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Ground-Water Storage in the Johnson Valley Area San Bernardino County, California

U.S. Geological Survey, Menlo Park, Calif Water Resources Div

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SAN BERNARDINO COUNTY, CALIFORNIA

By James J. French

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-130

Prepared in cooperation with the

Mojave Water Agency

April 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION TABLE

For readers who prefer metric units rather than English units, conversion factors for the terms used in this report are listed below:

Multiply English unit	*By*	*To obtain metric unit*
acres	4.047×10^{-1}	hectares
acre-ft (acre-feet)	1.233×10^{-3}	cubic hectometers
ft (feet)	3.048×10^{-1}	meters
ft/mi (feet per mile)	1.890×10^{-1}	meters per kilometer
gal/min (gallons per minute)	6.309×10^{-2}	liters per second
in (inches)	2.540×10	millimeters
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

GROUND-WATER STORAGE IN THE JOHNSON VALLEY AREA,

SAN BERNARDINO COUNTY, CALIFORNIA

By James J. French

ABSTRACT

The Mojave Water Agency includes several desert basins where ground water in storage is many times as great as the average annual recharge. The Johnson Valley area was evaluated to find (1) the quantity of ground water in storage, (2) the chemical quality of the ground water, and (3) the potential for storage of recharge water in the unsaturated zone.

Johnson Valley contains about 250,000 acre-feet of water in storage, of which about half can be considered recoverable. About 250,000 acre-feet of void space in the unsaturated alluvium is available for storage of imported water, but considerably less than this amount of recharged water could be recovered.

The quality of the water in storage is satisfactory for public consumption, although water from some areas has high fluoride concentrations and should be mixed with water of low fluoride concentration.

INTRODUCTION

The Mojave Water Agency (MWA) includes many desert basins that are not drained by the Mojave River (fig. 1) but are dependent solely on ground water or imported water. Because MWA is responsible for long-range water-resources planning, it requested the U.S. Geological Survey to estimate the quantity of ground water in storage in the Johnson Valley area.

The eastern part of the MWA is expected to receive water from the California Aqueduct by way of the proposed Desert Pipeline. The pipeline, if constructed, will take years to complete. Meanwhile the population of the Yucca Valley and Landers areas, southeast of Johnson Valley, is increasing, and the residents anticipate a shortage of potable water before imported water becomes available. The basins in the Johnson Valley area could be used as a source of supplemental water supply.

The purpose of this report is to address the following specific questions asked by MWA about the Johnson Valley area:

1. What is the quantity of water in storage?

2. What is the quality of the ground water?

3. Can the unsaturated zone above the water table be used for storage of low-cost, surplus water imported from northern California during periods of above-average rainfall?

The project area (fig. 2) is 214 mi^2 of typical desert environment below the north flank of the San Bernardino Mountains. The area consists of several alluvial basins separated by bedrock or by faults. The basins occupy about two-thirds of the area, and the rest is igneous and metamorphic bedrock of the hills and mountains.

The Johnson Valley basin as described by the California Department of Water Resources (1975) includes Rattlesnake, Fry, Johnson, and Upper Johnson Valleys. For this report the Johnson Valley ground-water basin is defined as the ground-water basin beneath Johnson Valley and the other basins are here named for the valleys or area to which they roughly correspond: Rattlesnake, Fry, Upper Johnson, and Means-Reche. Johnson Valley has the greatest potential for ground-water utilization, and the main part of this report concerns this basin. The ground-water basin beneath Johnson Valley is divided into two storage areas that, in the storage computations, are discussed separately.

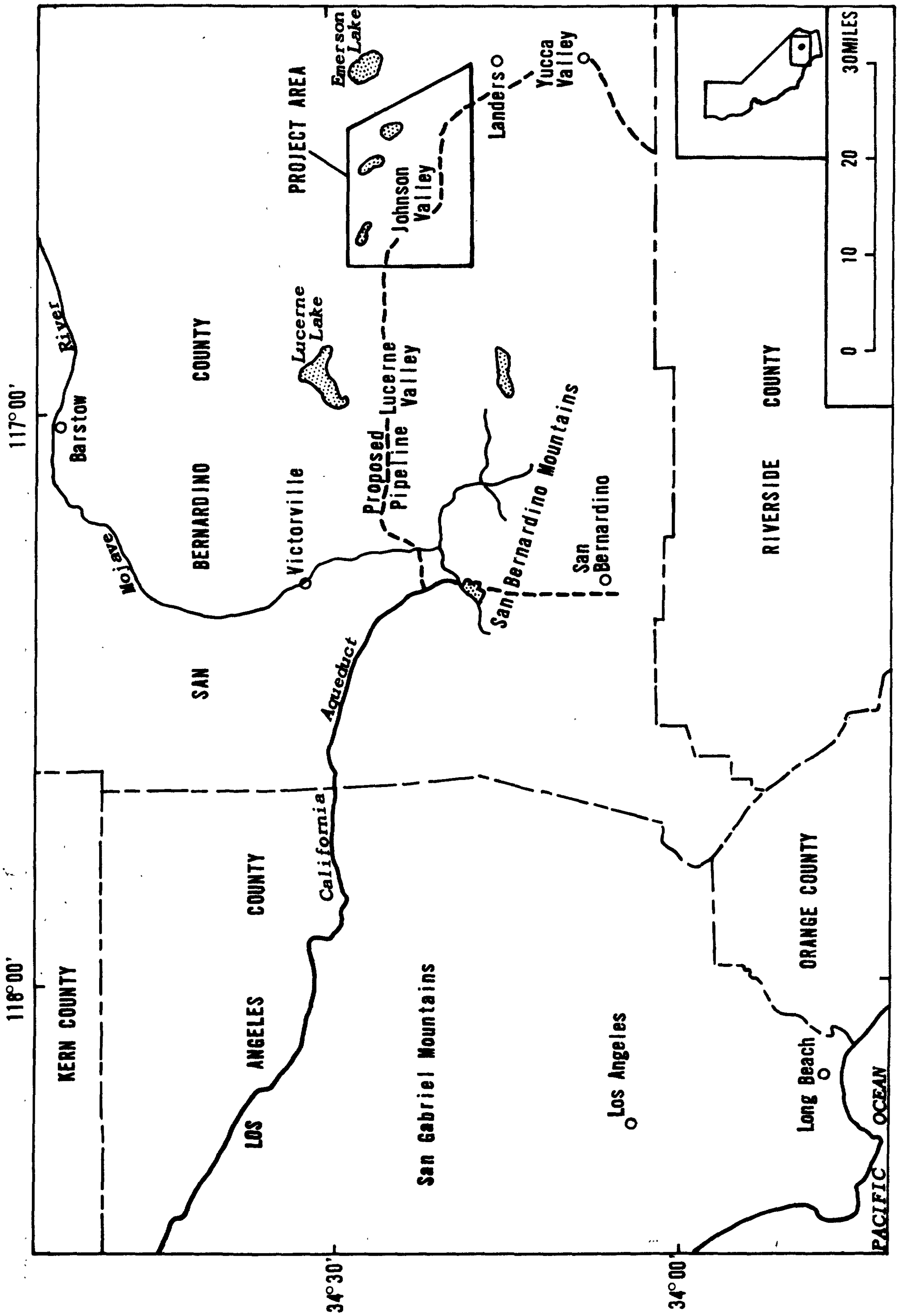


FIGURE 1.--Location map.

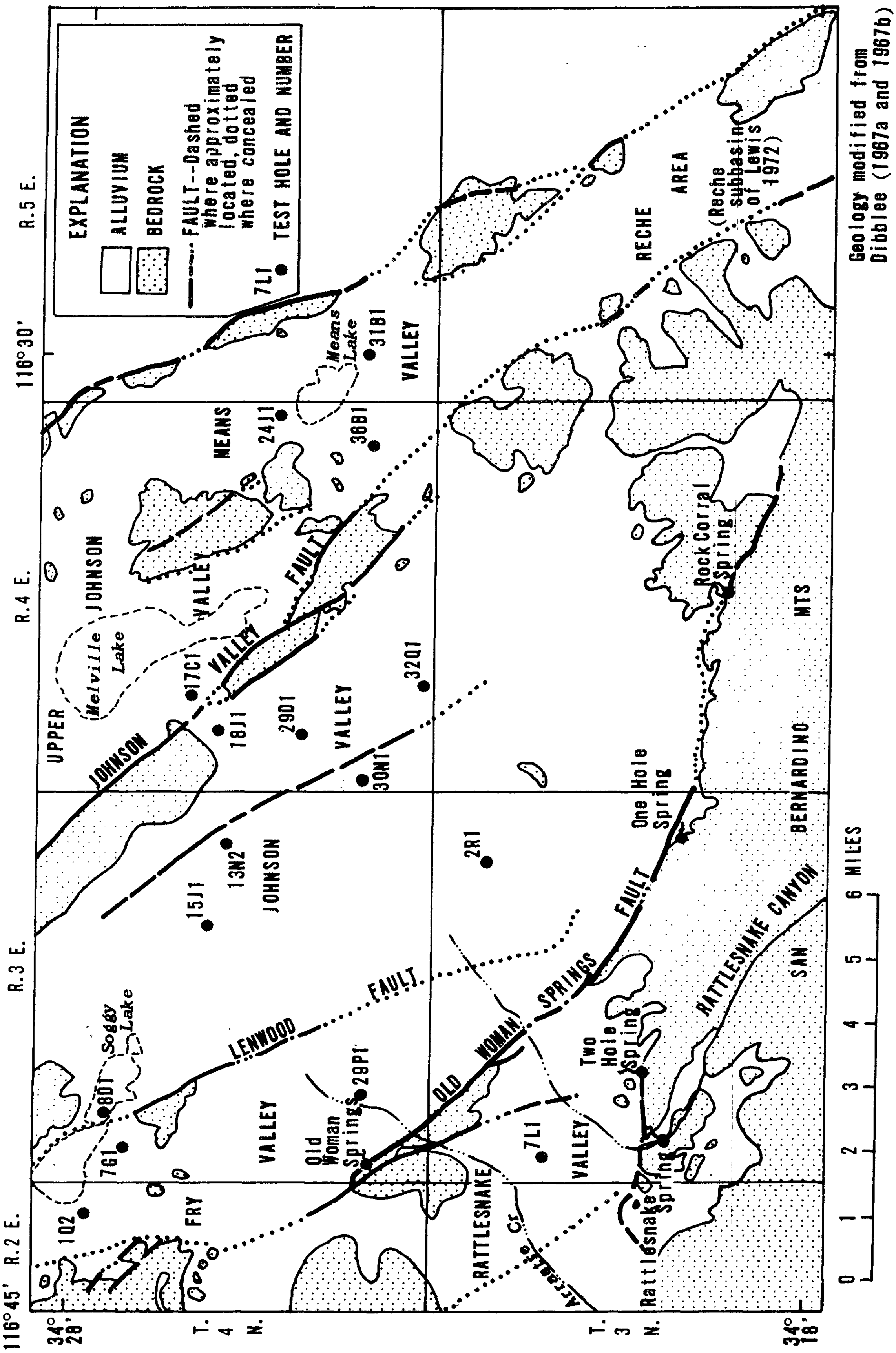
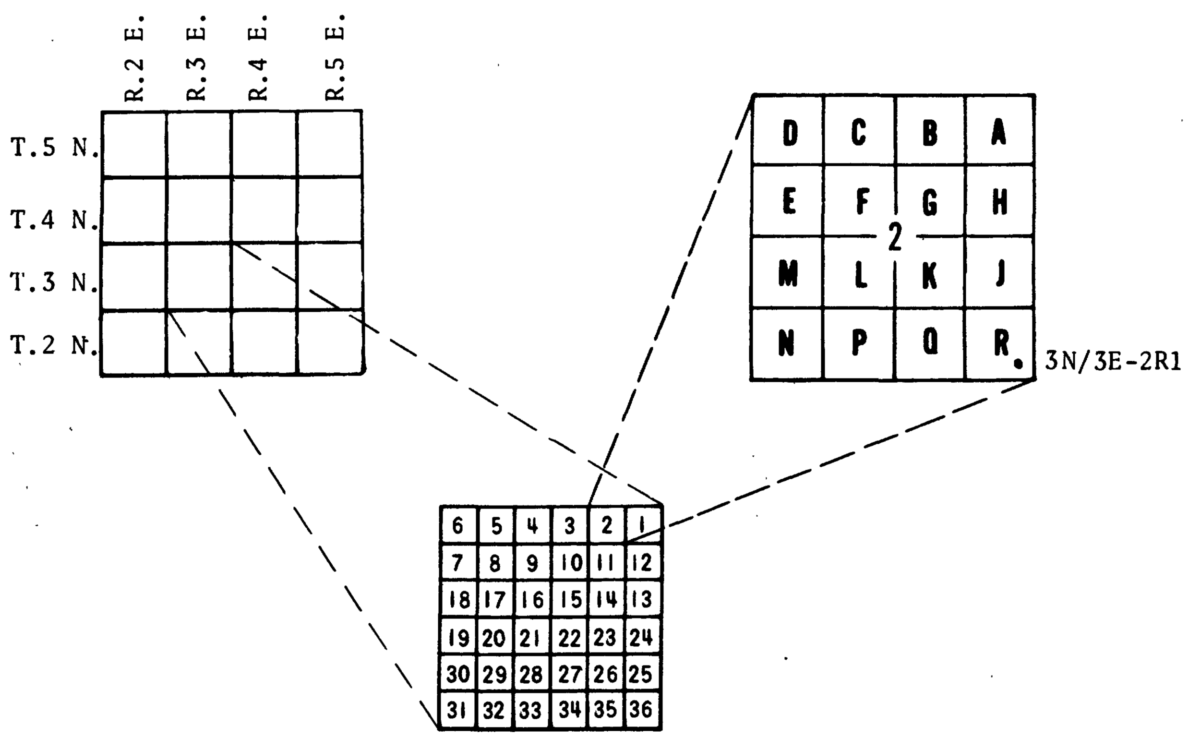


FIGURE 2.--Areal geology and location of hydrologic test holes.

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 3N/3E-2R1, the first two segments designate the township (T. 3 N.) and the range (R. 3 E.); the third number gives the section (sec. 2); 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. Springs are designated by adding an S after the final letter and before the final digit.



GROUND-WATER BASIN OF JOHNSON VALLEY

Johnson Valley occupies an area of about 54 mi^2 in southwestern San Bernardino County. The valley is bordered on the east by the Johnson Valley fault and on the west by the Lenwood fault. The San Bernardino Mountains form the southern boundary, and the northern boundary is formed by bedrock, either in outcrop or under a thin alluvial cover (fig. 2).

The valley is underlain by alluvial deposits consisting predominantly of sand and gravel. Data from drillers' logs and from a gravity survey indicate that the alluvial deposits may be as much as 700 ft thick in the southern part of the valley.

Hydrologically, the ground-water basin beneath Johnson Valley is a typical desert basin, shaped like a huge bowl and filled with alluvial clay, silt, sand, and gravel and partly saturated with water (fig. 3). The bowl is the bedrock that underlies and nearly surrounds the basin. The alluvium that fills the bowl was eroded from the surrounding bedrock, mainly from the San Bernardino Mountains.

Rainfall on the floor of the valley seeps into the soil but is used by vegetation or is evaporated so that little if any reaches the water table. The source of most of the ground water in Johnson Valley is the San Bernardino Mountains where rain and melting snow seep into the soil and migrate downslope through the soil and the weathered and fractured bedrock. Discharge of this water into Johnson Valley is shown by the presence of such springs as Rock Corral, One Hole, Two Hole, and Rattlesnake Springs along the faultline at the base of the mountains (fig. 2). Water crosses the faultline into the alluvium and percolates downward to the water table through the spaces between the pebbles and sand grains (fig. 4).

Movement of water through the alluvium is much slower than that of water in a stream. Ground water percolates through the connected open spaces between particles of alluvium by the force of gravity and by hydrostatic pressure. Commonly the movement is a few feet a year, and that is probably the rate of movement in Johnson Valley.

Water is contained in the basin because the bedrock that borders and underlies the alluvium is not very permeable. On the east and west sides of Johnson Valley, faults cut the alluvium (fig. 4), and in some places surface offset of bedrock is evident. Along these faults the alluvium has been crushed and perhaps welded by the heat and pressure associated with earth movement on the fault. This crushed zone acts as a dam, blocking or retarding the movement of ground water. Thus the basin fills with water to a level where either the water flows over the dam or hydrostatic pressure forces water through the dam.

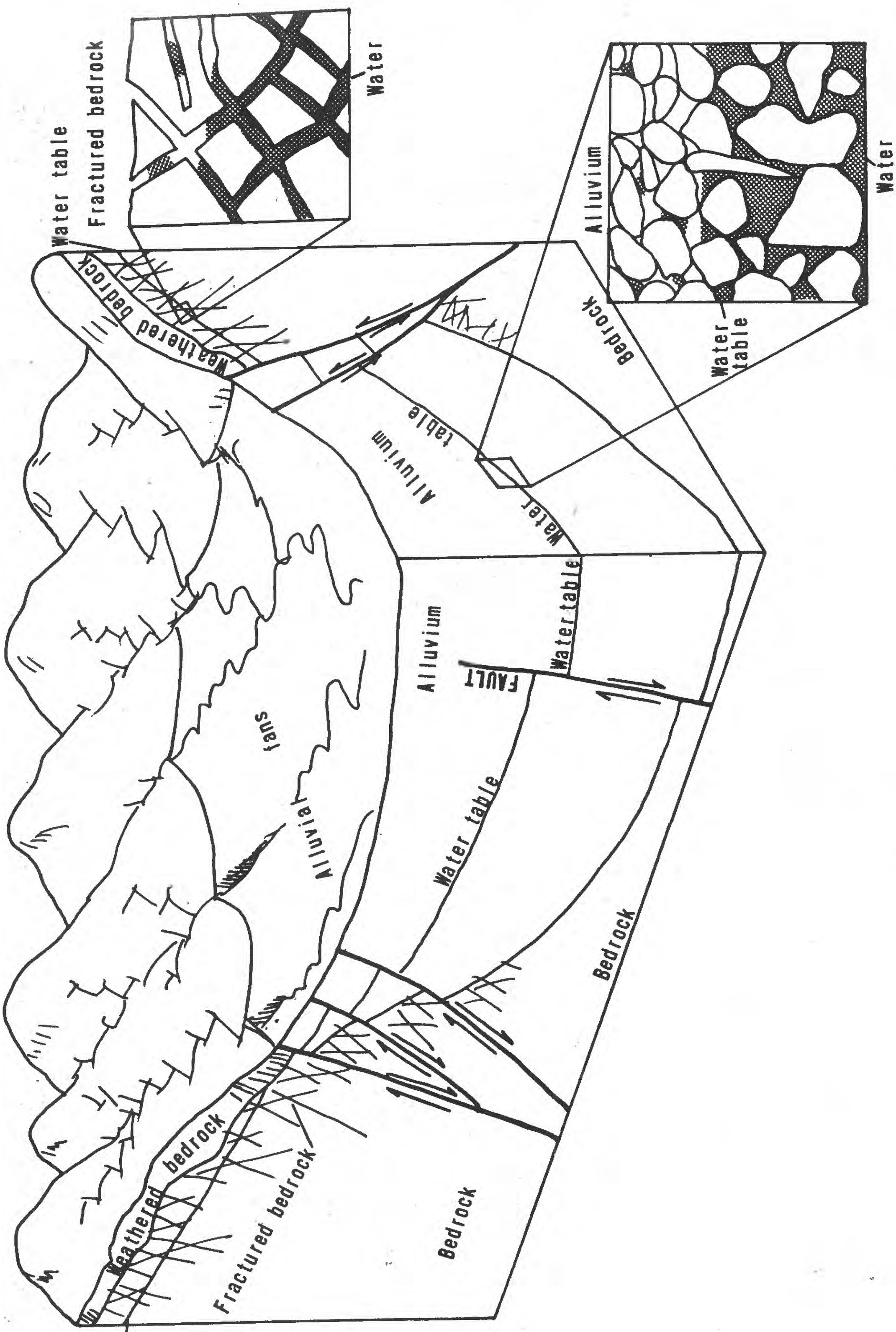


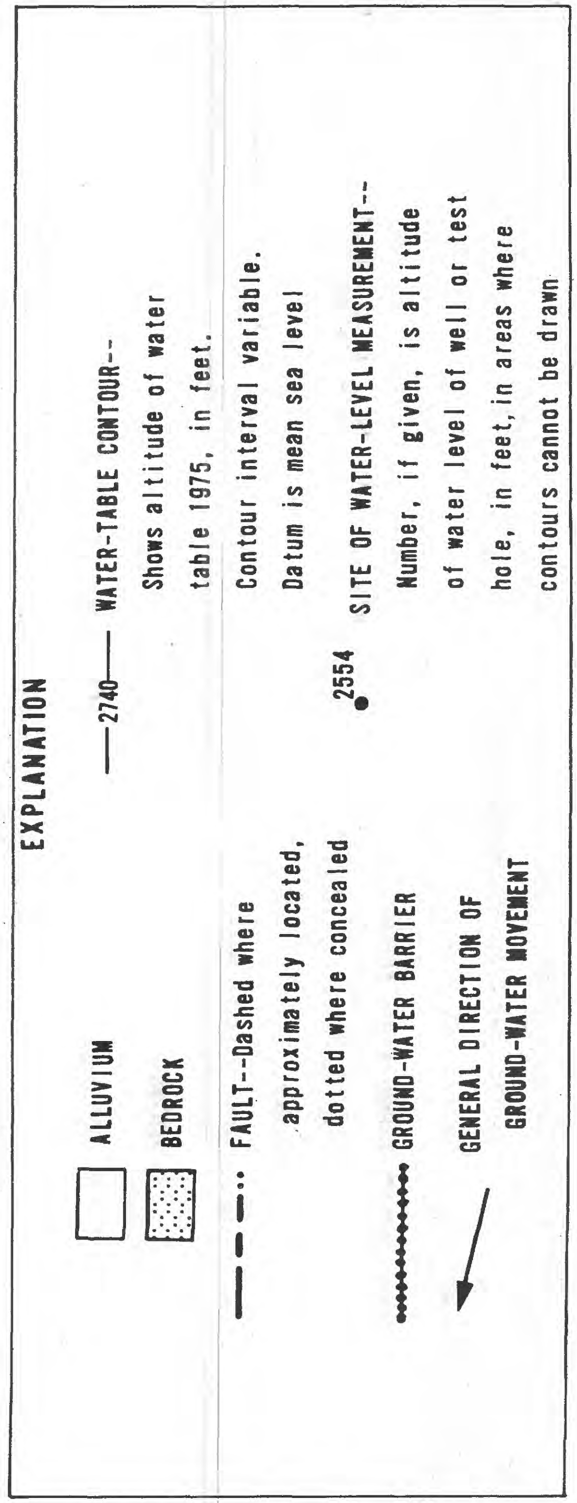
FIGURE 3.--Diagram of a typical alluvial ground-water basin.

Because the ground-water level in Fry Valley is higher than in Johnson Valley, water from Fry Valley seeps across the Lenwood fault into Johnson Valley. Ground water moves generally northeastward from Fry Valley and from the San Bernardino Mountains across Johnson Valley and seeps across the Johnson Valley fault into Upper Johnson Valley through a gap in the bedrock outcrop. Some water moves through another gap into Means Valley. Eventually the ground water in these two basins probably migrates across faults and through fractured bedrock to Emerson Lake (fig. 1).

Johnson Valley is cut by an unnamed fault that effectively divides it into two parts as shown by offset of the water-level contours in figure 4.

Ground-Water Storage

The capacity of Johnson Valley, or any other alluvial basin in an arid region, to store water is generally many times greater than the average annual recharge from natural sources. The basin contains ground water to a maximum depth of about 700 ft below ground level, but only part of this water can be recovered. The total quantity of water in the basin can be calculated by multiplying the total volume of saturated alluvium by the average porosity. In calculating the quantity of recoverable water, however, the volume of saturated alluvium is multiplied by the specific yield. Specific yield is the ratio of the volume of water a deposit will yield by gravity to its own volume (Meinzer, 1923, p. 28). That percentage of the total quantity of water that will not drain by gravity but, rather, clings to the particles is called specific retention.



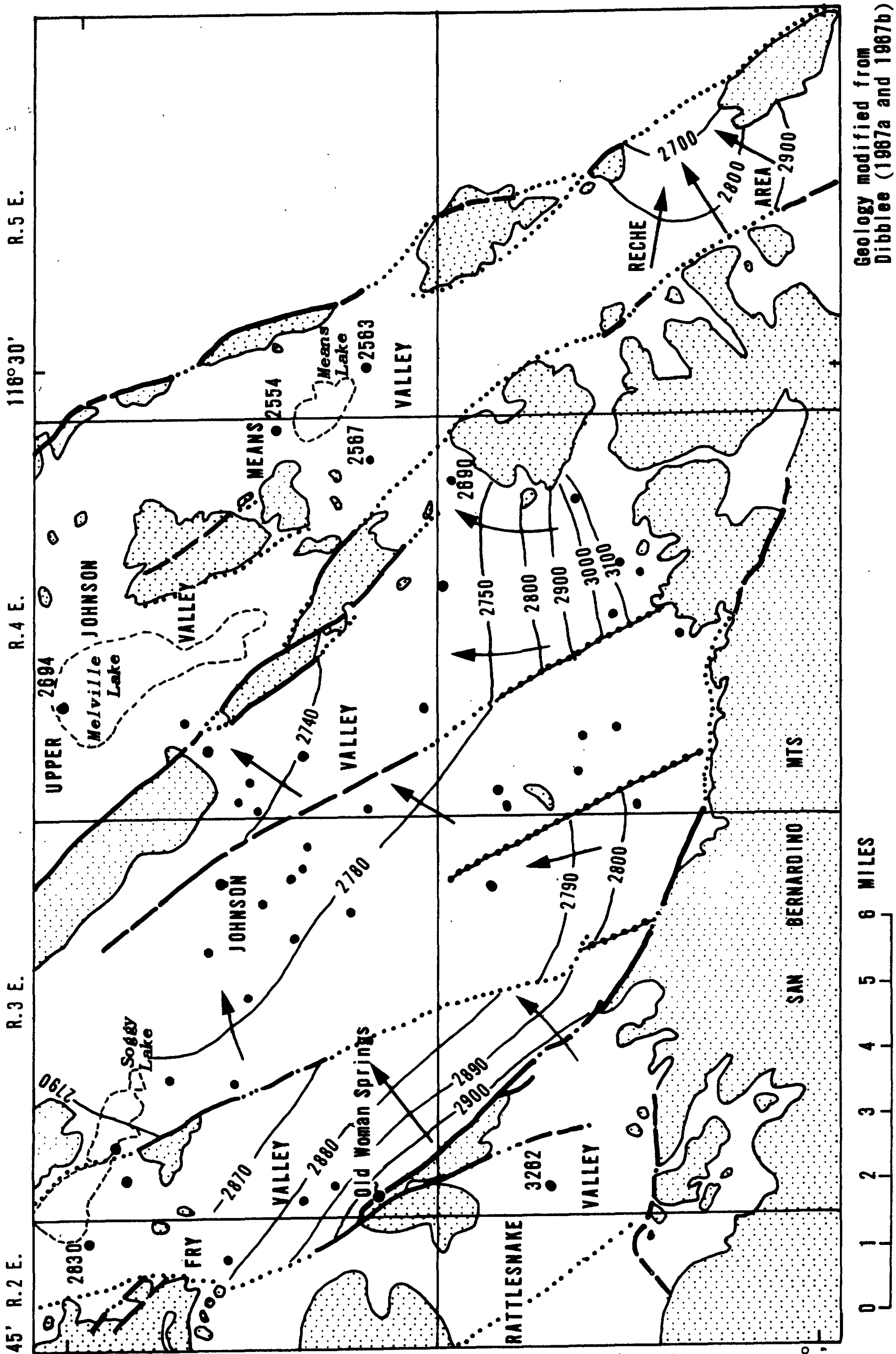


FIGURE 4.--Water-table contours and general direction of ground-water movement.

The average specific yield was derived as follows: (1) Drillers' terms used on well logs were grouped into five lithologic classes as shown in table 1, (2) specific-yield values, based largely on work reported by Davis, Green, Olmsted, and Brown (1959), were assigned to the five classes, and (3) the average specific yield was calculated.

TABLE 1.--*Specific-yield values used to estimate ground-water storage capacity*

[From Davis and others, 1959, p. 209]

Material	Assigned specific yield (percent)
Gravel, sand and gravel, gravelly deposits	25
Sand, medium to coarse, loose	25
Sand, fine, tight sand, tight sand and gravel	10
Silt, gravelly clay, sandy clay, sandstone	5
Clay and related fine-grained deposits	3

In determining the volume of the saturated alluvium it is necessary to define the shape and depth of the bedrock beneath the alluvium and the configuration and depth of the water table within the alluvium. The land-surface boundary of the basin is defined by the areas where bedrock crops out to form hills and mountains (fig. 2). In many of these bedrock areas geologic faults are traceable, and frequently the lineation of the faults across the basin is shown by offset of the alluvium at land surface. From surface evidence, there is no way to determine what effect the faults have on the buried bedrock.

Only four wells have penetrated to bedrock; therefore, it was not possible to determine the general shape of the bottom of the ground-water basin from such meager data. As a part of this project, test holes were drilled and a gravity survey was made. Supplemental data (tables 2-5) on wells, springs, chemical quality of water, and lithologic logs of test holes are included at the end of this report.

Twenty test holes were augered to define the water table and to indicate the difference in water level across faults. The location of these auger holes was influenced by the depth limitation of the equipment (about 100 ft). Eight of the test holes did not reach water and so are not described here. The other 12 holes are shown in figure 2 and described in table 5.

In addition, four deeper test holes were drilled with equipment designed to drill deep enough to reach bedrock. Three of these holes reached bedrock (table 5). The test hole in Rattlesnake Valley did not reach either water or bedrock.

The water table was defined by measurements in the test holes and existing wells (fig. 4).

The gravity survey supplemented the depth-to-bedrock data from the test holes and wells. A gravity survey indicates minute differences (anomalies) in the attraction of gravity, at various locations on the land surface, caused by differences in the density of the material beneath these locations. The differences may be used to interpret the geologic structure and general shape of the bedrock surface beneath the alluvium. In general, an area of low-gravity attraction corresponds to a thick section of alluvium, and an area of high-gravity attraction corresponds to bedrock outcrop or to a thin section of alluvium.

Because the density of the various types of rocks that make up the bedrock complex is unknown, an approximate density of 2.65 grams per cubic centimeter was assumed for the entire study area. Because of this assumption the gravity survey gives only an approximation of the depth to bedrock.

Measurements of gravity were made at 312 stations, which were generally a quarter of a mile to 1 mi apart. Measurements were made with a Worden[1] Gravity Meter, model 113.

All measurements were referred to a local base station near Old Woman Springs. This base station, in turn, was referred to the California Base Station Network at Victorville (Chapman, 1966) and thus is on the Woollard and Rose (1963) gravity datum. Corrections were applied to the field readings for meter drift, and the data were entered into a computer and corrected for latitude, altitude, and terrain effects, using Plouff's (1966) program. The regional gravity gradient was subtracted from the corrected field readings to indicate the gravity anomaly at each station.

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[1]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

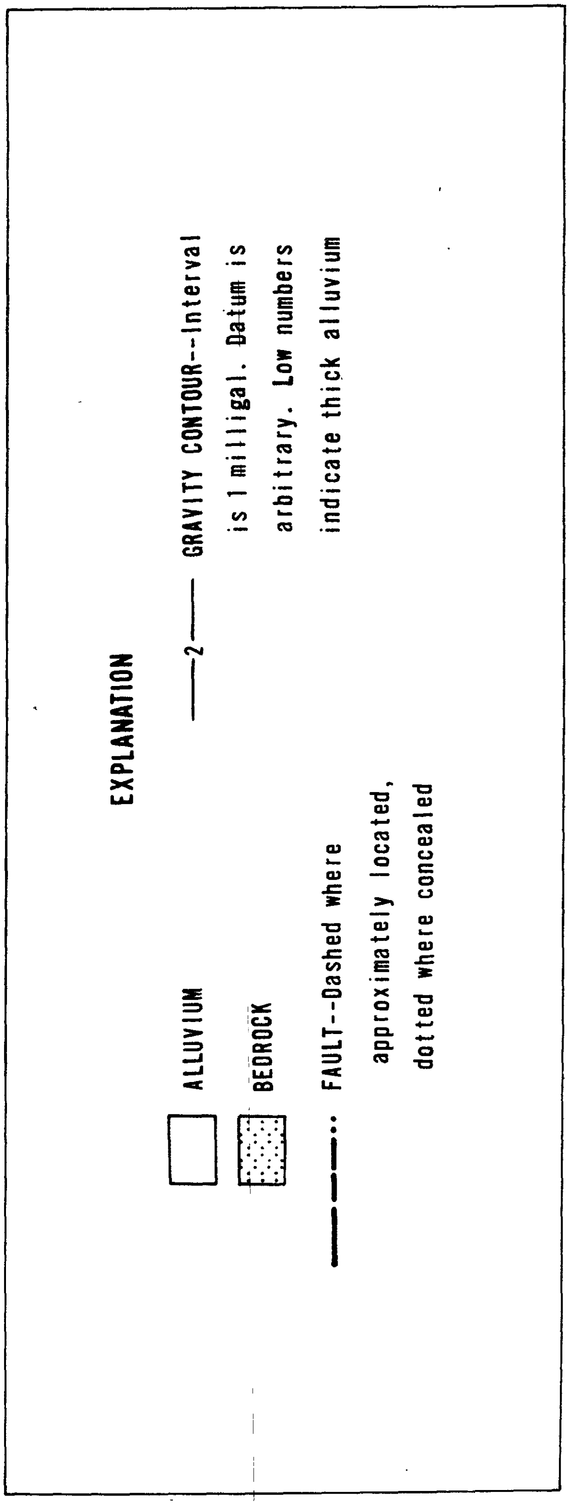
A residual-gravity contour map (fig. 5) was made by connecting points of equal residual-gravity anomaly by a line. When viewed in relation to the bedrock outcrop areas and the known or inferred faults, the general shapes of the ground-water basins are apparent.

By using the depths to bedrock known from wells and test holes in conjunction with the gravity survey, contours showing the approximate altitude of the bottom of the ground-water basin were drawn. Subtracting the altitude of bedrock from the altitude of the water table resulted in an approximation of the thickness of the saturated alluvial sediments (fig. 6). This map is useful for estimating the quantity of ground water in storage, but because of the generalized data on which it is based it is not an accurate representation of the thickness of saturated alluvium at specific points.

For the purpose of computing usable storage, the upper and lower limits of the saturated alluvial fill were defined by the water table on the top and by the 400-ft depth below land surface on the bottom. The 400-ft depth was chosen as the limit of economic pumping. It is recognized that pumping lifts are greater than 400 ft in many places, including Johnson Valley, but that depth is considered to be the practical limit for computations of usable storage.

Storage capacity was computed only for the parts of Johnson Valley that are potentially usable as reservoirs for ground-water storage and export.

The two parts of Johnson Valley on either side of the unnamed fault were considered as separate storage areas for computation of usable storage (fig. 7). The west storage area is bounded on the west by the Lenwood fault. Water in storage within 400 ft of land surface in this area is about 150,000 acre-ft. This quantity is not all available for withdrawal, however, because it is not



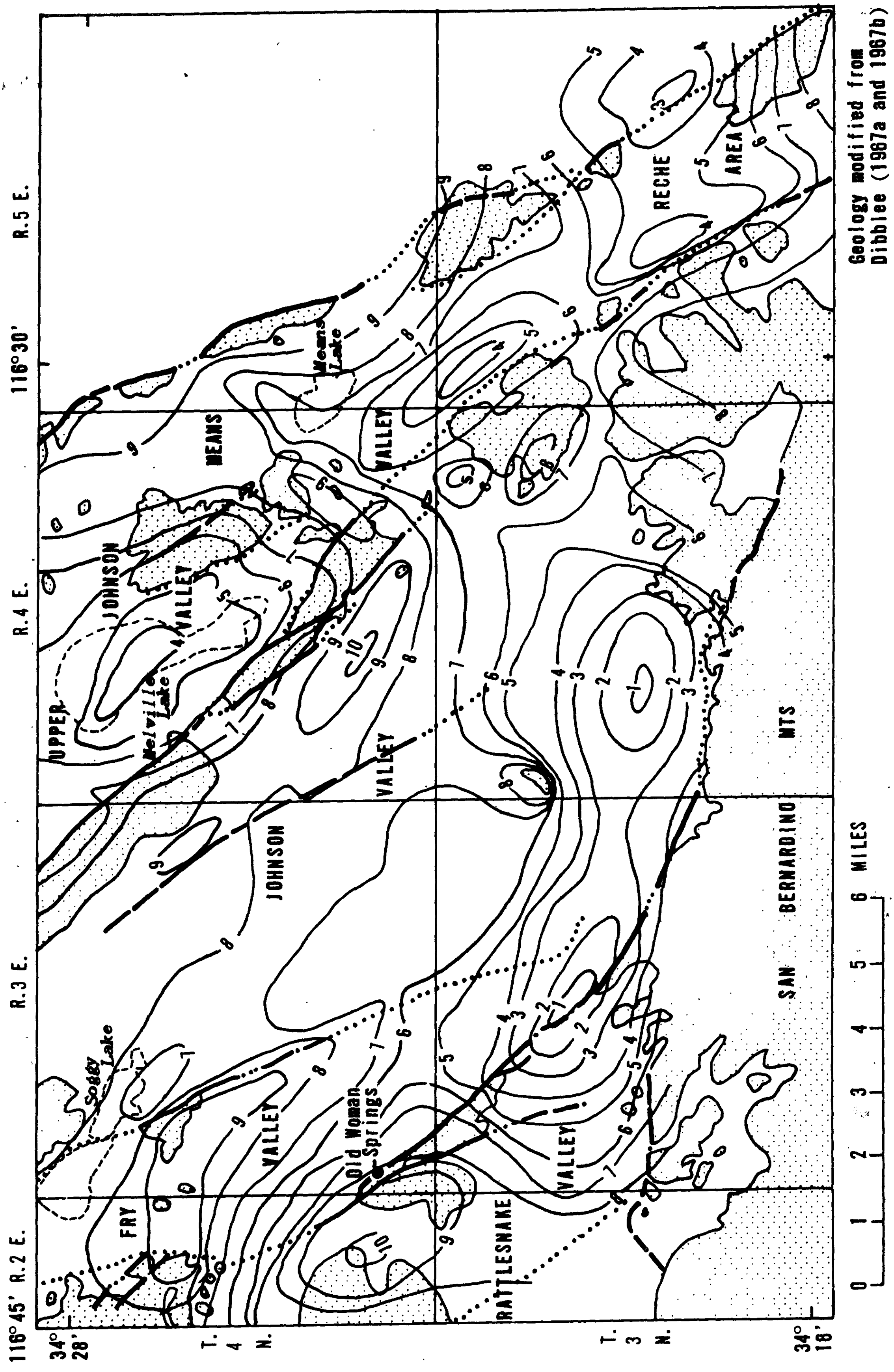


FIGURE 5.--Residual-gravity contours.

possible to drain the basin completely by pumping. Probably about half this quantity is available for use.

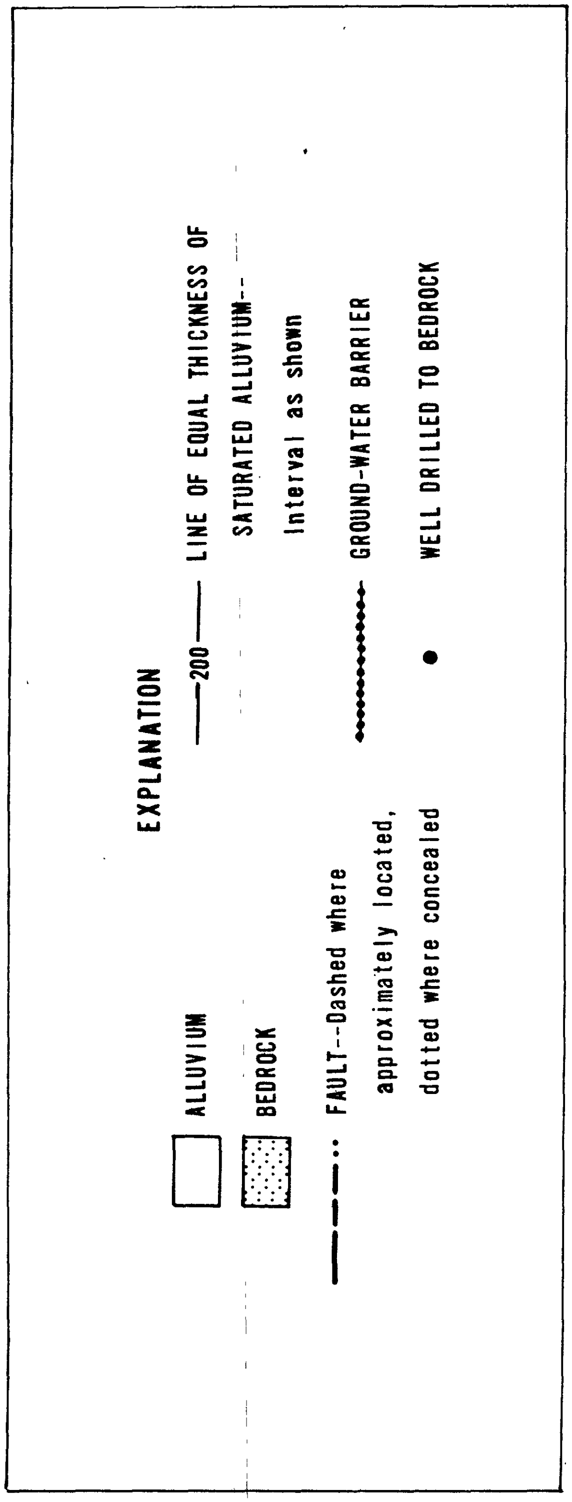
The east storage area is bounded on the east by the Johnson Valley fault. Water in storage within 400 ft of land surface is about 100,000 acre-ft. Probably about half of this is available for withdrawal.

The total quantity of water in both storage areas that may be economically withdrawn is about 125,000 acre-ft. The areas marked "potential well field" in figure 7 seem the more favorable for locating production wells, but a more detailed study of the hydraulic properties of the basin is needed before installing well fields.

The estimated volume of unsaturated alluvium available for storing imported water was based on the present water table as the base and the highest potential water table as the top. The highest potential water table was limited by the altitude of the lower parts of the valley that could be subject to waterlogging if the water table were raised sufficiently. In these areas the limit of the potential water table was arbitrarily assigned a depth of 20 ft below land surface and a potential water-level gradient was estimated between the areas of proposed artificial recharge and the potential waterlogged areas.

The volume of unsaturated alluvium multiplied by its average porosity gives about 100,000 acre-ft in the west storage area and 150,000 in the east storage area available for storage of imported water. Only about half this water could be recovered by pumps, however, because some water will be held by specific retention.

Potential areas for recharge of imported water are shown in figure 7, but detailed studies of the recharge potential should precede any recharge operations.



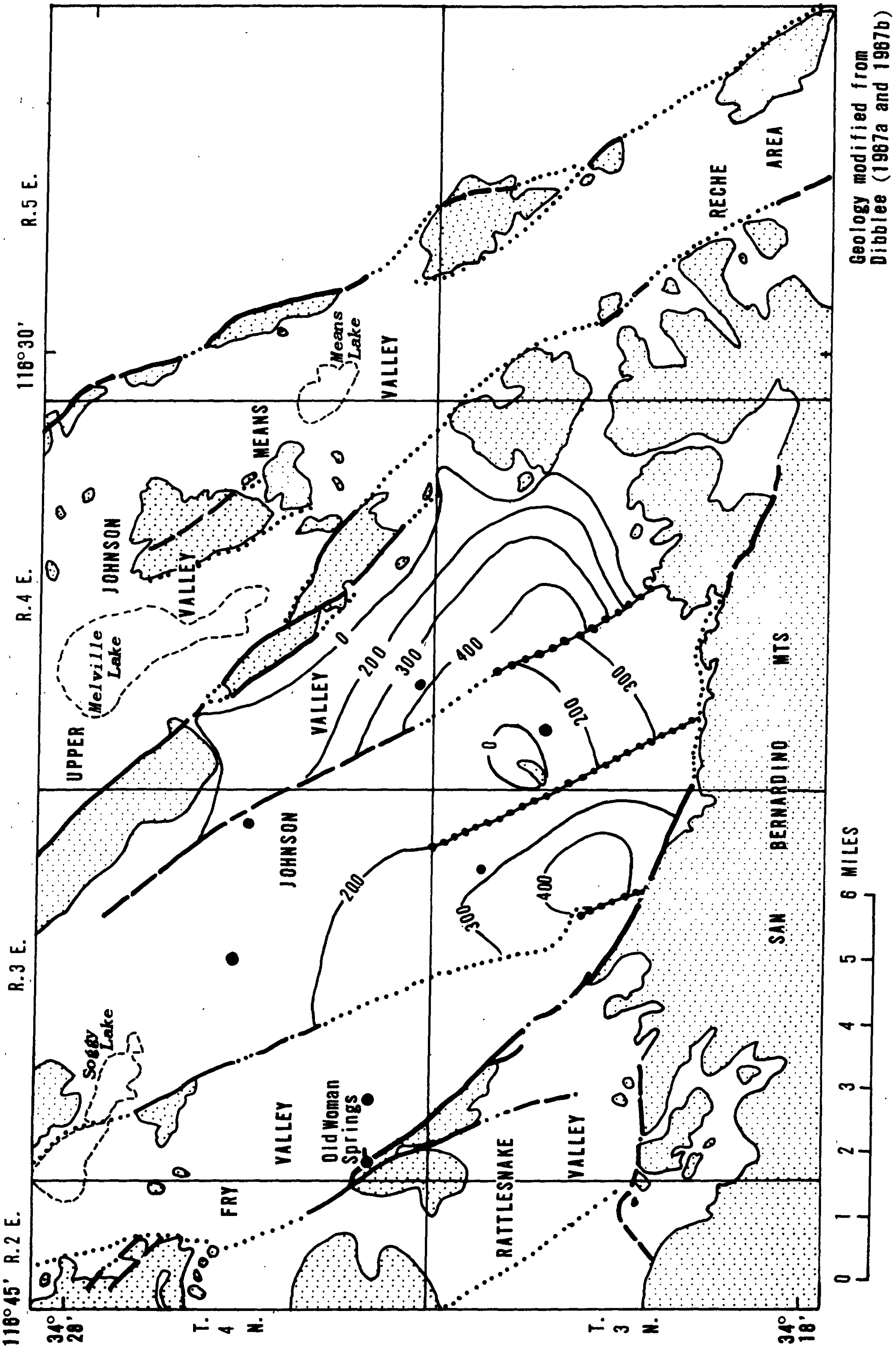


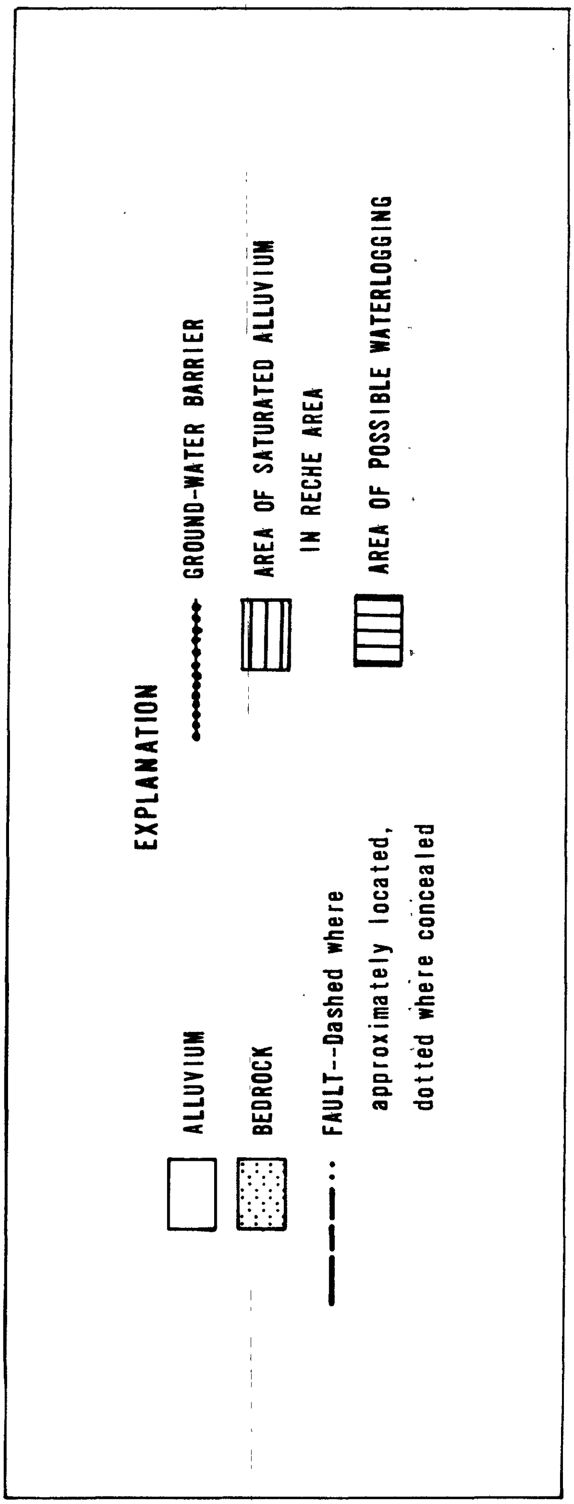
FIGURE 6.--Approximate thickness of saturated alluvium.

Chemical Quality of Ground Water

Figure 8 shows diagrams that illustrate the chemical quality of ground water in the project area. The ten diagrams were selected as representative of samples from 20 wells and springs. These diagrams (Stiff, 1951) are drawn using four parallel horizontal axes extending on either side of a vertical zero axis. Eight constituents, calculated as milliequivalents per liter, are plotted--one on each axis to the left and right of zero. The constituents are plotted in the same sequence in each diagram and the resulting points are connected into irregular polygons. When plotted on a map, the distinctive shape of each diagram permits visual comparison of the quality of ground water in different areas.

Two principal water-quality problems are evident from chemical analyses of water from wells in Johnson Valley: (1) High concentrations of dissolved solids and (2) high concentrations of fluoride. (See table 4.) In the northern part of the valley the dissolved-solids concentration ranges from almost 1,000 mg/L (milligrams per liter) to almost 2,000 mg/L (fig. 8). Sulfate is the most abundant ion; in nearly all analyses it exceeds the recommended limit of 250 mg/L (U.S. Environmental Protection Agency [EPA], 1972). Chloride concentration exceeds the recommended limit of 250 mg/L in samples of water from wells in the northern part of the east storage area of Johnson Valley.

Water in the southern part of Johnson Valley is of good quality, ranging between 300 and 500 mg/L in dissolved-solids concentration. The fluoride concentration reported in these samples, however, exceeds the recommended limit (EPA, 1972). The recommended limit for fluoride in drinking



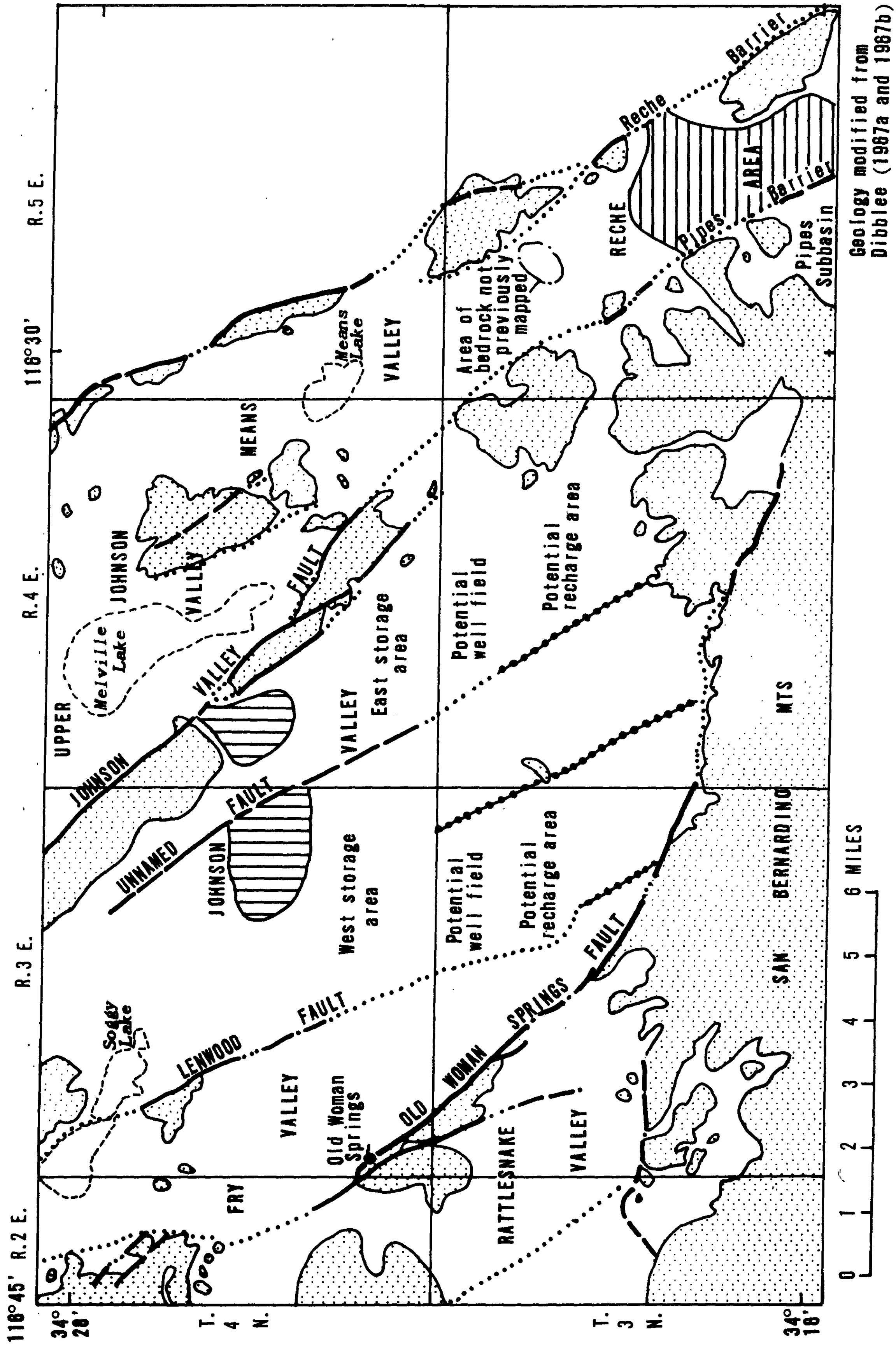


FIGURE 7.--Water-storage areas.

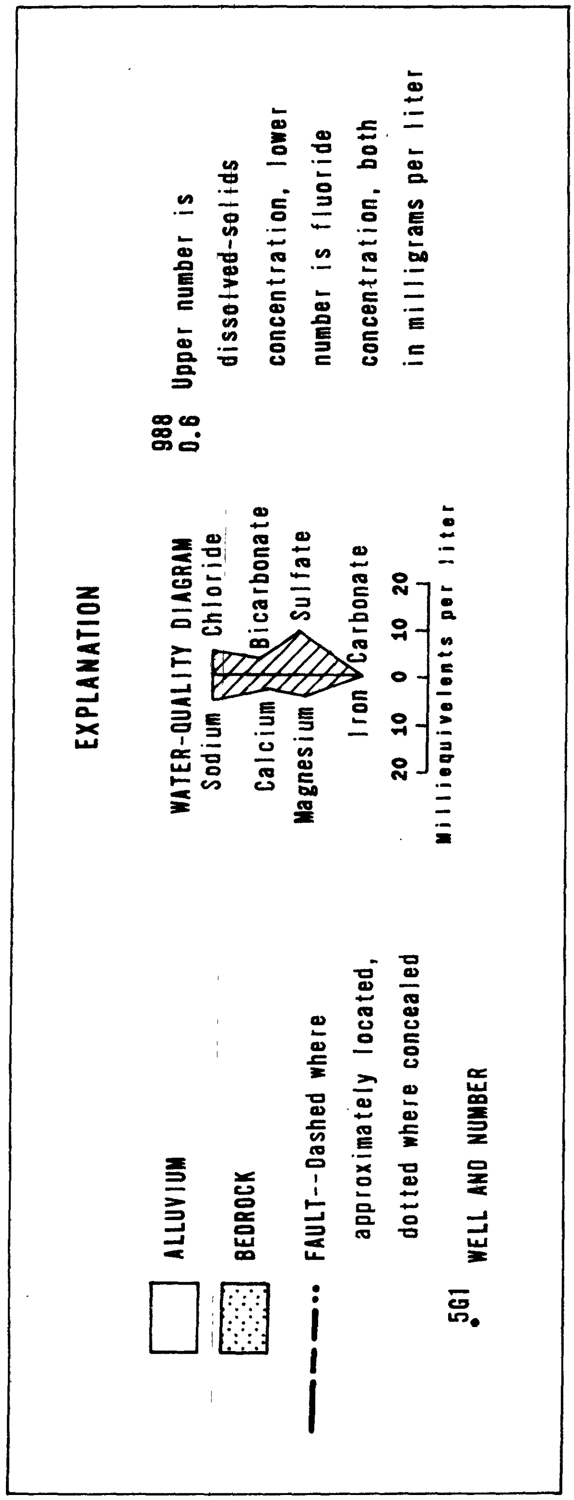
water is dependent on the climatic conditions where the water is to be used. This is because the quantity of water ingested by children (who are most affected by fluoride) is influenced by the air temperature. In areas with high air temperatures the recommended limit is lower than in areas of lower air temperatures. In Johnson Valley and adjacent areas the recommended limit is 1.4 mg/L. Fluoride concentrations in all but one sample in the southern part of Johnson Valley exceeded the limit, ranging from 1.8 mg/L to 9.0 mg/L. The excepted sample had 1.3 mg/L fluoride, nearly at the recommended limit.

The treatment of water to reduce the sulfate, chloride, or fluoride concentration probably would be too costly for consideration, but, as stated by Lewis (1972), the ground water from Johnson Valley could be blended with water from other sources to reduce the constituents to acceptable levels.

GROUND-WATER RESOURCES OF THE OTHER BASINS

The other ground-water basins in the project area were investigated and found not to be potential sources of supplemental water. A brief summary of each basin follows. In each summary the size of the basin, in square miles, refers only to the part underlain by alluvium. For some basins the surface-water drainage area is also mentioned.

Hydrologically, these are typical desert basins as described for Johnson Valley--that is, a basin of bedrock filled with alluvium and partly saturated with water.



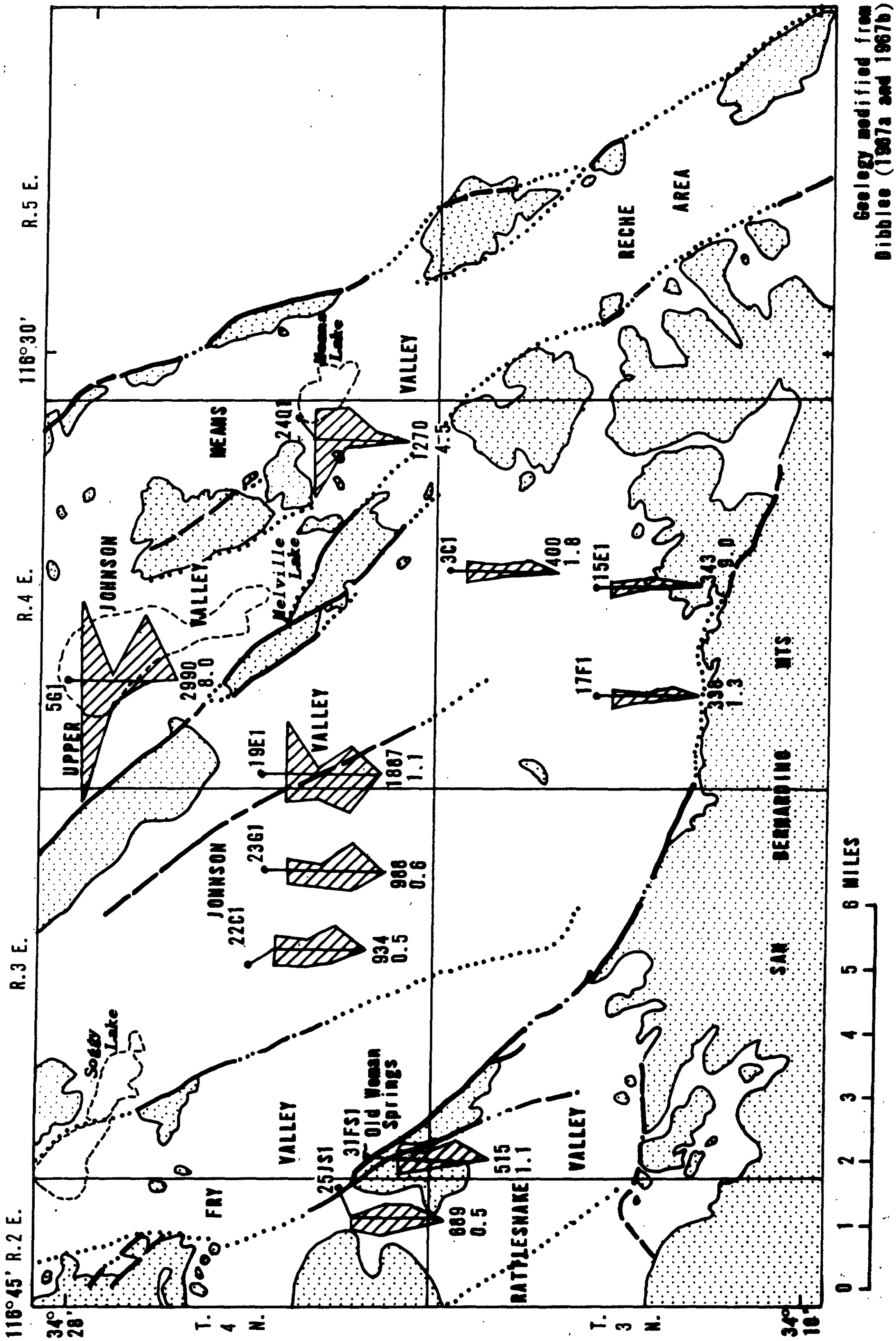


FIGURE 8.--Water-quality diagrams.

Rattlesnake Valley

Rattlesnake Valley is about 15 mi^2 in area and is filled with alluvium and basalt of unknown thickness. Test hole 1 (3N/3E-7L1 in fig. 2), drilled to 124 ft, did not reach bedrock or water. The material drilled through was a very hard mixture of mudstone and boulders. The gravity survey indicates that this basin is probably not more than 400 ft deep. The thickness of saturated alluvium is probably less than 200 ft.

The average specific yield in this basin, estimated from drill cuttings, is 10 percent or less.

Surface water enters Rattlesnake Valley from the San Bernardino Mountains in Arrastre Creek, Rattlesnake Canyon (fig. 2), and other small drainages only as a result of floodflow. The streams are not perennial in the valley. Most of the floodwater probably leaves the valley, but some infiltrates stream channels and may reach the water table. Most of the water that infiltrates is evaporated from the stream channels before it can migrate to the water table.

Ground-water seepage from the weathered and fractured bedrock across the fault along the base of the mountains probably supplies most of the water to the ground-water basin. Rattlesnake Spring and Two-Hole Spring are indications that the mountains yield a rather steady, year-round supply. Ground water in Rattlesnake Valley moves generally northeastward across Old Woman Springs fault into Fry Valley.

No chemical analyses of ground water are available from Rattlesnake Valley, but the water probably is similar to that from Old Woman Springs (4N/3E-31FS1, table 4).

Although water probably can be obtained from wells, the basin was considered not large enough to be a significant source of water for export.

Fry Valley

Fry Valley is about 17 mi^2 in area and is filled with alluvium and probably also contains basalt (Dibblee, 1967b), although no basalt has been reported in the few available well-drillers' logs. Test hole 2 (4N/3E-29P1 in fig. 2), drilled to 180 ft, reached bedrock but did not reach water. Two wells drilled about 1 mi northwest of this hole reached water at about the 200-ft depth and bedrock at 250 ft. Gravity data indicate that much of the basin is less than 200 ft deep. The thickness of saturated alluvium probably is less than 100 ft. The gravity map and two outcrops of bedrock, southwest of Soggy Lake, indicate a partly buried bedrock ridge that divides the Fry Valley ground-water basin into two parts.

Water enters the southern part of Fry Valley as surface flow only during flash floods and, as in Rattlesnake Valley, probably most, if not all, either runs off or is evaporated and probably little or none reaches the water table.

The southern part of Fry Valley is recharged by seepage through or over Old Woman Springs fault. The many outlets of Old Woman Springs are evidence of this recharge. Ground water in the southern part moves generally northeastward across Lenwood fault into Johnson Valley.

The northern part of Fry Valley receives some water during flash floods, but, as in the southern part, little or none reaches the water table. Occasionally floodwater will pond on Soggy Lake, but probably it all evaporates because it cannot infiltrate the lakebed clay.

Ground water moves into the northern part as seepage from weathered and fractured bedrock of the surrounding low mountains and perhaps through fractures in the bedrock ridge that separates it from the southern part. Ground-water outflow from the northern part is across Lenwood fault into Johnson Valley at Soggy Lake.

The quality of the water in the basin is adequate for most uses. Dissolved-solids concentrations in analyses are less than 1,000 mg/L, but sulfate generally exceeds the recommended limit.

Ground water in storage in Fry Valley was not estimated because the basin is too small to consider for exporting water. Water is presently being pumped for domestic use. One well in the southern part is reported to yield 100 gal/min, but most wells have much smaller yields.

Upper Johnson Valley

Upper Johnson Valley (fig. 2) occupies 45 mi^2 (including the valley area outside the project limits) and is filled with alluvium and lakebed clay. Depth to bedrock is unknown but probably is about 200 ft in the deepest part of the basin. The alluvium in the northern part of the basin probably is a thin cover over a bedrock pediment. A well drilled in the northern part of the basin, 6 mi north of the project area, penetrated 40 ft of alluvium and 84 ft of weathered bedrock and struck hard, fresh bedrock at 125 ft. Water was found at a depth of 480 ft in fractured bedrock.

Surface-water inflow to Upper Johnson Valley occurs only after infrequent thunderstorms. Little if any of this runoff percolates down to the water table. No surface-water outlets exist because Upper Johnson Valley is not drained.

Ground-water inflow is restricted to a small quantity of seepage across the Johnson Valley fault near test holes 17C1 and 18J1 in T. 4 N., R. 4 E. Ground-water discharges by evaporation at Melville Lake where the water table is shallow. Probably some ground water leaves the basin as seepage through bedrock fractures southeastward to Means Valley.

A sample of ground water from a shallow well on the north side of Melville Lake contained nearly 3,000 mg/L dissolved solids. The principal constituents were sodium, chloride, and sulfate; fluoride concentration was 8 mg/L.

Because of the poor chemical quality of the water and the limited volume of saturated alluvium, ground water in storage was not estimated.

Means Valley-Reche Area

This area is part of the Reche subbasin of Lewis' report (1972). For the present report, only the part of the Reche subbasin that is north of T. 2 N. was considered. Lewis suggested that ground water moved northeastward from the Pipes subbasin (fig. 7) and northward through the Reche subbasin to Means Valley. As a part of this project a test hole was planned to determine the depth to bedrock between the Reche area and Means Valley. Investigation of the proposed test-hole site showed that previously unmapped bedrock is exposed at the site. Because this bedrock divides the Reche subbasin (of Lewis, 1972) into two parts, the parts will be discussed separately as Means Valley and the Reche area.

Means Valley.--Means Valley is about 15 mi^2 in area and is filled with alluvium probably not more than 200 or 300 ft thick. No wells have been drilled to bedrock. Water levels in three shallow auger holes (fig. 4) define the water table, which is practically flat; the gradient toward Means Lake is less than 10 ft/mi.

Surface water enters Means Valley from Johnson Valley southwest of Means Lake and from the surrounding bedrock hills. The drainage divide between Means Valley and the Reche area is the exposed bedrock. Probably only a little surface water reaches the water table. No surface water leaves the valley because Means Valley is not drained.

Ground-water inflow is from seepage across the Johnson Valley fault southwest of Means Lake and probably from the north and northwest from seepage through bedrock fractures. Ground water discharges by evaporation at Means Lake where the water table is shallow. There is no known subsurface outlet, but probably some water migrates through fractures in bedrock toward Emerson Lake to the northeast (fig. 1).

Chemical analysis of the ground water in Means Valley shows about 1,300 mg/L dissolved solids, including 4.5 mg/L fluoride and 92 mg/L nitrate.

Although Means Valley is nearly filled with water it was not considered for potential export because: (1) The alluvium penetrated by the test holes contained much silt and clay, indicating a low specific yield; (2) the ground-water basin is not large enough to contain a worthwhile quantity for export; and (3) the chemical quality of the water is poor.

Reche area.--The Reche area covers about 8 mi^2, but less than 5 mi^2 contains saturated alluvium (fig. 7). The rest is occupied by dry alluvium, and whatever ground water is available is in bedrock fractures. The alluvial aquifer is restricted between the Pipes and Reche ground-water barriers (Lewis, 1972) on the west and east, respectively (fig. 7), and by bedrock on the north and south.

Surface water enters from an 8-mi^2 mountainous drainage area on the west. Little or none of the surface flow reaches the water table. Some of the precipitation in the mountainous area permeates the weathered and fractured bedrock and slowly migrates northeastward across part of the Pipes subbasin and into the Reche area.

The highest point in this drainage basin is 5,200 ft above sea level. Mean annual precipitation is less than 8 in. Eakin (1966, p. 260) considered that any watershed that is below 6,000 ft in altitude and has less than 8 in of mean annual precipitation contributes a negligible quantity of annual recharge to the adjacent ground-water basin. Even a very small quantity contributed throughout a long period of geologic time will amount to something, so, although the annual natural recharge to the Reche area may be very small, a ground-water basin does exist. Water pumped from this area, however, should be considered as mined and not replaceable. Ground-water outflow is by seepage across the Reche barrier to the northeast.

No chemical analyses of water from the Reche area are available, but the water is probably similar to that immediately to the south in T. 2 N., R. 5 E., which is of good quality--a calcium bicarbonate type water with 300 mg/L or less dissolved solids.

CONCLUSIONS

The Johnson Valley ground-water basin contains about 250,000 acre-ft of water in storage, of which about half can be considered recoverable. About 250,000 acre-ft of void space in the unsaturated alluvium is available for storage of imported water, but only about half could be recovered.

The quality of the water in storage is satisfactory for public consumption, although water from some areas has high fluoride concentrations and should be mixed with low fluoride water.

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EXPLANATION OF WELL TABLE

[Boxhead explanations are abstracted and modified from U.S. Geological Survey "Instructions for Using the Punch-Card System for the Storage and Retrieval of Ground-Water Data"]

Well No.: See well-numbering diagram.

Owner: The apparent owner or user.

Inventory date: The year the well was field canvassed; other information given generally applies for this date.

Method drilled:

A, Rotary
B, Bored or augered
C, Cable-tool
D, Dug
Z, Wire-line core.

Depth of well: Drilled depth, in feet below land-surface datum.

Diameter: Inside diameter of the well, in inches; nominal inside diameter, in inches, of the innermost casing at the surface for drilled cased wells.

Altitude of lsd: Altitude of land-surface datum, in feet, above or below (-) mean sea level. Land-surface datum is an arbitrary plane closely approximating land surface at the time of the first measurement and used as the plane of reference for all subsequent measurements.

Log data: Restricted information. Availability to public dependent upon requester securing owner's permission.

C, Caliper (diameter) survey
D, Driller's
E, Electric
G, Geologist or sample
J, Gamma-ray.

TABLE 2.--*Description of wells*

Well No.	Owner	Inventory date	Year drilled	Method drilled	Depth of well	Diameter	Altitude of land-surface datum	Log data
3N/3E-2R1	U.S. Geol. Survey	1976	1976	A	560	2	2,981	JECG
3N/3E-7L1	U.S. Geol. Survey	1976	1976	AZ	124	--	3,520	G
3N/4E-3C1	A. Cole	1975	1964	C	137	8	2,840	--
3N/4E-15E1	Goodridge	1969	--	--	420	--	3,178	--
3N/4E-17F1	M. A. Page	1969	1962	C	484	8	3,217	--
4N/2E-1Q2	U.S. Geol. Survey	1975	1975	B	82	2	2,880	G
4N/3E-7G1	U.S. Geol. Survey	1975	1975	B	97	2	2,895	G
4N/3E-8D1	U.S. Geol. Survey	1975	1975	B	102	2	2,869	G
4N/3E-13N2	U.S. Geol. Survey	1975	1975	B	60	2	2,822	G
4N/3E-15J1	U.S. Geol. Survey	1975	1975	B	90	2	2,863	G
4N/3E-22C1	Lafon	1973	1973	--	288	12	2,895	--
4N/3E-23G1	M. A. Donohue	1968	1950	C	154	10	2,850	D
4N/3E-29P1	U.S. Geol. Survey	1976	1976	A	180	--	3,115	G
4N/4E-5G1		1968	--	C	--	4	2,709	--
4N/4E-17C1	U.S. Geol. Survey	1975	1975	B	61	2	2,735	G
4N/4E-18J1	U.S. Geol. Survey	1975	1975	B	37	2	2,755	G
4N/4E-19E1	W. Shehorne	1968	1951	C	252	12	2,793	--
4N/4E-24J1	U.S. Geol. Survey	1975	1975	B	21.5	2	2,571	G
4N/4E-24Q1		1975	--	D	--	48	2,571	--
4N/4E-29D1	U.S. Geol. Survey	1975	1975	B	47	2	2,770	G
4N/4E-30N1	U.S. Geol. Survey	1975	1975	B	81.5	2	2,821	G
4N/4E-32Q1	U.S. Geol. Survey	1976	1976	A	490	2	2,825	JECG
4N/4E-36B1	U.S. Geol. Survey	1975	1975	B	72	2	2,630	G
4N/5E-31B1	U.S. Geol. Survey	1975	1975	B	92	2	2,615	G

TABLE 3.--*Description of springs*

Spring No.	Name of spring	Date measured	Water use	Temperature (degrees Celsius)	Altitude of land-surface datum (ft above msl)	Yield (gal/min)
4N/2E-25JS1	Cottonwood Spring	1976	Unused	--	3,165	0
4N/3E-31FS1	Old Woman Springs	1967	Domestic	21	3,220	25

TABLE 4.--*Chemical analyses of*

[Constituents and properties in milligrams

Well or spring No.	Date of sample	Temperature (degrees Celsius)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity as $CaCO_3$
3N/4E-3C1	9-29-69	20	30	14	82	4.7	82	0	67
3N/4E-15E1	6-10-66	--	22	3.0	93	5.0	140	0	--
3N/4E-17F1	6-10-66	--	27	3.0	72	6.0	76	0	--
4N/2E-25JS1	4-24-73	--	101	27	66	5.7	267	0	218
4N/3E-22C1	3-19-76	--	108	46	122	4.6	125	0	103
4N/3E-23G1	2-20-69	--	100	73	98	6.0	136	0	112
4N/3E-31FS1	4-24-73	--	58	22	104	4.9	133	0	109
4N/4E-5G1	1-13-54	--	127	2.0	880	15.4	61	0	--
4N/4E-19E1	6-11-74	--	174	144	200	6.5	138	0	113
4N/4E-24Q1	3-11-55	--	47	14	440	19.5	649	0	--

ground water in Johnson Valley

per liter unless indicated otherwise]

Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Total nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness (Ca, Mg)	Noncarbonate hardness	Specific conductance (micromhos)	pH	Well or spring No.
124	74	1.8	8.8	400	132	65	672	7.6	3N/4E-3C1
100	39	9.0	3.0	343	68	--	580	7.8	3N/4E-15E1
100	50	1.3	10	338	82	--	530	7.6	3N/4E-17F1
231	47	.48	.8	689	365	147	1,093	7.3	4N/2E-25JS1
390	149	.5	15	934	458	--	1,364	8.0	4N/3E-22C1
437	133	.6	3.4	988	549	437	1,321	8.2	4N/3E-23G1
282	38	1.1	2.4	515	233	124	912	7.9	4N/3E-31FS1
965	895	8.0	1.0	2,990	--	--	4,484	6.7	4N/4E-5G1
461	615	1.1	28	1,887	1,027	914	2,786	7.8	4N/4E-19E1
102	355	4.5	92	1,270	--	--	2,340	7.8	4N/4E-24Q1

TABLE 5.--*Lithologic logs of test holes*

	Thickness (feet)	Depth (feet)
3N/3E-2R1 (TH3). Drilled by U.S. Geological Survey in 1976. 2-inch casing, perforated 240-241.5 feet. Altitude 2,981 feet.		
Sand, coarse, soft	40	40
Sand and gravel, fresh, much mica	20	60
Sand, some gravel	10	70
Gravel, hard, tight	9	79
Boulder, quartz and feldspar	4	83
Gravel, gray	5	88
Sand, very coarse, black 40 percent, white 40 percent, pink 20 percent	20	108
Sand, coarse-very fine	4	112
Sand, very coarse and gravel, fine	15	127
Silt, sandy, soft	15	142
Silt, sandy, hard	10	152
Clay, soft, gray, sandy	8	160
Clay, silty, occasional white pebble, hard	42	202
Clay, sticky, white, with some coarse sand, some gypsum	20	222
Clay, soft, brown, silty	47	269
Clay, gray, silty	11	280
Silt, brown, gray, some very coarse sand	40	320
Silt, brown, gray, some very coarse sand becoming sandier, some pebbles	10	330
Clay, gray, sandy, very soft 331-335 feet	30	360
Clay, brown, gray, sandier, chips of white quartzite	5	365
Sand, coarse, some fine-very fine, and silt, hard	5	370
Clay, gray, gummy, silty	30	400
Sand and fine gravel	40	440
Clay, silty, tight	30	470
Sand, coarse, very coarse, some gravel	10	480
Sand and clay, very fine grained	35	515
Sand, coarse, angular, some gray sandy clay, very hard	9	524
Rock, very few cuttings, chips, pink and white with some gray clay, some silty clay balls	26	550
Rock, very hard (smooth drilling)	10	560

TABLE 5.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
3N/3E-7L1 (TH1). Drilled by U.S. Geological Survey in 1976. Altitude 3,520 feet.		
Sand and gravel	20	20
Sand, very fine-very coarse, soft gypsum chunks	35	55
Sand and gravel, white chips, some rotten black chips	6	61
Boulders and sand	28	89
Mudstone with pebbles, alternating with loose sand	35	124
Clay, soft, gray	<1	124
4N/2E-1Q2 (TH19D). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 80-82 feet. Altitude 2,880 feet.		
Sand, fine and clay, brown	17	17
Gravel, medium, fine sand and silt	8	25
Sand, coarse and silt, reddish-brown	7	32
Sand, fine and silt, some coarse gravel, white	18	50
Clay, tight, dry, gray	24	74
Clay, sandy and coarse sand, gray	8	82
4N/3E-7G1 (TH17D). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 95-97 feet. Altitude 2,895 feet.		
Sand, fine and silt, some sandy clay, brown	4	4
Sand, fine and silt, gray	9	13
Sand, fine and sandy clay, occasional layers of blue-gray clay	47	60
Clay, tight, dry, gray	4	64
Sand, coarse, brown, some sandy clay	33	97

TABLE 5.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
4N/3E-8D1 (TH16D). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 100-102 feet. Altitude 2,869 feet.		
Clay, brownish-gray and white	55	55
Silt and fine sand, moist	7	62
Sand, rock fragments, moist	7	69
Sand, tight, some rock fragments, moist	1	70
Sand, fine and clay	2	72
Clay	3	75
Clay and rock fragments	1	76
Clay and moist sand	1	77
Clay, moist (slow drilling)	25	102
4N/3E-13N2 (TH5A-2). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 58-60 feet. Altitude 2,822 feet.		
Sand, medium to coarse, some gravel, brown	7	7
Sand, medium to coarse, some silt, reddish-brown	3	10
Sand, fine and silt, some clay, reddish-brown	2	12
Hard clay	2	14
Sand, medium to coarse, some silt and clay, reddish-brown	16	30
Clay, hard, dry, gray	25	55
Sand, coarse, and sandy clay, brown	5	60
4N/3E-15J1 (TH2A-2). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 88-90 feet. Altitude 2,863 feet.		
Sand, fine and silt, some coarse gravel, white	14	14
Sand, fine and clay, some coarse gravel, greenish-white (hard drilling)	6	20
Gravel, medium	15	35
Clay, tight, dry, gray	42	77
Sand, coarse, brown, some sandy clay	13	90

TABLE 5.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
4N/3E-29P1 (TH2). Drilled by U.S. Geological Survey in 1976. Altitude 3,115 feet.		
Sand and gravel, igneous and metamorphic and basalt chips	50	50
Sand, very coarse, hard, brown and white	15	65
Sand, very coarse, rotten feldspar, some basalt	18	83
Silt, gray, mostly quartz grains	25	108
Silt, coarse sand, some lavender clay	32	140
Clay, silty, gray and brown	10	150
Sand and gravel, hard	20	170
Granitic rock, hard, fresh mica, black and clear chips pink, black, varicolored, clear	10	180
4N/4E-17C1 (TH8A). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 59-61 feet. Altitude 2,735 feet.		
Sand, fine and silt, gray-brown, tight between 29-30 feet	30	30
Sand, coarse, and gravel, gray-brown	31	61
4N/4E-18J1 (TH7A). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 35-37 feet. Altitude 2,755 feet.		
Sand, fine and silt, brown	15	15
Sand, medium to coarse, brown	15	30
Clay, sandy, gray-brown	7	37
4N/4E-24J1 (TH11C). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 19½-21½ feet. Altitude 2,571 feet.		
Sandy, fine and silt, some gray clay	4	4
Clay, sandy, gray	6	10
Clay, gray	11½	21½

TABLE 5.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
4N/4E-29D1 (TH4A). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 45-47 feet. Altitude 2,770 feet.		
Sand, fine and silt, occasional cobbles, brown	16	16
Sand, fine and silt, some sandy clay, brown	8	24
Clay, sandy, brown and cobbles	3	27
Clay, sticky, sandy, gray	10	37
Clay, sandy, very sticky, gray, appears like decomposed granite	10	47
4N/4E-30N1 (TH10B-2). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 79½-81½ feet. Altitude 2,821 feet.		
Sand, fine and silt, brown, some coarse gravel	25	25
Sand, medium to coarse, and some clay, greenish-brown	10	35
Sand, medium to coarse, and some clay and coarse gravel, brown	10	45
Clay, sandy, brown and medium gravel, moist	15	60
Clay, sandy, brown, very tight	21½	81½
4N/4E-32Q1 (TH4). Drilled by U.S. Geological Survey in 1976. 2-inch casing. Altitude 2,825 feet.		
Sand, coarse	67	67
Clay, sandy, gray, sticky	26	93
Clay, hard sandy	12	105
Clay, gray-brown, slick, some sand	15	120
Sand with clay streaks alternating	15	135
Clay, gray, soft, gummy	15	150
Sand and clay, alternating beds	40	190
Clay, green, silty, some sand pods	7	197
Clay, hard, olive	8	205
Clay, green, sandy, occasional coarse sand and fine gravel	10	215
Sand, very coarse, some clay and silt	5	220
Sand and clay, alternating, some pebbles	5	225

TABLE 5.--*Lithologic logs of test holes*--Continued

	Thickness (feet)	Depth (feet)
4N/4E-32Q1 (TH4)--Continued.		
Clay, very hard, dark-green	15	240
Clay, soft, green, some sand (fast drilling)	20	260
Clay, soft, gray, very little sand	5	265
Sand with clay streaks, coarse-very coarse	50	315
Gravel, rock chips	7	322
Clay, alternating hard and soft, white, green, brown	18	340
Clay, sand, gravel, gravel pink, white, salt and pepper	5	345
Sand, clean, coarse, some very fine	13	358
Sand and clay, fine to medium	17	375
Sand, coarse with clay streaks	30	405
Sand, very fine	5	410
Clay, hard, brown (high mud pressure, slow)	10	420
Clay, as above, becoming sandy	15	435
Clay, gray and green, mud thickening	5	440
Clay, becoming sandy and hard	34	474
Gravel, loose, unconsolidated, fine, also very coarse sand	2	476
Granitic rock, large (3/8 inch) pink and white chunks, smaller angular pieces of white, black, and green, some hard green clay and a few grains of powder gypsum	14	490
4N/4E-36B1 (TH22E). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 70-72 feet. Altitude 2,630 feet.		
Sand, fine and silt, brown	5	5
Sand, coarse and gravel	15	20
Sand, medium to coarse, some clay, brown	52	72
4N/5E-31B1 (TH13C-2). Augered by U.S. Geological Survey in 1975. 2-inch casing, perforated 90-92 feet. Altitude 2,615 feet.		
Sand, medium and silt, brown	5	5
Sand, medium to coarse, some silt and gravel	15	20
Sand, medium and some clay, brown	22	42
Sand, medium to coarse and some clay, gray	50	92