrigation. Agricultural activities in this area are small and mostly oriented to beef cattle.

A review of figures 13 through 17 indicates no significant degradation in the Betteravia area that could be attributed primarily to point-source discharge. This includes the stockyards and the Douglas Oil Refinery. A moderate, 5-mg/L nitrogen anomaly does encompass the Union Sugar Refinery evaporation-percolation ponds (fig. 17). Analyses of wastewater in these ponds (table 8) showed a general similarity to the quality of ground water in the area of discharge with the exception of bicarbonate and nitrogen. As mentioned earlier, the reuse of water from the ponds by the Union Sugar Refinery and potential clogging of the ponds by microorganisms and settling solids may account for minimal ground-water degradation associated with this point source. If 4.0 Mgal/d (1.5 x 10^4 m^3/d) were percolating from the ponds as suggested by Brown and Caldwell, Consulting Engineers (written commun., 1975), a nitrogen anomaly greater than 5 mg/L (fig. 17) would have been produced despite the potential consumption of available nitrogen (27 mg/L; table 8) by bacteria. More conservative chemical constituents such as chloride would have also shown an increase in local ground water.

The Union Oil Co. Wastewater-Treatment Facility is in an area of several east-west anomalies in the distribution of solutes. The anomalies described by dissolved solids, chloride, sulfate, calcium plus magnesium, and nitrogen (figs. 13 through 17) extend upgradient and downgradient from the refinery, which suggests that at least part of the degradation associated with the anomalies is from a source other than oil refining. Activities within these anomalies that could also influence ground-water quality include agriculture, oil production in the Santa Maria and Bradley Canyon oil fields (Oil Field Map Books, 1955, p. 62 and 64), poultry farms, and solid-waste landfills. Agriculture is most active in the area of T. 10 N., R. 33 W. The configuration of the 50-mg/L chloride contour in figure 14 suggests that oil production in Bradley Canyon is not contributing chloride to the degradation in T. 10 N., R. 33 W., and that the chloride anomaly is related to agriculture.

With the possible exception of a degrading influence on ground-water quality by supplementary or related activities in the areas of oil production, wastes from oil refining have been discharged to the ocean and into saline ground-water zones by well injection. Therefore, other than spills or sump percolation which were permitted in the past, oil refineries do not seem to have contributed significantly to ground-water degradation.

Stockyards, poultry farms, and golf courses also seem to have little impact on ground-water quality. A slight increase in chloride is evident about 2 mi (3 km) west of Orcutt, where a golf course is located (fig. 14).

No evidence was obtained that indicates the disposal of solid wastes to active landfills has, to the present (1976), influenced the ground-water quality. Inactive solid-waste disposal northwest of Santa Maria has influenced the concentration of chloride (fig. 14) and calcium plus magnesium (fig. 16). This landfill is now a city park. This increase could also be related to concentration of solutes by evaporation associated with water sprinklers at the park. Abandoned landfills near Guadalupe and the Santa Maria airport and adjacent to the presently active sites do not show similar increases.

Distribution of Nitrogen, Dissolved Organic Carbon (DOC), Detergents (as MBAS), Trace Elements, and Boron in Ground Water

The concentration of nitrogen in ground water in some areas of the basin is very high, as discussed earlier and as shown in figure 17, and according to the U.S. Environmental Protection Agency (1972, p. 73) use of water containing excessive concentrations may be injurious to public health. The source of the nitrogen is almost certainly the long-term application of fertilizers to irrigated fields. The three nitrogen anomalies centered within the 40-mg/L contours shown in figure 17 are related entirely or in part to the above source. Municipal and industrial wastewater also contributes some nitrogen to the ground water; however, this source is far less significant than fertilizer application. Use of wastewater for irrigation of feed crops makes available usable plant nutrients such as nitrogen and phosphorous and prevents part of them from returning to the ground-water system.

A 10-mg/L anomaly northeast of Santa Maria (fig. 17) is not in an agricultural area and is adjacent to the Santa Maria River. The recharge from the river should displace downgradient any one-time nitrogen waste discharge. Fertilizer applied to grass at a city of Santa Maria recreational facility (Suey Park) could be the source for this small and low-concentration anomaly.

The nitrogen anomaly contoured northwest of Betteravia (fig. 17), previously related in part to the long-term application of fertilizers to irrigated fields, is also due in part to a nitrogen concentration of 50 mg/L in water pumped from well 10N/35W-22G3. This well is at a plant that distributes pesticides, herbicides, and liquid fertilizers. Dispersion and movement of a nitrogen spill at this plant, sufficient to cover the area encompassed by the entire anomaly indicated by the 20-mg/L nitrogen contour without significantly influencing ground-water gradients, is doubtful. This plant may be contributing to nitrogen degradation, but nitrogen from widespread agricultural activity in this same area probably also is contributing to the anomaly.

Analyses of ground water for MBAS and DOC showed very low concentrations with no direct relation either to point or nonpoint sources. MBAS is an abbreviation for methylene-blue active substances which represents the concentration of synthetic detergents in water. All values observed were 0.5 mg/L or less. The U.S. Environmental Protection Agency (1972, p. 67) recommended limit for detergents is 0.5 mg/L. A concentration of 0.5 mg/L was present in water from wells 10N/35W-5J1 and 14G1 (fig. 3). Neither well by itself has any direct relation to a major point source. The detergents in these two wells may be from local septic tanks.

Detergents are commonly found in municipal and industrial wastewater and in ground water affected by percolation of the wastewater. Most detergents used today are of the LAS (linear alkaline sulfonates) type and are readily biodegradable when exposed to sunlight or oxygen for 120 hours at 25°C (Halvorson and Ishaque, 1969, p. 571-576). The lack of significant MBAS concentrations in ground water near areas of wastewater discharge may be related to the use of LAS-type detergents that would have been degraded during exposure in evaporation ponds and sprinkler irrigation on feed crops. A study at Barstow, Calif. (Hughes, 1975, p. 26), showed that wastewater containing detergents applied to a golf course resulted in an almost total removal of the detergents in the effluent by adsorption or as a nutrient to the grass.

DOC (dissolved organic carbon) is a constituent used to indicate the presence of organic compounds soluble in water. This constituent was successfully used in the Barstow study (Hughes, 1975), but difficulties in laboratory analytical accuracy have prevented its satisfactory application to mapping of an areal distribution of DOC in the Santa Maria area. However, unusually high DOC values of 12 and 13 mg/L were obtained for water from wells 9N/33W-10C1 and 10N/33W-30K1 near Bradley Canyon; a particularly high value of 44 mg/L was obtained from water in the Union Sugar Refinery evaporation-percolation ponds. Organic compounds are typically associated with oil production and sugar refining. Although a very high DOC concentration was observed in the Union Sugar Refinery ponds, water from wells downgradient from and adjacent to the ponds had DOC values less than 2.0 mg/L, once again indicating that, to date (1976), the effect on ground-water quality by these ponds has been minimal.

The results of analyses of ground water for trace elements are given in Hughes and Freckleton (1976). With the exception of boron and iron, which are a part of the standard water analysis, wells used to sample ground water for trace elements were restricted to the general vicinity of active or abandoned solid-waste landfills. The concentration and areal distribution of trace elements were sufficiently erratic to make it difficult to relate their distribution directly to solid waste deposited in the landfills.

Concentrations of mercury, zinc, lead, arsenic, chromium, copper, manganese, molybdenum, selenium, and vanadium in ground water are common derivatives of the type of solid wastes deposited in landfills. For example, zinc is used extensively in industry; lead is found in gasoline; arsenic is a major constituent in pesticides and is present in some detergents; copper is also extensively used in industry and is found in herbicides and pesticides; manganese is used in steel alloys, batteries, and glass; molybdenum is present in fertilizers, glass, and electrical equipment; selenium is used in insecticides, rubber, and paints; and vanadium is used in photography, dyes, metallurgy, and glass (California Water Resources Control Board, 1963; Hem, 1970).

The low solubility of carbonates and hydroxides of some metals, the potential for chemical reaction with more prevalent compounds or ions to form compounds of low solubility such as iron [$Fe(OH)_3$ + As] and sodium [$Na(BO_2)_4$], retention of trace metals in the lattice structure of organic compounds, and the subsequent adsorption of the organic compounds onto sediments all tend to immobilize trace elements brought into the ground-water system. It is difficult to associate these trace elements with a point source. It must also be kept in mind that all these elements occur in trace quantities in nature. Surface water analyzed from the Cuyama and the Sisquoc Rivers near Garey contained cobalt and lead concentrations of 50 and 100 µg/L (micrograms per liter). The U.S. Environmental Protection Agency (1972, p. 70) recommends a limit of 50 µg/L for lead in drinking water. All values for cobalt and lead found in ground water were less than 2 µg/L. Unusual concentrations of 580 and 320 µg/L for zinc were found in ground water from wells 10N/33W-7R2 and 11N/34W-33J1. All other ground-water samples had zinc concentrations of less than 20 µg/L. Concentrations of manganese, vanadium, and selenium were also high, but no pattern of distribution could be discerned.

The distribution of boron in ground water showed a definite pattern in areas downgradient from the City of Santa Maria Wastewater-Treatment Facility and in the area of the Guadalupe Wastewater-Treatment Facility. The pattern of distribution of boron (>300 µg/L) near these facilities is closely similar to the distribution of chloride (fig. 14). Boron is always present in domestic wastewater because it readily passes through the digestive tract and is present in high concentrations in urine. Boron is found in the milk of cows, is a constituent of cleaning agents and detergents, and is in some gasoline (Hem, 1970, p. 187). A boron concentration of 620 μg/L was present in ground water from wells 10N/35W-3N1 and 8E3 and 530 μg/L from well 10N/35W-22G3. Wells 10N/34W-17D1 and 18L1 and 10N/35W-13H1 and 23G1 had boron concentrations of 450, 470, 470, and 480 μg/L. California Water Resources Control Board (1963, p. 147) indicated sensitive crops such as artichokes and grapes can tolerate no more than 500-1,000 μg/L boron. Both of these crops are grown in the study area. Artichokes are more vulnerable because of their location with respect to the distribution of these high concentrations.

SOLUTE BALANCE

The development of a solute balance for any basin is a function of the accuracy of data and can vary greatly from actual conditions. The accuracy is, however, relative to the objectives; the primary purpose of this study was to evaluate the effects of point-source discharge on ground-water quality. Therefore, the introduction and evaluation of a solute balance in this report was to demonstrate the solute-load impact of point sources relative to the total solute load from all other sources.

A solute-balance equation for a hydrologic unit can be written

$$W_i - W_o \pm \Delta W_s = 0$$

The three W terms represent total weight of solute entering the system (W_i), weight leaving (W_o), and change in storage in the unit (W_s). Each of these terms can be expressed as the product of a concentration term C and a volume Q, when the weight represents something held in solution.

$$C_iQ_i - C_oQ_o \pm \Delta C_s \Delta Q_s = 0$$

A complete inventory of solutes entering and leaving a system requires consideration not only of dissolved material in the inflows and outflows but also the quantities of solids added by such items as fertilizer, soil-treatment chemicals, water-softener salt, and quantities extracted and shipped out in agricultural crops. The storage item must also include quantities of ions precipitated as sparingly soluble compounds especially calcium carbonate or gypsum, as well as the necessary increase in solute concentration of residual water when total amount of water in storage is decreased. Where pertinent, quantities incorporated in plant and animal tissues that are removed from the basin should also be considered.

Information available for the Santa Maria Valley is insufficient for a quantitative estimate of all the pertinent factors in the solute-balance equation. Processes which relate only to the storage term have a strong influence on the concentration of solutes in the stored water as has already been noted and shown in figures 13-17. In general, the impact of water use in the basin will tend to decrease outflow volume and increase concentrations of solutes in both the outflow water and the water in storage.

An indication of the impact of activities in the basin that involve recycling can be obtained by estimating the annual water volumes and solute loads involved. If it is assumed that 100,000 acre-ft/yr (123 hm^3/yr) is the volume of water pumped for irrigation (fig. 2) with an average 1,000 mg/L dissolved solids, the annual solute tonnage circulated is about 135,000 tons/yr (1.2×10^8 kg/yr). If 70 percent of the water is consumed by evapotranspiration, the potential concentration of the residual water would be more than 3,000 mg/L. Probably much of the solute load would be precipitated in the soil and subsoil before this concentration was reached. However, the solute tonnages in this estimate overshadow the annual quantities involved in the point sources that have been discussed earlier. It is estimated that the weight of solutes recycled by municipal and industrial uses is 13,000 tons (1.2×10^7 kg) per year, or less than 10 percent of the agricultural total. The concentrations of solutes in the water returned (table 8) also are much lower than the potential concentration of irrigation-return flow.

Because the movement of solutes through the unsaturated zone is slow and because sparingly soluble minerals may be deposited from the highly concentrated irrigation-return seepage, the full impact of irrigation use on water quality may be slow to develop. Upward trends since 1955 for dissolved concentrations of sulfate and chloride in water from some wells (fig. 12) illustrate the effect.

The degradation of ground water by point sources of waste discharge has been small when compared to that from other uses in the valley. This is not to suggest that these sources can or should be ignored. Discharge of wastes from point sources has thus far been acceptable only because of the location of the disposal sites with respect to public-water supplies, the careful monitoring of the wastes by State regulatory agencies, and the degree of treatment received by the wastes. The extent to which waste discharges will be acceptable in the future will depend largely on the accumulative solute load and the change in concentration of individual constituents in the wastewater discharge from point sources. As the urbanized area increases, as the chemical nature of domestic and industrial wastes changes, as the total accumulation of solutes in ground water associated with years of repeated use increases, and as the hydrologic balance becomes increasingly more difficult to maintain in terms of dilution and seawater intrusion, the needs for monitoring of both the waste discharge into and from the point sources and the effect of the quality of this discharge on ground water will become increasingly critical.

GROUND-WATER QUALITY MONITORING PROGRAM

The following criteria would be of value in selecting or drilling wells to be used to sample and monitor changes in ground-water chemistry:

1. Wells located in a position to be affected hydrologically by the waste discharge.

2. Each well selectively perforated in either the shallow or deep zone, not both.

3. Chemical analyses guided by the nature of waste to be monitored.

4. Existing wells selected on the basis of a history of sampling and chemical analysis.

The availability of wells that meet the above criteria will influence the monitoring program. The importance of each criterion can be weighed against the availability of the wells. To design a meaningful monitoring program, additional observation wells might be needed to supplement existing wells.

Not included in the above criteria is an appraisal of changing ground-water flow patterns that result from continued or sporadic pumping and recharge and from natural seasonal hydrologic changes. Both are critical because the quality of ground water at a site is affected by the location and magnitude of water withdrawals throughout the area.

Changes in ground-water flow can be identified and evaluated by a ground-water-level measurement program. Water levels in a few select wells can be measured annually in the nonpumping season (December-April). A major water-level measuring program performed every 5 years or less would be beneficial. Water samples collected during the pumping season (May-November) would best indicate changing ground-water quality.

The cost of a ground-water-quality monitoring program can be minimized by analyzing only for those constituents that would best reflect the influence of wastewater discharge. For example, concentrations of dissolved solids, chloride, sulfate, nitrogen as ammonia, nitrite, and nitrate, and organic carbon would best determine how ground water is being affected by domestic wastewater. Selected cations such as calcium and magnesium should be included if funding permits. Wastewater from feedlots will generally be high in nitrogen. Organic carbon and chloride can be used to monitor the effects of oil production and refining. If methods for determining hydrocarbons are improved, these constituents could be extensively used to evaluate effects on ground water of oil production and refining and the waste discharge from sugar-beet processing. Hydrocarbon analyses of the wastewater could identify the characteristics of a source, and subsequent analyses of ground water could reflect the impact and distribution of the wastewater discharge.

Wells that might be considered for ground-water sampling include but are not limited to:

10N/34W-17D1
18L1
10N/35W-7F1
8E2
8E3
10N/35W-13H1
14G1
16M1
10N/35W-16M2
23P1
36R1

Sampling of wells 10N/35W-12H1 and 22G3 would monitor the very high nitrogen concentrations observed during this study.

Results of the monitoring program, if reviewed frequently, would ensure that modifications in the sampling and analysis schedule required by changing conditions would be accomplished in a timely fashion.

SUMMARY AND CONCLUSIONS

Ground water is the principal source of water used in the Santa Maria Valley. Most of the water is pumped from unconsolidated sedimentary deposits. Natural recharge to these deposits is from infiltration of runoff in the Santa Maria River system. The Santa Maria River traverses the valley from east to west emptying into the Pacific Ocean. Since 1930, the volume of water recharging the ground-water basin from the river system, from irrigation return water, and from other sources has been less than the volume pumped. Pumpage has exceeded recharge by about 10,000 acre-ft/yr (12.3 hm^3/yr). Continued pumping in excess of the recharge rate may eventually lower the potentiometric surface below sea level making possible seawater intrusion into existing fresh-water zones.

In some areas of the valley, the quality of ground water has deteriorated during recent years. The deterioration is most pronounced in the area of confined ground water and is related to the concentration of solutes by use and reuse of ground water for irrigated agriculture. The application of fertilizer to irrigated land directly or by injection of liquid ammonia into irrigation lines in quantities greater than can be utilized by crops has resulted in high concentrations of nitrogen in ground water. Several areas within the valley have nitrogen concentrations of as much as 50 mg/L, and most of the water pumped from aquifers in the area of confined water has nitrogen concentrations in excess of 10 mg/L. The U.S. Environmental Protection Agency (1972, p. 73) recommends a limit of 10 mg/L of nitrate as nitrogen (NO_3 as N) for public drinking-water supplies.

Point-source waste discharge to ground water occurs from four municipal and industrial wastewater-treatment facilities, a sugar refinery, several stockyards, two golf courses, poultry farms, and solid-waste landfills. Degradation of ground-water quality by percolation of wastewater from these sources seems to be less significant than the degradation resulting from irrigation return. Approximately 10 times as much ground water is pumped for use in agriculture as for all other uses.

The solute contribution from irrigation return is approximately 135,000 tons/yr (1.2 x 10^8 kg/yr). The solute contribution from point sources is estimated at 13,000 tons/yr (1.2 x 10^7 kg/yr), or less than 10 percent of the contribution from irrigation.

The general direction of ground-water flow in the Santa Maria Valley is from east to west with ground-water discharge to the ocean. In 1975 the ground-water gradient during the nonpumping season (December-April) was approximately 35 ft/mi (6.6 m/km) east of California Highway 101 and 4.5-5.0 ft/mi (0.85 to 0.95 m/km) west of the highway.

The design of a water-quality monitoring network should consider the following factors: (1) Locations of wells should reflect the hydrologic effects of waste discharge; (2) individual wells should be perforated in either the shallow or deep aquifer but not in both; (3) chemical constituents and properties monitored should be guided by nature of waste; (4) existing wells selected for monitoring are most useful if there is some background quality information.

Recharge to and discharge from the ground-water system has produced several mounds and depressions in the potentiometric surface. The most significant change in the potentiometric surface is near the eastern limit of the area of confined water. Percolation of water from the Santa Maria River and from the City of Santa Maria Wastewater-Treatment Facility has created two recharge mounds separated by a pumping depression formed by withdrawals from sand and gravel zones interbedded with clay in the area of confined water. This situation has resulted in ground-water flow from irrigated lands in the area of confined ground water into the depression and recharge by this poor-quality water of the deeper zones in the area of confined water. Recharge of these deeper zones from the Santa Maria River and the City of Santa Maria Wastewater-Treatment Facility occurs simultaneously. The quality of water from these latter sources is, however, lower in nitrogen and sulfates than the receiving ground water. The net result of this complex flow system involving water of different quality is to degrade the water in the deeper interbedded sand and gravel in the area of confined water. The cyclic use of this water for agriculture will eventually increase solute and nitrogen concentrations in all horizons in the area of confined water. At present (1976) a few isolated zones of good-quality water do exist in the area of confined water.

Most of the situation described pertaining to ground-water degradation in the Santa Maria Valley has not resulted from neglect or from misuse of wastewater. The degradation has resulted from man's presence and his use of water to produce needed commodities. This situation is not unique to the Santa Maria Valley. An apparent solution is to use the available water supplies as effectively as possible and accept certain rates of degradation until either water can be imported from areas where it is both plentiful and of very good quality or technology improves sufficiently to improve the quality of local water supplies. To slow the rate of degradation, it is essential that the system be understood and that efforts be made to minimize such effects as loss of fertilizer nitrogen to ground water and the contamination of ground water with toxic substances that can make it unusable.

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