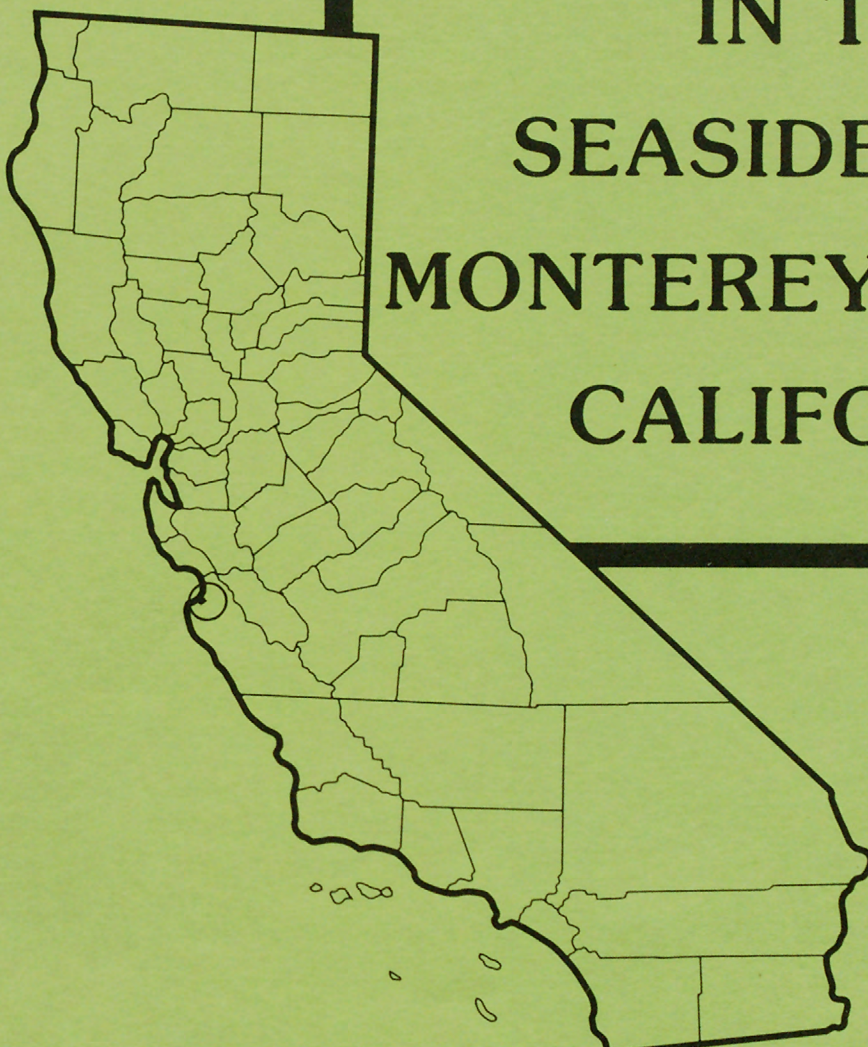
GROUND WATER IN THE SEASIDE AREA MONTEREY COUNTY CALIFORNIA



U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 82-10

Prepared in cooperation with the

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

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16. Abstract (Limit: 200 words) The ground-water resource in the Seaside area, in central coastal Monterey County, is described and evaluated. The Santa Margarita Sandstone, Paso Robles Formation, Aromas Sand, and the older dunes, with an aggregate maximum thickness of more than 1,000 feet, constitute the ground-water reservoir. The Monterey Shale and granitic rocks form the bottom and southern boundaries of the reservoir. Recharge to the ground-water reservoir occurs as infiltration of rain, subsurface inflow from adjacent areas, and seepage from streams. Rain infiltration accounts for about 75 percent of the recharge. Most of the area is classified as having a good-to-fair recharge potential. Areas in the east and along the southern boundary of the study area have a poor recharge potential. Ground water moves from the eastern part of the reservoir westward toward Monterey Bay. The amount of usable ground water in storage in the Seaside area in autumn 1979, was estimated to be 730,000 acre-feet. The coastal part of the area from Monterey Bay inland 1.5 miles had 9,000 acre-feet stored above sea level. The ground-water yield of the coastal part of the area is estimated to be more than 2,000 but less than 3,000 acre-feet per year, and the yield of the total reservoir system is estimated to range from 6,400 to 7,700 acre-feet per year. Ground water in the Seaside area is chemically suitable for most uses; however, dissolved-solids content and hardness are objectionably high for domestic use. Locally, dissolved iron is a problem. Seawater intrusion poses the major threat of water-quality degradation. An observation-well network could be established.

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

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CONVERSION FACTORS

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

Multiply	By	To obtain
acres	0.4047	hm^2 (square hectometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
acre-ft/yr (acre-feet per year)	0.001233	hm^3/yr (cubic hectometers per year)
ft (feet)	0.3048	m (meters)
gal/min (gallons per minute)	.003785	m^3/min (cubic meters per minute)
in (inches)	25.4	mm (millimeters)
in/h (inches per hour)	25.4	mm/h (millimeters per hour)
in/yr (inches per year)	25.4	mm/yr (millimeters per year)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.59	km^2 (square kilometers)
µmho (micromhos)	1	µS (microsiemens)

Degree Fahrenheit is converted to degree Celsius by using the formula:

$$(\text{Temp } ^\circ\text{F}-32)/1.8 = \text{temp } ^\circ\text{C}$$

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

GROUND WATER IN THE SEASIDE AREA,

MONTEREY COUNTY, CALIFORNIA

By K. S. Muir

ABSTRACT

The Seaside area is in central coastal Monterey County, adjacent to the city of Monterey, and occupies an area of about 24 square miles. The city of Seaside and part of the Fort Ord Military Reservation lie in the area.

The Santa Margarita Sandstone, Paso Robles Formation, Aromas Sand, and the older dunes, with an aggregate maximum thickness of more than 1,000 feet, constitute the ground-water reservoir. The Monterey Shale and granitic rocks form the bottom and southern boundaries of the reservoir. Ground water moves from the eastern part of the ground-water reservoir westward toward Monterey Bay.

Recharge to the ground-water reservoir occurs as infiltration of rain, subsurface inflow from adjacent areas, and seepage from streams. Rain infiltration accounts for most of the recharge. Most of the area is classified as having a good-to-fair recharge potential. Areas in the east and along the southern boundary of the study area have a poor recharge potential.

The amount of usable ground water in storage in the Seaside area in the autumn of 1979 was estimated to be 730,000 acre-feet. The coastal part of the Seaside area from Monterey Bay inland 1.5 miles had 9,000 acre-feet stored above sea level.

The ground-water yield of the coastal part of the Seaside area is estimated to be more than 2,000 but less than 3,000 acre-feet per year, and the yield of the total reservoir system is estimated to range from 6,400 to 7,700 acre-feet per year. During the period 1962-79 pumpage of ground water exceeded recharge and the amount of ground water in storage decreased.

Ground water in the Seaside area is chemically suitable for most uses; however, dissolved-solids content and hardness are generally objectionably high for domestic use, and, locally, dissolved iron is a problem. Seawater intrusion poses the major threat of water-quality degradation.

An observation-well network could be established in the Seaside area. Additional geologic and hydrologic exploration would better define the factors that control the storage and movement of ground water.

INTRODUCTION

Purpose and Scope

The purpose of this investigation is to describe and evaluate the ground-water resource of the Seaside area. This information will be used by the Monterey Peninsula Water Management District in planning the long-term utilization of this critical resource.

The scope of the investigation included the following:

1. An updated geologic description of the Seaside area that defines fault boundaries, structure, and geologic units that control the storage and movement of ground water;

2. An estimate of the amount of ground water in storage;

3. An estimate of potential ground-water yield;

4. A delineation of ground-water recharge areas;

5. An evaluation of the quality of ground water within the basin, with special emphasis on the existing and potential areas of water-quality degradation caused by seawater intrusion;

6. An evaluation of the adequacy of water-level and water-quality monitoring in the area; and

7. Identification of areas where additional geologic definition and well data are needed.

Location and General Features

The study area of this report is near Seaside in central coastal Monterey County, adjacent to the city of Monterey (fig. 1). It includes the area from Monterey Bay to several miles east of Laguna Seca, and north from Arroyo Del Rey into the Fort Ord Military Reservation, a major part of the study area (figs. 2 and 3). The southern boundary, established where recent geologic formations contact the Monterey Shale (fig. 2), and the north and east boundaries, in the vicinity of ground-water divides (fig. 3), delineate a ground-water reservoir occupying about 24 mi^2. The city of Seaside is the main population center. Most of the study area is within the Monterey Peninsula Water Management District.

Predominant land features of the area are dunes--young and active along the coast and mature east of the city of Seaside. Land-surface altitudes range from sea level to about 900 ft.

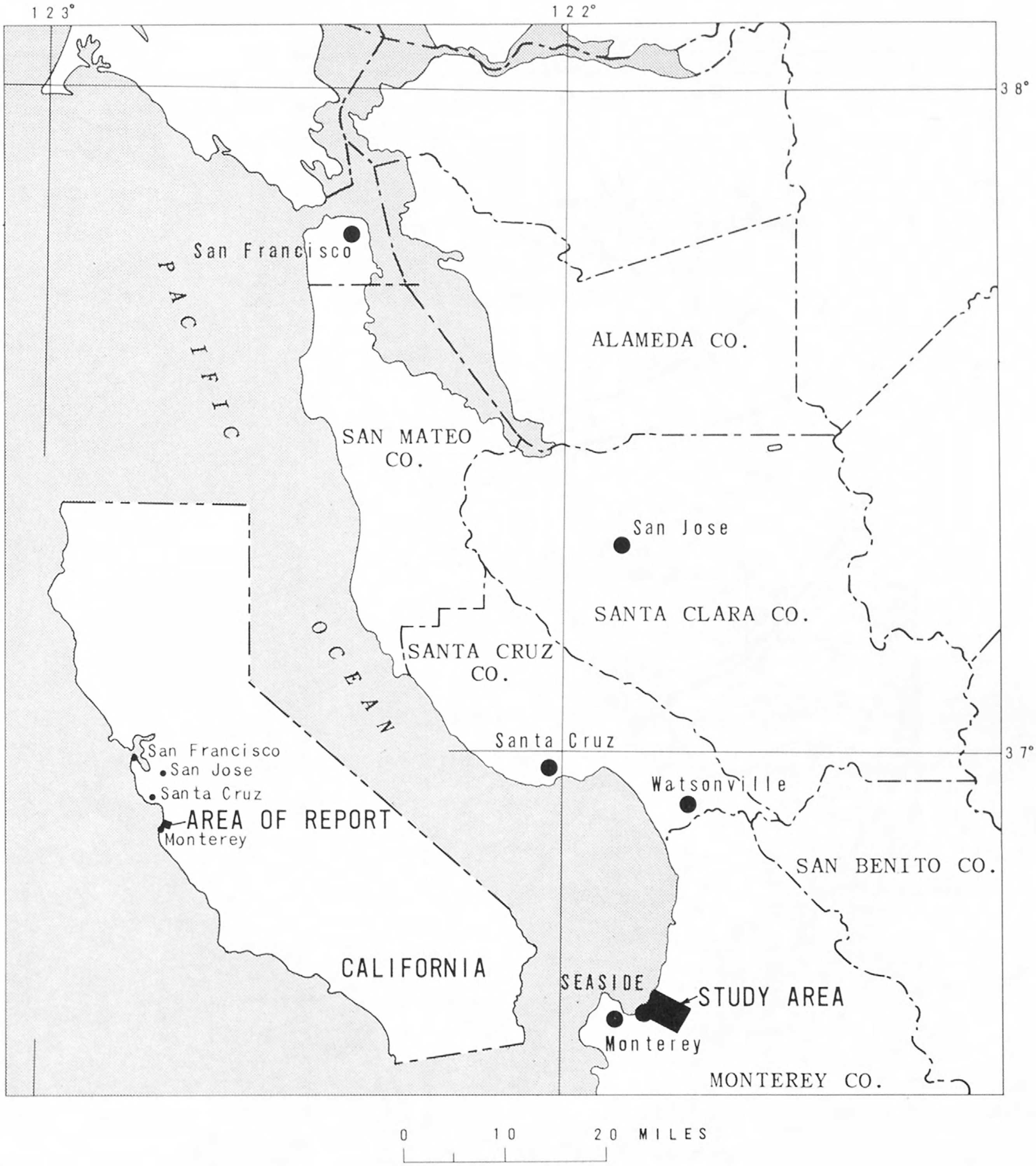
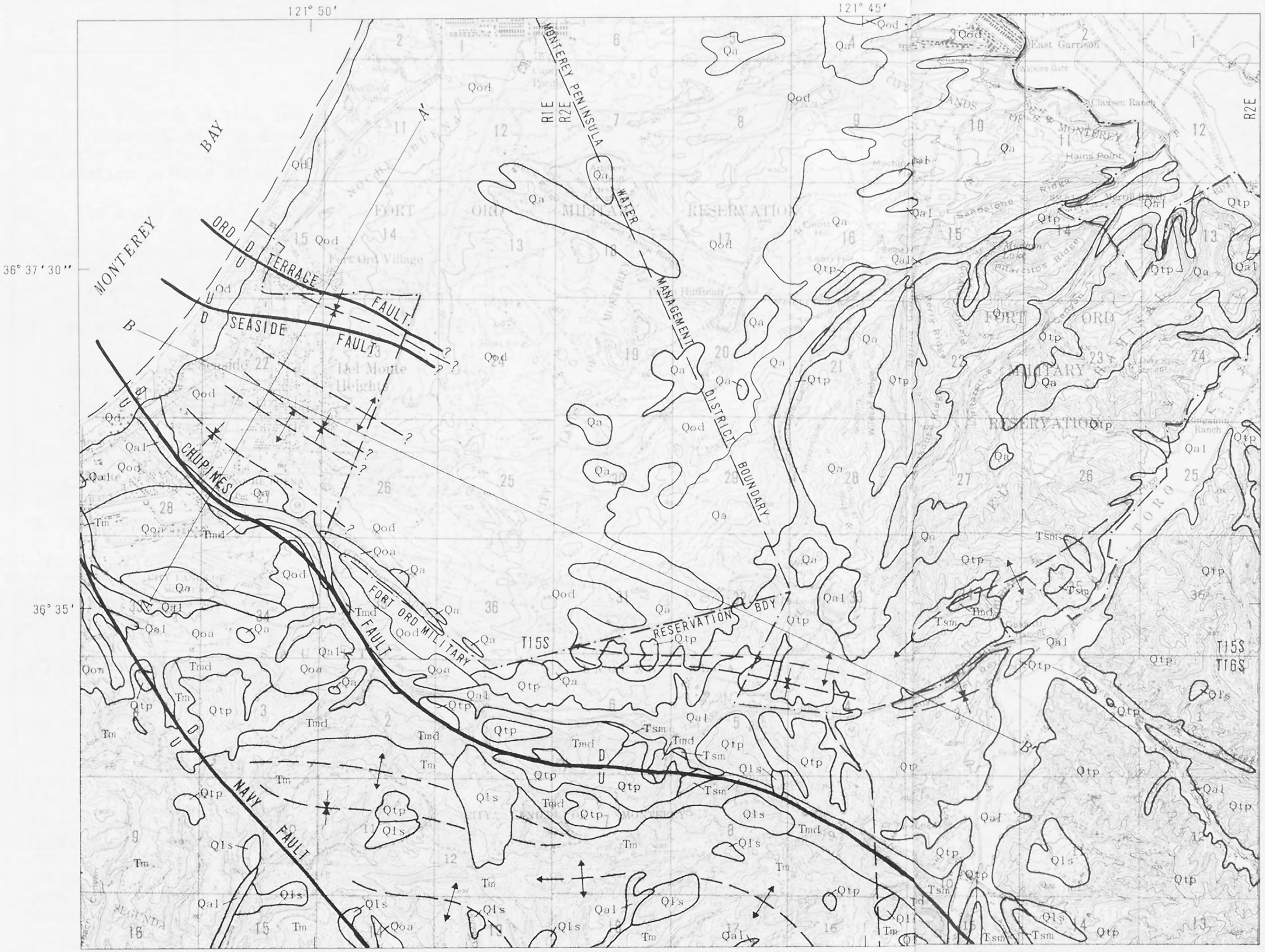


FIGURE 1.--Study area.



Base from U.S. Geological Survey, Monterey, 1947; Salinas, 1947.

0 1 2 3 MILES

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology by T. W. Dibblee, Jr. (1973), with minor modification by K. S. Muir, 1980.

FIGURE 2.--Generalized geology.

CORRELATION OF MAP UNITS

Qd	Holocene	QUATERNARY
Qal		
Qls	Holocene and Pleistocene	
Qod	Pleistocene	
Qoa		
Qa		
Qtp	Pleistocene, Pliocene and Miocene	
Tsm	Miocene	TERTIARY
Tmd		
Tm		

DESCRIPTION OF MAP UNITS

Qd	DUNE SAND (Holocene)
Qal	YOUNGER ALLUVIUM (Holocene)
Qls	LANDSLIDE DEBRIS (Holocene and Pleistocene)
Qod	OLDER DUNES (Pleistocene)
Qoa	OLDER ALLUVIUM (Pleistocene)
Qa	AROMAS SAND (Pleistocene)
Qtp	PASO ROBLES FORMATION (Pleistocene, Pliocene and Miocene)
Tsm	SANTA MARGARITA SANDSTONE (Miocene)
Tmd	MONTEREY SHALE Diatomite Member (Miocene)
Tm	MONTEREY SHALE Shale Member (Miocene)

CONTACT--Approximately located

FAULT--Approximately located; U, upthrown side; D, downthrown side; queried where doubtful

ANTICLINE--Showing crestline and direction of plunge

SYNCLINE--Showing troughline and direction of plunge

A——A' LINE OF GEOLOGIC SECTION

FIGURE 2.--Continued.

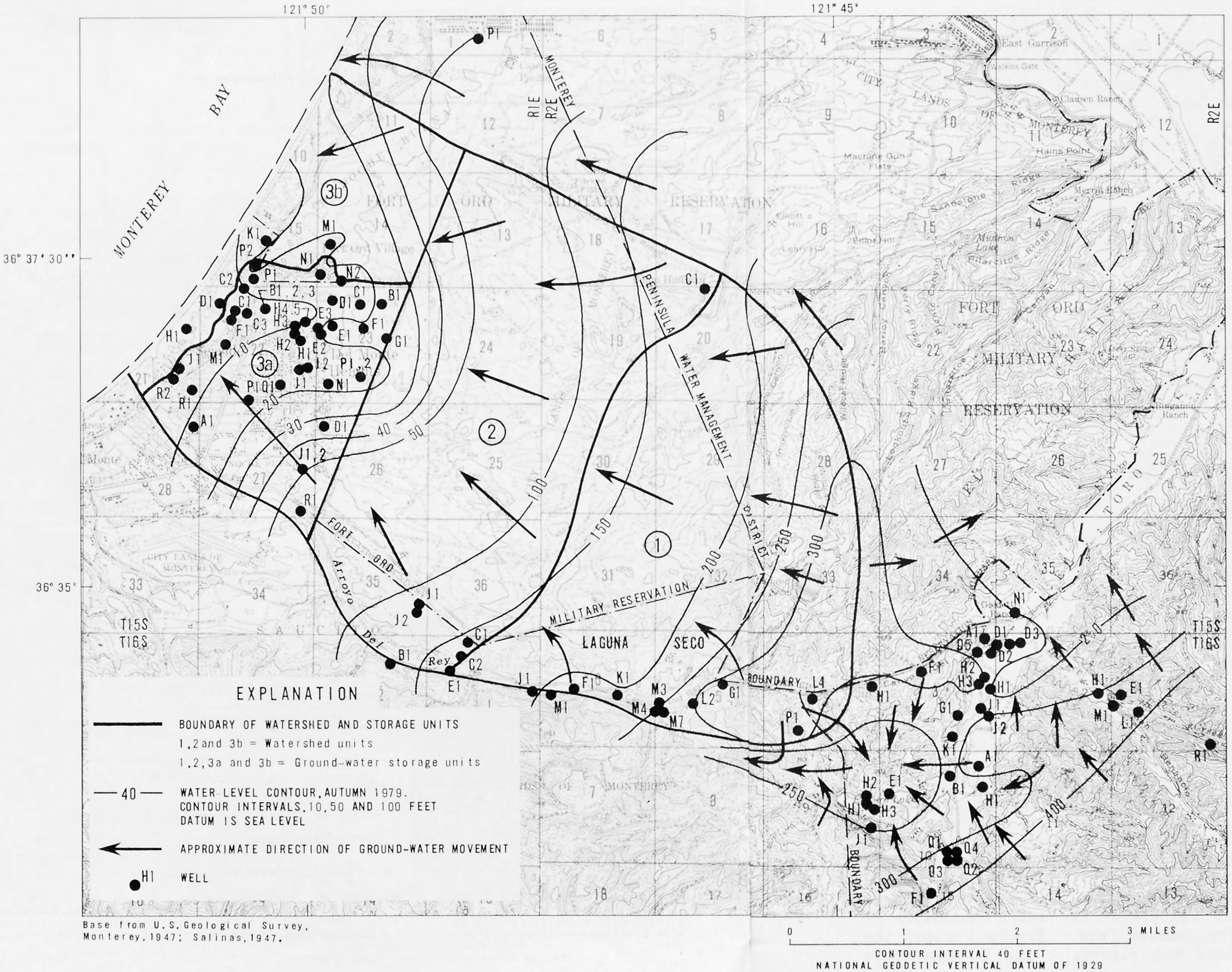


FIGURE 3.--Water levels with watershed and storage units.

Acknowledgments

Special thanks to John Logan and Richard Thorup, consulting geologists, for supplying their many private reports pertaining to the Seaside area and other data. Arvey Swanson of the California Department of Water Resources, supplied much basic data, as did Gene Taylor of the Monterey County Flood Control and Water Conservation District. Bruce Buel, general manager, and Kevin Walsh, engineer, Monterey Peninsula Water Management District, contacted numerous agencies to collect data from the Seaside area.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well 15S/1E-23G1, the first two segments designate the township (T. 15 S.) and the range (R. 1 E.); the third number gives the section (sec. 23); and the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram. The final digit is a serial number for wells in each 40-acre subdivision.

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

GROUND WATER

The Aquifer System

All geologic formations shown in figure 2 contain ground water. However, only the weakly consolidated formations that include the Santa Margarita Sandstone, Paso Robles Formation, Aromas Sand, and the older dunes of late Tertiary and Pleistocene age are considered by the author to yield significant quantities of ground water. Other unconsolidated formations, the older alluvium, landslide debris, younger alluvium, and dune sand (of Quaternary age), have limited areal extent and thickness and yield only small quantities of ground water, generally enough only for domestic use. Figure 2 shows the areal extent of the geologic formations and figures 4 and 5 show their thickness and stratigraphic sequence.

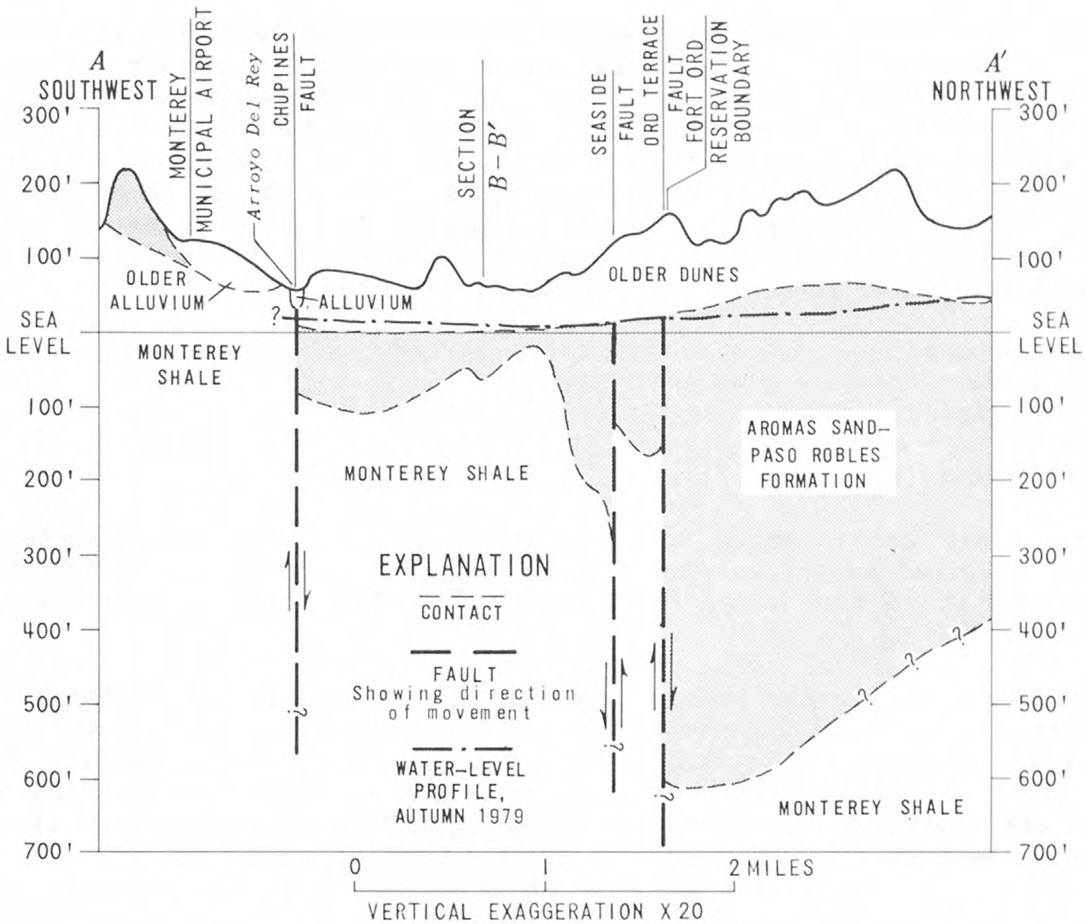


FIGURE 4.--Geologic section A-A' showing water-level profile, autumn 1979.

Consolidated rocks--mostly Monterey Shale--lie beneath the Santa Margarita Sandstone. They are of unknown thickness and crop out along the west boundary and underlie the study area. Granitic rocks have been found at depth in some deep test wells. The consolidated rocks contain water in fractures and in sandstone beds. Few wells penetrate these rocks so they are virtually unexplored as a source of water. As a minimum they seem to contain sufficient water for single family dwellings. They are also known to contain water of poor quality in many areas.

The Santa Margarita Sandstone, the oldest of the weakly consolidated deposits, consists of well-sorted, fine-to-coarse sand of marine origin having little clay content. It is up to 200 ft thick, is permeable, and yields moderate (50-200 gal/min) quantities of water to wells.

The Paso Robles Formation consists of interbedded sand, gravel, and clay and is as much as 700 ft thick. The upper part of the formation is composed of continental clastic sediments typical of alluviated mountain valleys, such as sand, sandy silt, gravel, and clay. They are partly consolidated to indurated and are characterized by abundant fragments of diatomaceous flint and chert. Below these continental sediments are as much as 150 ft of blue clay and clayey sand which contains shells and appears to be of a lagoonal or bay type. The formation is moderately permeable, and well yield depends on how many sand and gravel beds are penetrated.

The Aromas Sand is a horizontally bedded, water-laid sand formation locally interbedded with clay and gravel. It is up to 300 ft thick, is permeable, and yields moderate quantities of water to wells. In figures 4 and 5 the Aromas Sand and Paso Robles Formation are shown as one unit because they are difficult to tell apart in a well log.

The older dunes, which mantle a large part of the Seaside area, are probably reworked windblown Aromas Sand. Their thickness varies but is as much as 300 ft in some areas (figs. 4 and 5). They are permeable and yield water to wells.

The Chupines fault--one of several faults and folds in the Seaside area--has elevated the Monterey Shale on the south side, and led to erosion and removal of the main water-bearing formations on the south boundary of the basin (figs. 2 and 4). The geologic structures north of the Chupines fault control the thickness of the water-bearing formations (fig. 4). None of these structures seem to act as barriers to the movement of ground water.

Source

Sources of recharge to the aquifers in the Seaside area are infiltration of local precipitation, subsurface inflow from adjacent areas, and seepage from creeks. The north, south, and east boundaries of the source areas for local recharge to the reservoir system, and the area of subsurface inflow, were established from an evaluation of the ground-water flow (fig. 3) and local geology (fig. 2). Monterey Bay establishes the west boundary. The area which has been designated as receiving infiltration of local precipitation and seepage from creeks was divided into four units (fig. 3). The boundary lines between the four units were established arbitrarily on the basis of the ability of the units to receive local recharge and their distance from Monterey Bay. Most of the local recharge occurs over the areas of units 1, 2, and 3b. Unit 3a, in the city of Seaside, contributes little recharge to the ground-water reservoir because of its homes and paved streets. The ground-water-flow lines shown in figure 3 indicate that most of the subsurface inflow occurs in the vicinity of Laguna Seca. Other areas may contribute some subsurface inflow, but the author considers the amount of this inflow minimal.

The amount of recharge to the aquifers from infiltration of local precipitation and seepage from creeks varies widely from year to year. The controlling factor is precipitation; in wet years recharge is large and in dry years recharge is small.

Percolation of local precipitation is the most important source of recharge. It probably accounts for most of the total recharge to the area and occurs mainly over the outcrop area of the older dunes. These dunes absorb most of the rain that falls on them and little runoff is produced.

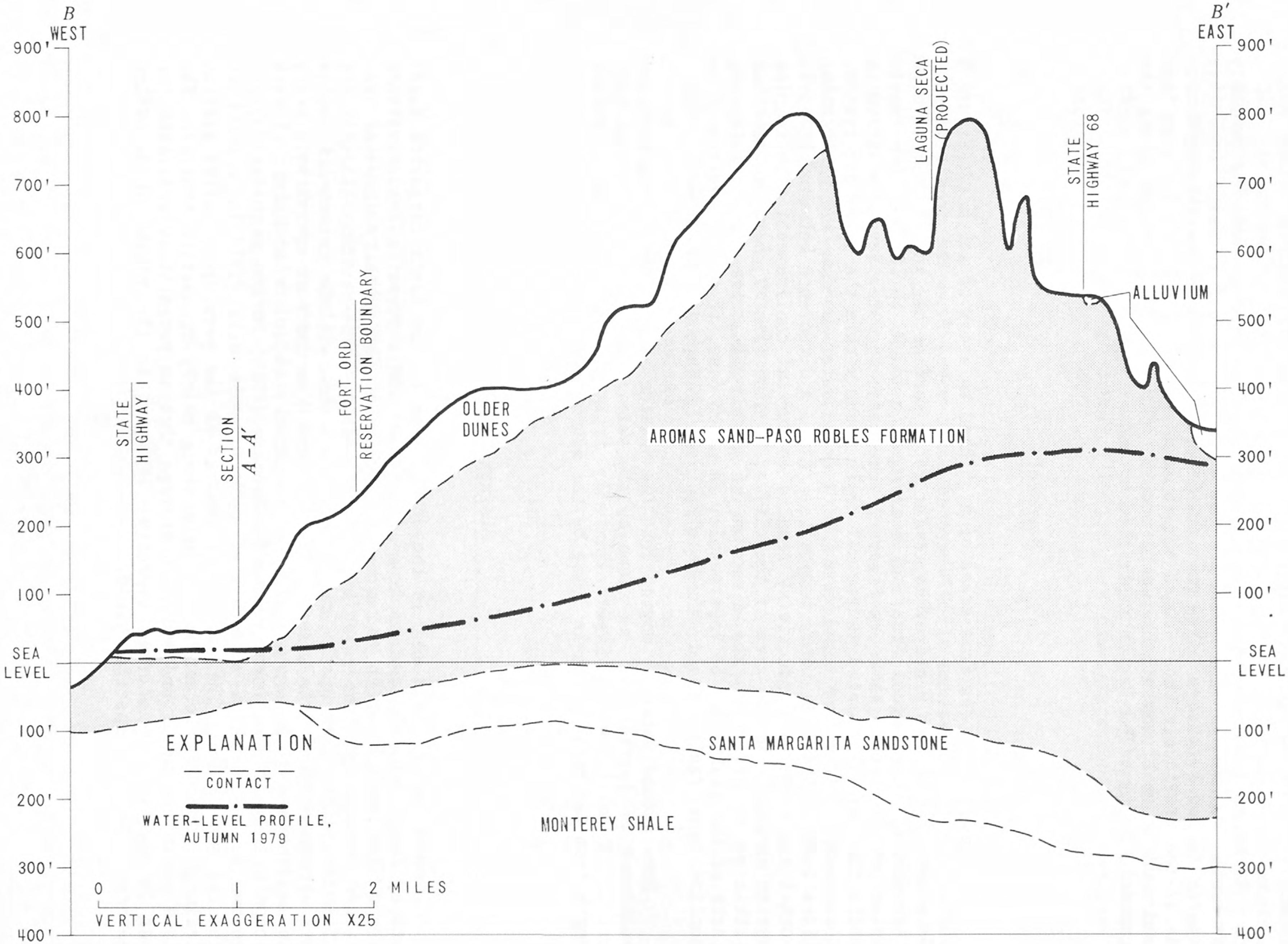


FIGURE 5.--Geologic section B-B' showing water-level profile, autumn 1979.

Data from Thorup (1976, p. 28) indicates subsurface inflow amounts to about 20 percent of total recharge.

Recharge from stream seepage occurring along Arroyo Del Rey probably accounts for only a small part of the total recharge. Recharge from this source is low because a large part of the drainage area is overlain by dunes. As stated previously these dunes absorb most of the rain which falls on them and only a small amount of runoff occurs. In addition, seepage along the channel of Arroyo Del Rey is restricted by underlying clay layers.

Movement

Ground water moves from areas of high head to areas of low head. Figure 3 shows that in the autumn of 1979 ground water moved from the area of Laguna Seca westward toward Monterey Bay. The water surface has an altitude of more than 300 ft near Laguna Seca and decreases to about 10 ft near the coast. Water-level contours shown in figure 3 were based on water levels measured in wells that are perforated in several depth zones within the reservoir system. Consequently, they are considered the average water levels, and the contour lines constructed from them, composite. Also, a difference between the horizontal and vertical conductivity results in partial confinement. The complex system of faults in the area of the city of Seaside (fig. 2) seems to have had little or no effect on the direction of ground-water movement. The deeper parts of the faults may be impermeable, in which case, if water levels were to decline, the faults could become effective in impeding ground-water flow.

Some ground water is moving into the Seaside area at depth from the area southeast of Laguna Seca, as shown by the water-level contour lines in figure 3. A small amount of water probably is moving into the study area at depth from the Monterey Shale lying to the south.

Storage

Ground water is stored in the interstices of the Santa Margarita Sandstone, Paso Robles Formation, Aromas Sand, and older dunes. The interstices are filled with water in the zone of saturation. The quantity of water contained depends upon the porosity of the deposits; however, the total quantity of water in the pore spaces and the quantity that will be released to wells are not equal. Only the water that will drain from the pore spaces by gravity is available for use by wells. The specific yield of a rock or soil with respect to water has been defined by Meinzer (1923) as the ratio of (a) the volume of water which a saturated rock or soil will yield by gravity to (b) its own volume. The water that remains in the pore spaces after gravity drainage (specific retention) is held there mainly by surface tension. The total quantity of ground water in storage that is potentially available for use by man (usable storage capacity) is equal to the volume of saturated material times its specific yield.

To compute the usable storage capacity of the aforementioned aquifers, the author divided the Seaside area into four storage units (1, 2, 3a, and 3b), as shown in figure 3. The boundaries of these units were determined after considering several factors--the location of pumping centers, distance to Monterey Bay, ground-water-flow patterns, and geology. It should be noted that the storage and watershed units coincide.

After the area was divided into storage units, the saturated material in the storage units was assigned a value for specific yield based on the classification by Evenson and others (1962). This classification is summarized in table 1.

TABLE 1. - Specific-yield classification

Drillers' terms	Assigned classification	Assigned specific yield (percent)
Gravel, gravel and sand, boulders.	Gravel	25
Sand, fine sand, decomposed granite sand, coarse sand.	Sand	20
Silt, packed sand, hard sand, sandy clay, soil, clay and sand.	Sand and clay	7
Clay and gravel, hard sand and gravel, cemented gravel.	Clay and gravel	5
Clay, adobe, shale, chalk rock.	Clay	1

Table 2 shows the amount of usable ground water stored in each of the storage units in the Seaside area in the autumn of 1979. One weighted average specific yield was used for all storage units because of the lack of drillers' logs in some of the units. A total number of 65 drillers' logs was used in the specific-yield determination. The amount of usable ground water in storage is estimated because a large part of the study area lies within the Fort Ord Military Reservation from which few hydrologic data are available.

TABLE 2. - Estimated amount of usable ground water in storage, autumn 1979, in the Seaside area

Storage unit	Average saturated thickness (ft)	Surface area (acres)	Volume (acre-ft)	Weighted average specific yield (percent)	Usable ground water (acre-ft)
1	550	6,200	3,400,000	12	410,000
2	350	5,700	2,000,000	12	240,000
3a	200	2,000	400,000	12	50,000
3b	200	1,400	280,000	12	30,000
Total					730,000

Ground water in storage units 3a and 3b is directly tapped by wells in the area of the city of Seaside. Because the storage unit is adjacent to the ocean, the amount of ground water in storage that is available for use without causing degradation is that which is stored above sea level. If ground-water storage is allowed to decline to or below sea level in this area, seawater could intrude. The amount of usable ground water stored above sea level in the autumn of 1979 in storage unit 3a was 5,000 acre-ft and in storage unit 3b, 4,000 acre-ft. There was about 60,000 acre-ft of usable ground water stored above sea level in storage unit 2 in the autumn of 1979, and about 170,000 acre-ft in storage unit 1. As shown on the hydrographs in figure 6, the net amount of ground water in storage in the coastal area declined slightly between 1962 and 1979.

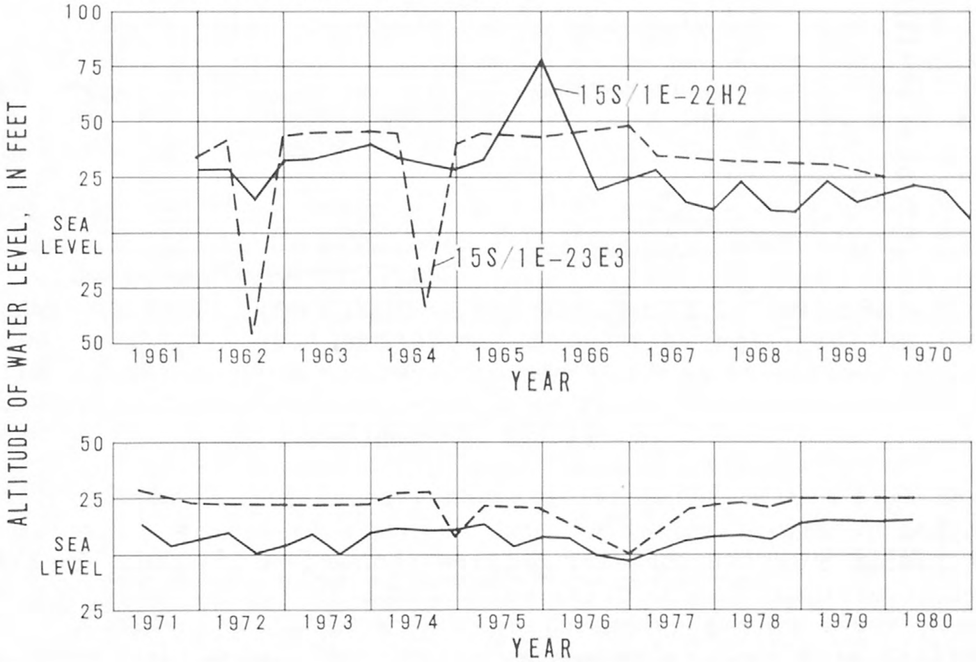
Water Sources and Uses

Ground water from local wells supplies most of the water used in the Seaside area. The California-American Water Company (CAL-AM) pumps the largest amount. Their service area lies within the city limits of Seaside. In addition to the Seaside wells, the California-American Water Company owns and operates a pipeline that extends from the Carmel Valley to the city of Seaside. In the past they have used this pipeline to deliver water from Carmel to Seaside. The U.S. Army at Fort Ord, the city of Seaside, and a number of private well owners also operate wells in the Seaside area. Table 3 shows the amount of ground water pumped in the Seaside area from 1960 to 1979. Pumpage by the California-American Water Company, the city of Seaside, and Fort Ord is metered.

Water pumped in the Seaside area is used mostly for domestic purposes. Some is used by golf courses, industry, and agriculture.

Well 15S/1E-22H2
CAL-AM well name 'LUXTON'
Depth, 289 feet; perforations 150-180, 265-277 feet
Land-surface altitude, 88 feet

Well 15S/1E-23E3
CAL-AM well name 'HARDING'
Depth, 225 feet; perforations 141-177, 201-225 feet
Land-surface altitude, 130 feet



Well 15S/1E-23P1
City of Seaside Well No. 1
Depth, 280 feet; perforations 250-280 feet
Land-surface altitude, 226 feet

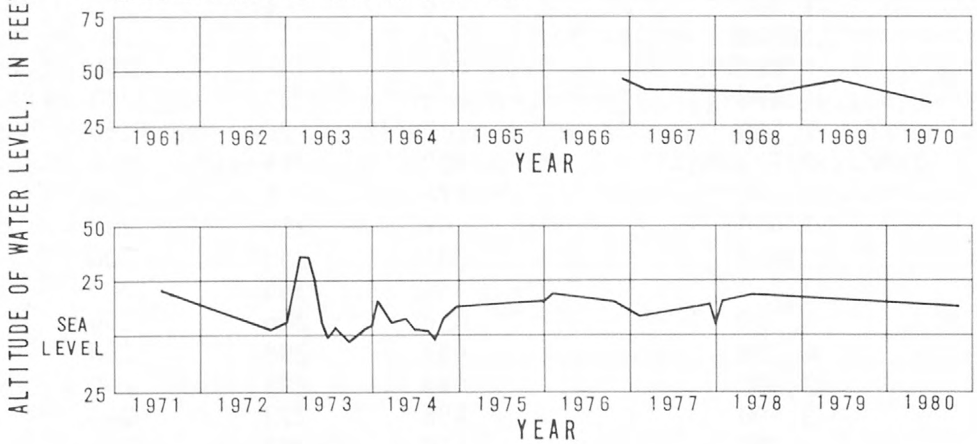


FIGURE 6.--Fluctuation of water level in wells 15S/1E-22H2, 23E3, 23P1, and 26D1.

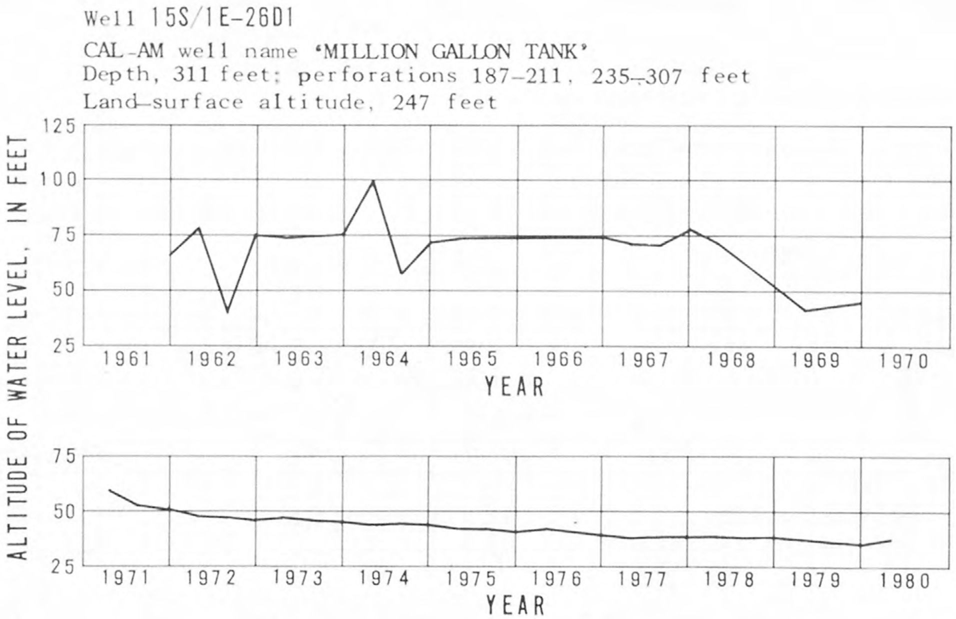


FIGURE 6.--Continued.

TABLE 3. - Ground-water pumpage in the Seaside area, 1960-79

Year	Pumpage, in acre-feet				
	California-American Water Company	City of Seaside	Fort Ord	Other pumpage[1]	Total
1960	1,640	0	6	200	1,846
61	1,970	0	1	200	2,171
62	1,700	0	22	200	1,922
63	1,920	0	55	200	2,175
64	1,870	0	132	200	2,202
65	1,520	0	126	200	1,846
66	2,700	123	15	200	3,038
67	2,640	176	138	200	3,154
68	3,480	267	350	200	4,297
69	2,620	331	353	200	3,504
1970	3,810	450	344	200	4,804
71	4,310	450	246	200	5,206
72	4,700	487	298	200	5,685
73	3,980	488	295	200	4,963
74	3,590	496	273	200	4,559
75	3,400	514	292	200	4,406
76	4,230	319	341	200	5,090
77	2,690	239	310	200	3,439
78	1,720	339	252	200	2,511
79	1,660	435	282	200	2,577

[1]Estimated. Includes industrial, individual domestic, and agricultural.

Yield

The term "ground-water yield" has many definitions, all of which are based on the long-term dependability of the water supply, as expressed by the balance of the items of the ground-water inventory (fig. 7). Rainfall infiltration, subsurface inflow, and stream seepage are the more important sources of inflow to the study area. Evapotranspiration and pumpage are the main items of outflow. The yield of the ground-water reservoirs in the Seaside area is the rate at which water can be pumped from wells year after year without decreasing ground water in storage to the point where the pumping lift would become economically infeasible or where water of poor quality would begin to intrude into the reservoir. In this area the intrusion of water of poor quality--seawater--probably would occur first.

The estimated amount of ground water in storage units 2, 3a, and 3b (fig. 3), which lie in the coastal part of the Seaside area, was 320,000 acre-ft in 1979. The ground-water storage can be depleted by pumping until water levels near the coast are drawn down to near sea level. When this occurs, the average annual pumpage should not exceed a quantity equal to the long-term average inflow to the reservoir minus the quantity that must flow to the ocean annually to maintain a barrier against seawater intrusion. This is the ground-water yield of the coastal part of the reservoir.

The yield of the Seaside area cannot be estimated with a high degree of accuracy because of a lack of complete data on inflow, outflow, and aquifer transmissivities and because ground water within the reservoir is not static, which means that the natural inflow-outflow relations of the reservoir system will probably continue to change with time. Pumping ground water from wells can change these relations. If pumping causes water levels to decline, the decline may cause subsurface inflow to increase.

Table 4 shows the inflow to the ground-water reservoir from rain infiltration and stream seepage for 1961 through 1979. The values shown in the table are determined by calculating the total amount of water available to the area, based on rainfall records from Monterey, and subtracting estimates of surface runoff and evapotranspiration. It should be noted that ground-water storage unit 3a (fig. 3) is not included in the inflow listing; it lies within the main part of the city of Seaside and most of the area is covered by houses and streets which minimize inflow from rain to the ground-water reservoir. Surface runoff was based on rainfall-runoff characteristics of Arroyo Del Rey. A value of 12 in/yr, based on data from the California Department of Water Resources (1975) and Earth Metrics, Inc. (1977) was used for evapotranspiration.

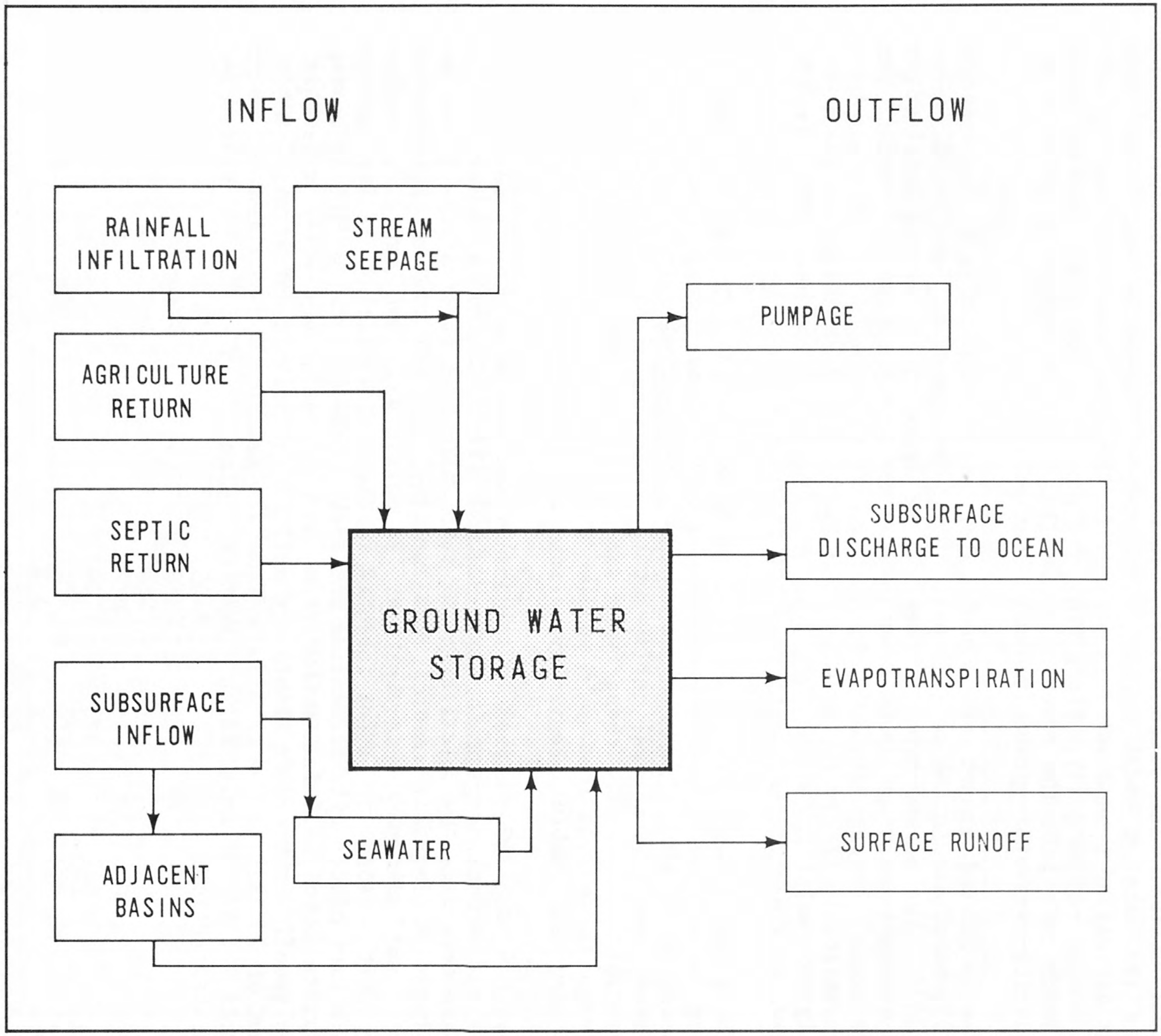


FIGURE 7.--Ground-water inventory.

TABLE 4. - Inflow to the ground-water reservoir from rain infiltration and stream seepage based on rainfall at Monterey

Year	Watershed units[1]	Rainfall at Monterey (inches)	Drainage area (acres)	Total available water (acre-ft)	Evapotrans-piration (acre-ft)	Runoff (acre-ft)	Inflow to ground-water reservoir (acre-ft)
1961	1+2+3b	10.85	13,300	12,000	13,300	100	0
	2+3b	10.85	7,100	6,400	7,100	60	0
1962	1+2+3b	15.37	13,300	17,300	13,300	500	3,500
	2+3b	15.37	7,100	9,200	7,100	300	1,800
1963	1+2+3b	20.72	13,300	22,600	13,300	700	8,600
	2+3b	20.72	7,100	12,100	7,100	400	4,600
1964	1+2+3b	18.42	13,300	20,000	13,300	600	6,100
	2+3b	18.42	7,100	10,600	7,100	300	3,200
1965	1+2+3b	21.14	13,300	23,900	13,300	1,700	8,900
	2+3b	21.14	7,100	12,800	7,100	900	4,800
1966	1+2+3b	14.85	13,300	16,000	13,300	500	2,200
	2+3b	14.85	7,100	8,500	7,100	300	1,100
1967	1+2+3b	24.80	13,300	27,900	13,300	2,000	12,600
	2+3b	24.80	7,100	14,900	7,100	1,000	5,900
1968	1+2+3b	15.73	13,300	17,300	13,300	500	3,500
	2+3b	15.73	7,100	9,200	7,100	300	1,800
1969	1+2+3b	25.77	13,300	27,900	13,300	2,000	12,600
	2+3b	25.77	7,100	14,900	7,100	1,000	5,900
1970	1+2+3b	23.48	13,300	26,600	13,300	1,900	11,400
	2+3b	23.48	7,100	14,200	7,100	1,000	6,100
1971	1+2+3b	13.06	13,300	14,600	13,300	100	1,200
	2+3b	13.06	7,100	7,800	7,100	100	600
1972	1+2+3b	14.12	13,300	16,000	13,300	500	2,200
	2+3b	14.12	7,100	8,500	7,100	300	1,100
1973	1+2+3b	27.87	13,300	30,600	13,300	2,100	15,200
	2+3b	27.87	7,100	16,300	7,100	1,200	8,000
1974	1+2+3b	17.78	13,300	20,000	13,300	600	6,100
	2+3b	17.78	7,100	10,600	7,100	300	3,200
1975	1+2+3b	14.17	13,300	16,000	13,300	500	2,200
	2+3b	14.17	7,100	8,500	7,100	300	1,100
1976	1+2+3b	11.46	13,300	13,300	13,300	100	0
	2+3b	11.46	7,100	7,100	7,100	70	0
1977	1+2+3b	12.88	13,300	14,600	13,300	200	1,100
	2+3b	12.88	7,100	7,800	7,100	100	600
1978	1+2+3b	26.40	13,300	29,300	13,300	2,100	13,900
	2+3b	26.40	7,100	15,600	7,100	1,100	7,400
1979	1+2+3b	22.93	13,300	25,300	13,300	1,800	10,200
	2+3b	22.93	7,100	13,500	7,100	1,000	5,400

[1]See figure 3; 1+2+3b = total inflow area, 2+3b = coastal inflow area adjacent to city of Seaside.

Figure 8 illustrates how important rain is to the amount of water available as inflow to the ground-water reservoir. In wet years there is a large amount of inflow and in dry years there is little. Rainfall records from the National Weather Service station at Monterey were used because good records for Seaside do not exist (or are not available). Professor R. J. Renard, a meteorologist with the Navy Postgraduate School in Monterey, is doing a study on Monterey Peninsula rainfall for the Monterey Peninsula Water Management District. His preliminary findings (R. J. Renard, oral commun., 1981) indicate that the Seaside area receives about 3 inches less rainfall per year than that recorded at Monterey. This is about 15 percent less rainfall than at Monterey. On the basis of these preliminary findings all the inflow figures shown in table 4 were reduced 15 percent prior to their use in yield determinations for the Seaside area.

Another source of inflow to the ground-water reservoir in the Seaside area is subsurface inflow. This occurs southeast of Laguna Seca, and is indicated by the trace of the water-level contours and ground-water flow directions shown in figure 3. Thorup (1976, p. 28) estimated this inflow to be about 2,000 acre-feet per year. Because better data were not available, the author used this figure in this report.

The amount of subsurface inflow into the Seaside area could change with time. Ground-water level is one of the elements that have considerable influence on the inflow regime. Changes in water levels, either from pumping or recharge, will change water-level gradients. This in turn will decrease or increase subsurface inflow.

Two ground-water yield values are presented in this report: a value for the coastal area, and a value for the Seaside area as a whole. The coastal area coincides with storage units 2, 3a, and 3b (fig. 3), and the whole area includes storage units 1, 2, 3a, and 3b. The time period 1962-79 was selected for the evaluation of yield because data on water levels, pumpage, and precipitation were available.

An approximation of the ground-water yield for the reservoir in the coastal area can be estimated by referring to the 5 years 1962-66, during which net ground-water storage seems to have remained constant (fig. 6). During 1962-66, inflow was equal to outflow. Thus, the yield of the coastal area was equal to the average pumping draft, or about 2,000 acre-ft/yr (table 5). Average annual inflow for 1962-66 was estimated to be 2,600 acre-ft/yr, as compared with the longer-term estimated annual inflow of 3,000 acre-ft/yr for 1962-79. On the basis of these estimates, the ground-water outflow to the ocean required to prevent seawater intrusion could be more than 600 acre-ft/yr. The exact amount cannot be determined with the existing data. Based on the preceding evaluation and the data in table 5, the yield of the coastal area is estimated to be more than 2,000 acre-ft/yr but less than 3,000 acre-ft/yr. The yield for the whole study area is estimated to be more than 6,400 acre-ft/yr and less than 7,700 acre-ft/yr.

To obtain maximum yield from the Seaside area, careful placement of wells and proper pumping techniques are needed. Because the values of yield determined in this report are based on the current level of hydrologic knowledge, the value of yield would need to be refined as additional hydrologic data become available (especially pertaining to rainfall and evapotranspiration).

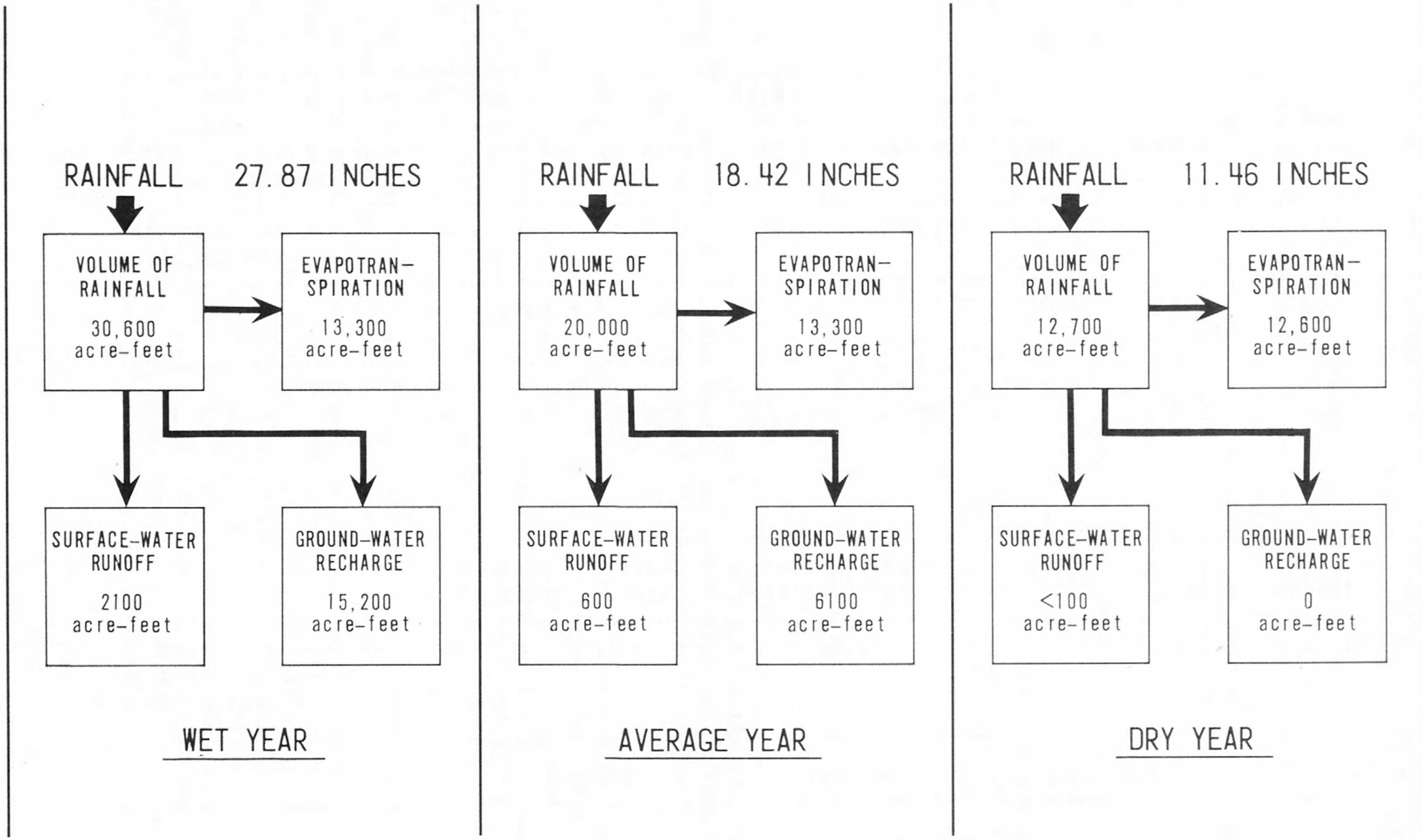


FIGURE 8.--Variation of inflow (recharge) to the ground-water reservoir from rain infiltration and stream seepage, based on rainfall at Monterey.

TABLE 5. - Rainfall, inflow, pumpage, and water-level response, 1962-66, 1967-76, 1977-79, and 1962-79

	1962-66		1967-76		1977-79		1962-79	
Estimated average rainfall in Seaside area, in inches	15.10		15.82		17.74		15.94	
	Coastal area[1]	Total area[2]	Coastal area[1]	Total area[2]	Coastal area[1]	Total area[2]	Coastal area[1]	Total area[2]
Average inflow, in acre-feet per year								
Rain infiltration and stream seepage	2,600	5,000	2,900	5,700	4,000	7,100	3,000	5,700
Subsurface	--	2,000	--	2,000	--	2,000	--	2,000
Total	2,600	7,000	2,900	7,700	4,000	9,100	3,000	7,700
Average pumpage, in acre-feet per year	2,000	2,200	4,400	4,600	2,600	2,800	3,400	3,600
Water-level response (fig. 6)	Steady	Unknown	Decline	Unknown	Rise	Unknown	Decline	Unknown

[1]Coincides with storage units 2, 3a, and 3b (fig. 3).
[2]Coincides with storage units 1, 2, 3a, and 3b (fig. 3).

Table 5 shows the relation in the coastal area between inflow and pumpage, and the water-level response (fig. 6). Water levels declined during 1967-76 and 1962-79, when average pumpage exceeded average inflow. In contrast, water levels rose during 1977-79, when inflow exceeded pumpage. Data are insufficient to be able to characterize basinwide water-level response.

The yield of the Seaside area could probably be increased by using one of several methods. One method could involve recovering some of the water lost to stream runoff or evapotranspiration. Basin yield would be increased by the amount recovered. Another method to increase yield would be to utilize the unsaturated part of the reservoir system that lies between the water table and the land surface. In 1979 this amounted to enough space for more than 100,000 acre-ft of water in the coastal part of the study area (storage units 3a and 3b), and more than 1,000,000 acre-ft of water for the area as a whole. Imported water or treated wastewater are examples of water that could be recharged into the ground-water reservoir to increase yield. It may not be simple to recharge the unsaturated zone with this "foreign" water. Physical and chemical changes to the aquifer or local water at the point of recharge could make a recharge program difficult to maintain. Also, only a part of the recharged water could be expected to be recovered by subsequent pumping from wells. A substantial part of the recharge water would be held within the aquifer by surface tension.

Recharge Area Evaluation and Classification

The land surface in the Seaside area was evaluated and classified as to its ability to absorb and transmit water to the ground-water reservoir. This enables the Monterey Peninsula Water Management District to identify areas where they can expect the most success in recharging if they obtain imported or surplus water.

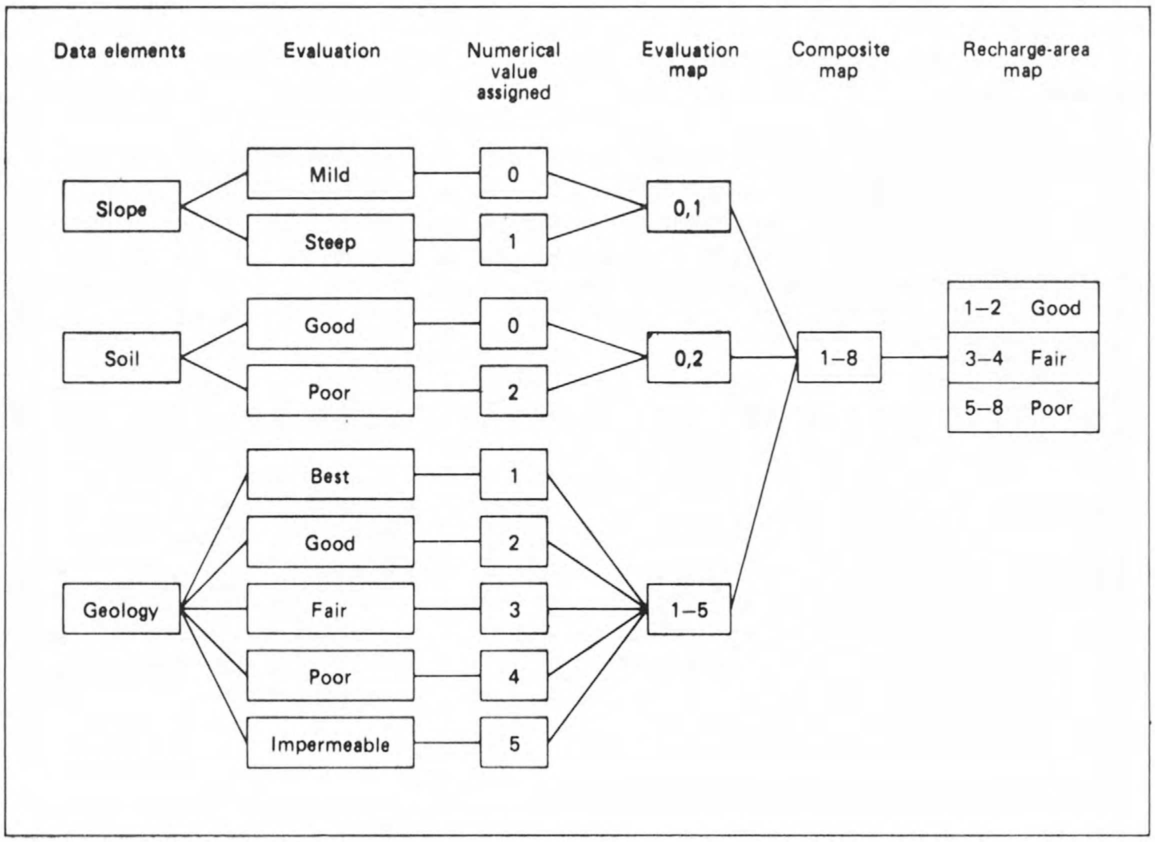
Several physical factors control the movement of water from land surfaces and streambeds into underlying aquifers. These factors determine whether an area has a good, fair, or poor recharge potential. Abundance of rainfall provides no guarantee that a recharge area is a good one. The surficial materials of the area must be able to absorb rainfall and allow transmission of the water through the soil zone and into an aquifer, where it can be tapped for a water supply.

The three basic physical elements that control the direct infiltration of precipitation into the ground are slope of the land surface, type of soil, and geology of the material underlying the soil zone. The slope (gradient) of the land surface controls, in part, how long rain will remain in contact with the soil at or near the point where it falls. Flat or mild slopes allow a relatively long residence time; steep slopes cause the rainfall to run off quickly. The longer the residence time, the better the chance for ground-water recharge to occur. The type of soil determines how much rainfall will be absorbed and transmitted to the underlying aquifers. The geology of material underlying the soil zone is important because to constitute an aquifer, the material must be able to receive, store, and transmit water.

Recharge from stream seepage is controlled by the same three elements that control recharge by direct infiltration of precipitation: (1) Slope of the streambed; (2) type of surface material of the streambed; and (3) geology of the aquifer materials that underlie the streambed.

A number of other elements affect ground-water recharge. Among these are land cover, such as vegetation and paving; rainfall duration and intensity; the angle at which rain hits the land surface; soil-moisture conditions prior to rainfall; and depth of water in streambeds. Unlike the three basic elements used in the classification, these elements are transitory, and some are subject to alteration by man. They tend to influence the amount of recharge but not so much the movement of recharge water from unaltered land surfaces or streambeds into underlying aquifers. They were not included in the classification scheme in this report.

The recharge delineations shown in figure 9 are the result of classification of three basic-data elements--slope, soil, and geology--evaluated separately for their effects on recharge. The numerical system used to facilitate the evaluation was based on a recharge-delineation system developed by Muir and Johnson (1979) for several areas in Santa Cruz County. The numerical system relates and weights the degree to which each data element influences recharge potential. Three separate numerical recharge evaluation maps were prepared for slope, soil, and geology for the Seaside area, then composited into a single numerical map. A classification system related the numbers on the composite map to good, fair, or poor recharge areas. The following flow diagram illustrates the method used to incorporate the three basic-data elements into the final recharge classification map.



Following are the criteria used in the recharge evaluation in the Seaside area and the corresponding numerical values that were assigned to the three data elements:

1. Slope--Slopes up to 15 percent were considered mild and assigned a numerical value of 0. Slopes over 15 percent were considered steep and assigned a value of 1. These mild and steep classifications are based on criteria used by the U.S. Soil Conservation Service. In general, steep slopes cause rapid runoff of precipitation and reduce the recharge potential.

2. Soil--The recharge potential of soils was evaluated by analyzing those factors that influence the absorption into, and movement of water through, the soil zone. Infiltration rate, surface roughness, internal structure, and lithology were the most important factors considered. Soil infiltration was considered rapid if the rate was greater than 0.6 in/h (Estrada, 1976). If it was less than this value, the infiltration rate was considered slow. Soils that were judged to have a good recharge potential were given a numerical value of 0. Those that were judged a poor recharge potential were given a value of 2. In the final recharge evaluation, therefore, soil effects were given twice the numerical weight of slope effects because the author considered soil to be more important to ground-water recharge than slope. The evaluation of soil was based on studies done by the U.S. Soil Conservation Service (1978).

3. Geology--Each geologic formation in the Seaside area was hydrologically evaluated as to its ability to receive, store, and transmit water. Each formation was subjectively assigned a numerical value that ranged from 1 for the best aquifers to 4 for those formations considered poorly permeable. Faults, fractures, crushed zones, and stream channels were considered in the evaluation of the formations. Geologic formations evaluated and their assigned numerical values are as follows:

Assigned Numerical Value

	1	2	3	4
Geological Formation	Dune sand Younger alluvium	Older dunes Older alluvium Paso Robles Formation Santa Margarita Formation	Aromas Sand	Monterey Shale

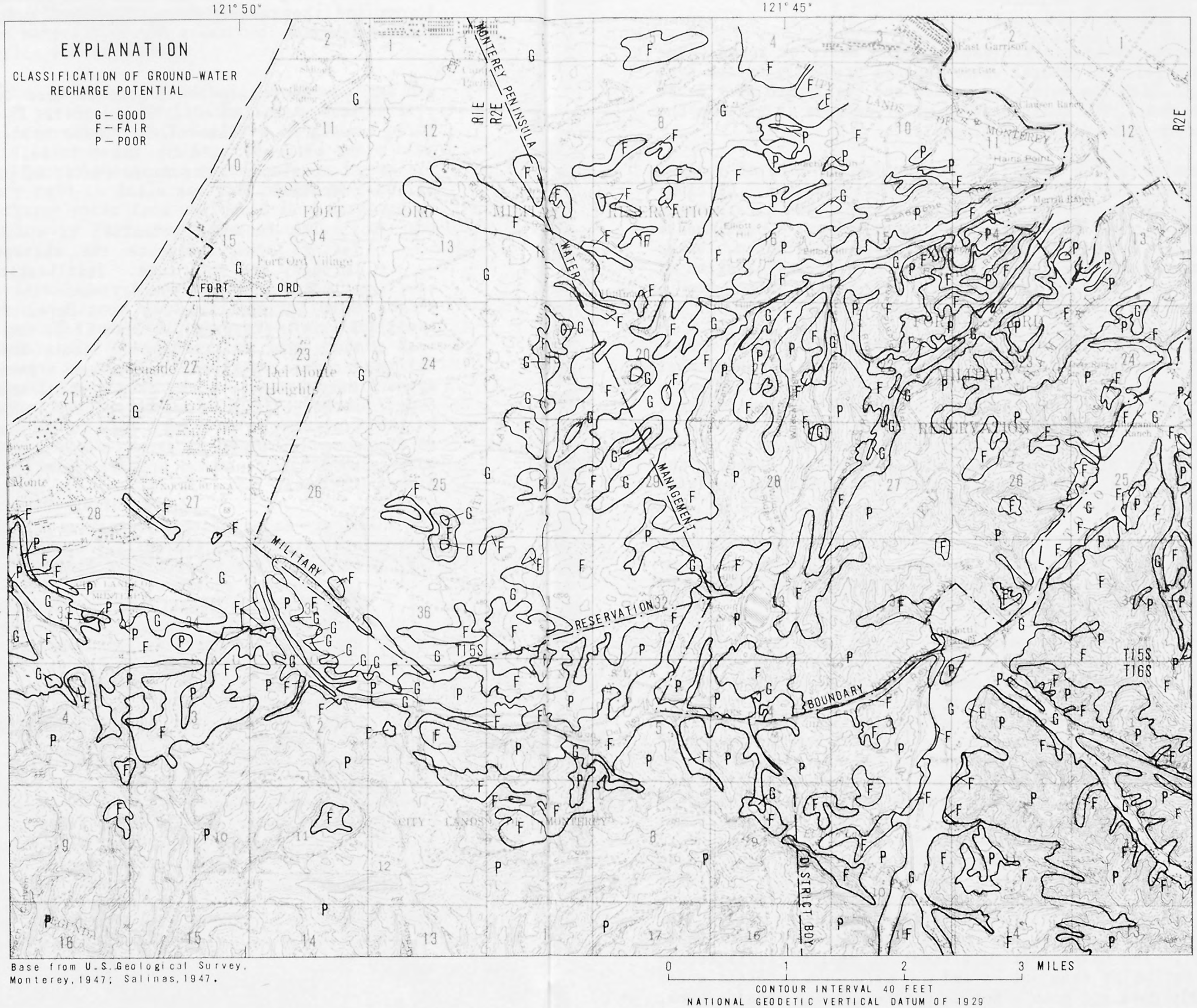


FIGURE 9.--Recharge area evaluation and classification.

Quality

All natural water contains minerals dissolved from soils or rocks. The quantity of dissolved minerals in natural water depends primarily on the type of rocks or soils through which the water has passed and the length of time it has been in contact with them. The quality of a water depends in part on the types and concentrations of these dissolved minerals.

The dissolved minerals in the water are mostly in the form of ionized particles--positively charged cations and negatively charged anions. Calcium, magnesium, sodium, and potassium are the more common cations, and bicarbonate, carbonate, sulfate, chloride, and nitrate are the common anions. Constituents generally present in smaller amounts include iron, fluoride, and boron. Water can be classified and compared according to its major ionic concentration of cations and anions. For example, a calcium bicarbonate water has a predominant calcium cation and a predominant bicarbonate anion.

The Seaside area seems to have two distinct water-quality type areas. The area that lies within the northern half of the city of Seaside, where most ground-water pumpage occurs, has ground water that can be classified as a sodium bicarbonate type. The other area, having a sodium chloride water type, lies adjacent to the southern boundary of the study area from Laguna Seca to Monterey Bay. There is no water-quality information for that part of the study area which lies in Fort Ord east of the city of Seaside. However, the ground water is probably a sodium bicarbonate type. Table 6 shows analyses representative of the Seaside area.

Water pumped in the Seaside area is used principally for domestic purposes, with some minor irrigation and industrial use. The ground-water chemical quality generally is suitable for all uses, although some treatment may be desirable for domestic uses.

Iron and nitrate concentrations, dissolved solids, and hardness are several factors that determine the suitability of water for domestic use. The average dissolved-solids concentration in water in the city of Seaside area in 1979 was about 600 mg/L and about 800 mg/L along the southern boundary of the study area. The 800 mg/L is the average of eight wells sampled by the Monterey County Flood Control and Water Conservation District in the autumn of 1979. The permissible upper limit for dissolved solids, determined by the California Department of Health (1973), is 1,000 mg/L. Hardness is objectionable in the entire Seaside area, where levels average more than 100 mg/L (as $CaCO_3$). Hardness becomes objectionable at levels higher than 100 mg/L (McKee and Wolf, 1963). Iron seems to be a problem only along the southern boundary of the study area, where its concentration may average more than 1 mg/L. Iron is objectionable in water supplies for general household use because it stains enamelware, laundered clothes, and many other items coming in contact with the water. It also imparts an unpleasant astringent taste to drinking water. Any water that contains more than 0.5 mg/L of iron in solution may cause these problems (Johnson, 1966). The California Department of Health (1973) recommended that the concentration of iron not exceed 0.3 mg/L in a domestic water supply. Nitrate generally does not pose a health problem in the Seaside area, as nitrate concentrations averaged less than 10 mg/L in water sampled in 1979.

TABLE 6. - Chemical analyses of water from the Seaside area

[Chemical analyses are in milligrams per liter except where noted. Analyzing laboratories are abbreviated as follows: CAL-AM, California-American Water Company, Monterey, Calif.; DWR, California Department of Water Resources, Bryte, Calif.; USGS, Geological Survey, Denver, Colo.]

Site No. (fig. 3)	Date of collection	Specific conductance (µmho/cm at 25°C)	pH (units)	Hardness as $CaCO_3$	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids (residue on evaporation at 180°C)	Nitrate (NO_3)	Boron (B)	Iron (Fe)	Analyzing laboratory
15S/1E-15K1	9-25-80	380	--	--	--	--	--	--	--	--	56	--	--	--	--	USGS
15S/1E-15P1	9-25-80	304	--	--	--	--	--	--	--	--	60	--	--	--	--	USGS
15S/1E-21H1	9-25-80	2,168	--	--	--	--	--	--	--	--	700	--	--	--	--	USGS
15S/1E-22B3	2-38-79	920	7.96	248	63	22	98	--	202	93	134	584	12.4	0.26	0.03	CAL-AM
15S/1E-22C2	9-25-80	651	--	--	--	--	--	--	--	--	130	--	--	--	--	USGS
15S/1E-22D1	9-25-80	965	--	--	--	--	--	--	--	--	130	--	--	--	--	USGS
15S/1E-23B1	2-28-79	1,000	7.16	304	87	21	97	--	293	84	133	640	1.6	.30	.06	CAL-AM
15S/1E-23D1	2-28-79	920	7.48	265	75	19	97	--	250	61	139	588	5.6	.33	.09	CAL-AM
16S/2E- 5L2	8-30-71	737	6.8	98	18	13	110	2.6	89	32	170	406	16.8	.08	--	DWR

Several factors have influenced, or could influence the water quality in the Seaside area. These include seawater intrusion and mineralized water in the area of the city of Seaside, and mineralized connate water and septic-system effluent along the southern boundary of the study area from Laguna Seca to the city of Seaside.

Few wells are situated adjacent to Monterey Bay, and there is a paucity of water-quality data from these wells. The limited water-quality data collected in September 1980 (table 6) and those shown in figure 10 indicate that there has been no general seawater intrusion in the Seaside area. The depth of wells sampled in September ranged from about 60 ft to more than 600 ft, and their pumping water levels were all below sea level. Well 15S/1E-21H1 is the only well sampled that had water with a relatively high chloride concentration--700 mg/L. This 70-foot-deep well is located in the sand dunes within a few hundred yards of Monterey Bay and has always had water with a high chloride concentration. In 1969, the chloride concentration was 1,600 mg/L, and in 1975 the chloride concentration was 1,090 mg/L. Water from well 15S/1E-21J1 has shown spikes of elevated chloride concentration (fig. 10). These elevated chloride concentrations can be related to years in which the well was heavily pumped, such as in 1966, 1974, and 1976. The heavy pumping caused water levels to decline to below sea level in the vicinity of the well, and seems to have temporarily induced seawater to move landward. This well has not been pumped since 1977 and was sealed in 1979.

The Monterey Shale which underlies the city of Seaside contains connate water. This connate water probably has an influence on the general ground-water quality by mixing with ground water in overlying formations to produce a mixture higher in dissolved solids than would otherwise occur. There have been problems with ground water along the Seaside fault (fig. 2), where well owners complain that water from their wells has the odor of hydrogen sulfide. Well 15S/1E-22C1, drilled in 1902 into the Monterey Shale along the Seaside fault, produced water with a sulfurous odor and a temperature of 120°F. Clark and others (1974) reported a sulfur hot spring in the same general area as the well. It produced water at 100°F. Local residents report that hot water was flowing at the surface as late as the 1940's. Regional geologic relations suggest that the Seaside fault probably cuts the Aromas Sand-Paso Robles Formation (fig. 4), and provides a path along which hot water could rise to the surface. The origin of the hot ground water is unknown.

Along the southern boundary of the study area, connate water from the adjacent Monterey Shale (fig. 2) mixes with ground water in the principal aquifers, causing an increase in dissolved solids. The area is not serviced by sewers, and septic systems could cause degradation of the ground water by increasing concentrations of dissolved solids and nitrate.

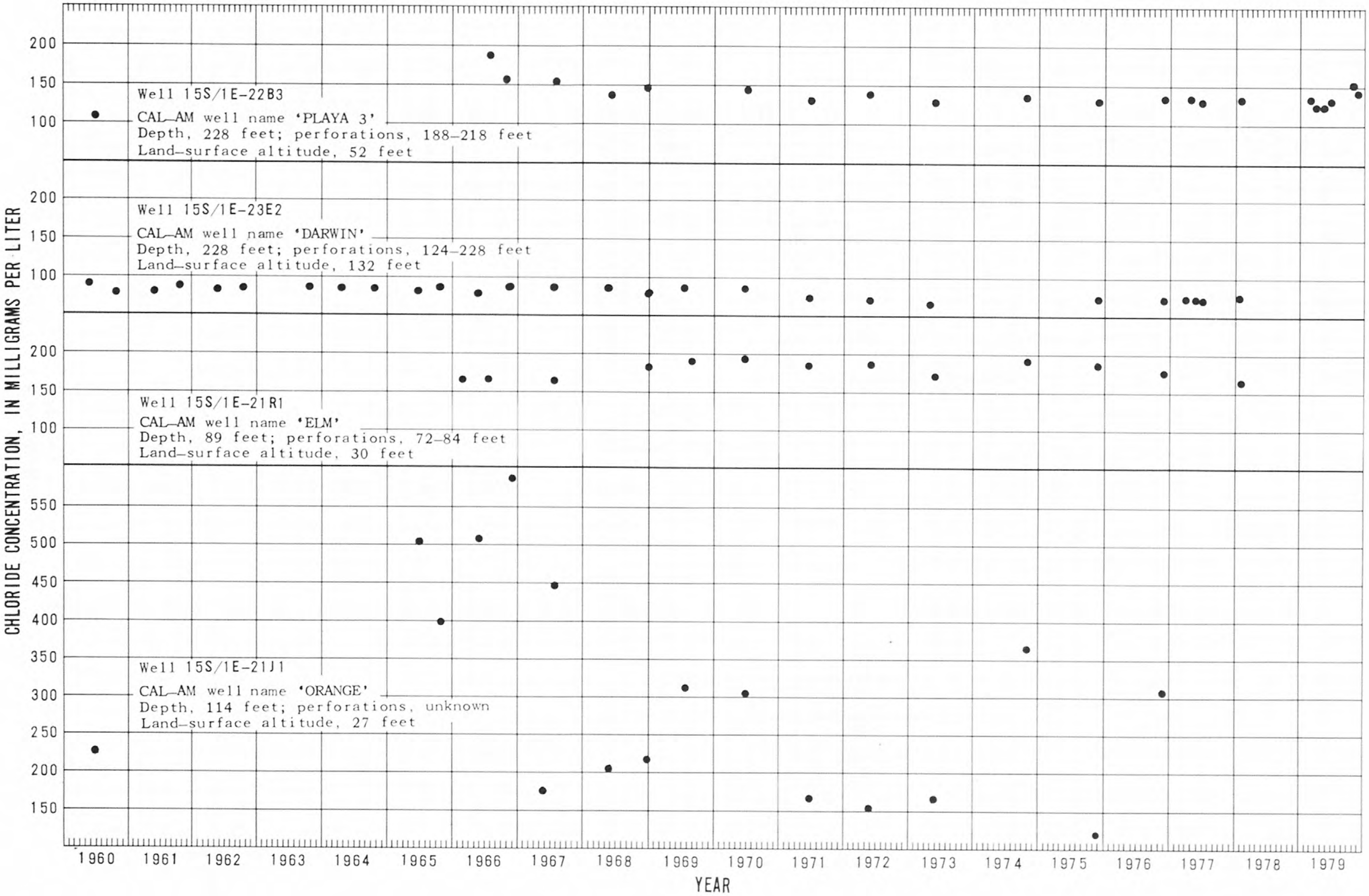


FIGURE 10.--Chloride concentration in ground water in wells 15S/1E-22B3, 23E2, 21R1, 21J1, 27J1, 27J2, 26D1 23D1, and 23B1.

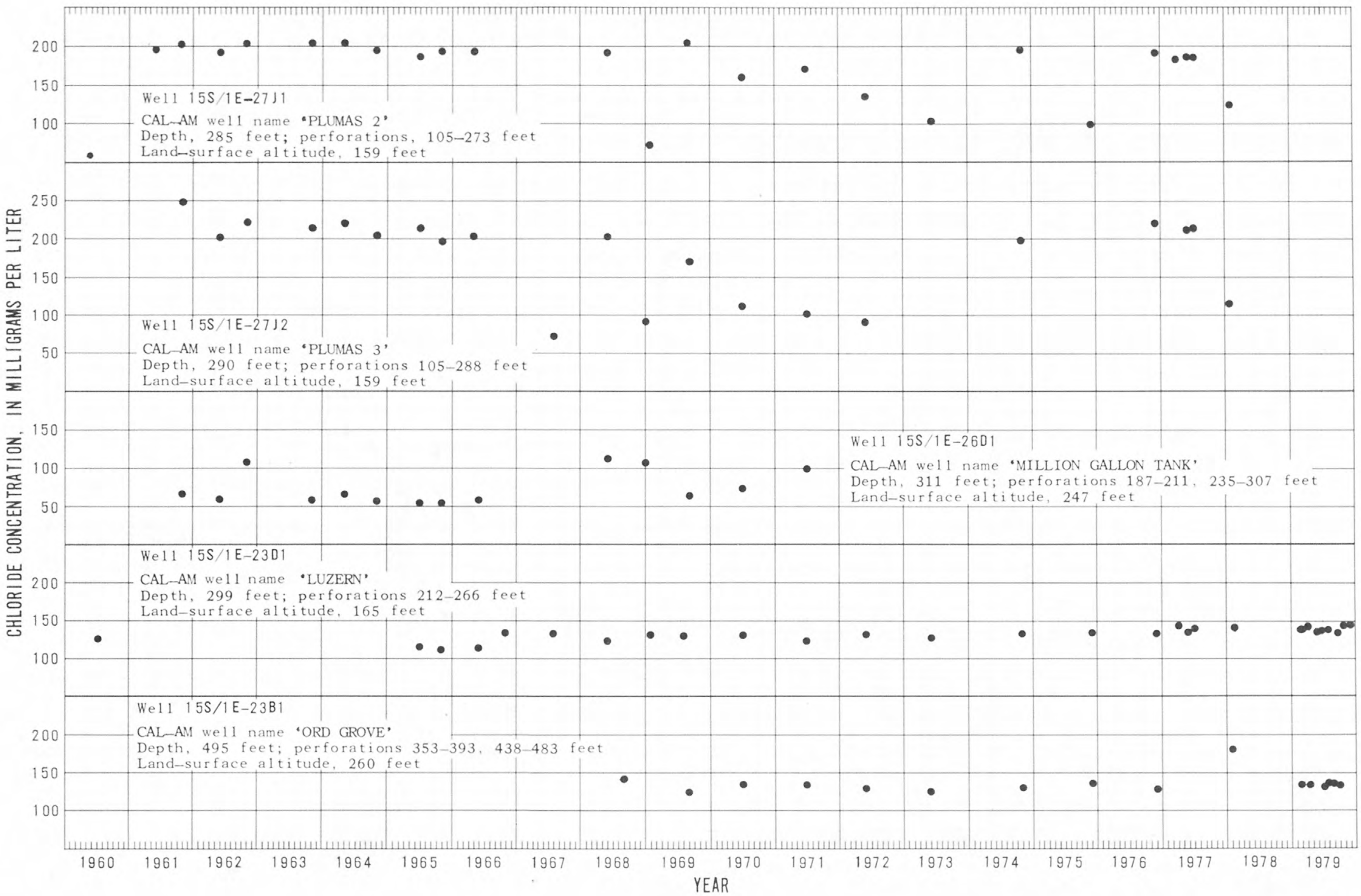


FIGURE 10.--Continued.

MONITOR-WELL NETWORK

The aim of an observation-well network in the Seaside area is to function as an early-warning system to detect adverse changes in the ground water and to alert those responsible for managing and protecting the ground-water resources. A minimum of two types of data could be collected: (1) Static water levels in wells, and (2) ground-water samples for water-quality analyses. Water levels in wells give an indication of the effects of pumping stresses on the ground-water system. They also can be used to monitor the status of ground-water storage--the amount in storage and whether it is increasing or decreasing. Ground-water sample analyses can be used to monitor the chemical character of the ground water.

A proposed network of 38 wells and water-quality characteristics to be measured or sampled are given in table 7. Locations of the wells are shown in figure 3. All the network wells have some historical water-level and chemical data available. Water levels could be measured and water samples collected in April and September each year. The September samples could be analyzed for major-ion concentration every fifth year, or whenever there is an indication that a quality change is occurring.

An observation well to monitor seawater intrusion is needed in 15S/1E-22E, in the coastal part of the Seaside area between the Seaside fault and Chupines fault. The well should have its perforations just above the contact with the Monterey Shale, and there should be a cement seal from the land surface to the top of the perforations.

SUGGESTED ADDITIONAL STUDIES

Geologic and hydrologic definitions are lacking along the east boundary of the city of Seaside and throughout the Fort Ord Military Reservation from the city of Seaside to Laguna Seca.

A north-south geophysical exploration program along the city boundary using seismic or gravity techniques may help delineate the shape and depth of the ground-water basin and the geologic structure that influences the occurrence and movement of ground water.

To determine the geologic and hydrologic conditions beneath Fort Ord at least three test wells would need to be drilled--one in 15S/1E-24F, one in 15S/1E-26R, and one in 15S/2E-31A. The wells would be drilled down to the Monterey Shale, probably at a depth between 700 and 1,000 ft. A detailed geologic log could be kept during drilling, and a geophysical log made when the well bottom is in Monterey Shale. Cores could also be collected and used to determine porosity, hydrologic conductivity, sorting, mineralogy, and so forth. The test wells could be cased so that water-level measurements could be made and water samples collected for chemical analyses. An aquifer pump test of each test well would provide data on the hydrologic properties of the reservoir system could be determined.

Consideration should be given to installing and maintaining at least three recording rain gages, sited so as to give areal coverage of the Seaside area.

TABLE 7. - Proposed observation-well network

Well No. (fig. 3)	Water levels	Type of data collected — Quality: Specific conductance (field determinations)	Chloride	Nitrate
15S/1E-15K1	x	x	x	
15P1	x	x	x	
21J1	x	x	x	
21R1	x	x	x	
22B3	x	x	x	
22C2	x	x	x	
22C3	x	x	x	
22D1	x	x	x	
22J2	x	x	x	
23B1	x	x	x	
23D1	x	x	x	
23E2	x	x	x	
23G1	x	x	x	
23P1	x	x	x	
26D1	x	x	x	
27J1	x	x	x	
27J2	x	x	x	
35J1	x	x	x	x
35J2	x	x	x	x
16S/1E- 1C1	x	x	x	x
1C2	x	x	x	x
1E1	x	x	x	x
1J1	x	x	x	x
16S/2E- 3A1	x	x	x	x
3G1	x	x	x	x
3H1	x	x	x	x
3J1	x	x	x	x
3J2	x	x	x	x
4H1	x	x	x	x
4L1	x	x	x	x
5G1	x	x	x	x
5L2	x	x	x	x
5M3	x	x	x	x
5M4	x	x	x	x
5M7	x	x	x	x
6F1	x	x	x	x
6K1	x	x	x	x
6M1	x	x	x	x

SUMMARY

1. The Santa Margarita Sandstone, Paso Robles Formation, Aromas Sand, and the older dunes of late Tertiary and Pleistocene age are the principal water-bearing units in the Seaside area. They form a heterogeneous mixture of gravel, sand, silt, and clay more than 1,000 ft thick. All are permeable and yield moderate quantities of water to wells.

2. The Monterey Shale and granitic rocks form the bottom and southern boundaries of the ground-water reservoir.

3. Recharge to the ground-water reservoir occurs as infiltration of rain, subsurface inflow from adjacent areas, and seepage from streams. Infiltration of precipitation probably accounts for most of the total recharge.

4. Ground water moves from the Laguna Seca area westward toward Monterey Bay.

5. The amount of usable ground water in storage in the Seaside area in the autumn of 1979 was estimated to be 730,000 acre-ft. In the coastal part of the study area from Monterey Bay inland 1.5 mi, 9,000 acre-ft were stored above sea level.

6. The ground-water yield, based on data from 1962 through 1979, for the seaward part of the Seaside area is estimated to be more than 2,000 acre-ft/yr but less than 3,000 acre-ft/yr. The long-term yield of the total Seaside area is estimated to be between 6,400 and 7,700 acre-ft/yr. During 1962 through 1979, average pumpage of ground water in the seaward part of the area exceeded the average recharge, and the amount of ground water in storage decreased.

7. Most of the Seaside area is classified as having a good-to-fair recharge potential. The areas with a poor recharge potential are at the east end and along the south boundary of the study area.

8. Ground water in the Seaside area is suitable for most uses; however, its dissolved-solids content and hardness are generally objectionably high for domestic use, and, locally, dissolved iron is a problem. Seawater intrusion poses the major threat of water-quality degradation. Potential for water-quality degradation also exists from mineralized connate water and septic systems.

9. An observation-well network could be established to function as an early warning system to alert those responsible for managing and protecting the ground-water resource to adverse changes in that resource.

10. Geophysical exploration in the vicinity of the city of Seaside, drilling and testing of wells on Fort Ord, and the installation of rain gages could supply much needed geologic and hydrologic data for the Seaside area.

California Department of Health, 1973, Law and regulations relating to domestic water supplies, quality and monitoring: Health and Safety Code, Div. 5, pt. 1, chap. 7, secs. 4026-4029, and Title 17, California Administrative Code, pt. 1, chap. 5, subchap. 1, group 1, 12 p.

California Department of Water Resources, 1963, Vegetative water use studies, 1954-1960: California Department of Water Resources Bulletin 113, 121 p.

_____ 1967, Vegetative water use: California Department of Water Resources Bulletin 113-2, 82 p.

_____ 1974, Zone 11 investigation, Carmel Valley and Seaside ground water basins, Monterey County: San Joaquin District, 25 p.

_____ 1975, Vegetative water use in California, 1974: California Department of Water Resources Bulletin 113-3, 104 p.

Clark, J. C., Dibblee, T. W., Jr., Greene, H. G., and Bowen, O. E., Jr., 1974, Preliminary geologic map of the Monterey and Seaside 7.5 minute quadrangles, Monterey County, California, with emphasis on active faults: U.S. Geological Survey Miscellaneous Field Studies Map MF-577.

Clayton, C. J., 1978, Review of studies and reports for supplemental water supply for Zone 11: Monterey County Flood Control and Water Conservation District, Zone 11, 44 p.

Collins, F. T., and Thorup, R. R., 1975, Final report on the water wells investigation in the vicinity of the Naval Postgraduate School, California: Berkeley, California, various pagination.

Dibblee, T. W., Jr., 1973, Geologic map of the Salinas Quadrangle, California: U.S. Geological Survey Open-File Map, scale 1:62,500.

Dibblee, T. W, Jr., and Clark, J. C., 1973, Geologic map of the Monterey Quadrangle, California: U.S. Geological Survey Open-File Map, scale 1:62,500.

Earth Metrics, Incorporated, 1977, Aquifer recharge case study technical report: Prepared for Association of Monterey Bay Area Governments, 68 p.

Estrada, D. C., 1976, Soil handbook for Santa Cruz County, California: U.S. Soil Conservation Service, 40 p.

Evenson, R. E., Wilson, H. D., Jr., and Muir, K. S., 1962, Yield of the Carpenteria and Goleta ground-water basins, Santa Barbara County, California, 1941-1958: U.S. Geological Survey open-file report, 112 p.

Greene, H. G., 1970, Geology of southern Monterey Bay and its relationship to the ground-water basin and salt water intrusion: U.S. Geological Survey open-file report, 50 p.

_____ 1977, Geology of the Monterey Bay Region: U.S. Geological Survey Open-File Report 77-718, 347 p.

Greene, H. G., Lee, W. H. K., McCulloch, D. S., and Brabb, E. E., 1973, Fault map of the Monterey Bay Region, California: U.S. Geological Survey Miscellaneous Field Studies MF-518.

Johnson, E. E., Incorporated, 1966, Ground water and wells: St. Paul, Minnesota, 440 p.

Lowney, J. V. and Associates, 1977, Observations and testing of test well construction, La Mesa Village, NPGS, Monterey, California: Palo Alto, California, various pagination.

McKee, J. E., and Wolf, H. E., 1963, Water quality criteria (2d ed.): California Water Resources Control Board, Pub. No. 3-A, 548 p.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geological Survey Water-Supply Paper 489, 321 p.

Metcalf and Eddy Engineers, 1976, Land application of wastewater in the Salinas-Monterey peninsula area: Palo Alto, California, various pagination.

Monterey County Surveyors, Incorporated, and Korestsky King Associates, Incorporated, 1977, Monterey County master drainage plan, Canyon Del Rey watershed, drainage and erosion: Monterey, California, various pagination.

Monterey Peninsula Water Management District, 1979, Report to the California Coastal Commission, re available water supply and demand, Monterey Peninsula, California: Monterey, California, various pagination.

Muir, K. S., and Johnson, M. J., 1979, Classification of ground-water recharge potential in three parts of Santa Cruz County, California: Menlo Park, Calif., U.S. Geological Survey Open-File Report 79-1065, 4 p.

Thorup, R. R., 1971, Groundwater report for Toro Water Committee: Monterey, California, 10 p.

______1974, Groundwater survey of Laguna Seca Ranch, Salinas-Monterey Highway 68, Monterey County, California: Monterey, California, 12 p.

______1976, Groundwater study of Highway 68: Monterey, California, 57 p.

U.S. Department of Agriculture, Soil Conservation Service, 1978, Soil survey of Monterey County, California: 228 p.

U.S. Department of the Army, Corps of Engineers, 1975, Hydrogeology of Fort Ord and vicinity, Monterey County, California: Sacramento District, 39 p.

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