GROUND-WATER QUALITY IN THE SANTA RITA, BUELLTON, AND LOS OLIVOS HYDROLOGIC SUBAREAS OF THE SANTA YNEZ RIVER BASIN, SANTA BARBARA COUNTY, CALIFORNIA

By Scott N. Hamlin

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CONVERSION FACTORS

For those readers who prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Inch-pound	Multiply by	SI
acres	0.4047	hectares
acre-ft (acre-feet)	0.001233	cubic hectometers
ft (feet)	0.3048	meters
ft^3/s (cubic feet per second)	0.02832	cubic meters per second
gal (gallons)	0.003785	cubic meters
$(gal/d)/ft^2$ (gallons per day per square foot)	0.0407	meters per day
gal/min (gallons per minute)	0.00006309	cubic meters per second
inches	25.40	millimeters
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

Degrees Fahrenheit are converted to degrees Celsius by using the formula:

$$\text{Temp } °C = (°F-32)/1.8$$

<u>Abbreviations used</u>

mg/L - milligrams per liter.
mL/L - milliliter per liter.
µS/cm - microsiemens per centimeter at 25°C.

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ABSTRACT

Ground-water quality degradation in the upper Santa Ynez Valley in Santa Barbara County, California, has resulted from a combination of natural and anthropogenic causes. The semiarid climate coupled with uneven distribution of rainfall has limited freshwater recharge and caused salt buildup in water supplies. Tertiary rocks, specifically the Monterey Shale, are also sources of mineralized water. Agricultural activities (irrigation-return flow containing fertilizers and pesticides, cultivation, feedlot waste disposal) are a primary cause of water-quality degradation. A shifting emphasis to urban development, which also causes water-quality degradation (introduced contaminants, wastewater disposal, septic system discharge, and landfill disposal of waste), has imposed stricter requirements on water-supply quality. A well network was designed to monitor changes in ground-water quality related to anthropogenic activities and natural factors. Information from this network may aid in more efficient management of the ground-water basins as public water supplies.

Ground-water management alternatives are centered around three basic procedures. The first is to increase freshwater recharge to the ground-water basins by conjunctive surface- and ground-water use and by surface-spreading techniques. The second is to optimize ground-water discharge by efficient temporal and geographic distribution of pumping. The third is to control and reduce sources of ground-water contamination; this may be accomplished by regulation of wastewater quality and distribution, and, preferably, by exportation of wastewaters from the ground-water basins.

INTRODUCTION

Location and General Features

The Santa Ynez River basin encompasses about 900 mi^2 in the southern part of Santa Barbara County, Calif. The study area is contained within the Santa Rita, Buellton, and Los Olivos hydrologic subareas of the Santa Ynez River basin (fig. 1). The basin is drained by the Santa Ynez River. The Santa Ynez River basin is separated from the coast by the narrow Santa Ynez Mountains (altitude, 2,000-4,000 feet), which are part of the Transverse Ranges. The basin is bounded on the north by the Purisima Hills and the San Rafael Mountains (altitude, 4,000-6,000 feet). Vegetation in the areas of high topographic relief consists mainly of brush interspersed with chaparral, live oak, and grassland. Agriculture (chiefly irrigated) and ranching are major activities in the area.

The climate is Mediterranean with hot, dry summers and cool, wet winters. Practically all precipitation occurs from November through April, and nearly 75 percent of the annual flow in the Santa Ynez River is concentrated in the period February through April. According to Upson and Thomasson (1951, p. 9), about two-thirds of the precipitation in the valley as a whole occurs in the Headwater subarea. Average annual precipitation for the period 1868-1976 at Santa Barbara is 17.67 inches, and for the Santa Ynez River basin it is probably 1 to 2 inches less. Average precipitation on the crests of nearby mountains is probably around 30 in/yr (Singer, 1979).

Problem

Ground water in the Santa Ynez River basin, generally of only fair quality for most uses, is adversely affected by urban and agricultural development. This rapidly developing area is primarily dependent on ground-water sources for irrigation and municipal use. Previously oriented toward agriculture, development now centers in urban areas. Urban use imposes stricter requirements on water quality. Consequently, the quality of water resources in the area has become a matter of increasing concern.

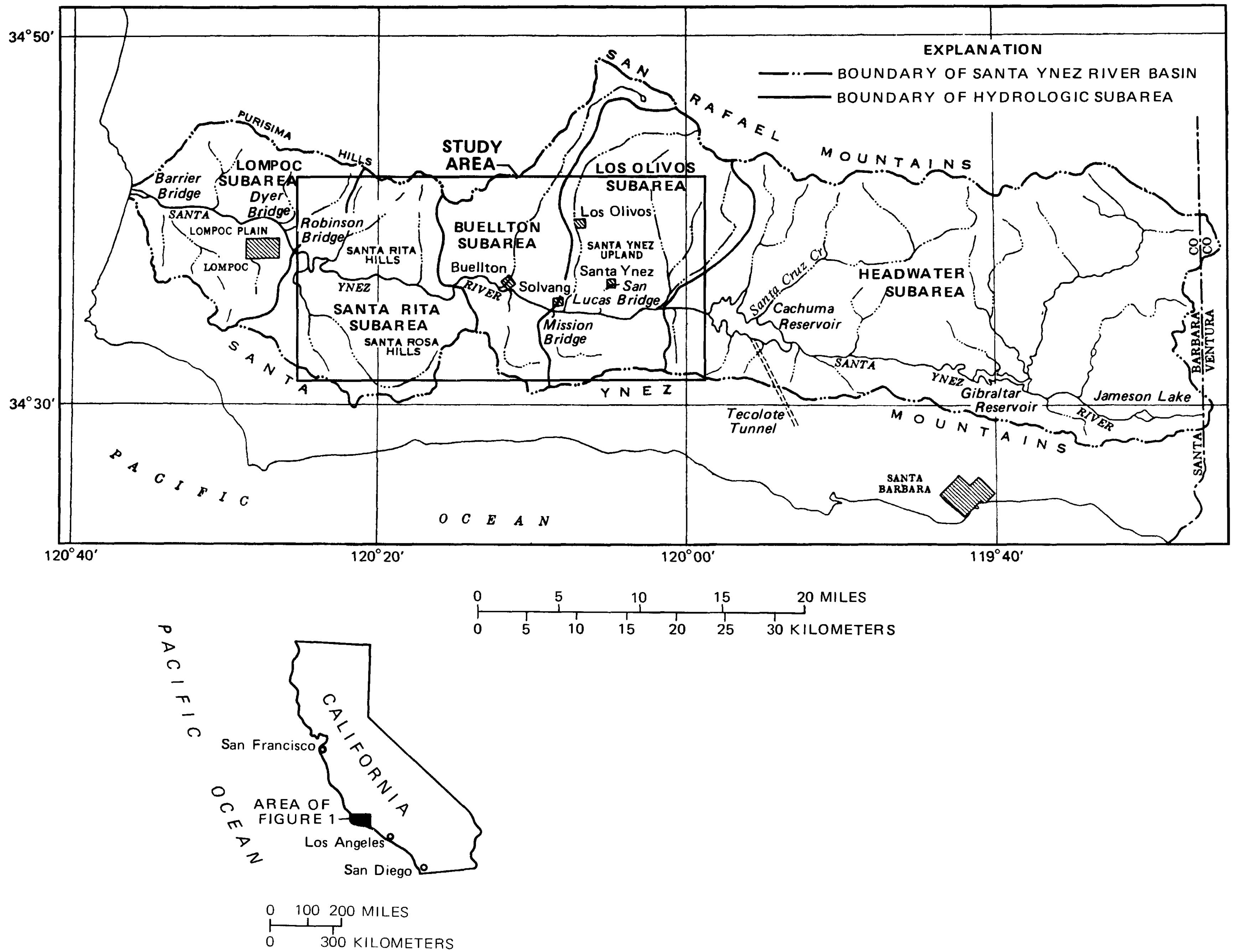


FIGURE 1. — Hydrologic subareas in the Santa Ynez River basin. (modified from Wilson, 1959)

Purpose and Scope

The primary objective of this study is to evaluate the ground-water quality in the Santa Rita, Buellton, and Los Olivos subareas of the Santa Ynez River basin. This is accomplished by (1) describing the hydrologic framework in terms of recharge, discharge, and flow; (2) defining ground-water quality, variation, and influencing factors; and (3) designing a ground-water monitoring network. Determination of factors that influence or control water quality provides the basis for preventive and restorative management of the ground-water resource.

The study area includes the larger parts of the Santa Rita, Buellton, and Los Olivos subareas (fig. 1), an area of roughly 66 square miles. Water-level data at specific wells were reviewed for the period 1942-80 and areal water-level surveys evaluated for 1945, 1964, 1972, and 1980. Ground-water-quality data from several hundred wells were reviewed and compiled for the pre-1970 and 1980-81 periods.

Approach

Previously assembled water-level and water-quality data were analyzed to determine variations in ground-water supply and quality within the Santa Ynez Valley. Well logs were examined and hydrographs were prepared to determine trends in long-term water-level fluctuation. Water-level contour maps and a water-level change map were then constructed. Historical water-quality data were used in the preparation of a pre-1970 dissolved-solids map. Maps for major ionic constituents and nutrients were prepared from data collected in 1980 and 1981. Ground-water hydrology and quality were then correlated to land-use activity.

Previous Work

Previous ground-water studies of the Santa Ynez River basin had little emphasis on water quality. Reports by Upson and Thomasson (1951) and by Wilson (1959) are concerned mainly with the geohydrologic framework of the basin, particularly of the Lompoc, or lower Santa Ynez River basin area. LaFreniere and French (1968) and Singer (1979) described the ground-water resources in the upper part of the basin.

Ground-water quality in the lower Santa Ynez River basin (Lompoc area) is emphasized in a report by Miller (1976) and is discussed by Evenson (1965). There are numerous consultants' reports on site-specific water problems, mainly related to wastewater discharges.

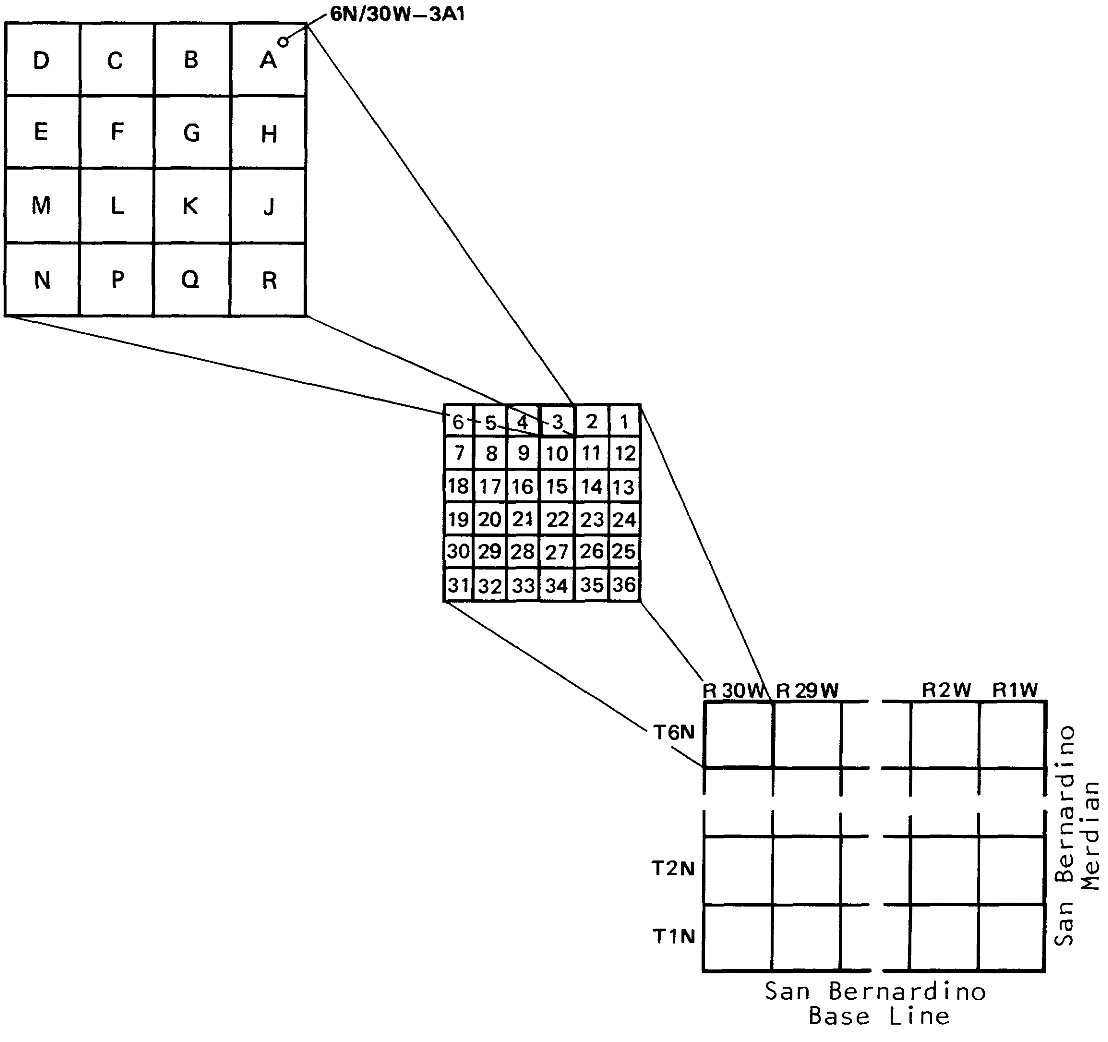
Dibblee (1950) has provided the most extensive information on the geology; however, geology is described briefly in the previously mentioned reports.

Acknowledgments

Appreciation is expressed to the many organizations and people who contributed data and information for this study, including Buellton Water District; Solvang Water District; Santa Ynez Water District; State and County Health Departments; and local residents and farmers. William Meece of the California Regional Water Quality Control Board, Central Coast Region, provided a land-use map for the area.

Well-Numbering System

Wells are numbered according to their location in the rectangular system of subdivision of public land. Where the land has not actually been surveyed, appropriate subdivisions are projected. A well number, such as 6N/30W-3A1, has two parts. The part that precedes the hyphen indicates the township and range (T. 6 N., R. 30 W.). The numbers following the hyphen indicate the section (sec. 3); the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram; and the final number is the serial number in the particular 40-acre tract. Accordingly, well 6N/30W-3A1 is the first well listed in the NE¼NE¼ sec. 3, T. 6 N., R. 30 W., San Bernardino base line and meridian.



GROUND-WATER GEOLOGY

In this report the geologic units of the Santa Ynez River basin have been grouped into two categories, based on their water-bearing characteristics: Consolidated rocks and unconsolidated deposits.

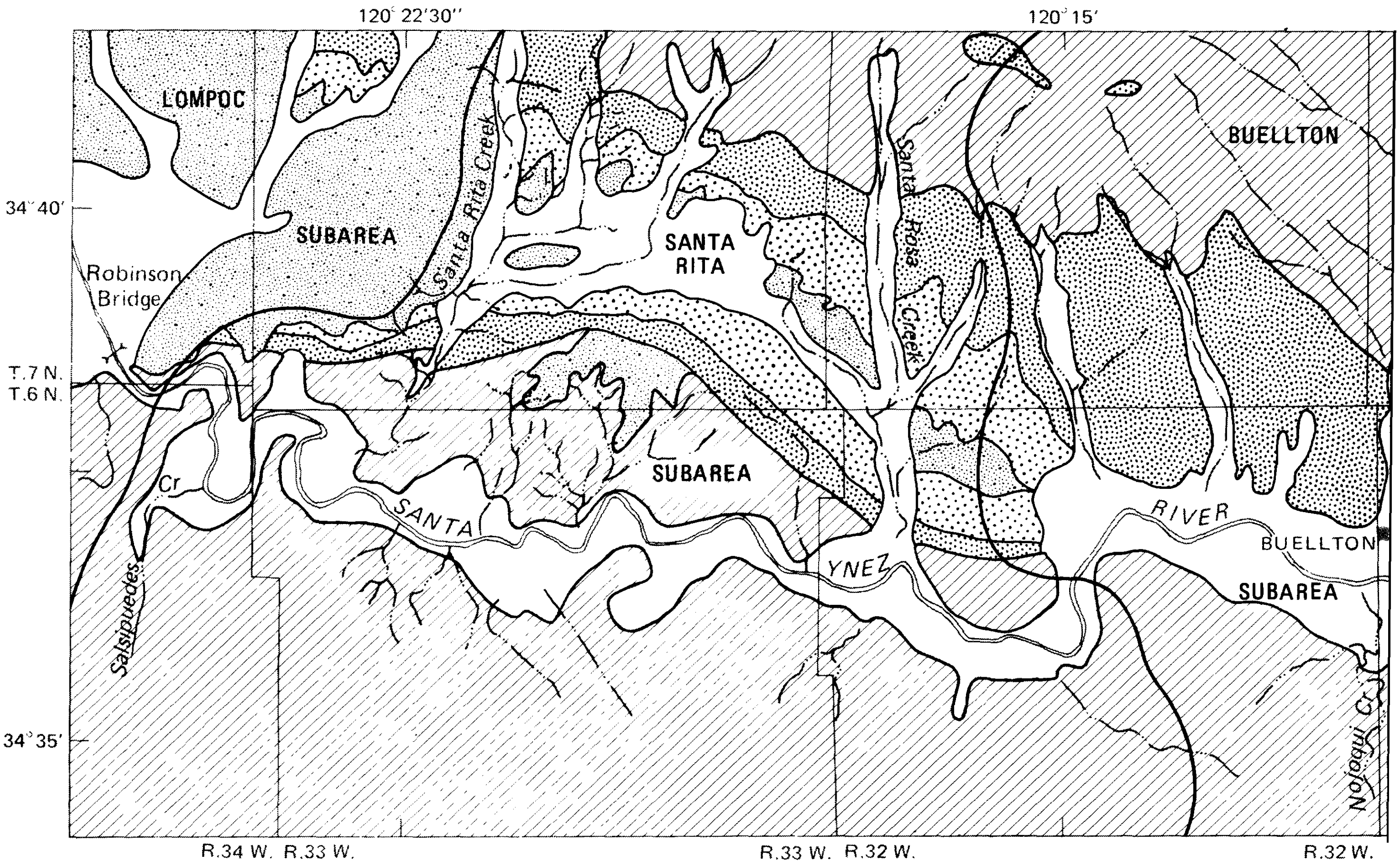
Consolidated rocks of Tertiary age underline the unconsolidated deposits and compose the surrounding hills. These consolidated rocks are marine in origin and consist of relatively impermeable fine-grained deposits of the Foxen Mudstone, Sisquoc Formation, and the Monterey Formation. Wells in these formations yield only small amounts of water from fracture zones and slightly permeable sandstones.

Unconsolidated deposits of Pliocene and younger age consist chiefly of sand, gravel, silt, and clay. Wells in unconsolidated deposits yield from several hundred to more than 1,000 gal/min (Miller, 1976). Only unconsolidated deposits are considered in quantitative evaluation of ground-water reserves. Primary ground-water basins in the Santa Ynez River basin are composed of alluvium along the tributaries of the Santa Ynez River, and the main river has several basins of limited volume composed of younger Holocene alluvium.

Main Water-Bearing Units

Water-bearing units in the study area are shown in figure 2. The Pliocene Careaga Sand, the Pliocene and Pleistocene Paso Robles Formation, the Pleistocene Orcutt Sand and terrace deposits, and the Holocene alluvium and river deposits are the most important hydrologically. Most ground water is pumped from shallow horizons. As water demand has increased, the trend has been toward deeper wells tapping the Paso Robles Formation. The Careaga Sand previously has been avoided as a water source because of well-sanding problems and its greater depth. Figure 3 shows the various formations across the Santa Ynez upland ground-water basin.

The Careaga Sand is a massive body of fine- to coarse-grained marine sand that ranges in thickness from 450 to 1,000 feet. It is overlain by the Paso Robles Formation (Upson and Thomasson, 1951, p. 32). In places, it is locally faulted against the Monterey Formation. The abundance of very fine, well-sorted loose sand has resulted in the well-sanding problem previously mentioned. However, improved well-completion techniques have resulted in yields of several hundred gallons per minute or more (LaFreniere and French, 1968). Generally, the unit thins from east to west. Where the Paso Robles Formation has been eroded through, the Careaga Sand is overlain directly by alluvial deposits of Holocene age. The Careaga Sand has an average permeability of about 70 $(gal/d)/ft^2$ (LaFreniere and French, 1968, p. 10).



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

EXPLANATION

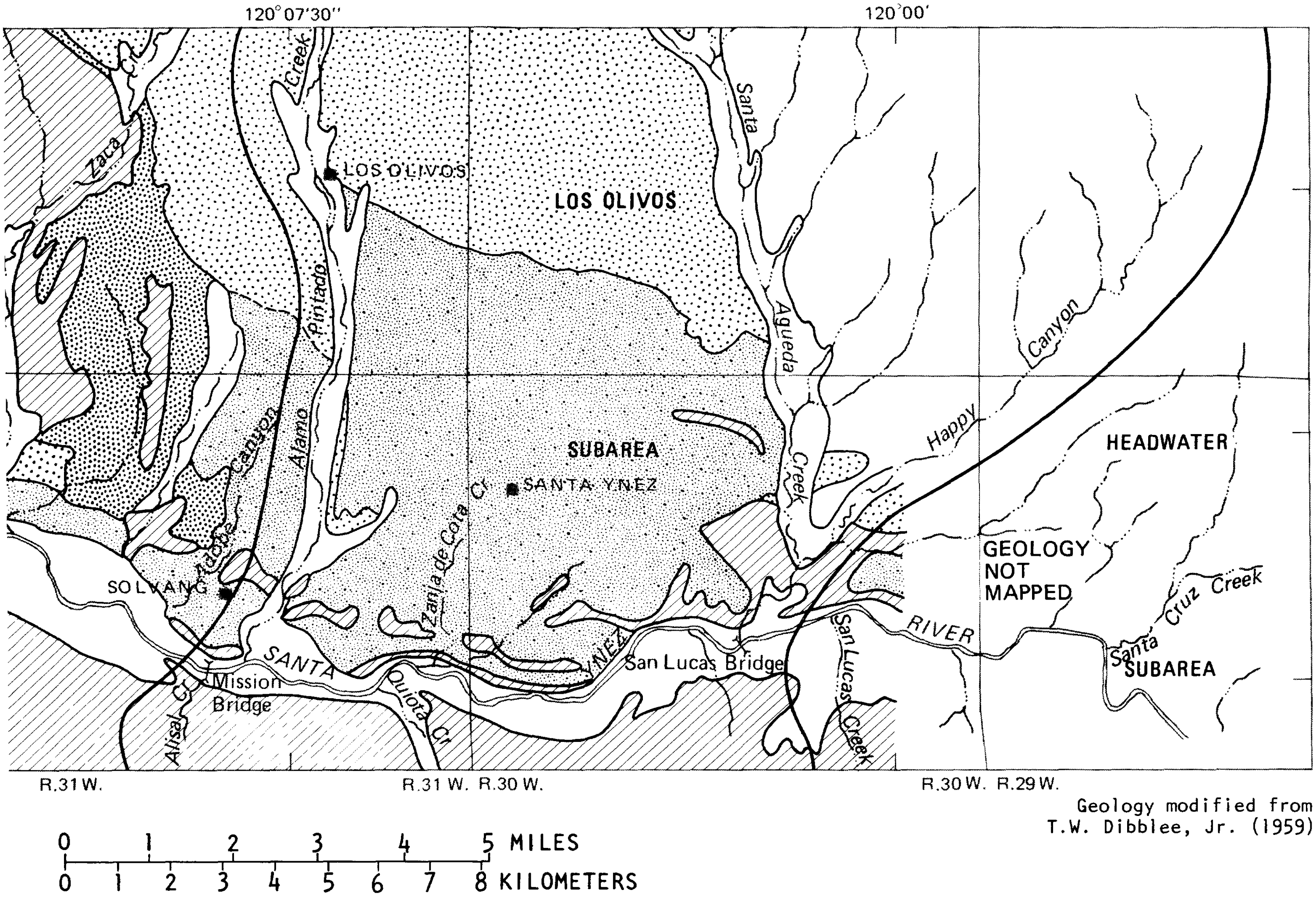
QUATERNARY
- Alluvium
- Orcutt Sand and terrace deposits
- Paso Robles Formation

TERTIARY
- Careaga Sand
- Consolidated rocks (includes Foxen Mudstone, Sisquoc Formation, and Monterey Shale)

CONTACT-Dashed where approximately located

HYDROLOGIC SUBAREA BOUNDARY

FIGURE 2.-Geologic map



Geology modified from
T.W. Dibblee, Jr. (1959)

of the study area.

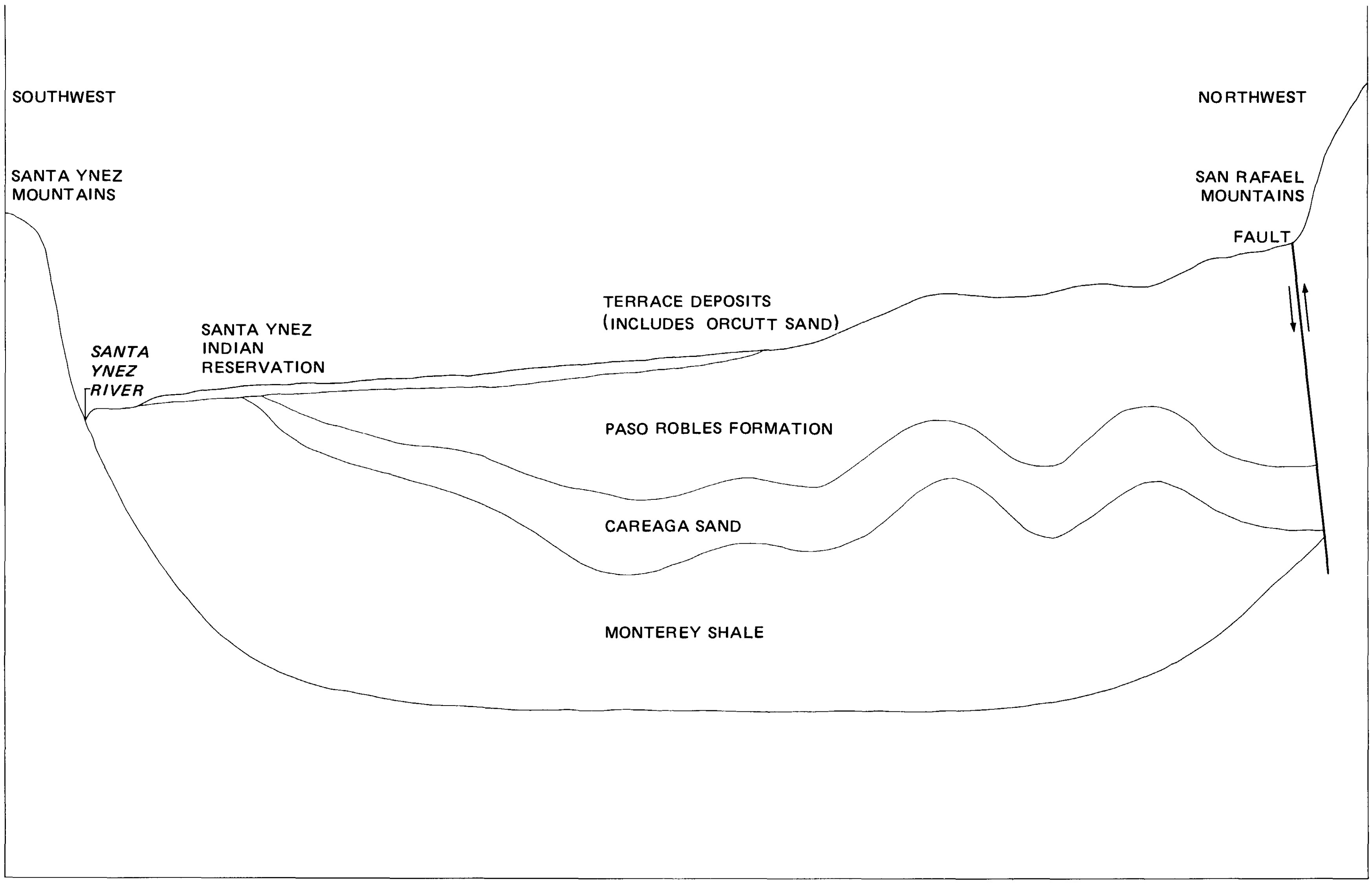


FIGURE 3. – Diagrammatic section across the Santa Ynez upland ground-water basin (modified from Singer, 1979).

The Paso Robles Formation is a nonmarine, heterogeneous deposit composed of coalescing alluvial fans laid down by streams flowing from the Santa Ynez and San Rafael Mountains. It is thickest in the northeastern part of the Santa Ynez subarea near the fault contact with older consolidated rocks (Upson and Thomasson, 1951, p. 35). The formation is as thick as 700 feet in the Santa Rita Valley, thinning to the west. Irrigation wells in the Santa Rita Valley derive much of their water from the Paso Robles Formation. Upson and Thomasson (1951, p. 38) reported that wells tapping this formation in the Santa Ynez River basin yield from 200 to 1,000 gal/min. The formation underlies the large foothill area north of the Santa Ynez upland where it receives rain infiltration and constitutes a large ground-water reservoir.

The Orcutt Sand is a body of unconsolidated well-sorted sand to clayey sand containing scattered pebbles or stringers of pebbles. In the Santa Ynez River basin it occupies the central part of a trough between the Santa Rita Hills and the Purisima Hills and extends east to the divide between Santa Rita and Santa Rosa Creeks. Its greatest known thickness is about 200 feet in the central part of the area. The Orcutt Sand contains considerable loose, coarse sand and a large quantity of water. However, numerous clay and silt lenses restrict water transmission and well yields. Because it occurs chiefly in hills and terraced areas, the Orcutt Sand is not widely tapped by wells, but it serves as a large catchment area for rain. Its loose sandy mantle absorbs rain readily and prevents virtually all runoff from the outcrop area during storms. Absorbed water enters, and in part is stored in the Orcutt Sand, and ultimately is probably transmitted to the underlying Paso Robles Formation (Upson and Thomasson, 1951, p. 40).

Terrace deposits overlie the Paso Robles and older formations. Dibblee (1950, p. 50) suggested that the oldest deposits in the Santa Ynez upland may be correlative with the Orcutt Sand which crops out in areas to the west. The terrace deposits consist of stream-laid gravel, sand, silt, and clay. The terrace deposits rarely exceed several tens of feet in thickness, except in the north part of the Santa Ynez upland where Upson (Upson and Thomasson, 1951, p. 42) estimated the maximum thickness to be 150 feet. Extensive terrace deposits are present along Zaca and Santa Cruz Creeks and Adobe Canyon. Terrace deposits yield water to wells in the Santa Ynez upland, but most wells over 20 to 30 feet deep also draw water from the Paso Robles Formation. The terrace deposits do not constitute an important source of water outside of the upland itself because they are of limited areal extent and commonly are above the zone of saturation (LaFreniere and French, 1968, p. 14).

The alluvium contains stream-laid sediments deposited on fans and along flood plains in Holocene time. The alluvium generally consists of gravel, sand, silt, and clay, averaging several tens of feet in thickness and having a maximum thickness of about 100 feet in the major stream valleys. In the Santa Ynez upland, most wells initially tapped the alluvium or terrace deposits. Increased pumping for irrigation and subsequent lowering of water levels necessitated deeper wells, commonly perforated in both the alluvium and Paso Robles Formation. Test pumping of wells screened in the alluvium in adjacent San Antonio Valley (Muir, 1964, p. 18) indicated yields of about 350 gal/min.

In general, the terrace deposits and alluvium are not significant sources of ground water. However, both act as major sources of ground-water recharge to the underlying Paso Robles Formation (Singer, 1979, p. 12).

Geologic Structure

The main structural features of the Santa Ynez River basin are large synclines and anticlines. Figure 4 shows the location of major faults and folds. The large folds are expressed in the distribution of the rocks and deposits in the lowland between the folded and faulted Santa Ynez Mountains on the south and the faulted San Rafael Mountains on the north. These structures determined the areas in which the unconsolidated water-bearing formations could accumulate, thus determining the position and extent of the major bodies of ground water. Late geologic and geomorphic events have determined the relation of the Santa Ynez River to the main ground-water bodies. A diagrammatic cross section (fig. 3) shows these features.

The Santa Ynez Mountains comprise a single high anticlinal fold in their eastern part, becoming a complexly folded and faulted mass in the western part. Locally, the north limb of the anticline is offset by a large fault that extends along the Santa Ynez River from the vicinity of Solvang to near the east end of the Santa Rita Hills. The San Rafael Mountains, which border the eastern part of the valley on the north, were uplifted several thousand feet along a fault zone that trends northwest.

Lowland folds between the Santa Ynez Mountains and the San Rafael Mountains trend west-northwest. Consolidated rocks of the Sisquoc and Monterey Formations are exposed in the central parts of the anticlines. Unconsolidated water-bearing formations are contained in the synclines.

HYDROLOGY

Precipitation

The mountains bordering the Santa Ynez River basin tend to complicate the distribution of precipitation. In general, the mean annual precipitation ranges from about 14 inches near the coast to about 40 inches along the eastern divide. Possibly as much as two-thirds of the precipitation in the valley as a whole occurs in the headwater subarea (Upson and Thomasson, 1951, p. 9), upgradient from the study area (fig. 1).

Precipitation occurs predominantly as rain; insignificant amounts of snow occasionally fall in the mountains and hills of the upper Santa Ynez Valley. The wet season normally begins in late October or November and ends in April or May. Little or no rain falls in the dry season, May through October. Because the water supply of the valley ultimately depends on precipitation, the magnitude and time distribution of the precipitation are important to the user. Rainfall records indicate that there have been wet and dry cycles between 1868 and 1976 that averaged about 25 years in duration (fig. 5).

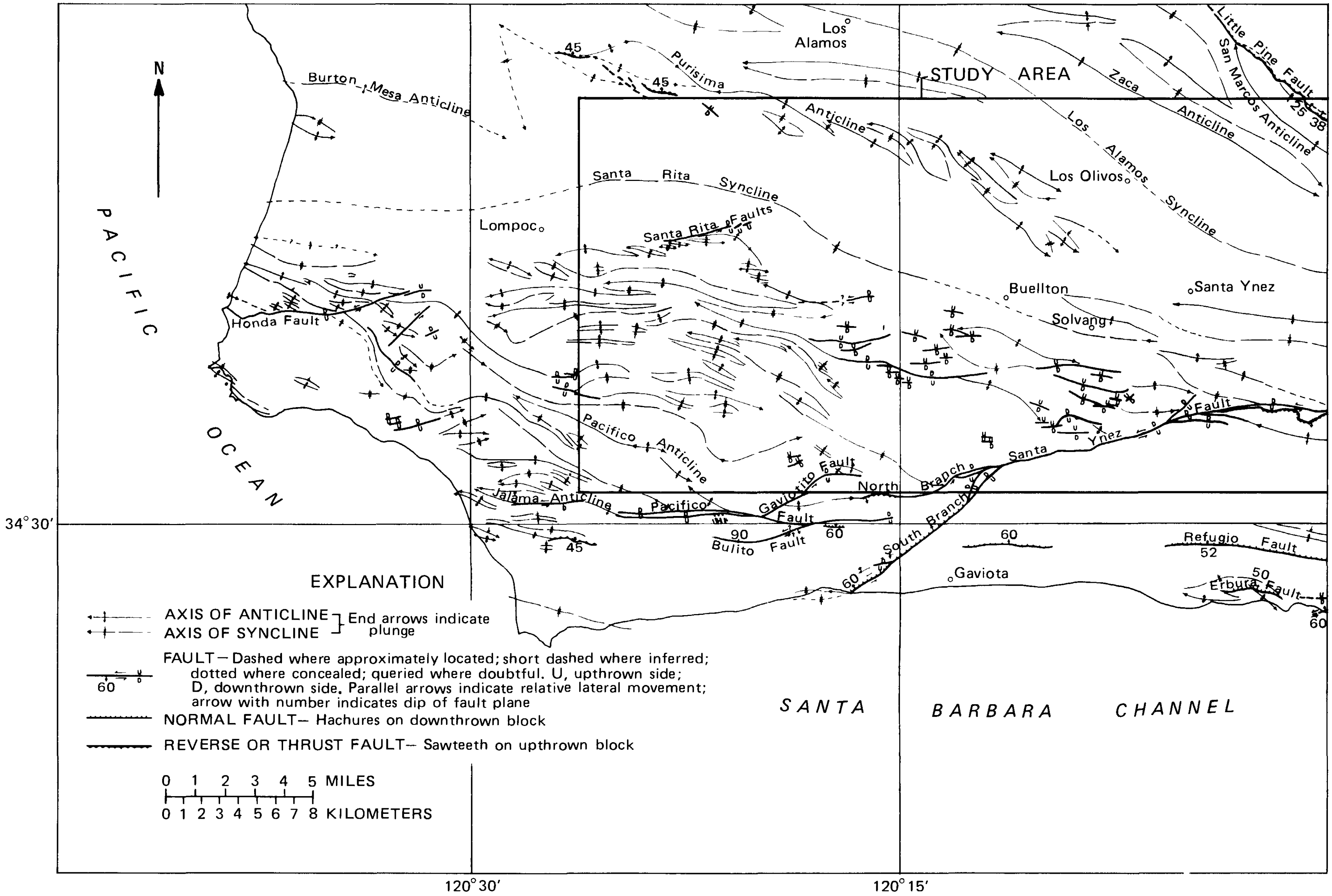


FIGURE 4.—Tectonic map of southwestern Santa Barbara County (from Dibblee, 1950, pl. 7).

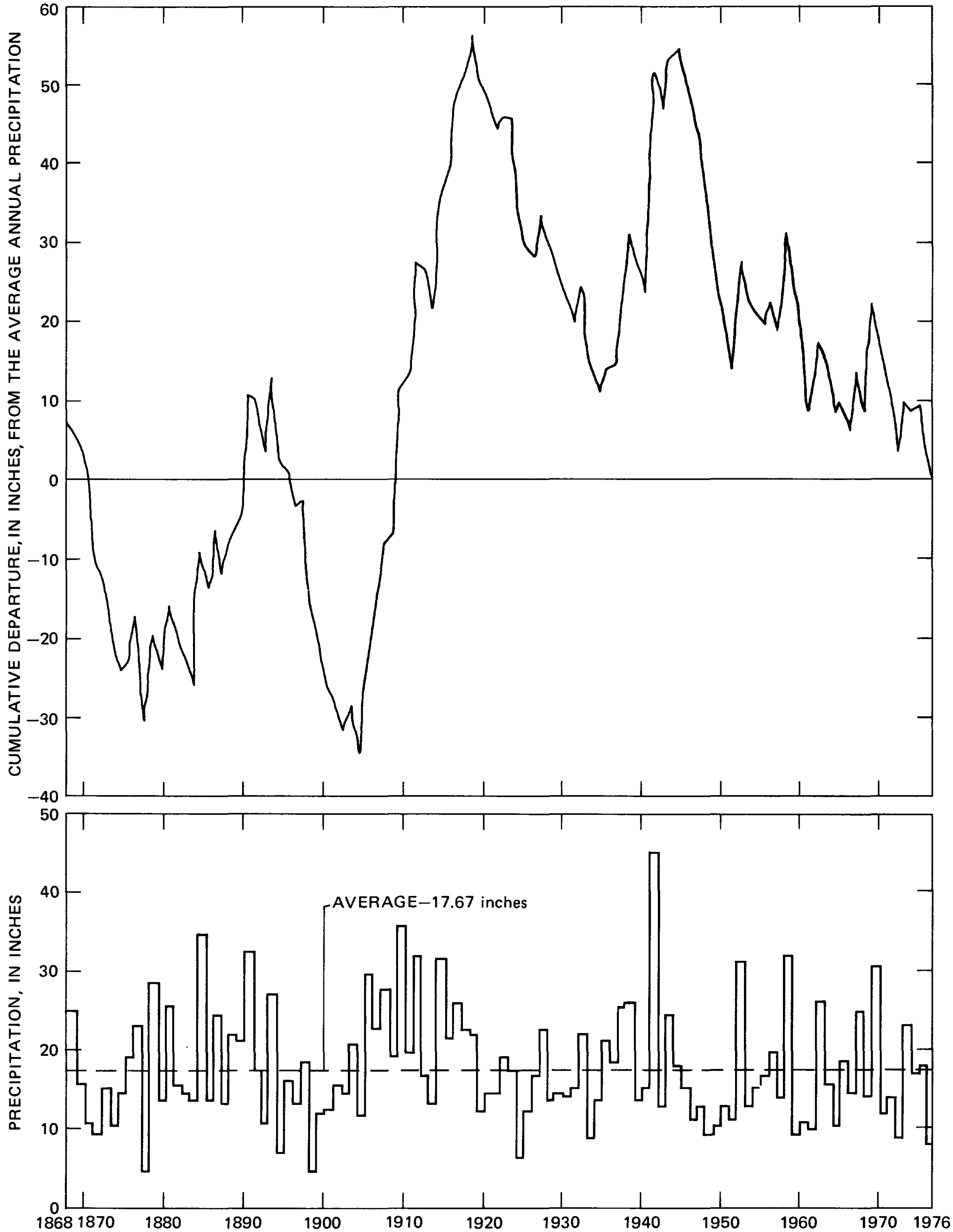


FIGURE 5.— Precipitation at Santa Barbara, 1868–1976 (from Singer, 1979).

The United States Engineering Office at Los Angeles (reported by Upson and Thomasson, 1951, p. 8) estimated that average annual precipitation is from 28 to 30 inches along the crest of the mountains, about 14 inches at the coast (at the northern foot of the mountains), and about 13 inches at San Lucas Bridge on the Santa Ynez River. However, the area between the divide and the river channel at the foot of the mountains averages only about 6 miles wide, and the total volume of water that falls there is fairly small (Upson and Thomasson, 1951, p. 8).

Surface- and Ground-Water Relations

A significant amount of the precipitation falling in the study area is returned to the atmosphere by evaporation and transpiration. The remainder either infiltrates to the water table or flows on the land surface as runoff. The amount of runoff is determined by topography, geology, the type and density of vegetative cover, soil conditions, and the climate. In the Santa Ynez River basin, storms are few, but at times rainfall is so great that large quantities of surface runoff occur. About 50 percent of the runoff occurs in about 1 to 4 percent of the time (Wilson, 1959). The Santa Ynez River has limited contact with the major water-bearing units and is not considered to be a significant source of recharge. The principal sources of recharge to unconsolidated deposits are seepage from tributaries and direct infiltration of precipitation.

Bradbury Dam, completed in 1953, was designed to divert an average of almost 30,000 acre-feet of water annually from the Santa Ynez drainage basin to the Santa Barbara coastal area. This diversion plus an annual evaporation from Lake Cachuma of about 10,000 acre-feet or more (Busby, 1973) and discharge regulation by the dam have tended to diminish flow in the Santa Ynez River. Pumping of ground water along the river has further reduced streamflow by decreasing ground-water recharge and increasing seepage of floodwater into the ground-water system.

The Los Olivos subarea comprises the drainage area tributary to the 7-mile reach of the Santa Ynez River from the San Lucas Bridge downstream to the Mission Bridge near Solvang. Throughout this reach the river flows in a narrow canyon cut in the consolidated rock and floored by alluvial material. The surface drainage of this area is 150 mi^2. Of this, about 30 mi^2 lie south of the river and are drained largely by San Lucas, Quiota, and Alisal Creeks. These short tributaries drain areas underlain by consolidated rocks which contribute virtually no water to base streamflow, and consequently these streams flow only in the rainy season. Tributaries from the north include Santa Agueda, Zanja de Cota, and Alamo Pintado Creeks. These streams drain the large body of unconsolidated deposits which underlies the Santa Ynez upland and the border in the foothills, immediately north of the consolidated-rock barrier along the river (fig. 3). Each was perennial at the rock barrier when Thomasson (Upson and Thomasson, 1951, p. 89) described the surface-water resources. Zanja de Cota Creek has gone dry for most of the summer during recent years (Singer, 1979, p. 20). The source of base flow for this creek is natural discharge from the Santa Ynez upland ground-water basin. Ground-water levels have been lowered by upgradient pumping until they no longer intersect the land surface and, subsequently, base flow in the creek ceases. The Santa Agueda Creek drainage area, 56.4 mi^2, comprises almost half of the area north of the river and includes the southwestern flank of the San Rafael Mountains. The streambed is evidently above the water table throughout much of its length, and some ground water probably moves from this area west to the Santa Ynez upland (Upson and Thomasson, 1951).

Buellton subarea includes a reach of about 10 miles along the Santa Ynez River. The lower end of the subarea is fixed geologically at the point where the river channel leaves the unconsolidated deposits of the Santa Rita syncline and re-enters the consolidated rock. The only tributary streams of appreciable size within the subarea are Nojoqui Creek, which enters the river from the south at the Buellton Bridge, and Zaca Creek, which enters from the north about half a mile below this bridge. Between Solvang and Buellton the characteristics of the river basin differ from those of the reach immediately upstream. Although the south-bank drainage areas are similar, most ground-water flow from the north is blocked by consolidated deposits near the river between Solvang and Buellton. For the subarea in general, the average discharge of ground water to the river during late autumn months has been approximately 5 ft^3/s, or 300 acre-ft per month (Upson and Thomasson, 1951, p. 92). At the time of the previous report, during the height of the pumping season, flow in the river decreased as much as 8 ft^3/s.

In the Santa Rita subarea, which extends downstream to within a mile of Robinson Bridge, the river flows in channel deposits within a narrow canyon cut in consolidated rock. Santa Rosa and Santa Rita Creeks enter the reach from the north and Salsipuedes Creek enters from the south. The creeks from the north drain an area underlain largely by unconsolidated deposits on which the rainfall is relatively light. Discharge from Santa Rosa Creek to the river is small and is chiefly storm runoff after heavy rainfall. Underground drainage from this creek basin can reach the Santa Ynez River only through a small cross section of alluvial deposits overlying consolidated rocks. The underflow through the alluvium is estimated to be not more than 0.05 ft^3/s (Upson and Thomasson, 1951, p. 93). Ground-water drainage from the main part of the Santa Rita Creek basin moves toward the west and does not reach the Santa Ynez River within the subarea. On the other hand, Salsipuedes Creek drains an area of 46.6 mi^2 south of the river on which precipitation is relatively heavy. Some of the runoff recharges the alluvium of the Santa Ynez River valley.

Ground Water

Local water-supply development has been almost entirely from ground-water resources. The principal water-bearing deposits in the study area occur north of the Santa Ynez River. The hydrologic subareas are considered separate ground-water basins because there is little or no ground-water underflow between the subareas except in alluvial deposits adjacent to the Santa Ynez River.

Hydrologic Subareas

In the Los Olivos subarea, ground water occurs mainly in the unconsolidated deposits that underlie the Santa Ynez upland and adjoining foothill areas. The unconsolidated deposits include the Careaga Sand, the Paso Robles Formation, the Orcutt Sand and terrace deposits, and Holocene alluvium along Alamo Pintado and Santa Agueda Creeks and other small stream channels (fig.2). A consolidated-rock barrier north of the Santa Ynez River separates the principal water-bearing deposits from a small body of water-bearing deposits in alluvium adjacent to the Santa Ynez River. La Freniere and French (1968) estimated that ground-water discharge north of the river averaged about 7,000 to 7,500 acre-feet per year during 1946-64; groundwater recharge during this same period was estimated at about 6,800 acre-feet per year.

The main water-bearing deposits in the Buellton subarea are alluvium adjacent to the Santa Ynez River (Upson and Thomasson, 1951). Underlying the area north of the river, the Paso Robles Formation and the Careaga Sand have not been extensively developed as a water supply; they are in hydraulic connection with alluvium adjacent to the river. Upson and Thomasson (1951) estimated that recharge to the Buellton subarea averaged about 7,600 acre-feet per year.

In the Santa Rita subarea north of the Santa Rita Hills, ground water occurs in the Careaga Sand, Paso Robles Formation, Orcutt Sand and terrace deposits, and the alluvium. Impermeable consolidated rocks underlying the Santa Rita Hills separate unconsolidated deposits and alluvium along the Santa Ynez River except for a small discharge through the gap occupied by Santa Rosa Creek. Upson and Thomasson (1951) estimated that recharge to the Santa Rita subarea averaged about 7,500 acre-feet per year during 1935-44; no data are available to refine their estimate.

Water-Level Variation

General trends in water-level fluctuation[1] in the study area between 1964 and 1980 are shown in the water-level change map (fig. 6). Of major concern is the region of extensive ground-water decline in the Los Olivos subarea. The extent of this lowering of water levels is shown in the hydrograph of well 7N/30W-29N2 (fig. 7). This area of decline is the result of heavy agricultural pumping. Alfalfa, one of the major crops, has a high water demand (Singer, 1979). This area of depressed water levels, seen in the 1945 water-level map (fig. 8), has expanded through subsequent years (fig. 9).

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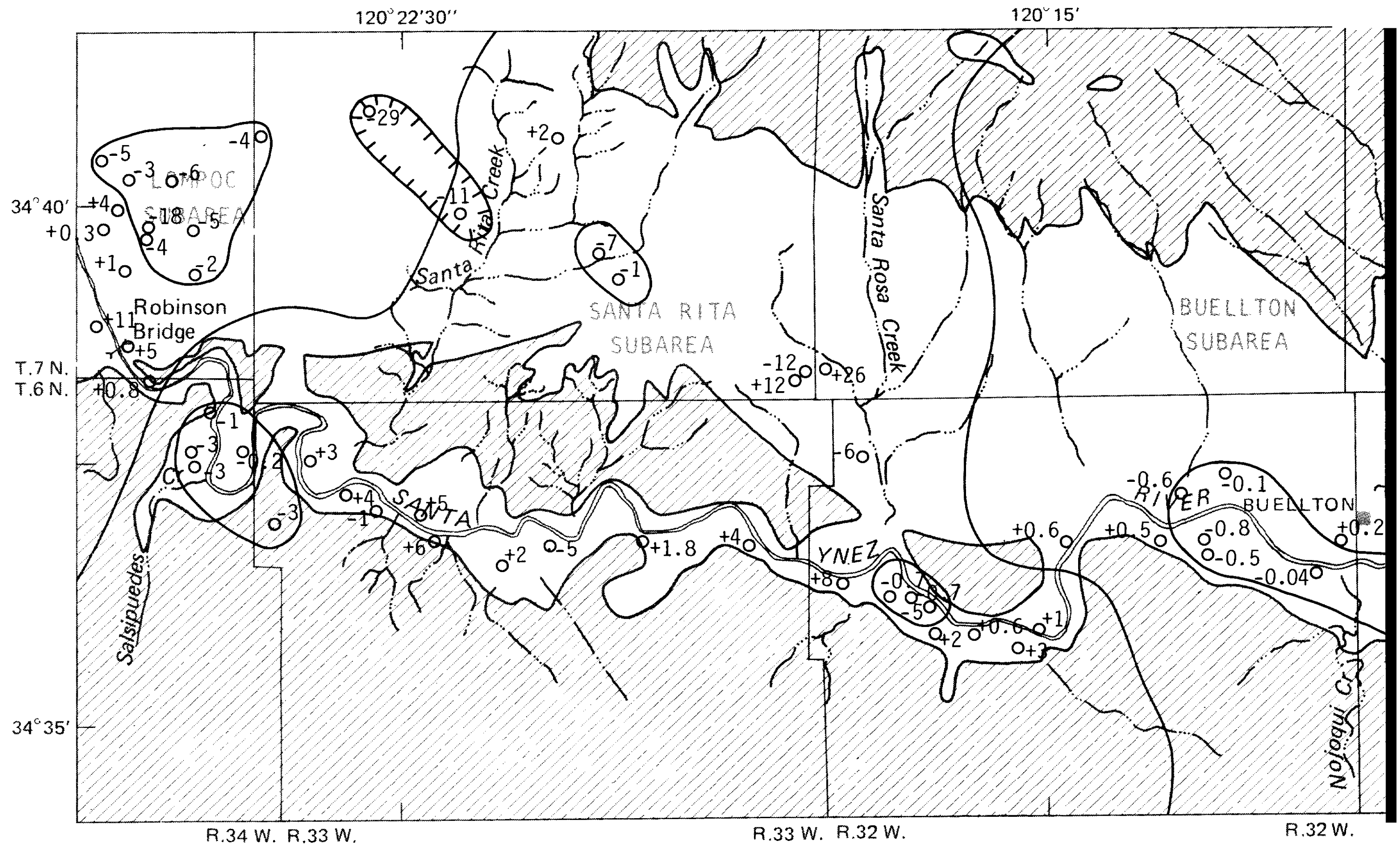
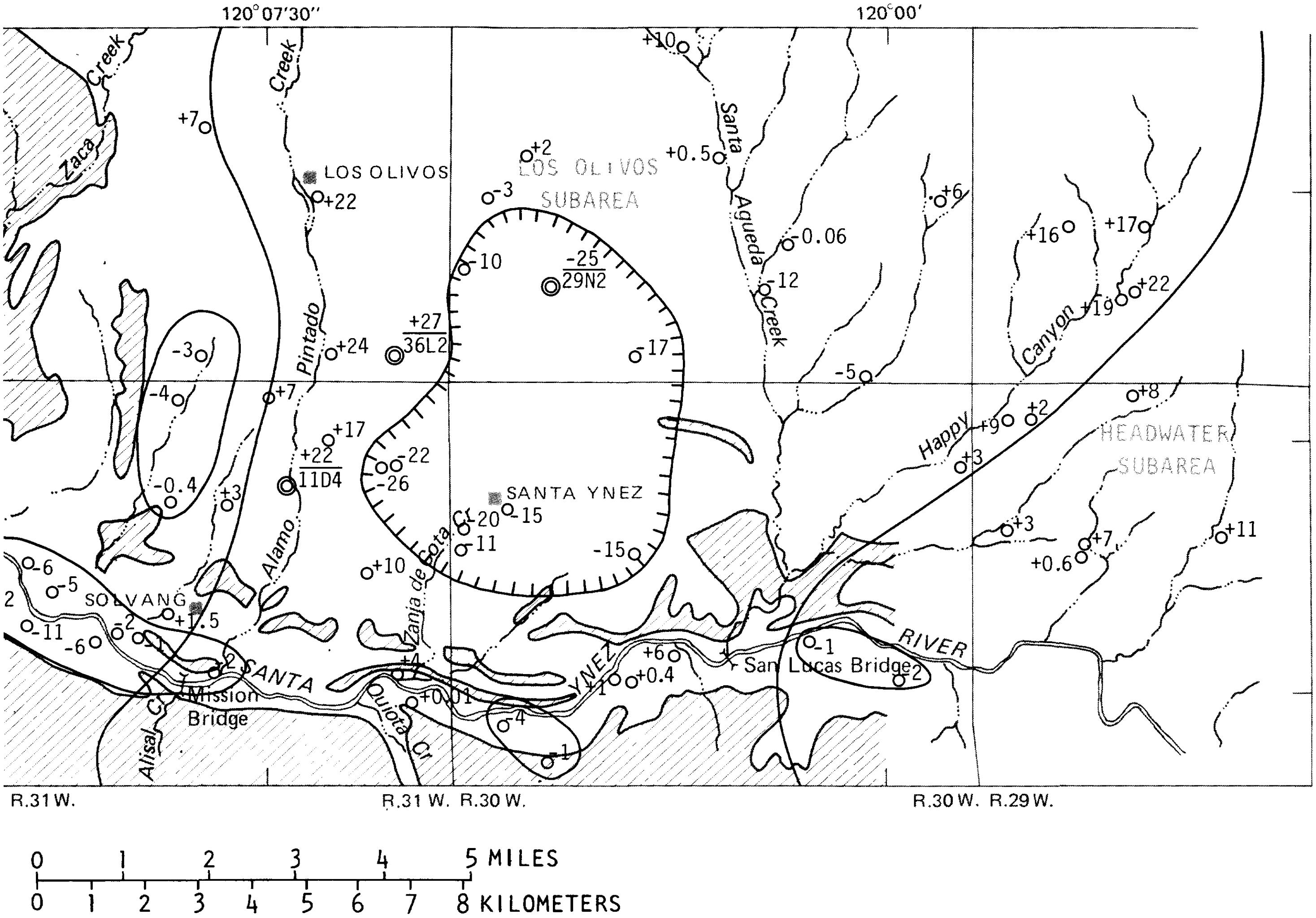
[1]Water-level data were used to construct a line representing mean values over the period of record. This process averages out seasonal fluctuations in water level and indicates long-term changes in storage. The endpoints were then compared to yield an estimate of change in mean water level. The agreement between calculated endpoints and observed data suggests a constant rate of change in water levels.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 6.-Water-level changes between



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

0-10 FEET WATER-LEVEL-DECLINE AREA

GREATER THAN 10 FEET WATER-LEVEL-DECLINE AREA

o+22 WELL-Number is water-level change, in feet. +indicates rise; -indicates decline

-25/29N2 HYDROGRAPH WELL-Number above line is water-level change, in feet. +indicates rise; - indicates decline. Number below line is well number (Hydrographs shown in figs. 7, 10, and 11.)

1964 and 1980 in the study area.

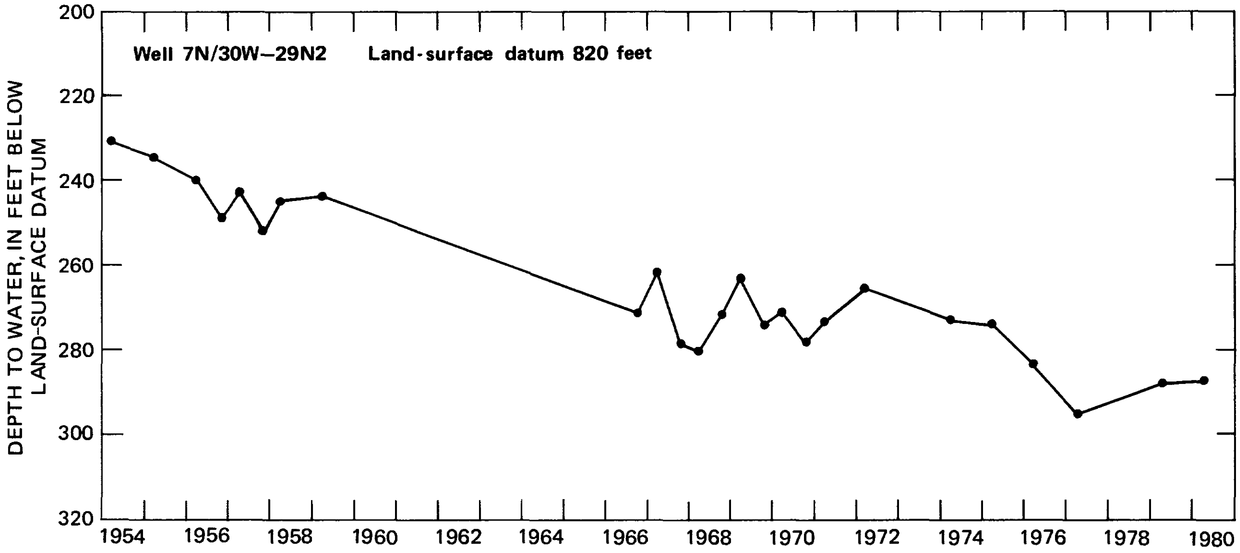


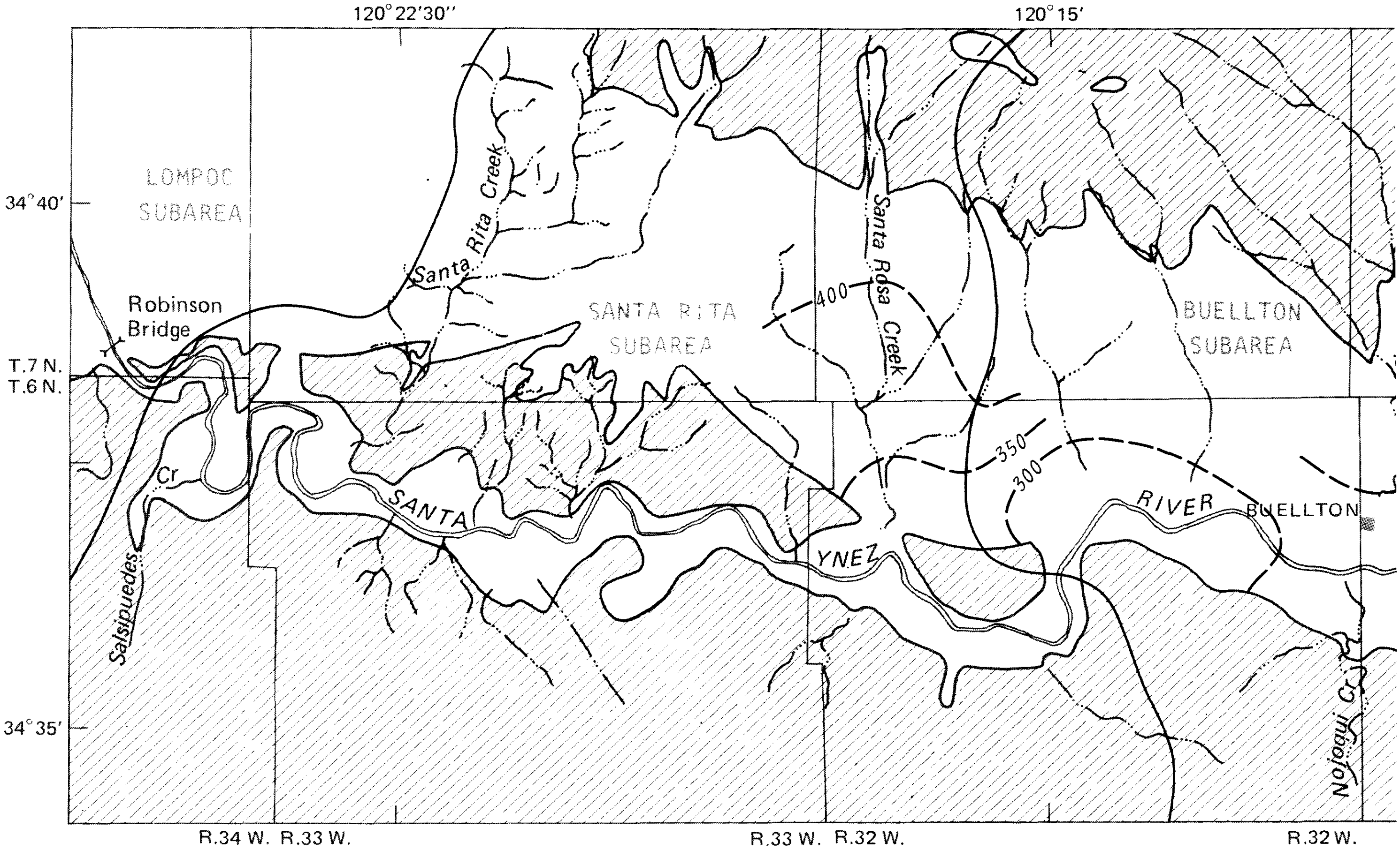
FIGURE 7. – Water-level data from well 7N/30W–29N2, 1954–80. (Location of well shown in figure 6.)

The ground-water gradient is generally to the southwest, following the topography. This reflects recharge from highland areas and flow toward, and eventually along, the axis of the Santa Ynez River Valley. Changes of this general pattern are produced by natural hydraulic barriers, such as the Santa Rita Hills, and man's activities, such as ground-water pumpage. The hills separating the Santa Ynez River from the upland basin of the Los Olivos subarea produce a channeling effect, routing ground-water flow through the gap in the Ballard Canyon area, thereby providing a source of recharge to the Buellton subarea.

Recent water-level data for much of the Los Olivos subarea north of the Santa Ynez River indicate a ground-water rise. However, long-term hydrographs show a previous decline with a dramatic reversal in 1969. For example the hydrograph of well 7N/31W-36L2 (fig. 10) depicts this long-term decline in ground-water level followed by a reversal and recovery continuing to the present. The reversal is probably the result of recharge of imported water from Lake Cachuma that is used to irrigate the area west of California Highway 154. Pumping in this area has probably decreased with importation of supplemental water (Singer, 1979). The water-level rise seen in the hydrograph of well 6N/31W-11D4 also probably reflects this phenomenon(fig.11).

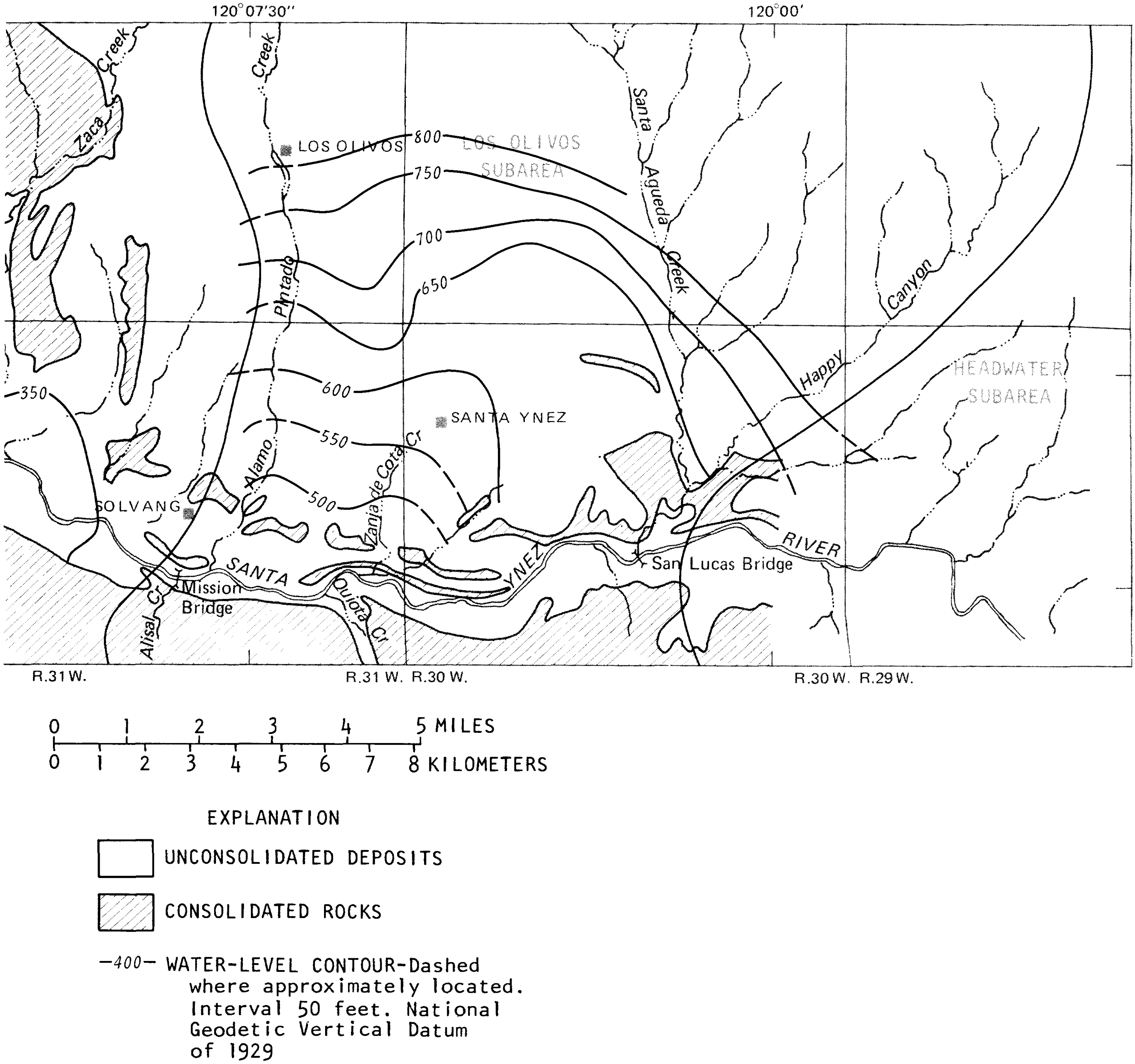
The area of depressed ground-water levels between Buellton and Solvang probably results from local pumpage. Also, average rainfall between 1944 and 1980 has been below average. Consistent reversal in this trend of low precipitation will produce recovery of ground-water levels. In the valley, areas of ground-water depression are of limited extent.

There is little development of the northern part of the Santa Rita subarea. Ground-water levels there should primarily reflect changes in recharge resulting from variation in rainfall patterns. Monitoring of water levels in this area would provide a general baseline for comparison with developed areas. The efficiency of rainfall recharge is dependent not only on quantity, but on time-distribution of precipitation. Hence, a wide temporal distribution of relatively lighter rainfall, not exceeding soil recharge capacity, is highly desirable to promote most efficient ground-water recharge.

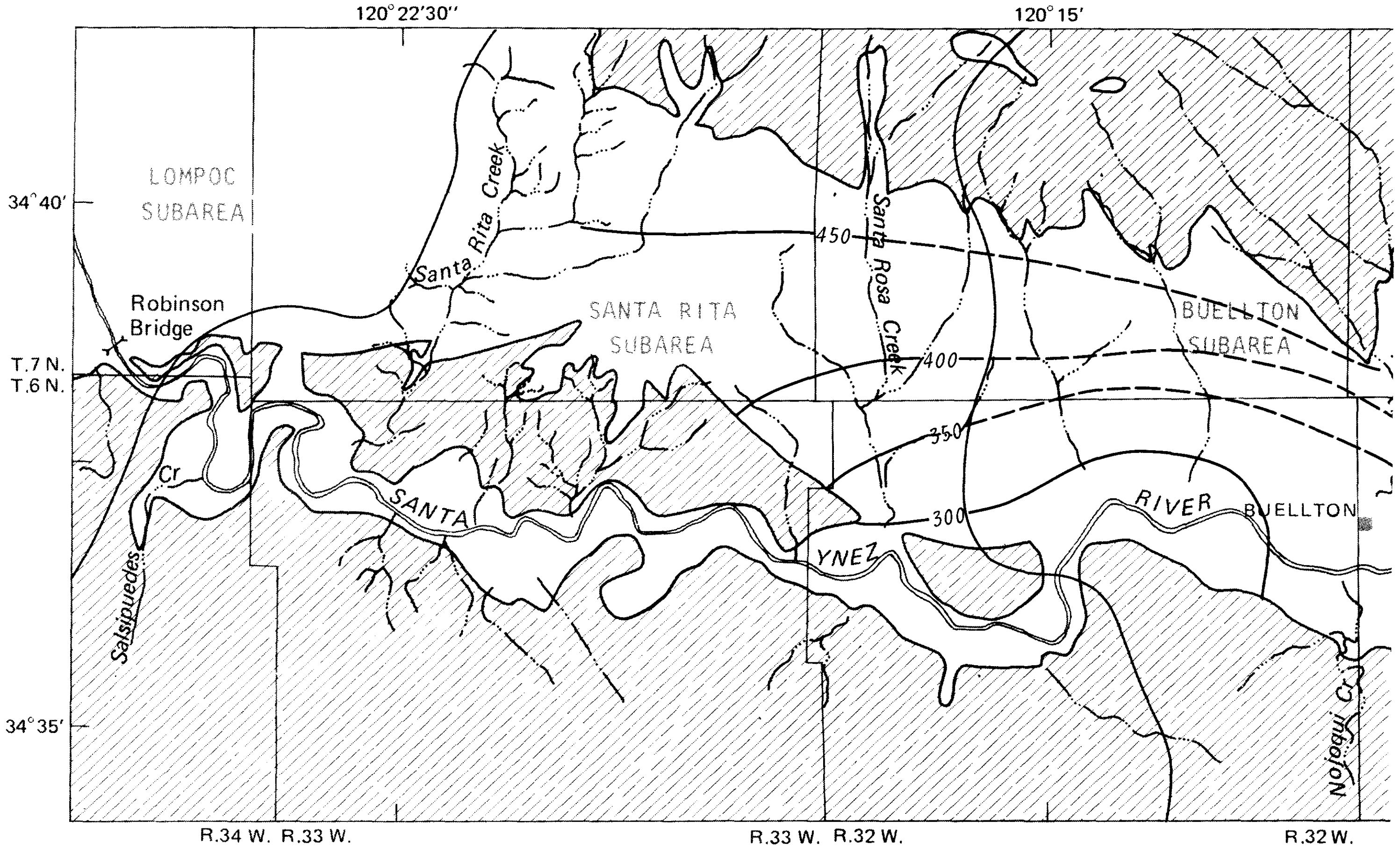


Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 8.-Water-level contours for the study area,

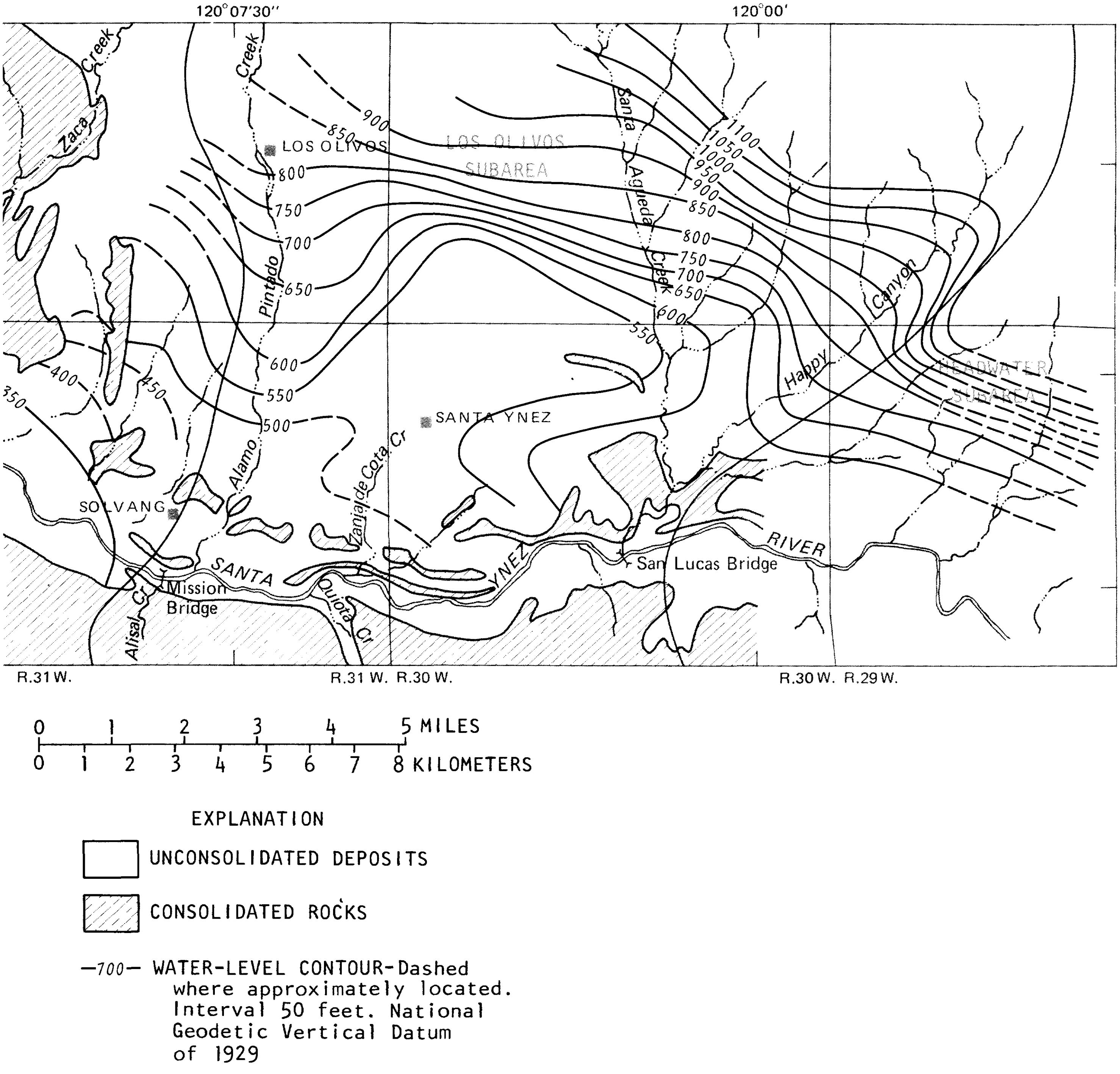


spring 1945 (from Upson and Thomasson, 1951).



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 9.-Water-level contours



for the study area, spring 1980.

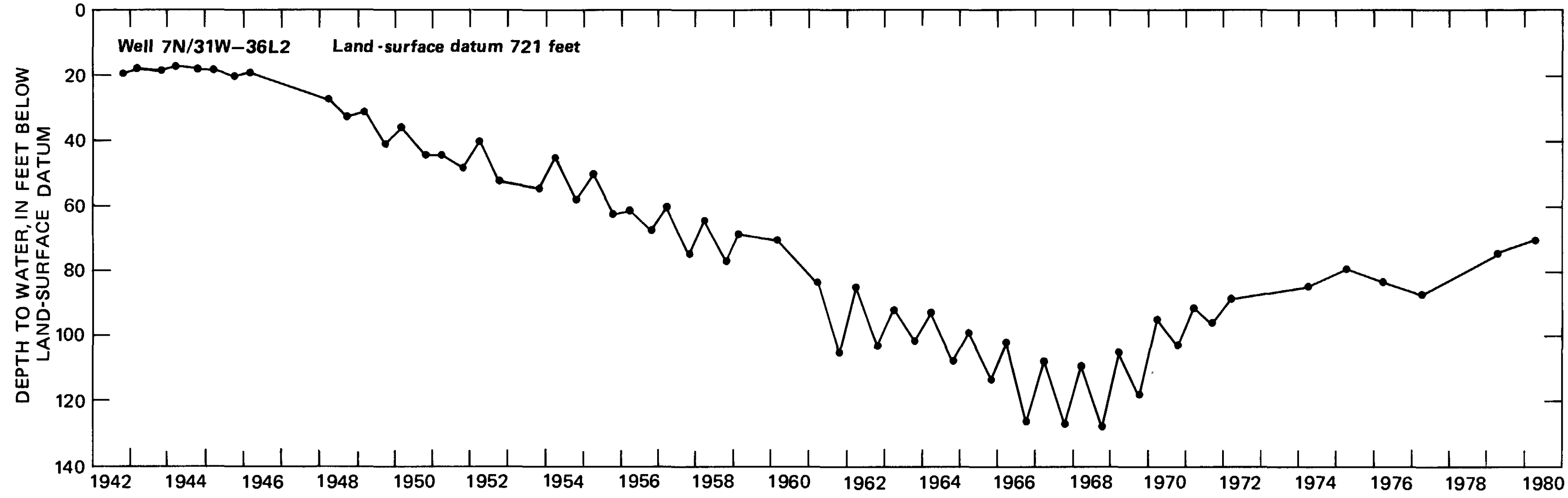


FIGURE 10. – Water-level data from well 7N/31W–36L2, 1942–80. (Location of well shown in figure 6.)

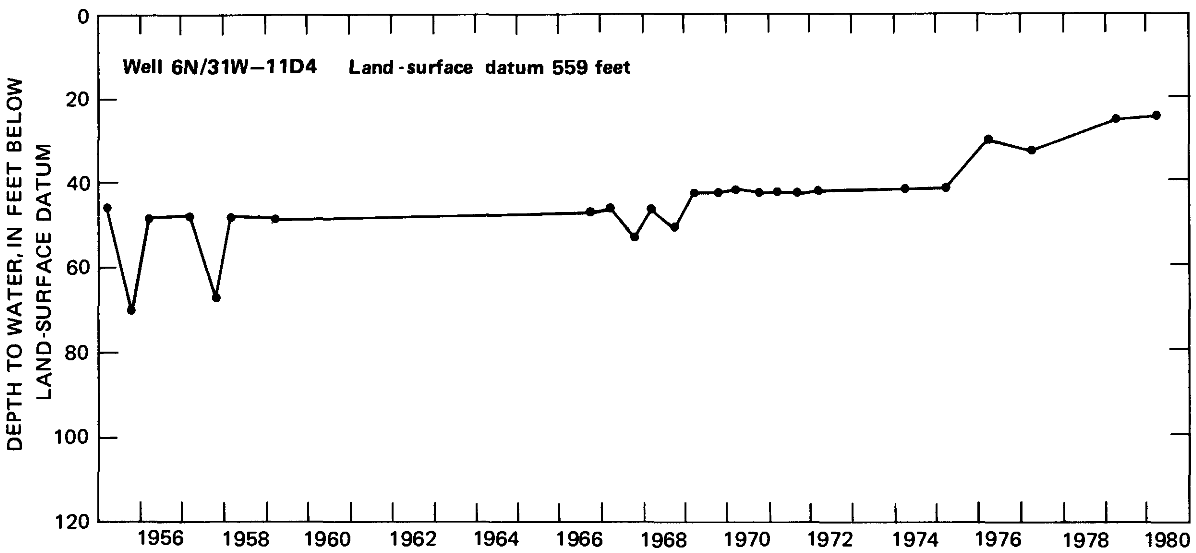


FIGURE 11. – Water-level data from well 6N/31W–11D4, 1955–80. (Location of well shown in figure 6.)

GROUND-WATER QUALITY

Natural Controls

Ground-water quality is influenced by natural environmental factors, primarily geology (mineralogy), surface-water infiltration (modified by evaporative concentration), and precipitation (affected by natural and artificial processes). These natural factors play varied roles of importance in the characterization of ground-water quality. The Santa Ynez River provides nearly all recharge to the adjacent water-bearing alluvium. Similarly, local ground-water quality is strongly influenced by surface water, as discussed in the "Surface- and Ground-Water Relations" section. Deep aquifers throughout the area may be strongly influenced by connate waters from adjacent consolidated rocks (Evenson, 1965).

Ground-water quality is related to the mineralogic composition of the aquifers. For example, ground water from aquifers containing calcite and (or) gypsum has alkaline-earth and bicarbonate contents, typically ranging from 50 to 200 mg/L Ca^{+2}, 10-50 mg/L Mg^{+2}, 100-250 mg/L HCO_3^-, and 50-300 mg/L SO_4^{-2} (Matthess, 1982, p. 285). Waters in the Santa Ynez Valley have similar ionic proportions and are probably affected by calcite and gypsum deposits.

Of the consolidated rocks, the Monterey Shale (fig. 2) probably exerts the strongest control over ground-water quality. Limestone (a source of Ca^{+2} and CO_3^{-2}) locally occurs in places in the basal section of the Monterey Shale as a bed as much as a foot thick (Dibblee, 1966, p. 47). Southwest of Solvang the basal limestone of the Monterey Shale is exposed along the south bank of the Santa Ynez River for a distance of about three-quarters of a mile. The Sierra Blanca Limestone crops out in Nojoqui Canyon and at several other localities in the Santa Ynez mountains (Dibblee, 1950, p. 80). The Monterey Shale locally contains thin laminae of bentonite (altered volcanic ash composed mostly of montmorillonite), and in the upper part contains phosphatic laminae.

In the Lompoc plain, three areas of peak chloride concentration occur where Holocene alluvial deposits overlie consolidated rocks and unconsolidated marine and terrestrial deposits (Evenson, 1965). Connate water, known to occur as oil-field brine in the consolidated rocks that border and underlie the unconsolidated sediments, probably has moved into the alluvium. The high-chloride, low-sulfate connate water is contained in permeable zones, probably in fractured Monterey Shale, and may be associated with faults that form conduits either in the shale or between the shale and unconsolidated sediments.

Anthropogenic Factors

Agricultural factors provide a major control over ground-water quality in the Santa Ynez Valley. In many areas of the country, these factors, in order of decreasing importance, are irrigation-return flow, application of chemical fertilizers or animal wastes, man-caused changes in vegetation, and use of pesticides (Miller, 1980). Irrigation-return flows are characterized by a relatively high dissolved-solids content and can introduce chloride and other substances into the ground-water reservoir by infiltration and leaching. Contaminants in irrigation-return flow may originate from many sources including applied water, soils, fertilizers, and pesticides and can be concentrated by evapotranspiration. Of the three major plant nutrients (nitrogen, phosphorus, and potassium), only nitrogen may pass in significant amounts into the ground water (Stromberg, 1966). Nitrogen generally stimulates the best crop yields and is commonly applied in amounts exceeding crop needs. In areas of intensive cultivation, such as vegetable growing and vineyards, nitrate concentrations of 100-1,000 mg/L have been measured in the ground water (Schmidt, 1974). Pesticide contamination of ground water is less common than nitrate contamination because many pesticides are retained by the soil and degrade naturally. However, some organic compounds, such as chlorinated hydrocarbons, are particularly resistant to decay and are notably stable in soil.

Much of the ground water pumped in the valley is derived from sand and gravel aquifers. Where such aquifers are in hydraulic connection with surface water, replenishment of water withdrawn from wells is partly from river infiltration. If ground-water contamination is from surface-water infiltration, then the most likely sources are discharge of waste fluids and (or) irrigation-return flow to surface-water bodies.

Animal feedlots in the valley may contaminate ground water in three ways: (1) runoff and infiltration from the feedlots themselves, (2) runoff and infiltration from animal waste products collected from the feedlots and disposed of on land, and (3) seepage or infiltration from a waste lagoon. The principal contaminants are phosphate, chloride, nitrate, and in some cases, heavy metals. Cattle-feeding operations are the most serious potential problem in terms of the volume of waste produced but sheep-, poultry-, and hog-feeding operations are also potential sources of ground-water contamination (Miller, 1980, p. 389). Table 1 lists general contaminant characteristics for typical feeding operations.

Table 1.--Typical contaminants from feeding operations

[Modified from Miller, 1980. All concentrations are in milligrams per liter, except those for nitrogen and potassium, which are in percent of total solids]

Constituent	Average runoff		
	Paved surface	Unpaved surface	Undefined surface
Sodium	235	1,000	1,675-2,490
Chloride	2,455	1,040	--
Nitrate	113	68	--
Total solids	11,260	4,900	--
Volatile solids	4,014	1,460	--
Suspended solids	4,250	1,096	--
Volatile suspended solids	2,720	619	--
Nitrogen	--	--	0.89-3.12
Ammonia nitrogen	--	--	--
Potassium	--	--	0.39-1.09
Calcium	--	--	5,580-9,800
Magnesium	--	--	3,934-4,450
Phosphorus	--	--	4,166-7,100
Zinc	--	--	56-66
Iron	--	--	4,810-8,825

In areas of residential development, septic tank systems, where used, rank highest in total volume of wastewater discharged directly to ground water. Typical composition of domestic sewage is shown in table 2. The most commonly observed deleterious effect of septic effluent is high nitrate concentration. Ammonia and reduced forms of organic nitrogen in sewage may be oxidized to nitrate by nitrifying bacteria. Fecal contamination in ground water and surface water in the town of Santa Ynez is documented (Singer, 1979). However, except in areas where well placement is near septic systems and well construction (sanitary seal) is poor, the overall health hazard is minimal. Most problems are related to individual home sites or subdivisions. Such problems can be alleviated by alternative disposal methods or by low-density zoning.

Table 2.--Typical composition of domestic sewage

[From Miller, 1980. All values except settleable solids are in milligrams per liter]

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1,200	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable solids (mL/L))	20	10	5
Biochemical oxygen demand, 5-day, 20°C	300	200	100
Total organic carbon	300	200	100
Chemical oxygen demand	1,000	500	250
Nitrogen (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrite	0	0	0
Nitrate	0	0	0
Phosphorus (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chloride[1]	100	50	30
Alkalinity (as $CaCO_3$)[1]	200	100	50
Grease	150	100	50

[1]Values should be increased by amount in carriage water.

Processing of muncipal wastewater may contaminate ground water by such direct routes as leakage from collecting sewers, leakage from the treatment plant, and land disposal of the treatment plant effluent. Contamination of ground water may also occur by leaching of land-disposed sludge. Many of the components of sludge may be categorized as plant nutrients: nitrogen, phosphorus, and potassium. Heavy metals in sludge from domestic sewage include those required for human nutrition, such as chromium, cobalt, copper, iron, manganese, molybdenum, selenium, and zinc; metals contributed through dissolution of plumbing, such as lead, copper, tin, and zinc; and in systems of combined sewers, metals from storm runoff, such as cadmium, lead, and zinc. Iron is often found in relatively high concentrations in sewage sludge because ferric chloride is frequently used in the treatment process. Other elements commonly occuring in sludge are boron, arsenic, selenium, tin, and antimony. The chemical behavior of domestic wastewater is described in table 3.

Table 3.--Behavior of contaminants from domestic wastewater

[From Miller, 1980]

Parameter	Disposal method	
	Irrigation	Infiltration-percolation
Nitrogen	Nutrients not used by plants or fixed in the soil can leach to ground water.	Significant quantities passed to ground water at most sites.
Phosphorus	Leaching of excess phosphorus is rare occurrence. Organic and clay soils absorb practically all the phosphorus.	Removal may be limited because granular soils are used.
Organics	Usually broken down by microorganisms and used by plants. Can appear in ground water when application rate is highest or when in open soil, such as sand or gravel, with a high percolation rate.	Evidence is that little organic matter reaches ground water.
Trace element	Toxic compounds can be changed by the chemical reaction of cation exchange and can be rendered nontoxic by bacteria. Chemical precipitates formed can be leached out, however.	Retention may be limited due to granular nature of soils.
Dissolved solids	Leaching can occur and buildup is possible.	Buildup is possible.
Enteric organisms	Usually removed or die out and do not reach ground water, especially if water table is kept low.	Spread of bacteria and viruses by insects or percolating water is of concern but unlikely under proper soil conditions.

Solid waste landfill disposal sites are potential sources of ground-water contamination as a result of leachate from water percolating through refuse and waste materials. Precipitation and runoff that infiltrate the landfill produce leachate. This is probably not a major concern in the Santa Ynez Valley. Because of the arid climate, most precipitation is removed from landfills by evaporation and runoff prior to infiltration. Leachate, when produced, is a highly mineralized fluid containing chloride, iron, lead, copper, sodium, nitrate, and a variety of organic chemicals. Table 4 lists typical leachate characteristics from municipal solid wastes.

Table 4.--Chemical characteristics of municipal solid waste leachate

[From Miller, 1980. Values are in milligrams per liter, except those for pH which are in units]

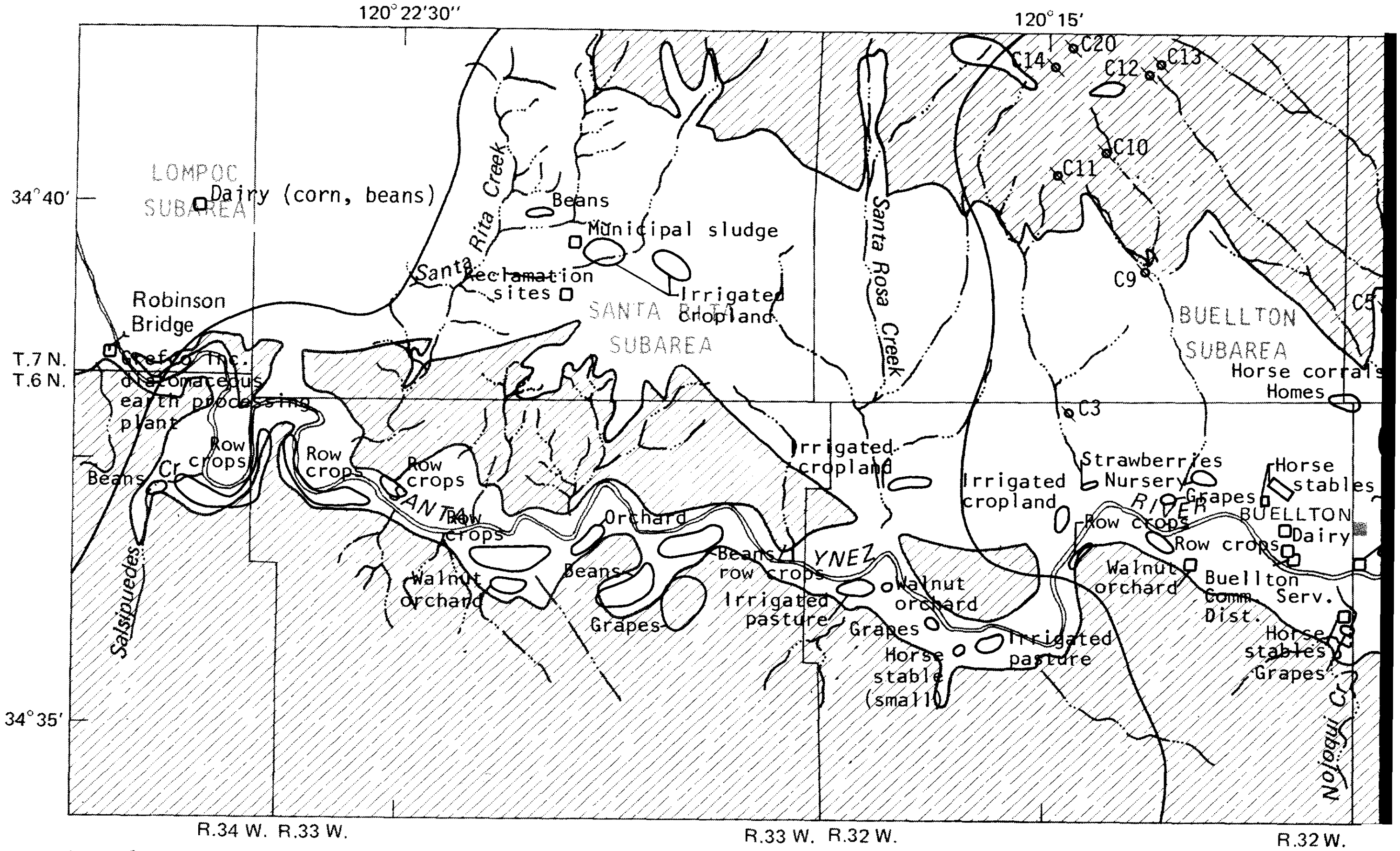
Components	Median value	Ranges of all values
Alkalinity ($CaCO_3$)	3,050	0-20,850
Biochemical oxygen demand, 5 days	5,700	81-33,360
Calcium (Ca)	438	60-7,200
Chemical oxygen demand	8,100	40-89,520
Copper (Cu)	.5	0-9.9
Chloride (Cl)	700	4.7-2,500
Hardness ($CaCO_3$)	2,750	0-22,800
Iron, total (Fe)	94	0-2,820
Lead (Pb)	.75	<0.1-2.0
Magnesium (Mg)	230	17-15,600
Manganese (Mn)	.22	0.06-125
Nitrogen (NH_4)	218	0-1,106
Potassium (K)	371	28-3,770
Sodium (Na)	767	0-7,700
Sulfate (SO_4)	47	1-1,558
Dissolved solids	8,955	584-44,900
Total suspended solids	220	10-26,500
Total phosphate (PO_4)	10.1	0-130
Zinc (Zn)	3.5	0-370
pH	5.8	3.7-8.5

Several oil fields have been developed to the north of the valley, and a few abandoned oil wells are located in the study area (fig. 12). Disposal of brine from oil and gas production activities has been a major cause of ground-water contamination in areas of intense exploration and development (Miller, 1980). In the study area, most oil wells are not located in the major water-bearing deposits, and contamination is not likely.

Historical Data

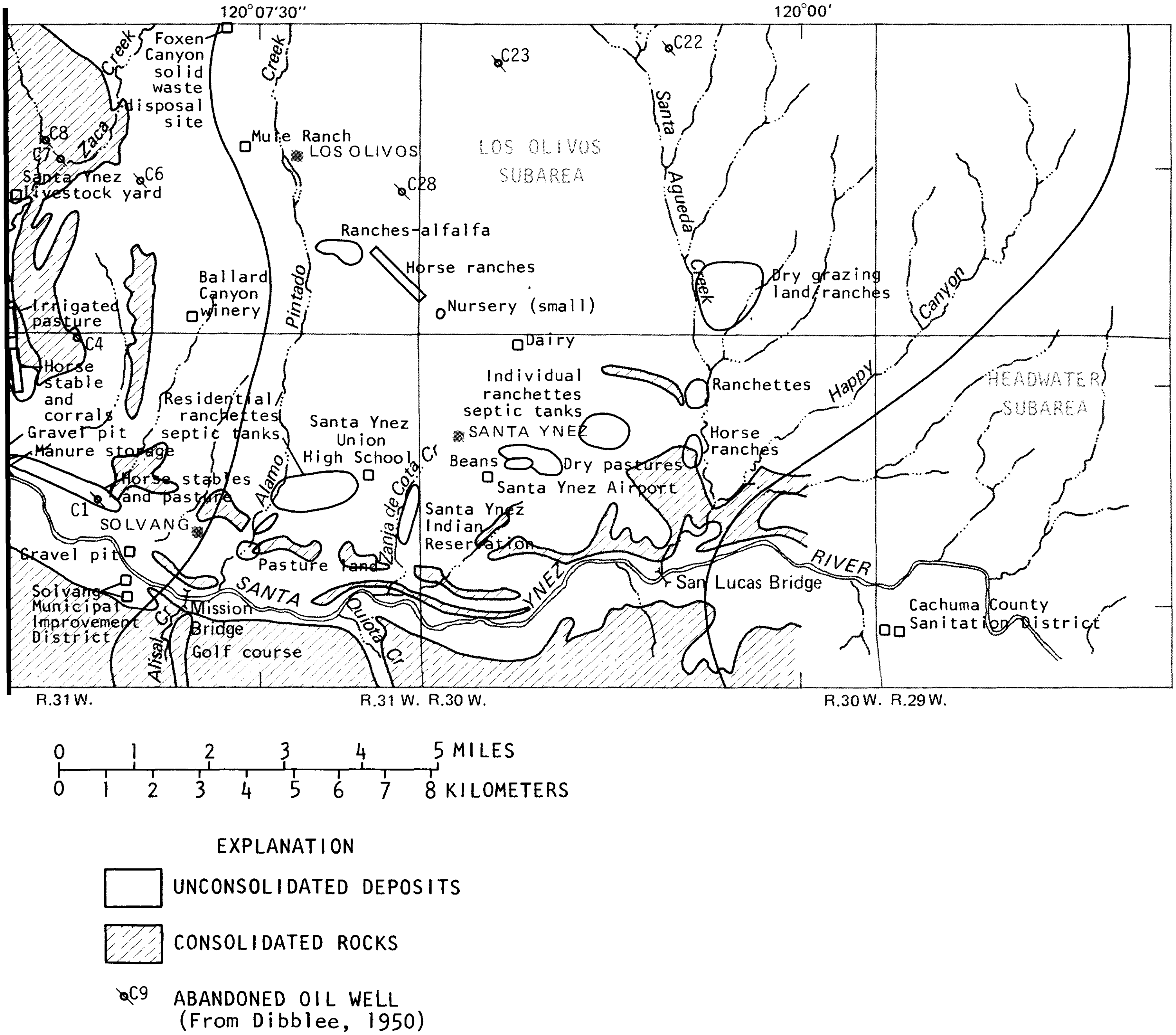
Water-quality data are generally sparse in the study area. Historical data are particularly limited. Enough data have been assembled, however, to present a simplified view of dissolved-solids variation (fig. 13) which draws on pre-1970 water-quality data. Screened intervals of sampled wells vary according to location and the aquifer(s) tapped. For example, wells tapping the alluvial aquifer along the Santa Ynez River are much shallower than the wells tapping the deeper water-bearing formation in the Santa Ynez upland. Therefore, water-quality data is representative of the water produced from specific water-bearing units within the hydrologic subareas and do not necessarily represent the same aquifers. This method of presenting data has been used in subsequent maps and is an attempt to describe general water-quality conditions based on limited information. Screened intervals and dissolved-solids data are given in table 5.

General water-quality conditions are apparent in the historical data. Through the years, the alluvial aquifer along the Santa Ynez River has contained the highest concentration of dissolved solids, particularly in the Santa Rita subarea. Only in the eastern and northwestern corner of the study area is dissolved-solids content less than the recommended limit of 500 mg/L (U.S. Environmental Protection Agency, 1979). Water having a dissolved-solids content greater than 1,000 mg/L may have adverse impacts on many crops and requires careful management practices (U.S. Environmental Protection Agency, 1976). Ground water in upstream areas of the Santa Ynez upland and in headwater subareas is generally less mineralized than that in downstream areas.

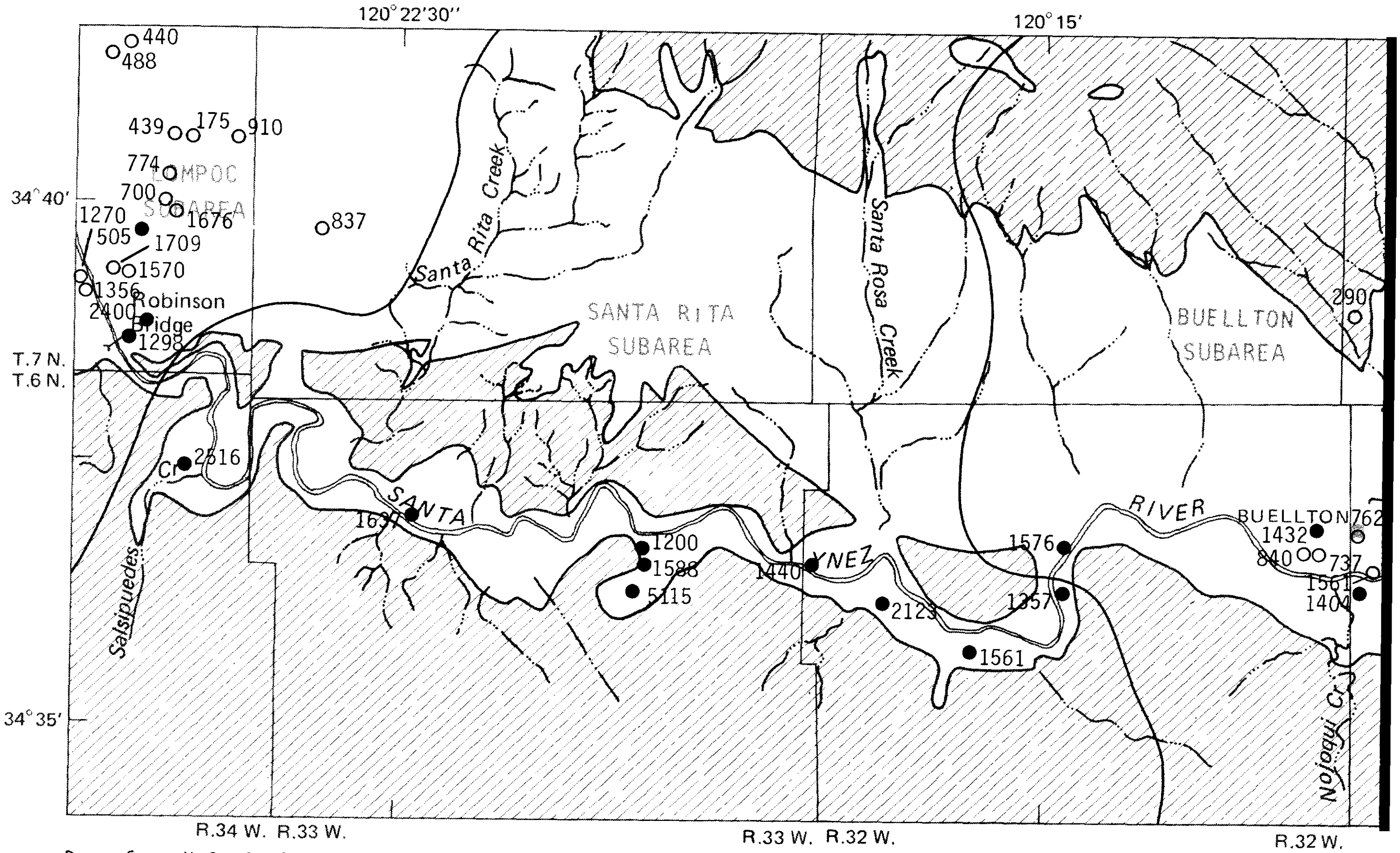


Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 12.-Land use in the study area (compiled by California

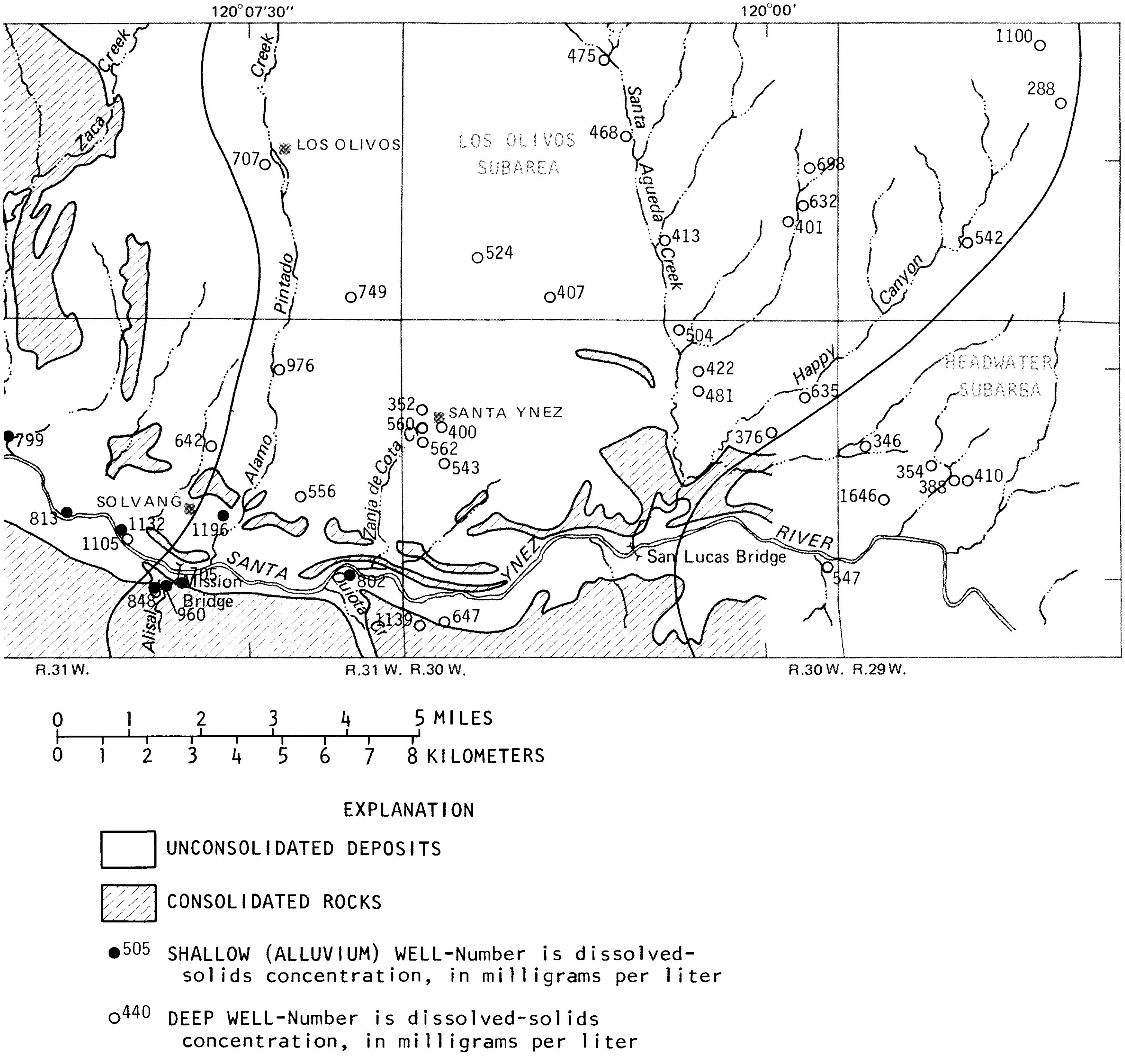


Regional Water Quality Control Board, Central Coast Region).



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 13.-Dissolved-solids distribution in



ground water in the study area, pre-1970.

Table 5.--Dissolved-solids, well-screen, and geologic data from selected wells in the Santa Ynez River basin, pre-1970

[Geologic units: Qal, alluvium; Qt, Orcutt Sand and terrace deposits; QTpr, Paso Robles Formation; Tc, Careaga Sand. See figure 13 for location of wells]

Well No.	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
6N/29W-7L2	346	--	--
-8P1	354	--	--
-9J1	628	--	--
-17A1	410	--	--
-17B1	388	--	--
-18G1	1,646	--	--
6N/30W-1Q1	635	--	--
-2M1	422	86-530	Qt
-2N1	481	1,400--	QTpr
-3A1	504	80-407	Qal,Qt
-7C4	352	98-113	Qt
-7F1	560	100-115	Qt
-7G1	400	80-95	Qt
-7L11	562	70-80	Qt
-7Q6	543	--	Qt
-12E1	376	--	--
-24H1	547	--	Qal
-30B1	647	--	--
-30C1	1,139	--	--
6N/31W-2L2	976	--	Qal
-7K1	799	0-45	Qal
-7L4	762	80-293	Qal
-7N2	1,404	0-90	Qal
-7P1	1,561	0-52	Qal
-14G2	556	--	Qal
-15K1	1,196	0-34	Qal
-16N4	1,132	0-70	Qal
-16N7	1,105	--	Qal
-17L1	813	0-80	Qal
-21J3	705	30-42	Qal
-21J4	960	25-52	Qal
-21K1	848	0-10	Qal
-24F2	802	0-44	Qal

Table 5.--Dissolved-solid, well-screen, and geologic data from selected wells in the Santa Ynez River basin, pre-1970--Continued

Well No.	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
6N/32W-7N1	1,440	49-56	Qal
-9J1	1,576	0-81	Qal
-12G1	1,432	0-55	Qal
-12K1	737	0-109	Qal
-12K2	840	220-1,000	Tc
-16A2	1,352	0-40	Qal
-17J2	1,561	19-46	Qal
-18H1	2,123	0-50	Qal
6N/33W-8G4	1,637	0-46	Qal
-11M1	1,200	4-63	Qal
-11M3	1,588	15-63	Qal
-14D2	5,115	0-59	Qal
6N/34W-12C4	2,516	--	Qal
-24K1	957	--	Qal
-24L1	1,568	36-64	Qal
-24R1	1,127	--	--
-25C1	2,606	--	--
-25D1	1,216	0-25	Qal
-25K1	562	--	--
-25P1	795	65-80	Qal
-26B1	1,297	0-45	Qal
7N/29W-10P1	1,100	--	--
-15L1	288	--	--
-29R2	542	--	--
7N/30W-16H1	475	--	--
-22E1	468	--	--
-24Q1	698	--	--
-25G1	632	--	QTpr
-25L1	401	--	--
-27Q2	413	--	--
-32D2	524	304-786	Qt,QTpr
-33M1	407	150-340	Qt,QTpr
7N/31W-23N5	707	--	--
-31D1	290	--	--
-36L2	749	--	--
7N/33W-30B1	837	219-225	Qt

Table 5.--Dissolved-solids, well-screen, and geologic data from selected wells in the Santa Ynez River basin, pre-1970--Continued

Well No.	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
7N/34W-14F3	488	169-397	Qt
-14G1	440	167-410	Qt
-24E2	439	119-140	Qal,Qt
-24F1	175	--	--
-24H2	910	--	--
-24N1	774	115-159	Qt
-25D1	700	80-92	Qal
-25D2	1,676	--	--
-25F1	505	0-83	Qal
-26Q2	1,709	45-58	Qal
-26Q3	1,570	48-51	Qal
-35C2	1,356	--	--
-35F12	1,270	109-125	Qal
-35H1	2,400	34-94	Qal
-35K3	1,298	42-79	Qal

Surface- and Ground-Water Quality Relations

Water quality in related surface-water and shallow ground-water systems is similar, particularly in the alluvial system along the Santa Ynez River (table 6). During periods of high flow, surface-water quality is primarily a function of precipitation and runoff characteristics. Under these conditions, most recharge occurs from surface water to the ground-water system. This situation may be reversed as runoff ceases or is reduced, and base flow is maintained by discharge from the alluvial aquifer system. Surface water is generally of poorer quality during periods of low flow (Miller, 1976). This observation may result from increased evaporative concentration of dissolved solids in surface water and (or) increased discharge of ground water containing a high concentration of dissolved solids.

The Santa Ynez River may be thought of as the primary sewerage for the study area. It provides drainage for numerous natural and artificial discharges along its length. Thus, it is not surprising that the dissolved-solids content increases downstream. This trend could result from a variety of factors, such as irrigation-return flow, waste discharge, mineral dissolution, and evaporative concentration.

Table 6.--Dissolved constituents in surface water and alluvial ground water along the Santa Ynez River

[Locations are in downstream order. Values are in milligrams per liter, except those for specific conductance, which are in microsiemens per centimeter at 25° Celsius. Ranges are given where sufficient data were available]

Location and date	Specific conductance	Calcium	Magnesium	Sodium	Chloride	Sulfate	Nitrogen (NO_2+NO_3)
Santa Ynez River at Lake Cachuma, near Santa Ynez							
1971	825-864	84-88	43-47	39-42	12-17	244-323	0.5-1.0
1980	778-841	--	--	--	11-14	252-274	0.0
6N/30W-19Q2							
1980	920	100	54	49	29	210	3.1
Santa Ynez River at Solvang							
1971	930-980	60-82	53-58	47-54	24	259-281	0-1.0
1980	974-1,120	--	--	--	29-36	282-300	--
6N/31W-17J2							
1980	940	88	55	47	27	240	0.91
6N/32W-12R3							
1980	1,120	110	63	62	47	290	.00
Santa Ynez River at Narrows, near Lompoc							
1980	1,550-1,600	130-150	78	110-120	130	400-410	0.0
7N/34W-35K12							
1980	2,250	210	120	180	220	570	0.18
Salsipuedes Creek near Lompoc							
1971	909-1,810	89-160	25-76	61-130	75-170	200-330	0.1-2.7
1980	410-1,400	120-140	54	110-120	120-130	240-310	0.5-0.8

Lake Cachuma provides a continuous source of water to the Santa Ynez River, primarily affecting surface-water quality in the upper part of the study area. The reservoir showed, in general, an inverse relationship between lake stage and dissolved-solids concentration during the period 1958-73 (Miller, 1976). The concentration of dissolved solids increased from about 430 to 640 mg/L during this period. Similarly, sulfate concentration increased from about 200 to 300 mg/L. This, along with associated increases in calcium and magnesium, apparently accounts for most of the noted increase in both dissolved solids and specific conductance. The quality of water is affected during downstream transport by a variety of factors and is interdependent with alluvial ground-water quality.

Rainwater quality may influence both surface-water and shallow ground-water quality, though probably to a lesser extent than other factors. Precipitation may be the most important single source of nitrogen in surface waters (Feth, 1966). Most atmospheric ammonia is attributed to industrial pollution. Nitric oxide and nitrogen dioxide, produced by internal combustion engines, are the most abundant oxides of nitrogen. Maps of ammonia and nitrate concentration in rainwater over the United States indicate that sources for both components are near the ground and over land. In the study area, consumption of ammonia-containing fertilizers may produce elevated ammonia concentrations in the atmosphere. Ammonia concentrations up to 2 mg/L in rainwater collected in the Santa Barbara area may be related to application of liquid fertilizer. In similar association, high levels of smog in the Los Angeles basin may be responsible for nitrate concentrations up to 1 mg/L in rainwater (Junge, 1958). Industrial regions with considerable sulfur dioxide emission have high sulfate ion content in precipitation (from 30 to more than 450 mg/L), contrasted with nonindustrialized cities (generally 15 to 30 mg/L), and rural areas (less than 15 mg/L). The relatively high bromine content in atmospheric particles is attributed to automobile exhaust gases (Matthess, 1982). Chloride content in rainwater is derived in a similar manner, by assimilation of atmospheric particles. Airborne chloride salts are formed from sea spray. Most of the salt particles are concentrated in a low-level atmospheric layer and are subsequently dissolved and transported to the ground surface by rainfall.

A basic control over water quality, particularly in the confined reach of river in the Santa Rita subarea, is the geology. In this location, basement rocks are composed chiefly of the consolidated, fractured Monterey Shale (see fig. 3). Shales are known to be a source of many dissolved constituents (Matthess, 1982, p. 287). High sulfate, chloride, calcium, magnesium, and sodium concentrations in ground water in this reach of the river are most likely derived from this source. General increases in dissolved-solids concentration in surface water may be related to evaporative concentration and to inflow of poor-quality ground water. Agricultural drainage may add dissolved constituents to the surface-water system in the form of fertilizers and soil amendments. Thus, quality of the surface- and ground-water system is controlled by a variety of factors, both natural and anthropogenic.

1980-81 Appraisal

Chemical analyses of major dissolved constituents during 1980-81 have been compiled for approximately 100 wells in the study area (table 9 at end of report). The wells used in this appraisal are listed in table 7, along with perforation and depth information; figure 14 shows well locations. Discussion of water quality is organized into groups of related constituents. As an aid to understanding the factors affecting ground-water quality, the reader is referred to figure 2, a geologic map of the area that includes distribution of the Monterey Shale and consolidated rocks, and to figure 12, a land-use map prepared from data collected by the California Regional Water Quality Control Board, Central Coast Region. The locations of anthropogenic activities that may alter or affect ground-water quality are shown in figure 12. Of chief interest are areas of agricultural irrigation, animal waste concentration, septic systems, municipal waste disposal, and urban development. In the study area, dissolved-solids concentrations in ground water decrease with increasing sample depth. This relationship is shown in figure 15, a plot of dissolved-solids concentration versus well-screen depth. These data point toward a surface source area for ground-water contaminants.

Table 7.--Dissolved-solids, well-screen, and geologic data from wells in the upper Santa Ynez Valley, 1980-81

[Geologic units: Qal, alluvium; Qt, Orcutt Sand and terrace deposits; QTpr, Paso Robles Formation; Tc, Careaga Sand. See figure 14 for location of wells. G, gravel-packed screen; F, gravel-packed perforations; S, screened; X, open hole]

Well No.	Total depth below land surface (ft)	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
6N/29W-6F1	53	629	35-53	Qal,Qt
6N/30W-1R3	240	539	28-240	Qal,Qt,QTpr
-3A1	407	464	80-407	Qal,Qt,QTpr
-6B1	487	431	G146-487	Qt,QTpr
-7C4	113	497	98-113	Qt
-7G6	410	462	F305-410	QTpr
-19Q2	46	677	22-46	Qal
6N/31W-1B2	815	--	250	Qt,QTpr
-1G5	240	727	100-240	Qt,QTpr
-1P3	490	683	195-490	QTpr
-2B4	130	1,040	105-130	Qt,QTpr
-2G1	333	647	200-333	Qt,QTpr
-2P3	432	604	--	Qt,QTpr
-4A2	235	326	113-235	Tc
-6D3	440	548	G350-440	QTpr,Tc
-6F3	260	768	160-260	QTpr

Table 7.--Dissolved-solids, well-screen, and geologic data from wells in the upper Santa Ynez Valley, 1980-81--Continued

Well No.	Total depth below land surface (ft)	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
6N/31W-7E4	293	788	80-293	Qal,Qt,QTpr
-7K2	304	603	188-304	Qt,QTpr
-8F3	261	506	181-261	Tc
-10C2	376	640	116-376	QTpr,Tc
-10L1	132	403	0-132	Qal,Qt
-11D2	170	947	48-170	Qal,QTpr
-11D3	368	1,060	56-368	Qal,QTpr
-12R4	192	647	150-192	Qt,QTpr
-13D3	159	681	116-159	Qt,QTpr
-13E1	129	604	110-129	Qt,QTpr
-13F1	69	501	64-69	Qt
-14G3	103	673	60-103	Qt
-15C1	57	399	18-57	Qal,Qt
-15R1	49	1,130	31-49	Qal
-16L1	290	774	G180-290	Qt
-17J2	70	630	42-70	Qal
-18A4	80	1,450	F0-80	Qal
-24F2	44	707	--	Qal
6N/32W-2C1	425	178	160-180 260-280 400-420	Tc
-2Q1	76	1,750	50-76	Qal
-3R2	600	536	480-600	Tc
-5E2	140	529	0-140	Qal,Qt
-6K3	155	372	140-155	QTpr
-7N5	75	1,980	69-75	Qal
-9J1	81	1,250	0-81	Qal
-10J1	66	1,190	43-66	Qal
-11D1	60	1,230	30-60	Qal
-11L2	60	1,040	0-60	Qal
-12E1	184	801	84-144 164-184	Qal,Qt,QTpr
-12N3	85	1,200	10-85	Qal
-12R3	56	815	18-56	Qal
-16P4	93	1,550	51-93	Qal
6N/33W-8E4	102	1,240	62-102	Qal
-9K2	182	3,020	107-182	Qal
-11M1	72	1,050	52-72	Qal
7N/29W-31J2	575	881	150-565	QTpr
7N/30W-27H1	171	618	145-171	QTpr
-28C1	359	355	120-359	QTpr
-29J1	509	438	200-509	QTpr
-29N2	--	375	--	--
-30G2	545	329	420-440 460-480 500-540	QTpr

Table 7.--Dissolved-solids, well-screen, and geologic data from wells in the upper Santa Ynez Valley, 1980-81--Continued

Well No.	Total depth below land surface (ft)	Dissolved solids (mg/L)	Depth of screened interval below land surface (ft)	Geologic unit
7N/30W-31G1	446	363	112-446	Qt,QTpr
-31H1	185	447	140-185	QTpr
-31P2	--	432	--	--
-32D2	786	367	304-786	QTpr
-32Q2	410	311	210-410	QTpr
-33F1	260	442	92-260	Qt,QTpr
-33M2	318	485	165-318	Qt,QTpr
-34K1	1,000	534	200-1,000	QTpr,Tc
7N/31W-14N1	285	684	88-285	QTpr
-22A3	218	643	95-218	QTpr
-22J1	165	560	97-165	QTpr
-23B2	134	352	99-134	QTpr
-23N4	125	500	60-125	QTpr
-23Q1	200	644	0-200	QTpr
-23Q5	214	487	110-214	Qt,QTpr
-23R3	1,300	521	640-1,300	QTpr,Tc
-25R1	215	448	118-215	Qt,QTpr
-26K1	120	724	85-100	Qt,QTpr
-26Q4	165	513	39-165	Qal,Qt,QTpr
-30K1	340	2,980	50-340	Qal
-34M1	--	218	--	--
-35A1	800	538	560-800	Tc
-35K1	--	1,200	--	--
-36A4	680	297	300-680	QTpr,Tc
-36G4	277	634	90-277	Qt,QTpr
7N/32W-30C1	251	1,840	150-251	Tc
-31K1	900	182	420-900	Tc
-36P1	810	457	0-810	Tc
7N/33W-17N2	--	418	--	--
-21G1	960	405	660-960	Tc
-26C1	522	452	502-522	QTpr,Tc
-26E2	467	290	462-467	QTpr,Tc
-27C3	414	467	S399-414	QTpr,Tc
-27J1	--	592	--	--
-28D3	590	507	G440-590	QTpr,Tc
-30B1	225	1,020	219-225	Qt/QTpr
-36J7	197	560	X190-197	Qt/QTpr
7N/34W-35K12	134	1,650	42-68 74-79	Qal

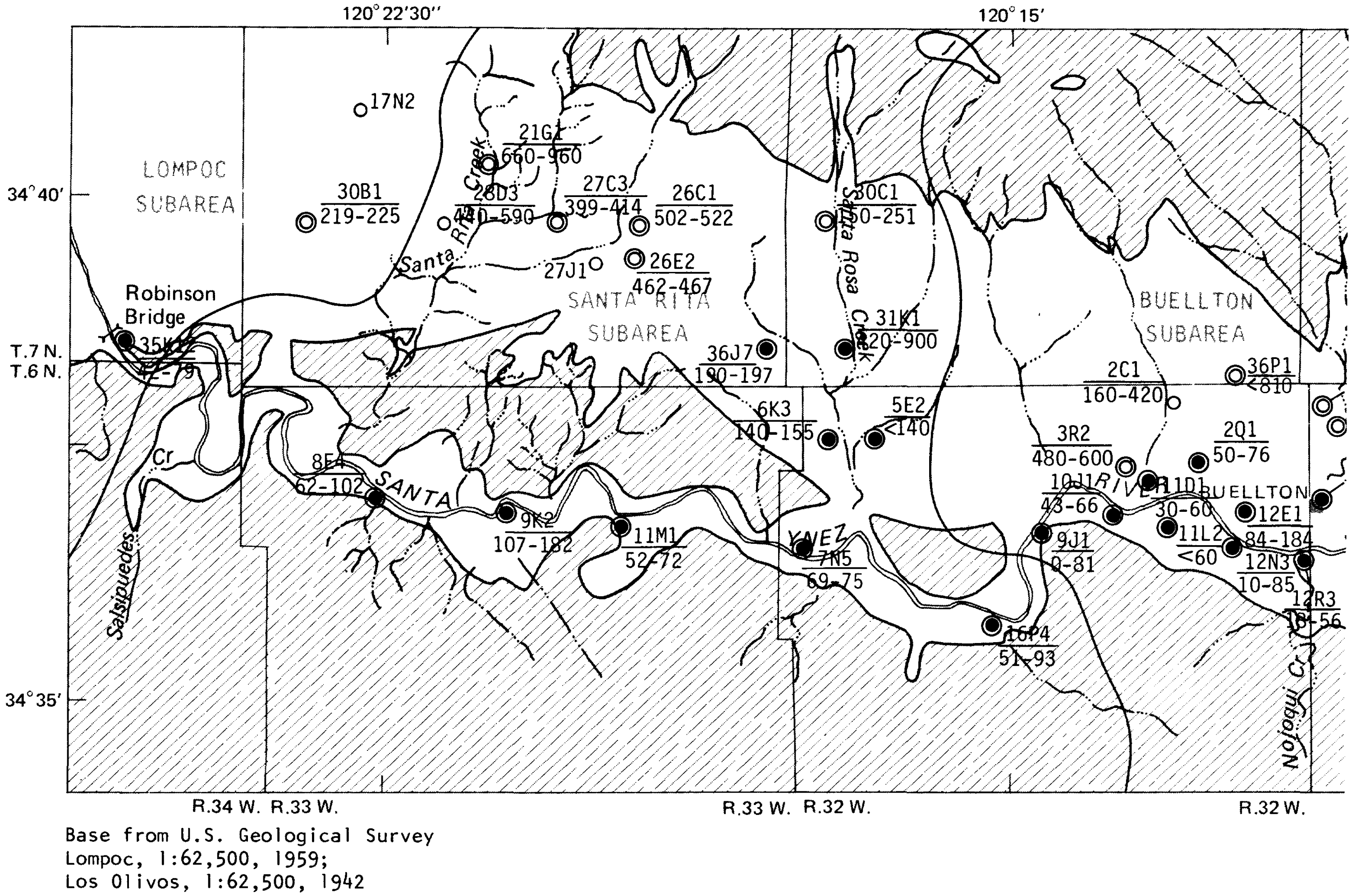
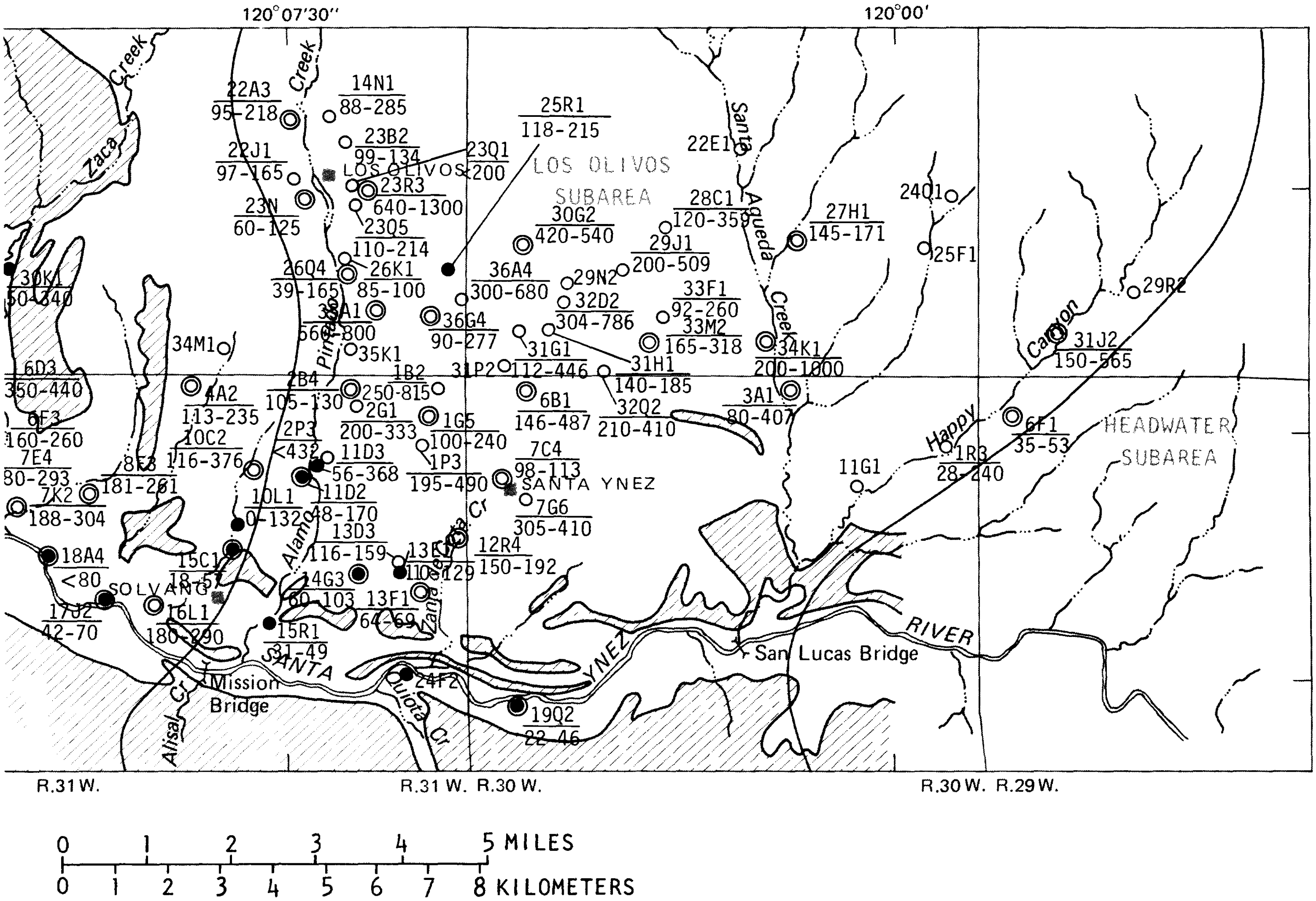


FIGURE 14.-Locations and screened intervals of wells sampled for chemical



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

WELL-Number above line is well number; number below line is screened interval of well, in feet

10L1 / 0-132 — SHALLOW (ALLUVIUM) WELL

2C1 / 160-420 — DEEP WELL

8E4 / 62-102; 30B1 / 219-225 — WELL IN PROPOSED MONITORING NETWORK

analyses, 1980-81, and location of wells in proposed monitoring network.

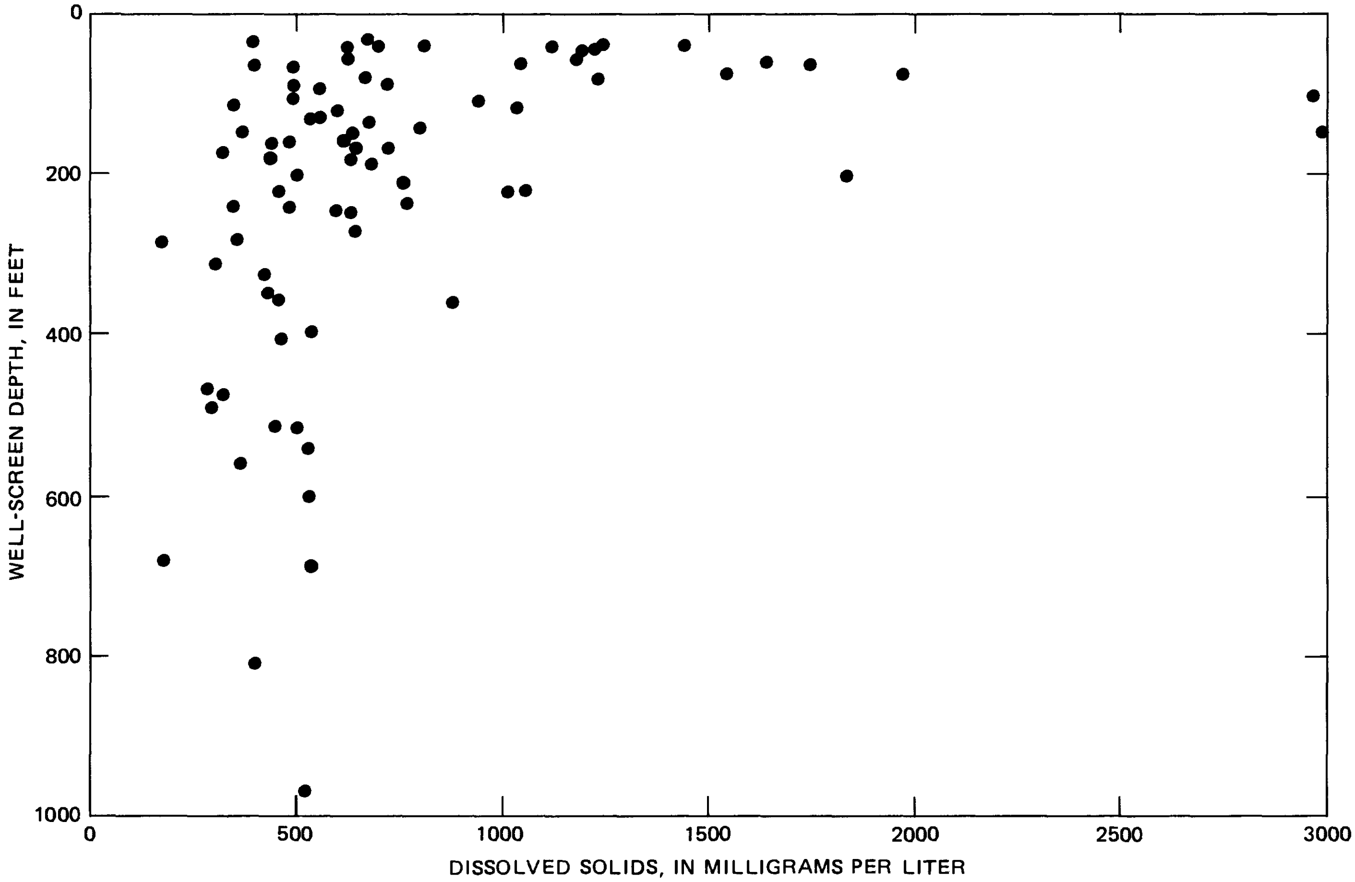


FIGURE 15.– Correlation of dissolved-solids concentration to well-screen depth.

Dissolved Solids and Specific Conductance

The close linear relation between dissolved solids and specific conductance (fig. 16) illustrates the usefulness of specific conductance as a general indicator of water quality. These data indicate that dissolved solids are about 0.60 times the values for specific conductance. In general, dissolved solids are 0.55 to 0.75 times the value for specific conductance (Hem, 1970). Stiff diagrams (fig. 17) are used to show water types and relative chemical variations. Areas of concern are the alluvial aquifer along the Santa Ynez River and the western part of the Los Olivos subarea. The Monterey Shale crops out along the Santa Ynez River, predominantly in the lower end of the reach and in the Purisima Hills north of Buellton. The shale is a possible source of water containing relatively high dissolved-solids concentrations (Evenson, 1965). Dissolved-solids concentrations are high (>1,000 mg/L) in the ground water in these areas. Well 7N/32W-30C1 taps the Monterey Shale and yields water with a high dissolved-solids concentration. The area of high concentration to the northwest of Buellton is in a region of varied activities. Agricultural irrigation, horse stables, and wastewater disposal all probably contribute to the observed water-quality conditions. The dissolved-solids concentration is also greater than 1,000 mg/L in the vicinity of Ballard and south to Solvang, probably as a result of seepage from septic systems, ranching activities, and urban development.

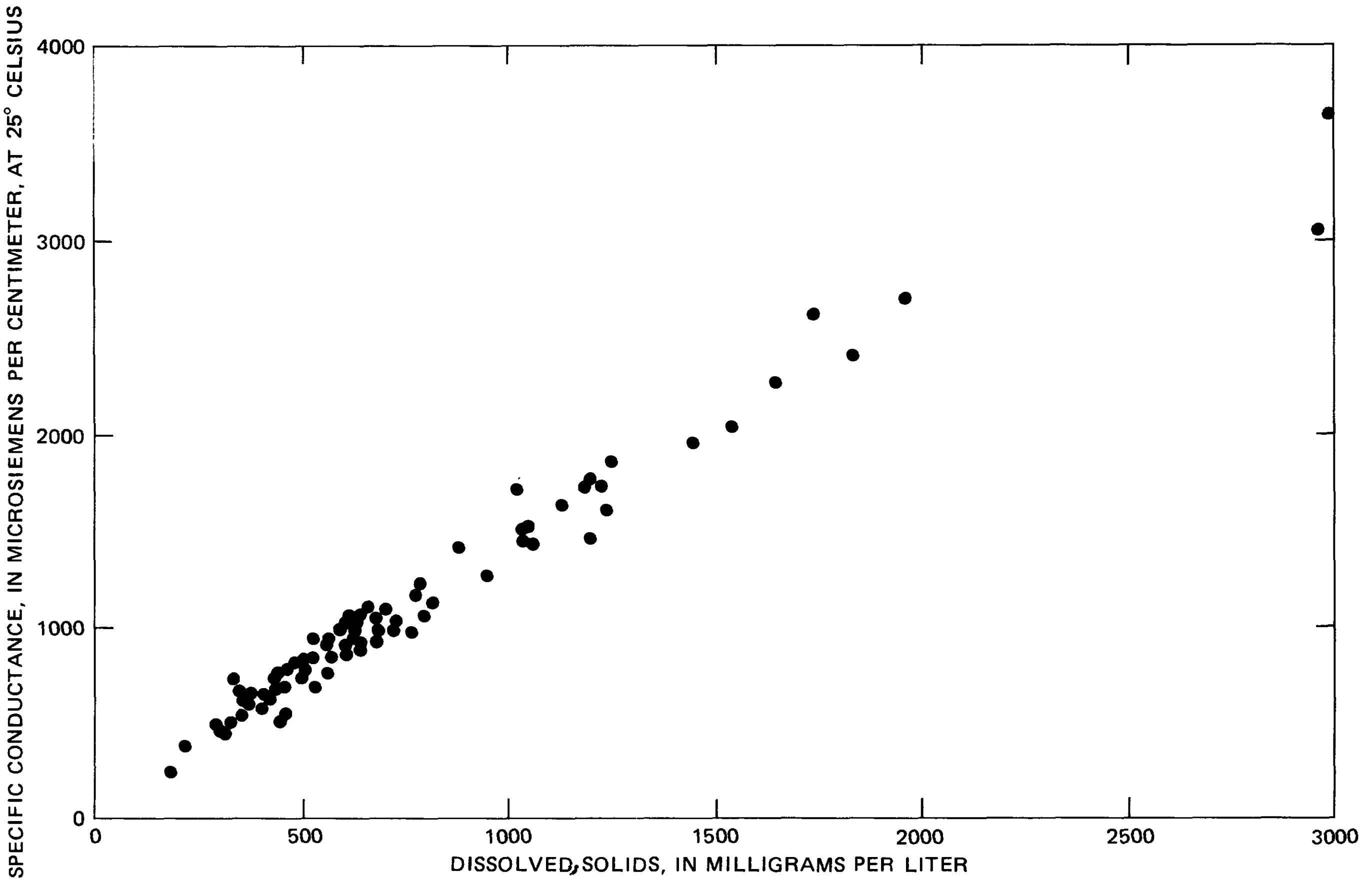
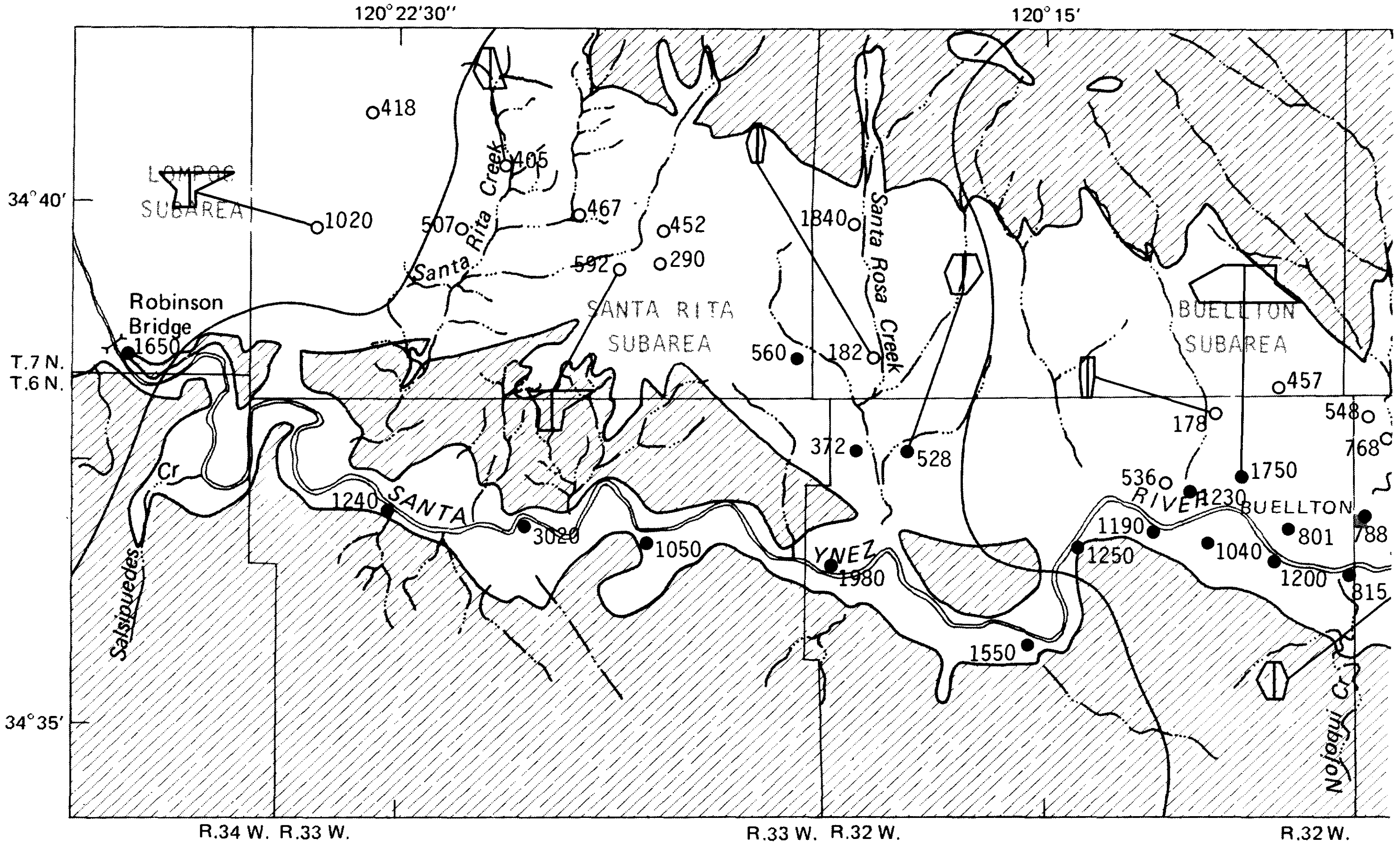
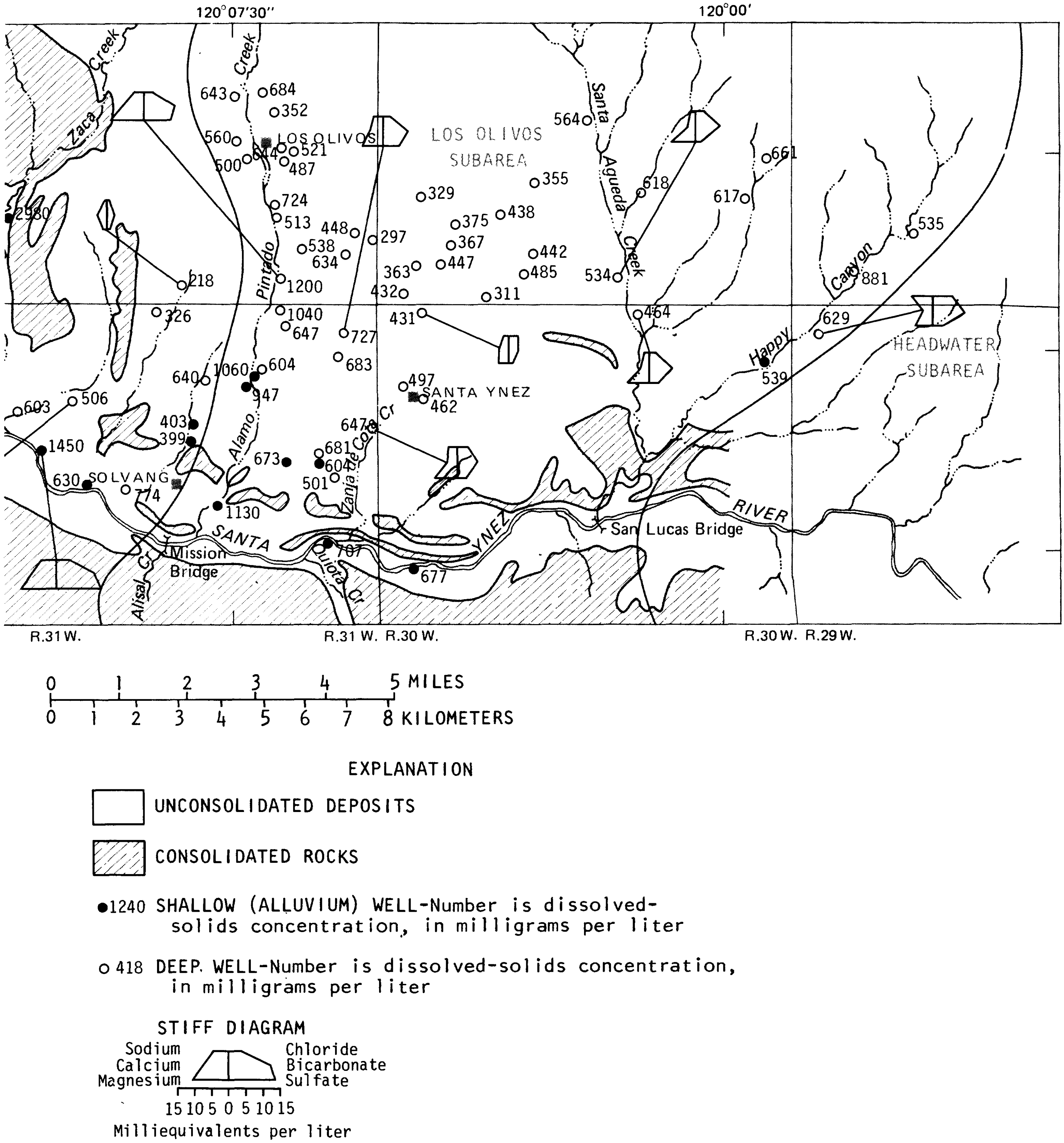


FIGURE 16. – Correlation of dissolved-solids concentration to specific conductance, 1980–81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 17.-Water-quality diagrams and dissolved-



solids concentrations in the study area, 1980-81.

Calcium, Hardness, and Sulfate

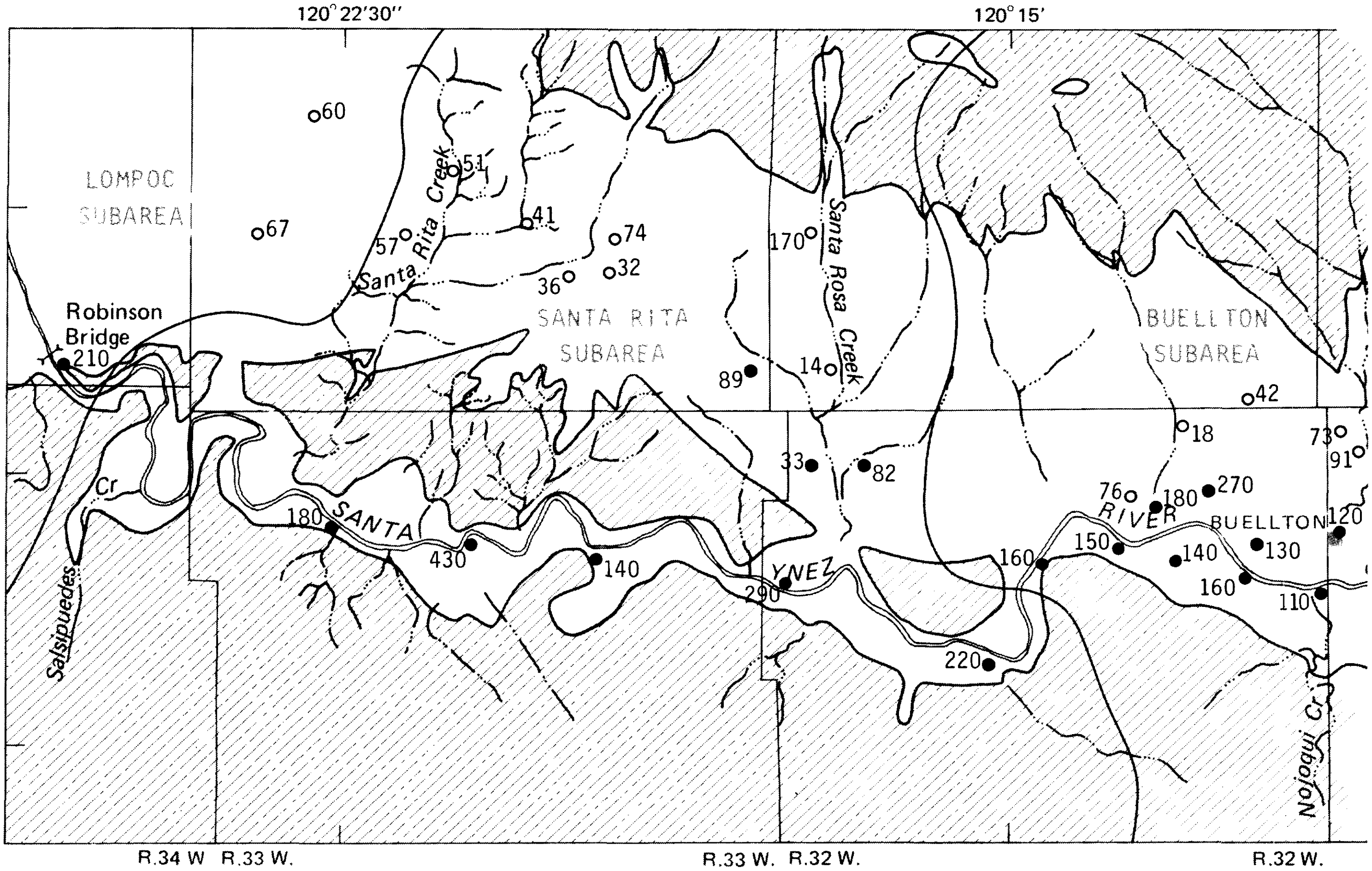
The distribution patterns of these constituents are similar to each other and to dissolved-solids and specific-conductance patterns. Calcium (fig. 18) correlates well to hardness (fig. 19) and sulfate (fig. 20), indicating a natural source, such as limestone or gypsum, or mutual concentration due to evaporation. Dissimilar ratios between ionic components in ground-water samples indicate a specific source of contamination. A general concentration of constituents points toward a nonspecific process, such as evaporation. Dissolved solids in agricultural return flow are concentrated by evaporation. Additionally, the concentration of specific constituents, particularly nitrate, may be elevated by application of fertilizers. Hardness is objectionable when it exceeds 100 mg/L, as it does in virtually all of the study area. However, an increase in hardness, most likely with a related decrease in sodium, has been statistically linked with a reduction in heart disease (Hem, 1970). Sulfate exceeds the drinking water criterion of 250 mg/L (U.S. Environmental Protection Agency, 1979) in most of the alluvial systems, particularly in areas of intense agricultural and urban development.

Sodium and Chloride

Sodium (fig. 21) and chloride (fig. 22) distributions are virtually the same. Between Los Olivos and Santa Ynez, some wells have chloride concentrations greater than 100 mg/L. Ranching activities and septic systems may account for this anomalously high chloride concentration. One well in the alluvial aquifer along the lower reaches of the Santa Ynez River contains water having a chloride concentration in excess of the recommended limit of 250 mg/L (U.S. Environmental Protection Agency, 1979). Agricultural activities or connate water probably is responsible for high chloride areas in T. 7 N., R. 33 W. Another area of high chloride and sodium concentrations is near Buellton where a combination of urban development (wastewater discharge) and agricultural development (stables and pasture land) has led to deterioration of water quality. However, concentrations of sodium and chloride are generally not excessive in most of the study area, and in comparison with sulfate, are not considered a major problem.

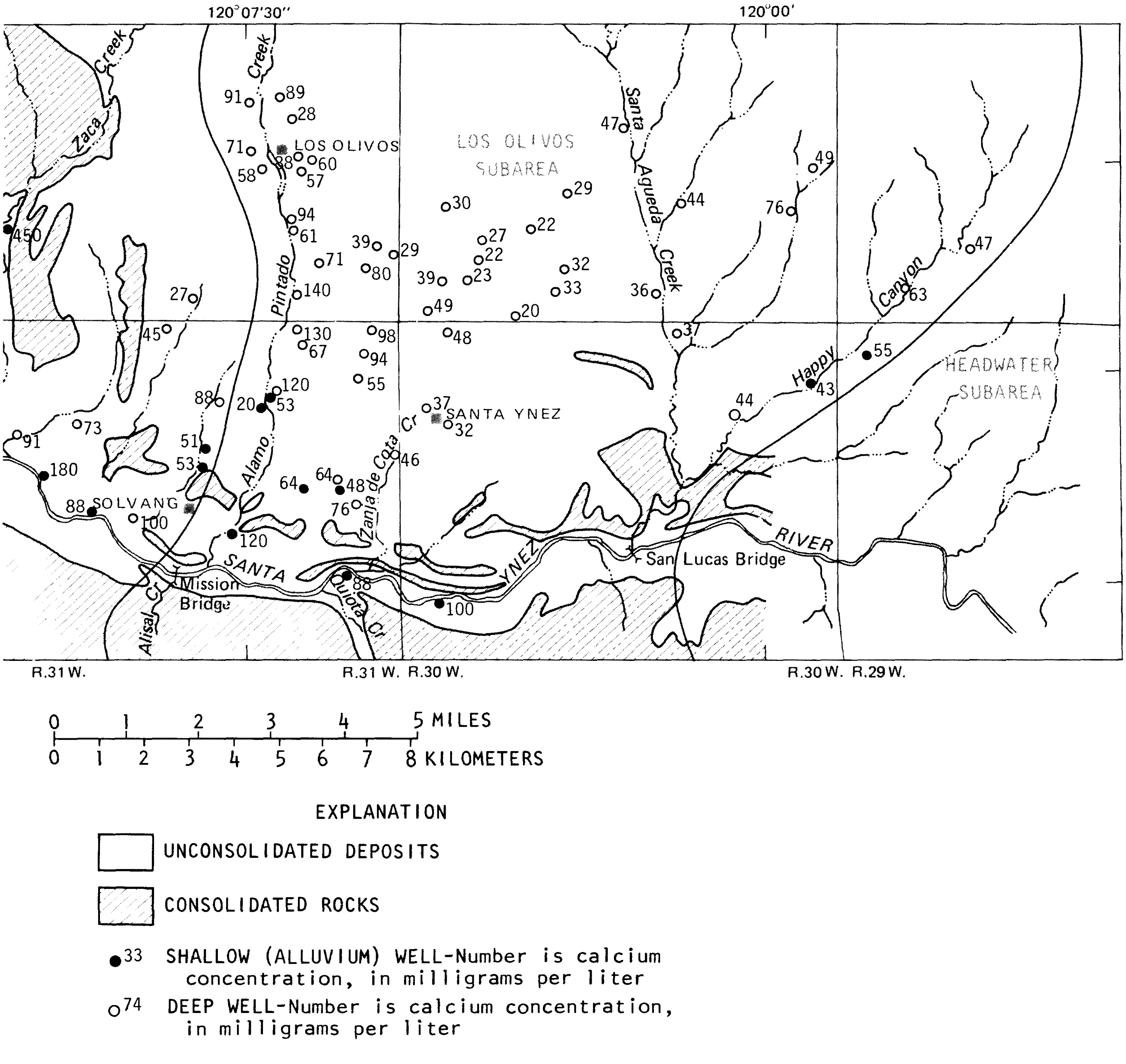
Nitrogen and Phosphate

Nitrogen (fig. 23) and phosphate (fig. 24) have similar distributions, though nitrogen was detected in higher concentrations over broader areas. Both may be derived from fertilizers and, particularly, animal waste. Phosphate ion concentrations in water are generally lower than those of the more mobile nitrate ion. Phosphorus has a strong tendency to form polymeric complexes, and it forms ionic complexes and compounds of low solubility with many metals. Natural nitrate accumulation in soil from organic matter is solubilized through cultivation of land for agricultural uses. The extensive use of nitrate fertilizers adds to the nitrate accumulation problem. Farm animals and septic systems are also major sources of nitrogenous waste. Nitrogen, along with sulfate, presents the most serious water-quality problem in the upper valley. Several areas have nitrate (as nitrogen) concentrations exceeding the safe drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 1976). The source of the nitrate in water from wells 7N/33W-30B1 and 6N/32W-5E2 probably is from water affected by local contamination from farming activities. Relatively high nitrogen concentrations around the towns of Buellton, Solvang, Santa Ynez, and Los Olivos probably result from both urban and agricultural activities. Water quality in the area near Buellton is probably influenced by wastes from livestock and discharge from the Buellton treatment plant. Contamination of ground water by septic tank systems near Santa Ynez has been, and still is, a problem. In the study area as a whole, the primary sources of nitrogen in ground water appear to be animal feedlots and high-density development where septic tank systems are used.

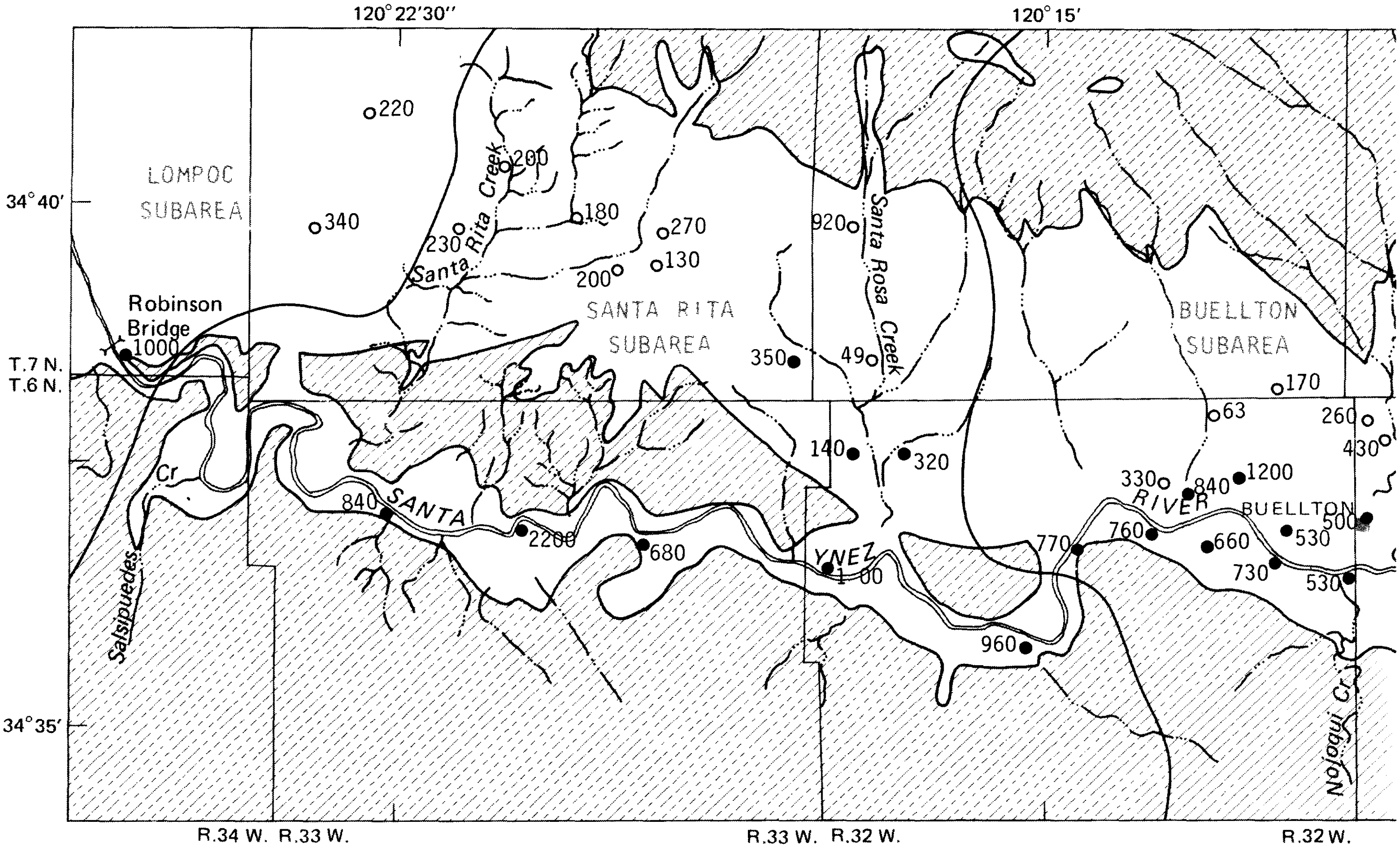


Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 18.-Calcium concentration in

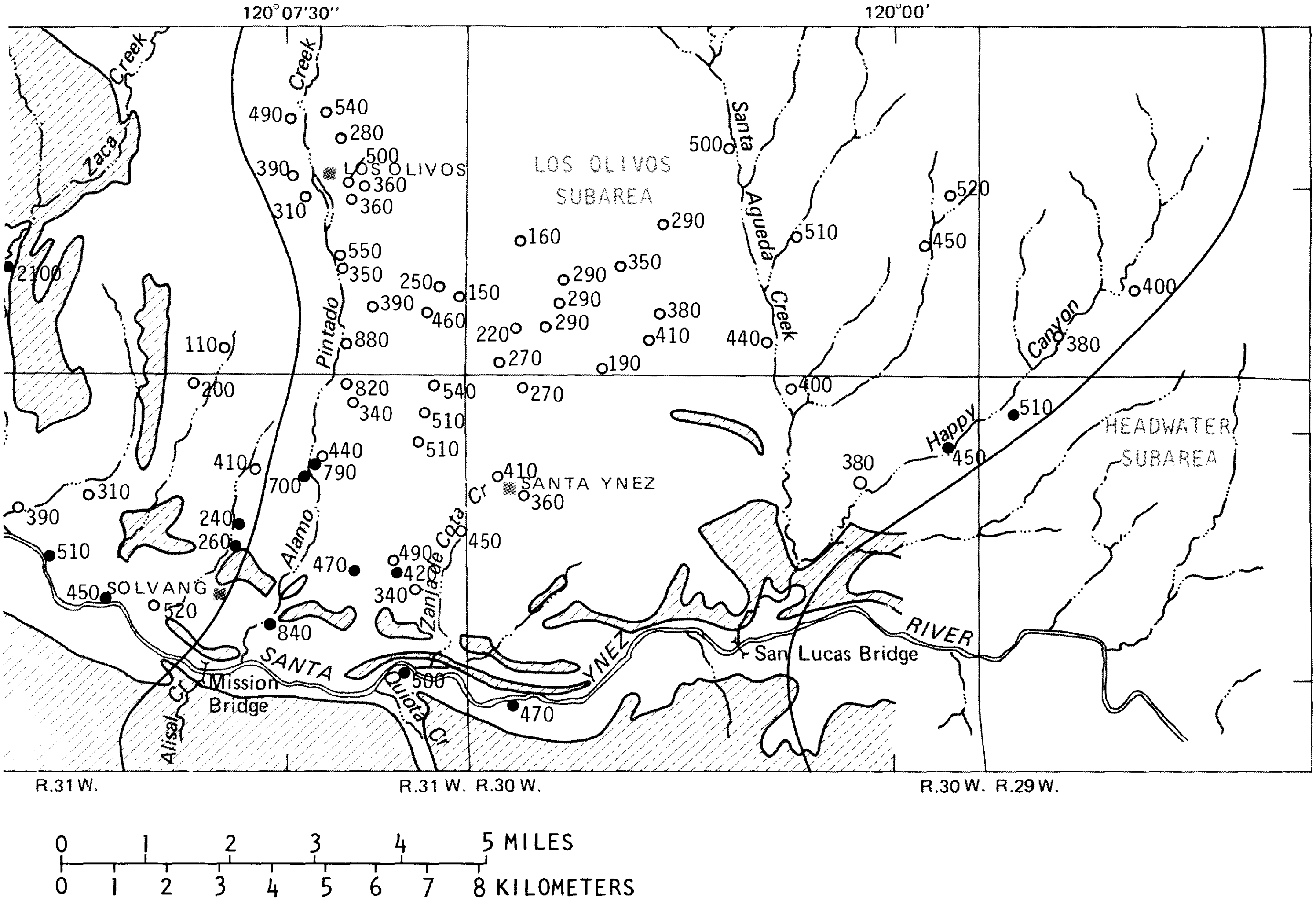


ground water in the study area, 1980-81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 19.-Hardness, as calcium carbonate,



EXPLANATION

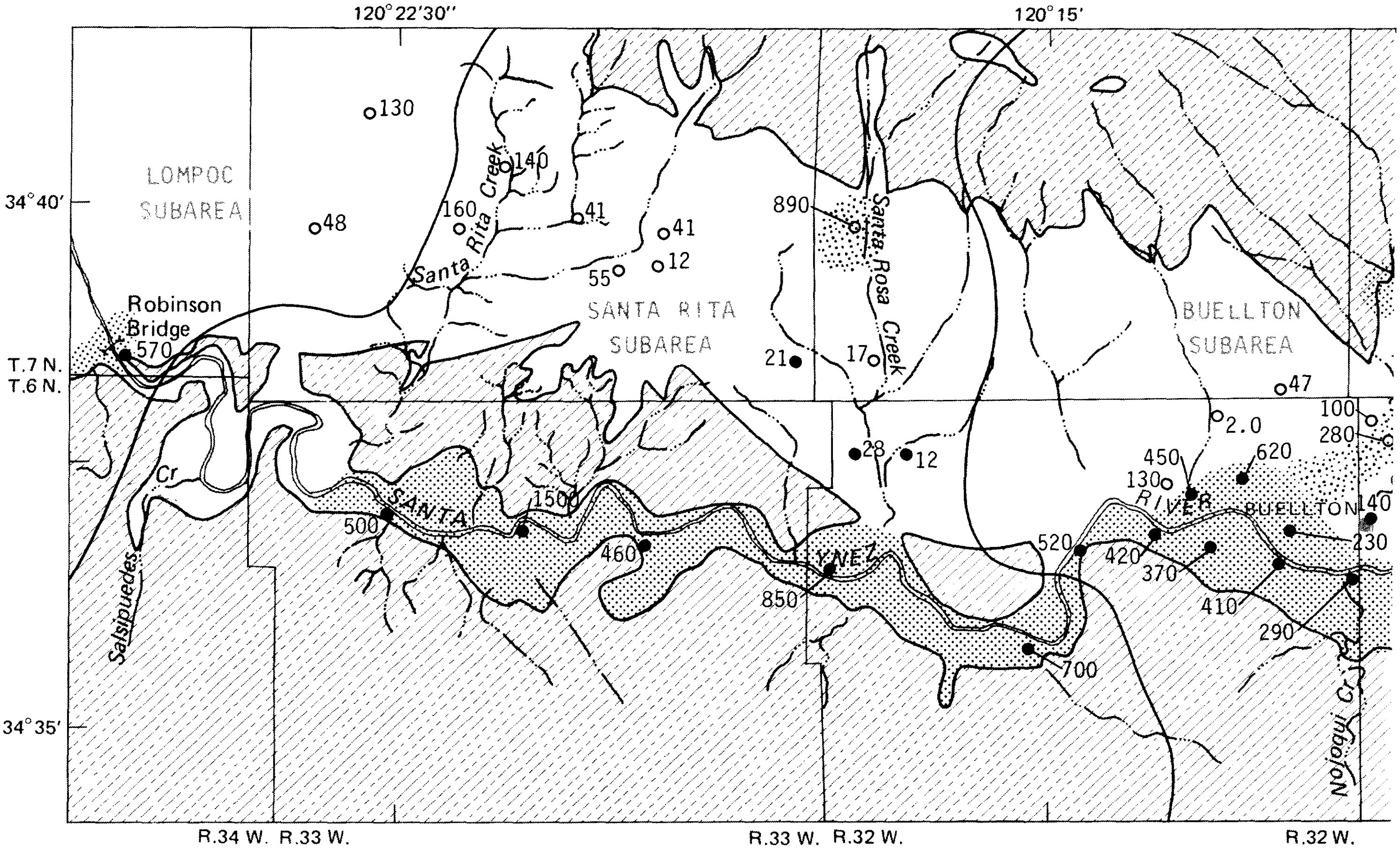
UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

●840 SHALLOW (ALLUVIUM) WELL-Number is hardness, in milligrams per liter of calcium carbonate

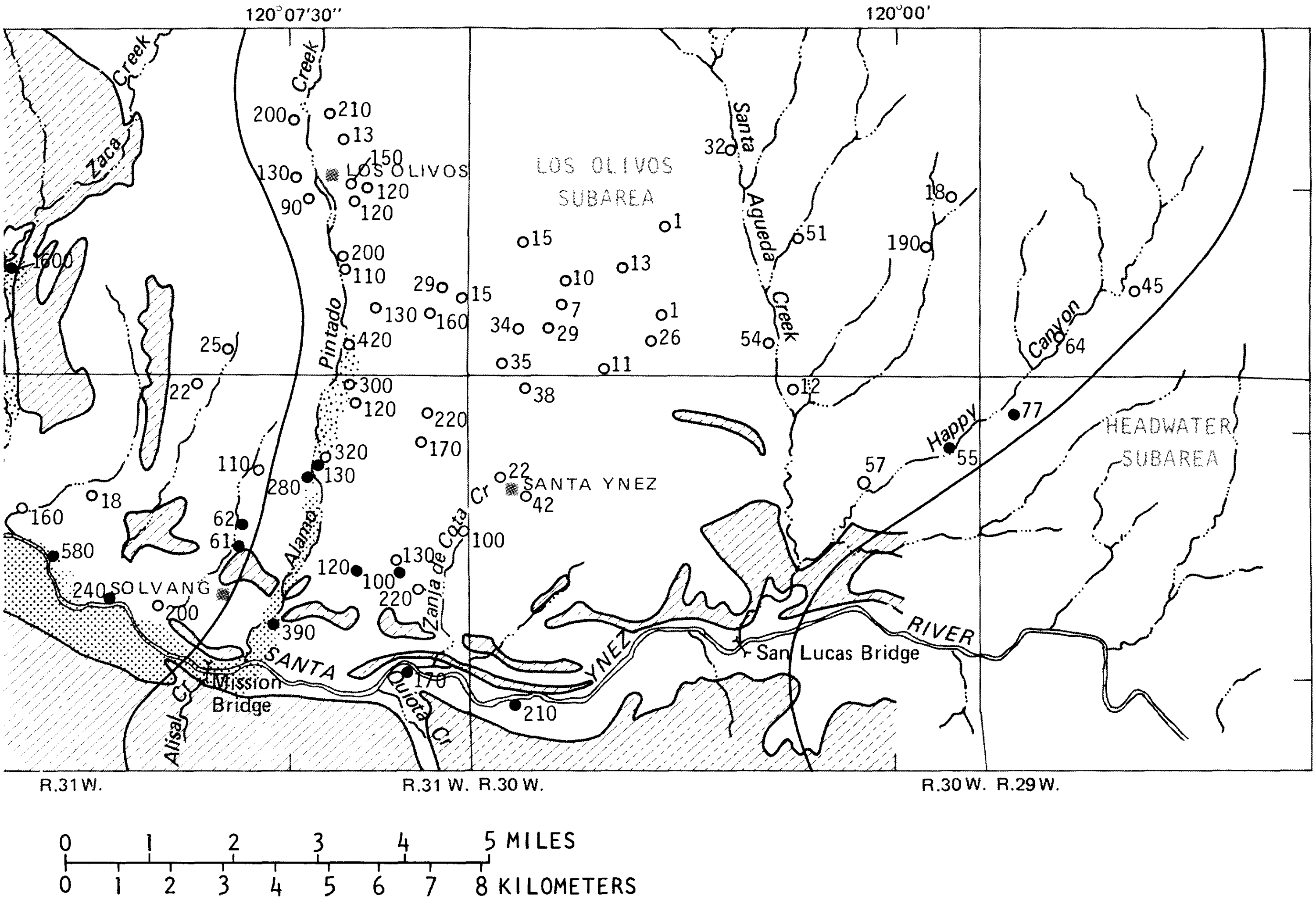
○220 DEEP WELL-Number is hardness, in milligrams per liter of calcium carbonate

of ground water in the study area, 1980-81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 20.-Sulfate concentration in



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

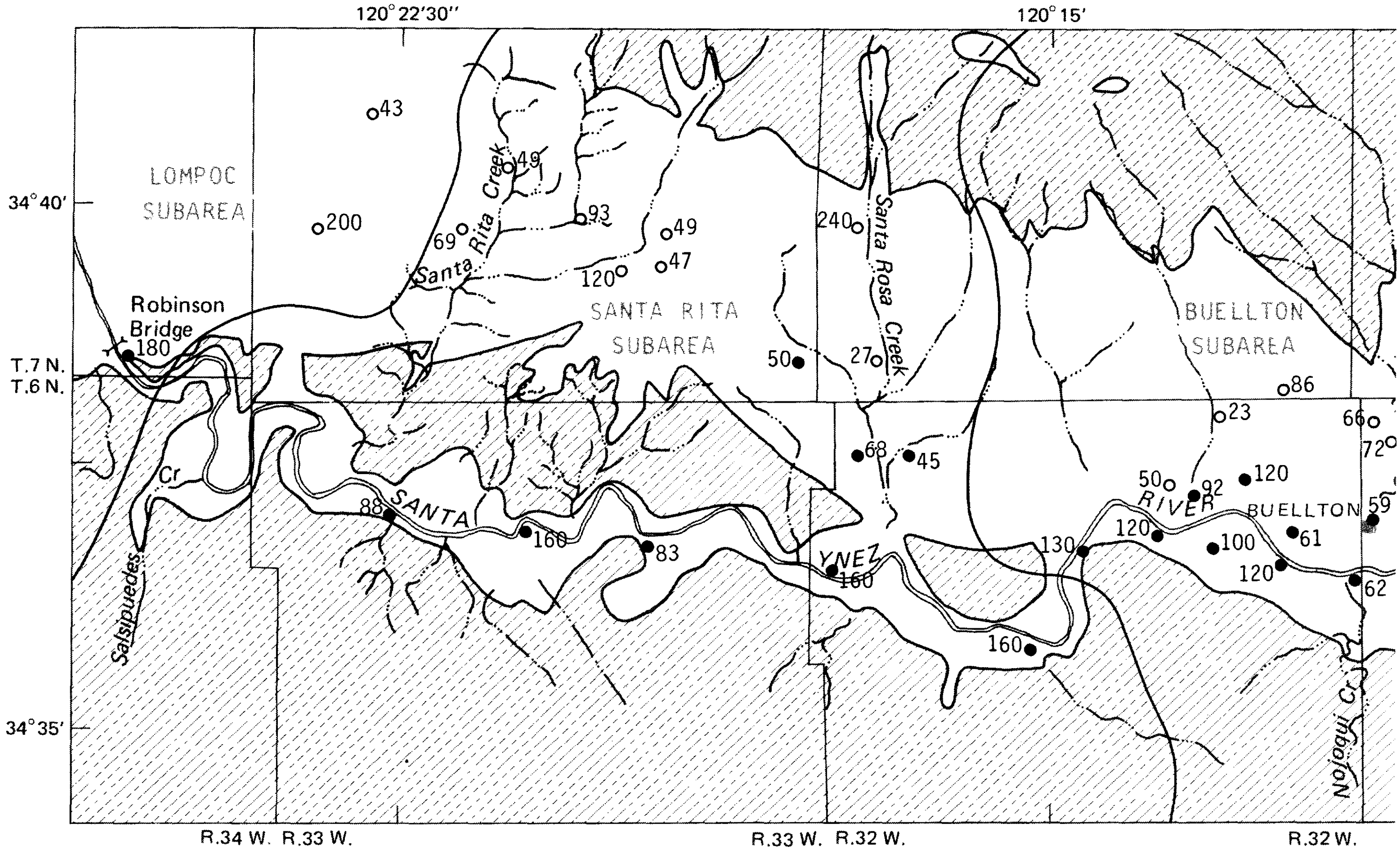
●21 SHALLOW (ALLUVIUM) WELL-Number is sulfate concentration, in milligrams per liter

○17 DEEP WELL-Number is sulfate concentration, in milligrams per liter

SULFATE CONCENTRATION EXCEEDING 250 MILLIGRAMS PER LITER IN SHALLOW (ALLUVIAL) GROUND WATER

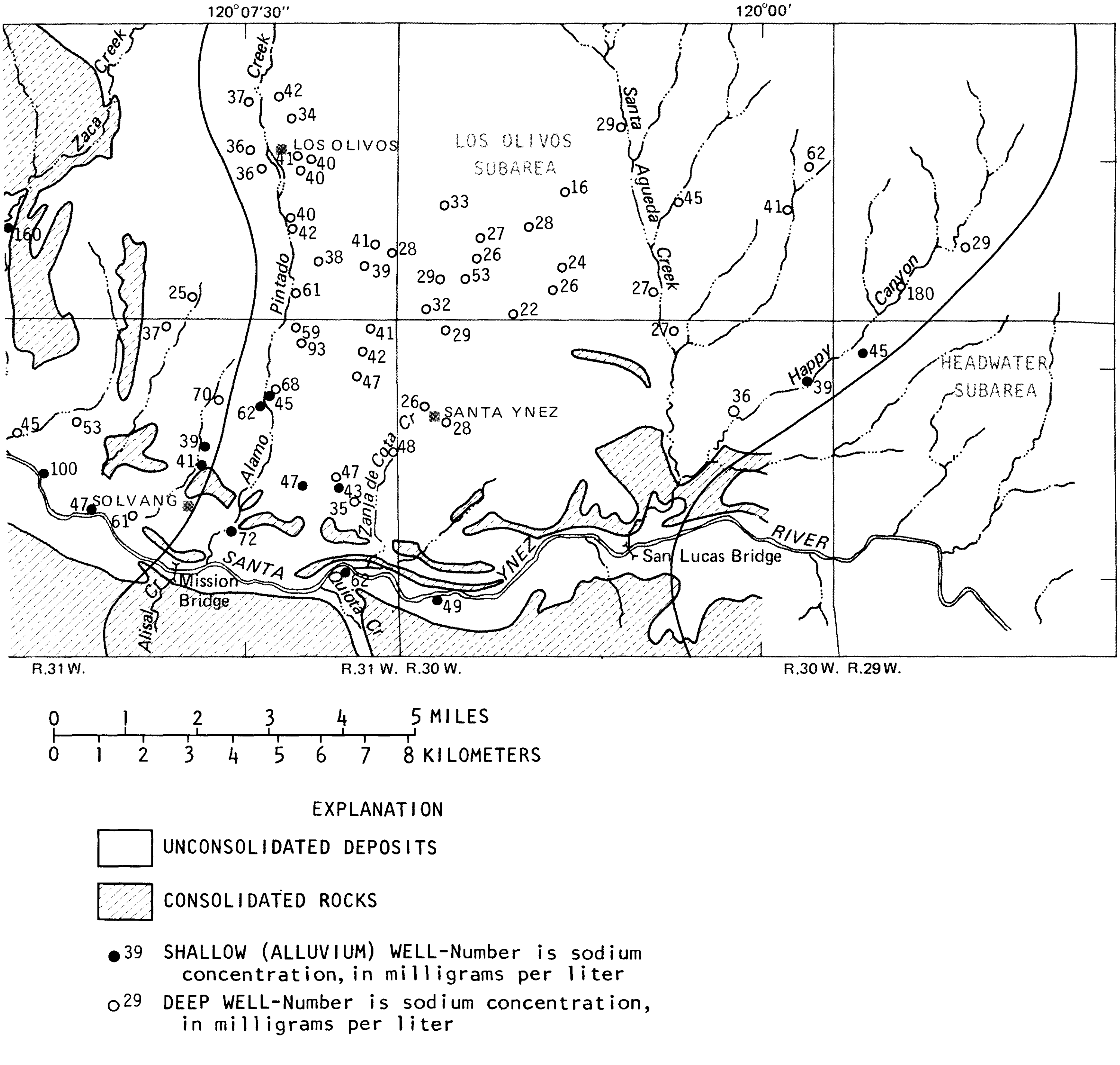
SULFATE CONCENTRATION EXCEEDING 250 MILLIGRAMS PER LITER IN DEEP GROUND WATER

ground water in the study area, 1980-81.

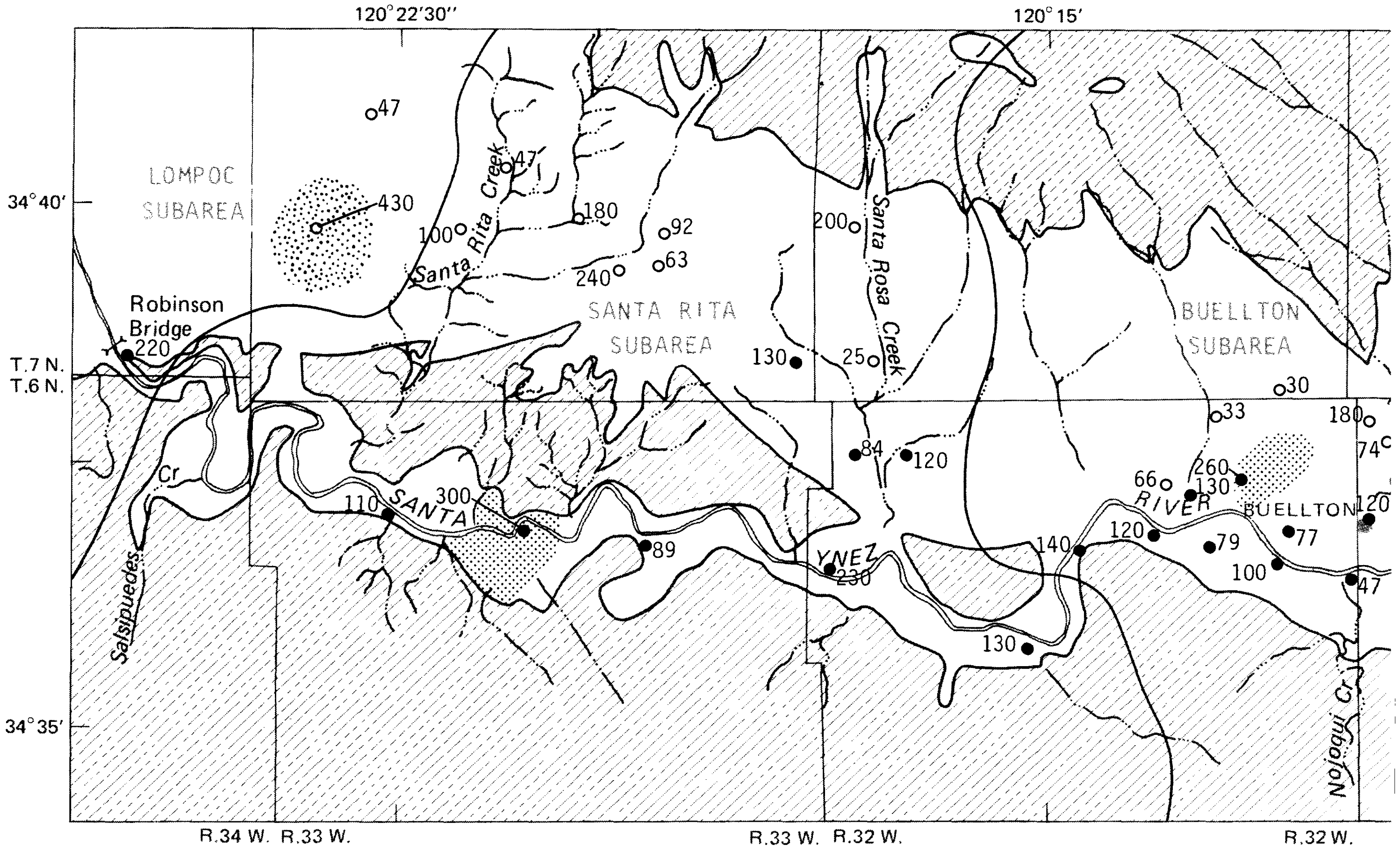


Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 21.-Sodium concentration in

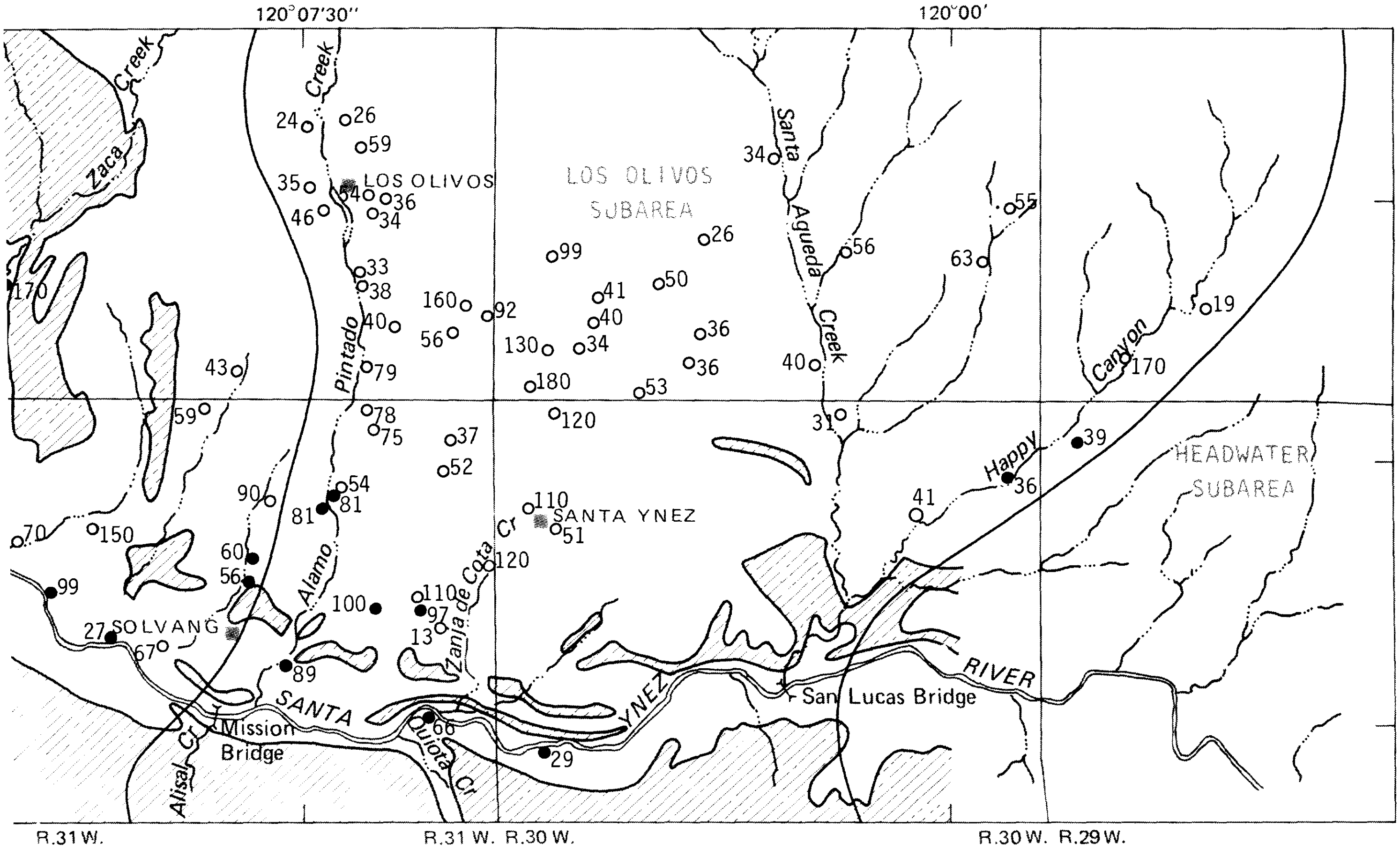


ground water in the study area, 1980-81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 22.-Chloride concentration in



0 1 2 3 4 5 MILES

0 1 2 3 4 5 6 7 8 KILOMETERS

EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

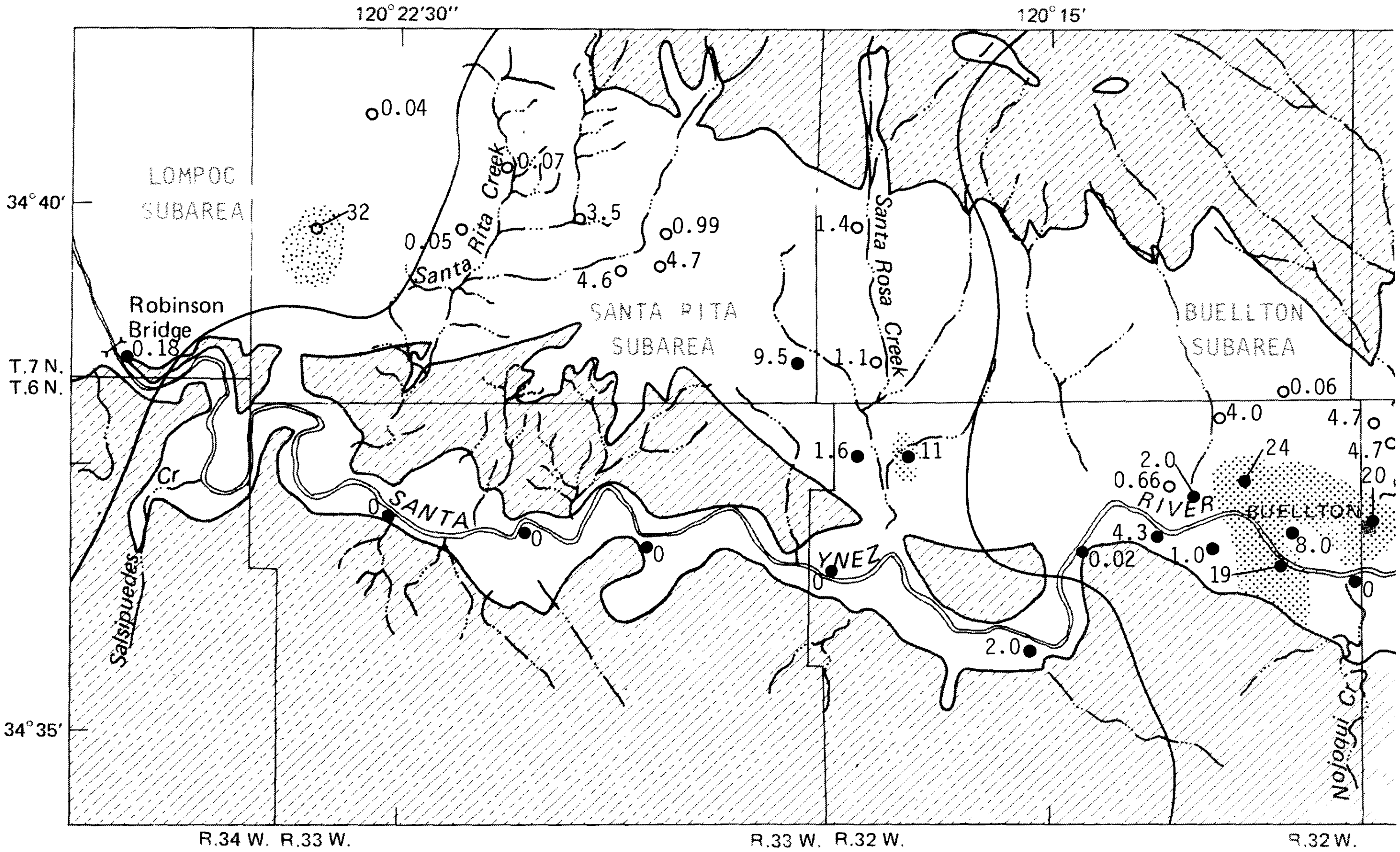
●120 SHALLOW (ALLUVIUM) WELL-Number is chloride concentration, in milligrams per liter

○130 DEEP WELL-Number is chloride concentration, in milligrams per liter

CHLORIDE CONCENTRATION EXCEEDING 250 MILLIGRAMS PER LITER IN SHALLOW (ALLUVIAL) GROUND WATER

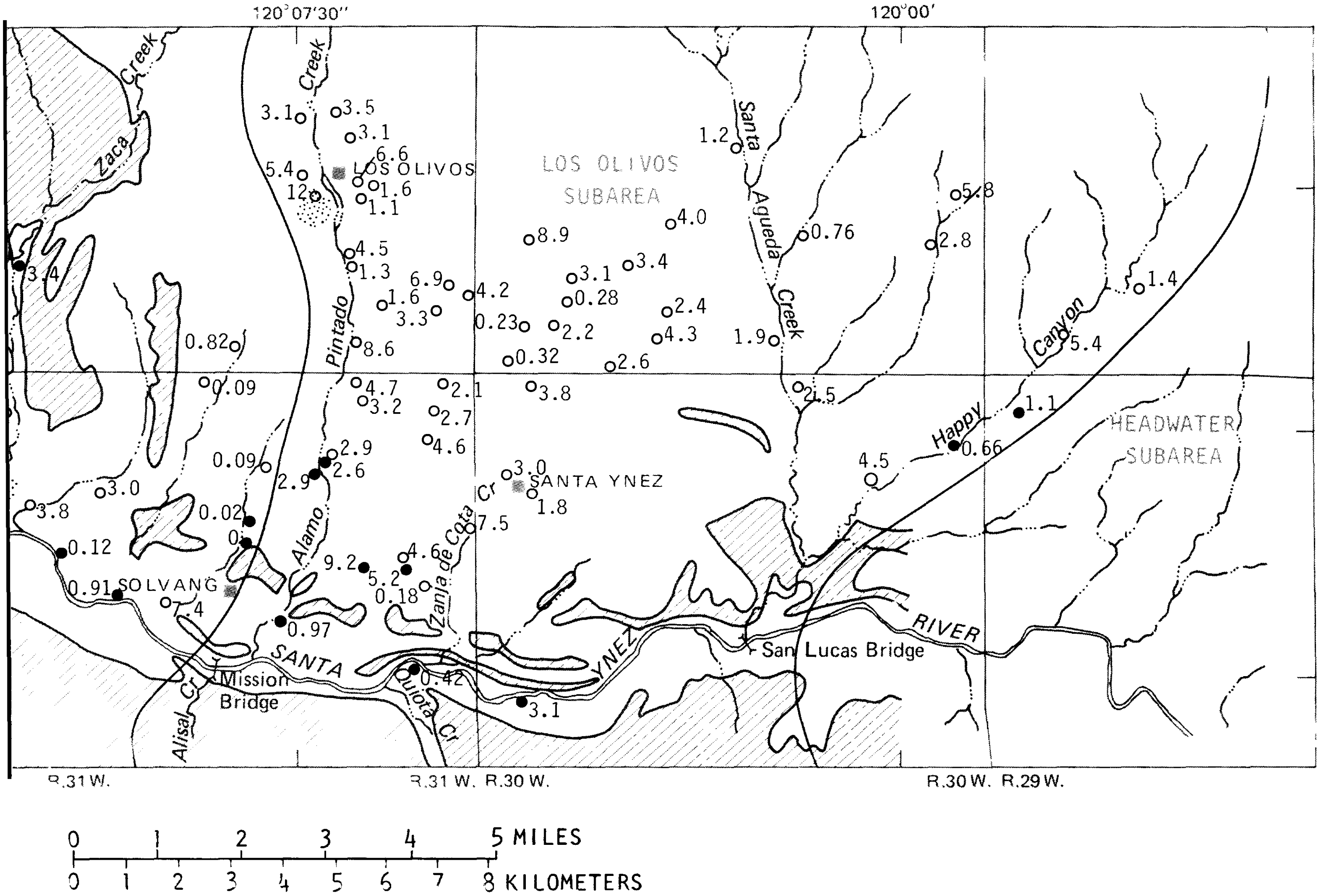
CHLORIDE CONCENTRATION EXCEEDING 250 MILLIGRAMS PER LITER IN DEEP GROUND WATER

ground water in the study area, 1980-81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 23.-Nitrogen (NO_2+NO_3) concentration



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

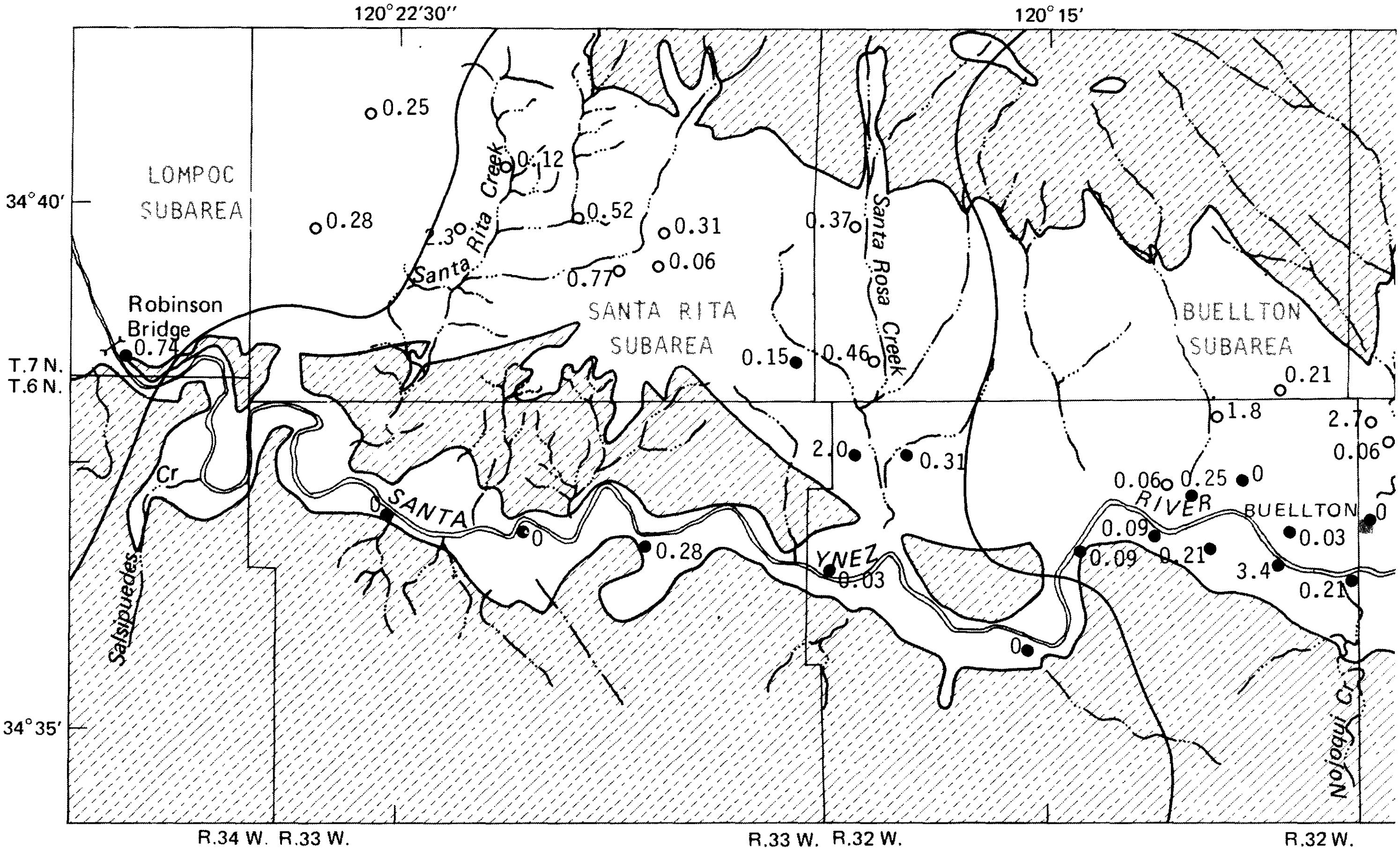
●2.6 SHALLOW (ALLUVIUM) WELL- Number is nitrogen (NO_2+NO_3) concentration, in milligrams per liter

○4.2 DEEP WELL- Number is nitrogen (NO_2+NO_3) concentration, in milligrams per liter

NITROGEN CONCENTRATION EXCEEDING 10 MILLIGRAMS PER LITER IN SHALLOW (ALLUVIAL) GROUND WATER

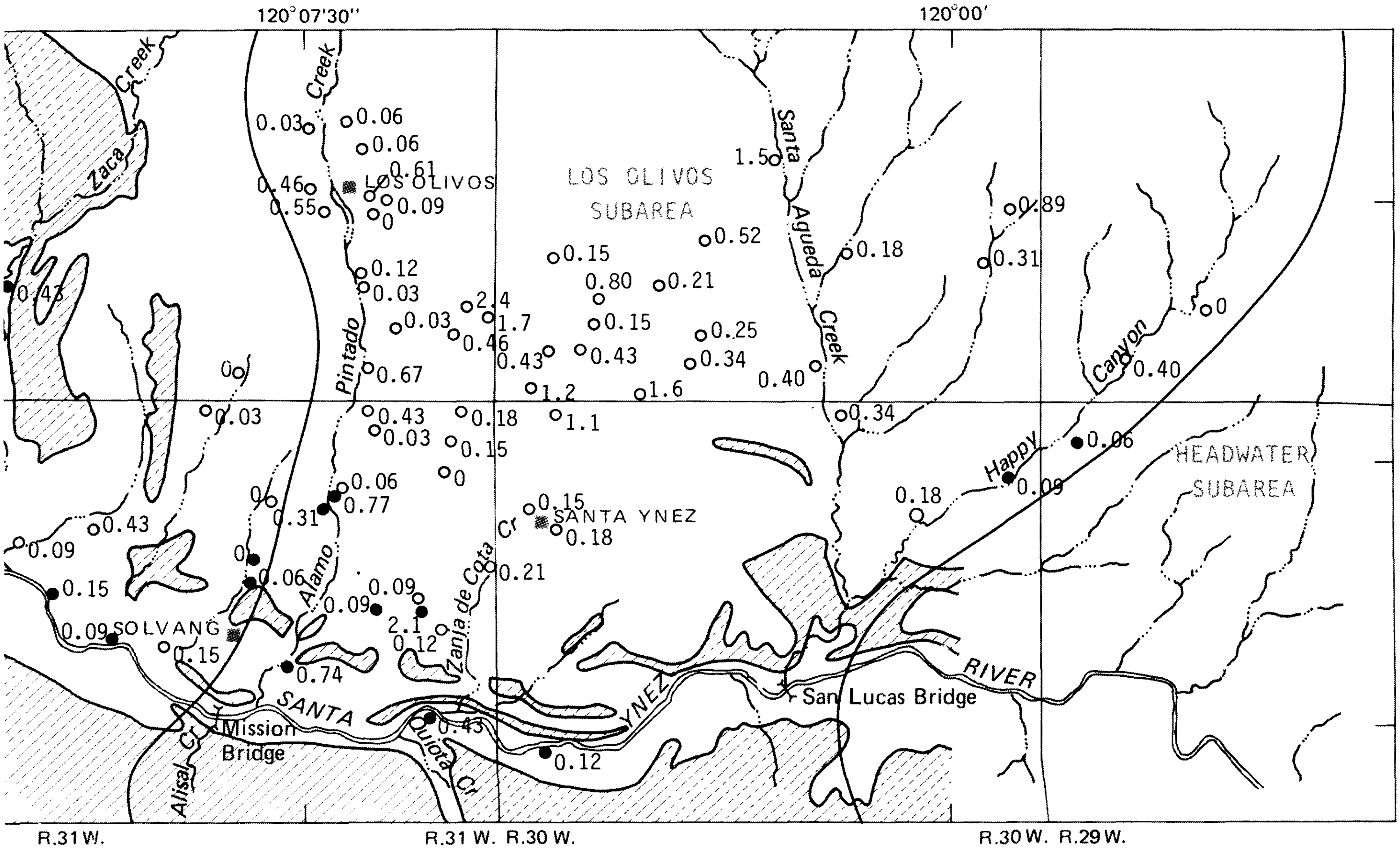
NITROGEN CONCENTRATION EXCEEDING 10 MILLIGRAMS PER LITER IN DEEP GROUND WATER

in ground water in the study area, 1980-81.



Base from U.S. Geological Survey
Lompoc, 1:62,500, 1959;
Los Olivos, 1:62,500, 1942

FIGURE 24.-Phosphate concentration in



0 1 2 3 4 5 MILES

0 1 2 3 4 5 6 7 8 KILOMETERS

EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

●0.09 SHALLOW (ALLUVIUM) WELL- Number is phosphate concentration, in milligrams per liter

o0.52 DEEP WELL- Number is phosphate concentration, in milligrams per liter

ground water in the study area, 1980-81.

Ground-Water-Quality Trends

Evaluation of sparse historical water-quality data shows that water quality is declining in some areas, particularly in localized areas of urban and agricultural development. This decline is evident in a plot of chloride data over a period of 24 years at well 7N/33W-30B1 (fig. 25). Comparison between maps of historical and present dissolved solids (figs. 13 and 17) indicates possible increases in both the concentrations of constituents and extent of contamination in some areas. The problem is amplified by several natural and anthropogenic processes. Low recharge and high evaporation rates tend to concentrate dissolved constituents in ground water. In some areas, ground water in unconsolidated deposits may be degraded by saline water from the underlying consolidated rocks. In addition to these natural processes, agricultural and municipal practices (including irrigation-return flow and wastewater discharges) tend to concentrate dissolved solids in ground water.

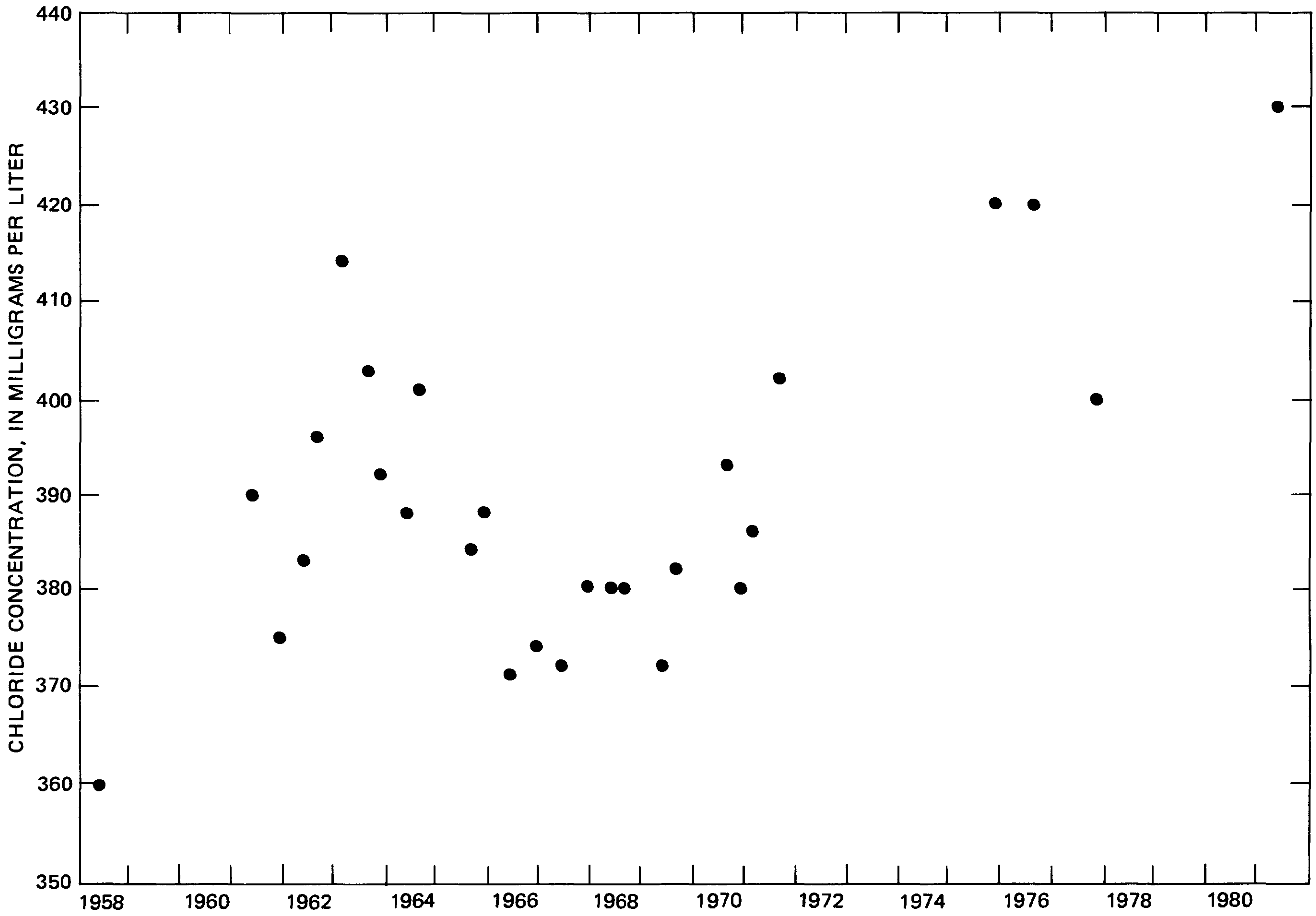


FIGURE 25. – Chloride variation in well 7N/33W–30B1, 1958–81.

MONITORING NETWORK

The establishment of a network of wells to monitor ground-water levels and quality will provide some of the data necessary for prudent and efficient ground-water development and management. Data may be used to establish baseline conditions and to determine spatial and temporal variations in ground-water levels and chemical quality. Screened interval(s) must be known for the monitoring wells so that data may be related to a specific aquifer. Wells were selected from those used in the development of the water-quality maps. This will allow comparison of future water-quality data with the 1980-81 data base.

Problem areas, noted from the contour maps, were given special attention in the design of the network. For most chemical constituents, areas of concern were in the Buellton-Los Olivos-Santa Ynez region, the lower extent of the alluvial aquifer along the Santa Ynez River, and in the upper Santa Rita subarea. The recommended list of sampled constituents reflects the condition and composition of local ground-water quality.

Water-quality constituents to be monitored include major ions, nutrients, and trace elements. Temperature, pH, and specific conductance should be measured in the field for each sample suite collected. These data will provide a baseline for comparison with potential future changes in ground-water quality. Gas chromatogram scans can be utilized as an indication of contamination of ground water by pesticides and (or) other organic compounds. Where contamination is indicated, follow-up analysis may be used to identify Environmental Protection Agency priority pollutants (personal commun., Rolland Grabbe, U.S. Geological Survey, Lakewood, Colo., 1983). Water-level data should be collected concurrently with water-quality data to determine possible correlation between the two and to monitor possible changes in ground-water storage.

Wells proposed for the monitoring network are shown on figure 14 and listed in table 8 along with sampling recommendations. Additional monitor wells are needed in the vicinity of the municipal sludge disposal site in 7N/33W, specifically to monitor possible adverse changes in shallow ground-water quality. Sampling frequency and constituents reflect environmental factors potentially affecting ground-water quality, such as wastewater disposal and irrigation return flow.

Table 8.--Proposed wells, sampled constituents, and sampling frequency for the Santa Ynez, Buellton, and Los Olivos hydrologic subareas

[Monitoring schedule: A, annual; B, biannual; L, once every 5 years; M, monthly. See figure 14 for locations of wells]

Well No.	Depth of screened interval below land surface (ft)	Major ions[1]	Trace constituents[2]	Nutrients[3]	Gas chromatogram scan (schedule 1381)
6N/29W-6F1	35-53	A	-	A	A
6N/30W-3A1	80-407	A	-	A	A
6N/30W-6B1	146-487	A	-	A	-
6N/30W-7C4	98-113	A	-	A	-
6N/30W-19Q2	22-46	A	-	A	-
6N/31W-1G5	100-240	A	-	A	-
6N/31W-2B4	105-130	M	L	B	A
6N/31W-4A2	113-235	A	-	A	-
6N/31W-6D3	350-440	B	L	B	-
6N/31W-6F3	160-260	M	L	M	-
6N/31W-7E4	80-293	A	-	M	A
6N/31W-7K2	188-304	A	-	B	-
6N/31W-8F3	181-261	A	-	B	A
6N/31W-10C2	116-376	A	-	A	-
6N/31W-11D2	48-170	A	L	B	A
6N/31W-12R4	150-192	B	L	B	A
6N/31W-13E1	110-129	A	L	B	A
6N/31W-14G3	60-103	B	L	M	A
6N/31W-15C1	18-57	A	-	A	A
6N/31W-16L1	180-290	A	-	B	-
6N/31W-17J2	42-70	A	A	A	-
6N/31W-18A4	0-80	A	A	A	A
6N/32W-2Q1	50-76	M	L	M	A
6N/32W-3R2	480-600	A	-	A	A
6N/32W-5E2	0-140	A	-	M	A
6N/32W-6K3	140-155	A	-	B	-
6N/32W-7N5	69-75	B	-	B	A
6N/32W-9J1	0-81	B	-	B	A
6N/32W-10J1	43-66	B	L	B	A
6N/32W-11D1	30-60	B	L	B	A
6N/32W-11L2	0-60	B	-	B	-
6N/32W-12E1	84-184	B	L	M	-
6N/32W-12N3	10-85	M	A	M	-
6N/32W-12R3	18-56	B	A	B	A
6N/32W-16P4	51-93	B	L	B	A

See footnotes at end of table.

Table 8.--Proposed wells, sampled constituents, and sampling frequency for the Santa Ynez, Buellton, and Los Olivos hydrologic subareas--Continued

Well No.	Depth of screened interval below land surface (ft)	Major ions[1]	Trace constituents[2]	Nutrients[3]	Gas chromatogram scan (schedule 1381)
6N/33W-8E4	62-102	B	L	B	A
6N/33W-9K2	107-182	B	A	-	A
6N/33W-11M1	52-72	B	-	A	A
7N/29W-31J2	150-565	A	-	B	-
7N/30W-27H1	145-171	A	-	A	-
7N/30W-30G2	420-540	A	-	B	A
7N/30W-33M2	165-318	A	-	A	-
7N/30W-34K1	200-1,000	A	-	A	A
7N/31W-22A3	95-218	A	-	A	A
7N/31W-23N4	60-125	B	L	M	A
7N/31W-23R3	640-1,300	A	L	A	-
7N/31W-26Q4	39-165	A	L	B	A
7N/31W-35A1	560-800	B	L	B	A
7N/31W-36G4	90-277	B	L	B	-
7N/32W-30C1	150-251	A	-	A	A
7N/32W-31K1	420-900	A	L	-	-
7N/32W-36P1	0-810	A	L	A	A
7N/33W-21G1	660-960	A	-	A	-
7N/33W-26C1	502-522	A	-	A	-
7N/33W-26E2	462-467	B	L	B	A
7N/33W-27C3	399-414	B	L	B	A
7N/33W-30B1	219-225	B	L	M	A
7N/33W-36J7	0-190	B	L	M	A
7N/34W-35K12	42-68 74-79	B	L	B	A

[1]Dissolved calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), silicon (Si), iron (Fe), manganese (Mn), boron (B), fluoride (F), sulfate (SO_4), chloride (Cl), bicarbonate (HCO_3), and solid residue.

[2]Dissolved arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), cyanide (CN), lead (Pb), zinc (Zn), selenium (Se), mercury (Hg).

[3]Dissolved nitrate plus nitrite as nitrogen, and orthophosphate.

GROUND-WATER-QUALITY MANAGEMENT ALTERNATIVES

Degradation of ground water in the study area results primarily from land-use activities. This problem may be alleviated by such management practices as increasing freshwater recharge, optimizing discharge (quantity and location of pumpage and drains), controlling sources of contamination, and exporting wastewater from the basin.

Maintenance of a usable ground-water basin requires that the salinity of ground water not increase to an undesirable or unusable level. The salt problem becomes most important for irrigated land in arid and semiarid regions, such as the study area. A high water table resulting from inadequate drainage results in excessive evapotranspiration of irrigation water and a gradual increase in the salt content of the soil. In some areas salt buildup in the soil can be controlled by lowering the local water table, reducing salinity by leaching, and installing a drainage system to transport saline water out of the basin. Disposal of wastewater into the Santa Ynez River may lead to degradation of ground-water quality in the alluvial aquifer. Ideally, wastewater would be exported from the basin.

Increasing freshwater recharge may alleviate degradation of ground-water quality in some areas. Several methods of recharge have been developed. The most widely practiced methods are types of water spreading--allowing the infiltration of water through the ground surface and eventual percolation to the water table. The most important factors governing the recharge rate are the area of recharge and the length of water-soil contact time. Water-spreading basins are the most favored method of recharge because of efficient use of space and ease of maintenance. For alluvial soils in the slope range of 0.1 to 10 percent, the long-time infiltration rate, W, in meters per day, is estimated by

$$W = 0.65 + 0.56\ i$$

where i is the natural ground slope, in percent (Todd, 1976).

Water spreading in a stream channel is accomplished by increasing the time and area over which water is recharged from a naturally losing channel. This involves both upstream management of streamflow and channel modifications to enhance infiltration. Channel modifications may include widening, leveling, scarifying, ditching, and installation of low check dams or dikes. Water may also be distributed to a series of ditches that are shallow, flat-bottomed, and closely spaced to obtain maximum water-content area. A pit excavated into a permeable formation serves as an ideal facility for ground-water recharge. Pits can reach materials with higher infiltration rates and the steep sides provide a high silt tolerance. In irrigated areas, water may be deliberately spread by irrigating cropland with excess water during dormant, winter, or nonirrigating seasons. Consideration must be given to the possible adverse effects of percolating water, particularly leaching. Supply wells can alternate as recharge wells, but injected water quality may cause problems when introduced into the ground-water system.

The salt balance has been adversely affected by wastewater disposal practices. Discharges of brine from onsite regeneration of water softeners to the wastewater-collection system has a marked effect on wastewater characteristics (Brown and Caldwell, 1972). Next to agricultural irrigation, disposal of municipal wastewater is a major source of ground-water degradation, particularly in the alluvial aquifer along the Santa Ynez River. Dissolved-solids content in shallow ground water in the Lompoc plain has increased at a rate of about 28 mg/L annually (Ahlroth and others, 1977). The cities of Solvang and Buellton discharge wastewater to percolation ponds in the Buellton ground-water basin. A significant amount of salts is added to ground water from percolation ponds (Banks, 1977). Constraints might be necessary to regulate disposal of water-softening chemicals in order to meet wastewater quality discharge requirements (Brown and Caldwell, 1972).

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Table 9.--Chemical analyses of water from wells

[Complete analyses displayed on one line on two consecutive pages]

Well No.	Local identifier	Date of sample (YMD)	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, field (mg/L as $CaCO_3$)
6N/29W-6F1	343746119583101	80-07-08	970	7.5	17.5	510	55	90	45	1.5	460
6N/30W-1R3	343718119592001	80-07-09	815	7.8	19.0	450	43	82	39	1.2	400
6N/30W-3A1	343803120011801	81-05-20	20	7.0	--	400	37	75	27	2.6	--
6N/30W-6B1	343803120043801	81-06-23	680	7.6	22.0	270	48	37	29	2.0	--
6N/30W-7C4	343708120045201	80-07-08	810	7.8	20.5	410	37	76	26	2.2	270
6N/30W-7G6	343651120043402	80-07-09	690	7.8	21.0	360	32	69	28	2.3	310
6N/30W-11G1	343649120001801	81-06-22	800	7.6	22.5	380	44	65	36	1.7	--
6N/30W-19Q2	343450120044401	80-07-09	920	7.5	22.0	470	100	54	49	2.6	310
6N/31W-4A2	343807120083701	80-07-11	492	7.5	22.0	200	45	22	37	2.4	170
6N/31W-1B2	343804120053801	81-05-21	1,000	7.4	21.0	540	98	71	41	2.5	--
6N/31W-1G5	343751120053701	81-06-30	1,020	7.4	--	510	94	68	42	2.7	--
6N/31W-1P3	343728120055101	80-07-09	972	--	--	510	55	91	47	3.3	330
6N/31W-2B4	343804120064501	80-07-09	1,440	7.4	19.5	820	130	120	59	1.2	480
6N/31W-2G1	343752120064001	80-07-11	900	7.4	21.5	340	67	41	93	3.5	320
6N/31W-2P3	343717120070401	80-07-11	845	7.7	23.0	440	53	75	45	2.6	310
6N/31W-6D3	343758120111701	80-07-14	885	6.7	22.5	260	73	19	68	3.5	53
6N/31W-6F3	343754120111101	80-07-14	960	7.3	22.5	430	91	50	72	3.8	210
6N/31W-7E4	343703120112001	81-07-16	1,200	7.6	29.0	500	120	49	59	2.3	--
6N/31W-7K2	343650120104501	81-06-24	890	7.5	24.0	390	91	39	45	2.4	--
6N/31W-8F3	343658120100801	81-06-24	840	7.6	19.5	310	73	32	53	2.0	--
6N/31W-10C2	343708120075801	80-07-18	1,020	7.5	19.5	410	88	45	70	3.1	320
6N/31W-10L1	343638120080601	80-08-15	650	7.4	20.0	240	51	28	39	2.9	200
6N/31W-11D2	343708120071301	80-07-22	1,260	7.4	17.0	700	120	96	62	1.8	420
6N/31W-11D3	343715120071001	80-07-22	1,425	7.4	15.5	790	120	120	61	1.7	500
6N/31W-12R4	343634120053102	81-06-23	1,050	7.7	23.0	450	46	82	48	2.2	--
6N/31W-13D3	343615120061101	80-07-17	980	7.5	19.5	490	64	81	47	2.3	300
6N/31W-13E1	343608120060801	80-08-13	1,020	7.6	25.0	420	48	74	43	2.4	290
6N/31W-13F1	343558120055101	80-07-17	790	7.6	18.5	340	76	37	35	2.7	170
6N/31W-14G3	343610120063903	80-07-17	960	7.6	20.5	470	64	75	47	2.0	300
6N/31W-15C1	343622120080701	80-07-18	570	7.7	19.0	260	53	30	41	2.8	190
6N/31W-15R1	343540120074101	80-07-21	1,625	7.7	16.5	840	120	130	72	3.2	470
6N/31W-16L1	343550120090701	80-08-18	1,150	7.1	20.5	520	100	65	61	2.4	350
6N/31W-17J2	343548120094102	80-08-15	940	7.3	19.0	450	88	55	47	2.5	270
6N/31W-18A4	343621120103102	81-06-24	1,950	7.4	19.0	510	180	140	100	3.9	--
6N/31W-24F2	343511120060201	80-07-21	1,085	7.4	18.0	500	88	67	62	3.9	350
6N/32W-2C1	343807120131001	81-06-24	230	7.7	21.0	63	18	4.3	23	1.3	--
6N/32W-2Q1	343719120124901	81-07-16	2,600	7.2	20.5	1,200	270	130	120	4.5	--
6N/32W-3R2	343724120134501	80-07-21	850	7.3	21.5	330	76	35	50	2.8	220
6N/32W-5E2	343745120163601	81-06-26	930	7.6	20.0	320	82	28	52	2.2	--
6N/32W-6K3	343738120171501	80-07-22	590	7.4	19.5	140	33	15	68	2.2	140
6N/32W-7N5	343638120175101	80-07-22	2,680	7.3	21.5	1,300	290	150	160	7.0	440
6N/32W-9J1	343642120144001	80-07-22	1,840	7.5	22.5	770	160	91	130	6.1	280
6N/32W-10J1	343644120134301	80-07-23	1,720	7.4	20.5	760	150	94	120	3.7	380
6N/32W-11D1	343712120132301	80-07-24	1,730	7.4	18.0	840	180	95	92	3.6	390
6N/32W-11L2	343646120130901	80-07-24	1,500	7.5	20.0	660	140	75	100	3.8	380
6N/32W-12E1	343657120121501	80-08-18	1,050	7.2	18.0	530	130	51	61	2.2	290
6N/32W-12N3	343638120122301	80-07-28	1,740	7.0	19.0	730	160	81	120	5.4	390
6N/32W-12R3	343627120113201	80-07-24	1,120	7.7	18.0	530	110	63	62	2.7	340
6N/32W-16P4	343545120151801	80-08-18	2,030	7.1	19.0	960	220	100	160	2.6	350
6N/33W-8E4	343702120223803	80-08-18	1,600	7.1	19.0	840	180	96	88	4.1	360

Table 9.--Chemical analyses of water from wells--Continued

Well No.	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SIO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Boron, dissolved (μg/L as B)	Chromium, dissolved (μg/L as Cr)	Iron, dis solved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)
6N/29W-6F1	77	39	.3	39	629	1.1	.06	260	--	20	--
6N/30W-1R3	55	36	.3	39	539	.66	.09	220	--	20	--
6N/30W-3A1	12	31	.1	40	464	2.5	.34	110	--	60	--
6N/30W-6B1	38	120	.1	62	431	3.8	1.1	40	--	30	3
6N/30W-7C4	22	110	.2	48	497	3.0	.15	90	--	20	--
6N/30W-7G6	42	51	.2	43	462	1.8	.18	110	--	<10	--
6N/30W-11G1	57	41	.2	47	480	4.5	.18	140	--	50	2
6N/30W-19Q2	210	29	0.4	32	677	3.1	0.12	310	--	10	--
6N/31W-4A2	22	59	.3	36	326	0.09	0.03	80	--	<10	--
6N/31W-1B2	--	--	.1	.3	--	2.1	.18	210	--	<10	--
6N/31W-1G5	220	37	.2	53	727	2.7	.15	110	--	60	7
6N/31W-1P3	170	52	.2	46	683	4.6	.00	140	--	<10	--
6N/31W-2B4	300	78	.5	45	1,040	4.7	.43	210	--	20	--
6N/31W-2G1	120	75	.3	40	647	3.2	.03	250	--	<10	--
6N/31W-2P3	130	54	.3	45	604	2.9	.06	120	--	<10	--
6N/31W-6D3	100	180	.3	51	548	4.7	2.7	60	--	10	--
6N/31W-6F3	280	74	.6	44	768	4.7	.06	230	--	20	--
6N/31W-7E4	140	120	.1	47	788	20	.00	150	--	50	5
6N/31W-7K2	160	70	.1	46	603	3.8	.09	90	--	40	5
6N/31W-8F3	18	150	.1	44	506	3.0	.43	70	--	50	7
6N/31W-10C2	110	90	.2	41	640	.09	.00	210	--	10	--
6N/31W-10L1	62	60	.3	38	403	.02	.00	90	--	1,800	--
6N/31W-11D2	280	81	.4	42	947	2.6	.31	170	--	30	--
6N/31W-11D3	320	81	.5	40	1,060	2.9	.77	240	--	<10	--
6N/31W-12R4	100	120	.1	47	647	7.5	.21	90	--	50	10
6N/31W-13D3	130	110	.2	46	681	4.6	.09	140	--	20	--
6N/31W-13E1	100	97	.2	42	604	5.2	2.1	150	--	10	--
6N/31W-13F1	220	13	.4	14	501	.18	.12	290	--	<10	--
6N/31W-14G3	120	100	.2	44	673	9.2	.09	120	--	40	--
6N/31W-15C1	61	56	.2	40	399	.00	.06	100	--	290	--
6N/31W-15R1	390	89	.5	40	1,130	.97	.74	310	--	20	--
6N/31W-16L1	200	67	.2	35	774	7.4	.15	260	--	10	--
6N/31W-17J2	240	27	.4	3.1	630	.91	.09	300	--	10	--
6N/31W-18A4	580	99	.2	31	1,450	.12	.15	570	--	320	380
6N/31W-24F2	170	66	.2	37	707	.42	.43	230	--	<10	--
6N/32W-2C1	2.0	33	.4	51	178	4.0	1.8	20	--	50	5
6N/32W-2Q1	620	260	.2	42	1,750	24	.00	230	0	60	10
6N/32W-3R2	130	66	.4	40	536	.66	.06	110	--	30	--
6N/32W-5E2	12	120	.1	45	528	11	.31	70	--	60	4
6N/32W-6K3	28	84	.2	50	372	1.6	2.0	160	--	<10	--
6N/32W-7N5	850	230	.4	24	1,980	.00	.03	600	--	2,900	--
6N/32W-9J1	520	140	.5	35	1,250	.02	.09	540	--	<10	--
6N/32W-10J1	420	120	.5	36	1,190	4.3	.09	590	--	70	--
6N/32W-11D1	450	130	.3	35	1,230	2.0	.25	320	--	<10	--
6N/32W-11L2	370	79	.4	35	1,040	1.0	.21	650	--	30	--
6N/32W-12E1	230	77	.2	40	801	8.0	.03	200	--	40	--
6N/32W-12N3	410	100	.2	4.9	1,200	19	3.4	480	--	10	--
6N/32W-12R3	290	47	.5	35	815	.00	.21	400	--	20	--
6N/32W-16P4	700	130	1.0	14	1,550	2.0	.00	1,300	--	400	--
6N/33W-8E4	500	110	.4	38	1,240	.00	.00	580	--	2,300	--

Table 9.--Chemical analyses of water from wells--Continued

Well No.	Local identifier	Date of sample (YMD)	Specific conductance (µS/cm)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, field (mg/L as $CaCO_3$)
6N/33W-9K2	343653120211601	80-08-18	3,600	6.9	22.0	2,200	430	270	160	11	500
6N/33W-11M1	343647120194601	80-07-24	1,515	7.5	21.0	680	140	81	83	4.7	270
7N/29W-29R2	343900119570301	80-07-28	795	7.8	20.0	400	47	68	29	1.6	235
7N/29W-31J2	343821119580001	81-05-22	1,400	7.4	23.0	380	63	54	180	2.4	--
7N/30W-22F1	344023120015101	81-05-12	940	7.3	20.5	500	47	92	29	1.3	--
7N/30W-24Q1	343956119592401	81-05-12	1,090	7.2	18.5	520	49	96	62	2.3	--
7N/30W-25F1	343931120060601	81-06-22	1,020	7.7	23.0	450	76	64	41	2.0	--
7N/30W-27H1	343935120010801	81-05-12	1,050	7.3	21.5	510	44	98	45	2.3	--
7N/30W-28C1	343955120024001	81-06-23	530	8.8	30.0	290	29	52	16	.9	--
7N/30W-29J1	343921120031201	81-05-13	750	7.7	22.0	350	22	72	28	1.7	--
7N/30W-29N2	343903120040701	81-05-13	650	7.0	21.0	290	27	54	27	1.3	--
7N/30W-30G2	343932120043001	81-05-21	725	7.8	22.0	160	30	20	33	2.0	--
7N/30W-31G1	343836120044301	81-05-21	600	6.7	20.0	220	39	30	29	1.4	--
7N/30W-31H1	343838120042701	81-05-21	500	6.4	20.0	290	23	56	53	.9	--
7N/30W-31P2	343816120044802	81-05-21	730	6.7	20.0	270	49	37	32	2.3	--
7N/30W-32D2	343848120035801	81-05-20	625	8.0	22.0	290	22	58	26	.3	--
7N/30W-32Q2	343818120033001	81-06-22	440	7.4	20.0	190	20	35	22	1.8	--
7N/30W-33F1	343844120024701	81-05-20	660	7.6	23.0	380	32	74	24	3.1	--
7N/30W-33M2	343834120030001	81-05-12	800	7.7	21.0	410	33	79	26	1.6	--
7N/30W-34K1	343833120012701	81-06-22	680	8.1	21.0	440	36	84	27	1.0	--
7N/31W-14N1	344049120065701	80-07-28	1,040	7.5	21.0	540	89	77	42	2.1	350
7N/31W-22A3	344044120072801	80-07-29	875	7.2	21.5	490	91	65	37	2.3	330
7N/31W-22J1	344010120072001	80-08-15	750	7.0	18.0	390	71	52	36	2.1	270
7N/31W-23B2	344034120064802	80-07-30	652	7.8	22.0	280	28	50	34	2.5	240
7N/31W-23N2	343956120071301	80-07-30	732	7.1	26.0	310	58	40	36	3.3	210
7N/31W-23Q1	344007120064001	80-07-30	1,040	7.4	21.5	500	88	68	41	1.9	340
7N/31W-23Q5	343955120064001	80-07-30	810	7.7	26.0	360	60	51	40	3.0	280
7N/31W-23R3	34955120062901	80-07-30	782	7.3	23.0	360	57	52	40	2.5	270
7N/31W-25R1	343904120053001	80-08-04	730	6.3	19.0	250	39	36	41	2.3	64
7N/31W-26K1	343921120064801	80-08-04	980	7.7	18.5	550	94	76	40	2.3	360
7N/31W-26Q4	343913120065001	80-08-04	810	7.3	23.5	350	61	48	42	2.6	270
7N/31W-30K1	343918120105401	80-08-04	3,000	6.7	21.0	2,100	450	240	160	10	500
7N/31W-34M1	343825120082001	81-07-16	370	7.1	22.5	110	27	9.5	25	1.8	--
7N/31W-35A1	343850120062301	80-08-05	840	7.5	22.0	390	71	51	38	2.5	260
7N/31W-35K1	343827120064601	81-06-22	1,450	7.6	20.0	880	140	130	61	1.8	--
7N/31W-36A4	343900120051901	80-08-05	460	6.8	27.0	150	29	18	28	3.0	57
7N/31W-36G4	343849120054601	80-08-06	970	7.3	18.5	460	80	64	39	2.4	280
7N/32W-30C1	343949120171601	80-08-05	2,390	6.9	19.5	920	170	120	240	14	240
7N/32W-31K1	343831120165701	81-06-30	240	7.0	21.0	49	14	3.5	27	2.6	--
7N/32W-36P1	343817120121701	81-06-22	680	7.9	23.0	170	42	17	86	7.9	--
7N/33W-17N2	344051120224901	81-06-23	630	7.7	25.0	220	60	16	43	3.5	--
7N/33W-21G1	344022120211501	81-06-29	640	7.7	25.0	200	51	17	49	3.6	--
7N/33W-26C1	343945120193001	81-06-29	540	7.5	23.0	270	74	21	49	3.4	--
7N/33W-26E2	343926120193401	80-08-06	480	7.0	20.0	130	32	12	47	2.6	110
7N/33W-27C3	343949120203201	80-08-05	780	7.6	20.5	180	41	18	93	4.2	85
7N/33W-27J1	343923120200101	81-06-29	1,000	6.6	21.0	200	36	26	120	3.9	--
7N/33W-28D3	343946120215301	80-08-05	795	6.8	23.0	230	57	22	69	3.8	75
7N/33W-30B1	343950120232801	81-06-29	1,700	6.4	22.0	340	67	43	200	6.2	--
7N/33W-36J7	343830120175502	80-08-05	900	7.7	21.5	350	89	32	50	2.8	250
7N/34W-35K12	343833120254301	80-08-07	2,250	7.0	20.5	1,000	210	120	180	11	500

Table 9.--Chemical analyses of water from wells--Continued

Well No.	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SIO_2)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Boron, dissolved (µg/L as B)	Chromium, dissolved (µg/L as Cr)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)
6N/33W-9K2	1,500	300	.5	22	3,020	.00	.00	410	--	26,000	--
6N/33W-11M1	460	89	.5	29	1,050	.00	.28	470	--	60	--
7N/29W-29R2	45	19	.4	5.5	535	1.4	.00	230	--	<10	--
7N/29W-31J2	64	170	.0	35	881	5.4	.40	290	--	110	--
7N/30W-22F1	32	34	.1	47	564	1.2	1.5	100	--	10	--
7N/30W-24Q1	18	55	.2	40	661	5.8	.89	130	--	30	--
7N/30W-25F1	190	40	.1	47	617	2.8	.31	90	--	20	--
7N/30W-27H1	51	56	.1	41	618	.76	.18	150	--	30	--
7N/30W-28C1	1	26	.1	56	355	4.0	.52	40	--	20	--
7N/30W-29J1	13	50	.1	44	438	3.4	.21	60	--	20	--
7N/30W-29N2	10	41	.1	45	375	3.1	.80	50	--	80	--
7N/30W-30G2	15	99	.2	69	329	8.9	.15	60	--	20	--
7N/30W-31G1	34	130	.1	61	363	.23	.43	40	--	30	--
7N/30W-31H1	29	34	.1	43	447	2.2	.43	110	--	<10	--
7N/30W-31P2	35	180	.1	63	432	.32	1.2	40	--	50	--
7N/30W-32D2	7	40	.1	44	367	.28	.15	50	--	40	--
7N/30W-32Q2	11	53	.1	66	311	2.6	1.6	50	--	10	--
7N/30W-33F1	1	36	.2	44	442	2.4	.25	70	--	<10	--
7N/30W-33M2	26	36	.1	42	485	4.3	.34	90	--	20	--
7N/30W-34K1	54	40	.1	43	534	1.9	.40	110	--	<10	--
7N/31W-14N1	210	26	.3	12	684	3.5	.06	140	--	<10	--
7N/31W-22A3	200	24	.2	11	643	3.1	.03	130	--	10	--
7N/31W-22J1	130	35	.3	47	560	5.4	.46	130	--	20	--
7N/31W-23B2	13	59	.5	7.0	352	3.1	.06	80	--	<10	--
7N/31W-23N2	90	46	.2	47	500	12	.55	110	--	10	--
7N/31W-23Q1	150	54	.6	7.2	644	6.6	.61	120	--	<10	--
7N/31W-23Q5	120	34	.4	5.5	487	1.1	.00	130	--	<10	--
7N/31W-23R3	120	36	.3	44	521	1.6	.09	120	--	10	--
7N/31W-25R1	29	160	.3	71	448	6.9	2.4	60	--	20	--
7N/31W-26K1	200	33	.5	42	724	4.5	.12	160	--	10	--
7N/31W-26Q4	110	38	.3	43	513	1.3	.03	130	--	10	--
7N/31W-30K1	1,600	170	.8	28	2,980	3.4	.43	470	--	120	--
7N/31W-34M1	25	43	.3	37	218	.82	.00	50	--	3,100	40
7N/31W-35A1	130	40	.4	42	538	1.6	.03	100	--	40	--
7N/31W-35K1	420	79	.4	45	1,200	8.6	.67	180	--	30	--
7N/31W-36A4	15	92	.4	59	297	4.2	1.7	60	--	20	--
7N/31W-36G4	160	56	.4	49	634	3.3	.46	130	--	20	--
7N/32W-30C1	890	200	.1	55	1,840	1.4	.37	1,500	--	400	--
7N/32W-31K1	17	25	1.4	56	182	1.1	.46	30	--	110	--
7N/32W-36P1	47	30	.3	52	457	.06	.21	410	--	10	--
7N/33W-17N2	130	47	.3	51	418	.04	.25	130	--	650	--
7N/33W-21G1	140	47	.2	37	405	.07	.12	170	--	260	--
7N/33W-26C1	41	92	.2	35	452	.99	.31	70	--	<10	--
7N/33W-26E2	12	63	.3	33	290	4.7	.06	80	--	750	--
7N/33W-27C3	41	180	.5	23	467	3.5	.52	180	--	<10	--
7N/33W-27J1	55	240	.1	53	592	4.6	.77	80	--	30	--
7N/33W-28D3	160	100	.6	47	507	.05	2.3	120	--	1,700	--
7N/33W-30B1	48	430	.2	54	1,020	32	.28	120	--	10	--
7N/33W-36J7	21	130	.2	43	560	9.5	.15	100	--	20	--
7N/34W-35K12	570	220	.4	32	1,650	.18	.74	860	--	100	--