

APPRAISAL OF GROUND-WATER RESOURCES IN THE SAN ANTONIO CREEK VALLEY,
SANTA BARBARA COUNTY, CALIFORNIA

By C. B. Hutchinson

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric units, the conversion factors for the terms used in this report are listed below:

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
acre	0.004047	km ² (square kilometer)
acre-ft (acre-foot)	1234	m ³ (cubic meter)
acre-ft/yr (acre-foot per year)	1234	m ³ /yr (cubic meter per year)
ft (foot)	0.3048	m (meter)
(ft/d)/ft (foot per day per foot)	0.3048	(m/d)/m (meter per day per meter)
ft ² /d (foot squared per day)	0.09290	m ² /d (meter squared per day)
ft ³ /s (cubic foot per second)	28.32	L/s (liter per second)
ft/mi (foot per mile)	0.1894	m/km (meter per kilometer)
gal/min (gallon per minute)	0.06309	L/s (liter per second)
Mgal/d (million gallons per day)	0.04381	m ³ /s (cubic meter per second)
in (inch)	25.4	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi ² (square mile)	2.589	km ² (square kilometer)
mi ³ (cubic mile)	4.166	km ³ (cubic kilometer)

Degree Fahrenheit (°F) is converted to degree Celsius (°C) by using the formula: °C = (°F - 32)/1.8.

Abbreviations Used

mg/L - milligram per liter

µg/L - microgram per liter

µmho/cm - micromho per centimeter

National Geodetic Vertical Datum of 1929 is a geodetic datum derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts and as such does not necessarily represent local mean sea level at any particular place. To establish a more precise nomenclature, the term "NGVD of 1929" is used in place of "Sea Level Datum of 1929" or "mean sea level."

APPRAISAL OF GROUND-WATER RESOURCES IN THE SAN ANTONIO CREEK VALLEY,
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ABSTRACT

The adequacy of the ground-water supply in the 154-square mile San Antonio Creek valley is a concern of agricultural, military, municipal, and domestic users. A nearly threefold increase in demand for water during the period 1958-77 has increased the potential for overdraft on the ground-water basin. The hydrologic budget for this period showed a perennial yield of about 9,800 acre-feet per year and an annual ground-water discharge of about 11,400 acre-feet per year, comprising net pumpage of 7,100 acre-feet, phreatophyte evapotranspiration of 3,000 acre-feet, and base streamflow of 1,300 acre-feet. The base flow in San Antonio Creek could diminish to zero when net pumpage reaches 13,500 acre-feet per year. The environmentally sensitive marshland area of Barka Slough may then become stressed as water normally lost through evapotranspiration is captured by pumpage.

The aquifer consists of alluvial valley fill that ranges in thickness from 0 to 3,500 feet, covering an area of 110 square miles. Ground water moves seaward from recharge areas along mountain fronts to a consolidated-rock barrier about 5 miles east of the Pacific coast. Upwelling of ground water just east of the barrier has resulted in the 550-acre Barka

Slough. Transmissivity of the aquifer, computed from pumping tests, ranges from 2,600 to 34,000 feet squared per day, with the lowest values occurring in the central part of the valley where the aquifer is thickest but probably finer grained.

For analytical purposes, the average transmissivity of the basin east of Barka Slough was considered to be 10,000 feet squared per day. With average values of transmissivity, storage coefficient, and leakance factor assigned to the conceptual model, an analysis of the impact of overdraft on the ground-water basin can be made.

The average dissolved-solids concentration in the ground water east of the barrier is 710 milligrams per liter, and in the agricultural parts of the valley, also east of the barrier, salinity problems are increasing. West of the barrier, stream and ground-water quality is poor, owing to seepage of saline water from the marine shale that underlies the area at shallow depths.

A proposed basinwide monitoring program includes 19 water-level sites, 14 water-quality sampling sites, 3 streamflow measuring sites, and periodic infrared aerial photography of Barka Slough. A computer model of the ground-water-flow system could be developed to assess the impact of various water-management alternatives.

INTRODUCTION

Demand for ground water in the predominantly rural 154-square mile San Antonio Creek valley increased approximately threefold between 1958 and 1978. Current (1978) withdrawals are greater than the preliminary perennial yield estimate of 7,000 acre-ft/yr. This dramatic increase in demand for water is due to growth of agriculture and the development of water supplies for Vandenberg Air Force Base (VAFB).

To plan for anticipated growth, Vandenberg Air Force Base has indicated its need for an up-to-date water-resources appraisal of San Antonio Creek valley with emphasis on potential overdraft. Data collected between 1958 and 1978 were used to reassess perennial yield and effects of ground-water development.

Purpose and Scope

This study evaluates the long-term availability of the ground-water supply by focusing on the following questions:

1. What are the current ground-water conditions in the San Antonio Creek valley?
2. What is the perennial yield of the San Antonio Creek ground-water basin? Is the basin currently in overdraft?
3. What quantity of water is available for long-term withdrawal at VAFB?
4. What is the health status of the vegetation in marshland areas?
5. What effect will increased agricultural expansion upgradient have on the water supply at VAFB?
6. What effect will increased withdrawals by VAFB have on the water resources in San Antonio Creek valley adjacent to VAFB, on underflow from the adjoining Santa Maria and Santa Ynez valleys, on the marshlands, and on inland movement of seawater?

7. What type of hydrologic monitoring program is necessary to obtain the information needed for environmental protection?

The project involved the collection and analysis of aerial photographs, data on water use, geologic logs, aquifer test results, ground-water levels, streamflow, and water quality. The data tabulated herein supplement information presented by Muir (1964). A conceptual model of the hydrologic regime that can be used by Federal, State, and local interests for the orderly development and management of the ground-water resources of the basin is formulated. Specifically, the results are designed to assist VAFB in its water-management plans.

Previous Studies

Reports describing the geology and hydrology of Santa Barbara County and the San Antonio Creek valley have been published by consulting engineers, State and County agencies, and the U.S. Geological Survey. Many of the reports that pertain to the study area are listed in the Selected References section of this report.

The geology of the San Antonio Creek valley was described by Dibblee (1950), Woodring and Bramlette (1950), and Muir (1964). Dibblee mapped the geology of the southern part of the valley at a scale of 1:62,500, Woodring and Bramlette applied geologic and structural overlays to aerial photographs at a scale of 1:24,000, and Muir mapped the geology on 1:48,000-scale topographic maps. Well logs from the California Department of Conservation, Division of Oil and Gas (1963) were used to define the ground-water basin boundaries, and to develop the bedrock map and the geologic section presented in this report.

The first appraisal of hydrologic conditions was done by Muir (1964), using a base period of 1943-58.

Aquifer boundaries and water levels were mapped for the first time, a streamflow station was established to monitor the ground-water and surface-water outflow from the basin, a hydrologic budget was made, ground-water quality was evaluated, and the preliminary estimate of perennial yield of 7,000 acre-ft/yr was made. Local ranchers commissioned the next in-depth study by Montgomery (1975), which included an appraisal of ground-water resources and supply potential of the easternmost 31-square mile sector of the valley. The Santa Barbara County Water Agency (1977), in a report on the adequacy of the ground-water basin, developed a rainfall-infiltration model and estimated the "safe yield" at 7,400 acre-ft/yr.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. The part of the number preceding the slash, as in 8N/34W-14A1, indicates the township (T. 8 N.); the number following the slash indicates the range (R. 34 W.); the number following the hyphen indicates the section (sec. 14); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision. A "Z" before the final digit indicates that the well is plotted from an unverified location description; the site was visited but no evidence of a well could be found.

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

Acknowledgments

The assistance and cooperation of the ranchers who provided information and aided in fieldwork is sincerely appreciated. Grateful acknowledgment is extended to the U.S. Air Force, California Division of Oil and Gas, the Santa Barbara County Water Agency, and the Los Alamos Community Service District for providing data essential to the study.

Special thanks are due to the U.S. Navy Seabees for their assistance with the test-drilling program at VAFB.

DESCRIPTION OF THE AREA

Topography, Drainage, and Land Use

The San Antonio Creek drainage basin is about 30 mi long and 7 mi wide and covers 154 mi² in west-central Santa Barbara County (fig. 1). The land slopes steeply from an altitude of more than 1,200 ft along ridges that flank the valley on the north, south, and east, to a narrow, flat floor that slopes gently westward from an altitude of about 800 ft to the Pacific Ocean.

The ground-water basin, with an area of about 110 mi², consists of unconsolidated valley-fill deposits bounded along much of the perimeter on the north, south, and west by relatively impermeable consolidated rocks of the Purisima, Casmalia, and Solomon Hills. On the east, and parts of the north and south, the ridges forming the drainage basin boundary serve as the ground-water basin boundary. The abutment of the Purisima and Casmalia Hills constitutes a barrier to the seaward flow of ground water. Upwelling of ground water just east of the barrier has established a 550-acre marshland known as Barka Slough.

San Antonio Creek, which runs the length of the valley, is fed by tributaries that are slowly dissecting the surrounding hills. East of Barka

GROUND-WATER RESOURCES, SAN ANTONIO CREEK VALLEY, CALIF.

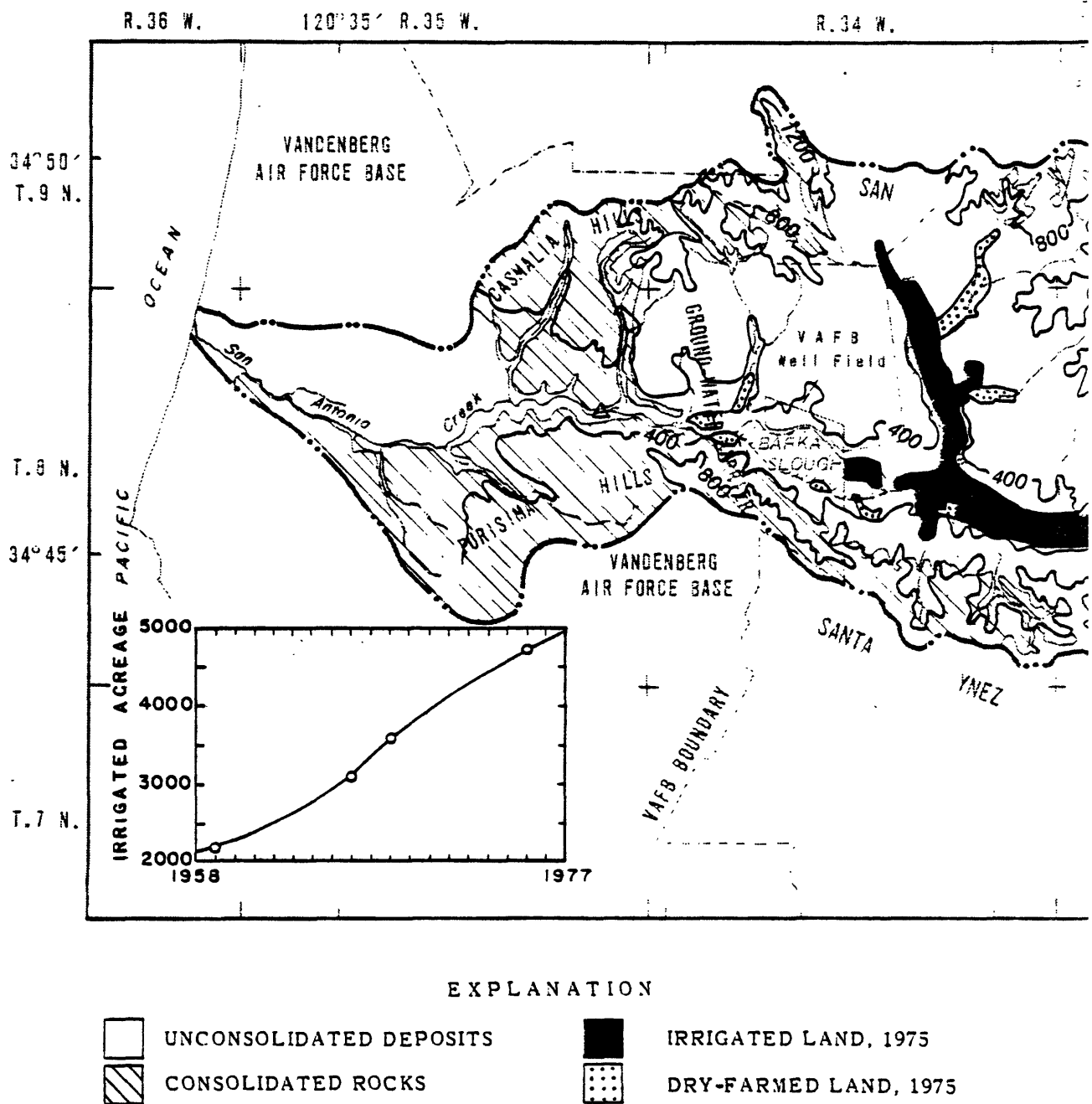
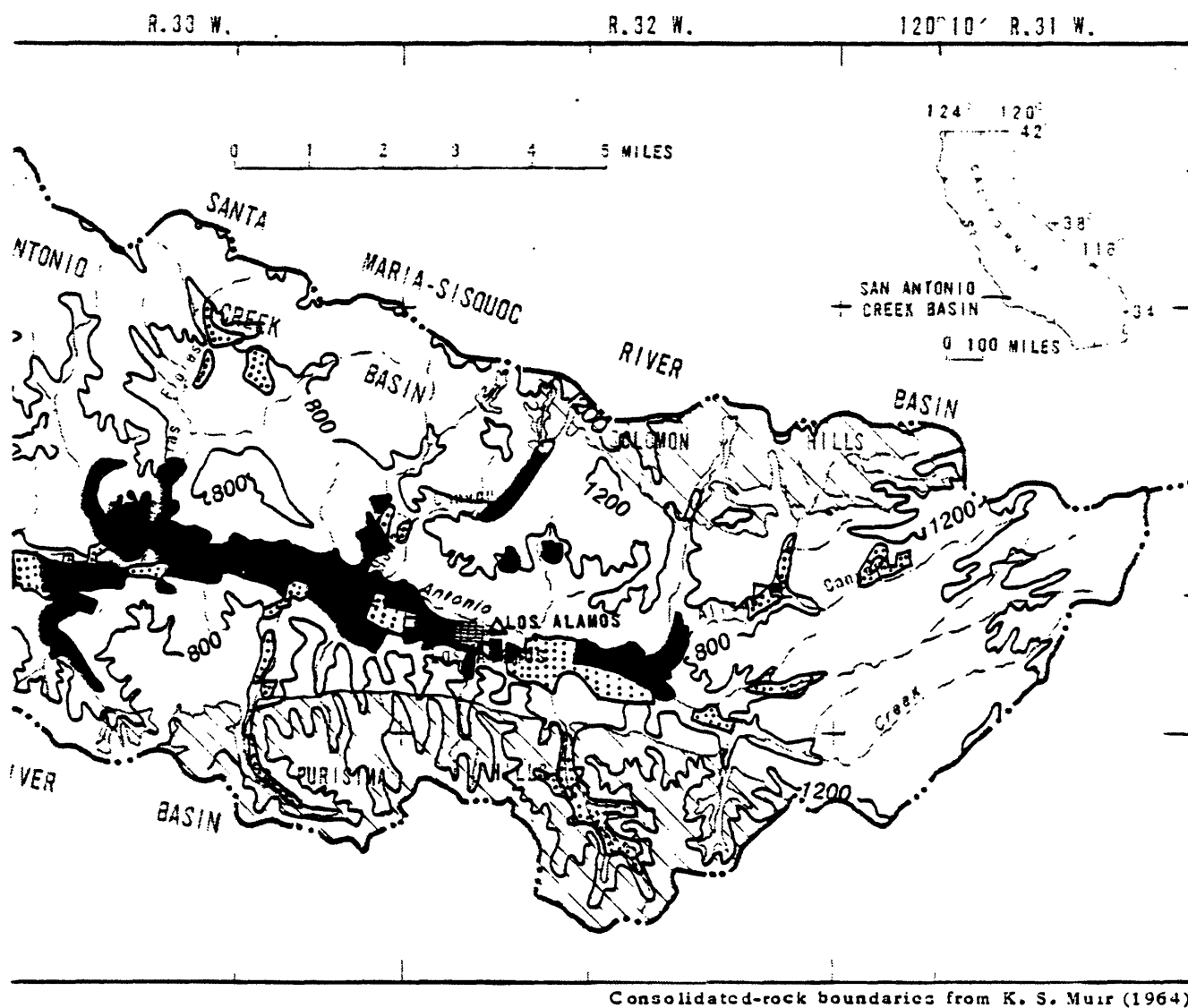


FIGURE 1.-- Topography and land use in the San Antonio Creek drainage basin.

DESCRIPTION OF THE AREA

5



Consolidated-rock boundaries from K. S. Muir (1964)

EXPLANATION -- Continued

- | | | | |
|------------|---|-----|--------------------|
| —— 1200 —— | TOPOGRAPHIC CONTOUR -- | --- | BASIN BOUNDARY |
| | Shows altitude of land surface. Contour interval 400 feet. National Geodetic Vertical Datum of 1929 | Δ | SURFACE-WATER GAGE |

FIGURE 1.--Continued

Slough the streamflow is intermittent because it is derived mainly from surface runoff during the rainy season. West of the slough the flow is perennial and during the dry season it is derived entirely from ground water discharged through the slough. Continuous streamflow records of San Antonio Creek are obtained at the town of Los Alamos and at a station 2 mi west of Barka Slough.

Land in San Antonio Creek valley is devoted to municipal, military, and agricultural uses, including grazing. The town of Los Alamos, population about 900 (Los Alamos Community Service District, oral commun., 1977), covers about half a square mile in the east-central part of the valley. VAFB owns the western quarter of the valley and, just north of Barka Slough, has a well field at the downgradient end of the ground-water basin (fig. 1). The rest of the valley is privately owned, with the upland parts primarily used for dry farming or grazing and the flatlands along the streams for irrigated farming.

Agricultural land use has been documented four times during the 1958-77 base period of this investigation (California Department of Water Resources, 1964, 1969; Santa Barbara County Water Agency, 1968, 1976). These data indicate that irrigated agriculture grew from about 2,200 acres in 1958 to about 5,000 acres in 1977 (see graph inset, fig. 1). The agricultural emphasis has shifted from field and pasture crops to large-scale vineyards and truck crops.

Aerial Photography

In 1978, VAFB began a program of infrared aerial photography to assess

vegetation changes in the Barka Slough area and in the downstream channel of San Antonio Creek. Barka Slough is one of the few pristine marshlands in southern California and is known or believed to be the habitat of at least nine threatened and endangered species of wildlife (Descheneaux, 1975). Conditions as of July 1, 1978, are documented in the infrared photomosaic of figure 2.

Climate

The San Antonio Creek valley has a semiarid climate characterized by mild temperatures and low rainfall. Temperatures during the winter generally range from 40° to 60°F and during the summer from 60° to 80°F. About 95 percent of the rainfall occurs between November and May and is uniformly distributed throughout the valley (Muir, 1964, p. 5). The long-term average (1909-77) rainfall at the National Weather Service station in Los Alamos is 15.18 inches. For the 1958-77 study period, rainfall averaged 14.61 inches, or about 4 percent below the long-term average.

A curve of cumulative departure of rainfall from the 1909-77 average (fig. 3) shows cyclical wet, dry, and near-average periods as follows:

Period	Date	Average rainfall (inches)	Percentage above (+) or below (-) average
Wet	1909-18	20.53	+35
Dry	1919-34	12.44	-18
Wet	1935-44	18.62	+23
Dry	1945-57	12.67	-17
Near average	1958-77	14.61	-4

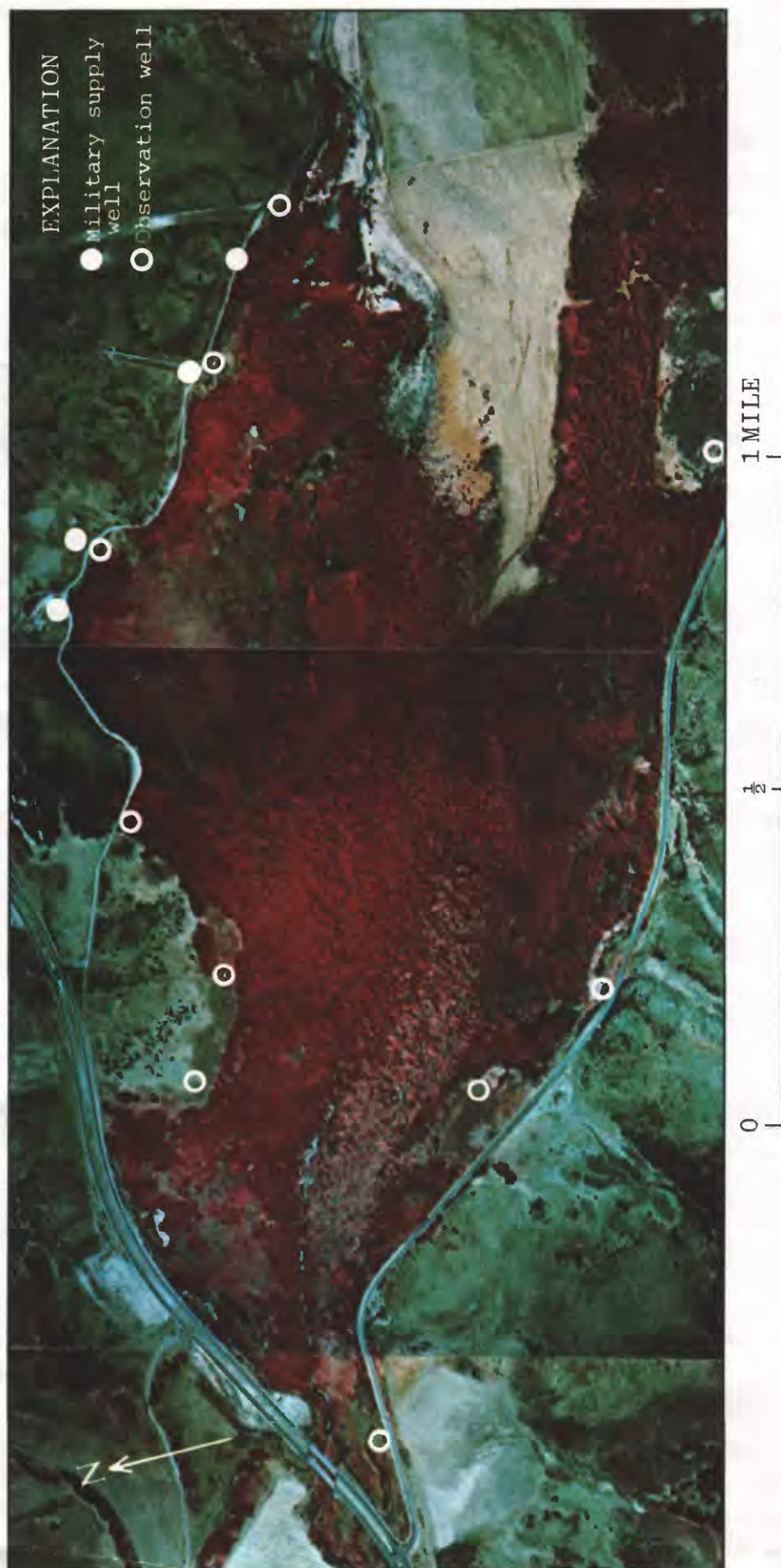


FIGURE 2.--Infrared aerial photomosaic of the Barka Slough area. This photomosaic was made from three pictures taken by the U.S. Air Force from an altitude of 9,044 feet, July 1, 1978. The deep red color denotes lush marshland vegetation; light red denotes either a stressed condition, possibly owing to lack of water, or a transition zone between marshland and chapparal-type vegetation; green denotes chapparal-type vegetation; black denotes water bodies; and white denotes denuded land.

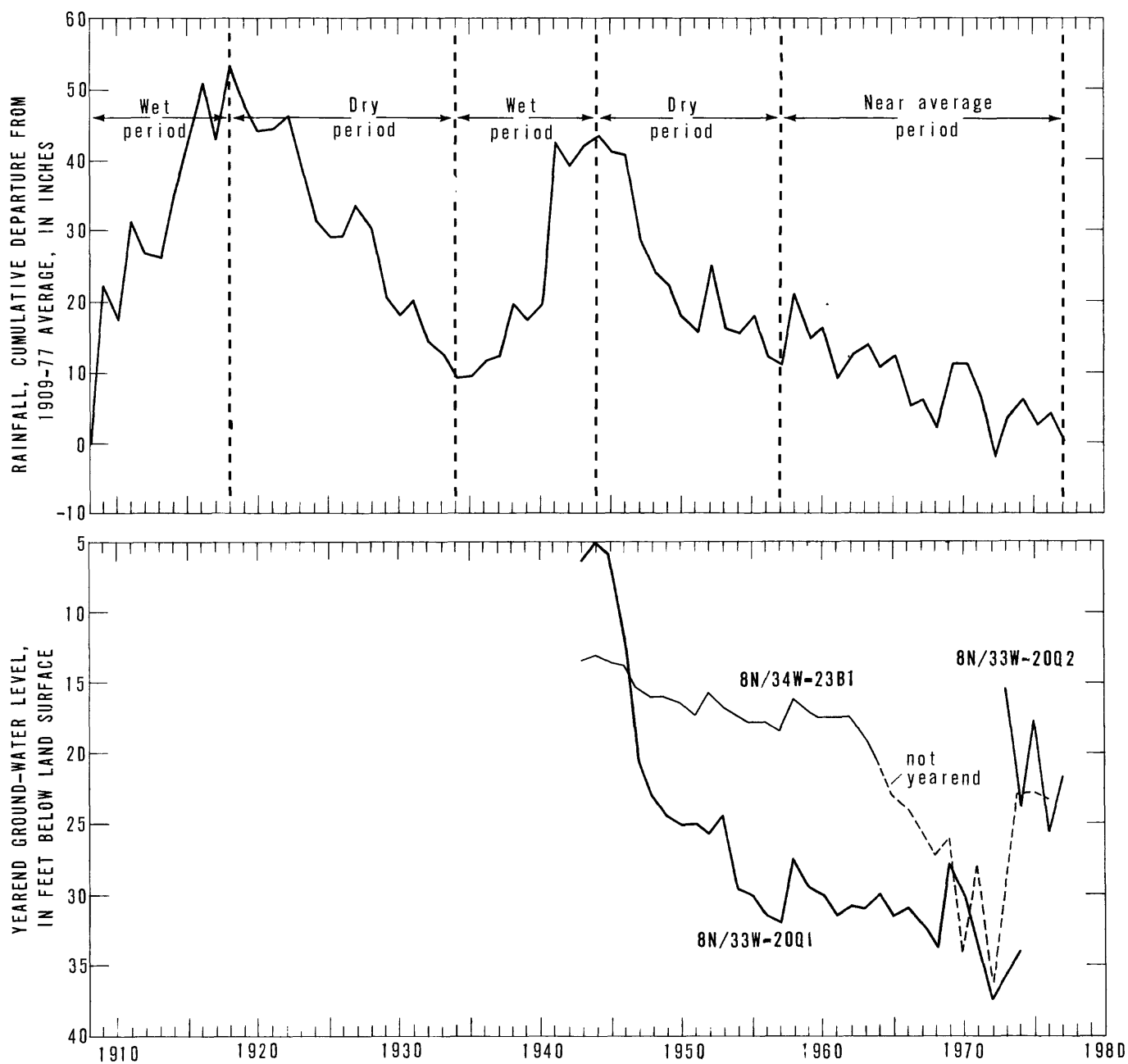


FIGURE 3.--Cumulative departure from 1909-77 average rainfall, and yearend ground-water levels.

A close correlation between the ground-water level measured in observation well 8N/33W-20Q1 and rainfall is easily seen in figure 3. During wet years the level rose as a result of increased recharge; during dry periods the discharge exceeded recharge, and the water level rapidly declined; and during the near-average period the water level dropped only slightly. The water-level fluctuations in well 8N/34W-23B1 were more subdued, the sharp decline in the late 1960's probably reflecting pumping.

The magnitude and distribution of rainfall are important factors in the evaluation of the San Antonio Creek ground-water regime. The 1943-58 analysis of perennial yield was based on rainfall data from the latest dry period and part of the normal period, and admittedly it contains climatic errors (Worts and Wilson, 1964, p. 38). In this investigation the influence of climatic variation is minimized because the years 1958-77 were in a period of near-average rainfall. An estimate of perennial yield derived from the later base period should be more nearly representative of long-term yield.

Water Use

Water for consumptive use in the San Antonio Creek valley is derived entirely from ground-water sources. The annual distribution of the various discharges from the ground-water basin is displayed graphically in figure 4 and shown in table 1. These discharges may be summarized as follows:

1. Evapotranspiration discharge. Evapotranspiration by phreatophytes draws from the ground-water supply naturally, just as pumping for irrigation draws from the resource artificially. Evapotranspiration by phreatophytes in Barka Slough and along the channel of San Antonio Creek, 6 mi east of the ground-water barrier, was estimated to be 3,000

acre-ft/yr in 1958 (Muir, 1964, p. 33). Because there was no apparent change in the vegetation of the marshland during the period 1958-77, the evapotranspiration rate is assumed to have remained stable, although the competition for ground water for municipal and domestic supplies, irrigation, and military supplies has dramatically increased. The water supply needed to maintain pristine conditions of the marshland and the stream channel was probably derived from a reduction in base flow and surface runoff.

2. Base flow. The base flow of San Antonio Creek is the component of total runoff sustained by ground-water discharge (fig. 5). The 1958-77 average base flow of 1,300 acre-ft/yr was computed by the separation technique of Kunkle (1962), using hydrographs of daily runoff at the station 2 mi west of Barka Slough. During this period base flow averaged one-third of the total runoff and ranged from a high of 2,331 acre-ft in 1963 to a low of 570 acre-ft in 1977. The apparent decline in base flow is in response to a combination of increased pumpage and competition for ground water by phreatophytes.

3. Municipal and domestic pumpage. Although it has nearly doubled over the past 20 years, municipal and domestic pumpage is the least significant component of ground-water discharge from the basin. Municipal supplies recorded by the Los Alamos Community Service District (oral commun., 1978) increased proportionately with population from about 80 acre-ft/yr in 1958 to 170 acre-ft/yr in 1977. Domestic pumpage from private wells and springs in 1976 was estimated at 90 acre-ft/yr by the Santa Barbara County Water Agency (1977, p. x-3). This is probably the average figure for the 1958-77 study period. The average municipal and domestic pumpage used for analytical purposes in this report is 200 acre-ft/yr.

GROUND-WATER RESOURCES, SAN ANTONIO CREEK VALLEY, CALIF.

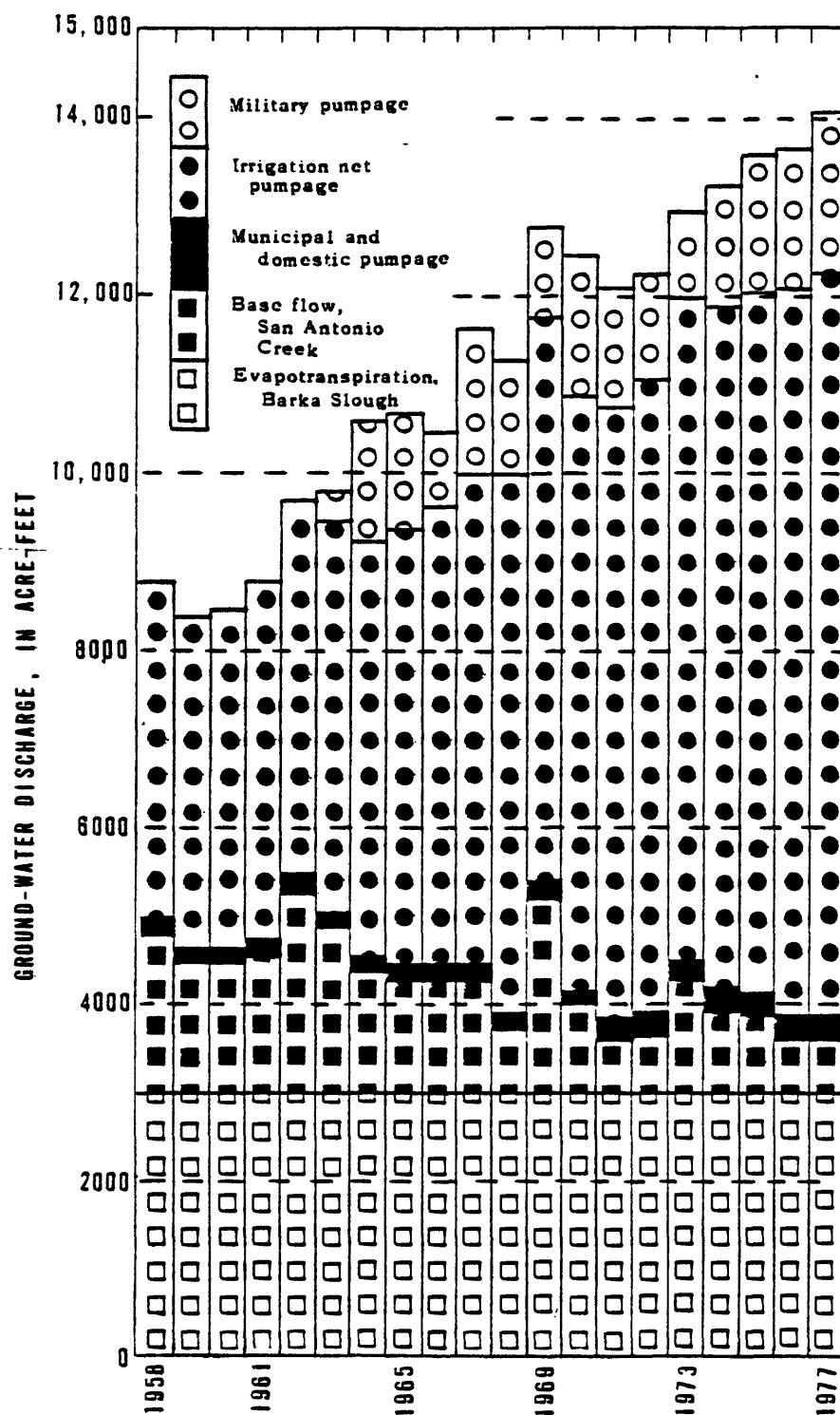


FIGURE 4.--Components of annual discharge from the San Antonio Creek ground-water basin, 1958-77.

TABLE 1. - Annual runoff and components of annual discharge from the San Antonio Creek ground-water basin

(in acre-feet)

Year	Evapo- trans- piration	Total runoff	Base flow	Muni- cipal and domestic pumpage	Irrigation net pumpage	Mili- tary pumpage	Total ground- water discharge
1958	3,000	13,630	1,818	170	3,860	0	8,848
1959	3,000	1,910	1,487	160	3,730	0	8,377
1960	3,000	2,550	1,510	150	3,860	0	8,520
1961	3,000	1,940	1,604	160	4,030	0	8,794
1962	3,000	11,320	2,331	160	4,200	0	9,691
1963	3,000	2,710	1,866	150	4,450	317	9,783
1964	3,000	2,000	1,364	170	4,700	1,338	10,572
1965	3,000	2,100	1,295	160	4,960	1,748	11,163
1966	3,000	1,620	1,277	160	5,210	833	10,480
1967	3,000	1,970	1,253	160	5,630	1,627	11,670
1968	3,000	916	750	170	6,050	1,346	11,316
1969	3,000	14,360	2,213	180	6,380	995	12,768
1970	3,000	1,480	968	200	6,720	1,622	12,510
1971	3,000	772	639	210	6,970	1,313	12,132
1972	3,000	1,150	653	230	7,220	1,163	12,266
1973	3,000	5,260	1,296	230	7,480	1,020	13,026
1974	3,000	2,840	972	230	7,730	1,334	13,266
1975	3,000	2,130	881	240	7,950	1,512	13,583
1976	3,000	990	595	250	8,230	1,655	13,730
1977	3,000	776	570	260	8,480	1,829	14,139
Average	3,000	3,600	1,300	200	5,900	1,000	11,400
(rounded)							

4. Irrigation net pumpage. The most significant component of ground-water discharge is irrigation net pumpage, which equals the amount of ground water that is consumptively used by crops. It is lower than total pumpage by the amount of return flow that soaks past the root zone and back to the ground-water reservoir. In the San Antonio Creek valley, during the period 1958-77, irrigation net pumpage steadily increased from 3,860 acre-ft/

yr to 8,480 acre-ft/yr, with an average of 5,900 acre-ft/yr. These figures are based on the crop-use technique for determining water use by assuming that 2.1 ft of water is applied per crop-acre and that return flow is 20 percent of total pumpage (Muir, 1964, p. 31; and California Department of Water Resources, 1964, p. 48).

5. Military pumpage. Military pumpage consists of water pumped from the well field north of Barka Slough.

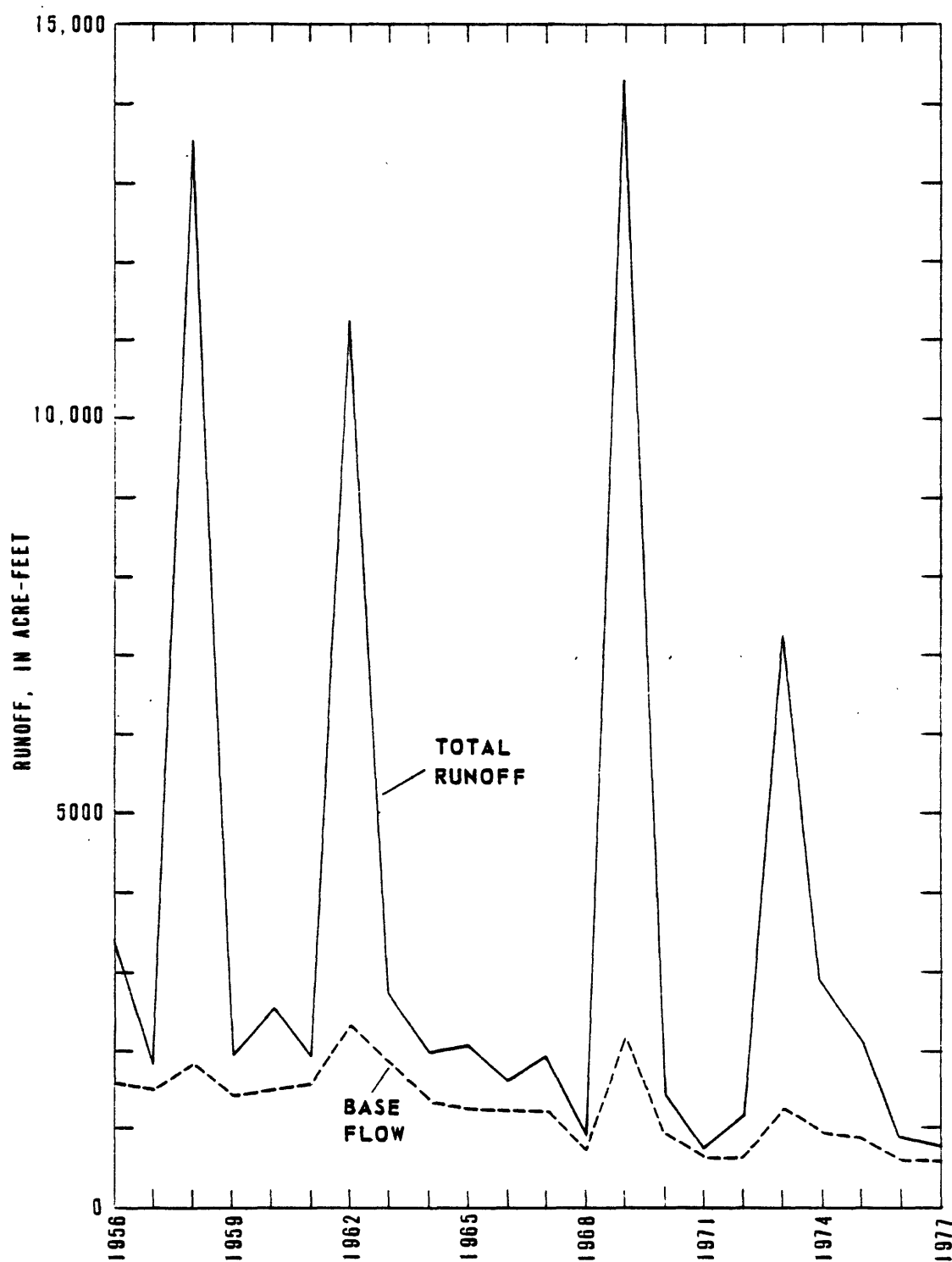


FIGURE 5.—Total streamflow and base flow in San Antonio Creek at gaging station 2 miles west of Barka Slough.

Pumping began in 1963 and gradually increased from an initial rate of 317 acre-ft/yr to 1,829 acre-ft/yr in 1977; the average for the 1958-77 period was 1,000 acre-ft/yr. The anticipated long-term rate of withdrawal has been estimated at 4,200 acre-ft/yr (Santa Barbara County Water Agency, 1977), probably a maximum rate deemed adequate to serve increased demands resulting both from expansion of the space-shuttle program and the shifting of pumping from another well field in the Santa Ynez River basin where ground-water quality is poor.

6. Total ground-water discharge. Total ground-water discharge increased from 8,848 acre-ft in 1958 to 14,139 acre-ft in 1977 and averaged 11,400 acre-ft/yr during the period 1958-77. The increase is due to a near three fold increase in pumping for municipal and domestic, irrigation, and military supplies. Assuming a perennial-yield estimate of 7,000 acre-ft/yr (Worts and Wilson, 1964, p. 36), it appears that the ground-water basin was in an ever-increasing state of overdraft, which averaged 4,200 acre-ft/yr during the 1958-77 period.

GEOHYDROLOGIC SYSTEM

Geologic Framework

The geologic structure underlying the San Antonio Creek valley is a major synclinal trough, the axis of which trends about N. 65° W. and passes through the town of Los Alamos (Dipolee, 1950, p. 59). This down-warp, known as the Los Alamos syncline, contains a series of marine and continental sediments, Miocene to Holocene in age, that totals about 10,000 ft in thickness. The stratigraphic units that compose this sequence, and their water-bearing characteristics, are summarized in table 2.

In this report the sediments are categorized as unconsolidated deposits

and consolidated rocks on the basis of their geohydrologic characteristics. The unconsolidated deposits consist of permeable sand and gravel layers, mostly of the Paso Robles Formation and Careaga Sand, that blanket the central part of the valley and form an aquifer that constitutes the ground-water basin. A surficial layer of Holocene alluvium about 100 ft thick and 1 mi wide constitutes an important water-bearing zone along San Antonio Creek and its tributary canyons. The consolidated rocks consist of relatively impermeable fine-grained deposits of the Foxen Mudstone, Sisquoc Formation, and Monterey Shale that underlie the unconsolidated deposits and form the stratigraphic base of the aquifer. The consolidated rocks also bound much of the perimeter of the ground-water basin, where they have been uplifted and exposed in the Casmalia, Purisima, and Solomon Hills (fig. 1).

A structure-contour map of the top of the consolidated rocks (fig. 6) and a geological section along the axis of the valley (fig. 7) are used to evaluate the storage capacity of the ground-water basin and the potential for salt-water intrusion into the fresh-water aquifer. Table 3 is a summary of test holes used to construct the map and section.

The surface of the consolidated rocks forms a nearly closed basin. This surface is one of high relief, its altitude generally ranges between 1,000 ft above sea level in the Solomon and Purisima Hills, and 2,600 ft below sea level east of Los Alamos (fig. 6). Where the rocks crop out, they clearly define the ground-water basin boundary. This boundary is obscured in areas on the east, south, and north where test holes at sites 7, 26, and 50 indicate that the consolidated rocks are blanketed by layers of unconsolidated deposits less than 1,000 ft thick. In these areas the San Antonio Creek ground-water basin is in hydrologic continuity with the

TABLE 2. - Stratigraphic units of the San Antonio Creek valley area

[Modified from Muir, 1964, p. 12]

Sys-tem	Series	Formation	Thickness (feet)	General lithologic character	Water-bearing properties
Quaternary	Holocene	Dune sand	0-100±	Sand, coarse to fine, well rounded, and in part actively drifting.	Unconsolidated; highly permeable, but yields only small amounts of water to wells because sand is mostly above zone of saturation.
		Unconformity			
		Alluvium	0-100±	Sand, clay, silt, and gravel of fluvial origin except near the coast, where the clay and sand probably are marine.	Unconsolidated; highly permeable and yields water to wells. One of the major aquifers of the area. Tapped by most wells.
	Pleistocene	Unconformity			
		Terrace deposits	0-75+	Crossbedded sand, gravel, and clay. Fluvial origin east of Barks Slough, marine origin west.	Unconsolidated; somewhat permeable but position causes rapid drainage, largely unsaturated.
		Unconformity			
		Orcutt Sand	0-150±	Sand and clay interbedded with gravel. Locally has a cap rock of indurated sandstone underlain by sand and clay and a lower member of sand and gravel. Fluvial in origin but includes some marine deposits.	Unconsolidated; locally yields small quantities of water to wells.
Tertiary	Pliocene	Unconformity			
		Paso Robles Formation	0-2,000±	Gravel, sand, silt, and clay containing occasional thin limestone beds near base and a few indurated sandstone beds. Nonmarine in origin.	Unconsolidated; yields water fairly freely to wells. The best aquifer in the area. Tapped by most wells. Locally contains artesian water.
		Local unconformity			
	Pliocene to Miocene	Consolidated rocks. Includes Foxen Mudstone, Siquoc Formation, and Monterey Shale	0-10,000	Mudstone, siltstone, diatomaceous and porcelaneous shale, sandstone, and siliceous shale.	Consolidated or highly compacted; poorly water bearing, except for minor supplies in joints or fractures. Not tapped by wells.

adjacent Santa Maria-Sisquoc and Santa Ynez River ground-water basins, and the boundary is defined by the topographic divide. Because the consolidated rocks are above sea level on the west (test hole at sites 30 and 45 on fig. 7), they tend to form a ground-water barrier, and salt-water intrusion into the ground-water basin is restricted.

The unconsolidated deposits compose an aquifer that is 0 to 1,000 ft thick along the basin boundary and more than 3,000 ft thick in the deepest part of the basin. The volume of the unconsolidated deposits is about 20 mi^3 .

Aquifer Characteristics

Aquifer tests indicate that the transmissivity varies widely in the basin. Results of aquifer tests showed transmissivity values ranging from 2,600 to 34,000 ft^2/d ; none of the wells used to test the aquifer penetrate much more than half the aquifer thickness. The highest values were obtained near the perimeter of the basin, where the materials are coarse grained, and the lowest in the central part, where the materials are fine grained.

The most reliable test results were obtained at VAFB, where a supply well was pumped at 1,050 gal/min and draw-down effects were measured in three observation wells. Analysis of this test indicated a transmissivity of $14,000 \text{ ft}^2/\text{d}$ and a storage coefficient of 0.001. At the Vandenberg location, where leaky artesian conditions occurred, a leakance factor of 0.0006 (ft/d)/ft was calculated from a 72-hour pump test on supply well 8N/34W-16C1. It seems probable that water discharged from the Vandenberg well field is derived from a combination of water in aquifer storage, reduction in the base flow in San Antonio Creek, and water salvaged from evapotranspiration in the marshlands.

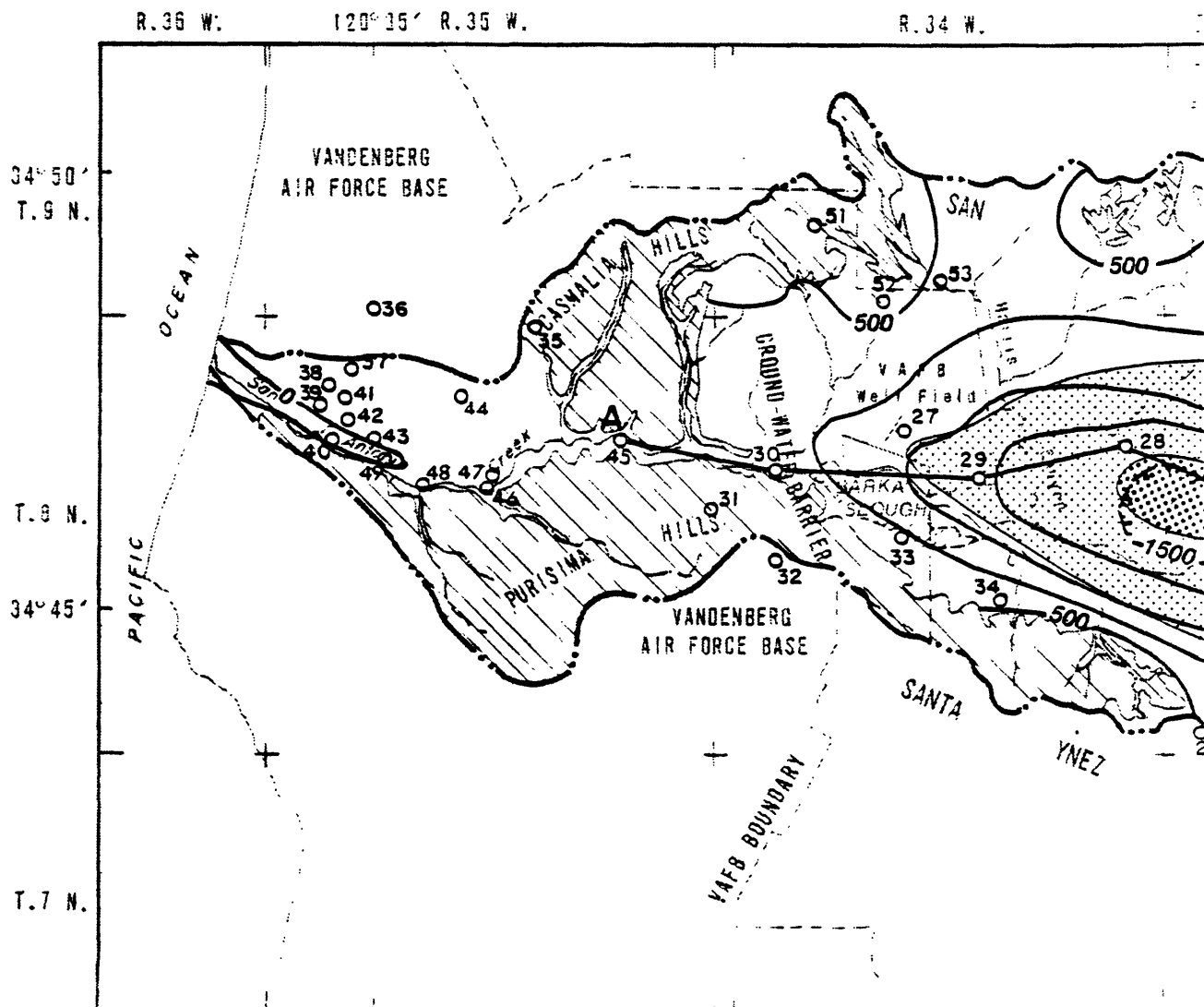
In the nearby Santa Ynez and Cuyama Valleys (off map), the specific yield

of the Paso Robles Formation was estimated to be 15 percent (Miller, 1976, p. 37; Singer and Swarzenski, 1970, p. 19). Based on these estimates and on the assumption that the aquifer characteristics of Santa Barbara County's ground-water basins are similar, a storage coefficient of 0.15 was selected as representative of the unconfined areas of the aquifer. Considering a specific yield of 15 percent and 20 mi^3 of unconsolidated sediments, the amount of recoverable ground-water storage is about 10 million acre-ft.

For analytical purposes, the average transmissivity of the basin east of Barka Slough was considered to be $10,000 \text{ ft}^2/\text{d}$. With average values of transmissivity, storage coefficient, and leakance factor assigned to the conceptual model, an analysis of the impact of overdraft on the ground-water basin can be made.

Ground-Water Conditions

A careful analysis of ground-water conditions was essential for an accurate determination of the water budget for San Antonio Creek valley. Recharge areas, directions of ground-water movement, discharge areas, and changes in ground-water storage during the 20-year period January 1958 to January 1978 were examined, using a water-level map and supporting data (fig. 8 and table 4). The water-level map for January 1978 is based on measurements or estimates of water levels in 114 wells, with particular emphasis placed on mapping along topographic divides bounding the drainage basin to determine the potential for ground-water movement between the San Antonio Creek valley and adjacent valleys. This section of the report also compares seasonal water-level fluctuations in the heart of the agricultural area with those in Barka Slough by analysis of hydrographs of wells equipped with continuous water-level recorders during the period of this investigation.



EXPLANATION



UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS

THICKNESS OF UNCONSOLIDATED DEPOSITS, IN FEET

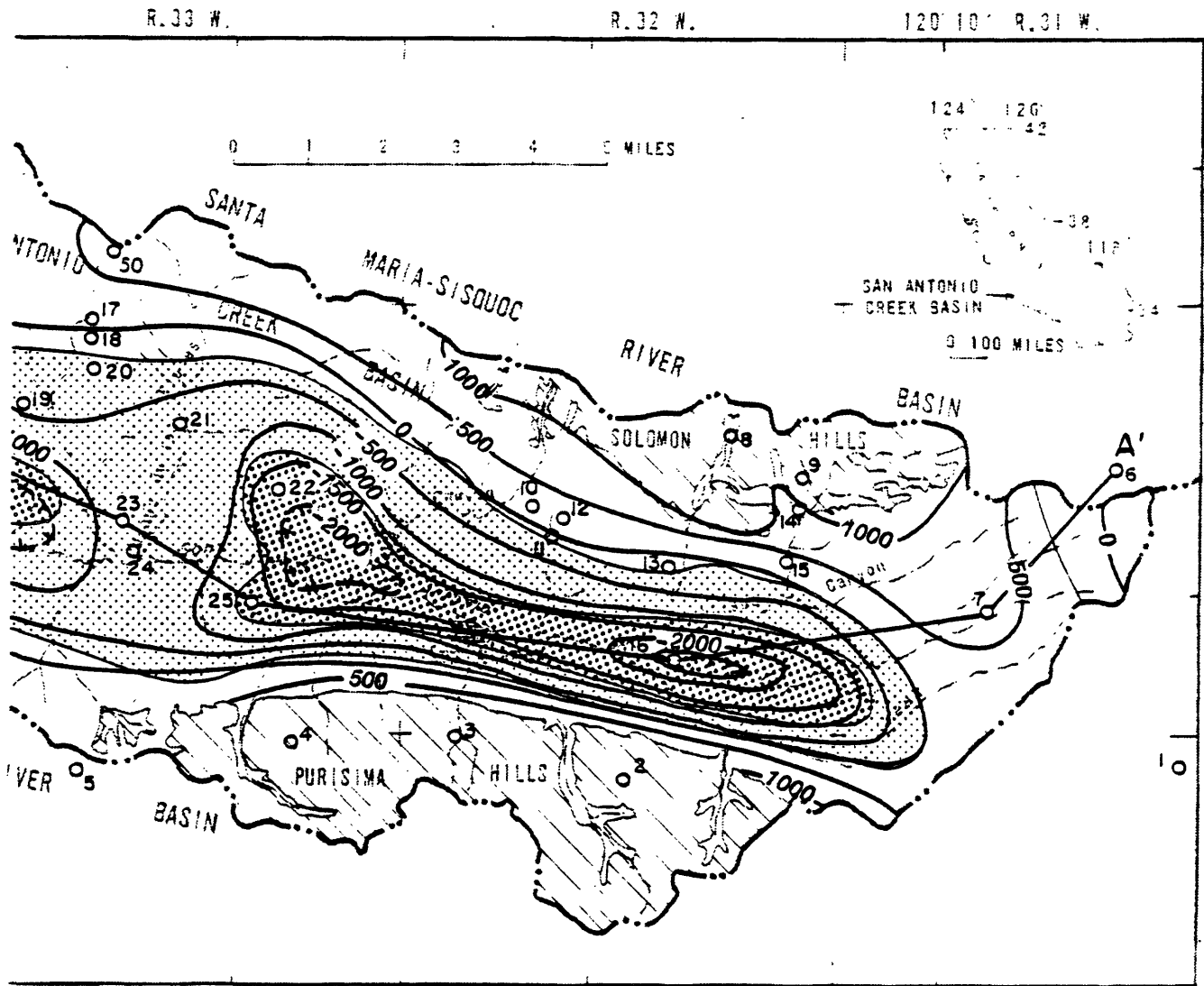


0-1000

1000-2000

> 2000

FIGURE 6.--Altitude of the top of the consolidated rocks and thickness of the unconsolidated deposits.



Consolidated-rock boundaries from K. S. Muir (1964)

EXPLANATION -Continued

— 500 — STRUCTURE CONTOUR--Shows altitude of consolidated-rock surface. Dashed where approximately located. Contour interval 500 feet. National Geodetic Vertical Datum of 1929

- - - BASIN BOUNDARY

A — A' LINE OF GEO-HYDROLOGIC SECTION
○² TEST-HOLE SITE AND NUMBER

FIGURE 6.--Continued

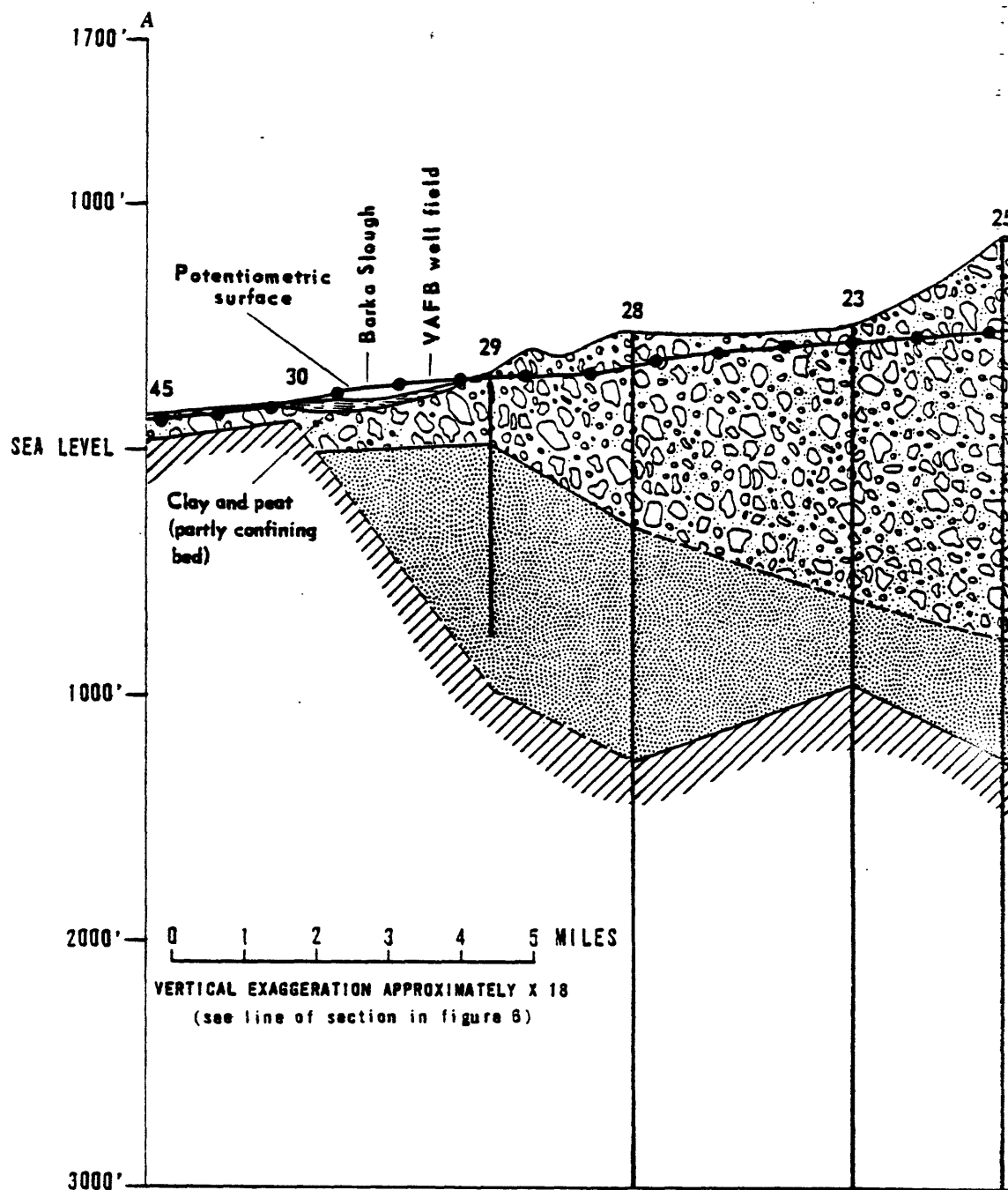


FIGURE 7.—Geohydrologic section.

TABLE 3. - Geologic summary of test holes in San Antonio Creek valley

[Source of data: CDOG, Division of Oil and Gas, California Department of Conservation; USGS, U.S. Geological Survey]

Site number	Township/range-section	Owner	Well name and number	Altitude of land surface (feet)	Altitude of top of Careaga Sand (feet)	Altitude of top of Foxen Mudstone (feet)	Thickness of unconsolidated deposits (feet)	Source of data
1	7N/31W-2	Tidewater Oil Co.	Carranza 54	1,059		-341	1,400	CDOG
2	7N/32W-3	So. Calif. Pet. Corp.	Archambault 1	1,275	Absent	Absent	0	CDOG
3	7N/32W-6	So. Calif. Pet. Corp.	Los Alamos 1	839	Absent	Absent	0	CDOG
4	7N/33W-2	Westates Pet. Corp.	1	1,320	Absent	Absent	0	CDOG
5	7N/33W-5	Union Oil Co.	Cherry Fee 1	1,053	Absent	Absent	0	CDOG
6	8N/31W-15	Union Oil Co.	Luton 1	1,275	875	-170	1,445	CDOG
7	8N/31W-28	Standard Oil Co.	Fithian 1	1,140	640	590	550	CDOG
8	8N/32W-11	Tidewater Oil Co.	Pezzoni 1	950		750	200	CDOG
9	8N/32W-13	Princes Oil Co.	Muscio 1	900		900	0	CDOG
10	8N/32W-17	Bel Air Oil Co.	Price 2	965		215	750	CDOG
11	8N/32W-21	Bel Air Oil Co.	Price 1	793		3	790	CDOG
12	8N/32W-21	Getty Oil Co.	Price 1	934		374	560	CDOG
13	8N/32W-22	Merchants Pet. Co.	Price Ranch 1	900	470	-15	915	CDOG
14	8N/32W-24	Socony Mobil Oil Co.	Wickenden 1	800		650	150	CDOG
15	8N/32W-24	Socony Mobil Oil Co.	Wickenden 2	792	422?	292	500	CDOG
16	8N/32W-34	Hamilton Dome Oil Co.	Confaglia Lease 1	675		-2,615	3,360	CDOG
17	8N/33W-5	Sunray Oil Co.	Careaga 1	840		80	760	CDOG
18	8N/33W-5	Sunray Oil Co.	Careaga 2	943		-32	975	CDOG
19	8N/33W-7	Gulf Oil Corp.	Careaga 1	815		-435	1,250	CDOG
20	8N/33W-8	Oaks and Coombs	Careaga 4	857		-417	1,274	CDOG
21	8N/33W-10	Richfield Oil Corp.	Los Flores 1	617		-823	1,440	CDOG
22	8N/33W-14	Amerada Pet. Corp.	Tognazzini 1	800		-1,850	2,650	CDOG
23	8N/33W-21	Tiger Oil	Los Alamos Vineyards 1	520		-930	1,450	CDOG

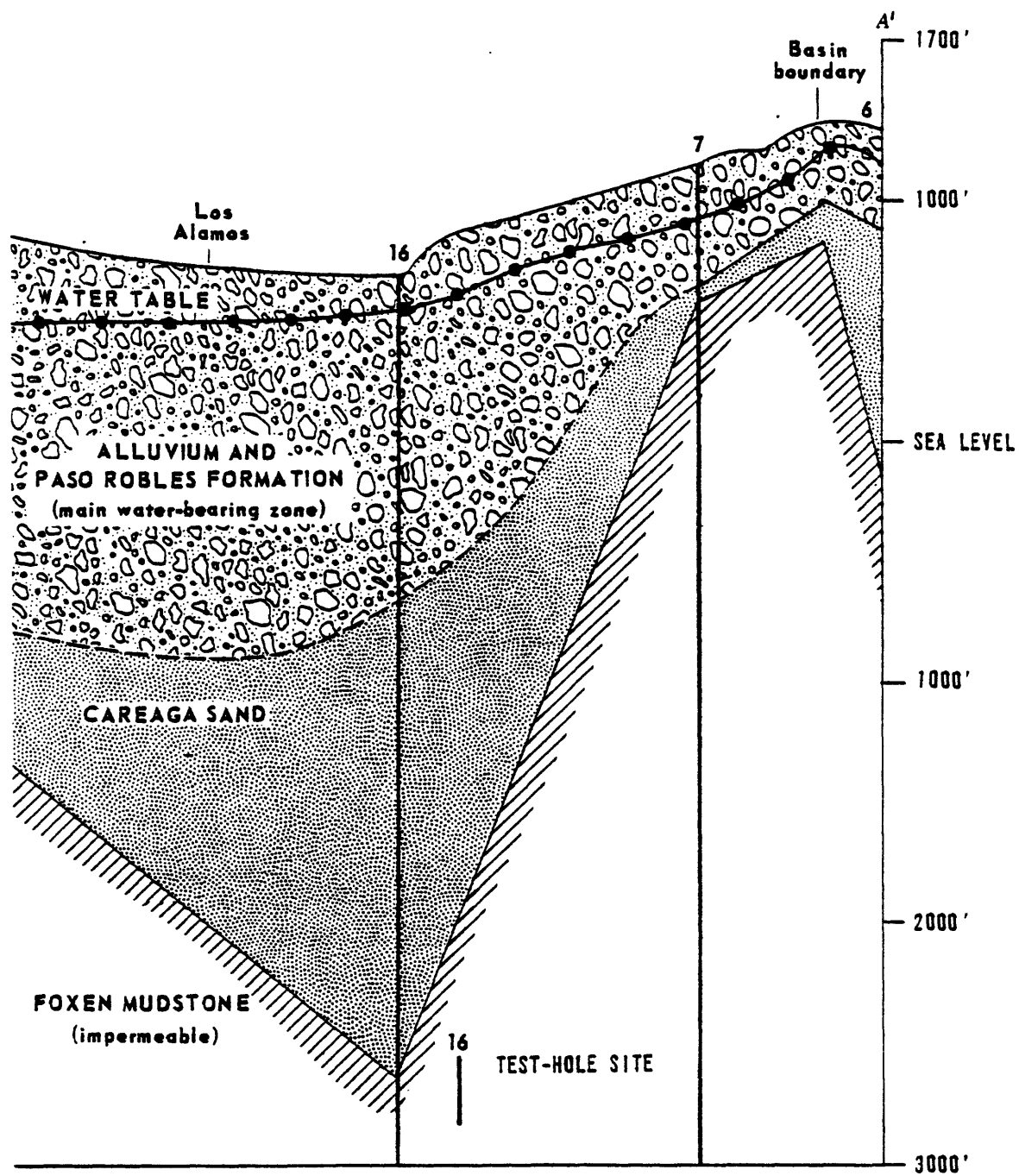
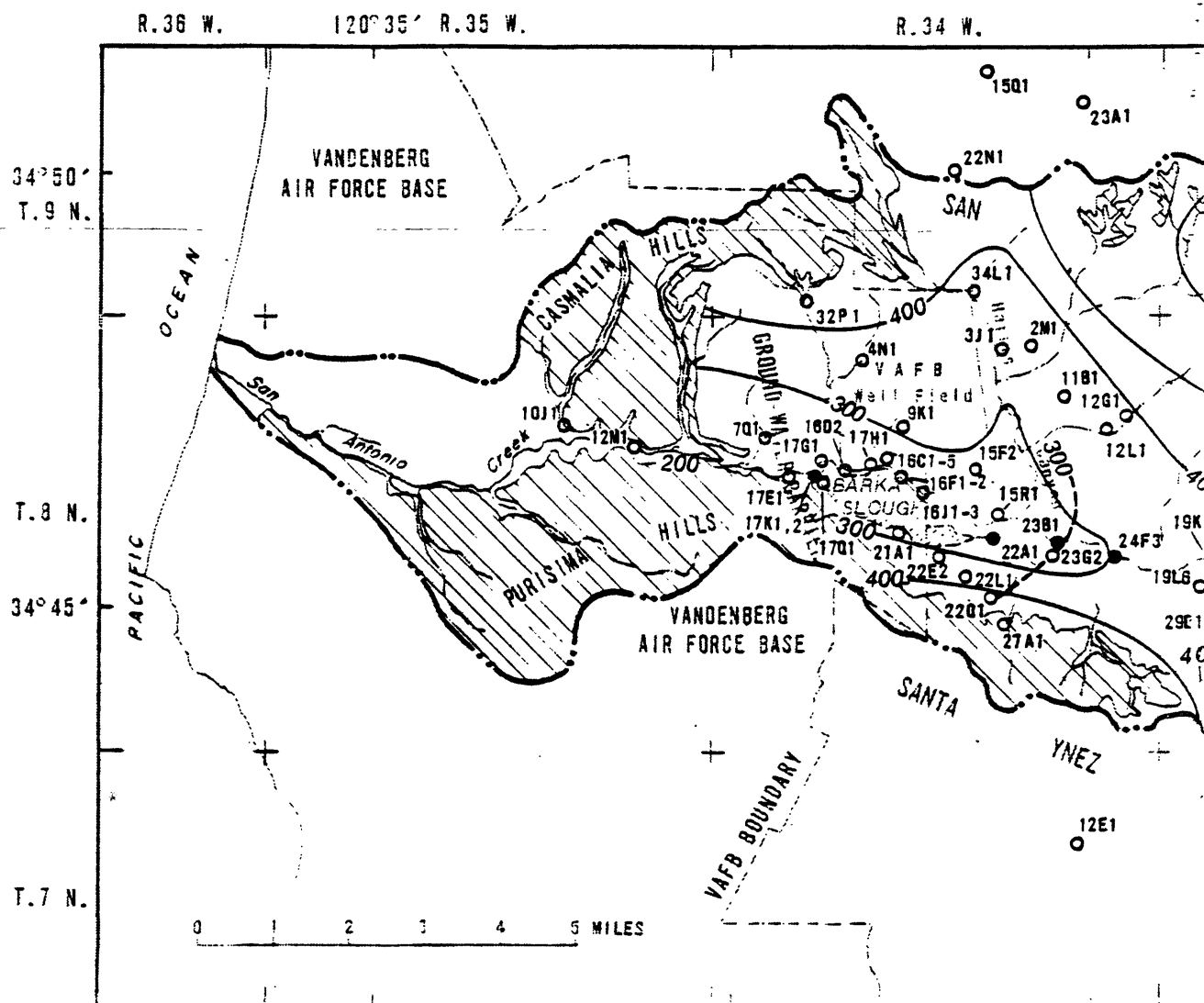


FIGURE 7.--Continued

GEOHYDROLOGIC SYSTEM

[illegible]



EXPLANATION




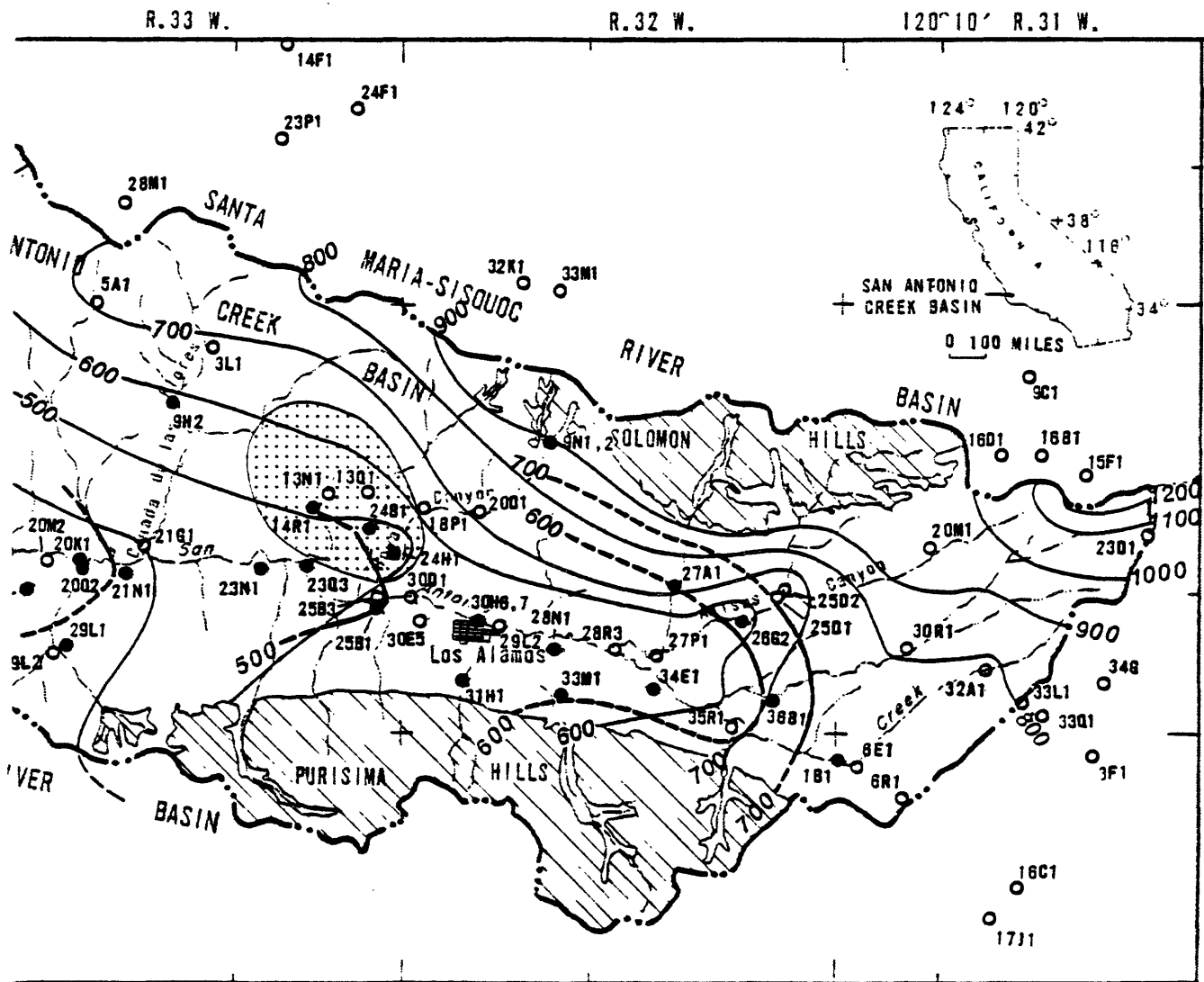
- | | | | |
|---|-------------------------|---|---|
|  | UNCONSOLIDATED DEPOSITS |  | AREA WHERE GROUND-WATER LEVELS DECLINED MORE THAN 25 FEET FROM JANUARY 1958 TO JANUARY 1978 |
|  | CONSOLIDATED ROCKS | | |

FIGURE 8.--Water levels in the aquifer of the San Antonio Creek valley, January 1958 and January 1978.



Consolidated-rock boundaries from K. S. Muir (1964)

EXPLANATION-- Continued

WATER-LEVEL CONTOUR-- Shows altitude of water table or potentiometric surface. Dashed where approximately located. Contour interval 100 feet. National Geodetic Vertical Datum of 1929.

— 500 — January 1958
 — 600 — January 1978
 --- BASIN BOUNDARY

● 181 WELL AND NUMBER--
 Water-level measurement January 1958 and 1978

○ 6E1 WELL AND NUMBER--
 Water-level measurement January 1978

FIGURE 8.--Continued

TABLE 4. - Water levels in wells in 1958 and 1978

[Altitude of water table: F, well is flowing; P, well is pumping.

Suggested future monitoring: M, monthly measurements; C, continuous record]

Well No.	Altitude of land surface (feet)	Altitude of water table (feet)		Water- level change (feet)	Sug- gested future moni- toring
		1958	January 1978		
7N/31W-3F1	960	--	759	--	--
6E1	830	--	718	--	--
6R1	960	--	720	--	--
16C1	--	--	645	--	--
17J1	760	--	732	--	--
7N/32W-1B1	830	Jan., 747	770	+23	--
7N/34W-12E1	385.8	--	66	--	--
8N/31W-7H1	990	July, 969	971	+2	--
9C1	1,095	July, 1,016	1,028	+12	--
15F1	1,290	July, 1,249	1,238	-11	--
16B1	1,140	--	1,078	--	--
16D1	1,090	July, 1,064	1,058	-6	--
20M1	1,060	Oct., 874	904	+30	--
23D1	1,500	--	1,142	--	--
30R1	920	--	867	--	--
32A1	1,045	--	756	--	--
33L1	1,100	--	800	--	--
33Q1	1,020	--	772	--	--
34G1	1,040	--	760	--	--
8N/32W-9N1	940	Jan., 878	--	--	--
9N2	940	P	884	--	--
18F1	675	June, 636	622	-14	--
20D1	760	--	710	--	--
25D1	763	--	713	--	M
25D2	760	--	672	--	--
26G2	738	Jan., 596	580	-16	--
27A1	725	Jan., 720	720	0	--
27F1	670	--	571	--	--
28N1	605	Jan., 556	603	+47	--
28R3	670	--	582	--	--
29L2	590	--	560	--	--
30D1	540	--	516	--	C
30E5	540	--	517	--	--
30H6	561	Jan., 538	--	--	--
30H7	563	--	532	--	--

TABLE 4. - Water levels in wells in 1958 and 1978--Continued

Well No.	Altitude of land surface (feet)	Altitude of water table (feet)		Water- level change (feet)	Sug- gested future moni- toring	
		1958	January 1978			
8N/32W-31H1	660	Jan.,	581	578	-3	--
33M1	654	Jan.,	600	594	-6	--
34E1	670	Jan.,	580	570	-10	--
35R1	830	--		688	--	--
36B1	826	Jan.,	719	720	+1	--
8N/33W-3L1	690	--		620	--	--
5A1	770	--		717	--	--
9H2	590	F		F	--	--
13N1	620	P		497	--	--
13Q1	680	--		507	--	--
14R1	545	Jan.,	539	528	-11	--
19K1	368	Jan.,	319	316	-3	--
19L6	375	--		342	--	--
20K1	400	Jan.,	393	369	-24	--
20M2	383	--		325	--	--
20Q2	408	Jan.,	378	385	+7	M
21G1	422	--		400	--	--
21N1	408	Jan.,	402	389	-13	--
23N1	470	Jan.,	466	460	-6	--
23Q3	490	Jan.,	481	478	-3	--
24B1	614	June,	547	491	-56	--
24H1	580	June,	542	492	-50	--
25B1	528	Jan.,	517	526	+9	--
25B3	530	P		519	--	--
29D1	430	Jan.,	344	364	+20	--
29L1	550	Jan.,	410	356	-54	--
29L2	540	--		305	--	--
8N/34W-2M1	420	--		337	--	M
3J1	401	--		327	--	--
4N1	460	Oct.,	302	<318	--	--
7Q1	280	--		276	--	M
9K1	425	--		338	--	M
11B1	460	--		341	--	--
12G1	540	--		343	--	--
12L1	480	--		366	--	--
15F2	310	--		¹ 304	--	C
15R1	285	--		286	--	--
16C1	340	--		293	--	--
16C2	340	--		296	--	--
16C3	340	--		308	--	--

See footnote at end of table.

GROUND-WATER RESOURCES, SAN ANTONIO CREEK VALLEY, CALIF.

TABLE 4. - Water levels in wells in 1958 and 1978--Continued

Well No.	Altitude of land surface (feet)	Altitude of water table (feet)		Water- level change (feet)	Sug- gested future moni- toring	
		1958	January 1978			
8N/34W-16C4	340	--	316	--	--	
16C5	360	--	286P	--	--	
16D2	280	--	F	--	M	
16F1	290	--	F	--	M	
16F2	322	--	278	--	--	
16G2	306	--	337	--	--	
16G3	290	--	277	--	M	
16G4	306	--	282	--	--	
16J1	300	--	285	--	M	
16J2	320	--	396	--	--	
16J3	280	--	F	--	M	
17E1	270	--	265	--	--	
17G1	260	--	F	--	M	
17H1	260	--	F	--	M	
17K1	273	--	F	--	--	
17K2	260	F	F	--	M	
17Q1	270	--	F	--	M	
21A1	300	--	297	--	C	
22A1	297	Feb.,	294	281	-13	--
22E2	315	P	309	--	--	
22L1	400	Mar.,	313	308	-5	--
22Q1	460	Mar.,	362	446	+84	--
23B1	315	Jan.,	297	294	-3	M
23G2	314	--	291	--	--	
24F3	350	Jan.,	309	300	-9	--
27A1	455	--	423	--	--	
8N/35W-10J1	118	--	110	--	--	
12M1	145	--	¹ 140	--	M	
9N/32W-32K1	725	--	666	--	--	
33M1	745	--	679	--	--	
9N/33W-14F1	700	--	251	--	--	
23P1	755	--	302	--	--	
24F1	560	--	369	--	--	
28M1	903	--	633	--	--	
9N/34W-15Q1	430	--	73	--	--	
22N1	465	--	395	--	--	
23A1	570	--	<70	--	--	
32P1	480	--	465	--	--	
34L1	434	Mar.,	341	315	-26	--

¹Estimated water level based on post-January 1978 measurement.

Because the ground-water divides generally coincide with topographic divides, it is evident that there is no significant ground-water movement into or out of the San Antonio Creek valley and that recharge is derived from rainfall within the valley (fig. 8). As rain falls on the unconsolidated deposits, it either is held as soil moisture, seeps into the aquifer, or runs off to stream channels and contributes to recharge by percolation through the permeable streambeds. Nearly all the rain that falls on the impermeable consolidated rocks runs off. High streambed permeability is evidenced in the channels of several small creeks that terminate where they meet the valley floor. The water in these creeks is lost to percolation before becoming tributary to San Antonio Creek.

Ground water moves laterally from the divides and the contact between the unconsolidated deposits and consolidated rocks toward San Antonio Creek, then westward toward a base level at the Pacific Ocean. The water-level surface slopes steeply from an altitude of more than 1,200 ft at the eastern basin boundary to 600 ft at the valley floor, an average gradient of about 120 ft/mi. Beneath the valley floor the water-level surface slopes gently from 600 ft to slightly less than 300 ft at Barka Slough, an average gradient of about 25 ft/mi.

An area of ground-water discharge is indicated by the trough in the water-level surface along San Antonio Creek from about 3 mi east of Los Alamos to the ground-water barrier. San Antonio Creek does not flow perennially east of Barka Slough, and most natural ground-water discharge in this area occurs in the wet period as base flow and evapotranspiration. During the dry period, base flow diminishes to zero, owing to lowering of the water table from the combined effects of natural ground-water discharge and pumping for irrigation. West of Barka

Slough the creek flows perennially, and ground water is discharged by evapotranspiration in the marshlands, by base flow in the creek, and by pumping at the Vandenberg well field.

The change in ground-water storage between 1958 and 1978 was estimated by comparing the water-level contour maps for January of those two years (fig. 8). By January 1978 the rainy season had begun, irrigation pumps were turned off, and water levels were recovering from stresses imposed during the dry season of 1977. The map for 1958 prepared by Muir (1964) represents similar conditions.

Comparison of the water-level contours for 1958 and 1978 is difficult because the 1958 map was based on many measurements along the middle part of the valley and the 1978 map was based on measurements over the entire valley, including wells drilled since 1958. In some wells measured during both periods the water levels were higher in 1978 than in 1958, but in many wells the reverse was true. Of particular note, water levels consistently ranged from 25 to 65 ft lower in 1978 than in 1958 in a 3-square mile area centered about 2 mi northeast of Los Alamos. Over the ground-water basin an estimated average water-level decline of 3 ft occurred in the 20-year period. Based on an average storage coefficient for the aquifer of 0.15 and a 110-square-mile surface area, this water-level decline would result in a 32,000-acre-foot depletion in recoverable ground-water storage over the 20-year period, an average rate of 1,600 acre-ft/yr.

The hydrographs of figure 9 represent ground-water-level fluctuations in the heart of the agricultural area (8N/32W-30D1, fig. 8) and at Barka Slough (8N/34W-15F2 and 21A1) during 1978, the second wettest year on record at Los Alamos. The water-level changes in the agricultural area reflect pronounced effects of local seasonal pumping on ground-water conditions, whereas at Barka Slough they

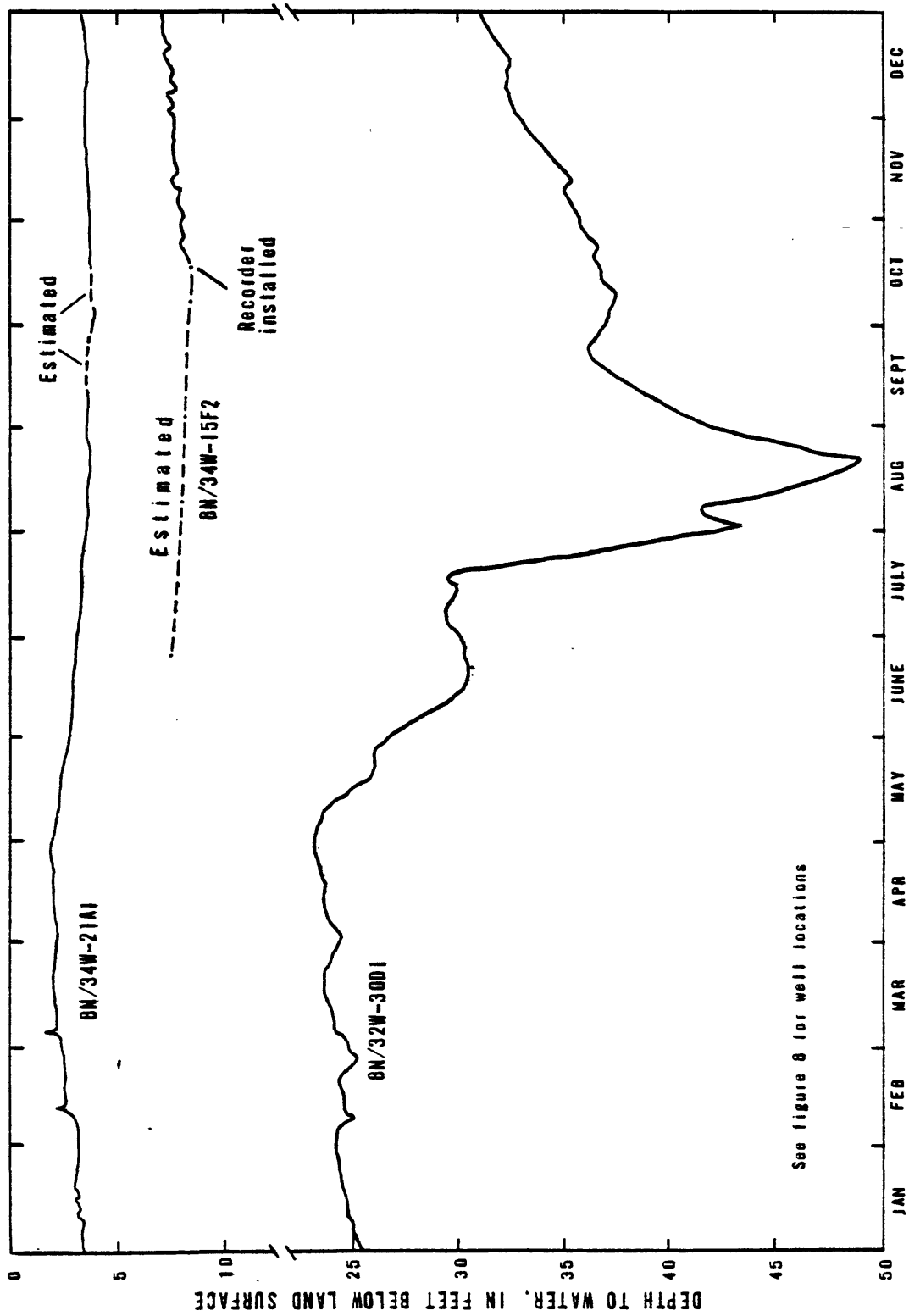


FIGURE 9.--Water levels in the aquifer during 1978.

represent ground-water conditions in an undeveloped area of environmental concern that is subtly affected by pumping in adjacent areas.

Water levels in each well rose only about 2 ft between January and April, a period in which nearly 40 inches of rain fell, thus indicating that the aquifer was nearly full prior to the rain or that its storage capacity is great. The well in the agricultural area is next to San Antonio Creek, which drains the area and which probably limits the high-water level in the well to about 24 ft below land surface, or an altitude of 540 ft. The well adjacent to the marshlands in the vicinity of Barka Slough monitors the artesian head of an aquifer capped by relatively impermeable clay and the peat formations of the marshland. When peak flows for San Antonio Creek were recorded February 10 and March 4, peak ground-water levels were also recorded in well 8N/34W-21A1, probably owing to loading of the aquifer as the high streamflows passed.

Ground-water-level declines, beginning in May, mark the end of the wet season. Nearby pumping was the principal cause for the water level decline of 26 ft in the agricultural-area well between May and August. At well 8N/34W-21A1, the water level declined 1.75-ft between May and August; little or no response can be attributed to a 2.7-Mgal/d average pumpage centered in the Vandenberg well field less than 1 mi to the north. The slight decline probably is the combined response to discharge of agricultural and military pumping as well as evapotranspiration in the marshlands and base flow of San Antonio Creek. Well 8N/34W-15F2 was installed in June 1978 and equipped with a recorder the following October. The water-level trend in the well correlates with that observed in well 8N/34W-21A1, which is downgradient and on the opposite side of Barka Slough.

Table 4 includes a suggested program for continued monitoring of ground-water levels that consists of monthly

measurements in 11 wells in and around Barka Slough, monthly measurements in 5 additional wells upgradient from the slough, and maintenance of the 3 continuous recorders installed for the duration of this investigation. The monitoring program in Barka Slough and agricultural areas would document water-level responses to pumping as well as to seasonal climatic factors.

In summary, ground-water divides coincide with topographic divides, suggesting that recharge to the basin is derived entirely from local rainfall and that there is virtually no underflow across the basin boundary. Ground-water levels declined an average of 3 ft over the 20-year period 1958-77, and the average rate of decline in recoverable ground-water storage was 1,600 acre-ft/yr. Because rainfall was near the long-term average, this decline is probably attributable to the increase in pumping from about 4,000 acre-ft in 1958 to about 10,600 acre-ft in 1977. Ground water is discharged naturally by evapotranspiration along streams and in the marshlands of Barka Slough and by base flow in San Antonio Creek. Although evapotranspiration has probably stabilized at 3,000 acre-ft/yr, base flow seems to be diminishing because of lowered ground-water levels in response to pumping. Seasonally, the aquifer in the agricultural area seems to be nearly full at the onset of the dry season, and water levels decline dramatically in response to irrigation pumping. In the Barka Slough area, agricultural and military pumping during the 1978 observation period seems to have had little effect on ground-water levels in the marshlands.

Water Quality

Chemical constituents in water vary with the environment. Rainwater becomes mineralized as it dissolves soluble minerals from the soil and rock through which it percolates. Ionic concentrations of ground water are

relatively low east of the ground-water barrier. The quartz sand that constitutes the aquifer is relatively insoluble, and clay particles tend to remove cations by adsorption. Ground water east of the barrier has calcium and bicarbonate as the principal ions but contains relatively high percentages of sodium and sulfate also.

Figure 10 shows, by use of pie diagrams, the areal variation in concen-

trations of selected chemical constituents in samples from 21 wells east of the ground-water barrier, a sample from a well west of the barrier, and samples from San Antonio Creek at 4 sites. A diagram of average ground-water quality east of the barrier is provided for comparison. Chemical analyses are presented in table 5.

Ground water has a dissolved-solids concentration averaging 710 mg/L. Con-

TABLE 5. - Chemical analyses
[Chemical analyses are in milligrams]

Stream site or well No.	Name or owner	Date of sample	Stream discharge (ft ³ /s) or well depth (ft)	Specific conductance (µmho/cm at 25°C)	pH (units)	Hardness as CaCO ₃	Calcium	Magnesium	Sodium
SURFACE WATER									
S-1 ¹	San Antonio Creek	5- 3-78	0.1	840	9.0	310	71	31	71
S-2 ¹	San Antonio Creek	5- 3-78	21.8	1,550	7.6	400	110	31	190
S-3	San Antonio Creek	5- 3-78	1.8	3,450	8.2	870	220	79	470
S-4	San Antonio Creek	5- 3-78	2<1	3,250	7.8	820	180	90	420
GROUND WATER									
7N/32W-1B1 ¹	Barham Ranch	5-15-78	--	700	7.7	270	65	25	55
8N/31W-20M1 ¹	S. F. Luton	5-18-78	--	930	7.4	330	84	28	78
8N/31W-33Q1	Getty Oil Co.	4-28-78	--	910	7.2	440	92	50	42
8N/32W-25D1	P. A. Greene	7-11-78	710	830	7.1	390	100	34	73
8N/32W-30H7 ¹	Los Alamos	5-15-78	310	640	6.8	220	50	22	54
8N/32W-33M1	E. T. Fields	5-18-78	--	1,400	7.2	410	91	45	130
8N/33W-31L ¹	Madonna Const. Co.	5-18-78	362	530	7.7	180	58	7.7	46
8N/33W-19G2 ¹	J. Carr	5-15-78	126	1,700	7.4	620	130	71	180
8N/33W-20M2	Carerri	5-15-78	--	1,000	7.6	350	90	30	110
8N/33W-20R1 ¹	V. Barca Estate	5-15-78	--	1,750	7.5	--	180	78	120
8N/33W-21H1	A. Ainscough	5-15-78	400	850	7.7	330	78	34	63
8N/33W-22H1 ¹	A. Monighetti	5-15-78	180	1,300	7.4	520	140	41	81
8N/33W-25B2	--	5-15-78	18	1,000	7.3	260	25	48	50
8N/34W-2M1	American Wines	6- 1-78	--	840	7.0	210	58	16	94
8N/34W-15F2	U.S. Air Force	8- 8-78	298	400	6.5	100	27	8.4	45
8N/34W-16C5 ¹	U.S. Air Force	5-18-78	334	700	7.7	210	64	13	63
8N/34W-21A1	U.S. Air Force	4-28-78	271	1,500	7.3	590	170	39	120
8N/34W-22A1 ¹	R. Barca	5-15-78	--	1,260	8.2	460	110	44	120
8N/34W-23B3	J. Harris Estate	5-15-78	--	1,300	7.0	410	100	40	130
8N/34W-24K1 ¹	Hanson	5-15-78	--	1,600	7.2	530	130	51	170
8N/35W-12M1 ¹	U.S. Air Force	7-11-78	100	5,850	6.6	950	200	110	1,100
9N/34W-34C1 ¹	G. B. Thompson	5-15-78	140	1,150	7.4	280	88	15	150
Recommended maximum for potable water ³			--	--	5.9	--	--	--	--

¹Suggested for annual sampling.

²Estimated.

³National Academy of Sciences and National Academy of Engineering (1972).

centrations tend to exceed the average in wells adjacent to San Antonio Creek in the lower part of the valley, between Los Alamos and the ground-water barrier. Concentrations tend to be below average in wells in the upper part of the valley and along its flanks. This phenomenon probably results from a combination of man-induced and natural causes. Irrigation return water tends to increase

dissolved-solids concentration through evaporation and leaching of the soil, thereby increasing the salinity of the ground water. Also, as ground water moves from the recharge area to the discharge area, soluble minerals are dissolved, thereby increasing the dissolved-solids concentration.

Because the Vandenberg Air Force Base well field is at the discharge end of the basin, water quality might

of surface and ground water
per liter except where noted]

Potas- sium	Bicar- bonate	Alka- linity as CaCO ₃	Sulfate	Chloride	Fluoride	Silica	Dissolved solids	Nitrite plus nitrate as N	Boron (µg/L)	Iron (µg/L)
SURFACE WATER										
5	170	170	210	57	0.5	39	587	0.38	200	70
11	400	330	180	190	.4	48	985	6	920	170
23	560	460	520	630	.4	38	2,280	4.9	2,500	130
12	550	450	410	620	.6	31	2,040	.71	1,400	70
GROUND WATER										
3	290	240	18	73	.1	36	451	7.5	100	20
4	340	280	120	60	.2	50	598	1.4	150	10
2	320	260	210	31	.6	33	625	1.5	110	110
4	310	250	220	38	.3	38	662	.18	140	660
3	130	110	130	63	.2	53	447	1.6	100	130
7	300	250	360	110	.1	48	949	2.2	490	50
2	190	160	23	55	.2	40	332	1.4	700	10
5	530	430	320	160	.2	37	1,170	1.7	460	30
5	280	230	250	59	.1	47	730	.06	330	30
3	560	460	310	180	.2	45	1,190	.05	250	40
3	300	250	130	69	.1	46	574	.53	150	60
4	300	250	78	190	.1	45	833	24	140	20
3	250	210	150	120	0	47	640	.02	260	3,000
5	120	98	96	120	.3	52	511	2.4	180	110
2	--	82	13	52	.3	35	263	6.5	60	920
3	200	160	73	75	.2	44	435	.09	110	120
7	310	250	400	130	.2	44	1,070	.01	550	4,000
6	360	300	200	150	.2	32	842	.44	260	60
6	240	200	160	210	.1	38	831	6.5	220	50
4	500	410	250	170	.1	44	1,080	2.9	380	0
28	1,500	1,230	23	1,500	.1	32	3,780	7.1	9,400	9,000
3	330	270	23	210	.3	15	670	.12	140	2,300
--	--	400-500	250	250	1.4	--	--	11	1,000	300

GROUND-WATER RESOURCES, SAN ANTONIO CREEK VALLEY, CALIF.

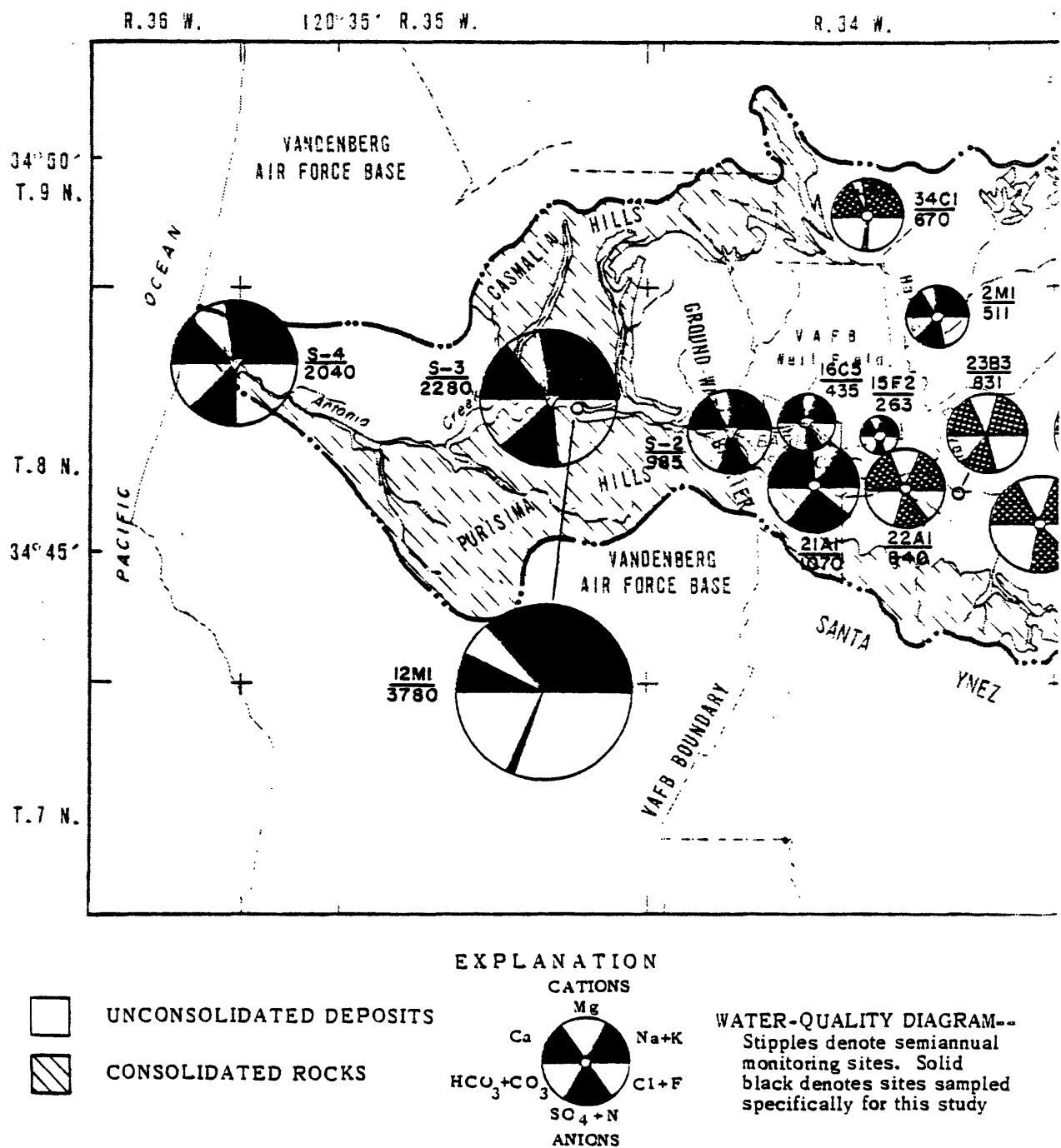
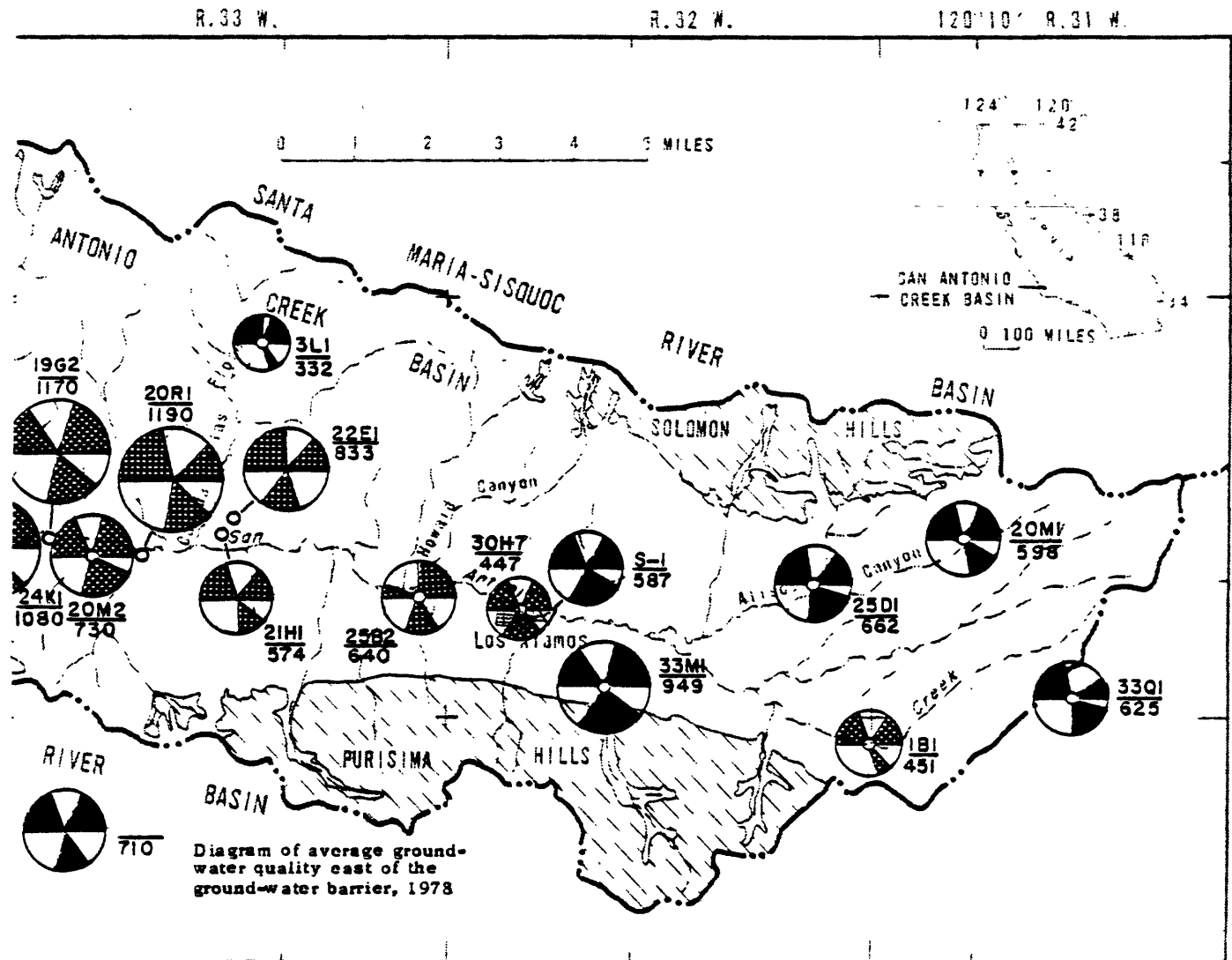


FIGURE 10.—Quality of surface and ground water.



Consolidated-rock boundaries from K. S. Muir (1964)

EXPLANATION—Continued

0 1 2 3 4
MILLIGRAMS
PER LITER,
in thousands

SCALE OF RADII—Radius of circle
represents dissolved-solids
concentration

--- BASIN BOUNDARY

WATER-QUALITY MONITORING
SITES, 1978--Upper number is
well or stream site. Lower
number is dissolved-solids
concentration, in milligrams
per liter

○ 1B1
451

Well

▽ S-1
587

Stream

FIGURE 10.—Continued

be expected to be poorer than average. A representative sample of ground water from the well field, collected from supply well 8N/34W-16C5, had a specific conductance of 700 $\mu\text{mho/cm}$ and a dissolved-solids concentration of 435 mg/L. The Paso Robles Formation is thin in this area; the production wells tap both the Paso Robles Formation and the underlying Careaga Sand. Since no wells are known to tap the Careaga Sand exclusively, the quality of water from the unit is unknown but may be better than that from the Paso Robles Formation. Another explanation for the water of good quality at the well field may be that the source is to the north in relatively pristine lands, rather than to the east where ground-water quality is known to be poor. Water from the well field has shown increases in concentrations of sulfate, manganese, and iron (E. W. Rodgers, U.S. Department of the Air Force, written commun., 1979).

Water from the aquifer west of the ground-water barrier has a high concentration of sodium chloride. Muir (1964, p. 48) recognized this from a 1958 analysis of water from well 8N/34W-17K1 (see fig. 8 for location) directly east of the ground-water barrier; he attributed the poor quality of ground water west of the barrier to seepage from the marine shale which underlies the area at shallow depths. The 1978 analysis of water from well 8N/35W-12M1, about 2 mi west of the barrier, also indicated moderately saline water (Hem, 1970, p. 219), having a dissolved-solids concentration of 3,780 mg/L. This probably supports the conclusion by Muir, because the aquifer at this site is entirely above sea level, therefore salt-water intrusion cannot account for the increased salinity. Heavy pumping near the barrier or along the edges of the ground-water basin could induce seepage of water of poor quality by upwelling or lateral seepage from consolidated rocks into the principal aquifer.

San Antonio Creek was sampled May 3,

1978, during a base-flow period. Flows of 0.1 and 1.8 ft^3/s were recorded at sites S-1 and S-3, respectively. The flow at site S-2 was estimated to equal that at site S-3, and at site S-4 to be less than 1 ft^3/s . At site S-1, near Los Alamos, stream-flow is derived from upgradient ground-water sources, and water quality is similar to that of average ground water. At site S-3, about 2 mi west of the barrier, the percentages of sodium and chloride are greater, owing to a combination of seepage from and dissolution of the underlying shale that forms the channel bottom in many stretches of the creek as it passes between the Purisima and Casmalia Hills. At site S-4, about 1 mi upstream from the Pacific Ocean, the water quality is similar to that at site S-3. This indicates that all the stream-quality degradation occurs in the area between the Purisima and Casmalia Hills.

Degradation of ground-water quality associated with agricultural development is commonly observed. In the San Antonio Creek valley the degradation could result from increased mineralization by irrigation return and by upward migration of deep ground water. If the perennial yield of the basin is exceeded, the ground-water circulation pattern may eventually resemble a closed basin, with no outflow. The consequent buildup of dissolved solids in irrigation water would eventually pose a salinity hazard to crops.

A recent report by Ayers (1977) has set guidelines for evaluating the salinity hazard of irrigation water through analysis of specific conductance, as follows:

Specific conductance ($\mu\text{mho/cm}$ at 25°C)	Salinity hazard
<750	No problem
750-3,000	Increasing problems
>3,000	Severe problems

Table 5 indicates that almost all the ground water in the central agricultural area of the valley is in the specific-conductance range for increasing salinity problems. West of the barrier, severe salinity problems exist in all water. The vegetable and field crops of the valley may be classed as moderately tolerant to the salinity of the water supply. The recent upward trend in grape production in the valley may be slowed by the low to moderate salinity tolerance of the plants.

Currently (1978), the U.S. Geological Survey monitors water quality from 12 wells in the San Antonio Creek valley. Four of the wells have been monitored semiannually or annually since the late 1950's. Eight wells have been sampled semiannually or annually since 1974. A graph of dissolved-solids concentration versus time indicates that the range of fluctuation in most samples is within 200 mg/L and that water quality remained fairly stable between 1958 and 1978 (fig. 11). Two samples, from wells 8N/33W-22E1 and 8N/33-20R1, showed a marked increase in dissolved-solids concentration. Dissolved solids in well 22E1 rose from 658 mg/L in May 1974 to 833 mg/L in May 1978. Between May 1958 and May 1978 the dissolved solids in well 20R1 rose from 781 to 1,190 mg/L. The causes for such marked increases in dissolved solids are unknown, but apparently there are general increases over a broad range of ionic constituents since the water-quality diagrams of the two wells are similar to that of average ground-water quality east of the barrier.

Five factors point toward the need for a revised water-quality monitoring network in the valley:

1. Construction characteristics of many wells, such as depth and perforated interval, are unknown or not well documented.

2. The wells are not evenly distributed throughout the valley. The

heaviest concentration occurs in the western half of the valley along San Antonio Creek.

3. Ten of the 12 current monitoring wells produced water of stable quality over the range of measurements. Because these wells are clustered, it will be necessary to retain only a few key monitoring wells.

4. Because changes in water quality occur gradually, semiannual monitoring is probably unnecessary.

5. Surface-water quality in San Antonio Creek is not being monitored regularly.

A revised water-quality monitoring program that includes 2 surface-water sites and 12 wells distributed throughout the valley is shown in table 5. The revised program samples sites downgradient of, within, and up-gradient of Barka Slough. The existing long-term ground-water monitoring sites and sites where degradation of water quality is now evident would be maintained. Surface-water quality above and below Barka Slough would be monitored. The revised monitoring program would alleviate many of the deficiencies inherent in the existing network.

HYDROLOGIC BUDGET

The hydrologic budget is a quantitative assessment of the inputs to and outputs from the San Antonio Creek ground-water basin. From year to year or season to season, differences between inputs and outputs are balanced by changes in storage, as reflected in fluctuations of ground-water levels, but over the long term, under natural or otherwise steady-state conditions, inputs and outputs tend to balance.

A conceptual model of the average annual hydrologic budget of the San Antonio Creek valley over the period 1958-77 is illustrated in figure 12

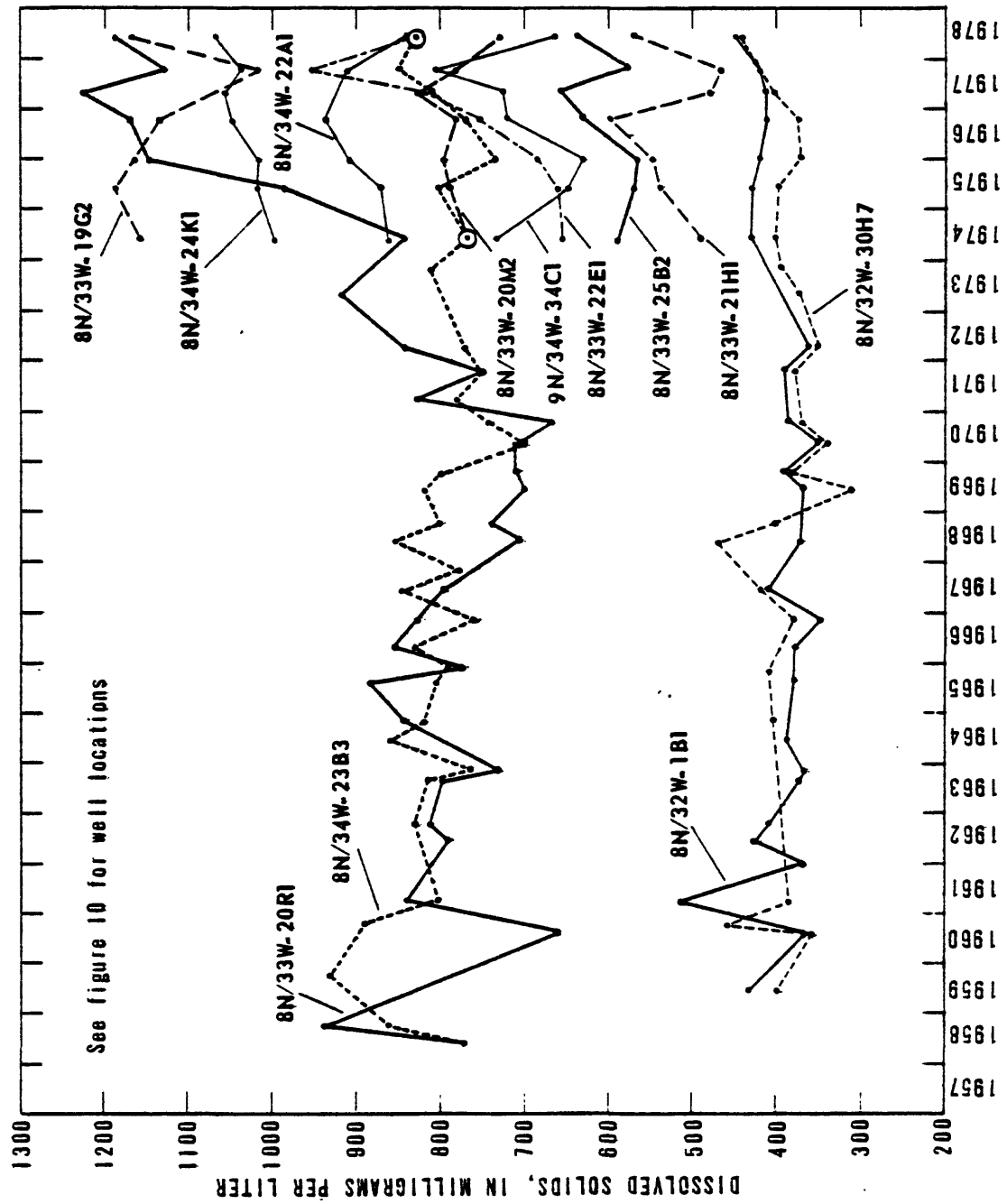


FIGURE 11.--Dissolved-solids concentration in ground water of the San Antonio Creek valley, 1958-78.

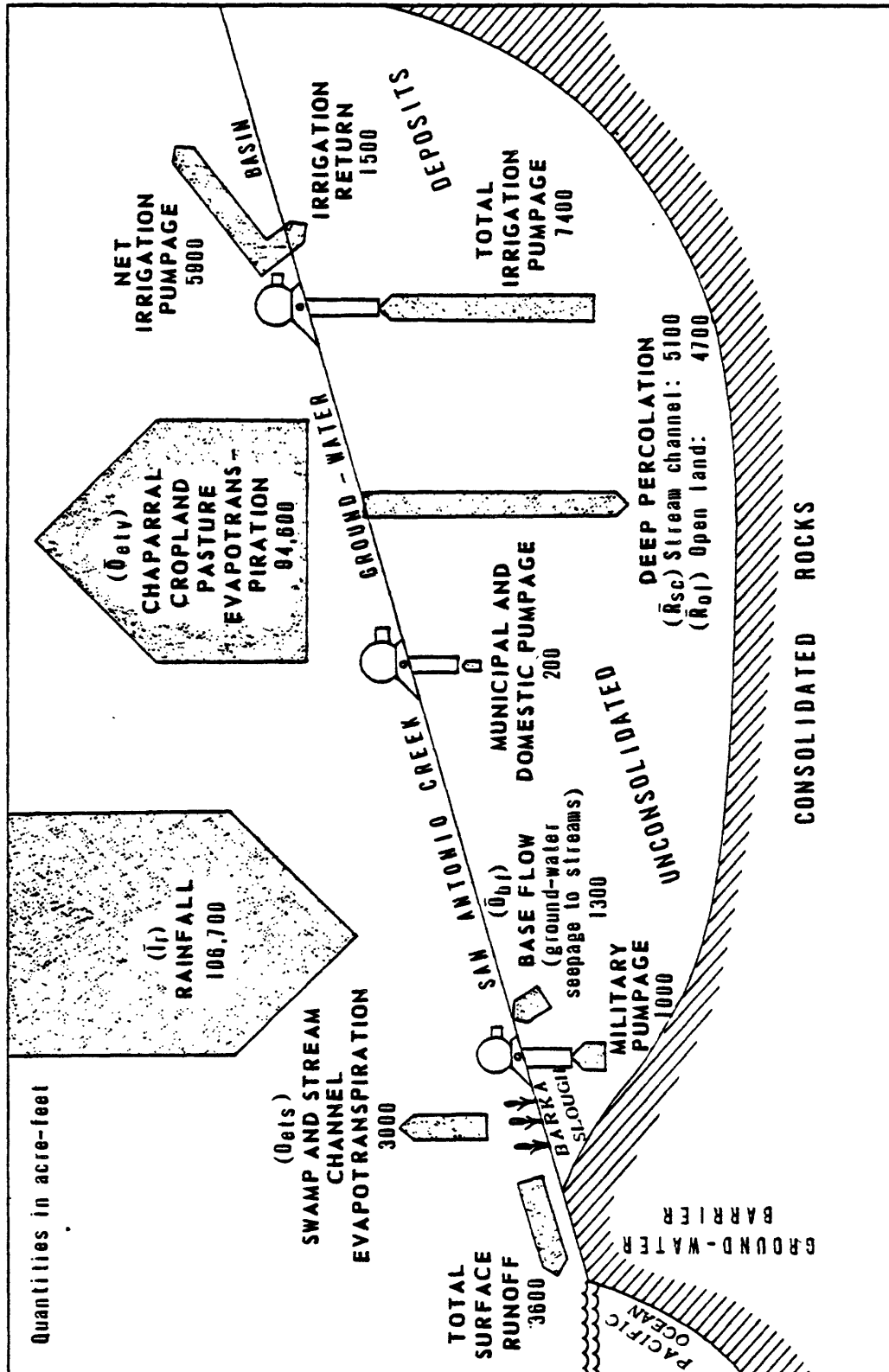


FIGURE 12.--Conceptual model of the annual hydrologic budget for the San Antonio Creek valley, based on the period 1958-77.

and may be expressed by the following terms:

INPUT - OUTPUT = CHANGE IN STORAGE

$$[\bar{I}_r + \bar{I}_{gw}] - [\bar{O}_{bf} + \bar{O}_s + \bar{O}_p + \bar{O}_{ets} + \bar{O}_{etv}] = \bar{\Delta S} \quad (1)$$

$$[106,700] - [108,300] = -1,600$$

where:

- \bar{I}_r , average input by rainfall,
= 106,700 acre-ft;
- \bar{I}_{gw} , average input by ground-water inflow by underflow from adjacent basins,
= 0 acre-ft;
- \bar{O}_{bf} , average output by base flow of San Antonio Creek,
= 1,300 acre-ft;
- \bar{O}_s , average output by surface runoff via San Antonio Creek, = 2,300 acre-ft;
- \bar{O}_p , average output by net pumpage of ground water,
= 7,100 acre-ft;
- \bar{O}_{ets} , average output by evapotranspiration by phreatophytes at Barka Slough and along the banks of San Antonio Creek,
= 3,000 acre-ft;
- \bar{O}_{etv} , average output by evapotranspiration in the upper valley in chaparral, cropland, and pasture lands,
= 94,600 acre-ft;
- $\bar{\Delta S}$, average annual change in ground-water storage,
= 1,600 acre-ft.

Output from the valley averaged 108,300 acre-ft/yr and exceeded input by the amount of water removed from ground-water storage, which averaged 1,600 acre-ft/yr. The basis for the determination of the eight components of the average annual hydrologic budget is as follows:

1. Rainfall (\bar{I}_r) is the average for 20 years of record (1958-77) at Los Alamos (National Oceanic and Atmospheric Administration, 1958-77), computed for the 154-square mile drainage basin.

2. The San Antonio Creek basin boundary coincides with ground-water divides; consequently, ground-water inflow (\bar{I}_{gw}) across the basin boundary is negligible.

3. The average base flow of San Antonio Creek (\bar{O}_{bf}), estimated in this report by hydrograph separation represents seepage to San Antonio Creek from the aquifer.

4. The average surface runoff (\bar{O}_s) represents the difference between average total streamflow and average base flow gaged at the station just downstream from the ground-water barrier.

5. The average net pumpage of ground water (\bar{O}_p) represents the military, municipal, and irrigation pumpages estimated earlier in this report. Irrigation pumpage is adjusted to a net figure by assuming a 20-percent return flow to the aquifer.

6. The average evapotranspiration (\bar{O}_{ets}) at Barka Slough and along the banks of San Antonio Creek, 5 mi up-gradient from the slough, was computed by Muir (1964, p. 32). Because vegetal conditions in 1977 are similar to those observed in 1958, annual evapotranspiration was assumed to be constant during the interim.

7. The average evapotranspiration (\bar{O}_{etv}) in the upper valley, representing the amount of water intercepted by the soil zone and plants before reaching the saturated zone, was computed as a residual in the hydrologic budget.

8. The average change in ground-water storage ($\bar{\Delta S}$) was computed previously by comparing water-table maps of January 1958 and January 1978.

The components of the hydrologic budget may be used to quantify the sources of recharge to the principal aquifer. Recharge occurs as infiltration of rainfall on open land and as deep percolation of surface water

along stream channels. The average annual recharge is estimated at 9,800 acre-ft/yr by the equation:

$$\bar{R}_{ol} + \bar{R}_{sc} = \bar{I}_r - (\bar{O}_s + \bar{O}_{etv}) \quad (2)$$

where:

\bar{R}_{ol} is the average annual recharge by infiltration of rainfall over open land;

\bar{R}_{sc} is the average annual recharge by stream-channel percolation;

\bar{I}_r , \bar{O}_s , \bar{O}_{etv} , the components of the average annual hydrologic budget described previously, = 9,800 acre-ft/yr.

The Santa Barbara County Water Agency has developed a set of general functions for determining the infiltration of rainfall over open land (Santa Barbara County Water Agency, 1977, p. C-1). The functions assume uniform temporal and areal distributions of rainfall without regard to intensity of individual storms; therefore, they are probably useful only for determining long-term average infiltration. As applied to the San Antonio Creek valley, the functions would take the following form:

1. Rate of recharge by infiltration in irrigated lands.

$$(a) \quad R_{ol} = (I_r - 10.5) / 1.833 \quad (10.5 \leq I_r \leq 16) \quad (3)$$

$$(b) \quad R_{ol} = (I_r - 12.7) / 1.087 \quad (I_r > 16) \quad (4)$$

2. Rate of recharge by infiltration in non-irrigated lands.

$$R_{ol} = (I_r - 17) / 1.550 \quad (I_r \geq 17) \quad (5)$$

The components of the infiltration equations are defined in equations 1 and 2 but are expressed in inches on

an annual basis rather than as 20-year averages. Note that the equations indicate that no infiltration occurs over irrigated lands until at least 10.5 inches of rain falls, or over nonirrigated lands until at least 17 inches of rain falls. During 6 of the 20 years between 1958 and 1977 rainfall totaled less than 10.5 inches; hence, no recharge by infiltration occurred. The 17-inch mark was exceeded in only 6 years.

Using the rainfall-infiltration functions, average annual infiltration over open land (\bar{R}_{ol}) was computed as

4,700 acre-ft during the period 1958-77. By substitution in equation 2, average annual recharge by stream-channel percolation is 5,100 acre-ft.

The components of the hydrologic budget may also be used to quantify the perennial yield of the San Antonio Creek ground-water basin. A preliminary estimate of 7,000 acre-ft/yr for the perennial yield was made by Worts and Wilson (1964, p. 36) on the basis of their definition of perennial yield as:

"...the rate at which water can be pumped from wells year after year without decreasing the stored water to the point where the rate becomes economically infeasible or where the quality of water deteriorates."

This definition implies that a depletion of ground-water storage (that is, excess of discharge over recharge) is acceptable. If this were the case, and the basin were pumped year after year in excess of its perennial yield, eventually it would dry up. An alternate definition, offered herein, is that perennial yield equals the average annual ground-water outflow from the basin plus the average annual change in ground-water storage. This definition is based purely on water balance and does not consider water-quality implications, which are becoming increasingly important factors in the management of the agricultural resources of the basin.

Perennial yield of the San Antonio Creek ground-water basin as defined in this report is determined by the equation:

$$\begin{array}{rcccl} \text{AVERAGE} & & \text{AVERAGE} & & \\ \text{GROUND-WATER} & + & \text{CHANGE IN} & = & \text{PERENNIAL} \\ \text{OUTFLOW} & & \text{STORAGE} & & \text{YIELD} \\ \\ [\bar{O}_{bf} + \bar{O}_p + \bar{O}_{ets}] + & \Delta \bar{S} & = & PY & (6) \end{array}$$

where: \bar{O}_{bf} , \bar{O}_p , \bar{O}_{ets} , components of the average annual hydrologic budget as defined previously, = 11,400 acre-ft/yr;

$\Delta \bar{S}$, average annual change in ground-water storage, = -1,600 acre-ft/yr; and
 PY, perennial yield, = 9,800 acre-ft/yr.

The perennial-yield estimate may be misleading in that it includes average base flow of San Antonio Creek (\bar{O}_{bf}) and average evapotranspiration by phreatophytes at Barka Slough and along the channel of San Antonio Creek (\bar{O}_{ets}), which should be maintained if it is desired to preserve existing environmental conditions. By eliminating these components of the hydrologic budget from equation 6, the component of perennial yield available for net pumpage of ground water totals 5,500 acre-ft/yr. Any increase in net pumpage over this figure would result in reductions in base flow, evapotranspiration, and ground-water storage.

The Santa Barbara County Water Agency (1977) estimated perennial yield for consumptive use (net pumpage) to be 7,400 acre-ft/yr under present (1977) conditions. This estimate is 1,900 acre-ft/yr higher than that presented herein and primarily the difference results from estimating 1,100 acre-ft/yr as total evapotranspiration and base flow as opposed to a 4,300 acre-ft/yr average documented in

this report. The basis for the Agency estimate was not defined.

Several management approaches may be employed to increase the perennial yield of the San Antonio Creek ground-water basin. Over the 20-year period 1958-77, the average pumpage has been great enough to upset the hydrologic balance of the basin, as evidenced by the decline in ground-water storage. Because pumpage in the 1970's and projected pumpage during the 1980's are greater than the average annual pumpage during the 1958-77 analysis period, ground-water level declines may accelerate. Four approaches that might increase perennial yield are:

1. Increasing precipitation. By inducing precipitation through a cloud-seeding program, recharge to the ground-water basin would increase and pumpage for irrigation should decrease. Results would be especially beneficial if the duration of the rainy season were extended. Santa Barbara County was involved in an effective experimental cloud-seeding program between 1967 and 1974 (Thompson and others, 1975).

2. Reducing base flow and slough evapotranspiration. By pumping large quantities of water from wells in the Barka Slough area, water levels could be lowered below the root zones of the marshland vegetation, and base flow and evapotranspiration could be captured for man's use. Because the marshlands of Barka Slough are an environmentally sensitive area, this approach to increasing perennial yield might not be feasible.

3. Reducing evapotranspiration in the upper valley. Chaparral, cropland, and pasture evapotranspiration approaches 100,000 acre-ft/yr. A 10-percent reduction in this figure could result in an appreciable increase in perennial yield. Management approaches might include mowing of chaparral lands, installation of drip-irrigation systems, and selection of water-efficient pasture grasses.

4. Reducing surface runoff. By constructing stream-channel barriers or recharge pits along stream channels above the valley flat, surface water normally discharged to the sea could be retained for infiltration to the water table, thereby increasing the perennial yield of the basin. This approach for ground-water basin management has been widely used in southern California.

Each of the management alternatives addresses a specific component of the hydrologic budget. Reducing average base flow (1,300 acre-ft/yr) and average phreatophyte evapotranspiration (3,000 acre-ft/yr) probably would not be acceptable from an environmental standpoint. Reducing evapotranspiration in the upper part of the valley or increasing precipitation are potentially attractive methods, but their impact is difficult to assess. Reducing surface runoff is a proved method; however, on the average only 2,300 acre-ft/yr is available for salvage, and if added to the component of perennial yield available for net pumpage (5,500 acre-ft/yr) the revised component of perennial yield available for net pumpage would have fallen short of the total net pumpage (10,570 acre-ft) in 1977.

IMPACT OF OVERDRAFT ON THE BASIN

Overdraft of the San Antonio Creek ground-water basin has steadily increased since 1964, when total ground-water discharge began to exceed perennial yield (table 1 and figure 4). By 1977 the ground-water discharge totaled 14,139 acre-ft, with a resulting overdraft of about 4,300 acre-ft. The impact of increased withdrawals could be to reduce water-level gradients to Barka Slough, thereby possibly reducing the base flow of San Antonio Creek and evapotranspiration in the marshlands.

The trend of declining base flow owing to increased pumping of ground water is illustrated empirically in

figure 13. Prior to 1964, base flow was erratic, and apparently it related more closely to the distribution and intensity of rainfall than to pumpage. By 1964, overdraft became appreciable, and during years of near-average rainfall a steady decline in base flow followed the steady increase in net pumpage. Because the slope of the regression line is about -0.2, about 80 percent of the pumpage is derived from sources in the hydrologic budget other than base flow. The interaction between pumpage and the other components is complex and impossible to solve analytically with the small amount of data on hand.

An estimate as to when base flow might decline to zero may be made by projecting the regression line of figure 13 to the point of zero base flow. By assuming that the relation between base flow and pumpage is linear during near-average rainfall years, base flow should reach zero when net pumpage reaches about 13,500 acre-ft/yr. During 1977 net pumpage totaled 10,570 acre-ft, an increase of about 3,000 acre-ft for the period 1968-77.

An environmental consequence of reducing base flow in San Antonio Creek is endangerment of flora and fauna in Barka Slough and in downstream water. Also, with no base flow the natural flushing action of the ground-water basin is halted, a condition that could result in an increased salinity hazard to crops. It should be noted, however, that increased pumping for irrigation necessarily results in increased runoff to San Antonio Creek, thereby compensating for some of the reduction in base flow. Nutrients and pesticides in the irrigation runoff could contribute to floral and faunal changes in Barka Slough. By periodically measuring streamflow and stream quality just east of Barka Slough, the contribution of irrigation runoff to total streamflow and stream quality during the irrigation season could be measured.

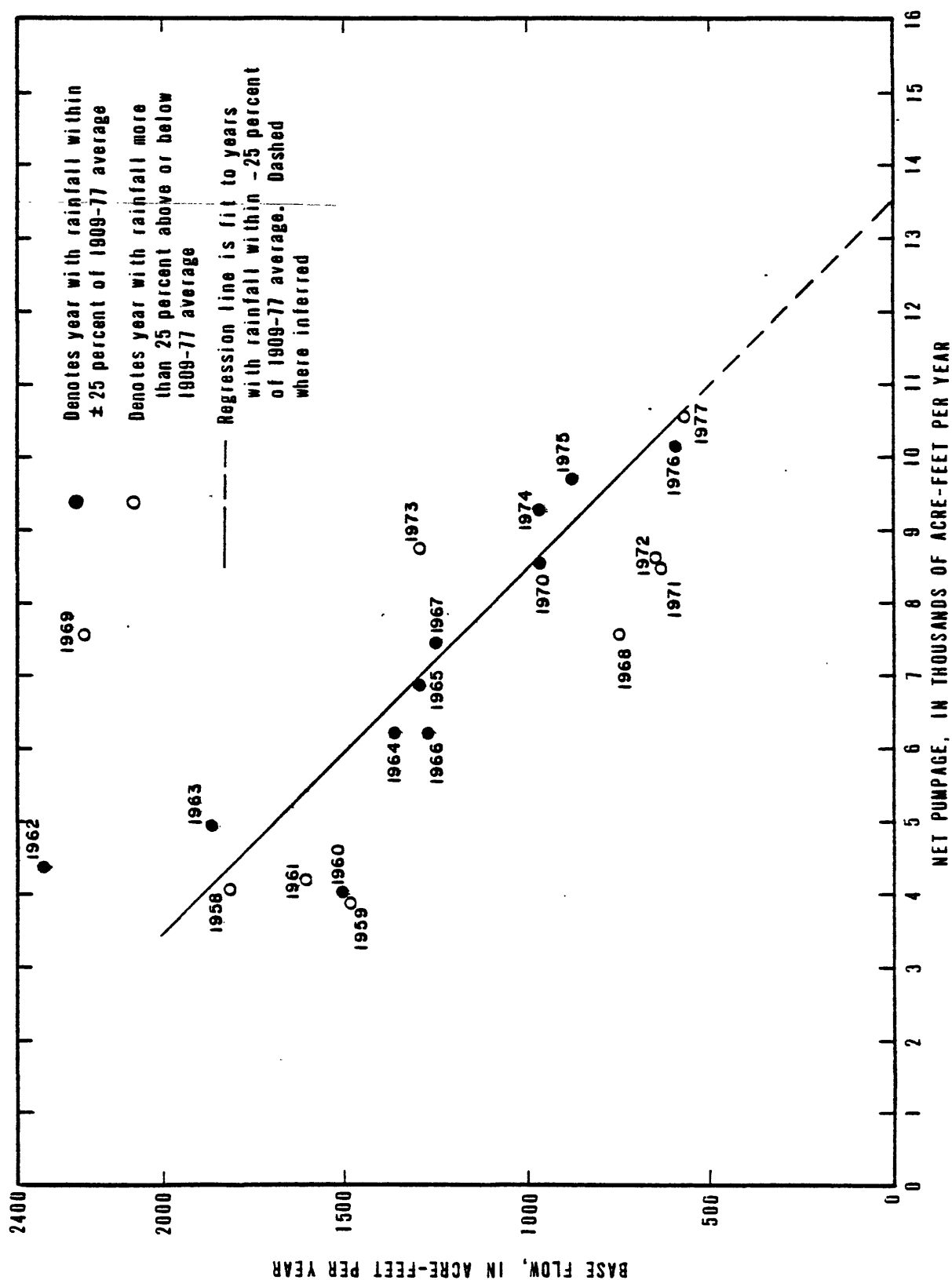


FIGURE 13.--Base flow in San Antonio Creek versus net pumpage from the ground-water basin.

An elementary hydrologic model showing the impact of future pumping on ground-water levels under a specified condition, and based on the hydraulic characteristics of the aquifer, was constructed by using a special drawdown scale developed by Conover and Reeder (1963). The scale was used to prepare a map of drawdown (fig. 14) that should result after 5 years of sustained pumping at the Vandenberg well field at a projected rate of 4,200 acre-ft/yr (Santa Barbara County Water Agency, 1977). Superimposed on this map is a map of drawdown that should result after 5 years of sustained net pumping for irrigation at a rate of 11,900 acre-ft/yr, which is 6,000 acre-ft/yr greater than the 1958-77 average net irrigation pumpage.

Because the model is a simple one, it does not account for recharge or an even areal distribution of discharge points, and it assumes that ground-water discharge is derived entirely from storage within the aquifer. At the Vandenberg well field the aquifer is confined; hence, recharge is accounted for by leakage to the aquifer, by either reducing evapotranspiration at Barka Slough or reducing base flow in San Antonio Creek, or both. By assuming that a steady-state condition existed prior to increasing pumping in the agricultural areas, recharge could be accounted for by withdrawing only the excess of projected pumpage over steady-state pumpage.

The hydraulic characteristics of the aquifer were derived from aquifer tests. At the Vandenberg well field it was assumed that pumping occurred at a single point, and in the agricultural area it was evenly distributed among three points along San Antonio Creek.

At the Vandenberg well field, water-level declines after 5 years of pumping would exceed 5 ft within a half-mile radius of the center of pumping and would be zero within about 2 mi. The impact on Barka Slough would be to

drop the potentiometric surface below land surface at the north side, which is nearest the well field; thus, water normally lost to base flow and evapotranspiration would be captured by pumping.

Water-level declines after 5 years of pumping for irrigation would be less than 4 ft in most of the area north of San Antonio Creek and between 4 and 6 ft in most of the area south of the creek. Declines should be greater in the southern part of the ground-water basin because of its proximity to the consolidated-rock boundary of the Purisima Hills.

Because the example is based on an elementary model, conclusions about overdraft must be generalized. Under the stated conditions, declines should be only a few feet rather than tens of feet. More accurate predictions could be made from a complex computer model. Such a model could be interrogated under a variety of water-management plans. The data presented in this report and its predecessor (Muir, 1964) should considerably facilitate a modeling project if one is undertaken.

CONCLUSIONS

The appraisal of ground-water resources in the San Antonio Creek valley has been directed toward the following questions and answers:

1. What are the current ground-water conditions in the valley? Recharge to the ground-water basin occurs as infiltration of rainfall over open land and as seepage through stream channels. Ground-water movement is directed toward the coast but is hindered by a geologic barrier, behind which upwelling to the land surface has resulted in a 550-acre marshland. During the period 1958-77, ground-water levels declined as much as 65 ft in one area of the valley, but the overall decline averaged about 3 ft. VAFB obtains some of the best water in the valley from its well

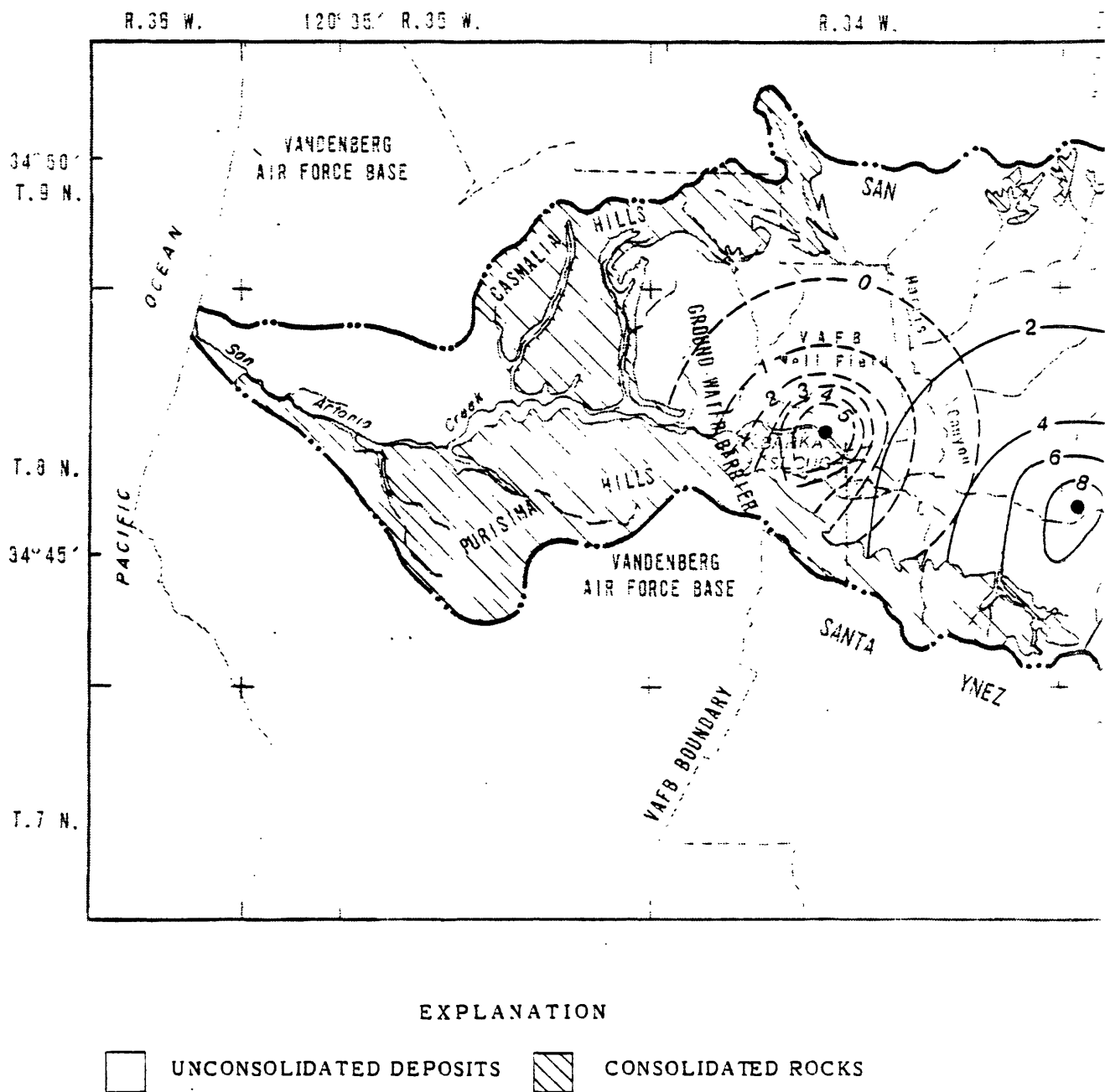


FIGURE 14.--Projected water-level declines in the San Antonio Creek ground-water basin after 5 years of specified pumping.

R. 33 W.

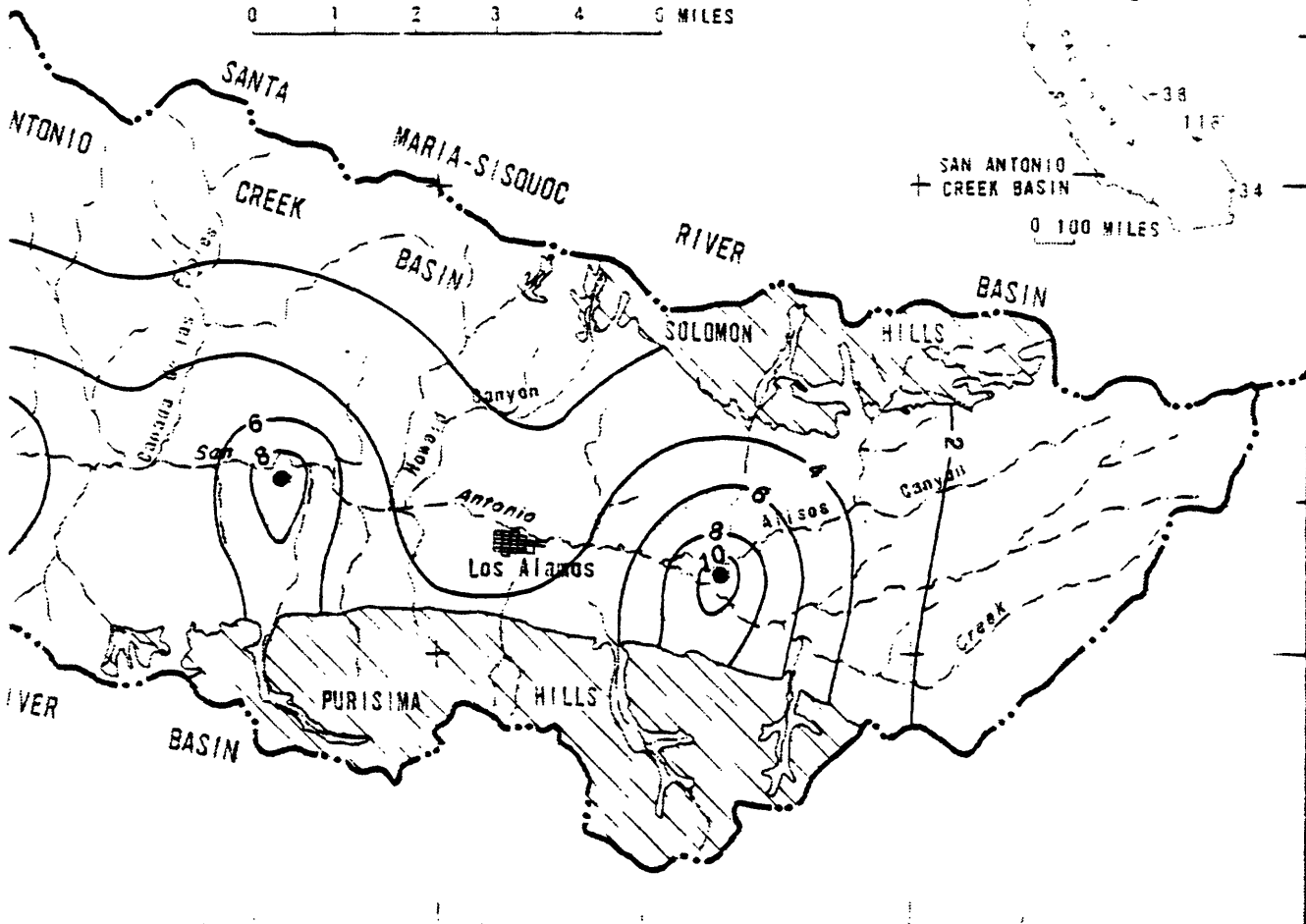
R. 32 W.

120° 10' R. 31 W.

0 1 2 3 4 5 MILES

124° 120°
42"SAN ANTONIO
CREEK BASIN

0 100 MILES



Consolidated-rock boundaries from K. S. Muir (1964)

EXPLANATION--Continued

- 8 — LINE OF EQUAL WATER-LEVEL DECLINE --
 Solid line denotes decline resulting from 11,900 acre-feet per year net irrigation pumpage. Dashed line denotes decline resulting from 4,200 acre-feet per year military pumpage. Interval 1 and 2 feet
- BASIN BOUNDARY
- PUMPING CENTER

FIGURE 14.--Continued

field, where the dissolved-solids concentration of a water sample was measured at 435 mg/L, a value which represents appreciably better quality than the average dissolved-solids concentration of 710 mg/L in ground water upgradient from the barrier. Between 1958 and 1977, water quality has gradually deteriorated in 2 of 13 wells currently sampled annually by the Survey. Many wells in the central agricultural area of the valley produce water whose quality falls within a range indicative of increasing salinity hazard.

2. What is the perennial yield of the San Antonio Creek ground-water basin? Is the basin currently in overdraft? During the period 1958-77 the ground-water discharge averaged 11,400 acre-ft/yr, but the perennial yield was 9,800 acre-ft/yr, indicating that overdraft of the ground-water resources averaged 1,600 acre-ft/yr. In 1977, discharge totaled 14,100 acre-ft/yr, and the basin was in overdraft by 4,300 acre-ft. Projected pumping conditions show a trend of increased overdraft.

3. What quantity of water is available for long-term withdrawal at VAFB? The ground-water supply is adequate to meet a projected demand of 4,200 acre-ft/yr at Vandenberg.

4. What is the health status of the vegetation in marshland areas? The vegetal cover of Barka Slough has remained stable during the period 1958-77. Flow in San Antonio Creek, resulting from upwelling of ground water in the marshland, has been perennial but is on the decline because of increased pumping. When total pumpage approximates 13,500 acre-ft/yr, and in drought years, base flow could decline to zero and there may not be a sufficient supply of water to sustain vegetation in the marshland. Changes in vegetational patterns could be evaluated periodically by using infrared aerial photography. A color infrared photomosaic depicting vegetal conditions July 1, 1978, is presented

in this report. The photomosaic is from the initial flight of a series programed by VAFB.

5. What effect will increased agricultural expansion upgradient have on the water supply at VAFB? If agricultural withdrawals were held constant at 11,900 acre-ft/yr, or 6,000 acre-ft/yr above the 1958-77 average, after 5 years a water-level decline of about 2 ft would be induced at the east boundary of VAFB. There would be little impact on the water supply at the Vandenberg well field; however, by reducing the water-level gradient toward Barka Slough, ground water normally discharged as base flow and natural evapotranspiration would be captured for agricultural use. The moderately saline ground water in the agricultural areas may eventually be drawn into the Vandenberg well field.

6. What effect will increased withdrawals by VAFB have on the water resources in the San Antonio Creek valley adjacent to VAFB, on inducement of underflow from the adjoining Santa Maria and Santa Ynez valleys, on the marshlands, and on inland movement of seawater? Under a projected maximum pumping rate of 4,200 acre-ft/yr for 5 years, water-level declines along the VAFB boundary would range from 0 to 5 ft. Because the cone of depression would extend only about 2 mi outward from the center of pumping, no underflow from adjoining valleys would be induced. The impact on Barka Slough would be to drop the potentiometric surface below land surface at the marshland's northern side nearest the well field; thus, water normally discharged as base flow and evapotranspiration would be captured by pumping. Large drawdowns at Barka Slough may be avoided by decentralizing the pumping, thereby spreading its effects over a larger area. Seawater intrusion into the principal aquifer is prevented by a geologic barrier to ground-water flow; however, seepage of water of poor quality from the nearby consolidated rocks could be

induced into the aquifer. A reduction in base flow, caused by pumping, might induce seawater intrusion into the shallow aquifer downgradient from Barka Slough; however, the impact on supplies would be insignificant, as the water in the aquifer is not potable.

7. What type of hydrologic monitoring program is necessary to obtain the information needed for environmental protection? Because the water supply at the Vandenberg well field is dependent upon the efficient management of the water resources by upgradient users, a basinwide monitoring program that includes collecting water-level, water-quality, streamflow, and infrared aerial photography data is proposed. The proposed water-level monitoring program, including monthly measurements in 16 wells and continuous measurements with recorders in 3 wells, would provide data on seasonal water-level fluctuations in Barka Slough and the upgradient agricultural area. The water-quality monitoring program, including annual analyses of common chemical constituents in water from 12 wells and 2 stream sites, would provide data on changing trends over the broad expanse of the valley in response to pumping. The stream-flow monitoring program includes maintaining two existing gaging stations and the addition of periodic measurements just upstream from Barka Slough to monitor the contribution of irrigation runoff to streamflow and stream quality during the dry season. Vandenberg Air Force Base has planned quarterly infrared photographic flights over Barka Slough to assess the impact of pumping on the health of marshland vegetation. Various resource management alternatives could be evaluated through a computer model of the ground-water flow system. An evaluation of the data collected in the monitoring program would guide more efficient utilization of the water resources of the valley and aid preservation of its natural beauty.

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