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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

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# RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF THE ELLWOOD-GAVIOTA AREA SANTA BARBARA COUNTY, CALIFORNIA

By

G. A. Miller and J. R. Rapp

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Prepared in cooperation with the
Santa Barbara County Water Agency

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# RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF THE ELLWOOD-GAVIOTA AREA, SANTA BARBARA COUNTY, CALIFORNIA

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## ABSTRACT

The Ellwood-Gaviota area in the southern part of Santa Barbara County, Calif., extends from the crest of the Santa Ynez Mountains to the Pacific Ocean. The area lies between the Ellwood Canyon drainage on the east and the Canada de la Gaviota drainage on the west. Agriculture and petroleum are the most important elements in the economy of the area. The climate is mild and frost is rare at low altitudes.

The area is on the south limb of a large anticline exposing a thick section of strata of Tertiary age. The strata consist largely of marine sandstone, siltstone, and shale, but beds of terrestrial origin also occur in the section. The chief aquifers presently utilized are the alluvium of Quaternary age and the Monterey Shale, Vaqueros Formation, and Sespe Formation of Tertiary age. In the older undifferentiated formations of Tertiary age, ground water occurs chiefly in fractures and in beds of loosely cemented sandstone.

Ground-water recharge to the area is primarily derived from the deep infiltration of rainfall. Some recharge, however, is derived by seepage from streams during floodflows and by infiltration of water imported into the area for irrigation.

Ground water from the mountainous area moves generally southward toward the coast at a steep hydraulic gradient. At the barrier formed by the impermeable mudstone of the Rincon Shale of the shale unit, ground water is forced to the surface and discharges into streams that drain the area. The base flow of the streams, which is derived from the discharging ground water, is about 5,000 acre-ft/yr (acre-feet per year) and represents most of the natural ground-water discharge from the area. Transpiration by phreatophytes along the water courses and evaporation from the ground and from open-water surfaces consume about 150 acre-ft/yr. Approximately 200 acre-ft/yr discharges as underflow directly into the ocean.

Withdrawal from wells is about 600 acre-ft/yr, but probably at least 100 acre-feet of this quantity returns to the ground-water body by infiltration, mainly from irrigated fields, and about 100 acre-ft/yr discharges from flowing wells. The net pumpage is thus about 500 acre-ft/yr, and the total discharge, including natural discharge and pumping, is about 6,000 acre-ft/yr. This quantity is probably equal to the average recharge.

Under present conditions the quantity of ground water that can be withdrawn annually, without resulting in a continuing decline of ground-water levels, is less than 6,000 acre-feet, because all natural discharge cannot be stopped if a favorable salt balance is to be maintained.

Ground-water levels are rising in the eastern part of the area as a result of the importation of irrigation water and the resultant decrease in pumpage.

No widespread sea-water intrusion is likely to occur, but intrusion could occur on a small scale if large quantities of water are pumped from wells drawing water from the permeable alluvium in stream valleys near the coast. Intrusion may also occur locally if large quantities of water are pumped from the Monterey Shale, which crops out seaward of the Rincon Shale. However, the Rincon Shale is nearly impermeable and would inhibit movement of sea water into the aquifers exposed landward of its area of outcrop.

Ground water in the Ellwood-Gaviota area has a medium to very high salinity hazard, but has a low sodium (alkali) hazard. The water can be used for irrigation if proper precautions are taken. The water is generally suitable for domestic purposes, although it is hard and high in dissolved solids.

# INTRODUCTION

## Purpose and Scope of the Investigation

In 1963 the U.S. Geological Survey, in cooperation with the Santa Barbara County Water Agency, began a study of the ground-water resources of the Ellwood-Gaviota area in the southern part of Santa Barbara County, Calif. The purpose of the study was to provide the water agency with basic hydrologic data for their water-management purposes. Management by the agency includes planning for participation in the California Water Plan. This plan is designed to transport water from northern California to areas where a present or anticipated supplemental water supply is needed.

The scope of this ground-water study was to determine at a reconnaissance level the nature, extent, and perennial yield of the ground-water reservoir, and to estimate the quantity of water in storage. Fieldwork consisted mainly of mapping the areas of alluvium and the shale-sandstone contact along the southern slope of the Santa Ynez Mountains. A canvass was made to obtain data for wells that had not been visited previously. In the spring and the autumn measurements of streamflow were made at or near where the streams crossed the shale-sandstone contact. Samples of water for chemical analysis were collected from streams and wells.

This project was begun in July 1963 by G. A. Miller who did most of the fieldwork and the data compilation. K. S. Muir assisted in the well canvass and other data collection. The work was done under the immediate supervision of L. C. Dutcher, chief of the Garden Grove subdistrict office, and under the general supervision of Walter Hofmann and R. S. Lord, successive district chiefs of the water resources division of the California district.

## Location and Extent of the Area

The Ellwood-Gaviota area covers about 105 square miles of the southern part of Santa Barbara County in the western part of southern California (fig. 1). The southern boundary of the area is the Pacific Ocean and the northern boundary is the crest of the Santa Ynez Mountains. The western boundary is the limit of the drainage basin of Canada de la Gaviota (fig. 2), and the eastern boundary is the limit of the drainage basin of Ellwood Canyon. The east-west extent of the area is about 20 miles; the north-south extent ranges from 3 miles to about 6 miles.

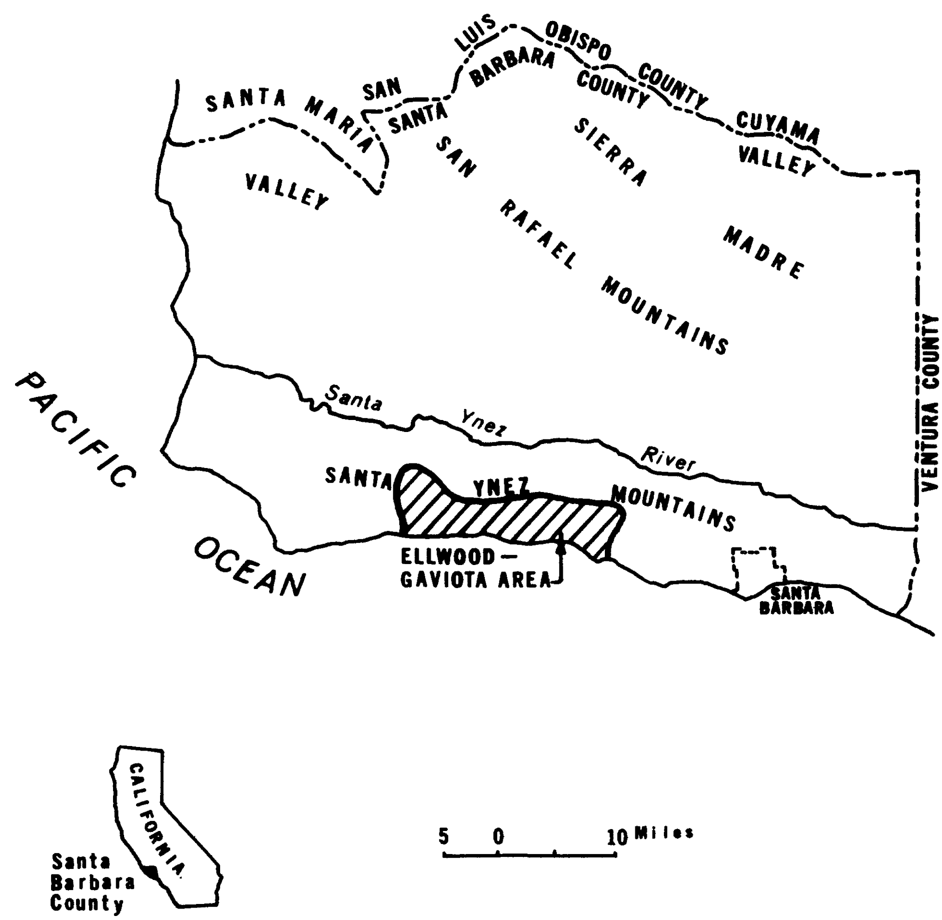



FIGURE 1.--Map of Santa Barbara County, California showing the Ellwood-Gaviota area.

## Previous Investigations

Several published geologic and water-resources reports provided useful data for this study area. The structural evolution of the Ellwood-Gaviota area was discussed by Reed and Hollister (1936) as a part of their work covering southern California, and Dibblee (1950) described the geology of southwestern Santa Barbara County which includes part of the Ellwood-Gaviota area. Terraces of Pleistocene age along the Santa Barbara coast were mapped by Upson (1949). Kleinpell and Weaver (1963) and Weaver and Kleinpell (1963) reported on the Oligocene biostratigraphy. Weaver and Molander (1964) described the Eocene fauna and geology near Gaviota Pass.

Rantz (1960 and 1962) discussed the effect of the construction of Tecolote Tunnel on the flow of springs and streams and provided valuable data that were used to estimate the perennial yield of ground water in the area. Upson (1951) studied the geology and ground-water resources of the Goleta area, which borders the Ellwood-Gaviota area on the east. The Goleta area was later restudied by Evenson and others (1961).

## Acknowledgments

The assistance and cooperation of many individuals and agencies who provided information used in this study are gratefully acknowledged. Mr. R. N. Williams, a consulting geologist at Santa Barbara, discussed the general hydrologic features of part of the report area with the writers and supplied much useful data. Local well drillers provided information about several wells. The Goleta County Water District furnished data on the quantity of water diverted from Lake Cachuma to the Ellwood-Gaviota area. The Cachuma Operation and Maintenance Board supplied information about flow from Tecolote Tunnel. The writers also appreciate the assistance of the many ranchers and other residents who gave information about wells and springs of the area and who assisted with the collection of data and water samples on their property.

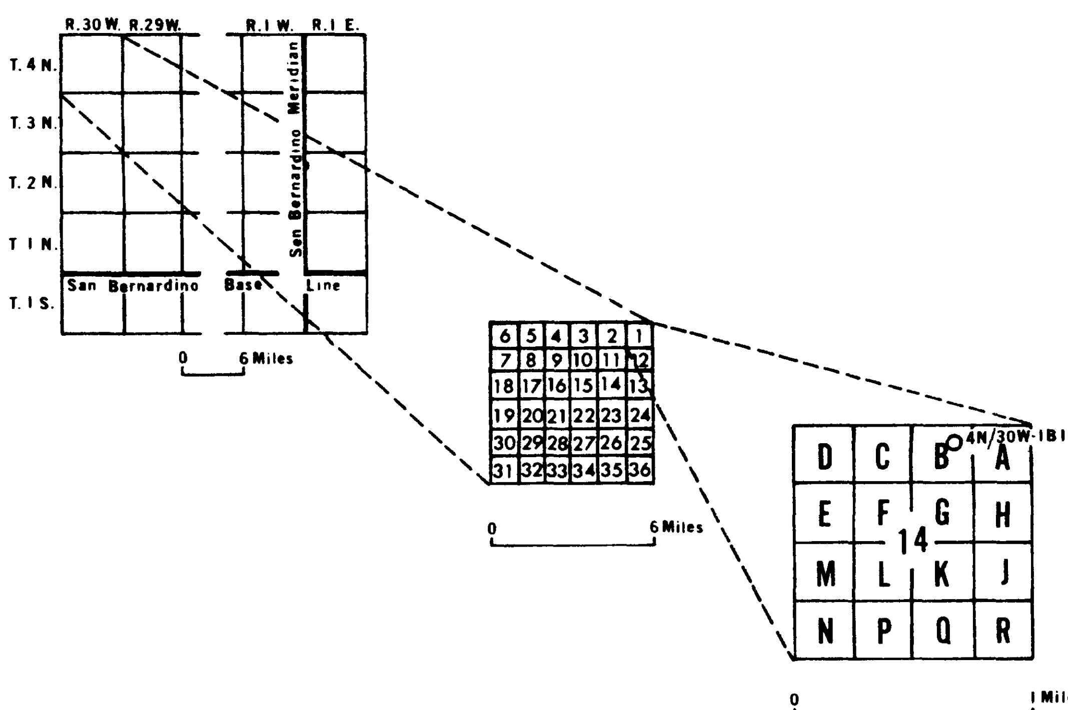
Most of the chemical analyses of water samples collected from wells, springs, and streams were made by the California Department of Water Resources. That agency also furnished some water-level measurements for wells in the area.

## Location-Numbering System

Wells and springs are numbered according to their location in the rectangular system for subdivision of public land. For example, for well 4N/30W-1B1, that part of the number preceding the slash indicates the township (T. 4 N.); the number following the slash indicates the range (R. 30 W.); the number following the hyphen indicates the section (sec. 1); the letter following the section number indicates the 40-acre subdivision of the section according to the lettered rectangle in the diagram below.

The final digit is a serial number for wells in each 40-acre subdivision. The numbering of springs in this report is the same as for wells except that an S is used between the 40-acre subdivision letter and the final digit as shown in the following: 5N/29W-30ES1. The final digit is omitted on the location number of water-sampling points along streams in table 5. The area covered by the report lies entirely in the northwest quadrant of the San Bernardino base line and meridian.

Those parts of the study area included in early Spanish land grants were not surveyed under the U.S. Public Lands Surveys. For the purpose of this report, the rectangular grid system has been projected into those areas.



## GEOGRAPHY

### Culture

Most of the area is sparsely populated, and the few towns are small. There are a general store, a few residences, and facilities for storing petroleum in Gaviota. In the eastern part of the area housing subdivisions have been completed or are being constructed to meet the needs of the increasing population in the Santa Barbara-Goleta area. During the 1950's the lowland area near Goleta, a few miles east of Ellwood, was an agricultural area; it is now primarily residential. As the population grows, development will probably expand westward so that eventually much of the Ellwood-Gaviota area will be urbanized, especially the easily accessible lowlands.

Most of the area, including private and national forest land, is used for grazing cattle, although about 1,150 acres are used for irrigated crops--citrus, walnuts, and avocados. Most of the farming is done along stream valleys, especially in the eastern part of the area where water diverted from Lake Cachuma is available. Some farming, mostly raising citrus crops, is done on the interstream areas where the land is relatively flat. More than half the area is within the boundaries of the Los Padres National Forest.

Petroleum is important to the local economy. Two oil fields, Ellwood and El Capitan, are onshore; a third oil field is offshore from the extreme southeastern part of the area.

Water is used in the Ellwood-Gaviota area chiefly for agriculture. Originally, springs and streams furnished water for irrigation and domestic needs. Since the 1930's wells have been the main source of water supply in most of the area. Water is imported from Lake Cachuma and is distributed as far west as Las Llagas Canyon. Hot springs occur about half a mile southeast of Las Cruces (fig. 2), and Waring (1915, p. 68) noted: "Four warm springs here furnish about 50 gallons a minute...."

The Ellwood-Gaviota area is served by the Southern Pacific Co. railroad near the coast. A four-lane divided highway, U.S. 101, provides access to the central part of the area. An unimproved road winds along the crest of the Santa Ynez Mountains.

## Landforms and Drainage

The Ellwood-Gaviota area is characterized by steep, rugged mountains which are bounded by long, narrow valleys that drain southward. The area includes the crest and southern slopes of a section of the Santa Ynez Mountains, an eroded anticlinal structure. The major geologic structures have influenced the evolution of the present physiographic features. Along the mountain front, erosion has exposed a succession of sedimentary rocks that strike east-west and dip southward at angles of as much as 40° to 50°. The beds crop out in bands along the mountain front. Stream tributaries have cut into the softer beds along the strike, leaving the undercut resistant beds as steep crags, which form a prominent part of the scenery.

The area can be divided into two main physiographic units, a lowland area and a mountain area. The lowland area includes the coast and the adjoining foothills, both of which are underlain in large part by the shale unit (fig. 2). The lowland area extends seaward to form a cliff, and below the cliff is a narrow discontinuous strip of beach. Inland from the sea cliff a series of marine terraces rises from altitudes of 75 to 1,000 feet above sea level (Upson, 1951, p. 29). The most prominent and best preserved terraces occur at about 60 to 90 feet above sea level. Higher terraces have been severely eroded, leaving only scattered remnants of terrace material.

The change from the foothills in the lowland area to the more rugged mountain area is marked by a sharp increase in slope which is generally delineated in figure 2 by the geologic contact between the shale unit and the sandstone unit. The mountain area is underlain mainly by sandstone and shale.

The crest of the Santa Ynez Mountains ranges in altitude from about 1,000 feet to about 4,300 feet above sea level. Because the distance from the ocean to the crest of the mountains is only about 3 to 7 miles, the mountain slopes are very steep. The gradient of the southern slopes ranges from more than 250 feet per mile in the extreme western part of the area to more than 900 feet per mile east of Gaviota.

The area is drained by numerous subparallel southward-flowing streams. Near the coast the average distance between valleys is less than 1 mile. The valleys are long and narrow with steep interstream divides. The major streams have steep gradients and are parallel to the dip of the geologic formations into which they are cut. Tributary valleys, which generally are short and narrow, are parallel to the strike of the beds and are normal to the main valleys. Parts of some stream courses run parallel to the main stream before turning toward their confluence. The drainage system thus forms a trellis pattern, which reflects the structural control imposed on the streams by the steeply dipping strata of different resistance to erosion.

## Climate

A semiarid, Mediterranean-type climate prevails in the Ellwood-Gaviota area. The summers are cool and dry, and the winters, during which most of the precipitation occurs, are mild. The records of the U.S. Weather Bureau at the Santa Barbara airport, about 3 miles east of the report area, show that in the low coastal area the average monthly temperature ranges between 50° and 60°F in the winter and between 60° and 70°F in the summer (table 1). Killing frosts are rare, so the growing season is almost year-round. When the temperature drops to near freezing, large air blowers or wind machines are used to promote circulation and thus protect orchards from frost. Freezing temperatures occur in the mountains during winter. Occasionally, snow blankets the higher parts of the mountains for a few days. Coastal fog is common and is particularly prevalent during the summer months when it usually begins to form during the afternoon or evening, lasts through the night, and normally is burned off by midmorning. Generally, the fog does not rise above an altitude of 1,000 to 1,500 feet.

Winds are usually light and of the sea-breeze-land-breeze type. During the day warm air rises over the land areas and is replaced by cooler air from the sea; at night the direction of the movement is reversed. The seaward wind normally is no more than a gentle breeze, but probably as a result of topography, the wind in the area between Refugio Beach State Park and Gaviota is strong and sometimes attains gale force.

TABLE 1.--*Average monthly precipitation and average monthly temperatures at the U.S. Weather Bureau station, Santa Barbara, Calif.*

| Month | Precipitation[1] (inches) | Temperature[2] (°F) |
|---|---|---|
| January | 3.82 | 52.6 |
| February | 3.74 | 54.0 |
| March | 2.74 | 56.0 |
| April | 1.49 | 58.6 |
| May | .33 | 61.1 |
| June | .08 | 63.3 |
| July | .03 | 67.1 |
| August | .04 | 67.4 |
| September | .05 | 66.8 |
| October | .49 | 63.1 |
| November | 1.33 | 58.5 |
| December | 3.49 | 54.7 |
| Average annual | 17.79 | 60.3 |

[1]Length of record, 97 years. [2]Length of record, 80 years.

Almost all the precipitation in the area occurs as rain. The average monthly precipitation recorded at the Santa Barbara weather station is shown in table 1. During the period June through September, the average precipitation amounts to only 0.20 inch. The wettest months are December, January, and February, during which the combined average precipitation is 11.05 inches. March is somewhat drier with an average of 2.74 inches. The average annual precipitation at Santa Barbara is about 17.8 inches, but the annual total ranges from less than 10 inches to more than 40 inches (fig. 3). The annual precipitation has a pattern of alternating wet and dry periods. However, the time-quantity relation of the pattern is sufficiently variable that hydrologic predictions based on the pattern are not reliable.

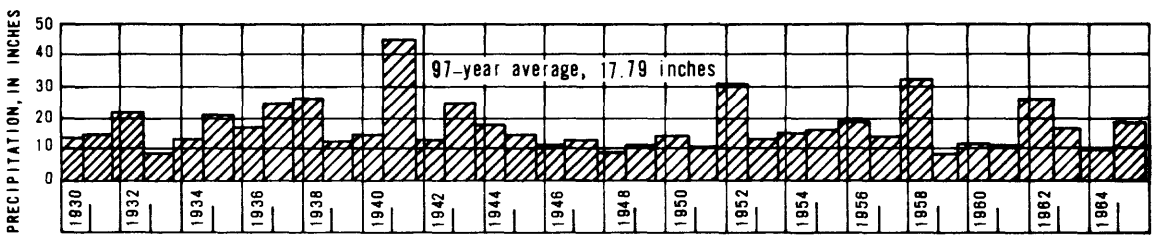



**FIGURE 3.--Precipitation, by water years, at Santa Barbara, California.**

The general areal distribution of precipitation in the report area is shown in an isohyetal map (fig. 4). The increase in rainfall with increase in altitude of the land is the result of the orographic effect of the mountains. The low coastal areas receive an average annual precipitation of less than 20 inches, whereas the higher mountains receive about 30 inches.

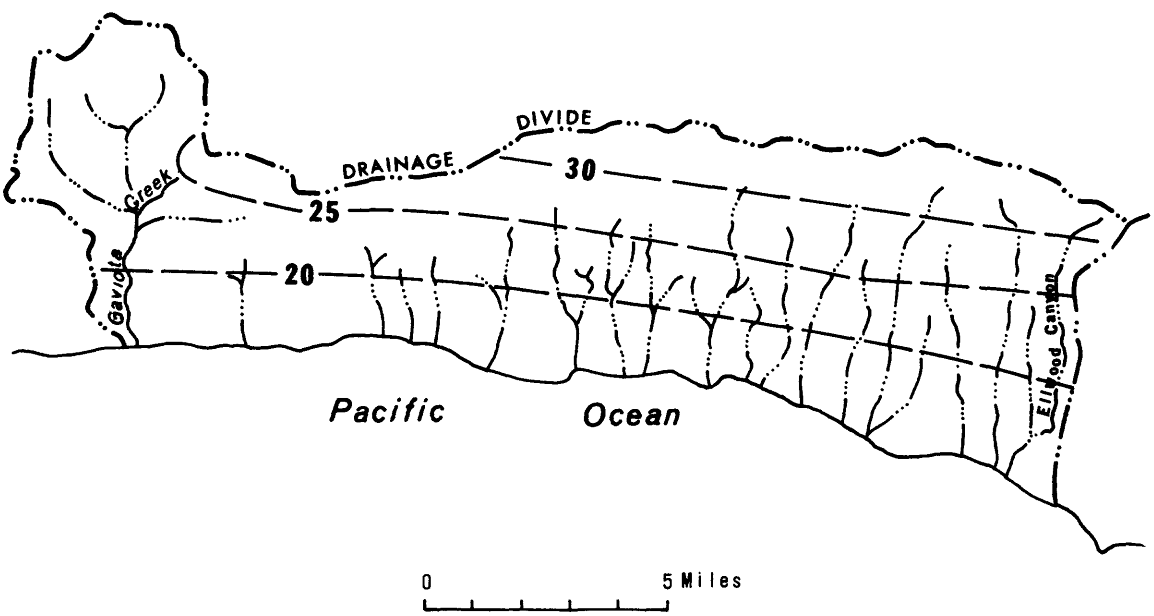



FIGURE 4.--Map of the Ellwood-Gaviota area showing general distribution of average annual precipitation, in inches.

### Natural Vegetation

Striking differences in the natural vegetative cover in the area are caused by changes in geologic and hydrologic conditions. An abrupt change in vegetation marks the contact between the lowland area underlain by shale and the mountainous area underlain mainly by sandstone and shale. The lowland area is covered with wild mustard, grasses, and patches of wild oak, whereas the mountain area is covered primarily with brush. A marked change in vegetation also occurs along the water courses. Willow, sycamore, live oak, and eucalyptus trees and a variety of grasses and bushes are concentrated along the valleys where surface water and shallow ground water are plentiful.

## GEOLOGY AND WATER-BEARING CHARACTERISTICS OF THE ROCKS

### Geologic History

The history of the deposition of the geologic formations (table 2) in the area is related to the accumulation of sediments under changing environmental conditions. The extremes of these environments are marine and continental conditions with intervening periods of oscillatory shoreline conditions. Therefore, vertical as well as lateral lithologic gradations are common both within and between formations.

During much of Eocene time, when marine conditions prevailed in the area, sand, gravel, silt, and clay were deposited in a basin of varying depth. Subsequently, during Eocene and Oligocene time, alluvial materials were deposited to form sandstone and conglomerate. Oceanward, contemporary shoreline and marine deposits of sandstone and minor shale and siltstone were accumulating. Succeeding shallow marine conditions predominated during Miocene time when the sand and gravel of the Vaqueros Formation were deposited. With further transgression by the sea during Miocene time, the marine sediments of the Rincon and Monterey Shales were deposited.

TABLE 2.--*Generalized geologic section*

| Geologic age | | Geologic formation | Thickness (feet) | Lithologic character | Water-bearing characteristics |
|---|---|---|---|---|---|
| *QUATERNARY* | *Pleistocene and Recent* | UNCONSOLIDATED DEPOSITS | | | |
| | | Alluvium | 0-100± | Clay, silt, sand and some gravel; underlies flood plains of stream valleys | Yields small to moderate quantities of water to wells |
| *TERTIARY* | *Miocene* | CONSOLIDATED ROCKS | | | |
| | | Shale unit | | | |
| | | Monterey Shale | 1,200-2,000 | Predominantly siliceous shale, some clayey shale, sparse limestone; of marine origin | Yields more than 100 gpm to wells in areas where siliceous shale is highly fractured; in large part only slightly permeable |
| | | Rincon Shale | 1,500± | Massive mudstone, generally bluish-gray; weathered slopes commonly show slump structures and landslides; of marine origin | Almost impermeable; no wells are known to tap this formation. Acts as confining bed for water in underlying sandstone formations |
| | | Sandstone unit | | | |
| | | Vaqueros Formation | 25-300± | Sandstone and conglomerate; of marine origin | Yields small to moderate quantities of water to wells |
| | *Eocene and Oligocene* | Sespe Formation | 2,000-2,800± | Sandstone and minor shale and siltstone of marine origin, conglomerate of nonmarine origin | Yields small to moderate quantities of water to a few wells |
| | *Eocene* | Undifferentiated formations | 3,500-4,000 | Sandstone, shale, siltstone, and some conglomerate; mostly of marine origin | Yield small to moderate quantities of water to a few wells |

Large-scale marine deposition in the area ended during Pliocene time as the sea became progressively shallow until finally the land emerged. This period of uplift ended with the formation of the large anticlinal fold of the Santa Ynez Mountains (fig. 5). Further structural adjustment in the area occurred during Pleistocene time and has continued to the present. The adjustment is marked by faults along which the beds have been broken and folded. The most prominent fault is the Santa Ynez fault (fig. 5), which parallels the mountain on the north side. Erosion, promoted and accelerated by these processes, has stripped off part of the uplifted formations so that the entire sequence of Tertiary rocks is exposed.

Land emergence and fluctuations of sea level during the Quaternary Period resulted in several (Upson, 1949) marine terraces and wave-cut benches along the coast.

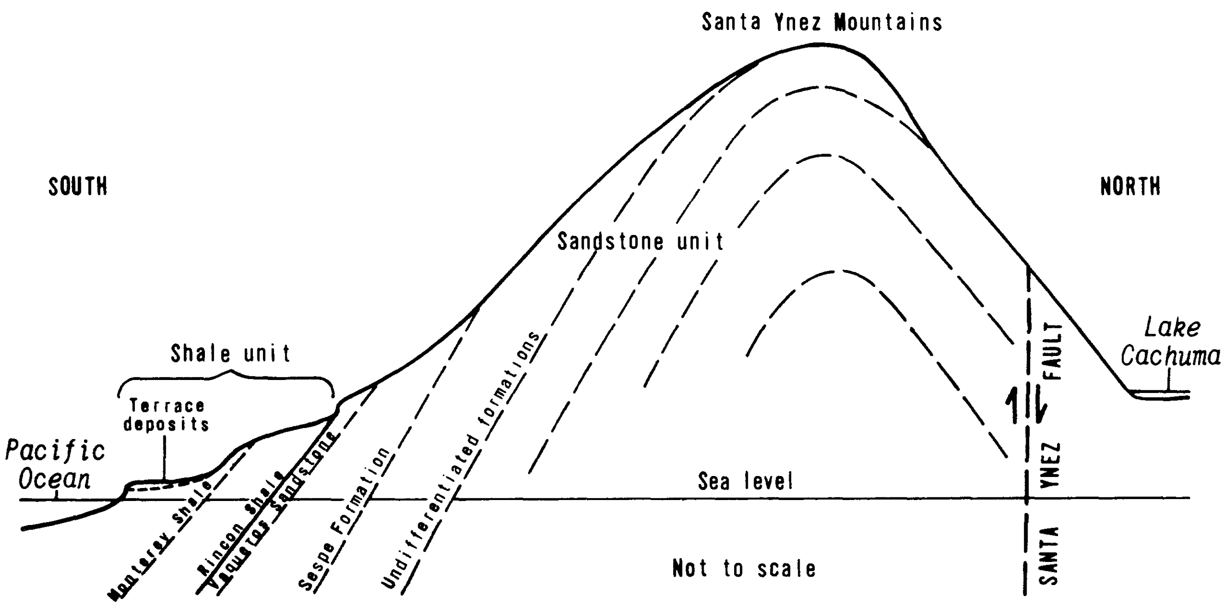



**FIGURE 5.--Diagrammatic section across the Santa Ynez Mountains.**

## Stratigraphy

Construction of a detailed geologic map was beyond the scope of this reconnaissance investigation. Therefore, only those details of the geology closely related to the hydrology of the area are considered. As shown in figure 2 and table 2 the geologic formations in the area are described under two general categories--consolidated rocks and unconsolidated deposits.

### Consolidated Rocks

Consolidated rocks of Tertiary age underlie most of the Ellwood-Gaviota area. These rocks are divided into two distinct units--the sandstone unit and the shale unit. The contact between the two units is the contact between the Vaqueros Formation and the overlying Rincon Shale. This contact in the field is prominently marked by a break in the topography and vegetation. Consolidated rocks of Cretaceous age crop out in a small area near Nojoqui Summit (Dibblee, 1950). Those rocks are similar in hydrologic character to the sandstone unit, and they are not discussed separately in this report.

Sandstone unit.--The sandstone unit, which underlies the crest and flanks of the mountainous area, consists mainly of beds of sandstone and conglomerate with intercalated beds of shale and siltstone of undifferentiated formations and the Sespe and Vaqueros Formations. Differential erosion has produced picturesque features in the steeply dipping strata. The general characteristics and age relations of the individual formations which form the unit are summarized in table 2.

Most of the older formations that make up the sandstone unit crop out only in the mountainous area and are penetrated by few wells. However, the Sespe and Vaqueros Formations in the unit do crop out on the lower flanks of the mountains and are tapped by wells. Data on some domestic, stock, and irrigation wells drawing water from those formations are listed in the following table.

| Well number | Aquifer | Depth to water (feet) | Discharge (gpm) | Drawdown (feet) | Specific capacity[1] (gpm/ft) |
|---|---|---|---|---|---|
| 5N/29W-31B1 | Sespe Formation | | 60 | | <1 |
| 31C1 | do. | 85 | 180 | 180 | 1.0 |
| 5N/31W-26G1 | do. | | | | .7 |
| 5N/32W-27E1[2] | do. | Flowing | 30 | | |
| 36G1[2] | do. | Flowing | 10 | | |
| 4N/30W-1B1 | Vaqueros Formation | | 175 | 190 | .9 |
| 5N/29W-25H1 | do. | | 254 | 165 | 1.5 |

[1]Gallons per minute per foot of drawdown.
[2]May tap both aquifers.

Wells drilled into either of those formations may be expected to yield from a few to as much as 250 gpm (gallons per minute) depending upon the local character of the aquifer, well construction, and on the size and number of fractures penetrated. The flowing wells listed in the preceding table were drilled nearly horizontally to tap fractured zones in the steeply dipping sandstone beds.

The quantity of water that might be developed from the sandstone unit is indicated by the flow of ground water into aqueduct tunnels that penetrate the mountains. The Mission Tunnel of the city of Santa Barbara was reported (Upson, 1951, p. 17) to yield 1 to 2 million gallons a day or about 1,120 to 2,240 acre-feet/yr.

Records maintained by the Goleta County Water District show that the ground-water outflow from the Tecolote Tunnel was about 3,440 acre-feet in 1962; 3,360 acre-feet in 1963; and 3,550 acre-feet in 1964. Although the long-term yields of existing tunnels through the mountains are not known, the flow that might be expected from the entire sandstone unit into a tunnel similar to Tecolote Tunnel presumably would be from about 1,000 to about 3,500 acre-feet/yr. The yield would depend upon the annual rainfall (Rantz, 1962, p. 9, 10) and upon the part of the mountains penetrated. For instance, if the area above the tunnel or other facility were at an altitude of 3,000 feet, the precipitation and presumably the yield would be considerably greater than if the area were at 2,000 feet.

Shale unit.--The shale unit comprises the Rincon and Monterey Shales, both of Miocene age and marine origin. It underlies the entire lowland area from the ocean to the base of the mountains. The Rincon Shale, which crops out in the higher part of the lowland area, is composed mainly of dark, massive, bluish-gray, foraminiferal mudstone. It is almost impermeable and weathers into clayey material. Numerous landslides mark the area underlain by the formation. The Monterey Shale, which crops out along the seaward side of the lowland area, consists of a dark-gray, siliceous shale that contains hard, brittle, siliceous and calcareous beds. Commonly, it weathers into an adobe soil containing blocky fragments.

The Rincon Shale is very fine grained and acts as a barrier that restricts or diverts the movement of ground water. The overlying Monterey Shale is locally permeable because of fractures in brittle siliceous and calcareous beds. Successful wells in this unit, therefore, must tap the fractured beds. Data show that well 5N/31W-36K1 was drilled to a depth of 250 feet in the Monterey Shale and yields 125 gpm with a drawdown of 89 feet.

### Unconsolidated Deposits

Alluvium.--The unconsolidated deposits of Quaternary age in the area include alluvium, terrace deposits, and small masses of landslide material. However, neither the terrace deposits nor the landslide material is significant with regard to the hydrology of the area. Therefore, for the purposes of this investigation, only the alluvium was mapped in the field and shown in figure 2.

The alluvium, which occurs along the major stream valleys, consists mainly of clay, silt, and sand, with local deposits of gravel. The alluvium forms narrow strips that extend northward from the coast into the mountain area. In the Goleta area to the east, wells reportedly have penetrated about 300 feet of alluvium. Similar thicknesses of alluvium may occur locally near the coast along some of the stream valleys in the Ellwood-Gaviota area; however, in most of the valleys it probably does not average more than 75 to 100 feet in thickness.

Data on wells are not adequate to determine the water-bearing properties of the alluvium. Many of the wells in the alluvium-filled valleys were probably drilled through the fine-grained alluvium to tap fractured zones in the underlying consolidated rocks, especially in the upper reaches of the streams above the shale unit-sandstone unit contact. Downstream from the contact, however, the alluvium has a greater saturated thickness and yields small to moderate quantities of water to wells.

## WATER RESOURCES

The source of most of the water in the Ellwood-Gaviota area is precipitation within the drainage boundaries. Some surface water is imported from Lake Cachuma through Tecolote Tunnel (fig. 2), and a small quantity of ground-water probably enters the area as inflow from across the drainage divide to the north. Most of the precipitation occurs as rain during the winter months. Most of the precipitation evaporates directly or is transpired by vegetation and thus returned to the atmosphere. Some of the precipitation reaches the ocean by stream runoff, and some seeps into the ground and recharges the ground-water reservoirs. The quantities of stream runoff and ground-water recharge are controlled by the intensity, frequency, duration, and distribution of the precipitation, by the basin topography and permeability of the soil and rocks, by stream-channel geometry and streambed permeability, and by the type and density of the vegetative cover.

Precipitation on the area increases with an increase in altitude. For example, during the 16-year period 1929-44, the rainfall at Santa Barbara (altitude 130 feet) was 19.10 inches and at San Marcos Pass (altitude 2,225 feet) was 32.37 inches. To estimate the rainfall in the Ellwood-Gaviota area, a map (fig. 4) showing the general distribution of average annual precipitation was constructed, and the average annual precipitation on the area was computed to be about 130,000 acre-feet.

### Surface Water

Many southward-flowing streams drain the area. During most of the time the flow in the streams is small, but during and shortly after periods of heavy precipitation, they may be swollen with runoff. The low flow or base flow is supplied mainly or entirely by ground-water discharge.

The base flow of streams is a measure of the ground-water discharge. During 1948-60 monthly measurements of base flow were made on most streams in the area east of Canada del Refugio (Rantz, 1960). The measurements were made at selected times when storm runoff did not affect the streamflow (C. E. Burgess, oral commun., 1966). In addition, two or more measurements of base flow were made on each stream during the period autumn 1963-spring 1964 (table 3). Several methods can be used to estimate base flow in areas where measurements of flow are few or are not available. The following estimates are based on the extrapolation of base flow from a gaged area and on the development of low-flow characteristics of streams in the area from limited streamflow data and gage records.

TABLE 3.--*Base flow of streams, in gallons per minute, measured near the contact between the shale and sandstone units*

| Stream | Flow autumn 1963 (gpm) | Flow spring 1964 (gpm) |
|---|---|---|
| Gaviota Creek | 200 | 50 |
| Canada San Onofre | 75 | 25 |
| Canada del Molino | 15 | 0 |
| Arroyo Hondo | 225 | 150 |
| Arroyo Quemado | 50 | 20 |
| Tajiguas Creek | 50 | 0 |
| Leon Canyon | 10 | 0 |
| Canada del Venadito | 1 | 0 |
| Canada del Corral | 80 | [1]50 |
| Canada del Capitan | 140 | 70 |
| Las Llagas Canyon | 125 | 110 |
| Las Varas Canyon | 75 | 80 |
| Dos Pueblos Canyon | 100 | 110 |
| Eagle Canyon | 5 | 0 |
| Tecolote Canyon | 40 | 40 |
| Bell Canyon | 15 | 25 |
| Creek northwest of Las Cruces | 10 | 0 |
| Refugio Creek | 0 | 5 |
| Totals (rounded) | 1,210 | 735 |

[1]Estimated.

The aggregate of base-flow measurements made during autumn 1963 and spring 1964, an extremely dry period (precipitation at Santa Barbara for October 1963 through September 1964 was 9.2 inches, compared to the long-term average of 17.8 inches), averaged about 2.1 cfs (cubic feet per second), or more than 1,500 acre-ft/yr. The flow measured on the same streams during the same months of the period 1948-60, a period when average annual precipitation at Santa Barbara was approximately equal to the long-term mean, averaged about 3.5 times the 1964-64 average. Rantz (1962, p. 10) found that the pattern of discharge from springs and streams in the area was similar to the pattern of precipitation at Santa Barbara. Therefore, the estimated average annual ground-water outflow as base flow in streams from the Ellwood-Gaviota area, in round numbers, is 5,000 acre-feet.

Another method of determining the approximate ground-water outflow from the area is to extrapolate base flow, in terms of acre-feet per square mile, from nearby gaged areas where the geology and hydrology are similar and where presumably the general climatic pattern has affected both areas equally. San Jose Creek, which is gaged near Goleta, is about 5 miles east of Ellwood and drains about 5.5 square miles of the Santa Ynez mountains. The mountain area there is hydrologically similar to much of the Ellwood-Gaviota area that is underlain by the sandstone unit. The gage is a short distance downstream from the toe of the mountain front, which there coincides with the sandstone-shale contact. A flow-duration curve (Searcy, 1959; Smith and Hains, 1961) for the period 1949-60, assuming that any flow below 1 cfs is base flow and this is equalled or exceeded 15 percent of the time, indicates that the average annual base flow is about 260 acre-feet, or about 47 acre-feet per square mile of drainage area. About 85 square miles of the Ellwood-Gaviota area is hydrologically similar to the San Jose Creek drainage; thus, the annual ground-water outflow as base flow from the area on the basis of the period 1949-60 may be about 4,000 acre-feet.

A flow-duration curve based on one year of gaged record on Gaviota Creek was extended to cover the period 1949-59, using the method described by Searcy (1959). The hydrograph of Gaviota Creek indicates that any flow below about 2.5 cfs is base flow, and the duration curve suggests this rate of flow is equalled or exceeded about 10 percent of the time. The projected curve suggests that the average annual base flow in the stream is about 35 acre-feet per square mile of drainage. Applying this yield to the hydrologically similar part of the entire Ellwood-Gaviota area indicates that the average annual yield of ground water as base flow might be about 3,000 acre-feet. Applying this method of low-flow determination to ungaged areas is not as reliable as a method based on actual base-flow measurements (Searcy, 1959, p. 17).

A more accurate method (Searcy, 1959, p. 17) of estimating the base flow for the area is to derive a relation of flow at the time of individual spot measurements to concurrent flow at a nearby gage. The monthly measurements made in the eastern part of the area during 1948-60 (Rantz, 1960) were related to concurrent flow at the San Jose Creek gage, assuming that the cessation of storm runoff occurred at the same time on each stream. Flow relations for the base flow of major streams for several years were used to synthesize a composite long-term flow-duration curve. This curve suggests that the average annual base flow from the sandstone unit in the eastern half of the area is about 2,500 acre-feet, or about 5,000 acre-feet for the entire Ellwood-Gaviota area.

Although only the base flows were measured, the total flow of streams in the project area can be estimated by using data collected in areas with similar topography, geology, and precipitation. The total flow of the streams, which includes the runoff from the area, is much greater than the base flow of streams. From gage records of similar streams in the Santa Barbara area W. M. Littlefield of the U.S. Geological Survey (oral commun., 1964) estimated the total flow for the area to be 230 acre-ft/yr per square mile. With an area of about 105 square miles and a runoff of 230 acre-ft/yr per square mile, the total flow of streams in the area would be about 24,000 acre-ft/yr.

A second estimate of the total flow can be made on the basis of streamflow in response to precipitation. The annual precipitation in the area determined from figure 4 is about 130,000 acre-feet. The runoff in similar areas is estimated at 20 percent of the average annual precipitation, so the total runoff would be about 26,000 acre-ft/yr. Thus, the figure of 24,000 obtained by using the runoff per square mile is compatible with the 26,000 obtained by using the percentage of total rainfall. An average of the two, about 25,000 acre-ft/yr, probably is a reasonable preliminary estimate of the total flow of streams in the area.

## Imported Water

Since May 1961 water has been imported to the Ellwood-Gaviota area from Lake Cachuma on the Santa Ynez River by way of Tecolote Tunnel through the mountains to the coastal area. The following tabulation of water delivered shows that, with the exception of 1963, the demands for imported water have increased significantly. The decrease in 1963 may be related to the above-normal precipitation during the year. The quantities are in acre-feet and are for the fiscal year, July through June.

| Use | 1961 | 1962 | 1963 | 1964 | 1965 |
|---|---|---|---|---|---|
| Domestic | 3.8 | 27.3 | 74.7 | 171.9 | 190.8 |
| Miscellaneous | 0 | 9.8 | 13.7 | 15.2 | 63.5 |
| Irrigation | 28.0 | 479.5 | 278.0 | 487.9 | 558.1 |
| Totals (rounded) | 32 | 517 | 366 | 675 | 812 |

The imported water is delivered to the eastern part of the area between Las Llagas and Ellwood Canyons.

## Ground Water

### Occurrence and Movement

In the Ellwood-Gaviota area most of the ground water occurs in the consolidated rocks. The water is in fractures and intergranular spaces in partly cemented sandstone. In the outcrop area the consolidated rocks contain water under water-table conditions. Downdip, however, beneath confining beds of nearly impermeable materials, the water is under artesian pressure. In the Monterey Shale of the shale unit, which underlies much of the lowland area, some of the brittle beds are fractured and contain water under artesian head.

Ground water also occurs in the unconsolidated alluvium in the valleys mainly under water-table conditions. Data are insufficient to determine whether artesian or perched water also occurs in the alluvium. In the Goleta area to the east, impermeable beds in the alluvium near the coast impede the vertical movement of water, thereby producing both perched water-table and artesian conditions. Similar conditions probably occur in the alluvium at least locally in the Ellwood-Gaviota area.

Ground-water movement is downgradient, at right angles to the water-level contours shown in figure 6 and generally southward toward the ocean. This map is generalized because of the scarcity of wells and the lack of water-level information. In the mountain area the gradient of the water table is steep, ranging from about 200 to 300 feet per mile. The gradient decreases in the lowland area where it is less than 50 feet per mile. The sharp change in gradient generally conforms with the break in the slope of the valley floors near the contact between the shale unit and the sandstone unit.

### Recharge

Recharge is the process by which water is added to the zone of saturation. Precipitation in the watershed is the primary source of recharge to the ground-water reservoirs in the Ellwood-Gaviota area. The precipitation enters the saturated zone by direct percolation and by seepage losses from stream channels during floods. Percolation of irrigation water is a minor source of recharge. Also, some ground-water underflow probably enters the area from the north side of the Santa Ynez Mountains.

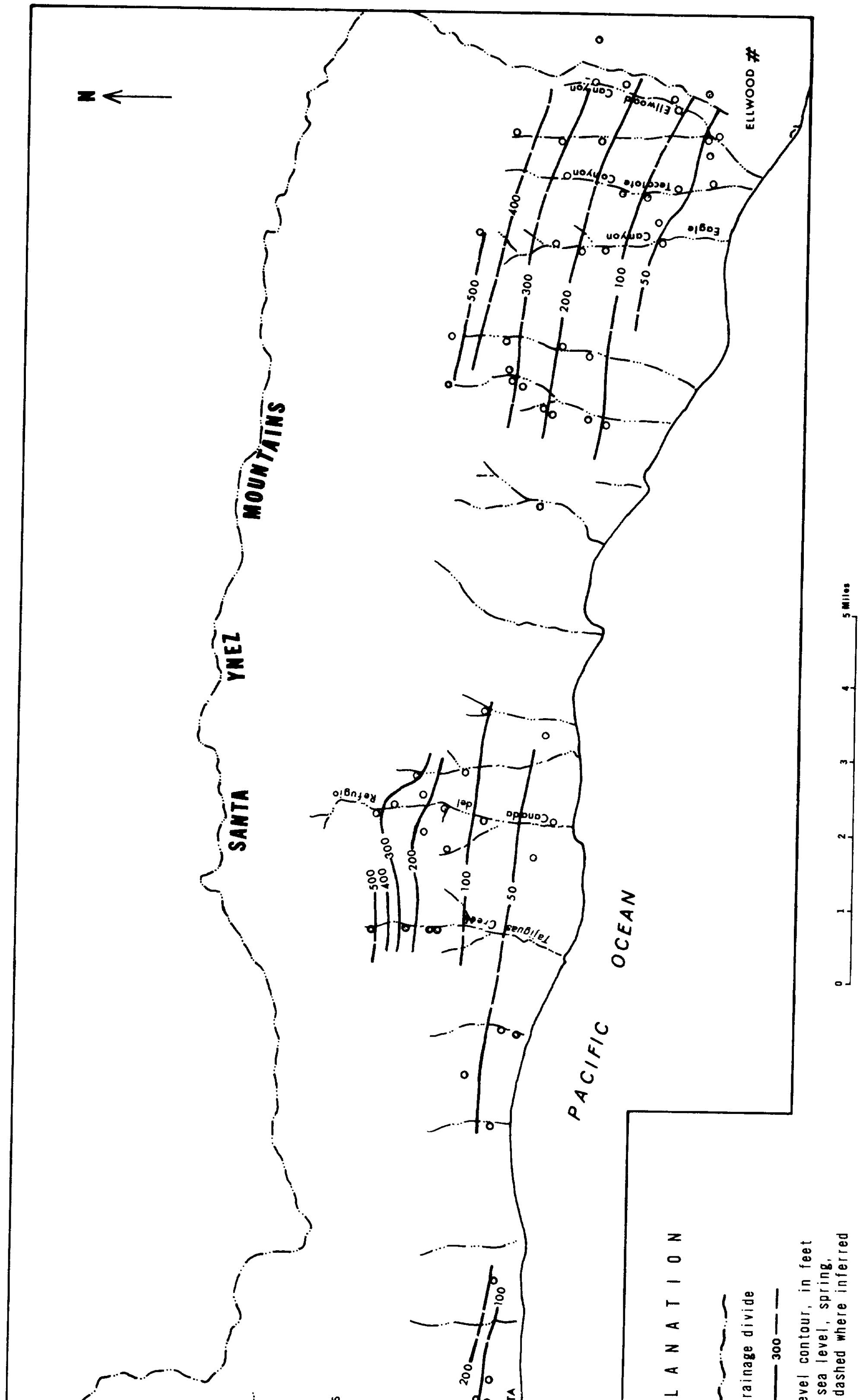



FIGURE 6.--Map of the Ellwood-Gaviota area showing water-level contours, spring 1964.

Precipitation.--In the Ellwood-Gaviota area precipitation averages about 130,000 acre-ft/yr. Of this quantity, an average of 25,000 acre-ft/yr runs off into the streams. The remaining 105,000 acre-ft/yr is either lost to the atmosphere through evapotranspiration or percolates to ground water. The quantity that percolates to ground water is determined by several factors, such as the terrain, type of vegetation, the frequency, intensity, and duration of storms, and the total seasonal rainfall.

In a study of deep penetration of rainfall in Ventura County, Calif., Blaney (1933) found that a general relation exists between seasonal rainfall and the quantity of rain that seeps to the ground-water reservoir. Blaney worked in an alluvial area of low relief, and therefore those data should only be applied to similar areas. Because of the high relief and the low permeability of the rocks in the Ellwood-Gaviota area, the runoff is probably greater and the quantity of ground-water recharge is probably less than in Blaney's study area. However, after making allowances for the differences in the two areas, Blaney's data and rainfall data for Santa Barbara were used, and an estimated average annual ground-water recharge for the Ellwood-Gaviota area of 8,000 acre-feet was obtained for the period September 1952 to August 1963. If additional adjustments were made for greater rainfall in the higher areas, the recharge figure would be even larger. On the basis of ground-water discharge from the area, however, the estimated figure of 8,000 acre-feet per year is probably too high. The recharge probably can be estimated more realistically from the quantity of ground water discharged, which is discussed later.

Percolation of irrigation water.--In the project area about 1,150 acres are planted to crops, which are mainly citrus, walnuts, and avocados. Irrigation water for those crops is obtained from wells, from Lake Cachuma by way of Tecolote Tunnel, and from streams. About 600 acre-ft/yr of ground water is supplied by pumped and flowing wells. (See section on wells under discharge.) In the 1964 fiscal year about 500 acre-feet of water was imported from Lake Cachuma for irrigation. Although the quantity of water diverted locally from streams is not known, an estimate has been made by assuming that the average water requirement of the crops is 1.5 acre-ft/yr in addition to normal precipitation. On this basis the annual water requirement to irrigate 1,150 acres of crops would be about 1,700 acre-feet. The quantity of local well water and imported water used is about 1,100 acre-ft/yr; therefore, about 600 acre-ft/yr is probably diverted from streams to meet the needs of the crops.

Of the 1,700 acre-ft/yr of water used for irrigation, about 350 acre-ft/yr, or 20 percent, seeps downward below the root zone of the crops and recharges the ground-water reservoir. The amount of this recharge water is small because good irrigation practices are followed to conserve water and because the underlying material generally is of low permeability. Thus, recharge from return of irrigation water probably includes about 100 acre-ft/yr from well water, about 150 acre-ft/yr from locally diverted stream water, and about 100 acre-ft/yr from imported water, or a total of 350 acre-ft/yr.

Total combined recharge.--The combined recharge from the above sources cannot be determined by direct methods because the quantity of precipitation that percolates to the ground-water reservoir is not known. Nevertheless, the total combined recharge can be estimated indirectly by determining the quantity of ground-water discharge. This is possible because, assuming the net change in storage in the ground-water reservoir in the report area is zero during a given period, recharge is equal to discharge. (See section on fluctuation of water levels.)

## Discharge

Ground-water discharge is the removal of water from the zone of saturation. Ground water can be discharged naturally as base flow of streams, by evapotranspiration, by spring flow, and by underflow into the ocean; it can be discharged artifically by wells. Most ground-water discharge in the Ellwood-Gaviota area has been by seepage into streams and by discharge from wells.

Streams.--The base flow, or low flow, of the local streams is supplied mainly or entirely by ground-water discharge. Hence, measurements of base flow were used to estimate the ground-water discharge. On the basis of base-flow measurements of streams in the area (table 3 and Rantz, 1960), the estimated average annual ground-water discharge into streams is 5,000 acre-ft/yr.

Evapotranspiration.--Evapotranspiration is the combined consumptive use of water by (1) vegetation, (2) direct evaporation from the capillary fringe above the water table where the capillary fringe is near the surface, and (3) evaporation from open-water surfaces. The term consumptive use means that water is removed from the system by being changed to the vapor phase and returned to the atmosphere. Most types of vegetation in the area are mesophytes, which utilize soil moisture that is well above the water table. Phreatophytes are plants that obtain their water supply from the zone of saturation or from the capillary fringe above it. In the Ellwood-Gaviota area, discharge by evapotranspiration from the ground-water reservoir occurs mostly along the stream channels where the water table is near the surface. Phreatophytes--willows, sycamores, salt grass, and tules--grow in narrow ribbons along the streams. The area of phreatophytes, estimated from air photographs and adjusted to a density of 100 percent, is about 50 acres in the area upstream from the contact of the shale unit and the sandstone unit. Wilson (1959, p. 50) estimated the evapotranspiration rate for similar vegetation in the Santa Ynez Valley to be 3 acre-feet per acre per year. If the same rate of consumptive use is applied in the Ellwood-Gaviota area, the average discharge by evapotranspiration along the streams is about 150 acre-ft/yr.

Springs and seeps.--The quantity of water discharged by small springs and seeps, which occur in many places in the project area, notably along the stream valleys, is about 50 acre-ft/yr. Because this discharge either flows into streams or is lost by evapotranspiration, and because these items of discharge have already been considered individually, this water was not accounted for as a separate item in the local water budget.

Underflow to the ocean.--An unknown quantity of ground water discharges directly into the ocean through undersea springs and seeps. The Monterey Shale of the shale unit is exposed to the ocean along most of the coast. Because this formation has a low overall permeability, probably only a small quantity of water is discharged directly into the ocean by underflow. However, there might be areas offshore where part of the sandstone unit which crops out in the mountains is in contact with the ocean. If so, ground water would discharge to the ocean in those areas. However, no information is available that relates to the size or location of such postulated offshore areas or to the quantity of discharge involved.

Most of the direct discharge to the ocean is probably by underflow through the alluvium of the stream valleys. Assuming that the saturated alluvium in the valleys near the coast is about 100 feet thick, that the oceanward ground-water gradient is 50 feet per mile, and that the permeability of the alluvium is 20 gallons per day per square foot at unit gradient, then the annual underflow to the ocean through the estimated 1 million square feet of alluvium would be about 200 acre-feet.

Wells.--The discharge by flowing wells, whose yields range from less than 1 gpm to as much as 30 gpm, is a small part of the total artificial withdrawal of ground water in the area. The flowing wells are either vertical or nearly horizontal and tap the sandstone unit. The few vertical wells which flow produce small yields. Well 4N/29W-2D1, for example, yields about half-a-gallon per minute. Most of the flowing wells that are drilled horizontally or at a small angle to the horizontal have higher yields. Generally, these wells are drilled in the Sespe Formation, although some may tap the Vaqueros Formation and undifferentiated formations older than the Sespe.
Wells 5N/32W-27E1, 35D1, and 36G1 are the only known horizontal wells in the report area. Their combined flow is about 40 gpm and the combined flow of all flowing wells is probably no greater than 60 gpm. The estimated total discharge from flowing wells is 100 acre-ft/yr.

Records are not available to indicate the pumpage before 1961. Since 1961 records of the amount of electrical power consumed in pumping water from the major producing wells in the area have been maintained by the U.S. Geological Survey. On the basis of these records, the average annual pumpage from wells for the period 1963-65 is estimated to be 500 acre-ft/yr. Adding to this the yield from flowing wells, the total discharge of ground water from wells during 1963-65 was about 600 acre-ft/yr. Of this 600 acre-ft/yr an estimated 100 acre-ft/yr returns to ground water leaving an estimated net withdrawal of 500 acre-ft/yr.

All other factors being equal, pumpage for irrigation in a given year varies with the rainfall. During periods of below-normal rainfall, pumpage is normally greater than during periods of above-normal rainfall. The period for which the above estimate was made was one of below-average rainfall. Precipitation in Santa Barbara during 1963 was about 90 percent of normal, but in 1964 precipitation was only about 50 percent of normal. Therefore, it seems likely that withdrawals by pumping and flowing wells would be somewhat less than 500 acre-ft/yr during years of normal precipitation or a net withdrawal of perhaps 400 acre-ft/yr.

Total combined discharge.--The items and quantities of ground-water discharge in the report area are summarized: (1) The aggregate base flow of the streams, which consists in large part of ground-water discharge is about 5,000 acre-ft/yr; (2) evapotranspiration, that is ground water used by phreatophytes or evaporated from the capillary fringe, is about 150 acre-ft/yr; (3) discharge from springs and seeps, which is disregarded (p. 26), is about 50 acre-ft/yr; (4) underflow to the ocean, probably about 200 acre-ft/yr; and (5) of the 500 acre-ft/yr withdrawn by pumping and flowing wells, about 100 acre-ft/yr returns to the ground-water reservoir, leaving a net estimated withdrawal of 400 acre-ft/yr. Thus: The total net ground-water discharge by all methods is about 6,000 acre-ft/yr.

Therefore, assuming that the net change in storage in the ground-water reservoir in the report area is zero, the recharge to the ground-water reservoir also is estimated to be 6,000 acre-ft/yr. This quantity of recharge is less than the 8,000 acre-ft/yr estimated in the section on recharge using Blaney's data and rainfall data for Santa Barbara, but it is probably a more accurate estimate.

## Storage

Storage in consolidated rocks.--Most of the usable ground water in storage in the Ellwood-Gaviota area is contained in the sandstone unit of the consolidated rocks in the Santa Ynez Mountain area (figs. 2 and 5).

During the construction of Tecolote Tunnel (fig. 2), data were collected (K. B. Hall, written commun., 1966) on lithology, permeability, and porosity of the sandstone and shale which are collectively called the sandstone unit. Those data, together with other information from geologic maps, wells, and examination of outcrops, suggest that the rocks above sea level in the Santa Ynez Mountains in the area consist of about 40 percent sandstone and conglomerate, and about 60 percent shale and siltstone. Eight north-south geologic sections were constructed between Ellwood and Gaviota to estimate the total saturated volume of material above sea level in the area. The estimated 2,200,000 acre-feet of ground water in storage (table 4) includes only ground water stored above sea level in the sandstone unit in the Santa Ynez Mountains south of the crest and beneath the north slope in an area above the 1,000-foot contour. The upper limit of saturation in rocks in the Santa Ynez Mountains was assumed to be a smooth plane coincident with the channel of perennial streams.

TABLE 4.--*Summary of ground-water storage in the sandstone unit of the consolidated rocks, Ellwood-Gaviota area*

| Item | South of crest | North of crest | Total |
|---|---|---|---|
| Area (acres) | 45,000 | 22,200 | [1]67,000 |
| Average saturated thickness (ft) | 1,000 | 1,700 | |
| Estimated volume (ac-ft), total | 45,000,000 | [1]38,000,000 | 83,000,000 |
| Estimated storage in sandstone and conglomerate part of sandstone unit (assuming specific yield = 5 percent) | 900,000 | 750,000 | 1,650,000 |
| Estimated storage in shale and siltstone part of the sandstone unit (assuming specific yield = 1 percent) | 270,000 | 230,000 | 500,000 |
| Estimated total ground water in storage | [1]1,200,000 | 980,000 | [1]2,200,000 |

[1]Rounded to two significant figures.

Storage in unconsolidated deposits.--The surface area underlain by an appreciable thickness of saturated alluvium in the valleys is about 2,000 acres. If the average saturated thickness of the material is 50 feet and the specific yield is 10 percent, then about 10,000 acre-feet of ground water is stored in the unconsolidated deposits in the Ellwood-Gaviota area.

Utilization of stored water.--Ground water now in storage in the area is being discharged by (1) pumpage and flow from wells, (2) base flow in streams, (3) drainage to Tecolote Tunnel, (4) evapotranspiration, and (5) flow from springs and seeps. Any substantial increase in the rate of discharge will tend to cause a lowering of the water table, which would reduce ground-water discharge by streamflow and by natural vegetation, thereby effecting a salvage of water. However, efficient recovery of large quantities of stored water by pumping from wells may be difficult because the permeability of the sandstone unit is not high enough to allow development of many large-yielding wells.

Tecolote Tunnel, which collects ground water, furnishes some data on the quantity of recoverable water in storage in the sandstone unit. As shown by figure 7 the monthly increment of ground-water outflow at the exit portal of the tunnel is similar to the graph of a drawdown curve of a pumped well. The curve is steep during the initial years when there was a rapid decline in the rate of release of ground water from storage; however, as the ground-water discharge approaches steady-state conditions, the curve gradually flattens.

Measurements made by the Cachuma Operation and Maintenance Board show that about 50,000 acre-feet of ground water was discharged from the tunnel during the period 1955-65. The rate of flow has declined from about 900 acre-feet per month when the tunnel was holed through in 1955, to less than 250 acre-feet per month in 1963-65. The discharge averaged about 4,600 acre-feet annually during the first 11 years of operation of the tunnel. The tunnel will probably continue to yield ground water for several years at the present rate of about 3,000 acre-feet annually, which is nearly 10 percent of the long-term annual yield (33,000 acre-feet) of water from Lake Cachuma (U.S. Bureau of Reclamation, 1956).

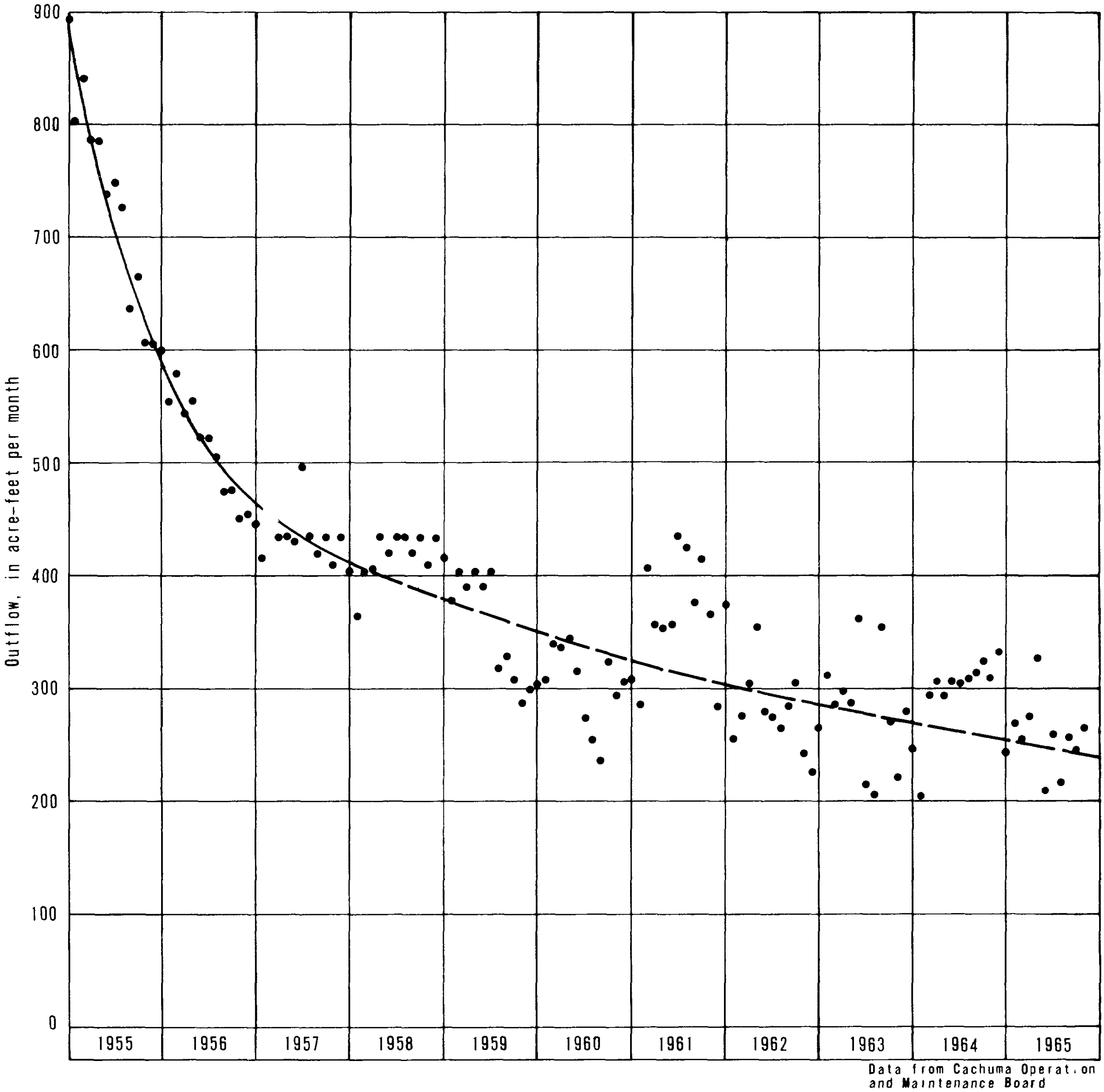



FIGURE 7.--Ground-water outflow from south portal of Tecolote Tunnel, in acre-feet per month, 1955-65.

## Fluctuation of Water Levels

Ground-water levels do not remain static but fluctuate in response to natural and artificial hydrologic factors. In the Ellwood-Gaviota area, where unaffected by pumping, ground-water levels generally reflect the marked seasonal variation in precipitation (table 1). During or shortly after the rainy season, ground-water levels rise; in response to the dry season, they decline. The water levels also respond to long-term trends in the precipitation, declining during dry periods and rising during wet periods.

The dry periods, whether seasonal or long-term, normally correspond to the periods when pumping is greatest. Therefore, in the areas of ground-water development the effects of pumping commonly intensify the natural seasonal fluctuations.

A knowledge of the causes and magnitude of fluctuations of ground-water levels is important in evaluating the ground-water resources and in managing the development of those resources. For this reason the Geological Survey began a program of periodic measurement of water level in selected observation wells in the Ellwood-Gaviota area in the latter part of 1962. Figure 8 shows representative hydrographs of the fluctuation of water levels in four wells. The period of measurement is too short to allow a clear determination to be made of the causes of long-term fluctuations, although some useful correlations can be made on the basis of the available data.

Water levels in the report area are affected by pumpage and by the infiltration of irrigation water. Since the importation of water began in September 1961, many wells formerly used for irrigation are no longer pumped or are pumped only at irregular intervals. Consequently, ground-water levels should have risen after the importation of water began, partly as a result of increased recharge and partly as a result of a decrease or cessation in pumping.

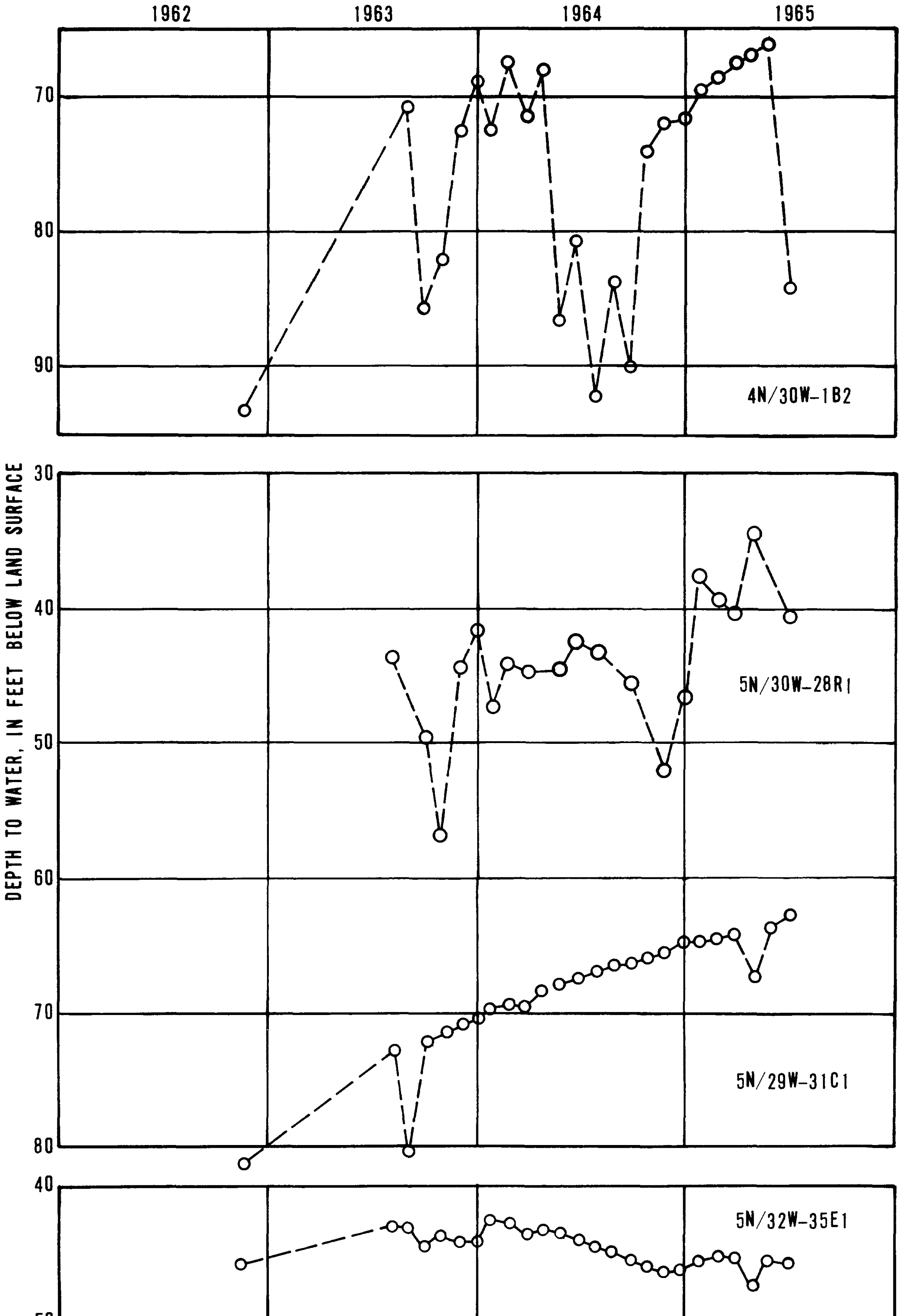



FIGURE 8.--Hydrographs of representative wells in the Ellwood-Gaviota area.

The hydrographs substantiate this expectation, at least in part. The water level in well 5N/29W-31C1 (fig. 8) rose 19 feet during the period of record, November 1962 to June 1965. During the same period, precipitation in the Santa Barbara area averaged slightly below normal. The rise in water level, therefore, is not attributable to climatic conditions, but probably is the result of a combination of the reduction in pumping in the general area and local recharge by infiltration of imported irrigation water to the ground-water body.

A similar though smaller rise in water level occurred in well 5N/30W-28R1 during the same period. Although the well was in use, the static water level in the well rose about 3 feet between the summers of 1963 and 1965. The rise is attributed chiefly to a general reduction in pumping in the area. In contrast to water levels in the above wells, the water level in well 5N/32W-35E1, which is in an area into which water is not imported, declined about 2 feet between the summers of 1964 and 1965. The decline is the result, at least in part, of pumping in the general area of the well, and in part of below-normal precipitation.

Most of the hydrographs do not show significant natural seasonal fluctuations of ground-water levels. The hydrograph of well 4N/30W-1B2, however, shows large fluctuations which, in part, may reflect natural seasonal fluctuations, but may be largely or entirely due to the seasonal pumping from a nearby well. Pumping during the period April to September 1964, resulted in a decline in water level of about 20 feet. When pumping ceased the water level rose, until in May 1965, the level was about the same as the previous year's high.

Few data are available on the change of water level in wells in the area before 1963. Incomplete records of water-level change in 12 wells during the period 1948-66 show that the level declined an average of about 20 feet in 6 of the wells and rose an average of about 20 feet in 6 other wells. This suggests that the net change in water level during the period was small, and, therefore, that the net change in ground water in storage was also small.

## Perennial Yield

The perennial yield of a ground-water reservoir is the rate at which ground water can be withdrawn annually over a long period without depleting the ground water in storage to such an extent that withdrawal at this rate is no longer feasible because of increased pumping costs or deterioration of water quality. Theoretically, the quantity of ground water that can be withdrawn is equal to the average annual recharge, which for the Ellwood-Gaviota area was estimated to be 6,000 acre-ft/yr. The perennial yield is generally less than the average annual recharge because seldom can all natural discharge be stopped. Under most conditions of ground-water development, it is necessary to permit some natural discharge to take place. Otherwise, the continual recycling of water within the area would ultimately result in a deterioration of the chemical quality of the ground water, owing to concentration of salts in the ground water and in the soil as a result of evaporation and transpiration. Under present conditions in the Ellwood-Gaviota area, therefore, the quantity of ground water that can be withdrawn safely on a long-term basis is probably less than 6,000 acre-ft/yr.

The long-term average annual recharge to many ground-water reservoirs can be increased by good management practices. For example, if water levels are near the ground surface in areas of potential recharge along streams, little of the stream flow will have an opportunity to percolate into the ground-water reservoir. Conditions similar to this prevail along most of the streams in the Ellwood-Gaviota area. The water table near perennial streams is at or above the level of the stream surface, and the ground water discharges into the channel. A substantial decline in ground-water levels beneath the streambeds would lessen the depletion of ground water by base flow in streams and probably result in a significant increase in the average annual recharge to the ground-water reservoir.

## Sea-Water Intrusion

The pumping of ground water from wells in a coastal area may cause sea water to move inland into the aquifers. In the Ellwood-Gaviota area, with minor local exceptions, intrusion of sea water probably does not pose a serious threat. The California Department of Water Resources (1958, p. 20) listed the Gaviota Basin, Cementario Basin, Tajiguas Basin, Canada del Refugio Basin, Canada del Corral Basin, Las Varas Basin, and Bell Canyon Basin as "Areas of suspected sea-water intrusion and areas of over 100 ppm chloride." Intensive pumping of wells near the shore in the permeable alluvium of the stream valleys or in areas of highly fractured Monterey Shale could induce sea-water intrusion which would result in eventual contamination of the ground water.

However, the majority of wells that are farther inland tap aquifers of the sandstone unit that are stratigraphically below but topographically above the Rincon Shale of the shale unit. These wells probably are protected from sea-water intrusion by the nearly impermeable shale and mudstone of the Rincon Shale of the shale unit. If the older aquifers are in hydraulic contact with the ocean in some area offshore, prolonged pumping from them could induce sea water to move landward beneath the overlying shale unit.

## Chemical Quality of the Water

The suitability of water for use by man depends partly upon its chemical quality. As part of the Ellwood-Gaviota area study, samples of surface water and ground water were collected and analyzed. The results of the analyses are listed in tables 5 and 6. Some of the properties and constituents reported in tables 5 and 6 are discussed on the following pages.

TABLE 5.--*Chemical analyses of surface water and springs, Ellwood-Gaviota area*

**All chemical analyses were made by the California Department of Water Resources except 4N/29W-5A, on 12-7-55, and 5N/32W-22F, which were made by the U.S. Geological Survey, Water Resources Division, Sacramento, Calif.**

| Name or description | Location number | Flow (cfs) | Date of collection | Water temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids: Calculated (Sum of determined constituents) | Dissolved solids: Residue on evaporation at 180°C | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Percent sodium | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Results in milligrams per liter (mg/l) | | | | | | | | | | | | | | | | | |
| U S Public Health Service drinking-water standards (1962) | | | | | | 0 3 | | | | | | | 250 | 250 | 1.0 | 45 | | 500 | 500 | | | | | |
| Bell Canyon | 4N/29W- 2M | 0.011 | 1- 9-64 | | 13 | | 136 | 84 | 108 | 3.0 | 441 | 0 | 411 | 92 | 0.8 | 9.3 | 0.46 | 1,070 | 1,160 | 625 | 323 | 25 | 1,520 | 8.2 |
| Eagle Canyon | 5A | | 12- 7-55 | 64 | 8.2 | | 148 | 131 | 238 | 4.0 | 513 | 0 | 745 | 141 | 1.1 | | .92 | 1,670 | 1,670 | 910 | 489 | 36 | 2,330 | 8.0 |
| | | .011 | 12-26-63 | 59.5 | 10 | | 325 | 229 | 430 | 3.0 | 342 | 0 | 1,780 | 358 | .8 | 12 | .98 | 3,320 | 3,710 | 1,750 | 1,470 | 35 | 3,700 | 7.7 |
| Dos Pueblos Canyon | 7C | | 2- 5-58 | 60 | 17 | | 62 | 16 | 17 | .9 | 177 | 0 | 93 | 11 | 0 | 5.1 | .07 | 309 | 313 | 320 | | 14 | 464 | 8.1 |
| | | | 11-23-60 | | 20 | | 199 | 71 | 98 | 2.3 | 357 | 0 | 564 | 80 | .9 | 11 | .09 | 1,220 | 1,290 | 790 | 498 | 21 | 1,670 | 8.2 |
| | | | 3- 9-62 | 57 | 6 | | 56 | 10 | 15 | 5 | 157 | 0 | 60 | 15 | .2 | 6 | .06 | 250 | 305 | 181 | 52 | 15 | 412 | 7.6 |
| | | .224 | 12-26-63 | 54.5 | 13 | | 89 | 83 | 78 | 1.5 | 232 | 0 | 449 | 62 | .2 | 0 | .20 | 925 | 1,070 | 565 | 375 | 23 | 1,240 | 7.9 |
| Bell Canyon | 10K | | 1-10-64 | 49.0 | 8.0 | | 212 | 134 | 365 | 3.0 | 657 | 0 | 798 | 339 | 2.0 | 0 | .90 | 2,180 | 2,300 | 1,080 | 542 | 42 | 2,900 | 7.8 |
| | 15D | | 2- 5-58 | 59 | 21 | | 43 | 27 | 22 | 3.0 | 140 | 0 | 106 | 22 | .3 | 8.6 | 0 | 322 | | | | | 517 | 7.8 |
| | | .034 | 12-26-63 | 50 | 8.9 | | 363 | 184 | 455 | 5.0 | 538 | 0 | 1,300 | 621 | .8 | 0 | .68 | 3,200 | 3,440 | 1,660 | 1,220 | 37 | 3,800 | 7.8 |
| Tecolote Canyon | 16A | | 2- 5-58 | 59 | 17 | | 53 | 15 | 17 | 1.8 | 143 | 3 | 91 | 12 | 0 | 6.6 | .07 | 287 | 292 | 193 | | 16 | 436 | 8.4 |
| | | | 2- 9-62 | 57 | 7 | | 47 | 11 | 14 | 3 | 143 | 0 | 58 | 12 | .1 | 8 | .54 | 231 | 275 | 164 | 46 | 15 | 360 | 7.5 |
| | | .089 | 12-26-63 | 61.0 | 11 | | 114 | 118 | 170 | 3.0 | 301 | 0 | 668 | 138 | .2 | 0 | .49 | 1,370 | 1,550 | 770 | 523 | 32 | 1,650 | 7.9 |
| Las Varas Canyon | 4N/30W- 1K | | 10-11-55 | 60 | 18 | | 170 | 72 | 119 | 2.2 | 516 | 0 | 360 | 129 | 1.6 | .3 | .35 | 1,120 | 1,130 | 772 | 244 | 26 | 1,700 | 8.0 |
| | | .168 | 12-26-63 | 54.0 | 11 | | 103 | 54 | 107 | 2.6 | 289 | 0 | 320 | 87 | .8 | 37 | .32 | 865 | 974 | 477 | 290 | 33 | 1,220 | 8.1 |
| Las Llagas Canyon | 2D | .034 | 12-31-63 | 48.0 | 15 | | 113 | 72 | 149 | 2.4 | 390 | 0 | 419 | 110 | .6 | 3.6 | .33 | 1,080 | 1,120 | 675 | 255 | 36 | 1,470 | 8.0 |
| Canada del Venadito | 5D | .002 | 12-31-63 | 53 | 17 | | 321 | 158 | 295 | 5.5 | 559 | 0 | 965 | 443 | 1.0 | 1.3 | .92 | 2,480 | 2,620 | 1,450 | 992 | 31 | 3,400 | 7.8 |
| Las Varas Canyon (spring) | 5N/29W-30ES1 | .011 | 12-26-63 | 56.0 | 17 | | 79 | 63 | 53 | 1.4 | 288 | 0 | 274 | 43 | .2 | 0 | .07 | 672 | 784 | 458 | 222 | 20 | 960 | 7.8 |
| Ellwood Canyon | 35M | .034 | 1-10-64 | 51.0 | 18 | | 185 | 55 | 56 | 1.8 | 290 | 0 | 505 | 34 | .4 | 0 | .08 | 998 | 1,190 | 686 | 449 | 15 | 1,310 | 8.0 |
| Canada del Refugio | 5N/30W-19C | .112 | 10-24-63 | | 15 | | 82 | 26 | 66 | 1.6 | 311 | 0 | 140 | 30 | .4 | 0 | .2 | 514 | 514 | 310 | 55 | 31 | 820 | 8.1 |
| Canada del Corral | 29J | .55 | 12- 5-63 | 56.0 | 15 | | 128 | 34 | 56 | 1.6 | 259 | 0 | 317 | 34 | .2 | 0 | .17 | | 726 | 462 | 250 | 21 | 1,000 | 7.8 |
| | 31M | | 10-24-63 | | 12 | | 279 | 124 | 220 | 3.3 | 261 | 0 | 1,117 | 232 | .6 | 0 | .7 | 2,120 | 2,250 | 1,200 | 989 | 28 | 2,650 | 7.8 |
| | 31N | 25± | 2- 5-58 | 61 | 19 | | 41 | 18 | 29 | 2.4 | 122 | 0 | 94 | 30 | .2 | 3.8 | .0 | 297 | 330 | | | | 476 | 7.8 |
| | | | 2-19-58 | | 10 | | 53 | 10 | 13 | 3.2 | 166 | 0 | 49 | 13 | .6 | 5.0 | .06 | 239 | 250 | 176 | | 14 | 384 | 7.8 |
| | | 260± | 2- 9-62 | 57 | 8 | | 45 | 9 | 17 | 4.0 | 137 | 0 | 53 | 15 | .1 | 4.0 | .14 | 223 | 310 | 151 | 38 | 19 | 343 | 7.8 |
| Canada del Capitan | 33A | 1± | 11-23-60 | 65 | 15 | | 104 | 15 | 30 | 1.1 | 245 | 0 | 205 | 21 | .4 | 0 | .08 | | 548 | 369 | 168 | 15 | 804 | 7.9 |
| | 33Q | .25± | 12-23-63 | 59.5 | 16 | | 72 | 59 | 61 | 1.5 | 244 | 0 | 298 | 34 | .4 | 0 | .13 | | 720 | 420 | 220 | 24 | 990 | 8.2 |
| Arroyo Quemado | 5N/31W-22N | .1± | 12- 2-63 | | 11 | | 86 | 38 | 55 | 1.9 | 251 | 0 | 232 | 28 | .4 | 0 | .18 | | 618 | 370 | 164 | 24 | 890 | 7.9 |
| Tajiguas Creek | 23G | .11 | 12-13-63 | 53.0 | 14 | | 75 | 40 | 73 | 1.2 | 338 | 0 | 173 | 35 | .2 | 0 | .12 | | 596 | 356 | 79 | 31 | 900 | 7.9 |
| Arroyo Hondo | 29R | .50 | 12- 5-63 | | 14 | | 99 | 34 | 75 | 2.1 | 265 | 0 | 226 | 74 | .2 | 0 | .63 | | 668 | 390 | 173 | 29 | 900 | 8.2 |
| Canada del Molino | 31L | .033 | 12-13-63 | 55.0 | 12 | | 152 | 102 | 85 | 2.5 | 379 | 0 | 551 | 84 | .4 | 0 | .12 | | 1,310 | 798 | 487 | 19 | 1,500 | 7.7 |
| Arroyo Quemado | 34E | .117 | 12- 2-63 | | 16 | | 115 | 111 | 165 | 3.2 | 318 | 0 | 621 | 144 | .8 | 0 | .88 | | 1,450 | 742 | 481 | 33 | 1,780 | 7.3 |
| Leon Canyon | 35C | .022 | 12-13-63 | | 12 | | 433 | 107 | 190 | 1.3 | 512 | 0 | 1,190 | 142 | .6 | 73 | .50 | | 2,550 | 1,520 | 1,100 | 21 | 2,780 | 7.9 |
| Tajiguas Creek | 35N | 1± | 11-23-60 | 60 | 15 | | 275 | 125 | 204 | 2.5 | 529 | 0 | 880 | 231 | .8 | 0 | .69 | | 2,110 | 1,200 | 763 | 27 | 2,800 | 7.8 |
| | 35P | .04 | 12-13-63 | 55.0 | 10 | | 206 | 114 | 210 | 3.0 | 364 | 0 | 850 | 179 | .6 | 0 | .54 | | 1,890 | 984 | 686 | 32 | 2,300 | 7.8 |
| Gaviota Creek | 5N/32W-15F | .45 | 12-31-63 | 51.0 | 15 | | 131 | 71 | 130 | 1.8 | 309 | 0 | 346 | 216 | .8 | 0 | 3.0 | | 1,140 | 619 | 366 | 31 | 1,580 | 8.0 |
| Canada de las Cruces | 16R | .36 | 12-31-63 | 48.0 | 12 | | 135 | 78 | 198 | 3.5 | 297 | 0 | 527 | 209 | .8 | 0 | .62 | | 1,370 | 656 | 413 | 39 | 1,960 | 8.1 |
| Unnamed tributary of Canada de la Gaviota, NW of Las Cruces | 21A | .02 | 12-13-63 | 57.5 | 19 | | 181 | 84 | 203 | 2.7 | 423 | 0 | 522 | 235 | .8 | 0 | .51 | | 1,650 | 795 | 448 | 36 | 2,200 | 8.0 |
| Canada de la Gaviota (hot spring) | 22FS1 | .022 | 9-14-62 | 99.0 | 38 | 0 | 15 | 2.3 | 196 | 1.4 | 423 | 0 | 27 | 58 | 6.6 | 1.1 | 1.4 | 555 | | 349 | 0 | 89 | 856 | 8.1 |
| Canada de la Gaviota | 33H | | 2- 5-58 | 62.0 | 17 | | 87 | 23 | 57 | 2.2 | 177 | 3 | 179 | 76 | .7 | 7.1 | .42 | 539 | 571 | 313 | | 28 | 839 | 8.4 |
| | | .225 | 2- 9-62 | 57.0 | 8 | | 72 | 17 | 30 | 4.0 | 228 | 0 | 106 | 21 | .9 | 1.0 | .20 | 372 | 440 | 252 | 65 | 20 | 568 | 7.4 |
| | | .45 | 12-13-63 | 53.0 | 16 | | 231 | 39 | 255 | 4.0 | 319 | 0 | 459 | 387 | 1.0 | 0 | 1.4 | | 1,630 | 740 | 478 | 43 | 2,200 | 7.8 |
| Canada San Onofre | 36M | .17 | 12-13-63 | 54.0 | 17 | | 149 | 38 | 62 | 1.5 | 275 | 0 | 353 | 55 | .2 | 0 | .10 | | 876 | 528 | 302 | 20 | 1,160 | 7.8 |

TABLE 6.—*Chemical analyses of water from wells, Ellwood-Gaviota area*

Analyzing laboratory: DWR, California Department of Water Resources; USGS, U.S. Geological Survey, Water Resources Division, Sacramento, Calif.

| Well number | Date of collection | Depth of well (feet) | Water temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids: Calculated (Sum of determined constituents) | Dissolved solids: Residue on evaporation at 180°C | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Percent sodium | Specific conductance (micromhos at 25°C) | pH | Analyzing laboratory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Results in milligrams per liter (mg/l) | | | | | | | | | | | | | | | | | | | | | |
| U.S. Public Health Service drinking-water standards (1962) | | | | | 0.3 | | | | | | | 250 | 250 | 1.0 | 45 | | 500 | 500 | | | | | | |
| 4N/29W- 2D1 | 1- 9-64 | 382 | | 10 | | 20 | 1.2 | 365 | 2.5 | 582 | 11 | 182 | 110 | 1.0 | 0 | 1.0 | 991 | 1,040 | 55 | 0 | 93 | 1,500 | 8.3 | DWR |
| 2M1 | 1-10-64 | 72 | | 12 | | 74 | 61 | 135 | 1.0 | 172 | 0 | 401 | 135 | .8 | 2.1 | .54 | 879 | 944 | 435 | 294 | 40 | 1,300 | 8.1 | DWR |
| 4J1 | 7-27-54 | | 64 | 16 | | 152 | 48 | 69 | 2.0 | 419 | 0 | 289 | 55 | .7 | .4 | .45 | 838 | 838 | 576 | 232 | 21 | 1,230 | 7.2 | USGS |
| 5A1 | 10-11-55 | | 82 | 1 | | 4.2 | .2 | 226 | 1.5 | 223 | 0 | .4 | 199 | 8.0 | 1.5 | 6.1 | 656 | 574 | 12 | 0 | 97 | 1,030 | 7.5 | USGS |
| | 11-23-60 | | | 20 | | 123 | 50 | 124 | 1.6 | 360 | 0 | 358 | 85 | 2.8 | 1.9 | .61 | 950 | 937 | 528 | 208 | 34 | 1,390 | 7.4 | DWR |
| | 6-28-62 | | 79 | 12 | | [illegible] | 0 | 227 | 1.7 | 206 | 3.0 | [illegible] | 202 | 7.0 | 0 | 6.8 | 567 | 710 | 11 | 0 | 97 | 970 | 8.4 | DWR |
| | 8-16-63 | | 77 | 13 | | 2.2 | .6 | 227 | 3.0 | 220 | 0 | 21 | 195 | 8.0 | 0 | 4.2 | 581 | 604 | 8 | 0 | 98 | 1,000 | 8.2 | DWR |
| 6B1 | 6- 9-65 | 59 | | | | 26 | 11 | 26 | 1.0 | 65 | 0 | 87 | 16 | .0 | .6 | .02 | 202 | 206 | 109 | 56 | 33 | 351 | 7.8 | DWR |
| 9D1 | 9-26-61 | | | 19 | | 214 | 57 | 153 | 3.5 | 250 | 0 | 646 | 163 | [illegible] | 5.3 | .35 | 1,380 | 1,450 | 770 | 565 | 30 | 1,910 | 7.8 | DWR |
| 10G1 | 4-24-53 | 446 | | | | 91 | 44 | 181 | 3.3 | 440 | 0 | | 108 | | .1 | | 644 | | | | 99 | 1,490 | 7.9 | USGS |
| | 12-20-63 | | 74 | 16 | | 93 | 67 | 217 | 1.8 | 534 | 0 | 283 | 162 | .8 | 0 | 1.5 | 1,100 | 1,100 | 458 | 48 | 49 | 1,500 | 8.0 | DWR |
| 10J1 | 8-20-59 | | 70 | 15 | | 473 | 133 | 245 | 11 | 446 | 0 | 928 | 266 | .9 | 10 | .65 | 2,300 | 2,230 | 1,180 | | 31 | | 7.5 | DWR |
| | 9-19-60 | | 68 | 7 | | 266 | 109 | 280 | 1.0 | 573 | 0 | 833 | 293 | .6 | 1.6 | .87 | 2,070 | 2,280 | 1,110 | 643 | 35 | 3,050 | 7.3 | DWR |
| 10K1 | 7-27-54 | 100 | 74 | 21 | | 128 | 116 | 248 | .8 | 116 | 0 | 787 | 256 | .5 | 34 | .98 | 1,650 | 1,650 | 796 | 701 | 40 | 2,210 | 7.7 | USGS |
| 10Q1 | 7-24-54 | 70 | 66 | 18 | | 214 | 94 | 228 | .8 | 386 | 0 | 538 | 365 | .7 | 12 | .5 | 1,660 | 1,660 | 922 | 605 | 35 | 2,430 | 7.5 | USGS |
| | 8-20-59 | | 68 | 13 | | 113 | 63 | 192 | 2.7 | 360 | 0 | 321 | 238 | .7 | 5 | .28 | 1,130 | 1,180 | 543 | | 43 | 1,540 | 7.8 | DWR |
| | 9-19-60 | | 68 | 12 | | 159 | 60 | 297 | 1.0 | 521 | 0 | 354 | 353 | .4 | 2.1 | .3 | 1,500 | 1,790 | 642 | 215 | 50 | 2,460 | 7.9 | DWR |
| | 6-28-62 | | | 10 | | 57 | 29 | 55 | 5.4 | 176 | 0 | 174 | 37 | .6 | 0 | .42 | 455 | 520 | 264 | 119 | 31 | 695 | 7.8 | DWR |
| | 8-27-63 | | | 8.0 | | 68 | 29 | 52 | 3.5 | 189 | 0 | 207 | 34 | .6 | 0 | 4.3 | 500 | 608 | 293 | 138 | 27 | 785 | 8.1 | DWR |
| 4N/30W- 1B1 | 7-18-61 | 388 | 74 | 34 | | 263 | 13 | 78 | 2.7 | 305 | 0 | 545 | 64 | 1.1 | 9.9 | .05 | 1,160 | 1,180 | 710 | 460 | 19 | 1,570 | 7.0 | DWR |
| | 6-28-62 | | 73 | 28 | | 246 | 19 | 75 | 4.5 | 303 | 0 | 499 | 64 | 1.0 | 0 | .26 | 1,080 | 1,210 | 695 | 447 | 19 | 1,450 | 7.7 | DWR |
| | 7-27-64 | | | 1.2 | | 221 | 22 | 99 | 3 | 233 | 0 | 547 | 61 | 1.2 | 0 | .27 | 1,070 | 1,110 | 639 | 448 | 25 | 1,420 | 7.6 | DWR |
| 4N/31W- 1F1 | 7-27-64 | | | | | 222 | 148 | 230 | 11 | 548 | 0 | 558 | 449 | .4 | 0 | .68 | 1,890 | 1,950 | 1,170 | 718 | 30 | 2,500 | 7.5 | DWR |
| 5N/29W-31G1 | 7-27-54 | 144 | 81 | 15 | | 52 | 32 | 57 | 1.4 | 247 | 0 | 157 | 19 | .5 | 1.0 | .18 | 457 | 457 | 262 | 59 | 32 | 691 | 7.5 | USGS |
| | 8-20-59 | | | 7.5 | | 46 | 18 | 21 | 1.4 | 125 | 0 | 111 | 9 | .11 | 0 | .36 | 276 | 327 | 191 | | 19 | 452 | 7.8 | DWR |
| 31Q1 | 6-28-62 | 235 | | .8 | | 36 | 12 | 34 | 2.5 | 107 | 0 | 86 | 22 | .1 | 32 | .02 | 278 | 272 | 141 | 53 | 34 | 420 | 7.7 | DWR |
| | 8-27-63 | | | 7.1 | | 66 | 38 | 42 | 1.6 | 301 | 0 | 123 | 29 | .2 | 0 | .11 | 455 | 596 | 322 | 75 | 22 | 780 | 7.8 | DWR |
| 34B1 | 12-20-63 | | 68 | 11 | | 119 | 51 | 61 | 1.5 | 458 | 0 | 141 | 84 | .1 | 14 | .26 | 709 | 738 | 508 | 133 | 21 | 980 | 7.5 | DWR |
| 34B2 | 12-20-63 | | 64 | 0 | | 281 | 30 | 220 | 1.7 | 15 | 0 | 1,170 | 60 | .2 | 0 | .79 | 1,840 | 1,770 | 822 | 810 | 37 | | 6.8 | DWR |

| Well number | Date of collection | Depth of well (feet) | Water temperature (°F) | Results in milligrams per liter (mg/l) | | | | | | | | | | | | | | | | | Percent sodium | Specific conductance (micromhos at 25°C) | pH | Analyzing laboratory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids: Calculated (Sum of determined constituents) | Dissolved solids: Residue on evaporation at 180°C | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | | | | |
| .S Public Health Service drinking-water standards (1962) | | | | | 0.3 | | | | | | | 250 | 250 | 1.0 | 45 | | 500 | 500 | | | | | | |
| N/30W-26F1 | 9-26-61 | 610 | | 16 | | 40 | 16 | 142 | 2.0 | 323 | 0 | 152 | 41 | 1.2 | 3.1 | 0.08 | 572 | 573 | 168 | 0 | 64 | 918 | 7.9 | DWR |
| 28R1 | 11- 8-61 | 198 | 65 | 29 | 0.76 | 143 | 10 | 39 | 1.2 | 273 | 0 | 224 | 21 | .44 | .5 | .06 | 603 | 610 | 339 | 175 | 18 | 870 | 7.3 | DWR |
| 30C1 | 11-18-63 | 170 | 67 | 15 | | 70 | 35 | 59 | 1.3 | 228 | 0 | 66 | 39 | .2 | 0 | .18 | 397 | 558 | 319 | 83 | 28 | 770 | 7.8 | DWR |
| 30F1 | 10-24-63 | 444 | | 20 | | 127 | 50 | 67 | 2.2 | 348 | 0 | 299 | 51 | .4 | 0 | .16 | 787 | 840 | 522 | 237 | 22 | 1,040 | 8.0 | DWR |
| 30N1 | 7-18-61 | | | 21 | | 244 | 70 | 113 | 2.3 | 397 | 0 | 613 | 135 | 1.0 | 8.1 | .15 | 1,400 | 1,460 | 893 | 573 | 21 | 2,000 | 7.3 | DWR |
| | 6- 9-65 | | | | | 84 | 30 | 66 | 2.0 | 301 | 0 | 170 | 39 | .5 | 0 | .08 | 540 | 567 | 331 | 85 | 30 | 875 | 8.2 | DWR |
| 30N2 | 10-24-63 | 93 | 66 | 18 | | 164 | 90 | 122 | 1.7 | 382 | 0 | 544 | 119 | .4 | 22 | .34 | 1,270 | 1,400 | 780 | 467 | 25 | 1,750 | 7.8 | DWR |
| 31N1 | 3- 1-61 | | | 16 | | 256 | 96 | 176 | 2.5 | 436 | 0 | 778 | 195 | .6 | 0 | .75 | 1,740 | 1,880 | 1,030 | 676 | 27 | 2,450 | 7.5 | DWR |
| | 6-20-62 | | | 15 | | 238 | 85 | 190 | 20 | 396 | 0 | 728 | 186 | .6 | 11 | .54 | 1,670 | 1,770 | 940 | 615 | 30 | 2,180 | 7.5 | DWR |
| | 8-17-63 | | | 18 | | 174 | 134 | 198 | 4.0 | 456 | 0 | 717 | 218 | .8 | 3.9 | .43 | 1,690 | 1,840 | 986 | 611 | 30 | 2,400 | 7.4 | DWR |
| | 10-24-63 | | | 16 | | 211 | 127 | 217 | 4.3 | 508 | 0 | 736 | 262 | .6 | 1.3 | .47 | 1,820 | 1,940 | 1,050 | 633 | 31 | 2,260 | 7.8 | DWR |
| | 7-15-64 | | | | | 198 | 125 | 223 | 4 | 376 | 0 | 734 | 293 | .9 | 8.2 | .61 | 1,770 | 1,910 | 1,010 | 702 | 32 | 2,540 | 7.6 | DWR |
| | 9- 9-65 | | | | | 239 | 92 | 178 | 4.0 | 441 | 0 | 669 | 201 | .75 | 0 | .49 | 1,600 | 1,740 | 970 | 608 | 28 | 2,290 | 7.5 | DWR |
| 31N2 | 7-28-54 | 25 | 70 | 26 | .01 | 416 | 121 | 267 | 3.0 | 590 | 0 | 1,040 | 382 | .9 | 4.2 | .62 | 2,550 | 2,550 | 1,540 | 1,060 | 27 | 3,460 | 7.4 | USGS |
| | 3- 1-61 | | | 15 | | 244 | 84 | 150 | 3.3 | 382 | 0 | 729 | 135 | .6 | 0 | .76 | 1,550 | 1,580 | 905 | 591 | 26 | 2,000 | 7.7 | DWR |
| | 8-27-63 | | | 17 | | 124 | 169 | 177 | 4.3 | 455 | 0 | 749 | 184 | .6 | 0 | .52 | 1,650 | 1,850 | 1,010 | 632 | 28 | 2,300 | 7.5 | DWR |
| | 10-24-63 | | | 18 | | 271 | 103 | 185 | 4.0 | 486 | 0 | 804 | 209 | .4 | 0 | .61 | 1,840 | 1,920 | 1,100 | 698 | 27 | 2,230 | 7.5 | DWR |
| | 6- 9-65 | | | | | 196 | 81 | 152 | 4.0 | 368 | 0 | 625 | 148 | .7 | .6 | .38 | 1,390 | 1,540 | 820 | 519 | 29 | 2,000 | 7.9 | DWR |
| 32L1 | 10-23-63 | | | 21 | | 10 | 3.0 | 290 | 2.5 | 521 | 0 | 34 | 149 | 4.0 | 0 | .75 | 772 | 774 | 37 | 0 | 94 | 1,180 | 8.2 | DWR |
| 32P1 | 7-28-54 | | 102 | 24 | .01 | 16 | 4.4 | 1,010 | 5.0 | 972 | 87 | 1.2 | 915 | 5.0 | 5.3 | 3.9 | 2,550 | 2,650 | 0 | 58 | 97 | 4,400 | 8.9 | USGS |
| 33A1 | 7-28-54 | 304 | 76 | 27 | .01 | 80 | 9.4 | 23 | .9 | 196 | 0 | 88 | 20 | .3 | .2 | .08 | 346 | | 238 | 77 | 17 | 525 | 8.2 | USGS |
| | 11- 8-61 | | 68 | 30 | .1 | 89 | 6 | 24 | 1.2 | 205 | 0 | 108 | 18 | .40 | .5 | .04 | 378 | 385 | 248 | 80 | 17 | 571 | 7.5 | DWR |
| 35L1 | 9-26-61 | 495 | 70 | 28 | | 140 | 21 | 27 | 1.2 | 262 | 21 | 203 | 28 | .5 | 43 | .02 | 642 | 607 | 435 | 185 | | 1,020 | 8.5 | DWR |
| 35P1 | 9-26-61 | 20 | | 21 | | 68 | 19 | 22 | 1.2 | 116 | 0 | 170 | 20 | .5 | 1.9 | .03 | 381 | 378 | 170 | 75 | 16 | 583 | 8.0 | DWR |
| | 6-28-62 | | | 20 | | 129 | 24 | 33 | 1.7 | 275 | 0 | 221 | 35 | .4 | 0 | .07 | 599 | 646 | 424 | 198 | 15 | 880 | 7.3 | DWR |
| N/31W-23G1 | 11-12-63 | | 64 | 26 | | 91 | 57 | 165 | 1.8 | 360 | 0 | 384 | 87 | .2 | 0 | .19 | 989 | 1,020 | 460 | 165 | 44 | 1,330 | 7.9 | DWR |
| 23Q1 | 11-18-63 | 635 | 76 | 16 | | 6.8 | 1.2 | 220 | 1.0 | 321 | 20 | 51 | 90 | 2.2 | 0 | 1.6 | 567 | 580 | 22 | 0 | 95 | 880 | 8.7 | DWR |
| 25G1 | 10-25-63 | 400 | 71 | 32 | | 166 | 22 | 32 | 1.2 | 315 | 0 | 260 | 28 | .2 | 0 | .10 | 696 | 738 | 505 | 247 | 12 | 910 | 7.2 | DWR |
| 25G2 | 10-25-63 | 500 | 69 | 31 | | 250 | 22 | 37 | 2.0 | 397 | 0 | 394 | 52 | .2 | 0 | .12 | 984 | 1,030 | 714 | 388 | 10 | 1,180 | 7.2 | DWR |

| Well number | Date of collection | Depth of well (feet) | Water temperature (°F) | Results in milligrams per liter (mg/l): Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Carbonate ($CO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Boron (B) | Dissolved solids: Calculated (Sum of determined constituents) | Dissolved solids: Residue on evaporation at 180°C | Hardness as $CaCO_3$ | Noncarbonate hardness as $CaCO_3$ | Percent sodium | Specific conductance (micromhos at 25°C) | pH | Analyzing laboratory |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U.S. Public Health Service drinking-water standards (1962) | | | | | 0.3 | | | | | | | 250 | 250 | 1.0 | 45 | | 500 | 500 | | | | | | |
| 5N/31W-25H1 | 10-25-63 | 530 | 73 | 31 | | 152 | 22 | 36 | 1.2 | 335 | 0 | 210 | 41 | 0.2 | 0 | 0.07 | 658 | 696 | 462 | 187 | 14 | 880 | 7.4 | DWR |
| 26E1 | 11-18-63 | 510 | 72 | 30 | | 127 | 13 | 29 | 9.0 | 292 | 0 | 168 | 25 | .1 | 0 | .08 | 545 | 568 | 373 | 134 | 14 | 700 | 7.8 | DWR |
| 26G1 | 11-12-63 | 320 | 69 | 20 | | 62 | 19 | 145 | 1.3 | 339 | 0 | 163 | 73 | .4 | 0 | .55 | 651 | 648 | 236 | 0 | 57 | 1,000 | 7.5 | DWR |
| 28Q1 | 11-18-63 | | | 29 | | 142 | 7.2 | 23 | .9 | 289 | 0 | 148 | 25 | .2 | 0 | .10 | 517 | 546 | 385 | 148 | 12 | 810 | 7.4 | DWR |
| 32A1 | 9-23-55 | 35 | 63 | | | 118 | 29 | 60 | .9 | 293 | 0 | 193 | 67 | .5 | 1.9 | .28 | 615 | 649 | | | 24 | 1,020 | 7.7 | DWR |
| | 8-20-59 | | | 19 | | 214 | 31 | 57 | 1.3 | 265 | 0 | 219 | 71 | .4 | 5.6 | .18 | 749 | 669 | 420 | | 23 | 970 | 7.6 | DWR |
| | 11-23-60 | | | 16 | | 132 | 29 | 62 | 1.3 | 302 | 0 | 224 | 80 | .4 | 0 | .57 | 694 | 702 | 448 | 200 | 23 | 1,080 | 7.3 | DWR |
| | 6-29-62 | | | 13 | | 111 | 34 | 58 | 2.0 | 253 | 0 | 235 | 66 | .2 | 0 | .39 | 644 | 702 | 419 | 211 | 23 | 990 | 7.3 | DWR |
| | 8-28-63 | | | | | 116 | 29 | 65 | | 271 | 0 | | 63 | | | | | | | | | 1,000 | | DWR |
| | 11-18-63 | | | 16 | | 126 | 29 | 63 | 1.5 | 301 | 0 | 230 | 71 | .2 | 0 | .47 | 685 | 728 | 435 | 188 | 24 | 920 | 7.2 | DWR |
| 35B1 | 7-18-61 | 76 | 68 | 15 | | 292 | 117 | 161 | 2.0 | 506 | 0 | 887 | 160 | .7 | 12 | .18 | 1,900 | 1,930 | 1,210 | 793 | 22 | 2,540 | 7.6 | DWR |
| | 10-25-63 | | 65 | 16 | | 246 | 84 | 183 | 1.3 | 248 | 0 | 893 | 142 | .4 | 9.3 | .45 | 1,700 | 1,890 | 960 | 757 | 29 | 2,500 | 8.1 | DWR |
| 36K1 | 10-24-63 | 250 | | 24 | | 212 | 98 | 113 | 11 | 533 | 0 | 491 | 179 | .4 | 16 | .53 | 1,410 | 1,490 | 935 | 498 | 21 | 1,800 | 7.2 | DWR |
| 5N/32W-27E1 | 11-18-63 | 670 | | 28 | | 50 | 23 | 175 | 3.0 | 255 | 0 | 91 | 206 | 1.6 | 0 | .72 | 705 | 712 | 221 | 12 | 63 | 1,100 | 7.8 | DWR |
| 33H1 | 7- 9-54 | 19 | 68 | 32 | | 312 | 61 | 439 | 5 | 408 | 0 | 412 | 900 | 1 | 2.6 | 3.2 | 2,370 | 2,370 | 1,030 | 695 | 48 | 3,950 | 7.9 | USGS |
| | 8-20-59 | | | 29 | | 55 | 13 | 166 | 2.5 | 232 | 0 | 77 | 195 | 1.0 | 1 | .42 | 654 | 675 | 193 | | 65 | 958 | 8.2 | DWR |
| | 9-19-60 | | | 10 | | 257 | 59 | 346 | 4.0 | 316 | 0 | 389 | 709 | 1.0 | 0 | 3.2 | 1,930 | 2,550 | 880 | 621 | 46 | 3,300 | 7.5 | DWR |
| | 6-29-62 | | 69 | 20 | | 271 | 67 | 400 | 22 | 383 | 0 | 467 | 745 | 1.2 | 0 | 3.8 | 2,190 | 2,390 | 948 | 633 | 47 | 3,350 | 7.4 | DWR |
| | 8-27-63 | | | 22 | | 315 | 45 | 380 | 3.0 | 403 | 0 | 476 | 665 | 1.2 | 0 | 4.1 | 2,110 | 2,140 | 970 | 640 | 47 | 3,300 | 7.5 | DWR |
| 35E1 | 11-23-60 | 402 | | 15 | | 34 | 1.8 | 445 | 3.2 | 320 | 0 | 60 | 514 | 7.0 | 2.5 | 7.6 | 1,250 | 1,230 | 93 | 0 | 91 | 2,160 | 7.8 | DWR |
| 35F1 | 7-29-54 | | 87 | 29 | 0.01 | 46 | 11 | 217 | 2.6 | 310 | 0 | 168 | 140 | .7 | 2.2 | .91 | 778 | 770 | 160 | | 74 | 1,270 | 7.9 | USGS |
| | 9-23-55 | | 64 | | | 58 | 13 | 213 | 1.8 | 363 | 0 | 169 | 140 | .7 | 1.4 | .91 | 777 | 793 | 200 | 0 | 70 | 1,340 | 7.9 | DWR |
| | 8-20-59 | | 72 | 21 | | 37 | 12 | 218 | 3.7 | 272 | 0 | 177 | 135 | .8 | 1.0 | .84 | 741 | 735 | 143 | | 76 | 976 | 7.9 | DWR |
| | 11-23-60 | | | 17 | | 73 | 9 | 200 | 3.3 | 357 | 0 | 174 | 138 | .5 | 0 | 1.2 | 792 | 786 | 219 | 0 | 66 | 1,290 | 7.7 | DWR |
| | 8-27-63 | | | 19 | | 49 | 19 | 215 | 9.0 | 354 | 0 | 188 | 139 | .6 | 0 | 1.0 | 814 | 768 | 202 | 0 | 69 | 1,300 | 7.9 | DWR |
| | 10-25-63 | 900 | | 18 | | 37 | 8.4 | 215 | 2.3 | 261 | 0 | 182 | 138 | .6 | 0 | 1.3 | 731 | 748 | 126 | 0 | 78 | 1,040 | 8.2 | DWR |

## Interpretation of the Chemical Analyses

The salinity and alkali hazards of water from some of the wells are plotted in a diagram proposed by Wilcox (1955) for the classification of irrigation water (fig. 9). The samples collected from streams are plotted on another diagram (fig. 10), because concentration of salts probably has occurred in some of the samples as a result of evaporation, transpiration by plants, and irrigation return along the stream channels. This is most likely to occur along streams with a low base flow.

As shown in figure 9, most of the well water is in class C3-S1. In water of this class, salinity hazard is high but sodium (alkali) hazard is low; the water can be used only on soils with good drainage. Three samples, from wells 5N/30W-31N1, 5N/31W-35B1, and 5N/32W-33H1, have very high salinity hazard. Water from those wells can be effectively used for irrigation only under special circumstances.

Ground water in the report area generally is low in sodium and high in calcium and magnesium. Residual sodium carbonate is not present and does not pose a threat to irrigated crops. The concentration of boron is less than 1 mg/l (milligram per liter) in most samples, which is within the commonly accepted limits for most agricultural uses. However, water from two wells in the western part of the area, wells 5N/32W-33H1 and 35F1, contains, respectively, 4.1 mg/l and 1.3 mg/l boron.

The concentration of fluoride in water from a few wells and from the base flow of a few streams in the area is above the upper limit of 1 mg/l recommended by the U.S. Public Health Service (1962). The fluoride concentration in base-flow samples from Bell, Eagle, and Las Varas Canyons tends to be at or above the recommended upper limits (table 5). Fluoride in the hot springs near Las Cruces in Canada de la Gaviota is several times the recommended limit. Water from about 10 wells in the area is relatively high in fluoride; the concentration ranges from slightly more than 1 mg/l to 8 mg/l. Most of these wells tap the youngest beds of the sandstone unit; however, water from two wells in the Corral Canyon area that tap the Monterey Shale contains as much as 5 mg/l fluoride.

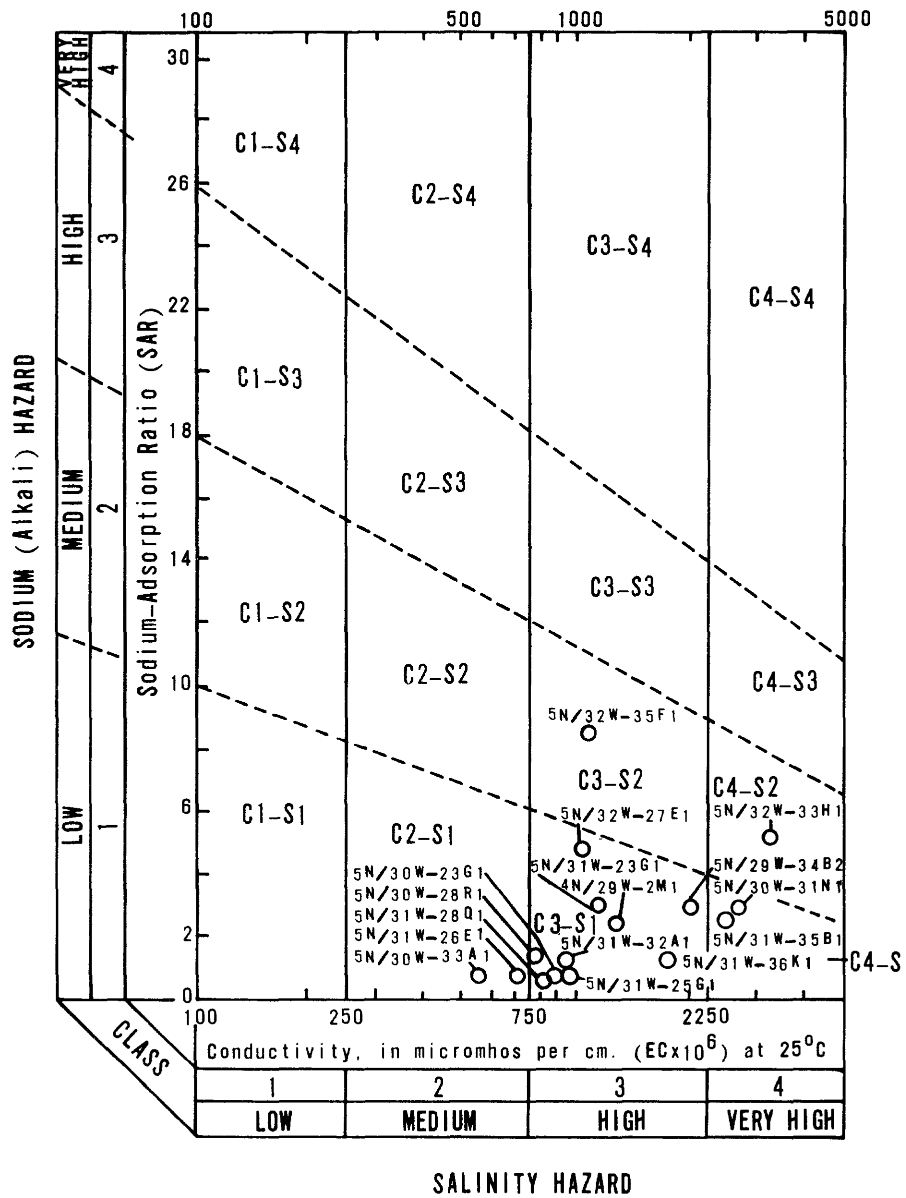



FIGURE 9.--Classification of well water for irrigation on the basis of conductivity and sodium-adsorption ratio.

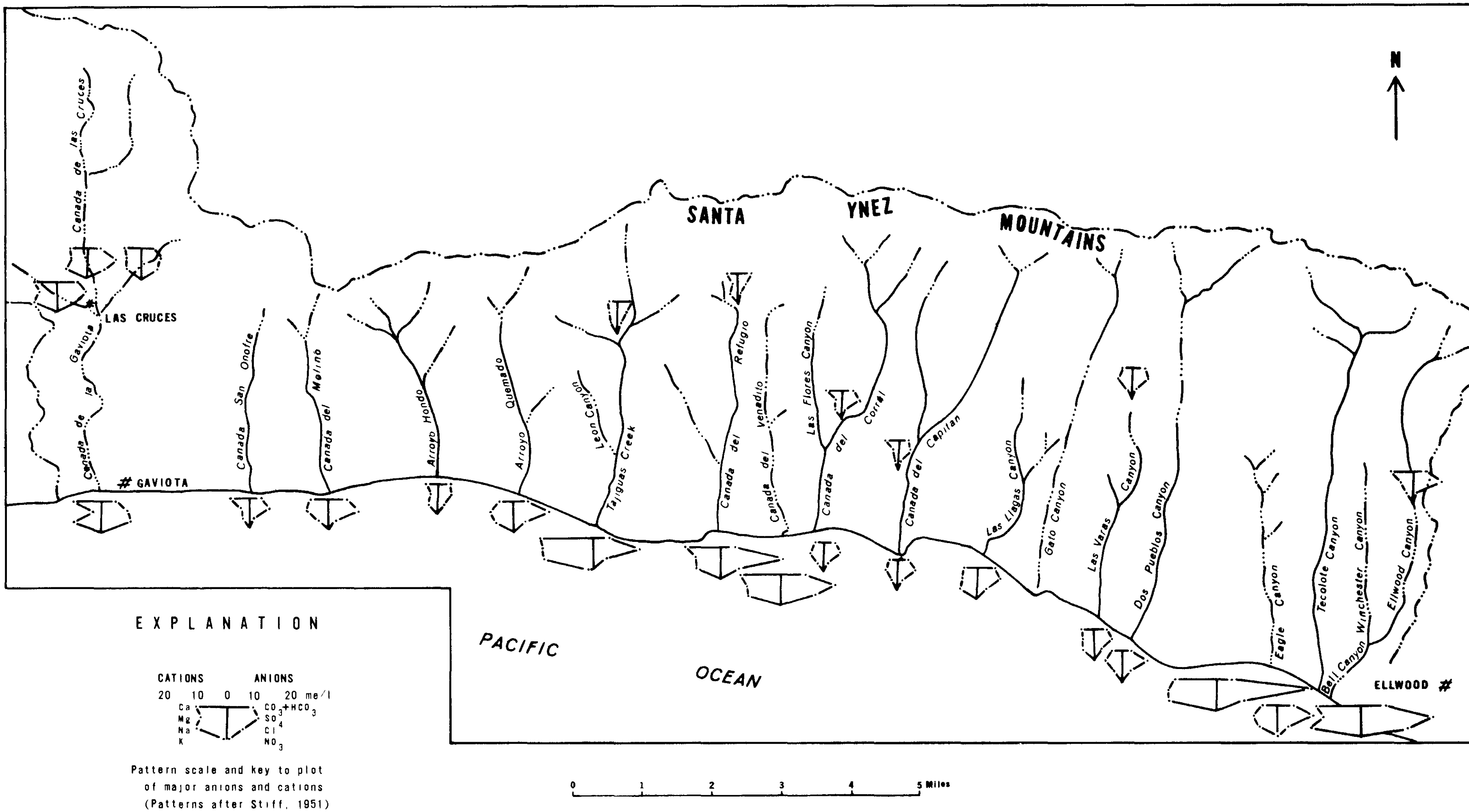



FIGURE 10.--Map of the Ellwood-Gaviota area showing general distribution and concentration of major ions in base flow of streams, winter 1963-64.

Water from about half the wells in the area is acceptable for domestic use, although the water is high in dissolved solids and generally is very hard. Softening would be required for most domestic uses. Water from the remaining wells is sufficiently high in dissolved solids to be objectionable for many uses.

The base flow of streams in the area is sustained largely by ground-water outflow, and the chemical nature of the base flow is similar to that of the local ground water.

Excess irrigation water enters several of the streams and makes up part of the base flow; this and evapotranspiration along the stream course alter the chemical nature of the water. Figure 10 shows the general distribution of major ions in the base-flow water of most streams. The basic data for figure 10 is from samples taken during periods of base flow in the winter of 1963-64. The patterns show concentrations in me/l (milliequivalents per liter) after Stiff (1951, p. 15). The patterns plotted offshore from the coast in figure 10 were constructed from analyses of water samples collected above the tidal zone near the mouth of the streams. The patterns plotted inland from the coast represent chemical analyses of base-flow water collected upstream from irrigated areas.

The most intensively irrigated areas are along the streams in Bell, Ellwood, Winchester, Dos Pueblos, Las Varas, and Refugio Canyons, and along Tajiguas Creek. The base-flow water near the mouth of most of these streams contained a significantly higher quantity of dissolved constituents than the base-flow water of most other streams. Also, the diagrams show that waters in the upper reaches of Ellwood, Las Varas, Refugio, and Tajiguas Canyons are similar to waters near the mouth of many streams where little or no land along the stream is irrigated. The base flow in the streams in Canada del Capitan, and Canada de la Gaviota shows slight change in the total or relative concentration of major ions in solution in the water along the stream reach from headwater to the mouth. There is little irrigation along those streams, and the base flow (table 3) is probably sufficient to highly dilute additions of poor quality water.

Tecolote Canyon, where several areas were irrigated until the late 1950's, is presently being urbanized. The low concentration of dissolved constituents in the base flow at the mouth of the canyon probably now reflects, in part, the change in land use.

## Suitability for Domestic Use

The suitability of water for domestic use is in part determined by the concentration of the total dissolved solids and certain ions. Although clear-cut limits ordinarily cannot be established, the U.S. Public Health Service drinking water standards (1962) serve as a useful guide. A summary of these standards for the more common objectionable constituents follows:

| Constituent | Recommended limit (mg/l) | Effect |
|---|---|---|
| Nitrate ($NO_3$) | 45 | Methemoglobinemia in infants |
| Fluoride (F) | [1]1.0 | Proper balance with temperature will tend to prevent dental cavities. Excess produces dental fluorosis |
| Chloride (Cl) | 250 | Taste |
| Sulfate ($SO_4$) | 250 | Taste, cathartic effect |
| Total dissolved solids | 500 | Taste |

[1]Recommended limits vary with annual average of maximum daily air temperature.

The foregoing limits do not necessarily indicate harmful levels for the ions but serve as a guide in determining the suitability of water for human consumption. In addition to the foregoing constituents, the hardness of water used for domestic supply should also be considered.

Hardness, which generally refers to the soap-consuming power of water, is usually caused by calcium and magnesium ions. Free acid also causes hardness but is seldom present in large enough quantities to have a significant effect on the hardness. Hardness adversely affects the taste of water and is responsible for deposits of scale in boilers, pipes, and radiators. In general, water with 60 mg/l hardness (calculated as $CaCO_3$) or less is rated soft; water with 60 to 120 mg/l hardness is rated slightly hard; water with 120 to 180 mg/l hardness is rated moderately hard; and water with over 180 mg/l hardness is rated very hard. Most water in the Ellwood-Gaviota area is rated as very hard. About 80 percent of the analyses in tables 5 and 6 are of waters where hardness is greater than 200 mg/l. In many analyses reported by others hardness is expressed in terms of grains per gallon. Grains per gallon may be converted to mg/l by multiplying by 17.12.

## Suitability for Irrigation Use

Wilcox (1955, p. 7-12) described the chemical properties of water and evaluated water for irrigation on the basis of its chemical properties. The most important properties, in Wilcox's classification, are the salinity hazard and the sodium (alkali) hazard. However, the concentration of bicarbonate, boron, and other ions also is used as a criterion for the evaluation of water for irrigation. Wilcox's method of classification is sed in this report.

Salinity hazard.--On the basis of the electrical conductivity of a water supply, Wilcox (1955, p. 7) divided water into four classes. The dividing points between the classes are 250, 750, and 2,250 micromhos per centimeter (fig. 9). All other factors being equal, water of low conductivity is more suitable as a water supply than water of high conductivity. Wilcox provided the following classification of irrigation water with respect to salinity hazard:

"1. Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

"2. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

"3. High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

"4. Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances."

Sodium (alkali) hazard.--The sodium, or alkali, hazard is indicated by the sodium-adsorption-ratio (SAR), which is defined as

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

in which concentrations are expressed in me/l. A high alkali hazard exists if the proportion of sodium (Na) among the cations is high; but if calcium (Ca) and magnesium (Mg) are high in proportion to sodium, the alkali hazard is low. Wilcox proposed the following classification of water with respect to alkali hazard:

> "1. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stonefruit trees and avocados may accumulate injurious concentrations of sodium.
>
> "2. Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.
>
> "3. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter addition.
>
> "4. Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except under special circumstances."

Bicarbonate ion.--The hazard involved in the use of water whose bicarbonate-ion concentration is high is measured by the residual sodium carbonate (RSC) which is defined by the formula

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

in which concentrations are in me/l. Water is not suitable for irrigation if the residual sodium carbonate is greater than 2.5 me/l. The water is of marginal quality if the residual sodium carbonate ranges between 1.25 and 2.5 me/l. If the residual sodium carbonate is less than 1.25 me/l, the water probably can be used safely for irrigation.

Boron.--Boron almost invariably is present in natural water in minute quantities that range from a trace to several milligrams per liter. Boron is an important constituent in irrigation water because it is essential, in small quantities, to plant growth. At concentrations slightly higher than the optimum, however, it is highly toxic to most plants. In general, if the concentration of boron exceeds 3 mg/l, the water is injurious. Limits for boron in irrigation water, depending on the sensitivity of the crop, were proposed by Scofield (1936, p. 286).

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