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HYDROLOGIC RESPONSE TO IRRIGATION PUMPING IN DIAMOND VALLEY, EUREKA AND ELKO COUNTIES, NEVADA, 1950-65

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With section on

Surface Water

By

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ABSTRACT

This second appraisal on the water supply of Diamond Valley was made 4 years after the first cooperative study. The first report described the hydrology of the valley under nearly natural conditions and indicated that the recharge from precipitation within the basin was insufficient to account for the observed discharge. Estimates derived during the present study indicate that, of the 30,000 acre-feet of natural discharge each year, about 21,000 acre-feet is from precipitation within the basin and about 9,000 acre-feet is by interbasin flow from the adjacent Garden Valley area.

Nearly all ground-water development has been in the southern half of the valley, herein called the South Diamond subarea. In 1965, the total net pumpage was 12,000 acre-feet, which is less than half the estimated perennial yield of 30,000 acre-feet for Diamond Valley. Permits to pump about 150,000 acre-feet per year have been granted, mostly in the South Diamond subarea. Because most of the pumping occurs about 10 miles south of the nearest area of natural discharge, local overdraft is certain to occur long before an appreciable amount of natural discharge can be salvaged.

Pumping during the 16-year period 1950-65 has resulted in an estimated ground-water storage depletion of 60,000 acre-feet, which is roughly equal to the total net pumpage for the period. This is only 3 percent of the 2 million acre-feet of water estimated to be in storage in the upper 100 feet of saturated alluvium in the South Diamond subarea. If future pumping continues to be concentrated in the same general areas as in 1965, the amount of storage depletion necessary before a new equilibrium can be achieved is about 3 million acre-feet for a sustained net pumpage of only 12,000 acre-feet per year; the ultimate maximum drawdown would be about 200 feet below 1965 levels. Pumpage increased at a rate of about 2,000 acre-feet per year between 1960 and 1965; if the same rate of increase prevails, a new equilibrium may not be achieved in the future until increased pumping costs result in a decrease or relocation of pumping.

The first approximation of transmissibility distribution in the South Diamond subarea suggests that the values range from less than 50,000 gpd per foot in the northern part of the subarea to more than 100,000 gpd per foot locally in the southern part. The long-term storage coefficient may average about 0.14 for the entire subarea but locally may be as high as 0.20.

The chemical quality of the water in 1965 was satisfactory for irrigation, domestic, and stock use. However, over the long term, recycling of pumped water and the possibility of migration of poor quality water from beneath the playa could result in a gradual deterioration in water quality in the areas of use.

INTRODUCTION

Purpose and Scope

This is the second report on the hydrology of the Diamond Valley area prepared by the U. S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. The first report, (Eakin, 1962) was a reconnaissance and provided preliminary estimates of recharge to and discharge from the valley.

The need for the present study was expressed by the State because of the extensive development of ground water for irrigation since 1962. Development has been concentrated in the south-central part of the valley. By 1964 permits to pump more that 150, 000 acre-feet per year had been issued which greatly exceeded the preliminary estimates of recharge for the entire valley. A local overdraft in the area of concentrated pumping and a potential overdraft for the entire valley was suspected. Furthermore, continued lowering of the water level by depletion of water from storage might induce underflow of poor quality from beneath the playa into the area of development. Therefore, the principal purposes of this report are: (1) to reappraise the hydrology of the valley with special emphasis upon the initial effects of the present (1965) development; (2) to predict the possible future effects of this development; (3) to appraise the chemical quality of the water to provide a basis for comparison in the future; and (4) to evaluate the structural basin and associated carbonate-rock aquifers to determine the outer hydraulic boundaries of the valley.

To accomplish these objectives, this report includes: (1) a reappraisal of the main elements of the natural hydrologic system, including precipitation, recharge, interbasin flow, and natural discharge; (2) an estimate of the average annual surface-water inflow to the valley and its distribution within the valley; (3) a description of the ground-water reservoir; (4) an estimate of the magnitude of depletion of ground water in storage; (5) estimates of pumpage, ground-water yield, possible overdraft, and effects of future development; and (6) an analysis of the chemical quality of the ground water to establish a base for comparing changes in salt balance that probably will occur in the future.

Field work began in April 1964 when 14 small-diameter test wells were drilled in undeveloped parts of the valley. Water-level measurements of selected wells were made in October 1964 and in April 1965. Intensive field work began in August 1965 and was completed by July 1966. This work consisted of canvassing all wells in the area, measuring the water levels in wells after the 1965 irrigation season and before the 1966 season, making pumping tests on wells, estimating the annual pumpage, measuring discharges of major springs and flowing wells, and inventorying the chemical quality of the water. Surface-water inflow to the valley was estimated from periodic streamflow measurements made during the course of this study.

This reevaluation is consistent with the objectives of the long-range cooperative program (Shamberger, 1962, p. 14) for the orderly study of the water resources of Nevada which provides for additional detailed studies in areas where moderate to substantial development has occurred and where records are available through a continuing inventory over a prolonged period of time.

Location and General Features

Location and Areal Extent

Diamond Valley is an intermountain valley in east-central Nevada. It lies within an area bounded by lat 39°27' and 40°15' N. and long 115°47' and 116°12' W. Most of the valley is in Eureka County; however, the north end extends about 8 miles into the southwestern part of Elko County (fig. 1). It is roughly elliptical in shape, the long axis extending about 56 miles from Prospect Peak at the southern end to Bailey Mountain at the northern end. The maximum width is approximately 20 miles at the latitude of T. 22 N. and the average width is about 12 miles. The total area of the drainage basin is about 735 square miles.

The area is bounded on the east by the Diamond Mountains and on the west by the Sulphur Spring Range, Whistler Mountain, and the Mountain Boy Range (pl. 1). The southern boundary is formed by the Fish Creek Range and the northern boundary by the Diamond Hills. These surface boundaries form a closed basin except for Devils Gate, which is a topographic low between Whistler Mountain and the Mountain Boy Range and which permits surface and subsurface inflow from Antelope, Kobeh, and Monitor Valleys.

Garden Valley is about 22 miles long, 5 to 6 miles wide, and is on the west flank of the Sulphur Spring Range at the southeast end of Pine Valley. It is separated from Pine Valley by the Roberts Mountains and Table Mountain and surficially drains into Pine Valley through two topographic lows at the southern end of Table Mountain.

The lowest part of Diamond Valley, altitude about 5,770 feet, is the playa which covers most of the northern part of the valley floor. Southward from the playa the valley floor rises at a gradient of about 9 feet per mile. Areas at altitudes above 9,000 feet are found only in the Fish Creek Range and Diamond Mountains. The highest point is South Diamond Peak, in the Diamond Mountains, at an altitude of 10,614 feet.

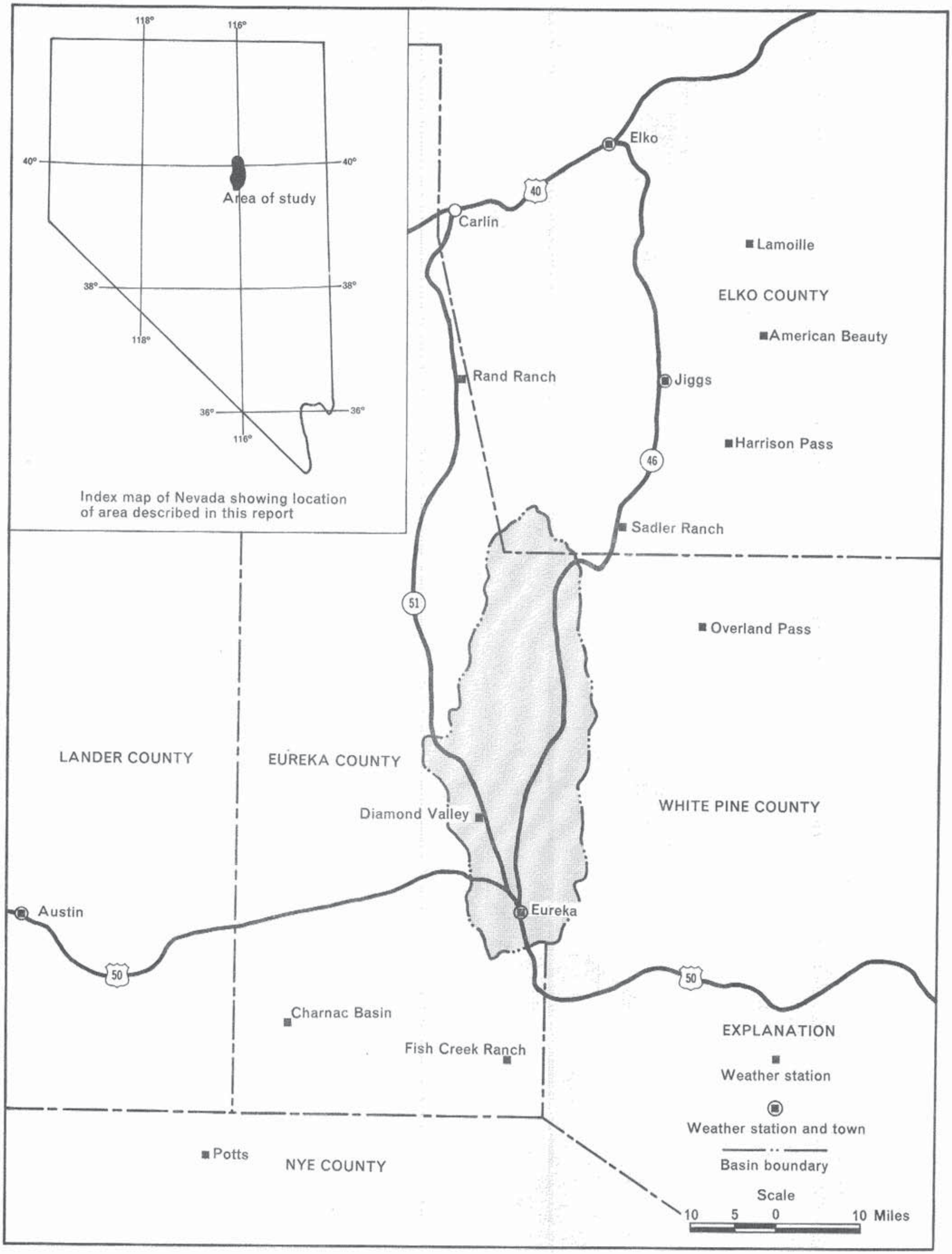

Figure 1.—Location of area, principal communities and weather stations

Eureka, population 605 (Nevada Dept. of Economic Development, 1965 estimate), is the only town in the area and is the county seat of Eureka County. It is in the southern end of the valley on the lower slopes of the Fish Creek Range. U. S. Highway 50 crosses the southern part of the valley and passes through Eureka. State Highway 51 joins U. S. Highway 50 about 3 miles northwest of Eureka and traverses part of the west side of the valley. It leaves the area at Garden Pass and extends northward to U. S. Highway 40 at Carlin (fig. 1). State Highway 46, a graded and gravel road, originates in Eureka, traverses the east side of the valley, and leaves the area at Railroad Pass; from there it extends northward through Huntington Valley and connects with U. S. Highway 40 at Elko. The remainder of the valley floor is traversed by graded and gravel roads. Graded roads have been constructed along most section lines in developed areas and permit access in all but the most severe weather. The nearest rail connections are at Ely, about 76 miles east of Eureka, and at Carlin and Elko, about 100 miles north of Eureka.

Subareas

For the purpose of this report, the valley has been divided into the South Diamond and the North Diamond subareas. The subareas are shown on plate 1. The South Diamond subarea lies south of the cross-valley road from Sulphur Springs to Thompson Ranch in T. 23 N., R. 54 E. It has a total area of about 276,000 acres and contains the area of major ground-water development. The North Diamond subarea lies north of the above described cross-valley road. It has a total area of about 194,000 acres and contains all but a small part of the area of natural discharge. The west side of this subarea is characterized by a large volume of spring discharge.

Economic Development

Diamond Valley has developed into a major agricultural area; however, the area was developed initially to exploit the mineral resources of the Eureka district. The first ore was discovered in 1864, a few miles southwest of the present town of Eureka. In 1869 rich ore bodies were discovered in Ruby Hill, and Eureka developed into a prosperous mining district. Mining activity continued to increase steadily, and by 1880 the Eureka district, according to Hague (1892, p. 6), was the most successful in the State at that time. During the period 1871-80, the town of Eureka had a population in excess of 9,000 (Myrick, 1962, p. 91). The total value of lead and silver produced up to 1959 was approximately 122 million dollars (Nolan, 1962, p. 57), most of which was produced in the period 1871-80. In 1880 the major ore bodies in Ruby Hill were apparently bottomed. Production continued on a reduced scale and no new discoveries were made until 1940, when ore was found in the hanging-wall side of the Ruby Hill fault.

A new shaft, the Fad, was started in 1941 to exploit the newly discovered ore. Development was interrupted by the war, but in 1948 when the shaft had reached a depth of 2,465 feet, a large flow of water was encountered in the 2,250-foot level drift. This resulted in a flooding problem which was not economically solved for many years. About 5,000 acre-feet of water was pumped from the shaft during the period from March 1948 to December 1948 (Stuart, 1955, p. 2), in an unsuccessful attempt to dewater the shaft. Most of the pumped water recharged the valley-fill reservoir by infiltration through relatively permeable alluvial deposits. Until the water problem was solved, exploratory work was concentrated in the region north of the Fad shaft. The T. L. shaft, approximately 1.1 miles northwest of the Fad shaft, was constructed in 1954. It was sunk to a depth of 1,034 feet and was operated until 1958 when it closed for economic reasons. At the present time, grouting the major water-bearing formations has permitted the Fad shaft to be dewatered with relatively small pumping rates. Pumped water currently is run either into the Locan or T. L. shafts. At the end of 1965 a sampling and exploration program was terminated and operations were temporarily suspended, pending the completion of metallurgical tests.

The first agricultural development in the valley was associated with the raising of livestock. Initial development consisted of no more than systems of ditches to distribute the available water. Meadows of native grasses were sustained by surface-water runoff in the lower parts of some canyons and by spring discharge along the sides of the valley. Ranching operations consequently were established in those areas.

Spring discharge along the west side of the valley was supplemented by the drilling of flowing wells on the Romano Ranch in 1948 and the Flynn Ranch in 1949.

The first ground-water development in the South Diamond subarea was attempted in 1949, when two wells were drilled on the east side of the valley. From 1950 to 1958 a few wells were drilled each year, then in 1958 renewed effort was made to develop land for irrigation. In 1961 an estimated 85 wells were completed (Eakin, 1962, p. 29). By 1965 more than 200 irrigation wells had been drilled; however, probably not more than 80 have been pumped during any single growing season. The maximum use of land probably will not occur for several more years.

Previous Studies

The geology of the Eureka Mining District has been the subject of much detailed study. Early investigators, King (1878), Hague (1883, 1892), and Walcott (1884), described a stratigraphic section from locations in the vicinity of the Eureka district which was long used as a standard for the central Great Basin. The economic aspects of the area were described by Curtis (1884) and Emmons (1910).

Detailed studies and subsequent revisions of small parts of the section were made by Walcott (1908a, b, 1923), Wheeler and Lemmon (1939), Gianella (1946), Sharp (1947), and Easton and others (1953). However, the most comprehensive and detailed study of the stratigraphic section in the vicinity of Eureka has been reported by Nolan, Merriam, and Williams (1956). A detailed study, which summarizes the geology of the Eureka Mining District, was made by Nolan (1962). Merriam (1963) described the Paleozoic rocks of Antelope Valley.

A preliminary geologic map of Eureka County, scale 1:200,000, was compiled by Lehner, Tagg, Bell, and Roberts (1961), and a preliminary geologic map of the Diamond Springs Quadrangle, scale 1:62,500, was made by Larsen and Riva (1963). A geologic map, scale 1:12,000, is included in Nolan's study of the Eureka Mining District (1962). Mabey (1964) made a gravity survey of Eureka County and adjoining areas.

Interest in possible oil development has led to the drilling of two exploratory wells in Diamond Valley. In 1954, a 1,072-foot well was drilled by the Diamond Oil Corp. in sec. 15, T. 26 N., R. 54 E., and in 1956 the Shell Oil Company drilled an exploratory well to a depth of 8,042 feet in sec. 30, T. 23 N., R. 54 E.

The first hydrologic studies made in the area were concerned with mine drainage. A general description of the drainage problem was given by Mitchell (1953). Stuart (1955) described the results of a pumping test of the Fad shaft which was made in 1952; at that time Stuart and Metzger also made a general study of the region to assist in evaluating the problem.

A reconnaissance of the ground-water resources of Diamond Valley was made by Eakin (1962); it is the only study which gives a preliminary evaluation of the hydrology of the entire valley. The hydrology of areas adjacent to Diamond Valley has been studied at reconnaissance level by Eakin (1960, 1961) and by Rush and Everett (1964, 1966a, b).

Climate

The climate in Diamond Valley is similar to that of most valleys in east-central Nevada. Air masses which move eastward across Nevada are generally deficient in moisture. Areas at low elevations commonly receive less moisture than areas at higher elevations. This results in semiarid conditions in the valleys and subhumid conditions in the surrounding mountains. Winter precipitation generally falls as snow from regional storms, whereas summer precipitation is localized as thunderstorms of short duration and high intensity.

Table 1 lists the average monthly and annual precipitation, in inches, at 14 stations in central Nevada. Eureka and Diamond Valley are the only stations within the area of study. At Eureka, the maximum annual precipitation, 20.64 inches, occurred in 1907; the minimum, 6.13 inches, occurred in 1928. The record at Diamond Valley is too short and incomplete to provide a valid average. Data available suggests that the average annual precipitation on the valley floor is several inches less than at Eureka, possibly about 8 inches.

Temperature is subject to large daily and seasonal variations. Summer days generally are hot and nights cold. Freezing temperatures have been recorded at Eureka in every month of the year. Winters normally are severe. The average annual temperature at Eureka for the period 1953 to 1959 is 46°F. Short-term records at Diamond Valley suggest that the average temperature there throughout most of the year is several degrees lower than at Eureka. Additional information on precipitation is given in the section on recharge. The effects of thermal inversion on the growing season in the South Diamond subarea are discussed in the section on growing season.

Acknowledgments

Acknowledgment is made of the cooperation of the local residents of the valley in supplying data and permitting use of their wells for pumping tests and water-level observations during the course of this investigation. The writer is grateful for the wholehearted assistance received from Federal, State, and local governmental agencies. Most of the drillers' logs and other pertinent data on well construction used in this investigation were furnished by the Nevada State Engineer.

Mr. Ivan B. Jones, assistant County Agent, of Eureka and White Pine Counties, furnished records of crop acreages. Data on the status of privately owned lands were made available by the U. S. Bureau of Land Management. Lithologic and electric logs of Shell Oil Company tests, Diamond Valley No. 1, were provided by Mr. Robert Horton formerly of the Nevada Bureau of Mines.

Table 1.--Average monthly and annual precipitation, in inches, at 14 stations in central Nevada

[From published records of the U.S. Weather Bureau]

Location[1]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1 Elko	1.23	0.96	0.92	0.70	0.86	0.68	0.35	0.28	0.33	0.66	0.76	1.06	8.7
2 Lamoille	1.42	1.60	1.94	2.40	2.29	1.42	.66	.57	.77	1.44	1.37	1.50	17.3
3 American Beauty	--	--	--	--	--	--	--	--	--	--	--	--	21.5
4 Rand Ranch	.75	.96	.98	1.02	1.30	1.11	.28	.47	.48	.68	.94	.94	9.9
5 Jiggs	1.01	.89	1.14	1.27	1.60	.90	.41	.50	.53	.82	.90	1.14	11.1
6 Harrison Pass	1.95	1.73	1.84	2.12	2.13	1.26	.63	.65	.68	.91	1.36	2.11	17.3
7 Sadler Ranch	--	--	--	--	--	--	--	--	--	--	--	--	7.9
8 Overland Pass	--	--	--	--	--	--	--	--	--	--	--	--	10.2
9 Diamond Valley	--	--	--	--	--	--	--	--	--	--	--	--	7.4
10 Eureka	.87	.86	.90	1.60	1.14	1.29	.74	1.57	.76	.56	1.15	1.34	12.7
11 Austin	1.13	1.05	1.47	1.57	1.46	.79	.55	.53	.49	.84	.80	.90	11.5
12 Charnac Basin	.92	1.46	1.12	1.24	2.02	.66	.41	.66	.63	.62	1.04	.83	11.6
13 Fish Creek Ranch	.44	.32	.53	.51	.62	.34	.55	.48	.53	.33	.59	.50	5.7
14 Potts	.56	.66	.74	.72	.95	.36	.51	.44	.27	.33	.37	.42	6.33

1. Stations listed according to geographic location, from north to south, and locations shown on figure 1.

	Altitude	Location Section	 Township	 Range	Period of record	Remarks
1	5,047	16	34 N.	55 E.	95 years, 1870-1964	
2	6,260	6	32 N.	58 E.	54 years, 1911-64	
3	8,000	33	31 N.	58 E.	4 years, 1959-62	Storage gage
4	5,047	33	30 N.	52 E.	9 years, 1957-65	
5	5,465	34	30 N.	56 E.	21 years, 1945-65	
6	7,300	2	28 N.	57 E.	14 years, 1951-64	Storage gage, records prorated monthly
7	5,690	26	27 N.	55 E.	16 years, 1950-65	Storage gage
8	6,789	29	25 N.	57 E.	16 years, 1950-65	Storage gage
9	5,850	18	21 N.	53 E.	3 years, 1963-65	Poor record, best available values within the area
10	6,540	13	19 N.	53 E.	20 years, 1922-30, 1939-42, 1953-59, 1965	
11	6,594	19	19 N.	44 E.	73 years, 1890-98, 1900-1908, 1911-64	
12	8,500	20	17 N.	49 E.	7 years, 1955-61	Storage gage, records prorated monthly
13	6,050	10	16 N.	53 E.	19 years, 1944-62	
14	6,635	35	15 N.	47 E.	28 years, 1892-1919	

GENERALIZED GEOLOGY

Physiography

The landforms in Diamond Valley are typical of those which occur in the Great Basin. The valley is a structural depression which is partly filled by unconsolidated and semiconsolidated lacustrine and subareal deposits. Physiographically, the valley may be divided into three parts, the mountains, the alluvial apron, and the playa. The alluvial apron and playa together form the valley floor. Pleistocene lake features have been developed largely on the alluvial apron.

Mountains

The mountains that border Diamond Valley are composed principally of complexly faulted and folded Paleozoic sedimentary rocks (pl. 1). The overall size and shape of the mountains is the result of regional uplift and warping associated with normal faulting. The complex internal structures have had little control over the gross topographic features; however, the effects of internal structures may be pronounced in certain areas, and fault scarps and ridges formed by relatively resistant beds are locally prominent. The mountains are areas of active erosion and are generally deeply dissected. This dissection is prominent in the Diamond Mountains. Areas underlain by volcanic rocks typically have smooth convex upper surfaces and steep talus-covered slopes.

Alluvial Apron

The alluvial apron is the area of intermediate slope between the mountains and the comparatively flat playa. The apron generally is composed of coalescing alluvial fans but may also contain pediments, or areas in which the bedrock is covered by a thin sheet of alluvium.

The slopes on the alluvial apron decrease from about 100 feet per mile near the mountain fronts to only a few feet per mile near the playa. Local relief may be as much as 25 feet, due principally to stream entrenchment on the higher slopes and bars, spits, and beach deposits on intermediate and lower slopes.

Lake Features

During Pleistocene and possibly earlier time, a large lake occupied Diamond Valley. In Pleistocene time the level of the lake fluctuated between the present level of the playa (altitude 5,770 feet) and the outlet level at Railroad Pass (altitude approximately 6,040 feet). The material near the shore was reworked by the action of waves and nearshore currents. In places where the shoreline extended onto the alluvial apron, terraces, cliffs, bars, spits, and beaches were formed upon the then-existing alluvial fans and pediments.

At the north end of the valley a series of beaches, terraces, cliffs, and spits are prominent between altitudes of 5,860 and 6,040 feet. The altitude of the highest terrace is the same as that of the outlet altitude in Railroad Pass, approximately 6,040 feet. Subsequent erosion has lowered the altitude of the pass to 5,895 feet.

Lake features are best preserved along the west side and at the north end of the valley; however, shoreline features may be observed along the east side. Many lacustrine features have been destroyed by the action of recent intermittent streams.

Playa

The playa occupies the northern part of the valley floor. Its surface is nearly flat, and it covers an area of about 50,000 acres (pl. 1). Fine-grained wind-blown material from the playa and lower slopes of the alluvial apron form low dunes locally along the margins of the playa.

Principal Lithologic Units

For the purposes of this report, the lithologic units in Diamond Valley are divided into two major groups on the basis of their hydrologic properties: (1) unconsolidated deposits which form the valley fill, are highly porous, and commonly transmit water readily; and (2) consolidated rocks which occur in the mountains and at depth beneath the valley fill, commonly have low porosities and permeabilities and, except for certain carbonate rocks, do not readily transmit appreciable quantities of water.

Six principal lithologic units used in this report are presented in table 2, which was compiled largely from the work of Nolan (1962); Nolan, Merriam, and Williams (1956); Merriam (1963); Lehner, Tagg, Bell, and Roberts (1961); Larson and Riva (1963); Merriam and Anderson (1942); and Stuart and Metzger (written commun., 1961). The six units are carbonate sedimentary rocks, clastic sedimentary rocks, granitic rocks, volcanic rocks, older alluvium, younger alluvium, and playa deposits. Distribution of the units, listed in table 2, is shown on plate 1.

Table 2.--Principal lithologic units in Diamond Valley

Age		Unit designation		Thickness	Lithology and geologic formations	Occurrence	General hydrologic properties
QUATERNARY	Pleistocene and Recent	VALLEY FILL	Playa deposits	0 to 100±[a]	Silt, clay, and evaporites. Includes some dune sand.	Occurs beneath playa in north-central Diamond Valley.	High interstitial porosity and low permeability.
			Younger alluvium	0 to 200±	Unconsolidated alluvial and colluvial deposits of interbedded sand, gravel, silt, and clay. Materials generally moderately to well sorted and form lenticular bodies.	Occurs primarily as Lake Diamond and associated deposits. Includes some slope wash, flood-plain, and channel deposits formed during and after the lake receded. Fine-grained, lake-bottom deposits predominate near the center of the valley; coarse-grained beach-gravel and bar deposits predominate along edges and southern end of valley.	Sand and gravel deposits highly permeable and capable of yielding large quantities of water to wells. Buried beach gravels are the highest yielding deposits of the valley fill. Lake-bottom deposits of fine-grained sand, silt, and clay are less capable of yielding water to wells.
	Pleistocene		Older alluvium	0 to 1500±[b]	Alluvial and colluvial deposits of sand, gravel, silt, and clay. Materials range from well sorted to poorly sorted. Partially consolidated (cemented) in localized areas and at depth. Deposits at depth in the center of the valley generally moderately to well sorted.	Occurs principally as alluvial-fan deposits, also slope wash, talus deposits, upland alluvial surfaces, and high-level shore-line deposits. Locally includes some surficial recent alluvial-fan deposits and channel deposits. Fan deposits locally have been uplifted, faulted, dissected by erosion, and marked by shore-line features of various lake stages. Occurs at depth in the center of the valley as lake deposits which overlie valley-fill deposits of Tertiary age.	Permeability ranges from low to high. Zone of high permeability generally associated with buried channel deposits.
TERTIARY and QUATERNARY		CONSOLIDATED ROCKS	Volcanic rocks undivided	0 to 700+ exposed	Flows, dikes, sills, and small plugs of andesite, basalt, rhyolite, and rhyolitic tuff.	Northeast end of Fish Creek Range, northeast flank Sulphur Spring Range, Table Mountain.	Commonly have little or no interstitial porosity; may transmit small amounts of water through joints and zones between flows.
CRETACEOUS and TERTIARY			Granitic rocks	--	Alaskite stock, quartz diorite plugs, quartz porphyry sills and dikes.	Stock forms Whistler Mountain, plugs at north end of Ruby Hill and in northern Diamond Mountains.	Virtually no interstitial porosity and permeability; may transmit small amounts of water through near-surface fractures and weathered zones.
CAMBRIAN TO CRETACEOUS			Clastic sedimentary rocks	9,000±[c]	Primarily sandstone, quartzite, shale, or conglomerate. Includes: Prospect Mountain Quartzite; Pioche Shale; Secret Canyon Shale; Dunderberg Shale; Vinini Formation; Eureka Quartzite; Pilot Shale; Chainman Shale; Diamond Peak Formation; Carbon Ridge Formation; Garden Valley Formation; and Newark Canyon Formation.	Exposed in parts of the Diamond Mountains, Fish Creek Range, Mountain Boy Range, Sulphur Springs Range, and Roberts Mountains.	Do not readily transmit water, except in areas of intense structural deformation where some water may be transmitted along fractures.
CAMBRIAN TO PENNSYLVANIAN			Carbonate sedimentary rocks	14,000±[c]	Primarily limestone or dolomite with some interbedded sand and shale. Includes: Eldorado Dolomite; Geddes Limestone; Hamburg Dolomite; Windfall Formation; Pogonip Group; Hanson Creek Formation; Roberts Mountains Formation; Lone Mountain Dolomite; Nevada Formation; Devils Gate Limestone; Joana Limestone, and Ely Limestone.	Principal exposures in Sulphur Springs Range, Fish Creek Range, Mountain Boy Range, and west flank Diamond Mountains in Tps. 21 and 22 N.	Some carbonate rocks readily transmit water through fractures and solution openings.

a. May overlie older playa deposits of indeterminate thickness.
b. 1,500 feet is total thickness of unconsolidated or poorly indurated material logged in the upper portion of the valley fill in the Shell Oil test hole (sec. 30, T. 23 N., R. 54 E.).
c. Aggregate thickness

VALLEY-FILL RESERVOIR

The valley-fill ground-water reservoir is formed by the older and younger alluvium and the playa deposits which fill the structural depression underlying Diamond Valley (pl. 1). This reservoir is the most feasible source for the extensive development of ground-water supplies. Therefore, the hydrology of the basin is discussed in terms of its relationship to the valley-fill reservoir.

Extent and Boundaries

The valley-fill reservoir is approximately 45 miles long, 6 to 12 miles wide, and has a surface area of about 410 square miles. The bedrock surfaces of the adjacent mountain blocks and their subsurface extensions form the lateral and bottom boundaries of the valley-fill reservoir.

The exact configuration of the reservoir is not known. However, several generalizations as to the overall size and shape of the reservoir may be made on the basis of gravity data (Mabey, 1964) and information from an oil-test hole (Shell Diamond Valley No. 1, drilled in 1956).

A large gravity low underlies Diamond Valley. It is measured by the differences between the densities of the valley-fill material (2.2 to 2.5 g per cm^3) and those of the consolidated rocks of the mountain blocks (2.6 to 2.7 g per cm^3). The magnitude of the low is a rough indication of the thickness of fill. The low generally conforms with the elliptical shape of the valley; however, the largest values (maximum residual relief of about 40 mgals) are east of the center of the valley, suggesting that the fill is thickest there. Approximately 7,485 feet of the valley fill was logged in the Shell Oil test hole (sec. 30, T. 23N., R. 54 E.), and Mabey (1964) stated that the maximum thickness of fill probably is not much greater than this. Relatively permeable Pleistocene and Recent deposits form only the upper part (1,500± feet) of the valley fill. The remaining part is composed of Tertiary or older deposits.

The gravity gradient along the southwest margin of the valley from Devils Gate to Garden Pass is markedly less than it is along the margin of the valley in other areas. Merriam and Anderson (1942) reported that a pediment extends eastward from Whistler Mountain and the ridge to the north. In sec. 5, T. 20N., R. 53 E., small knolls of bedrock protrude through the valley fill. To the north, wells 21/53-18cc (depth 134 feet), 21/53-20cc (depth 150 feet), and 21/53-20db (depth 183 feet) were bottomed in "hard rock," presumed to be bedrock. Merriam and Anderson (1942, p. 1715) indicated that a small scarp, about a mile east of Whistler Mountain, may mark the east edge of the pediment. Thus, much of the valley fill between Whistler Mountain and Garden Pass, west of State Highway 20, is underlain by bedrock at fairly shallow depths; locally bedrock may extend east to the edge of the developed area.

Subsurface Distribution of Sand and Gravel

in the South Diamond Subarea

Examination of drillers' logs of wells in the South Diamond subarea revealed that thick accumulations of sand and gravel are present in localized areas and that these deposits yield most of the water to wells. A knowledge of the overall distribution of sand and gravel therefore would provide generalized information about variations in the water-bearing properties of the valley fill.

Any information derived from well logs is subject to certain limitations. The major difficulty is the amount of interpretation involved. An initial interpretation is made when the driller logs the material which he has drilled. Most drillers are consistent in their descriptions and interpretations but when reports made by several drillers are compared some differences are apparent. An interpretation must then be made of the drillers' lithologic descriptions to reduce them to terms suitable for comparison and analysis. The interpretation used in this report is similar to that used by Bredehoeft (1963, p. 32) and is summarized in table 3. This interpretation necessarily is highly subjective, and although the results obtained from any one log may be slightly in error, the sum of all interpretations probably represents overall conditions with a reasonable degree of accuracy. This contention is supported by the fact that results obtained from logs of adjacent wells were in good agreement.

An analysis was made of the distribution of sand and gravel in the upper 100 feet of saturated valley fill (1965 data). The logs of 117 wells were used, selected on the basis of their location and clarity. For each well the percentage of sand and gravel within the upper 100 feet of saturation was determined and this value plotted on a map. Areas showing the percentage distribution of sand and gravel were then drawn, and the results are shown in figure 2. The same procedures were followed to ascertain the distribution for the upper 150 feet of valley fill, and nearly identical results were obtained for this partly saturated interval.

The areas in which a high percentage of sand and gravel is indicated roughly coincide with areas where well yields are large. A possible exception to this is at the extreme southwestern end of the valley where the yields of several wells are not as high as those of wells which have penetrated comparable thicknesses of sand and gravel in other parts of the valley. The sand and gravel deposits there are partly indurated (cemented) and are not as productive as the unconsolidated sand and gravel deposits to the north. A linear zone deficient in sand and gravel is near the east side of the valley (fig. 2). In most cases, suitable irrigation wells have been developed there; however, to obtain

Table 3.--Classes of material described in drillers' logs

Drillers' description	Geologic interpretation	Estimated composition	Percentage of sand, gravel or both
Gravel	Gravel	100% gravel	100
Sand and gravel	Interbedded layers of medium to coarse-grained sand and gravel	50% sand 50% gravel	100
Sand, gravel, and clay Gravel and clay, cemented gravel	(1) Pebbles in a matrix of sand, silt, and clay, matrix is indurated in the case of cemented gravel (2) Interbedded layers of sand, gravel, and clay	20% gravel 20% sand 60% silt and clay	40
Sand	Fine, medium, or coarse-grained sand	100% sand	100
Sand and clay, sandy clay	Interbedded layers of medium-grained sand, silt, and clay	30% sand 70% silt and clay	30
Clay, silt, mud, muck	Interbedded silt and clay in varying proportions	0 to 100% clay 0 to 100% silt	0

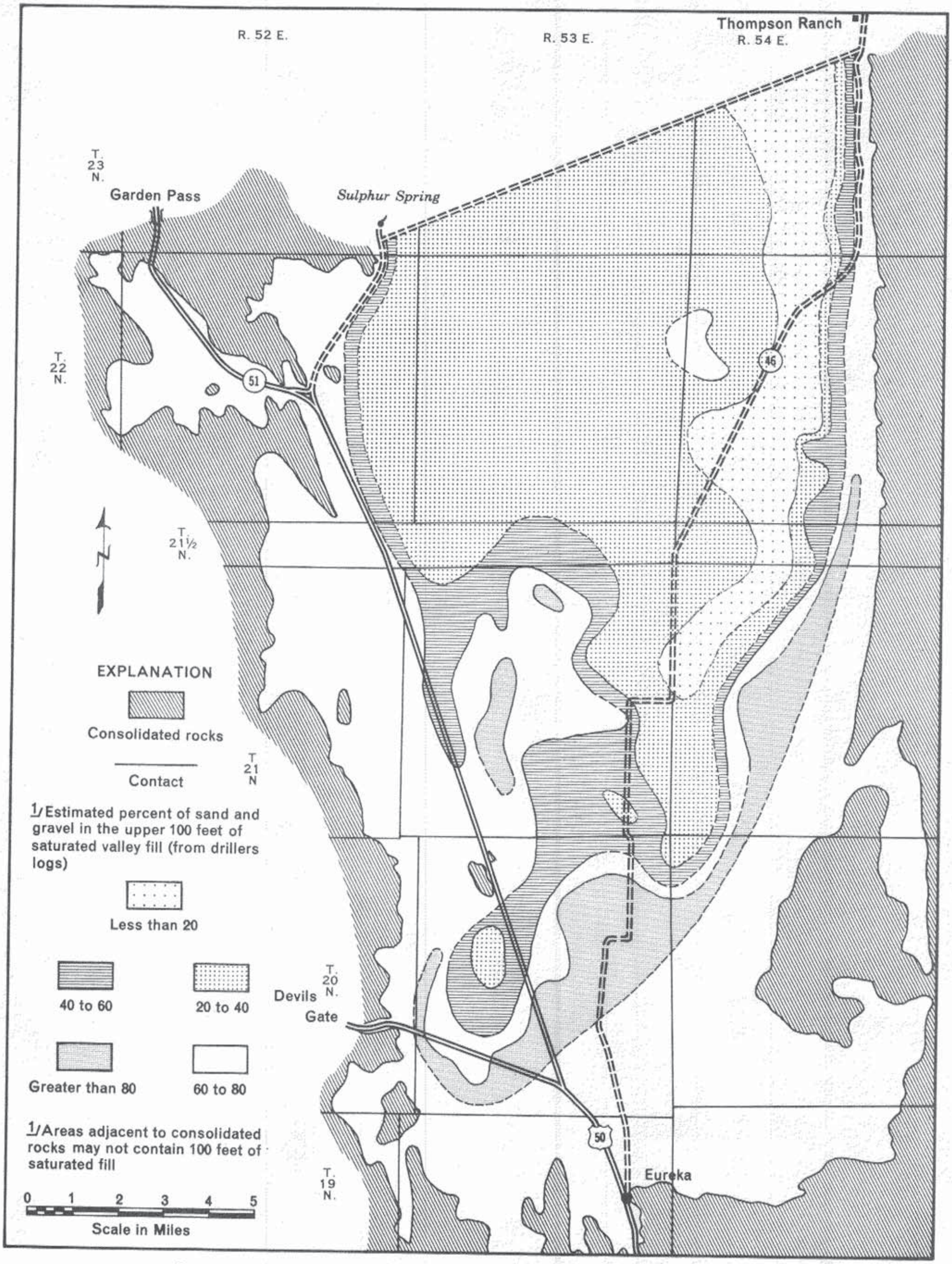

Figure 2.—Sub surface distribution of sand and gravel, South Diamond subarea

comparable yields they have had to penetrate a thicker section of saturated deposits than wells in adjacent areas.

Coefficients of Transmissibility and Storage

The coefficients of transmissibility, T, and storage, S, express the water-bearing properties of the valley fill. Transmissibility is a measure of the capability of an aquifer or reservoir system to transmit water. It is dependent upon the permeability of the material involved and the thickness of the aquifer. The coefficient of storage is a measure of the amount of water that will be released from storage, within a unit area, as water levels are lowered. These coefficients may be used in the construction of analog models, in the computation of drawdowns and storage changes caused by pumping, or in the determination of subsurface flow.

Coefficients of transmissibility may be estimated from specific capacities of wells, which are usually expressed as yield in gallons per minute per foot of drawdown. Properly designed wells in deposits with high transmissibilities have higher specific capacities than wells in deposits with low transmissibilities.

Six pumping tests of 40 to 90 minutes duration were made to determine representative values and ranges of transmissibility. The values of transmissibility determined ranged from 27,000 to 250,000 gpd (gallons per day) per foot. Transmissibilities were also estimated from about 84 commercially determined specific capacities. These values provide the basis for the approximate distribution of transmissibility in the South Diamond subarea shown in figure 3. The values shown are representative only of that thickness of the valley fill affected by pumping. As might be expected, the agreement between the distribution of sand and gravel (fig. 2) and transmissibility (fig. 3) is reasonably good; that is, the areas underlain by high percentages of sand and gravel generally are the areas of high transmissibility. In cases where deep circulation occurs, such as underflow toward the playa, the transmissibility may be greater than that shown in figure 3, because of the greater thickness of material involved.

Only one coefficient of storage was calculated. A value of .0002 was determined from observations made in well 21/53-15ac while well 21/53-15db was pumping. This artesian coefficient (value of less than .001) indicates that the horizontal permeability of the valley fill is much greater than the vertical permeability and that the flow system for short-term periods responds to pumping stress much like an artesian system. Over the long term, however, all deposits will drain slowly in response to pumping, and the coefficient of storage will be nearly equal to the specific yield. Thus, in analyzing long-term cause and effect relations, the valley-fill reservoir must be considered as a

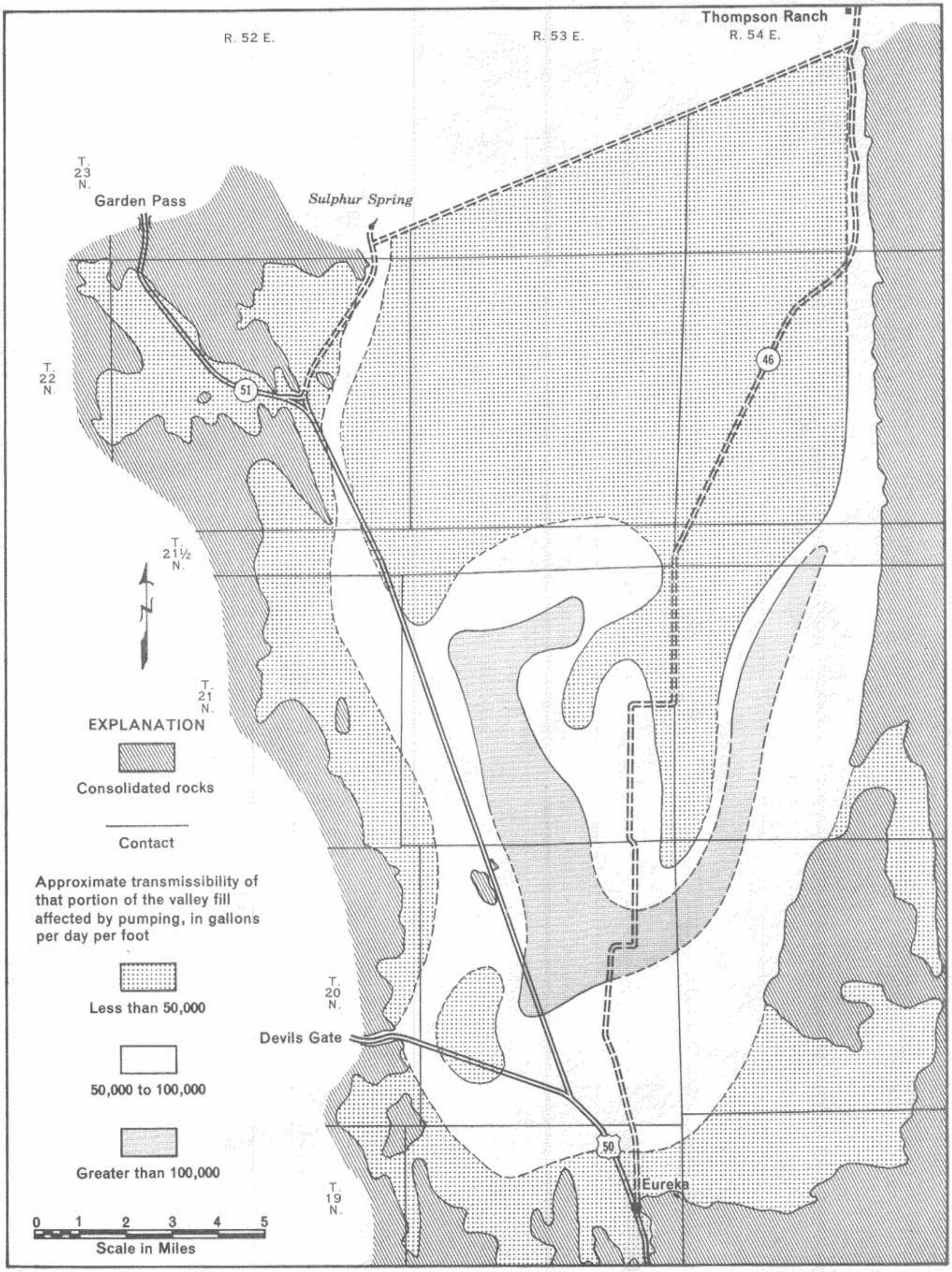

Figure 3.—Preliminary transmissibility map, South Diamond subarea

water-table system. Storage coefficients may be approximated from the specific yield values, as discussed later in the section on ground-water storage. (See fig. 7 and table 11.)

Source, Occurrence, and Movement of Ground Water

Ground water in the valley-fill reservoir is derived principally from the infiltration of precipitation that falls within the drainage basin. Other sources are: infiltration of surface-water inflow at Devils Gate, subsurface inflow at Devils Gate, and subsurface inflow of deep circulating ground water from the adjacent Garden Valley area.

Ground water occurs in the saturated part of the valley fill where it occupies the interstices or voids in the granular clastic deposits and chemical precipitates. It is present under both water-table and artesian conditions. Artesian conditions occur where the saturated permeable deposits are overlain by relatively impermeable strata and where the water at the top of the acquifer is under greater than atmospheric pressure. Water-table conditions exist where the saturated deposits are not confined by impermeable strata and where the water at the top of the zone of saturation, the water table, is under atmospheric pressure.

Artesian conditions were encountered in most of the irrigation wells drilled north of T. 22 N. In that area, the water level is noticeably higher in deeper wells. Springs and flowing wells are common along the west side of the North Diamond subarea where artesian conditions predominate. In T. 22 N. and to the south, artesian conditions exist where lenses of silt and clay confine the water in underlying deposits. The clay lenses are most extensive along the east side of the valley but locally are present in other parts of the area.

Ground water moves along the path of least resistance from areas of high hydraulic head to areas of lower hydraulic head. The rate of movement depends upon the hydraulic gradient and the permeability and porosity of the material through which water is moving. Typical rates range from several feet per year to several hundred feet per year.

The horizontal movement of ground water in the valley fill is parallel to the slope of the water surface. The slope of the water surface is indicated on plate 2, which shows contours of the altitude of the water levels in wells for the spring of 1950, prior to any extensive withdrawal of ground water by pumping. Therefore, the contours indicate the general direction of ground-water movement under natural conditions. The direction of movement is perpendicular to the contours. Ground water moves from areas of recharge in the mountains and borders of the valley floor toward the playa and surrounding phreatophyte-covered discharge areas in the north-central part of the valley where the altitudes are 5,770 feet or lower.

Water-level contours downgradient from Devils Gate suggest that recharge there is no greater than from adjacent areas (pl. 2).

Ground-water movement in the southern end of the valley-fill reservoir may have been affected locally by the large withdrawals from the Fad shaft. A localized trough or depression in water levels may have developed during initial periods of heavy pumping. Subsequent pumping in which water withdrawn from the Fad shaft was put down either the Locan or T. L. shafts probably has had little or no effect on ground-water movement in the developed area.

Figure 4 shows the approximate depth to water in the South Diamond subarea in the spring of 1966. In the heavily pumped area, nonpumping levels are between 35 and 120 feet below land surface. Most pumping levels in 1966 were 30 to 75 feet more than the "static" spring levels of 1966.

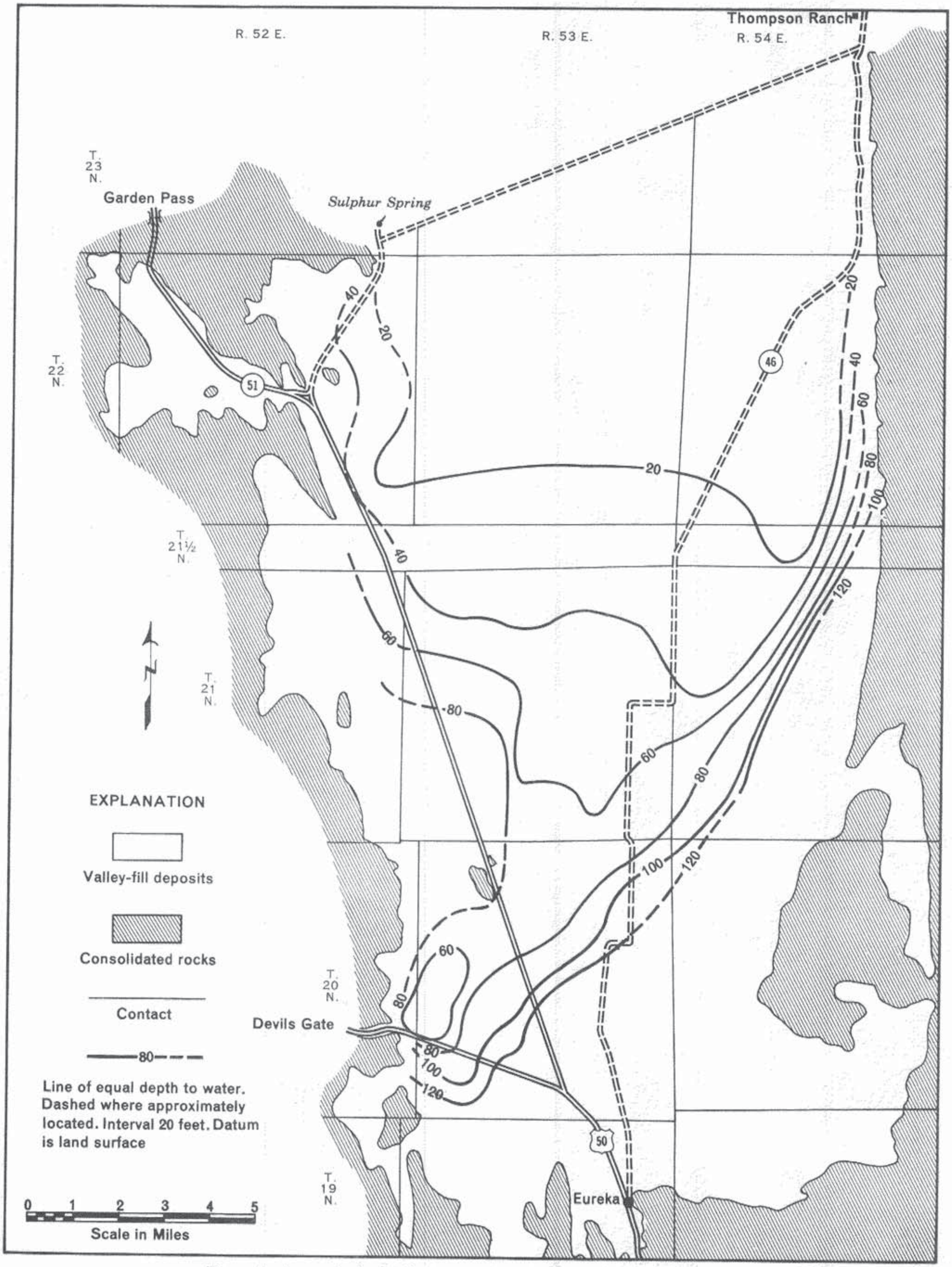

Figure 4.—Approximate depths to water April 1966, South Diamond subarea

INFLOW TO THE VALLEY-FILL RESERVOIR

Runoff

By

R. D. Lamke

The estimated average annual runoff within Diamond Valley is only 5,800 acre-feet. The methods and data used to calculate this value are briefly described below, and a general description of the streams in the valley is presented.

Only a few perennial streams occur in the valley, all of which are on the east side on the slopes of the Diamond Mountains. Cottonwood and Simpson Creeks are the two most prominent streams, and the only ones that support ranching operations. The only other streams with a seasonal snowmelt runoff of any significant volume are also in the Diamond Mountains. The remainder of the streams in Diamond Valley are ephemeral and have minor seasonal snowmelt runoff.

Most of the streams flow radially inward from the mountains toward the playa in the north-central part of the valley. Streams in the mountains are short, have well-formed channels, and generally have drainage areas of less than 10 square miles. The point of maximum streamflow occurs near the base of the mountains. Streamflow diminishes downslope on the alluvial apron because of increased infiltration, irrigation diversions, and evapotranspiration. Consequently, stream channels become poorly defined with increasing distance from the mountain front.

Measurements of streamflow and channel dimensions were obtained at 13 representative points, near the base of the mountains. Table 4 lists these points, shows the date and discharge of streamflow measurements, and estimated average annual streamflow; figure 5 shows the location of these points. Average annual flow for the ephemeral channels was estimated by a method developed by W. B. Langbein (oral commun., 1964) which is based on an empirical relation between average annual flow and channel geometry. Average annual flow for the perennial or seasonal snowmelt streams was determined by a method described by D. O. Moore (oral commun., 1965). Generally, the method relates a streamflow measurement or measurements at a miscellaneous-measurement site to long-term average flow for gaged sites on other comparable streams to obtain an estimate of average annual flow at the miscellaneous-measurement site. The measurements at the miscellaneous sites were adjusted to an average annual discharge value using three nearby long-term gaging station records: Cleve Creek near Ely (average discharge for 8 water years 1915, 1916, and 1960-65), Lamoille Creek near Lamoille (average discharge for 29 water years 1916-22, 1944-65), and Huntington

Table 4.--Selected streamflow data and estimated average annual streamflow at representative points

(Measuring points shown in fig. 5)

Map no.	Name	Location	Date	Discharge (cfs)	Average annual streamflow [1/] (acre-feet per year)		
					(1)	(2)	(3)
1	Four-Mile Canyon	25/54-10ba	4- 1-66	dry	73	--	50
			10-19-66	dry			
2	Davis Canyon	25/54-28a	4- 1-66	dry	136	--	172
			10-19-66	dry			
3	Telegraph Canyon	23/54-2aa	5-13-65	0.24	--	75	113
			4- 1-66	dry			
			10-19-66	dry			
4	Homestead Canyon	22/54-12bd	5-13-65	0.39	84	121	98
			4- 1-66	0.06			
			5-17-66	0.02			
			6-27-66	0.02			
			10-19-66	0.01			
5	Green Canyon	21/54-11ba	5-13-65	dry	93	--	69
			3-31-66	dry			
			6-27-66	dry			
6	Pedrioli Creek	21/54-23cb	5-13-65	0.63	222	196	186
			9-21-65	dry			
			3-31-66	dry			
			6-27-66	dry			
7	Cottonwood Creek	20/54-10bd	5-13-65	1.75	--	439	433
			9-21-65	0.24			
			3-31-66	0.38			
			5-17-66	0.15			
			6-27-66	0.02			
			10-20-66	dry			
8	Hildebrand Canyon	20/54-9cc	5-13-65	0.41	--	150	237
			9-21-65	0.10			
			3-31-66	0.06			
			5-17-66	0.04			
			6-27-66	dry			
9	Torre Creek	20/54-21db	5-13-65	0.34	--	177	128
			9-21-65	0.16			
			3-31-66	0.16			
			5-17-66	0.08			
			6-27-66	0.05			
			10-20-66	0.01			

Table 4.--Continued

Map no.	Name	Location	Date	Discharge (cfs)	Average annual streamflow[1] (acre-feet per year) (1)	(2)	(3)
10	Simpson Creek	19/54-16ba	5-13-65	0.47	--	267	267
			9-21-65	0.37			
			3-31-66	0.39			
			5-17-66	0.34			
			6-27-66	0.27			
			10-20-66	0.37			
11	Spring Valley Canyon	19/53-33ab	4- 1-66	dry	90	--	a 90
			6-25-66	dry			
12	Garden Pass Creek	22/52-22bb	3-31-66	dry	123	--	b108
			6-26-66	dry			
13	Unnamed	26/53-5ba	4- 1-66	dry	18	--	b 28
			10-19-66	dry			

1. Column notes:
   - (1) Calculated from channel geometry.
   - (2) Calculated from streamflow measurements.
   - (3) Computed, using altitude-runoff relation (fig. 5).
     - (a) Computed, using 25 percent of runoff values (see fig. 5).
     - (b) Computed, using 75 percent of runoff values (see fig. 5).

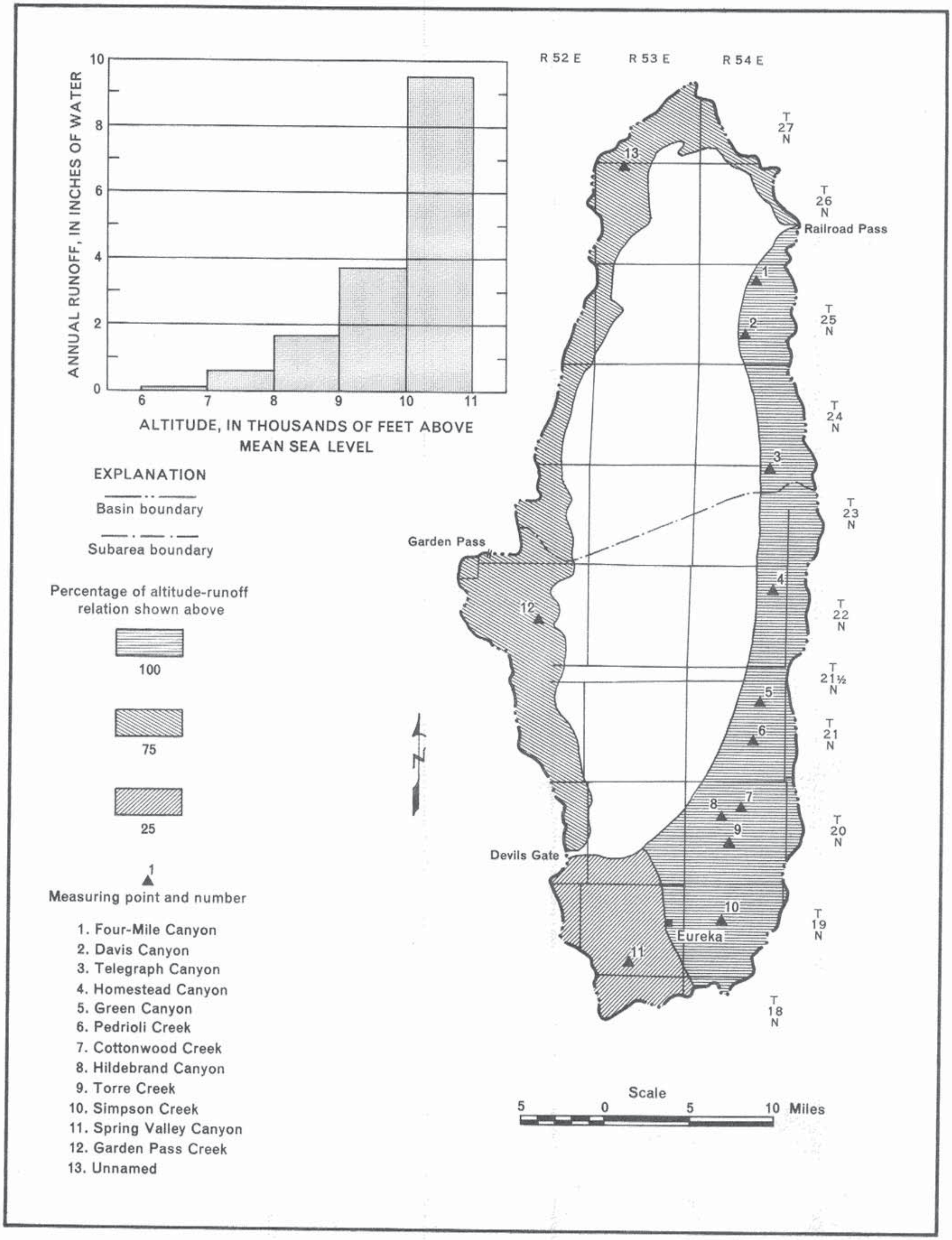

Figure 5.—Relation between runoff and altitude and map showing areas having similar runoff characteristics

Creek near Lee (average discharge for 17 water years 1949-65).

Streamflow data (numbers 1-10 in table 4 and fig. 5) were used to develop the relation between average annual runoff and altitude, shown in figure 5, applicable to the Diamond Mountains. The procedure used is described in detail by Riggs and Moore (1965, p. D199-D202). This runoff-altitude relationship for the Diamond Mountains was adjusted for other mountains around the valley on the basis of field observations of the physical and hydrologic characteristics of the mountains and average annual discharge figures obtained at three sites (numbers 11-13 in table 4 and fig. 5). From these data three areas having different runoff characteristics were identified and are shown in figure 5.

Table 5 shows the estimated average annual runoff for the North and South Diamond subareas, which totals 5,800 acre-feet, calculated from altitude-runoff relations. Average annual runoff of about 5,000 acre-feet occurs from the Diamond Mountains and about 800 acre-feet from the rest of the valley margins.

Inflow at Devils Gate

Water from Monitor, Antelope, and Kobeh Valleys enters Diamond Valley as surface and subsurface flow at Devils Gate. Surface flow is intermittent, most occurring in the early spring and usually diminishing to near zero by summer. The channel is dry during most summers, except for short periods of flow after summer storms. In very wet years, a small amount of flow may be maintained throughout the year. Recharge to the valley-fill reservoir from the infiltration of surface water occurs mainly during the spring runoff, because this is the only time during the year when an appreciable flow is maintained.

The estimated average annual surface-water inflow is 100 acre-feet per year, on the basis of channel-geometry measurements made by R. D. Lamke. Inflow during the spring of 1964, a high runoff year, is estimated to have been about 1,000 acre-feet, on the basis of measurements of 15 cfs (cubic feet per second) on April 14 and 21, an estimated flow of 2.5 cfs on May 19, and an estimated peak of 50 cfs on April 17 or 18. Inflow in the spring of 1965 and 1966 was negligible. These observations suggest that the long-term average inflow is on the same order of magnitude as the estimate obtained from channel geometry.

The alluvial deposits in the vicinity of Devils Gate are relatively permeable. Most of the inflow probably infiltrates to recharge the valley-fill reservoir.

Subsurface inflow is probably small. The canyon at Devils Gate is about 100 feet wide at its narrowest point on the surface, and probably less wide at depth. The fill in the canyon is estimated to be no greater

Table 5.--Estimated average annual runoff

Altitude zone (feet)	Area (acres)[1]	Percentage of altitude-runoff relation (fig. 5)	Depth of runoff (feet) (fig. 5)	Average annual runoff (acre-feet per year)	
				Subtotal[1]	Total[1]
		North Diamond Subarea			
9,000 to 10,000	110	100	.305		30
8,000 to 9,000	3,800	100	.136	520	
	190	75	.102	20	540
7,000 to 8,000	8,900	100	.045	400	
	5,600	75	.034	190	590
6,000 to 7,000	12,200	100	.006	70	
	35,500	75	.004	140	210
Subarea total (rounded)					1,400
		South Diamond Subarea			
Above 10,000	170	100	.792		130
9,000 to 10,000	1,900	100	.305	580	
	300	25	.076	20	600
8,000 to 9,000	10,400	100	.136	1,400	
	40	75	.102	trace	
	2,100	25	.034	70	1,500
7,000 to 8,000	31,700	100	.045	1,400	
	3,700	75	.034	130	
	10,600	25	.011	120	1,700
6,000 to 7,000	44,900	100	.006	270	
	33,600	75	.004	130	
	17,500	25	.001	20	420
Subarea total (rounded)					4,400

1. Units rounded to nearest ten below 1,000 units and to nearest hundred above 1,000 units.

than 100 feet thick. Assuming a hydraulic gradient of 10 feet per mile, the same as the land-surface gradient through Devils Gate, and a permeability of 2,000 gpd per square foot for the fill material in the canyon, the calculated subsurface inflow is less than 40 acre-feet per year.

Precipitation Within the Basin

Precipitation is the source of virtually all the water entering the hydrologic system in Diamond Valley. Of the precipitation that falls on the valley, part runs off, part is evaporated or transpired sometime after it enters the ground, and part ultimately recharges the ground-water system.

The average annual recharge to the valley-fill reservoir may be estimated as a percentage of the average annual precipitation within the basin (Eakin and others, 1951, p. 79-81). Hardman (1936) demonstrated that in gross aspect, the average annual precipitation in Nevada is related closely to the altitude of the land surface and that it can be estimated with a reasonable degree of accuracy by assigning precipitation rates to altitude zones. Thus, the recharge may be estimated as a percentage of the precipitation within each zone.

In Diamond Valley, for any specified altitude zone, precipitation is generally greater at the northern end of the valley than at the southern end. This statement is supported in part by data presented in table 1 and figure 6, which suggest a regional trend in the precipitation-altitude relationship,by field observations of vegetation, by the results of investigations in adjacent areas (Eakin, 1960, 1961; Rush and Everett, 1964, 1966a, b), and by the distribution of precipitation zones as shown on a Nevada precipitation map (Hardman, 1965).

The north-south division of precipitation zones shown in figure 6 affords only a rough approximation of the overall differences that exist in the precipitation-altitude relationship within the study area. It does no more than to equate the probable precipitation conditions at the north end of the valley with those believed to exist in the adjacent Pine and Huntington Valley areas and conditions at the southern end of the valley with those believed to exist in the adjacent Kobeh and Newark Valley areas. Significant differences also exist in the precipitation-altitude relationships for the east and west sides of the valley and those parts of the valley that are affected by a rain shadow from the Roberts Mountains; however, further refinement is not justified at this time because of the lack of precipitation data within the basin.

Estimates of recharge for Diamond Valley are summarized in table 6. Recharge from precipitation within the basin is approximately 21,000 acre-feet per year, or about 5 percent of the total estimated precipitation. This value is higher than the 16,000 acre-feet estimated by Eakin (1962) because of the north-south division of precipitation zones

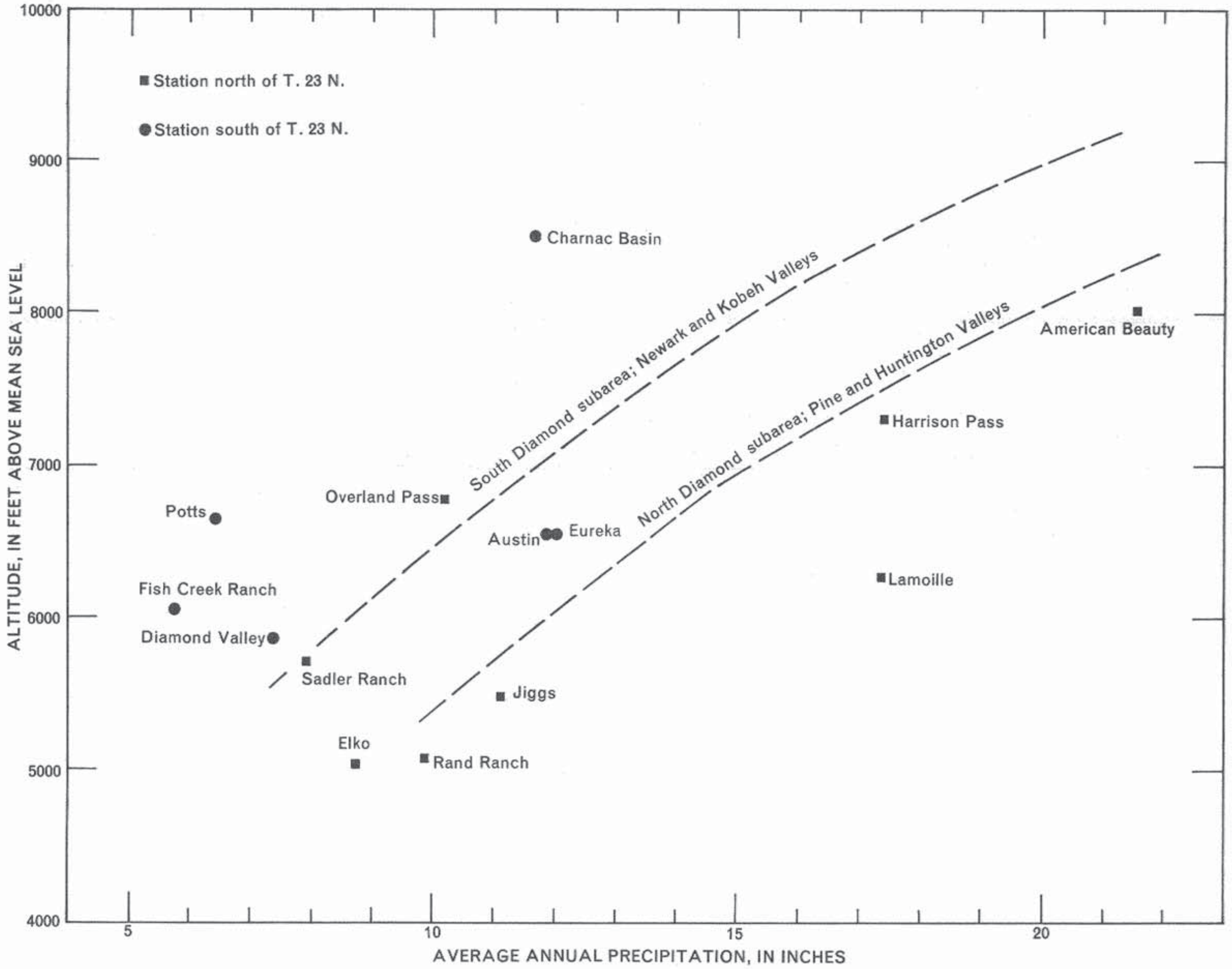

Figure 6.—Relation between precipitation and altitude

Table 6.--Estimated average annual precipitation and ground-water recharge from precipitation

Precipitation zone (feet)	Area (acres)	Estimated annual precipitation			Estimated recharge from precipitation	
		Range (inches)	Average (feet)	Average (acre-feet)	Percent of precipitation	Acre-feet per year
		North Diamond Subarea				
Above 8,000	4,100	> 20	1.8	7,200	25	1,800
7,000 to 8,000	14,500	15 to 20	1.5	22,000	15	3,300
6,000 to 7,000	47,700	12 to 15	1.1	53,000	7	3,700
5,840 to 6,000[1]	9,200	8 to 12	.8	7,400	3	200
Below 6,000 or 5,840[2]	119,300	< 8	.6	71,000	0	--
Subtotal (rounded)	194,800			160,000		9,000
		South Diamond Subarea				
Above 9,000	2,400	> 20	1.8	4,300	25	1,100
8,000 to 9,000	12,500	15 to 20	1.5	19,000	15	2,900
7,000 to 8,000	46,000	12 to 15	1.1	51,000	7	3,600
6,000 to 7,000[3]	197,500	8 to 12	.8	160,000	3	4,800
Below 6,000[4]	17,400	< 8	.6	10,000	0	--
Subtotal (rounded)	275,800			240,000		12,000
Total (rounded)	470,000			400,000		21,000

1. North of T. 25 N.
2. Below 5,840 north of T. 25 N.
   Below 6,000 south of T. 26 N.
3. Below 7,000 south of T. 23 N.
   6,000 to 7,000 in T. 23 N.
4. In T. 23 N.

used in this report. The estimated recharge appears high, however, when compared to the estimated runoff of only 5,800 acre-feet per year. If both estimates are reliable, they suggest that about one-fourth the recharge is derived from runoff and that most recharge from precipitation in the mountains moves to the valley-fill reservoir as underflow through carbonate rocks across the bedrock-alluvial contact.

Subsurface Inflow from Garden Valley

The valley-fill reservoir in the North Diamond subarea probably is recharged in part by interbasin flow from the adjacent Garden Valley (pl. 1). This was suggested by Eakin (1962, p. 21).

Moreover, in the Pine Valley study, which included Garden Valley, Eakin (1961) estimated that recharge exceeded the discharge by a substantial amount. The subsurface inflow may be substantiated only by indirect evidence, because no data are available concerning the eastward movement of ground water beneath the Sulphur Spring Range. In general, interbasin flow is possible only if a hydraulic gradient exists between basins and if the bedrock separating them is capable of transmitting water.

The altitude of the major springs along the west side of the North Diamond subarea is approximately 5,800 feet, whereas in Garden Valley, some 5 to 6 miles west, the altitude of the water table ranges from a low of 5,960 feet, where Garden Valley drains into Pine Valley, to more than 6,400 feet along the flood plain of Henderson Creek (pl. 2). Therefore, the potential hydraulic gradient from Garden Valley to Diamond Valley ranges from 25 to 120 feet per mile.

The Sulphur Spring Range is composed primarily of Paleozoic carbonate rocks (pl. 1). In Garden Valley these rocks are overthrust by shale and chert of the Ordovician Vinini Formation, but locally are exposed through windows in the nearly horizontal and presumably thin thrust plate. The Garden Valley Formation unconformably overlies parts of the thrust plate and forms a prominent ridge along the southeast margin of Garden Valley. Structures in the area are complex, and features formed during the thrusting and subsequent deposition of the Garden Valley Formation have been modified by periods of later normal faulting. Consequently, the rocks of all formations, depending upon local conditions, are fractured and brecciated to varying degrees.

The general hydrologic properties of the rocks are given in table 2 and are mentioned here only with respect to local conditions. Sequences of carbonate rocks are considered capable of transporting appreciable quantities of water through solution-enlarged fractures. The shale and chert of the Vinini Formation normally would present effective barriers to the movement of ground water. In the Sulphur Spring Range, however, they are present in a relatively thin plate near the surface and have undergone a high degree of deformation. Therefore, they are considered capable locally of transmitting moderate quantities of water to underlying carbonate rocks. The sandstone and conglomerate beds of the Garden Valley Formation probably do not transmit water readily, except in areas where they have been highly fractured or brecciated.

In gross aspect, the bedrock separating the two basins is considered to be capable of transmitting appreciable subsurface flow. Movement would be complex, and local barriers, due to either structure or lithology, would be common. Deep circulation is suggested by the fact that most of the spring discharge in Diamond Valley is warm.

To estimate the quantity of water available for interbasin flow, a ground-water budget of the Garden Valley area was developed. Recharge was estimated in the same manner as for Diamond Valley. The precipitation zones used are the same as those used for the North Diamond subarea and those used by Eakin (1961) in his reconnaissance study of Pine Valley.

Ground water is discharged by phreatophytes growing along the flood plain of Henderson Creek and by springs and seeps near the points where Garden Valley drains into Pine Valley. Nearly all the spring discharge and ground-water seepage flows out of the area before it is evaporated or transpired by plants. The volcanic rocks of Table Mountain are a barrier to ground-water movement and probably transmit only a small amount of water to Pine Valley.

Estimates of recharge to and discharge from the ground-water reservoir in Garden Valley are summarized in table 7. The estimated recharge exceeds the estimated discharge by 9,000 acre-feet per year, which is an estimate of the subsurface inflow from Garden Valley to Diamond Valley. This quantity is adequate to account for the observed spring discharge along the west side of the North Diamond subarea. However, the hydrologic boundaries in the Roberts Creek Mountains probably do not coincide exactly with topographic boundaries and some ground water derived from adjacent Kobeh Valley (Rush and Everett, 1964, p. 24) may enter Diamond Valley.

Table 7.--Estimated ground-water budget for Garden Valley

RECHARGE (1):

Precipitation zone (feet)	Area (acres)	Estimated annual precipitation			Estimated recharge from precipitation	
		Range (inches)	Average (feet)	Average (acre-feet)	Percentage of recharge	Acre-feet per year
Above 8,000	3,300	> 20	1.8	5,900	25	1,500
7,000 to 8,000	18,900	15 to 20	1.5	28,000	15	4,200
6,000 to 7,000	57,500	12 to 15	1.1	63,000	7	4,400
Below 6,000	400	8 to 12	.8	320	3	Tr.
Total (rounded)	80,100			97,000		10,000

DISCHARGE (2):

Discharge by phreatophytes

Type	Area (acres)	Average annual consumption of ground water	
		(feet)	(acre-feet)
Rabbitbrush and greasewood, some sparse saltgrass	700	.3	210
Meadow grass	300	1.2	360
Subtotal (rounded)			600

	acre-feet per year
Portion of average annual outflow to Pine Valley which is maintained by spring discharge near Table Mountain	300 to 400
Water transitted to Pine Valley through volcanic rocks of Table Mountain	Tr.
Total	900 to 1,000

DIFFERENCE (1) - (2): 9,000

NATURAL OUTFLOW FROM THE VALLEY-FILL RESERVOIR

Evapotranspiration

Natural discharge of ground water occurs where the water table in the valley fill is near the surface. Discharge takes place principally in three ways: (1) by evapotranspiration in areas of phreatophytes; (2) by direct evaporation where the capillary fringe extends to within a short distance of the land surface; and (3) by spring discharge where the water table intersects the land surface, or where artesian conditions cause ground water to rise to the surface. In Diamond Valley, the water discharged by springs then is consumed by evapotranspiration.

The principal phreatophytes are rabbitbrush, greasewood, saltgrass, and meadowgrass. As shown on plate 2, the grasses are most abundant in areas supported by spring discharge, whereas the rabbitbrush and greasewood are mainly in a band 1 to 3 miles wide around the margin of the playa. Evaporation from bare soil occurs mainly on the playa. Some of the vegetation shown in the North Diamond subarea (pl. 2) is supported in part by discharge from flowing wells. The flow from the wells is included with natural discharge, because most of the wells have flowed for 10 to 15 years with no control and are in the areas of natural discharge. The discharge by flowing wells probably is partly compensated for by local reductions in seepage and spring discharge.

Estimates of the natural discharge of ground water in each of the subareas are summarized in table 8. These estimates are based upon annual rates of consumption of ground water by phreatophytes in other areas, as described by Lee (1912), White (1932), Young and Blaney (1942), Houston (1950), and Robinson (1965). The rates are about the same as those used by Eakin (1962). Little information is available concerning the rate at which ground water is evaporated from the surface of the playa. Descriptions of a salt marsh at the north end of the playa by Vanderburg (1938, p. 65-66) indicate that there the water level is within 4 feet of the surface and that salt incrustations are readily formed by the evaporation of ground water that is brought to the surface by capillary action. At the south end of the playa the depth to water in well 23/53-4cc is 3.5 feet. The depth may be greater in the central part of the playa. The estimated average rate of evaporation of 0.1 foot per year for the entire playa is based on rates used in hydrologically similar areas of the State.

The estimated annual discharge of ground water is about 30,000 acre-feet, of which 5,000 acre-feet is evaporation from the playa and 25,000 acre-feet is evapotranspiration by phreatophytes and spring-supported vegetation. These figures are in reasonable agreement with the annual discharge of 23,000 acre-feet, which does not include evaporation from the playa, estimated by Eakin (1962) in his reconnaissance study

Table 8.--Estimated evapotranspiration of ground water

Dominant process of ground-water discharge	Phreatophyte	Areal density	Depth to water (feet)	Area (acres)	Annual Evapotranspiration Acre-feet per acre	Annual Evapotranspiration Acre-feet (rounded)
		North Diamond subarea				
Evapotranspiration	Rabbitbrush, greasewood, sparse saltgrass	Moderate to low	5 to 20	46,000	0.3	14,000
Evapotranspiration in areas supported by spring discharge	Meadowgrass, hay, some saltgrass	--	< 5	4,500	1.2	5,400
Do.	Wet meadow, marsh, normally flooded; includes some acreage of alfalfa	--	< .5	1,500	3.0	4,500
Evaporation from bare soil (playa)	--	--	< 5	50,000	.1	5,000
Subtotal (rounded)				102,000		29,000
		South Diamond subarea				
Evapotranspiration	Rabbitbrush, greasewood, sparse saltgrass	Moderate to low	5 to 20	4,000	.3	1,200
Evapotranspiration in areas supported by spring discharge (seepage)	Meadowgrass, saltgrass	--	< 5	150	1.2	180
Subtotal (rounded)				4,200		1,400
Total (rounded)				106,000		30,000

of the area.

Spring Discharge

In South Diamond subarea small springs occur along the east side of the valley mostly as seepage areas near the bases of alluvial fans. The discharge in these areas is about 180 acre-feet per year, and most of the water is consumed by vegetation.

In the North Diamond subarea there is one fairly large spring on the east side of the valley at Thompson Ranch, sec. 3, T. 23 N., R. 54 E. There, water flows from bedrock outcrops mapped as klippe of western facies rocks of Ordovician(?) age by Larsen and Riva (1963). The water is warm, and the spring is considered to be in a fault-controlled area of discharge of moderately deeply circulating ground water. Other small seepage areas are common along the east side of the subarea. The western margin of the subarea is characterized by a number of pond springs at altitudes of approximately 5,800 feet. All the springs discharge warm water and all are in alluvial material near the bases of alluvial fans or pediments.

Drillers' logs of wells and field observations indicate that the alluvial fill in the vicinity of the springs along the west side of the North Diamond subarea is composed predominantly of interbedded sand, gravel, and clay, and is capable of transmitting appreciable quantities of water. This coarse-grained valley fill is underlain by bedrock at shallow depth. Logs of wells drilled nearer the center of the valley indicate that there the valley fill is predominantly silt, clay, and fine sand, and is less capable of transmitting water. These springs probably are fault controlled and supplied principally by deeply circulating ground water that passes from bedrock into a narrow band of coarser material and then is discharged at the surface.

Table 9 lists the locations, names, discharges, and dates of measurements of the major springs. Slight decreases in discharge have occurred in both Shipley Hot Spring and Thompson Ranch spring. These changes are interpreted as adjustments to local development or as natural fluctuations, which may represent below-average precipitation in the 1950's, as indicated by Eakin and Lamke (1966, p. 19) for stations in the adjacent Humboldt River basin, rather than to pumping in the South Diamond subarea. Eventually, a gradual decrease of spring discharge in the North Diamond subarea should occur in response to pumping in the South Diamond subarea as sufficient water is removed from storage to induce subsurface flow from the spring areas toward the well field.

Table 9.--Discharge of major springs in the North Diamond subarea

Location	Name or owner	Date	Discharge (cfs)	Discharge (acre-feet per year)
West side:				
23/52-25b	Tule Dam Spring	11-16-65	.12	90
23/52-36b	Sulphur Spring	11-18-65	.09	60
24/52-23d	Shipley Hot Spring	9-22-65 4- 1-66 10-19-66	7.19 7.01 6.20	4,900
24/52-26d	Unnamed	12- 7-65 4- 1-66	.66 .82	540
24/52-36c	Unnamed spring at Bailey Ranch	11-19-65	1.14	820
24/53-6cab	Siri Ranch spring	12- 7-65	.58	420
Subtotal			9.47	6,800
East side:				
23/54-3db	Thompson Ranch spring	9-21-65 4- 1-66 10-19-66	2.33 2.11 2.06	1,600
Subtotal			2.17	1,600
Total			11.64	8,400

Discharge Supported by Interbasin Flow

The quantity of interbasin flow from Garden Valley to Diamond Valley may be estimated from the measured discharge of springs and flowing wells in the western part of the North Diamond subarea. Warm water is discharged by at least half of these wells, which suggests a source similar to that which supplies the springs. The combined discharge from the major springs along the west side of the valley is approximately 6,800 acre-feet per year (table 9); that from flowing wells is about 1,300 acre-feet per year (table 20). The amount of discharge supported by interbasin flow is estimated at between 7,000 and 8,000 acre-feet per year. This estimate probably is low because it was not possible to measure effluent seepage downgradient from many of the springs; however, the quantity of water measured is on the same order of magnitude as the quantity estimated by indirect methods.

EQUILIBRIUM CONDITIONS OF THE NATURAL SYSTEM

Prior to the development of ground-water supplies, the hydrologic system of the valley-fill reservoir was in a state of dynamic equilibrium. Over the long term, recharge equaled discharge and no net change occurred in the quantity of ground water stored in the system.

Water Budget

Table 10 is a ground-water budget which lists the several estimates of recharge to and discharge from the valley-fill reservoir under natural conditions. The estimated total average annual recharge to the valley-fill reservoir of 30,000 acre-feet per year is the same as the estimated discharge.

The table also shows a substantial imbalance between recharge and discharge for both subareas--the difference for one being about equal to and offsetting the difference for the other. These differences are reasonable in view of the fact that about 95 percent of the total discharge occurs in the North Diamond subarea (pl. 2).

Ground Water in Storage

The potentially recoverable ground water in storage is the amount of water that will drain by gravity from the valley-fill reservoir in response to pumping. It is the product of the area, the selected depth of dewatering, and the specific yield of the deposits composing the valley-fill reservoir. Figure 7 shows that the area used in this computation is somewhat less than that of the valley-fill reservoir. The selected depth for this study is the uppermost 100 feet of saturation.

The specific yield of a deposit with respect to water is the ratio of (1) the volume of water which, after being saturated, the deposit will yield by gravity to (2) its own volume, usually expressed as a percentage (Meinzer, 1923, p. 28). Estimates of the specific yield of the upper 100 feet of saturated material were made by methods similar to those used to show subsurface distribution of sand and gravel in the South Diamond subarea. Lithologic descriptions from drillers' logs were grouped into five general categories and a specific-yield value was assigned to each category (table 11).

The average specific yield for the upper 100 feet of saturated valley fill below prepumping water levels in each of 70 selected wells was calculated, using the above categories and drillers' descriptions of the lithologies. From these values a map showing specific-yield distribution was prepared (fig. 7). The area of highest specific yield is in the South Diamond subarea, and the lowest is beneath the playa in the North Diamond subarea. The area of pumping in 1966 roughly

Table 10.--**Ground-water budget, in acre-feet per year, for equilibrium conditions in Diamond Valley**

(All values estimated, as described in text)

Budget item	North Diamond subarea	South Diamond subarea	Total
RECHARGE:			
Precipitation (table 6)	9,000	12,000	21,000
Inflow at Devils Gate (p. 21)	--	150	150
Subsurface inflow from Garden Valley (table 7)	9,000	--	9,000
Total (rounded): (1)	18,000	12,000	30,000
DISCHARGE:			
Evapotranspiration (table 8)			
In areas of shallow ground water	14,000	1,200	15,000
In areas of spring discharge	9,900	180	10,000
From the playa	5,000	--	5,000
Total (rounded): (2)	28,900	1,400	30,000
IMBALANCE: (1) - (2)	-10,900	+10,600	0

Table 11.--Specific yields of materials described in drillers' logs

Lithologic category (based on drillers' descriptions)	Assigned specific-yield value [1] (percent)
Medium and coarse sand	30
Gravel, sand and gravel	25
Sand, gravel, and clay Gravel and clay	15
Fine sand, sand and clay Sandy clay, cemented gravel	10
Clay, silt, mud, muck	5±

1. Assigned specific-yield values based on Morris and Johnson (1966).

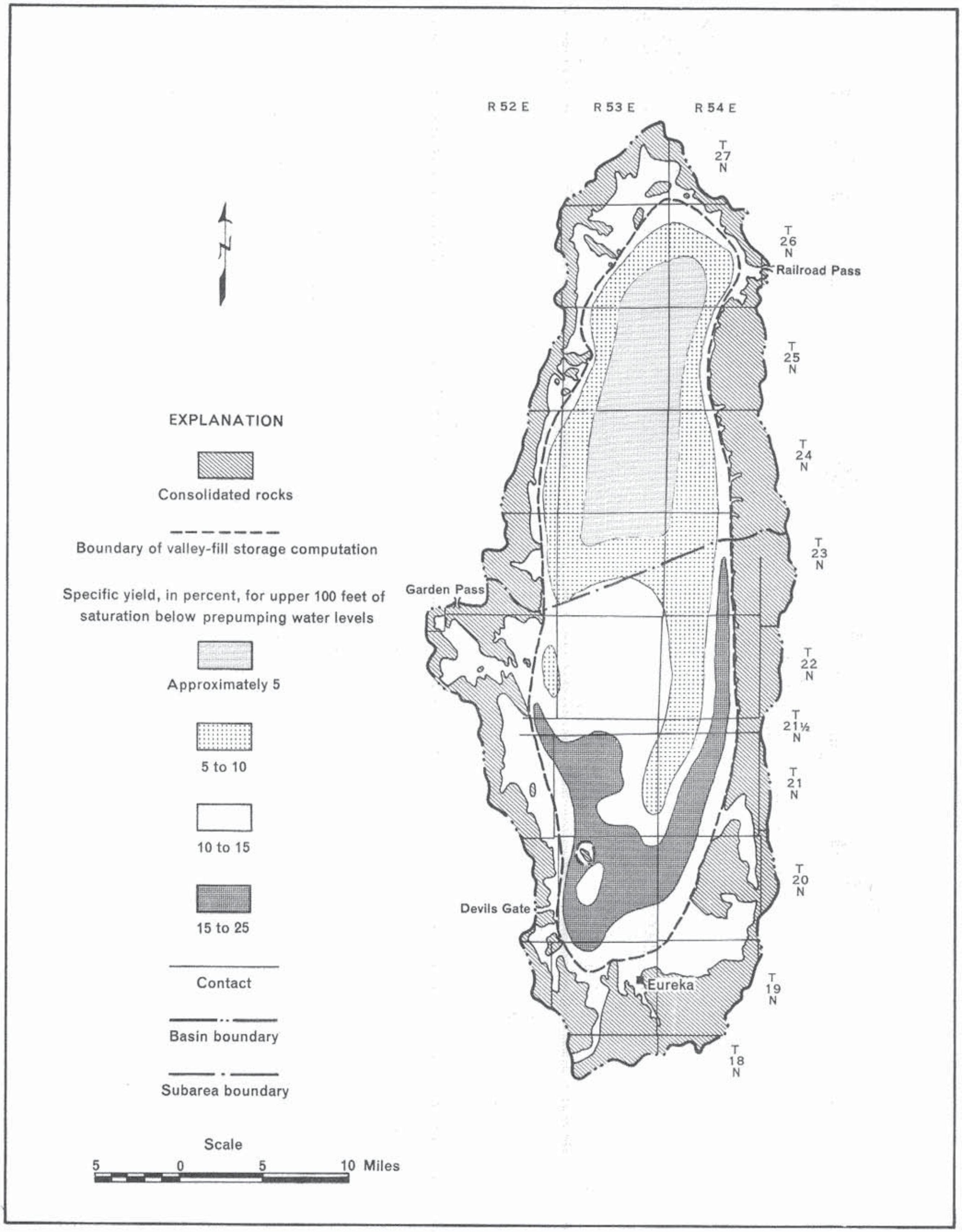

Figure 7.—Estimated specific-yield distribution

corresponds to the area of highest specific yield, which means that more water will be supplied from storage per foot of drawdown in that area than in any other area of similar size in the valley.

Table 12 summarizes the recoverable ground water stored in the upper 100 feet of saturation in the valley-fill reservoir. The estimated total storage is 2,800,000 acre-feet, about 70 percent of which is in the South Diamond subarea. The difference in total storage between subareas is attributed largely to the predominance of playa deposits in the North Diamond subarea, which have an estimated specific yield of only 5 percent and underlie about 40 percent of the subarea.

To assist in estimating the probable effects of future water-level decline on storage, the valley was divided into east-trending subdivisions, or strips, bordered on the north and south by township lines. The estimated amount of water that must be withdrawn from each subdivision to drop water levels 1 foot was computed (table 13) from the distribution of specific yield shown in figure 7.

Table 12.--Estimated recoverable water stored in the upper 100 feet of saturation in the valley-fill reservoir

Specific yield (percent) Range[1]	Specific yield (percent) Average value	Area[1] (acres)	Storage[2] (acre-feet)
South Diamond subarea			
5 to 10	7.5	24,600	180,000
10 to 15	12.5	77,400	970,000
15 to 25	20	41,400	830,000
Subtotal	a 14	143,400	2,000,000
North Diamond subarea			
Approximately 5	5	47,700	240,000
5 to 10	7.5	51,700	390,000
10 to 15	12.5	18,000	220,000
Subtotal	a 7	117,400	850,000
Total (rounded)	a 11	260,800	2,800,000

1. As shown on figure 7.
2. Storage = 100 x average specific yield x area.
a. Weighted areal average specific yield.

Table 13.--**Estimated recoverable water per foot of storage in the upper 100 feet of saturation**

Subdivision[1]	Necessary withdrawal (acre-feet)
T. 19 N., R. 53, 54 E.	600
T. 20 N., Do.	5,000
T. 21, 21½ N., R. 52, 53, 54 E.	7,000
T. 22N., Do.	5,300
T. 23 N., Do.	3,700
T. 24 N., Do.	2,700
T. 25 N., R. 53, 54 E.	2,000
T. 26 N., Do.	1,900
T. 27 N., Do.	<100
Total (rounded)	28,000

1. Townships and ranges shown in figure 7.

CHEMICAL QUALITY OF WATER

Analyses of 45 ground-water samples were made during this study to determine the quality of the water as of 1966, to relate variations in water quality to the ground-water flow system, and to determine the suitability of ground water for use. The results of these analyses are listed in table 14 along with the results of 4 additional analyses that had been made prior to this study.

Types of Water

For the purpose of this report, waters are classified on the basis of their predominate cations and anions. The method used has been described by Piper (1944) and is shown in figure 8. Points plotted in the diamond-shaped field indicate the character of the water as represented by the relationships among groups of ions, namely, the Na + K, Ca + Mg, $CO_3 + HCO_3$, and $Cl + SO_4$. The size of the circle is proportional to the dissolved-solids content of the water. Assignment of a water sample to a chemical type is based on determination of the group or groups that comprise more than 50 percent of the total anions or cations, respectively.

Variations in Quality

As ground water moves from areas of recharge to areas of discharge, the quality of the water changes in response to changing conditions in its environment. The dissolved-solids content generally is low in areas of natural recharge near the mountains and increases as water moves toward areas of natural discharge in the valley lowlands. In areas of natural discharge, the dissolved-solids content usually increases as water moves upward toward the surface.

There is a systematic variation in the occurrence of the three main types of water. In general, ground water near the recharge areas is a calcium magnesium bicarbonate type. This type changes downgradient into a sodium potassium bicarbonate type, which in turn changes to a sodium potassium chloride sulfate type in the central part of the valley. These changes are effected principally by the combined processes of ion exchange and leaching. Concentration by evapotranspiration increases dissolved-solids concentrations in discharge areas.

The relationship of water quality to ground-water flow is shown in figure 9. The approximate direction of the flow is indicated by arrows, the dissolved-solids content is indicated by the distribution of specific conductance at selected points, and the type of water is represented by generalized areas where quality is similar. Part of the data used was obtained from shallow observation wells and may not be representative of the quality of water that would be obtained by a deep well at the same location. This is evident on the east side of the valley where water

Table 14.--Chemical analysis of water from Diamond Valley

Part I.--Detailed analyses by the U.S. Geological Survey

Location	Source	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Milligrams per liter (upper number) and milliequivalents per liter (lower number) for indicated cations and anions: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Dissolved solids (calculated, mg/l)	Hardness as $CaCO_3$ (mg/l): Calcium magnesium	Hardness as $CaCO_3$ (mg/l): Noncarbonate	pH	Specific conductance (micromhos at 25°C)	SAR	RSC (me/l)
19/53-15bd	Fad shaft	1-21-53	56	11	0.02	52	26	8.3	1.4	0	238	38	10	2.6	0	0.06	267	236	42	7.8	467	.2	0
						2.59	2.14	0.36	0.04	0	3.90	0.79	0.28	0.04	0								
19/53-25d	Springs	5- 7-58	48	39	0	69	10	15	1.2	0	242	41	6.7	1.5	.4	.10	303	213	14	7.6	476	.4	0
						3.44	0.82	0.65	0.03	0	3.97	0.85	0.19	0.02	0.02								
20/52-26	Slough Creek	4-10-54	46	21	.06	41	94	1,020	98	35	834	918	800	.08	1.0	1.8	3,440	489	0	8.3	5,370	20	5.05
						2.05	7.73	44.37	2.51	1.16	13.67	19.11	22.56	0.01	0.05								
20/53-17cc	Well	5- 5-66	65	28	.01	72	25	62	8.2	0	398	52	31	.5	.5	.1	475	282	0	7.8	760	1.6	.88
						3.59	2.05	2.70	0.21	0	6.52	1.08	0.87	0.01	0.03								
20/53-21ad	Well	5- 9-66	58	39	0	51	20	17	5.1	0	220	45	14	2.7	.3	0	302	208	28	7.6	467	.5	0
						2.54	1.62	0.74	0.13	0	3.61	.94	0.39	0.04	0.02								
21/53- 3ab	Well	7-11-66	54	44	0	63	13	85	8.8	0	302	76	60	.8	.3	.2	500	212	0	7.8	788	2.6	.71
						3.14	1.10	3.70	0.23	0	4.95	1.58	1.69	0.01	0.02								
21/53- 5cb	Well	5-18-66	54	42	.01	66	25	60	8.8	0	312	71	50	1.0	.5	.1	478	268	12	7.8	758	1.6	0
						3.29	2.07	2.61	0.23	0	5.11	1.48	1.41	0.02	0.03								
21/53-13da	Well	5-17-66	54	28	0	46	16	17	2.2	0	207	39	6.0	.4	.1	0	257	179	9	7.5	406	.6	0
						2.30	1.28	0.74	0.06	0	3.39	.81	0.17	0.01	0.01								
21/53-28cc	Well	5-17-66	60	38	0	74	25	43	6.8	0	368	45	30	.2	.4	.1	444	288	0	7.8	709	1.1	.27
						3.69	2.07	1.87	0.17	0	6.03	.94	0.85	0.00	0.02								
21/53-33da	Well	7-11-66	58	37	0	78	26	73	12	0	406	68	54	.6	.6	.1	549	300	0	7.8	878	1.9	.65
						3.89	2.11	3.18	0.31	0	6.65	1.42	1.52	0.01	0.03								
21/53-36ac	Well	5-20-66	53	16	.01	57	10	13	1.2	0	204	34	8	2.8	.1	0	242	185	18	7.7	400	.4	0
						2.84	0.86	0.57	0.03	0	3.34	.71	0.23	0.05	0.01								
22/53-27aa	Well[1]	5-17-66	56	11	.18	46	21	224	22	0	354	173	180	1.9	.7	.6	854	200	0	8.1	1,430	.5	1.80
						2.30	1.70	9.74	0.56	0	5.80	3.60	5.08	0.03	0.04								
22/53-30cc	Well[1]	5-17-66	56	8.4	.01	21	17	88	16	8	262	34	48	.6	.3	.3	371	124	0	8.6	635	3.4	2.08
						1.05	1.43	3.83	0.41	.27	4.29	.71	1.35	0.01	0.02								
22/54-34ab	Well	3-10-54	54	37	.13	78	36	27	5.5	0	356	77	16	5.5	.6	.12	458	342	51	7.4	709	.6	0
						3.89	2.96	1.17	0.14	0	5.83	1.60	0.45	0.09	0.03								
23/52-13ca	Well	5- 5-66	62	26	.01	41	27	39	8.2	4	264	45	25	.6	.4	.1	346	212	0	8.3	560	1.2	.09
						2.05	2.19	1.70	0.21	.13	4.33	.94	0.71	0.01	0.02								
23/53-34dd	Well	5-17-66	52	15	.02	26	22	216	26	0	374	5	220	2.5	.6	.5	718	154	0	7.9	1,300	7.6	3.05
						1.30	1.78	9.40	0.66	0	6.13	.1	6.21	0.04	0.03								
23/54- 3db	Spring	5-17-66	69	19	.01	73	22	23	5.1	0	318	51	6.5	1.1	.4	0	358	274	13	7.8	583	.6	0
						3.64	1.84	1.00	0.13	0	5.21	1.06	0.18	0.02	0.02								
24/52-23ca	Spring	4-16-63	94	30	0	55	21	30	6	0	288	33	17	.6	.5	.1	330	224	0	7.6	529	.8	.25
						2.74	1.73	1.31	0.15	0	4.72	.69	0.48	0.01	0.03								
24/53-6ac	Well	5- 5-66	95	25	0	51	20	15	3.4	0	255	25	10	.5	.4	0	276	210	1	8.0	449	.4	0
						2.54	1.66	0.65	0.09	0	4.18	.52	0.28	0.01	0.02								

1. Shallow test well augered by U.S. Geological Survey.

Note: Chemical constituents reported in metric units of milligrams per liter and milliequivalents per liter. The metric values are respectively equal to parts per million and equivalents per million for samples with specific conductances up to about 10,000 micromhos, and are slightly more than parts per million and equivalents per million for samples with specific conductances greater than 10,000 micromhos.

Table 14.--Continued

Part II.--Field analyses by the U.S. Geological Survey

				Milligrams per liter (upper number) and milliequivalents per liter (lower number) for indicated cations and anions							Hardness as $CaCO_3$ (mg/l)					
Location	Source	Date of collection	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)[1]	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Calsium magnesium	noncarbonate	pH	Specific conductance (micromhos at 25°C)	SAR	RSC (me/l)
20/53- 1ac	Well	8-17-65	52	21 1.05	22 1.83	31 1.35	0 0	116 1.90	100 2.08	9.0 0.25	144	49	7.8	335	1.1	0
20/53- 4dd	Well	8-19-65	54	77 3.84	28 2.31	79 3.44	0 0	382 6.26	80 1.67	59 1.66	308	0	7.6	806	2.0	.11
20/53-23ac	Well	5-19-66	56	84 4.19	22 1.80	0 0	0 0	234 3.84	16 0.33	64 1.81	300	108	7.6	655	0.0	0
20/53-30db	Well	8-19-65	-	37 1.85	27 2.23	12 0.53	0 0	237 3.88	25 0.52	7.4 .21	204	10	7.5	389	.4	0
21/53- 2ac	Well	7-12-66	60	45 2.25	20 1.65	20 0.85	0 0	210 3.44	40 0.83	17 0.48	195	23	8.0	411	.6	0
21/53- 3cd	Well	7-11-66	55	26 1.30	22 1.78	121 5.24	0 0	264 4.33	83 1.73	80 2.26	154	0	8.2	749	4.2	1.25
21/53- 3db	Well	8-17-65	52	16 0.80	30 2.44	69 3.02	0 0	216 3.54	67 1.39	47 1.33	162	0	7.8	569	2.4	.30
21/53-21ad	Well	8-18-65	62	60 2.99	40 3.32	75 3.28	0 0	406 6.65	68 1.42	54 1.52	316	0	7.3	806	1.8	.34
21/54- 4ad	Well	8-20-65	53	66 3.29	69 5.70	41 1.78	0 0	400 6.56	156 3.25	34 0.96	450	122	7.3	907	.8	0
21/54-16cd	Well	7-12-66	53	28 1.40	9.2 0.76	2.1 0.09	0 0	109 1.79	13 0.27	6.8 0.19	108	19	7.8	198	.9	0
22/52-13ca	Well[2]	9- 2-65	56	7.5 0.37	5.5 0.45	122 5.32	0 0	244 4.00	42 0.87	45 1.27	41	0	8.0	558	8.3	3.18
22/53- 1aa	Well[2]	9- 2-65	53	11 0.55	13 1.09	382 16.62	20 0.67	600 9.83	15 0.31	264 7.45	82	0	8.5	1,740	18.0	8.86
22/53-17aa	Well[2]	9- 2-65	54	24 1.20	27 2.24	873 37.95	0 0	396 6.49	480 9.99	883 24.91	172	0	8.2	4,110	29.0	3.05
22/53-32cd	Well[2]	9- 2-65	54	9.5 0.47	37 3.07	98 4.28	0 0	300 4.92	65 1.35	55 1.55	177	0	8.1	680	3.2	1.38
22/53-36cc	Well[2]	12- 8-65	53	32 1.60	15 1.20	72 3.14	0 0	244 4.00	39 0.81	40 1.13	140	0	7.8	506	2.7	1.20
22/54- 8dd	Well	8-18-65	60	18 0.90	33 2.68	32 1.39	0 0	231 3.79	42 .87	11 0.31	179	0	8.0	427	1.0	.21
22/54-18db	Well	8-18-65	57	32 1.60	18 1.44	18 .80	0 0	190 3.11	25 0.52	7.4 0.21	152	0	8.1	325	.7	.07
22/54-22bd	Well	8-18-65	55	16 0.80	29 2.40	43 1.86	0 0	195 3.20	73 1.52	12 0.34	160	0	7.9	444	1.5	0
23/53- 4cc	Well[2]	5-17-66	52	1.6 0.08	1.0 0.08	5,320 231.41	964 32.13	1,880 30.81	2,300 47.89	4,280 120.74	8	0	9.1	16,400	818.0	62.78
23/53-27bb	Well[2]	9- 2-65	55	23 1.15	13 1.07	244 10.61	0 0	352 5.77	26 0.54	231 6.52	111	0	8.0	1,230	10.0	3.55
23/53-30dd	Well[2]	9- 2-65	55	15 0.75	61 5.00	768 33.39	0 0	427 7.00	308 6.41	912 25.73	288	0	8.2	3,890	20.0	1.25
23/53-33cc	Well[2]	9- 2-65	55	3 0.15	0.6 .05	321 13.96	245 8.17	27 0.44	50 1.04	160 4.51	10	0	10.3	1,430	44.0	8.41
23/54-29aa	Well[2]	9- 2-65	55	8 0.40	4.9 0.40	613 26.66	103 3.43	1,100 18.03	39 0.81	184 5.19	40	0	8.8	2,310	42.0	20.66
23/54-29dd	Well	9- 2-65	58	12 .6	27 2.2	36 1.55	0 0	204 3.34	35 0.73	10 0.28	140	0	8.0	382	1.3	.54
23/54-33bb	Well[2]	5-16-66	50	3.4 0.17	11 0.87	489 21.27	142 4.73	904 14.82	12 0.25	89 2.51	52	0	8.7	1,680	30.0	18.51
25/53- 5cb2	Well	5- 5-66	80	33 1.65	36 2.93	13 0.56	0 0	267 4.38	23 0.48	10 0.28	229	10	7.7	419	.4	0
25/54-28bc	Well	8-18-65	-	5.1 0.25	42 3.45	50 2.19	0 0	268 4.39	52 1.08	15 0.42	185	0	8.1	506	1.6	.69
26/53- 8a	N. T. Spring	9- 3-65	49	8.8 0.44	78 6.39	33 1.42	0 0	345 5.65	106 2.21	14 0.39	342	59	8.2	631	.8	0
26/54-15cd	Well	9- 3-65	52.	35 1.75	25 2.09	34 1.48	0 0	263 4.31	20 0.42	21 0.59	192	0	8.1	588	1.1	.47
26/54-23c[3]	Bailey Sp.	9- 3-65	60	24 1.20	6.6 0.54	32 1.41	0 0	136 2.23	24 0.50	15 0.42	87	0	7.3	296	1.5	.49

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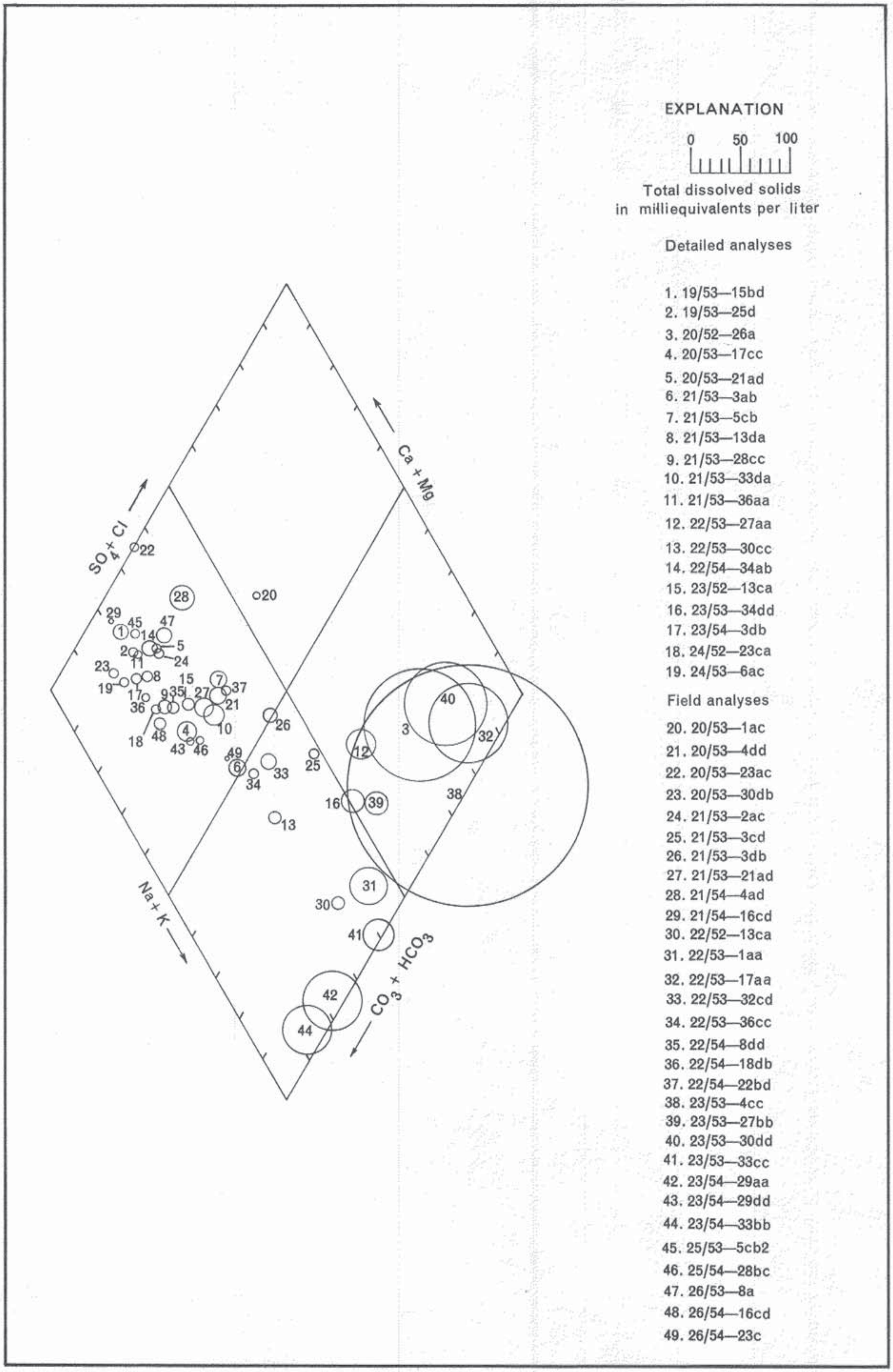
1. Determined by difference
2. Shallow test well augered by U.S. Geological Survey.
3. Sample taken at stock tank
   Spring is at 27/54-14a



EXPLANATION

Total dissolved solids in milliequivalents per liter

Detailed analyses

1. 19/53—15bd
2. 19/53—25d
3. 20/52—26a
4. 20/53—17cc
5. 20/53—21ad
6. 21/53—3ab
7. 21/53—5cb
8. 21/53—13da
9. 21/53—28cc
10. 21/53—33da
11. 21/53—36aa
12. 22/53—27aa
13. 22/53—30cc
14. 22/54—34ab
15. 23/52—13ca
16. 23/53—34dd
17. 23/54—3db
18. 24/52—23ca
19. 24/53—6ac

Field analyses

20. 20/53—1ac
21. 20/53—4dd
22. 20/53—23ac
23. 20/53—30db
24. 21/53—2ac
25. 21/53—3cd
26. 21/53—3db
27. 21/53—21ad
28. 21/54—4ad
29. 21/54—16cd
30. 22/52—13ca
31. 22/53—1aa
32. 22/53—17aa
33. 22/53—32cd
34. 22/53—36cc
35. 22/54—8dd
36. 22/54—18db
37. 22/54—22bd
38. 23/53—4cc
39. 23/53—27bb
40. 23/53—30dd
41. 23/53—33cc
42. 23/54—29aa
43. 23/54—29dd
44. 23/54—33bb
45. 25/53—5cb2
46. 25/54—28bc
47. 26/53—8a
48. 26/54—16cd
49. 26/54—23c

Figure 8.—Chemical character and dissolved solids content of water samples

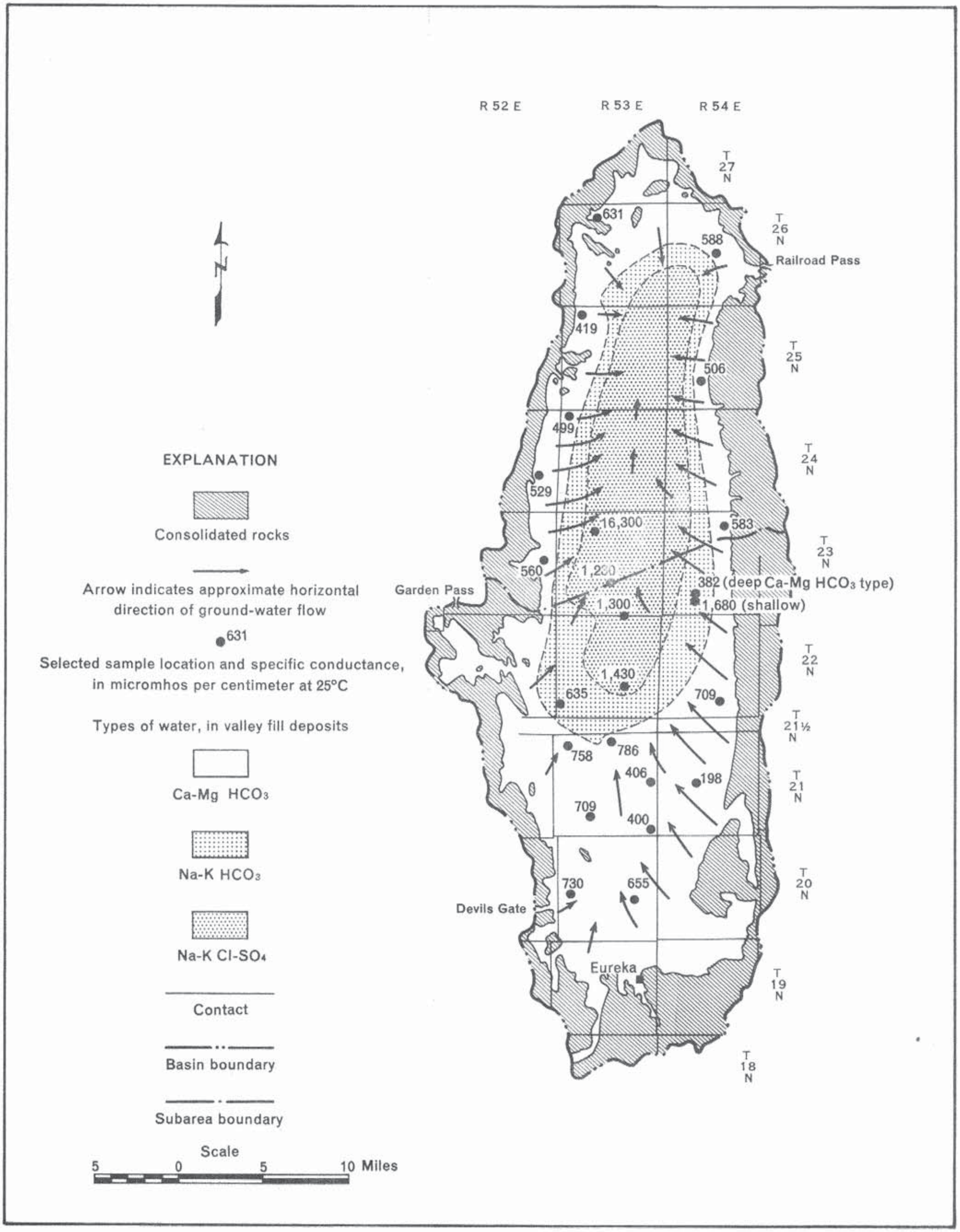


Figure 9.—Generalized relation between water quality and ground-water flow

obtained from well 23/54-33bb (22 feet deep), is a sodium potassium bicarbonate type with a very high salinity, whereas water from well 23/54-29dd (50 feet from well 23/54-33bb, is 320 feet deep, and has no perforations above 144 feet) is a calcium magnesium bicarbonate type with a moderate salinity.

The highly saline sodium potassium chloride sulfate type water in the north-central part of the South Diamond subarea probably forms a fairly thin layer beneath the water table. The high concentration may result from current leaching both of saline soils and of residual salts accumulated at a time when a small lake occupied Diamond Valley and the area of natural discharge extended much farther south than it does at present. The dissolved-solids content of the water in the North Diamond subarea may decrease with depth as it does in some other areas of Nevada. Near the edges of the playa and downgradient from the major springs (table 9), water of good quality may overlie accumulations of saline water.

Water in wells along the west side of the developed part of the South Diamond subarea has a higher dissolved-solids content and slightly higher proportion of sodium than water in wells in the center and along the southern side of the valley. The reason for this was not determined but may be associated with moderately deep circulation along faults, as is suggested by slightly higher water temperatures on the west side of the valley.

Suitability for Agricultural Use

The dissolved-solids content, the percentage of sodium in the water compared to the total cation content, and the concentration of elements and compounds that may be toxic to plants and animals are the most significant factors regarding the suitability of water for agricultural use (U. S. Department of Agriculture, 1954).

Dissolved-solids content as it is related to the suitability of water for agricultural use commonly is referred to as "salinity hazard." Salinity hazard usually is defined in terms of specific conductance, which is a measure of the ease with which an electric current will pass through the water. The U. S. Department of Agriculture (1954) defines salinity hazard and its relation to specific conductance as follows:

Salinity hazard	Specific conductance (micromhos per centimeter at 25°C)	Classification
Low	0 to 250	C1
Medium	251 to 750	C2
High	751 to 2,250	C3
Very high	greater than 2,250	C4

The sodium adsorption ratio (SAR) of irrigation water, is related to the experimentally determined adsorption of sodium by soil, and is defined by the following equation in which all the constituents are expressed in milliequivalents per liter (milliequivalents per liter are given in table 14):

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

Waters from springs and irrigation wells are classified according to their salinity hazard and sodium hazard on the basis of a diagram prepared by the U. S. Department of Agriculture (fig. 10). Salinity hazard is directly related to specific conductance. Sodium hazard is defined in terms of SAR values; however, as shown on the diagram, fixed values of SAR cannot be assigned to the various sodium-hazard classes because the sodium hazard increases as the specific conductance increases.

All samples of water from irrigation wells and springs in Diamond Valley had a low sodium hazard; approximately 75 percent had a medium salinity hazard, and 25 percent had a high salinity hazard. In places where the salinity hazard is high, some treatment of the soil or the water may be necessary in the future to alleviate accumulation of excessive amounts of salt in the soil.

Residual sodium carbonate (RSC) is another factor that affects the chemical suitability of water for irrigation. It was defined by Eaton (1950) as:

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

where the values are expressed in milliequivalents per liter (see table 14). According to Eaton, water having an RSC value larger than 2.5 me/l (milliequivalents per liter) generally is unsuitable for irrigation because calcium and magnesium will be precipitated from the water, causing the sodium hazard of the water to increase. Water having an RSC value of 1.25 me/l to 2.5 me/l is considered marginal, and water having an RSC value of less than 1.25 me/l probably is safe. All samples of irrigation water had RSC values of less than 1.25 me/l and are therefore safe for irrigation in this regard.

Boron is one of the most critical constituents in irrigation water. It is essential for proper plant nutrition in small quantities but is toxic to many plants in amounts only slightly more than the needed amounts. Most of the crops raised in the area are classified by the U. S. Department of Agriculture (1954) as semitolerant and tolerant with respect to boron. The semitolerant crops include most small grains, potatoes, and some other vegetables. Alfalfa is listed as a tolerant crop. Scofield (1936) showed permissible boron concentrations for semitolerant and

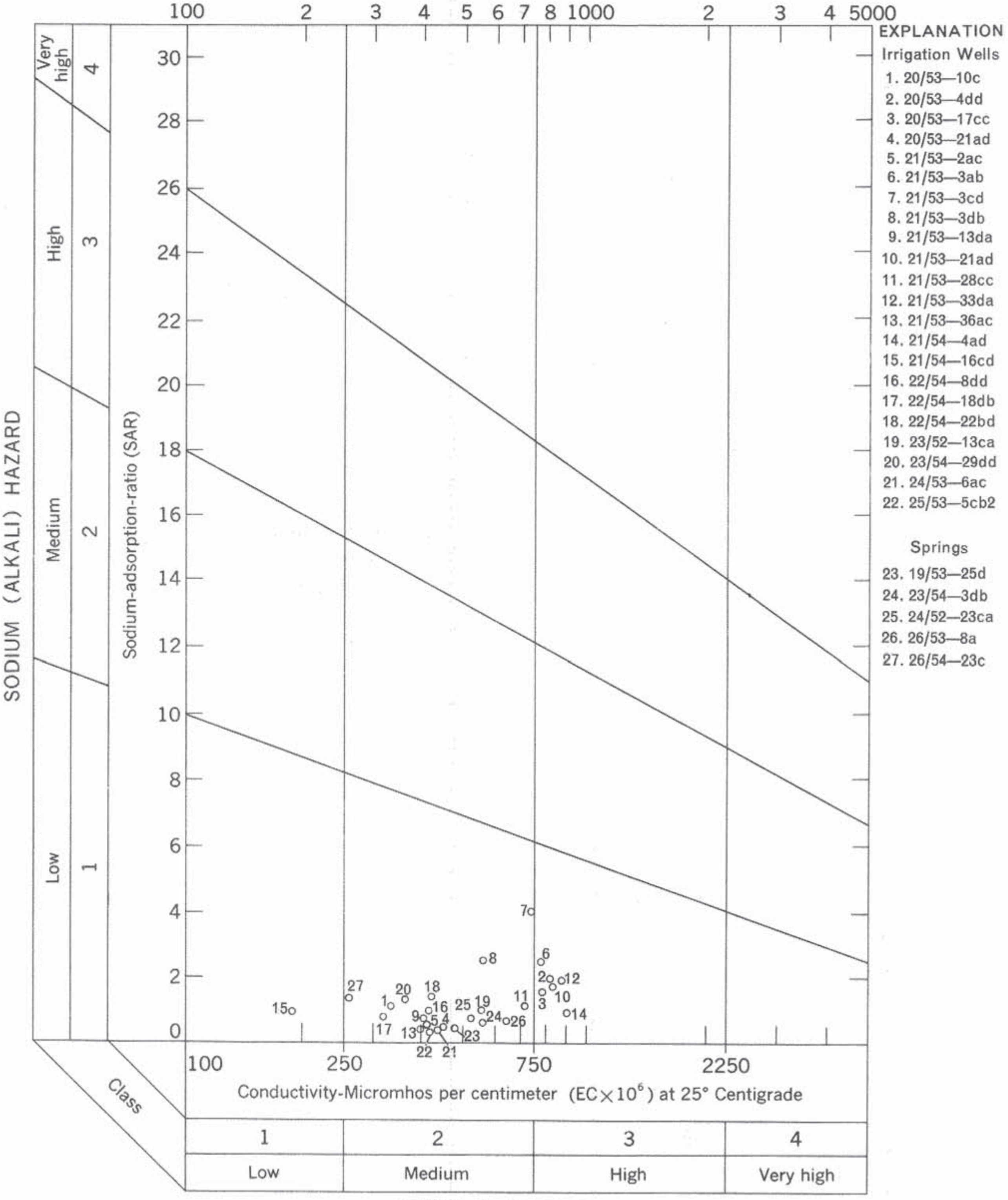


Figure 10.—Classification of water from springs and irrigation wells based on conductivity and sodium adsorption ratio (After U.S. Department of Agriculture 1954)

tolerant crops as follows:

Classes of water		Boron content	
Rating	Grade	Semitolerant crops (mg/l)	Tolerant crops (mg/l)
1	Excellent	less than 0.67	less than 1.00
2	Good	.67 to 1.33	1.00 to 2.00
3	Permissible	1.33 to 2.00	2.00 to 3.00
4	Doubtful	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	more than 2.50	more than 3.75

The boron content of all samples of irrigation water from Diamond Valley was less than the amount that might be harmful to semitolerant crops.

Water from shallow wells in the north-central part of the South Diamond subarea is poorly suited for agricultural use. However, these samples may not be representative of the quality of water that would be obtained from deeper wells in the same locations. The limited data available suggest that quality improves with depth; however, samples must be obtained from deeper wells before meaningful conclusions can be made concerning the suitability of water for use in this area.

Suitability for Domestic Use

The limits recommended by the U.S. Public Health Service (1962) for water used on interstate carriers for drinking purposes commonly are cited as standards for domestic use. Listed below are some of the chemical substances which should not be present in water in excess of the listed concentration where more suitable supplies are available.

Constituents	Concentration (milligrams per liter)
Chloride (Cl)	250
Iron (Fe)	0.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Fluoride (F)	a 1.7
Total dissolved solids	500 (1,000 permitted)

a. Varies inversely with mean temperature; for example, higher temperature results in more water intake and permissible concentration is lower.

At the present time, 1965, less than 25 families use water obtained from the valley-fill reservoir. However, as the area becomes more fully developed, domestic use is expected to increase. The chemical constituents of all samples obtained from irrigation and stock wells during the course of this study are within the permitted limits for domestic use (table 14). This is also true of the water obtained from the Fad shaft.

GROUND-WATER DEVELOPMENT

Initial Development

The earliest development in the valley was in the North Diamond subarea where settlers constructed ditches and shallow pits to utilize the discharge of springs. As ranching became established along the east and west sides of the valley, additional improvements were made to utilize all readily available discharge from springs. No attempts were made to develop additional supplies until the 1940's when flowing wells were drilled on the Romano and Flynn Ranches. These wells were successful, and subsequently flowing wells were also drilled on the Siri and Saddler Ranches.

In 1966, 15 wells in the North Diamond subarea were flowing (table 20), but at rates substantially less than the reported initial discharge; two wells were pumped during the irrigation season; and irrigation water was pumped from the pond at Thompson's spring. The hydrologic system in this area was considered to be adjusting to a new set of equilibrium conditions, because these ground-water developments were either in or adjacent to areas of natural discharge and were being compensated for by local reductions in natural discharge.

Development in the South Diamond Subarea

The extensive well development in the South Diamond subarea began in 1949 when wells 22/54-27ca and 22/54-33dd were drilled along the east side of the valley. Development continued at the rate of a few wells each year until 1958, when extensive efforts were begun to develop land for irrigation. By 1964, when the area was closed to additional development, permits to pump more than 150,000 acre-feet per year had been granted, more than 200 irrigation wells had been drilled, and approximately 35,000 acres of land was to be irrigated by pumping ground water. Due to problems inherent in developing new land, production has lagged behind acquisitions, and in 1965 only 7,600 acres of cropland was harvested. The acreage is increasing each year, and maximum production probably will occur within the next decade.

Irrigation Practices

Sprinkling has been the most widely used method of applying irrigation water during the initial phases of land acquisition and development. In the summer of 1965 sprinkler systems were used with about two-thirds of the 70 to 75 wells pumped. In July 1966 sprinkler systems were being used with 51 of the 74 pumping wells. Lateral and main-line and self-propelled rotary systems are the principal types used. The lateral and main-line systems consist basically of sprinkler lines that are connected to a main line from the well. These lateral lines may be almost a quarter of a mile long and are commonly mounted on wheels so that the entire lateral may be moved to different positions along the main line. Laterals not mounted on wheels must be broken down into individual sections to be moved. Self-propelled rotary systems, also called "Valley sprinklers," consist of one sprinkler line, as much as a quarter of a mile long, mounted on hydraulically driven wheels. The entire system rotates about a pivot at one end of the line which is connected to a well in the center of a 160-acre field. Other methods use ditches or gated pipes to distribute water.

In Diamond Valley, sprinkling generally requires less water than other irrigation methods, because infiltration is reduced in areas of sandy soil. However, wells that discharge through sprinklers must pump against a 70- to 170-foot head in the sprinkler system, in addition to lifting the water to the land surface. The cost of pumping and sprinkling water per acre-foot is higher than with other methods, but the cost of labor and land preparation is generally less.

Sprinkling probably will remain the most commonly employed method of applying water for some time in the future, largely because of the current success, because of the high infiltration rates in local areas, and because of present investment in equipment. For the long term, increased lifts may raise pumping costs sufficiently for some owners to consider reducing pumping costs by using gravity distribution from the well head.

Growing Season

The growing season is determined largely by temperature, and varies with the type of crop grown. Temperature data have been recorded at Diamond Valley, Eureka, Fish Creek Ranch, Jiggs, and Rand Ranch. Table 15 shows the daily minimum temperatures, published by the U.S. Weather Bureau, used in determining the longest period of consecutive days during each year in which the temperature did not go below 32°F, 28°F, and 24°F, respectively, at four of these stations. For example, at Eureka a crop which experienced a killing frost at 28°F would have an average growing season of 118 days.

The effects of topographic position and exposure on the growing season are illustrated by the data in table 15. Both Fish Creek Ranch and Rand Ranch, which have the shortest growing seasons, are in the lower parts of the valleys. Jiggs, on the alluvial apron, has a slightly longer growing season. Eureka, on the lower slopes of the Fish Creek Range, has the longest growing season. These variations may be due in part to differences in station exposure but probably also reflect conditions of thermal inversion which are common in valleys of Nevada.

Table 15.--Longest period, in days, in which temperatures did not go below the indicated values at four stations in east-central Nevada

[From published records of the U.S. Weather Bureau]

Year	Eureka[1]			Fish Creek Ranch[2]			Jiggs[3]			Rand Ranch[4]		
	24°F	28°F	32°F	24°F	28°F	32°F	24°F	28°F	32°F	24°F	28°F	32°F
1948	--	--	--	125	50	29	--	--	--	--	--	--
1949	--	--	--	119	80	40	--	--	--	--	--	--
1950	--	--	--	88	40	33	--	--	--	--	--	--
1951	--	--	--	94	81	9	--	--	--	--	--	--
1952	--	--	--	142	87	44	--	--	--	--	--	--
1953	129	128	111	89	69	3	--	--	--	--	--	--
1954	150	115	96	98	70	48	--	--	--	--	--	--
1955	143	117	108	88	82	63	--	--	--	--	--	--
1956	133	109	109	135	58	28	--	--	--	--	--	--
1957	96	96	95	121	35	28	--	--	--	--	51	27
1958	140	134	93	139	98	73	--	--	--	128	100	60
1959	131	112	27	121	79	44	131	91	52	60	43	24
1960	--	--	--	141	87	87	63	63	56	--	--	--
1961	--	--	--	110	91	65	118	110	93	110	99	47
1962	--	--	--	122	77	27	132	78	76	114	76	22
1963	--	--	--	146	142	48	124	98	49	58	22	11
1964	--	--	--	117	80	46	117	103	59	91	47	25
1965	130	129	73	--	--	--	112	108	60	79	49	28
Average	131	118	89	117	77	42	114	93	64	91	61	30

1. Altitude 6,500 feet.
2. Altitude 6,050 feet.
3. Altitude 5,450 feet.
4. Altitude 5,047 feet.

Temperature records available from the Diamond Valley station, which is closest to the agricultural area in Diamond Valley (fig. 1), are too short and incomplete to provide valid averages, but suggest that conditions of thermal inversion exist throughout much of the year. The growing season in the developed part of the South Diamond subarea probably is longer than at Jiggs and shorter than at Eureka.

Limited attempts were made to prevent frost damage to alfalfa by sprinkling in the fall of 1965. Should this practice prove feasible, the effective growing season might be extended as much as several weeks.

Crop Types, Acreages, and Consumptive Use

The principal crops grown commercially are wheat, oats, and barley, alfalfa, and potatoes. Sorghum, onions, and some grass-legume mixes have been tried on a small scale. According to Mr. Ivan B. Jones of the White Pine-Eureka Counties Branch of the Cooperative Extension Service, University of Nevada (written commun., 1966) other crops that might be grown in the area with proper care are peas, beans, clover, safflower, sugar beets, and cool-season grasses. The major types of irrigated crops, computed seasonal consumptive use of water, and approximate acreages for the summers of 1961-65 are listed in table 16. Because the area has not yet reached its full potential production, new crops and varieties are still being tried, and a permanent pattern of land usage may not become established for several more years. As of the summers of 1965-66, small grains were the predominate crops; however, the acreage and relative proportion of alfalfa has increased each year. Potatoes have met with only limited success, and no large-scale attempts to raise them have been made since 1962.

Estimated Pumpage 1950-65

Estimates of pumpage for the 16-year period 1950-65 were made from pumpage inventories, crop acreages, and the number of wells considered to have been operated during a given year. For the purposes of computation, 75 percent of the total amount of water pumped is assumed to be consumed by crops (65 percent) or lost by spray and surface evaporation (10 percent). The remaining 25 percent is assumed to be recirculated (returns to ground water). A moderately low percentage of recirculated water is used, because most crops are irrigated by sprinkling.

Inventories of pumpage furnished by the State Engineer are available for 1958 and 1959, and a pumpage canvass was made in 1965 as a part of this study. Crop acreages are available for 1961-65. Eakin (1962, p. 29) estimated that the pumpage for 1961 was between 4,000 and 7,000 acre-feet, probably about 5,000 acre-feet. Estimates for the remaining years are based on the number of wells considered to be in operation during that year and on partial reports of pumpage. Table 17

Table 16.--Approximate acreages and computed seasonal consumptive use for major irrigated crops

Crop	Approximate growing season	Computed seasonal consumptive use[1] (acre-feet per acre)	Crop acreages[2]				
			1961	1962	1963	1964	1965
Alfalfa[3]	5 to 5½ months[4]	1.9	70	300	400	985	2,132
Small grains	3 months	1.2	2,900	3,000	3,740	4,710	5,453
Potatoes	4 months	1.4	220	2,200	700	41	19
Onions	4 months	1.4	--	100	--	--	--
Total acreage			3,200	5,600	4,800	5,736	7,604

1. Consumptive use was estimated, using the general method outlined by Houston (1950). The percentage of daylight hours used is for a latitude of 39°40', the average monthly temperatures are those for Eureka, and a consumptive-use coefficient of 0.5 for alfalfa is used for periods of relatively slow growth before and after the frost-free period (Blaney and Hansen, 1965, p. 25).

2. Acreages from information furnished by Cooperative Extension Service, University of Nevada, White Pine and Eureka Counties Branch.

3. Includes mixtures of alfalfa and grain.

4. Includes periods of slower growth before and after the frost-free period.

Table 17.--Estimated pumpage, 1950-65

(All estimates rounded to two significant figures)

Year	Gross pumpage	Net pumpage[1]	Cumulative net pumpage
1950	300	220	220
1951	600	450	670
1952	800	600	1,300
1953	800	600	1,900
1954	800	600	2,500
1955	1,000	750	3,200
1956	1,000	750	4,000
1957	1,200	900	4,900
1958	a 1,200	900	5,800
1959	a 1,800	1,400	7,200
1960	2,400	1,800	9,000
1961	b 6,100	4,600	14,000
1962	b11,000	8,200	22,000
1963	b 9,700	7,300	29,000
1964	b12,000	9,000	38,000
1965	c16,000	12,000	50,000
Totals (rounded)	67,000	50,000	50,000

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1. Net pumpage is assumed to be 75 percent of gross pumpage.

a. Inventory by office of Nevada State Engineer.

b. Based principally on crop inventories (table 16).

c. Based principally on pumpage inventory by the author.

lists the gross pumpage, net pumpage, and cumulative net pumpage for the period 1950-65.

Effects of Pumping on the Ground-Water System

Effects on Natural Conditions

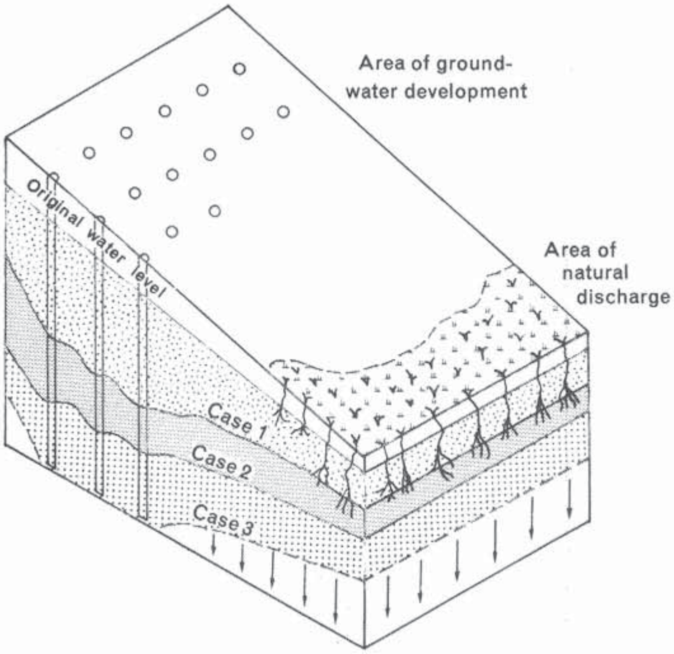
Prior to any development the ground-water system over the long term was in a state of dynamic equilibrium, where recharge equaled discharge and the quantity of water in storage remained constant. Pumping creates an imbalance in the system, where total discharge (natural discharge plus net pumpage) exceeds the recharge. Consequently, water is pumped from storage and water levels decline until natural discharge is reduced sufficiently to bring the system to a new equilibrium, where recharge equals a reduced natural discharge (sometimes to zero) plus net pumpage. However, if net pumpage exceeds the predevelopment natural discharge, water levels will decline indefinitely and a new equilibrium will never be reached.

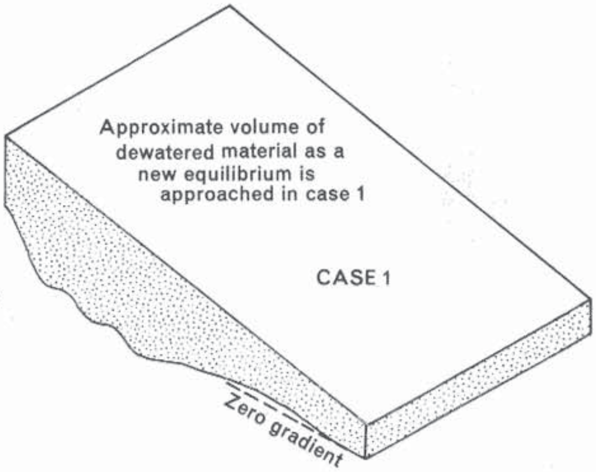
Effects of Specific Developments

The amount by which water levels will decline in any given place is dependent on the quantity of water pumped in relation to the quantity of natural discharge, the distance from the area of pumping to areas of natural discharge, the degree to which pumping is localized, and the coefficients of transmissibility and storage. Development in the South Diamond subarea is: (1) distributed asymmetrically with respect to the area of natural discharge, (2) concentrated in a localized area, and (3) at least 10 miles away from any area where an appreciable quantity of natural discharge may be salvaged (the distance is based on the area with the highest concentration of pumping, T. 21 N., R. 53 E.).

These three conditions indicate that, regardless of the pumping rate, a great deal of water must be withdrawn from storage and water levels lowered appreciably before any new equilibrium is possible. Figure 11 shows the long-term effects of three rates of pumping on the natural system. The distribution of pumping in relation to the area of natural discharge, as shown, is similar to that which exists in the South Diamond subarea.

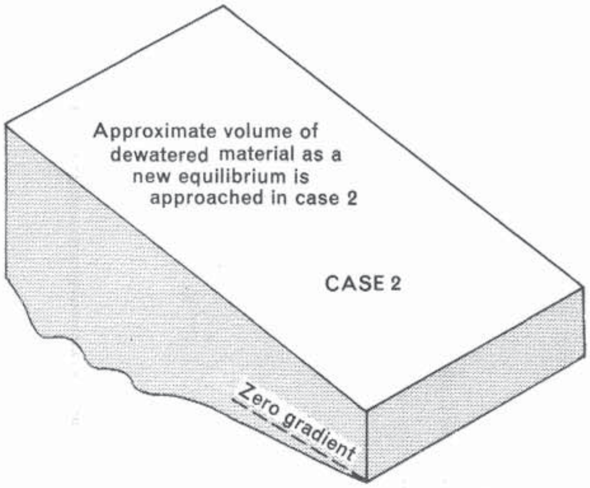
The extent to which various pumping rates in the South Diamond subarea will eventually affect conditions in the North Diamond subarea may be estimated approximately from figure 12, which shows the area of ground-water development and the cumulative natural discharge from the vicinity of the pumping area to the northern end of the valley. In estimating the areal extent of pumping effects, it must be realized that the natural discharge in the southern area would not be completely eliminated before the area to the north is affected. For example, if equilibrium conditions were approached for a net pumping rate of





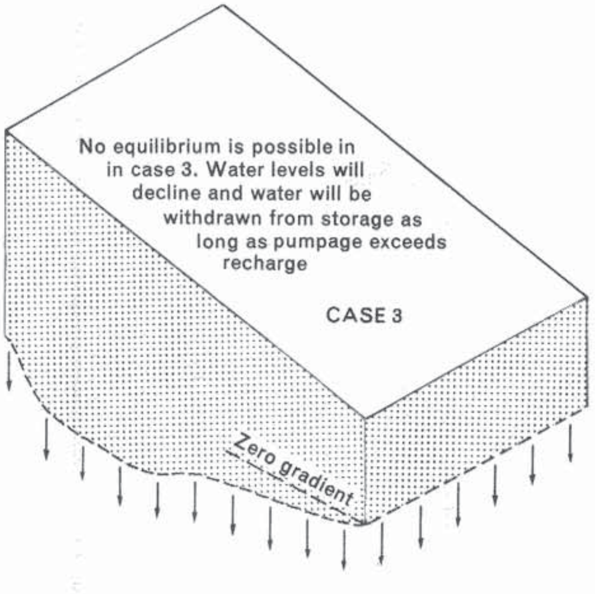
CASE 1—Annual pumpage is less than average annual recharge and natural discharge

Water is pumped from storage and water levels decline until natural discharge is reduced by an amount equal to the rate of pumping. A local depression develops in the pumping area. A slight reversed gradient from parts of the area of natural discharge toward the pumping area may develop; however, natural discharge continues at a reduced rate



CASE 2—Annual pumpage equals average annual recharge and natural discharge

Water is pumped from storage and water levels decline until natural discharge is eliminated. Water levels continue to drop at a reduced rate until a slight reversed gradient is established toward the pumping area allowing all recharge to flow toward and ultimately be discharged by pumping



CASE 3—Annual pumpage exceeds average annual recharge and natural discharge

Water is pumped from storage and water levels decline throughout the area. When natural discharge is eliminated, the rate at which water is pumped from storage about equals the amount by which pumpage exceeds recharge to the area. Water levels will continue to decline until pumpage is decreased or terminated because of (1) increased lifts and costs or (2) a deterioration in water quality

Figure 11.—Long-term effects of three rates of pumping on the ground-water system

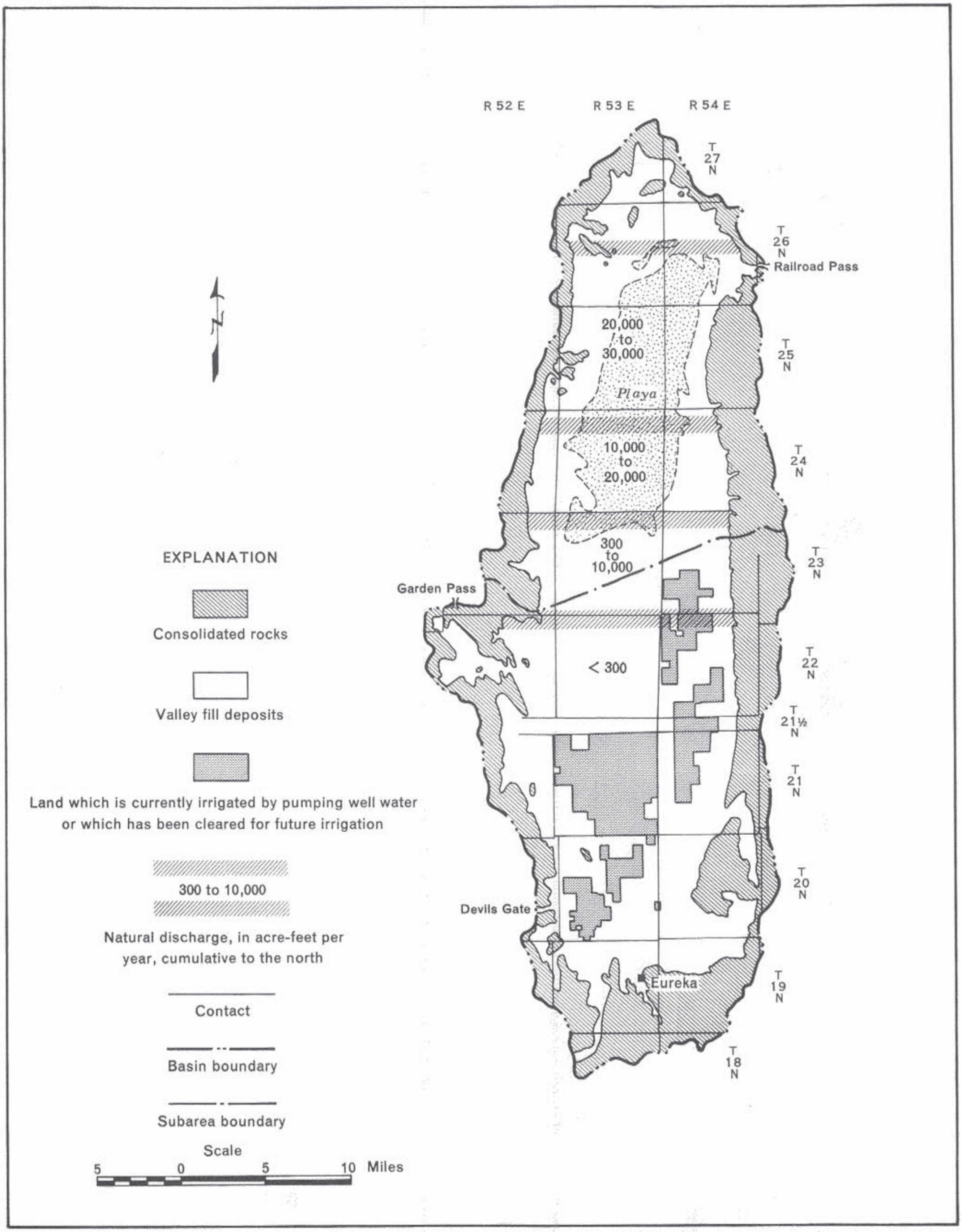


Figure 12.—Location of major ground-water development with respect to the distribution of natural discharge in 1965

12,000 acre-feet per year in the South Diamond subarea (estimated 1965 rate, table 17), then the natural discharge in Tps. 22 and 23 N. would be greatly reduced while discharge in T. 24 N. and possible parts of T. 25 N. would be reduced progressively, but to a lesser extent. The total reduction in natural discharge eventually would equal 12,000 acre-feet per year, and the conditions of Case I in figure 11 would be achieved.

Changes in Water Quality

In hydrologically closed basins, the chemical quality of pumped water generally deteriorates with time. This change is attributed to (1) the reversal of natural gradients which may cause water of poor quality to flow into the pumping area from beneath the playa, and (2) an unfavorable salt balance caused by the recycling of irrigation water in the area of pumping. The effects of both of these processes are lessened by mixing with locally derived water of good quality so considerable pumping may be required before changes in water quality will cause significant reductions.

The problem of an unfavorable salt balance in time may pose a threat to the future of the existing ground-water development. As pointed out by Hem (Halpenny and others, 1952, p. 149):

> "It has long been recognized that if an irrigation project is to be permanently successful it must be so designed and operated that the drainage leaving the area of irrigation carries off the accumulating soluble salt from the whole area. Ideally, the amount of mineral matter that must be removed should at least be equivalent to the amount entering the area in the irrigation water supply and from other sources. This is essentially the principal of salt balance."

Drainage from the South Diamond subarea under natural conditions was by subsurface flow toward the playa. As natural gradients are reversed by pumping, drainage from the area will be eliminated and salts which are not removed by crops or wind action will remain either in the soil or in that part of the irrigation water which returns to the zone of saturation. Soluble salts are continually being brought into the area, either in ground water or in fertilizers. This results in an unfavorable salt balance and, over the long term, an insidious but cumulative deterioration in the quality of the pumped water.

The Nonequilibrium Condition

Water-Level Decline

Rate.--Development along the east side of the valley in Tps. 21 and 22 N. has existed since the early 1950's; however, the area of heaviest pumping, T. 21 N., R. 53 E., was not developed to any degree until 1958. The hydrographs in figure 13 show the effects of the duration and extent of development on the magnitude and rate of water-level decline in three wells over periods of 16 to 18 years. Hydrographs of wells 22/54-10ac and 22/54-33dd, on the east side of the valley, show a nearly constant decline since 1950. In well 21/53-22cd, near the center of the most heavily pumped area, water levels did not begin to drop appreciably until 1958, but since then have declined more rapidly than in the wells on the east side of the valley. The pronounced annual fluctuations shown since 1960 are the result of seasonal pumping.

Well 22/54-10ac is in the extreme southeastern part of the natural-discharge area. The lowering of water levels in that area indicates that small local reduction in natural discharge is occurring; however, no large-scale reduction will occur until water levels begin to decline in the main area of natural discharge some 5 to 6 miles farther north.

Figure 14 is a diagrammatic cross section showing the overall water-level decline for one year in the most heavily pumped part of the developed area. It was constructed by projecting the net changes for one year, spring 1965 to spring 1966, in some 16 selected wells onto a north-south section through the approximate center of the most heavily pumped area. Additional pumping occurred some 4 to 6 miles east of the line of section, in T. 22 N., R. 54 E., but the effect on observation wells in the center of the valley was negligible.

The rate of water-level decline in the central part of the pumped area is somewhat irregular, but averages 1.5 to 2 feet per year, whereas the rate of decline in wells outside of the pumped area decreases with distance from the pumped area. The net change-distance relationship suggested is similar to the drawdown-distance relationship obtained from the cone of depression of a single pumped well. On the basis of this similarity, increases in the rate of pumping may produce moderately large increases in the rate of water-level decline beneath the pumped area with progressively smaller increases in the rate of water-level decline with increasing distance from the pumping area.

Net change, 1950-66.--Contours drawn for the high water levels in the spring 1966 in the South Diamond subarea are shown in figure 15. In the developed area, water levels are substantially lower than those shown for the spring of 1950 on plate 2. The area in which water levels have declined and the amount of the decline were determined from these two maps and extrapolated from changes observed in individual wells having shorter records. Figure 16 shows the net decline in water levels from spring 1950 to spring 1966.

The maximum change noted was 12.2 feet in well 21/53-36dc. The area of maximum change does not coincide exactly with the area of

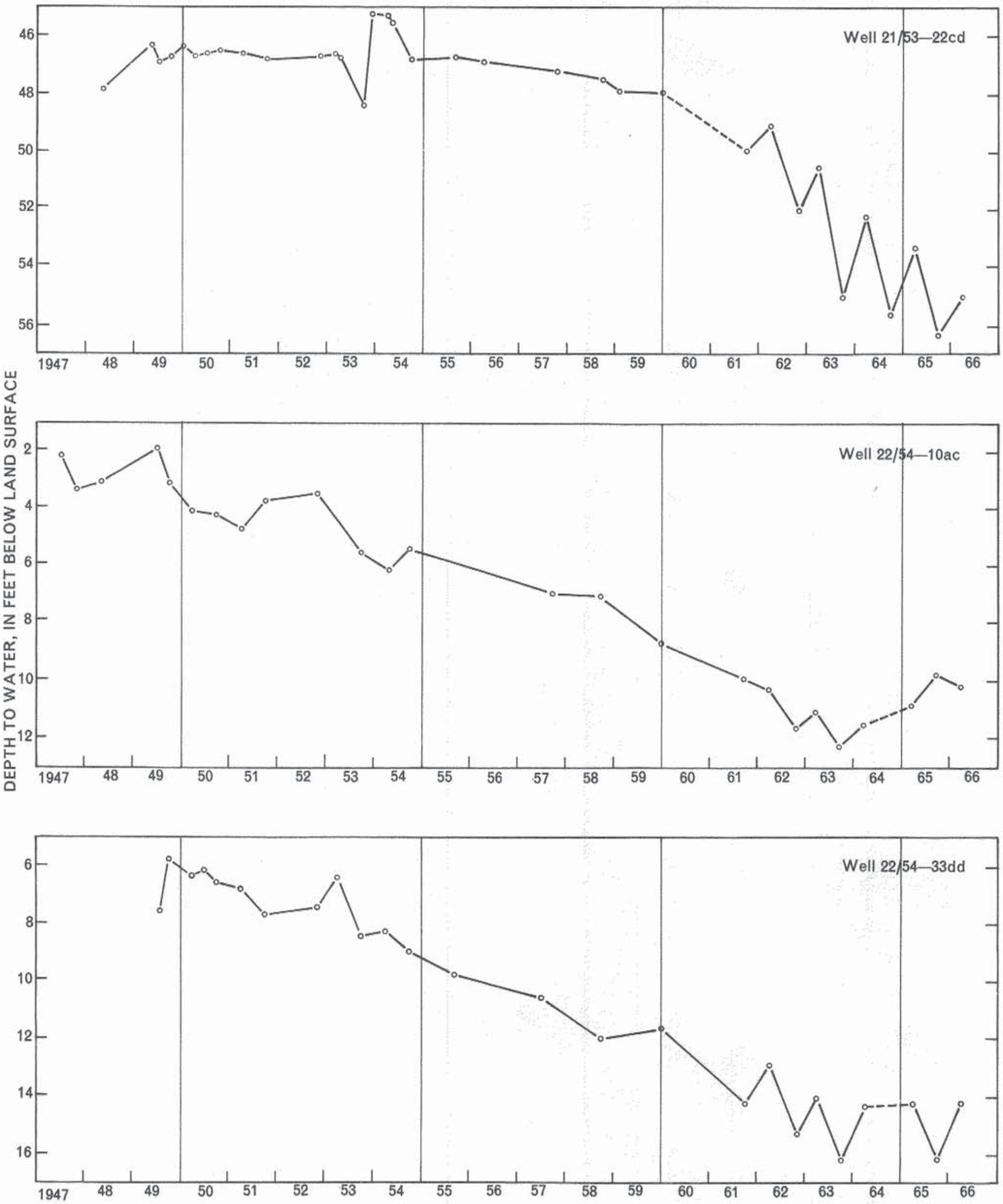


Figure 13.—Hydrographs of three wells

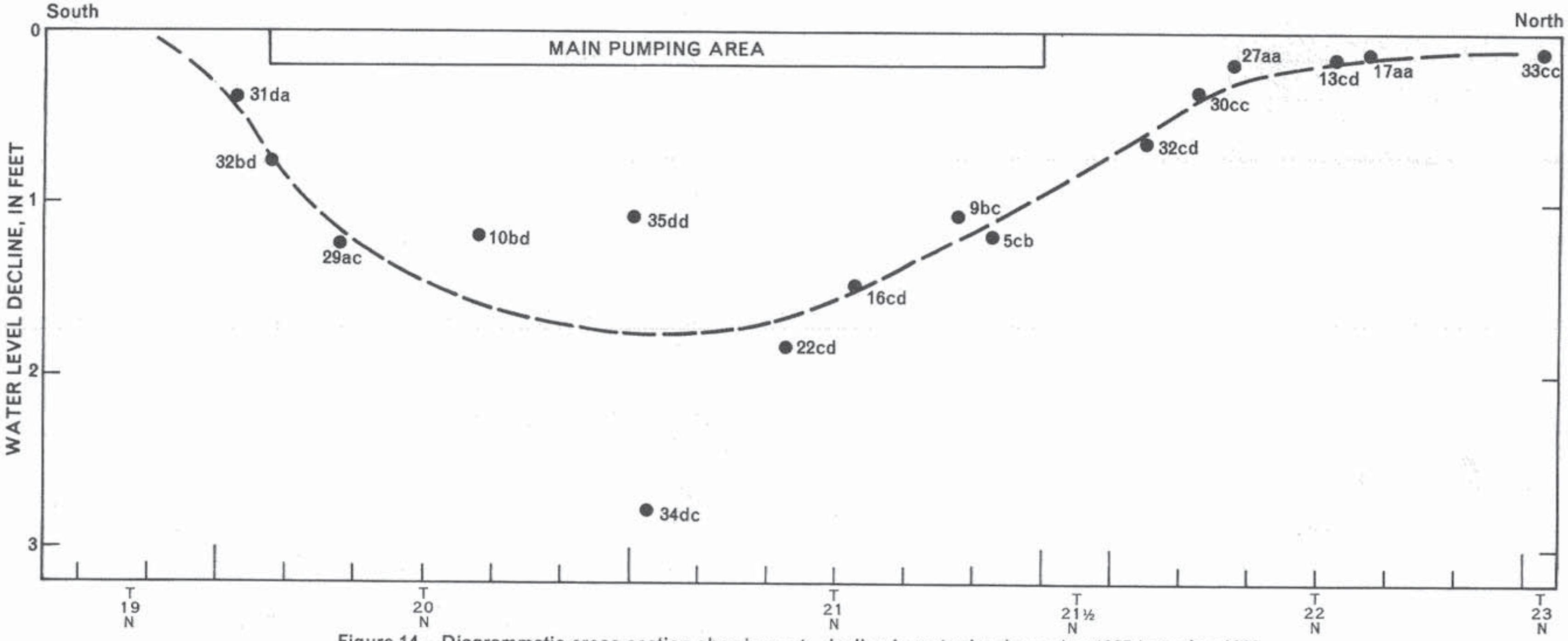


Figure 14.—Diagrammatic cross section showing net decline in water levels, spring 1965 to spring 1966

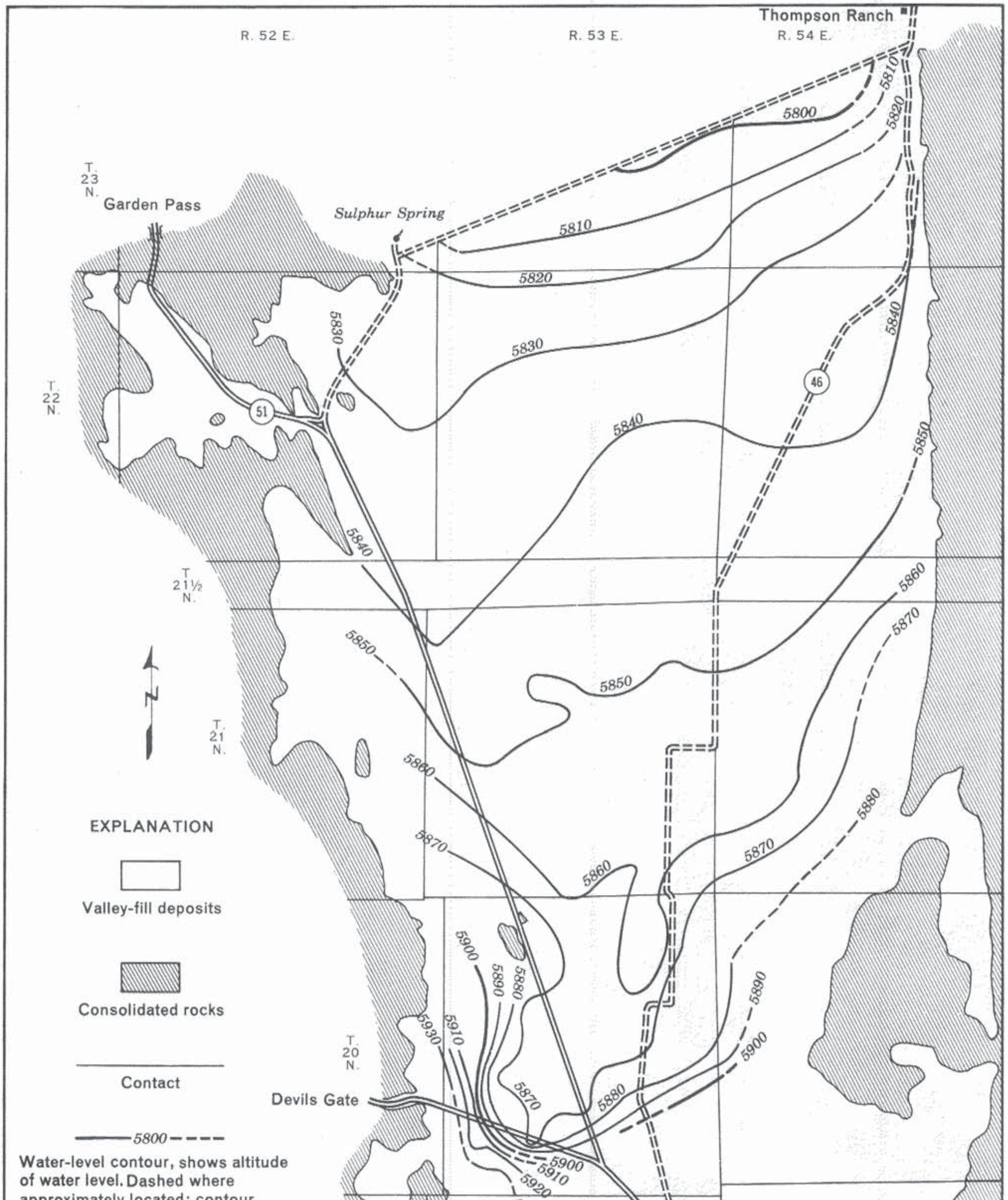


Figure 15.—Water-level contours for April 1966, South Diamond subarea

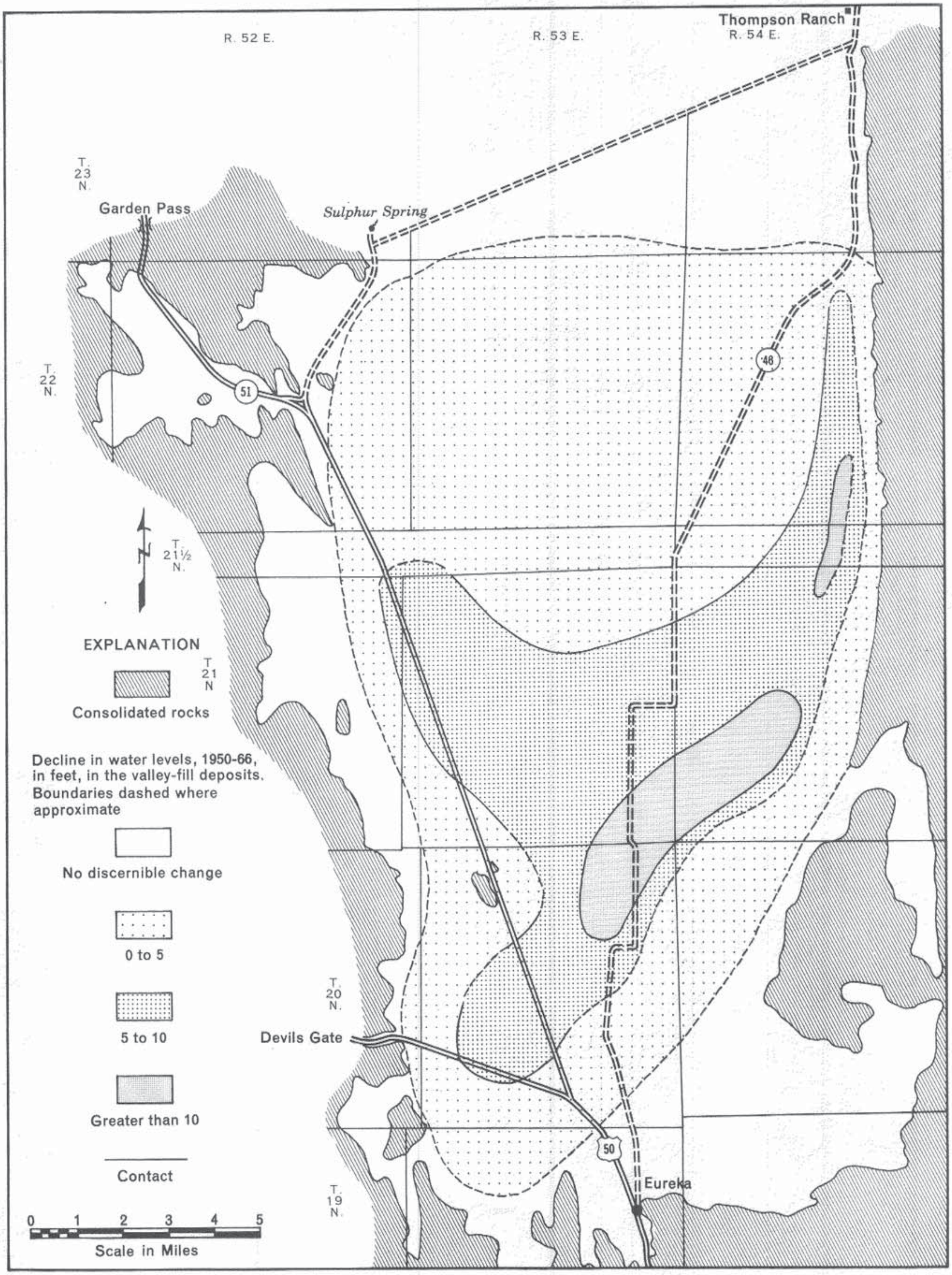


Figure 16.—Approximate net decline of water levels in the south Diamond subarea, 1950-66

heaviest pumping. It is offset slightly toward the Diamond Mountains and is attributed in part to fine-grained lenses in the valley fill which cause semiconfined conditions under the southeast part of the developed area. In most of the developed area the net change is between 5 and 10 feet. At the extreme northeastern end of the developed area, in T. 23 N., R. 54 E. (fig. 16), no substantial pumping has occurred and no measurable change in water levels was noticed.

Storage Depletion as of Spring 1966

Water that has been removed from storage by pumping during the 16-year period, spring 1950-spring 1966, was estimated by the same method used to determine the recoverable storage in the upper 100 feet of saturated valley fill. For purposes of estimating the depletion the specific yields for the upper 100 feet of saturated valley fill shown on figure 7 are considered to be roughly equivalent to those of the thinner interval dewatered during the 16-year period. The volume of the dewatered interval was determined from the net water-level declines shown in figure 16.

Table 18 shows an estimated storage depletion of 60,000 acre-feet. That value is larger than, but on the same order of magnitude as, the estimated total net pumpage of 50,000 acre-feet for the 16 years, 1950-65 (table 17). Under ideal conditions, these quantities should be equal, because the area of net change (fig. 16) has not yet salvaged any appreciable quantity of natural discharge, which indicates that virtually all pumpage has been from storage. The difference of 10,000 acre-feet, or about 18 percent, in these two estimates is attributed to inaccuracies in the assumptions made, to a time lag in the draining of finer grained deposits, to a time lag in the return of recirculated water to the zone of saturation, and to water-level declines in some wells that may represent changes in pressure head rather than actual storage depletion.

Ground-Water Budget, 1950-66

Table 19 summarizes the effects of 16 years of pumping on the hydrologic system, a period of nonequilibrium conditions. Virtually all the change has occurred in the South Diamond subarea. When all the recharge to the valley-fill reservoir during the 16-year period is compared to all the discharge, a net loss of approximately 48,000 acre-feet, or 3,000 acre-feet per year, is noted. If all estimates are correct, the net loss of 48,000 acre-feet (budget item 3) should equal the estimated net storage depletion of 60,000 acre-feet (budget item 4), which was computed independently. The imbalance between methods of 12,000 acre-feet, which is only a little more than 2 percent of the recharge or discharge, is attributed largely to errors in estimates of net pumpage and storage depletion. In the event that the larger estimates of recharge from precipitation, inter-basin flow, and natural discharge, which were computed for the long-term average, are not representative of or imposed some change on the system for the period 1950-60, the budget may be even more in error.

Table 18.--Estimated net storage depletion for the 16-year period 1950-66

Net change (feet)		Area (acres)	Volume dewatered (acre-feet)	Average specific yield (percent)	Storage depletion (acre-feet)
Range	Average				
0 to 5	1	14,000	14,000	20	2,800
	1	51,000	51,000	12.5	6,400
	1	11,000	11,000	7.5	820
5 to 10	7	19,000	130,000	20	26,000
	7	9,600	67,000	12.5	8,400
	7	4,600	32,000	7.5	2,400
Greater than 10	11	4,600	51,000	20	10,000
	11	1,900	21,000	12.5	2,600
	11	200	2,200	7.5	160
Totals (rounded)	[a] 3.3	116,000	380,000		60,000

[a] Average weighted water-level decline.

Table 19.--Ground-water budget, in acre-feet, for nonequilibrium conditions in Diamond Valley, 1950-66

(All values estimated, as described in text)

Budget item[1/]	16-year period	Average annual
RECHARGE:		
Precipitation (table 6)	336,000	21,000
Inflow at Devils Gate (p. 21)	2,400	150
Subsurface inflow from Garden Valley (table 7)	144,000	9,000
Total (rounded) (1):	482,000	30,000
DISCHARGE:		
Evapotranspiration (table 8)	480,000	30,000
Net pumpage (table 17)	50,000	3,100
Total (rounded) (2):	530,000	33,000
IMBALANCE (3): (1) - (2)	-48,000	-3,000
STORAGE DEPLETION (table 19) (4):	-60,000	-3,800
DIFFERENCE BETWEEN METHODS: (3) - (4)	12,000	800

1. All items, except pumpage and storage depletion, based on long-term average rather than for period 1950-66.

THE AVAILABLE GROUND-WATER SUPPLY

The available ground-water supply in Diamond Valley can be expressed in several ways: (1) the natural yield, which is provided by the springs, principally in the North Diamond subarea; (2) the perennial yield, or the maximum amount of salvable natural discharge; (3) storage depletion, which is sometimes referred to as the "one-time reserve"; and (4) the possible future development and its relation to the available supply. These are discussed in the following sections.

Natural Ground-Water Yield

The large springs, principally in the North Diamond subarea (pl. 2), provide a natural ground-water supply of about 8,400 acre-feet per year (table 9). For many years most of the discharge has been used to irrigate hay, natural pasture, alfalfa, and native grasses. Because of the relatively uniform flow throughout the year and because of the short growing season, only about a third of the total spring discharge is put to beneficial use. The bulk of the flow is consumed largely by nonbeneficial evapotranspiration in areas of phreatophytes downstream from the spring outlets.

In time, as the effects of ground-water development begin to reduce natural discharge, the spring flow probably will begin to decrease. If ranchers eventually drill wells and pump in this area, the spring flow can be expected to decrease more rapidly.

Perennial Yield

The perennial yield of a ground-water reservoir may be defined as the maximum amount of water of usable chemical quality that can be withdrawn and consumed economically each year for an indefinite period of time. If the perennial yield is continually exceeded, water levels will decline until the ground-water reservoir is depleted of water of usable quality or until pumping lifts become uneconomical to maintain. Perennial yield cannot exceed the natural recharge to or discharge from the reservoir. Moreover, the perennial yield ultimately is limited to the maximum amount of natural discharge that can be economically salvaged for beneficial use.

Table 6 shows that the estimated average annual recharge to the ground-water reservoir is 30,000 acre-feet, and table 8 shows that the average annual discharge is the same. Thus, with an ideal distribution of pumping so as to salvage all natural discharge and with no deterioration in water quality, the perennial yield of the valley-fill reservoir also is approximately 30,000 acre-feet.

The estimated net pumpage in 1965 was 12,000 acre-feet (table 17), which is considerably less than the estimated yield. However, from 1960 to 1965, net pumpage increased from 1,800 to 12,000 acre-feet, or at an average rate of about 2,000 acre-feet per year. If this rate should continue, net pumpage would equal the perennial yield by about 1975. Moreover, because permits to pump nearly 150,000 acre-feet per year have been granted in this same area, the rate of increase might be accelerated and the yield equaled even sooner. Eventually it could be greatly exceeded.

The maximum amount of natural discharge that can be salvaged by pumping in the general area of development in 1966 in the South Diamond subarea (fig. 12) will be governed by the rate at which pumping lifts become uneconomical to maintain or at which a significant influx of poor-quality water from the playa area might occur. Because of the unfavorable distribution of pumping with respect to salvage of natural discharge, lifts in much of the developed area would have to increase substantially over those in 1966 to salvage even an amount of natural discharge equal to the estimated net pumpage of 12,000 acre-feet in 1965. Figure 12 shows that all natural discharge in Tps. 22 and 23 N., Rs. 52, 53, and 54 E., and about 10 percent of that in T. 24 N., Rs. 52, 53, and 54 E. would have to be salvaged to equal this pumpage. The northernmost salvage would be some 15 miles north of the area of concentrated pumping in T. 21 N., R. 53 E.

Sustained annual pumping much in excess of 12,000 acre-feet per year would produce accelerated rates of water-level decline in the pumped area, and any new equilibrium (fig. 11, Case I) probably could not be attained before lifts would become uneconomical to maintain. Thus, pumpage much in excess of 12,000 acre-feet per year in the area of development in 1966 probably will lead to a paradox, common in Nevada valleys; a condition of local overdraft in the South Diamond subarea, while more than 15,000 acre-feet per year goes to waste in the North Diamond subarea.

Storage Depletion

The quantity of storage depletion necessary before the hydrologic system can attain a new equilibrium at a rate of pumpage equal to or less than the perennial yield is dependent primarily upon the distribution of pumping with respect to natural discharge. With properly spaced wells in or near the area of natural discharge, the necessary storage depletion becomes minimal. Conversely, the necessary storage depletion increases as pumping is moved away from the natural-discharge area or is asymmetrically distributed with respect to it.

In Diamond Valley the necessary storage depletion required to reach a new equilibrium is difficult to predict, because of the many unknown and variable hydrologic factors. Moreover, as previously mentioned, the unfavorable distribution of pumping with respect to natural discharge, as of 1965, probably will result in a local overdraft in the South Diamond subarea long before a new equilibrium could be approached with a net pumpage equal to the perennial yield. Therefore, an example is considered in terms of that storage depletion necessary before the system can approach a new equilibrium where net pumpage equals 12,000 acre-feet per year (the 1965 rate) from the general area of development shown in figure 12. Although this rate represents only 40 percent of the perennial yield, it may approximate the maximum amount of natural discharge that can be economically salvaged by pumping in the South Diamond subarea. The following assumptions are utilized to obtain an estimate: (1) Pumping in the future would continue to be concentrated in the same general areas as in 1965 (fig. 12); (2) Net pumpage would continue at the 1965 rate of 12,000 acre-feet per year; (3) A hydraulic gradient from the playa toward the area of pumping would develop as equilibrium is approached (fig. 11, Case I); (4) The area affected would include most of the valley fill south of T. 24 N., Rs. 52, 53, and 54 E. and some valley fill in the southern part of T. 24 N., Rs. 52, 53, and 54 E. (fig. 12)--a total of roughly 200,000 acres; (5) The water-level decline would range from about 10 feet in the playa area in T. 24 N., R. 53 E. to 200 feet at the south edge of the pumped area in Tps. 19 and 20 N., R. 53 E., and the weighted areal decline would be roughly 125 feet; and (6) The estimated specific-yield distribution shown on figure 7 also would apply at depths greater than the uppermost 100 feet of saturation, and is computed to average about 12 percent.

Utilizing these assumptions together with the distribution of transmissibility (fig. 3), the storage depletion is computed to be about 3 million acre-feet, most of which would occur in the South Diamond subarea. Figure 17 shows diagrammatically the effect on water levels of a storage depletion of this magnitude in the South Diamond subarea. The economic significance of this large quantity is that locally water levels in the area of development may be expected to decline as much as 200 feet below the 1965 levels (as much as 300 feet below land surface), if net pumpage were held at about the 1965 rate of 12,000 acre-feet. Pumping at greater rates would result in more rapid storage depletion in the developed area, causing larger increases in the rate of water-level decline in the vicinity of the pumping and smaller increases in the rate of decline near the area of natural discharge. Moreover, if net pumpage were held to 12,000 acre-feet per year, the estimated 3 million acre-feet of storage would not be exhausted for 300 to 400 years, depending on the rate at which natural discharge would be salvaged. At that time water levels would stabilize, and all the net pumpage of 12,000 acre-feet per year would be supplied by recharge moving directly to the pumping wells.

Future Pumpage

The foregoing sections on yield indicate that large drawdowns will result if pumping is restricted to the areas of development shown on

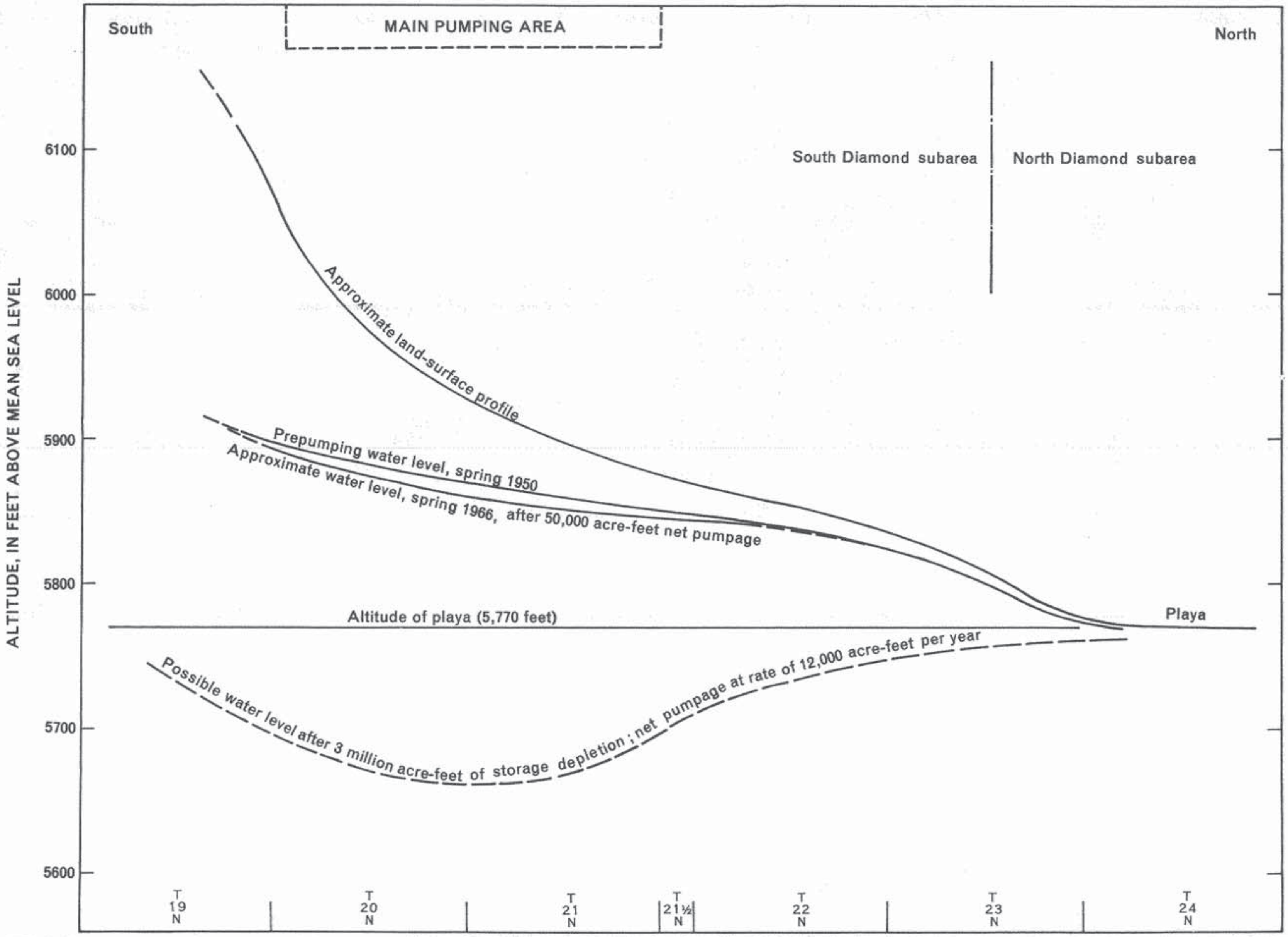


Figure 17.—Diagrammatic water-level profiles in South Diamond subarea

figure 12. A local overdraft will occur in the South Diamond subarea long before any new equilibrium is reached. Moreover, even without any increase in net pumpage rate, pumping lifts locally could become uneconomical to maintain within the next 10 to 20 years.

As previously mentioned, permits to pump approximately 150,000 acre-feet per year in Diamond Valley have been granted by the State. Thus, future utilization of existing permits will result in a massive local overdraft and accelerated rates of water-level decline.

CONCLUSIONS

This second appraisal of the water resources of Diamond Valley has led to the following conclusions regarding the adequacy of supply, effects of development, and types of data needed to refine the flow system and response characteristics of the valley-fill reservoir:

1. All development to date and all applications for future development are in the South Diamond subarea--total permits to pump about 150,000 acre-feet per year have been granted. This is considerably in excess of the estimated perennial yield of 30,000 acre-feet for Diamond Valley.

2. The estimated net pumpage in 1965 was 12,000 acre-feet, or less than half the estimated yield. Virtually all net pumpage of record (1950-65), which totals an estimated 50,000 acre-feet, has been supplied from ground water in storage in the South Diamond subarea.

3. Because the area of pumping is remote from areas of natural discharge, storage depletion will continue for many years in the future. An example demonstrated that if net pumpage were held to only 12,000 acre-feet per year, about 3 million acre-feet of storage depletion would be required before 12,000 acre-feet per year of natural discharge could be salvaged. Water levels in the area of concentrated pumpage (T. 21 N., R. 53 E.) would be drawn down as much as 200 feet below 1965 levels. The time required to reach the new equilibrium would be from 300 to 400 years.

4. The rate of increase in estimated net pumpage from 1,800 acre-feet in 1960 to 12,000 acre-feet in 1965 suggests that net pumpage may equal the perennial yield by 1975. Even if the perennial yield is not exceeded, local overdraft is likely to occur in the South Diamond subarea and water levels locally may be drawn down below economic pumping lifts.

5. Pumping in the South Diamond subarea eventually should decrease the natural discharge from springs in the North Diamond subarea, which during the summer 1965 was largely being used beneficially. In time, the discharge from springs may have to be supplemented or replaced by pumping from wells. Although more costly, this procedure would salvage the large amount of water (about 6,000 acre-feet per year) now running to waste during the nongrowing season.

6. The cost of pumping will increase in about direct proportion to the increase in pumping lift, provided that other fixed

costs remain constant. To the extent possible, new or replacement pumping should be situated farther north near the playa, where the cost of pumping would be less and where salvage of natural discharge would tend to reduce the rate of water-level decline. This in turn would reduce the rate of pumping-cost increase.

7. The cause-and-effect relations (pumpage versus the distribution and amount of water-level decline and associated factors) for the 16-year period 1950-66 are first approximations developed from an estimated gross pumpage of 67,000 acre-feet (estimated 50,000 net pumpage). Future refinements of these relations will require reasonably accurate records of the annual pumpage, periodic water-level measurements in most wells, preferably in the spring before pumping begins, periodic discharge measurements of the major streams and springs, and monitoring the chemical quality of pumped water. Additional precipitation stations on the valley floor and in the surrounding mountains also would provide valuable data for refining runoff and recharge estimates.

8. A reappraisal of Diamond Valley about in 1975, or sooner if pumpage increases substantially, would be desirable to evaluate the effects of pumping on the flow system, the magnitude of the storage depletion, and the extent of any overdraft that might then exist. Those findings would provide the basis for timely decisions for the administration and management of the water resources of Diamond Valley.

Numbering System for Wells and Springs

The numbering system for wells and springs in this report is based on the rectangular subdivisions of the public lands, referenced to the Mount Diablo base line and meridian. It consists of three units: the first is the township north of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; and the third unit, separated from the second by a dash, lists the section number followed by two letters that designate the quarter section, and the quarter-quarter section, respectively. The northeast quarter of a subdivision is designated by the letter a, the northwest quarter by the letter b, the southwest quarter by the letter c, and the southeast quarter by the letter d. Following the letters, a number indicates the order in which the well or spring was recorded within the 10-acre subdivision. For example, well 21/53-1ac1 is the first well recorded in the southwest quarter of the northeast quarter of sec. 1, T. 21 N., R. 53 E., Mount Diablo meridian.

Because of the limitation of space, wells and springs are identified on plates only by that part of the number which designates the subdivision of the section and, if two or more wells are in one subdivision, the order in which the well or spring was recorded in that section.

Table 20.--Records of selected wells and testholes

Owner: BLM, U.S. Bureau of Land Management
Use: D, domestic; I, irrigation; O, observation; S, stock;
U, unused; Des, destroyed
Specific capacity: In gallons per minute (gpm) per foot of drawdown
Altitude: Determined from topographic maps
Water-level measurements: Depth, in feet, below land-surface datum
State log number: Log number in the files of the State Engineer
Remarks: Dis, discharge

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
19/53-8ab	"Old Holly Well"	--	--	6	Des	--	6,110	3-16-50	179.82	--	
-14ad	--	--	--	--	I,S	--	6,360	4-26-66	19.86	--	
-14da	Eureka County School District	1962	265	8	I	--	6,465	4- 5-66	44.37	8329	
20/53-1ac	Lavern Machacek	1960	173	17	I	14	5,960	do.	86.38	5542	
-2ac	--	1966	220+	16	I	[illegible]	5,937	5-17-66	67.08	--	
-2dd	L. W. Wilbanks	1963	250	16	I	--	5,966	4- 6-66	105.69	8114	
-4ad	M. C. Kelly	1961	131	13	I	103	5,928	4- 4-66	60.63	6313	
-4dd	do.	1961	177	13	I	66	5,931	4- 5-66	60.71	6152	
-10ad	R. Wilson	1961	180	16	I	64	5,942	do.	83.05	6117	
-10bd	do.	1963	220	16	I,S	--	5,935	do.	67.44	7401	
-10cd	do.	1963	220	16	I	--	5,943	do.	73.06	7402	
-10dd	do.	1961	200	16	I	60	5,952	do.	91.65	6118	
-11ad	Harvey Rife	1965	110	6	D	--	5,972	do.	100.04	--	
-11bd	do.	1962	182	16	I	--	5,958	do.	103.01	6889	
-11cc	Coleman Wade	1962	300	16	I	--	5,955	do.	91.36	8124	
-11dd	do.	1962	275	16	I	--	5,970	do.	97.84	8125	
-15bc	BLM	--	--	--	Des	--	5,952	3-17-50	75.21	--	
-15cd	W. S. Agnew	1964	398	16	I	--	5,984	4- 5-66	121.54	8231	
-17aa	G. S. Wiggins	1965	225	16	I	--	5,942	4- 4-66	72.09	8721	
-17cc	W. E. Baker	1964	175	16	I	--	5,948	do.	46.32	7625	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
20/53-17dc	G. S. Wiggins	1963	214	16	I	--	5,950	4- 4-66	71.63	7586	
-18dc	W. E. Baker	1962	165	16	I	--	5,957	do.	48.19	6454	
-20ac	Verlea Vogelsmeier	1965	275	16	I	--	5,962	do.	97.06	8497	
-20bd	Clarence Allamong	1964	260	16	I	--	5,952	do.	81.63	8132	
-20ca	do.	1961	200	16	I	16	5,960	do.	91.83	7641	
-20dd	Gladys Allamong	1961	200	16	I	30	5,960	do.	91.64	7640	
-21ad	E. B. Johnson	1961	213	16	I	60	5,975	4- 5-66	106.98	6116	
-21bd	E. C. Bishop	1962	200	16	I	72	5,960	4- 4-66	98.29	6523	
-21dc	do.	1964	248	16	I	--	5,972	do.	124.29	7993	
-22bd	E. B. Johnson	1964	320	16	I	22	6,010	4- 5-66	137.33	8017	
-23ac	BLM	1961	--	6	S	--	6,012	do.	140.94	--	
-24dd	Ed. Melka	1956	155	8	I	--	6,110	do.	125.00	3566	
-28ad	Mrs. L. B. Bishop	1962	225	16	I	--	6,024	4- 4-66	154.14	6522	
-28bd	do.	1965	230	16	I	--	5,995	do.	118.73	8589	
-29ac	B. A. Peters	1963	302	16	I,S	11	5,980	do.	105.97	7465	
-29bc	--	--	--	--	--	--	5,974	do.	95.88	--	
-29bd	Lions Club of Eureka	1949	141	6	Des	--	5,988	8-16-49	111	1063	
-29dd	A. H. Peters	1965	320	16	I	--	6,005	4- 4-66	136.00	8618	
-30ab	James Ithirriude	1960	150	16	I	16	5,978	do.	59.23	6644	
-30db	do.	--	--	--	S	--	6,000	--	--	--	
-30dc	do.	1963	210	16	I	--	6,012	4-26-66	94.19	7352	
-31da	Pastorino Well	--	--	6	S,O	--	6,099	3-16-50	165.25	--	
-32bb	Rex Collingwood	1965	--	16	I		6,030	4- 4-66	87.98	--	
-32bd	Fred Minoletti	1961	218	12	I	--	6,038	do.	112.98	6312	
-32ca	D. Collingwood	1962	255	14½	I	35	6,059	do.	123.99	7301	
20/54-19bb	BLM	1961	189	8	S	--	6,055	4-23-65	172.19	--	
21/53-1bd	Robert Wilson	1961	210	16	I	--	5,885	4- 6-66	36.57	6721	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
21/53-1cd1	Robert Wilson	1961	182	16	I	31	5,887	4- 6-66	37.98	6155	
-1cd2	do.	1961	210	16	I	--	5,887	do.	36.98	6058	
-1db	Valley Grain	1961	184	16	I	--	5,884	do.	37.73	6722	
-1dd	do.	1961	184	16	I	--	5,885	do.	41.64	6376	
-2bd	Everett Veatch	1961	182	16	I	38	5,884	do.	37.74	6146	
-2cd	Katherine Veatch	1961	182	16	I	38	5,886	--	--	6061	
-2db	Ed Knowles	--	--	16	I	38	5,885	4- 6-66	36.84	--	
-3ab	George Knowles	1961	182	16	I	43	5,882	do.	37.72	6060	
-3cd	Dr. J. S. Gaynor	1964	182	16	I	--	5,885	do.	40.00	8149	
-3db	do.	1961	182	16	I	72	5,884	do.	39.12	6166	
-4ad	C. C. Cooper	1961	182	16	I	--	5,883	do.	40.38	6709	
-4bd	do.	1963	188	16	I	--	5,880	do.	34.34	7426	
-4cd	do.	1960	182	16	I	--	5,884	do.	38.03	--	
-4dd	E. R. Cooper	1963	188	16	I	--	5,884	do.	40.35	7425	
-5cb	--	--	--	--	S,O	--	5,879	do.	34.71	--	
-6ad	Elaine Burnham	1963	210	15	I	--	5,875	4-26-66	28.20	7445	
-6cc	Steimley Bailey	1962	120	16	I	--	5,883	4- 6-66	43.22	6670	
-6dc	Robert Burnham	1962	175	14	I	--	5,881	do.	39.22	6640	
-7aa	--	1965	--	16	I	--	5,890	10-18-65	45.85	--	
-7bd	--	1964	182	16	I	--	5,885	4- 6-66	52.31	7874	
-7dd1	--	1962	164	18½	I	--	5,899	do.	51.75	7328	
-7dd2	--	1962	--	18½	I	--	5,899	do.	51.42	--	
-8aa	M. A. Farley	1962	184	13	I	41	5,885	do.	40.72	6669	
-8ca	Alfred Farley	1961	164	13	I	88	5,894	do.	48.04	6062	
-8dd	M. A. Farley	1961	192	13	I	--	5,895	do.	46.18	6063	
-9ad	Jean Stearns	1964	183	16	I	50	5,887	do.	41.02	8144	
-9bc	H. E. Stearns	1964	183	16	I	36	5,886	do.	37.53	8143	
-9cc	do.	1961	182	16	I	66	5,894	do.	43.79	6148	
-9db	E. J. Conaway	1961	182	17½	I	58	5,894	do.	43.70	6149	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
21/53-10ac	L. W. Dillon	1962	176	17	I	60	5,887	4- 6-66	42.74	7364	
-10bc	D. E. Morrison	1962	176	17	I	70	5,886	--	--	7363	
-10cc	do.	1961	182	13	I	44	5,894	4- 6-66	49.80	6161	
-10dc	L. W. Dillon	1961	182	13	I	53	5,894	do.	43.83	6150	
-11aa	J. D. Carr	1962	192	16	I	--	5,885	do.	43.73	8692	
-11ba	Denver Kelly	1960	192	16	I	31	5,886	--	--	5578	
-11ca	do.	1960	186	17	I	20	5,890	4- 6-66	42.65	5551	
-11da	J. D. Carr	1962	183	16	I	--	5,894	do.	42.65	8693	
-12aa	Jackie Cooper	1963	230	16	I	--	5,887	do.	37.99	7429	
-12bc	Grannell Tolliver	1961	200	16	I,D	--	5,892	do.	41.39	6689	
-12cc	do.	1961	200	16	I	--	5,894	do.	44.28	6688	
-12dd	Neil Cooper	1961	192	16	I	25	5,889	do.	38.69	6162	
-13aa	B. A. DuBose	1962	250	16	I	--	5,895	do.	42.50	6631	
-13ba	Ruthel DuBose	1961	182	16	I	--	5,896	do.	43.99	--	
-13ca	Bruce DuBose	1960	171	17	I	33	5,898	do.	43.98	5545	
-13da	do.	1962	250	16	I	--	5,897	do.	44.05	6630	
-14aa	B. S. Murphy	1961	182	16	I	41	5,896	do.	45.63	6154	
-14ba	do.	1963	182	16	I	--	5,896	do.	45.18	6979	
-14ca	M. S. Murphy	1962	180	16	I	--	5,899	do.	48.25	6754	
-14da	do.	1960	182	16	I	--	5,900	do.	46.97	--	
-15ac	J. W. Cooper	1961	180	16	I	--	5,899	do.	48.39	6724	
-15bc	Vida Cooper	1960	182	16	I	32	5,898	do.	46.10	5548	
-15cd	do.	1962	182	16	I	--	5,900	do.	47.83	7419	
-15db	J. W. Cooper	1962	180	16	I	--	5,900	do.	47.88	7420	
-16aa	T. M. Tynes	1962	182	16	I	--	5,899	--	--	6638	
-16bc	Max Allen	1962	182	16	I	--	5,900	4- 6-66	50.80	7447	
-16cd	do.	1960	183	16	I	108	5,910	do.	61.37	5550	
-16dc	T. M. Tynes	1962	182	16	I	--	5,911	do.	60.88	6888	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
21/53-17bb	--	1964	165	16	I	--	5,910	4- 6-66	60.01	7854	
-17cc	--	1964	200	16	I	--	5,922	do.	74.52	7888	
-18cc	--	1964	134	16	I	--	5,921	do.	74.15	7873	
-18dd	--	1964	165	16	I	--	5,922	do.	76.22	7646	
-20ac	James Kahle	1961	196	16	I	72	5,926	do.	74.73	6169	
-20ba	E. K. Nunneley	1961	172	16	I	33	5,929	do.	80.51	6168	
-20ca	do.	1962	150	16	I	38	5,938	do.	85.42	6509	
-20cc	do.	--	--	--	-	--	5,941	do.	85.72	--	
-20db	V. E. Nelson	1962	183	16	I	120	5,935	do.	82.92	6769	
-21ad	F. C. Cannedy	1961	182	16	I	45	5,906	do.	53.12	6153	
-21bc	M. A. Allen	1961	190	16	I,D	--	5,918	do.	63.55	6725	
-21cd	do.	1962	186	16	I	--	5,930	do.	79.82	7448	
-21db	F. C. Cannedy	1963	180	16	I	--	5,913	do.	57.59	7872	
-22ad	J. B. Bonds	1962	260	16	I	24	5,903	do.	50.12	6978	
-22ba	B. A. Cooper	1963	180	16	I	--	5,904	do.	53.06	7430	
-22ca	do.	1962	222	16	I	--	5,910	do.	54.47	6964	
-22cd	--	--	--	6	S,O	--	5,911	3-17-50 4- 6-66	46.70 55.34	--	
-22dc	Louis Heller	1960	117	16	I	62	5,910	do.	55.15	5546	
-23aa	K. M. Murphy	1960	172	17	I	66	5,903	do.	47.30	5547	
-23ba	do.	1962	216	16	I	--	5,902	do.	50.29	6632	
-23ca	Dewey Murphy	1961	177	16	I	47	5,904	do.	53.91	6147	
-23da	do.	1960	166	17	I	75	5,904	do.	52.62	5544	
-24aa	A. W. Machacek	1961	186	17	I	5	5,902	do.	46.92	6287	
-24ba	do.	1962	400	16	I	--	5,902	do.	45.17	7115	
-24dc	--	--	--	--	-	--	5,918	do.	62.40	--	
-26aa	J. D. Knupps	1961	181	13	I	74	5,907	do.	58.40	6167	
-26ba	Dale Mackibe	1960	176	16	I	37	5,907	do.	53.12	5581	
-26ca	do.	1962	162	--	I	--	5,908	do.	58.44	6720	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
21/53-26da	J. D. Knupps	1964	218	16	I	--	5,909	4- 6-66	55.09	7954	
-27aa	--	---	--	--	-	---	5,906	do.	55.18	--	
-27bb	Dr. Clifford Fisher	1962	232	17	I	43	5,912	do.	56.96	6770	
-27cc	do.	1960	151	16	I	51	5,914	do.	60.25	5597	
-27da	K. E. Griffith	1961	184	13	I	6	5,910	--	--	6673	
-28ac	W. D. Anderson	1964	210	16	I	---	5,916	4- 6-66	57.54	7953	
-28bc	Dorothy Gallagher	1964	185	16	I	--	5,938	do.	86.13	8151	
-28cc	do.	1964	186	16	I	31	5,944	do.	85.60	7652	
-28da	W. D. Anderson	1961	209	16	I	40	5,916	do.	60.22	6437	
-29ab	J. O. Meyers	1961	188	16	I	---	5,941	do.	86.61	6751	
-29ba	do.	1964	170	16	I	---	5,940	do.	88.47	8251	
-29bd	do.	1960	250	16	I	18	5,941	do.	85.74	5270	
-33ad	R. D. Nichols	1961	112	17	I	86	5,920	do.	61.67	6157	
-33da	L. C. Enzminger	1961	112	17	I	62	5,927	4- 5-66	72.20	6156	
-34ac	L. W. Kelly	1962	126	17	I	52	5,916	do.	66.08	6863	
-34bb	do.	1961	128	13	I	88	5,920	do.	62.34	6674	
-34cb	---	---	---	---	-	--	5,920	do.	62.07	--	
-34dc	H. M. Nichols	1961	157	13	I	67	5,922	do.	57.82	6675	
-35ab	O. G. Gullett	1963	300	16	I	---	5,923	do.	65.76	7434	
-35bd	--	---	---	---	-	---	5,919	do.	59.47	--	
-35ca	--	---	---	---	-	---	5,923	do.	70.08	--	
-35cd	O. G. Gullett	1961	195	18¼	I	---	5,927	---	---	5969	
-35dd	C. F. Gullett	1961	187	16¼	I	40	5,932	4- 5-66	69.72	5968	
-36ab	E. M. Machacek	1960	152	17	I	12	5,935	do.	69.10	5543	
-36ac	do.	1963	300	16	I	30	5,938	do.	71.17	7286	
-36ad	do.	1962	300	16	I	29	5,942	do.	78.75	6550	
-36cd	do.	---	--	16	I	--	5,941	do.	78.77	--	
-36dc	--	--	108.5	6	U	--	5,952	6-15-48 5- 4-66	67.57 79.80	--	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
21/54-4ad1	C. E. Pollard	1949	73	12	I,O	--	5,900	3-17-50 4- 7-66	37.50 47.22	981	
-4ad2	do.	1950	120	12	I	--	5,893	do.	39.14	1478	
-4dd	do.	--	182	14	I	--	5,910	do.	47.80	--	
-5aa	T. I. Loiter	1964	244	16	I	--	5,869	4- 6-66	22.18	7974	
-5ba	Roy Ruthford	1962	150	--	I	--	5,869	4- 7-66	23.43	7700	
-5cd	C. E. Pollard	1962	190	14	I	--	5,875	do.	27.95	6641	
-5dc	T. I. Loiter	--	--	--	-	--	5,875	do.	24.14	--	
-8cd	P. H. Burnham	1964	203	16	I	--	5,893	do.	33.44	8061	
-8dd	M. A. Burnham	1964	245	16	I	--	5,902	do.	46.47	8081	
-9bc	--	--	--	6	U	--	5,881	do.	24.81	--	
-16cd	Bill Palmer	1960	240	16	I	28	5,930	do.	119.02	7324	
-17ab	Gordon Woods	1963	210	16	I	--	5,902	do.	45.59	7101	
-17bb	J. T. Woods	1962	225	16	I	--	5,887	do.	38.14	7124	
-17cd	do.	1962	240	16	I	--	5,920	do.	62.33	6637	
-17dd	Gordon Woods	1962	200	16	I	--	5,949	do.	89.50	6635	
-20aa	--	--	--	--	I	--	5,947	do.	84.43	--	
-20ba	--	--	--	--	I	--	5,921	do.	67.90	--	
-20cc	F. D. Glass, Jr.	1962	230	16	I	--	5,933	do.	83.05	6633	
-20dd	Josephine Glass	1962	240	16	I	--	6,000	do.	145.85	6634	
-29cb	Raymond LaBarry	1953	130	8	S	--	5,958	do.	92.49	2216	
-32db	--	--	--	--	S	--	6,040	do.	162.43	--	
21½/52-1bc	--	--	--	--	S	--	5,888	4- 8-66	48.78	--	
21½/54-3cc	--	--	--	16	I	--	5,897	4- 7-66	44.16	--	
-3cd	V. H. Politiski	1963	200	16	I	--	5,930	do.	82.01	7480	
-4bc	--	--	--	13	I	--	5,865	do.	18.06	--	
-4cc	Grace Krueger	1962	148	13	I	9	5,868	do.	19.70	6563	
-4dc	--	--	195	12	I	--	5,873	do.	18.87	--	
-4dd	A. W. Krueger	1962	102	18	I	55	5,880	4-26-66	32.08	6436	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement Date	Water-level measurement Depth	State log number	Remarks
22/54-18ab	--	--	--	14½	I	--	5,844	4- 7-66	11.90	--	
-18da	Edward Siudmak	1961	200	12	I,D	--	5,850	do.	12.35	5866	
-18db	--	1958	222	12	I	4	5,848	do.	11.90	5885	
-19ab	Charles Poorbaugh	1962	192	15	I	--	5,854	do.	16.51	6596	
-19bb	H. H. Schmoll	1962	192	16	I	--	5,856	do.	13.91	6599	
-19cb	Dr. Jones	--	--	16	I	--	5,856	do.	16.09	--	
-19dc	Charles Poorbaugh	1960	182	14	I	15	5,856	do.	16.01	5552	
-22bd	Raymond LaBarry	1961	200	16	I	9	5,860	4- 6-66	20.42	6726	
-22cc	Willie Dixon	1962	120	19½	I,S	9	5,858	4- 7-66	12.58	7157	
-27ca	Robert Stucki	1949	94	12	I,D	17	5,859	3-17-50	7.64	982	
								4- 7-66	15.52		
-27cc	Willie Dixon	1962	148	19½	I,S	6	5,859	do.	14.46	7156	
-28ad	Oscar Carrol	1958	184	12	I,D	36	5,856	--	--	4389	
-28bd	do.	1961	232	14	I	32	5,857	4- 7-66	14.53	5919	
-28dc	D. F. Palmore	1961	220	12	I	20	5,862	do.	14.62	5920	
-32cc1	R. Burnam	1963	208	15	I	--	5,866	do.	22.02	7424	
-32cc2	do.	--	--	--	I	--	--	--	--	--	
-32dd1	do.	1963	250	16	I	--	5,865	4- 7-66	19.58	7423	
-32dd2	do.	--	--	--	-	--	--	--	--	--	
-33bb	Bailey Bros.	1961	300	14	I	--	5,865	4- 7-66	15.68	7291	
-33dd	A. L. Jones	1949	191	12	I,D	5	5,864	3-17-50	6.24	983	
								4- 7-66	14.28		
-34ab	BLM	--	50	6	S	--	5,885	3-17-50	30.31	--	
								4- 7-66	38.27		
23/52-11ad1	J. Bachelor	--	98	6	S	--	5,810	11-19-65	flows	--	Wells ad1 and ad2 dis. 41 gpm
-11ad2	do.	--	--	--	-	--	5,810	do.	do.		
-13ba	do.	--	--	--	D	--	5,815	do.	do.	--	Dis. 9 gpm
-13bb1	do.	--	80	10	I,D	--	5,805	do.	do.	--	Dis. 13 gpm
-13bb2	do.	1957	157	14	I	50	5,815	9-15-61	4.89	3708	

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
23/52-13bc1	J. Bachelor	1948	--	--	I	--	5,800	11-18-65	flows	--	Dis. 13 gpm
-13bc2	do.	1948	--	6	I,S	--	5,810	do.	do.	--	Dis. 33 gpm
-13bc3	do.	1948	--	6	I	--	5,820	do.	do.	--	Wells bc3 and bc4 dis. 16 gpm
-13bc4	do.	1948	--	--	I	--	--	--	do.	--	
-13ca1	do.	--	--	--	I	--	5,810	11-18-65	do.	--	Dis. 102 gpm
-13ca2	do.	--	--	8	I	--	5,810	11-19-65	do.	--	Dis. 137 gpm
-13ca3	do.	--	--	6	I,S	--	5,810	do.	do.	--	Dis. 30 gpm
-13cd	do.	--	--	--	I	--	5,810	do.	do.	--	Dis. 46 gpm
-24ab	do.	--	--	--	I	--	5,805	do.	do.	--	Dis. 81 gpm
23/53-9bb	U.S.G.S. no. 16	1966	8	1½	O	--	5,775	4- 8-66	3.35	--	
-27bb	U.S.G.S. no. 4	1964	22	1½	O	--	5,819	do.	12.97	--	
-30dd	U.S.G.S. no. 9	1964	22	1½	O	--	5,821	do.	14.52	--	
-33cc	U.S.G.S. no. 6	1964	22	1½	O	--	5,831	do.	13.25	--	
-34dd	U.S.G.S. no. 7	1964	22	1½	O	--	5,832	do.	12.77	--	
23/54-18db	U.S.G.S. no. 3	1964	32	1½	O	--	5,800	do.	16.69	--	
-20dd	C. M. Russell	1964	245	16	I	--	5,820	4- 7-66	0.40	7834	
-27ac	L. Maggini	1963	339	6	S	--	5,850	do.	12.86	--	
-28cc	B. A. Russell	1962	262	16	I,D	--	5,825	do.	0.63	7835	
-29aa	U.S.G.S. no. 2	1964	22	1½	O	--	5,821	do.	15.30	--	
-29cd	U. J. Doty	1964	189	16	I	--	5,829	do.	1.62	7861	
-29dd	Richard Doty	1964	320	16	I	--	5,830	do.	3.54	7862	
-30ba	U.S.G.S. no. 1	1964	22	1½	O	--	5,824	do.	16.83	--	
-30cd	Blake Briscoe	1964	220	16	I	--	5,828	do.	1.21	7868	
-30dd	L. D. Williamson	1965	220	16	I	--	5,829	do.	2.31	8629	
-32aa	U.S.G.S. no. 8	1964	22	1½	O	--	5,830	do.	11.43	--	
-32cd	Melvin Bailey	1964	280	16	I	--	5,835	do.	2.21	7937	
-32dd	Alleen Bailey	1964	232	16	I	--	5,835	do.	4.04	7902	
24/52-13bd	Sadler Ranch	1960	135	16	I	--	5,782	8-15-65	flows	5526	Dis. 100 gpm

Table 20.--continued

Well number	Owner	Year drilled	Depth (feet)	Diameter (inches)	Use	Specific capacity	Altitude (feet)	Water-level measurement		State log number	Remarks
								Date	Depth		
24/53-6bd	George Brown	--	190	14	I,S	--	5,788	12- 7-65	flows	--	Dis. 200 gpm pumped 800 gpm
24/54-4ba	Ted Thompson	1950	130	10	D	--	5,830	4- 8-66	9.74	1350	
25/53-5bc	Joe Flynn	1949	100	6	I	--	5,830	--	--	1009	
-5cb1	do.	1949	131	6	I	--	5,835	5- 5-66	1.78	1008	
-5cb2	do.	1949	91	6	I	--	5,835	do.	flows	943	Dis. 10-15 gpm
-5cc1	do.	1949	176	6	I	--	5,855	do.	2.58	944	
-5cc2	do.	1949	70	6	I	--	5,840	do.	flows	1038	Dis. 2-3 gpm
25/54-9db1	Ted Thompson	--	35	60	S	--	5,855	--	--	--	
-9db2	do.	1952	80	8	S	--	5,843	4- 8-66	35.61	1910	
-28bc	--	--	--	6	S	--	5,810	do.	8.79	--	
26/53-12db	FERA no. 16	--	13	60	S	--	5,783	do.	8.50	--	
26/54-15cd	BLM	--	9.5	60	S	--	5,779	do.	6.03	--	

Table 21.--Selected drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
20/53-2dd L. W. Wilbanks		
Topsoil	2	2
Gravel, large	23	25
Clay	5	30
Sand and clay	20	50
Gravel	4	54
Clay	6	60
Gravel	1	61
Clay	20	81
Gravel	5	86
Clay and gravel	4	90
Clay	6	96
Gravel	148	244
Clay	6	250
20/53-4dd M. C. Kelly		
Soil	5	5
Sand and gravel, dry	39	44
Clay, sand, and gravel layers	48	92
Gravel	11	103
Clay	19	122
Sand and gravel	17	139
Clay and cemented gravel	38	177
20/53-10cd Robert Wilson		
Topsoil	10	10
Sand	10	20
Clay, blue	15	35
Gravel	1	36
Clay, blue	42	78
Gravel	20	98
Clay	16	114
Gravel	14	128
Clay	2	130
Gravel	24	154
Clay	2	156
Gravel	30	186
Sand rock	8	194
Gravel	11	205
Clay	15	220
20/53-11dd B. C. Wade		
Topsoil	20	20
Sand	23	43
Gravel	22	65
Clay and gravel	7	72
Gravel, coarse	58	130
Gravel, pea	14	144
Clay	1	145
Gravel	41	186
Clay	14	200
Gravel	15	215
Clay	6	221
Gravel	25	246
Clay, hard	29	275
20/53-15cd W. S. Agnew		
Topsoil	1	1
Gravel and clay, mixed	24	25
Sand	21	46
Gravel, pea	8	54
Gravel	46	100
Gravel, pea	20	120
Gravel, coarse	9	129
Sand and rock	1	130
Gravel, coarse	56	186
Clay	19	205
Gravel, pea	2	207
Gravel, cemented	33	240
Gravel	10	250
Clay	1	251
Gravel	3	254
Gravel, cemented, in layers, and free gravel	129	383
Rock, hard, white	15	398
20/53-18dc W. E. Baker		
Clay	5	5
Sand	6	11
Clay, sandy	17	28
Clay and gravel	16	44
Conglomerate	2	46
Gravel	31	77
Silty sand	13	90
Gravel	12	102
Sand, coarse	23	125
Clay, sandy	15	140
Granite, decomposed	3	143
Gravel	5	148
Sand, clay, gravel	14	162
Shell, hard	3	165

Table 21.--Continued

Material	Thickness (feet)	Depth (feet)
20/53-20ca C. H. Allamong		
Soil	5	5
Gravel and sand, fine	11	16
Silt and clay	7	23
Gravel, fine, sandy	45	68
Gravel, cemented, large	51	119
Clay, tight, white	18	137
Clay	14	151
Clay and sand lenses, cemented	14	165
Sand, gravel, loose, water-bearing	35	200
20/53-22bd E. B. Johnson		
Topsoil	3	3
Gravel	37	40
Gravel and hard clay	100	140
Boulders and gravel	35	175
Gravel, cemented	5	180
Gravel, layers of free and cemented	30	210
Gravel and boulders in layers	15	225
Gravel and boulders	5	230
Gravel, loose	15	245
Gravel, cemented	13	258
Gravel, hard, cemented	62	320
20/53-24dd Ed Melka		
Topsoil	26	26
Boulders and gravel	14	40
Gravel, coarse, and clay	80	120
Clay and gravel	15	135
Gravel and clay	20	155
20/53-32bd Fred Minoletti		
Soil	8	8
Clay	82	90
Gravel, cemented	30	120
Gravel	5	125
Gravel, cemented	5	130
Gravel	20	150
Gravel, cemented	5	155
Sand and gravel	40	195
Gravel, cemented	20	215
Gravel	3	218
21/53-1bd Robert Wilson		
Topsoil	3	3
Gravel	27	30
Sand and gravel	28	58
Clay and gravel	6	64
Sand and gravel	4	68
Clay	7	75
Gravel	2	77
Clay	59	136
Gravel, fine	7	143
Clay	2	145
Gravel	3	148
Clay	1	149
Gravel	4	153
Clay	10	163
Gravel	10	173
Clay and gravel	2	175
Gravel	8	183
Clay	2	185
Gravel	11	210
Clay	14	210
21/53-4ad C.C. Cooper		
Topsoil	5	5
Gravel and sand, fine	20	25
Sand, coarse, and fine gravel	7	32
Sand and gravel, coarse	36	68
Clay and sand mixture	2	70
Sand and gravel, coarse	10	80
Clay and gravel mixture	2	82
Gravel and sand, coarse, good	28	110
Clay, tough, white	7	117
Clay and gravel mixture	2	119
Gravel and sand, good	2	121
Clay streak, white	1	122
Gravel and sand, clean, water-bearing	26	148
Clay, white	3	151
Gravel and sand, clean	16	167
Clay	2	169
Gravel and sand, clean	10	179
Clay	3	182

Table 21.--Continued

Material	Thickness (feet)	Depth (feet)
21/53-6cc Steimley Bailey		
Topsoil	3	3
Sand and gravel	27	30
Clay and gravel	10	40
Gravel	10	50
Sand, coarse	28	78
Clay	2	80
Gravel, good	17	97
Clay and gravel	5	102
Gravel, good	3	105
Clay and gravel	1	106
Clay	4	110
Gravel, good	8	118
Gravel, hard	2	120
21/53-8aa M. A. Farley		
Topsoil	3	3
Hardpan	3	6
Gravel	24	30
Clay and gravel	5	35
Clay	5	40
Gravel	10	50
Clay and sand	5	55
Sand	5	60
Gravel	5	65
Clay and gravel	3	68
Gravel	25	93
Sand and clay	5	98
Clay	9	107
Gravel	8	115
Clay	5	120
Gravel, good	8	128
Gravel and clay	2	130
Gravel, good	14	144
Clay	5	149
Gravel, good	16	165
Clay	5	170
Gravel	4	174
Clay	6	180
Clay and sand	4	184
21/53-11ba Denver Kelly		
Topsoil and overburden	4	4
Sand and gravel	44	48
Clay, gray	20	68
Clay, black	28	96
Sand and gravel, black	52	148
Clay, soft	2	150
Sand, medium	6	156
Clay, soft	2	158
Sand and gravel, good	34	192
Bottomed in soft clay at 192 feet		
21/53-13da Bruce DuBose		
Topsoil	3	3
Sand, coarse, and gravel	27	30
Gravel, coarse	12	42
Clay, colored	50	92
Sand, fine	4	96
Clay	9	105
Gravel, black	4	109
Clay	1	110
Clay and coarse sand	4	114
Sand, fine	2	116
Clay	4	120
Gravel, coarse	7	127
Clay	12	139
Gravel, coarse	2	141
Gravel with clay streamers	2	143
Gravel, coarse	7	150
Clay, brown	5	155
Gravel, coarse	3	158
Sandstone and clay	2	160
Sand, fine	2	162
Clay	18	180
Gravel, coarse	7	187
Clay and gravel	2	189
Gravel, coarse and some rocks	8	197
Clay and gravel	2	199
Clay and coarse gravel	11	210
Gravel, coarse	7	217
Gravel, coarse and clay	17	234
Gravel, coarse	9	243
Clay and gravel	7	250

Table 21.--Continued

Material	Thick-ness (feet)	Depth (feet)
21/53-16aa T. M. Tynes		
Topsoil	3	3
Sand and gravel	32	35
Clay and gravel	3	38
Gravel	27	65
Clay	3	68
Gravel, coarse	32	100
Clay and coarse gravel	8	108
Gravel, coarse	36	144
Clay	8	152
Gravel	28	180
Clay	2	182
21/53-18cc Unknown		
Topsoil	2	2
Gravel	26	28
Sand	4	32
Clay	10	42
Sand	3	45
Gravel	20	65
Sand	1	66
Sandstone	3	69
Clay	5	74
Sand, fine	3	77
Gravel	8	85
Clay	3	88
Sandstone	1	89
Shale	3	92
Gravel, coarse	13	105
Sand	6	111
Clay, white	1	112
Gravel, cemented	4	116
Gravel and stone	9	125
Clay, cemented gravel, and coarse sand	9	134
21/53-20db V. E. Nelson		
Surface soil	2	2
Sand and gravel	22	24
Clay	6	30
Sand and gravel	60	90
Clay	11	101
Sand and gravel	39	140
Clay	10	150
Sand and gravel	32	182
Rock, hard	1	183

Material	Thick-ness (feet)	Depth (feet)
21/53-23ba K. M. Murphy		
Topsoil	3	3
Sand and gravel	17	20
Clay	5	25
Sand and gravel	5	30
Gravel, coarse	4	34
Clay, colored	61	95
Clay and black gravel	5	100
Clay	4	104
Clay and black gravel	3	107
Clay	8	115
Gravel, coarse	7	122
Clay and gravel	1	123
Clay, light	3	126
Clay and coarse gravel	3	129
Gravel, coarse	6	135
Clay and coarse gravel	1	136
Clay	6	142
Gravel, coarse	11	153
Sandstone	1	154
Clay	3	157
Clay and gravel	1	158
Gravel, coarse	4	162
Clay	9	171
Clay and coarse gravel	1	172
Gravel, coarse	3	175
Clay	12	187
Sand, fine	5	192
Clay	13	205
Clay and coarse gravel layers	4	209
Clay	7	216
21/53-27bb Dr. Clifford Fisher		
Surface soil	2	2
Sand and gravel	21	23
Sand, fine, and clay	33	56
Sand, gravel, and clay stringers	14	70
Sand, fine, gravel, and clay	26	96
Sand, coarse, and gravel	24	120
Clay	75	195
Sand and gravel	5	200
Clay	4	204
Sand and gravel	12	216
Clay	4	220
Sand and gravel	11	231
Clay	1	232

Table 21.--Continued

Material	Thickness (feet)	Depth (feet)
21/53-33da L. C. Enzminger		
Soil	5	5
Sand and gravel	19	24
Clay, gray	14	38
Sand, clay, and gravel	11	49
Clay	9	58
Sand and gravel	14	72
Clay and sand	8	80
Sand and gravel	31	111
Clay	1	112
21/53-36ad E. M. Machacek		
Soil	4	4
Sand, coarse, and fine gravel	32	36
Clay, brown	33	69
Gravel, medium to coarse, and sand	23	92
Gravel, partly cemented, and clay	68	160
Clay with occasional thin sand streaks	32	192
Clay, solid tan	63	255
Clay with occasional sand streaks	45	300
21/54-16cd Bill Palmer		
Topsoil	4	4
Gravely clay	11	15
Cobblestones, gravel, clay	58	73
Gravel, fine	7	80
Boulders	50	130
Rock, solid	8	138
Rocks and free gravel	5	143
Clay	1	144
Boulders	12	156
Gravel, coarse	17	173
Clay	1	174
Gravel	38	212
Clay	2	214
Boulders	21	235
Clay and boulders	5	240
21/54-20cc F. D. Glass, Jr.		
Topsoil	3	3
Clay and gravel	17	20
Sand	5	25
Clay	3	28
Sand	2	30
Clay	1	31
Sand	8	39
Clay	21	60
Clay and gravel	2	62
Gravel	13	75
Shale and gravel	55	130
Gravel	41	171
Clay	3	174
Gravel	36	210
Clay	20	230
21½/54-3cd V. H. Politiski		
Topsoil	2	2
Clay and rock	78	80
Gravel	70	150
Rock	4	154
Gravel, loose	16	170
Rock	4	174
Gravel, loose	11	185
Rock	8	193
Clay and gravel	7	200

Table 21.--Continued

Material	Thickness (feet)	Depth (feet)
21½/54-5cc R. F. Krueger		
Soil	3	3
Sand and fine gravel	9	12
Clay, brown	8	20
Sand, fine	12	32
Sand, fine, and small gravel	4	36
Ooze, soft, black	12	48
Sand, fine, black	11	59
Gravel streak	3	62
Clay, white	48	110
Clay, blue	12	122
Clay, white	15	137
Gravel streak with fine sand	4	141
Clay, solid, blue	71	212
Ooze, black	5	217
Ooze, black, with very fine sand	13	230
Clay, white	5	235
Ooze, black, and fine sand	7	242
Gravel, fine, with sand, water	10	252
Gravel, coarse, and sand	5	257
22/54-4cc M. H. Moshier		
Topsoil	4	4
Sand and gravel	12	16
Clay, black	24	40
Mud, black	22	62
Clay, different collored	76	138
Clay and sand	12	150
Clay	12	162
Sand	11	173
Clay	47	220
Sand and clay	10	230
Clay	40	270
Clay and gravel	5	275
Clay	10	285
Sand and fine gravel	10	295
Gravel	5	300
Clay and gravel	15	315
22/54-6cc Paul Camer		
Topsoil	3	3
Gravel	17	20
Sand and clay	10	30
Clay	25	55
Clay and black gravel	2	57
Gravel, black	4	61
Clay	14	75
Sand, coarse	4	79
Clay and gravel layers	7	86
Gravel, black	1	87
Clay	1	88
Sand, coarse	4	92
Clay	4	96
Clay and gravel	7	103
Sand, coarse	7	110
Clay and gravel	5	115
Clay	24	139
Sand, coarse	6	145
Clay	1	146
Gravel	2	148
Clay and gravel	4	152
Clay and sand	1	153
Sand	8	161
Clay	2	163
Gravel	7	170
Clay	2	172
Sand and gravel	3	175
Clay and gravel	2	177
Clay	1	178
Sand	5	183
Clay and sand	3	186
Clay	2	188
Sand and gravel	4	192
Clay	40	232
Sand	6	238
Clay	2	240
Sand	4	244
Clay	2	246
Sand	4	250

Table 21.--Continued

Material	Thickness (feet)	Depth (feet)
<u>22/54-8cc L. L. Pollard</u>		
Sand and gravel	28	28
Shale or sandy clay	22	50
Clay, blue, and sand	30	80
Shale	18	98
Clay, blue	10	108
Sand and gravel; water	12	120
Shale, sandy	7	127
Shale and gravel	16	143
Gravel, water-bearing	9	152
Shale, blue	2	154
<u>22/54-19dc Charles Poorbaugh</u>		
Topsoil	6	6
Sand	17	23
Clay, soft	70	93
Sand	9	102
Clay, soft	13	115
Sand, medium	6	121
Clay, soft	17	138
Sand, medium	8	146
Clay, soft	16	162
Sand, medium	3	165
Sand and clay layers, loose and soft	17	182
<u>22/54-22bd Raymond LaBarry</u>		
Topsoil	9	9
Sand and gravel	10	19
Clay, yellow	4	23
Sand and gravel	7	30
Clay, black	8	38
Clay, yellow, large rock	11	49
Sand, gravel, and large rock	6	55
Clay, yellow, rocky	7	62
Sand and gravel	8	70
Clay, yellow, rocky	7	77
Sand, loose, and gravel	13	90
Clay, yellow, rocky	15	105
Sand and gravel	10	115
Clay, yellow, rocky	35	150
Sand and gravel	11	161
Clay, yellow, rocky	14	175
Sand and gravel	4	179
Clay, rocky	6	185
Sand and gravel	15	200
<u>22/54-28dc D. F. Palmore</u>		
Soil	4	4
Gravel, fine, sandy	17	21
Clay ooze, black	39	60
Clay, gray	10	70
Clay, brownish	32	102
Clay, tough, white	10	112
Clay, white, semi-sandstone	5	117
Clay, brown	10	127
Clay mixed with gravel	5	132
Gravel, good	8	140
Clay lense, white	3	143
Clay, dense green	9	152
Clay, dark green	6	158
Clay, dense green	37	195
Gravel with thin cemented lenses	15	210
Gravel with some cementation and large loose boulders	10	220
<u>23/52-13bb2 J. Bachelor</u>		
Gravel	14	14
Clay	8	22
Gravel	14	36
Clay	28	64
Gravel	2	66
Clay	12	78
Sandstone	2	80
Clay	8	88
Gravel	34	122
Clay	16	138
Gravel	6	144
Conglomerate	8	152
Limestone	5	157

Table 21.--Continued

23/54-20dd C. M. Russell

Material	Thickness (feet)	Depth (feet)
Topsoil	2	2
Hardpan	2	4
Sand and gravel	13	17
Clay, black	33	50
Clay	25	75
Sand, coarse	1	76
Clay	65	141
Sand, fine	9	150
Clay	20	170
Sand, fine	2	172
Clay	3	175
Sand, fine	2	177
Sand and clay	31	208
Sand, fine	22	230
Sand and gravel	15	245
Clay - bottom		

23/54-30cd Blake Briscoe

Material	Thickness (feet)	Depth (feet)
Silt	2	2
Clay	6	8
Gravel	18	26
Clay, black	46	72
Gravel	3	75
Clay, blue	4	79
Gravel	6	85
Shale, hard, gray	25	110
Shale, soft	35	145
Shale and sand	5	150
Shale, gray	10	160
Sand and gravel	18	178
Shale, gray	11	189
Sand and gravel	31	220

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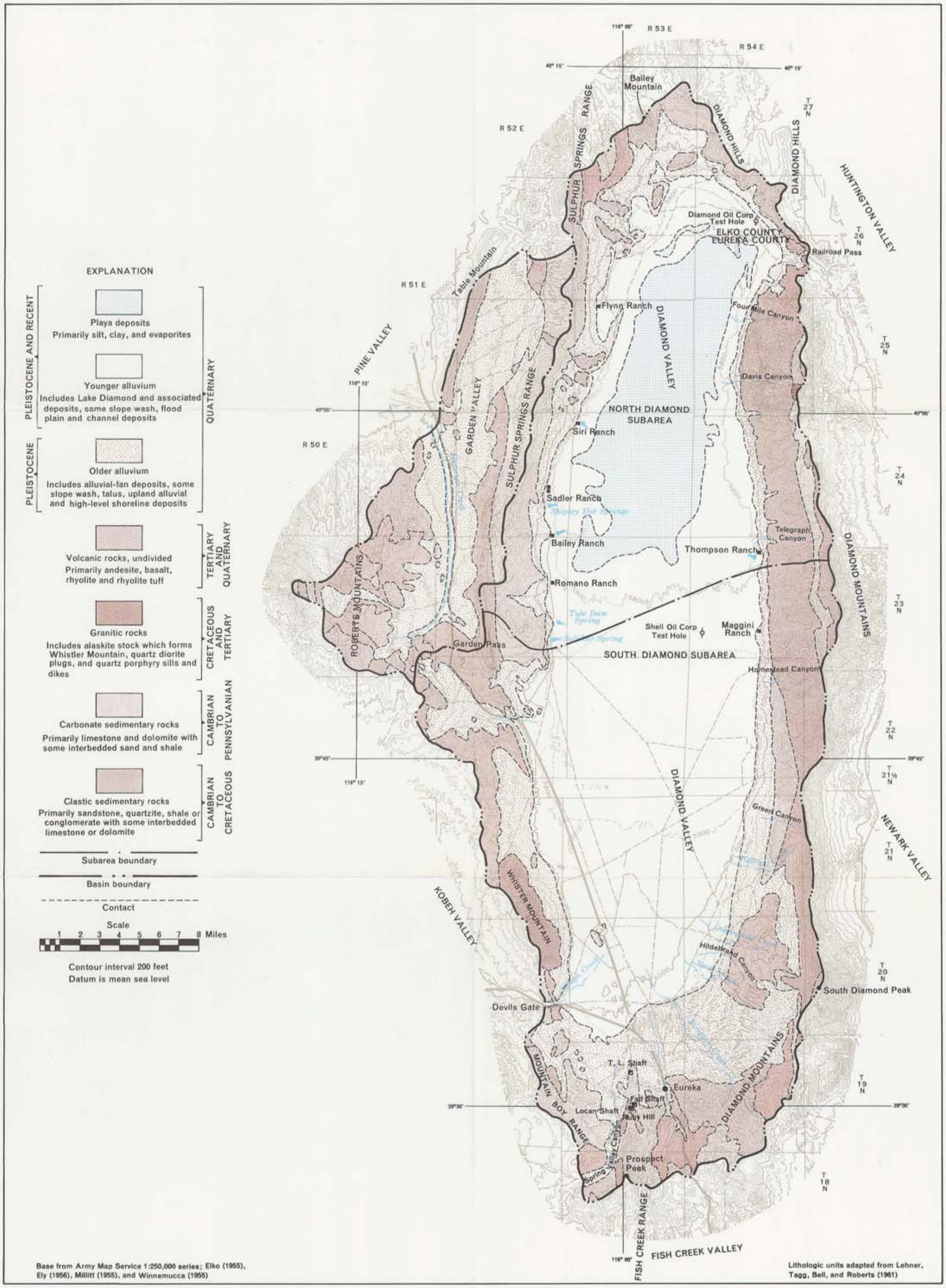

Base from Army Map Service 1:250,000 series; Elko (1955), Ely (1956), Millitt (1955), and Winnemucca (1955)

Lithologic units adapted from Lehner, Tagg, Bell, and Roberts (1961)

PLATE 1.—MAP OF DISTRIBUTION OF PRINCIPAL LITHOLOGIC UNITS, SUBAREAS, AND GEOGRAPHIC AND CULTURAL FEATURES, DIAMOND VALLEY, EUREKA AND ELKO COUNTIES, NEVADA

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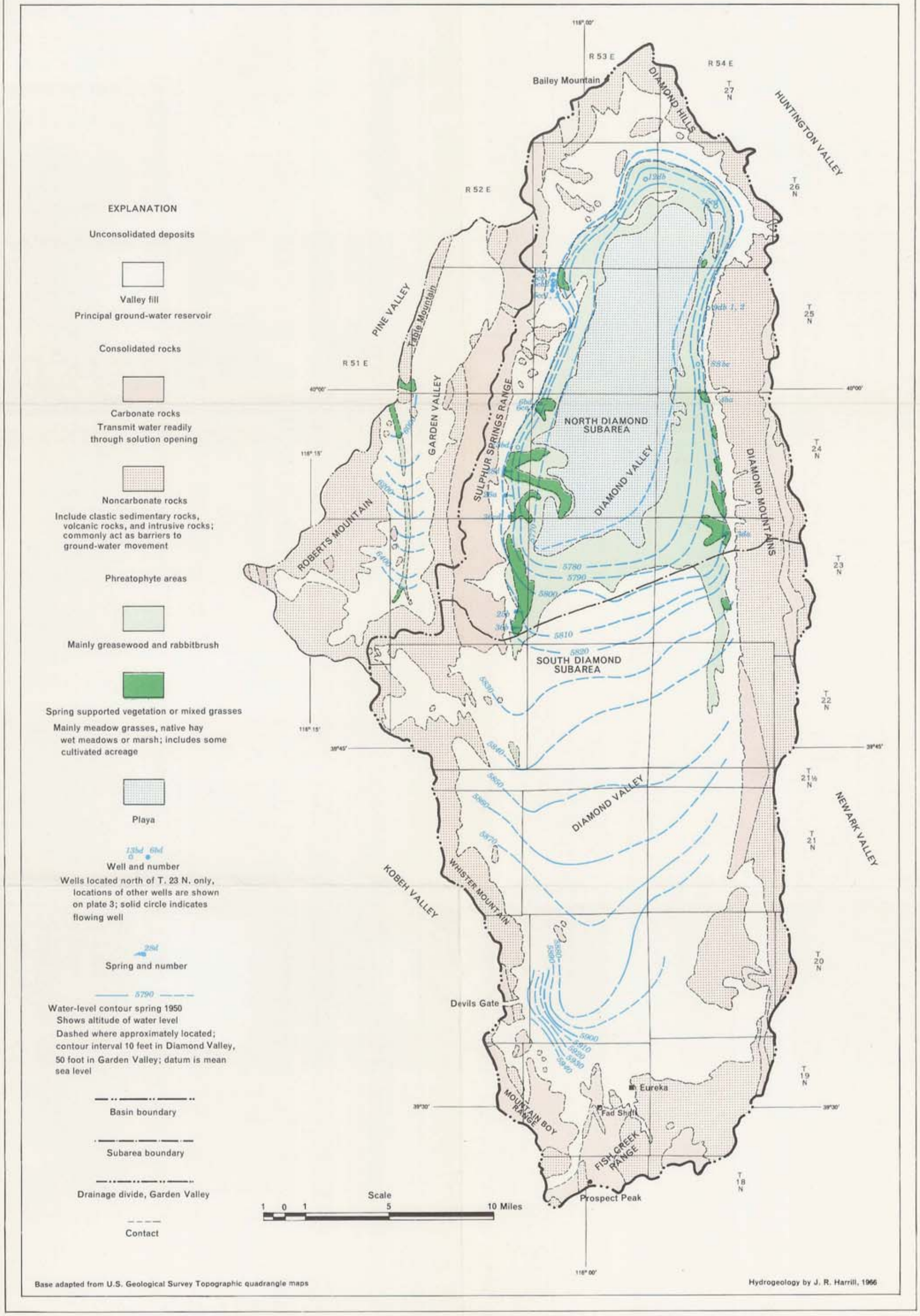

Base adapted from U.S. Geological Survey Topographic quadrangle maps

Hydrogeology by J. R. Harrill, 1966

PLATE 2.—MAP SELECTED LITHOLOGIC UNITS, PHREATOPHYTES, AND WATER-LEVEL CONTOURS FOR 1950, DIAMOND VALLEY, EUREKA AND ELKO COUNTIES, NEVADA

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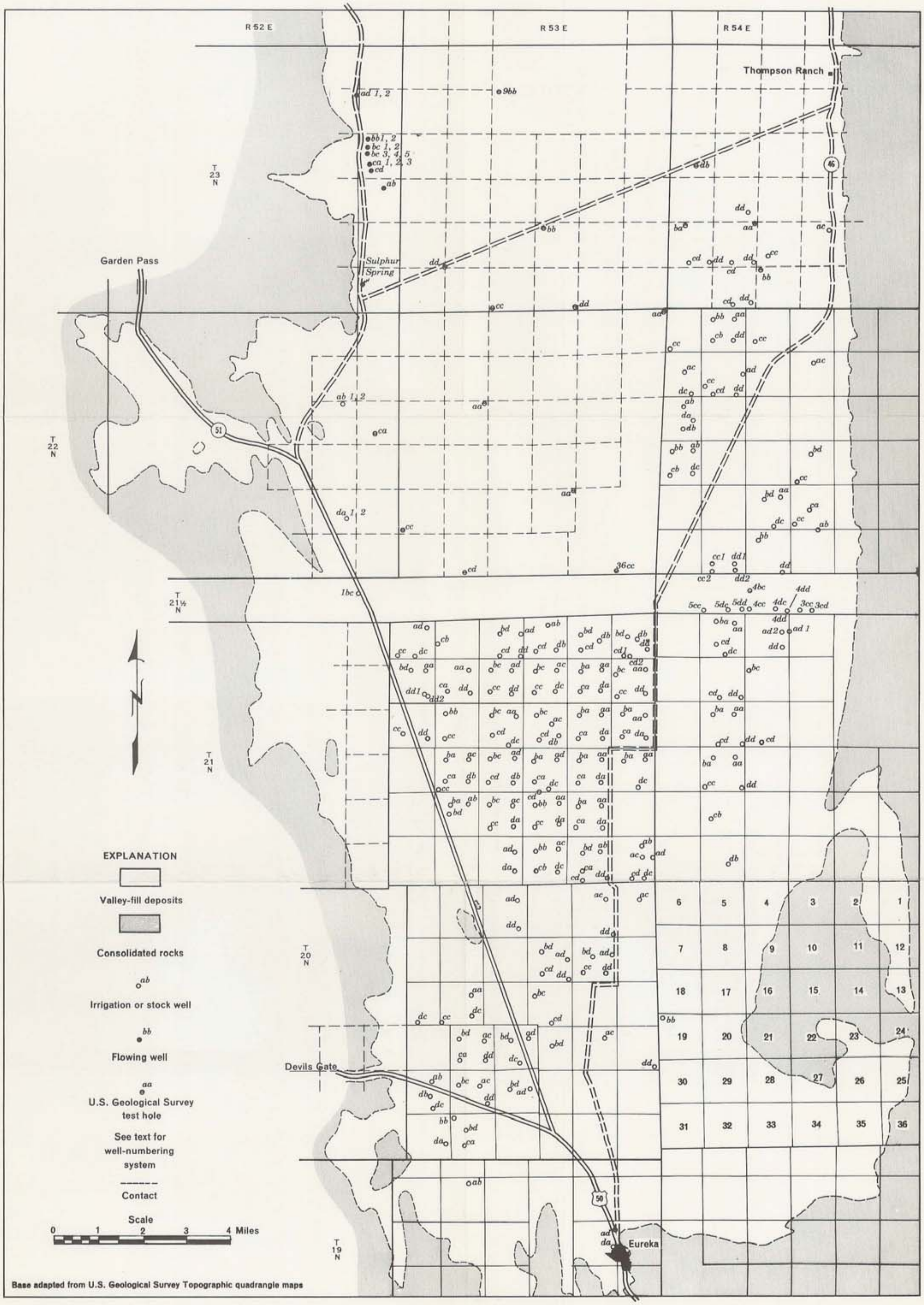

PLATE 3.—MAP LOCATION OF WELLS AND TEST HOLES DRILLED SOUTH OF T. 24 N. IN DIAMOND VALLEY, EUREKA COUNTY, NEVADA