GEOLOGY and GROUND WATER in NORTH-CENTRAL SANTA CRUZ COUNTY, CALIFORNIA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 80-26

Prepared in cooperation with the
SANTA CRUZ COUNTY FLOOD CONTROL
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North-central Santa Cruz County is underlain mainly by folded sedimentary rocks of Tertiary and Cretaceous age that have been highly fractured by movements in the San Andreas fault system. Ground water is stored in fractures within shale and mudstone formations and in intergranular pore spaces within fine- to very fine-grained sandstone and siltstone formations. Fewer than 10 percent of the wells yield more than 15 gallons of water per minute. The water in most wells is moderately hard to very hard, is generally of a sodium bicarbonate or calcium bicarbonate type, and commonly has excessive concentrations of iron or manganese. Of the many geologic units in the study area, only the Purisima Formation of Pliocene age has the potential to sustain well yields greater than 100 gallons per minute.

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and Water Conservation District

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September 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

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Menlo Park, Calif. 94025

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain metric unit
acre-ft (acre-feet)	1,233	m^3 (cubic meters)
ft (feet)	0.3048	m (meters)
gal/min (gallons per minute)	0.06309	L/s (liters per second)
(gal/min)/ft (gallons per minute per foot)	0.2070	(L/s)/m (liters per second per meter)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Degrees Fahrenheit (°F) are converted to degrees Celsius (°C) by using the formula: °C = (°F-32)/1.8.

Abbreviations used:
- mg/L (milligrams per liter)
- µg/L (micrograms per liter)
- µmho/cm at 25° C (micromhos per centimeter at 25° Celsius)

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

GEOLOGY AND GROUND WATER IN NORTH-CENTRAL SANTA CRUZ COUNTY, CALIFORNIA

By Michael J. Johnson

ABSTRACT

North-central Santa Cruz County is underlain mainly by folded sedimentary rocks of Tertiary and Cretaceous age that have been highly fractured by movements in the San Andreas fault system. Ground water is stored in fractures within shale and mudstone formations and in intergranular pore spaces within fine- to very fine-grained sandstone and siltstone formations. Fewer than 10 percent of the wells yield more than 15 gallons of water per minute. The water in most wells is moderately hard to very hard, is generally of a sodium bicarbonate or calcium bicarbonate type, and commonly has excessive concentrations of iron or manganese. Of the many geologic units in the study area, only the Purisima Formation of Pliocene age has the potential to sustain well yields greater than 100 gallons per minute.

INTRODUCTION

Purpose and Scope

This report was prepared by the U.S. Geological Survey, in cooperation with the Santa Cruz County Flood Control and Water Conservation District, on the basis of work done in the years 1976-78 to assess the water-bearing potential of the various geologic units in north-central Santa Cruz County. This area is undergoing residential growth, and the demand for water is expected to increase. Water shortages have already occurred in the northwestern part of the study area.

The scope of the investigation was to identify the principal water-bearing units and evaluate their potential for ground-water development. To do this, an understanding of the geology and hydrology was necessary. This report presents the geology and briefly describes the occurrence, source, direction of movement, and chemical quality of ground water in the area.

Previous Investigations

This is one in a series of reports on ground water in Santa Cruz County prepared by the U.S. Geological Survey. Previous studies include the Soquel-Aptos area (Akers and Hickey, 1967; Hickey, 1968), Scotts Valley area (Akers, 1969), Pajaro Valley area (Muir, 1972, 1974, 1977), and western Santa Cruz County area (Akers and Jackson, 1977). An earlier study of the entire county was made by the California State Water Resources Board (1953).

The major geologic units of the Coast Range province and their relation to fault blocks and fault movement are discussed in a bulletin of the California Division of Mines and Geology (1966). Structural relationships and basement tectonics in the study area were described by B. L. Clark (1930), Gribi (1957), Ross and Brabb (1973), and J. C. Clark and Rietman (1973). The geologic units and their lithologic sequence were discussed by Cummings, Touring, and Brabb (1962), Brabb (1964, 1970), Clark and Rietman (1973), Simoni (1974), and Akers and Jackson (1977). Geologic reports with detailed maps by Fairchild (1957), Melendres (1958), Burford (1961), McLaughlin and others (1971), Hall, Sarna-Wojcicki, and Dupre (1974), and Osbun (1975) also were consulted during this study.

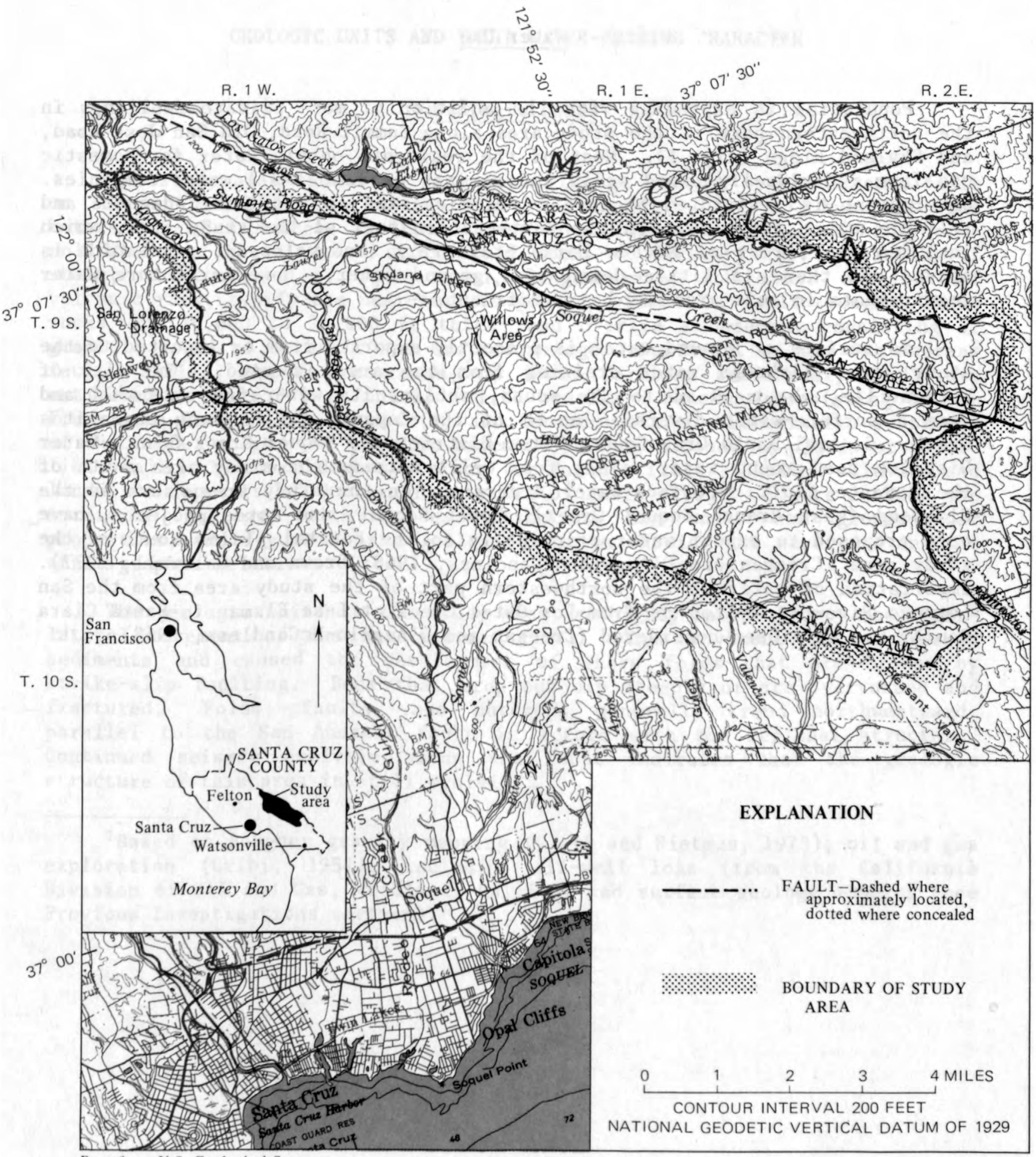
The most recently published geologic map that includes all of north-central Santa Cruz County is a 1:125,000-scale map by Clark and Rietman (1973); more detailed mapping of the area is underway at this time. Detailed geologic maps have been completed by the Geological Survey for the Los Gatos and Laurel 7½-minute quadrangles (Dibblee and Brabb, 1978; Dibblee and others, 1978) and one for the Loma Prieta quadrangle is in preparation.

Location and General Features of Study Area

The study area is in the north-central part of Santa Cruz County (fig. 1) commonly referred to as the Soquel-Aptos highlands. It covers about 45 mi^2 from the Santa Clara County line on the north to the Zayante fault on the south, and from Highway 17 on the west to Corralitos Creek on the east.

The terrain is mountainous and incised by V-shaped canyons. Altitudes range from 400 ft in the lower stream-cut canyons to about 3,200 ft at the county line near Loma Prieta. Mean annual precipitation ranges from 30 inches at lower altitudes along Corralitos Creek to 48 inches at higher altitudes along Summit Road (Rantz, 1971). Mean annual runoff ranges from 8 to 16 inches (Rantz, 1974). The area is drained mainly by Soquel and Aptos Creeks which flow into Monterey Bay.

Vegetation varies from thickly forested slopes and gullies to chaparral-covered ridges and knolls. In the past, the flatter areas of land were cleared, cultivated, and planted in orchards and vineyards, many of which are now neglected and overgrown. During the early part of the 20th century, extensive logging depleted most of the virgin redwood trees. At present, there is some logging of second-growth trees. The primary impact on the area, however, is from the increasing urban development.



Base from U.S. Geological Survey
Sheet 3, San Francisco Bay Region,
1:125,000, 1970

FIGURE 1.--Location of the study area.

Water Use

Population is expanding with the addition of more private dwellings in the northwestern part of the study area along Summit Road, Old San Jose Road, and Skyland Ridge (fig. 1). Most of the residents obtain water for domestic use from individually owned wells and springs or from small water companies. Development is restricted because of difficulties in providing adequate and reliable water supplies. In the southeastern part of the study area, which includes The Forest of Nicene Marks State Park (undeveloped), population is sparse and there is little demand for ground water. However, future water requirements in this area may be significant.

No surface or ground water is presently exported from or imported to the study area, although water draining from the area is used. The city of Watsonville, about 10 mi to the south, obtains its water from one well and from a surface-water diversion north of the Zayante fault along Corralitos Creek. Central Santa Cruz County Water District and Soquel Creek County Water District use ground water solely from wells outside the study area south of the Zayante fault. Surface-water diversions in the study area, such as the Glenwood (West Branch Soquel Creek), Upper Soquel, and Aptos projects, have been proposed to export water principally to the coastal plains south of the study area (Creegan and D'Angelo-McCandless, 1968; Brown and Caldwell, 1977). Importation of water to the northwestern part of the study area from the San Lorenzo River at Felton or from Los Gatos Creek at Lake Elsman in Santa Clara County has also been considered (Creegan and D'Angelo-McCandless, 1968).

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTER

Geologic Units

The study area is mostly in a fault trough bounded by the Zayante fault on the south and the San Andreas fault on the north (fig. 1), but part lies between the San Andreas fault and the Santa Clara County line. Partly consolidated and consolidated sedimentary rocks of Tertiary age, consisting of shale, mudstone, clay, silt, sand, conglomerate, and minor deposits of volcanic rock, typify the near-surface geology within the fault trough. These rocks are 10,000 to 14,000 ft thick[1] and overlie a basement consisting of granitic rocks of Jurassic and Cretaceous age. Northeast of the San Andreas fault, similar Upper Cretaceous and lower Tertiary sedimentary rocks are estimated to be 6,000 ft thick[1] and to overlie a basement consisting of the Franciscan Complex of Jurassic(?) and Cretaceous age. Immediately southwest of the fault trough, the granitic basement rock is exposed in places or underlies shallow Tertiary deposits along the Zayante fault. Shallow alluvial and landslide deposits of Quaternary age are of small extent. Figure 2 shows the surficial geology, with a description of map units and ground-water properties, and figure 3 is a geologic section showing the structure and the stratigraphic relations.

The geologic units in the study area are highly influenced by the right-lateral movement of the San Andreas fault. This movement has compressed sediments and caused the development of sharp folds that are broken by strike-slip faulting. Beds that crop out dip steeply or are overturned and fractured. Folds, faults, and outcrops generally trend northwestward, parallel to the San Andreas fault in accord with the regional structure. Continued seismic activity along the fault indicates that the geologic structure of this area is still evolving.

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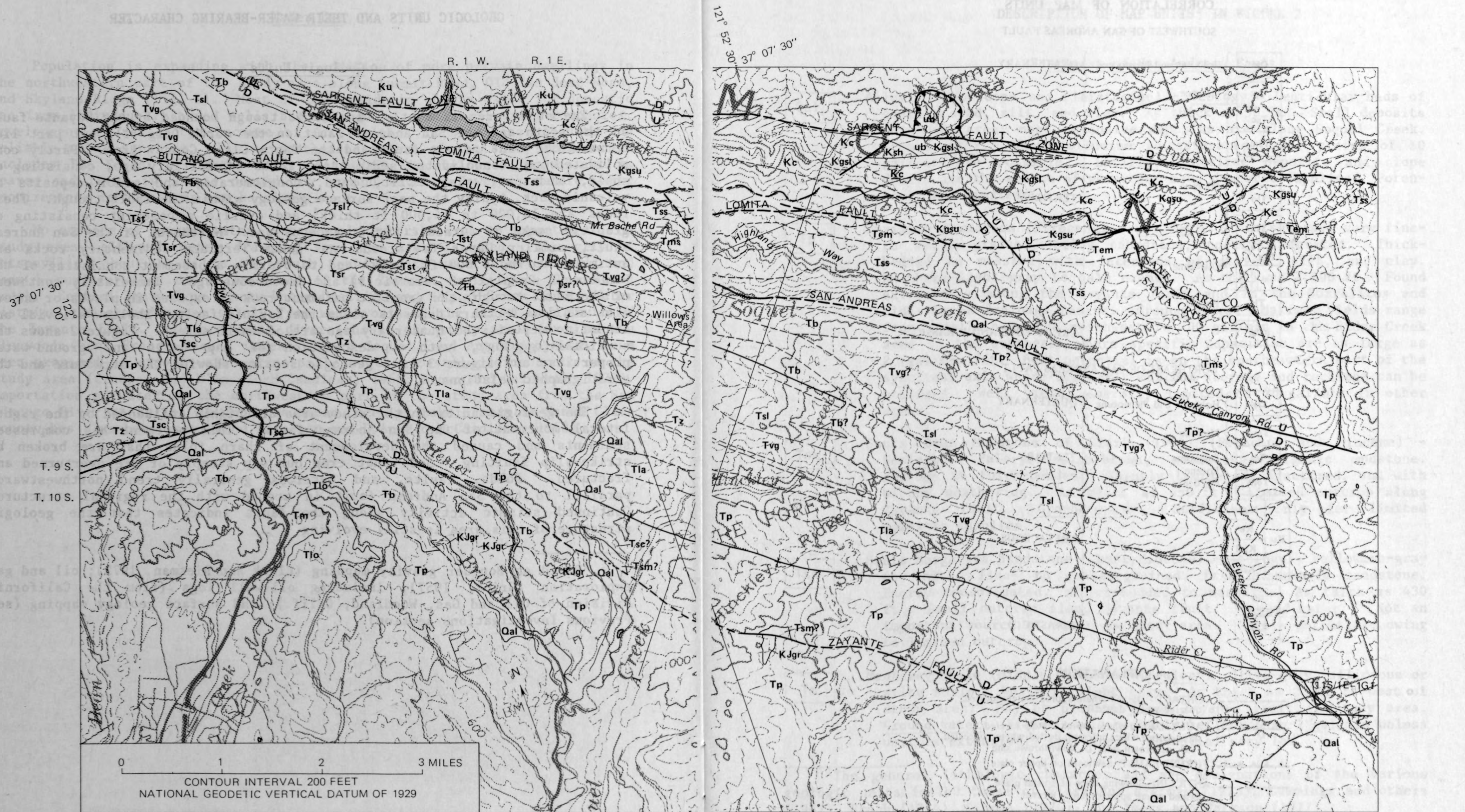
[1]Based on Bouguer gravity mapping (Clark and Rietman, 1973); oil and gas exploration (Gribi, 1957), including oil-well logs (from the California Division of Oil and Gas, Woodland, Calif.); and surface geology mapping (see Previous Investigations section).

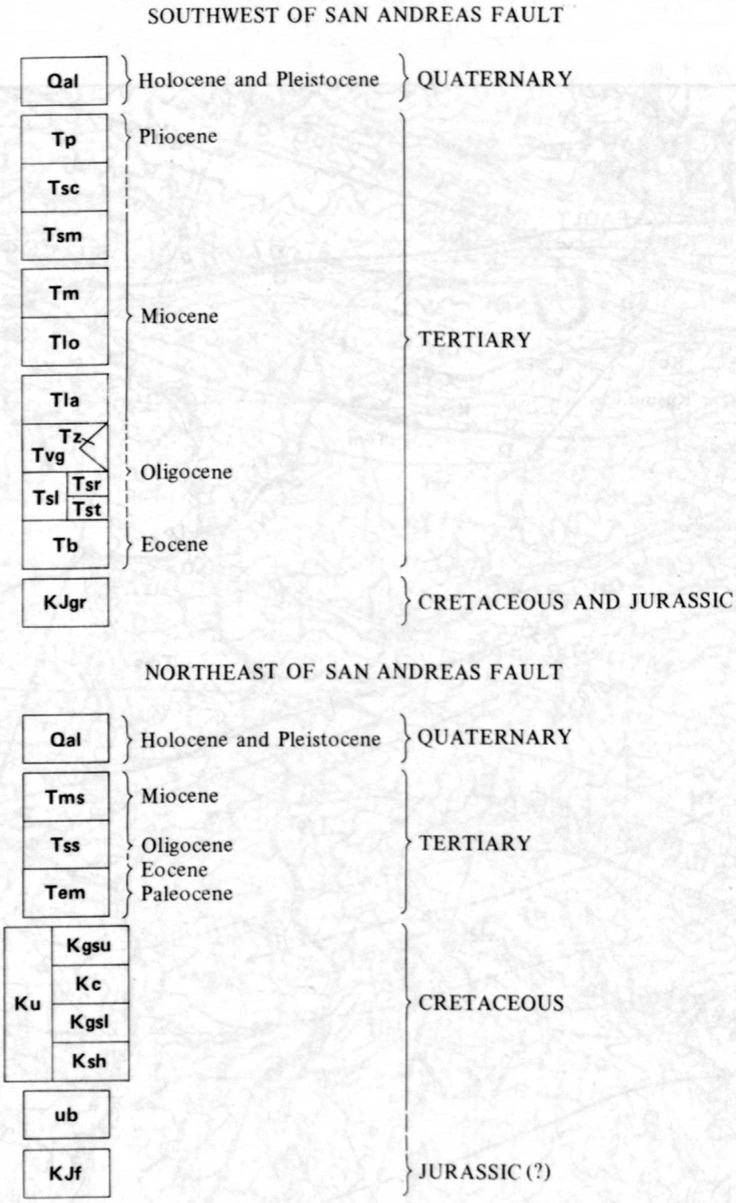


Base from U.S. Geological Survey
Sheet 3, San Francisco Bay Region,
1:125,000, 1970

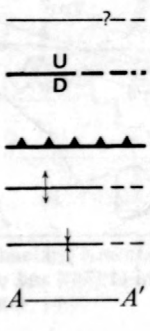
Geology from Clark and Rietman (1973),
Simoni (1974), and others

FIGURE 2.--Areal geology, with a description of map units and ground-water properties.

CORRELATION OF MAP UNITS



EXPLANATION



CONTACT - Dashed where approximately located; queried where doubtful

FAULT - Dashed where approximately located, short-dashed where inferred, dotted where concealed. **U**, upthrown side; **D**, downthrown side

THRUST FAULT - Sawteeth on upper plate

ANTICLINE-Showing trace of crustal plane, dashed where approximately located

SYNCLINE - Showing trace of crustal plane, dashed where approximately located

TRACE OF GEOLOGIC SECTION SHOWN IN FIGURE 3

FIGURE 2.--Continued.

DESCRIPTION OF MAP UNITS[1] IN FIGURE 2

Southwest of San Andreas Fault

Qal — Alluvium (Holocene and Pleistocene) - Geology: Lenticular beds of gravel, sand, silt, and clay. As thick as 50 ft. Small deposits in study area; most extensive deposits are along Soquel Creek. Ground water: Where alluvium is saturated, well yields of 50 gal/min are possible. Locally, landslide deposits and slope debris are the source of water for many domestic supplies. Potential very limited.

Tp — Purisima Formation (Pliocene) - Geology: Greenish-gray, very fine- to medium-grained, silty sandstone; poorly indurated. Thick-bedded to massive with interbeds of gravel, silt, and clay. Weathers light gray to pale orange. As thick as 2,000 ft. Found extensively along the Zayante fault and in the Corralitos and Rider Creek drainage basins. Ground water: Maximum yields range from 5 gal/min in the northwest to 200 gal/min in the Rider Creek area in the southeast where specific capacities are as large as 2 (gal/min)/ft. Best potential is on the southeastern part of the synclinal axis where aquifer's maximum storage and recharge can be utilized. Well yield generally limited to 20 gal/min in other areas.

Tsc — Santa Cruz Mudstone of Clark (1966) (Pliocene and Miocene) - Geology: Pale-yellowish-brown, siliceous, organic mudstone. Medium- to thick-bedded. Faintly laminated, fractured, and with blocky weathering. As thick as 450 ft. Limited outcrop along Zayante fault. Ground water: Sufficient only for limited domestic supplies.

Tsm — Santa Margarita Sandstone (Upper Miocene) - Geology: Yellowish-gray to white, fine- to coarse-grained, friable arkosic sandstone. Poorly consolidated. Thick-bedded to massive. As thick as 430 ft. Small outcrop along Zayante fault. Ground water: Not an important source of water in study area. Little potential, owing to limited outcrop.

Tm — Monterey Shale (Middle Miocene) - Geology: Olive-gray, siliceous or silty shale. Weathers light gray. As thick as 2,700 ft west of study area. May be present along Zayante fault in study area. Ground water: Yields would probably be less than 2 gal/min unless unit is extensively fractured. Potential very low.

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[1]The general lithologic character and age designations of the various geologic units follow those of Clark and Rietman (1973), Cummings and others (1962), Brabb (1964), Simoni (1974), and Akers and Jackson (1977).

Tlo

Lompico Sandstone of Clark (1966) (Middle Miocene) - Geology: Yellowish-gray, fine- to medium-grained, arkosic sandstone. Poorly consolidated. Thick-bedded to massive. As thick as 500 ft west of study area. Small deposits may be present along Zayante fault. Ground water: Fairly permeable aquifer. Known to yield as much as 40 gal/min from thicker sections elsewhere in Santa Cruz County. Little potential in study area, owing to small areal extent.

Tla

Lambert Shale (Lower Miocene) - Geology: Light-gray sandy shale. Thin to medium bedded with phosphatic laminae and lenses in lower part. Moderately folded and fractured. As thick as 1,300 ft. Located in and parallel to fault trough. Ground water: Supplies water to wells along Old San Jose Road. Potential well yields less than 5 gal/min and only where intensely fractured.

Tvq

Vaqueros Sandstone (Miocene and Oligocene) - Geology: Yellowish-gray, fine- to medium-grained, arkosic sandstone. Lower part thin-bedded, alternating with beds of mudstone and shale. Upper part thick- to massive-bedded, unindurated but cliff forming. Intensively folded and faulted. May locally contain basaltic flows. Weathers very pale orange or buff. As thick as 2,800 ft. Found along the length of the fault trough. Ground water: Yields are generally less than 10 gal/min, but specific capacities are low, 0.01 to 0.2 (gal/min)/ft. One well in the upper Corralitos drainage basin yielded 22 gal/min. North of Butano fault the known well yields are generally less than 6 gal/min. Formation yields enough water in most areas for domestic supplies. Not considered a potential source for large quantities of water, owing to fine grain size.

Tz

Zayante Sandstone (Oligocene) - Geology: Bluish-gray, moderately to poorly sorted, pebbly, medium- to coarse-grained, biotite-bearing, arkosic sandstone. Thick bedded with interbedded pebble and cobble conglomerate and sandy siltstone beds. Weathers yellowish-orange. As thick as 200 ft. Limited deposition within Vaqueros Sandstone unit. Ground water: Poorly permeable aquifer. Probable yields less than 3 gal/min. Not a potential source of much water.

Tsl San Lorenzo Formation (Oligocene and Eocene) - Geology: Interbedded sequence of shale and mudstone. As thick as 2,000 ft. Found extensively in the study area's fault trough. Tsr Upper Rice's Mudstone Member - Olive-gray nodular mudstone mixed with siltstone and very fine-grained arkosic sandstone. Poorly sorted. Weathers light gray. Tst Lower Twobar Shale Member - Olive-gray, laminated shale. Weathers reddish brown. Both members are moderately to intensively folded and fractured. Ground water: Yields small quantities of water to wells, generally less than 5 gal/min. Southwest of the Butano Sandstone, in sec. 27 (T. 9 N., R. 1 W.) between Laurel Creek and Old San Jose Road, wells are known to go dry during the summer months; in sec. 35 (T. 9 N., R. 1 W.) southwest of Old San Jose Road, wells and springs depend on shallow ground water draining off Skyland Ridge through fractures in the exposed Upper Twobar Shale Member into the Rice's Mudstone Member. Northeast of the Butano Sandstone, wells yield better, as much as 10 gal/min, with proximity to the Butano fault's fracture zone; in the Skyland Ridge area, yields vary, depending on proximity and connection to water storage in sandstone units, but they are generally only a few gallons per minute. Potential small.

Tb Butano Sandstone (Eocene) - Geology: Yellowish-gray, fine- to medium-grained arkosic sandstone. Thin- to thick-bedded with interbedded olive-gray nodular siltstone. Predominance of micaceous shale and granitic conglomerate in lower part. Consolidated, highly fractured, and intensely folded and faulted. As thick as 5,000 ft. Found extensively in study area. Ground water: Yields of 2 to 15 gal/min can be expected with specific capacities from 0.1 to 0.5 (gal/min)/ft. Off Skyland Ridge in the Willows area to the south and between Skyland Ridge and the San Andreas fault to the north, yields of 25 gal/min have been measured, although 4 to 7 gal/min are more common. Generally yields enough water for domestic supplies from sandstone outcrops and from highly fractured shale and conglomerate outcrops. Potential exists for domestic wells and small community systems.

KJgr Granitic rocks (Cretaceous and Jurassic) - Geology: Predominantly black and white quartz diorite and brownish adamellite, ranging from gabbro to granite. Principal basement rock southwest of San Andreas fault. Ground water: Not known to contain water in study area. Might yield some water along erosional surfaces and where fractured.

Northeast of San Andreas Fault

Qal Alluvium (Holocene and Pleistocene) - Geology: Beds of gravel, sand, silt, and clay. As thick as 40 ft. Very small deposits along Laurel and Corralitos Creeks. Ground water: Where alluvium is saturated it yields quantities of water sufficient for domestic supplies. Potential low.

Tms — Mudstone (Miocene and Oligocene) - Geology: Olive-gray, siliceous mudstone. Highly fractured. Weathers light gray. Lithologically similar to Monterey Shale. As thick as 800 ft. Ground water: Yields 1 to 2 gal/min to wells off Mt. Bache Road. Springs along Highland Way and Eureka Canyon Road supply some homes. Potential marginal for domestic supplies.

Tss — Sandstone (Miocene, Oligocene, and Eocene(?)) - Geology: Yellowish-gray arkosic sandstone with interbedded dark-gray mudstone. Lithologically similar to the lower Tertiary sandstones southwest of San Andreas fault. As thick as 1,300 ft. Ground water: Generally yields quantities of water sufficient for domestic use. Yields of 2 to 15 gal/min can be expected, with specific capacities of 0.1 to 0.5 (gal/min)/ft. Where unit is highly fractured along fault zones, yields of 30 and 50 gal/min have been recorded. Potential source of supply for domestic wells and small community systems.

Tem — Mudstone (Eocene or Paleocene) - Geology: Olive-gray nodular mudstone. As thick as 1,000 ft. Ground water: May yield small quantities of water from fractures. Potential low, even in fractured zones.

Ku — Undifferentiated sedimentary rocks (Upper Cretaceous) - Geology: Includes: Kgsu upper, interbedded graywacke and silty shale with minor interbedded conglomerate lenses; Kc middle, boulder and cobble conglomerate in a matrix of graywacke; Kgsl lower, interbedded graywacke and shale; Ksh basal mudstone. As thick as 5,200 ft. These Upper Cretaceous rocks are overlain by the Tertiary rocks between the San Andreas and Lomita faults. They are exposed east of the Lomita fault and extend to Sargent fault beyond the study area. Ground water: Unit mostly dry. The middle and upper units have some potential for spring development.

ub — Ultrabasic intrusive rocks (Tertiary, Cretaceous and Jurassic) - Geology: Predominantly serpentinite, greenstone gabbro, quartz, and keratophyre intrusives. Occur in Franciscan rocks and along fault zones in undifferentiated sedimentary rocks. Ground water: Not known to contain water in study area.

KJf — Franciscan Complex (Jurassic(?) and Cretaceous) - Geology: A bedded, structurally coherent body of graywacke, siltstone, shale, and altered mafic volcanic rocks; minor chert, limestone, pyroclastic greenstone, and conglomerate. Principal basement rock northeast of San Andreas fault. Ground water: Not known to contain water in study area. Deeply buried.

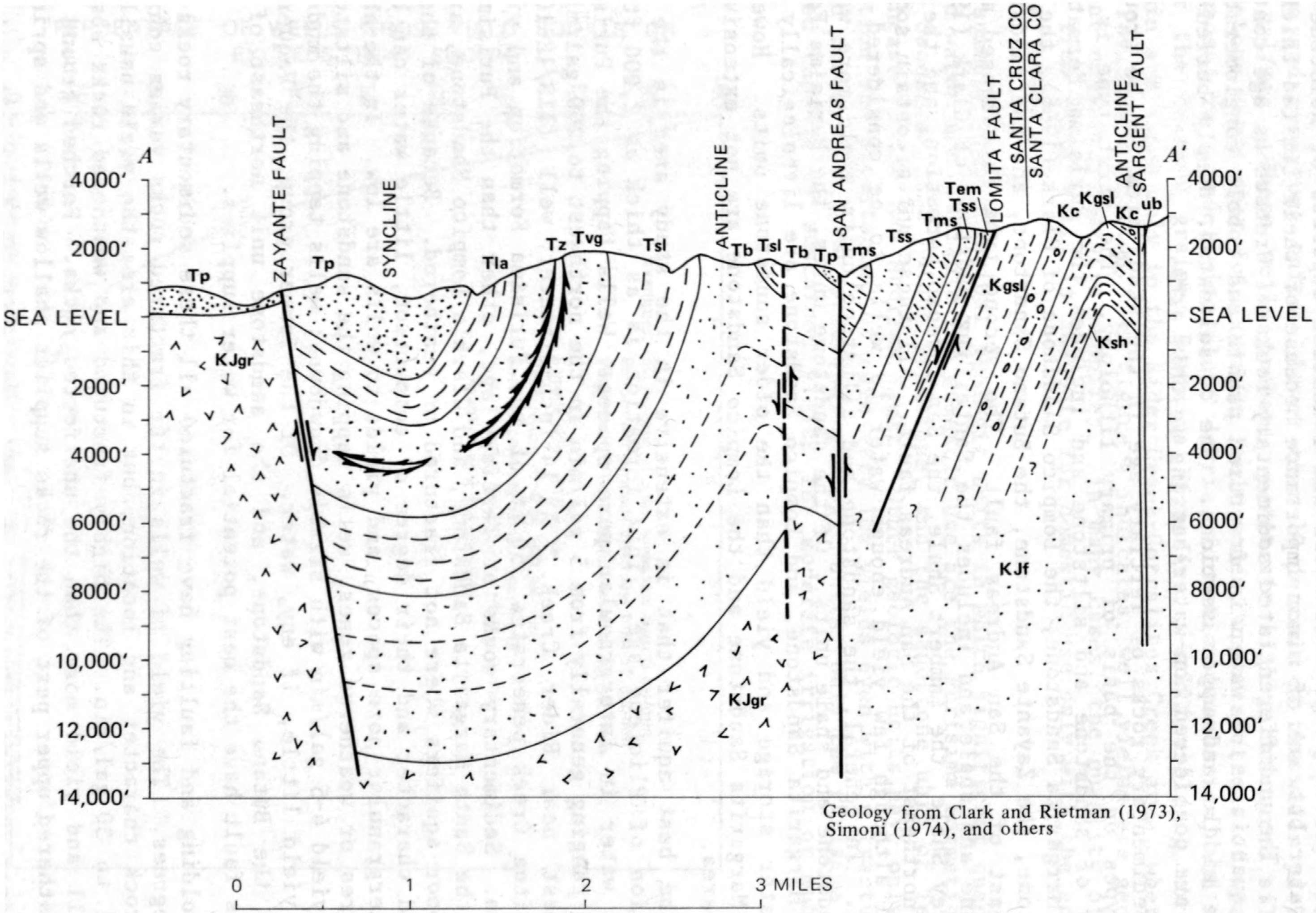


FIGURE 3.--Geologic section A-A', showing structure and stratigraphic relations.

Water-Bearing Character of the Geologic Units

The main water-bearing units in the study area are in the sedimentary rocks of Tertiary age. Alluvial and landslide deposits of Holocene age contain water but are of minor importance because of their limited thickness and extent. The undifferentiated sedimentary rocks of Cretaceous age contain only small quantities of water in fractured pebble and cobble conglomerate lenses in the middle and upper sections. The consolidated, deeply buried basement rocks are considered non-water-bearing in this area.

Sedimentary rocks of Tertiary age in the study area can be grouped into two types on the basis of primary lithology. The first type is composed mainly of sandstone and siltstone and includes the Purisima Formation, the Santa Margarita Sandstone, the Lompico Sandstone of Clark (1966), the Vaqueros Sandstone, the Zayante Sandstone, the Butano Sandstone, and the sandstone unit northeast of the San Andreas fault. The second type is composed mainly of mudstone and shale and includes the Santa Cruz Mudstone of Clark (1966), the Monterey Shale, the Lambert Shale, the San Lorenzo Formation, and the mudstone units northeast of the San Andreas fault. All these units contain some ground water, although few yield enough water to wells to be considered good aquifers. In general, the sandstone and siltstone units yield more water than the mudstone and shale units. Of the sandstone units, the Purisima Formation, Santa Margarita Sandstone, and Lompico Sandstone are lithologically superior for water storage and yield than the older sandstone units. However, the Santa Margarita Sandstone and the Lompico Sandstone are not extensive in the study area.

The best aquifer that is extensive in the study area is the Purisima Formation of Pliocene age. This formation is as thick as 2,000 ft, and it stores water in intergranular pore spaces. Wells tapping the Purisima have yields ranging generally from 5 gal/min in the northwest to 200 gal/min in the southeast near Rider Creek. A 14-inch-diameter well (11S/1E-1G1) near Corralitos Creek penetrates 350 ft of the Purisima Formation and yields 400 gal/min. Sedimentary rocks of Tertiary age, other than the Purisima Formation, the Santa Margarita Sandstone, and Clark's Lompico Sandstone, are generally poor aquifers where not fractured or weathered. Because of their fine-grained character and their degree of compaction, little water can be stored in intergranular pore spaces, and yields to wells are low. In the absence of fractures or weathered zones, wells tapping the sandstone and siltstone typically yield 4-5 gal/min with sizable drawdowns; wells tapping the mudstone and shale yield little, if any, water. Of the former group, the Vaqueros Sandstone, the Butano Sandstone, and the sandstone unit northeast of the San Andreas fault have the best potential for water supplies.

Folding and faulting have fractured all these sedimentary rocks to varying degrees. The yield of wells in the fractured rocks varies considerably with rock character and location, but in this area the yield usually ranges from 1 to 30 gal/min. The highly fractured and weathered rocks absorb more rainfall and yield more than the unaffected rocks. Perched ground water in the weathered upper part of the rocks supplies shallow wells and springs.

Large sustained yields are uncommon from wells in fractured rock in steep terrain. Initial large yields usually decrease rapidly as the small amount of stored water is extracted.

Figure 4 shows the percentage of wells that exceed a given yield as derived from drillers' tests of wells in the study area. More than 50 percent of the wells yield less than 5 gal/min. The majority of wells probably penetrate fractured mudstone and shale units or unfractured to poorly fractured siltstone and sandstone units. Fewer than 10 percent of the wells yield more than 15 gal/min. These wells probably penetrate highly fractured siltstone and sandstone rocks near fold axes or fault zones; upper sections of weathered or decomposed rock underlying slope debris, formation boundaries, and streambeds; or the coarser grained Purisima Formation. Wells yielding more than 50 gal/min are known only in the Rider Creek-Corralitos Creek area, where they tap the Purisima Formation. As figure 4 indicates, well yields are generally sufficient only for domestic supplies. In many cases, the quantity of water supplied from these wells is adequate for domestic use only with the addition of storage tanks.

In summary, the principal geologic units in which significant quantities of ground water are available for domestic use are the Purisima Formation, the Vaqueros Sandstone, the Butano Sandstone, and the sandstone unit of Tertiary age northeast of the San Andreas fault. Other geologic units have only local distribution and importance, or have very low yields even within fractured or weathered areas. Of these principal geologic units, only the Purisima can be considered capable of sustained yields for moderate irrigation or municipal needs.

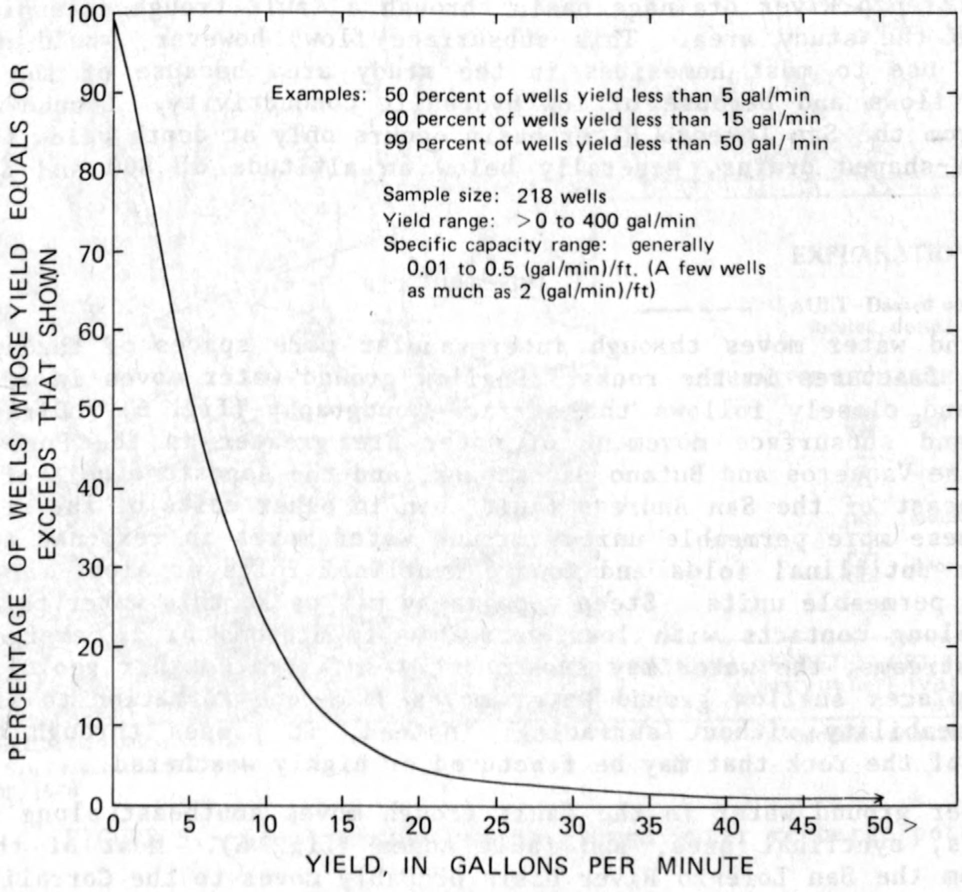


FIGURE 4.--Percentage of wells that exceed a given yield in north-central Santa Cruz.

GROUND WATER

Recharge

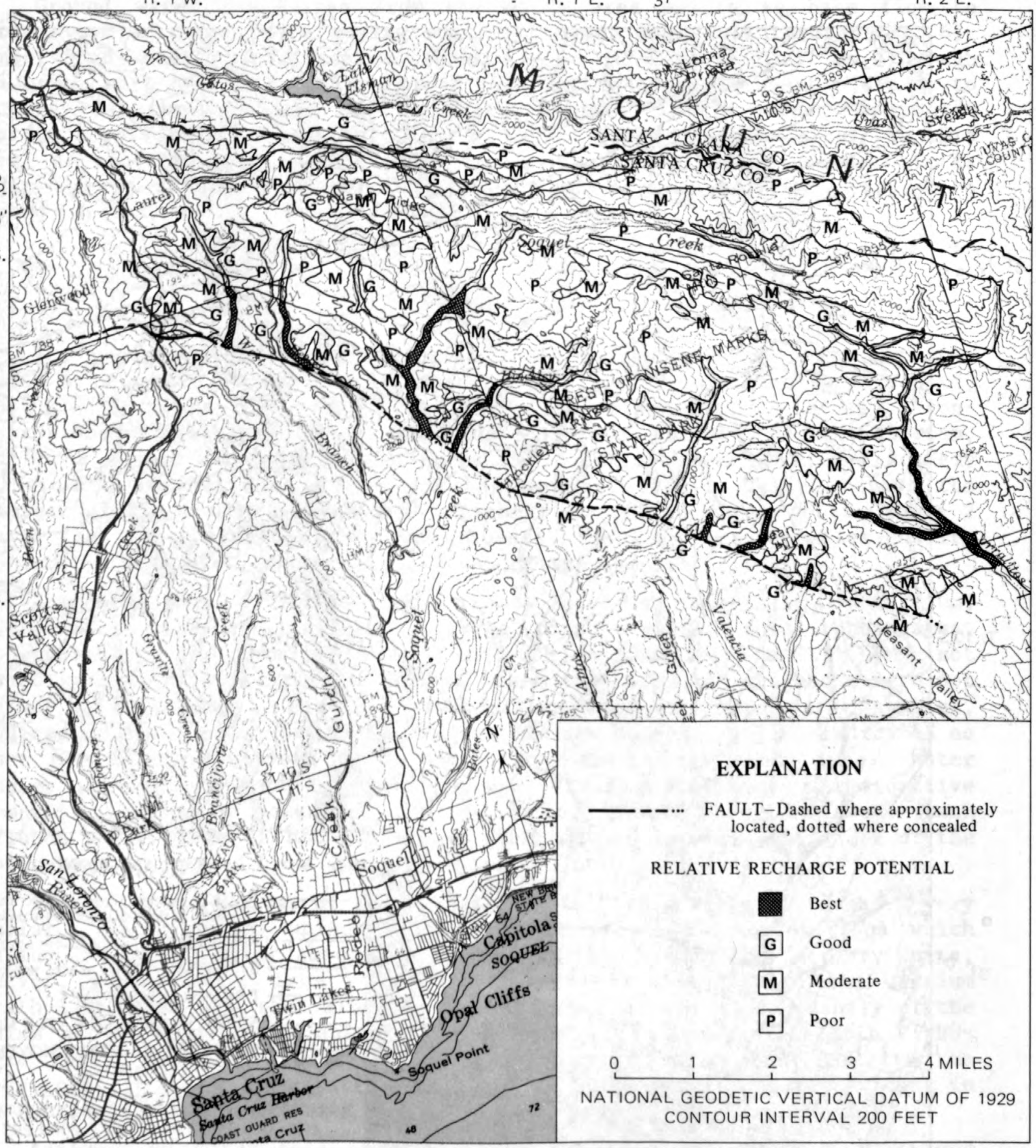
Ground-water recharge in the study area is mainly from precipitation that enters the geologic units through direct infiltration on the land surface or through seepage from streams. Figure 5 shows the areal variations in ground-water recharge potential as modified from Muir and Johnson (1979). The poorest potential for recharge is in areas underlain by mudstone and shale units such as the San Lorenzo Formation and the mudstone units of Tertiary age northeast of the San Andreas fault; the best potential is along stream channels that cross sandstone units, such as the Purisima Formation, at lower altitudes. Weathered zones and surface soils that overlie tight formations may intercept and temporarily retain rainfall for subsequent recharge into more permeable formations by way of stream channels. With increasing altitude, however, stream drainage areas are reduced and the importance of stream infiltration decreases; also, the steeper topography speeds runoff and reduces recharge from direct infiltration. Permeable formations have sustained high yields only where they are effectively recharged. Lithologically and geographically, the Purisima Formation has the greatest recharge potential in the study area.

Limited recharge may occur by subsurface inflow from the eastern part of the San Lorenzo River drainage basin through a fault trough extending southeast into the study area. This subsurface flow, however, would not be of practical use to most homesites in the study area because of the depth at which it flows and because of low hydraulic conductivity. Ground-water recharge from the San Lorenzo River basin occurs only at depth below the deeply incised V-shaped drains, generally below an altitude of 800 and as low as 600 ft.

Movement

Ground water moves through intergranular pore spaces or through interconnected fractures in the rocks. Shallow ground water moves in response to gravity and closely follows the surface topography (fig. 6). Direct infiltration and subsurface movement of water are greater in the Purisima Formation, the Vaqueros and Butano Sandstones, and the sandstone unit of Tertiary age northeast of the San Andreas fault than in other units of the study area. Within these more permeable units, ground water moves in response to gravity away from anticlinal folds and toward synclinal folds or along the contacts with less permeable units. Steep topography may cause this water to emerge as springs along contacts with less permeable formations or to emerge as base flow of streams; the water may subsequently infiltrate other geologic units. In many places shallow ground water moves from one formation to another of less permeability without surfacing; instead, it passes through the upper sections of the rock that may be fractured or highly weathered.

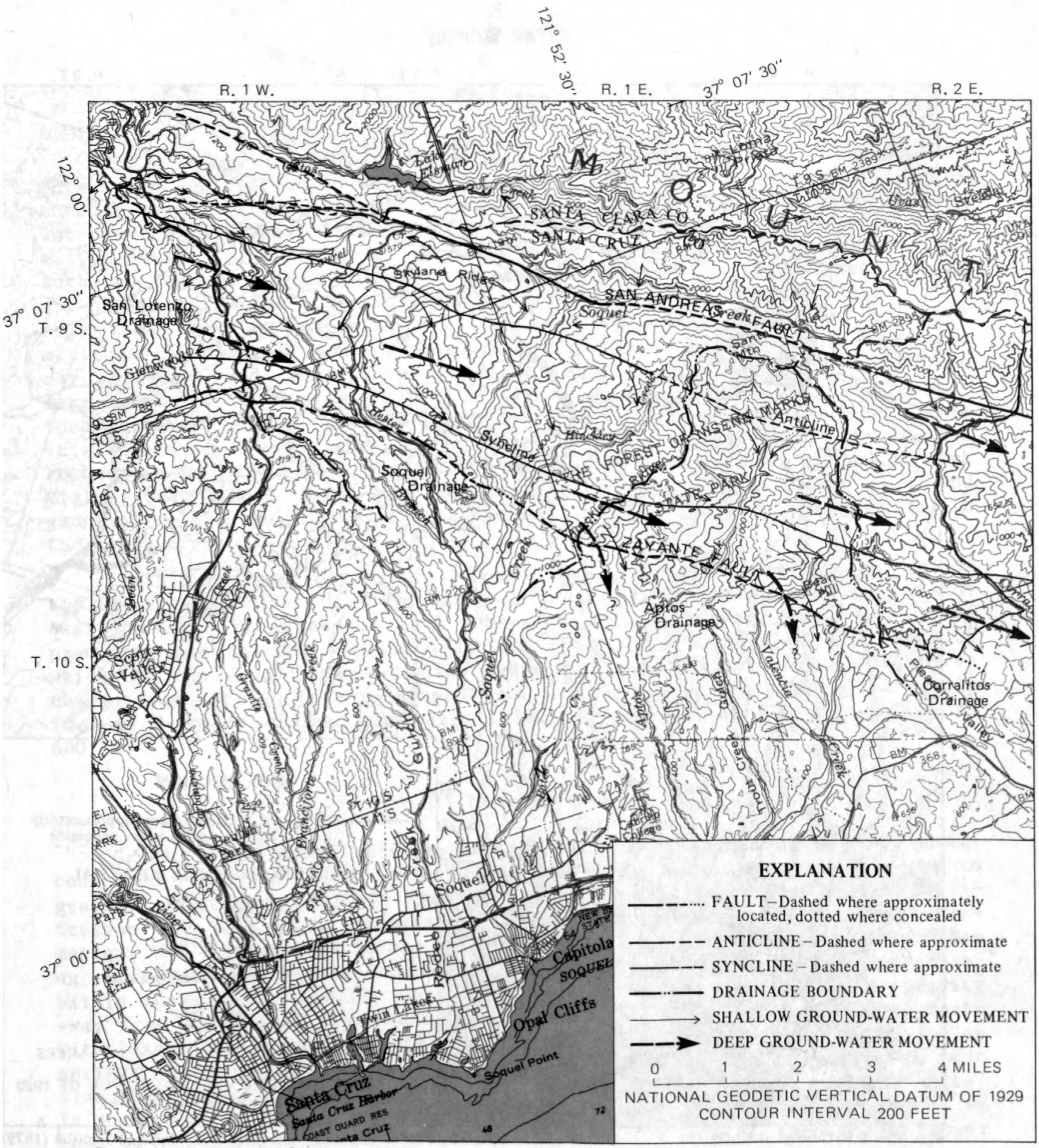
Deeper ground water in the fault trough moves southeast along formation boundaries, synclinal axes, and fault zones (fig. 6). Most of the ground water from the San Lorenzo River basin probably moves to the Corralitos Creek drainage along the major synclinal axis of the fault trough within the Vaqueros Sandstone and the more permeable Purisima Formation (Hickey, 1968).



Base from U.S. Geological Survey
Sheet 3, San Francisco Bay Region,
1:125,000, 1970

Modified from Muir and Johnson (1979)

FIGURE 5.--Areal variations in ground-water recharge potential.



Base from U.S. Geological Survey
Sheet 3, San Francisco Bay Region,
1:125,000, 1970

FIGURE 6.--Drainage basins and ground-water movement (generalized).

Discharge

Ground water discharges from the study area mainly as base flow to streams and as deeper flow moving southeast along the fault trough (fig. 6). Some ground water also discharges south across the Zayante fault and through the upper part of the Purisima Formation. This water subsequently drains to Monterey Bay through Aptos and Corralitos Creeks. Little ground water discharges across the Zayante fault in the Soquel Creek drainage area. In this area, immediately southwest of the fault, the consolidated basement rocks underlie very shallow rocks of Tertiary age and form an effective barrier to ground-water flow.

Quality

The ground water in north-central Santa Cruz County is generally of a sodium bicarbonate or calcium bicarbonate type, moderately hard to very hard, and commonly has a high concentration of iron or manganese. Locally, concentrations of dissolved solids, fluoride, chloride, sulfate, sodium, calcium, and boron exceed water-quality criteria for drinking water (National Academy of Sciences and National Academy of Engineering, 1973). Table 1 shows the chemical analyses of the ground-water samples used in this report, table 2 shows the concentrations of constituents that may cause water-quality problems, and figure 7 shows the location of the sampling sites.

Concentrations of other constituents such as magnesium, potassium, bicarbonate, carbonate, silica, nitrite plus nitrate, total phosphorus, orthophosphate, and chemical properties such as alkalinity and pH does not exceed water-quality criteria. Metals other than iron and manganese were not tested in this study. Previous chemical analyses of ground-water samples, required by the county Health Department for new domestic wells, indicated no other metal concentrations that were a problem in the study area. Water samples were not tested for bacterial or viral indicators or radioactive elements. There is potential degradation of ground water by septic-tank effluent where there is not sufficient vertical and lateral separation of the septic-tank drain field and the ground water.

Because the lithology of the Tertiary units within the study area is very similar, there are no unique chemical constituents or compositions which distinguish ground water among the various units. Within the Tertiary units, however, ground water from sand and silt is predominantly of the calcium bicarbonate type, and that from clay, mud, and shale is predominantly of the sodium bicarbonate type (table 1). Many Tertiary units contain both lithologic types, but the ground-water quality from a given unit reflects the predominant lithology penetrated by the well. This is particularly evident in the Butano Sandstone and, to a lesser extent, in the San Lorenzo Formation.

Analyses made for this study indicate that concentrations of dissolved ions increase with depth within the lower Tertiary units. These formations are of marine origin, and saline connate water may be present where there has been insufficient flushing by fresher ground water. The highest concentrations of dissolved ions are found at depth in the mudstone and shale of the Butano Sandstone and the San Lorenzo Formation, and in the mudstone units east of the San Andreas fault (table 1). To a lesser extent, ion concentrations also increase with depth in the siltstone and sandstone.

TABLE 1. - Chemical analyses of

[Samples collected and analyzed by U.S.

Well or spring No.	Water-bearing unit (See fig. 2 for explanation of symbols)	Primary lithologic type	Date of collection	Depth of well (s-spring) (ft)	Specific conductance (µmho/cm at 25°C)	pH (units)	Water temperature (°C)	Hardness as $CaCO_3$ (mg/L)	Calcium, dissolved (Ca) (mg/L)	Magnesium, dissolved (Mg) (mg/L)	Sodium, dissolved (Na) (mg/L)
9S/1W-21A	Tvq	Sand	07-06-77	100	333	6.8	20	104	28	8.1	16
9S/1W-21L	Tb	Sand	07-06-77	250	741	7.4	18.5	276	84	16	47
9S/1W-21Q	Tb	Sand	07-06-77	s	926	7.6	20.5	398	120	24	48
9S/1W-22P	Tsl?,Tb?	Shale	07-06-77	540	892	8.5	22.5	8	2.4	0.5	192
9S/1W-22Q	Tb?,Tsl?	Shale	07-06-77	130	1700	7.5	19.0	248	54	25	278
9S/1W-25K	Tss	Sand	06-30-77	300	684	7.1	18.5	284	84	18	36
9S/1W-25M[1]	Tb	Clay-sand	01-xx-77	150	770	7.0	-	259	72	19	87
9S/1W-25Q[1]	Tms	Mudstone	08-xx-76	210	2540	7.4	-	444	100	47	530
9S/1W-26Q[1]	Tsl?	Shale	11-xx-75	185	680	7.8	-	83	25	5	128
9S/1W-27D	Tb	Shale	07-06-77	s	2850	8.3	19.0	175	37	20	628
9S/1W-28R	Tvq	Sand	06-30-77	s	1000	6.7	17.0	371	104	27	80
9S/1W-33A	Tvq	Clay-sand	06-30-77	50	170	6.1	22.0	33	8.2	2.7	20
9S/1W-33K	Tp	Sand	06-30-77	90	250	6.5	24.5	108	20	14	9.5
9S/1W-34A[1]	Tvq	Sand	09-xx-76	150	369	7.4	-	163	40	15	18
9S/1W-34G[1]	Tvq	Sand	06-xx-76	147	365	6.8	-	103	25	10	14
9S/1W-34G[1]	Tvq	Sand	06-xx-76	297	635	7.2	-	296	78	24	26
9S/1W-34H[1]	Tvq	Sand	08-xx-76	225	467	7.8	-	132	29	15	14
9S/1W-34R[1]	Tla	Shale	03-xx-76	260	540	6.4	-	128	20	19	65
9S/1W-35B[1]	Tb	Shale-sand	03-18-77	225	1700	8.4	19.8	9.8	1.3	1.5	248
9S/1W-35D	Tsl	Shale	07-12-77	80	1430	7.9	22.0	155	39	14	282
9S/1W-35G[1]	Tsl	Shale	05-xx-76	100	280	6.8	-	87	22	7.7	20
9S/1W-35H[1]	Tsl	Shale	10-20-76	170	555	8.4	16.1	29	5.4	3.0	127
9S/1W-35H	Tb	Sand-clay	07-12-77	310	190	6.7	23.5	52	10	6.7	16
9S/1W-35K	Tsl	Shale	07-12-77	165	666	8.0	20.0	93	28	5.6	106
9S/1W-35N[1]	Tvq	Sand	10-xx-76	435	615	6.7	-	262	50	33	45

See footnotes at end of table.

water from wells and springs

Geological Survey, except where noted]

Potassium, dissolved (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Carbonate (CO_3) (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate, dissolved (SO_4) (mg/L)	Chloride, dissolved (Cl) (mg/L)	Fluoride, dissolved (F) (mg/L)	Silica, dissolved (SiO_2) (mg/L)	Dissolved solids, residue at 180°C (mg/L)	Dissolved solids, calculated sum of constituents[2] (mg/L)	Nitrite plus nitrate, dissolved as N (mg/L)	Phosphorus, total as P (mg/L)	Phosphorus, dissolved orthophosphate as P (mg/L)	Boron, dissolved as B (µg/L)	Iron, total as Fe (µg/L)	Manganese, total as Mn (µg/L)
0.7	63	0	52	67	12	-	32	225	196	0.02	0.02	0.01	>0	400	240
2.4	245	0	201	144	18	-	37	512	471	0.21	0.01	0.02	100	530	310
2.6	311	0	255	210	14	-	24	650	597	0.21	0.00	0.01	300	20	10
0.6	508	0	417	0.3	5.2	-	10	506	463	0.02	0.01	0.01	2100	120	>0
4.0	291	0	239	534	39	-	18	1130	1095	0.02	0.02	0.01	500	1300	140
3.0	368	0	302	51	7.9	-	24	404	405	0.08	0.00	0.01	>0	>60	>0
5.1	304	0	304	25	40	0.3	-	-	(540)	0.11	-	-	-	520	200
12	482	0	482	0.7	900	0.1	-	-	(1778)	0.02	-	-	-	9000	460
3.5	272	0	272	22	28	0.8	-	-	(476)	1.00	-	-	-	140	17
4.0	1140	0	935	46	391	-	15	1750	1711	1.00	0.17	0.13	4300	>210	>30
2.4	419	0	344	176	12	-	26	636	635	0.08	0.11	0.02	200	840	160
0.5	36	0	30	7.7	24	-	38	139	158	2.1	0.07	0.04	>0	>50	>60
2.2	122	0	100	10	10	-	67	208	200	1.5	0.39	0.25	>0	90	>0
1.2	166	0	166	21	15	0.2	-	-	(258)	2.5	-	-	-	60	90
1.0	106	0	106	10	8	0.2	-	-	(256)	0.1	-	-	-	50	4
1.9	270	0	270	20	12	0.2	-	-	(444)	0.1	-	-	-	300	1100
1.0	130	0	130	32	16	0.2	-	-	(327)	0.02	-	-	-	1300	250
3.0	216	0	216	48	20	0.4	-	-	(378)	1.0	-	-	-	170	160
3.8	-	-	973	32	45	2.6	-	-	(1285)	0.31	-	-	-	50	200
2.0	529	0	434	277	22	-	10	955	911	0.59	0.04	0.02	2000	420	20
1.0	130	0	130	7	4	0.2	-	-	(193)	0.1	-	-	-	490	70
2.1	-	-	285	38	7.4	0.96	-	-	(379)	0.16	0.01	-	-	1630	200
0.5	76	0	62	11	6.3	-	35	138	129	0.80	0.03	0.03	>0	2500	20
1.0	287	-	235	77	7.4	-	13	405	383	0.01	0.02	0.03	700	2400	170
2.8	278	0	278	14	41	0.2	-	-	(431)	0.03	-	-	-	450	280

TABLE 1. - Chemical analyses of water

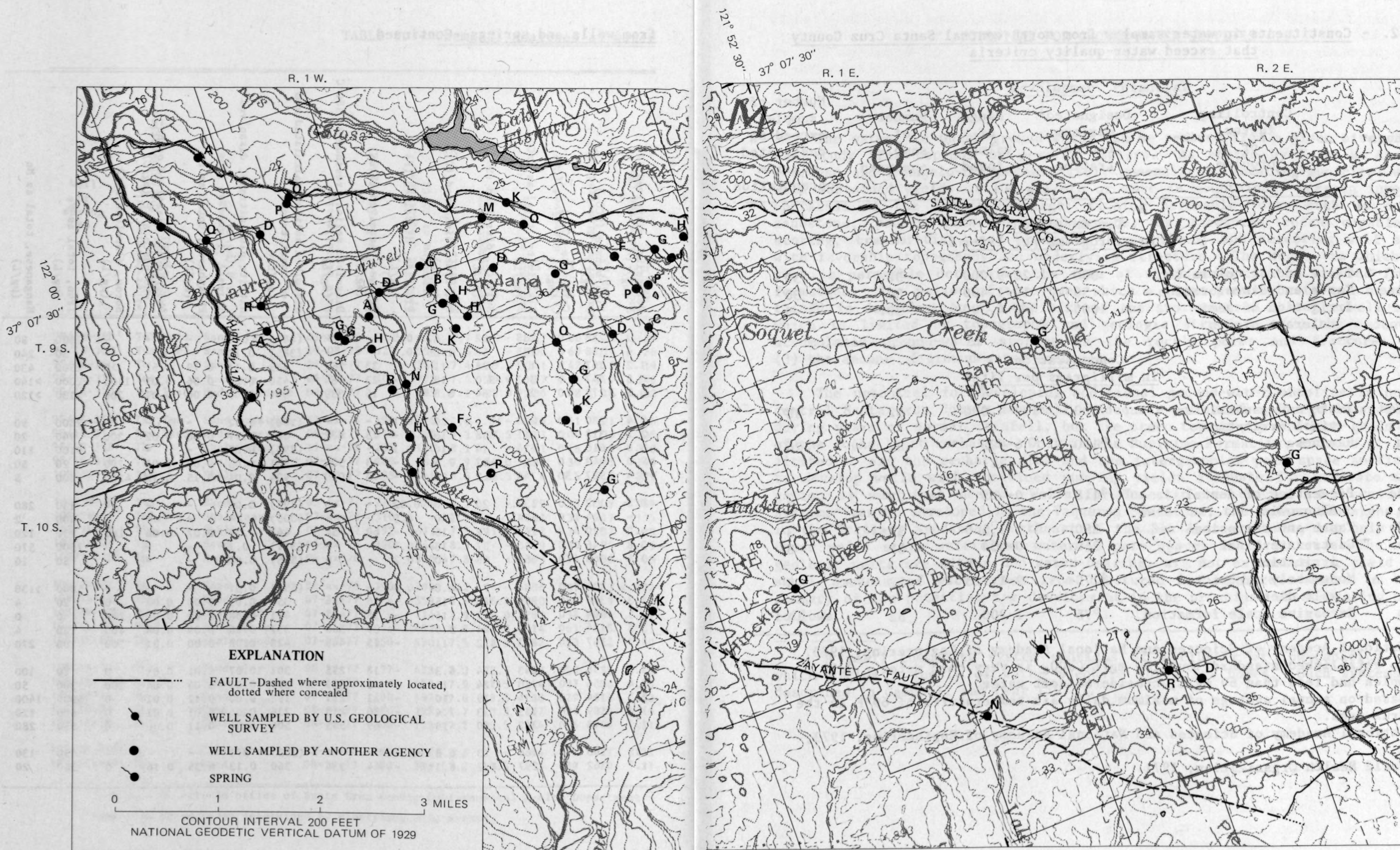
Well or spring No.	Water-bearing unit (See fig. 2 for explanation of symbols)	Primary lithologic type	Date of collection	Depth of well (s-spring) (ft)	Specific conductance (µmho/cm at 25°C)	pH (units)	Water temperature (°C)	Hardness as $CaCO_3$ (mg/L)	Calcium, dissolved (Ca) (mg/L)	Magnesium, dissolved (Mg) (mg/L)	Sodium, dissolved (Na) (mg/L)
9S/1W-36D[1]	Tb?,Tsl?	Sand-clay	05-xx-76	210	641	7.7	-	257	60	25	37
9S/1W-36G[1]	Tvq?,Tb?	Sand	09-08-75	120	550	7.5	-	208	60	14	26
9S/1W-36Q	Tb	Sand	07-12-77	-	362	7.4	19.0	141	42	8.8	19
9S/1E-31F	Tms	Mudstone	06-30-77	101	799	7.4	20.0	87	22	7.7	146
9S/1E-31G	Tms,Tss?	Mudstone-sand	06-30-77	s	585	7.1	32.0	236	68	16	32
9S/1E-31H[1]	Tss,Tms	Sand-mudstone	12-xx-76	190	510	7.6	-	219	51	21	16
9S/1E-31J	Tms,Tss?	Mudstone-sand	06-30-77	110	1240	7.3	27.5	623	200	30	36
9S/1E-31P[1]	Tb	Shale-sand	11-xx-75	205	1140	8.1	-	61	18	4.0	280
9S/1E-31P	Tb	Shale	07-06-77	280	882	7.9	26.0	130	34	11	146
10S/1W-1G	Tsl	Shale	07-12-77	285	1545	8.8	23.5	6	1.5	0.7	399
10S/1W-1K[1]	Tvq	Sand	03-xx-77	270	280	8.2	-	79	25	3.9	29
10S/1W-1L[1]	Tsl,Tvq	Shale-sand	03-xx-76	310	-	7.9	-	101	31	17	1125
10S/1W-2F	Tla	Shale	07-13-77	192	671	7.5	11.0	217	34	32	70
10S/1W-2P[1]	Tp	Sand	06-xx-76	300	444	8.3	-	209	34	30	19
10S/1W-3H[1]	Tp	Sand	04-xx-76	-	850	7.8	-	333	74	36	38
10S/1W-3K[1]	Tp	Sand	08-xx-76	390	792	8.2	-	436	87	53	32
10S/1W-12G	Tla?	Sand	07-21-77	s	559	8.4	16.0	290	108	4.9	20
10S/1W-13K	Tp	Clay-sand	07-21-77	s	714	7.9	16.0	223	38	31	87
10S/1E-6C	Tsl?	Sand-shale	07-06-77	s	452	6.8	19.0	214	61	15	21
10S/1E-6D	Tb	Shale-sand	07-06-77	450	570	7.5	18.5	182	53	12	80
10S/1E-10G	Qal	Sand-clay	08-19-77	37	473	7.3	22.5	187	50	15	41
10S/1E-18Q	Tp	Sand	07-21-77	s	559	7.9	17.5	334	37	10	55
10S/1E-24G	Tp	Sand	08-19-77	200	547	7.0	18.5	88	29	16	13
10S/1E-27R	Tp	Sand	08-19-77	200	327	7.7	20.5	167	34	20	10
10S/1E-28H	Tp	Sand	08-19-77	100	798	7.2	18.5	354	76	40	31
10S/1E-28N[1]	Tp	Clay-sand	12-xx-76	700	360	7.8	-	94	19	11	32
10S/1E-35D	Tp	Sand	08-19-77	180	263	7.2	17.5	263	89	10	21

[1]From data on file in office of Santa Cruz County Environmental Health Department.

[2]Number in parentheses determined by electromagnetic method.

from wells and springs--Continued

Potassium, dissolved (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Carbonate (CO_3) (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate, dissolved (SO_4) (mg/L)	Chloride, dissolved (Cl) (mg/L)	Fluoride, dissolved (F) (mg/L)	Silica, dissolved (SiO_2) (mg/L)	Dissolved solids, residue at 180°C (mg/L)	Dissolved solids, calculated sum of constituents[2] (mg/L)	Nitrite plus nitrate, dissolved as N (mg/L)	Phosphorus, total as P (mg/L)	Phosphorus, dissolved orthophosphate as P (mg/L)	Boron, dissolved as B (µg/L)	Iron, total as Fe (µg/L)	Manganese, total as Mn (µg/L)
9	288	0	288	62	8	0.5	-	-	(449)	0.1	-	-	-	2300	80
4	188	0	188	53	1.2	0.1	-	-	(385)	0.18	-	-	-	30	240
1.2	167	0	137	28	11	-	33	251	229	0.11	0.79	0.57	>0	2500	430
0.8	447	0	367	9.0	18	-	23	454	450	0.01	0.06	0.01	1100	>2000	>140
0.8	279	0	229	64	6.8	-	16	339	341	0.05	0.00	0.01	200	>130	>120
2.4	280	0	280	18.4	20	0.1	-	-	(360)	0.02	-	-	-	2800	90
2.2	318	0	261	358	16	-	23	872	823	0.17	0.00	0.02	300	940	20
5.0	616	0	616	14	16	0.1	-	-	(798)	0.65	-	-	-	9100	110
3.0	443	0	361	67	7.6	-	13	524	501	0.05	0.00	0.01	700	20	50
3.4	907	50	744	8.2	20	-	9.3	1020	924	0.01	0.15	0.12	4200	1200	8
0.8	132	0	132	20	6.0	0.02	-	-	(195)	0.02	-	-	-	130	280
-	504	0	504	7	1540	4.5	-	-	(4000)	-	-	-	-	400	2
4.2	320	0	262	72	16	-	60	452	447	0.29	0.07	0.06	100	130	120
3.8	146	0	146	37	18	<0.7	-	-	(311)	0.1	-	-	-	7500	570
9.4	368	0	368	60	40	<0.2	-	-	(595)	0.68	-	-	-	50	10
14.5	334	0	334	71	40.8	0.3	-	-	(555)	0.01	-	-	-	5000	1130
1.3	316	0	259	23	15	-	26	356	354	0.03	0.03	0.07	>0	20	4
2.5	404	0	331	45	16	-	38	481	441	0.08	0.00	0.04	200	40	0
3.5	184	0	151	101	5.0	-	39	366	337	0.06	0.04	0.04	100	120	4
2.7	247	0	203	132	11	-	15	448	428	0.08	0.00	0.01	300	100	270
1.2	296	0	243	24	6.3	-	18	295	301	0.07	0.01	0.01	0	20	100
4.4	256	0	210	24	15	-	35	331	307	0.01	0.04	0.04	200	300	50
2.3	164	0	134	19	10	-	21	211	198	0.00	0.12	0.01	0	5900	1400
1.6	189	0	155	23	7.4	-	36	219	226	0.06	0.01	0.01	0	600	120
7.7	418	0	342	60	18	-	69	505	508	0.04	0.11	0.06	0	570	280
12	166	0	166	13	6.8	<0.1	-	-	(252)	0.1	-	-	-	450	130
1.7	362	0	297	8.7	6.3	-	44	334	360	0.13	0.35	0.16	0	580	20



Base from U.S. Geological Survey
Sheet 3, San Francisco Bay Region,
1:125,000, 1970

FIGURE 7.--Location of ground-water sampling sites.

TABLE 2. - Constituents in water samples from north-central Santa Cruz County that exceed water-quality criteria

Constituent	Controlling factor or problem	Designated[1] maximum concentration	Range of values found	Number of samples analyzed	Number of samples exceeding designated maximum concentration
		Concentration, in micrograms per liter			
Iron	Taste and discoloration	300	20-9,000	52	30
Manganese	Taste and discoloration	50	10-1,400	52	30
Boron	Irrigation of semi-tolerant plants	1000	0-4,300	30	5
		Concentration, in milligrams per liter			
Dissolved solids	Taste and gastrointestinal irritation	500	129-4,000	52	18
Calcium carbonate	Hardness	[2]180	6-623	52	26
Fluoride	Prevention of dental fluorosis	[3]1.8	0-4.5	22	2
Chloride	Taste and corrosion	250	1-1,540	52	3
Sulfate	Gastrointestinal irritation	250	0-534	52	8
Sodium	Moderately restricted salt diet	[4]270	9-1,125	52	8
Calcium	Excessive scale formation	[5]75	1-200	52	11

[1]National Academy of Sciences and National Academy of Engineering, 1973.

[2]No established standard, but 180 mg/L $CaCO_3$ is very hard water. Only six samples had less than 60 mg/L, considered soft water.

[3]Based on annual average of maximum daily air temperatures of 69°F in the Santa Cruz area.

[4]National Academy of Sciences and National Academy of Engineering, 1973, p. 88.

[5]World Health Organization, 1971.

POTENTIAL FOR GROUND-WATER SUPPLIES

Development Potential

The extent to which ground water can be removed from a given site within the study area depends on several factors. As stated by Frank W. Atchley (Creegan and D'Angelo-McCandless, 1961, appendix A), locating municipal wells with sustained yields of 100 gal/min or more in mountainous terrain involves appraisal of the annual recharge; finding permeable rocks such as coarse sandstone, poorly cemented conglomerate, or fractured rocks capable of storing, transmitting, and producing large flows; and selecting well sites with favorable topography and underlying structure. The degree to which the rock is permeable determines the rate at which water can be removed from a formation. The period of time over which a given pumping rate can be maintained is dependent on (1) the size of the storage area that the well taps, which is limited by topography and geologic structure, (2) the amount of accumulated ground-water storage in the rock's pores and fractures, and (3) the amount of ground-water recharge.

The potential for developing additional ground-water supplies in north-central Santa Cruz County is small. Adequate potential recharge is available during years of normal rainfall, but the steep topography and fine-grain size of the rocks limit recharge. Only in the Purisima Formation, located at lower altitudes, are the recharge area and the intergranular pore space sufficient to develop wells with sustained pumping yields adequate for moderate irrigation or municipal needs. Wells for domestic use or for small community systems[2] can be developed in the Vaqueros Sandstone, the Butano Sandstone, and in the Tertiary Sandstone northeast of the San Andreas fault, but only where these units store sufficient water in pore spaces and fractures. The other geologic units are either non-water-bearing, are not extensive, or yield very small amounts of water even from fractured or weathered zones. A brief summary of the potential for development in the principal water-bearing units follows.

[2] A small community system consists of a cluster of low-capacity wells which yields a supply of water adequate for a few homes. Such systems are described in Campbell and Lehr (1973).

The Purisima Formation is extensive in the study area along the Zayante fault and near Corralitos and Rider Creeks. The best potential for development is along the axis of the structural trough in the southeastern part of the study area where properly designed and constructed wells more than 200 ft deep are known to yield as much as 200 gal/min and have a specific capacity of 2 (gal/min)/ft. Favorable sites in the Purisima are along Rider Creek, Valencia Creek, Aptos Creek, Bridge Creek, Hinckley Creek, and Soquel Creek near the axis of the syncline. At these sites, maximum yields could range from 100 to 200 gal/min. These areas are favorable for wells because (1) shallow ground-water storage areas are recharged by local precipitation, and (2) the relatively low altitude of these areas makes it feasible for some wells to tap the deeper ground water moving southeastward down the syncline trough. Some of this deep water probably originates in recharge areas as far away as the northeastern San Lorenzo drainage basin. A small potential for development exists just south of and parallel to the San Andreas fault near Eureka Canyon Road, where 200-foot wells could yield 20 gal/min, a supply sufficient for small community systems.

Because of their greater compaction, fine-grained character, and geographic location the Vaqueros, Butano, and other Tertiary sandstones have less potential for long-term, high yields than the Purisima Formation. Where favorable grain sizes or open fractures increase the formation permeability, a few wells yielding as much as 20-50 gal/min may be developed. However, specific capacities would probably be less than 0.5 (gal/min)/ft. Domestic wells or small community systems could be constructed at many sites in these formations. Favorable sites occur in highly fractured siltstone and sandstone near fold axes, formation boundaries, or fault zones; or in upper parts of weathered or decomposed rock underlying slope debris, formation boundaries, and streambeds. Many of these sites presently have wells. Most potential well sites are deficient in one or more factors necessary for maintaining sustained yields and would require storage tanks to meet local water requirements.

Annual Recharge and a Water Budget

The quantity of ground water stored in the rock's pores and fractures could amount to many times the annual recharge; however, only small quantities might be extractable at a given well site. Most wells in the study area tap very small storage volumes and must depend on frequent recharge to maintain local storage and, therefore, well yield. Most of the residences in the study area are located at higher altitudes, where recharge from precipitation maintains ground-water storage. However, at many sites the quantity of extractable ground-water storage fluctuates with wet and dry years.

Considering local rainfall as the sole source, and disregarding the possibility of some inflow from the San Lorenzo drainage basin, the mean annual precipitation in the study area was determined from an isohyetal map (Rantz, 1971) to be 101,000 acre-ft (table 3). Projecting recorded streamflow by direct correlation (Rantz, 1974), the estimated mean annual runoff totaled 31,300 acre-ft or 31 percent of the mean annual precipitation. The implication is that 69,700 acre-ft must be accounted for by evapotranspiration and recharge to ground-water storage.

Evapotranspiration is the use of water by growing vegetation plus water evaporation from adjacent soil. Evapotranspiration in the study area was estimated by correlating class "A" pan evaporation measurements from the State's agroclimatic station in the coastal fog belt at Santa Rita (California Department of Water Resources, 1975, Appendix D) to the study area, also under coastal influence; by applying seasonal "A" pan coefficients to obtain potential evapotranspiration (see footnote to table 3); and by converting potential to net evapotranspiration by using the seasonal conversion coefficients derived for the Pescadero Creek drainage in the Stanford watershed model No. 4 modified for Pescadero Creek at gage 11162500 (K. L. Wahl, U.S. Geological Survey, oral commun., December 1977). The Pescadero drainage area in San Mateo County is similar to the study area in size, surface geology, topography, vegetation, and seasonal climatic conditions.

Actual evapotranspiration is estimated at 52,500 to 59,600 acre-ft or 52 to 59 percent of the total mean annual precipitation (table 3). This leaves 10,100 to 17,200 acre-ft available for infiltration to the ground-water system in the drainage basins during an average water year, or 10 to 17 percent of the mean annual precipitation. At this rate, recharge to just the Soquel-Aptos area north of the Zayante fault would range from about 7,500 to 13,000 acre-ft.

The ground-water recharge figures shown in table 3 are rough estimates based upon limited data. To better define these estimates for an average water year, additional detailed data collection is needed, due to the steep coastal topography. Precipitation increases rapidly with a rise in land altitude, causing large variations in runoff per unit of drainage area. Also, evaporation rates vary within the coastal fog belt with distance from the coast and with changing topography.

The amount of recharge to the ground-water system varies considerably from year to year. The duration, intensity, and distribution of the precipitation in any given year affect the amount of ground-water recharge. From season to season, precipitation in this area varies over wide limits and may be less than 40 percent of mean or more than 200 percent, or anywhere between.

TABLE 3.--Estimated water budget for north-central Santa Cruz County

Drainage basin	Area (mi^2)	Precipitation	Runoff	Evapo-transpiration	Ground-water recharge
		acre-ft			
Soquel	26.63	62,300	19,800	32,400-36,760	5,740-10,100
Aptos	8.31	17,200	5,300	8,900-10,150	1,750- 3,000
Corralitos	10.65	21,500	6,200	11,200-12,690	2,610- 4,100
Total	45.59	101,000	31,300	59,600-52,500	10,100-17,200
Percent		100	31	[1]52-59	10-17

[1]Potential evapotranspiration would be in the range of 73 to 84 percent.

CONCLUSIONS

Although ground water occurs in most of the geologic units in the study area, few units are considered to be even fair aquifers, and only the Purisima Formation can, in part, be considered a good aquifer. Water is stored mainly in fractures and weathered zones in the older Tertiary and Cretaceous units, whereas intergranular storage is predominant in the younger Purisima Formation. Wells tapping fractures in strata in steep topography would not support large sustained yields but may supply small well systems serving small clusters of homes. Deep wells in the southeastern part of the study area probably could have sustained yields of 100 to 200 gal/min, sufficient for maintaining moderate irrigation or municipal needs. Although the best ground-water potential exists in the Purisima Formation in the southeastern part of the study area, most of the ground-water demand comes from the area underlain by older Tertiary units in the northeast where the population is centered.

The source for most of the usable ground water in the study area is direct infiltration of rainfall on the land surface or stream seepage. Movement of this water at shallow depth generally follows surface topography. Movement of water at greater depth is influenced considerably by geologic structure and is generally to the southeast. Limited recharge enters at depth in the fault trough from the San Lorenzo River basin to the northwest. However, only deep wells at lower altitudes would tap this source.

The ground-water quality is suitable for most uses. Locally, iron and manganese concentrations in the water are high enough to be objectionable. High concentrations of dissolved salts also may be present, particularly in the older mudstone and shale units. There is a potential for degradation of ground water by septic-tank effluent and saline connate water.

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