ARTIFICIAL RECHARGE IN THE NORTHERN PART OF CHINO GROUND-WATER BASIN, UPPER SANTA ANA VALLEY, CALIFORNIA

By J. H. Koehler

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 82-4122

Prepared in cooperation with the

CALIFORNIA DEPARTMENT OF WATER RESOURCES

June 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, SECRETARY

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Federal Building, Room W-2235
2800 Cottage Way
Sacramento, Calif. 95825

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25424, Federal Center
Denver, Colorado 80225
Telephone: (303) 234-5888

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

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

Multiply	By	To obtain
acres	0.4047	hm^2 (square hectometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
ft/d (feet per day)	0.3048	m/d (meters per day)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
µmho/cm at 25°C (micromhos per centimeter at 25° Celsius)	1.000	µS/cm at 25°C (microsiemens per centimeter at 25° Celsius)

ALTITUDE DATUM

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

ARTIFICIAL RECHARGE IN THE NORTHERN PART OF CHINO GROUND-WATER BASIN, UPPER SANTA ANA VALLEY, CALIFORNIA

By J. H. Koehler

ABSTRACT

This study was made to help management design and implement a recharge-recapture system for State Water Project water in Chino Basin. Nine test holes were drilled in the study area. Analyses of data from these test holes and drillers' logs of water wells indicate the presence of clay deposits. The clay deposits cannot be correlated between holes, which indicates that they are discontinuous beds or lenses. The existence and location of two ground-water barriers, barrier "J" and Red Hill barrier, have been postulated in previous reports. Water-level data indicate that barrier "J" is probably not effectively stopping the movement of ground water. Data are insufficient to determine the effectiveness of the Red Hill barrier.

Five existing recharge facilities in the study area were previously constructed to control floodflow. Infiltration tests at three of the facilities indicate infiltration rates of 2.6 feet per day at Day Creek, 2.0 feet per day at East Etiwanda, and 1.3 feet per day at San Sevaine. A total of about 9,000 acre-feet of State Water Project water was recharged between June 1980 and July 1981. Rising water levels in wells indicate that recharge water is percolating down to the water table.

INTRODUCTION

Purpose and Scope

The purpose of this study was to evaluate the geohydrologic characteristics that influence sustained artificial recharge and to determine long-term infiltration rates in the northern part of Chino ground-water basin. Results of this study will help management to design and implement a recharge-recapture system in Chino Basin.

Nine test holes were drilled, long-term infiltration tests were made, and drillers' logs and water-level data were evaluated to determine the probable effects of recharging the ground-water basin. The study was concentrated in the northern part of Chino Basin, where recharge is proposed.

Location and Description of Area

The Chino ground-water basin is an area of about 230 mi^2. It is part of the upper reaches of the Santa Ana River drainage system which is commonly known as the upper Santa Ana Valley. Parts of the basin are in Los Angeles, San Bernardino, and Riverside Counties. The basin is bounded on the east by the Rialto-Colton fault; on the southeast by the Jurupa Mountains and Santa Ana River; on the southwest by the Puente Hills; on the northwest by the San Jose fault; and on the north by the San Gabriel Mountains (fig. 1).

Most of the effort for this study was concentrated in the northern part of the basin, north of Foothill Boulevard (fig. 2).

Acknowledgments

This report was prepared by the U.S. Geological Survey in cooperation with California Department of Water Resources (DWR) as part of an investigation of artificial recharge potential in southern California ground-water basins. Special thanks are given to the personnel of DWR and Metropolitan Water District of Southern California, who collected data and did the fieldwork, and to the water agencies, land owners, well drillers, and individuals who also supplied data for this study.

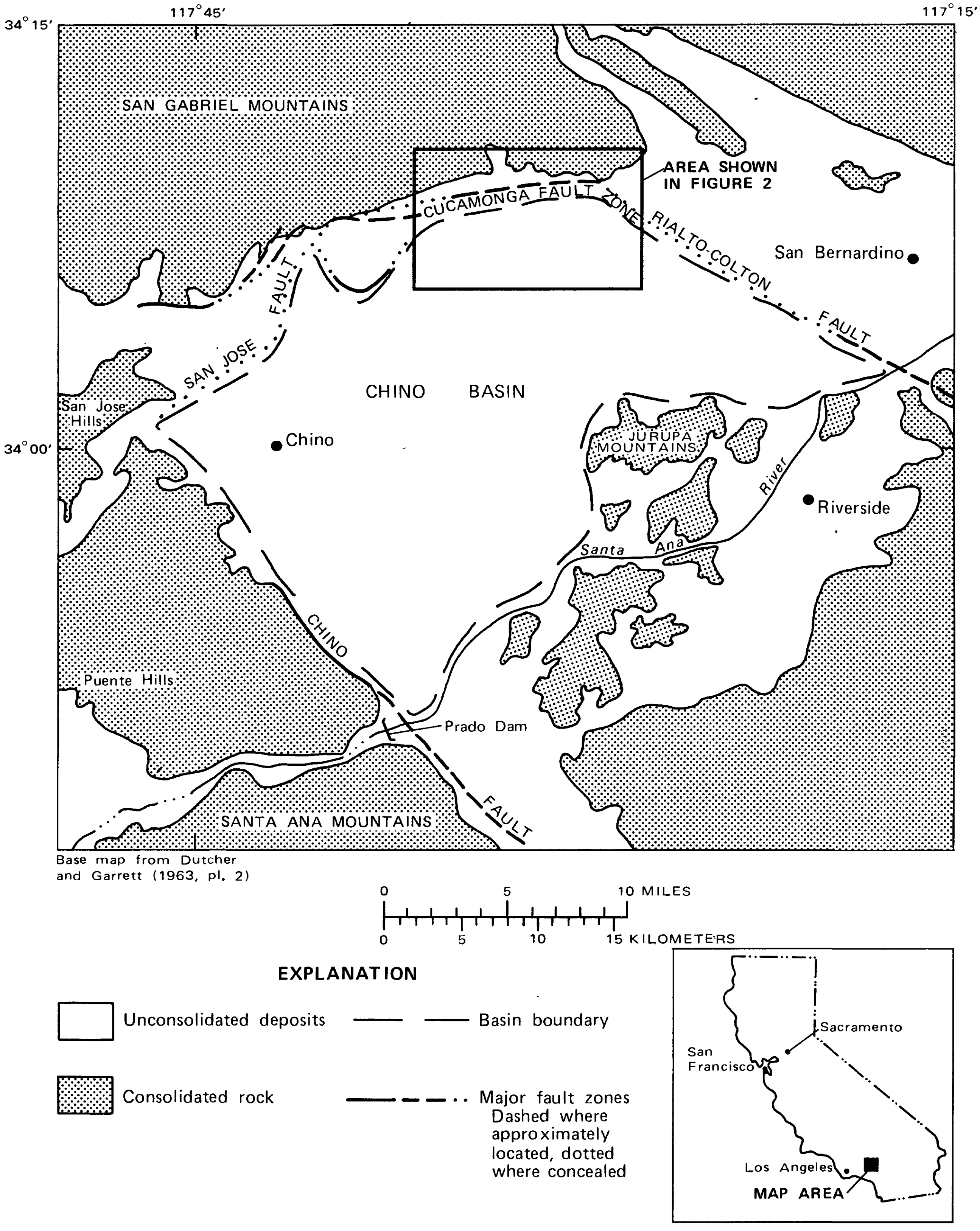


FIGURE 1. – Chino Basin and physiographic features of study area.

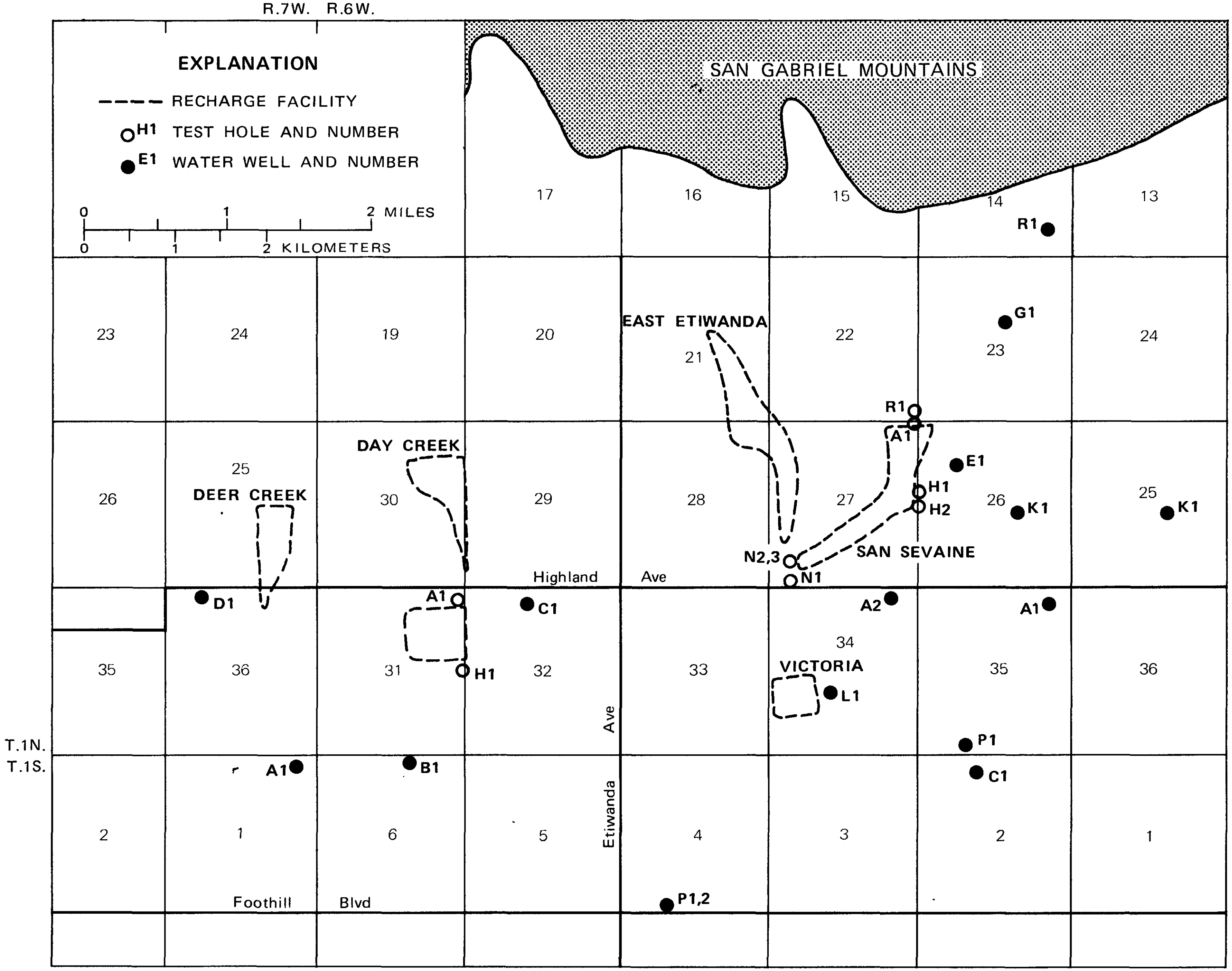
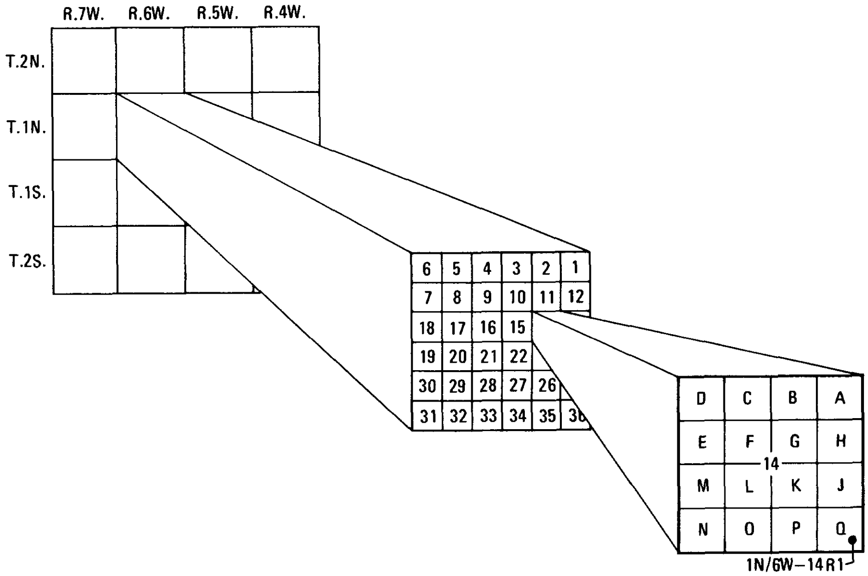


FIGURE 2. — Test holes, water wells, and recharge facilities in study area.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. As shown by the diagram, that part of the number preceding the slash, as in 1N/6W-14R1, indicates the township (T. 1 N.); the number following the slash indicates the range (R. 6 W.); the number following the hyphen indicates the section (sec. 14); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision. All wells mentioned in this report are referred to the San Bernardino base line and meridian.



GEOLOGY

The land surface of Chino Basin slopes southward from the foot of the San Gabriel Mountains to the Santa Ana River bottom lands. North of the Chino Basin the crest of the San Gabriel Mountains rises to an altitude of about 10,000 feet. The altitude of the basin ranges from 2,000 to 2,500 feet at the foot of the mountains and slopes down to about 500 feet near the Santa Ana River.

The present landforms are chiefly a result of geologic activity in Pleistocene and Holocene time. Crustal blocks of consolidated rocks that form the San Gabriel and Santa Ana Mountains as well as the Puente Hills have undergone progressive uplift with accompanying erosion. The consolidated rocks consist of metamorphic and igneous formations, and in this report they are not considered water bearing. The Chino Basin is an area of depression that has received a thick accumulation of erosional products from the surrounding landmasses. The thickness of the alluvial fill ranges from about 300 to 3,000 feet (Shellooe, 1979).

The alluvium consists of boulders, gravel, sand, silt, and clay. Coarse material, such as sand and gravel, transmits water freely and generally has the capacity to transmit more water than is able to enter the ground at the surface. Fine material, such as silt and clay, transmits water at a much slower rate and is generally considered to retard the movement of ground water. The logs of several water wells and test holes (fig. 2) were analyzed to determine the existence, type, and extent of clay deposits in the area. Figure 3 is a graphic representation of the lithology in the upper 500 feet of eight water wells in the northern part of the basin. Clay deposits exist at each of the well sites and constitute the predominant lithology at several of the sites. Clay and silt deposits cannot be easily correlated between well sites, indicating that they probably occur as discontinuous beds or lenses.

Nine test holes were drilled in the vicinity of the San Sevaine and Day Creek recharge facilities (fig. 2). Test hole 1N/6W-27N1 is 500 feet deep, and the other test holes are about 100 feet deep. Electric logs and natural gamma log were run in test well 27N1 (fig. 4), and natural gamma logs were run in seven shallow test holes (fig. 5). As shown in the graphic representation of the driller's log of well 27N1, clay and silt compose the predominant lithology from a depth of 28 feet to the bottom of the hole. The shallow test holes, except for 1N/6W-27N2 and N3, have little or no clay in the upper 20 to 30 feet but below this level contain considerable clay deposits. The natural gamma logs of test wells 27N2 and N3 do not show clay near the surface, indicating that the clay deposits may be thin. As in the water wells, lithologic correlation between test holes is not evident, again indicating discontinuous beds or lenses.

Faults in unconsolidated alluvium affect the suitability of an area as a recharge site because they commonly act as barriers that restrict the lateral movement of ground water. Figures 1 and 6 show the location of several faults in the study area. The Chino fault trends southeastward along the margin of the Puente Hills and Santa Ana Mountains. The Chino fault is about 15 miles downgradient from the recharge area and should have no effect on recharge. The Rialto-Colton fault, marking the northeast boundary of the Chino Basin, is upgradient and east of the recharge facilities and thus has no direct effect on recharge rates, although it may restrict underflow into Chino Basin from areas to the northeast. The San Jose fault, the northwest boundary of the basin, may restrict underflow into the basin from the northwest. The Cucamonga fault zone is a series of faults that trend east-west near the foot of the San Gabriel Mountains. This fault zone is north of the recharge facilities and should have no effect on recharge. The Red Hill barrier (fig. 6) is south of the Deer Creek recharge facility and trends northeasterly through the northern part of the Day Creek recharge facility. This barrier could impede the southward movement of recharge water from the Deer Creek and Day Creek recharge facilities. Dutcher and Garrett (1963) postulated a northeast-trending barrier, barrier "J," to the south of the present recharge facilities. This barrier could have a significant effect on sustained recharge by not allowing recharge water to move southward into the main part of Chino Basin.

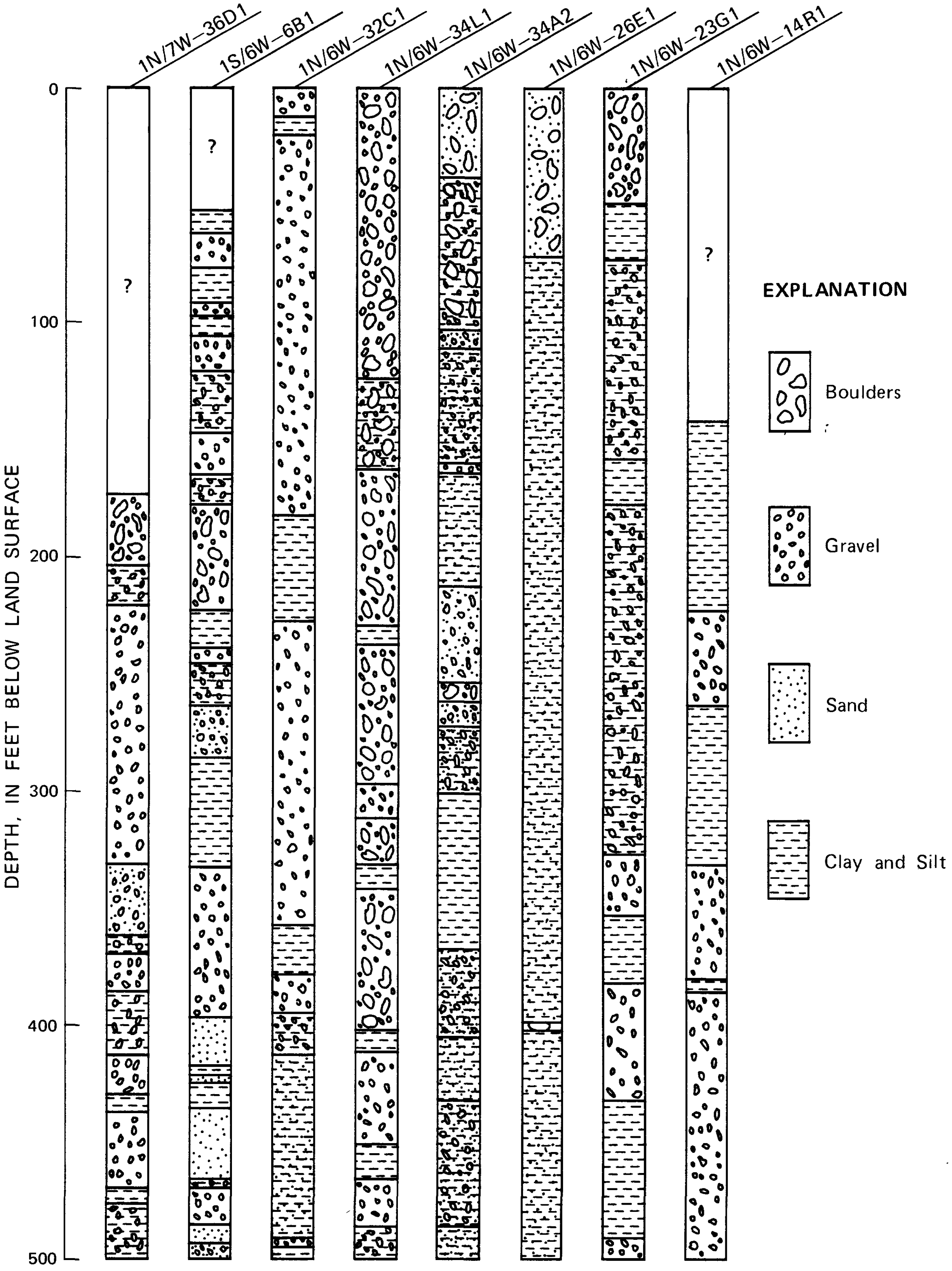


FIGURE 3. – Graphic representation of lithology at selected well sites.

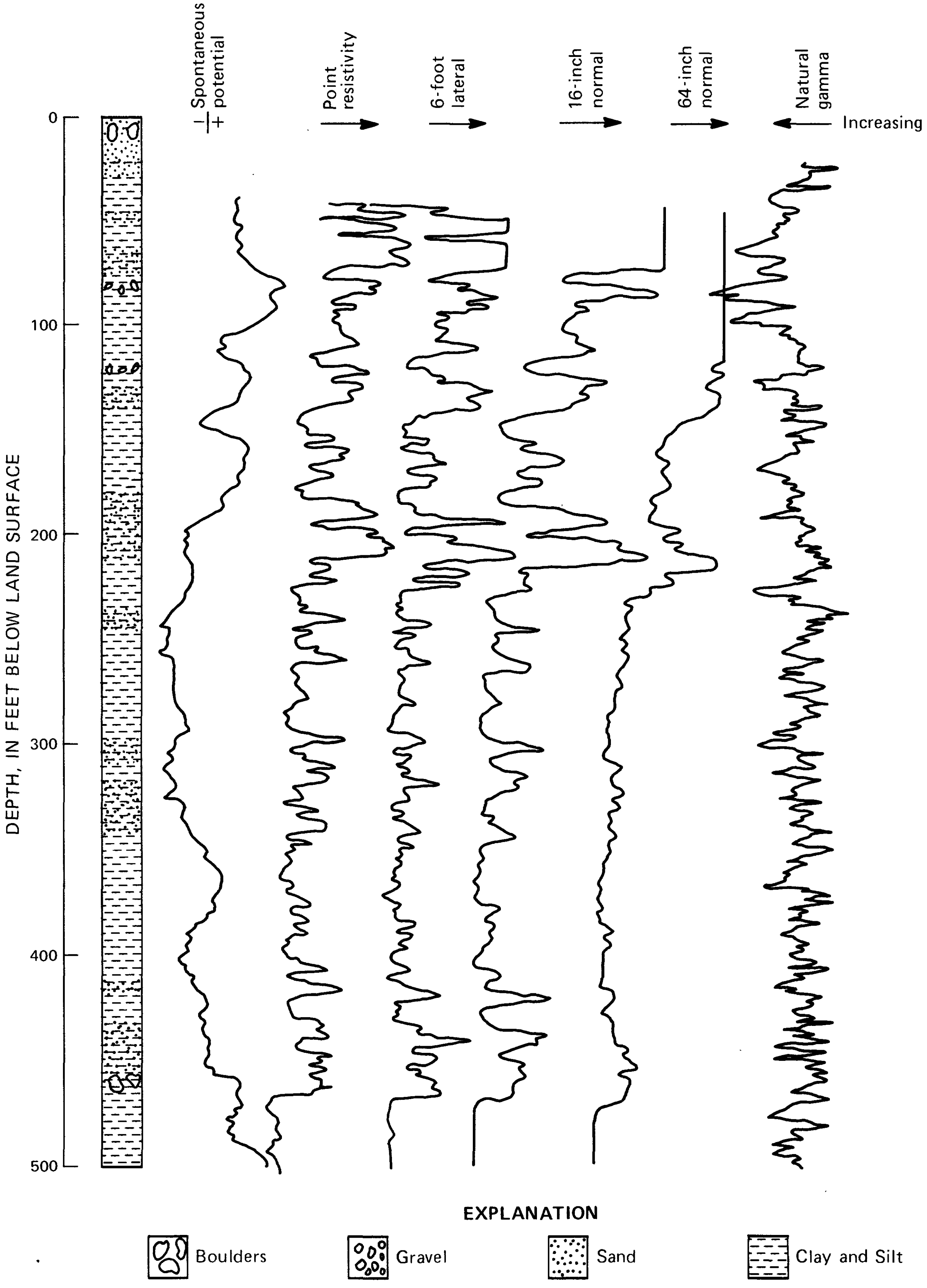


FIGURE 4. – Graphic representation of lithology and geophysical logs of well 1N/6W–27N1.

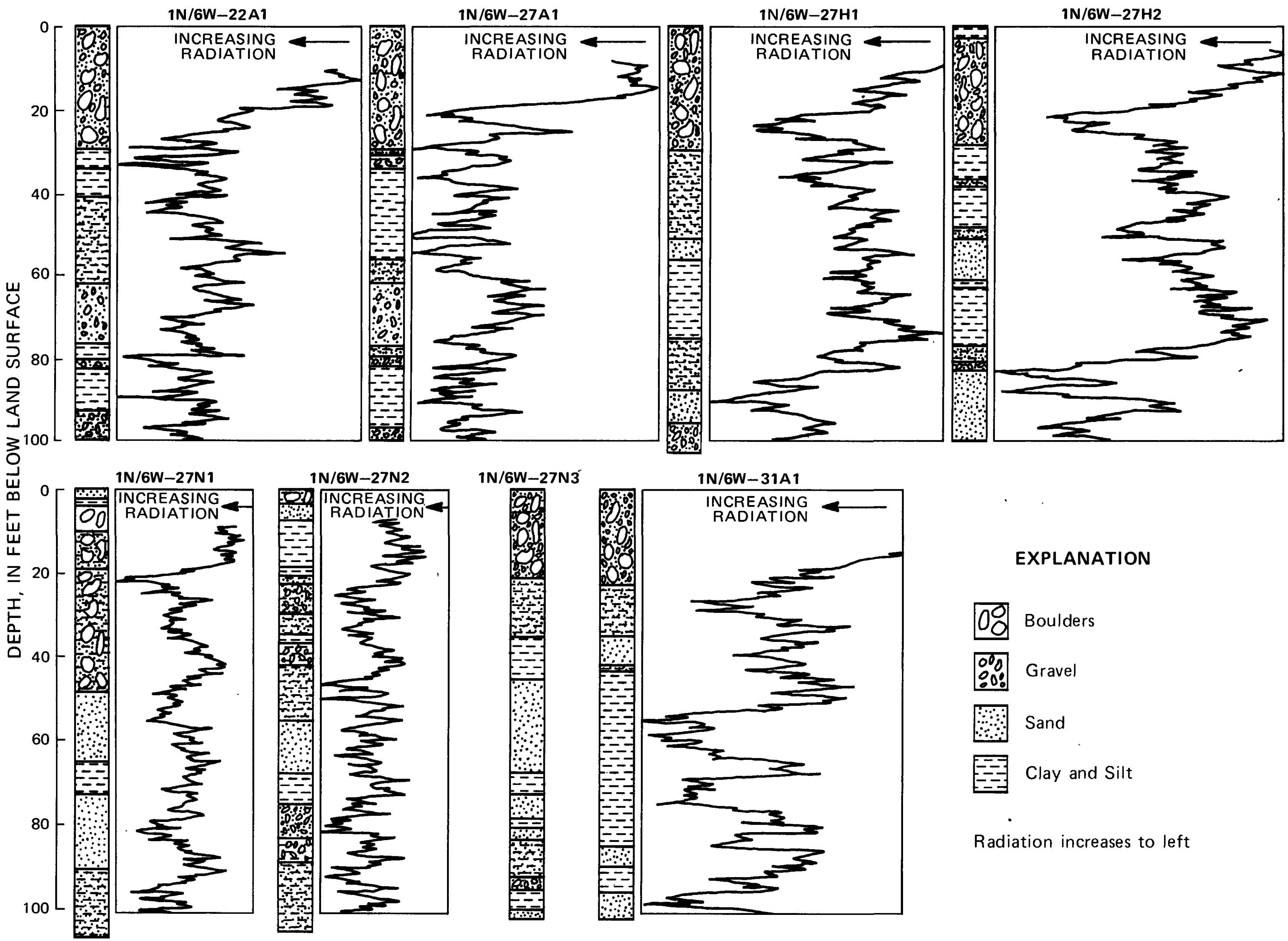


FIGURE 5. – Graphic representation of lithology and natural gamma logs of test holes.

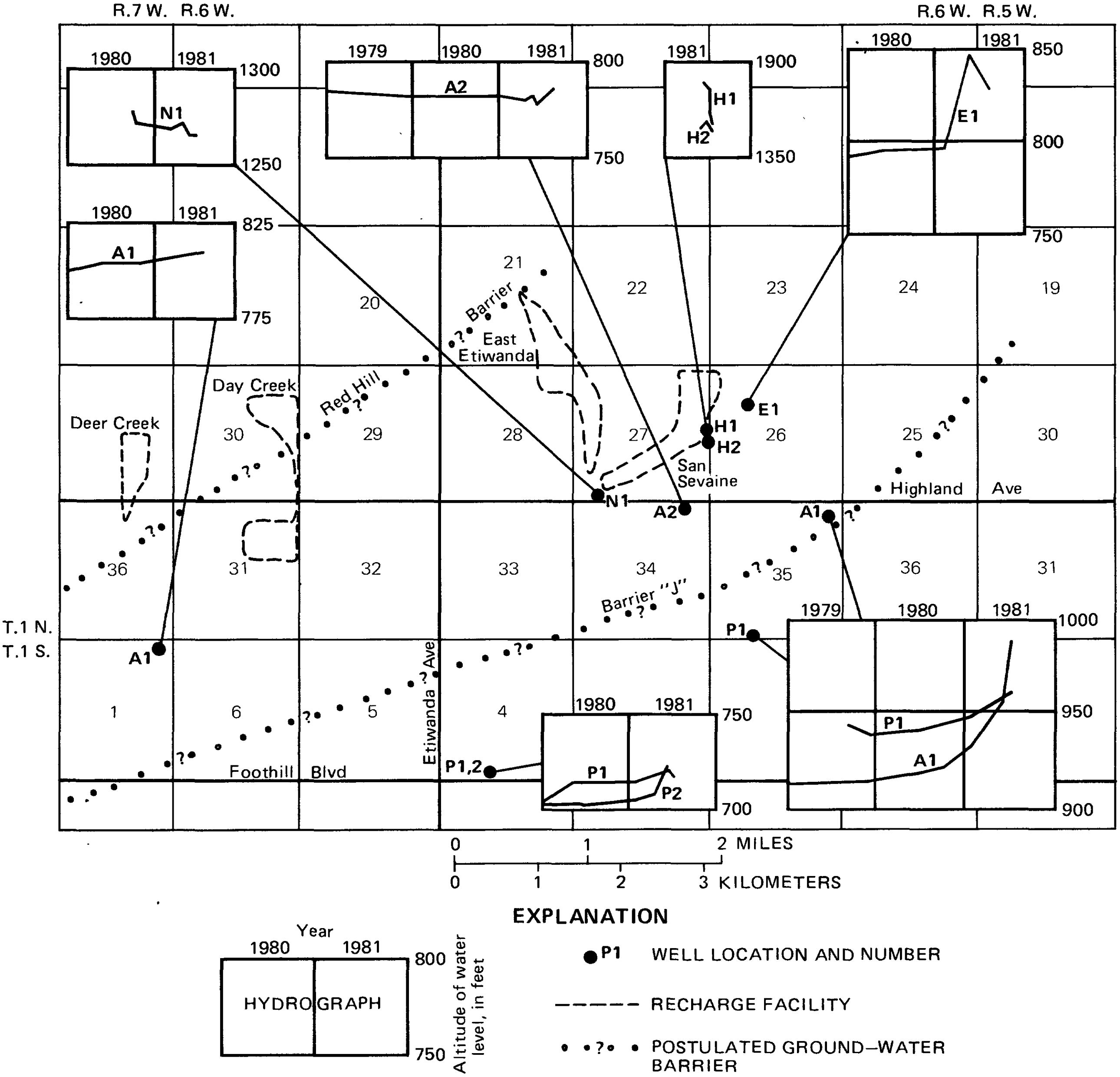


FIGURE 6. – Ground-water barriers and hydrographs of selected wells.

HYDROLOGY

Precipitation

Precipitation in the area is seasonal. As is typical in southern California, little precipitation occurs during the period July through September. Mean annual precipitation ranges from 12 inches in the extreme southern part of the basin to 25 inches in the northern part (Rantz, 1969). Mean annual precipitation is as much as 40 inches in the southern flank of the San Gabriel Mountains, which drains into the basin. Mean annual precipitation at a rain gage in San Bernardino is 16.11 inches (National Oceanic and Atmospheric Administration). Table 1 shows the annual precipitation in San Bernardino from 1971 through May 1981.

Most of the precipitation that falls on the basin proper evaporates or is consumed by vegetation; the remainder percolates into the ground. Runoff from the surrounding mountain slopes within the watershed enters the basin as surface flow, much of which seeps into the ground through stream channels and manmade surface diversions. During severe floods some of the surface flow reaches the Santa Ana River.

TABLE 1. - *Precipitation at San Bernardino*

[Data from National Oceanic and Atmospheric Administration]

Year	Precip-itation (inches)	Year	Precip-itation (inches)	Year-month	Precip-itation (inches)
1971	13.46	1976	15.07	1981-Jan.	4.33
1972	6.85	1977	14.91	Feb.	.88
1973	14.50	1978	30.83	Mar.	2.69
1974	15.06	1979	16.46	Apr.	1.08
1975	11.93	1980	26.57	May	.19

Ground Water

Ground-water recharge to the Chino Basin occurs by direct infiltration of precipitation on the basin floor, by infiltration of surface flow, and by underflow of ground water from adjacent basins. Water-level contours for 1945 (Garrett and Thomasson, 1949) show that ground water moved from all parts of the basin toward Prado Dam in the southern part of the basin. The general direction of ground-water flow has remained the same except where pumping has created local ground-water depressions (Shellooe, 1979). The ground-water gradient is generally steeper in the northern part of the basin than in the south.

Depth to water ranges from more than 500 feet below land surface in the northern part of the basin to near land surface in the southern part. Historical measurements indicate a relatively constant water-level decline from the early twenties to the midthirties. From the midthirties to 1945 water levels remained constant or recovered slightly. From 1945 to 1979 water levels have continued to decline. Generally, the declines have been greater in the central and northern parts of the basin.

Shellooe (1979, p. 12) reported about 8.2 million acre-feet of water are in storage in the basin, an additional 1.2 million acre-feet of water could be stored in the basin, which would raise the water level to the 1940 level.

The quality of ground water in the Chino Basin is generally good. The dissolved-solids concentration ranges from about 200 mg/L (milligrams per liter) in the northern part of the basin to about 600 mg/L in the southern part. The increase in dissolved solids toward the south probably results from the use and reuse of the water. Table 2 shows the chemical quality of water from selected wells in the study area and the chemical quality of water that is being recharged into the system.

TABLE 2. - *Chemical analyses of recharge water and water from selected wells*

[Results are shown in milligrams per liter except specific conductance (in micromhos per centimeter at 25°C), pH, and percent sodium. Well depth is in feet]

	Recharge water	1S/6W-2C1		1S/6W-4P2	1N/6W-25K1	1N/6W-26K1	1N/6W-27H1	1N/6W-27N1	
Date	2-11-81	2-4-81	5-14-81	3-9-61	12-16-46	12-16-46	5-14-81	2-4-81	5-14-81
Well depth	--	685	685	820	--	--	100	500	500
Silica	14.2	32	--	28	--	--	15	29	--
Calcium	19	42	--	35	47	76	60	31	--
Magnesium	10	7	--	6.0	8.0	15	12	6.0	--
Sodium	33	13	--	16	9.0	17	13	12	--
Potassium	1.9	1.7	--	2.0	2.0	--	2.4	1.4	--
Bicarbonate	81	166	--	143	160	226	122	113	--
Carbonate	0	0	--	0	2.0	--	0	0	--
Sulfate	32	15	--	25	30	76	--	21	--
Chloride	39	7.0	4.0	9.0	5.0	11	48	5.0	5.0
Fluoride	.11	.24	--	--	.4	--	.16	.16	--
Nitrate as NO_3	3.75	10.7	11.4	3.5	5.0	--	8.5	8.3	7.0
Dissolved solids	193	212	--	186	198	307	--	170	--
Hardness as $CaCO_3$	89	134	138	--	--	--	100	102	--
Noncarbonate hardness	23	0	--	--	--	--	9.7	9	--
Percent sodium	44	17	--	--	--	--	--	20	--
Specific conductance	347	309	319	290	335	460	465	243	244
pH	8.3	8.0	7.9	7.0	8.3	8.0	7.8	8.2	8.5

ARTIFICIAL RECHARGE

Recharge is the replenishment of ground water by natural or artificial means. Natural recharge is the percolation of surface water into the ground-water reservoir through soil, stream channels, or lakebeds under natural conditions. Artificial recharge may be defined as the practice of deliberately increasing the amount of water that enters a ground-water reservoir, which can be done by admitting or diverting water into basins, ditches, or furrows; extending the time in which water remains in natural channels; applying excess water for irrigation; diverting water into pits or other excavations of shallow depth; or injecting water into a ground-water reservoir through wells or shafts.

Artificial recharge in the study area began in the early 1900's in the form of spreading and impounding local storm runoff. Moreland (1972) discussed the historical development of artifical recharge in the area in more detail.

Existing Recharge Facilities

The five recharge facilities in the study area are Deer Creek, Day Creek, East Etiwanda, San Sevaine, and Victoria (fig. 2). These facilities, constructed for flood control, capture local runoff and allow it to percolate into the ground. The Victoria facility consists of one large basin, and the other facilities consist of a series of basins at successively lower altitudes with spillways between them.

Floodflow may deposit silt and other debris in the recharge basins, causing a severe reduction in percolation rates. Once fine-grained material has covered the basins, they may have to be scraped and graded to restore percolation rates. The scraping and grading occasionally change the configuration of the basin and grade of the basin surface in relation to the spillway, resulting in a change in total potential wetted area. When these recharge facilities do not contain water from local storm runoff, they could be used for artificially recharging excess State Water Project water.

Infiltration Rates

In general, infiltration rates depend on the ability of the surface soil to accept water and the subsurface geologic units to transmit the water to the water table. The ability of the surface soil to accept water depends mainly on the intrinsic permeability of the soil, but several other variables also control infiltration rates:

1. Silt derived from inflowing water, bank erosion, and wind settles to the bottom of the recharge basin. The silt may move into the soil matrix, plugging the pore space, or form a layer of fine-grained material over the soil surface.
2. Biological clogging may occur as bacterial growth within the soil matrix or as algal growth over the soil surface.
3. Chemical clogging may occur from chemical precipitates or through chemical interaction of recharge water and soil. Recharge water containing a high percent sodium may cause reduced permeability in clayey soils through deflocculation.
4. Compaction or rearrangement of soil particles due to submergence may cause a significant reduction in permeability.
5. Air trapped by downward moving water reduces available pore space, thereby reducing infiltration rates until the air escapes.
6. Burrowing animals (worms, gophers, and insects) and root channels formed by decaying root systems may greatly increase permeability.

These variables can be regulated to a large degree by treatment of the recharge water and proper management of the surface of the recharge facility.

Long-term or sustained recharge is controlled by surface conditions and also by subsurface geologic and hydrologic conditions. After recharge water enters the soil, it must move down and away from the recharge site to allow more water to enter at the surface. If recharge water is unable to move away from the recharge site, the ground in the vicinity of the recharge site will become waterlogged, so that recharge decreases or stops.

Zones of low permeability control the movement of recharge water down and away from the recharge site. The zones of low permeability are generally clay layers or lenses and fault barriers. As downward-percolating water encounters a clay layer, its movement is retarded or stopped. A saturated mound will form above the clay layer, and the water will begin to move laterally. If the clay layer is discontinuous, such as a lens, or is dissected from erosion, the water will move laterally until it comes to the end of the clay layer and then continue downward. A ground-water barrier like a fault inhibits the lateral movement of water, forming a zone of saturation behind the barrier that backs up to the recharge site and eventually impedes or stops recharge.

For this study infiltration tests were made at the Day Creek, East Etiwanda, and San Sevaine facilities in May 1981. The water was from the Rialto pipeline and was therefore virtually free of sediment. Water for the San Sevaine facility was transported from the outlet about 0.3 mile to the facility in an unlined channel; consequently, it may have contained some silt when it entered the facility.

Each of the facilities tested was kept full for at least a month before the test was made. This was to insure that a fairly stable rate of infiltration had occurred. At the time of the test the inflow water was shut off and the water-level decline in each basin within the facility was observed and recorded. Table 3 shows the results of these tests.

Artificial recharge using State Water Project water began in June 1980. Prior to that time the recharge facilities occasionally contained water from local storm runoff. Records are not available of the amount of storm runoff that was recharged. Table 4 shows the amount of State Water Project water delivered to the recharge facilities from June 1980 to July 1981. In 1980 only the combined delivery of water for all three facilites was monitored. In March 1981 individual metering devices were installed at the Day Creek and East Etiwanda facilities, and deliveries to San Sevaine were calculated from the difference. From June 1980 to July 1981 a total of about 9,000 acre-feet of water was delivered to the recharge facilities. Except for a slight amount lost to evaporation, probably all the delivered water was recharged into the basin.

Water-Level Change in Observation Wells

For this study monthly water-level observations were made in several wells and test holes from November 1979 through August 1981. Hydrographs for these wells are shown in figure 6.

Test well 1N/6W-27N1 was drilled to a depth of 500 feet in September 1980 and cased with 2-inch plastic pipe, perforated from 450 to 500 feet. The water level in 27N1 was 123 feet below land surface when it was drilled and declined to 133 feet below land surface by August 1981. The water-level data for 27N1 are questionable because the resistivity logs (fig. 4) indicate static water level at about 470 feet below land surface, which is about where it should be, judging from other water levels in the vicinity. An artesian head is probably not responsible for the shallow water level, because artesian head is absent from other wells in the vicinity. The shallow water level is probably due to water left in the well when the drilling mud was washed out. For this reason, the water-level data shown in figure 6 and the water-quality data shown in table 2 are questionable. The water in this well would have to be sampled after the well has been pumped or bailed out to a depth of about 500 feet and then allowed to recover in order to substantiate the water-level and water-quality data.

TABLE 3. - *Infiltration tests at three recharge facilities*

Basin No.	Size (acres)	Percolation rate (ft/d)	Condition of basin
		Day Creek Recharge Facility	
1	0.45	1.6	Good; some algal growth.
2	.47	2.3	Excellent; some silt and dried algae.
3	.45	2.6	Excellent; some dried algae.
4	.60	3.2	Excellent; some water loss due to leakage.
5	.66	3.5	Excellent; some silt in parts of basin.
Total------------	2.63	Average---- 2.6	
		East Etiwanda Facility	
4	0.4	2.2	Sandy clay.
5	.4	.33	Do.
6	1.0	2.0	Do.
7	.8	2.6	Silt and algae.
8	1.3	2.7	Do.
Total-----------	3.9	Average---- 2.0	
		San Sevaine Facility	
1	14.7	0.39	Recently graded.
2	17.9	1.7	Do.
3	14.2	1.8	Do.
Total-----------	46.8	Average---- 1.3	

TABLE 4. - *Water delivered to recharge facilities*

(in acre-feet)

Date	Facility			Subtotal
	Day Creek	East Etiwanda	San Sevaine	
1980				
June	Individual facility not monitored.			1,495
July				1,426
Aug.				1,296
Sept.				793
1981				
April	260	166	415	841
May	362	255	700	1,317
June	103	79	183	365
July	438	265	733	1,436
Total				8,969

Test holes 1N/6W-22R1, 27A1, H1, H2, N2, N3, 31A1, and 31H1 (fig. 2) were drilled in September 1980. Each hole was about 100 feet deep and was dry when drilled, and all except 27H1 and H2 remained dry through August 1981. Water was first observed in test holes 27H1 and H2 in May 1981, indicating that recharge water was moving laterally eastward from the San Sevaine facility at a shallow depth. The water level in wells 26E1 and 35A1 started rising in 1980 and rose abruptly in the first part of 1981. These wells--852 and 558 feet deep, respectively--reflected water-table conditions; rising water levels in these wells indicated that recharge water was percolating down to the water table, which is more than 500 feet below land surface. The water level in well 34A2 (800 feet deep) started rising in the middle of 1981 but rose only slightly, which may mean that the recharge water from the San Sevaine facility was moving more southeasterly than southerly. Well 1S/7W-1A1, 964 feet deep, showed a gradual rising water level. The water level in this well was probably affected by recharge in the Day Creek facility. Wells 1N/6W-35P1 (675 feet deep), 1S/6W-4P1 (810 feet deep), and 4P2 (820 feet deep) each showed rising water levels, which indicates that recharge water was crossing barrier "J".

Table 1 shows that precipitation in San Bernardino was 26.57 inches in 1980, which is higher than the mean of 16.11 inches. The higher-than-average precipitation and the probable increase in runoff from the San Gabriel Mountains may have contributed to the rising water levels in the wells, including those south of barrier "J". However, in 1978, when precipitation was 30.83 inches, water level in well 1N/6W-35A1 did not rise, indicating that higher-than-average precipitation did not have an immediate effect on water levels in the area. A longer period of recharge and water-level monitoring would be required to substantiate the absence of a ground-water barrier at this location. Data are insufficient to determine what effect, if any, the Red Hill barrier has on recharge water.

Change in Water Quality

There are considerable differences in the concentration of chemical constituents between the recharge water and the native ground water, notably in concentrations of silica, calcium, sodium, bicarbonate, chloride, nitrate, noncarbonate hardness, and percent sodium (table 2). The concentration of chemical constituents changes as the recharge water migrates through the ground. The change in quality is evident in the water sample collected from test well 1N/6W-27H1.

Test well 27H1 was drilled to a depth of 100 feet in September 1980, and initially it was dry. The pilot recharge program began in June 1980, and water first appeared in well 27H1 in May 1981, at which time a water sample was collected for analysis. Changes occurred in the concentration of chemical constituents as the water moved from the recharge pond to the well site (a lateral distance of about 200 feet). Of those constituents mentioned earlier, only the concentration of silica and chloride remained nearly unchanged. A monitoring program to determine the presence of recharge water in the native ground water would place greater significance on these constituents. Mixing of recharge water with native ground water should result in a decrease in silica content and an increase in chloride content.

POSSIBLE EFFECTS OF SUSTAINED RECHARGE

In order to predict the effects of sustained recharge, the geohydrologic conditions of the area must be known, but the data that are available are not definitive enough to determine with certainty the nature of the geologic structure or the existence of barriers. Several possibilities are depicted diagrammatically in figure 7. The existing conditions could be any of these cases or a combination.

The condition shown in figure 7A is idealistic. Recharge water would enter the ground at the recharge site and migrate downward, unhindered, to the water table and disseminate throughout the basin. The recharge water could be recovered anywhere downgradient from the recharge site. There would be no problem with stagnated saturation in the vicinity of the recharge site because of the distance to the water table and large capacity of the basin. Data from well logs, however, indicate clay deposits between the surface and the water table; therefore, these ideal conditions probably do not exist in the study area.

Figure 7B shows a continuous clay layer beneath the recharge site and above the water table. The clay layer would hinder the downward migration of recharge water and effectively reduce the available storage space. Recharge would have to be discontinued when the available storage space became saturated. Water-level data in the study area indicate that the recharge water was able to reach the water table, as was shown by the rising water level in the deep wells 1N/6W-26E1 and 35A1. Therefore this condition does not exist, at least not in the vicinity of the San Sevaine facility.

Figure 7C show discontinous clay layers or lenses that hinder the downward migration of recharge water but do not stop it. The clay layers indicated by available drillers' logs cannot be correlated, so these conditions probably exist in the study area. Erosional products possibly were deposited in the fan area and then dissected by succeeding floods. The degree to which downward migration is effected is a function of the lateral and vertical extent of the clay lenses.

Figure 7D shows a ground-water barrier. A barrier would prevent recharge water from being disseminated throughout Chino Basin and would effectively reduce the storage space available to the recharge water. Recharge would have to be discontinued when the available storage space became saturated. Two ground-water barriers that could affect sustained recharge have been postulated in the study area, barrier "J" and the Red Hill barrier. As previously discussed, rising water levels in wells south of barrier "J" indicate that it is not effectively stopping the movement of water to the south. The Red Hill barrier trends northeastward and runs through the north end of the Day Creek facility and just south of the Deer Creek facility. No recharge water was put into the Deer Creek facility during this study; consequently, the effectiveness of the Red Hill barrier could not be determined.

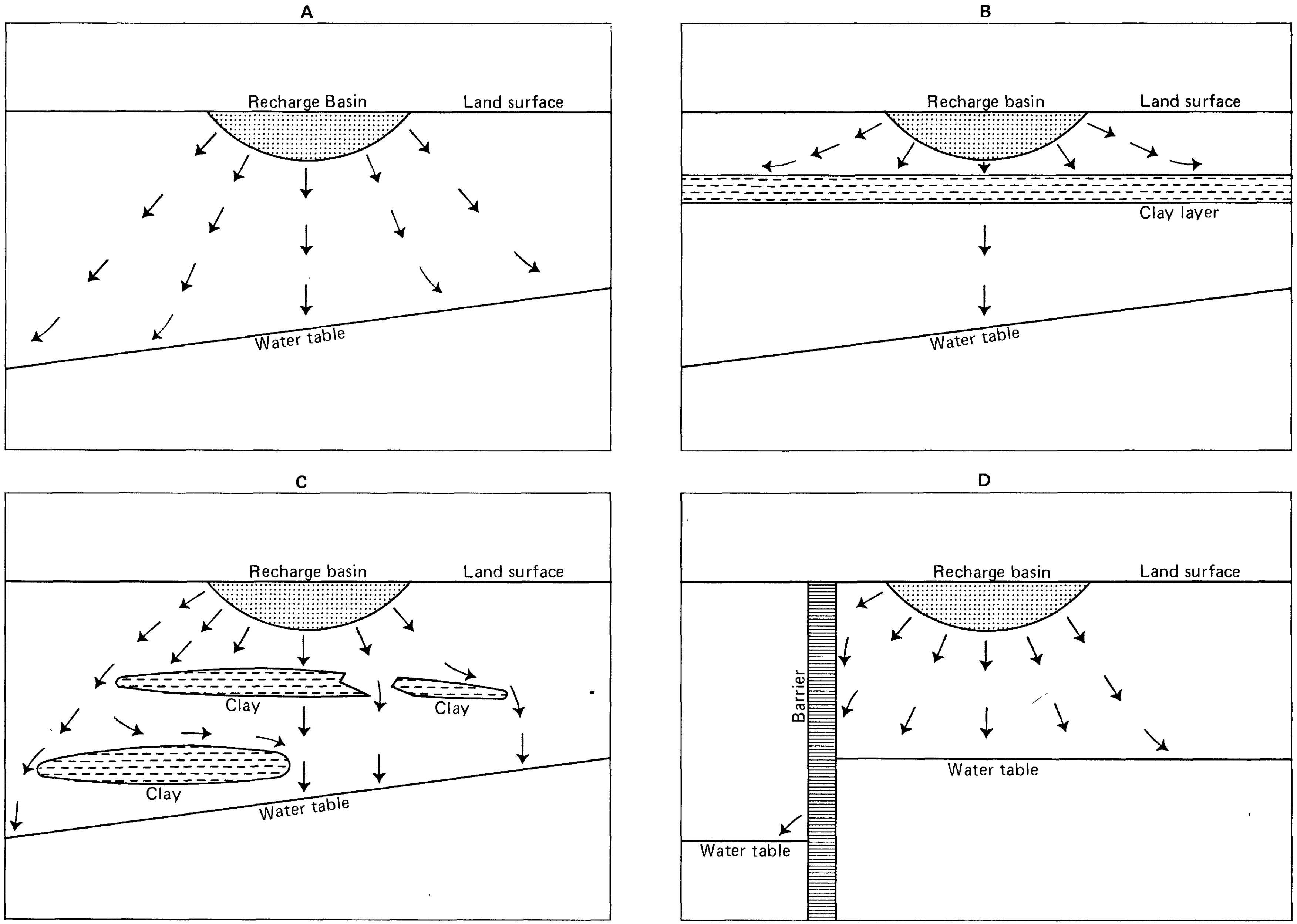


FIGURE 7. — Graphic representation of several conditions that could exist in study area: A— Idealistic; B— Continuous clay layer; C— Discontinuous or lens type clay layers; D— Ground-water barrier.

SUMMARY AND CONCLUSIONS

Water-level data indicate that the general movement of ground water in the Chino Basin is toward Prado Dam in the southern part of the basin. Depth to water ranges from more than 500 feet below land surface in the northern part to near land surface in the southern part of the basin. Previous studies indicated that about 8.2 million acre-feet of water is in storage and an additional 1.2 million acre-feet could be stored in the basin. The quality of ground water in the Chino Basin is generally good. Dissolved solids range from about 250 mg/L in the north to about 600 mg/L in the south.

Infiltration tests were made at three of the recharge facilities in April 1981. Results of these tests show infiltration rates of 2.6 ft/d at the Day Creek facility, 2.0 ft/d at the East Etiwanda facility, and 1.3 ft/d at the San Sevaine facility. With a properly implemented maintenance program these infiltration rates could be maintained or even increased. Infiltration rates can be expected to decrease drastically each time natural storm runoff enters the facility. On these occasions major rehabilitation and silt removal may be required to restore infiltration rates.

Water-level data indicate that recharge water can percolate to the water table. Rising water levels in wells south of barrier "J" may indicate that recharge water is passing through the postulated barrier and entering the main part of Chino Basin. Not enough data are available to speculate on the effectiveness of the Red Hill barrier.

The water-level and recharge-monitoring programs, if continued, would more accurately define the effects of sustained recharge. Periodic infiltration tests conducted at each facility would help to formulate a rehabilitation and maintenance program.

REFERENCES CITED

Dutcher, L. C., and Garrett, A. A., 1963, Geologic and hydrologic features of the San Bernardino area, California, with special reference to underflow across the San Jacinto fault: U.S. Geological Survey Water-Supply Paper 1419, 114 p.

Garrett, A. A., and Thomasson, H. G., Jr., 1949, Ground-water outflow from Chino Basin, California, and the controlling geologic and hydrologic conditions: U.S. Geological Survey open-file report, 143 p.

Moreland, J. A., 1972, Artificial recharge in the upper Santa Ana Valley, southern California: U.S. Geological Survey open-file report, 51 p.

National Oceanic and Atmospheric Administration, 1971-81, Climatological data for California: Annual summary, no. 13, volumes 75 through 85.

Rantz, S. E., 1969, Mean annual precipitation in the California region: U.S. Geological Survey open-file map.

Shellooe, J. F., 1979, Preliminary evaluation of State Water Project ground-water storage program, Chino Basin: California Department of Water Resources, 48 p.