EVALUATION OF THE SAN DIEGUITO, SAN ELIJO, AND SAN PASQUAL HYDROLOGIC SUBAREAS FOR RECLAIMED WATER USE, SAN DIEGO COUNTY, CALIFORNIA

By John A. Izbicki

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer International System (SI) Units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	0.4047	ha (hectares)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
acre-ft/yr (acre-feet per year)	0.001233	hm^3/a (cubic hectometers per annum)
feet	0.3048	m (meters)
ft^2/d (feet squared per day)	0.0929	m^2/s (meters squared per day)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
gal/d (gallons per day)	0.003785	m^3/d (cubic meters per day)
(gal/d)/ft (gallons per day per foot)	0.04047	(L/d)/m (liters per day per meter)
gal/min (gallons per minute)	0.06309	L/s (liters per second)
(gal/min)/ft (gallons per minute per foot)	0.2070	(L/s)/m (liters per second per meter)
inches	25.4	mm (millimeters)
in/h (inches per hour)	25.4	mm/h (millimeters per hour)
miles	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
µmho/cm at 25°C (micromhos per centimeter at 25° Celsius)	1.000	µS/cm at 25°C (microsiemens per centimeter at 25° Celsius)

Abbreviations used:
mg/L - milligrams per liter
µg/L - micrograms per liter
µm - micrometers

ALTITUDE DATUM

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

DEFINITIONS

Reclaimed water: Treated municipal wastewater; the required level of treatment is related to the degree of public contact as specified in Wastewater Reclamation Criteria, Title 22 of the California Administrative Code.

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. (To obtain (gal/d)/ft from ft^2/d, multiply by 7.46.)

Water year: The water year starts October 1 and ends September 30; it is designated by the calendar year in which it ends.

EVALUATION OF THE SAN DIEGUITO, SAN ELIJO, AND SAN PASQUAL HYDROLOGIC SUBAREAS FOR RECLAIMED WATER USE, SAN DIEGO COUNTY, CALIFORNIA

By John A. Izbicki

ABSTRACT

Reclaimed water use is contemplated for three small hydrologic subareas in San Diego County, California. As a preliminary step, the hydrology of each subarea was studied to determine suitability for reclaimed water use.

Reclaimed water use in the San Dieguito hydrologic subarea would be primarily within the alluvial aquifer where storage is estimated to be 52,000 acre-feet. The alluvial aquifer has been intruded by seawater and water from surrounding marine sedimentary rock. In 1981-82, dissolved-solids concentrations ranged from 1,350 to more than 20,000 milligrams per liter. Only small areas in alluvium-filled side canyons yielded water with dissolved-solids concentrations less than 1,000 milligrams per liter. A seasonally high water table, lack of a consistent source of recharge, seawater intrusion, and intrusion of ground water from surrounding marine sedimentary rock may affect reclaimed water use plans.

In the San Elijo hydrologic subarea, water levels are at or near land surface throughout much of the alluvial aquifer, restricting reclaimed water use to suitable soils in upland areas. The small storage capacity in the alluvial aquifer (8,500 acre-feet) may limit manipulation of the ground-water table within the alluvium.

Reclaimed water use in the San Pasqual hydrologic subarea would be primarily within the alluvial aquifer, although some soils in upland areas could accept reclaimed water. Ground-water storage within the alluvium is estimated to be 58,000 acre-feet. In recent years, agricultural water use has impacted water quality in the aquifer. In 1981-82, dissolved-solids concentrations ranged from less than 400 milligrams per liter in the upper part of the basin to 1,900 milligrams per liter in the discharge area. Irrigation return from imported water is partly responsible for the high concentrations of dissolved solids found in some areas of the alluvial aquifer.

Presently, ground water is of limited value as a water-supply source. Reclaimed water use is feasible and expected to improve ground-water quality, creating a new source of water for agricultural use.

INTRODUCTION

The San Diego region is experiencing rapid growth and attendant increase in demand for water. While demand for water is increasing, availability of imported water from the Colorado River will decrease with completion of the Central Arizona Project in 1985. To meet expected shortfalls, reclaimed water use is contemplated for several small hydrologic subareas in San Diego County, Calif.

Purpose and Scope

The purpose of this study was to update hydrologic data and refine understanding of the hydrologic system within the San Dieguito, San Elijo, and San Pasqual hydrologic subareas in San Diego County, Calif., and to evaluate the suitability of these areas for reclaimed water use. This report was prepared in cooperation with the Department of Public Works, San Diego County; the San Diego County Water Authority; the California Department of Water Resources; and several San Diego County sanitation districts to provide the hydrologic information necessary to assist in developing reclaimed water-use plans that could help maximize the use of San Diego's water resources. Data collected during the study could also serve as a baseline from which changes in water quality and quantity induced by reclaimed water use may be evaluated.

The scope of this study included compilation of existing geologic and hydrologic data, inventorying wells and springs, collecting ground-water-level and quality data, and collecting surface-water flow and quality data. This report summarizes data collected and evaluates the suitability of each hydrologic subarea for reclaimed water use.

Previous Work and Acknowledgments

Published reports and maps pertaining to the study area are listed in the "Selected References" section of this report and include data on geology, precipitation, wells, and springs. Agencies contributing unpublished data to this study are the California Department of Water Resources, San Diego County, San Diego County Water Authority, and the U.S. Geological Survey. The city of San Diego provided data from its hydrologic monitoring network in San Pasqual Valley to supplement the Geological Survey's data-collection efforts. The cooperation and assistance of many individuals within each agency, particularly Joseph Barry and Ron Larosa of the Department of Public Works, San Diego County; Larry Michaels of the San Diego County Water Authority; Arthur Coe of the California Regional Water Quality Control Board, San Diego Region; as well as individual well owners is gratefully acknowledged. The assistance of Dr. Ahmad Hassan, Sanford Werner, Miran Bedros, and Evelyn Tompkins of the California Department of Water Resources was invaluable in the preparation of this report.

Data Collection

Surface-water and ground-water data were collected during autumn 1981 and spring 1982. Water-quality samples were analyzed for alkalinity, B, Ca, Cl, F, Fe, K, Mg, Na, nutrients (kjeldahl nitrogen, NH_4, NO_2, NO_2+NO_3, organic nitrogen, and orthophosphate), residue on evaporation at 180°C (dissolved solids), total organic carbon, SiO_2, and SO_4. Measurements were made of pH and specific conductance. Percent sodium, sodium absorption ratio, and the sum of dissolved constituents were calculated. At selected sites a semiquantitative scan was made for the following: Ag, Al, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Ge, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, SiO_2, Sn, Sr, Ti, V, Zn, Zr. Although not all data are discussed in the text, they provide a baseline from which to assess the impact of reclaimed water use on the study areas.

Field Methods

Instantaneous discharge measurements were made using a current meter (Carter and Davidian, 1968) for streams flowing more than 0.5 ft^3/s. Discharge measurements were made using a modified Parshall flume (Kilpatrick, 1965) for streams flowing less than 0.5 ft^3/s.

Depth to water in wells was determined using a steel tape. Data from recently pumped wells were omitted from the analyses.

Surface-water-quality samples were collected using a DH48 suspended sediment sampler (Guy and Norman, 1970). The sampler was painted with a nonmetallic white epoxy paint, and a teflon nozzle and silicon gasket were used to minimize contamination. Equal width increment method (U.S. Geological Survey, 1978) was used to collect the samples.

Where possible, ground-water-quality samples were collected from pumping wells. Wells were pumped long enough to insure that at least 1.5 times the casing volume was removed before the sample was collected. During autumn 1981, where pumping wells were not available, samples were collected at the perforated interval using a Kemmerer bottle. During spring 1982, open wells were pumped with an air compressor. Specific conductance of discharge water was monitored and sampling was delayed until after specific conductance stabilized and at least 1.5 times the casing volume was pumped. Samples were then collected at the perforated interval using a Kemmerer bottle.

Samples for dissolved constituents were filtered in the field through 0.45-μm pore-size membrane filters. Samples for cations were acidified to a pH of less than 2. Portable meters were used for making field measurements of pH and specific conductance. Water-temperature measurements were made with hand-held mercury-filled thermometers that have a full-scale accuracy of 0.5°C and were calibrated with an American Society for Testing and Materials standard laboratory thermometer. All samples were chilled and sent within 24 hours to the U.S. Geological Survey Water Quality Laboratory in Denver, Colo.

Laboratory Methods

Nutrient samples were analyzed using automated colorimetric methods given in Skougstad and others (1979, p. 389-399, 407, 415-417, 433-439, 445-447, 479-481, and 491-493). Samples for calcium, magnesium, sodium, and potassium were analyzed by atomic absorption spectrometric methods given in Skougstad and others (1979, p. 107 and 108, 177 and 178, 229 and 230, and 255-256). Automated colorimetric methods (Skougstad and others, 1979, p. 333-335, 375-377, 497-499, and 501-504) were used to analyze samples for iron, chloride, silica, and sulfate. Samples for boron were analyzed by a non-automated colorimetric method (Skougstad and others, 1979, p. 315 and 316). Bicarbonate was calculated from a fixed-endpoint alkalinity determination done by the electrometric titration method (Skougstad and others, 1979, p. 517 and 518). Fluoride determinations were done by electrometric ion-selective electrode method (Skougstad and others, 1979, p. 525-528).

Data Limitations

Data were collected during a wet period which began in 1978. In 1981-82, many streams which typically flow for only brief periods flowed throughout the year. Alluvial aquifers were filled to capacity and seasonal variations in water levels, which are often important in small alluvial aquifers, were small during the study period. Data collected in autumn 1981 and spring 1982 reflect water quantity and quality during a wet cycle.

To gain a greater understanding of hydrologic processes in dry years, historical water-level and water-quality data from other agencies were used. Although data were screened for accuracy, there are inherent problems in analyzing data provided by other agencies because collection methods are frequently unknown.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in well number 12S/1W-29D1S, that part of the number preceding the slash indicates the township (T. 12 S.); the number and letter following the slash indicate the range (R. 1 W.); the number following the hyphen indicates the section (sec. 29); the letter following the section number (D) indicates the 40-acre subdivision of the section; the final digit (1) is a serial number for wells in each 40-acre subdivision; and the final letter (S) indicates the San Bernardino base line and meridian. Forty-acre subdivisions of a section are lettered in the following order:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Location of the Study Area

The San Dieguito, San Elijo, and San Pasqual hydrologic subareas are located in west central San Diego County along the northern boundary of the city of San Diego (fig. 1). Each hydrologic subarea contains a small alluvial aquifer which is the most important ground-water body within the subarea. In the text, the alluvial aquifer is referred to as the basin. Areas within the hydrologic subarea but outside the alluvial basin are referred to as uplands.

The San Dieguito hydrologic subarea (State hydrologic unit number Z-5.A1, California Department of Water Resources, 1964) is 37 mi^2 in area. It is the lower part of the San Dieguito River drainage basin below Lake Hodges. The San Dieguito hydrologic subarea includes Basin 9-12 (California Department of Water Resources, 1975). Parts of the city of San Diego, the city of Del Mar, and the community of Rancho Santa Fe lie within the subarea. Land use is primarily low-density residential and agricultural.

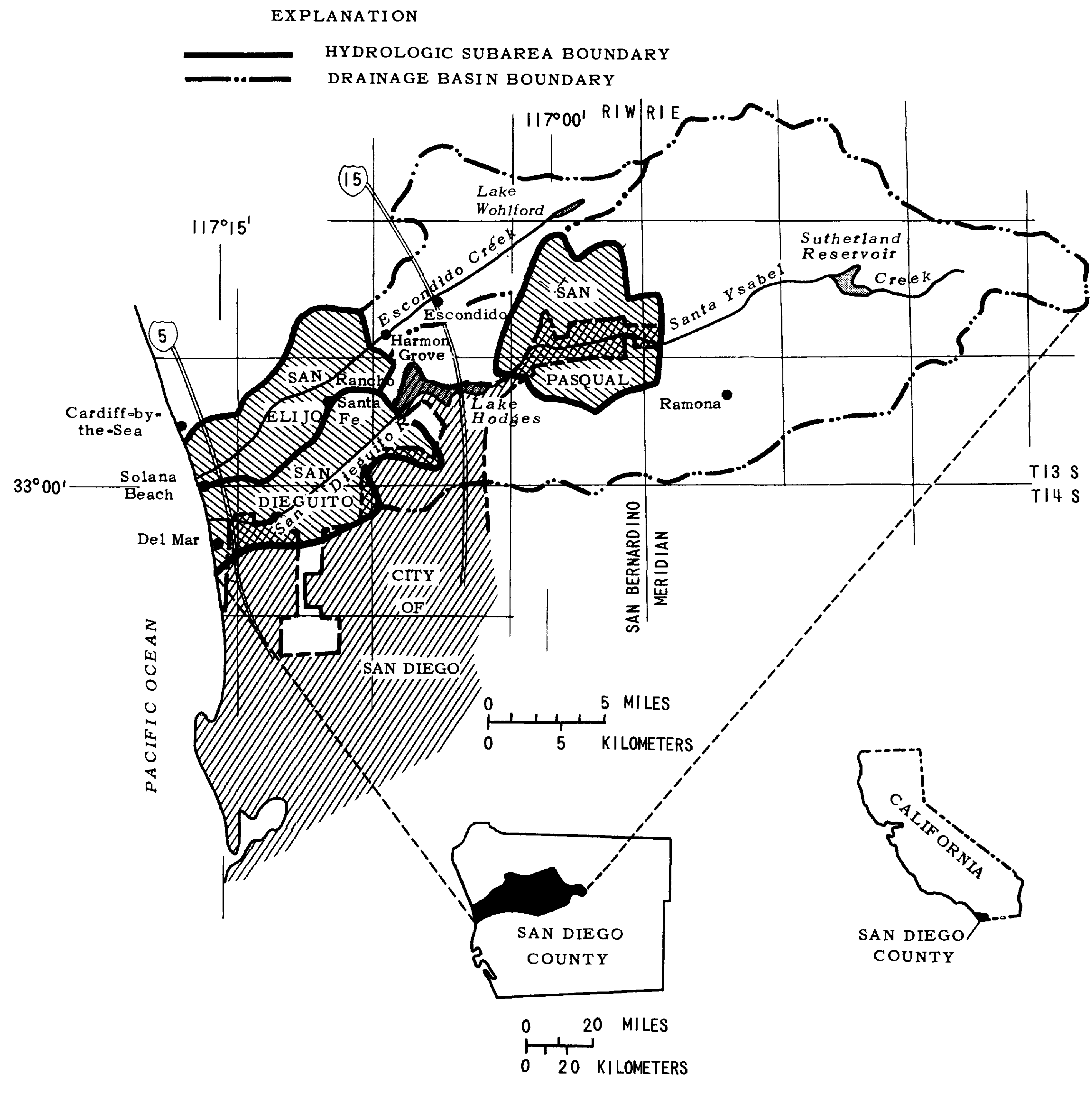


FIGURE 1.--Location of the study area.

The San Elijo hydrologic subarea (State hydrologic unit number Z-4.F1, California Department of Water Resources, 1964) lies to the north of the San Dieguito hydrologic subarea. It is 31 mi^2 in area and is the lower part of the Escondido Creek drainage basin. The San Elijo hydrologic subarea includes Basin 9-23 (California Department of Water Resources, 1975), and lies entirely outside the city of San Diego. Parts of the communities of Cardiff-by-the-Sea, Rancho Santa Fe, and Solana Beach lie within the subarea. Land use is primarily low-density residential and agricultural.

The San Pasqual hydrologic subarea (State hydrologic unit number Z-5.C2, California Department of Water Resources, 1974) lies to the east of the San Dieguito and San Elijo hydrologic subareas. It is 31 mi^2 in area and is located within the San Dieguito River basin. The San Pasqual hydrologic subarea includes Basin 9-10 (California Department of Water Resources, 1975). The alluvial valley floor within the San Pasqual subarea is owned by the city of San Diego and is managed as an agricultural preserve. With the exception of the western edge of the subarea, the uplands are largely undeveloped and remain in native vegetation.

Climate and Precipitation

The study area has a Mediterranean climate, with warm, dry summers and mild winters. Mean annual temperature is between 54° and 58°F. Inland areas have a wider range of temperature than coastal areas. Because of coastal fog, humidity is fairly high along the coast during the summer, but decreases rapidly farther inland.

Precipitation is unevenly distributed throughout the year with most occurring between November and April. Precipitation is lowest in coastal areas, between 11 and 15 inches annually, and increases inland to the headwaters of the San Dieguito River which receive over 30 inches of precipitation annually (fig. 2). There is generally light snowfall in winter at higher altitudes.

In 1981-82, precipitation was as much as 120 percent above normal in all three hydrologic subareas.

EXPLANATION

HYDROLOGIC SUBAREA BOUNDARY

DRAINAGE BASIN BOUNDARY

—14— LINE OF EQUAL MEAN ANNUAL PRECIPITATION, IN INCHES, 1897-1947. Interval variable

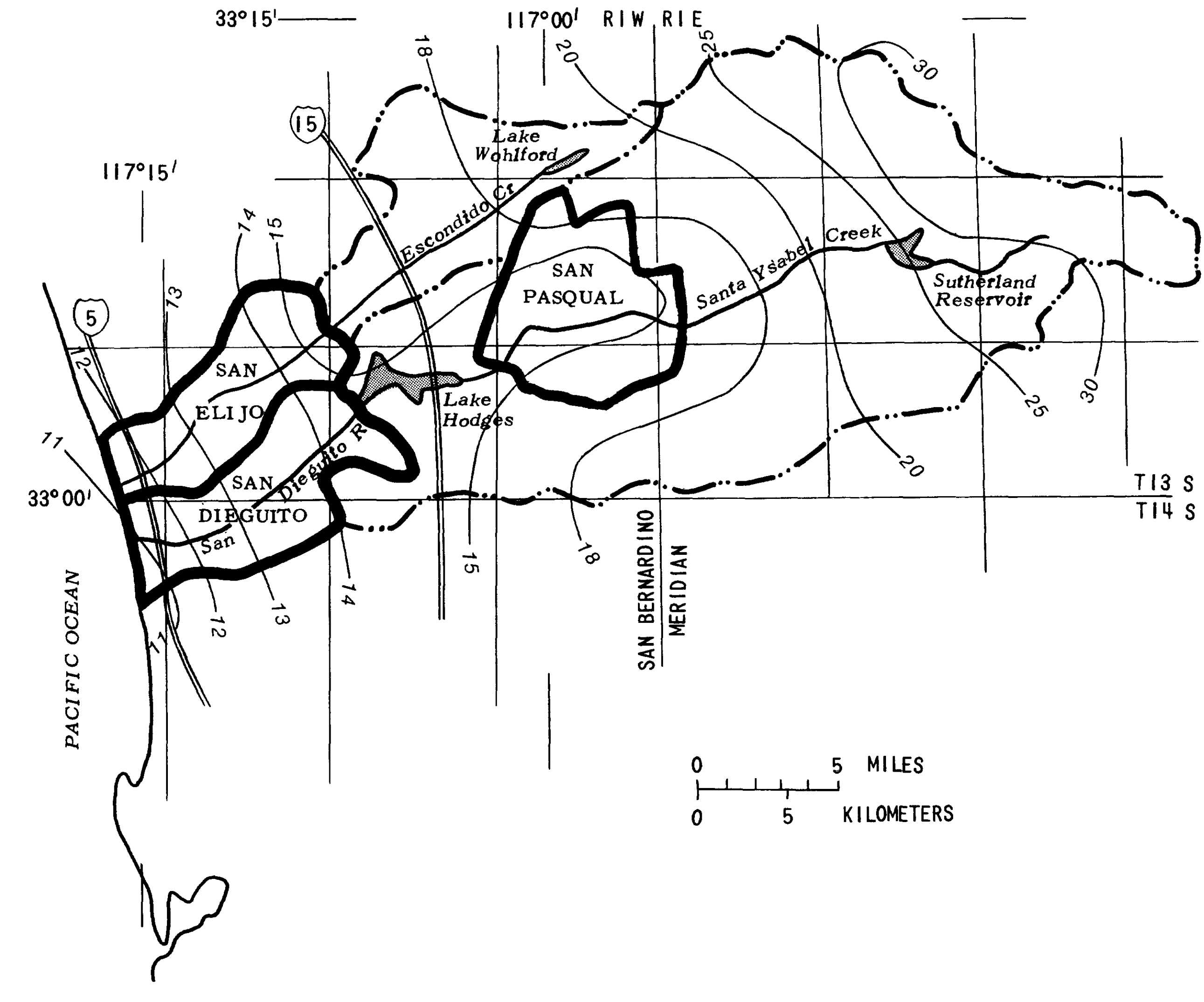


FIGURE 2.--Mean annual precipitation in the study area, (California Department of Water Resources, 1967).

Geology

The San Dieguito hydrologic subarea can be divided into two physiographic zones: Peninsular Range Province and Pacific Coastal Plain (fig. 3).

Peninsular Range Province

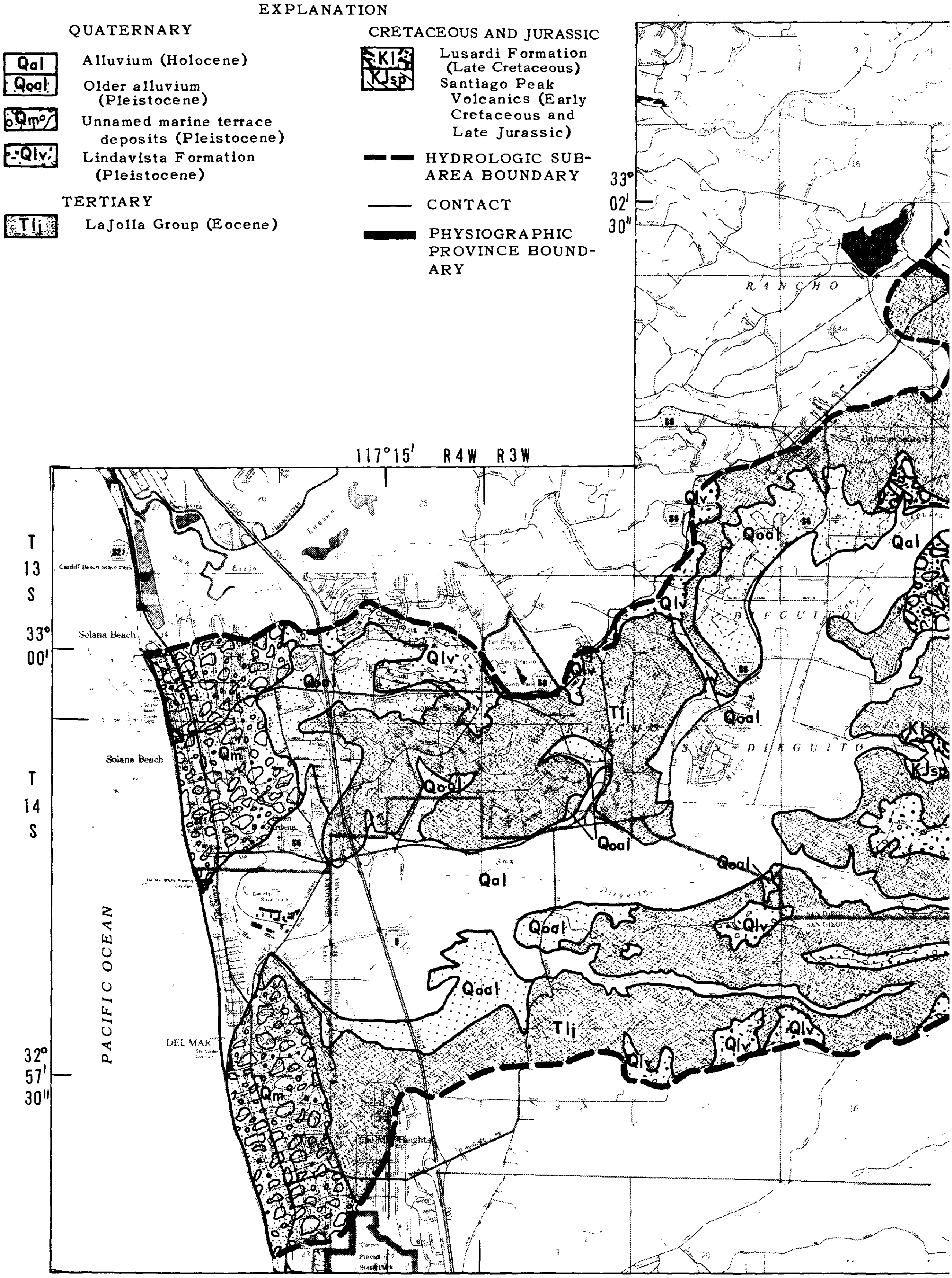
The upper San Dieguito hydrologic subarea is within the interior upland, or Peninsular Range Province of San Diego County. Topography is characterized by steep-sided, boulder-covered slopes of the Santiago Peak Volcanics, which form the westernmost of the generally north-south trending mountain ranges of San Diego County. Santiago Peak Volcanics slope to the west and range from over 1,000 feet above sea level to a subsurface elevation more than 1,000 feet below sea level in a distance of less than 7 miles, and are the basement complex upon which later sediments were deposited. Santiago Peak Volcanics range from a highly metamorphosed welded tuff to only slightly metamorphosed breccia and volcanic conglomerate (Kennedy, 1973).

The Lusardi Formation is a boulder fanglomerate derived from the Santiago Peak Volcanics. It is poorly exposed and covered in many places by marine sedimentary rock of the coastal plain. Thickness of the Lusardi Formation has been estimated to be 375 feet (Nordstrom, 1970).

Pacific Coastal Plain

The lower San Dieguito hydrologic subarea lies within the Pacific Coastal Plain. In this area the coastal plain is 5 to 8 miles wide and characterized by gently rolling to highly dissected mesa-like hills, commonly topped by remnants of marine terraces.

The Lindavista Formation is the most extensive marine terrace in the San Dieguito hydrologic subarea. It is a thin (maximum thickness 100 feet), very hard, erosion-resistant cap rock, characterized by concretionary iron deposits (California Department of Water Resources, 1967). Three additional unnamed marine terrace deposits can be identified along the coast. These terrace deposits are thin (up to 25 feet), weakly cemented cobble conglomerates, which do not form the mesa-like ridges characteristic of the Lindavista Formation (Hanna, 1926).



Base from county map, San Diego, California

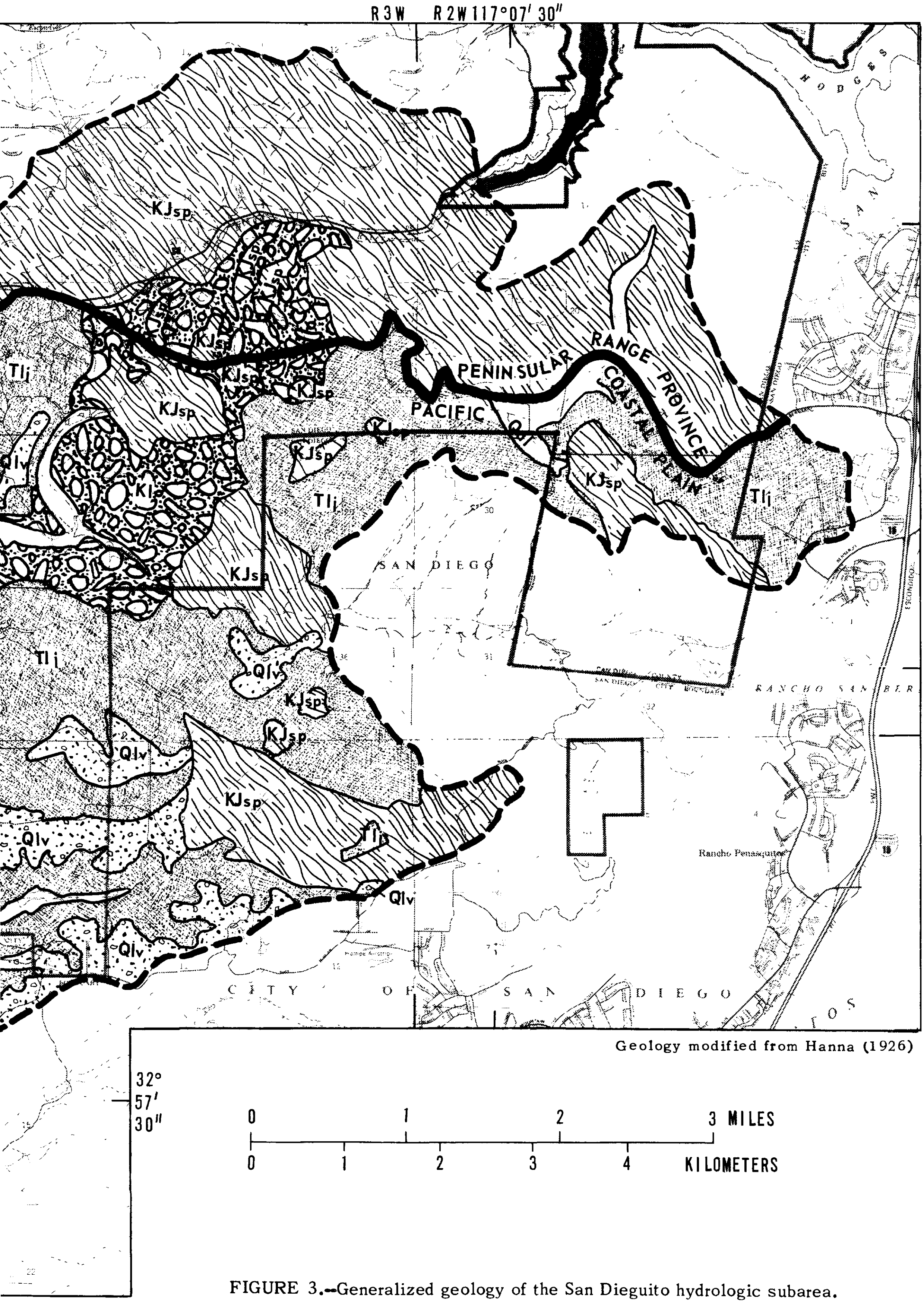


FIGURE 3.--Generalized geology of the San Dieguito hydrologic subarea.

Flat-lying Eocene marine sedimentary rocks of the La Jolla Group are the most widely represented rocks in the subarea and are exposed in or underlie the entire Pacific Coastal Plain. The La Jolla Group is composed of six formations, two of which are well exposed in the San Dieguito area. The Del Mar Formation is a massive marine mudstone that is generally best exposed near the ocean and is found at greater depths inland. The Torrey Sandstone is a soft, friable sandstone that overlies the Del Mar Formation, forming steep inland cliffs that surround the San Dieguito Valley. Total thickness of the La Jolla Group is about 1,650 feet (California Department of Water Resources, 1967), and two oil exploration wells (14S/4W-1Q1 in the San Dieguito subarea, and 13S/4W-24P1 in the San Elijo subarea) penetrate over 1,000 feet of Eocene marine sedimentary rock without reaching the basement complex.

The Pacific Coastal Plain is incised by the San Dieguito River. The valley floor trends northeasterly in a curving arc about 6 miles long, and several smaller valleys join the main valley from the east. The valley, partly backfilled with alluvium, covers about 3,900 acres and is between 0.5 and 1 mile wide. In many places the valley fill is surrounded by remnants of an older alluvial valley.

Soils

Soils develop in response to topographic expression, microclimate, native vegetative cover, and the specific geologic parent material from which it weathers. In reclaimed water use applications it is the first media which reclaimed water contacts, and also the media in which many biologically mediated reactions occur. If a soil is not suitable for reclaimed water use because it is too thin, has low permeability, excessive slope, unusual chemical reactions, a hardpan, or a high water table, usefulness of an underlying aquifer for storage or movement of reclaimed water is reduced.

On the basis of topographic expression and geologic parent material, six soil associations have been identified in the San Dieguito subarea (fig. 4): Exchequer-San Miguel; Marina-Chesterton; Las Flores-Huerhuero; Diablo-Altamont; and a miscellaneous association of broken land, terrace escarpments, and sloping gullied land are found in upland areas; Visalia-Tujunga soils are found in the valley floor. The discussion that follows is based primarily on work by the U.S. Soil Conservation Service (1973).

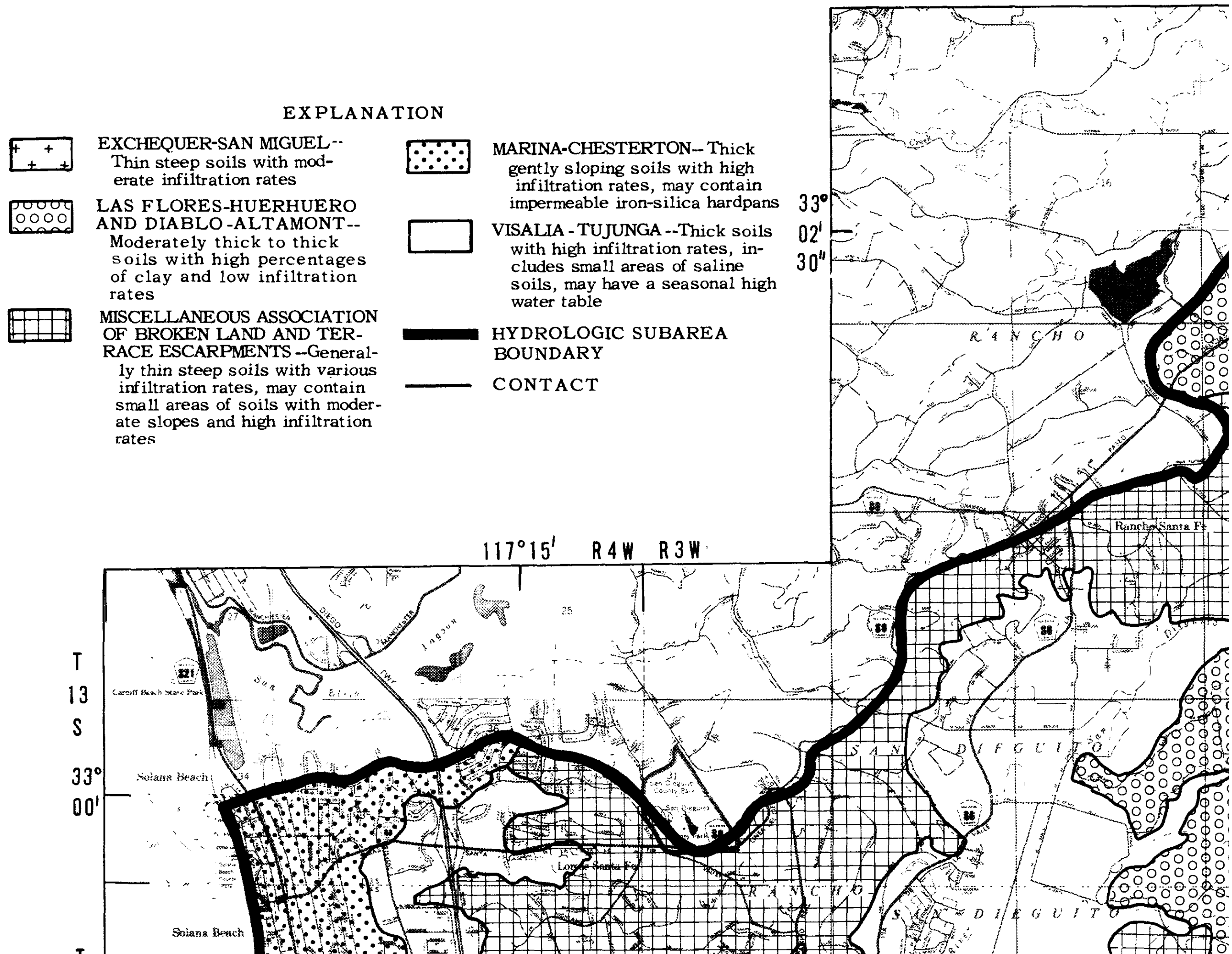
Soils of the Exchequer-San Miguel association have developed in the Peninsular Range Province of the San Dieguito subarea over the Santiago Peak Volcanics. These are thin soils, commonly less than 1.5 feet thick, on steep slopes with only moderate infiltration rates (0.6 to 2.0 in/h for Exchequer soils, and 0.06 to 0.2 in/h for San Miguel soils).

In general, soils that have developed over the unnamed marine terrace deposits belong to the Marina-Chesterton association. The Marina-Chesterton association is typified by gently sloping, excessively drained sandy loam which frequently contains an impermeable iron-silica hardpan. Two soils typical of the Marina-Chesterton association are Chesterton and Huerhuero loams. Chesterton soils are 2 to 3 feet thick and Huerhuero soils are greater than 5 feet thick; both have well-developed hardpans with infiltration rates less than 0.06 in/h. Other soils within this association, particularly Marina and Corralitos, do not have well-developed hardpans and have high infiltration rates throughout the entire soil profile (greater than 20 in/h for Marina soils, and between 6.3 to 20 in/h for Corralitos soils). Both Marina and Corralitos soils are greater than 5 feet thick.

In the uplands of the Pacific Coastal Plain, soils of the Las Flores-Huerhuero and Diablo-Altamont associations predominate. These associations have developed over marine sedimentary rock of the La Jolla Group, exposures of the Lusardi Formation, and the Santiago Peak Volcanics. These soils contain considerable clay and consequently have low infiltration rates (ranging from less than 0.06 in/h for Las Flores and Huerhuero soils to between 0.06 and 0.2 in/h for Altmont and Auld soils).

Where the Lindavista Formation has not entirely eroded away, soils belong to a miscellaneous association of broken land, terrace escarpments, and sloping gullied land. Soils weathered from the Lindavista Formation are characterized by resistant iron concretions near the surface, resulting in poor infiltration (less than 0.06 in/h), rapid runoff, and subsequent erosion of surrounding marine sandstone. Soils developed on sandstone slopes surrounding exposures of the Lindavista Formation are usually highly permeable but are thin and have excessive slope. Small areas of Corralitos soils, with moderate slope and high infiltration rates, may be found near stream channels and on small hills within the coastal plain.

In the upland areas, thick soils with high infiltration rates, such as Marina and Corralitos, are the most suitable for applications of reclaimed water. These soils pose few limitations on application rates and volumes and insure adequate percolation and soil contact before reclaimed water enters underlying aquifers. Soils with low infiltration rates or well-developed hardpans, such as Las Flores and Chesterton, pose limitations on application rates and volumes. These limitations are necessary to prevent waterlogging, shallow circulation, and discharge of reclaimed water to springs and seeps. Thin soils, such as Exchequer and San Miguel, may not provide adequate soil contact before reclaimed water enters underlying aquifers, particularly if ground-water movement through the aquifer is primarily through fractures.



Base from county map, San Diego, California

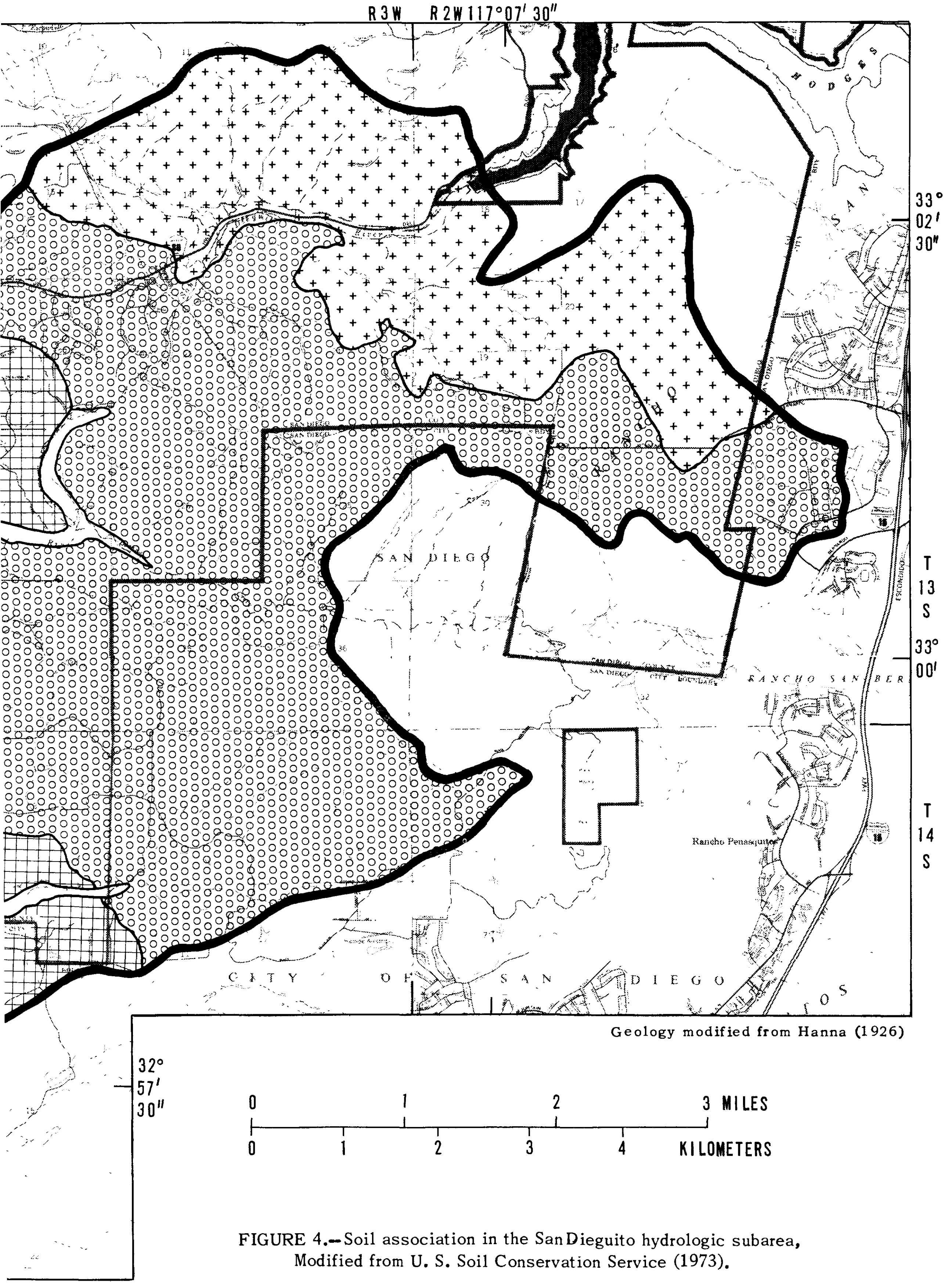


FIGURE 4.--Soil association in the SanDieguito hydrologic subarea, Modified from U. S. Soil Conservation Service (1973).

The Visalia-Tujunga association has developed over alluvial deposits in the San Dieguito River valley. Soils of the Visalia-Tujunga association are thick and sandy. Infiltration rates range from 2.0 to 6.3 in/h for Gaviota soils to greater than 20 in/h for Tujunga soils. These soils have the highest infiltration rates of any soils in the San Dieguito hydrologic subarea. The Visalia-Tujunga association also contains small areas of saline soils similar to those of the Salinas-Corralitos association found within the San Elijo hydrologic subarea. All soils within the Visalia-Tujunga association are greater than 5 feet thick. The primary limitation on application of reclaimed water to soils of the Visalia-Tujunga association is a high water table, often within several feet of land surface much of the year.

Surface Water

Streamflow Characteristics

The San Dieguito hydrologic subarea is the lower 37 mi^2 of the 345 mi^2 San Dieguito River basin. Flow in the river is regulated at Lake Hodges and Sutherland Dam. Construction of another reservoir, Palmo Dam, has been proposed. Streamflow data are summarized in table 1, and location of stream gages is shown in figure 5.

Before the construction of Hodges Dam in 1919, flow in the San Dieguito River was unregulated. Few flow data are available prior to construction of Hodges Dam; however, the river typically flowed only during winter. Maximum measured annual discharge in the San Dieguito River prior to construction of Hodges Dam was 32,000 acre-ft in 1916.

Records of spill over Hodges Dam dating from 1919-82 show that spill occurred in 23 out of 63 years, or approximately one year out of three. Discharge from Hodges Dam has not been uniformly distributed through time (fig. 6). During wet years (1935-46) the dam spilled on a routine basis; however, periods of no spill have been as long as 24 years (1954-77). Ground-water management in the San Dieguito hydrologic subarea will be influenced by spill from Hodges Dam and subsequent recharge to the alluvial aquifer which is dependent on long-term trends in precipitation. During dry periods, flow in the San Dieguito River may be limited to leakage from the dam (less than 15 acre-ft/yr) and surface runoff originating within the 43 mi^2 drainage basin below Hodges Dam.

Surface runoff originating within the San Dieguito hydrologic subarea is confined to peak flows from major storms. Lusardi Creek, Gonzales Creek, and La Zanja Canyon may all flow after major storms, but judging from the lack of well-developed stream channels, runoff from these small canyons only rarely reaches the San Dieguito River, and when it does, streams flow for only a brief time. However, stormflows are important in their respective canyons.

TABLE 1.--Summary of flow data for the San Dieguito hydrologic subarea

[USGS, U.S. Geological Survey; >, greater than; --, no data]

Station name	USGS No.	Period of record	Drainage area (mi^2)	Annual discharge (acre-ft) average	Annual discharge (acre-ft) median	Maximum discharge for period of record instantaneous (ft^3/s)	Maximum discharge for period of record annual (acre-ft)
San Dieguito River at Bernardo	11029500	05-1912 to 12-1916	226	--	--	11,000	72,000
San Dieguito River at Lake Hodges	11030000	01-1916 to 01-1919	303	--	--	310,000	32,000
San Dieguito River at Lake Hodges spillway[1]	--	01-1919 to 12-1981	303	18,000	9,000	--	130,000
San Dieguito River at Del Mar	11030500	10-1913 to 09-1914	328	--	--	--	>3,800

[1]Station operated by San Diego County

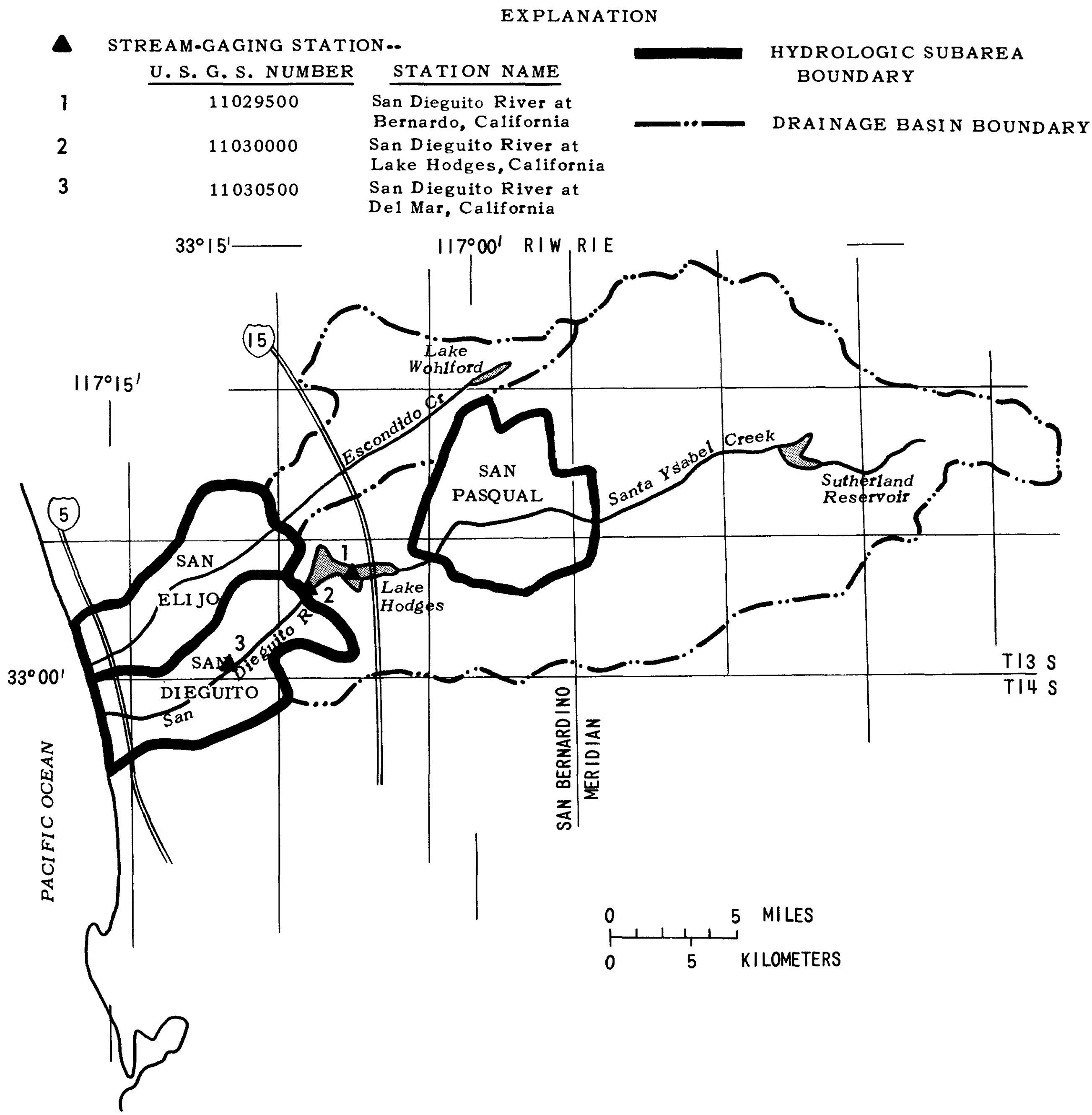


FIGURE 5.--Location of stream-gaging stations in the San Dieguito hydrologic subarea.

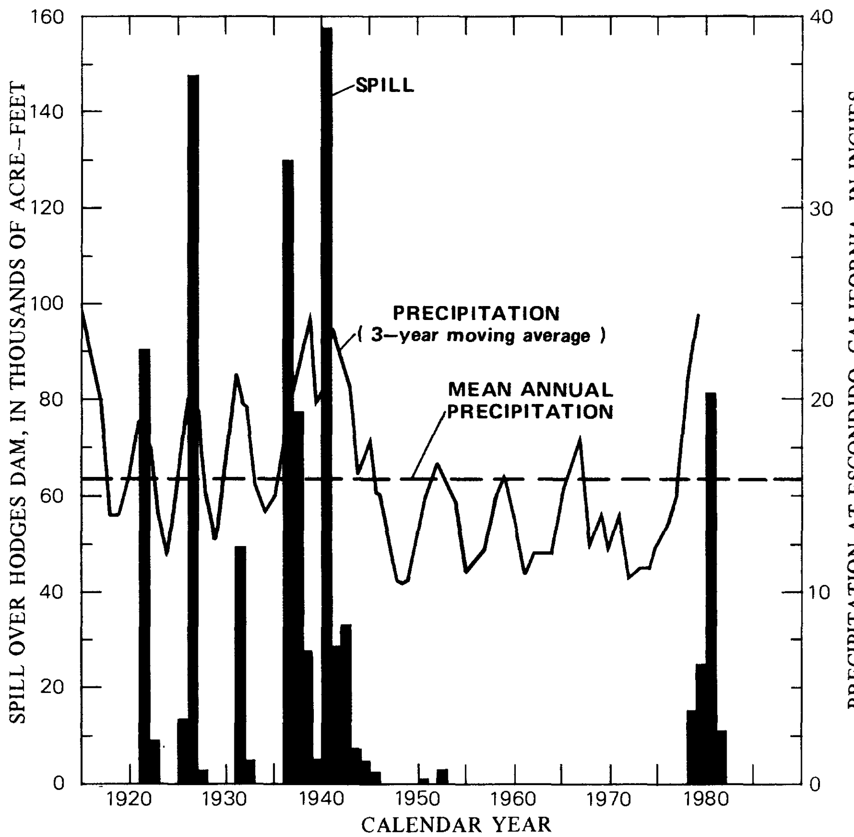


FIGURE 6. – Annual spill data for the San Dieguito River at Hodges Dam.

Surface-Water Quality

Water-quality data for the San Dieguito River below Lake Hodges are summarized in table 2. Typically, dissolved solids exceed 1,000 mg/L and have been observed as high as 2,090 mg/L. Discharge data are not available to associate with water-quality analyses and to separate baseflow from stormflow; however, minimum concentrations given in table 2 probably reflect stormflow water quality. Throughout the period of record, water in the San Dieguito River has been a mixed type, although relative concentrations of dissolved species have been variable.

In 1981 and 1982, water-quality data for the San Dieguito River were updated. Two samples were collected, one during autumn to reflect baseflow and another during the recessional flow of a late spring storm. Dissolved-solids concentrations were 1,200 and 620 mg/L, respectively, reflecting the difference between baseflow and stormflow. Both baseflow and stormflow were a mixed water type (appendix A).

TABLE 2.--Summary of water-quality data for the San Dieguito River below Lake Hodges, 1946-81

[<, less than; --, no data]

	Number of observations	Minimum	Median	Maximum
Instantaneous discharge-----------ft^3/s--	0	--	--	--
Specific conductance µmho/cm at 25°C------------	78	334	1,400	2,660
pH--------------------------	81	7.0	8.1	9.0
Dissolved solids-------mg/L--	81	219	1,120	2,090
Sodium-----------------mg/L--	85	23	130	320
Calcium----------------mg/L--	85	26	96	240
Magnesium--------------mg/L--	85	7	38	100
Chloride---------------mg/L--	85	29	130	460
Sulfate----------------mg/L--	85	21	290	770
Alkalinity as $CaCO_3$----mg/L--	81	64	167	373
Boron------------------µg/L--	28	<10	170	510

Ground Water

Peninsular Range Province

Water-yielding characteristics of the Peninsular Range Province vary with local geologic conditions. Santiago Peak Volcanics typically yield only small quantities of water (less than 2 gal/min) from fractures. However, in areas where weathering has been extensive, wells yield up to 125 gal/min (table 3). Specific-capacity data are unavailable for wells in the Santiago Peak Volcanics.

Geohydrology of the Lusardi Formation has not been explored. The formation may be thought of as partly consolidated. Numerous ground-water seeps occur along exposures of the Lusardi Formation in the spring of the year.

Pacific Coastal Plain

Marine terraces of the Pacific Coastal Plain are generally above the regional water table and do not yield water to wells.

In the San Dieguito area, well yields from the La Jolla Group may be as much as 50 gal/min, although yields between 10 and 20 gal/min are more common. In general, well yields in the La Jolla Group are greater from the Torrey Sandstone than from the Del Mar Formation.

Drillers' data and previous reports (California Department of Water Resources, 1968a) show that in the past, wells drilled through the alluvium into the La Jolla Group have flowed. Although this suggests confinement of ground water in the La Jolla Group, it is possible to have flowing wells in unconfined aquifers. Given a uniformly permeable material (the La Jolla Group) which receives recharge in interstream areas (precipitation) and from which water discharges into streams (the San Dieguito River valley), cased wells at or near the stream reach water under greater pressure as depth increases (Lohman, 1979). The presence of flowing wells and water-quality data (which will be discussed later) illustrate the hydraulic connection between the upper 200 feet of saturated thickness in the La Jolla Group and the alluvial aquifer it encircles.

Alluvial Aquifer

The alluvium of Holocene age stretches from the mouth of the San Dieguito River at Del Mar to the head of Osuna Valley, 6.5 miles inland. It covers 3,900 acres and is between 0.5 and 1 mile wide. Alluvial thickness exceeds 180 feet near the Pacific Ocean and decreases inland (fig. 7). The alluvial aquifer contains 384,000 acre-ft of fill. If an average specific yield of 0.13 (California Department of Water Resources, 1968a) is applied, ground-water storage is estimated at 50,000 acre-ft. The alluvial fill is a water-table aquifer and ground water is not confined.

Based on drillers' information, well yields in the alluvial aquifer may be as much as 1,800 gal/min. Best producing areas are along the eastern edge of the upper part of the basin, including all of Osuna Valley. Wells in this area have an average yield of 700 gal/min, and several wells yield over 1,000 gal/min. In contrast, wells outside this area have an average yield of 230 gal/min, and a maximum yield of 600 gal/min.

TABLE 3.--Water-yielding characteristics of aquifers

[Data from drillers' information.

Geologic unit	Map symbol	Exposure in subarea (acres) San Dieguito	Exposure in subarea (acres) San Elijo	Maximum thickness (feet)	Description
Alluvium	Qal	4,100	1,680	>150	River and stream deposits of sand, silt, and clay.
Older alluvium	Qoal	1,050	570	unknown	River and stream deposits of gravel, sand, silt, and clay. Partly cemented and weathered.
Unnamed marine terrace deposits	Qm	1,270	500	25	Weakly cemented cobble conglomerate.
Lindavista Formation	Qlv	1,540	1,060	100	Marine sandstone and cobble conglomerate with abundant iron oxide concretions.
La Jolla Group	Tlj	8,450	4,970	1,650	--
Torrey Sandstone of La Jolla Group		--	--	--	Marine sandstone, coarse and poorly consolidated.
Del Mar Formation of La Jolla Group		--	--	--	Massive marine mudstone, siltstone, and shale.

in the San Dieguito and San Elijo hydrologic subareas

>, greater than; --, no data]

Water-yielding characteristics			
General	Well yield (gal/min)	Specific capacity ((gal/min)/ft of drawdown)	Transmissivity (ft^2/d)
Yields water freely to wells.	As much as 1,800.	Typically less than 16, but may be as much as 60.	Typically less than 4,000, but may be as much as 16,000.
Yields water to wells.	As much as 75.	No data, but less than alluvial aquifer.	No data, but less than alluvial aquifer.
Permeable, but generally above regional water table.	--	--	--
Impermeable and generally above regional water table.	--	--	--
Yields small quantities of water to wells.	Typically between 10 and 20, but may be as much as 50.	As much as 0.4.	Unknown.
Somewhat more permeable.	Higher average.	Higher average.	Unknown.
Somewhat less permeable.	Lower average.	Lower average.	Unknown.

TABLE 3.--Water-yielding characteristics of aquifers in the

Geologic unit	Map symbol	Exposure in subarea (acres) San Dieguito	San Elijo	Maximum thickness (feet)	Description
Lusardi Formation	Kl	1,870	500	375	Massive nonmarine boulder conglomerate with arkosic sandstone matrix.
Santiago Peak Volcanics	KJsp	5,620	10,470	Basement complex	Variable, ranges from highly metamorphosed welded tuff to slightly metamorphosed breccia and volcanic conglomerate. Locally intruded by quartz diorite from the southern California batholith.

Clean sand and gravel in buried river channels are the most productive zones within the alluvial aquifer. Fine, dark-colored silt and some clay surround the deposits of river sand. Near the ocean, deposits of sand and gravel decrease and the surrounding matrix contains more blue and green clay. Drillers have found shells in this clay matrix, possibly indicating the presence of lagoonal sediments near the ocean.

Specific capacities are highest along the eastern edge of the upper basin and in Osuna Valley. In this area, specific capacities average 18 (gal/min)/ft of drawdown, with a maximum of 60 (gal/min)/ft of drawdown. Specific capacities in the remainder of the basin average less than 6 (gal/min)/ft of drawdown, with a maximum of 16 (gal/min)/ft.

Water-yielding characteristics			
General	Well yield (gal/min)	Specific capacity ((gal/min)/ft of drawdown)	Transmissivity (ft^2/d)
Water-yielding potential has not been explored. Seeps are common along exposed faces.	--	--	--
Variable, yields small quantities of water to wells from fractures, and larger quantities where metamorphism is slight and weathering intense.	Generally less than 2, but may be as much as 125.	--	--

An estimate of aquifer transmissivity from specific-capacity data can be obtained by multiplying specific-capacity data by 250. This value is based on statistical correlations done by Thomasson and others (1960) in California's Central Valley, and has been routinely extended to California's coastal and desert basins. Using this figure, aquifer transmissivities are as high as 15,000 ft^2/d and average 4,500 ft^2/d in areas of the San Dieguito basin where good deposits of sand and gravel are found. In the remainder of the basin where silt and clay predominate, aquifer transmissivities are less than 4,000 ft^2/d and average 1,500 ft^2/d. Areas of high transmissivity, greater than 4,000 ft^2/d, have been delineated using drillers' data (fig. 7).

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Lindavista Formation (Pleistocene) and La Jolla Group (Eocene)

LUSARDI FORMATION (Late Cretaceous)

SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

CONTACT

BOUNDARY OF GROUND-WATER BASIN

125 LINE OF EQUAL THICKNESS OF ALLUVIUM, IN FEET--Interval 25 and 50 feet

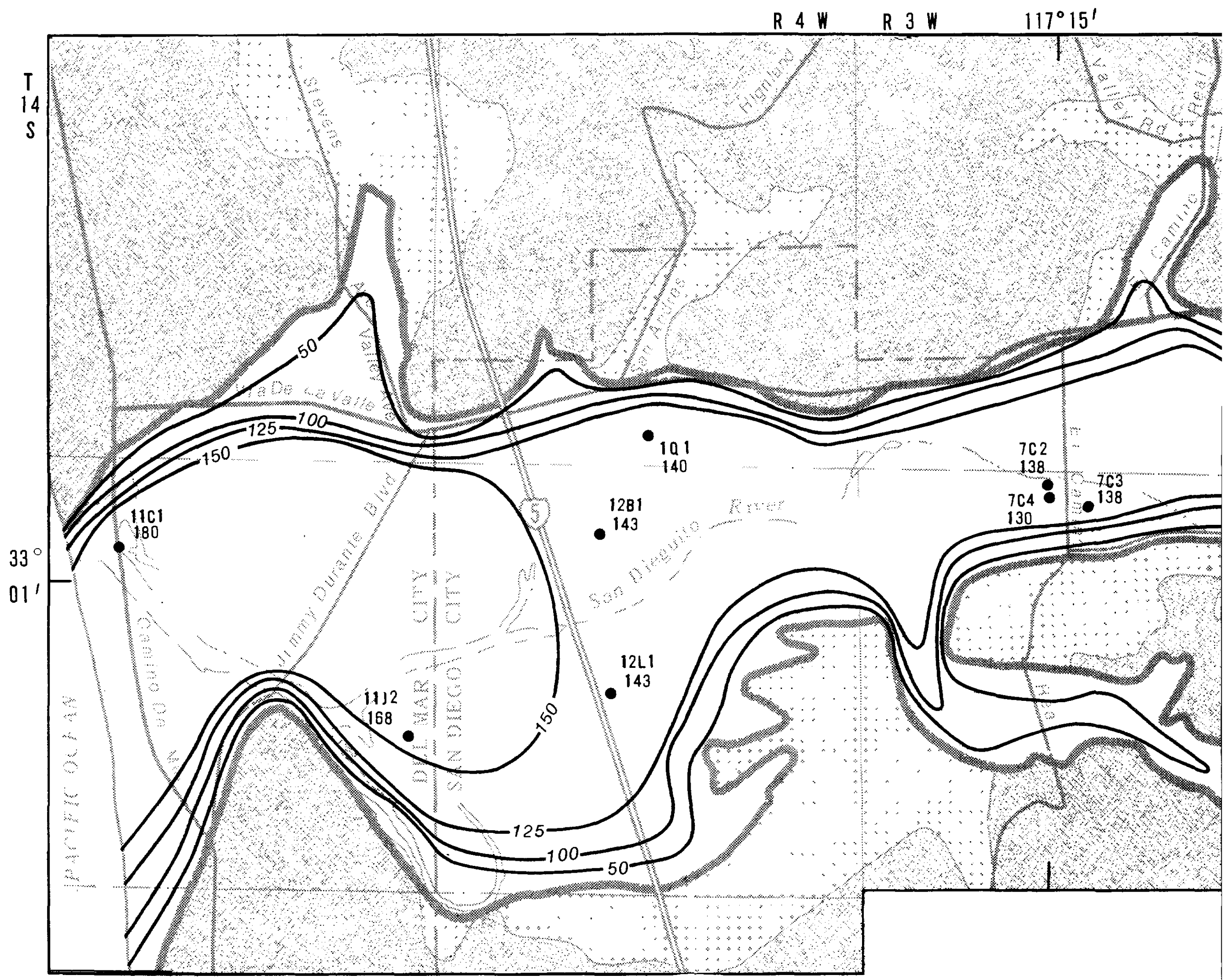
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY--

Less than 4000

More than 4000

12B1
143

WELL--Upper number is well number. Lower number is thickness of alluvial fill, in feet



Base from county map, San Diego, California

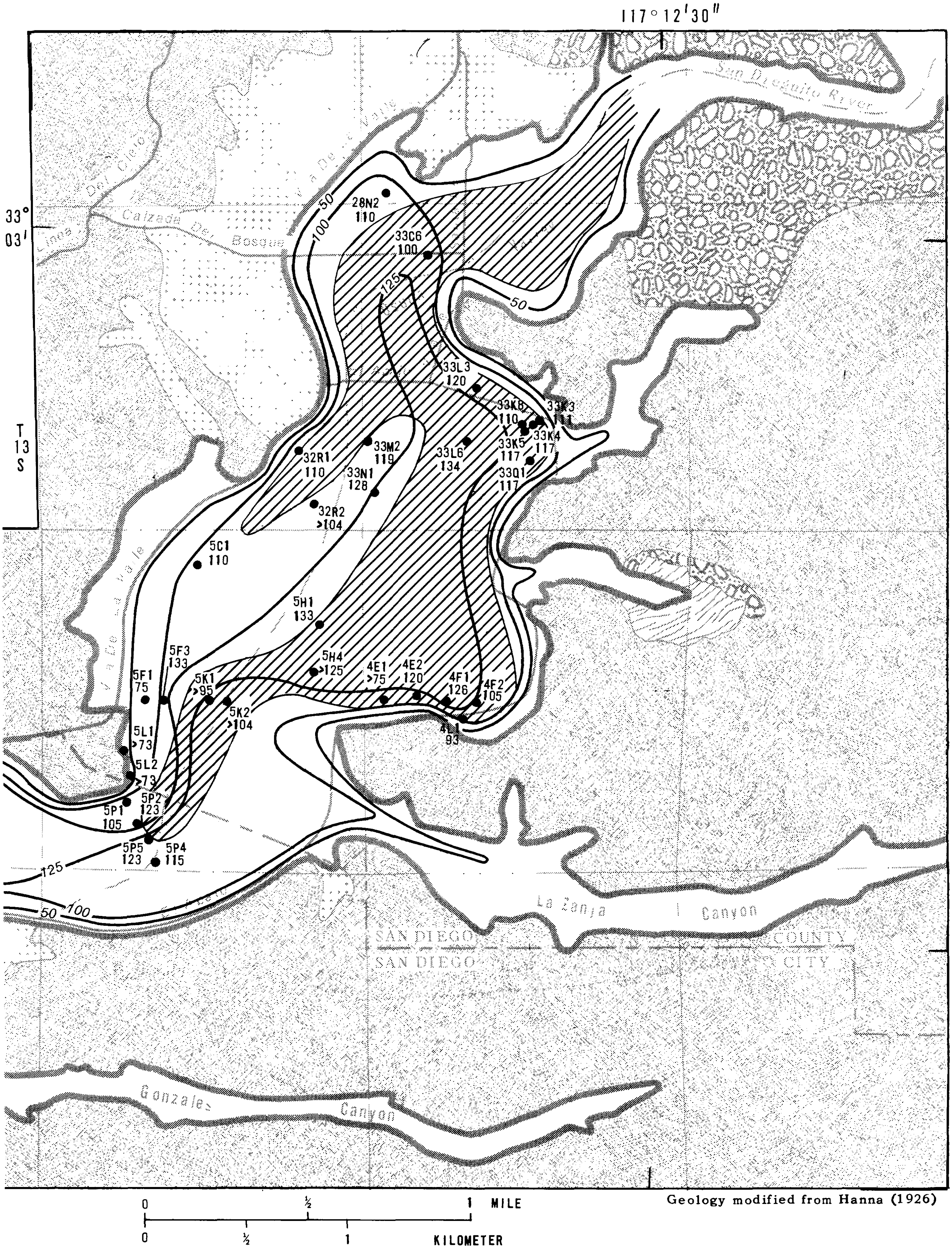


FIGURE 7.--Thickness of the San Dieguito alluvial aquifer.

An older alluvial aquifer (Pleistocene age) surrounds the Holocene alluvium of the San Dieguito subarea. The older alluvium is composed of river gravel, sand, silt, and clay which have been partly cemented and weathered. Well yields in the older alluvium are lower than Holocene alluvium, but may exceed 75 gal/min. No specific-capacity data are available for wells in the older alluvium.

Hydrologic continuity is assumed between Pleistocene and Holocene alluvium, and ground water probably moves freely between the two. However, because of the greater relief of older alluvial fill, depth to water is greater than in younger alluvial fill.

Recharge.--Historically, virtually all recharge to the San Dieguito alluvial aquifer has been from the San Dieguito River. Since construction of Hodges Dam in 1919, recharge has been reduced. Currently, potential recharge from the San Dieguito River is sporadic and water available for recharge ranges from 15 acre-ft as leakage under Hodges Dam in a dry year, to well over the total storage capacity of the alluvial aquifer in wet years when Hodges Dam spills. Since 1919, imported water[1] and leakage from surrounding marine sedimentary rock have become important sources of recharge. Surface flow originating in the hydrologic subarea and precipitation falling directly upon the alluvial fill contribute small amounts of recharge which may be locally important.

Imported water use in the San Dieguito subarea increased from 4,500 acre-ft in 1970, to 8,800 acre-ft in 1980. However, not all this water was used for irrigation or ended up as deep percolation to the alluvial aquifer. Based on calculations by the California Department of Water Resources (California Department of Water Resources, 1983), 160 acre-ft of irrigation return water became deep percolation and contributed to recharge in the alluvial aquifer in 1970. By 1980, this total increased to 210 acre-ft.

Leakage from surrounding marine sedimentary rock is the largest source of recharge to the alluvial aquifer when spill does not occur at Hodges Dam, and hydraulic gradients between the alluvial aquifer and the surrounding marine sedimentary rock are great. Between 1952 and 1978, no spill occurred at Hodges Dam. Analysis of the water budget showed leakage from marine sedimentary rock of the La Jolla Group to the alluvial aquifer averaged 600 acre-ft/yr during part of this time (1965-78).

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[1]In this context, imported water is water originating outside the hydrologic subarea and includes Colorado River water, northern California water, and local water supplies.

Occurrence and movement.--Historically, movement of ground water in the alluvial aquifer has been from the major source of recharge in Osuna Valley downgradient to the discharge area at the Pacific Ocean. No other discharge areas were described or mapped by early workers in the area.

Before the construction of Hodges Dam and the beginning of ground-water exploitation, water levels were near land surface much of the year and little additional storage was available (Ellis and Lee, 1919). Data from the U.S. Geological Survey (1937-55) and unpublished data from the Vulcan Water Company (an early water purveyor in the area) show water levels were at or near land surface in Osuna Valley and swampy conditions prevailed. Farther downgradient, water levels in well 13S/3W-33L averaged 8 feet below land surface, and well 14S/3W-6, in the middle San Dieguito Valley, had water levels within 10 feet of land surface throughout the year (fig. 8 and 9).

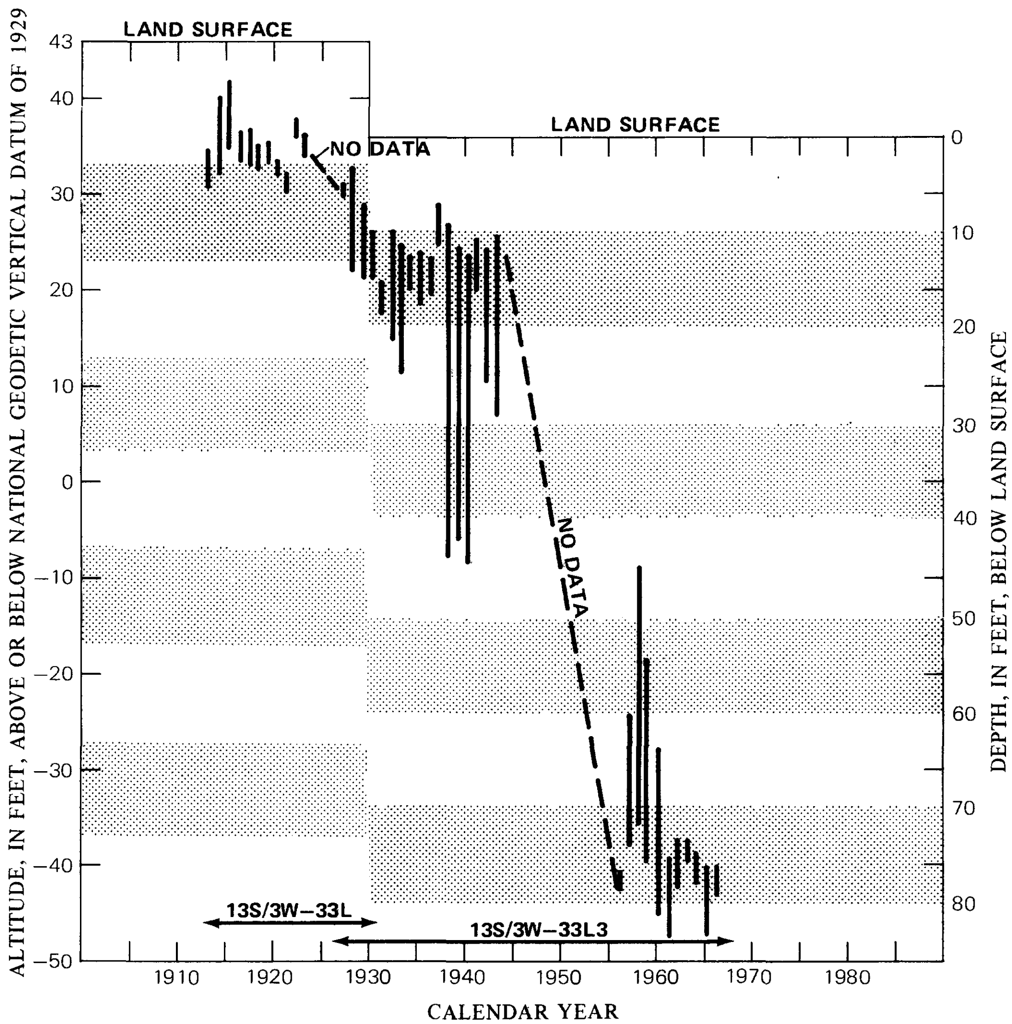


FIGURE 8. – Hydrographs for wells in the upper part of the San Dieguito basin. Vertical bar indicates range of water–level fluctuation during year. (Location of wells shown in appendix C.).

Extensive ground-water development began after World War II. In 1965, in the upper San Dieguito basin and for the aquifer as a whole, ground-water levels reached a low of 49 feet below sea level (90 feet below land surface) (fig. 10). Water-level contours show that the gradient in the alluvium had been reversed. Water was moving from the lower part of the basin into the upper San Dieguito basin and the Pacific Ocean was the major source of recharge. During spring 1965, storage in the aquifer was reduced to 31,500 acre-ft, or approximately 60 percent of capacity. Nearly all the reduction in storage was in the upper part of the basin and Osuna Valley, where only 10,500 acre-ft of water remained in storage.

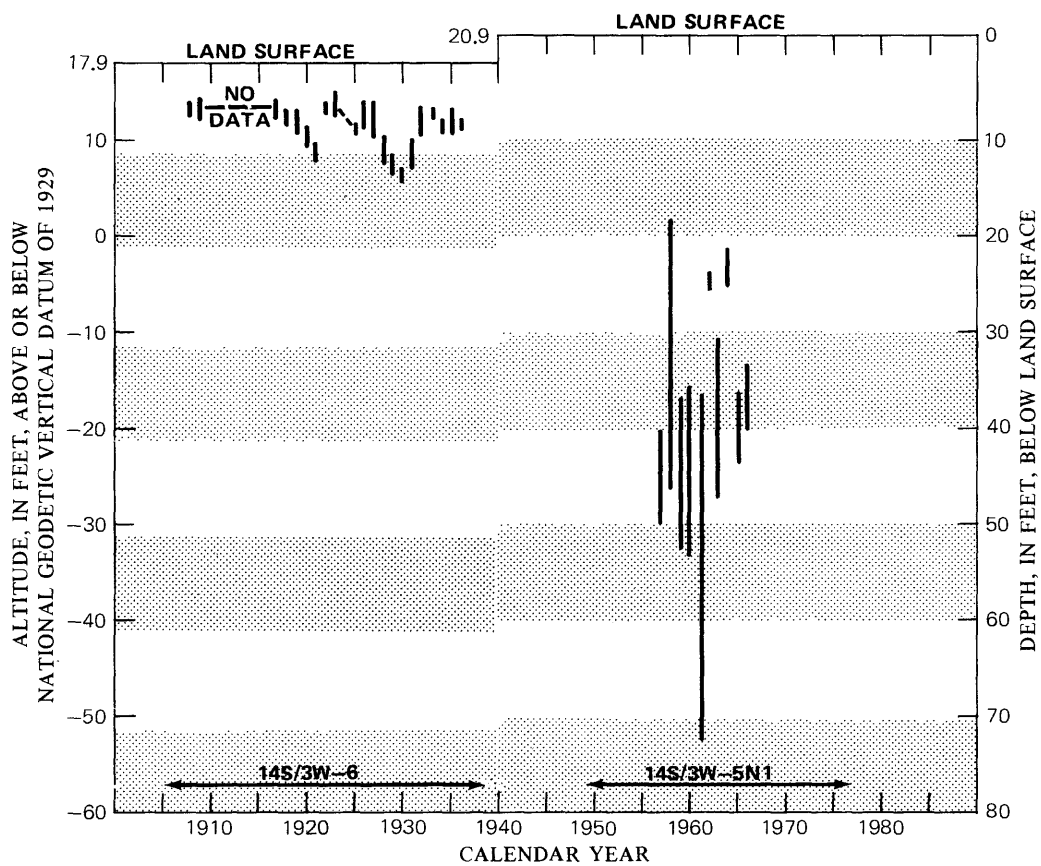


FIGURE 9. – Hydrographs for wells in the lower part of the San Dieguito basin. Vertical bar indicates range of water–level fluctuation during year. (Location of wells shown in appendix C.).

Water-level measurements before 1978, when Hodges Dam spilled and significant recharge water was available from the San Dieguito River, indicate that the alluvial aquifer had partially filled. On the average, water levels in the upper part of the basin and Osuna Valley rose 30 feet, representing an increase in storage of approximately 10,000 acre-ft.

Water-level contours for spring 1982 show the alluvial aquifer was full and the major source of recharge was again the San Dieguito River (fig. 11). Ground water was again moving downgradient from Osuna Valley to its discharge point at the Pacific Ocean. Water levels within the alluvial fill were within 10 feet of land surface throughout much of the basin, and nowhere exceeded 25 feet below land surface. Hence, very little if any of the estimated total storage of 52,000 acre-ft was available for storage of reclaimed water in 1982.

When the basin is full, ground water will not move from surrounding marine sedimentary rock into the alluvial aquifer. Historical evidence suggests the reverse occurs, and water moves from the alluvial aquifer into the surrounding formations (California Department of Water Resources, 1968a, and Ellis and Lee, 1919).

Ground-Water Quality

Quality of ground water within the San Dieguito hydrologic subarea is variable and depends upon the geologic formation from which it is obtained. Typical water type in each geologic formation is summarized in table 4.

Peninsular Range Province

Water from the Santiago Peak Volcanics is generally a mixed type and sodium, calcium, chloride, and sulfate are the most predominant ions. Dissolved-solids concentrations are generally greater than 2,000 mg/L. Some wells in this formation have yielded high-quality water in the past, but these wells are wide, shallow dug wells, and probably act as cisterns, reflecting quality of local precipitation and surface water.

No information is available on the quality of the water in the Lusardi Formation.

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Lindavista Formation (Pleistocene) and La Jolla Group (Eocene)

LUSARDI FORMATION (Late Cretaceous)

SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

CONTACT

BOUNDARY OF GROUND-WATER BASIN

-20 WATER-TABLE CONTOUR--Shows altitude of water table below National Geodetic Vertical Datum of 1929. Dashed where approximately located. Contour Interval 5 and 10 feet

DEPTH TO WATER, IN FEET BELOW LAND SURFACE

0 - 25

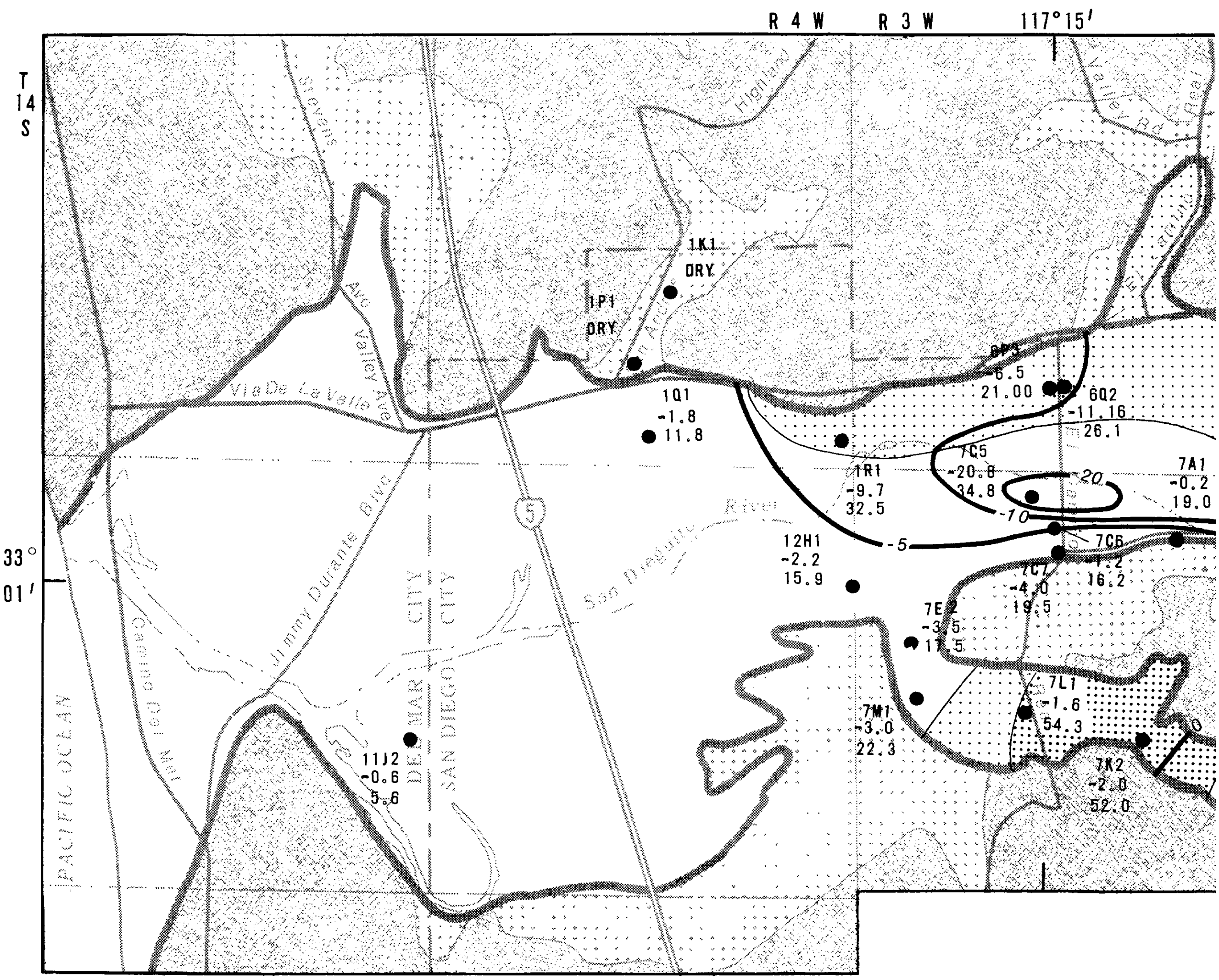
25 - 50

50 - 75

Greater than 75

1R1
-9.7
32.5

WELL--Upper number is well number. Middle number is water-table altitude, in feet above and (-) below National Geodetic Vertical Datum of 1929. Lower number is depth below land surface, in feet



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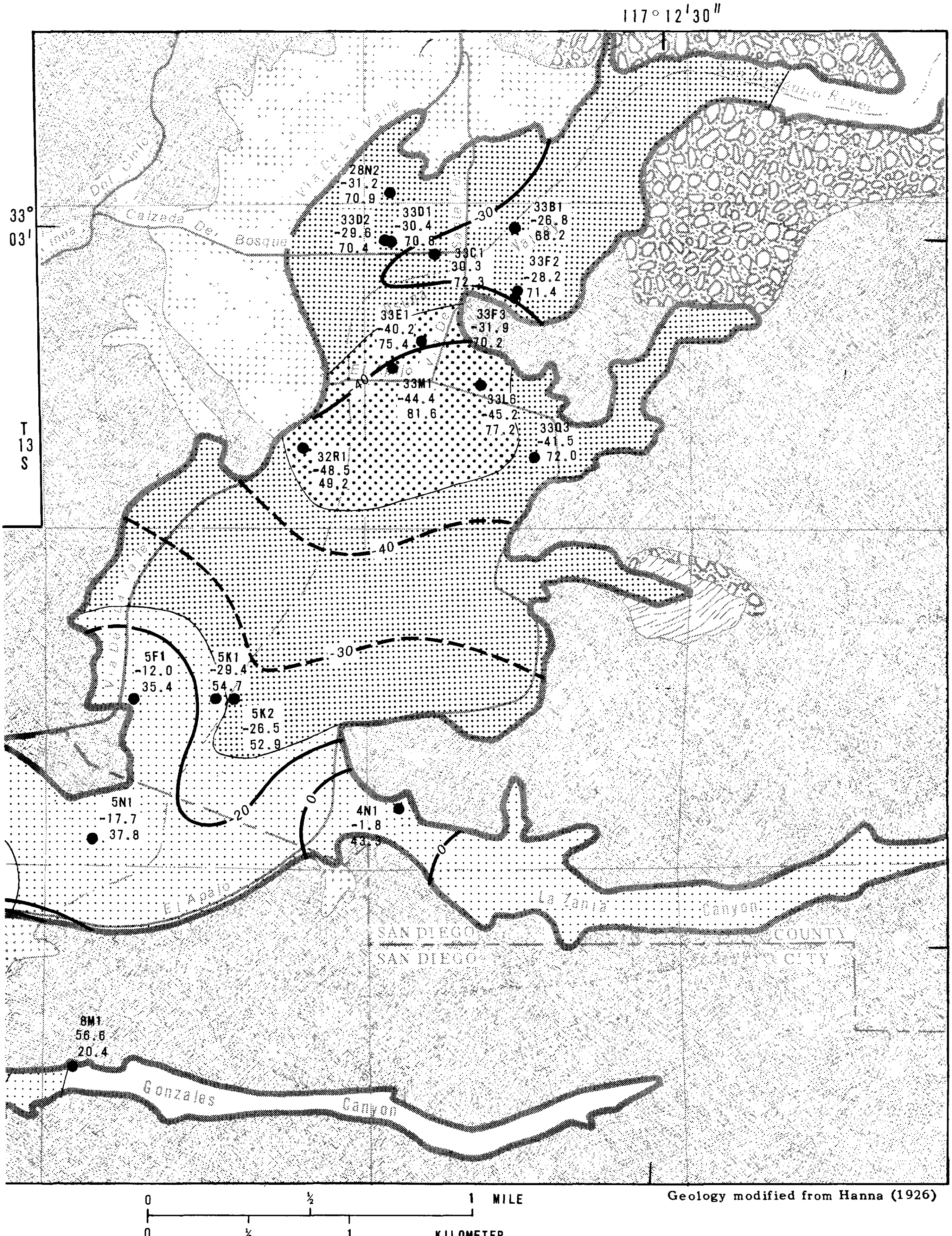


FIGURE 10.--Water-level contours and depth to water in the San Dieguito alluvial aquifer, spring 1965.

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Lindavista Formation (Pleistocene) and La Jolla Group (Eocene)

LUSARDI FORMATION (Late Cretaceous)

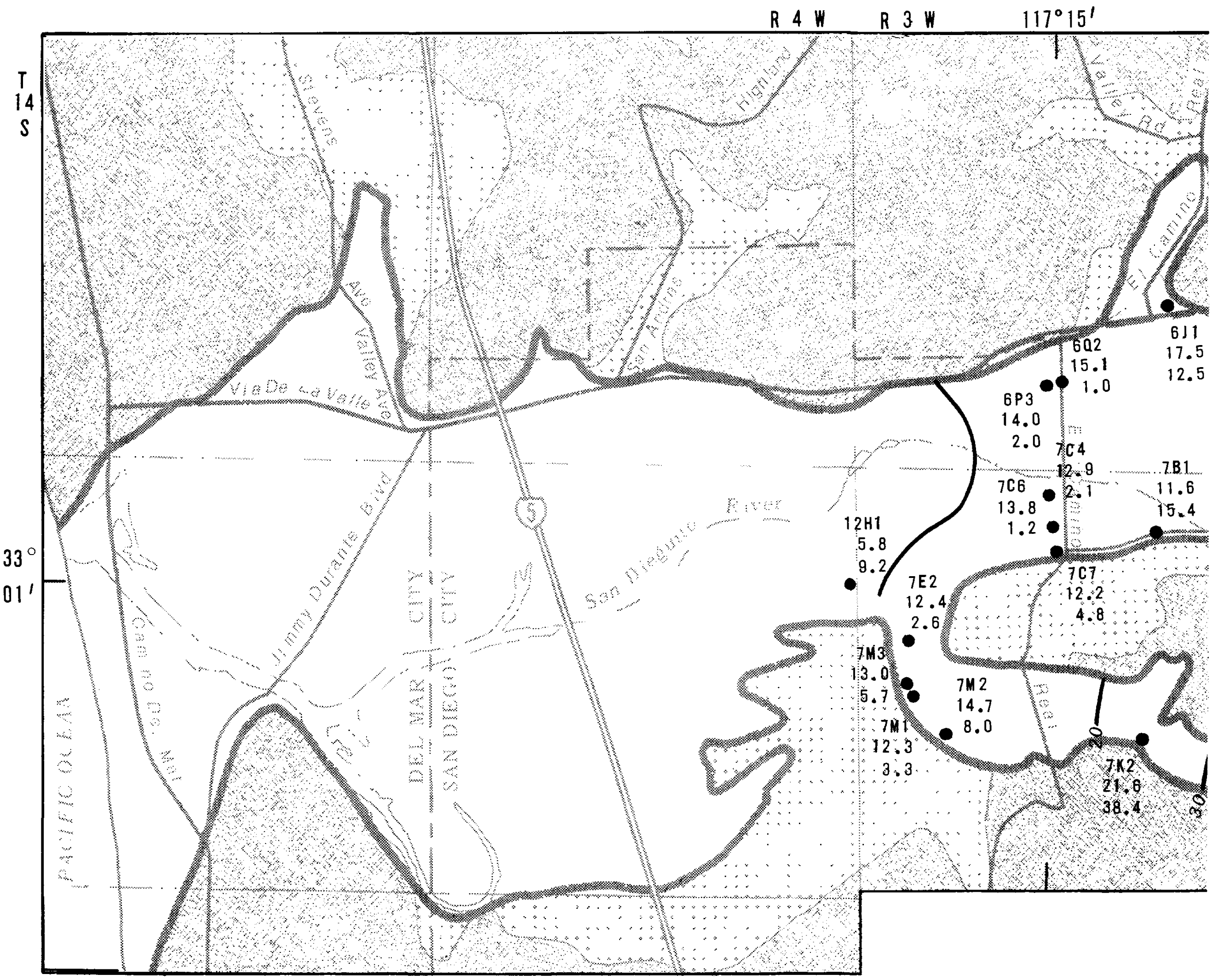
SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

CONTACT

BOUNDARY OF GROUND-WATER BASIN

10 WATER-TABLE CONTOUR--Shows altitude of water table above National Geodetic Vertical Datum of 1929. Dashed where approximately located. Contour interval 10 feet

32H1
13.2
● 44.8 WELL--Upper number is well number. Middle number is water-table altitude, in feet above National Geodetic Vertical Datum of 1929. Lower number is depth below land surface, in feet



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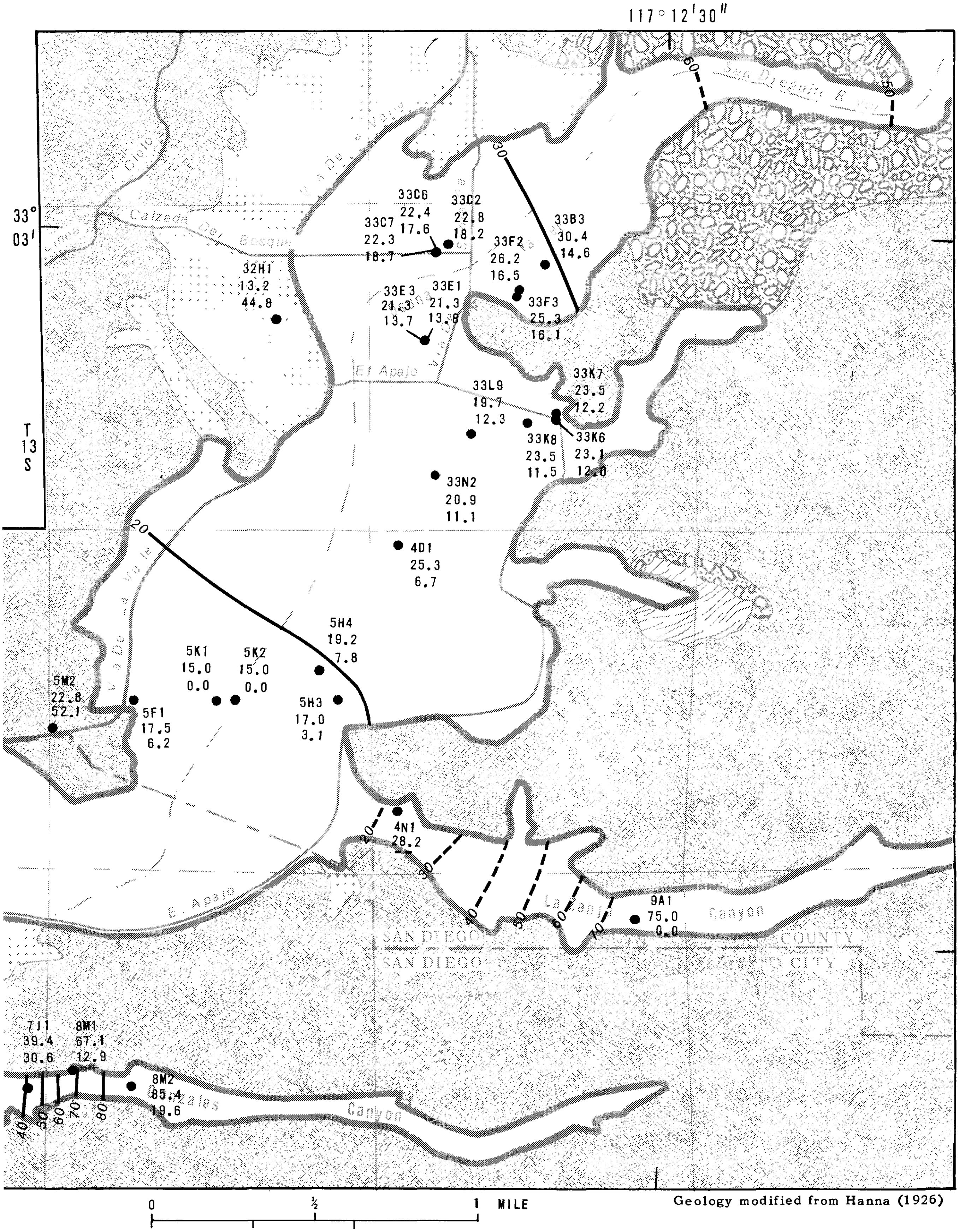


FIGURE 11.--Water-level contours and depth to water in the San Dieguito alluvial aquifer, spring 1982.

TABLE 4.--Ground-water quality in the San Dieguito and San Elijo hydrologic subareas

[Data from drillers' information. --, no data]

Geohydrologic unit	Map symbol	Exposure in subarea (acres)		Typical dissolved solids	Typical water type
		San Dieguito	San Elijo		
Alluvium	Qal	4,100	1,680	Variable, generally between 1,000 to 2,000 mg/L in the upper basin to greater than 5,000 mg/L near the ocean. Tributary canyons may yield water with less than 1,000 mg/L dissolved solids.	Variable, mixed in upper basin and small canyons sodium chloride near the ocean.
Older alluvium	Qaol	1,050	570	Between 1,000 to 2,000 mg/L.	Mixed.
Unnamed marine terrace deposits	Qm	1,270	500	--	--
Lindavista Formation	Qlv	1,540	1,060	--	--

La Jolla Group	Tlj	8,450	4,970	Between 1,000 to 2,000 mg/L where extensive leaching of salts has occurred; 2,000 to 5,000 mg/L where leaching has not occurred.	Mixed where extensive leaching of salts has occurred; sodium chloride where leaching has not occurred.
Torrey Sandstone of La Jolla Group				Between 1,000 to 2,000 mg/L.	Generally mixed.
Del Mar Formation of La Jolla Group				Variable, but generally greater than 2,000 mg/L; sometimes between 1,000 to 2,000 mg/L.	Generally sodium chloride.
Lusardi Formation	Kl	1,870	500	Unknown. Assumed to be greater than 1,000 mg/L.	Unknown. Assumed to be mixed.
Santiago Peak Volcanics	KJsp	5,620	10,470	Generally greater than 2,000 mg/L.	Mixed.

Pacific Coastal Plain

Water quality in the La Jolla Group is variable. Deep wells in the La Jolla Group and wells completed in the Del Mar Formation yield sodium chloride type water having dissolved-solids concentrations greater than 2,000 mg/L. Water having dissolved-solids concentrations less than 1,500 mg/L is yielded by shallower wells and wells near major river channels, particularly in the Torrey Sandstone. Deeper wells in the La Jolla Group yield sodium chloride type water, and water grades to a mixed type at shallower depths, suggesting that sodium chloride salts have been preferentially leached by infiltrating precipitation.

In areas where other water supplies are unavailable, the La Jolla Group provides water for washing, cleaning, fire protection, and irrigation of salt-tolerant plants. However, mesa-like topography and regional drainage by the San Dieguito River have combined to produce depths to water often over 300 feet. This and water high in dissolved solids have restricted the development of the La Jolla Group as a water-supply source.

Alluvial Aquifer

Historical water quality.--Quality of water in the alluvial aquifer has been variable. In general, ground water has higher dissolved solids near the ocean and in silt, and lower dissolved solids in sand and gravel farther from the ocean.

Few data are available that describe original water quality in the alluvial aquifer. The earliest available water analysis is from well 14S/3W-6, which was sampled in autumn 1914. The water was a mixed quality type and had a dissolved-solids concentration of 2,500 mg/L. In 1940, water from well 13S/3W-33L3 had a dissolved-solids concentration of 600 mg/L. Because no geologic or depth data are available from either well, all that can be inferred is water quality varied areally and some wells yielded water with dissolved-solids concentrations less than 1,000 mg/L.

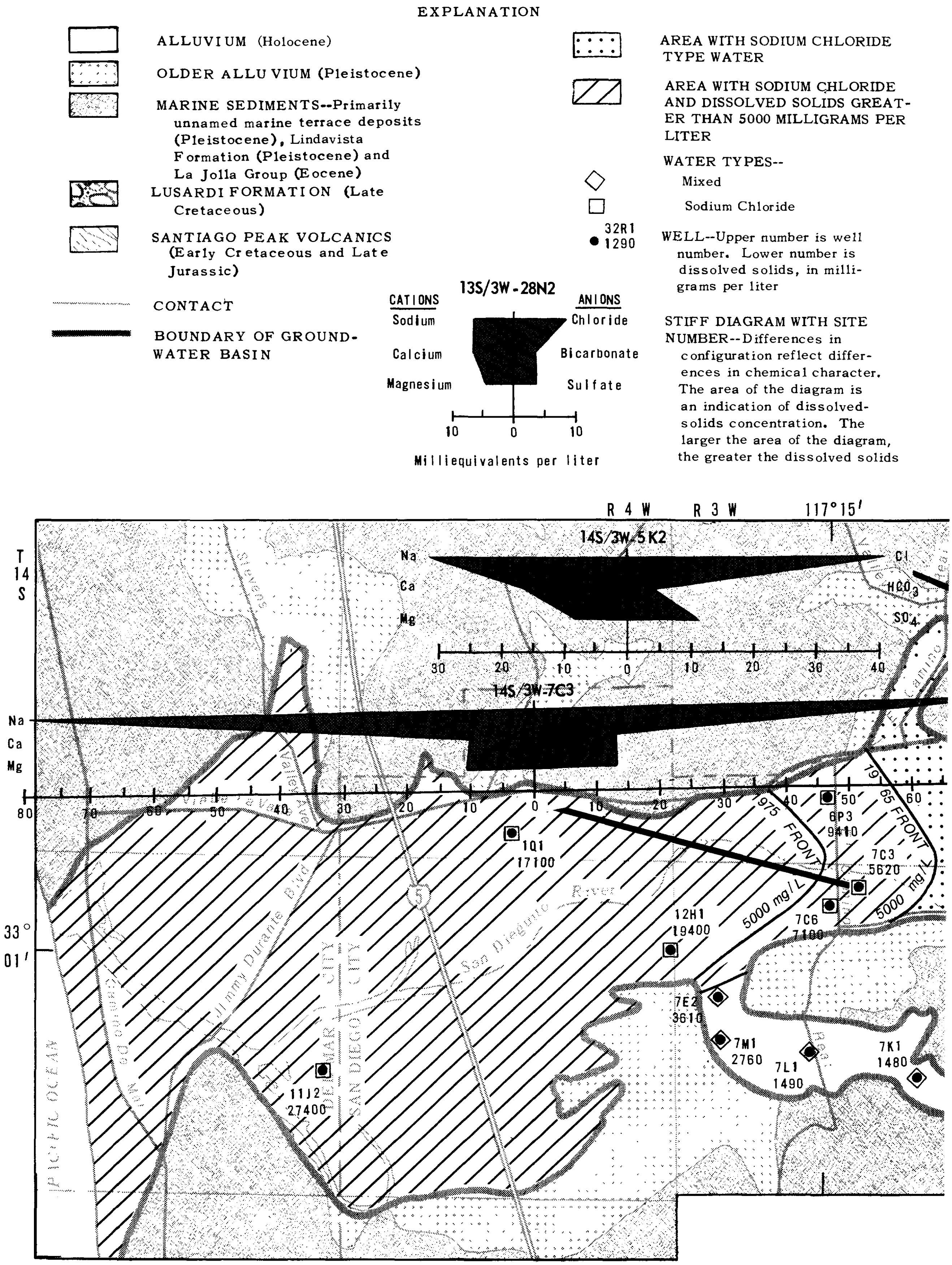
In the early 1950's, all wells sampled in Osuna Valley and some wells in the upper part of the basin yielded water with dissolved solids less than 1,000 mg/L. Several wells in Osuna Valley yielded water with dissolved solids less than 700 mg/L. Seawater intrusion in the lower part of the basin was already a problem.

In 1965, dissolved solids increased downgradient from Osuna Valley toward the Pacific Ocean and ranged from less than 1,000 to greater than 19,000 mg/L. Figure 12 shows a 5,000-mg/L line of equal dissolved solids for 1957 and 1965. Between these years, ground water with dissolved solids exceeding 5,000 mg/L moved inland approximately 0.3 mile in response to pumping and drought conditions.

The small diagrams to the side of the alluvial basin in figure 12 are stiff diagrams. Stiff diagrams graphically show relative magnitude of major dissolved ions in water. Differences in configuration reflect differences in chemical character, and the area of the diagram is an indication of dissolved-solids concentration. In 1965, ground water from Osuna Valley was a mixed quality type. Downgradient toward the Pacific Ocean, water changed to a sodium chloride type. The position of the sodium chloride wedge is shown for 1957 and 1965. During those 8 years, sodium chloride water moved up to 1 mile inland. The most rapid movement of sodium chloride water was through permeable sand and gravel deposits along the eastern edge of the aquifer (fig. 7).

When plotted on a trilinear diagram (fig. 13), differences can be seen between sodium chloride ground water from the alluvial aquifer (solid circles), and ground water from surrounding marine sedimentary rock (solid squares). This strongly suggests the source of sodium chloride water, even in the upper part of the basin, was seawater (solid triangle). A strong resemblance is seen between water from some wells in alluvium having a mixed water type (hexagons), and water from surrounding marine sedimentary rock, suggesting that movement of water from the La Jolla Group was induced by pumping in the alluvial aquifer. The remaining samples from wells in alluvium are a mixed water type and grade between waters native to the alluvial aquifer, ground water from marine sedimentary rock, and sodium chloride water from the lower part of the basin. However, it should be remembered that all wells were impacted to some degree by irrigation return, intrusion from marine sedimentary rock, or seawater intrusion, and no sample strictly reflects original water quality.

Present water quality.--In the main stem of the alluvial aquifer dissolved-solids concentrations frequently exceeded the basin objective of 1,500 mg/L (fig. 14). In spring 1982, dissolved solids in Osuna Valley ranged from 1,320 to 1,810 mg/L. Dissolved solids increase downgradient and exceed 20,000 mg/L near the Pacific Ocean. The 5,000-mg/L line of equal dissolved solids has retreated from its 1965 position but has not returned to its 1957 position.



Base from county map, San Diego, California

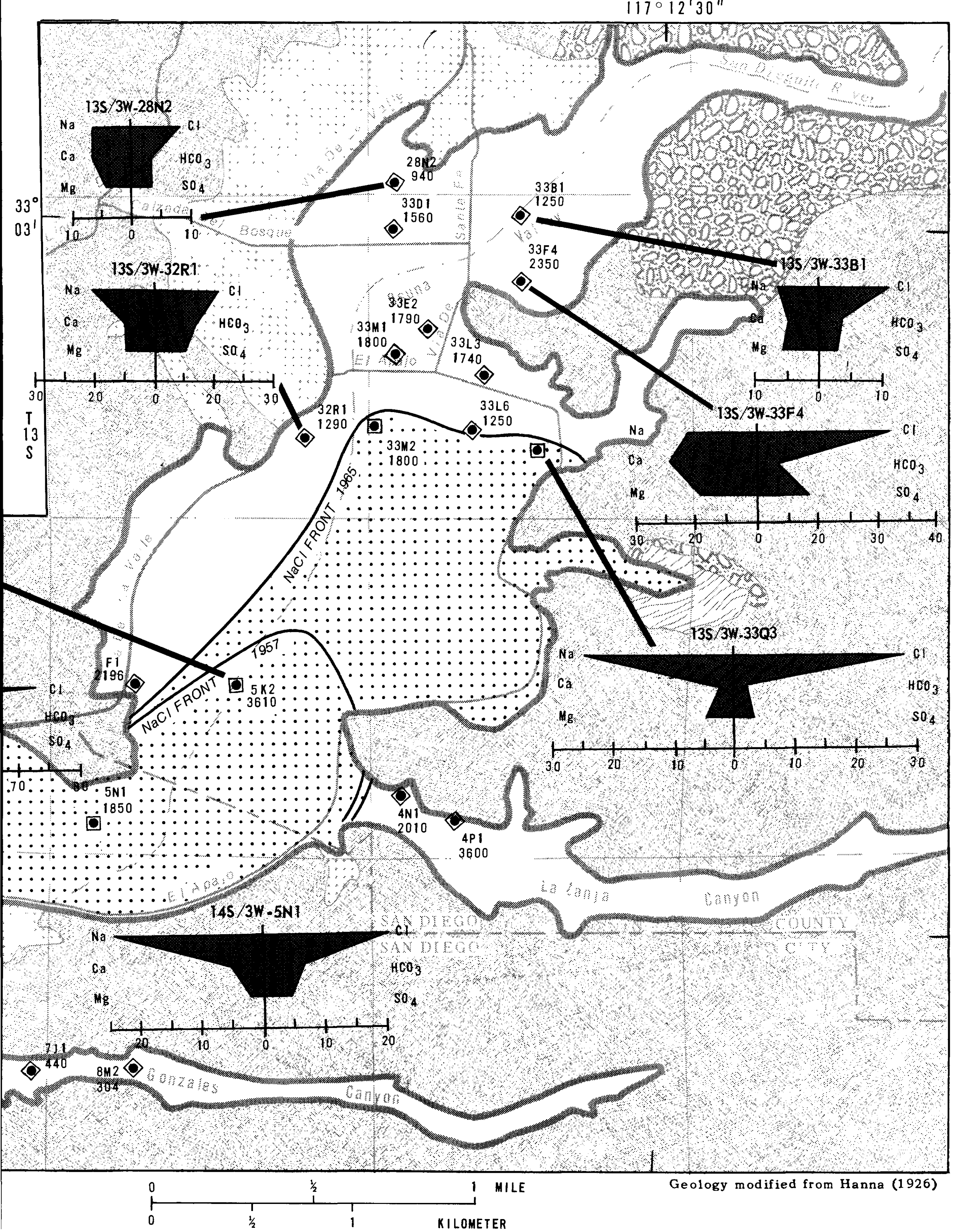


FIGURE 12--Water quality in the San Dieguito alluvial aquifer, spring 1965.

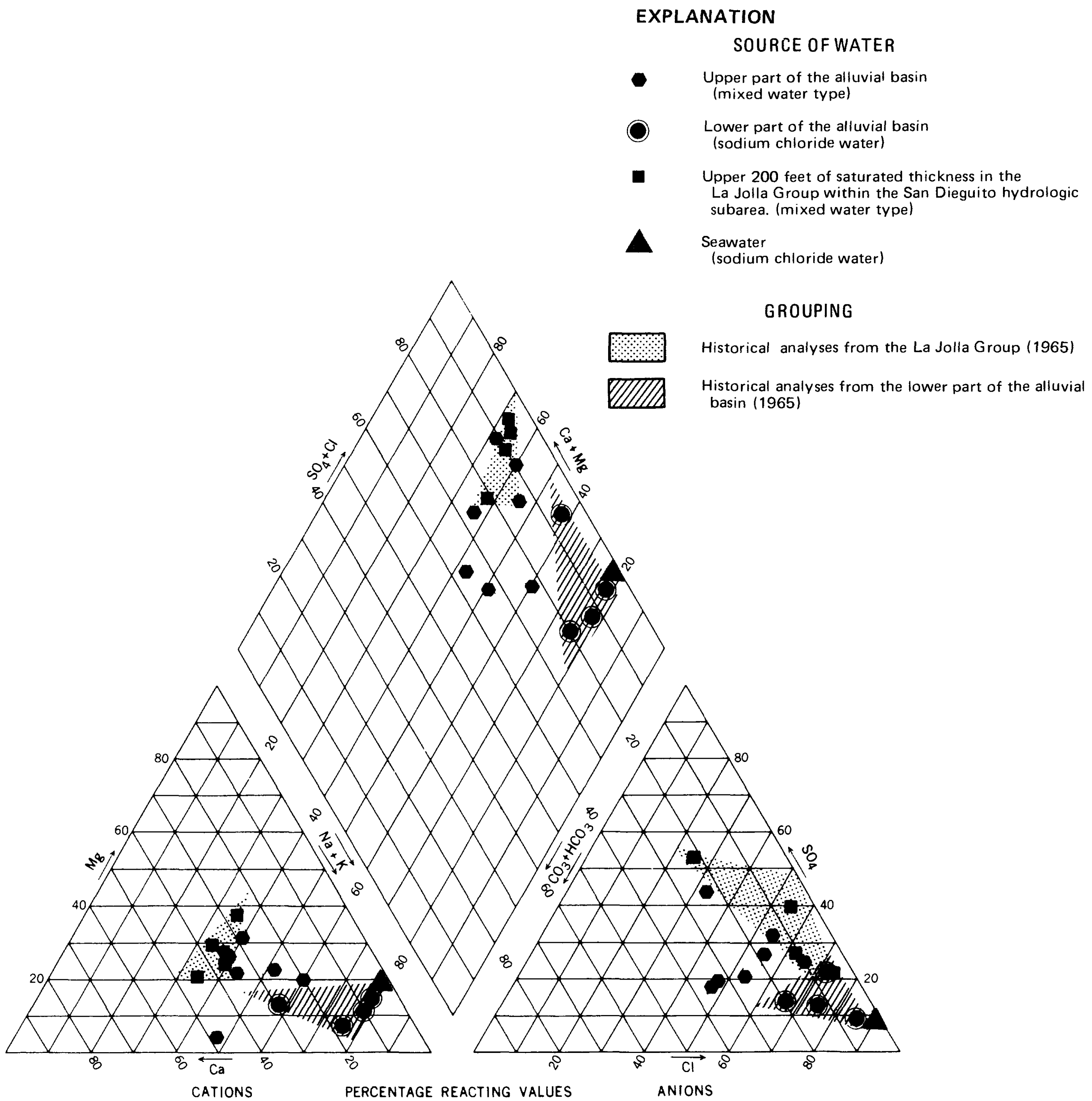


FIGURE 13. – Trilinear diagram showing water quality in the San Dieguito hydrologic subarea, spring 1965.

Field measurements of specific conductance were converted to dissolved-solids concentration using the following relation:

$$DS=0.73SC-170,$$

where

DS is dissolved-solids concentration, in milligrams per liter; and
SC is specific conductance, in micromhos per centimeter at 25°C.

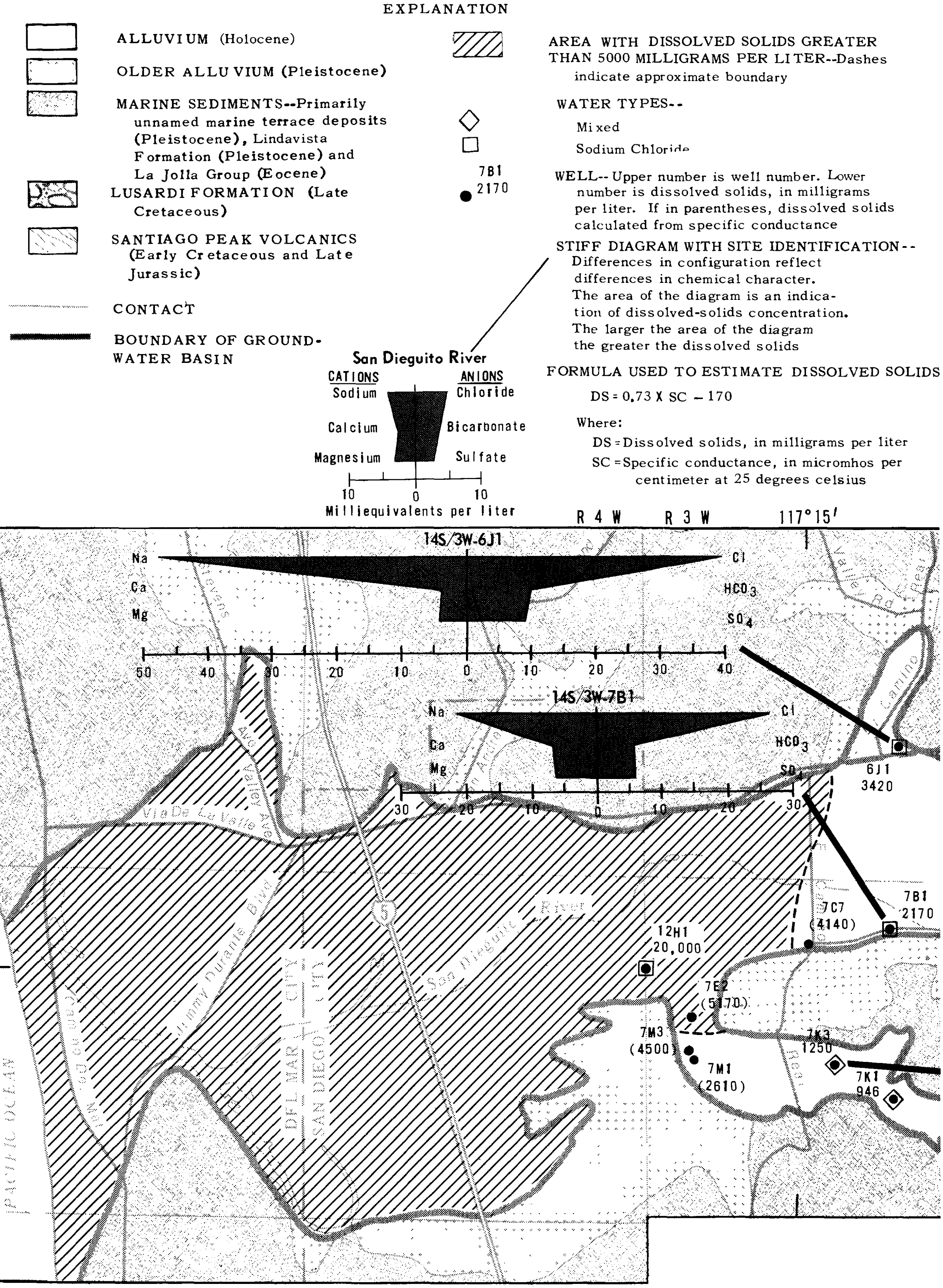
This relation was developed using linear regression on data collected by the U.S. Geological Survey between autumn 1981 and spring 1982. Eighteen samples with dissolved-solids concentrations ranging from 947 to 3,420 mg/L were used and an R^2 of 0.94 was obtained. (R^2 is a statistic which describes the "goodness of fit" of data about a line. It may range from 0 for a very poor fit to 1 for a very good fit.) This relation is basin specific and care should be used when extrapolating to other areas.

One shallow well in the upper part of the basin (14S/3W-5H3) yielded water with an estimated dissolved-solids concentration greater than 6,000 mg/L. This well flows in spring, and the high dissolved-solids concentration is probably the result of evaporative concentration of salts, and may not be representative of water at depth.

Water with the lowest dissolved-solids concentration is found in Gonzales Canyon where wells 14S/3W-7K1 and K3 yielded water with dissolved-solids concentrations of 947 and 1,250 mg/L, respectively.

Throughout the alluvial aquifer, chloride and sulfate frequently exceed EPA (U.S. Environmental Protection Agency, 1976) suggested limits of 250 mg/L for drinking water (appendix B). In general, water quality with respect to these constituents was best in Osuna Valley and deteriorated downgradient. Water from well 14S/3W-7K3 in Gonzales Canyon, although low in dissolved solids, exceeded EPA limits for sulfates. Iron exceeded the EPA suggested limit of 300 μg/L in several wells in Osuna Valley and in the upper part of the basin.

In spring 1982, mixed type ground water was found in Osuna Valley, and sodium chloride ground water was found near the Pacific Ocean. Because of sparse data it is impossible to locate the position of the sodium chloride wedge and determine if it has retracted since 1965. Comparison of 1965 water-quality data (fig. 13) with that of 1982 (fig. 15) shows a similarity between water in the upper part of the basin (hexagons) and surrounding marine sedimentary rock (shaded area). All water samples, with the exception of sodium chloride water from the lower basin, resemble ground water from marine sedimentary rock. This is possible only if marine sedidmentary rock contributed significant amounts of recharge to the alluvial aquifer between 1965 and 1978, before Hodges Dam spilled and recharge was available from that source.



Base from county map, San Diego, California

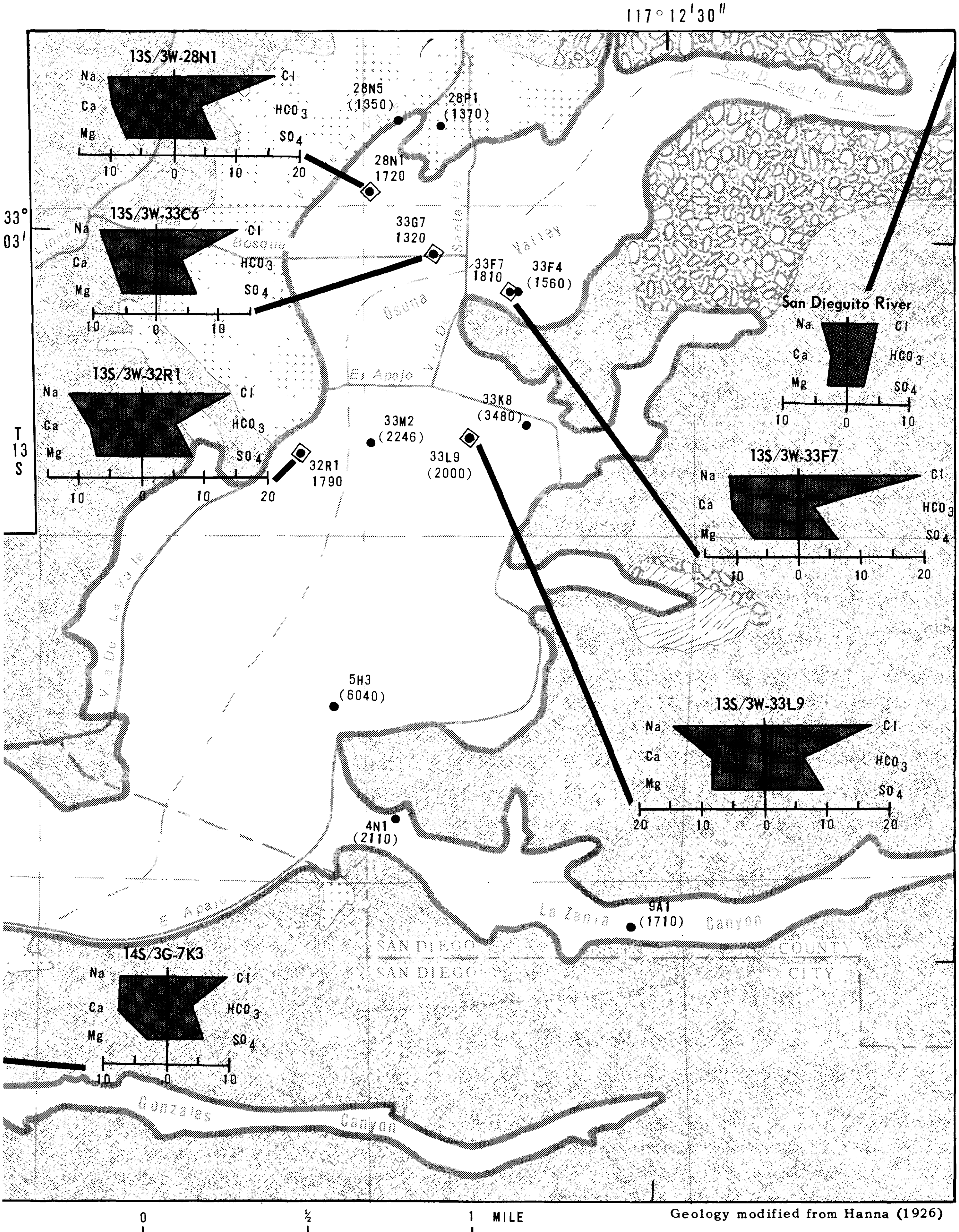


FIGURE 14.--Water quality in the San Dieguito alluvial aquifer, spring 1982.

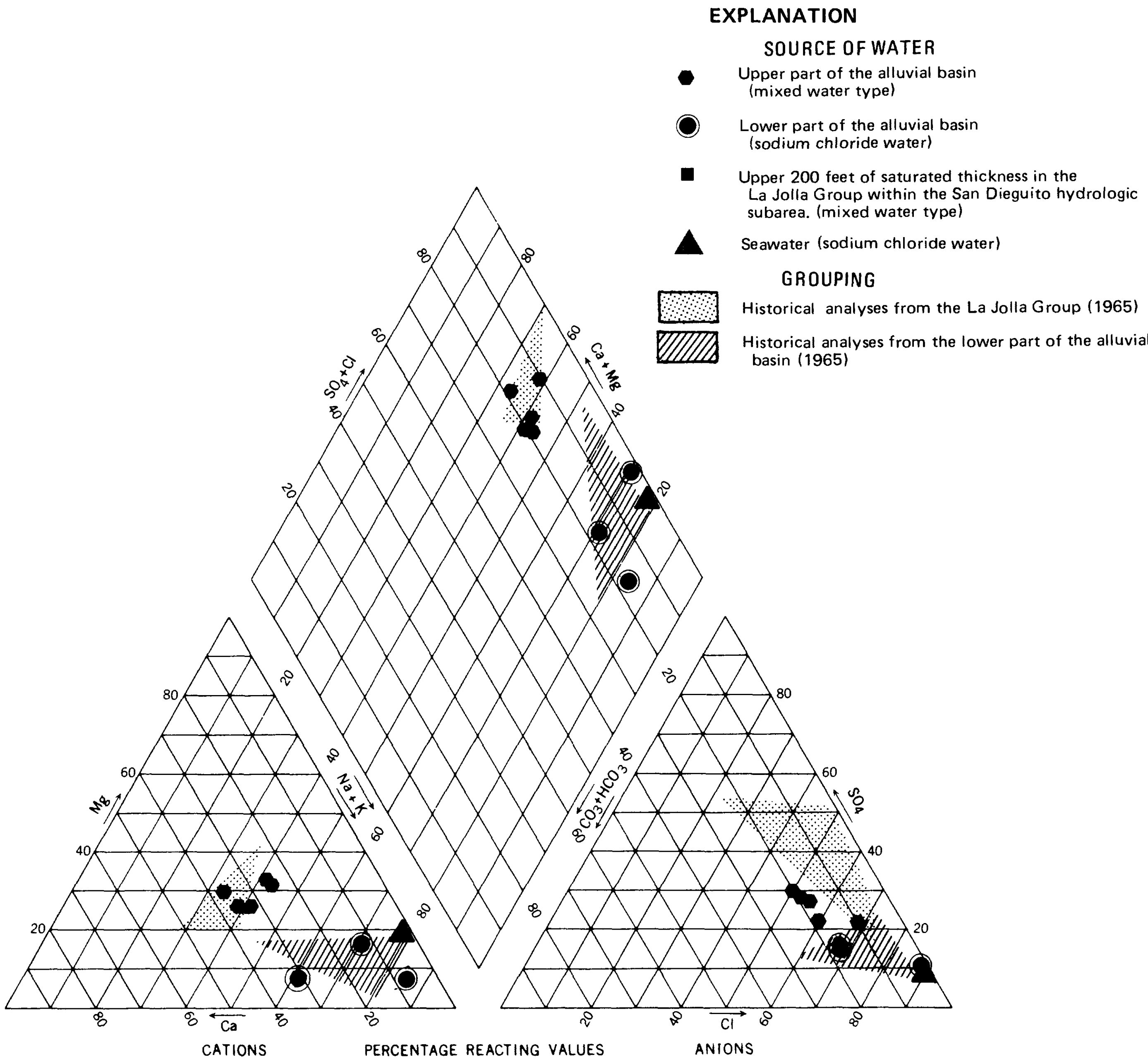


FIGURE 15. – Trilinear diagram showing water quality in the San Dieguito hydrologic subarea, 1982.

Impact of Reclaimed Water Use

The impact of reclaimed water use in the San Dieguito hydrologic subarea will depend greatly upon the reclaimed water management scheme ultimately used by the county of San Diego. To be properly evaluated, the impact of reclaimed water use should be compared to and contrasted with possible future trends in water quantity and water quality.

Most ground-water development in the San Dieguito hydrologic subarea has been restricted to the alluvial aquifer. Changes in ground-water quantity and quality outside this area are unlikely to occur in the near future. Currently, only small amounts of ground water are being used from the upper part of the basin and Osuna Valley. Ground water in the remainder of the alluvial aquifer is largely unused because of water-quality problems. Seawater intrusion, intrusion of saline water from surrounding marine sedimentary rock, and changes in natural recharge have produced ground water with concentrations of dissolved solids typically greater than 1,000 mg/L and commonly greater than 5,000 mg/L. If a reclaimed water use plan is not implemented, sporadic recharge from the San Dieguito River may not be sufficient to flush poor-quality water from the alluvial aquifer. As a consequence, the ground-water resource will not improve with time and will remain largely unused.

Reclaimed Water Quality

Reclaimed water designated for use would be secondary treated sewage effluent generated by expected development in the northwest San Diego area, and from existing wastewater treatment facilities within the hydrologic subarea. Reclaimed water would have an average dissolved-solids concentration ranging between 660 and 850 mg/L (California Department of Water Resources, 1983), and typically be a sodium chloride water resembling imported water rather than native ground water. Nitrate concentrations in reclaimed water would not exceed EPA limits of 10 mg/L as nitrogen, 45 mg/L as nitrate (Larry Michaels, San Diego County Water Authority, oral commun., 1982).

Reclaimed Water Use Plans

The use of reclaimed water in upland areas as an alternative to irrigation with imported water has been proposed by the California Department of Water Resources and the County of San Diego Department of Sanitation and Flood Control (Joseph Barry, County of San Diego Department of Sanitation and Flood Control, oral commun., 1982). Each site must be evaluated individually and application rates adjusted accordingly if waterlogging, surface ponding, and discharge of water through shallow circulation to surface seeps are to be avoided. Because existing water quality is poor, deep percolation of reclaimed water is not likely to have an adverse impact on ground-water quality in the La Jolla Group, which underlies most of the hydrologic subarea. However, depending upon the specific application site, reclaimed water applied on upland areas may enter the alluvial aquifer.

The use of reclaimed water as an alternative to irrigation with imported water has also been proposed for the alluvial valley floor. The most ambitious plan hopes to improve ground-water quality in the alluvial aquifer through the use of reclaimed water.

The alluvial aquifer has been divided into three management areas by the San Diego County Water Authority (fig. 16) (Larry Michaels, San Diego County Water Authority, written commun., 1982). The upper part of the basin and Osuna Valley would not receive reclaimed water but would be managed as a recharge area for high-quality water from the San Dieguito River. The middle part of the basin would be managed for reclamation and would receive large quantities (up to 3,500 acre-ft/yr) of reclaimed water for use. The lower basin would be managed as an export basin and ground water moving through the basin would be intercepted and exported for use outside the hydrologic subarea. The lower basin would also be used to control seawater intrusion. Parts of the aquifer west of Interstate 5 would not be employed for reclaimed water use.

The objective of the management plan is to obtain ground water with dissolved-solids concentrations less than 1,000 mg/L. In order to succeed, the plan must be able to deal successfully with seawater intrusion and movement of ground water from surrounding marine sedimentary rock while receiving only sporadic recharge from the San Dieguito River.

Currently, water levels in the alluvial aquifer are near land surface and little additional storage capacity is available for reclaimed water. If reclaimed water were applied during a wet cycle when groundwater levels are high, waterlogging of soils and surface runoff could occur. To combat this problem, the reclaimed water use plan proposes to lower water levels by pumping ground water currently stored in the aquifer. This water would then be exported for use outside the hydrologic subarea. Ground water currently in storage has dissolved-solids concentrations over 1,000 mg/L. Under current management plans, water would be replaced by reclaimed water with a dissolved-solids concentration between 660 and 845 mg/L. Therefore, transfer of water from the alluvial aquifer also represents a net transfer of dissolved solids. Salt-balance calculations by the San Diego County Water Authority (Larry Michaels, San Diego County Water Authority, written commun., 1982) indicate dissolved-solids concentrations may be reduced to below 1,000 mg/L; however, the degree of improvement depends on how the reclaimed water is used. Evaporation and transpiration losses will concentrate dissolved solids. In general, evapotranspiration will be less from percolation ponds than from irrigation applications. In any event, it is unlikely that concentrations would be reduced to levels found during the early 1950's, when areas of Osuna Valley yielded water with dissolved-solids concentrations less than 700 mg/L. Regardless of the dissolved-solids concentration eventually obtained, the final water produced would approach a sodium chloride type, strongly resembling reclaimed water and imported water from which it originated rather than native ground water.

Because storage in the alluvial aquifer is small (52,000 acre-ft) with respect to the maximum potential annual recharge, the aquifer could fill in one rainy season, and despite intensive management efforts, there may not always be sufficient storage available to accept reclaimed water.

During dry periods (such as 1965) there would be ample available storage in the aquifer (fig. 10). However, at these times, possible water-quality problems associated with seawater intrusion and intrusion of poor-quality water from surrounding marine sedimentary rock (up to 600 acre-ft/yr) would be most severe. Historical evidence (fig. 6) shows natural recharge may not be available from the San Dieguito River during extended dry periods.

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Lindavista Formation (Pleistocene) and La Jolla Group (Eocene)

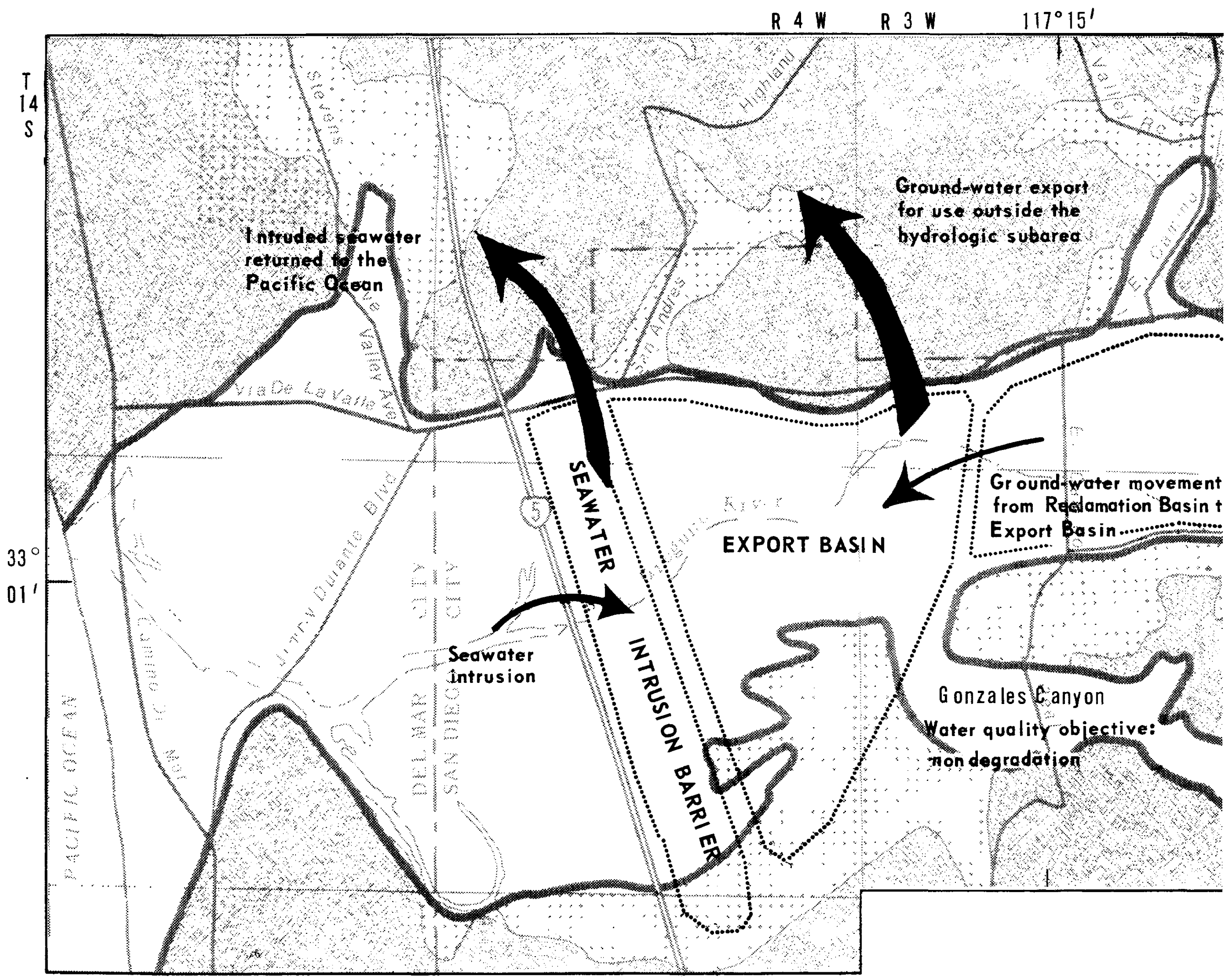
LUSARDI FORMATION (Late Cretaceous)

SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

CONTACT

BOUNDARY OF GROUND-WATER BASIN

PROPOSED MANAGEMENT BOUNDARIES--San Diego County Water Authority



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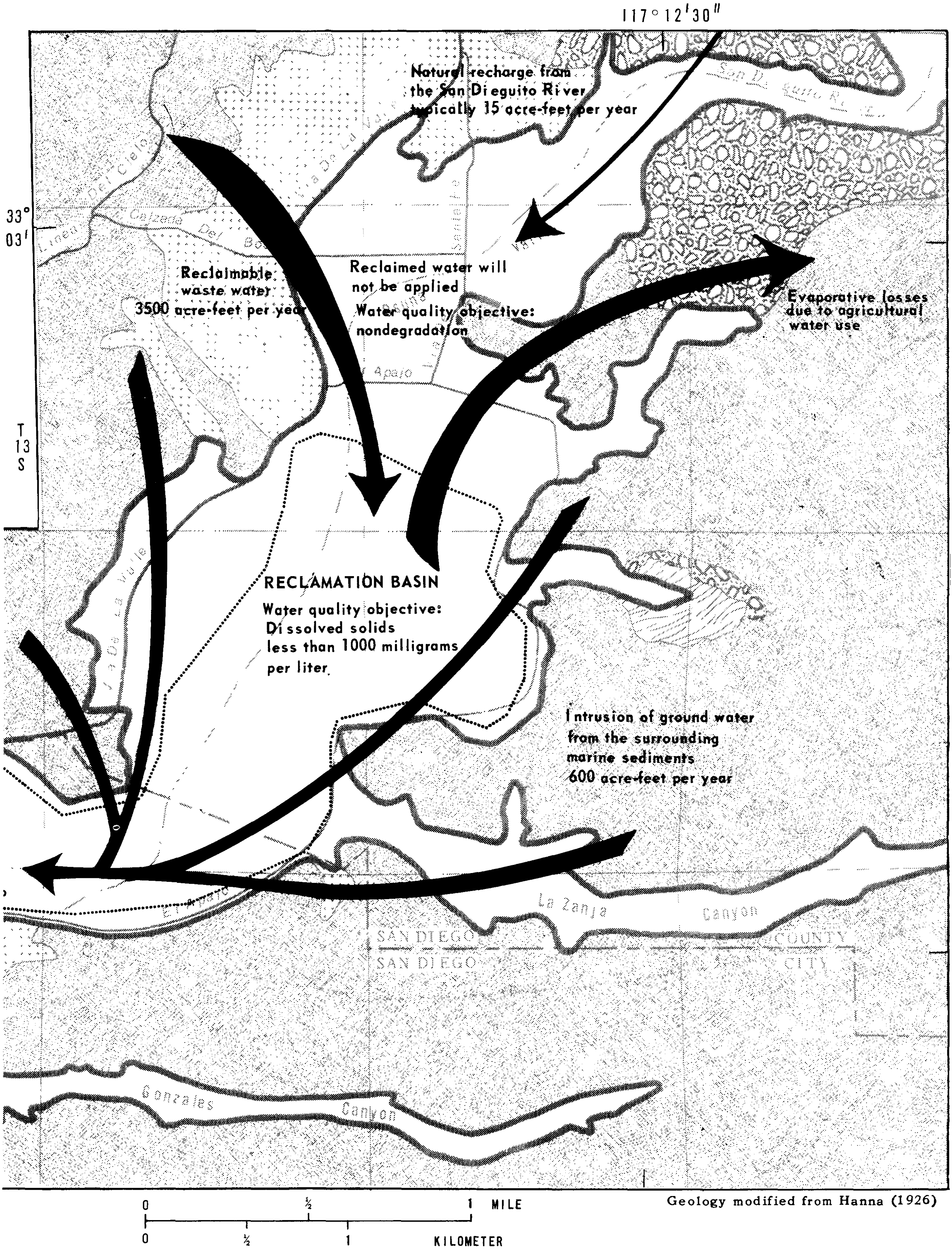

FIGURE 16.--A possible reclaimed water management plan for the San Dieguito alluvial aquifer.

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SAN ELIJO HYDROLOGIC SUBAREA

Geology

Like the San Dieguito subarea, the San Elijo hydrologic subarea has two distinct physiographic zones: Peninsular Range Province and Pacific Coastal Plain (fig. 17). Geologic formations within each physiographic zone are discussed in the "Geology" section of the San Dieguito hydrologic subarea. The primary differences between the two subareas are the relative exposure of each formation, and the greater percentage of quartz diorite in the Santiago Peak Volcanics of the San Elijo subarea.

In the San Elijo subarea, the Pacific Coastal Plain is incised by the alluvium-filled San Elijo Valley. Alluvial fill trends northeasterly from the Pacific Ocean to the Peninsular Range Province and averages less than 0.5 mile in width. A smaller alluvial valley, La Orilla Canyon, branches off from the main valley and runs in an easterly direction. In many areas the valley fill is bounded by terraced remnants of an older alluvial valley.

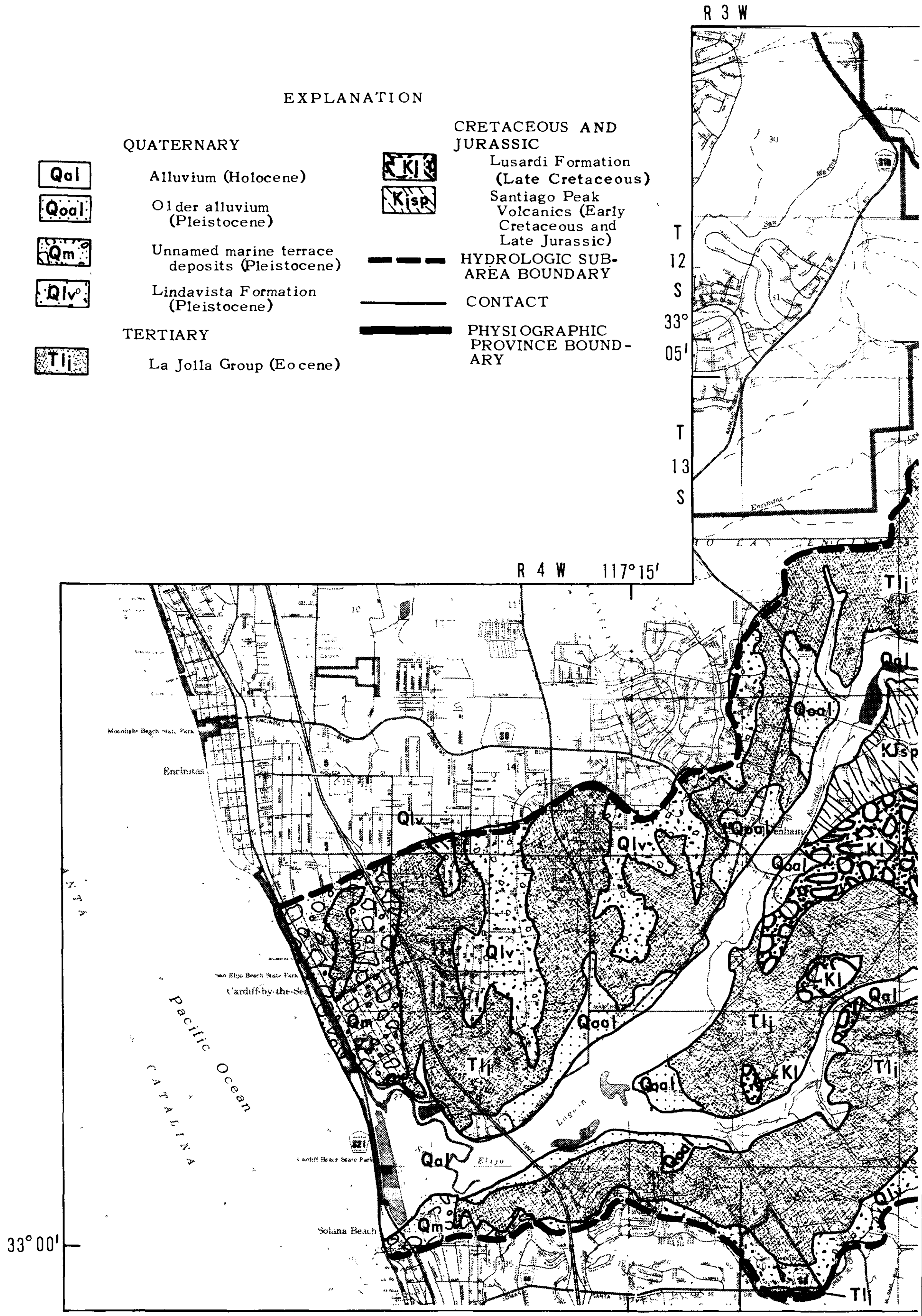
Soils

Soils are similar in the uplands of the San Elijo and San Dieguito subareas (fig. 18), and have been discussed in the "Soils" section of the San Dieguito subarea. Thick, saline soils of the Salinas-Corralitos association have developed over alluvial fill in the San Elijo Valley. Infiltration rates range from 0.6 to 2.0 in/h for Chino soils, which comprise the bulk of the valley floor, and are greater than 20 in/h for Tujunga soils at the head of the San Elijo Valley. The primary limitations for application of reclaimed water to these soils are a high water table, at land surface much of the year, and the effect saline soils might have on the quality of infiltrating water.

Surface Water

Streamflow Characteristics

Surface drainage in the San Elijo hydrologic subarea is through Escondido Creek. Escondido Creek drains 80 mi^2 of largely agricultural and urban watershed. Flow is regulated at Lake Wohlford above the city of Escondido (fig. 19). In recent years Escondido Creek has become a perennial stream with summertime flow being primarily irrigation return, and prior to 1973, wastewater discharge from the Hale Avenue Wastewater Treatment Plant in Escondido. Median annual discharge in Escondido Creek, as measured at Olivenhain, is 3,550 acre-ft (table 5). Maximum annual discharge was 22,300 acre-ft during water year 1978. Most of this water leaves the San Elijo hydrologic subarea and enters the Pacific Ocean.



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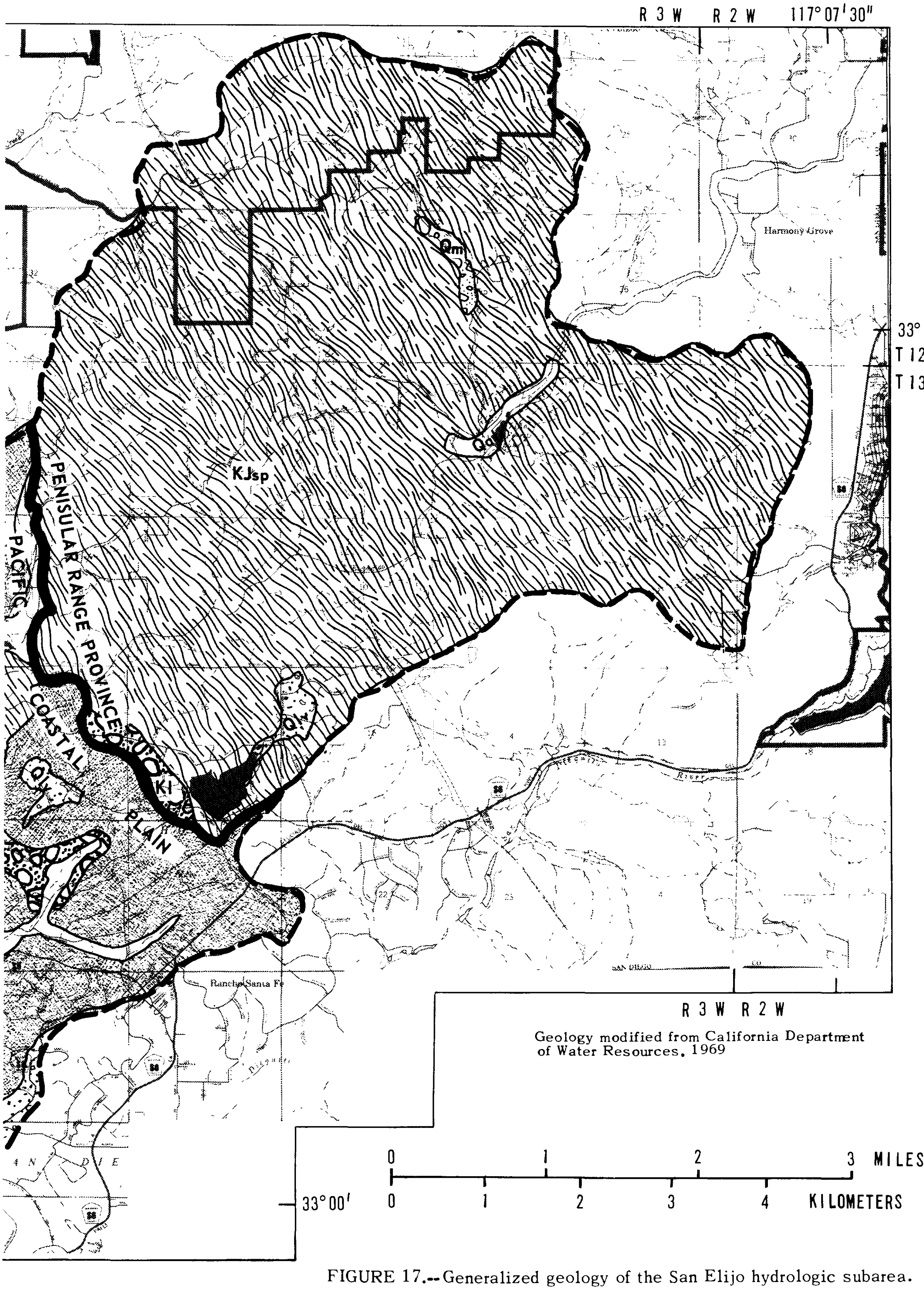
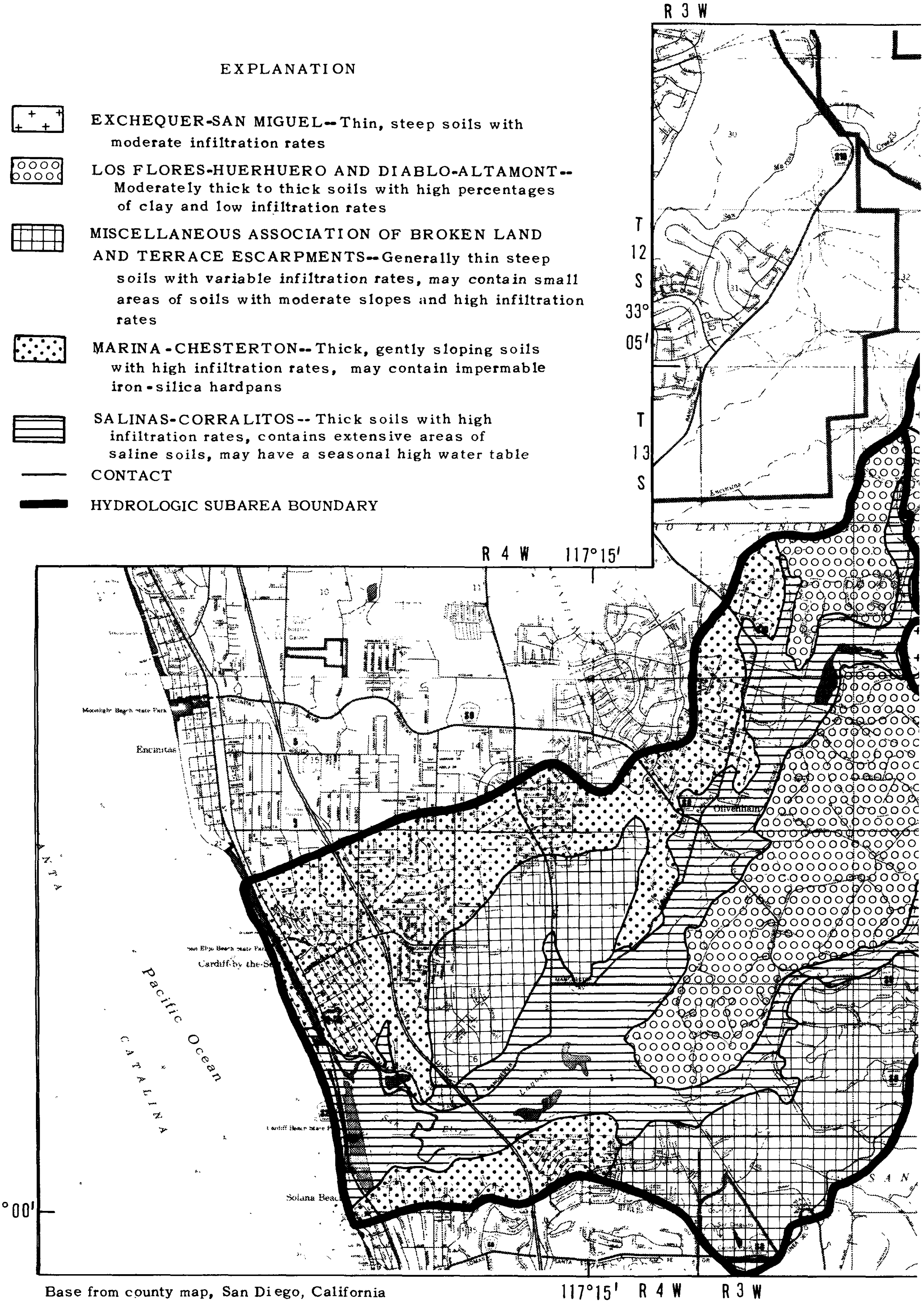


Geology modified from California Department of Water Resources, 1969

FIGURE 17.--Generalized geology of the San Elijo hydrologic subarea.



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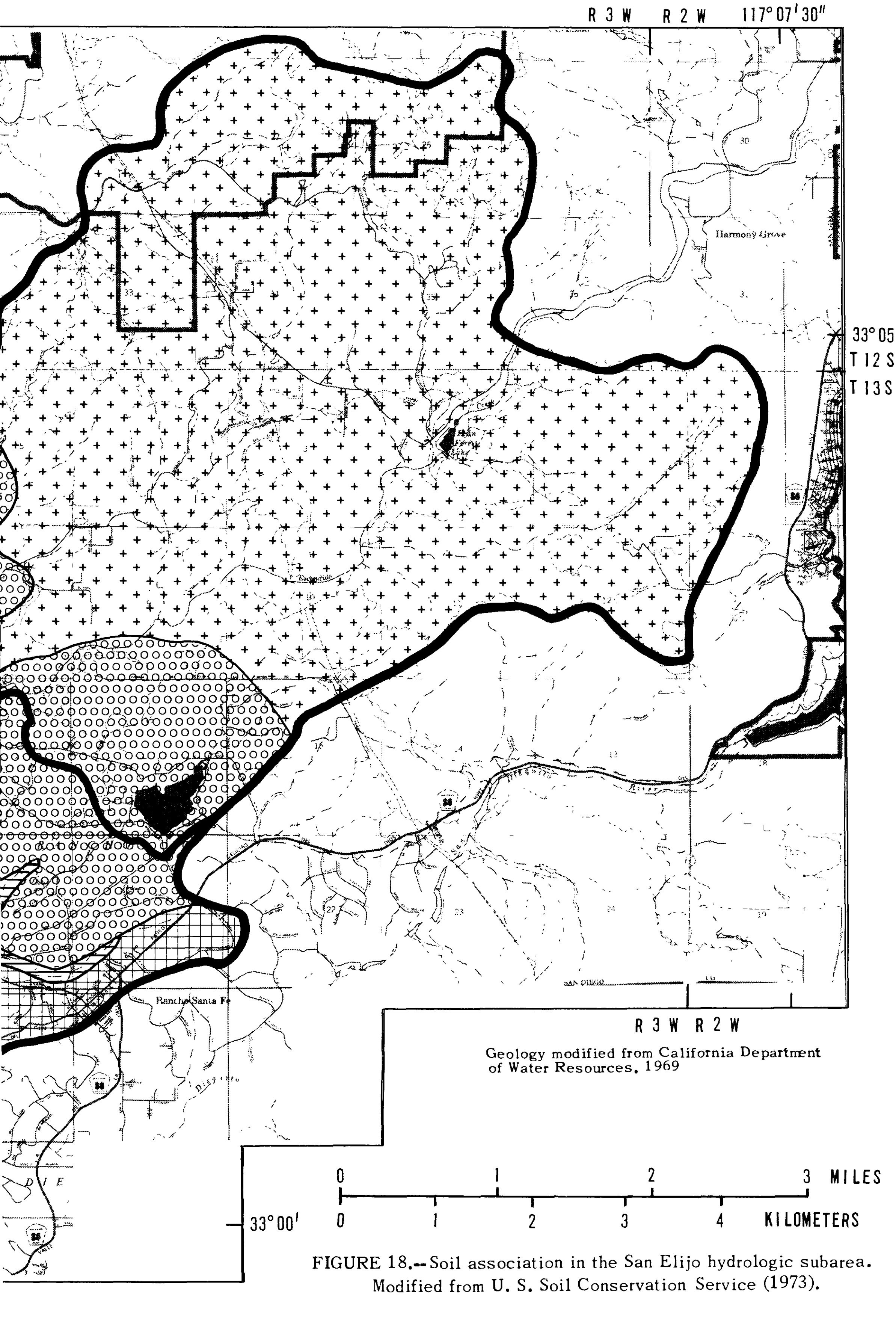


FIGURE 18.--Soil association in the San Elijo hydrologic subarea. Modified from U. S. Soil Conservation Service (1973).

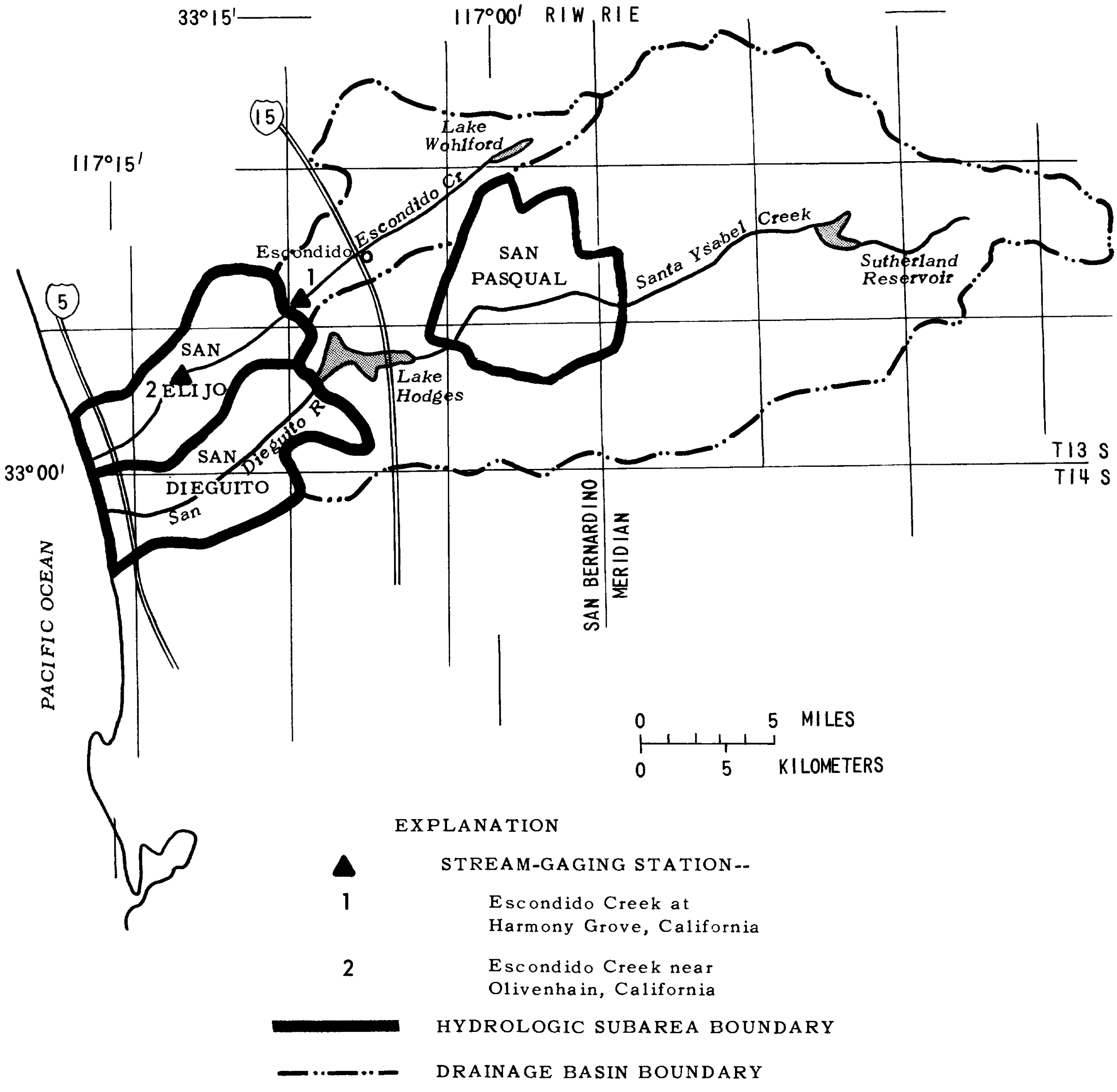


FIGURE 19.-- Location of stream-gaging stations in the San Elijo hydrologic subarea.

TABLE 5.--Summary of flow data for the San Elijo hydrologic subarea

[Data from San Diego County]

Station name	Latitude longitude	Period of record	Drainage area (mi^2)	Annual discharge (acre-ft) average	Annual discharge (acre-ft) median	Maximum discharge for period of record: instantaneous (ft^3/s)	Maximum discharge for period of record: annual (acre-ft)
Escondido Creek at Harmony Grove	33°06'36" 117°06'40"	10-1969 to 09-1977	46	6,430	4,640	1,585	12,400
Escondido Creek near Olivenhain	33°03'02" 117°12'51"	10-1971 to 09-1973 10-1974 to 09-1978	65	6,970	3,550	4,280	22,300

Surface-Water Quality

Historical water-quality data for Escondido Creek, collected at the gaging station at Harmony Grove, date from 1950 to 1982. Until 1973, water in Escondido Creek was impacted by discharges from the Hale Avenue Wastewater Treatment Plant. After 1973, an ocean outfall was constructed and wastewater from Escondido was no longer discharged to Escondido Creek. The stream continued to flow year round with irrigation return water from the Escondido and Harmony Grove areas.

Water-quality data reflect removal of sewage effluent and increased importance of irrigation return water. After 1973, minimum concentrations of dissolved solids, chloride, and sulfate increased (table 6). Dissolved solids in baseflow have remained above 1,000 mg/L and range from 1,020 to 1,380 mg/L. Stormflow in Escondido Creek typically had dissolved-solids concentrations much less than baseflow, sometimes as low as 200 mg/L.

Throughout the period of record, water in Escondido Creek has generally been a mixed type, dominated by sodium and chloride. In 1981-82, two samples were collected from Escondido Creek, one in autumn to reflect baseflow, and another during the recessional flow of a late spring storm. Both analyses revealed water of a mixed type dominated by sodium chloride. Dissolved-solids concentrations were 1,330 and 1,040 mg/L, respectively. In general, the analyses were similar to past water-quality analyses and are summarized in appendix A.

Ground Water

Little information is available on ground water in the San Elijo hydrologic subarea. Where geologic conditions are similar, data from the San Elijo and San Dieguito subareas have been combined and discussed in the "Ground Water" section of the San Dieguito hydrologic subarea.

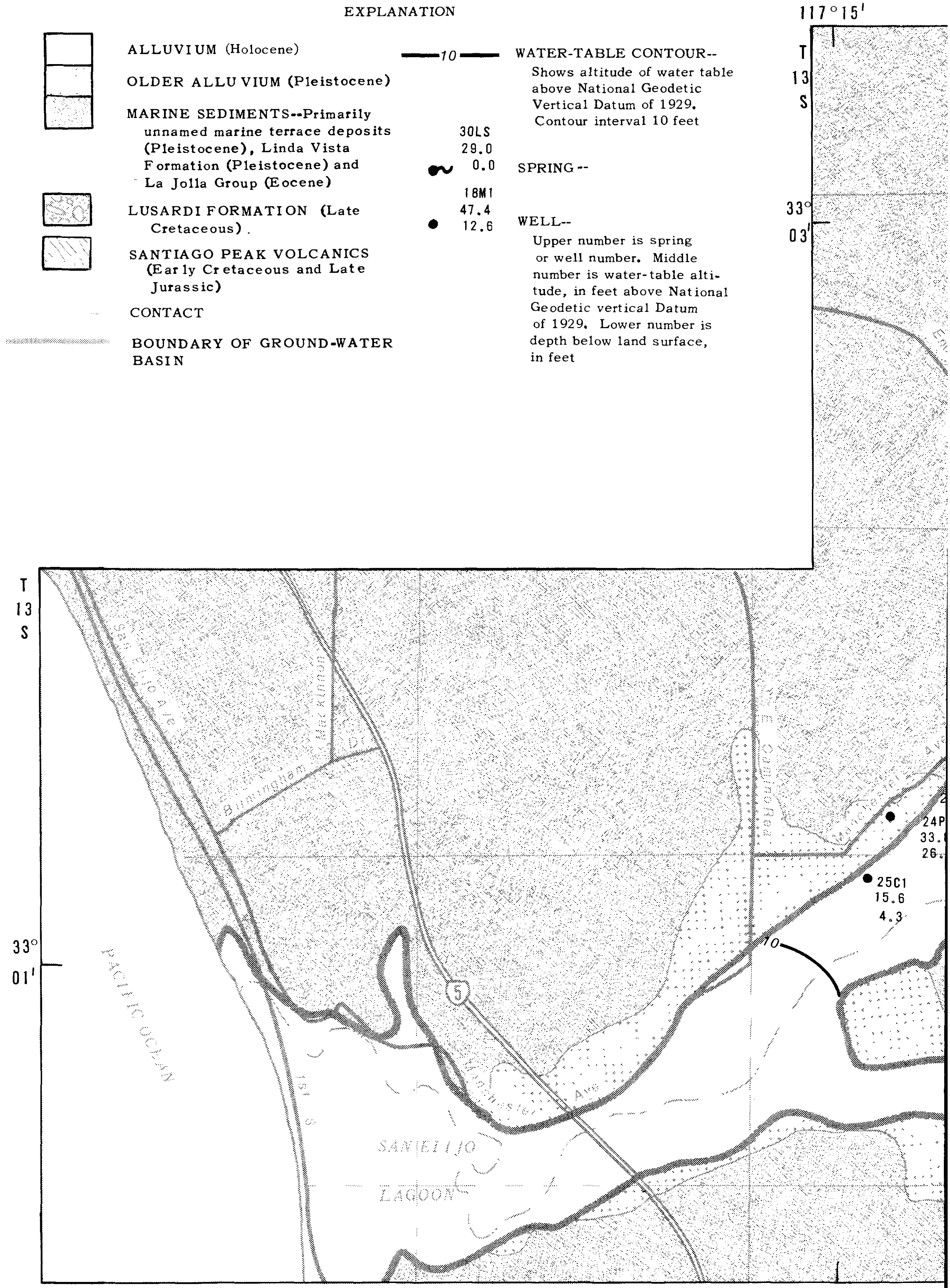
Alluvial Aquifer

Alluvial fill of Holocene age stretches 6 miles from the mouth of Escondido Creek to the edge of the Peninsular Range Province (fig. 20). Including La Orilla Canyon, the aquifer covers 1,620 acres and is generally less than 0.5 mile wide. Alluvial thickness exceeds 70 feet and probably approaches 100 feet beneath San Elijo Lagoon, but in most of the aquifer, fill is less than 50 feet thick. The alluvial aquifer, including La Orilla Canyon, contains less than 66,000 acre-ft of fill. If an average specific yield of 0.13 (based on drillers' logs from the San Dieguito subarea) is applied, ground-water storage is estimated as less than 8,500 acre-ft. The alluvium is a water-table aquifer and ground water is not confined.

TABLE 6.--Summary of water-quality data for baseflow in Escondido Creek at Harmony Grove, 1950-81

[<, less than; --, no data]

	1950-72				1974-81			
	Number of observations	Minimum	Median	Maximum	Number of observations	Minimum	Median	Maximum
Instantaneous discharge----------ft^3/s--	127	<0.1	1.5	8.0	25	2.0	4.0	7.0
Specific conductance-- µmho/cm at 25°C-----------	126	970	1,980	3,010	25	1,500	1,930	2,180
pH-------------------------	114	6.0	7.4	9.0	25	8.0	8.1	9.0
Dissolved solids-------mg/L--	58	835	1,260	1,500	24	1,020	1,240	1,380
Sodium----------------mg/L--	73	150	260	330	1	--	220	--
Calcium---------------mg/L--	56	50	83	110	1	--	84	--
Magnesium-------------mg/L--	56	32	44	61	1	--	61	--
Chloride--------------mg/L--	125	130	320	460	24	260	330	450
Sulfate---------------mg/L--	61	180	290	360	24	200	270	300
Alkalinity as $CaCO_3$----mg/L--	114	84	214	290	0	--	--	--



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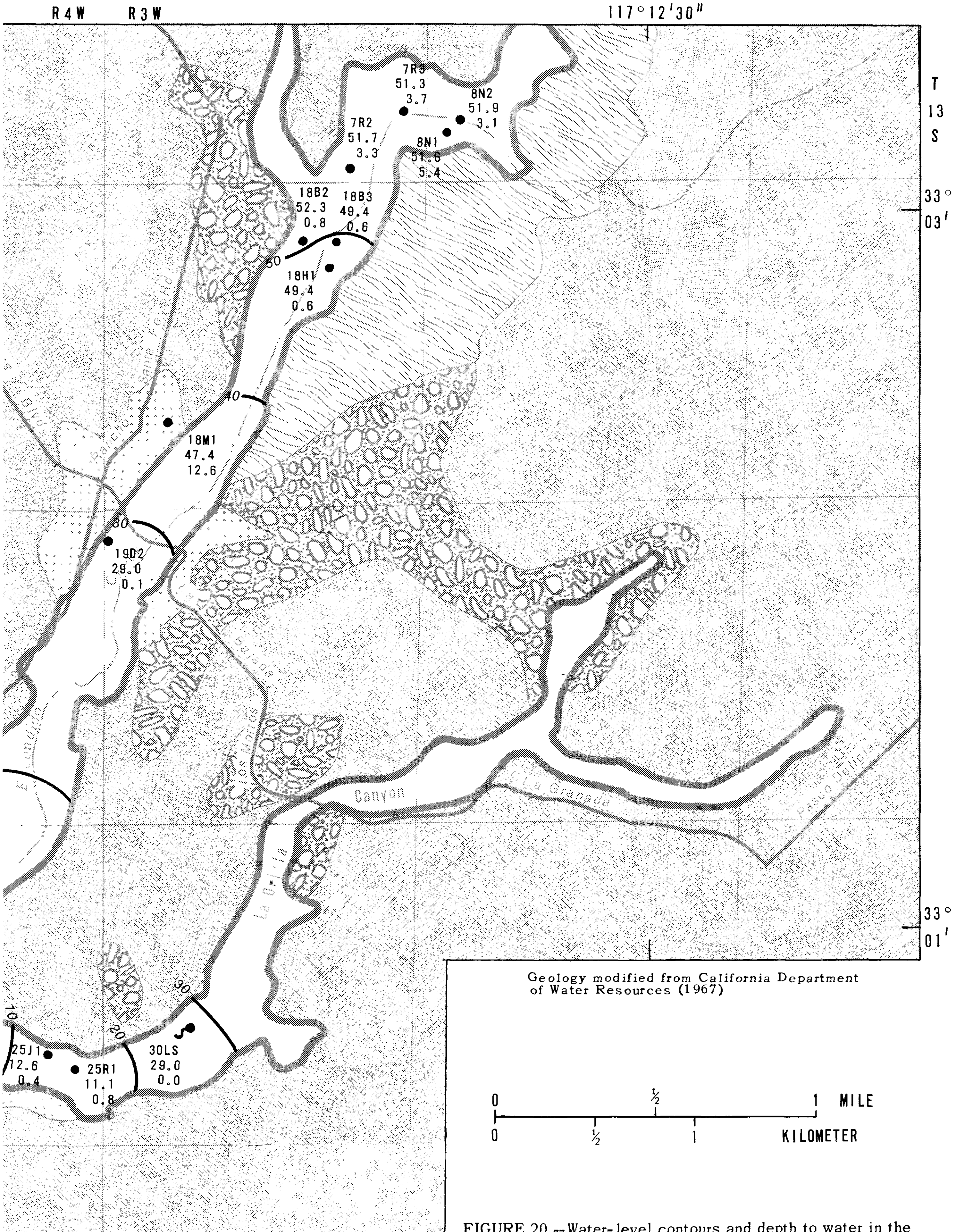


FIGURE 20.--Water-level contours and depth to water in the San Elijo alluvial aquifer, spring 1982.

Many wells in the alluvium are shallow and date from before the turn of the century; consequently, no well yield or specific-capacity data are available. However, by observation and correlation with the San Dieguito subarea, sand and gravel at the head of the basin have better water-yielding characteristics than lagoonal sediment near the ocean.

Recharge.--Recharge to the San Elijo alluvial aquifer is primarily from Escondido Creek. Smaller amounts of recharge occur as runoff originating within the hydrologic subarea (particularly from La Orilla Canyon), water imported into the hydrologic subarea, leakage from surrounding marine sedimentary rock, and direct precipitation.

Imported water use in the San Elijo subarea has increased in recent years in response to increasing residential land uses. In 1970, 5,700 acre-ft of water was imported to the subarea. In 1980, 8,600 acre-ft of water was imported (California Department of Water Resources, 1983). Based on available information, it is impossible to estimate how much of this imported water became deep percolation and recharged the alluvial basin.

La Orilla Canyon contributes a small amount of recharge from irrigation return to the alluvial basin. Springs in section 13S/3W-30L flow year round. Flow from these springs disappears as it leaves La Orilla Canyon and enters the main valley.

Occurrence and movement.--Spring 1982 water-level contours are shown in figure 20. Contours reflect movement of ground water from the major source of recharge at the inflow of Escondido Creek downgradient to San Elijo Lagoon and the Pacific Ocean. In spring 1982, water levels in the alluvial fill were at or near land surface. Average depth to water was less than 2 feet and standing water was observed throughout the valley. Ground-water levels in the upper part of La Orilla Canyon are unknown.

Using aquifer characteristics similar to those in the San Dieguito subarea and Darcy's Law, outflow from the alluvium has been estimated using the following equation:

$$Q=KA\Delta h/\Delta x,$$

where

- Q is ground-water flow, in gallons per day;
- K is average hydraulic conductivity, in this case approximately 320 (gal/d)/ft;
- A is average cross-sectional area of the aquifer over a given reach, in this case 25,000 ft^2; and
- $\Delta h/\Delta x$ is hydraulic gradient over the same reach, in this case 30 ft/10,800 ft.

Average ground-water discharge from the main stem of the alluvial aquifer was 22,000 gal/d, or approximately 25 acre-ft/yr.

Ground-Water Quality

Few ground-water analyses are available for the San Elijo hydrologic subarea. Where geohydrology is similar, the San Elijo and San Dieguito subareas have been combined and discussed in the "Ground-Water Quality" section of the San Dieguito hydrologic subarea.

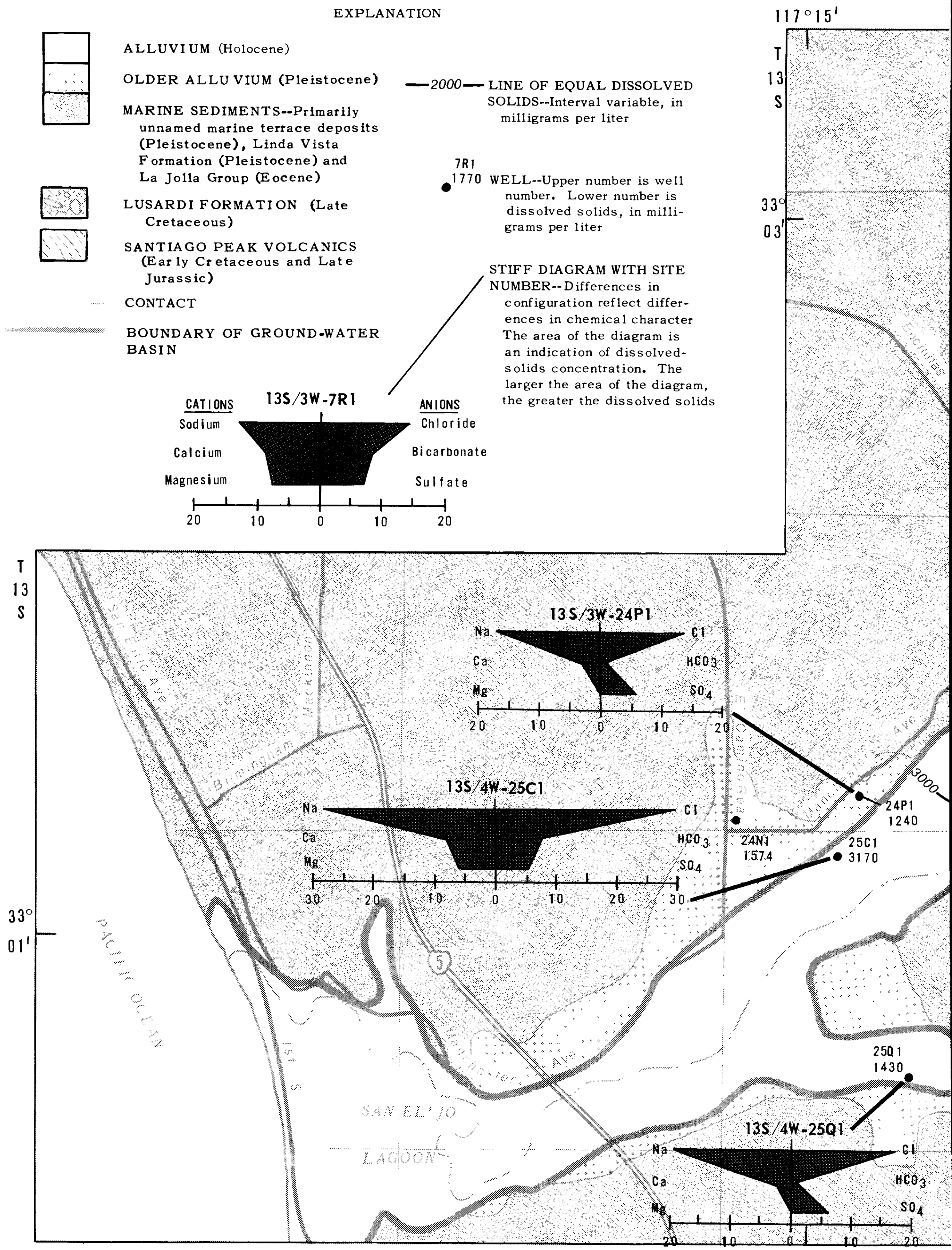
Alluvial Aquifer

Historical water quality.--No ground-water analyses from the alluvial aquifer are available prior to the mid 1950's. After the mid 1950's, no wells sampled in the San Elijo alluvium yielded water with dissolved-solids concentrations less than 1,000 mg/L.

In autumn 1962, dissolved-solids concentrations in wells ranged from 1,770 mg/L in the upper part of the basin to 3,170 mg/L in the lower basin (fig. 21). Well 13S/4W-25Q1 yielded water with a dissolved-solids concentration of 1,430 mg/L; however, drillers' logs show that the well penetrates the alluvial fill and is completed in the La Jolla Group. Shallow wells penetrating just below the water table yielded water with lower dissolved-solids concentrations than deeper wells nearby. For example, well 13S/3W-19D2, less than 10 feet deep, yielded water with a dissolved-solids concentration of 1,840 mg/L, while less than 50 feet away well 13S/3W-19D1, penetrating the entire alluvial thickness, yielded water with a dissolved-solids concentration of 2,500 mg/L. Consequently, because many of the wells in the alluvial fill are shallow, they do not accurately reflect quality of water in the alluvial aquifer.

In 1962, water was a mixed quality type at the head of the San Elijo basin and a sodium chloride type in the lower part of the basin. Two analyses, one from well 13S/4W-24P1 and the other from well 13S/4W-25Q1, are markedly different in chemical character than other analyses. Although both wells yielded sodium chloride water, they were lower in magnesium and bicarbonate. Both are deep wells which penetrate the alluvium and draw water from the marine sandstone of the La Jolla Group, most likely the Del Mar Formation. Water from these wells is lower in dissolved solids than water from surrounding alluvial fill.

Present water quality.--In spring 1982, dissolved-solids concentrations of water in the alluvial aquifer ranged from 1,170 to 5,090 mg/L (fig. 22). The basin objective is 750 mg/L. Dissolved-solids concentrations are lowest in the upper part of the basin near the inflow of Escondido Creek and increase downgradient toward San Elijo Lagoon and the Pacific Ocean. Well 13S/4W-24P1 also yielded water relatively low in dissolved solids (estimated 1,150 mg/L), but this reflects water quality from underlying marine sedimentary rock rather than alluvial deposits. Many wells sampled in 1981-82 are shallow and probably do not accurately reflect water quality throughout the alluvial aquifer.



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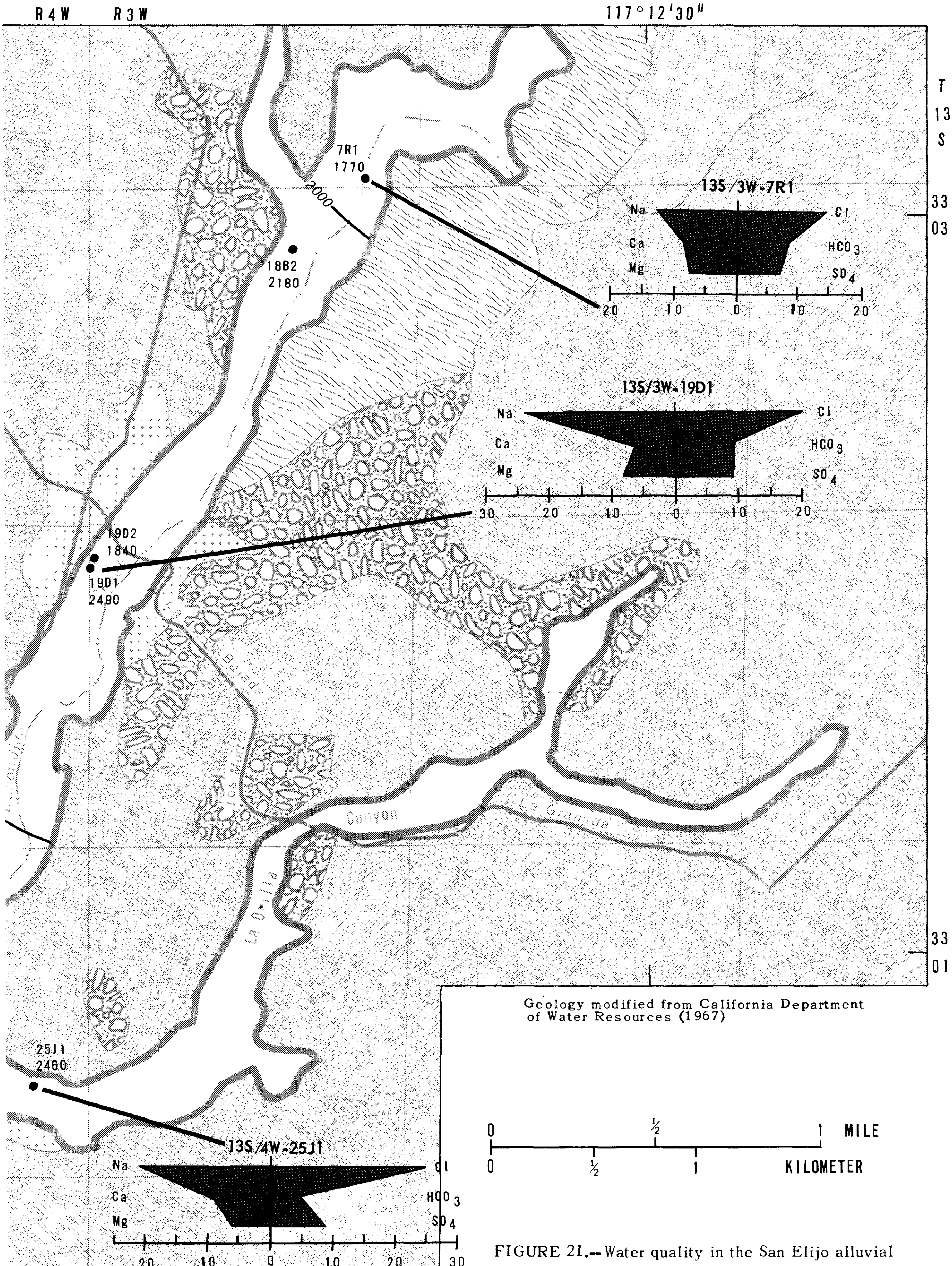
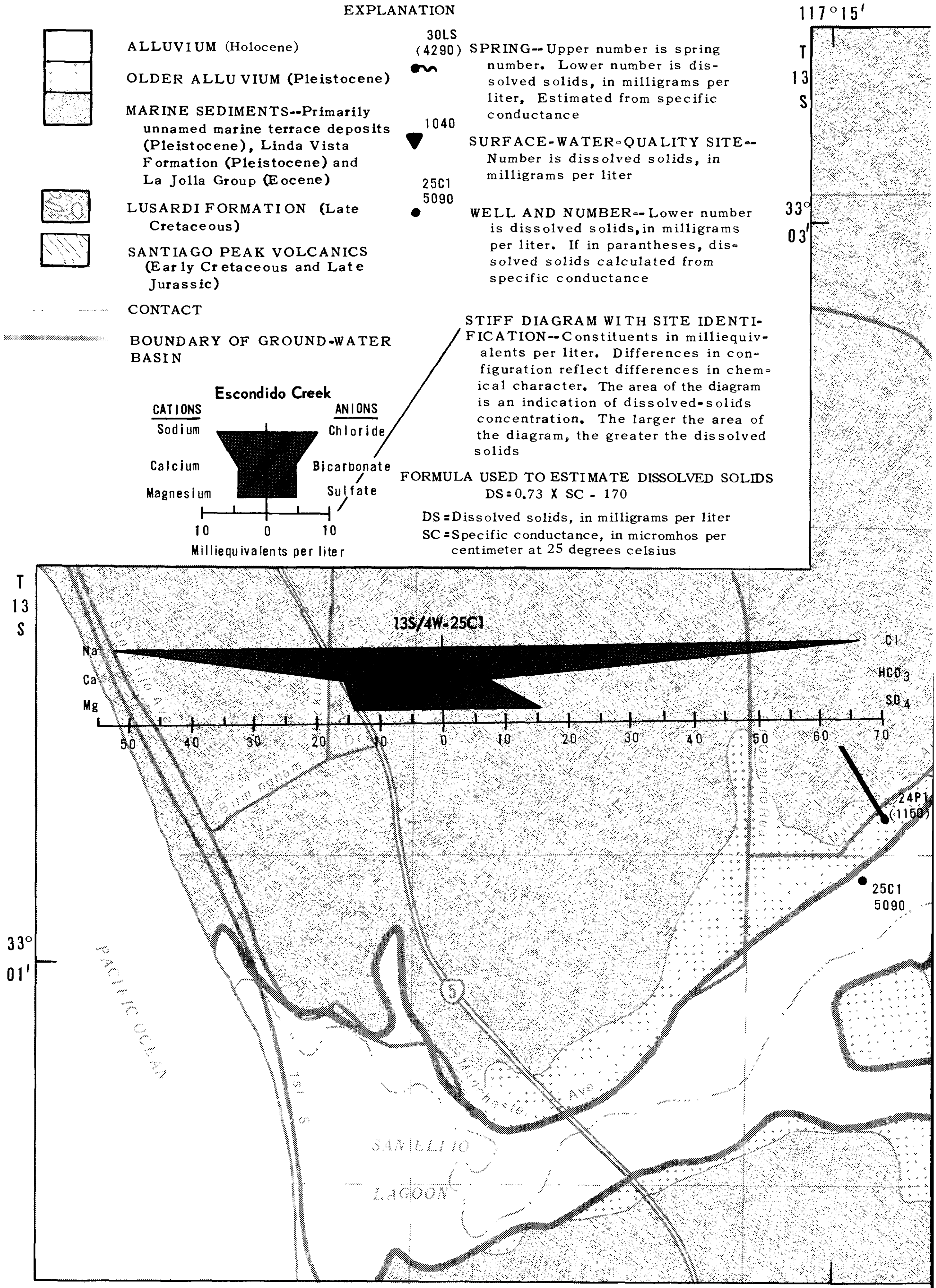


Geology modified from California Department of Water Resources (1967)

FIGURE 21.--Water quality in the San Elijo alluvial aquifer, spring 1962.



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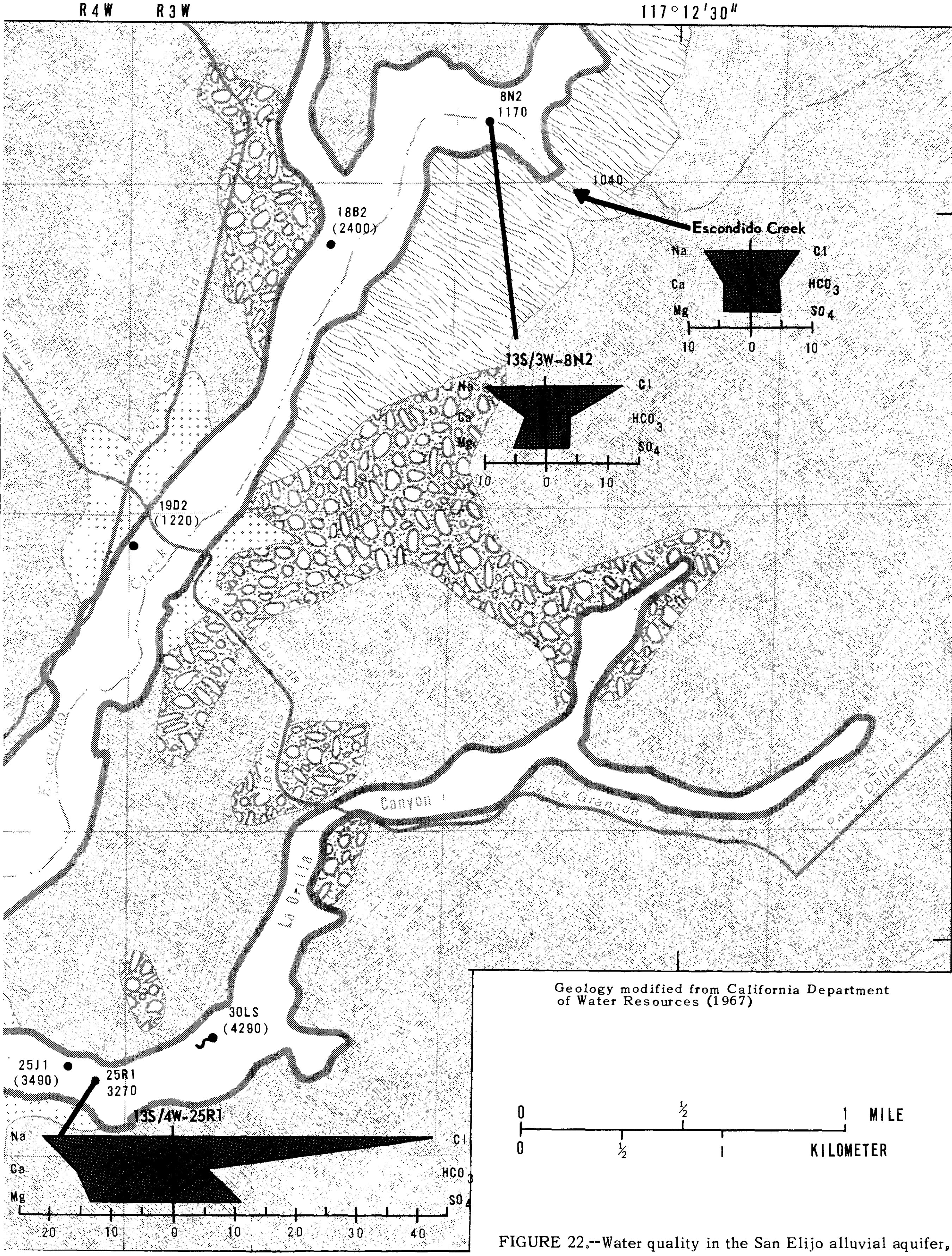


FIGURE 22.--Water quality in the San Elijo alluvial aquifer, spring 1982.

The regression relation developed for the San Dieguito alluvial aquifer was used to estimate dissolved-solids concentrations from field measurements of specific conductance. This relation was used in the San Elijo subarea because of similar hydrology and water quality.

Chloride exceeded the EPA suggested limit of 250 mg/L for drinking water in all wells sampled. Sulfate exceeded the EPA suggested limit of 250 mg/L for drinking water in wells in the lower part of the basin. Nitrate did not exceed 10 mg/L as N in any of the wells sampled.

Impact of Reclaimed Water Use

The impact of reclaimed water use in the San Elijo hydrologic subarea will depend greatly upon the reclaimed-water management scheme ultimately used by the county of San Diego. To be properly evaluated, the impact of reclaimed water use should be compared to and contrasted with possible future trends in water quantity and quality.

Water-quality problems associated with dissolved solids greater than 1,000 mg/L, and chloride and sulfate greater than 250 mg/L, have severely limited ground-water development in the San Elijo hydrologic subarea. Currently, in addition to water-quality problems, ground-water levels are near or at land surface throughout much of the alluvial fill, and swampy conditions prevail much of the year (fig. 20). In the absence of extensive ground-water development, current hydrologic conditions will persist for some time into the future.

Reclaimed Water Quality

Reclaimed water would be secondary treated sewage effluent from existing wastewater treatment plants within the hydrologic subarea. Reclaimed water would have an average dissolved-solids concentration from 650 to 1,000 mg/L, and would be a sodium chloride water type, chemically resembling imported water rather than native ground water (California Department of Water Resources, 1983). Nitrate concentrations in reclaimed water would not exceed EPA limits of 10 mg/L as nitrogen, 45 mg/L as nitrate (Larry Michaels, San Diego County Water Authority, oral commun, 1982).

Reclaimed Water Use Plans

Use of reclaimed water in upland areas as an alternative to irrigation with imported water has been proposed by the California Department of Water Resources and the County of San Diego Department of Sanitation and Flood Control (Joseph Barry, County of San Diego Department of Sanitation and Flood Control, oral commun., 1982). Many upland soils in the San Elijo hydrologic subarea have high infiltration rates and could accept, transmit, and rejuvenate reclaimed water without waterlogging, surface ponding, and discharge of water through shallow circulation to surface seeps. Because existing water quality is poor, deep percolation of reclaimed water is not likely to have an adverse impact on ground-water quality in the La Jolla Group, which underlies most of the subarea. Reclaimed water applied in the upper areas of La Orilla Canyon would surface in section 13S/3W-30L (fig. 20). Water quality at that point could be monitored to assure reclaimed water is properly renovated before coming to the surface.

Currently there is no available storage in the alluvial aquifer, and application of reclaimed water would result in waterlogging and surface runoff of reclaimed water. Because of limited ground-water storage (8,500 acre-ft), extensive management of the alluvial basin through pumping and exportation of ground water (in a manner similar to plans proposed for the San Dieguito and San Pasqual hydrologic subareas) probably would not be economically feasible.

(page 73 follows)

SAN PASQUAL HYDROLOGIC SUBAREA

Geology

The San Pasqual hydrologic subarea lies entirely within the Peninsular Range Province. Crystalline rocks of the southern California batholith are exposed in or underlie the entire subarea (fig. 23).

The most extensive rocks are granodiorites which cover slightly over 50 percent of the subarea. These rocks are resistant to weathering and form prominent hills and ridgetops.

Green Valley Tonalite is exposed in approximately 30 percent of the subarea. Green Valley Tonalite is not resistant to erosion and forms deeply weathered lowlands and hilly topography, especially in the vicinity of faults. Green Valley Tonalite may weather to several hundred feet in depth, forming a material known locally as residuum, or decomposed granite (DG). These deeply weathered exposures occupy 1,550 acres, or slightly over 8 percent of the subarea.

Small exposures of gabbro and diorite and metamorphic rock occur as scattered remnants or roof pendants within the more extensive crystalline rocks of the subarea. In some instances these rocks, particularly the gabbro, are deeply weathered and resemble weathered outcrops of Green Valley Tonalite.

Quaternary alluvium stretches across the southern half of the San Pasqual hydrologic subarea. Three smaller alluvium-filled valleys join the main valley from the northwest, northeast, and south. In total, alluvium covers almost 15 percent of the subarea.

Soils

There are three major soil associations within the San Pasqual hydrologic subarea. Fallbrook-Vista and Cienba-Fallbrook soils are found in upland areas. Visalia-Tujunga soils are found in the valley floor (fig. 24).

Soils of the Fallbrook-Vista association have developed along the western edge of the subarea and near San Diego Wild Animal Park. This association is characterized by Fallbrook and Vista soils, between 1.5 to 4 feet thick, and shallow Cienba soils, generally less than 1.5 feet thick. Deep soils are atypical of this association and only small areas of Ramona soils, developed over weathered tonalite, attain thicknesses greater than 5 feet. Infiltration capacities are high to moderate throughout most of the Fallbrook-Vista association, ranging from 0.6 to 2.0 in/h for Fallbrook soils, to 20 in/h for Cienba soils. Ramona soils are characterized by a clay hardpan at a depth of 1.5 feet; consequently, infiltration rates for Ramona soils are poor and range between 0.2 to 0.6 in/h.

EXPLANATION

QUATERNARY

Qal — Alluvium (Holocene)

CRETACEOUS

Kgr — Undifferentiated granodiorites and Leucogranodiorites

Kt — Green Valley tonalite

Ktw — Green Valley tonalite, deeply weathered

JURASSIC

Jg — Undifferentiated gabbros and diorites

Jm — Hybrid and undifferentiated metamorphic rocks

HYDROLOGIC SUBAREA BOUNDARY

CONTACT

0 1 2 MILES

0 1 2 3 KILOMETERS

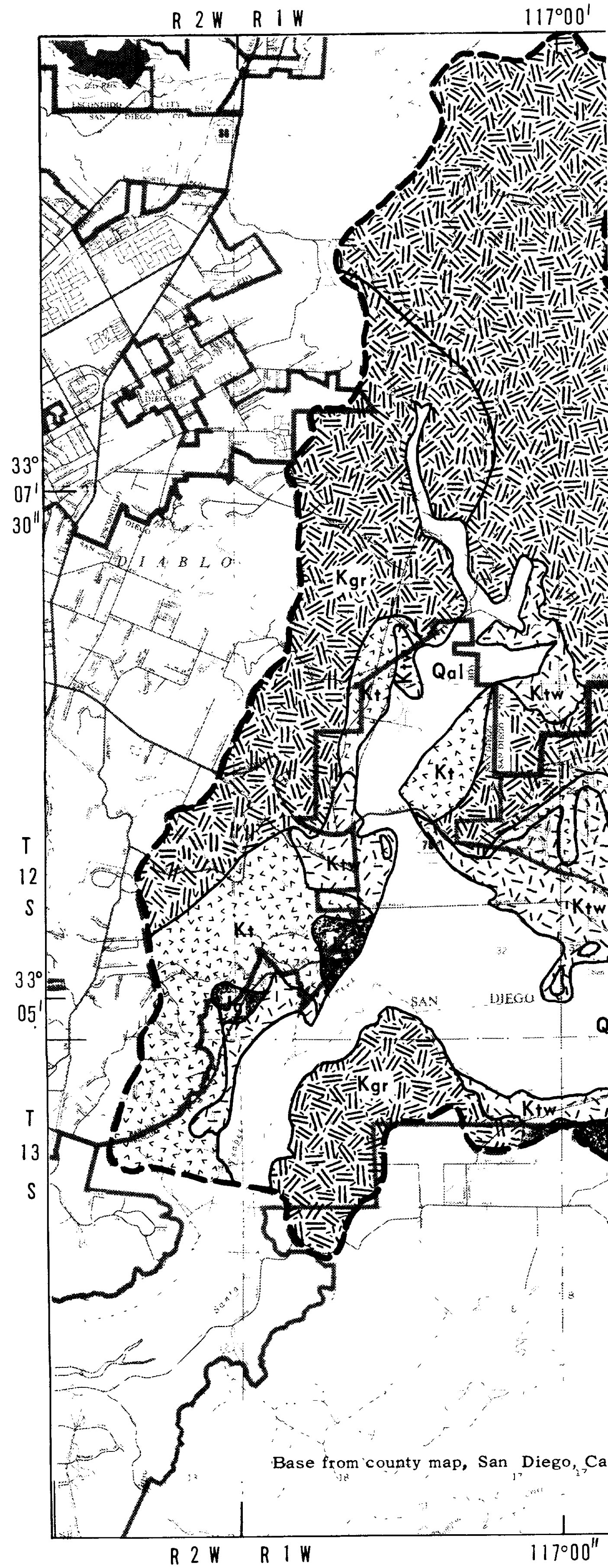
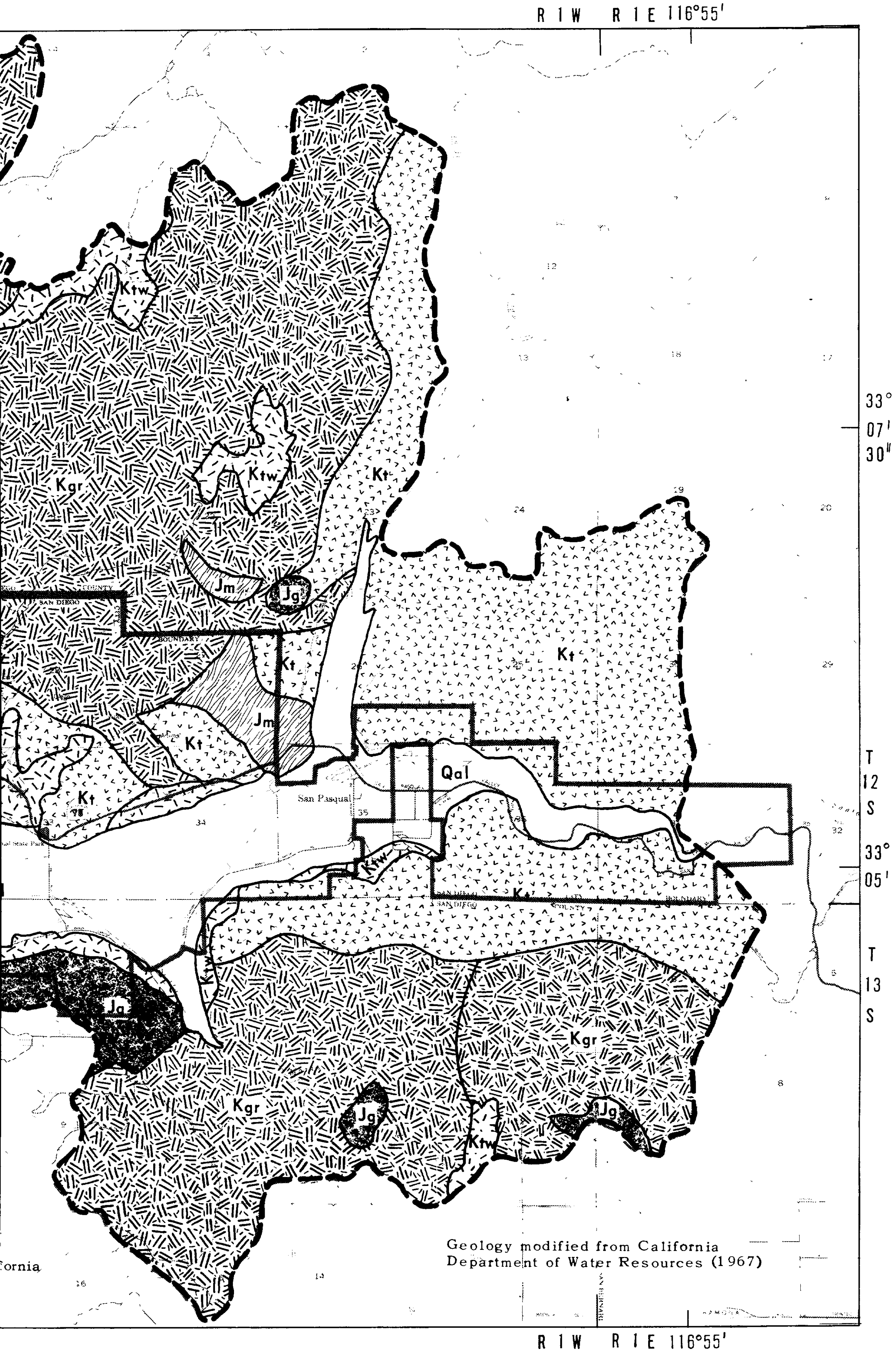


FIGURE 23.--Generalized geology of the San Pasqual hydrologic subarea.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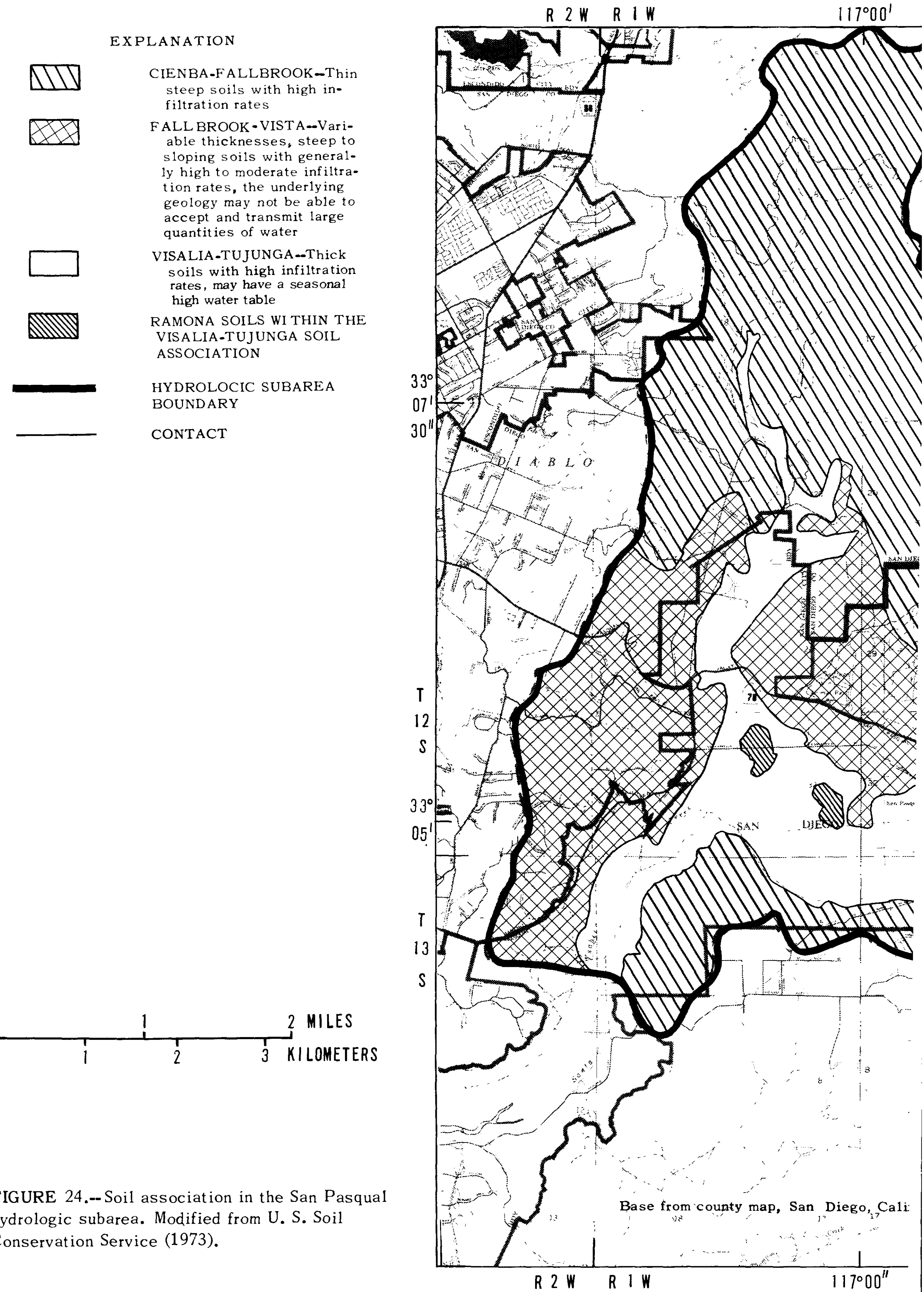
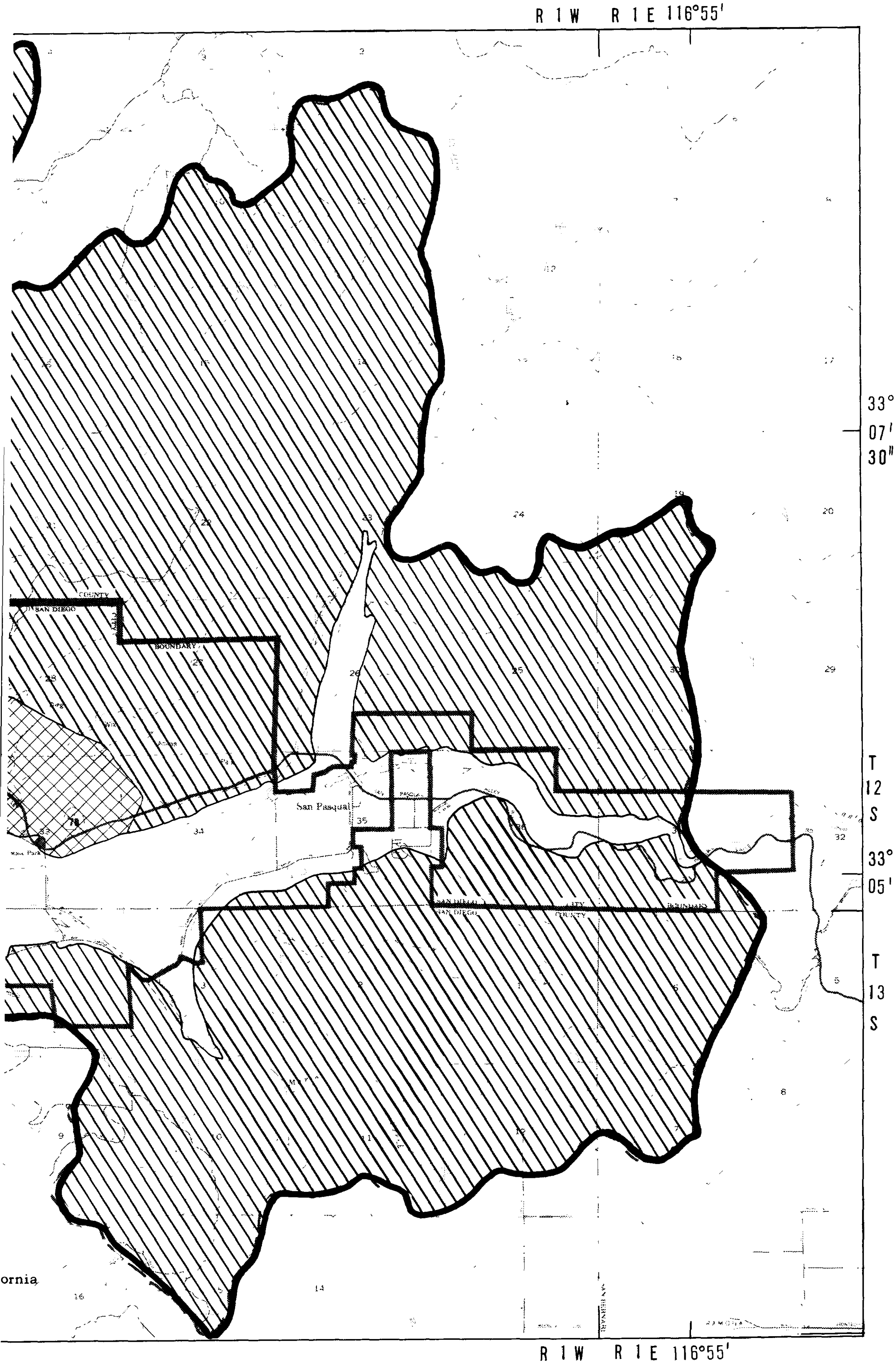


FIGURE 24.--Soil association in the San Pasqual hydrologic subarea. Modified from U. S. Soil Conservation Service (1973).


R 1W R 1E 116°55'
33° 07' 30"
T 12 S
33° 05'
T 13 S
SAN DIEGO
COUNTY
BOUNDARY
San Pasqual
ornia
R 1W R 1E 116°55'

The Cienba-Fallbrook association has many of the same soils as the Fallbrook-Vista association, but in different proportions. Shallow Cienba soils developed over granodiorite dominate this association. However, small areas of Fallbrook and Vista soils have developed over exposures of tonalite and gabbro.

Limitations on applying reclaimed water to upland soils are soil thickness and the ability of the underlying soil profile and geology to accept, filter, and transmit water. Presently, many agricultural areas in the uplands are able to transmit irrigation return water from hillside avocado groves only through shallow circulation and subsurface discharge to springs. If this were reclaimed water, there could be health hazards associated with viruses not killed by wastewater treatment processes or removed by limited soil contact. Proper choice of application sites, methods, rates, and amounts should minimize shallow circulation and surface discharge of reclaimed water, thus minimizing health concerns associated with reclaimed water use on upland soils.

Soils of the Visalia-Tujunga association have developed over the alluvium. All soils within this association are greater than 5 feet thick. In general, infiltration capacities are high and range from 2.0 to 6.3 in/h for Visalia soils, to greater than 20 in/h for Tujunga soils. Small areas of Ramona soils are also present in the Visalia-Tujunga association, particularly where alluvial fill is thin. The primary limitation on application of reclaimed water to soils of the Visalia-Tujunga association is a high water table, within several feet of land surface much of the year.

Surface Water

Streamflow Characteristics

Streamflow data are summarized in table 7, and the locations of stream gages are shown in figure 25. Streamflow into the San Pasqual hydrologic subarea is from Santa Ysabel, Guejito, Santa Maria, and Cloverdale Creeks. A small amount of streamflow originates as springs in uplands of the hydrologic subarea. All surface-water flow leaves the hydrologic subarea through the San Dieguito River at San Pasqual Narrows.

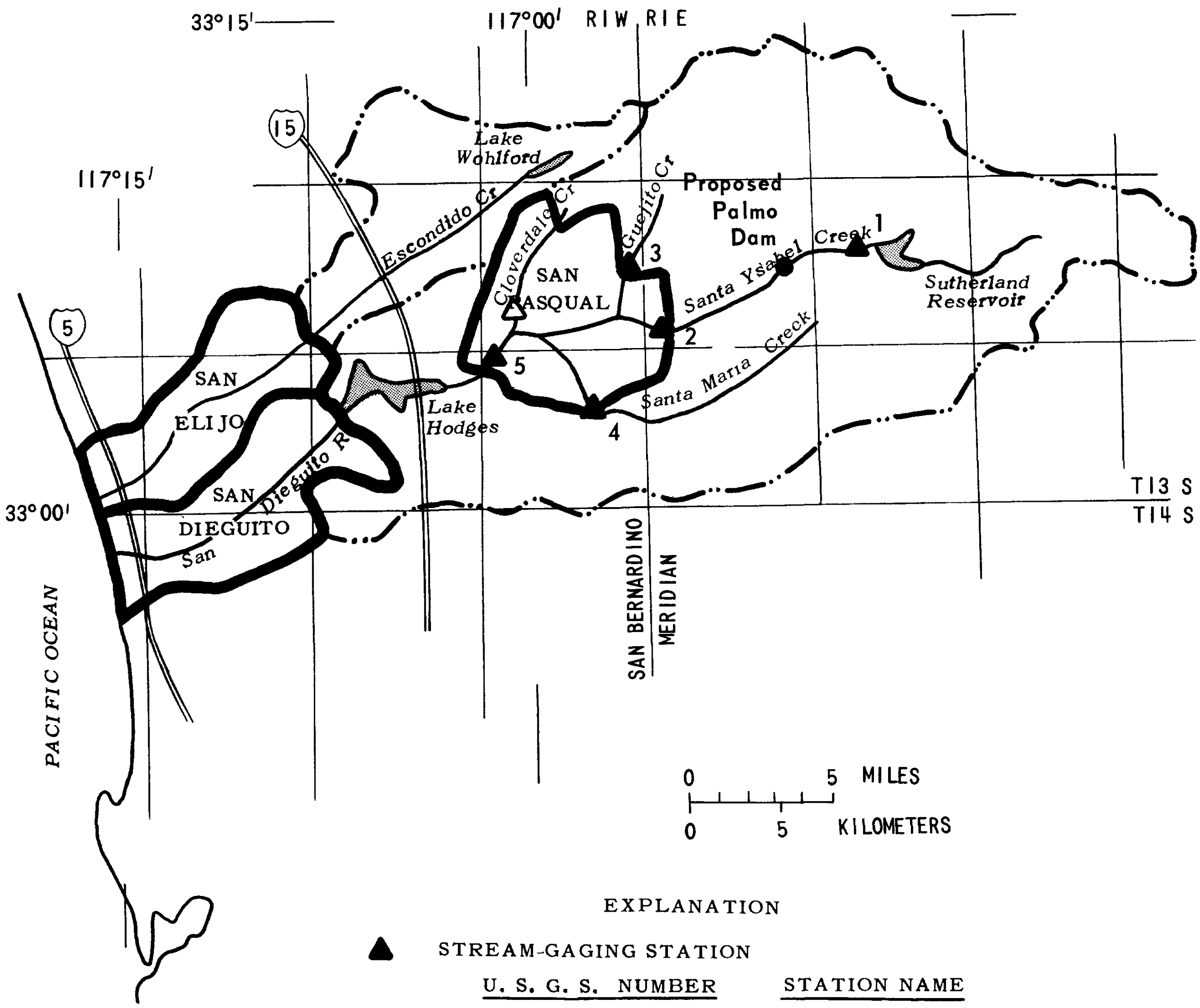
Santa Ysabel Creek is the largest stream, draining 128 mi^2 of largely undeveloped land above the San Pasqual hydrologic subarea. Large parts of its watershed are within Cleveland National Forest and several Indian reservations. Streamflow in Santa Ysabel Creek has been regulated since July 1954 by Sutherland Reservoir, which has a capacity of 29,680 acre-ft, and may further be controlled by the proposed Palmo Dam, which will have a capacity of 30,000 acre-ft and an average annual yield of 8,500 acre-ft.

TABLE 7.--Summary of flow data for the San Pasqual hydrologic subarea

[USGS, U.S. Geological Survey]

Station name	USGS No.	Period of record	Drainage area (mi^2)	Annual discharge average (acre-ft)	Annual discharge median (acre-ft)	Median number of days with flow greater than 0.1 ft^3/s	Maximum discharge for period of record instantaneous (ft^3/s)	Maximum discharge for period of record annual (acre-ft)
Santa Ysabel Creek near Ramona[1]	11025500	02-1912 to 02-1923 10-1943 to 09-1981	112	14,900	3,912	180	28,400	149,000
Santa Ysabel Creek near San Pasqual[1]	11026000	12-1905 to 09-1910 03-1911 to 09-1912 [2]04-1947 to 11-1955 04-1956 to 03-1980	128	5,000	507	102	12,500	29,700
Guejito Creek near San Pasqual	11027000	12-1946 to 09-1981	22	2,110	290	148	3,940	23,900
Santa Maria Creek near Ramona	11028500	11-1912 to 09-1920 10-1946 to 09-1981	58	4,050	145	53	15,200	43,500
San Dieguito River near San Pasqual[1]	11029000	[2]04-1947 to 04-1956 05-1956 to 09-1965	250	[3]1,610	0	0	[3]3,600	[3]14,500

[1]Flow in stream has been regulated since July 1954 by Sutherland Reservoir which has a capacity of 29,680 acre-ft. There are additional small diversions above the station.
[2]Records compiled for irrigation season only.
[3]Based on one flow event in 1958.



EXPLANATION

▲ STREAM-GAGING STATION

	U. S. G. S. NUMBER	STATION NAME
1	11025500	Santa Ysabel Creek near Ramona, California
2	11026000	Santa Ysabel Creek near San Pasqual, California
3	11027000	Guejito Creek near San Pasqual, California
4	11028500	Santa Maria Creek near Ramona, California
5	11029000	San Dieguito River near San Pasqual, California

△ INSTANTANEOUS DISCHARGE MEASUREMENTS--
At Cloverdale Creek near San Pasqual, California

HYDROLOGIC SUBAREA BOUNDARY

DRAINAGE BASIN BOUNDARY

FIGURE 25.--Location of stream-gaging stations in the San Pasqual hydrologic subarea.

Santa Ysabel Creek near San Pasqual typically flows 102 days during the year and median annual discharge is 510 acre-ft. Maximum annual flow in Santa Ysabel Creek was 29,700 acre-ft in 1979. Data for Santa Ysabel Creek near Ramona (table 7) indicate Santa Ysabel Creek may actually flow for a much longer period each year, and may discharge as much as 3,900 acre-ft of water annually. However, these data reflect natural flow regime before completion of Sutherland Dam, and a generally wetter period of record.

With respect to median annual discharge, Guejito Creek is the second largest stream in the hydrologic subarea. Guejito Creek near San Pasqual drains a largely undeveloped watershed of 22 mi^2, with flow unregulated except for several small diversions. This stream flows about 148 days each year (median value) and has a median annual discharge of 290 acre-ft. Maximum annual flow from Guejito Creek was 23,900 acre-ft in 1978, almost as much as the maximum annual flow from Santa Ysabel Creek.

Santa Maria Creek drains a largely agricultural watershed of 58 mi^2. Streamflow is unregulated except for several small diversions. Although the drainage area is much larger than that of Guejito Creek, flows in Santa Maria Creek are dampened by another ground-water basin farther upstream. Santa Maria Creek near Ramona flows about 53 days each year (median value) and in many years it does not flow at all. Median annual flow from Santa Maria Creek is 145 acre-ft and the maximum annual flow was 43,500 acre-ft in 1916.

Cloverdale Creek drains an 18 mi^2 agricultural watershed. Streamflow is unregulated and ungaged. Irrigation return water from hillside avocado groves has turned Cloverdale Creek into a perennial stream. Instantaneous discharge measured on November 24, 1981, and March 25, 1982, was 2.0 and 3.6 ft^3/s, respectively. This water was primarily irrigation return water, and will be discussed in the section on recharge.

Median annual surface-water flow into the hydrologic subarea, excluding Cloverdale Creek, is about 940 acre-ft. In a typical year, no surface-water flow leaves the subarea. In wet years and during floods, enough surface water is available to provide flow in the San Dieguito River at San Pasqual Narrows. Because the period of record includes years 1946-77, the driest period in the last 400 years (Larry Michaels, San Diego County Water Authority, written commun., 1982), estimates of streamflow characteristics may be low.

Surface-Water Quality

Historical water-quality data for Santa Ysabel Creek below Sutherland Dam from 1956-81 are summarized in table 8. No discharge data are available to determine the relation between water quality and discharge, and to separate baseflow from stormflow. However, minimum concentrations given in table 8 probably reflect quality of stormflow, and maximum concentrations probably reflect quality of baseflow. Throughout the period of record, water in Santa Ysabel Creek has been a mixed type, dominated by bicarbonate on the anionic side; relative concentrations of dissolved species have remained constant. Historical water-quality data are not available for Guejito, Santa Maria, or Cloverdale Creeks.

Surface-water-quality data for the San Pasqual hydrologic subarea were collected in 1981-82. Two samples were collected from Santa Maria, Guejito, and Cloverdale Creeks, one in autumn to reflect baseflow, and another during the recessional flow of a late spring storm. Only one sample was collected from Santa Maria Creek, as there was no flow in autumn 1981. Dissolved-solids concentrations were lowest in Santa Ysabel and Guejito Creeks, 321 and 366 mg/L, respectively, and were highest in Cloverdale Creek, 1,040 mg/L. Santa Maria Creek had an intermediate dissolved-solids concentration of 734 mg/L. Water was a mixed type in all streams. However, water from Cloverdale and Santa Maria Creeks was dominated by sodium chloride and bore a strong resemblance to imported water. Water from Santa Ysabel and Guejito Creeks was well mixed on the cationic side, but dominated by bicarbonate on the anionic side. No stream seems to contribute large amounts of sulfate to the hydrologic subarea. Water-quality analyses are listed in appendix A.

TABLE 8.--Summary of water-quality data for Santa Ysabel Creek below Sutherland Dam, 1956-81

[<, less than; --, no data]

	Number of observations	Minimum	Median	Maximum
Instantaneous discharge-----------ft^3/s--	0	--	--	--
Specific conductance µmho/cm at 25°C------------	41	260	480	642
pH--------------------------	40	7.0	8.4	10
Dissolved solids-------mg/L--	39	180	306	406
Sodium-----------------mg/L--	41	17	38	160
Calcium----------------mg/L--	41	22	32	100
Magnesium--------------mg/L--	41	5	15	31
Chloride---------------mg/L--	41	19	49	140
Sulfate----------------mg/L--	41	5	36	360
Alkalinity as $CaCO_3$----mg/L--	36	85	130	157
Boron------------------µg/L--	10	<10	90	220

Ground Water

Crystalline Rocks

Granodiorite and much of the Green Valley Tonalite are weathered to only a shallow depth, but may have fractures which can yield small quantities of water to wells. In the San Pasqual area, well yields from fractured crystalline rocks are as high as 15 gal/min, but typically less than 2 gal/min. Specific capacities for wells in fractured crystalline rocks of the San Pasqual subarea are less than 0.04 (gal/min)/ft of drawdown.

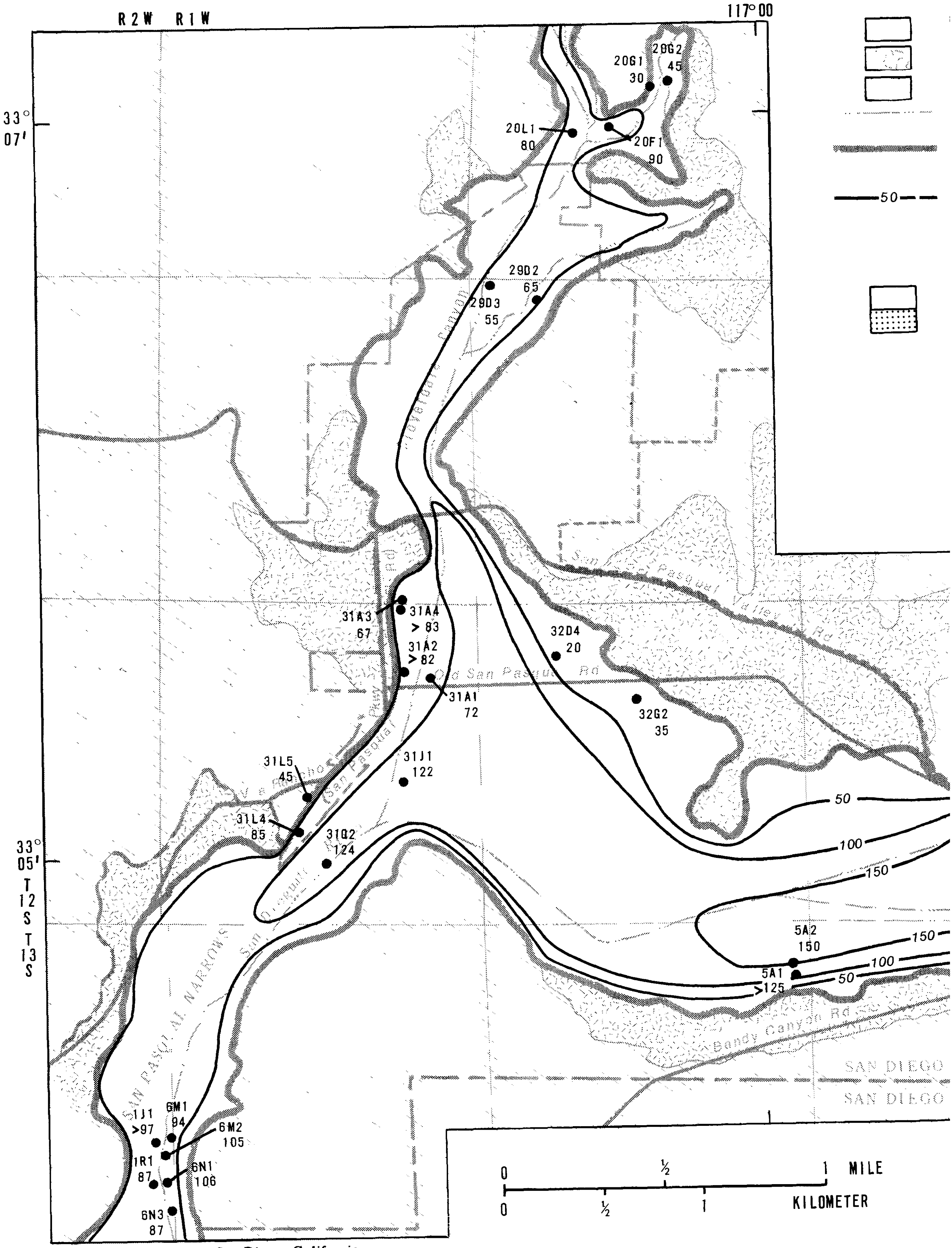
Residual Aquifer

Deeply weathered exposures of Green Valley Tonalite form the residual aquifer. Water-yielding characteristics are summarized in table 9. In the San Pasqual subarea, well yields are as high as 600 gal/min and the median yield is 40 gal/min. Specific capacities for wells in weathered tonalite are as high as 0.7 (gal/min)/ft of drawdown with a median value of 0.4 (gal/min)/ft of drawdown. In addition to surface exposures, drillers' logs reveal considerable weathered tonalite buried beneath alluvial fill. If this material is accounted for and the average depth of weathered material is assumed to be 100 feet, by using an average specific yield of 0.01 (Ramsahoye and Lang, 1961) the total storage in the residual aquifer is estimated to be less than 5,000 acre-ft.

Water generally moves from the residual aquifer downgradient into the alluvial fill. Movement between the two is accelerated during periods of low ground-water levels in the alluvium. Although the residual aquifer contains only a small quantity of water, it may be locally important during such times.

Alluvial Aquifer

Alluvial fill covers 3,410 acres or almost 15 percent of the San Pasqual subarea. Alluvial thickness exceeds 120 feet in San Pasqual Narrows and increases to over 200 feet in the upper part of the basin (fig. 26). The alluvial aquifer contains 364,000 acre-ft of fill. Drillers' logs and specific-capacity data indicate alluvial fill in the San Pasqual subarea has better water-yielding characteristics than the San Dieguito subarea farther downstream, therefore an average specific yield of 0.16 was used to estimate storage. Total ground-water storage in the alluvial aquifer is approximately 58,000 acre-ft. The alluvial fill is a water-table aquifer and ground water is not confined.



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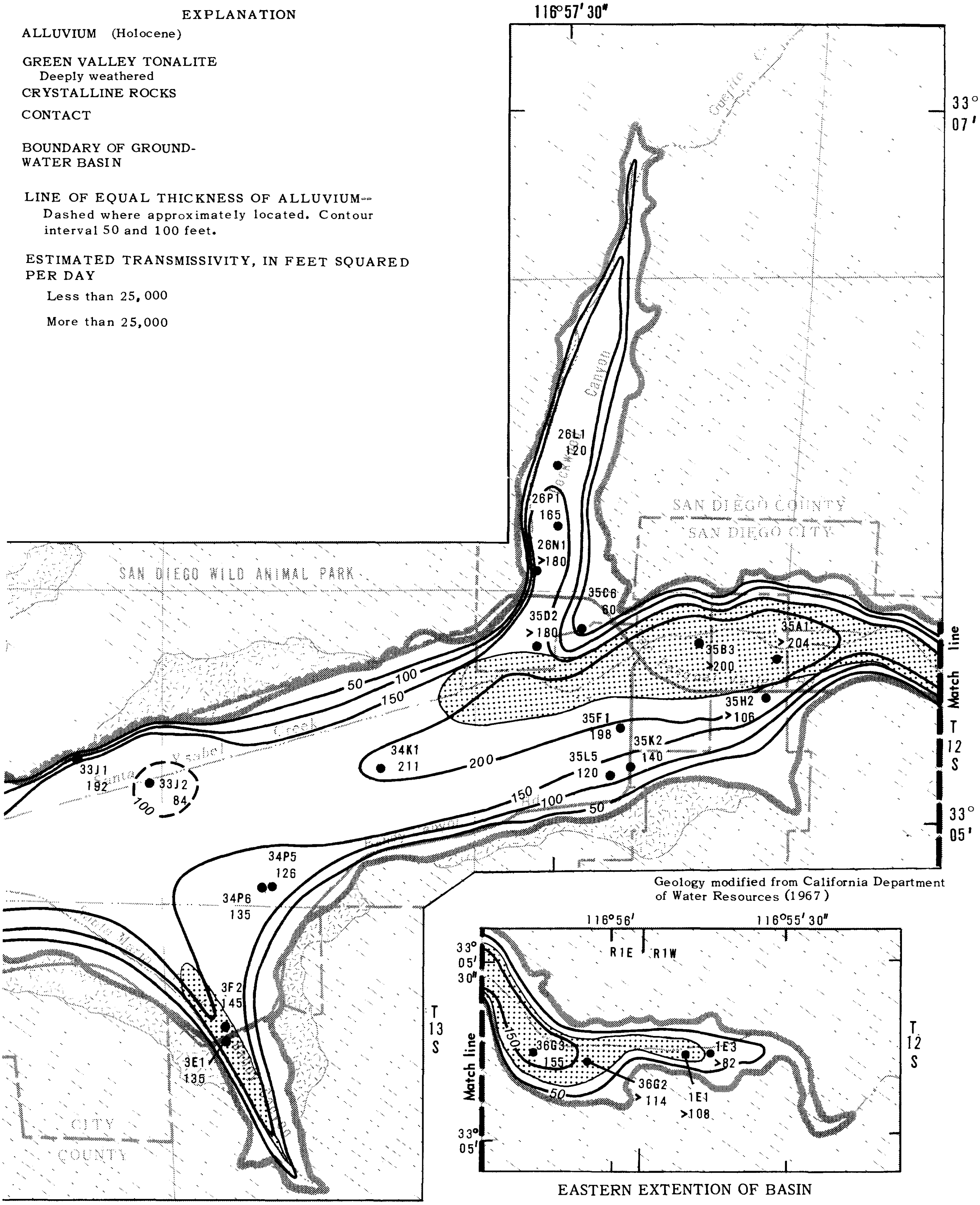


FIGURE 26.--Thickness of the San Pasqual alluvial aquifer.

TABLE 9.--Water-yielding characteristics of aquifers

[Data from drillers' information.

Geologic unit	Map symbol	Exposure in subarea (acres)	Maximum thickness (feet)	Description
Alluvium	Qal	3,410	>200	River and stream deposits of gravel, sand, silt, and clay.
Crystalline rocks of the southern California batholith	Kgr, Kt, Jg, Jm	15,040	Basement complex	Primarily unweathered granodiorite and tonalite.
Deeply weathered exposures of Green Valley Tonalite	Kt_1	1,550	Plus or minus 100, variable	Deeply weathered Green Valley Tonalite, frequently covered by a thin layer of alluvium.

Wells in the alluvium yield as much as 1,600 gal/min. Although highest yields are in the upper part of the basin, wells yielding almost 1,000 gal/min are found throughout the main canyon and Rockwood and Bandy Canyons.

Well logs show a mixture of clean sand, gravel, and silt throughout the alluvium. In general, well logs indicate a greater percentage of clean sand and gravel in the upper basin and a greater percentage of silt in the lower basin and San Pasqual Narrows (Kohler and Miller, 1982).

Specific-capacity data reflect generalized distribution of sand, gravel, and silt within the aquifer. Several wells, most located in a line along the northern edge of the upper basin from the mouth of Rockwood Canyon east to the inflow of Santa Ysabel Creek, have specific capacities in the San Pasqual hydrologic subarea

>, greater than; --, no data]

Water-yielding characteristics			
General	Well yield (gal/min)	Specific capacity ((gal/min)/ft of drawdown)	Transmissivity (ft^2/d)
Yields water freely to wells.	As much as 1,600.	Typically 16, but may exceed 100.	Typically 4,000, but may exceed 25,000.
Yields small quantities of water to wells from fractures.	Less than 2, but may be as much as 15.	Less than 0.1.	--
Yields water to wells from weathered granite matrix and fractures.	Typically less than 40, but may be as much as 600.	Typically less than 0.4, but may be as much as 0.7.	--

greater than 100 (gal/min)/ft of drawdown. One well in Bandy Canyon also has a specific capacity greater than 100 (gal/min)/ft of drawdown. Specific-capacity data from wells in the remainder of the aquifer average 16 (gal/min)/ft of drawdown with a maximum of 75 (gal/min)/ft.

Estimates of transmissivity can be obtained by multiplying specific capacity by 250. This value is based on statistical correlations done by Thomasson and others (1960) in California's Central Valley, and has been routinely extended to California's coastal and desert basins. Using this method, aquifer transmissivities along the northern edge of the upper San Pasqual basin and Bandy Canyon exceed 25,000 ft^2/d (fig. 26). In the remainder of the alluvium, transmissivities are less than 20,000 ft^2/d and average 4,000 ft^2/d.

Recharge.--Recharge to the alluvial aquifer originates primarily outside the hydrologic subarea as flow in Santa Ysabel, Guejito, and Santa Maria Creeks. In a typical year no flow leaves the subarea and all surface water becomes ground-water recharge, about 940 acre-ft/yr. During wet years flow may be great enough to fill the alluvial aquifer, with the excess leaving the subarea as flow in the San Dieguito River. Additional recharge is provided by water imported to the subarea for agricultural use. Streamflow originating inside the subarea, leakage from the surrounding residual aquifer, and precipitation contribute small amounts of recharge that may be locally important.

Imported water use in the San Pasqual subarea has grown in recent years. In 1970, 2,140 acre-ft of water was imported to the subarea and in 1980, 3,560 acre-ft of imported water was used. Currently, imported water is used primarily in San Diego Wild Animal Park and hillside avocado groves west of Cloverdale Canyon.

Based on calculations by the California Department of Water Resouces (California Department of Water Resources, 1983), 710 acre-ft of imported water used for irrigation was available for deep percolation and recharge to the alluvial aquifer in 1970. By 1980 this figure increased to 1,160 acre-ft. This was sufficient to turn Cloverdale Creek into a perennial stream in 1977 and to maintain water levels in Cloverdale Canyon near land surface. At that time, water levels throughout the remainder of the alluvial aquifer were generally greater than 40 feet, and occasionally as deep as 85 feet below land surface.

Occurrence and movement.--Movement of ground water is from the major source of recharge at the inflow of Santa Ysabel Creek and from smaller recharge areas in Rockwood, Bandy, and Cloverdale Canyons, downgradient to the discharge area in San Pasqual Narrows. With the exception of evapotranspiration losses, all water entering the alluvial aquifer exits through San Pasqual Narrows.

In the early 1900's before the beginning of extensive ground-water development, water levels were very near land surface throughout much of the alluvial aquifer (fig. 27 and 28). Water levels remained high throughout the 1930's, and declined only gradually during the 1940's and 1950's. Rate of water-level decline increased in the early 1960's and historically low water levels occurred in 1965 and 1977.

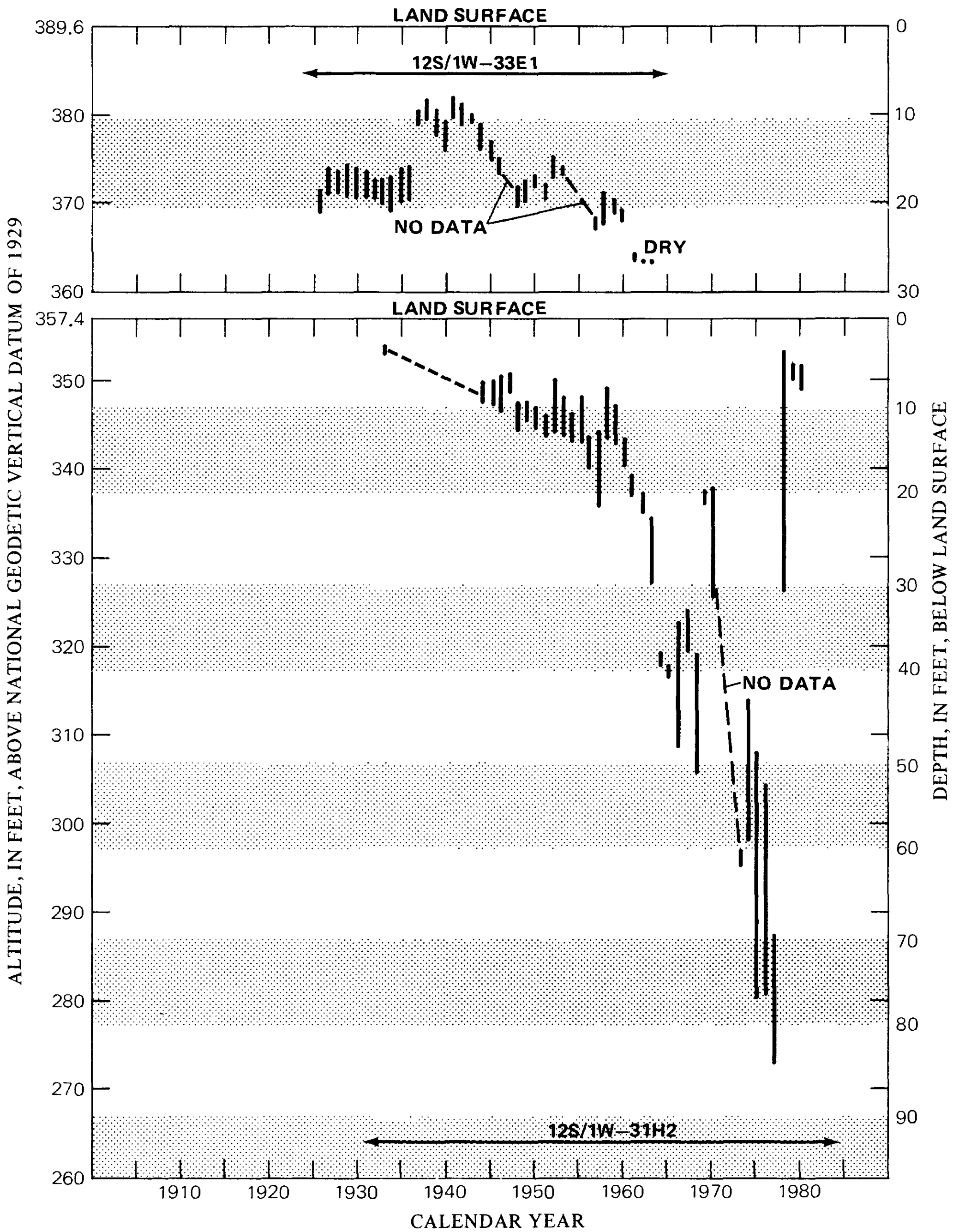


FIGURE 27. – Hydrographs for wells in the lower part of the San Pasqual basin. Vertical bar indicates range of water–level fluctuation during year. (Location of wells shown in appendix C.).

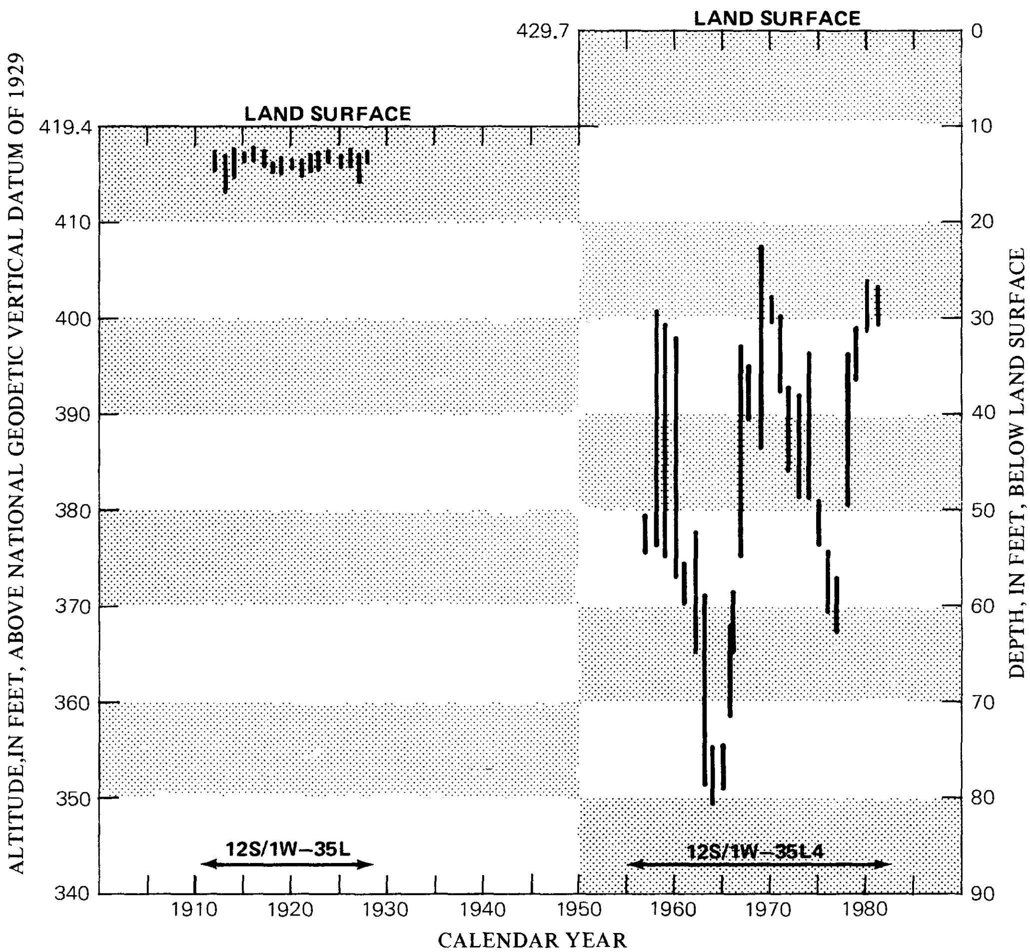


FIGURE 28. – Hydrographs for wells in the upper part of the San Pasqual basin. Vertical bar indicates range of water–level fluctuation during year. (Location of wells shown in appendix C.).

Figure 29 is a water-level-contour map for spring 1977. At that time, water levels in the San Pasqual alluvium were the lowest ever recorded prior to the beginning of an irrigation season. The hydraulic gradient through San Pasqual Narrows was reversed, and ground water was moving into the basin from outside the hydrologic subarea. The only discharge from the San Pasqual subarea was through evapotranspiration of agricultural crops. Depth to water was greater than 40 feet throughout most of the alluvium and exceeded 80 feet in some places. This represented a reduction in storage of 23,800 acre-ft. Storage remaining in the basin was 34,200 acre-ft, or 60 percent capacity.

Water levels rose rapidly in 1978 in response to a wet year. The alluvial aquifer filled, and ground-water movement returned to normal.

Figure 30 is a spring 1982 water-level-contour map. Ground-water movement was again downgradient from major sources of recharge at Santa Ysabel Creek, Rockwood Canyon, and Bandy Canyon to the discharge area in San Pasqual Narrows. A new source of recharge was irrigation return from avocado groves along the western edge of the lower basin and Cloverdale Canyon. Irrigation return moves from hillsides through the residual aquifer, surfacing as springs in many places, eventually entering the alluvial aquifer. In only a small part of the alluvium were depths to water greater than 10 feet, and nowhere was depth to water greater than 30 feet (fig. 30). The aquifer was full in spring 1982.

Ground-Water Quality

Crystalline Rocks

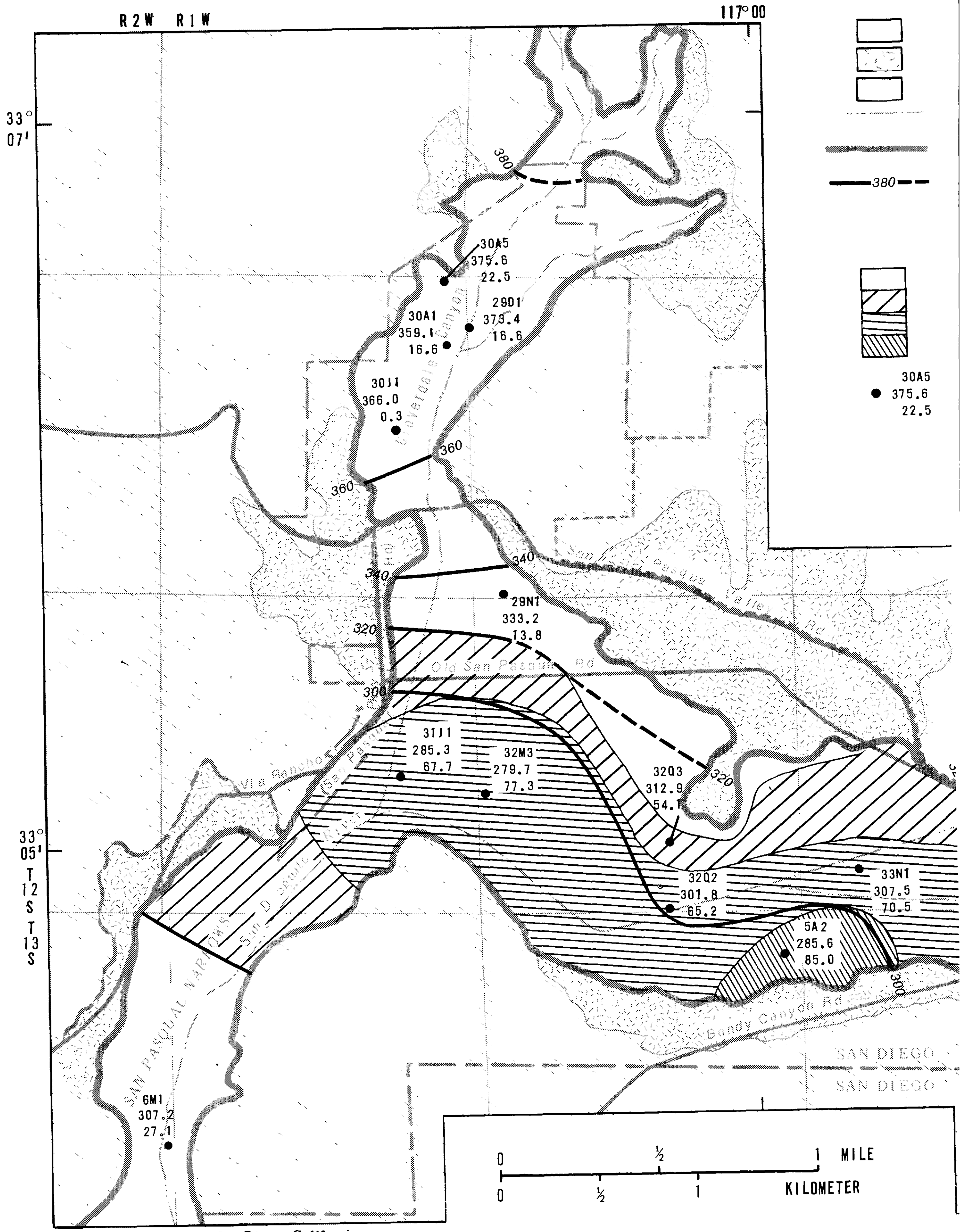
Water from wells in fractured crystalline rocks in San Diego County has a median dissolved-solids concentration less than 500 mg/L (California Department of Water Resources, 1967). However, because wells in this material yield water from fractures which have little ability to adsorb or filter pollutants, quality of the water is easily degraded. Little information is available on current water-quality problems in crystalline areas of the San Pasqual hydrologic subarea.

Residual Aquifer

Prior to 1967, water from weathered granite aquifers in San Diego County had a median dissolved-solids concentration between 500 and 600 mg/L (California Department of Water Resources, 1967). In the San Pasqual subarea, dissolved-solids concentrations in 1981 and 1982, estimated from specific conductance, were as high as 1,430 mg/L, with a median concentration of 1,040 mg/L. In the residual aquifer dissolved solids (as reflected by specific conductance) tend to be higher downgradient from agricultural land.

Dissolved-solids concentrations in water from the residual aquifer are on the average somewhat lower than dissolved-solids concentrations in water from the alluvium in Cloverdale Canyon and the lower part of the basin. Several wells in shallow alluvial fill (12S/1W-20M1 and 12S/1W-30A5) which were completed in the residual aquifer yield water lower in dissolved solids than nearby wells completed only in the surrounding alluvium (fig. 33). When ground-water levels are low in Cloverdale Canyon and the lower basin, the residual aquifer contributes water with a lower average dissolved-solids concentration to the alluvial aquifer, and may actually improve water quality (with respect to dissolved-solids concentration) in some wells.

Water in some areas of the residual aquifer has elevated concentrations of nitrate that could move into the alluvium when ground-water levels are low, particularly in the vicinity of San Diego Wild Animal Park.



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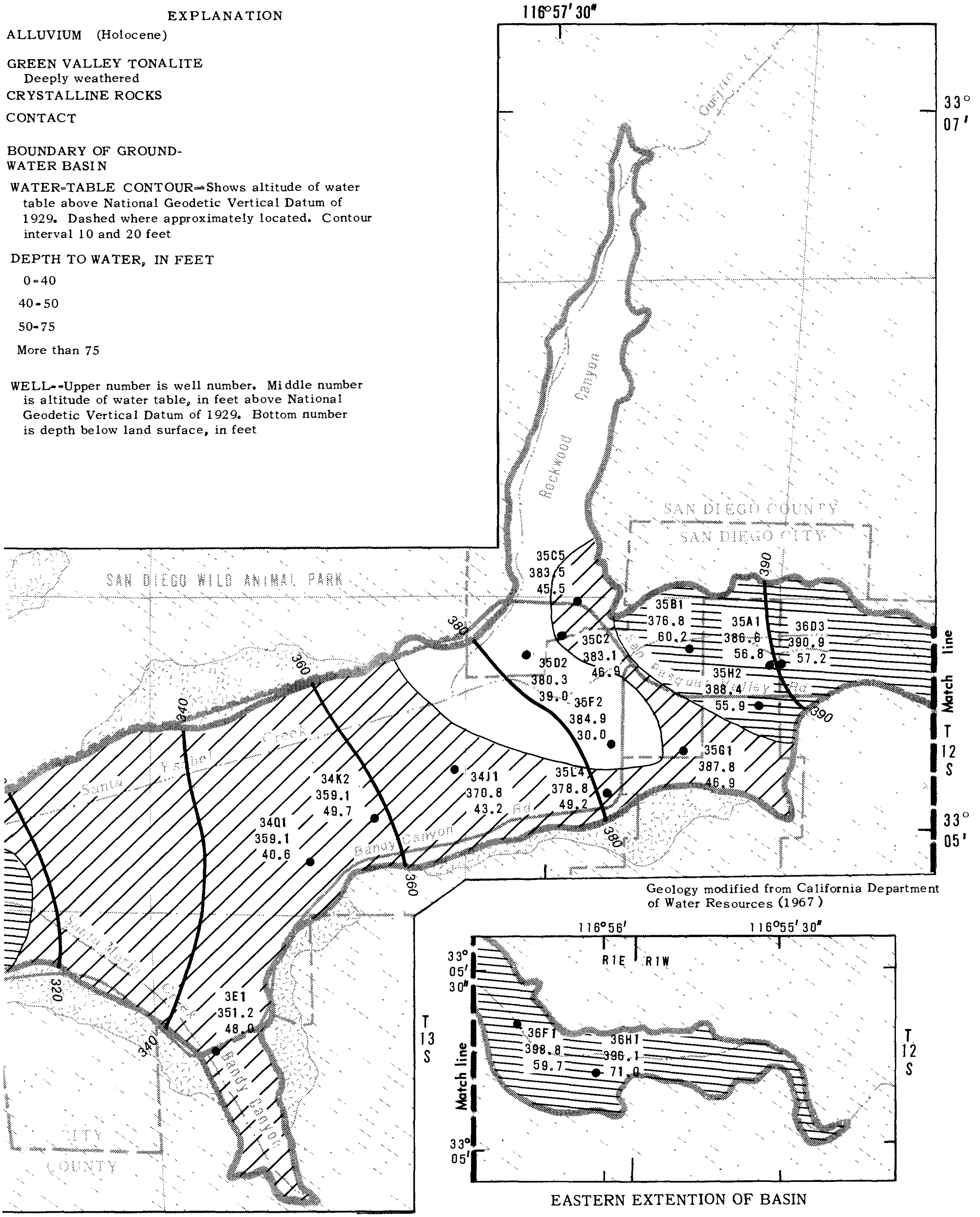
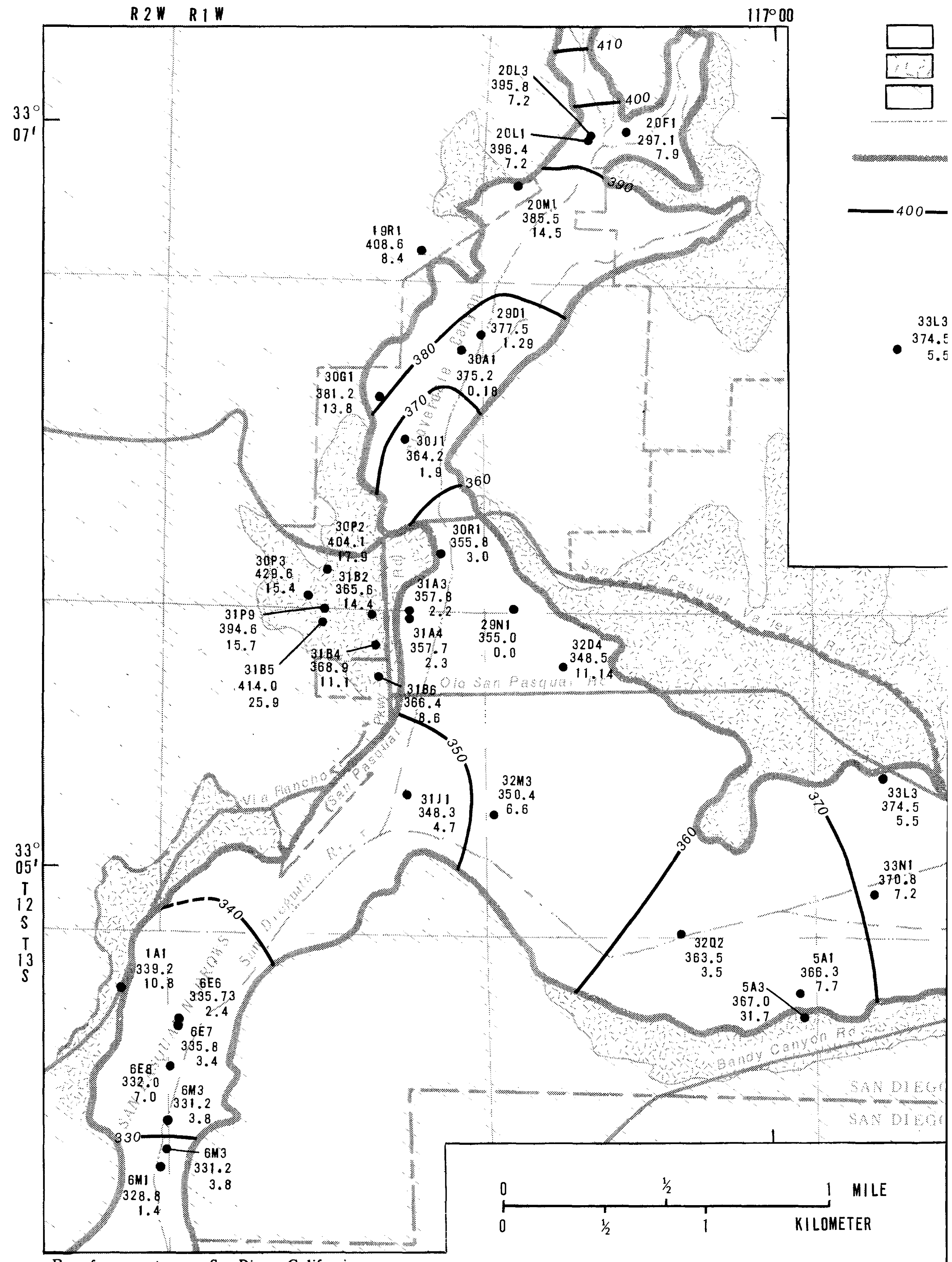


FIGURE 29.--Water-level contours and depth to water in the San Pasqual alluvial aquifer, spring 1977.



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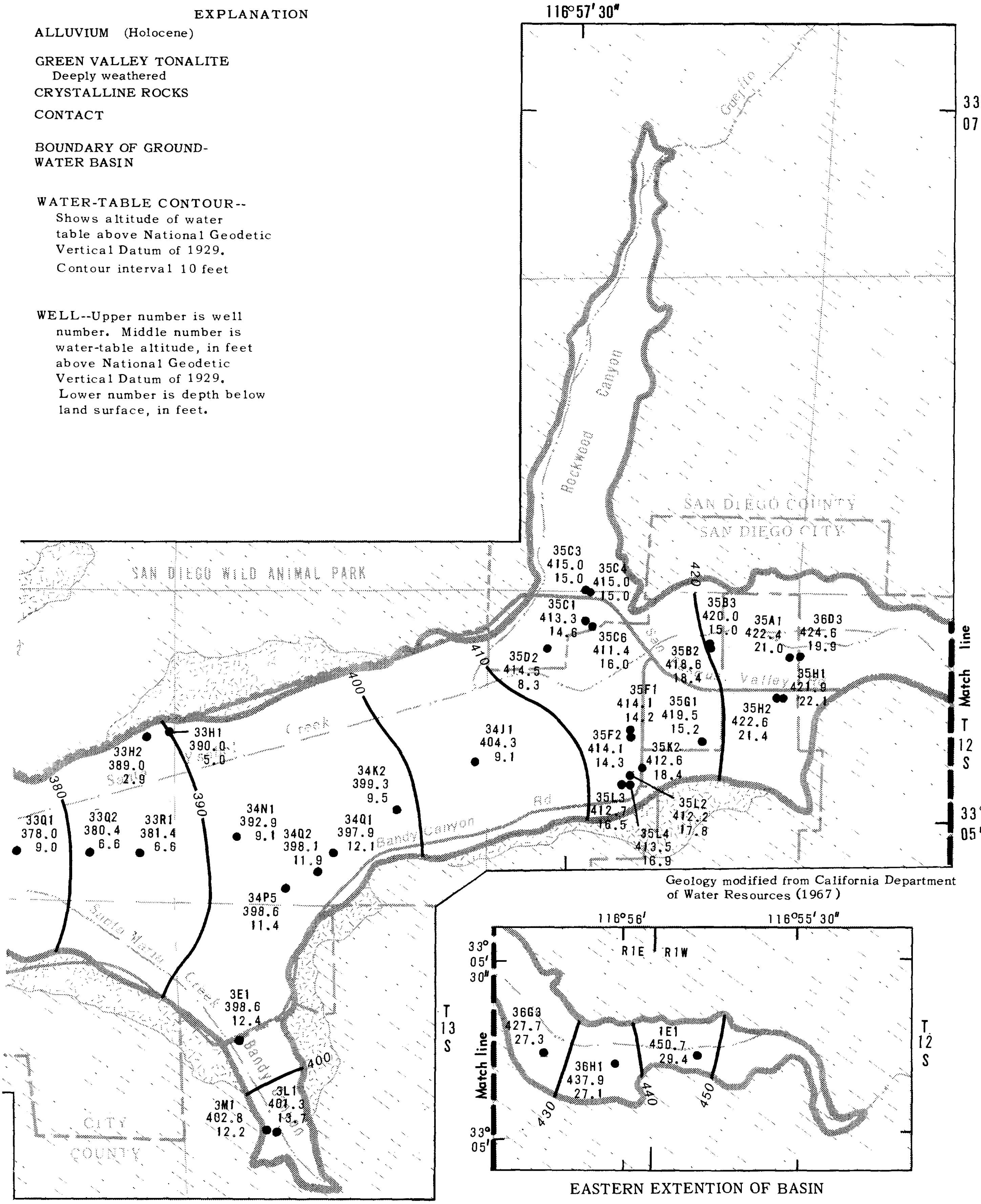


FIGURE 30.-- Water-level contours and depth to water in the San Pasqual alluvial aquifer, spring 1982.

Alluvial Aquifer

Historical water quality.--Figure 31 is a ground-water-quality map of the alluvial aquifer in spring 1957, prior to the increased water-level declines of the 1960's. At that time, only one of the sampled wells (12S/1W-30R1) yielded water with dissolved-solids concentrations greater than 1,000 mg/L. Dissolved-solids concentrations from highly transmissive areas in the upper basin were less than 500 mg/L.

During spring 1957, ground water in the alluvium was generally a mixed type. Calcium and sodium were the predominant cations. Calcium predominanted in the highly transmissive areas of the upper basin and sodium predominanted downgradient. Bicarbonate was the predominant anion and sulfate was of minor importance throughout the aquifer.

Water from upper reaches of Cloverdale Canyon was a sodium chloride bicarbonate type. Sodium and chloride increased as water moved downgradient through Cloverdale Canyon, becoming a sodium chloride type as it left the canyon to enter the main body of the aquifer.

By the time ground water left the subarea at San Pasqual Narrows, dissolved solids increased but did not exceed 1,000 mg/L. The percentage of sulfate also increased and ground water was again a mixed type.

Historically, nitrate has been a problem in the alluvial aquifer. Figure 32 shows wells which have yielded water with nitrate concentrations greater than EPA drinking water limits of 10 mg/L as N. Most of the wells are located in the upper part of the basin and may be associated with dairy and poultry operations in that area.

Present water quality.--Present water quality in the alluvium is variable (fig. 33). Lowest dissolved-solids concentrations are found in highly transmissive parts of the upper basin and Rockwood Canyon. Ground water from these areas generally has less than 500 mg/L dissolved solids. Downgradient from highly transmissive parts of the upper basin dissolved-solids concentrations increase, but generally remain below the basin objective of 1,000 mg/L. Dissolved-solids concentrations in water in the lower basin and San Pasqual Narrows are generally above 1,000 mg/L and are as high as 1,550 mg/L. Dissolved-solids concentrations in Cloverdale Canyon and in parts of the upper basin also exceed 1,000 mg/L. Increasing dissolved-solids concentrations in these areas may be related to land use. Irrigation return water appears to contribute to high concentrations of dissolved solids in ground water from Cloverdale Canyon.

Field measurements of specific conductance were converted to dissolved-solids concentration using the following relation:

$$DS=0.7SC-40,$$

where

DS is dissolved-solids concentration, in milligrams per liter; and
SC is specific conductance, in micromhos per centimeter at 25°C.

This relation was developed using linear regression on data collected by the U.S. Geological Survey and the city of San Diego between autumn 1981 and spring 1982. Twenty-three samples with dissolved-solids concentrations ranging from 414 to 2,480 mg/L were used and an R^2 of 0.96 was obtained. This relation is basin specific and care should be used when extrapolating to other areas.

Chloride and sulfate exceed the EPA suggested limit for drinking water of 250 mg/L in ground water from San Pasqual Narrows and Cloverdale Canyon.

Ground water in highly transmissive areas of the alluvial aquifer is a mixed type and resembles recharge water from Santa Ysabel and Guejito Creeks. Cations are well mixed and the percent difference between calcium, sodium, and magnesium is only a few milliequivalents. Bicarbonate and chloride are the dominant anions in the upper basin. Sulfate is relatively unimportant in ground water from highly transmissive areas of the upper basin. Downgradient, the relative importance of sulfate increases. This is probably due to agricultural water use, soil amendments (particularly calcium sulfate, used when irrigating with water high in sodium), and irrigation return water. Increasing importance of sulfate does not seem to be related to recharge water from Santa Maria Creek.

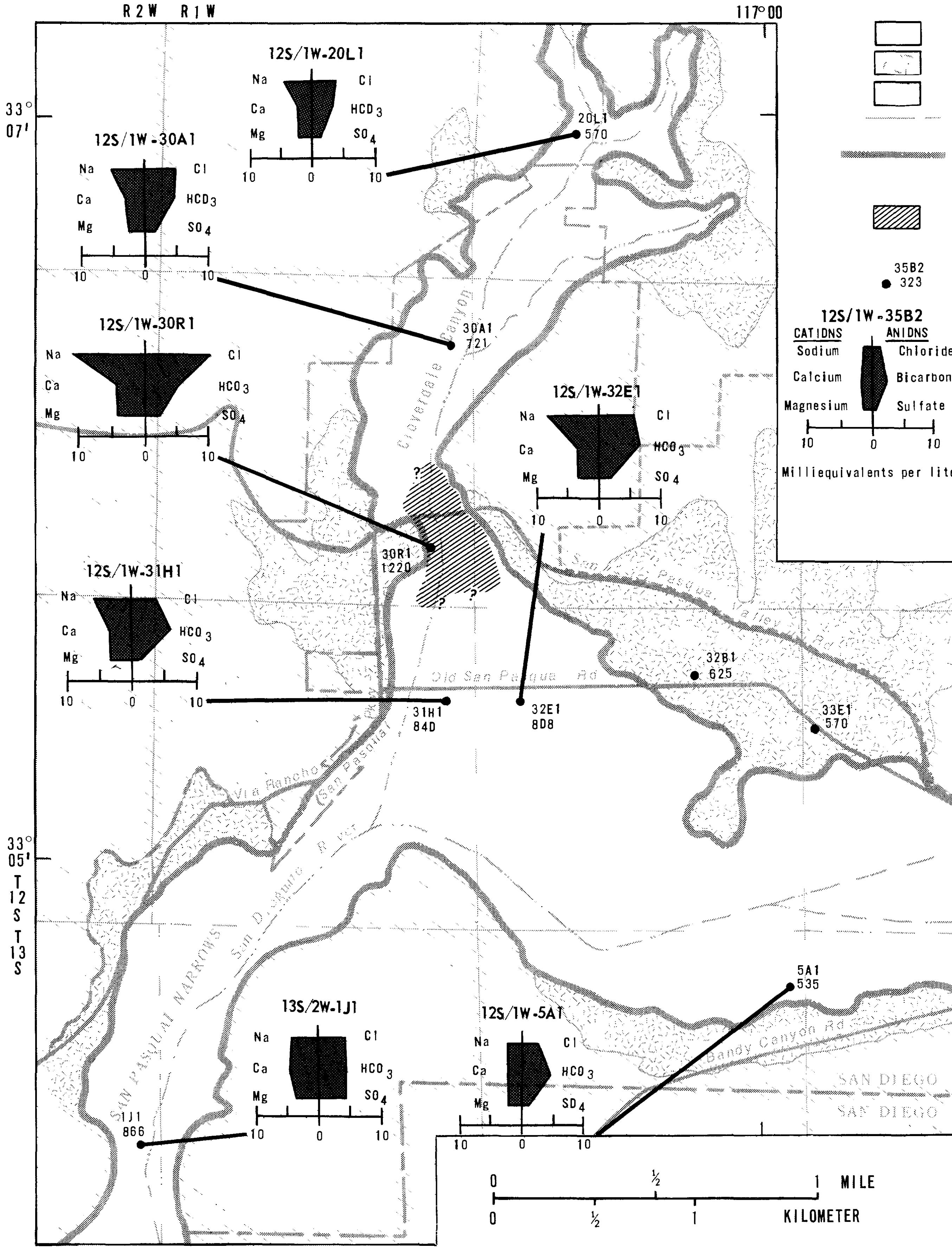
When ground water leaves the subarea at San Pasqual Narrows, it is different from its original composition. Ground water in the Narrows is a sodium chloride sulfate type and reflects agricultural water use in the San Pasqual subarea, and mixing of native water with irrigation return water imported from the Colorado River and northern California.

In 1981 and 1982, only two wells for which chemical analyses were available (12S/1W-34K2 and 12S/1W-35H2) yielded water with nitrate concentrations greater than the EPA recommended limit for drinking water of 10 mg/L nitrate as nitrogen (45 mg/L nitrate as nitrate). Both wells are in the upper part of the basin where dissolved-solids concentrations are below 1,000 mg/L. High nitrate levels in these wells indicate there is still a nitrate problem in the alluvial aquifer, particularly the upper basin, despite the recent filling of the aquifer after floods in 1978.

Impact of Reclaimed Water Use

The impact of reclaimed water use in the San Pasqual hydrologic subarea will depend greatly upon the reclaimed-water management scheme ultimately used. To be properly evaluated, the impact of reclaimed water use should be compared to and contrasted with possible future trends in water quantity and quality for the San Pasqual hydrologic subarea.

If reclaimed water is not used, the amount of ground water in storage in the alluvial aquifer will follow historic patterns of filling and subsequent depletion that are closely associated with long-term trends in precipitation (fig. 27 and 28). During prolonged dry spells, such as occurred prior to 1966 and 1978, ground-water levels will decline and many wells will go dry. The value of the ground-water resource will be greatly diminished when needed most.



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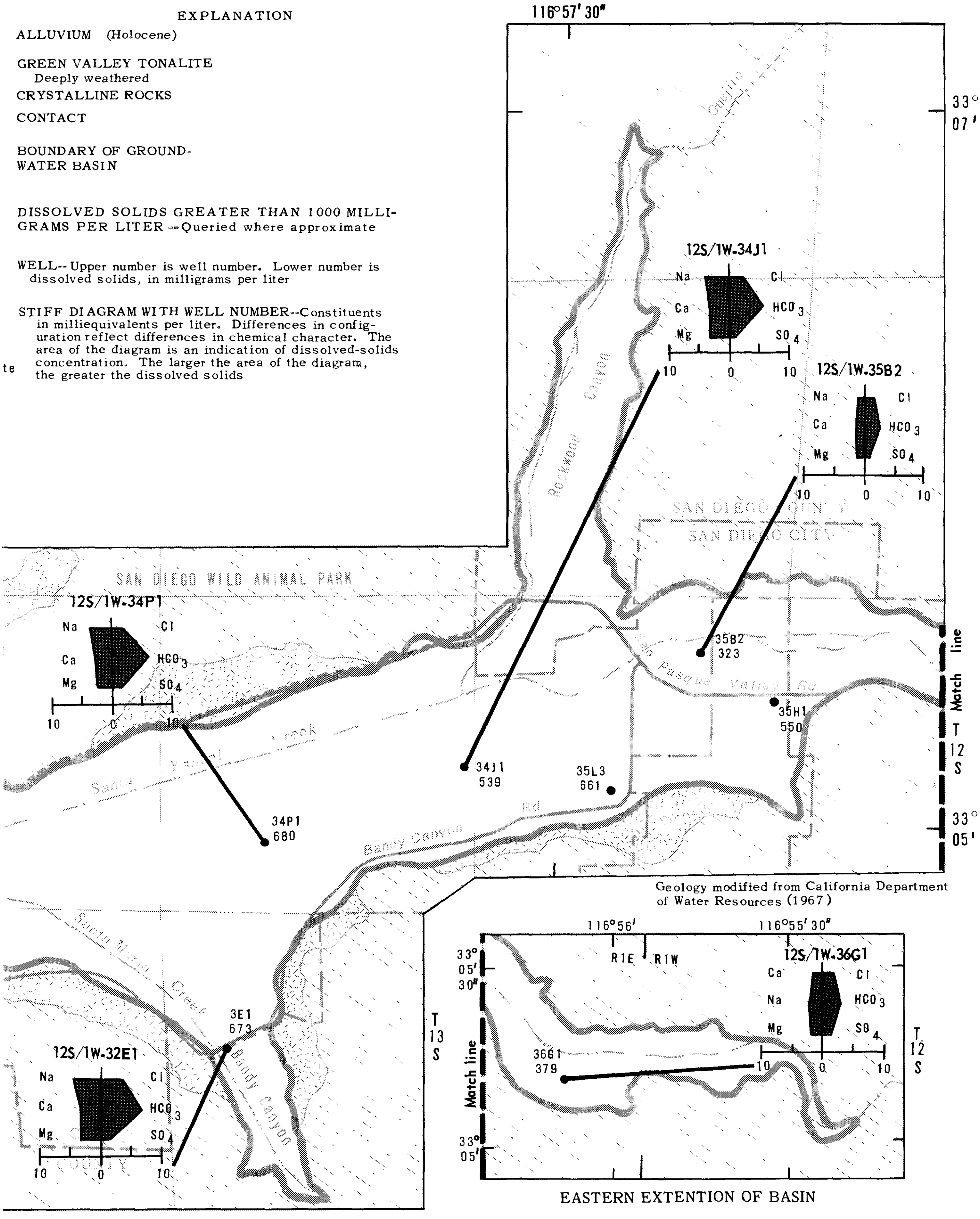
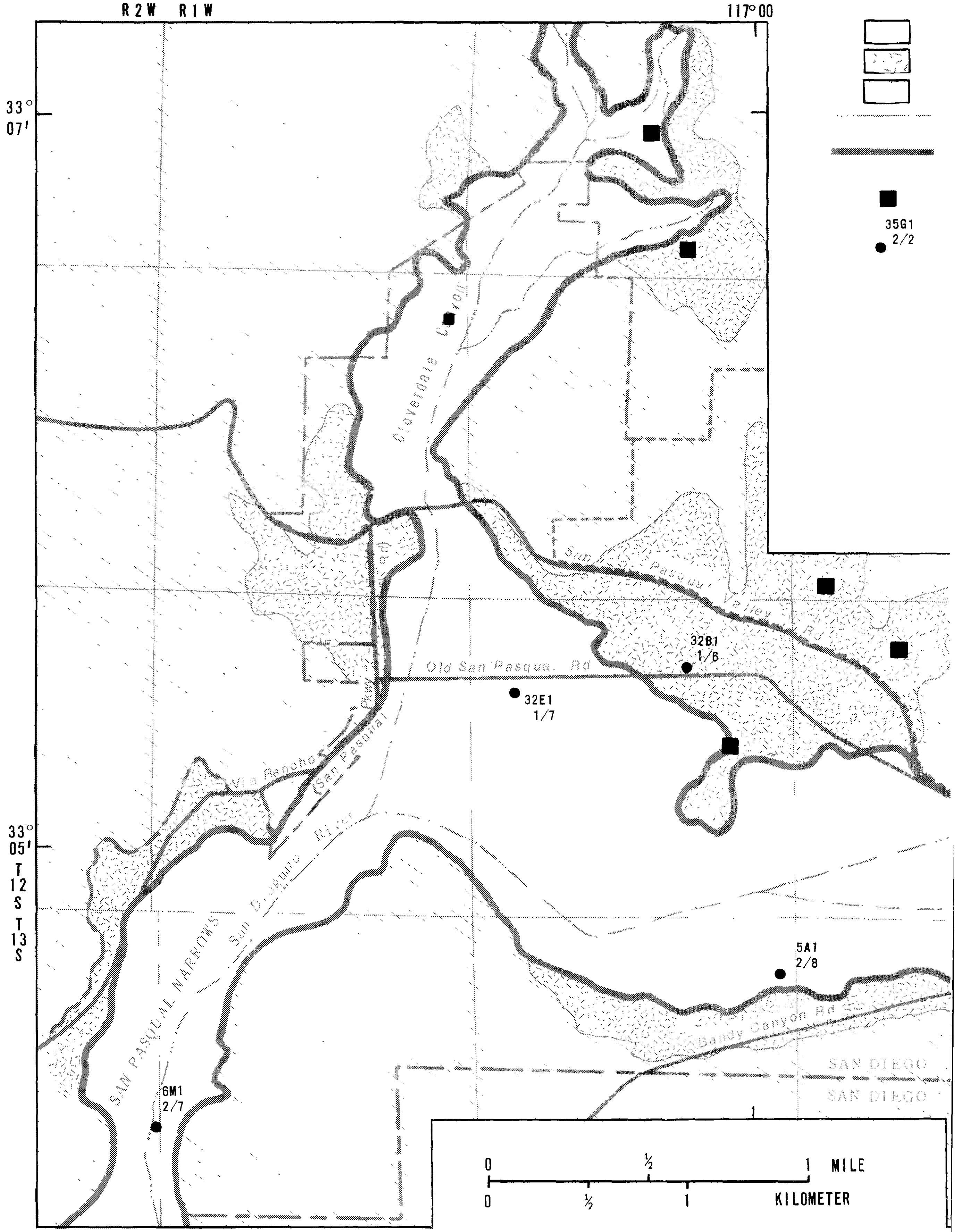
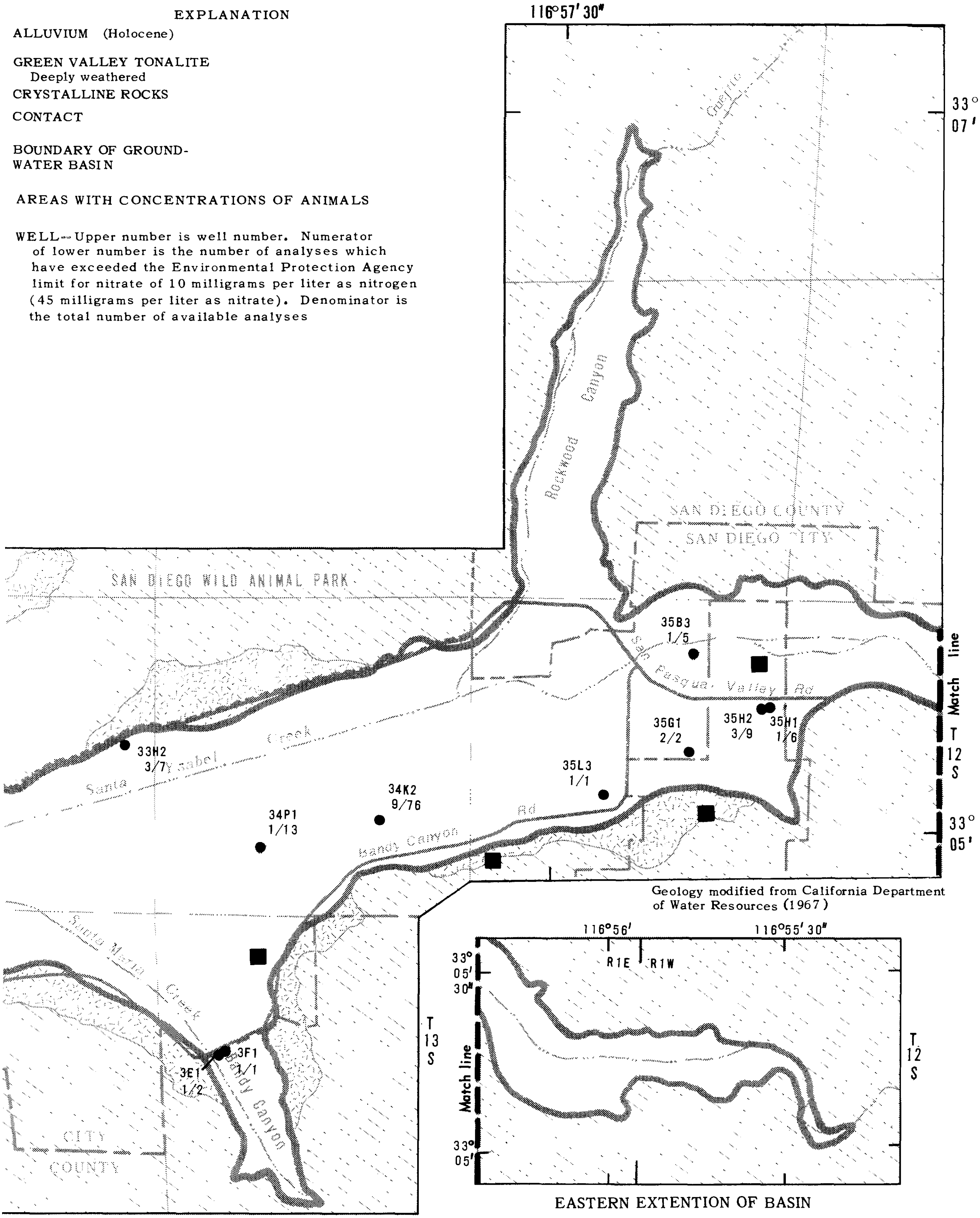


FIGURE 31.--Water quality in the San Pasqual alluvial aquifer, spring 1957.

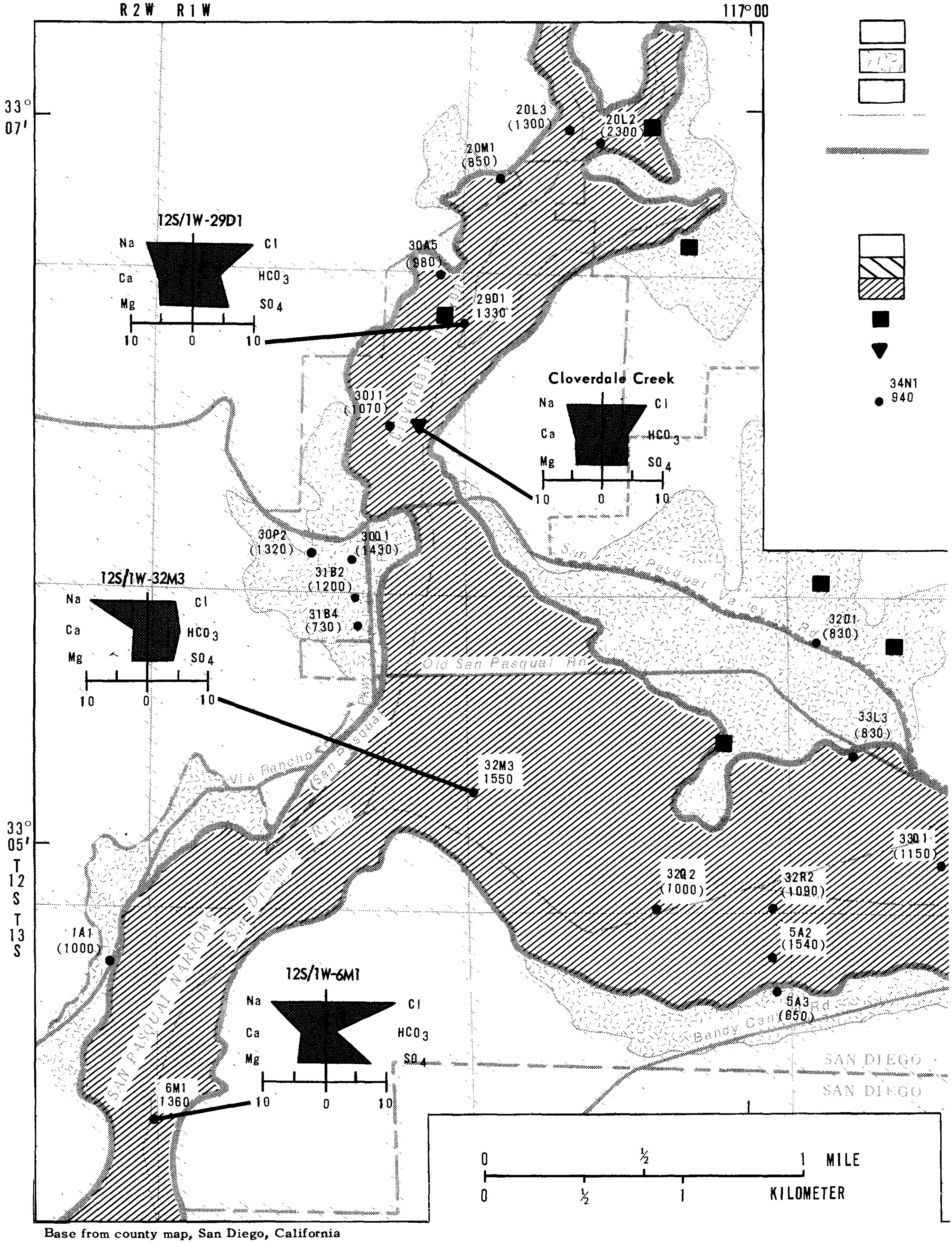


Base from county map, San Diego, California

FIGURE 32.-- Location of wells that have yielded water with



high concentrations of nitrate, San Pasqual alluvial aquifer, 1950-81.



Base from county map, San Diego, California

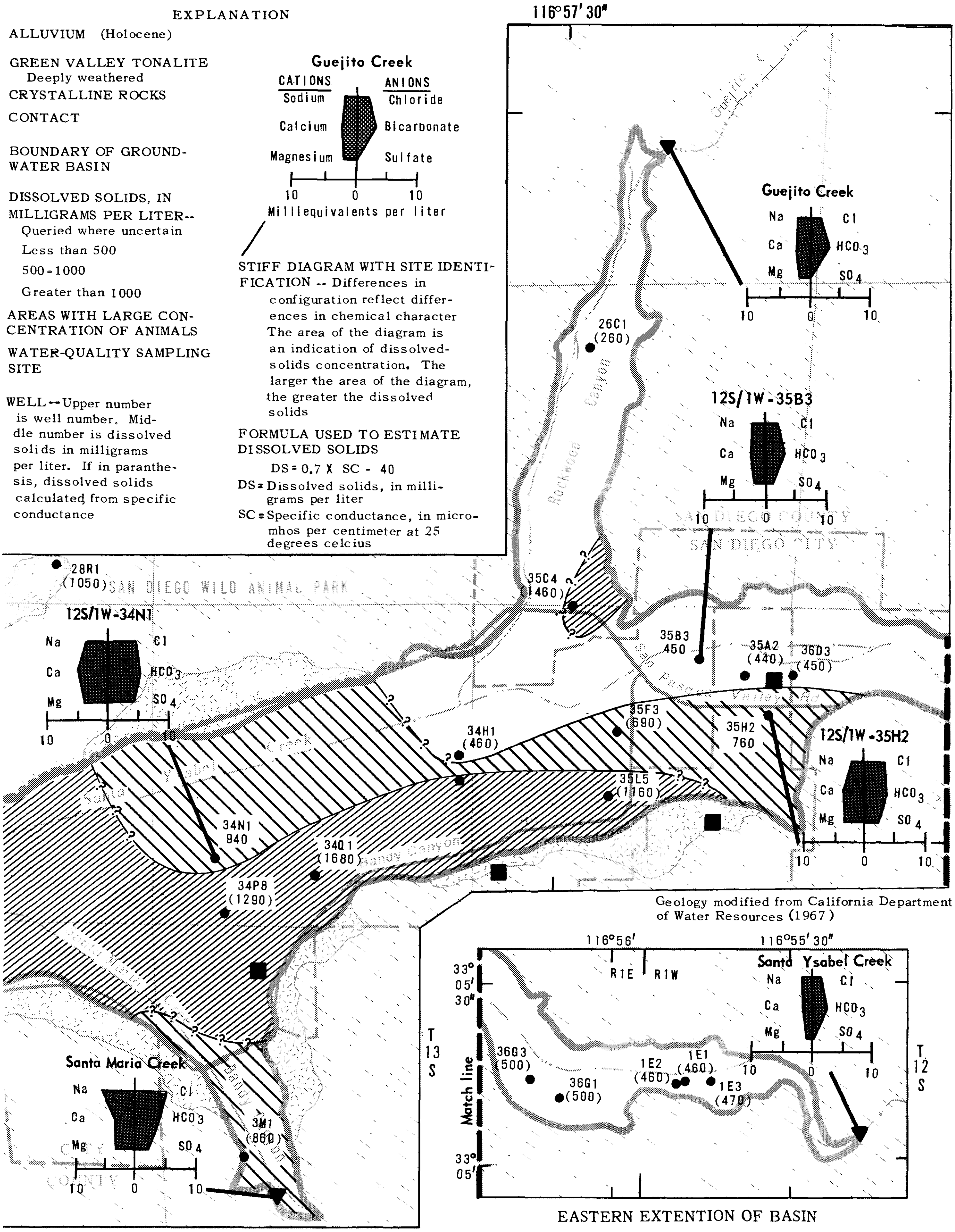


FIGURE 33.—Water quality in the San Pasqual alluvial aquifer, spring 1982.

The quality of the water in the alluvial aquifer has deteriorated since 1957. Changes in ground-water quality are evident when comparing ground-water-quality maps for 1957 and 1982 (fig. 31 and 33). During this period, dissolved-solids concentrations increased in much of the aquifer and now exceed the basin objective of 1,000 mg/L. Sulfate and chloride concentrations also increased and now exceed the EPA suggested limit of 250 mg/L for public water supplies by the time ground water leaves the subarea at San Pasqual Narrows. Ground-water types in Cloverdale Canyon and the lower part of the basin have changed and now resemble irrigation return water that comprises a significant part of the recharge. Water quality in the alluvium will probably continue to deteriorate through agricultural water use.

Changes in agricultural practices may further degrade ground-water quality. Currently, slopes surrounding the upper part of the basin are not used for agriculture. However, many of these slopes, particularly in the neighborhood of Bandy and Rockwood Canyons and the northeastern edge of the upper basin, are being converted to avocado groves and are being irrigated with imported water. Springs and seeps below these groves now flow year round and ground-water quality in the Rockwood Canyon area has already been affected (fig. 33). If this trend continues, water quality throughout the alluvial aquifer may deteriorate and begin to resemble ground-water quality now found in Cloverdale Canyon.

Further development of surface-water resources along Santa Ysabel Creek at Palmo Dam may affect the quantity of recharge available to the alluvial aquifer, particularly during dry years. This may affect water quality and ground-water movement in the upper part of the basin.

Reclaimed Water Quality

Reclaimed water will be secondary treated sewage effluent from the Hale Avenue Wastewater Treatment Plant in Escondido. Reclaimed water has an average dissolved-solids concentration ranging from 650 to 950 mg/L, and is a sodium chloride type, chemically resembling imported water rather than native ground water (California Department of Water Resources, 1983). Nitrate concentrations in the reclaimed water would not exceed EPA limits of 10 mg/L as nitrogen (45 mg/L as nitrate) (Larry Michaels, San Diego County Water Authority, oral commun., 1982).

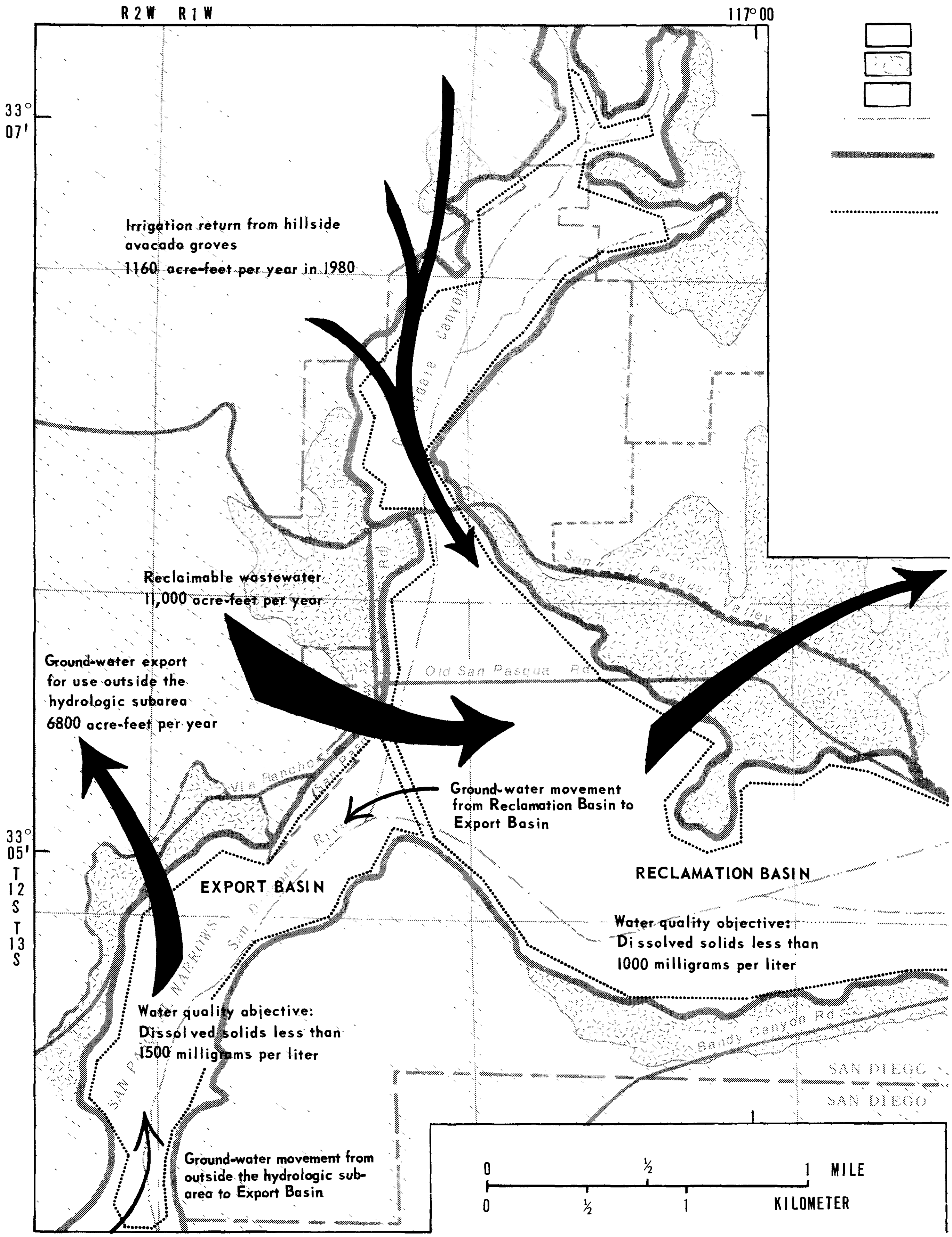
Reclaimed Water Use Plans

Use of reclaimed water in upland areas surrounding Cloverdale Canyon and the lower part of the basin as a substitute for irrigation with imported water has been proposed by the California Department of Water Resources (1983). Upland soils may be suitable for reclaimed water use if application rates and techniques are selected on a site-specific basis so that shallow circulation and discharge of water to surface seeps can be avoided. In many upland areas where reclaimed water use is possible, the underlying residual aquifer has already been impacted by agricultural irrigation return and would not be further degraded by applications of reclaimed water unless application techniques are used that allow evaporative and transpirative concentration to become excessive.

Reclaimed water applied to upland areas in the San Pasqual hydrologic subarea will eventually enter the alluvial aquifer.

Current reclaimed water use plans for the alluvial aquifer, proposed by the San Diego County Water Authority, divide the aquifer into three subareas (fig. 34) (Larry Michaels, San Diego County Water Authority, written commun., 1982). The upper part of the basin will not receive reclaimed water. The lower basin will be managed as a reclamation basin and will receive large quantities (up to 11,000 acre-ft/yr) of reclaimed water. San Pasqual Narrows will be managed as an export basin. Ground-water discharge through the narrows will be intercepted and exported for use outside the hydrologic subarea to prevent reclaimed water from entering Lake Hodges, a public water-supply reservoir.

Objectives of this management plan are to obtain ground water having dissolved-solids concentrations less than 1,000 mg/L in the lower part of the basin. The plan also tries to maintain high ground-water quality in the upper part of the basin. Irrigation return water from Cloverdale Canyon and hills along the western edge of the lower basin, and possible future reclaimed water use in those areas will be important considerations in successful management.



Base from county map, San Diego, California

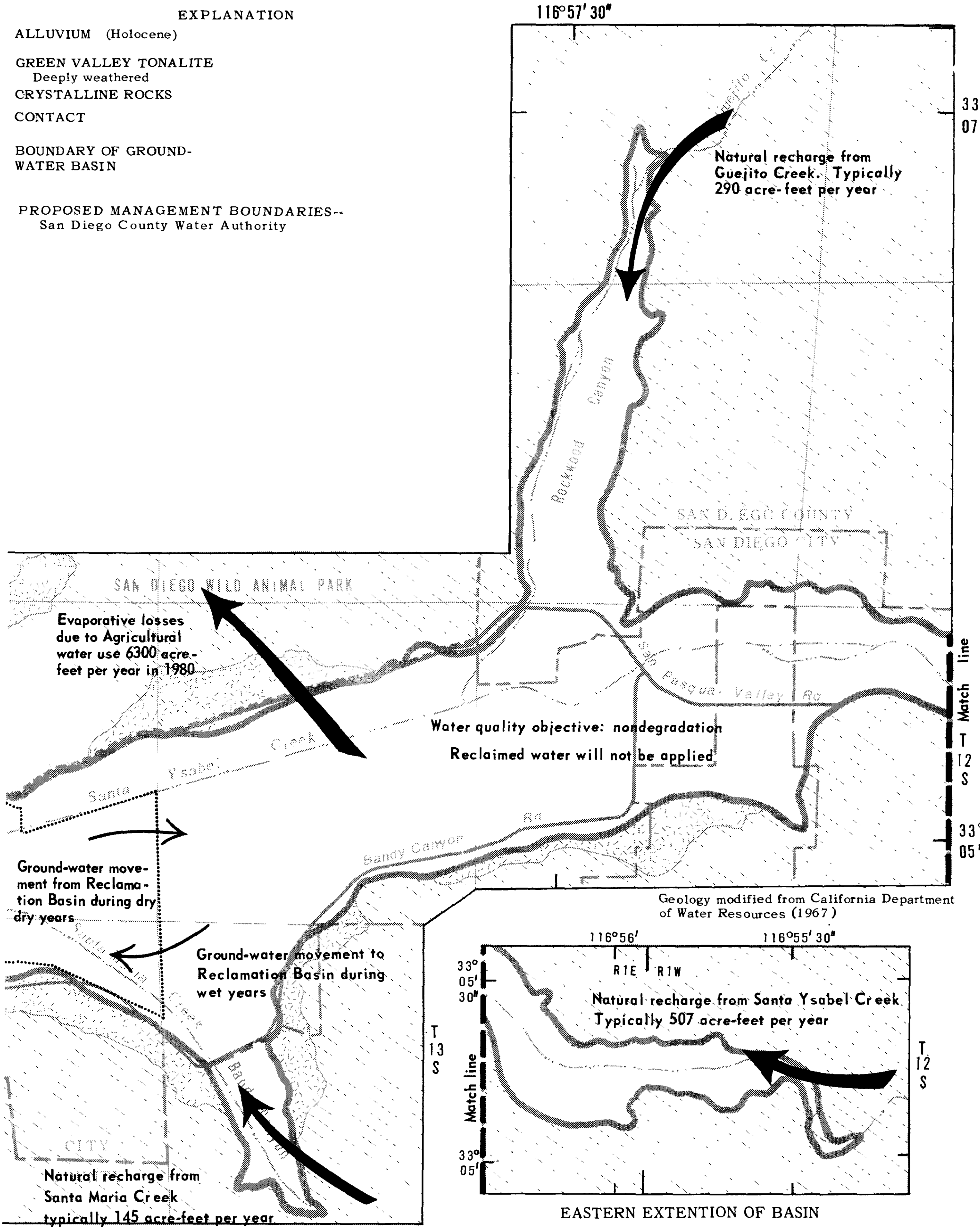


FIGURE 34.--A possible reclaimed water management plan for the San Pasqual alluvial aquifer.

In 1982, water levels in the alluvial aquifer were near land surface and little additional storage capacity was available for reclaimed water. If reclaimed water is applied during a wet cycle when ground-water levels are high, waterlogging of the soil and surface runoff could occur. To combat this problem, the reclaimed water use plan proposes to lower water levels by pumping ground water presently stored in the lower part of the basin. This water would then be exported for use outside the hydrologic subarea. Ground water presently in storage has dissolved-solids concentrations greater than 1,000 mg/L. Under current management proposals, this water would be replaced by reclaimed water with dissolved-solids concentrations between 650 and 950 mg/L. Therefore, transfer of ground water from the hydrologic subarea also represents a net transfer of dissolved solids. Water quality, with respect to dissolved solids, may improve with time. Salt-balance calculations by the San Diego County Water Authority indicate dissolved-solids concentrations may be reduced to below 1,000 mg/L (Larry Michaels, San Diego County Water Authority, 1982).

Because storage in the alluvial aquifer is small (58,000 acre-ft) when compared to the maximum annual streamflow into the subarea of 110,000 acre-ft[2], the alluvial aquifer could fill in one rainy season (as it did in 1978), and despite intensive management efforts, there may not always be sufficient storage available to accept reclaimed water. Reclaimed water use would have to be adjusted accordingly.

In dry years such as 1977, there would be ample available storage in the lower part of the basin to accept reclaimed water (fig. 27). However, during dry periods, ground-water levels would be low throughout the entire aquifer except where reclaimed water is being applied. Applied water would create a local ground-water high, with some reclaimed water flowing to the export area in San Pasqual Narrows and some flowing to the upper part of the basin. Because ground-water movement is slow, only a small potential exists for reclaimed water to move from the reclamation basin to the upper part of the basin where it could contaminate potable water supplies, except during periods of extended drought. During drought periods, movement of reclaimed water and ground-water quality could be monitored to protect water quality in the upper part of the basin.

The current reclaimed water use plan proposed by the San Diego County Water Authority does not incorporate changes in land use practices and surface-water development which may alter the hydrologic system. However, changes in water quality will occur with or without reclaimed water use and reclaimed water may act to partly alleviate future water-quality problems.

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[2]Calculated as the sum of maximum measured annual recharge from Santa Ysabel, Guejito, and Santa Maria Creeks (table 7).

SUMMARY

Reclaimed water could be used to augment water supplies in the San Diego area. Of the three hydrologic subareas studied, San Elijo has the least opportunities for reclaimed water use, and San Pasqual the most. The San Dieguito hydrologic subarea has possibilities for reclaimed water use, but presents several difficulties to effective implementation of reclaimed water use plans.

In the San Dieguito hydrologic subarea the greatest possibility for reclaimed water use is in the alluvial aquifer (52,000 acre-ft of storage). Ground-water quality within the alluvium has deteriorated as a result of seawater intrusion, intrusion of ground water from surrounding marine sedimentary rock, and changes in natural recharge patterns. Currently, the aquifer is of limited value as a water supply, and dissolved-solids concentrations typically exceed the basin objective of 1,000 mg/L and may exceed 5,000 mg/L. Application of large quantities of reclaimed water may, in time, improve water quality within the aquifer and increase its usefulness.

During dry years, considerable storage would be available to accept reclaimed water. During wet years when recharge is available from the San Dieguito River, ground-water levels and storage would have to be manipulated to avoid waterlogging of soils and surface runoff of applied reclaimed water. If ground-water levels are lowered below sea level, seawater intrusion would have to be controlled. It will not be possible to eliminate intrusion of ground water from surrounding marine sedimentary rock.

Limited use of reclaimed water may be made in upland areas of the San Dieguito hydrologic subarea.

Reclaimed water use possibilities in the San Elijo hydrologic subarea are confined primarily to upland areas of the Pacific Coastal Plain having deep soils, high infiltration rates, and a gently rolling topography. In some areas reclaimed water applied to upland areas may enter the alluvial aquifer.

The alluvium within the San Elijo hydrologic subarea is not a water-supply source and presently is of limited value because of water-quality problems. Dissolved-solids concentrations exceed the basin objective of 1,000 mg/L, and concentrations of chloride and sulfate are greater than EPA drinking water standards of 250 mg/L. Reclaimed water use is undesirable because ground-water levels are at or near land surface much of the year. The small storage within the alluvium (8,500 acre-ft) would probably prohibit extensive manipulation of ground-water levels and available storage.

Reclaimed water use possibilities within the San Pasqual hydrologic subarea are greatest in the alluvial aquifer. Alluvial fill attains a maximum thickness of slightly over 200 feet and ground-water storage is approximately 58,000 acre-ft. Ground-water quality in the alluvium has deteriorated in recent years due to agricultural water use. In 1982 the dissolved-solids concentration in many areas, particularly the lower part of the basin, exceeded the basin objective of 1,000 mg/L. High concentrations of nitrates (greater than 10 mg/L as N) are another water-quality problem, particularly within the upper part of the basin. Changes in land use patterns in the surrounding uplands may, in the future, cause further deterioration of ground-water quality.

During dry cycles, considerable storage would be available to accept reclaimed water. During wet years, ground-water levels and storage would have to be manipulated to avoid waterlogging of soils and surface runoff of reclaimed water. Further development of surface-water resources on Santa Ysabel Creek above the San Pasqual hydrologic subarea may affect the quantity of recharge water available to the alluvial aquifer.

Reclaimed water may be used in upland areas along the western edge of the San Pasqual hydrologic subarea. However, waterlogging, surface ponding, and shallow circulation of reclaimed water to surface seeps are problems that may be encountered. Each upland site would have to be evaluated individually to assess its suitability for reclaimed water use. Reclaimed water applied in these areas would enter the alluvial aquifer.

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APPENDIX A.--Water-quality data

Ground-water data from U.S. Geological Survey

LOCAL IDENT-I-FIER	DATE OF SAMPLE	TIME	SAM-PLING DEPTH (FEET)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
012S001W29D01S	82-04-02	1000	68.0	1950	7.1	19.0	554	300	118	63
012S001W34N01S	82-04-22	1200	--	1440	7.2	18.5	499	230	106	57
013S003W08N02S	81-10-30	1400	20.0	1750	7.6	--	437	330	53	74
	82-04-06	1100	20.0	2000	8.0	18.5	457	270	74	66
013S003W28N01S	81-10-20	1030	95.0	2000	7.1	21.0	638	420	140	70
	82-03-31	1100	95.0	2190	7.5	17.0	853	620	190	92
013S003W32R01S	81-10-22	1030	110	2250	7.0	20.5	774	510	160	91
	82-04-08	1100	110	2680	6.8	21.0	813	520	174	92
013S003W33C07S	81-10-13	1330	110	2100	7.0	21.0	576	390	130	61
	82-04-07	1300	110	2080	6.9	20.0	650	450	150	67
013S003W33F07S	81-10-13	1600	70.0	2300	6.6	20.5	887	760	210	88
013S003W33L07S	81-10-22	1600	118	2710	7.2	21.0	952	620	200	110
013S003W33L09S	82-04-19	1100	100	2400	7.3	20.5	836	510	170	100
013S004W25C01S	81-10-09	1325	17.0	7100	--	22.0	1558	1300	360	160
	82-04-07	1000	17.0	8500	7.5	14.0	1499	1200	320	170
013S004W25R01S	82-04-06	1400	23.0	5620	7.6	18.5	1499	1200	320	170
014S003W07B01S	81-10-14	1300	50.0	2870	7.3	23.0	641	350	120	83
	82-03-31	1400	50.0	3600	7.2	--	687	400	140	82
014S003W07K01S	81-10-27	1000	150	1495	8.7	20.5	92	<1.0	19	11
014S003W07K03S	82-04-15	1000	112	1890	7.5	20.5	556	360	160	38
014S004W12H01S	81-10-29	1400	90.0	27500	6.6	--	3941	3900	1100	290
	82-04-14	1300	90.0	25200	6.2	21.0	3228	3200	600	420

LOCAL IDENT- I- FIER	DATE OF SAMPLE	SODIUM, DIS- SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD- SORP- TION RATIO	POTAS- SIUM, DIS- SOLVED (MG/L AS K)	ALKA- LINITY LAB (MG/L AS CACO3)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, DIS- SOLVED (MG/L AS F)	SILICA, DIS- SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)
012S001W29D01S	82-04-02	210	45	3.9	1.5	250	340	.3	42	1250
012S001W34N01S	82-04-22	110	32	2.2	3.5	270	180	.3	38	939
013S003W08N02S	81-10-30	270	57	5.7	3.5	110	620	.3	1.9	1210
	82-04-06	230	52	4.7	3.4	190	450	.4	5.7	1170
013S003W28N01S	81-10-20	210	41	3.7	3.1	220	450	.3	33	1430
	82-03-31	240	37	3.6	4.1	230	600	.3	34	1720
013S003W32R01S	81-10-22	250	40	4.0	7.4	260	490	.3	32	1610
	82-04-08	270	41	4.2	7.8	290	510	.4	35	1790
013S003W33C07S	81-10-13	190	41	3.5	5.3	190	500	.3	21	1270
	82-04-07	210	40	3.6	6.7	200	450	.3	38	1320
013S003W33F07S	81-10-13	260	38	3.9	5.9	130	700	.1	24	1810
013S003W33L07S	81-10-22	320	41	4.6	12	330	640	.3	27	1950
013S003W33L09S	82-04-19	340	46	5.2	12	330	600	.4	28	2000
013S004W25C01S	81-10-09	1100	60	12	5.3	260	2400	1.4	33	5040
	82-04-07	1200	63	13	6.7	340	2400	1.3	37	5440
013S004W25R01S	82-04-06	600	46	6.9	2.9	280	1500	.8	13	3400
014S003W07B01S	81-10-14	500	62	8.8	9.3	290	830	.5	36	2050
	82-03-31	510	61	8.6	9.0	290	950	.6	37	2170
014S003W07K01S	81-10-27	330	87	15	9.1	250	320	.5	5.8	947
014S003W07K03S	82-04-15	180	41	3.4	4.2	200	340	.7	31	1250
014S004W12H01S	81-10-29	1600	46	11	26	1.0	17000	.2	1.7	29400
	82-04-14	3800	71	29	64	17	11000	.4	16	20000

LOCAL IDENT-I-FIER	DATE OF SAMPLE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, ORGANIC DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)
012S001W29D01S	82-04-02	1220	.020	9.2	<.060	--	.64	.070
012S001W34N01S	82-04-22	914	<.020	8.2	.120	.48	.60	.060
013S003W08N02S	81-10-30	1160	.000	.02	.480	.40	.88	.050
	82-04-06	1120	<.020	<.10	.230	.43	.66	<.020
013S003W28N01S	81-10-20	1340	.060	6.6	.090	.89	.98	.040
	82-03-31	1640	<.020	6.8	.140	.45	.59	.080
013S003W32R01S	81-10-22	1540	<.020	1.2	.070	.57	.64	.090
	82-04-08	1670	<.020	.96	.130	.32	.45	.100
013S003W33C07S	81-10-13	1150	.010	1.1	.140	.55	.69	.050
	82-04-07	1350	.020	1.3	.170	.55	.72	<.020
013S003W33F07S	81-10-13	1700	.040	6.8	.250	.95	1.2	.030
013S003W33L07S	81-10-22	1970	<.020	<.09	1.20	.50	1.7	<.020
013S003W33L09S	82-04-19	1900	<.020	.27	1.60	.50	2.1	.040
013S004W25C01S	81-10-09	4970	.030	1.6	.090	.37	.46	.020
	82-04-07	5090	<.020	.10	.130	.58	.71	.080
013S004W25R01S	82-04-06	3270	<.020	.10	.340	.50	.84	<.020
014S003W07B01S	81-10-14	2020	<.020	4.4	<.060	--	.72	<.020
	82-03-31	2240	<.020	12	.080	.51	.59	.120
014S003W07K01S	81-10-27	946	<.020	.03	1.50	.20	1.7	.200
014S003W07K03S	82-04-15	1190	<.020	5.9	.090	.62	.71	.020
014S004W12H01S	81-10-29	26700	<.020	<.10	19.0	.00	19	.050
	82-04-14	17800	<.020	<.10	8.70	.30	9.0	.170

LOCAL IDENT- I- FIER	DATE OF SAMPLE	BORON, DIS- SOLVED (UG/L AS B)	IRON, DIS- SOLVED (UG/L AS FE)	LITHIUM DIS- SOLVED (UG/L AS LI)	CARBON, ORGANIC TOTAL (MG/L AS C)
012S001W29D01S	82-04-02	--	40	10	3.3
012S001W34N01S	82-04-22	90	<9	20	1.7
013S003W08N02S	81-10-30	230	460	--	7.6
	82-04-06	240	<9	--	2.5
013S003W28N01S	81-10-20	140	94	--	4.4
	82-03-31	170	60	--	2.7
013S003W32R01S	81-10-22	160	80	--	3.5
	82-04-08	190	22	10	2.8
013S003W33C07S	81-10-13	120	2700	--	3.8
	82-04-07	150	210	10	3.0
013S003W33F07S	81-10-13	110	4100	--	3.3
013S003W33L07S	81-10-22	210	1200	--	4.4
013S003W33L09S	82-04-19	250	2400	10	3.3
013S004W25C01S	81-10-09	3600	160	--	4.5
	82-04-07	4100	3200	--	16
013S004W25R01S	82-04-06	490	8500	--	9.2
014S003W07B01S	81-10-14	450	110	--	1.7
	82-03-31	480	80	20	1.4
014S003W07K01S	81-10-27	1700	360	--	2.7
014S003W07K03S	82-04-15	250	140	80	.6
014S004W12H01S	81-10-29	2600	6600000	--	23
	82-04-14	3500	200000	70	41

Surface-water data from U.S. Geological Survey

LOCAL IDENT-I-FIER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
CLOVERDALE CREEK	82-03-25	1000	3.6	1590	7.9	15.0	444	230	92	52
SAN DIEGUITO RIVER	81-11-24	1000	--	1900	8.2	13.0	576	320	117	69
	82-03-22	1700	144	1020	8.3	17.0	310	120	60	39
SANTA YSABEL CREEK	81-11-24	1100	--	775	8.2	14.0	234	34	49	27
	82-03-24	1100	26	510	8.3	13.5	167	27	37	18
ESCONDIDO CR	81-10-08	1100	--	1990	8.2	18.5	617	320	120	77
	82-03-22	1000	9.5	1420	8.0	16.0	474	240	96	57
GUEJITO CREEK NR SAN PAS	81-11-24	1030	1.0	610	8.4	13.0	211	21	45	24
	82-03-24	1400	7.6	590	8.4	15.0	192	12	44	20
SANTA MARIA CREEK AT FEN	82-03-25	1300	13	1190	8.4	14.0	308	110	64	36

LOCAL IDENT-I-FIER	DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY LAB (MG/L AS CACO3)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
CLOVERDALE CREEK	82-03-25	140	39	2.9	15	210	250	.4	40	969
SAN DIEGUITO RIVER	81-11-24	180	40	3.3	3.3	260	260	.5	41	1200
	82-03-22	100	40	2.5	4.9	190	170	.3	26	647
SANTA YSABEL CREEK	81-11-24	69	38	2.0	2.3	200	100	.3	43	442
	82-03-24	41	34	1.4	2.4	140	61	.2	36	321
ESCONDIDO CR	81-10-08	250	46	4.4	5.1	300	370	.5	13	1370
	82-03-22	170	43	3.4	4.4	230	270	.3	36	1100
GUEJITO CREEK NR SAN PAS	81-11-24	50	33	1.5	1.9	190	72	.2	43	366
	82-03-24	49	35	1.5	1.9	180	68	.3	38	374
SANTA MARIA CREEK AT FEN	82-03-25	130	47	3.3	7.0	200	180	.3	33	734

LOCAL IDENT- I- FIER	DATE OF SAMPLE	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N)	NITRO- GEN, ORGANIC DIS- SOLVED (MG/L AS N)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N)
CLOVERDALE CREEK	82-03-25	945	6.40	.170	6.6	.440	1.4	1.9
SAN DIEGUITO RIVER	81-11-24	1140	3.70	.080	3.8	.120	.72	.84
	82-03-22	635	--	<.020	.12	<.060	--	.94
SANTA YSABEL CREEK	81-11-24	443	.23	.020	.25	.080	1.4	1.5
	82-03-24	298	--	<.020	.28	<.060	--	.51
ESCONDIDO CR	81-10-08	1330	2.20	.060	2.3	.100	.90	1.0
	82-03-22	1040	6.40	.060	6.5	.060	1.6	1.7
GUEJITO CREEK NR SAN PAS	81-11-24	367	.19	.020	.21	.080	.61	.69
	82-03-24	349	--	<.020	.52	<.060	--	.58
SANTA MARIA CREEK AT FEN	82-03-25	714	5.10	.080	5.2	<.060	--	1.5

LOCAL IDENT- I- FIER	DATE OF SAMPLE	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)	BORON, DIS- SOLVED (UG/L AS B)	IRON, DIS- SOLVED (UG/L AS FE)	CARBON, ORGANIC TOTAL (MG/L AS C)
CLOVERDALE CREEK	82-03-25	.420	130	41	9.1
SAN DIEGUITO RIVER	81-11-24	.340	160	25	5.1
	82-03-22	.040	110	10	9.0
SANTA YSABEL CREEK	81-11-24	<.020	60	15	1.9
	82-03-24	.030	40	43	4.8
ESCONDIDO CR	81-10-08	.260	210	60	--
	82-03-22	.210	170	24	8.9
GUEJITO CREEK NR SAN PAS	81-11-24	<.020	40	40	1.4
	82-03-24	.010	40	32	4.4
SANTA MARIA CREEK AT FEN	82-03-25	.570	130	20	10

Results of semiquantitative scan for trace elements

[Data from U.S. Geological Survey; <, less than]

	Well No. 13S/3W-33L9	Well No. 13S/3W-33C7
Sample date---------	04-19-82	04-07-82
Aluminum------μg/L--	<50	<50
Antimony------μg/L--	<30	<30
Barium--------μg/L--	300	70
Beryllium-----μg/L--	<1	<1
Bismuth-------μg/L--	<1,000	<1,000
Boron---------μg/L--	300	100
Cadmium-------μg/L--	<1	<1
Calcium-------mg/L--	100	100
Chromium------μg/L--	<50	<50
Cobalt--------μg/L--	30	30
Copper--------μg/L--	<10	<10
Gallium-------μg/L--	<30	<30
Germanium-----μg/L--	300	100
Iron----------μg/L--	3,000	3,000
Lead----------μg/L--	<30	<30
Lithium-------μg/L--	30	30
Magnesium-----mg/L--	100	50
Manganese-----μg/L--	1,000	1,000
Molybdenum----μg/L--	<10	<10
Nickel--------μg/L--	<50	<50
Silica--------mg/L--	30	10
Silver--------μg/L--	<10	<10
Sodium--------mg/L--	300	100
Strontium-----μg/L--	1,000	500
Tin-----------μg/L--	500	500
Titanium------μg/L--	<5	<5
Vanadium------μg/L--	<10	<10
Zinc----------μg/L--	30	300
Zirconium-----μg/L--	<5	<5

Ground-water data from city of San Diego

LOCAL IDENT- I- FIER	DATE OF SAMPLE	SAM- PLING DEPTH (FEET)	TEMPER- ATURE (DEG C)	HARD- NESS (MG/L AS CACO3)	HARD- NESS NONCAR- BONATE (MG/L AS CACO3)	CALCIUM TOTAL RECOV- ERABLE (MG/L AS CA)	MAGNE- SIUM, TOTAL RECOV- ERABLE (MG/L AS MG)	SODIUM, TOTAL RECOV- ERABLE (MG/L AS NA)	PERCENT SODIUM	SODIUM AD- SORP- TION RATIO
012S001W31J01S	77-03-07	133	--	1200	--	290	120	250	--	--
012S001W32B01S	77-03-09	--	--	126	--	31	12	96	--	--
012S001W32M03S	77-03-07	--	--	480	--	120	47	110	--	--
	80-10-07	--	22.0	320	87	70	36	120	46	3.0
	81-04-03	--	18.9	690	430	160	72	140	30	2.2
	81-08-06	--	26.2	1000	597	210	120	540	54	7.3
	81-09-29	--	22.6	210	--	33	30	200	--	--
012S001W32Q03S	77-03-09	--	--	410	--	77	52	110	--	--
012S001W33H02S	75-07-17	--	--	660	378	150	67	150	34	2.6
	75-11-04	--	--	670	358	150	71	150	34	2.6
	76-03-02	--	--	600	345	140	64	140	34	2.4
	76-05-05	--	--	640	373	150	66	140	33	2.5
	76-08-31	--	--	600	336	140	60	130	33	2.3
	80-10-07	--	22.1	610	402	150	57	97	26	1.7
	81-03-31	--	22.2	350	155	78	38	78	33	1.8
	81-09-29	--	22.7	490	262	110	52	98	31	1.9
012S001W33N01S	77-03-09	160	--	520	--	120	53	100	--	--
012S001W34K02S	75-11-04	--	--	560	194	120	61	110	30	2.0
	76-05-05	--	--	520	197	120	57	110	32	2.0
	80-10-07	--	22.0	200	180	21	36	140	63	4.5
	81-04-03	--	16.9	550	235	120	60	110	31	2.0
012S001W35B03S	76-05-05	142	--	220	69	50	22	50	35	1.7
	80-10-07	142	22.3	210	65	50	21	46	33	1.4
	81-04-03	142	17.0	250	84	57	26	54	33	1.5
	81-09-29	142	23.3	220	67	54	21	48	33	1.4
012S001W35G02S	75-11-04	75.0	--	540	194	110	62	110	32	1.1
	76-05-05	75.0	--	550	209	120	63	110	31	2.0
012S001W35H02S	75-11-04	81.0	--	440	133	100	44	76	30	14
	76-05-05	81.0	--	420	196	94	44	80	30	1.7
	80-10-07	81.0	22.0	330	141	77	33	65	31	1.6
	81-04-03	81.0	18.9	430	221	95	46	66	26	1.4
	81-09-29	--	22.7	340	146	84	33	73	32	1.7
012S001W36F01S	75-11-04	75.0	--	230	78	49	25	52	35	1.5
013S001W06M01S	75-07-12	85.0	--	550	301	110	68	170	41	3.1
	75-11-04	85.0	--	570	338	110	71	160	40	3.0
	76-03-02	85.0	--	590	409	120	68	180	40	3.2
	76-05-05	85.0	--	570	417	96	80	120	32	2.1
	76-08-31	85.0	--	520	387	90	70	160	43	3.2
	80-10-07	85.0	22.0	480	460	88	63	190	47	3.8
	81-04-03	85.0	17.3	600	585	120	70	190	41	3.4
	81-09-29	85.0	22.8	480	431	86	62	190	--	--

LOCAL IDENT- I- FIER	DATE OF SAMPLE	POTAS- SIUM, TOTAL RECOV- ERABLE (MG/L AS K)	BICAR- BONATE IT-LAB (MG-L - HCO3)	ALKA- LINITY LAB (MG/L AS CACO3)	SULFATE (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, TOTAL (MG/L AS F)	SILICA, DIS- SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L)	NITRO- GEN, NITRATE TOTAL (MG/L AS N)
012S001W31J01S	77-03-07	6.6	222	182	660	600	.4	--	2480	.11
012S001W32B01S	77-03-09	28	405	332	3.9	150	.4	--	513	.50
012S001W32M03S	77-03-07	4.1	315	258	230	190	.5	--	956	.74
	80-10-07	2.1	289	237	200	110	.4	--	684	.04
	81-04-03	4.2	320	262	420	200	.3	--	1230	.81
	81-08-06	12	516	423	800	590	.4	--	2840	36
	81-09-29	14	392	321	150	130	.3	--	750	.03
012S001W32Q03S	77-03-09	8.9	292	239	13	330	.4	--	1010	.32
012S001W33H02S	75-07-17	8.0	342	280	350	220	.3	58	1340	12
	75-11-04	5.2	376	308	370	210	.2	57	1260	9.2
	76-03-02	7.0	316	259	285	210	.4	58	1110	12
	76-05-05	5.0	331	271	320	210	.4	60	1220	13
	76-08-31	7.3	322	264	280	210	.4	53	1190	2.6
	80-10-07	3.8	251	206	310	200	.1	--	1120	6.1
	81-03-31	3.2	243	199	150	120	.3	--	672	1.7
	81-09-29	3.6	283	232	20	160	.4	--	930	2.9
012S001W33N01S	77-03-09	3.8	282	231	360	130	.4	--	999	.32
012S001W34K02S	75-11-04	5.0	447	366	150	160	.1	32	928	8.4
	76-05-05	5.2	400	329	160	150	.2	36	837	.84
	80-10-07	12	24	20	130	220	.2	--	598	1.1
	81-04-03	3.9	389	319	200	160	.2	--	941	11
012S001W35B03S	76-05-05	7.0	179	187	72	67	.3	46	414	6.8
	80-10-07	2.4	182	149	64	72	.2	--	399	2.1
	81-04-03	3.0	203	166	81	78	.2	--	441	1.4
	81-09-29	2.9	187	153	62	77	.2	--	367	1.8
012S001W35G02S	75-11-04	6.3	425	348	160	160	.2	62	1470	9.5
	76-05-05	4.3	418	343	130	160	.3	68	1130	19
012S001W35H02S	75-11-04	7.8	379	311	130	120	.2	32	772	8.6
	76-05-05	6.5	273	224	110	120	.2	56	794	10
	80-10-07	2.7	228	187	95	110	.0	--	608	8.1
	81-04-03	4.5	245	207	130	130	.2	--	734	14
	81-09-29	3.7	232	190	110	120	.6	--	704	10
012S001W36F01S	75-11-04	5.6	183	150	76	66	.1	27	555	6.5
013S001W06M01S	75-07-12	13	309	253	320	260	.1	6.0	1310	21
	75-11-04	12	278	228	300	270	.1	5.5	1270	9.5
	76-03-02	6.0	218	179	300	270	.3	7.2	1380	34
	76-05-05	15	189	155	310	270	.3	1.4	1310	3.5
	76-08-31	18	157	130	400	270	.2	4.9	1320	2.9
	80-10-07	9.1	29	24	400	350	<.1	--	1210	2.3
	81-04-03	9.0	18	15	460	380	.0	--	1350	1.2
	81-09-29	9.9	55	45	350	380	<.1	--	1340	1.9

LOCAL IDENT- I- FIER	DATE OF SAMPLE	ALUM- INUM, TOTAL RECOV- ERABLE (UG/L AS AL)	ARSENIC TOTAL (UG/L AS AS)	BORON, TOTAL RECOV- ERABLE (UG/L AS B)	CADMIUM TOTAL RECOV- ERABLE (UG/L AS CD)	CHRO- MIUM, TOTAL RECOV- ERABLE (UG/L AS CR)	COPPER, TOTAL RECOV- ERABLE (UG/L AS CU)	IRON, TOTAL RECOV- ERABLE (UG/L AS FE)	MANGA- NESE, TOTAL RECOV- ERABLE (UG/L AS MN)
012S001W31J01S	77-03-07	<10	--	--	--	--	--	180	3600
012S001W32B01S	77-03-09	10	--	--	--	--	--	2200	1400
012S001W32M03S	77-03-07	<10	--	--	--	--	--	50	1200
	80-10-07	--	3	--	4	<20	46	4500	1200
	81-04-03	--	<2	--	<3	<20	<10	470	2000
	81-08-06	--	<2	--	<3	<20	12	430	16
	81-09-29	--	<2	--	<3	<20	13	4400	40
012S001W32Q03S	77-03-09	20	--	--	--	--	--	1400	1800
012S001W33H02S	75-07-17	<10	--	--	<3	<20	<10	20	30
	75-11-04	<10	--	--	<3	<20	<10	60	<10
	76-03-02	<10	--	--	5	<20	<10	140	20
	76-05-05	<10	--	--	3	--	--	70	<10
	76-08-31	<10	--	--	<3	<20	<10	50	<10
	80-10-07	--	<2	--	<3	<20	14	160	40
	81-03-31	--	<2	--	<3	<20	<10	10	220
	81-09-29	--	<2	--	3	<20	<10	20	240
012S001W33N01S	77-03-09	<10	--	--	--	--	--	280	40
012S001W34K02S	75-11-04	<10	--	--	5	<20	<10	120	210
	76-05-05	<10	--	<10	<3	--	--	170	5
	80-10-07	--	7	--	<3	<20	24	4000	1200
	81-04-03	--	6	--	<3	<20	6	80	250
012S001W35B03S	76-05-05	<10	--	<10	<3	--	--	60	20
	80-10-07	--	3	--	<3	<20	<10	190	102
	81-04-03	--	5	--	<3	<20	20	190	20
	81-09-29	--	<2	--	<3	<20	6	<10	10
012S001W35G02S	75-11-04	<10	--	80	<3	<20	<10	490	40
	76-05-05	<10	--	120	<3	--	--	390	<10
012S001W35H02S	75-11-04	<10	--	30	<3	<20	<10	140	20
	76-05-05	<10	--	--	<3	--	--	150	8
	80-10-07	--	4	--	4	<20	22	3200	40
	81-04-03	--	5	--	<3	<20	10	540	130
	81-09-29	--	2	--	<3	<20	<10	1400	20
012S001W36F01S	75-11-04	<10	--	70	<3	<20	<10	400	20
013S001W06M01S	75-07-12	<10	--	--	<3	<20	41	230	1100
	75-11-04	<10	--	--	<3	<20	<10	820	350
	76-03-02	<10	--	--	6	<20	<10	2400	480
	76-05-05	20	--	30	15	--	--	3600	920
	76-08-31	<10	--	70	<3	<20	<10	3300	400
	80-10-07	--	8	--	4	<20	31	3700	270
	81-04-03	--	9	--	<3	<20	10	4100	<0
	81-09-29	--	<2	--	<3	<20	8	4800	420

LOCAL IDENT- I- FIER	DATE OF SAMPLE	MERCURY TOTAL RECOV- ERABLE (UG/L AS HG)	SELE- NIUM, TOTAL (UG/L AS SE)	ZINC, TOTAL RECOV- ERABLE (UG/L AS ZN)	METHY- LENE BLUE ACTIVE SUB- STANCE (MG/L)
012S001W31J01S	77-03-07	--	--	--	--
012S001W32B01S	77-03-09	--	--	--	--
012S001W32M03S	77-03-07	--	--	--	--
	80-10-07	<.2	<1	990	.11
	81-04-03	<.2	2	20	.08
	81-08-06	.3	11	20	<.01
	81-09-29	<.2	4	20	.08
012S001W32Q03S	77-03-09	--	--	--	--
012S001W33H02S	75-07-17	--	--	10	.14
	75-11-04	--	--	<10	.09
	76-03-02	--	--	80	.08
	76-05-05	--	--	--	.10
	76-08-31	--	--	40	.12
	80-10-07	.4	5	70	.10
	81-03-31	<.2	<1	230	.06
	81-09-29	<.2	17	210	.10
012S001W33N01S	77-03-09	--	--	--	--
012S001W34K02S	75-11-04	--	--	<10	.16
	76-05-05	--	--	--	.10
	80-10-07	<.2	6	80	.07
	81-04-03	<.2	57	<10	.16
012S001W35B03S	76-05-05	--	--	--	.14
	80-10-07	<.2	2	<10	.14
	81-04-03	<.1	8	40	.10
	81-09-29	<.2	3	<10	.14
012S001W35G02S	75-11-04	--	--	<10	.17
	76-05-05	--	--	--	.08
012S001W35H02S	75-11-04	--	--	<10	.13
	76-05-05	--	--	--	.16
	80-10-07	.4	5	50	.10
	81-04-03	<.2	7	40	.08
	81-09-29	.3	8	20	.01
012S001W36F01S	75-11-04	--	--	<10	.10
013S001W06M01S	75-07-12	--	--	<10	.08
	75-11-04	--	--	50	.13
	76-03-02	--	--	20	.08
	76-05-05	--	--	--	.14
	76-08-31	--	--	20	.17
	80-10-07	<.2	<1	60	.12
	81-04-03	<.2	<1	10	.10
	81-09-29	<.2	4	20	.13

APPENDIX B.--Public water supply criteria

[Data from McKee and Wolf, 1963; National Academy of Sciences, National Academy of Engineering, 1973; U.S. Environmental Protection Agency, 1976]

	Maximum concentration (mg/L)	Maximum concentration (µg/L)
Arsenic (As)	--	50
Barium (Ba)	1	--
Boron (B)	--	750
Cadmium (Cd)	--	10
Chloride (Cl)	250	--
Chromium (Cr+6)	--	50
Copper (Cu)	1	--
Cyanide (CN)	.2	--
Dissolved solids	500	--
Fluoride (F)	[1]1.4 to 2.4	--
Hardness	300	--
Iron (Fe)	.3	--
Lead (Pb)	--	50
Manganese (Mn)	--	50
Mercury (Hg)	--	2
Nitrate-Nitrogen (N)	10	--
Nitrate (NO_3)	45	--
Selenium (Se)	--	10
Specific conductance	[2]800	--
Sulfate (SO_4)	250	--
Zinc (Zn)	5	--

[1]Depends on annual average of maximum daily air temperature.

[2]Specific conductance reported in micromhos per centimeter at 25 degrees Celsius.

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Lindavista Formation (Pleistocene) and La Jolla Group (Eocene)

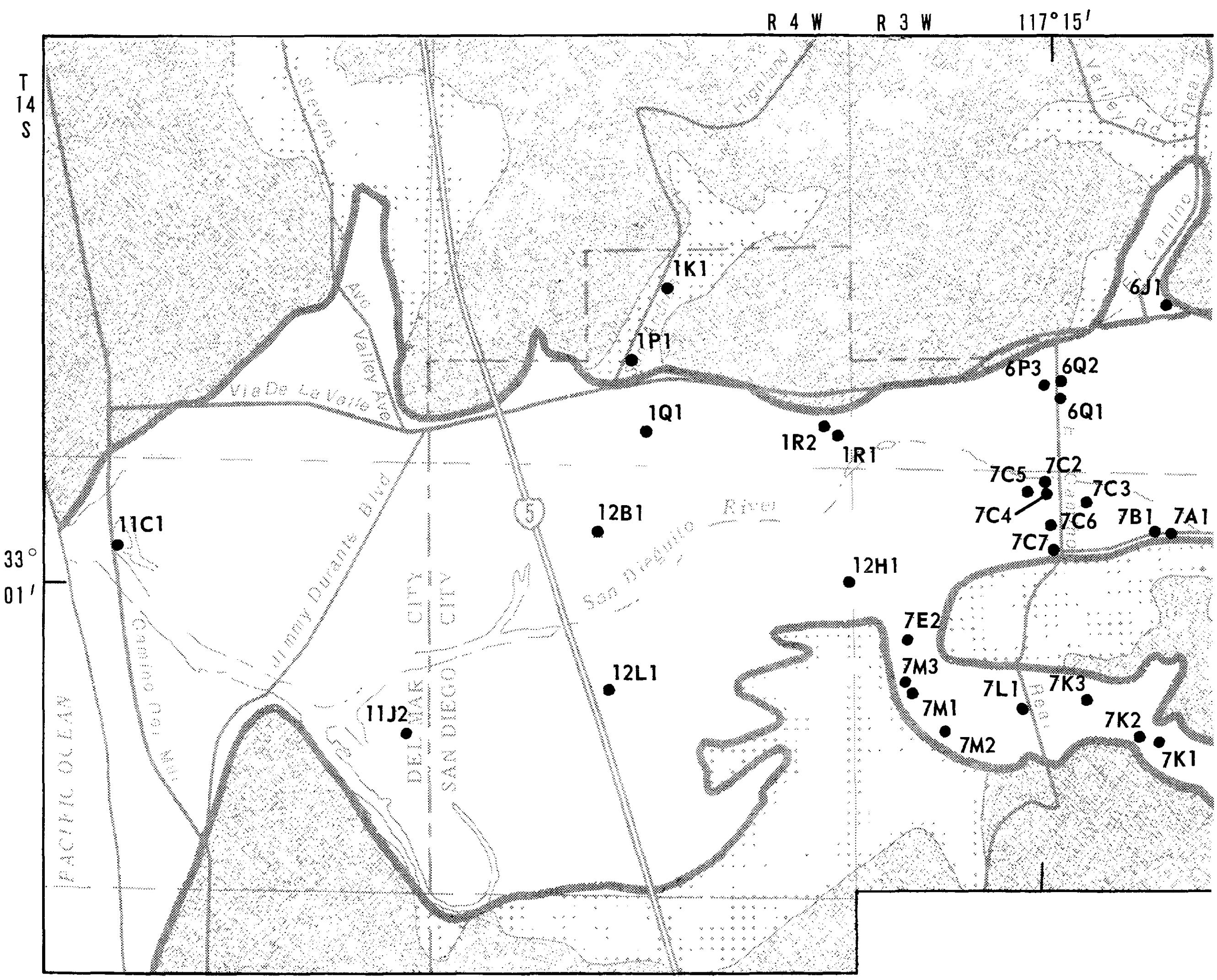
LUSARDI FORMATION (Late Cretaceous)

SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

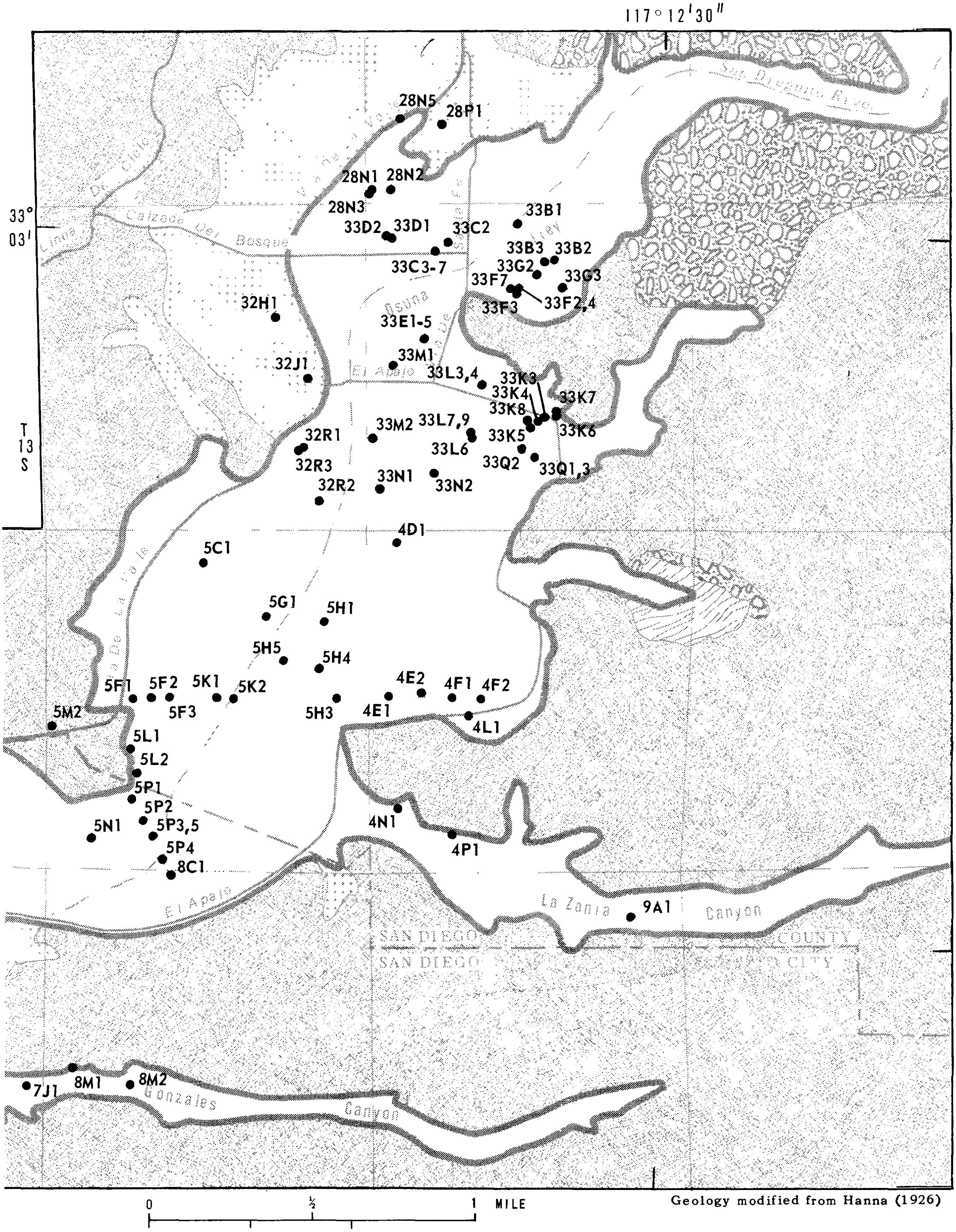
CONTACT

BOUNDARY OF GROUND-WATER BASIN

•5C1 WELL AND NUMBER



Base from county map, San Diego, California



APPENDIX C.--Location of wells in the San Dieguito alluvial aquifer.

EXPLANATION

ALLUVIUM (Holocene)

OLDER ALLUVIUM (Pleistocene)

MARINE SEDIMENTS--Primarily unnamed marine terrace deposits (Pleistocene), Linda Vista Formation (Pleistocene) and La Jolla Group (Eocene)

LUSARDI FORMATION (Late Cretaceous)

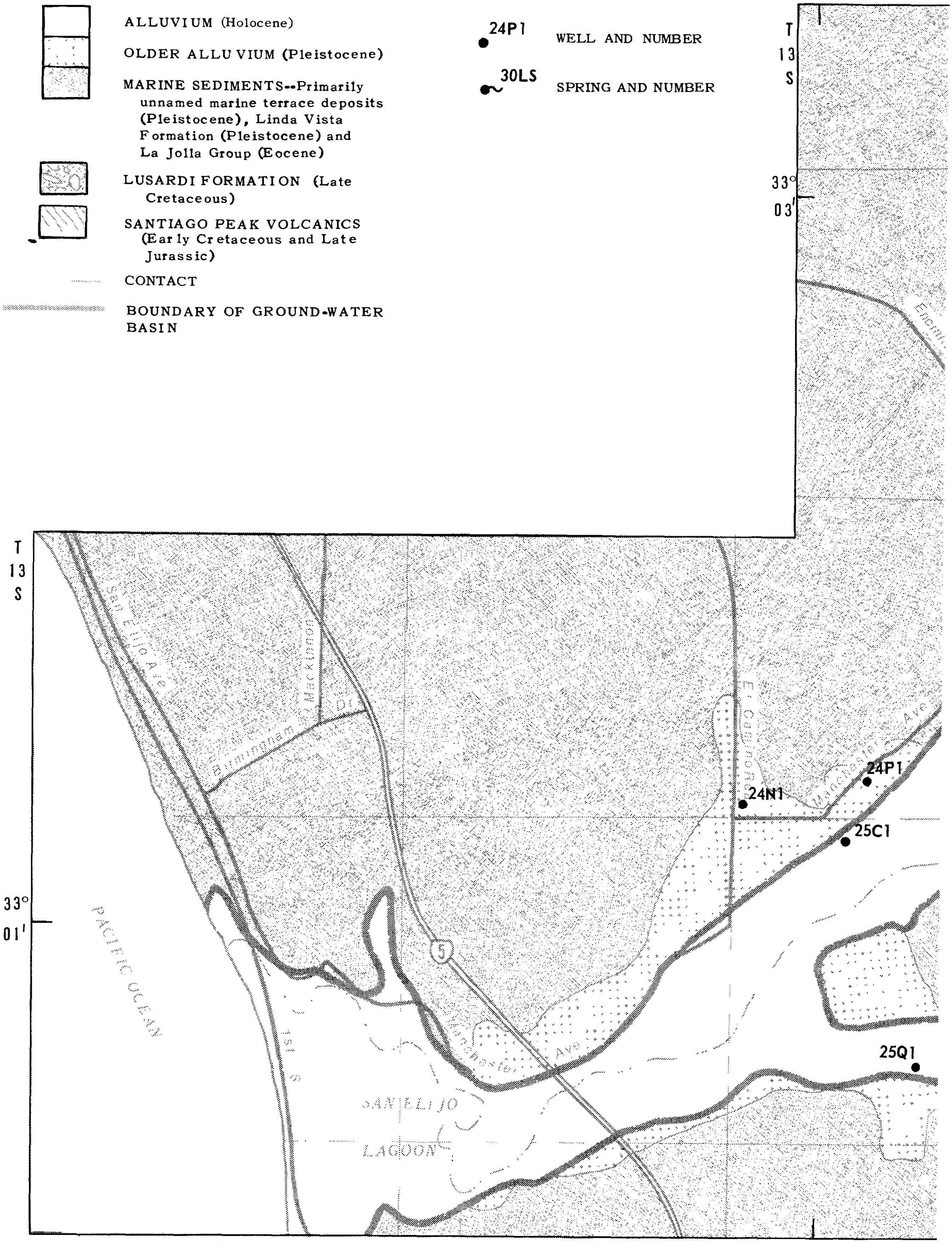
SANTIAGO PEAK VOLCANICS (Early Cretaceous and Late Jurassic)

CONTACT

BOUNDARY OF GROUND-WATER BASIN

24P1 WELL AND NUMBER

30LS SPRING AND NUMBER



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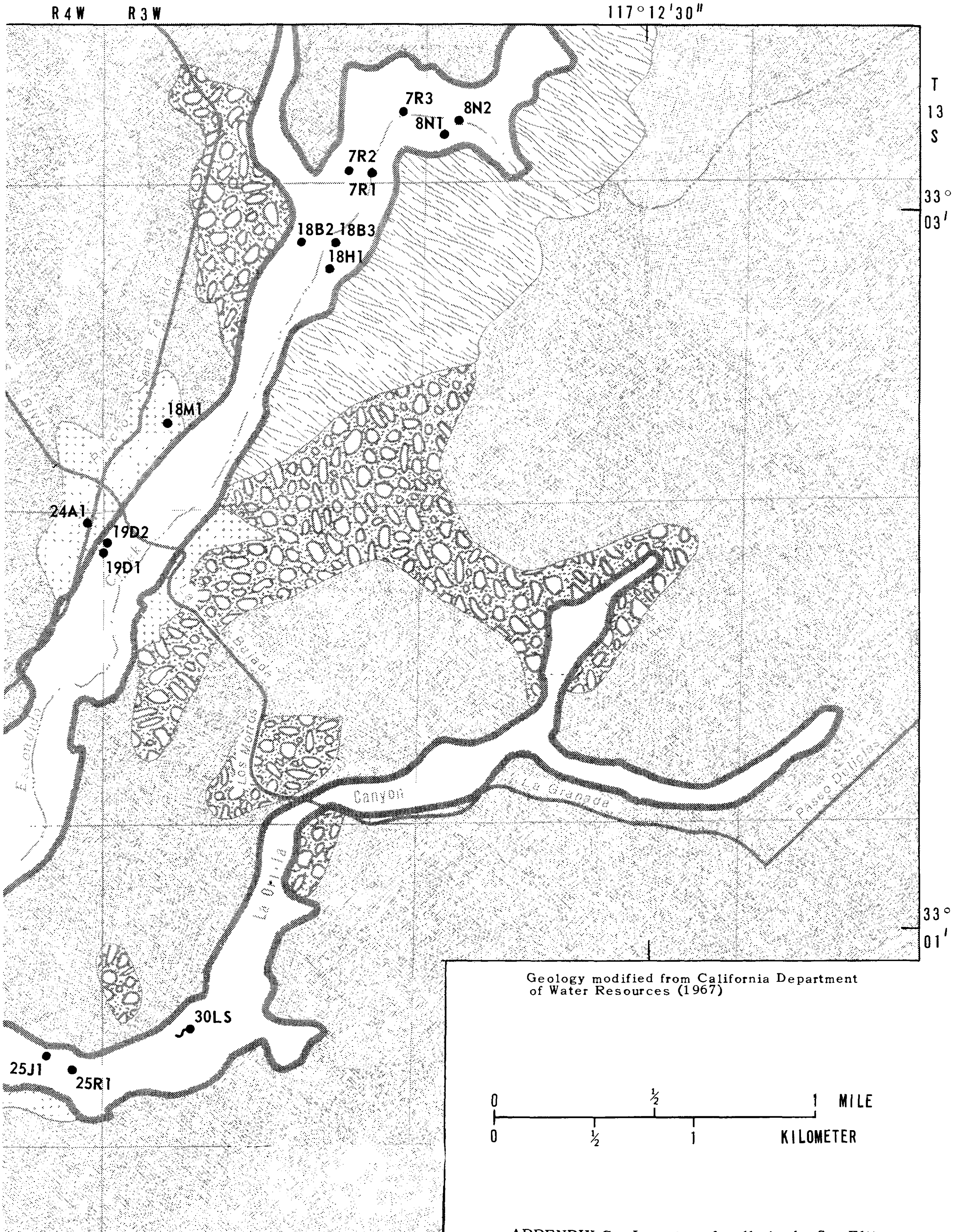
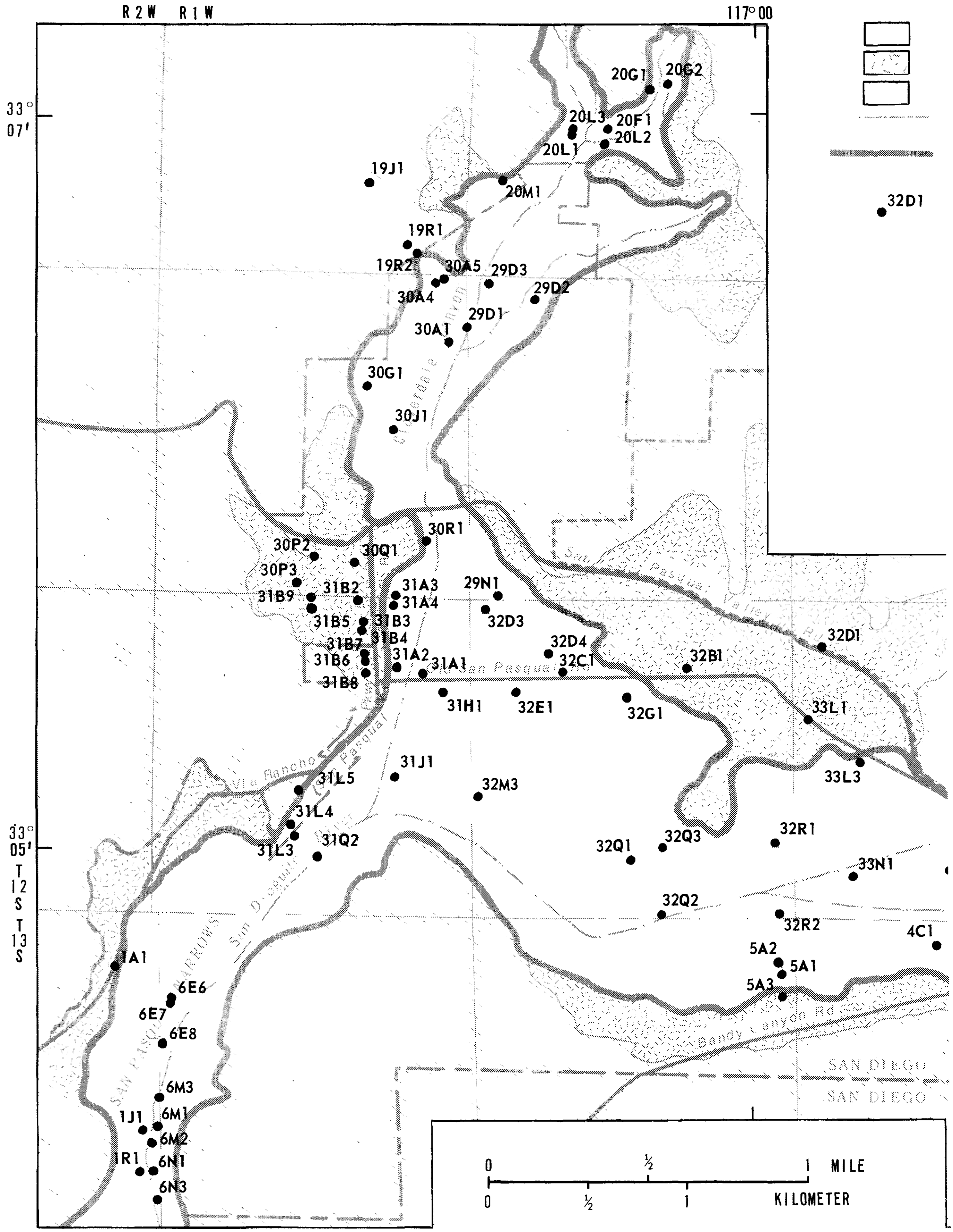
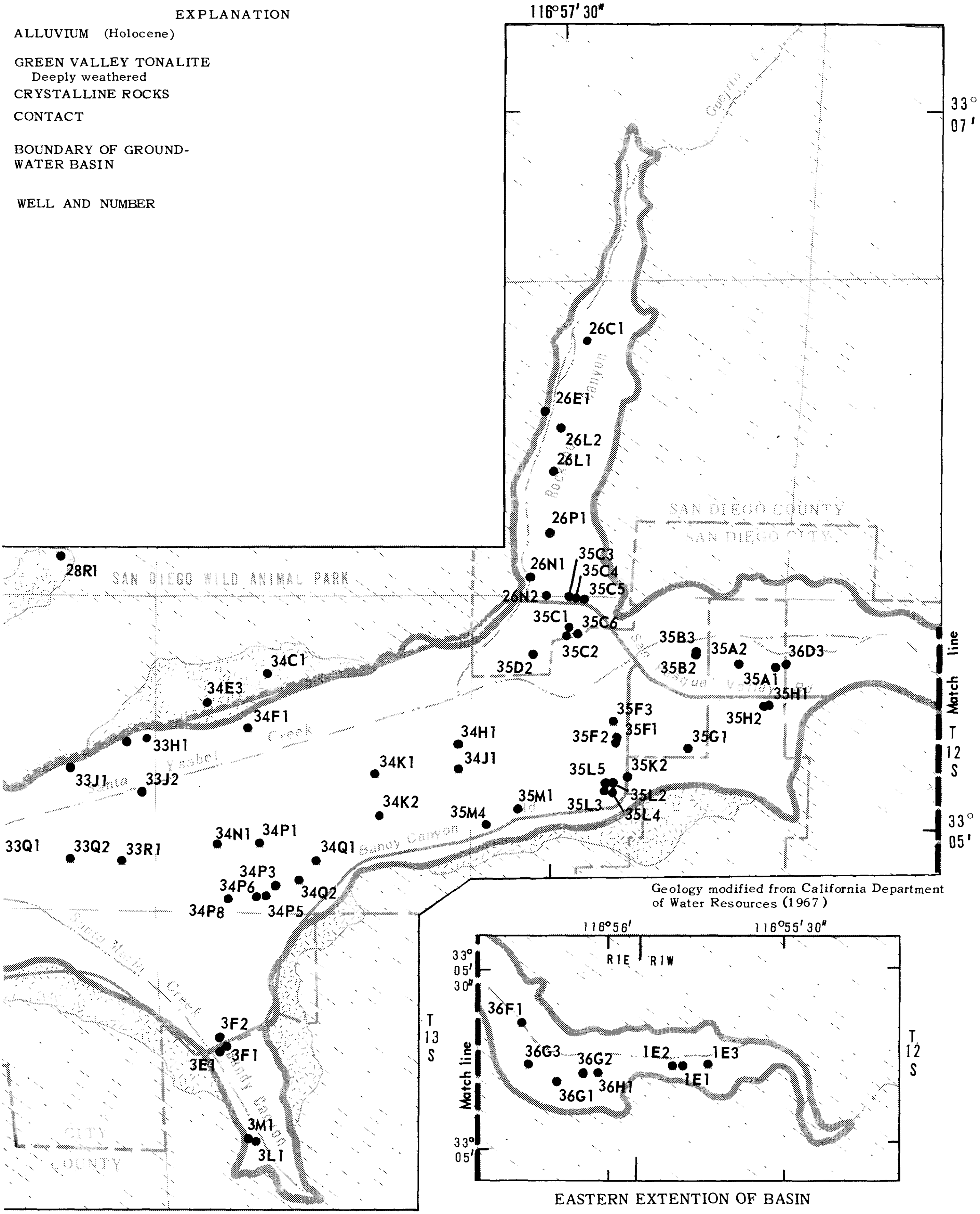


APPENDIX C.—Location of wells in the San Elijo alluvial aquifer.



Base from county map, San Diego, California



APPENDIX C.--Location of wells in the San Pasqual alluvial aquifer.