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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

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CONTENTS

ILLUSTRATIONS

Page

TABLES

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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.

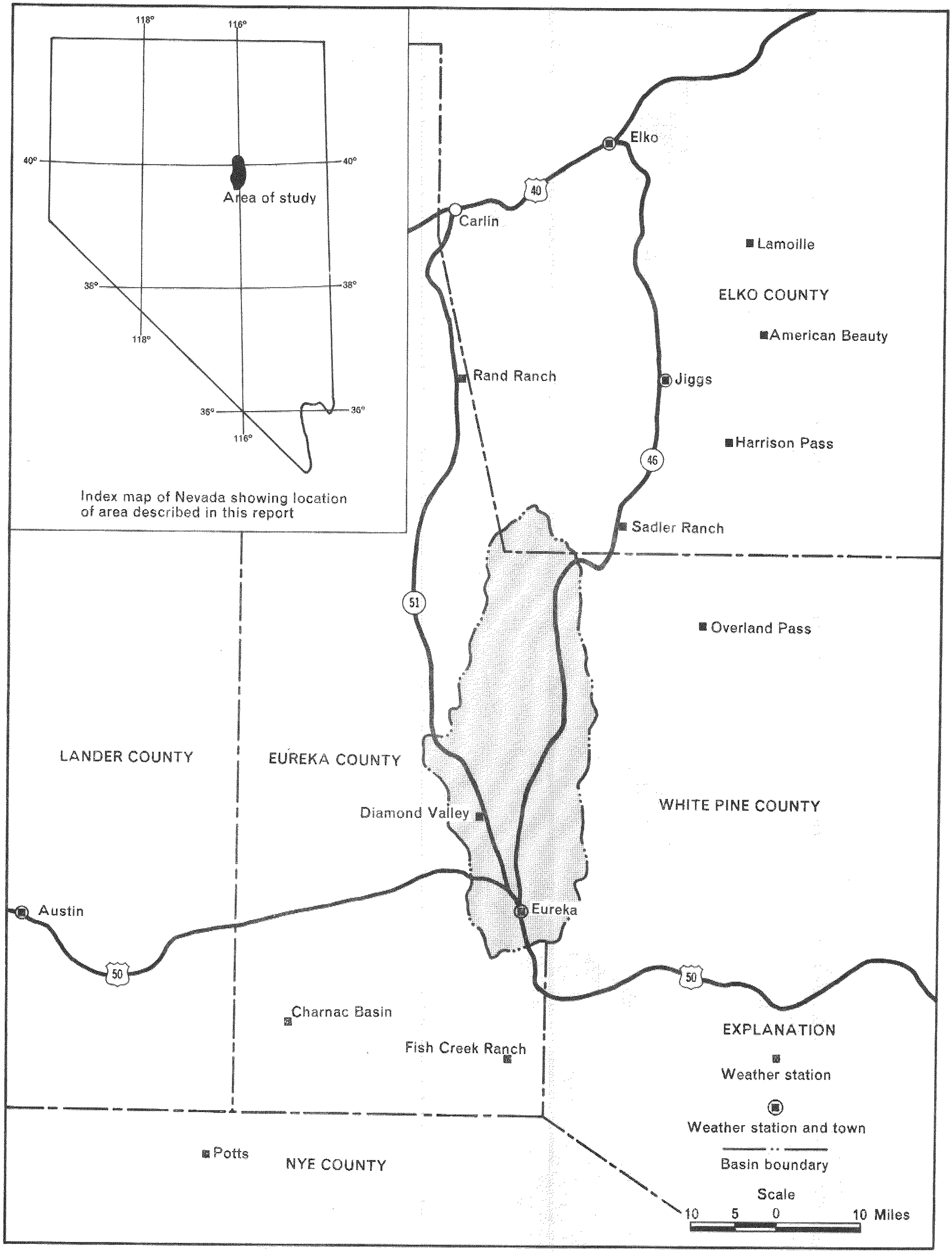


Figure 1.—Location of area, principal communities and weather stations

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 weretemporarily 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[illegible]
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[illegible]
3 American Beauty	--	--	--	--	--	--	--	--	--	--	--	--	21.5[illegible]
4 Rand Ranch	.75	.96	.98	1.02	1.30	1.11	.28	.47	.48	.68	.94	.94	9.9[illegible]
5 Jiggs	1.01	.89	1.14	1.27	1.60	.90	.41	.50	.53	.82	.90	1.14	11.1[illegible]
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[illegible]
7 Sadler Ranch	--	--	--	--	--	--	--	--	--	--	--	--	7.9[illegible]
8 Overland Pass	--	--	--	--	--	--	--	--	--	--	--	--	10.2[illegible]
9 Diamond Valley	--	--	--	--	--	--	--	--	--	--	--	--	7.4[illegible]
10 Eureka	.87	.86	.90	1.60	1.14	1.29	.74	1.57	.76	.56	1.15	1.34	12.7[illegible]
11 Austin	1.13	1.05	1.47	1.57	1.46	.79	.55	.53	.49	.84	.80	.90	11.5[illegible]
12 Charnac Basin	.92	1.46	1.12	1.24	2.02	.66	.41	.66	.63	.62	1.04	.83	11.6[illegible]
13 Fish Creek Ranch	.44	.32	.53	.51	.62	.34	.55	.48	.53	.33	.59	.50	5.7[illegible]
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	Location: Township	Location: 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.
QUATERNARY	Pleistocene and Recent	VALLEY FILL	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.
QUATERNARY	Pleistocene	VALLEY FILL	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		CONSOLIDATED ROCKS	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		CONSOLIDATED ROCKS	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		CONSOLIDATED ROCKS	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

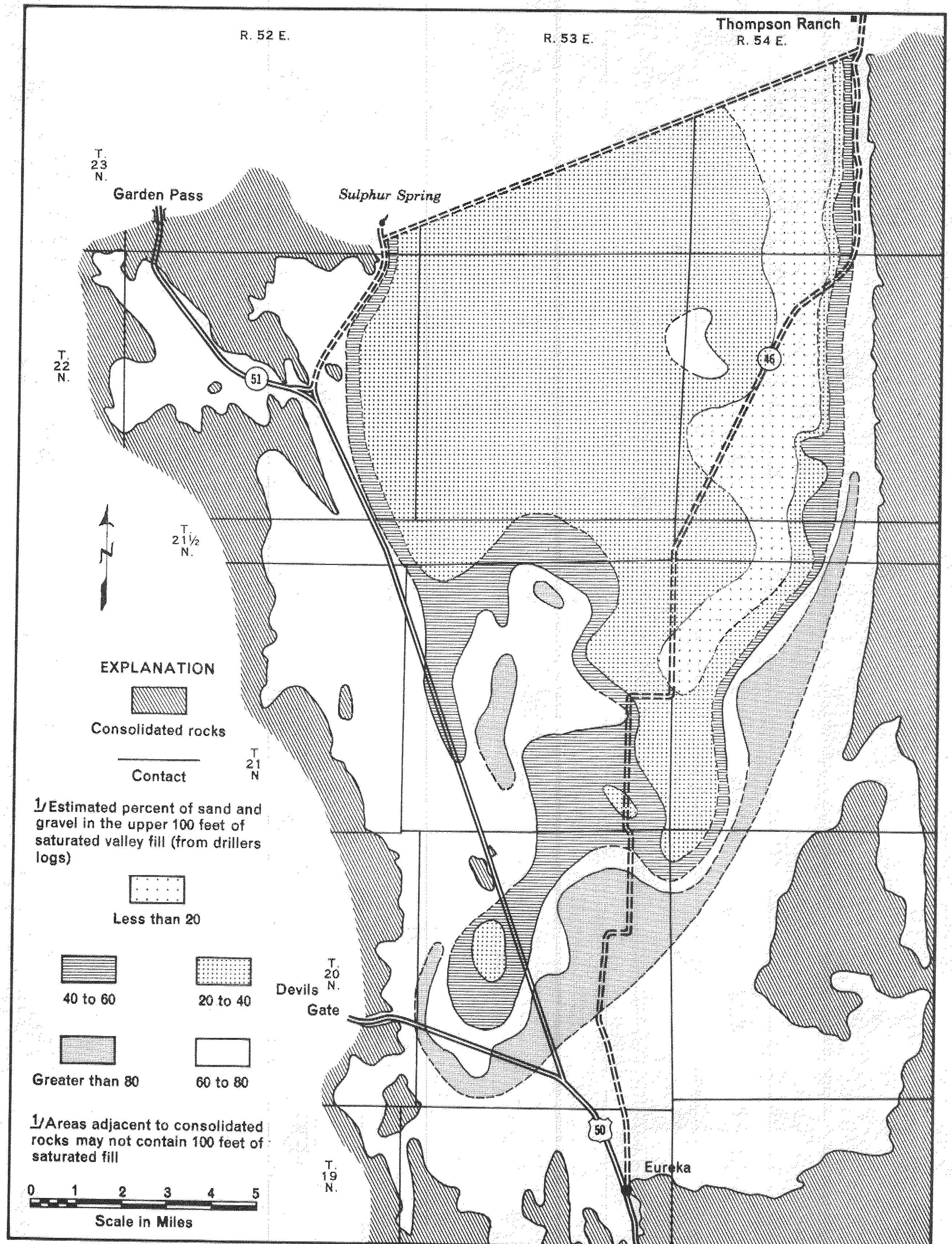


Figure 2.—Sub surface distribution of sand and gravel, South Diamond subarea

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

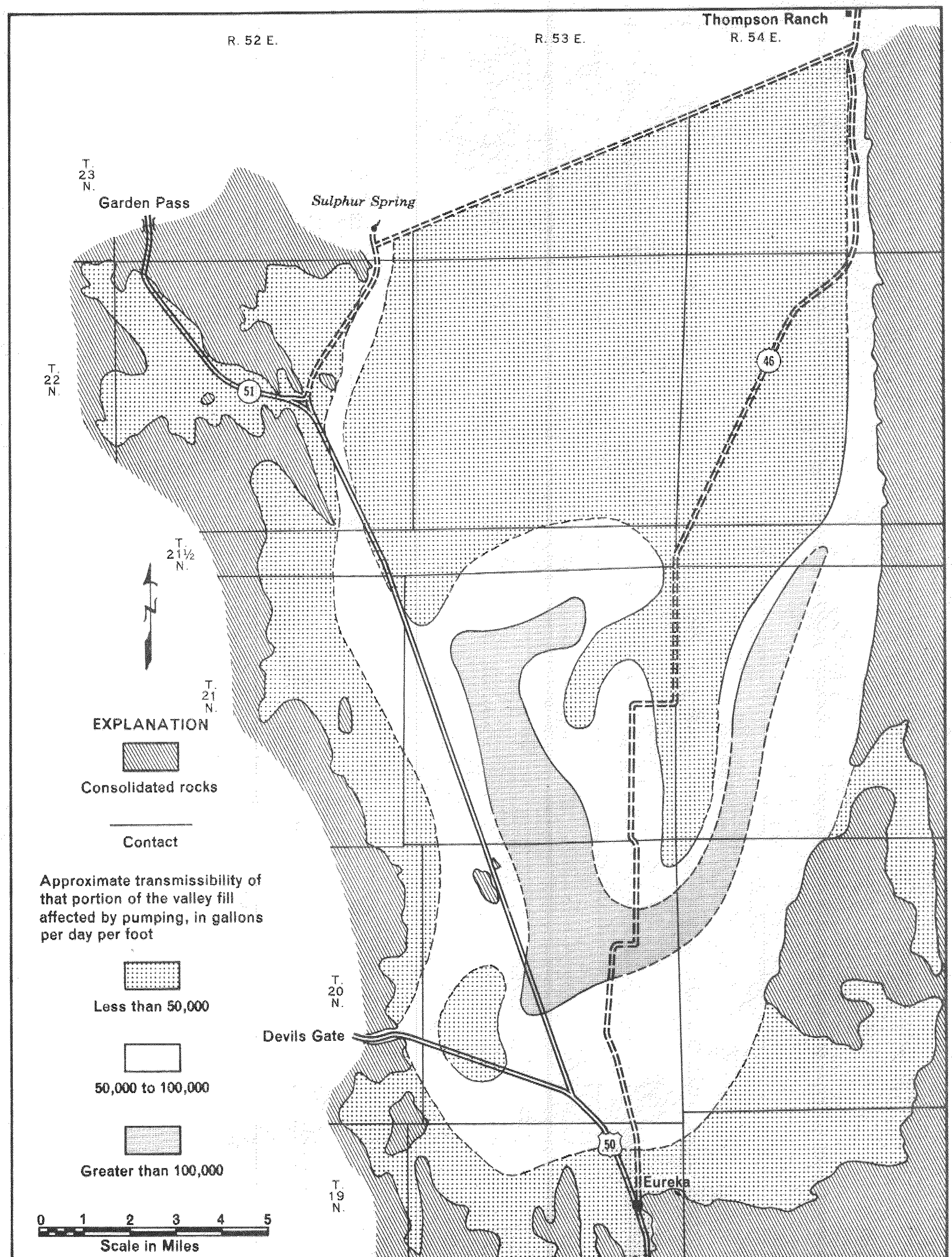


Figure 3.—Preliminary transmissibility map, South Diamond subarea

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.

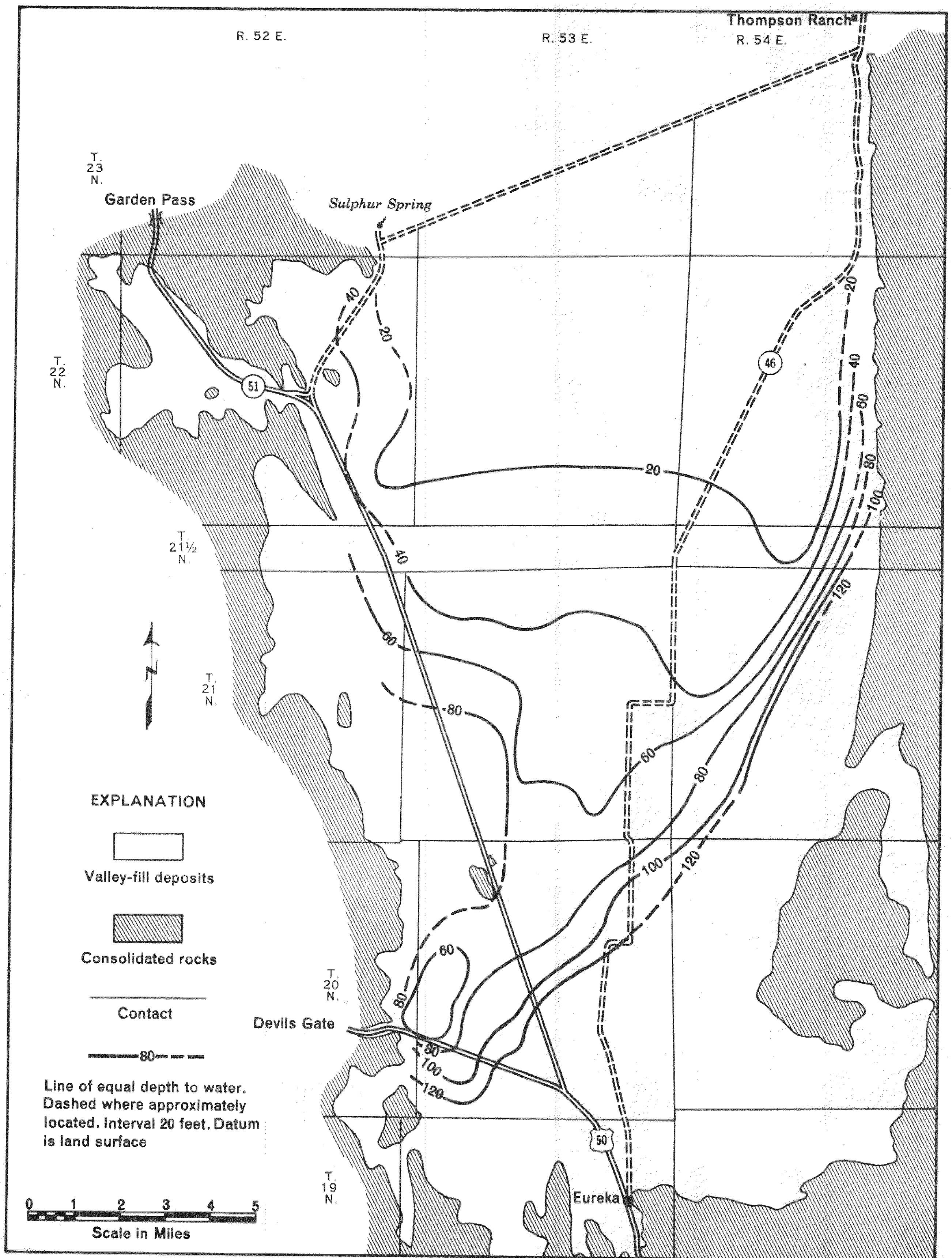


Figure 4.—Approximate depths to water April 1966, South Diamond subarea

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).

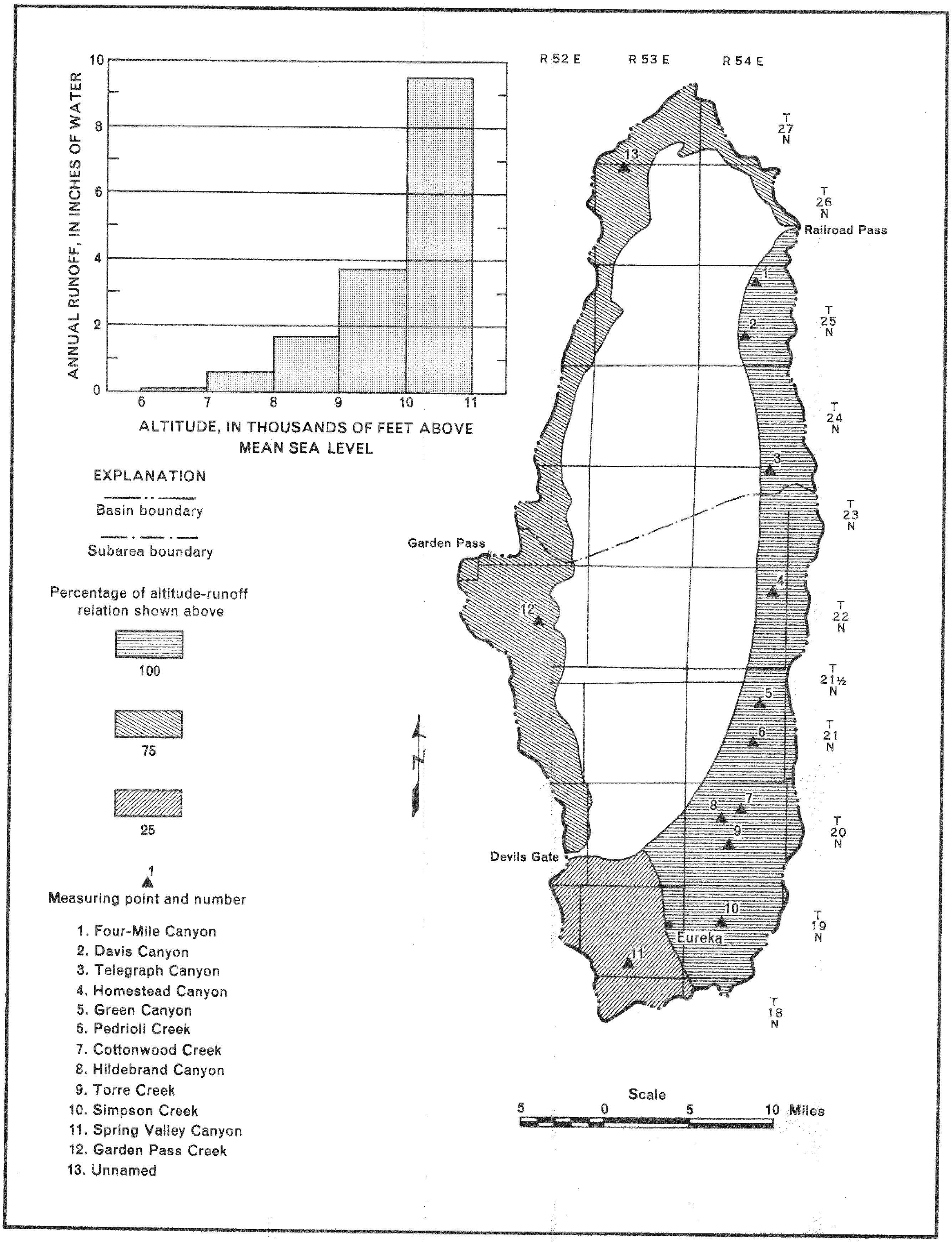


Figure 5.—Relation between runoff and altitude and map showing areas having similar runoff characteristics

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

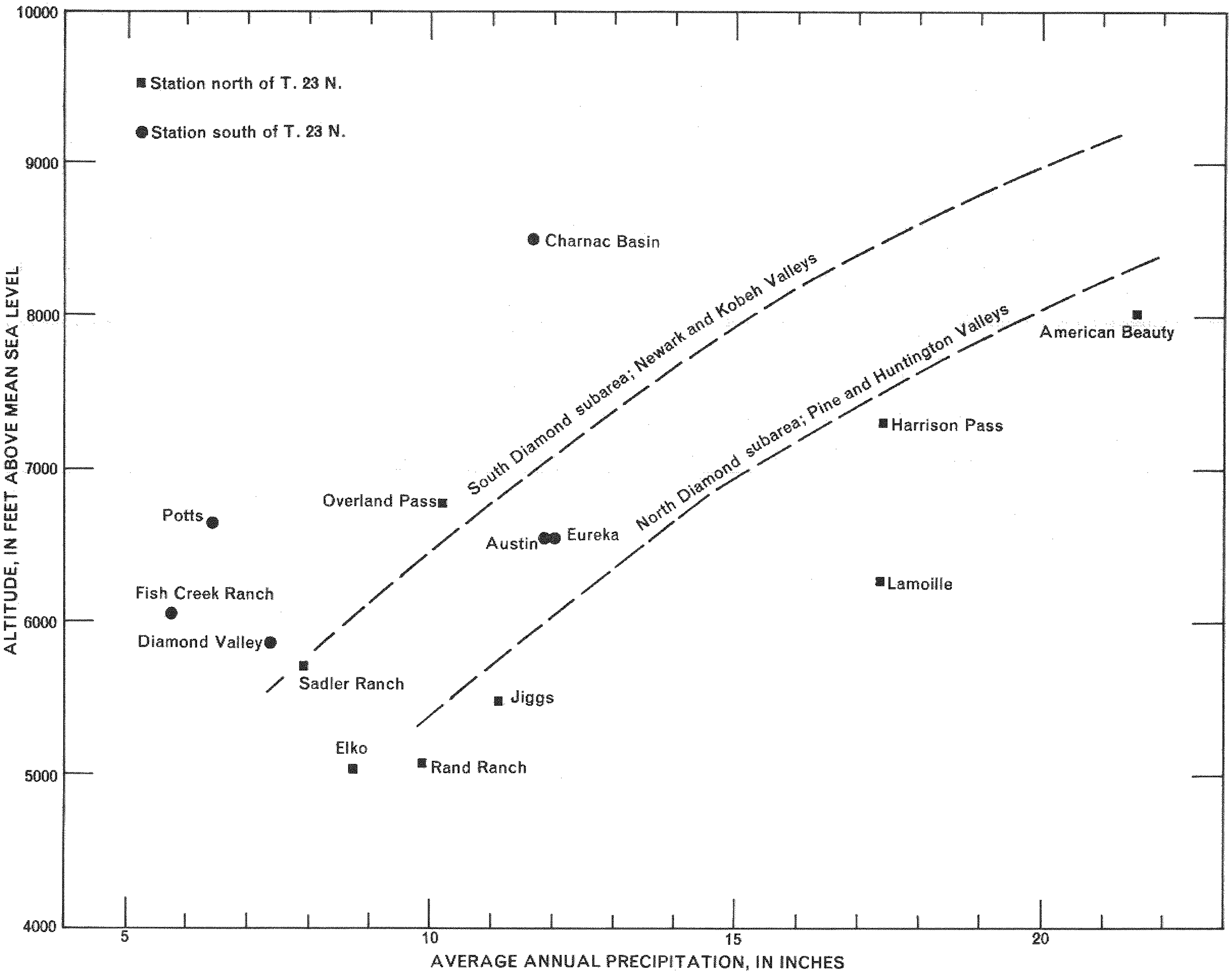


Figure 6.—Relation between precipitation and altitude

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

Precipitation zone (feet)	Area (acres)	Estimated annual precipitation Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge from precipitation 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 Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge from precipitation 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 Crdovician(?) 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	7.19	
		4- 1-66	7.01	4,900
		10-19-66	6.20	
24/52-26d	Unnamed	12- 7-65	.66	540
		4- 1-66	.82	
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	2.33	
		4- 1-66	2.11	1,600
		10-19-66	2.06	
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).

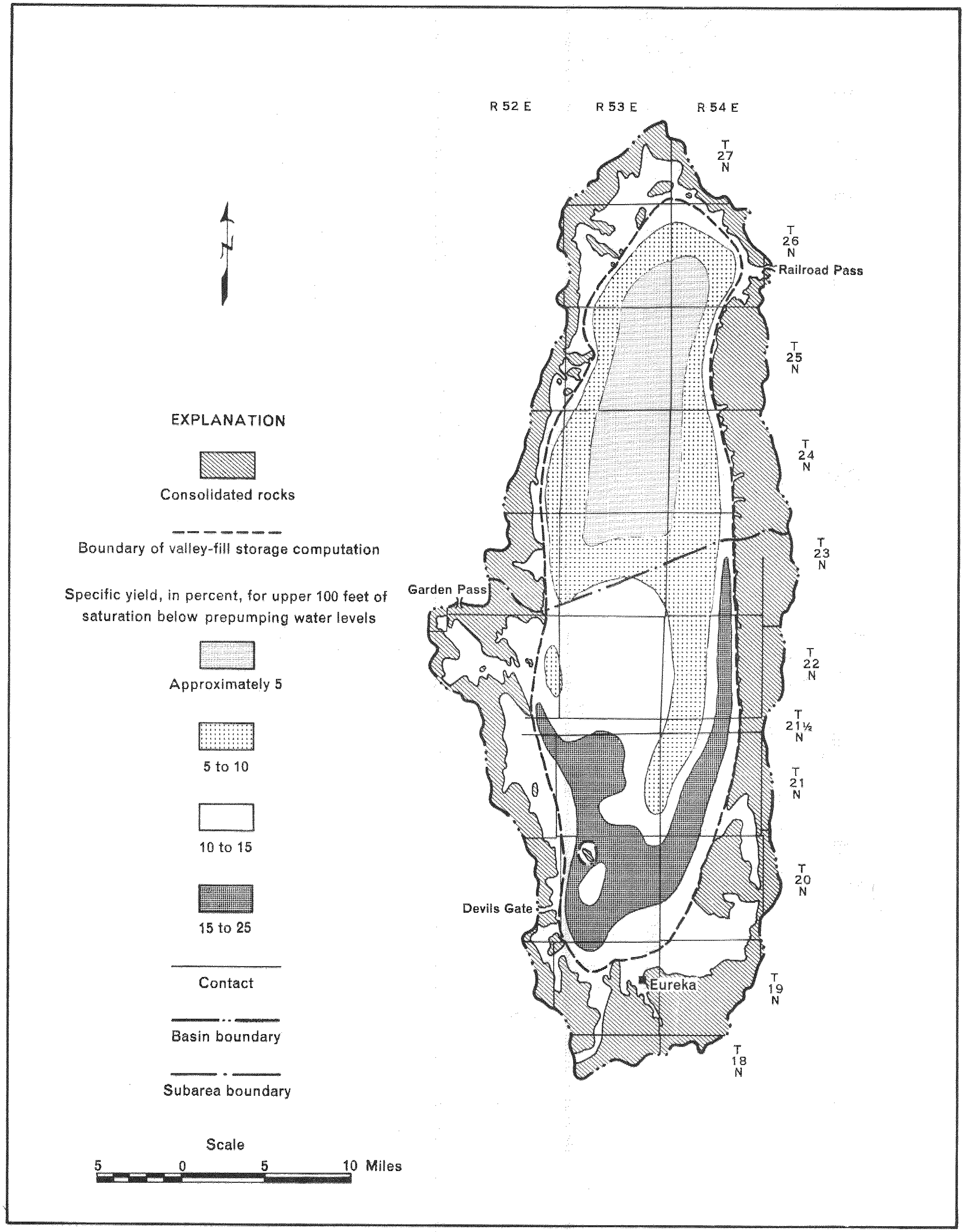


Figure 7.—Estimated specific-yield distribution

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]	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)	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)
						Milligrams per liter (upper number) and milliequivalents per liter (lower number) for indicated cations and anions																	
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	786	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.

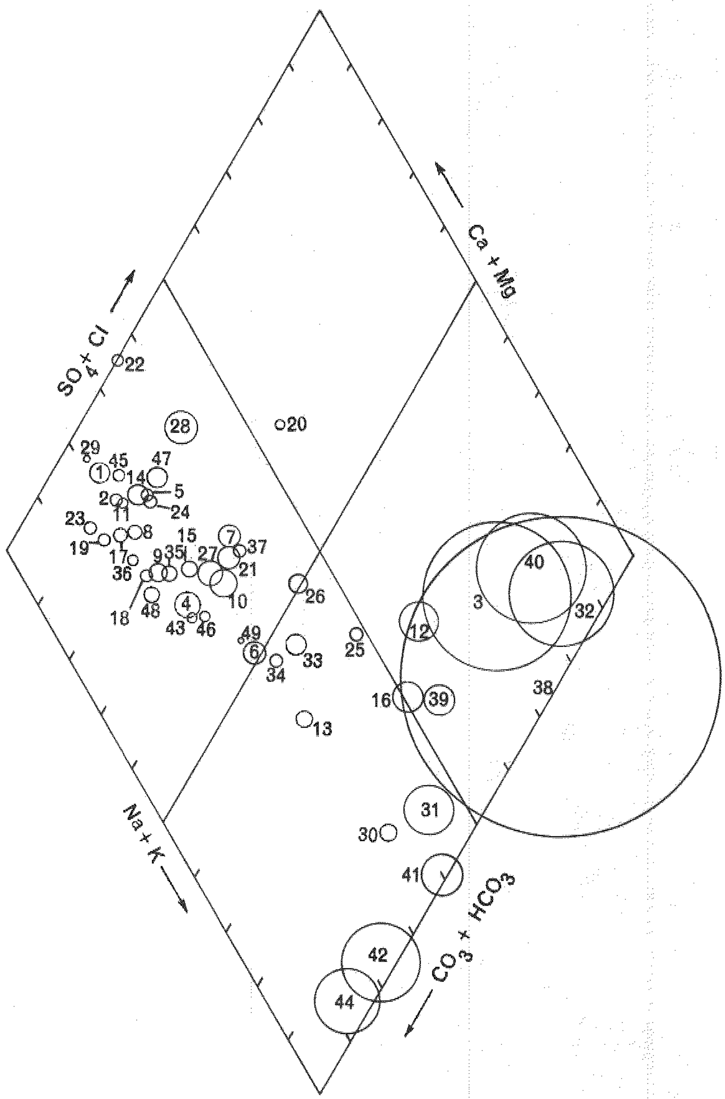
Note: Chemical constituents reported in metric units of milligrams per liter and milliequivalents per liter. The metric values are respectively equal to parts per million and equivalents per million for samples with specific conductances up to about 10,000 micromhos, and are slightly more than parts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

Location	Source	Date of collection	Temperature (°F)	Milligrams per liter (upper number) and milliequivalents per liter (lower number) for indicated cations and anions: Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)[1]	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$ (mg/l): Calcium 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

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

0 50 100

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

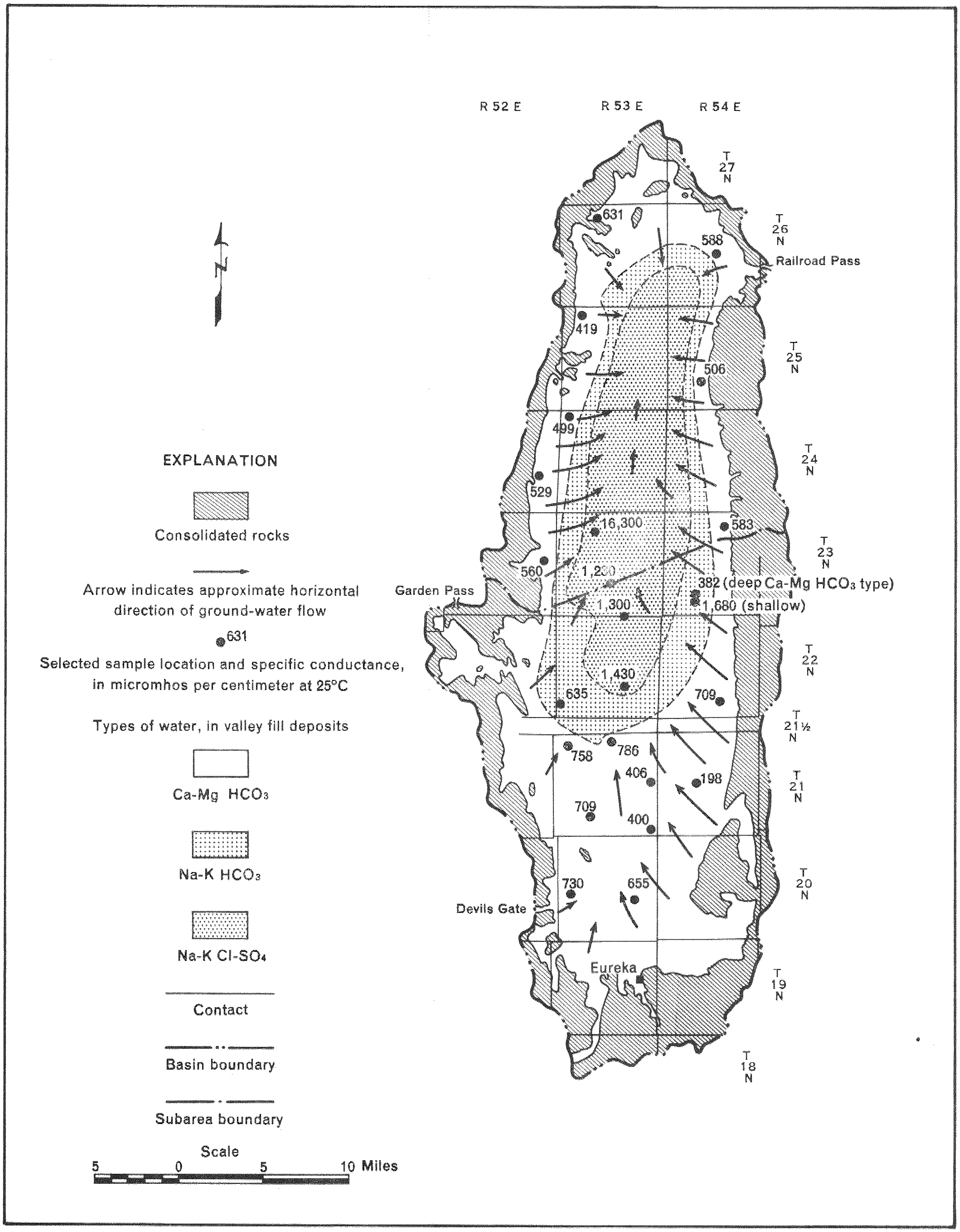


Figure 9.—Generalized relation between water quality and ground-water flow

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

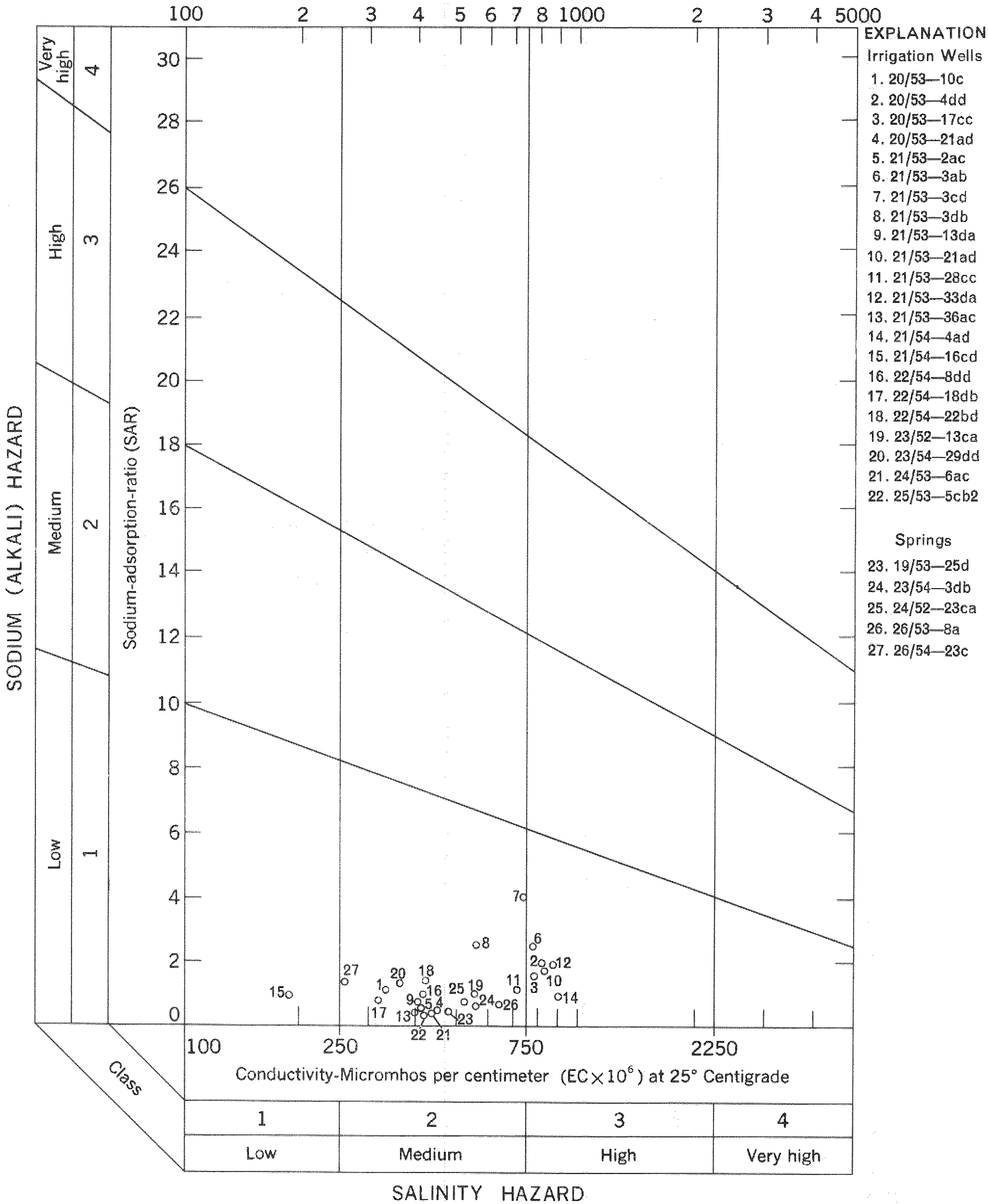


Figure 10.—Classification of water from springs and irrigation wells based on conductivity and sodium adsorption ratio (After U.S. Department of Agriculture 1954)

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.

21/54-4ad1. Owner, W. A. Jones. Altitude, 5,893 feet. Drilled irrigation well; casing diameter 12 inches; depth 120 feet. Equipped with a turbine pump and a diesel engine. Discharge estimated at 1,000 gpm. Pumpage for 1951 estimated at 100 acre-feet. Measuring point, slot in casing which is 0.7 foot above land surface. Depth to water, 38.25 feet, September 13, 1961. (Also prior water level measurements). Driller's log:

Material	Thickness (feet)	Depth (feet)
Clay, gray-green	28	28
Clay, sandy, some pebbles	17	45
Gravel and clay, stratified	35	80
Gravel, some coarse	8	88
Clay, yellow	5	93
Hard pan and cemented gravel	27	120
	Total depth	120

21/54-9bc2. Owner, not determined. Altitude, 5,881 feet. Drilled stock well; casing diameter 6 inches. Equipped with cylinder pump and windmill. Measuring point, top of casing which is 2.75 feet above land surface. Depth to water below land surface 87.22 feet, September 13, 1961.

21/54-29cb1. Owner, Raymond Labarry. Altitude, 5,955 feet. Drilled stock well; casing diameter 8 inches; depth 130 feet. Equipped with cylinder pump and windmill. Measuring point, top of casing collar which is 0.4 foot above land surface. Depth to water below land surface, 87.22 feet, September 13, 1961. (Also prior water level measurements). Driller's log:

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Clay and gravel	90	95
Sand and gravel	5	100
Clay and gravel	25	125
Sand and gravel	5	130
	Total depth	130

22/52-14ab1. Owner, formerly A. C. Florio. Altitude, 5,862 feet. Dug stock and observation well; casing diameter 60 inches; depth 50 feet, later caved to a depth of 34.4 feet. Depth to water below land surface, 37.27 feet, September 16, 1950. (Also prior water level measurements). Well dry, December 18, 1959.

22/54-7dd1. Owner, Mr. Maddox. Altitude, 5,843 feet. Drilled domestic well; casing diameter 4 inches; depth 192 feet. Equipped with pump and internal combustion engine. Measuring point, top of casing which is 0.4 foot above land surface. Depth to water below land surface 12.87 feet, September 14, 1961.

22/54-8cc1. Owner, Louis L. Pollard. Altitude, 5,842 feet. Drilled domestic and irrigation well; casing diameter 10 inches; depth 154 feet. Discharge reported as 550 gpm. Measuring point, top of casing which is 1.7 feet above land surface. Depth to water below land surface, 12.31 feet, September 14, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
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-bearing	12	120
Shale, sandy	7	127
Shale and gravel	16	143
Gravel, water-bearing	9	152
Shale, blue	2	154
Total depth		154

22/54-8ad1. Owner, Owen Pollard. Altitude, 5,843 feet. Drilled irrigation well; casing diameter 14 inches; depth 155 feet. Discharge reported 1,200 gpm with a drawdown of 50 feet. Measuring point, top of casing which is 1.4 feet above land surface. Depth to water below land surface, 9.10 feet, September 14, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Sand and gravel	21	21
Clay, blue, black	33	54
Sand, light colored	26	80
Gravel, with clay layers	46	126
Gravel and sand	14	140
Gravel, coarse	15	155
Total depth		155

22/54-8dd1. Owner, Louis Pollard. Altitude, 5,842 feet. Drilled irrigation well; depth 222 feet. Equipped with pump and internal combustion engine. Discharge reported as 1,100 gpm with a drawdown of 45 feet. Measuring point, slot in casing which is 0.5 foot above land surface. Depth to water below land surface, 9.25 feet, September 14, 1961.

22/54-10ac1. Owner, not determined. Altitude, 5,849 feet. Drilled stock well; casing diameter 6 inches. Measuring point, top of casing which is 1.2 feet above land surface. Depth to water below land surface, 9.88 feet, September 13, 1961. (Also prior water level measurements).

22/54-18dd1. Owner, Beverly Holmes. Altitude, 5,852 feet. Drilled irrigation well; casing diameter 12 inches; depth 222 feet. Discharge reported as 350 gpm with a drawdown of 47 feet. Depth to water below land surface, 15.98 feet, September 14, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Sand and gravel	25	25
Sandy clay	28	53
Sand	9	62
Clay	4	66
Sand and gravel	4	70
Clay, blue	25	95
Sandstone, soft	10	105
Sandy clay	10	115
Sandstone	5	120
Clay	18	138
Sandstone	7	145
Clay	5	150
Sandy clay	16	166
Sand	4	170
Clay	7	177
Sand	13	190
Clay	27	217
Sand	5	222
Total depth		222

22/54-28aa1. Owner, Oscar Carroll. Altitude, 5,855 feet. Drilled domestic and irrigation well; casing diameter 12 inches; depth 184 feet. Equipped with centrifugal pump. Discharge reported as 1,000 gpm. Measuring point, top of casing which is 0.75 foot above land surface. Depth to water below land surface, 13.53 feet, September 14, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Loamy soil	3 1/2	3 1/2
Hard pan	1 1/2	5
Sand	2	7
Shale, sandy	5	12
Shale, hard	4	16
Sand, hard	4	20
Muck	2	22
Sand, shale, clay	3	25
Sand, water-bearing	2	27
Mud, blue	9	36
Mud, black	8	44
Shale, sandy	6	50
Mud, blue	5	55
Sand, mud	4	59
Sand	5	64
Sand	3	67
Mud, blue	2	69
Sand	4	73
Shale, sticky	2	75
Sand	2	77
Shale, hard, blue	2	79
Sand	2	81
Sand and gravel	2	83
Sand	12	95
Sand and shale	5	100
Gravel, shale	1	101
Sand	6	107
Shale	3	110
Sand	3	113
Sand and shale	27	140
Sand and gravel	16	156
Gravel, small	4	160
Sand, gravel and rock	24	184
Total depth		184

22/54-34ab1. Owner, not determined. Altitude, 5,882 feet. Drilled stock well; casing diameter 6 inches; depth 50 feet. Equipped with cylinder pump and windmill. Measuring point, top of casing which is 2.4 feet above land surface. Depth to water below land surface, 40.13 feet, September 14, 1961. Chemical analysis. Temperature 54°F.

Water levels, in feet, below land surface

Date	Water level	Date	Water level	Date	Water level
June 17, 1947	28.67	June 19, 1950	29.80	Apr. 8, 1954	33.03
Oct. 27	29.60	Sept. 16	30.60	Sept. 16	32.82
May 6, 1948	29.33	Mar. 15, 1951	31.03	Aug. 29, 1955	34.49
June 17, 1949	28.73	Sept. 11	32.07	Sept. 6, 1957	35.05
July 8	29.02	Oct. 1, 1952	31.23	Sept. 5, 1958	35.82
Sept. 12	29.62	Mar. 3, 1953	31.30	Dec. 18, 1959	36.37
Dec. 16	30.51	Sept. 15	32.75	Sept. 14, 1961	40.13
Mar. 17, 1950	30.31	Mar. 10, 1954	32.71		

23/52-13bb1. Owner, L. Reitman Cattle Co. Altitude, 5,815 feet. Drilled irrigation well; casing diameter 14 inches; depth 157 feet. Equipped with a turbine pump and a diesel engine. Discharge reported as 700 gpm with a drawdown of 14 feet. Depth to water below land surface, 4.89 feet, September 15, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
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, tan colored	5	157
Total depth		157

25/53-5cb1. Owner, Joe Flynn. Drilled irrigation well; casing diameter 6 inches; depth 150 feet. Flowing well. Yield reported June 28, 1949, 25 gpm. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil, brown	10	10
Clay, blue	24	34
Clay, gray; small gravel	33	67
Clay, brown; small rock, water-bearing	8	75
Clay, brown; small rock, water-bearing	2	77
Clay, red; fine rock, water-bearing	6	83
Clay, gray; fine rock	2	85
Clay, red; fine rock; increasing water with depth	20	105
Clay, black; sand	12	117
Clay, brown; sand	33	150
Total depth		150

25/54-9db1. Owner, Ted Thompson. Dug stock and observation well; diameter 60 inches; depth 35 feet. Equipped with cylinder pump and windmill. Measuring point, top of 2-inch by 8-inch cribbing which is 1.0 foot above land surface. Depth to water below land surface, 32.57 feet, June 17, 1947; 33.30 feet, October 27, 1947; 33.14, May 6, 1948.

23/52-13ca1. Owner, formerly A. C. Florio. Drilled well; casing diameter 13 inches; depth 58 feet. Flowing well. Yield estimated June 16, 1947 as 115 gpm, September 15, 1961, 115 gpm.

23/52-13ca2. Owner, formerly A. C. Florio. Drilled stock and irrigation well; casing diameter 6 inches; depth 176 feet. Flowing well. Measured flow of 88 gpm, September 15, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	15	15
Clay, blue	20	35
Clay, blue-gray, sandy; small gravel	25	60
Clay, gray, sandy	25	85
Clay, light gray, sandy	6	91
Gravel streak, loose	2	93
Gravel, loose; pinkish clay	4	97
Gravel, coarse; sand; pink clay	28	125
Sand; gravel; clay	20	145
Sand, coarse and gravel streak	2	147
Clay, pink; sand; gravel	29	176
Gravel, cemented		176
Total depth		176

26/53-12db1. Owner, Ted Thompson. Altitude, 5,783 feet. Dug stock and observation well; diameter, 5 feet by 9 feet; depth 13 feet. Equipped with cylinder pump and windmill. Measuring point, top of 2- by 8-inch cribbing which is 3.5 feet above land surface. Depth to water below land surface, 9.39 feet, June 17, 1947; 10.95 feet, October 27, 1947; 9.77 feet, May 6, 1948; 9.10 feet, September 14, 1961.

26/54-15cd1. Owner, Bureau of Land Management. Altitude, 5,779 feet. Dug stock well; diameter 5 feet by 7 feet; depth, 9.5 feet. Equipped with cylinder pump and windmill. Measuring point, top of 2- by 12-inch sill which is 2.5 feet above land surface. Depth to water below land surface, 8.29 feet, October 27, 1947; 7.41 feet, May 6, 1948; 6.23 feet, September 14, 1961.

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Appendix--Generalized Stratigraphy of Diamond Valley and Vicinity

After Nolan, Merriam, and Williams (1956), Regnier (1960, p. 1191), and Humphrey (1960, p. 41-46).

Age	Formation	Lithology	Thickness
Quaternary	Alluvium	Unconsolidated sand, gravel, silt, and clay in fanglomerate; stream, lake, beach, playa, and dune deposits	0-200 or 300
		Unconformity	
Middle Pliocene to middle Pleistocene	Hay Ranch Formation of Regnier	Fanglomerate, conglomerate, sandstone, clay, and limestone. Some vitric tuff mostly, altered to zeolite	Possibly several thousand feet
		Slight angular unconformity	
Pliocene and (or) Pleistocene	Belmont Fanglomerate of Humphrey	Chiefly unbedded gravel fanglomerate	?
		Unconformity	
Early Pliocene	Carlin Formation of Regnier	Tuffaceous sandstone and conglomerate, vitric tuff, shale, limestone, and diatomite. (not present in Pine Valley)	600+
		Slight angular unconformity	
Late Miocene and (or) Pliocene	Lake Newark Formation of Humphrey	Bedded rhyolite tuff and coarser pyroclastics; in part lacustrine	430
		Unconformity	
Late Miocene or early Pliocene	Palisade Canyon Rhyolite of Regnier		500
		Slight angular unconformity	

Age	Formation	Lithology	Thickness (feet)
Late Miocene	Raine Ranch Formation of Regnier	Lapilli tuff, volcanic breccia, lava flows, vitric tuff, diatomaceous shale, and limestone	2,000
Slight angular unconformity			
Late Oligocene (?) or early Miocene (?)	Safford Canyon Formation of Regnier	Tuffs, tuffaceous conglomerate, and sandstone	700
Slight angular unconformity			
Oligocene (?)	Rand Ranch Formation of Regnier	Sandstone and conglomerate	1,700
Erosional unconformity			
Eocene	Illipah Formation of Humphrey	Fresh-water limestone, conglomerate, and interbedded tuff	1,500±
Unconformity			
Early Cretaceous	Newark Canyon Formation	Heterogeneous assemblage of fresh-water limestone, conglomerate, silt, sandstone, and grit	1,800
Unconformity			

Age	Formation	Lithology	Thickness (feet)
Permian	Carbon Ridge Formation	Heterogeneous, predominately calcareous rocks including abundant bedded sandy limestone; many beds of brown, yellow, or purple sandstone near base	1,750
Early and Middle Pennsylvanian	Ely Limestone	Massive bedded blue-gray limestone with some sandstone and rarely conglomerate beds near base . . .	1,500
Late Mississippian	Diamond Peak Formation	Quartzite with large but varying portions of shale, conglomerate, and limestone; abundant fossils . .	420
Late Mississippian	Chainman Shale	Black shale with some thin beds of sandstone, Rather siliceous in Diamond Mountains	5,000
		Unconformity	
Early Mississippian	Joana Limestone	Dense, porcelaneous limestone, coarsely crystalline limestone locally conglomeratic, nodular cherty limestone, black platy shale, thin quartzite or sandstone beds, and subordinate black chert . . .	0-135

Age	Formation	Lithology	Thickness (feet)
Missis-sippian and Devonian	Pilot Shale	Platy generally calcareous shale, tan to black in color on fresh fracture; approaches 1,000 feet in thickness in Pancake Range	420
Middle and Late Devonian	Devils Gate Limestone	Thick-bedded gray to blue-gray hard, dense, brittle limestone; few thinner beds of platy, flaggy limestone; some dolomite or dolo-mitic limestone near base; divided into Hayes Canyon and Meister members . . .	1,200
Early and Middle Devonian	Nevada Formation	Dominantly dolomite but appreciable thickness of sandstone and limestone; divided into five members inwhich a sandstone unit and a dominantly limestone unit separate three dolo-mite units; members, younger to older, are Bay State Dolomite, Wood-pecker Limestone, Sentinel Mountain Dolomite, Oxyoke Canyon Sandstone, and Beacon Peak Dolomite Members	2,900

Unconformity

Age	Formation	Lithology	Thickness (feet)
Silurian	Lone Mountain Dolomite	Characteristically heavy-bedded to massive finely granular to coarsely saccharoidal light-gray dolomite; some beds of corase crinoidal dolomite near base	1,500-2,200
		Unconformity	
Late Ordovician	Hanson Creek Formation	Dark-gray to black dolomite, intensely fractured and brecciated in Eureka area; mostly limestone and calcareous shale in Roberts Mountains. .	300+
		Unconformity	
Middle and Late (?) Ordovician	Eureka Quartzite	Typically vitreous fine-to medium-grained sugary gleaming white quartzite, much fractured, brecciated, and locally recrystallized.	500-
		Unconformity	
Pogonip Group (eastern facies), composed of Antelop Valley Limestone, Ninemile Formation, and Goodwin Limestone			
Early and Middle Ordovician	Antelope Valley Limestone	Thick-bedded or massive medium of light-blue-gray fine-grained limestone; tends to be flaggy or platy, with argillaceous partings, in upper part . . .	430
Early Ordovician	Ninemile Formation	Platy, thin-bedded fine-grained to porcelaneous olive-green or greenish blue limestone. Some light-gray crystalline, sandy limestone, limy sandstone, and shale partings . .	540
Early Ordovician	Goodwin Limestone	Dominantly well-bedded, fairly massive light-gray to blue-gray limestone; much very fine grained, asphanitic, locally platy light-gray to white chert in lower 350 feet . . .	1,000±

Age	Formation	Lithology	Thickness (feet)
Late Cambrian	Windfall Formation	Includes, in descending order: Bullwhacker Member, thin-bedded platy sandy or shaly limestone between units characterized by massive limestone (400 feet); and Catlin Member, massive limestone beds and thinner sandy or silty limestone beds (250 feet)	650
Late Cambrian	Dunderberg Shale	Approximately equal thicknesses of shale and zones of interbedded shale and thin nodular, lenticular limestone beds	265
Middle and Late Cambrian	Hamburg Dolomite	Mostly composed of light-to medium-dull-gray coarsely crystalline dolomite, porous and vuggy, considerable local variation in bedding, texture, color, and composition	1,000
Middle Cambrian	Secret Canyon Shale	Includes: Clarks Spring Member, thin-bedded fine-grained silty blue-gray limestone with prominent yellow and red argillaceous partings (425-450 feet); lower shale member, argillaceous shale with little interbedded limestone; unweathered shale is massive blocky siltstone with little or no fissility (200-225 feet)	650
Middle Cambrian	Geddes Limestone	Well bedded, flaggy blue limestone with thin shale partings and some nodular black chert	330

Age	Formation	Lithology	Thickness (feet)
Middle Cambrian	Eldorado Dolomite	Massively bedded carbonate rock, ranging from nearly pure limestone to nearly pure dolomite; common type is light-gray rather coarsely crystalline dolomite, generally textureless but locally porous and vuggy; considerably modified by hydrothermal alteration . .	2,500±
Early Cambrian	Pioche Shale	Commonly micaceous sandy shale; includes some sicaceous sandstone quartzite and white and black limestone beds	400-500
Early Cambrian	Prospect Mountain Quartzite	White to gray fairly well sorted quartzite; micaceous sandy shale interbeds make up less than 5 percent of formation and tend to be more numerous in lower part . .	1,500±

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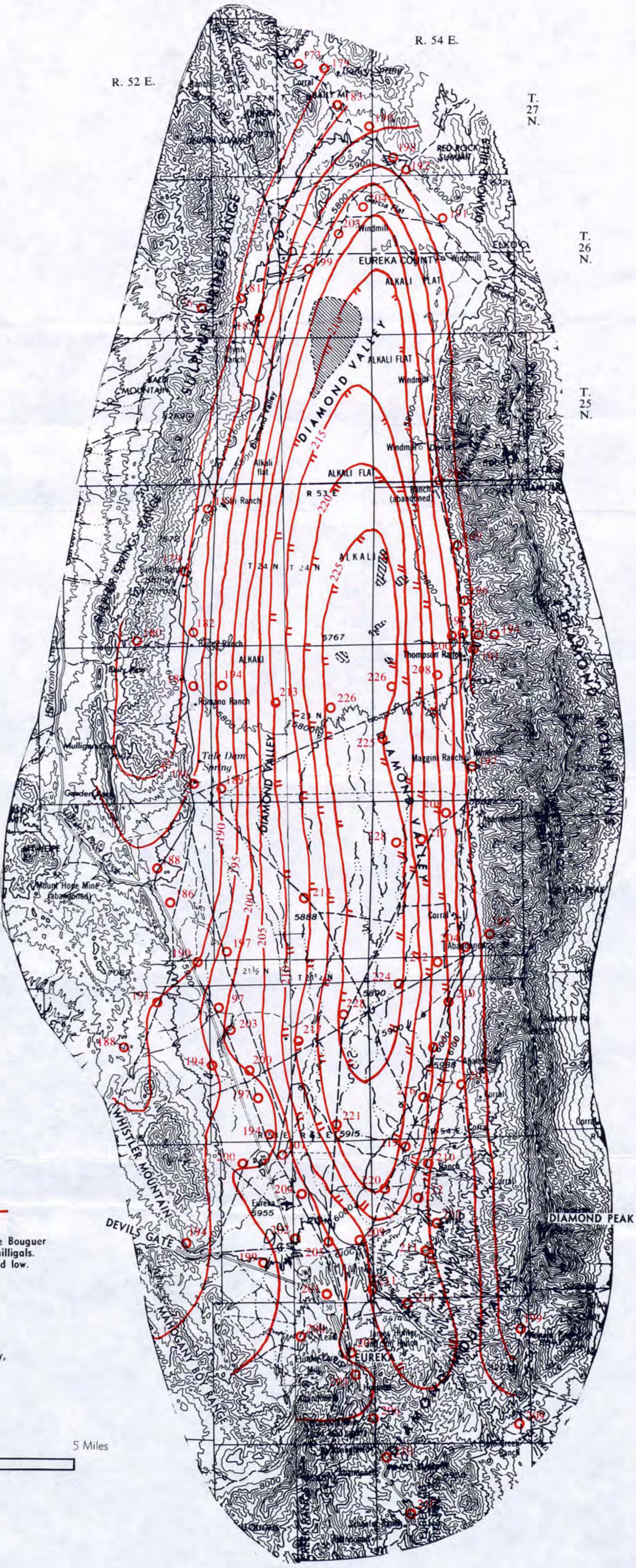


EXPLANATION

Contours, in milligals, of simple Bouguer anomaly; contour interval, 5 milligals. Ticks on contour indicate closed low.

225

Gravity station, and simple Bouguer anomaly, in milligals.

Scale 1:250,000

5 0 5 Miles

(Base: Army Map Service 1:250,000 scale topographic maps, Elko (1958), Ely (1959), Millett (1959), and Winnemucca (1958)).

Geophysical data by D. R. Mabey, 1961

PLATE 2. MAP OF DIAMOND VALLEY, SHOWING GENERALIZED CONTOURS OF SIMPLE BOUGUER ANOMALY.

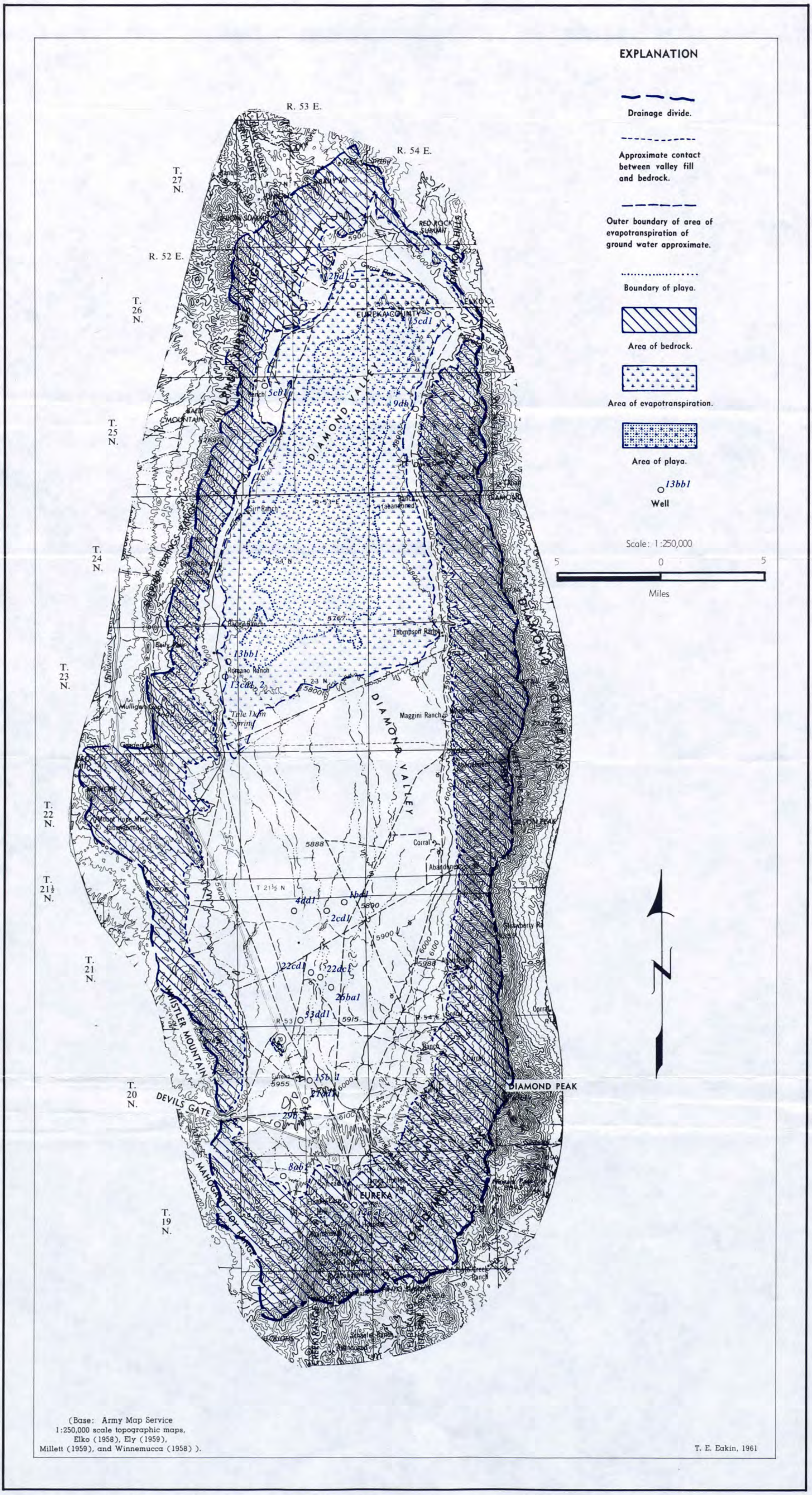


PLATE 1. MAP OF DIAMOND VALLEY, EUREKA AND ELKO COUNTIES, NEVADA

SHOWING AREAS OF BEDROCK, VALLEY FILL, PLAYA, AND EVAPOTRANSPIRATION, AND LOCATION OF WELLS.

evaporated or transpired, processes which tend to concentrate dissolved chemical constituents in the remaining ground water.

Although no samples of water were collected for analysis during this investigation, several analyses were made during the investigation of the mining hydrology in the Eureka region by Stuart and Metzger (written communication, 1961). Table 7 lists analyses for water from two wells, the Fad shaft, one spring, and surface-water flow in Devil's Gate.

Of these analyses only the sample of surface water in Devil's Gate has a dissolved-solids content in excess of 500 ppm (parts per million). The surface-water sample was collected during a period of low flow. Some of this water probably infiltrates to the ground-water reservoir but the quantity is small and thus probably affects the quality of this ground water only in a small area to the east and north of Devil's Gate.

The two analyses of ground water indicate that the quality of ground water in the southern part of Diamond Valley generally is of a bicarbonate type and that it is suitable for irrigation.

Table 7. --Chemical analyses of selected samples of water from Diamond Valley

Location	Date collected	Constituents: Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bi carbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Specific conductance (Micromhos at 25°C.)	Hardness as $CaCO_3$: Total	Noncarbonate	Dissolved solids	Percent sodium	pH
Fad shaft (19/53-15bd) a/	1-21-53	11	.02	52	26	8.3	1.4	--	238	38	10	0.0	2.6	.06	467	236	42	267	7	7.8
Surface water at Devil's Gate (20/52-26A) a/	4-10-54	21	.47	41	94	1,020	98	35	834	918	800	1.0	.8	1.8	5,370	489	0	3,440	78	8.3
Well (20/53-15cb1) b/	6- 6-49	27	.75	37	14	-	-	-	247	16	25	-	-	.2	-	-	-	294	-	8.4
Well (22/54-34ab1) a/	3-10-54	37	.18	78	36	27	5.5	-	356	77	16	.6	5.5	.12	709	342	51	458	14	7.4
Shipley Hot Spr. (24/52-23da) a/	9-18-52	40	.01	57	21	29	5.9	0	279	35	21	.2	.0	.26	540	228	0	346	21	7.2

a/ Analyses by Geological Survey, U. S. Department of the Interior.

b/ Analyses by Twining Laboratories, Fresno, Calif. for Eureka Corporation, Ltd.

Although the analyses are suggestive of the chemical quality of ground water in the principal area of present development, they should not be relied upon as representing the quality of all ground water in this area because the samples were collected from points adjacent to the area of development.

The analyses also do not represent the chemical quality of ground water in and adjacent to the playa which extends northward from the north part of T. 23 N. Because ground water is discharged by evapotranspiration adjacent to and in the playa area, it would be expected that the ground water here would have a higher dissolved-solids content than the water in the southern part of the valley.

The chemical quality of water from the Fad shaft, which is from bedrock formations, is generally similar to the analyses of ground water from the valley fill. This similarity tends to support the idea that the ground water in the bedrock and valley fill are a single gross hydrologic system in Diamond Valley. This is in agreement with general hydrologic and geologic principles for the occurrence and movement of water in interior valleys.

It would appear to be desirable to obtain and analyze samples of water from various parts of the valley, including the area of principal development. The data so obtained would be valuable not only to better determine the character of water with respect to suitability for various crops, but also, would be of substantial assistance in further defining ground-water hydrology of Diamond Valley.

Development

Prior to about 1940, development of ground water in Diamond Valley largely involved the utilization of spring discharge for the production of hay from meadows and pasture land. The larger springs so used are located on ranches near the east and west sides of Diamond Valley principally in Tps. 23 and 24 N.

In about 1943, drilling on the Romano Ranch resulted in the development of several flowing wells. The wells generally were less than 200 feet deep and the combined flow of six wells was about 600 gallons per minute. Over the years the flow gradually diminished and now may be on the order of 200 gpm.

The water from these wells was used for irrigation of meadow and pasture. The water also was used to flood brush land. During the winter, the water would freeze and kill the brush. The water further was used to leach the land of salts. The combined effect of these two processes resulted in increasing the acreage of meadow or pasture land.

In the late 1940's several wells with small flows, were drilled on the Flynn ranch, and the water was used for irrigation of meadows.

In 1949, public land withdrawals were made by Wm. and A. L. Jones and R. Stucki. Three irrigation wells were drilled of which two were successful, the largest yield about 1,200 gpm. Irrigation from these wells has continued for several years. (See photograph 4.)

Two additional irrigation wells were drilled in 1958 on public land withdrawals in T. 22 N., R. 54 E. However, the principal development began in 1960 and substantial drilling has continued through September 1961. During the summer season of 1961 about 50 pumped wells were used during all or part of the summer season in the areas where ground water is the only irrigation supply. Photograph 5 is representative of irrigation well installations in the valley. Photograph 6 shows a type of sprinkler system used to a limited extent.

Data are not available to make a firm estimate of the amount of water pumped for irrigation during 1961. However, a crude estimate, based on few data and incomplete information relating to acreage irrigated, number of wells pumped, and approximate average pumping, suggest that withdrawal apparently was within the range of 4,000 to 7,000 acre-feet, and probably was about 5,000 acre-feet.

Drilling continued through the summer and in September about 85 wells had been completed. It is expected that most of these will be equipped for production by next summer. Apparently additional irrigation wells will be drilled during the fall and winter.

The recent well development has been accompanied by increased efforts to develop or better utilize water on the older ranches. A well was drilled and equipped for relatively large production at the Romano Ranch. Additional development of springs has been and continues to be carried out to improve control and use of water. On the Thompson Ranch, about 56 acres of alfalfa are being irrigated by sprinklers, the water being pumped from the main spring pool.

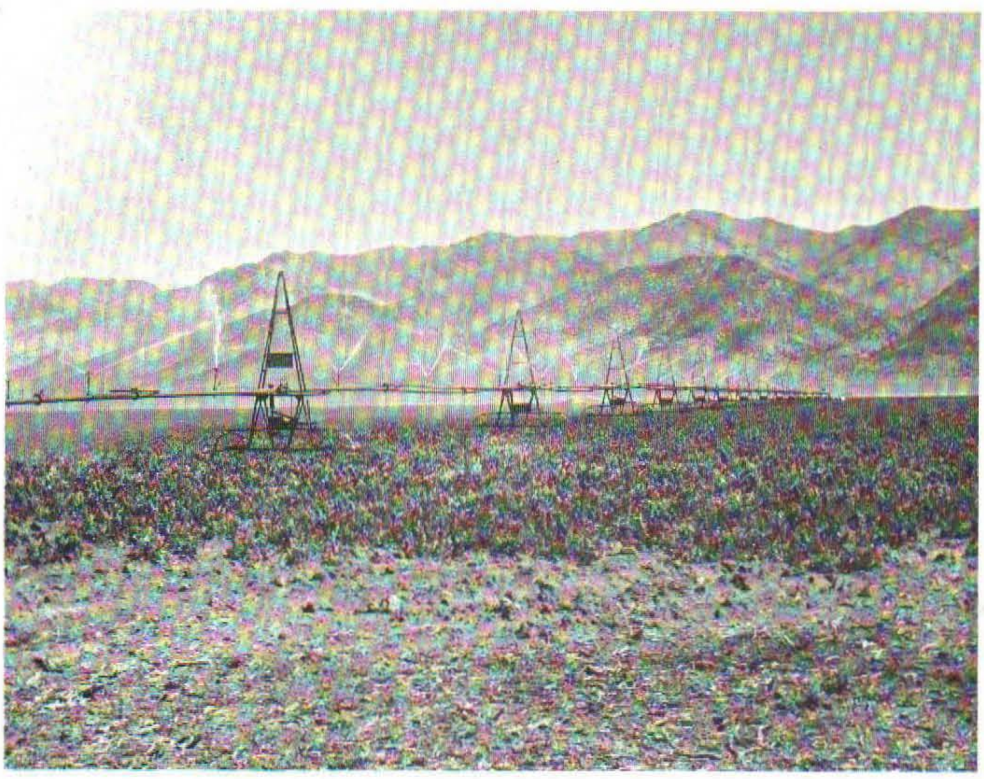
On the basis of development activity during the past year, and which is continuing at present, it appears that the summer of 1962 will be the first full season of large-scale irrigation pumpage in Diamond Valley.

Proposals for Additional Studies

In compliance with the request of Hugh A. Shamberger, Director, Department of Conservation and Natural Resources, State of Nevada, suggestions for special studies that are listed below are recommended for obtaining needed basic data and for obtaining a better understanding of the factors that influence or control ground water in Diamond Valley and similar areas in Nevada. These studies are separate from the normal areal investigations that commonly are needed after the development of ground water in a given area becomes substantial.

1. A detailed study of artificial withdrawal of ground water and discharge from principal springs during the irrigation season of 1962:

Photograph 5. View northwest showing typical well installation in Diamond Valley in field of small grain. Discharge from well goes directly into aluminum pipe which, in turn, is connected with sprinkler lines.



Photograph 6. View of "valley" sprinkler in 160-acre field of potatoes. Sprinkler line is self-propelled by hydraulic action. Line is connected with well at one end and rotates around well which is in the center of the quarter section.

It is expected that the summer of 1962 will be the first year of full scale irrigation pumpage in Diamond Valley. It is vitally important to obtain a firm determination of pumpage early in the history of a valley in which substantial development is taking place, as it will provide a firm reference on which to analyze the effects of intensive pumpage after 5 and 10 years of development. Obviously too, an early record of annual withdrawal will provide useful data to the farmers and ranchers of the valley and will aid in obtaining a better understanding of the ground-water resource on which their farming is based.

The study would include making pumping tests, discharge measurements of springs and wells at different times during the irrigation season, and obtaining water-level measurements during the irrigation season together with additional data required to estimate total ground-water withdrawal for irrigation in the valley. In order to obtain the necessary data field work on this study probably should be ready to begin by April 15, 1962.

2. An investigation of the microclimate of the lower part of Diamond Valley. This study was proposed previously in the report on Long Valley (Eakin, 1961, p. 27-28). It is repeated here because the current development of Diamond Valley makes it desirable to obtain information that can be used directly in the area.

An investigation of this type, although not entirely related to ground-water resources, is necessary for resolving certain water-resources problems, and additionally, it would have considerable economic value to irrigation interests.

The investigation would be directed toward the study of temperature variations with respect to topography, location, orientation, and exposure, in closed or nearly closed valleys. A second objective would be a similar study on the distribution of precipitation within the same area. Together the data would be valuable in explaining variations in the length of the growing season in different parts of a closed valley. Valuable information could be obtained also on direct precipitation as a partial water supply for cropland in various topographic positions in a closed valley.

3. A detailed study of the chemical character of water in Diamond Valley. This investigation would be useful not only for determination of the suitability for use for a wide variety of crops that may be tested in the valley, but also, for providing data in further defining the ground-water hydrology of the area.

4. Geophysical surveys of Diamond Valley. The results of a segment of a reconnaissance gravity survey are shown in plate 2 and are briefly discussed in this report. The data very broadly indicate the gross form of the valley fill, which includes Tertiary deposits. Better definition of the configuration of the subsurface contact between the bedrock and valley fill could be obtained by a detailed gravity survey. However, this would require more

control data from additional deep wells such as the Shell oil test. The deep wells would be required to provide more data on lithology, porosity, permeability and gravity of the valley fill and to provide positive control points on the position of the bedrock.

Magnetic and seismic surveys also may provide valuable data to define further the physical environment of Diamond Valley.

The time which geophysical surveys of the above types may be undertaken is dependent upon the availability of control data of and the economic need for comprehensive data on the ground-water hydrology of the valley.

DESIGNATION OF WELLS

The wells in this report are designated by a single numbering system. The number assigned to the well is both an identification number and a location number. It is referenced to the Mount Diablo base line and meridian established by the General Land Office.

A typical number usually consists of three units. The first unit is the township north of the Mount Diablo base line. The second unit, a number separated by a slant line from the first, is the range east of the Mount Diablo meridian. The third unit, separated from the second by a dash, is the number of the section in the township. The section number is followed by one or two lower case letters, the first of which designates the quarter section, the second, the quarter-quarter section, and, finally, a number designating the order in which the well was recorded in the smallest subdivision of the section. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest and southeast quarters and quarter-quarters of the section.

For example, well number 21/53-4dd1 indicates the first well recorded in the southeast quarter of the southeast quarter of sec. 4, T. 21 N., R. 53 E.

Owing to limitation of space, wells on plate 1 and figure 2 are identified only by the section number, quarter section and quarter-quarter section letters and serial number. The township in which the well is located can be ascertained by the township and range numbers shown at the margin of plate 1 and figure 2.

Wells listed in table 8 are shown either on plate 1 or figure 2.

Table 8.--Records of selected wells in Diamond Valley

19/53-8ab1. Owner, formerly A. C. Florio. Altitude 6,110 feet. Drilled stock well; casing diameter 6 inches. Equipped with cylinder pump and internal combustion engine. Measuring point, top of pipe clamp at land surface. Depth to water below land surface 178.3 feet, September 28, 1960. (Also prior water level measurements).

19/53-12C1. Owner, Irene Anderson. Altitude 6,440 feet. Dug domestic well; casing diameter 2 1/2 feet; depth of well 7.6 feet. Temperature 46°F. Measuring point, top of concrete curb which is 2.4 feet above land surface. Depth to water below land surface 5.49 feet, March 9, 1961.

20/53-1bd1. Owner, Mr. Mahacheck. Altitude 5,955 feet. Drilled irrigation well; depth of well 181 feet. Equipped with turbine pump and internal combustion engine. Measuring point, access tube on west side of pump, about 0.2 foot above land surface. Depth to water below land surface 81.83 feet, September 12, 1961.

20/53-4dd1. Owner, not determined. Altitude 5,928 feet. Drilled irrigation well; concrete casing, 13 inches in diameter. Equipped with turbine pump and diesel engine. Depth of well 180 feet, reported. Measuring point, 1-inch hole in pump base which is at land surface. Depth to water, below land surface, 56.5 feet, September 13, 1961.

20/53-10ad1. Owner, Mrs. Michael Mahacheck. Altitude, 5,994 feet. Drilled irrigation well; casing diameter 16 inches, depth 180 feet. Measuring point, top of casing, about 1 foot above land surface. Depth to water, below land surface, 72.54 feet, September 13, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	6	6
Gravel, loose coarse, and sand	27	33
Gravel, medium to coarse, and sand	9	42
Gravel, tight, coarse, and sand	18	60
Gravel, medium, with sand	11	71
Gravel, cemented	2	73
Gravel, loose, coarse sand	10	83
Gravel, loose, coarse, water-bearing	15	98
Gravel, partly cemented	4	102
Gravel, loose, coarse, water-bearing	29	131
Gravel streak, cemented	2	133
Gravel, medium to small	16	149
Gravel streak, cemented	2	151
Gravel, medium to fine	12	163
Gravel, good coarse, water-bearing	20	183
Total depth		183

20/53-10dd1. Owner, Joseph A. Mahacheck. Altitude, 5,953 feet. Drilled irrigation well; steel casing diameter 16 1/4 inches, depth 200 feet. Measuring point, top of casing, about 1 foot above land surface. Depth to water below land surface, 79.97 feet, September 13, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	6	6
Gravel, coarse, sand, silt	26	32
Gravel, medium to coarse, with sand	9	41
Gravel, coarse, tight, and sand	21	62
Gravel, sand and clay	6	68
Gravel, cemented, and clay	2	70
Gravel, loose	9	79
Gravel, loose, coarse, water-bearing	16	95
Gravel, partly cemented	3	98
Gravel, loose, coarse, water-bearing	29	127
Gravel, partly cemented	2	129
Rock, coarse, and smaller gravel	17	146
Gravel, partly cemented	2	148
Gravel, partly cemented, clay	5	153
Gravel, medium fine to coarse	8	161
Lime, cemented, gravel streak	1	162
Gravel, fine to medium	18	180
Lime, cemented, gravel streak	2	182
Gravel, medium to fine loose	14	196
Lime, cemented, gravel streak	2	198
Gravel, loose medium to fine	2	200
Total depth		200

20/53-15B1. Owner, not determined. Altitude, 5,951 feet. Dug stock well; casing diameter 48 inches; depth 99 feet. Equipped with cylinder pump and windmill. Measuring point, top of 4- by 4-inch timber at land surface. Depth to water below land surface, 77.2 feet, September 13, 1961. (Also prior water-level measurements.)

20/53-21adl. Owner, Elaine B. Johnson. Altitude, 5,970 feet. Drilled irrigation well; casing diameter 16 inches; depth 213 feet. Measuring point, top of casing about 1 foot above land surface. Depth to water below land surface, 100.95 feet, September 15, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Gravel, medium to fine	10	15
Clay, soft	15	30
Clay, hard gray	2	32
Clay, light colored	25	57
Gravel, partly cemented	5	62
Gravel, cemented	30	92
Gravel, large washed, loose	10	102
Gravel, clean, large, water-bearing	10	112
Gravel, coarse, and sand	46	158
Clay, brown	4	162
Gravel, partly cemented	20	182
Semi-sandstone, fine grained	5	187
Clay and gravel mixed	13	200
Gravel, tight cemented	13	213
Total depth		213

20/53-23dbl. Owner, not determined. Altitude, 6,030 feet. Drilled stock well; casing diameter 6 inches. Equipped with cylinder pump and windmill. Measuring point, 1/8-inch hole in casing, about 1 foot above land surface. Depth to water below land surface, 134.23 feet, September 12, 1961.

20/53-29B1. Owner, Lions Club, Eureka. Altitude, 5,988 feet. Drilled stock well; casing diameter 6 inches; depth 142 feet. Equipped with jet pump and electric motor. Perforated from 112-142 feet. Well reported to have been bailed at 40 gpm. Temperature reported as 40°F. Measuring point, top of casing which is 0.7 foot above land surface. Depth to water below land surface, 103.9 feet, August 28, 1956. (Also prior water-level measurements.) Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil, brown	6	6
Sand, gravel, brown, clay	14	20
Clay, sandy, blue-gray	50	70
Clay, brown, sand and gravel	66	136
Sand and gravel, water-bearing	6	142
Total depth		142

20/54-19bc1. Owner, not determined. Altitude, 6,070 feet. Unused drilled well; casing diameter 8 3/4 inches; depth 189 feet. Measuring point, top of casing, about 3 feet above land surface. Depth to water below land surface, 168.07 feet, September 12, 1961.

21/53-1bd1. Owner, not determined. Altitude, 5,882 feet. Drilled irrigation well; casing diameter 16 inches. Equipped with turbine pump. Measuring point, top of casing which is about 1 foot above land surface. Depth to water below land surface, 32.40 feet, September 13, 1961.

21/53-1cd2. Owner, not determined. Altitude, 5,886 feet. Drilled irrigation well; casing diameter 16 inches. Measuring point, top of casing which is 0.5 foot above land surface. Depth to water below land surface, 36.58 feet, September 13, 1961.

21/53-3cd1. Owner, Katherine Veatch. Altitude, 5,883 feet. Drilled irrigation well; casing diameter, 16 inches; depth 182 feet. Equipped with turbine pump and diesel motor. Measuring point, 1-inch hole in pump base which is about 0.5 foot above land surface. Depth to water below land surface, 37.80 feet, September 13, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Sand and gravel	41	46
Clay	37	83
Sand and gravel	32	115
Clay	15	130
Sand and gravel	26	156
Clay	5	161
Sand and gravel	8	169
Clay	4	173
Sand and gravel	9	182
Total depth		182

21/53-3db1. Owner, Sam Dick. Altitude, 5,883 feet. Drilled irrigation well; casing diameter, 16 inches; depth, 182 feet. Equipped with turbine pump and diesel motor. Measuring point, 1-inch hole in pump base, about 1 foot above land surface. Depth to water below land surface, 38.24 feet, September 13, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Sand and gravel	27	32
Sand layers and clay	50	82
Sand and gravel	30	112
Gravel with clay layers	20	132
Sand (fine) layers and soft clay	30	162
Sand and gravel	20	182
Total depth		182

21/53-4dd1. Owner, C. Clayton Cooper. Altitude, 5,885 feet. Drilled irrigation well; casing diameter 16 inches; depth 182 feet. Equipped with turbine pump and diesel motor. Discharge reported as 2,160 gpm. Temperature reported as 58°F. Measuring point, 1-inch hole in pump base which is about 1 foot above land surface. Depth to water below land surface, 34.10 feet, September 12, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Sand, dry and gravel	31	36
Clay, soft	11	47
Sand, fine	3	50
Clay, soft	13	63
Sand and gravel	28	91
Clay, soft	3	94
Sand and gravel with small clay layers	88	182
Total depth		182

21/53-4dd2. Owner, C. Clayton Cooper. Altitude, 5,886 feet. Drilled irrigation well. Equipped with turbine pump and internal combustion engine. Measuring point, top of 1-inch hole in pump base which is about 1 foot above land surface. Depth to water below land surface, 37.59 feet, September 12, 1961.

21/53-5cb1. Owner, formerly A. C. Florio. Altitude, 5,879 feet. Dug and drilled stock well; casing diameter 4 feet; depth 42 feet. Equipped with cylinder pump and windmill. Measuring point, top of steel plate over casing which is 1.5 feet above land surface. Depth to water below land surface, 30.89 feet, September 12, 1961.

Water levels, in feet, below land surface

Date	Water level	Date	Water level	Date	Water level
June 17, 1947	28.94	Sept. 11, 1951	28.92	Feb. 3, 1959	29.27
Oct. 27	28.90	Oct. 1, 1952	28.86	Feb. 16	29.23
Apr. 25, 1948	28.78	Mar. 3, 1953	28.76	Mar. 3	29.23
June 15	28.72	Sept. 15	28.69	Mar. 17	29.23
June 17, 1949	28.92	Mar. 8, 1954	28.61	Apr. 1	29.24
Sept. 13	28.98	Apr. 8	28.65	Apr. 14	29.22
Dec. 16	28.94	Sept. 16	28.68	Apr. 28	29.25
Mar. 17, 1950	28.83	Aug. 29, 1955	28.96	May 11	29.26
June 19	28.85	Mar. 26, 1956	28.93	July 1, 1960	29.50
Sept. 16	28.90	Aug. 28	29.00	Oct. 1	29.65
Mar. 15, 1951	28.87	Jan. 21, 1959	29.21	Sept. 12, 1961	30.89

21/53-8dc1. Owner, Alfred Farley. Altitude, 5,896 feet. Drilled irrigation well; casing diameter 13 inches; depth 192 feet. Temperature reported as 59°F. Measuring point, top of casing, about 1 foot above land surface. Depth to water below land surface, 42.12 feet, September 12, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Sand	7	12
Sand and gravel with clay layers	72	84
Sand, gravel and clay layers	79	163
Gravel	6	169
Clay, soft	10	179
Gravel	13	192
Total depth		192

21/53-10dc1. Owner, not determined. Altitude, 5,892 feet. Drilled irrigation well; casing diameter 13 inches. Measuring point, top of casing which is 0.5 foot above land surface. Depth to water below land surface, 41.87 feet, September 13, 1961.

21/53-12cc1. Owner, not determined. Altitude, 5,895 feet. Drilled irrigation well; casing diameter, 16 inches. Equipped with turbine pump and diesel motor. Measuring point, top of 1-inch hole in pump base which is 1 foot above land surface. Depth to water below land surface, 41.70 feet, September 13, 1961.

21/53-13bb1. Owner, Ruthel DuBose. Altitude, 5,897 feet. Drilled irrigation well; casing diameter, 16 inches; depth 182 feet. Equipped with turbine pump. Discharge reported as 2,300 gpm with a drawdown of 57 feet. Measuring point, top of casing which is at land surface. Depth to water below land surface, 42.23 feet, September 13, 1961.

21/53-14aa1. Owner, Betty Sue Murphy. Altitude, 5,898 feet. Drilled irrigation well; casing diameter, 16 inches; depth 182 feet. Equipped with turbine pump and internal combustion engine. Discharge reported as 2,350 gpm with a drawdown of 57 feet. Depth to water below land surface reported April 15, 1961 as 42 feet.

21/53-14da1. Owner, Melvin S. Murphy, Altitude, 5,900 feet. Drilled irrigation well; casing diameter, 16 inches; depth 182 feet. Discharge reported as 1,480 gpm with a drawdown of 74 feet. Temperature reported as 58°F. Depth to water below land surface 44.51 feet. Measuring point, top of casing which is at land surface. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	4	4
Sand, dry and gravel	14	18
Clay, soft	8	26
Sand and gravel	18	44
Clay, soft	12	56
Sand, black and gravel	48	104
Clay, soft, gray	18	122
Sand, fine	14	136
Clay, soft	4	140
Sand and gravel	8	148
Clay	4	152
Gravel and coarse sand	4	156
Clay	3	159
Gravel and coarse sand	11	170
Clay	6	176
Sand and gravel	6	182
Total depth		182

21/53-15bc1. Owner, Vida Cooper. Altitude, 5,900 feet. Drilled irrigation well; casing diameter 16 inches; depth 182 feet. Discharge reported as 2,250 gpm with a drawdown of 68 feet. Equipped with a turbine pump and diesel engine. Temperature reported as 58°F. Depth to water below land surface, 43.27 feet, September 13, 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	5	5
Sand, dry and gravel	20	25
Sand and clay layers	21	46
Gravel and sand	23	69
Clay, soft	22	91
Gravel, big, coarse	11	102
Sand, fine	14	116
Sand and gravel with small clay layers	66	182
Total depth		182

21/53-20aa1. Owner, not determined. Altitude, 5,930 feet. Drilled irrigation well; casing diameter 16 inches; depth 196 feet. Measuring point, top of casing which is 0.5 foot above land surface. Depth to water below land surface, 70.83 feet, September 12, 1961.

21/53-21aa1. Owner, Faye Cannedy. Altitude, 5,910 feet. Drilled irrigation well; casing diameter 16 inches; depth 182 feet. Equipped with turbine pump and diesel engine. Discharge reported as 2,410 gpm with a drawdown of 50 feet. Depth to water below land surface reported as 48 feet, March 15, 1961.

21/53-21bc1. Owner, not determined. Altitude, 5,917 feet. Drilled irrigation well; casing diameter 16 inches. Measuring point below top of casing which is 1.5 feet above land surface. Depth to water below land surface 59.25 feet, September 12, 1961.

21/53-22cd1. Owner, not determined. Altitude, 5,910 feet. Drilled stock well; casing diameter 6 inches. Equipped with cylinder pump and windmill. Measuring point, top of coupling on 6-inch casing. Depth to water below land surface, 50.35 feet, September 13, 1961. (Also prior water-level measurements.)

21/53-22dc1. Owner, Louis Heller. Altitude, 5,910 feet. Drilled irrigation well; casing diameter 16 inches; depth 117 feet. Discharge reported as 1,750 gpm with a drawdown of 26 feet. Temperature reported as 58°F. Depth to water below land surface, 47.6 feet, June 7, 1960. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	4	4
Sand, dry, and gravel	13	17
Clay, soft	3	20
Sand and gravel	40	60
Clay, soft	11	71
Sand, black, very fine	7	78
Sand and gravel, water-bearing	39	117
Total depth		117

21/53-23da1. Owner, Dewey F. Murphy. Altitude, 5,905 feet. Drilled irrigation well; casing diameter 17 inches; depth 166 feet. Equipped with a turbine pump and an internal combustion engine. Discharge reported as 2,040 gpm with a drawdown of 27 feet. Measuring point, lip of 1 1/4-inch pipe which is 0.5 foot above land surface. Depth to water below land surface, 49.88 feet, September 13, 1961. Temperature reported as 58°F. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	12	12
Gravel, dry; and sand	10	22
Clay	6	28
Sand, dry	18	46
Clay, gray, blue, soft	54	100
Sand	6	106
Clay, soft	4	110
Gravel, clean, water-bearing	12	122
Sand and gravel with some clay layers	19	141
Clay, soft	11	152
Gravel	14	166
Clay		166
Total depth		166

21/53-26aa1. Owner, not determined. Altitude, 5,910 feet. Drilled irrigation well; casing diameter 13 inches. Measuring point, top of casing which is at land surface. Depth to water below land surface, 50.64 feet, September 13, 1961.

21/53-26ba1. Owner, Delma Kibbe. Altitude, 5,910 feet. Drilled irrigation well; casing diameter 16 inches; depth 176 feet. Equipped with a turbine pump and a diesel engine. Discharge reported as 2,250 gpm with a drawdown of 61 feet. Depth to water below land surface 54 feet, November 11, 1960. Temperature reported as 58°F. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	4	4
Sand, dry, and gravel	28	32
Clay, soft, gray	18	50
Clay, soft, black	11	61
Sand, black, medium to fine	14	75
Clay, soft, gray	20	95
Sand, very fine	4	99
Clay, soft	7	106

Material	Thickness (feet)	Depth (feet)
Sand and gravel, water-bearing	37	143
Clay, soft	11	154
Sand, medium	11	165
Gravel, water-bearing	9	174
Clay, white	2	176
Total depth		176

21/53-27cc1. Owner, Clifford Fisher. Altitude, 5,915 feet. Drilled irrigation well; casing diameter 16 inches; depth 151 feet. Equipped with a turbine pump and a diesel engine. Discharge reported as 2,480 gpm with a drawdown of 49 feet. Measuring point, top of 1-inch hole in pump base which is 0.5 foot above land surface. Depth to water below land surface, 54.40 feet, September 12, 1961. Temperature reported as 59°F. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	4	4
Sand, dry	11	15
Clay, soft	6	21
Clay, soft, blue	21	42
Sand, medium	13	55
Clay	10	65
Gravel, water-bearing	12	77
Clay	2	79
Sand and gravel	70	149
Clay	2	151
Total depth		151

21/53-33ac1. Owner, not determined. Altitude, 5,920 feet. Drilled irrigation well; casing diameter 13 inches; depth 118 feet. Equipped with turbine pump and diesel engine. Reported depth to water when drilled, 56 feet. Discharge reported as 2,400 gpm with a drawdown of 37 feet.

21/53-33dd1. Owner, not determined. Altitude, 5,922 feet. Drilled irrigation well; casing diameter 13 inches; depth 118 feet. Equipped with a turbine pump and a diesel engine. Depth to water below land surface reported as 56 feet when drilled.

21/53-34bb1. Owner, not determined. Altitude 5,922 feet. Drilled irrigation well; casing diameter 13 inches. Measuring point, top of casing which is 0.5 foot above land surface. Depth to water below land surface 57.13 feet, September 13, 1961.

21/53-35cd1. Owner, Ola G. Gullett. Altitude, 5,922 feet. Drilled irrigation well; casing diameter 18 1/4 inches; depth 195 feet. Casing perforated 150 feet to 195 feet, 1/8-inch by 7/8-inch perforations. Equipped with a turbine pump. Discharge reported as 1,640 gpm with a drawdown of 42 feet. Measuring point, top of casing which is 0.5 foot above land surface. Water level below land surface, 51.62 feet, September 13, 1961. Temperature reported as 54°F. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	4	4
Sand, fine; and small gravel	11	15
Sand, coarser; and small gravel	10	25
Clay, gray	3	28
Gravel, fine; conglomerate	4	32
Gravel	8	40
Clay, gray	4	44
Gravel, fine	8	52
Clay, brown	23	75
Gravel, fine	5	80
Clay, gray	5	85
Clay and gravel mixture	1	86
Sandstone, brown	9	95
Gravel, fine, water-bearing	5	100
Clay, gray	6	106
Gravel, small, water-bearing	3	109
Clay	8	117
Gravel, coarse	5	122
Clay	9	131
Gravel	1	132
Gravel and clay mixture	8	140
Gravel	1	141
Clay	4	145
Gravel	3	148
Gravel and clay mixture	2	150
Sand and gravel, water-bearing	45	195
Total depth		195

Generally, precipitation in Diamond Valley averages 8 inches or less on the valley floor. The average precipitation is greater on the mountains which drain to the valley floor. In the most favorable higher parts of the Diamond Mountains the maximum average annual precipitation may exceed 20 inches.

The climatic summary of records of temperature at Eureka, prior to 1931, show an average annual temperature of 47.4°F. A current average is not given because of incomplete records since 1931. However, it seems likely that the earlier average of about 47°F probably approximate the long-time average. The extremes of temperature for the period of record are 110° and -26°F.

The records of temperature at Fish Creek Ranch show an average annual temperature of 42.2°F for the 16 years ending 1960. The extremes of temperature for the period of record are 98° and -34°F.

Comparison of the two records suggest that temperatures at the Fish Creek Ranch generally are somewhat lower than at Eureka. This may be due to the differences in topographic location of the two stations. Eureka is in a canyon on the flanks of the mountains. Fish Creek Ranch is on the floor of Fish Creek Valley. If this relationship is significant, the area of irrigation in Diamond Valley, which also is on the valley floor, may have a shorter growing season than that at Eureka.

Recent Weather Bureau records list freeze dates rather than killing frost dates. The dates are listed for the last spring minimum and the first fall minimum for temperatures of: 32°F or below, 28°F or below, 24°F or below, 20°F or below, and 16°F or below. From these data, the number of days between the last spring minimum and the first fall minimum are given for each temperature group. Table 4 lists the number of days between the last spring minimum and the first fall minimum of the three principal temperature groups for Eureka and Fish Creek Ranch as available during the period 1951-60. For the 7-year period of correlative record 1953-59, the average at Fish Creek Ranch is consistently shorter than at Eureka for each temperature group. The apparent relative shortness of the growing season in Diamond Valley suggests that this will be one of the important factors in the long-time success of irrigation in the valley. Because of the importance of length of growing season, it would seem prudent to establish stations for obtaining precipitation and temperature data in the principal area of irrigation as a future aid in estimating the length of growing season.

Table 4.--Freeze data for Eureka and Fish Creek Ranch stations 1951-60

(from published records of the U.S. Weather Bureau)

	Number of days between temperatures of:					
	$32^{\circ}F$ or below		$28^{\circ}F$ or below		$24^{\circ}F$ or below	
Year	Eureka	Fish Creek Ranch	Eureka	Fish Creek Ranch	Eureka	Fish Creek Ranch
1951	--	9	--	81	--	94
1952	--	44	--	87	--	142
1953	111	3	128	69	129	89
1954	96	48	115	70	150	98
1955	108	7	117	82	143	88
1956	109	11	109	58	133	135
1957	95	28	96	35	96	121
1958	93	2	134	98	140	139
1959	27	8	112	79	131	121
1960	--	87	--	87	--	141
10-year average		25		75		117
Average for 1953-59	91	15	116	70	117	113

Physiography and Drainage

Diamond Valley is an intermontane valley in the central part of the Great Basin section of the Basin and Range Province of Fenneman (1931, p. 328). It is roughly elliptical, elongate in a northerly direction.

Its southern end terminates in the Fish Creek Range, several miles south of Eureka. The Diamond Mountains form the east boundary of the valley and connect with the Fish Creek Range on the south. The Sulphur Springs Range, Whistler Mountain, and Mahogany Boy Range form the west boundary of the valley. The valley is closed at the north end by the Diamond Hills which connect the Diamond Mountains with the Sulphur Springs Range in the vicinity of Baily Mountain.

Diamond Peak, T. 20 N., R. 55 E., is the highest point in the area with an altitude of 10,614 feet. Most of the crest altitudes of the Diamond Mountains are 9,000 feet or higher. Prospect Peak, south of Eureka, is 9,571 feet above sea level. Most of the crest altitudes of the Sulphur Springs Range are between 7,000 and 7,500 feet.

Devil's Gate Gap, between Whistler Mountain and Mahogany Boy Range, is a topographic low which permits drainage, both surface and subsurface, into Diamond Valley from Antelope, Kobeh, and Monitor Valleys.

Railroad Pass in the northeast part of the valley was an outlet for drainage from Diamond Valley into Huntington Valley in Pleistocene time. The altitude of the divide in Railroad Pass is now about 125 feet above the playa in the valley.

The large playa or alkali flat at an altitude of about 5,770 feet, which occupies the floor of the valley north of the latitude of the Romano and Thompson Ranches, is the lowest part of the valley, the floor of the valley rises southward. Near the airport, about 20 miles south of the edge of the playa, the altitude is 5,945 feet. Thus, the average gradient is about 9 feet per mile. The south part of the floor of the valley has been somewhat modified by stream channels and Pleistocene lake features.

Beaches and slopes are prominent locally in the vicinity of Railroad Pass, northwest of the Romano Ranch, and elsewhere. Shoreline features are best developed at altitudes between 5,860 and 6,040 feet. These features were developed in late Pleistocene time.

Physiographically, the valley may be divided into three parts: the mountain, the alluvial apron, and the valley floor.

The mountains are areas of erosion and are characterized by steep slopes. (See photographs 1 and 2.) Canyons commonly are deeply incised, especially in the Diamond Mountains. The streams draining the mountains not only carried off excess water from the heavy precipitation but also transported weathered rock and soils. As they discharged from the canyons, they dumped much of their load thereby forming alluvial fans. As the alluvial fans expanded, they merged with adjacent fans to form the alluvial apron. (See photograph 3)

The alluvial apron was formed principally during Pleistocene time when runoff from the mountains was much greater than in Recent time. The surface slopes of the alluvial apron commonly have gradients of 200 to 500 feet per mile. In Recent time the reduced runoff from the mountains has resulted in less sediment being transported from the mountains. This, in turn, has resulted in some dissection of parts of the alluvial apron below the mouths of canyons.

The valley floor occupies the central part of Diamond Valley. It includes the playa and the lowland area to the south that generally lies below an altitude of 6,000 feet. The playa is a nearly flat surface covering an area of almost 50,000 acres. The lowland area south of the playa has a northward gradient generally less than 10 feet per mile. Where the valley floor merges with the alluvial apron gradients increase gradually but ordinarily do not exceed 100 feet per mile.

The valley lowland south of the playa has been modified by streams flowing from the mountains in the southeast and south part of the valley, by Slough Creek which drains a large area to the west and southwest of Diamond Valley, and by earlier formed beaches, bars and spits developed by currents in late Pleistocene lakes of Diamond Valley. These modifications have produced bluffs and channels which have a local relief of 10 to 25 feet. Some of the channels contain well-developed oxbows which commonly are features associated with perennial streams having relatively low gradients.

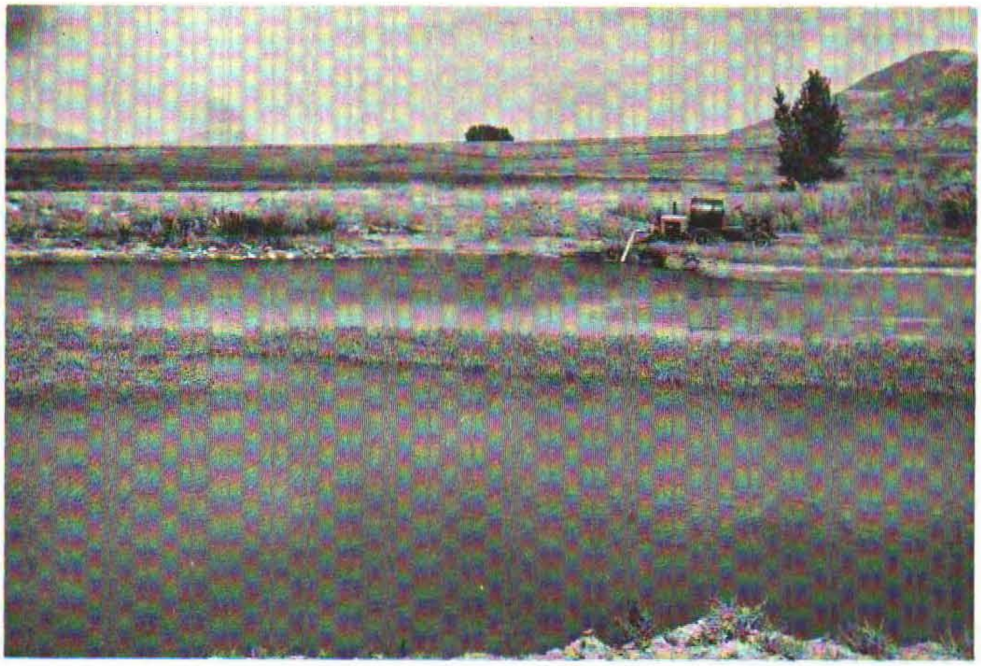
Present-day streams are principally confined to a few of the canyons in the mountains, and discharge to the alluvial apron or valley lowland only during periods of spring or flood runoff.

GENERAL GEOLOGY

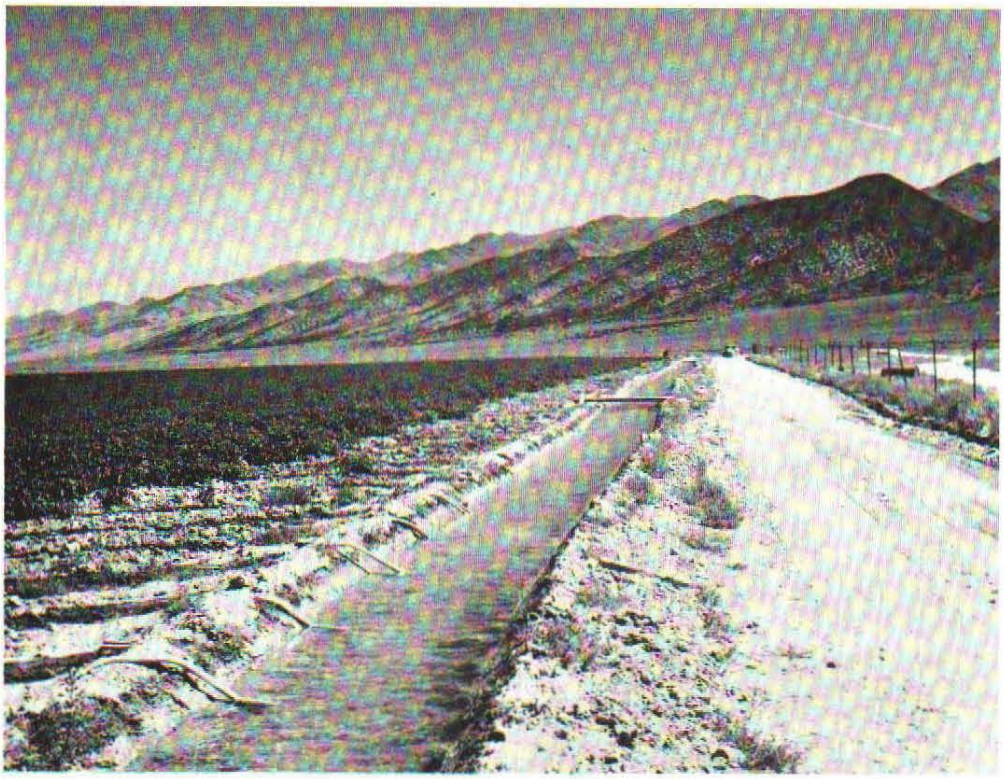
The rocks of Diamond Valley may be divided into two major units, the bedrock and the valley fill, on the basis of their general relation to topography and ground water.

The bedrock includes: rocks of Paleozoic age consisting principally of dolomite, limestone, and lesser amounts of shale, sandstone (or quartzite), and conglomerate; fresh-water limestone, conglomerate, silt, sandstone and grit of Early Cretaceous age; intrusive rocks of Late Cretaceous or early Tertiary age; extrusive lavas and associated pyroclastics of Tertiary age. These rocks crop out in the mountains and underlie the valley fill.

The valley fill includes clay, silt, sand, gravel, evaporites, and probably fresh-water limestone and pyroclastics deposited under subaerial and lacustrine conditions. It is construed that the valley fill also includes deposits of Cenozoic age and probably is several thousands of feet thick beneath the floor of Diamond Valley. Plate 1 shows the general distribution of bedrock and valley fill in Diamond Valley.



Photograph 3. Main spring pool at Thompson Ranch. Note portable pumping plant used to supply field of alfalfa in left middle distance. Alfalfa is irrigated by sprinkler system.



Photograph 4. View north in T. 21 N., R. 54 E. showing main ditch, siphons and furrow irrigation of potato field.

Bedrock in the Mountains

The bedrock in the mountains have been extensively studied in the Eureka area by Nolan, Merriam, and Williams (1956). Merriam and Anderson (1942) reported on an extensive reconnaissance survey of the R oberts Mountains which lie just west of and connect with the Sulphur Springs Range. Dott (1955) discussed the Pennsylvanian stratigraphy of the northern part of the Diamond Mountains. Carlisle, Murphy, Nelson, and Winterer (1955) reported on the Devonian stratigraphy of the Sulphur Springs Range. Nolan (1943) and Roberts, Hotz, Gilluly, and Ferguson (1958) have discussed broad aspects of Paleozoic formations and structure. Currently Lehner, Tagg, Bell, and Roberts (written communication, 1961) of the Geological Survey are completing a reconnaissance of Eureka County as part of the cooperative program between U.S. Geological Survey and the Nevada Bureau of Mines. These and other studies, both published and unpublished, provide a good reference framework on which to consider the bedrock formations in Diamond Valley.

Valley Fill

The valley fill of Diamond Valley has not been studied to an appreciable extent. Generally, however, it may be considered as the detritus, derived from the surrounding mountains and adjacent region, that underlies the present area of the valley lowland and contiguous alluvial apron and that is unconsolidated or only partially consolidated.

Regnier (1960) studied in Pine Valley to the west of the Sulphur Springs Range and describes the Cenozoic geology and anmes several Tertiary formations that might not be too dissimilar from deposits of Tertiary age which are included as valley fill in Diamond Valley. Also, Humphrey (1960) in his study of the White Pine Mining District describes two Tertiary formations that are exposed in the alluvial apron of Newark Valley. Typically the Tertiary formations described by Regnier and Humphrey contain a substantial proportion of pyroclastic material associated in part with shale, sandstone and conglomerate, but which include diatomite and fresh-water limestone. They also include vitric or welded tuff that may be closely related to the ignimbrites described in other areas of central Nevada. Ignimbrites are volcanic rocks generally considered to be deposited as a gaseous cloud and have some characteristics of both lava flows and pyroclastic rocks.

The maximum thickness of the valley fill, as here used, is not known. The thickness is substantial in some places as is indicated by the exploratory well drilled by the Shell Oil Company in 1956. This exploratory well, in sec. 30, T. 23 N., R. 54 E., is reported by Campbell and Hebrew (1957, p. 1, 246) to have penetrated 7,485 feet of valley fill and undifferentiated Tertiary strata before entering Paleozoic rocks.

The configuration of the bottom of the valley fill is determined by the pre-Tertiary bedrock surface upon which the valley fill was deposited. The bedrock surface was irregular when Tertiary deposition began and was deformed further to its present shape by structural activity during Cenozoic time.

Although the present shape of the pre-Tertiary bedrock surface is not known in detail the general form of the surface is suggested by recent reconnaissance regional gravity studies, which includes Diamond Valley, made by Mabey and others.

Plate 2 shows contours of the simple Bouguer anomaly in milligals as reported by Mabey (written communication, 1961) for the Diamond Valley part of the area investigated.

The gravity low in Diamond Valley is produced by a density contrast between the Cenozoic rocks and the generally more dense older rocks. The amplitude of the anomalies is dependent upon the density contrast and the thickness of the Cenozoic valley fill. The gravity anomaly in Diamond Valley is about 40 milligals and the Shell exploratory well shows that the valley fill is 7,485 feet at the well site. Thus, as an approximation, it can be assumed that each milligal of anomaly indicates about 200 feet of fill. This assumption requires a density contrast between the Cenozoic fill and the underlying bedrock of about 0.4 gram per cubic centimeter. Density contract of this order has been found to be a good approximation in most of the Basin and Range province (Mabey, written communication, 1961).

In general then, the basin in which the valley fill occurs in Diamond Valley apparently is an elongate trough about parallel to the surficial configuration of the valley, with the deeper part being somewhat closer to the Diamond Mountains than to the Sulphur Springs Range. This approximation is adequate for most purposes of the investigation of ground water at this time. At a later time, when more well data are available, and when a comprehensive investigation is warranted, it also may be desirable to conduct detailed gravity or other geophysical surveys to aid in more closely defining the configuration of the bottom of the valley fill.

Stratigraphy

The stratigraphy in the vicinity of Diamond Valley is summarized in the Appendix for those readers who may wish to examine the descriptions. Descriptions of Paleozoic and Mesozoic rock units in the mountains surrounding Diamond Valley are adapted from Nolan, Merriam, and Williams (1956). The descriptions of Cenozoic strata are adapted from Regnier (1960, p. 1191) and Humphrey (1960, p. 41-46). The Tertiary stratigraphic names are those used by Regnier and Humphrey and are not necessarily those of the U.S. Geological Survey. The description of Tertiary formations are given only to illustrate the types of Tertiary lithology that might be penetrated in drilling below Quaternary sediments in Diamond Valley.

Geologic History

The geologic history of an area provides a convenient outline of the sequence of events that have occurred. This sequence is an aid to obtaining a better understanding of the physical controls on the movement and occurrence of ground water.

Much additional investigation is needed to define the details of the geologic history of central Nevada, especially the Cenozoic history. The following outline of events is therefore highly generalized and approximate only.

1. Deposition of dolomite, limestone, sandstone, shale, and minor amounts of coarser clastic sediments during Paleozoic time. Development of a "linear swell" or positive area in Early or Middle Ordovician time and renewed in Late Devonian to Permian time. The swell had a marked effect on the lithologic character of the sediments and also resulted in several angular unconformities within the Paleozoic rock sequence.

2. Intensive diastrophism in one or more periods, including folding related extensive thrust faulting, accompanied by erosion from highland areas and continuing through much of Mesozoic time.

3. In Early Cretaceous time, erosion of highland areas and deposition in lowland areas of the Newark Canyon formation, consisting of fresh-water limestone, conglomerate, grit, sandstone and silt.

4. Emplacement of rocks in Late Cretaceous and early Tertiary time, probably accompanied by folding and high-angle faulting. The largest exposure is the Tertiary andesitic intrusive which forms the core of Whistler Mountain.

5. Extrusion of lavas and pyroclastic rocks in Tertiary and Quaternary time. Principal exposures in Diamond Valley are southeast of Eureka and scattered outcrops on the east flank of the Sulphur Springs Range north of the Siri Ranch.

6. Deposition in Tertiary and Quaternary time of pyroclastic rocks and lavas as well as diatomite, limestone, shale, sandstone and conglomerate, most of which are buried in Diamond Valley beneath the Quaternary deposits of the alluvial apron and the valley floor.

7. Faulting and folding intermittently during Cenozoic time. That involving the Quaternary lavas resulted in essentially the present day form of Diamond Valley.

8. Erosion in the mountains and deposition in the valley during Pleistocene time. Sedimentation occurred under subaerial and lacustrine environments. Sediments range in size from clay to gravel and locally include evaporites. One or more lakes occupying the valley in late Pleistocene time resulted in the formation of beaches and spits which are still prominently preserved, as in the vicinity of Railroad Pass, and near the ranches along the west side of the valley. These remnants occur principally between altitudes of about 5,880 and 6,040 feet.

9. Since the last Pleistocene lake, alternating periods of aridity and humidity, which probably resulted in alternation of shallow lakes and dry lake conditions in the present playa area. Streams flowing to the playa area from the south during the more humid periods dissected or removed late Pleistocene beach features in the south part of the valley. These streams probably were perennial for relatively long periods to permit the development of meander scrolls along the drainage ways in the valley floor. Concurrent dissection of stream channels crossing the alluvial apron, and deposition of relatively fine-grained sediments or evaporites, principally in the playa area.

Water-Bearing Properties of the Rocks

The oldest rocks in Diamond Valley are of Paleozoic age and are exposed principally in the mountains. They consist chiefly of limestone and dolomite with lesser but substantial amounts of shale and sandstone or quartzite. Consolidated rocks of these types usually have low primary permeability--that is, the openings present at the time of deposition were small or have been filled. However, the rocks in central Nevada have been substantially folded, faulted, weathered and otherwise altered and locally contain many secondary openings, mainly joints. These fractures, which locally have been enlarged by solution, have created a substantial secondary permeability that locally is quite important with respect to movement of ground water in the bedrock. Studies by Stuart (1955, p. 11 and Stuart and Metzger, written communication, 1961) indicate that formations or parts of formations such as the Eldorado Dolomite, Hamburg Dolomite, and the Geddes, Goodwin and Antelope Valley Limestones are capable of transmitting water in moderate to large quantities at least locally, as in the area of the Fad shaft near Eureka. In the same reference, Stuart indicates that formations such as the Dunderberg Shale, Secret Canyon Shale, and Prospect Mountain Quartzite are relatively impermeable and normally would transmit small to negligible amounts of ground water. Additionally, Shipley Hot Springs (T. 22 N., R. 52 E.) and other principal pool springs at ranches along the east and west sides of the valley are located near bedrock outcrops and probably are supplied to a substantial extent by water moving through secondary openings in bedrock formations of Paleozoic age.

Paleozoic rocks underlie the valley fill at varying but usually substantial depths. However, the degree to which they would yield water to wells is not known.

The limestone, conglomerate, silt, sandstone, and grit comprising the Newark Canyon Formation of Cretaceous age is consolidated and may be expected to transmit only small to negligible quantities of water through fractures. The known distribution of this formation is generally above the regional zone of saturation, but perched water may move through fractures to supply small springs in the mountains in the area of outcrop west of Diamond Peak.

The Tertiary and Quaternary volcanic rocks generally should be capable of transmitting only small supplies of water through fractures, especially the lavas. The amount of water so transmitted probably is only sufficient to maintain small springs locally in the mountains.

The Tertiary and Quaternary deposits that form the valley fill probably span nearly the complete range of sedimentary and pyroclastic rock types and includes evaporites. The proportion of the various rock types cannot yet be evaluated with the data at hand. Although these deposits differ greatly from place to place in their capacity for storing ground water, collectively they store a large volume of water.

A large part of the valley fill probably has a relatively low permeability and therefore will not yield water readily to wells. However, the valley fill also contains sand and gravel strata which are quite permeable and which are capable of yielding water freely to adequately constructed wells. Examples of these strata are shown by the logs of most of the irrigation wells in T. 21 N., R. 53 E. (see table 8). It will be noted that most of these wells are less than about 200 feet deep. As the valley fill may have a maximum thickness of several thousand feet, it can be assumed that the known distribution of permeable sand and gravel strata probably represents only a small fraction of the total volume of the valley fill.

GROUND-WATER APPRAISAL

General Conditions

Ground water in Diamond Valley is presumed to originate largely within the drainage basin, supplemented to a limited but unknown extent by surface and subsurface flow through Devil's Gate, south of Whistler Mountain. Precipitation as snow or rain on the flanks of the Diamond Mountains and the mountain mass at the south end of the valley, and to a lesser extent the Sulphur Springs Range, undoubtedly supplies most of the water that recharges the ground-water reservoir. Precipitation on the alluvial apron at times may be of such intensity, duration, and distribution as to result in recharge to the ground-water reservoir. The valley floor south of the playa commonly is underlain by permeable deposits between the land surface and the water table. This suggests favorable conditions for some recharge from the melting of snow on the valley floor, from moderate to heavy precipitation of adequate duration, or from streamflow on the valley floor.

Some surface and subsurface flow enters Diamond Valley through Devil's Gate from the large drainage area to the west that includes Antelope, Monitor, and Kobeh valleys. Ordinarily the amount of water coming through the gap is small, but in years of very large runoff from the west, streamflow through Devil's Gate might be at a substantial rate for limited periods. The long-time average recharge to the ground-water reservoir in Diamond Valley from this source probably is small.

The valley fill is the principal ground-water reservoir. The bedrock also contains a considerable volume of ground water, as shown by the studies of Stuart and Metzger (written communication, 1961). The degree to which ground water in the bedrock and in the valley fill is hydraulically connected is not yet known. However, on a valley-wide basis, the connection probably is good, although it may be localized.

The amount of ground water in storage in the valley fill is substantial and is many times the volume represented by the average annual recharge to and discharge from the valley fill.

Ground water is discharged from Diamond Valley by transpiration of phreatophyte vegetation and evaporation through the soil where the water table is at or relatively near the land surface. Ground water discharged from the springs along east and west sides of the valley and marginal to the playa is finally discharged from the valley by transpiration of vegetation and evaporation from the soil and free-water surface of ponds or wet meadows.

The water table in the valley fill generally is within a few feet of the land surface in the area of the playa and its immediate vicinity. Numerous small gravity springs and seeps marginal to the playa testify to the shallow depth to water in this area. Springs also occur along the lower edge of the alluvial apron, principally in Tps. 23 and 24 N. on the west and east sides of the valley. Most of the larger springs, such as Shipley Hot Spring and the main spring at Thompson Ranch, have artesian heads. (See photographs 2 and 3). That artesian conditions are operative in these areas is further supported by the flowing wells on the Romano Ranch. Discharge from the artesian springs and upward leakage in the vicinity has resulted in a shallow water table in the meadow areas down-gradient from the springs.

The water table generally increases in depth from the playa area to the mountains. In the valley lowland, the altitude of the water table rises gradually from 5,770 at the playa to about 5,870 feet in the vicinity of well 20/53-21ad1. Irregularity of the land surface results in considerable variation in the depth to water. Commonly though the depth to water in many of the irrigation wells ranges from 10 to 60 feet.

Under long-time natural conditions, the amount of recharge to a given ground-water system is balanced by the amount of water discharged from that system. For any particular year recharge and discharge probably will not be equal, but will involve a change in the amount of ground water in storage. Many data, which are not collected in these reconnaissance investigations, are required to make reasonably accurate estimates of ground-water recharge or discharge. However, crude estimates of recharge and discharge can be made on the basis of the long-time average rainfall and evapotranspiration, and are useful for those concerned with water development and management. The methods used in this report to estimate average annual recharge and discharge are the same as those used in prior reports of this reconnaissance series.

Estimated Average Annual Recharge

An estimate may be made of the average annual recharge to the ground-water reservoir as a percentage of the average annual precipitation within the valley (Eakin and others, 1951, p. 79-81). A brief description of the method follows: Zones in which the average annual precipitation ranges between specified limits are delineated on a map, and a percentage of the precipitation is assigned to each zone which represents the estimated probable average recharge from the average annual precipitation of that zone. The degree of reliability of the estimate so obtained, of course, is related to the degree to which the values approximate the actual longtime average precipitation and the degree to which the assumed percentages represent the long time average recharge from that zone. Neither of these factors is known precisely enough to assure a high degree of reliability for any one valley. However, the method permits application of a system from valley to valley, and has proved useful for reconnaissance estimates. Additionally, experience suggests that in many areas the estimates probably are relatively close to the actual long-time average annual recharge.

The precipitation map of Nevada (Hardman and Mason, 1949, p. 10) was compared to the topographic map used as the base for plate 1. Precipitation zones were modified slightly to fit the better controlled topographic map. The division between the zones of less than 8 inches and 8 to 12 inches of precipitation was delineated at the 5,800-foot contour south of T. 24 N. and the 6,000-foot contour north of T. 23 N., between the 8 to 12 inches and 12 to 15 inches of precipitation at the 7,000-foot contour, between 12 to 15 inches and 15 to 20 inches of precipitation at the 8,000-foot contour, between the 15 and 20 inches and the over 20 inches of precipitation at the 9,000-foot contour. The valley floor area between the 5,800- and 6,000-foot contours south of T. 24 N. was included in the zone of 8 to 12 inches of precipitation because of the somewhat permeable character of the deposits between land surface and the water table in that area, as shown by several well logs, which would favor recharge resulting from snow or localized high-intensity rains in this area.

The average precipitation assumed for the respective zones beginning with the zone of less than 8 inches is 7 inches (0.58 foot), 10 inches (0.83 foot), 13.5 inches (1.12 feet), 17.5 inches (1.46 feet), and 21 inches (1.75 feet).

The average annual recharge, estimated as a percentage of the average annual precipitation for each zone, is as follows: less than 8 inches, 0 percent; 8 to 12 inches, 3 percent; 12 to 15 inches, 7 percent; 15 to 20 inches, 15 percent; and over 20 inches, 25 percent.

Table 5 summarizes the computation. The approximate average annual recharge, in acre-feet (column 5) for the zone of 15 to 20 inches of precipitation is obtained by multiplying the area of the zone, in acres, (column 2) by the average precipitation (column 3) by the percentage of recharge (column 4) divided by 100, and rounding the product. Thus, for the 15- to 20-inch precipitation zone: 17,000 x 1.46 x 15 ÷ 100 =3,700 acre-feet. Estimates of the recharge for the other zones are computed in a similar manner.

The estimated average annual recharge from precipitation, as shown in table 5, is on the order of 16,000 acre-feet. This is substantially less than the estimated average annual discharge of 23,000 acre-feet, which is discussed in the following section. The reason for the large difference between these estimates was not determined.

It was noted, however, that the ground-water discharge on the west side of the valley in Tps. 23 and 24 N. appeared to be relatively large, considering the relatively limited drainage area westward to the topographic divide of the Sulphur Springs Range. Recharge in this part of Diamond Valley in part may be supplied from areas beyond the topographic divide; that is, from the upper part of the drainage area of Garden Valley. However, there are no data to confirm this and at best it can be only a hypothesis until a more detailed investigation can be made.

Table 5.--Estimated average annual ground-water recharge from precipitation in Diamond Valley

(1) Precipitation zone (inches)	(2) Approximate acreage of zone	(3) Estimated average annual precipitation	(4) Percent recharge	(5) Approximate recharge (acre-feet) (2x3x4÷100)
20+	3,000	1.75	25	1,300
15-20	17,000	1.46	15	3,700
12-15	63,000	1.12	7	4,900
8-12	245,000	.83	3	6,400
8-	127,000	.58	--	----
Total				(16,300)
		Rounded		16,000

Estimated Average Annual Discharge

Ground water is ultimately discharged from Diamond Valley by transpiration of water-loving vegetation (phyreatophytes) and by evaporation from soil and free-water surfaces. Discharge by springs eventually is discharged from the valley by the above processes. Thus, an estimate of natural discharge of ground water may be made by evaluating the amount of water that is evaporated and transpired.

Ground water discharge by wells and consumptively used for cultivated crops or evaporated in the irrigation process would be in addition to the natural discharge. Some of the water pumped for irrigation probably returns to the ground-water reservoir and, thus, would not be removed from the ground-water system. Ground water pumped from wells for irrigating crops is discussed in a later section.

Table 6 summarizes the estimates of discharge by transpiration of phreatophyte vegetation and related evaporation from soil and free-water surfaces. Rates of use are adapted from studies of evapotranspiration of certain phreatophytes made by Lee (1912) and White (1932) in the Great Basin and by Young and Blaney (1942) in Southern California. Rates of use were assigned on the basis of vegetative types, density, and depth to water table.

Table 6. --Estimated average annual natural ground-water discharge from Diamond Valley

Process of discharge	Area (acres)	Approximate discharge (acre-feet per year)
Native vegetation:	47,000	14,100
Principally greasewood, rabbitbrush, saltgrass in varying proportions; density moderate to low but locally moderate to heavy; depth to water ranges from a few to about 20 feet, averaging about 10 feet below land surface. Average annual use about 0.3 foot.		
Meadow and pasture grasses:	5,600	8,900
Mixed grasses, depth to water 0 to 5 feet. Largely irrigated by discharge from springs and shallow ground water. Excludes that part supplied by streamflow and direct precipitation. Includes about 4,600 acres with an estimated average annual ground-water use of about 1.25 feet, and about 1,000 acres of meadow, which normally is flooded with water discharged from springs, estimated average annual use of 3 feet.		
Playa area:		
(Ground-water discharge not estimated)	49,000	---
Total:		23,000+

The areas of phreatophytes and playa and consequently the principal areas of discharge are largely in the northern part of the valley floor. The principal areas of native meadow and pasture are alined along the east and west margins of the valley floor in the latitude of Tps. 23 and 24 N. The greasewood, rabbit-brush, and salt grass areas are generally distributed as a band marginal to the playa.

The shallow water table in the playa area indicates that some ground water is being evaporated. However, the average annual rate of evaporation of a not known. Therefore, no estimate is given in table 6, although evaporation is a few thousand acre-feet a year might occur. A recommendation to investigate the rate of evaporation of ground water from playas was made previously (Eakin, 1960, p. 19). Data from such investigations would be of valuable assistance in making reconnaissance and more detailed estimates of discharge in other valleys of Nevada which contain playas.

Perennial Yield

The perennial yield of the ground-water system is ultimately limited by the average annual recharge to and discharge from the system. It is the upper limit of the amount of water that can be withdrawn for an indefinite period of time from a ground-water system without permanent depletion of the stored water. The average recharge from precipitation and the average discharge by evapotranspiration, discharge to streams, and underflow from a valley are measures of the natural inflow to and outflow from the ground-water system.

In an estimate of perennial yield, consideration should be given to the effects that ground-water development by wells may have on the natural circulation of the ground-water system. Development by wells may, or may not, induce recharge in addition to that received under natural conditions. Part of the water discharged by wells may re-enter the ground-water reservoir by downward percolation, especially if the water is used for irrigation. Ground water discharged by wells usually would be offset eventually by a reduction of the natural discharge. In practice, however, it is difficult for well discharge to reduce fully the natural discharge, except when the water table can be lowered quickly to a level that eliminates both ground-water outflow and evapotranspiration in the areas of natural discharge. The numerous pertinent factors are so complex that, in effect, specific determination of perennial yield of a valley requires a very extensive investigation, based in part on data that can be obtained economically only after there has been substantial development of ground water for several years.

As a preliminary measure of the long-term perennial yield of Diamond Valley, the estimate of average annual discharge is used. Thus, the estimated annual discharge of about 23,000 acre-feet also is considered to be the preliminary estimate of the perennial yield. On the one hand, this may be a conservative estimate to the extent that additional ground water is discharged by evaporation from the playa area. But, on the other hand, the estimate may be too high, because the estimated average ground-water recharge of 16,000 acre-feet may be more nearly correct. It is apparent then that the upper limit of the perennial yield of the natural ground-water system may be several thousand acre-feet more or less than the 23,000 acre-feet here estimated.

Movement

Ground water in general moves from areas of recharge to areas of discharge.

From the areas of recharge in the mountains the ground water moves slowly (perhaps on the general order of a few feet or a few tens of feet a year) toward the area of discharge which surrounds the playa in Diamond Valley.

Figure 2 shows generalized water-level contours of the ground water in the principal area of recent development south of the playa. It will be noted that the altitude of the contours decrease northward which indicates general movement toward the playa area. The northward swing of the contours on the east side indicates movement of ground water from the Diamond Mountains. Control is meager on the west side, but there is a suggestion of some movement of ground water from the mountains on the west side of the valley also. Pumping during the irrigation season of 1961 has modified the natural contours to some extent as is suggested by the irregularity of some individual contours, such as the 5,860-foot contour. No attempt has been made in this investigation to determine the precise effect of the pumping. This would require instrumental leveling to obtain close altitude control for well-measuring points and more detailed information of conditions prior to the time of measurements in September 1961. However, it appears that effects of pumping in the vicinity of the pumped wells locally may have amounted to several feet. It is not known whether these effects represent a "permanent" lowering of water level in the specific areas or whether full recovery from the pumping season had not occurred at the time of measurement.

Movement of ground water also is indicated by fluctuations in the water surface of the ground-water reservoir.

Figure 3 shows the fluctuation of water-levels in 2 wells during the period 1947-61. These hydrographs are based on occasional measurements and thus do not show details of fluctuations. However, they do show longer-term trends. Under natural conditions the water level fluctuates in response to storage changes and other factors in the ground-water reservoir, the storage changes in response to the relative balance between recharge and discharge. Fluctuations due to changes in storage commonly are small in areas relatively distant from areas of recharge or discharge. The hydrograph of well 21/53-5cb1 is generally representative of a small range of fluctuation of this type. The decline in the 1960-61 period may be, in part, a response to recent pumping. The location of well 22/54-34ab1 is close to ground-water recharge from the Diamond Mountains. Accordingly, its natural range of fluctuation would be expected to be greater than that for well 21/53-5cb1. It may be that most of the magnitude of decline in water levels in this well is a response to the drought periods of the last 10 years. It seems likely too that at least some of the decline may be induced by pumping, but the magnitude can not be estimated from present information.

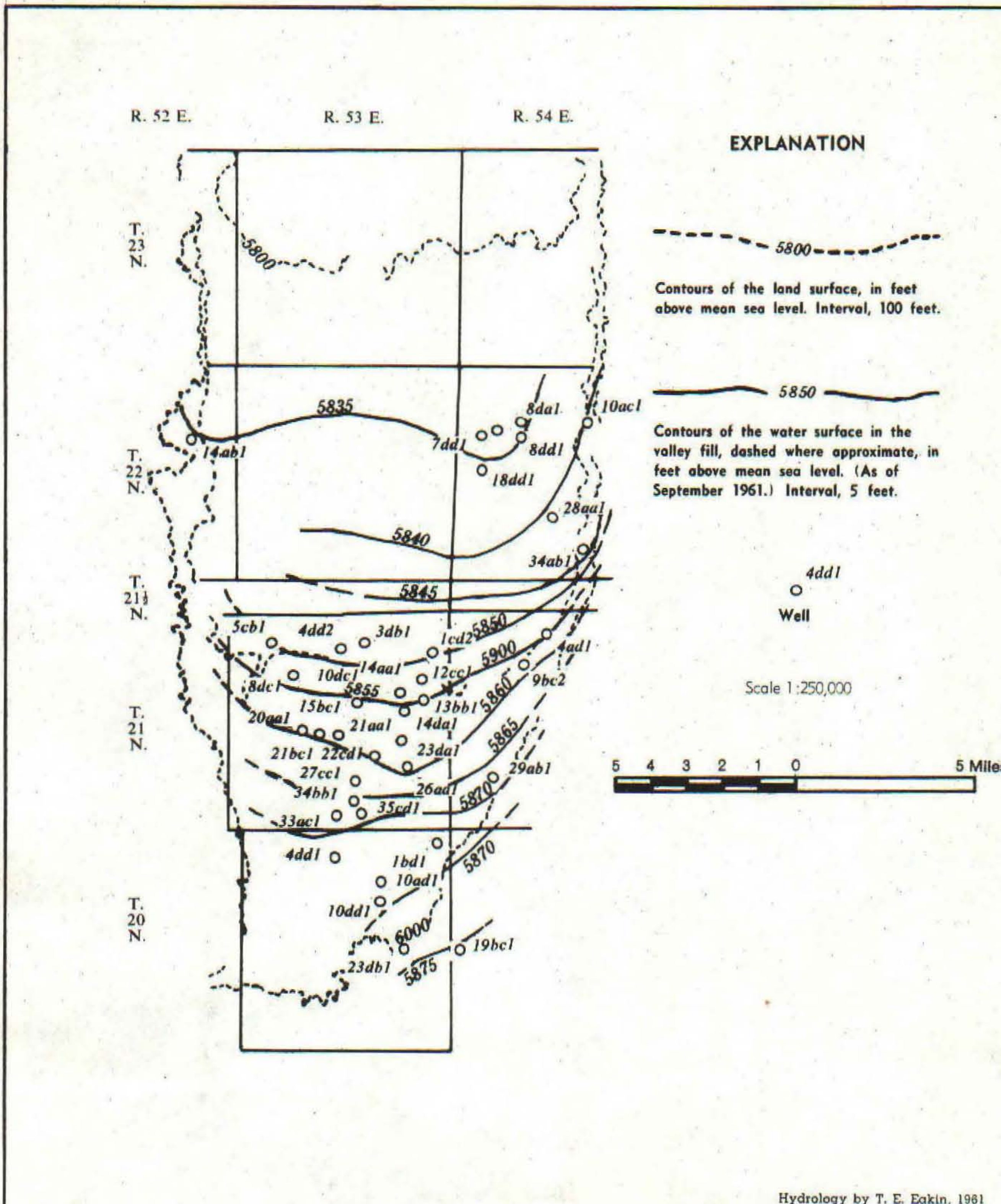


Figure 2. Sketch of principal area of ground-water pumping in Diamond Valley, showing generalized water-level contours.

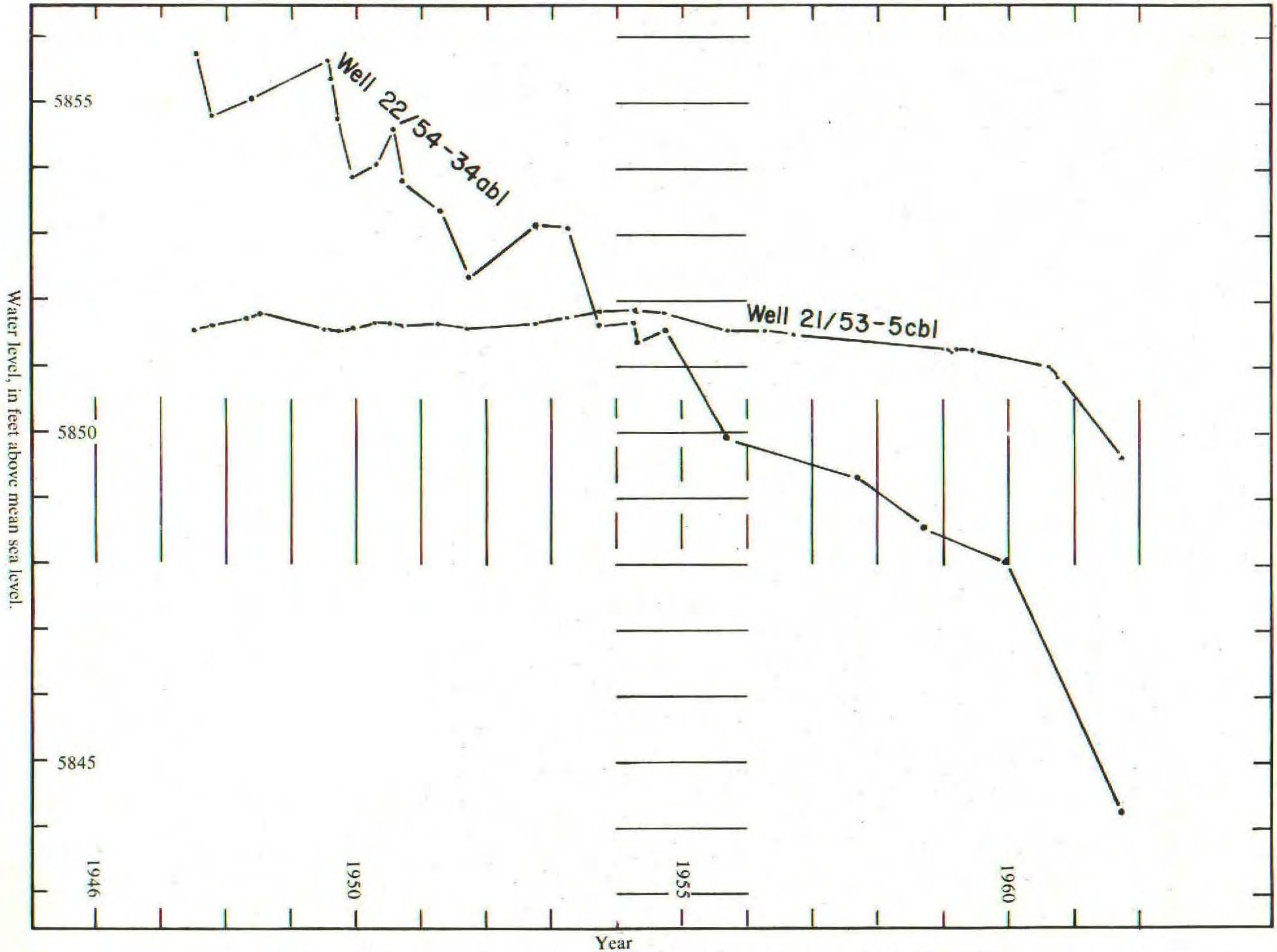


Figure 3. Hydrographs of two wells, in Diamond Valley, showing fluctuations of water level, 1947–61.

The relation of the movement of ground water in valley fill to the movement of ground water in bedrock is not known in detail. Investigations (Stuart and Metzger, written communication, 1961) of the mining hydrology in the vicinity of the Fad shaft, 1.4 miles west-southeast of Eureka, has shown substantial complexity of ground-water movement in the bedrock formations, but that, in general, the movement of ground water is northward. It is logical to expect that the detailed movement from the bedrock to the valley fill also is complex but, in the overall sense, that it functions as part of a single gross hydrologic system in Diamond Valley.

Storage

A large amount of ground water is stored in the valley fill in Diamond Valley. It is many times the volume of the annual ground-water recharge and discharge. Some concept of the magnitude of the ground water in storage may be obtained by the following calculation: The surface area of the valley fill lying below the 6,000-foot contour south of the playa is on the order of 140,000 acres. If it is assumed that only about 100,000 acres of this is the surface area beneath which the valley fill is saturated, and if a value of 15 percent is assumed as the specific yield (drainable pore space) of the saturated fill, then about 15,000 acre-feet of ground water is theoretically available from storage for each saturated foot of thickness of valley fill. This is equivalent to about 65 percent of the estimated average annual ground-water discharge under natural conditions. On this basis, the amount of ground water in storage in a 100-foot thick section of the valley fill, for the area cited, would be equal to about 1.5 million acre-feet or 65 times the natural annual discharge from the ground-water reservoir.

In addition to the water in the valley fill, there is an unknown amount of groundwater stored in the bedrock. Thus, it is evident that the total amount of ground water in storage is many times the average annual recharge to and discharge from the ground-water system in Diamond Valley. The water so stored provides a reserve for maintaining an adequate supply for pumping during protracted periods of drought or for limited periods of high demand under emergency conditions. This reserve further increases the reliability of ground water as a dependable source of irrigation supply and is an important asset in semi-arid regions where surface-water supplies are widely variable from year to year.

Quality

The chemical quality of ground water in interior valleys generally varies considerably as the water moves through the ground-water system. In general, the concentration of dissolved chemical constituents normally is low in the areas of recharge. As the water moves toward areas of discharge it is in contact with rock materials which have different solubilities. The extent to which the water dissolves chemical constituents from the rock materials is governed in large part by the solubility, volume, and distribution of the different rock materials, the time the water is in contact with the rocks, and the temperature and pressure in the ground-water system. In the areas of natural discharge, the ground water is

9-185
(October 1950)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

check loc. in de

WELL SCHEDULE

Date Sept, 1961 Field No. 29/52-
Record by TEE + H. Winchester Office No.
Source of data Field

1. *Location:* State Nevada County Eureka
Map Diamond Valley
NE ¼ NE ¼ sec. 23 T 24 N R 52
2. *Owner:* Sadler Bros Address Eureka, Nev.
Tenant (Sadler Ranch) Address
Driller J B Reynolds Address Fallon, Nev.
3. *Topography*
4. *Elevation* ft. above/below
5. *Type:* Dug, drilled, driven, bored, jetted 19
6. *Depth:* Rept. 139 ft. Meas. ft.
7. *Casing:* Diam. in., to in., Type
Depth ft., Finish
8. *Chief Aquifer* From ft. to
Others
9. *Water level* ft. rept./meas. 19 above/below
which is ft. above/below surf
10. *Pump:* Type Capacity G. M.
Power: Kind Horsepower
11. *Yield:* Flow 500± G. M., Pump G. M., Meas., Rept. Est.
Drawdown ft. after hours pumping G.
12. *Use:* Dom., Stock, PS., RR., Ind., Irr., Obs.
Adequacy, permanence
13. *Quality* Temp
Taste, odor, color Sample Yes/No
Unfit for
14. *Remarks:* (Log, Analyses, etc.)

See back

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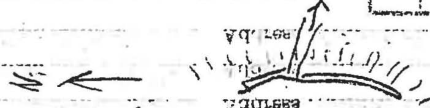
Generalized log

	thick	depth
Clay blue	70	70
Boulders dry [?]		95(?)
Total depth		139 [?]

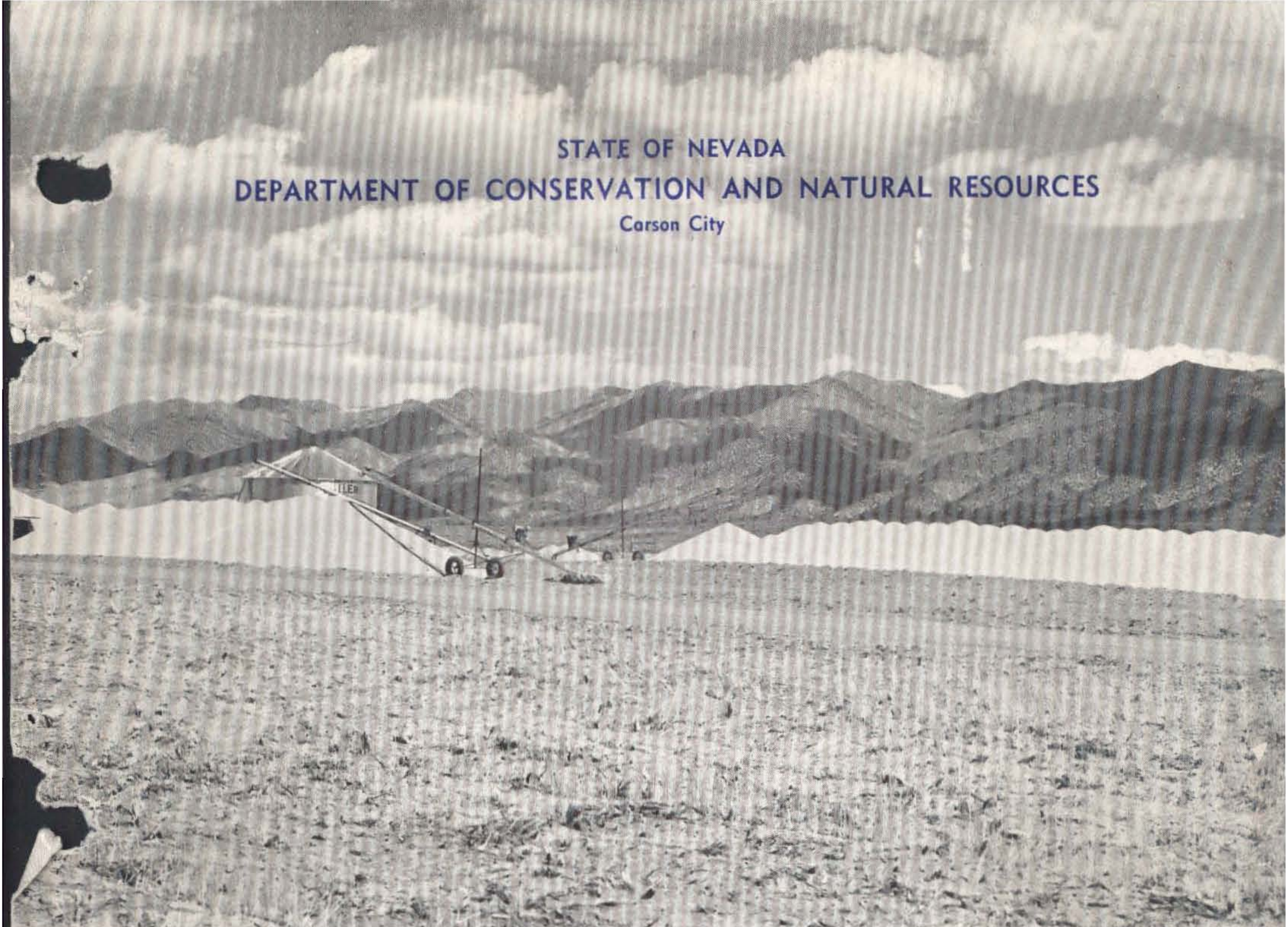
Note! Said [?] developed a spring in NE1/4 SE1/4 26-24/52 rept disch about 2 1/2 cfs present est disch 1 1/2 [illegible] cfs. Consists of trench cut parallel to contour at 12 ft deep and about 300 ft long



cut is in cemented (partially) boulder gravel.

Rept Shepley Hot Spr. disch abt. 12 1/2 cfs.

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



Diamond Valley—View of stored grain and Diamond Mountains

GROUND-WATER RESOURCES - RECONNAISSANCE SERIES
REPORT 6

GROUND-WATER APPRAISAL OF DIAMOND VALLEY, EUREKA AND ELKO COUNTIES, NEVADA

By
THOMAS E. EAKIN
Geologist

Price $1.00

Prepared cooperatively by the
Geological Survey, U. S. Department of Interior

FEBRUARY 1962

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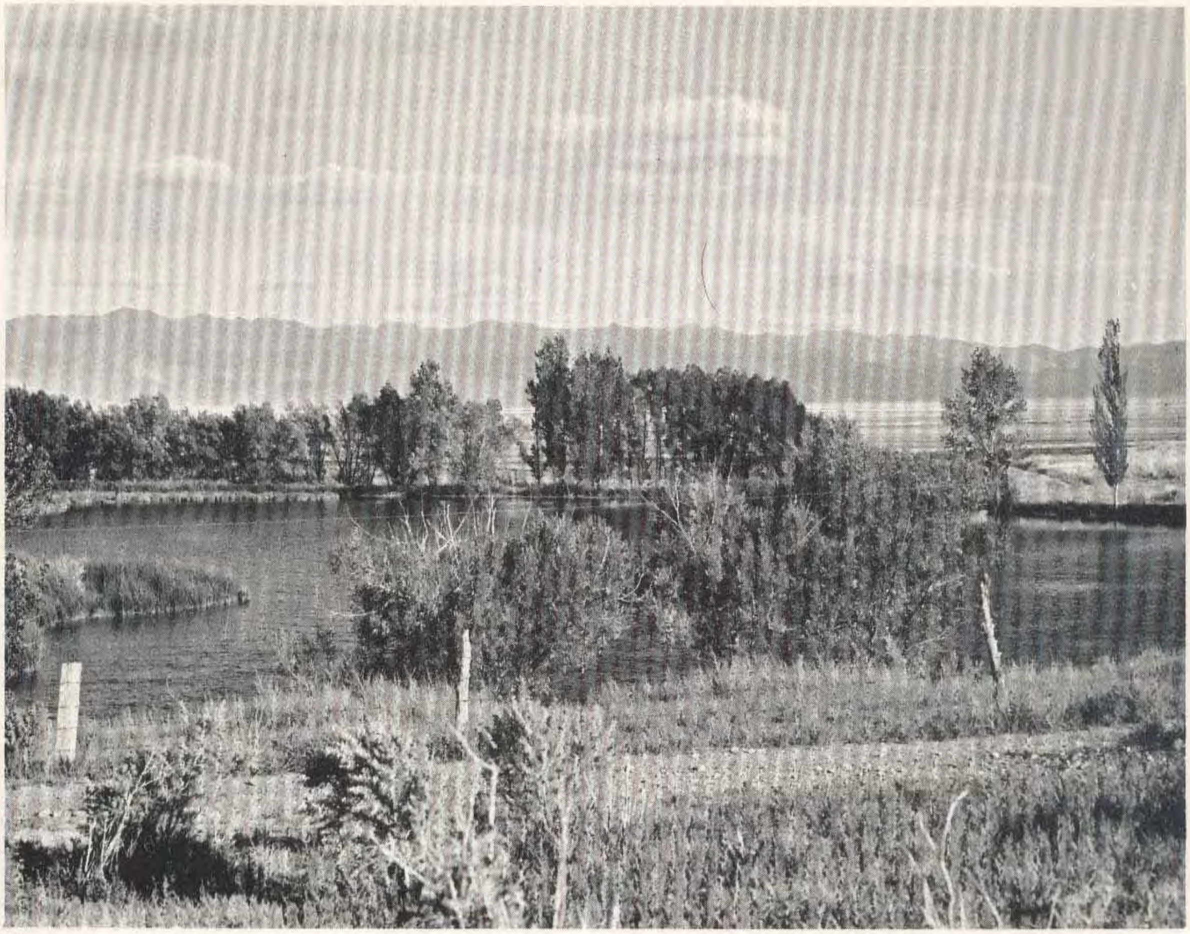

SHIPLEY HOT SPRINGS

View east of Shipley Hot Springs pool in T. 24 N., R. 52 E. Discharge is reported to be about 15 cfs. Water is used largely for irrigated meadows. Diamond Mountains are in the background.

COVER PHOTOGRAPH

View northeast from sec. 1, T. 21 N., R. 53 E. showing part of stored grain produced in 1961 in Diamond Valley. Central part of Diamond Mountains, in the latitude of the Maggini ranch, in the background.

GROUND-WATER RESOURCES - RECONNAISSANCE SERIES

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U. S. Department of the Interior

February

1962

FOREWORD

This is the sixth in the series of ground-water reconnaissance reports which were initiated by the 1960 legislature. The potential of the state's ground water basins is well set forth in this report as indicated by the recent ground water development in Diamond Valley. The report indicates that considerable development can continue without over-pumping.

It is the hope of this Department that the legislature will continue support of this reconnaissance program so that in time we will have information as to the ground water resources of all of the valleys in Nevada.

As the use of ground water increases in the various valleys, more detailed ground water studies will be carried on under the general cooperative program with the U. S. Geological Survey.

This report, as well as the others in this series, have been printed in this office under the direction of Mrs. Alta Thiex, Administrative Assistant.

Hugh A. Shamberger

Hugh A. Shamberger, Director
Department of Conservation and
Natural Resources

CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER APPRAISAL OF DIAMOND VALLEY

EUREKA AND ELKO COUNTIES, NEVADA

by

Thomas E. Eakin

SUMMARY

The results of this reconnaissance indicate that the average annual ground-water discharge by natural processes is on the order of 23,000 acre-feet. This estimate is believed to be reasonable and compatible with information developed for other valleys of Nevada where more extensive studies have been made. The estimate of natural discharge provides an initial guide for the amount of ground water that may be withdrawn annually on the basis of permanent development. The estimate can be re-evaluated at such time as a great many more data can be obtained and economic or other conditions warrant.

The estimate of average annual ground-water recharge, based on precipitation and altitude zones, is about 70 percent of the estimate of discharge. It has been found that the estimates of recharge may vary widely from the estimates of discharge for a specific valley although the estimates in general are in reasonable agreement. To the extent that the estimate of recharge for Diamond Valley is correct, the estimate of perennial yield, based on the estimate of discharge, is optimistic. However, available information suggests that the estimate of discharge probably is more reliable and therefore it is given the principal weight in this reconnaissance.

The amount of ground water in storage has been estimated to be on the order of 15,000 acre-feet per foot of saturated thickness in the valley fill within a 100,000-acre area south of the playa. On the same basis, the upper 100 feet of saturated valley fill would contain about 1,500,000 acre-feet in storage. This latter amount, which is equivalent to 65 times the estimated average annual discharge, is indicative of the very large amount of ground water in reserve for maintaining pumping withdrawals during protracted periods of drought.

The few chemical analyses of ground water that are available suggest that the ground water in the newly developed area generally is of a calcium-bicarbonate type and suitable for irrigation. However, additional analyses are needed to identify local differences in quality. This information probably is needed even more in Diamond Valley than in some other areas because a wide variety of crops are being used to test the capabilities of the valley.

The development of new lands by means of pumped irrigation wells began in 1949 in Diamond Valley. A small acreage was irrigated for several years. In

1958 a few additional wells were drilled, but substantial development began in 1960. By September 1961 about 85 irrigation wells had been drilled. Many of these wells were not in operation during the 1961 irrigation season, but may represent the approximate number of wells that will be operating during the 1962 irrigation season.

The water has been used to irrigate principally small grains with smaller acreages of potatoes and alfalfa. The principal area of development is in T. 21 N., R. 53 E. and T. 22 N., R. 54 E. To date, most wells have developed water from sand and gravel in the upper 200 feet of the valley fill. Yields for individual wells of 1,000 to 2,500 gpm commonly have been reported.

It is estimated very roughly, that about 5,000 acre feet of water was pumped during the 1961 irrigation season, and several times that amount may be pumped next year.

Information suggests that the pumpage has resulted in some decline of water levels in the newly developed areas, and this should be expected. However, available data are not sufficient to determine the area and extent of the decline with any degree of precision.

INTRODUCTION

The present development of ground water for irrigation in Diamond Valley is an example of the general effort in Nevada to develop additional water supplies for irrigation. Throughout the State additional development is needed not only for irrigation, but also for public supply and other uses.

The increasing interest in ground-water development has resulted in a substantial demand for information on ground-water resources throughout the State. Recognizing this need, the State Legislature enacted special legislation (Chap. 181, Stats. 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. The authorization and funding was continued in the 1961-62 biennium. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources.

The emphasis of these reconnaissance studies is to provide as quickly as possible a general appraisal of the ground-water resources in valleys or areas where published information is not available. For this reason each reconnaissance is limited severely in time, field work for each area generally averaging about two weeks.

Additionally, the Department of Conservation and Natural Resources has established a special report series to expedite the publication of the results of these reconnaissance studies. Figure 1 shows the areas for which reports have been published in this series. A list of the previous reports is given at the end of this report. The present report is the 6th in the reconnaissance series. It describes the physical conditions of Diamond Valley and includes observations of the interrelationship of climate, geology, and hydrology as they affect ground-water resources. It includes also a preliminary estimate of the average annual natural recharge to and discharge from the ground-water reservoir.

The investigation was made under the administrative supervision of Omar J. Loeltz, district engineer in charge of ground-water studies in Nevada. The writer wishes to acknowledge his appreciation to personnel of the district office for constructive discussions and review, relative to this report, all of which have been most helpful.

H. G. Winchester, of Nevada Division of Water Resources, accompanied and assisted the writer in the field for several days. Roger Lyman of the district office also assisted in the collection of field data on wells. The field assistance of Messrs. Winchester and Lyman materially expedited the field phase of this reconnaissance.

Special thanks are due to W. T. Stuart and D. G. Metzger of the Geological Survey for permission to draw upon the draft of their report dealing with mining hydrology in the vicinity of the Fad shaft near Eureka.

The well drillers, equipment suppliers, farmers, and ranchers in Diamond Valley were most helpful in supplying information which was valuable in this study.

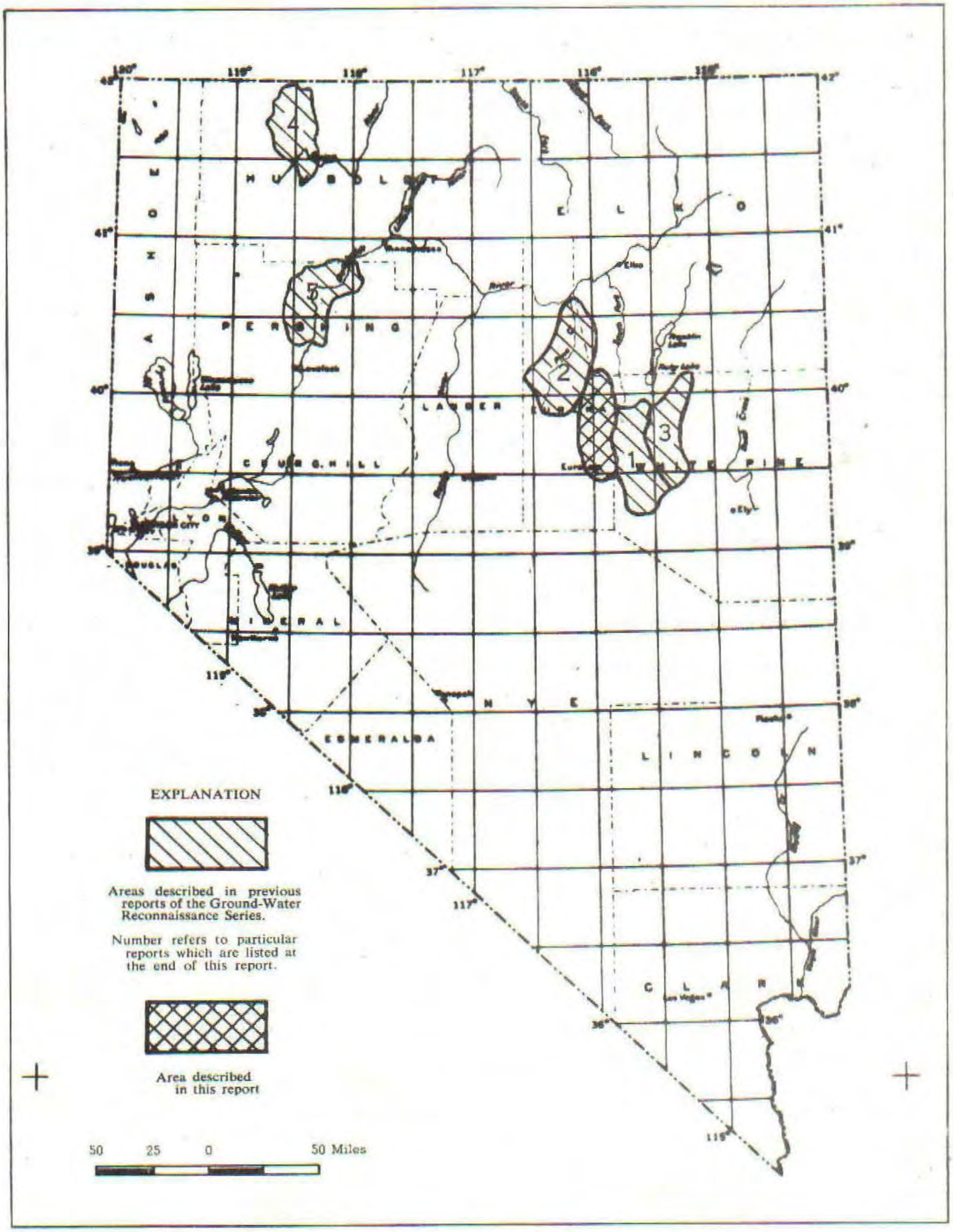

Figure 1.—Map of Nevada showing areas described in previous reports of the Ground-Water Reconnaissance Series and in this report.

Location and General Features

Diamond Valley, in east-central Nevada, lies within an area enclosed by lat 39°27' and 40°15' N., and long 115°47' and 116°12' W. It is principally in Eureka County but its northern end extends about 8 miles into southwestern Elko County.

The valley extends northward about 56 miles from the latitude of Pinto Summit on U.S. Highway 50. Its maximum width is about 20 miles in the latitude of township 22 north. Its average width is somewhat more than 12 miles. The total area within the drainage divide is about 700 square miles.

The lowest part of the valley is at an altitude of about 5,770 feet in the playa at the north end of the valley. South Diamond Peak in the Diamond Mountains, with an altitude of 10,614 feet, is the highest point.

Principal access to the valley is by transcontinental U.S. Highway 50 which goes through Eureka and the southern part of the valley. State Highway 20 which joins U.S. Highway 50 about 3 miles northwest of Eureka, traverses part of the west side of the valley and connects with U.S. Highway 40 at Carlin 89 miles and Elko 112 miles to the north. State Highway 46, a graded and gravel road, traverses the east side of the valley connects with U.S. Highway at Elko by way of Huntington Valley. Between Eureka and Thompson Ranch in Diamond Valley, State Highway 46 is being rerouted in the area of development. Additional roads or trails are being constructed to provide access to the newly developed land in the south-central part of the valley. Gravel or graded roads and trails permit access to other parts of the valley during good weather. The Eureka-Nevada railroad, completed in 1875 but now abandoned, connected Eureka with the transcontinental railroads at Palisade on the Humboldt River. The roadbed follows an alinement roughly parallel to State Highway 20.

Economic Development

Mining was the principal economic factor in the area. Mines near Eureka have produced silver, lead, gold, copper and zinc which, according to Couch and Carpenter (1943, p. 60), represented a gross yield of more than 52 million dollars (1,837,615 tons) during the period 1866 to 1940. Some additional mining in the past has been carried out at the Mount Hope mine on the west side of the valley and in the Diamond district at the north end of the Diamond Mountains.

During the past 20 years, efforts to develop a substantial new ore body by the Fad shaft resulted in a mine dewatering problem that as yet has not been solved economically.

The Fad shaft was sunk to a depth of somewhat more than 2,250 feet (altitude, 4,655) in the late 1940's. According to Stuart and Metzger (written communication, 1961), the maximum pumping rate during the sinking of the shaft was less than 2,000 gpm (gallons per minute). However, after a drift was started toward the ore body, a sudden increase in flow was developed that was greater than the pumping capacity and the pumping station was drowned.

Additional pumps were installed and renewed efforts to dewater the shaft area began in the spring of 1948. Over a period of several months the pumping rate was increased to 8,000 gpm and the water level was lowered to within 170 feet of the 2,250-foot level. Further increase of the pumping rate to 9,000 gpm resulted in removing fine material from the fissure conduits and provided better, freer hydraulic connection with the shaft. After this, a pumping rate of 9,000 gpm only maintained a water level 400 feet above the 2,250-foot level. During the 8 or 9 months period of pumping about 6,000 acre-feet of ground water was pumped from the Fad shaft.

In December 1952 W. T. Stuart and D. W. Metzger of the U.S. Geological Survey conducted a pumping test of the Fad shaft and a general study of the region to evaluate the magnitude of the dewatering problem.

In 1954 the T. L. shaft, about one mile northwest of the Fad shaft, was sunk to a depth of 1,037 feet. Although water was encountered in considerable amounts, it was possible to handle it. In 1958, mining through the T. L. shaft was terminated for economic reasons. Stuart (Stuart and Metzger, written communication, 1961) indicates that apparently 8,500 acre-feet of water was pumped from the T. L. shaft during the period August 1954 to March 1958.

The interest in possible oil development during the last 15 years in central and eastern Nevada resulted in the drilling of a number of exploratory wells to determine subsurface conditions. In 1956 the Shell Oil Company drilled an exploratory well to a depth of 8,042 feet (Campbell and Hebrew, 1957 p. 1125), in sec. 30, T. 23 N., R. 54 E. Reportedly this well penetrated 7,485 feet of valley fill (including undifferentiated Tertiary strata) before entering Paleozoic rocks.

Raising livestock has provided a continuing base for the economy of the valley for many years. Cattle have been fed principally on the range, supplemented by native hay from meadows and pastures. Meadows have been supplied mainly with water from spring discharge, the water being "developed" to the extent that ditches are used to distribute the water in the meadow area.

In the 1940's, additional water was developed by the construction of flowing wells on the Romano ranch for irrigation. In 1949 several flowing wells were drilled on the Flynn ranch and the water was used for irrigation. In 1949 also, two wells were drilled in T. 22 N., R. 54 E. in an effort to develop land under the Desert Entry act.

Renewed effort to develop public land for irrigation began in 1958. From 1948 to September 1961, about 85 wells have been drilled for irrigation of newly developed land. It may be too early to say that this development will be a permanent success, but certainly the effort and expenditure of funds being applied to the development of these lands suggest that the development will be a real test of the possibility of developing new land for irrigation in this part of Nevada. One might say that the effort warrants full available assistance from the agencies interested in the further development of Nevada.

Climate

The climate of east-central Nevada generally is semiarid in the valleys, but in the higher mountains may be subhumid. In the valleys, precipitation and humidity are generally low and summer temperatures, wind movement, and evaporation rates are high. Precipitation is very irregular but generally is least on the floors of the valley and greatest in the higher mountains. Winter precipitation occurs as snow and is moderately well distributed over several months. Summer precipitation commonly is localized as thundershowers. The range in temperature is large, both daily and seasonally. The growing season is relatively short.

Precipitation has been recorded at Eureka since 1888, but the record has been broken during the periods 1894-1901, 1919-21, and 1943-52 and only partial records were obtained during 1888, 1890, 1892, 1893, and 1960. The average monthly and annual precipitation for the period of record at Eureka, according to records of the Weather Bureau, is given in table 1. Additionally, the average monthly and annual precipitation are listed for Austin about 70 miles west of Eureka; Fish Creek Ranch, 15 miles south of Eureka, and Jiggs, 70 miles northeast of Eureka. The records show that precipitation varies considerably from month to month and year to year. The maximum and minimum recorded monthly and annual precipitation at Eureka is shown in table 2. Regional precipitation was below average during the period 1951-60. Table 3 lists recorded annual precipitation for Austin, Eureka, Fish Creek Ranch and Jiggs during the period 1951-60. As shown in the table, annual precipitation was above the long-time average in only 3 of 10 years at Austin, 1 of 7 at Eureka, 3 of 10 at Fish Creek Ranch, and 1 of 10 at Jiggs.

Table 1.--Average monthly and annual precipitation in inches, at four stations in the region of Diamond Valley (from published records of the U.S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Austin 1/	1.17	1.18	1.46	1.60	1.45	0.73	0.54	0.53	0.50	0.84	0.79	1.10	11.89
Eureka 2/	1.11	1.08	1.49	1.33	1.49	.86	.73	.66	.66	.89	.66	.82	11.78
Fish Creek Ranch 3/	.47	.25	.56	.56	.58	.39	.47	.43	.56	.40	.63	.55	5.85
Jiggs 4/	1.17	1.05	1.23	1.50	1.44	.83	.54	.49	.61	1.08	.93	1.23	12.10

1/ Altitude, 6,543 feet. Location, sec. 19, T. 19 N., R. 44 E. Period of record: 1877-79, 1890-98, 1900-1908, 1911-60 (continuing). Partial record in 1880, 1888, and 1889.

2/ Altitude, 6,550 feet. Location sec. 13, T. 19 N., R. 53 E. Period of record: 1889, 1891, 1902-18, 1922-30, 1939-42, 1953-60 (continuing). Partial record in 1888, 1890, 1892-94, 1919-21.

3/ Altitude, 6,050 feet. Location, sec. 10, T. 16 N., R. 53 E. Period of record: 1943-60 (continuing).

4/ Altitude, 5,450 feet. Location, sec. 4, T. 29 N., R. 56 E. Period of record: 1910-42, 1946-60 (continuing). Partial record 1943, 1945. Station first known as Skelton, name changed to Hylton in 1913 and to Jiggs in 1945. Location changed: 1 mile south prior to August 1952, and 3 miles south-southeast prior to May 1945, from present location.

Table 2.--Maximum and minimum monthly and annual precipitation, in inches, at Eureka for period of record (1888-1960 discontinuous). (from published records of the U. S. Weather Bureau).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Maximum	1.51	1.22	1.67	3.04	2.16	2.31	1.75	2.66	0.92	2.50	1.81	2.31	23.86
Minimum	.70	.18	.84	.22	.32	.96	.81	.34	.00	.55	.42	.79	6.13

Table 3.--Annual precipitation, in inches, for four climatological stations in the region of Diamond Valley, 1951-60 (from published records of the U.S. Weather Bureau)

Year	Austin	Eureka	Fish Creek Ranch	Jiggs
1951	11.38	--	5.66	10.36
1952	10.34	--	5.76	10.12
1953	6.73	7.36	2.17	8.11
1954	9.92	9.09	4.66	6.74
1955	e 12.12	e 10.48	e 7.68	13.59
1956	12.30	6.33	2.77	10.62
1957	12.70	e 14.54	e 9.77	11.27
1958	e 8.98	6.83	e 5.66	7.60
1959	e 5.90	7.67	e 5.49	8.78
1960	8.49	--	e 6.08	9.24

e/ estimated by Weather Bureau.

Case No. 72317

In the Supreme Court of Nevada

Electronically Filed
Apr 18 2017 09:59 a.m.
Elizabeth A. Brown
Clerk of Supreme Court

EUREKA COUNTY AND DIAMOND NATURAL RESOURCES PROTECTION & CONSERVATION ASSOCIATION,

PETITIONERS,

VS.

THE SEVENTH JUDICIAL DISTRICT COURT OF THE STATE OF NEVADA IN AND FOR THE COUNTY OF EUREKA AND THE HONORABLE GARY D. FAIRMAN, DISTRICT COURT JUDGE,

RESPONDENTS,

AND

SADLER RANCH, LLC; ET AL.,

REAL PARTIES IN INTEREST.

SADLER RANCH, LLC'S APPENDIX

VOLUME 1 OF 5

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CHRONOLOGICAL APPENDIX
TO SADLER RANCH, LLC'S ANSWERING BRIEF

DOCUMENT	DATE	BATES	
United States Department of the Interior, Geological Survey, Water Resource division, September 1961, Field Notes of Shipley Spring Discharge, Eakin and Winchester	1961	SR APP 1	SR APP 2
Eakin, Thomas E., 1962, Ground-water appraisal of Diamond Valley in Eureka and Elko Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources-Reconnaissance Series Report 6	02/1962	SR APP 3	SR APP 76
Harrill, J.R., and Lamke, R.D., 1968, Hydrologic Response to Irrigation Pumping in Diamond Valley, Eureka and Elko Counties, Nevada: State of Nevada, Department of Conservation and Natural Resources, Water Resources Bulletin No. 35	1968	SR APP 77	SR APP 190
State Engineer Order 541	12/22/1975	SR APP 191	SR APP 192
State Engineer Order 717	07/10/1978	SR APP 193	SR APP 194
Permit No. 34561	09/20/1978	SR APP 195	SR APP 196

Garside, Larry J, and Schilling, John H., 1979, Thermal Waters of Nevada: Nevada Bureau of Mines and Geology Bulletin 91; pp.29-35, 95-98	1979	SR APP 197	SR APP 208
Transcript of Proceedings of the Hearing before the State Engineer, State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Monday, May 24, 1982, District Courtroom, Eureka County Courthouse, Eureka, Nevada, In the Matter of Evidence and Testimony Concerning Possible Curtailment of Pumpage of Ground Water in Diamond Valley, Eureka County, Nevada.	05/24/1982	SR APP 209	SR APP 380
State Engineer Order 809	12/01/1982	SR APP 381	SR APP 382
State Engineer Order 813	02/07/1983	SR APP 383	SR APP 383
Transcript of Hearing before the State Engineer, State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Wednesday, March 19, 2009, Eureka, Nevada, In the Matter of Concern Re: Eureka County, Nevada.	03/19/2009	SR APP 384	SR APP 479
Appellant Eureka County's Opening	12/27/2012	SR APP 480	SR APP 560

Brief, Case No. 61324			
Smith, Dwight L., September 11, 2013, Shipley Hot Spring Historic and Current Discharge, and Evidence for Impact to Flow Due to Groundwater Pumping in Diamond Valley, Eureka County, Nevada.	09/11/2013	SR APP 561	SR APP 580
Letter to State Engineer re: Request for Adjudication of Big Shipley and Indian Camp Springs	06/11/2014	SR APP 581	SR APP 582
State Engineer Ruling 6290	08/15/2014	SR APP 583	SR APP 646
Petition for Judicial Review, CV-1409-204	09/12/2014	SR APP 1299	SR APP 1309
Letter from DWR re: Request for Adjudication	02/10/2015	SR APP 647	SR APP 647
Sadler Ranch Opening Brief	02/13/2015	SR APP 1310	SR APP 1352
Petition for Judicial Review, CV 1503-213	03/13/2015	SR APP 1353	SR APP 1358
Motion to Dismiss Petition for Curtailment in Diamond Valley	06/03/2015	SR APP 648	SR APP 654
Verification of Petition for Curtailment in Diamond Valley	06/11/2015	SR APP 655	SR APP 658
Shipley Springs Flow Data	06/17/2015	SR APP 1359	SR APP 1359
DWR Notice of Hearing re: Diamond	06/29/2015	SR APP 659	SR APP 665

Valley Hydrographic Basin			
Opposition to Respondent's Motion to Dismiss	07/02/2015	SR APP 666	SR APP 676
Request for Review	07/14/2015	SR APP 677	SR APP 679
Reply in Support of Motion to Dismiss Petition for Curtailment in Diamond Valley	07/22/2015	SR APP 680	SR APP 683
Eureka County Comments on Proposed Order Designating Diamond Valley as a CMA	07/23/2015	SR APP 684	SR APP 687
Ex Parte Request for Immediate Stay of Proceedings	08/03/2015	SR APP 688	SR APP 704
Eureka County's Response to Ex Parte Request for Immediate Stay of Proceedings	08/10/2015	SR APP 705	SR APP 707
Request for Review	08/12/2015	SR APP 708	SR APP 711
Response to Petitioner's Ex Parte Request for Immediate Stay of Proceedings	08/12/2015	SR APP 712	SR APP 715
State Engineer Order 1263	08/21/2015	SR APP 716	SR APP 717
Notice of State Engineer Order 1263	08/21/2015	SR APP 718	SR APP 724
Letter to Kristen Geddes regarding Comments on Proposed Order Designating Diamond Valley as CMA	08/24/2015	SR APP 725	SR APP 732
Notice of Entry of Order	08/27/2015	SR APP 733	SR APP 739

Motion to Strike a Portion of Eureka County's Notice of State Engineer's Order 1263	10/07/2015	SR APP 740	SR APP 744
Opposition to Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/13/2015	SR APP 745	SR APP 752
Joinder to Opposition to Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/14/2015	SR APP 753	SR APP 755
Reply in Support of Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/23/2015	SR APP 756	SR APP 792
Order Granting Leave to File First Amended Petition	11/09/2015	SR APP 793	SR APP 794
Notice of Entry of Order	11/16/2015	SR APP 795	SR APP 799
Supplement to First Amended Petition	11/19/2015	SR APP 800	SR APP 804
Verification of First Amended Petition for Curtailment in Diamond Valley	01/27/2016	SR APP 805	SR APP 808
Notice of Entry of Order of Findings of Fact, Conclusions of Law, and Order Partially Granting Petition for Judicial Review	02/22/2016	SR APP 1360	SR APP 1388
Notice of Entry of Order Granting in	07/20/2016	SR APP 809	SR APP 824

Part and Denying in Part Motion to Dismiss First Amended Petition for Curtailment in Diamond Valley			
Case No. 71090, Verified Petition for Writ, Document 2016-26135	08/23/2016	SR APP 825	SR APP 856
Letter from Eureka County to State Engineer Requesting Postponement of Hearing	08/23/2016	SR APP 857	SR APP 857
State Engineer Order Vacating Hearing	08/23/2016	SR APP 858	SR APP 859
Declaration of Mark Moyle in Support of Answer to Writ	08/29/2016	SR APP 860	SR APP 865
Answer to Alternate Writ of Mandamus and First Amended Petition for Curtailment in Diamond Valley	08/30/2016	SR APP 866	SR APP 980
Answer to First Amended Petition for Curtailment in Diamond Valley	09/14/2016	SR APP 981	SR APP 1009
Answer of Intervenor Ruby Hill Mining Company, LLC and Joinder to Answer to Alternate Writ of Mandamus and First Amended Petition for Curtailment in Diamond Valley of DNRPCA Intervenors	09/14/2016	SR APP 1010	SR APP 1015
Answer to First Amended Petition for Writ of Mandamus	09/14/2016	SR APP 1016	SR APP 1046
Eureka County's Motion to File Answer to First Amended Petition for	09/14/2016	SR APP 1047	SR APP 1081

Curtailment in Diamond Valley in Excess of Page Limitations			
Order to Provide Court Reporter at Show Cause Hearing	09/30/2016	SR APP 1082	SR APP 1083
Order Granting Eureka County's Motion to File Answer to First Amended Petition for Curtailment in Diamond Valley in Excess of Page Limitations	09/30/2016	SR APP 1084	SR APP 1085
Order Relocating Show Cause Hearing to Eureka Opera House	09/30/2016	SR APP 1086	SR APP 1087
Sadler Ranch, LLC's Reply to Answers to the First Amended Petition for Curtailment in Diamond Valley	10/24/2016	SR APP 1088	SR APP 1129
Notice of Entry of Order	10/31/2016	SR APP 1130	SR APP 1139
State Engineer Ruling 6371	11/01/2016	SR APP 1140	SR APP 1167
Notice of State Engineer Ruling 6371	11/04/2016	SR APP 1168	SR APP 1200
Senate Bill No. 73—Committee on Natural Resources	11/17/2016	SR APP 1201	SR APP 1207
Supplemental Petition for Judicial Review, Case No. CV-1409-204	11/30/2016	SR APP 1208	SR APP 1243
Notice of Entry of Order Denying Eureka County's Motion for Reconsideration and Notice of Motion	12/05/2016	SR APP 1288	SR APP 1298
Intervenors' Answer to Alternate Writ	02/10/2017	SR APP 1244	SR APP 1252

of Mandamus and First Amended Petition for Curtailment in Diamond Valley			
Nevada Appeal Article	03/22/2017	SR APP 1253	SR APP 1254
Eureka County's Motion to continue Show Cause Hearing and Notice of Motion	03/31/2017	SR APP 1255	SR APP 1266
Ruby Hill Mining Company, LLC's Response to Eureka County's Motion to continue Show Cause Hearing and Notice of Motion	04/03/2017	SR APP 1267	SR APP 1268
Sadler Ranch, LLC's Motion in Limine	04/04/2017	SR APP 1269	SR APP 1279
Eureka County Testimony on AB 298	04/04/2017	SR APP 1280	SR APP 1284
Joinder to Motion to Continue Show Cause Hearing	04/13/2017	SR APP 1285	SR APP 1287

ALPHABETIC INDEX TO
SADLER RANCH, LLC'S ANSWERING BRIEF

Eakin, Thomas E., 1962, Ground-water appraisal of Diamond Valley in Eureka and Elko Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources-Reconnaissance Series Report 6	02/1962	SR APP 3	SR APP 76
Eureka County Comments on Proposed Order Designating Diamond Valley as a CMA	07/23/2015	SR APP 684	SR APP 687
Eureka County Testimony on AB 298	04/04/2017	SR APP 1280	SR APP 1284
Eureka County's Motion to continue Show Cause Hearing and Notice of Motion	03/31/2017	SR APP 1255	SR APP 1266
Eureka County's Motion to File Answer to First Amended Petition for Curtailment in Diamond Valley in Excess of Page Limitations	09/14/2016	SR APP 1047	SR APP 1081
Eureka County's Response to Ex Parte Request for Immediate Stay of Proceedings	08/10/2015	SR APP 705	SR APP 707
Ex Parte Request for Immediate Stay of Proceedings	08/03/2015	SR APP 688	SR APP 704

Garside, Larry J, and Schilling, John H., 1979, Thermal Waters of Nevada: Nevada Bureau of Mines and Geology Bulletin 91; pp.29-35, 95-98	1979	SR APP 197	SR APP 208
Harrill, J.R., and Lamke, R.D., 1968, Hydrologic Response to Irrigation Pumping in Diamond Valley, Eureka and Elko Counties, Nevada: State of Nevada, Department of Conservation and Natural Resources, Water Resources Bulletin No. 35	1968	SR APP 77	SR APP 190
Intervenors' Answer to Alternate Writ of Mandamus and First Amended Petition for Curtailment in Diamond Valley	02/10/2017	SR APP 1244	SR APP 1252
Joinder to Motion to Continue Show Cause Hearing	04/13/2017	SR APP 1285	SR APP 1287
Joinder to Opposition to Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/14/2015	SR APP 753	SR APP 755
Letter from DWR re: Request for Adjudication	02/10/2015	SR APP 647	SR APP 647
Letter from Eureka County to State Engineer Requesting Postponement of Hearing	08/23/2016	SR APP 857	SR APP 857

Letter to Kristen Geddes regarding Comments on Proposed Order Designating Diamond Valley as CMA	08/24/2015	SR APP 725	SR APP 732
Letter to State Engineer re: Request for Adjudication of Big Shipley and Indian Camp Springs	06/11/2014	SR APP 581	SR APP 582
Motion to Dismiss Petition for Curtailment in Diamond Valley	06/03/2015	SR APP 648	SR APP 654
Motion to Strike a Portion of Eureka County's Notice of State Engineer's Order 1263	10/07/2015	SR APP 740	SR APP 744
Nevada Appeal Article	03/22/2017	SR APP 1253	SR APP 1254
Notice of Entry of Order	08/27/2015	SR APP 733	SR APP 739
Notice of Entry of Order	11/16/2015	SR APP 795	SR APP 799
Notice of Entry of Order	10/31/2016	SR APP 1130	SR APP 1139
Notice of Entry of Order Denying Eureka County's Motion for Reconsideration and Notice of Motion	12/05/2016	SR APP 1288	SR APP 1298
Notice of Entry of Order Granting in Part and Denying in Part Motion to Dismiss First Amended Petition for Curtailment in Diamond Valley	07/20/2016	SR APP 809	SR APP 824
Notice of Entry of Order of Findings of Fact, Conclusions of Law, and Order Partially Granting Petition for Judicial Review	02/22/2016	SR APP 1360	SR APP 1388

Notice of State Engineer Order 1263	08/21/2015	SR APP 718	SR APP 724
Notice of State Engineer Ruling 6371	11/04/2016	SR APP 1168	SR APP 1200
Opposition to Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/13/2015	SR APP 745	SR APP 752
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Order Granting Leave to File First Amended Petition	11/09/2015	SR APP 793	SR APP 794
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Order to Provide Court Reporter at Show Cause Hearing	09/30/2016	SR APP 1082	SR APP 1083
Permit No. 34561	09/20/1978	SR APP 195	SR APP 196
Petition for Judicial Review, CV 1503-213	03/13/2015	SR APP 1353	SR APP 1358
Petition for Judicial Review, CV-1409-204	09/12/2014	SR APP 1299	SR APP 1309
Reply in Support of Motion to Dismiss	07/22/2015	SR APP 680	SR APP 683

Petition for Curtailment in Diamond Valley			
Reply in Support of Petitioner's Motion Requesting Leave to File First Amended Petition for Curtailment in Diamond Valley	10/23/2015	SR APP 756	SR APP 792
Request for Review	07/14/2015	SR APP 677	SR APP 679
Request for Review	08/12/2015	SR APP 708	SR APP 711
Response to Petitioner's Ex Parte Request for Immediate Stay of Proceedings	08/12/2015	SR APP 712	SR APP 715
Ruby Hill Mining Company, LLC's Response to Eureka County's Motion to continue Show Cause Hearing and Notice of Motion	04/03/2017	SR APP 1267	SR APP 1268
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Smith, Dwight L., September 11, 2013, Shipley Hot Spring Historic and Current Discharge, and Evidence for Impact to Flow Due to Groundwater Pumping in Diamond Valley, Eureka County, Nevada.	09/11/2013	SR APP 561	SR APP 580
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State Engineer Order 541	12/22/1975	SR APP 191	SR APP 192
State Engineer Order 717	07/10/1978	SR APP 193	SR APP 194
State Engineer Order 809	12/01/1982	SR APP 381	SR APP 382
State Engineer Order 813	02/07/1983	SR APP 383	SR APP 383
State Engineer Order Vacating Hearing	08/23/2016	SR APP 858	SR APP 859
State Engineer Ruling 6290	08/15/2014	SR APP 583	SR APP 646
State Engineer Ruling 6371	11/01/2016	SR APP 1140	SR APP 1167
Supplement to First Amended Petition	11/19/2015	SR APP 800	SR APP 804
Supplemental Petition for Judicial Review, Case No. CV-1409-204	11/30/2016	SR APP 1208	SR APP 1243
Transcript of Hearing before the State Engineer, State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Wednesday, March 19, 2009, Eureka, Nevada, In the Matter of Concern Re: Eureka County, Nevada.	03/19/2009	SR APP 384	SR APP 479
Transcript of Proceedings of the	05/24/1982	SR APP 209	SR APP 380

Hearing before the State Engineer, State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, Monday, May 24, 1982, District Courtroom, Eureka County Courthouse, Eureka, Nevada, In the Matter of Evidence and Testimony Concerning Possible Curtailment of Pumpage of Ground Water in Diamond Valley, Eureka County, Nevada.			
United States Department of the Interior, Geological Survey, Water Resource division, September 1961, Field Notes of Shipley Spring Discharge, Eakin and Winchester	1961	SR APP 1	SR APP 2
Verification of First Amended Petition for Curtailment in Diamond Valley	01/27/2016	SR APP 805	SR APP 808
Verification of Petition for Curtailment in Diamond Valley	06/11/2015	SR APP 655	SR APP 658

CERTIFICATE OF SERVICE

Pursuant to NRAP 25(c), I hereby certify that I am an employee of TAGGART & TAGGART, LTD., and that on this date I served, or caused to be served, a true and correct copy of the foregoing document, as follows:

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DATED this 17th day of April, 2017.

/s/ Sarah Hope
Employee of TAGGART & TAGGART, LTD.