STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City

Aerial View of Beatty, Nevada

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES

REPORT 10

GROUND–WATER APPRAISAL OF SARCOBATUS FLAT AND OASIS VALLEY, NYE AND ESMERALDA COUNTIES, NEVADA

By
GLENN T. MALMBERG
and
THOMAS E. EAKIN
Geologists

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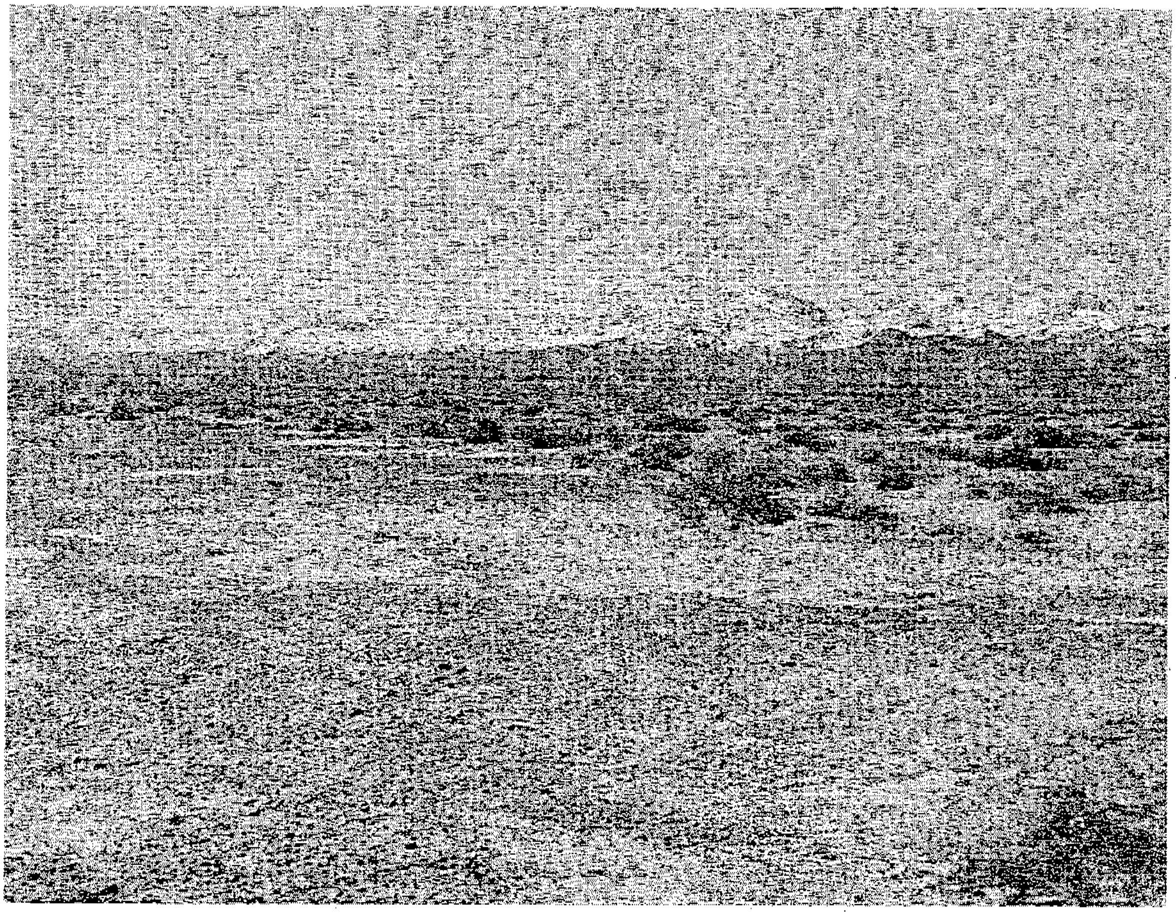

View southwest from T. 9 S., R. 45 E., toward Grapevine Mountains which bound the southwest side of Sarcobatus Flat. Light cover of snow (April 1962) lies above an altitude of 5,200 feet. Foreground shows very low density of southern margin of phreatophyte area.

CORRECTIONS TO:

Ground-Water Resources - Reconnaissance Series, Report 10
"Ground-Water Appraisal of Sarcobatus Flat and Oasis Valley,
Nye and Esmeralda Counties, Nevada"

Please make the following corrections:

Page 13 - Under heading - "SARCOBATUS FLAT"

Sub-heading - "Source, Occurrence, and Movement of Ground Water":

Line 2: Change page 17 to read page 9.

Page 24 - Under sub-heading - "Estimated Average Annual Recharge":

3rd paragraph, line 4: Insert (p. 25-26).

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June

1962

FOREWORD

This is the tenth report in the current series of ground-water reconnaissance studies and covers the ground-water appraisal of Sarcobatus Flat and Oasis Valley in Nye and Esmeralda Counties.

The study was made and report prepared by Glenn T. Malmberg and Thomas E. Eakin, Geologists, United States Geological Survey, Carson City, Nevada.

Great interest is being shown by the public and many Federal and State agencies over this particular type of study. We are hoping that the next legislature will appropriate sufficient money so that for the next biennial period twenty-four such reports can be completed. We expect to publish two more reports between now and January 1, 1963. These will cover Hualapai Flat, Washoe, Humboldt, and Pershing Counties, Nevada, and Ralston-Stone Cabin Valleys in Nye County, Nevada.

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

October, 1962.

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GROUND-WATER APPRAISAL OF SARCOBATUS FLAT AND OASIS VALLEY,

NYE AND ESMERALDA COUNTIES, NEVADA

By

Glenn T. Malmberg and Thomas E. Eakin

SUMMARY

The estimated average annual recharge to and discharge from the ground-water reservoir in Sarcobatus Flat is on the order of 3,500 acre-feet. Approximately 1,200 acre-feet of the recharge is derived from precipitation within the drainage basin and 2,300 acre-feet from ground-water underflow from Stonewall Flat and Gold Flat.

Ground-water discharge from Sarcobatus Flat includes about 3,000 acre-feet of evapotranspiration by native vegetation and 500 acre-feet of ground-water underflow out of the basin to Grapevine Canyon. Ground-water pumpage in 1961 was less than 100 acre-feet.

The amount of ground water that can be pumped from the ground-water reservoir in Sarcobatus Flat on a perennial basis depends largely on the annual recharge to the ground-water system that can be diverted to wells, which could not exceed the total discharge of about 3,500 acre-feet without exceeding the perennial yield.

Ground water in Sarcobatus Flat commonly contains relatively high concentrations of sodium and bicarbonate, and consequently moderate to extensive leaching will be required for irrigating most crops.

The estimated average annual recharge to and discharge from Oasis Valley is on the order of 2,000 acre-feet. About 250 acre-feet is derived from precipitation within the drainage basin and about 1,800 acre-feet is derived from underflow from Gold Flat.

Discharge of ground water in Oasis Valley is affected by evapotranspiration and underflow through the Amargosa Narrows to the Amargosa Desert. The estimated average annual natural discharge by evapotranspiration is about 1,900 acre-feet and the estimated average annual spring discharge and underflow to the Amargosa Desert is about 400 acre-feet. Ground-water development in Oasis Valley has been limited largely to the development of numerous springs along the flood plain of the Amargosa River. Six of these springs are used for the municipal water supply for the town of Beatty. Although the water supply from the springs is adequate to meet the current municipal demands, the fluroide content of the water is about four times higher than the limit

recommended by the U. S. Public Health Service (1962). Water samples collected throughout the valley suggest that all ground water in Oasis Valley, except that derived from precipitation on the Bullfrog Hills northwest of Beatty, contains excessive concentrations of fluoride. Although the estimated recharge to the ground-water reservoir resulting from the infiltration of precipitation on the Bullfrog Hills is less than 20 acre-feet per year, a considerable amount of water of low fluroride content may be in storage in the alluvium bordering the hills.

Development of the ground water in the alluvial fans at the base of the Bullfrog Hills may be possible by properly spaced wells. Because of the limited amount of recharge to this system, the withdrawal of ground water in quantities sufficient to meet municipal demands would result in a depletion of the amount of ground water in storage and therefore this source of water would be temporary.

INTRODUCTION

Ground-water development in Nevada has increased substantially in recent years partly as a result of bringing new land into cultivation. Existing development also requires greater reliability of water supplies. The increased interest in ground-water development has created a substantial demand for information of ground-water resources through the State. Recognizing this need, the Nevada Legislature enacted special legislation (Chapt. 181, Stats. 1960) for reconnaissance studies of the ground-water resources of the State by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources.

The studies are intended to provide, as quickly as possible, a general appraisal of the ground-water resources of areas where information is needed urgently. For this reason, each reconnaissance study is limited in time, the field work for each area generally averaging about two weeks.

The Department of Conservation and Natural Resources has established a special report series to expedite publication of the results of the reconnaissance studies. Figure 1 shows the areas for which reports have been published in this series. The present report is the tenth in the reconnaissance series. It describes some of the physical conditions of Sarcobatus Flat and Oasis Valley and includes observations on the interrelation of climate, geology, and hydrology as they affect ground-water resources. It also includes preliminary estimates of the average annual recharge to and discharge from the ground-water reservoirs. The chemical quality of ground water in Oasis Valley is emphasized to provide information to help solve a critical problem of water supply for the town of Beatty. The fluoride content of the town's present water supply is considerably above the limit recommended by the U. S. Public Health Service (1962). Two possible areas in Oasis Valley, where ground water containing permissible concentrations of fluoride may be obtained, are discussed.

Location and General Features:

Sarcobatus Flat and Oasis Valley are in southwestern Nevada adjacent to the Nevada-California State line. (See figure 1 and plates 1, 3.) The two areas are entirely in Nye County except for a few square miles of the drainage area of the northwest part of Sarcobatus Flat which is in Esmeralda County. Sarcobatus Flat and Oasis Valley together are in an area enclosed by latitude 36°55' and 37°30' N. and longitude 116°20' and 117°20' W. and have a drainage area of 820 and 450 square miles, respectively.

The highest point in the area is Grapevine Peak, altitude 8, 740 feet, in the Grapevine Mountains on the southwest side of Sarcobatus Flat (see photograph 2). The altitude of Stonewall Mountain at the north end of Sarcobatus Flat is 8, 275 feet. Timber Mountain, on the east side of Oasis Valley, has an altitude of 7, 445 feet.

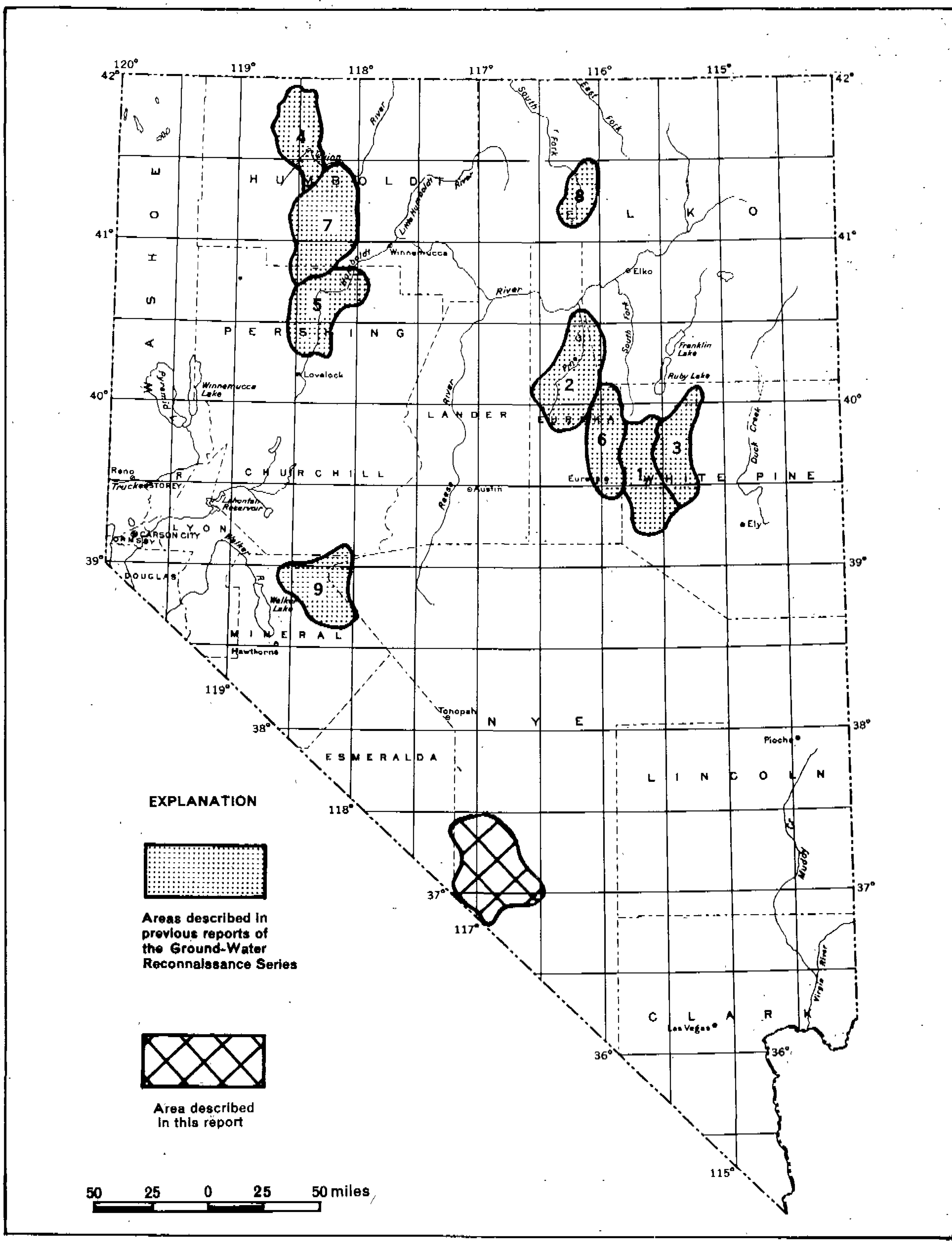


Figure 1. MAP OF NEVADA

showing areas described in previous reports of the ground water reconnaissance series and the area described in this report.

The lowest part of Sarcobatus Flat is the playa or "dry lake", 7 to 10 miles south of Scottys Junction, at an altitude of somewhat less than 4,000 feet. The lowest part of Oasis Valley is about 3,200 feet above sea level in the Amargosa Narrows south of Beatty. The total relief, therefore, is about 5,000 feet.

Principal access to the two areas is U.S. Highway 95 which connects Las Vegas and Tonopah and which traverses the west side of Oasis Valley and the northeast side of Sarcobatus Flat. State Highway 72 extends southwest from U.S. Highway 95 at Scottys Junction to the California State line. Numerous trails provide access to various parts of both areas during dry weather. The only town in the area is Beatty (see cover photograph), which is at the south end of Oasis Valley along U.S. Highway 95. The population of Beatty is about 500 and has been increasing in recent years. Another hundred people are estimated to live at the ranches in Oasis Valley and in the vicinity of Scottys Junction and the Highway Maintenance Station in Sarcobatus Flat.

In the early 1900's, the area near Beatty was the scene of substantial mining activity. Mining still is being carried on, but on a very limited scale. Prior to the mining boom, ranches had been developed in Oasis Valley adjacent to the several springs. Recently, development of land by irrigation from wells has started in the vicinity of Scottys Junction in Sarcobatus Flat.

Climate:

The climate of southwestern Nevada is characterized by low precipitation and humidity and high summer temperatures and evaporation. Precipitation varies from month to month and year to year. It is irregularly distributed areally and commonly is least on the valley floor and greatest in the mountains. Summer precipitation usually occurs as localized showers and most of the winter precipitation commonly occurs as snow. The daily and seasonal temperature range commonly is large.

Table 1 lists precipitation data for the period 1951-60 at Sarcobatus (Highway Maintenance Station) and Beatty. The stations are in the lower parts of the valleys; thus, the data indicate that the average annual precipitation in the lower parts of Sarcobatus Flat and Oasis Valley is on the order of 4 inches, although for some years it may be much above or much below average.

Table 2 lists the average monthly and average annual temperature at Sarcobatus and Beatty for the period 1951-60. The recorded extremes of temperature are as follows: maximum, 111°F July 18, 1959, at Sarcobatus and 115°F July 11, 1961, at Beatty; minimum, -5°F January 13, 1955, at Sarcobatus and 11°F January 11, 1952, at Beatty. The average annual maximum daily temperature for the period of record 1931-52 at Sarcobatus is 73.7°F and at Beatty is 76.2°F, according to the U.S. Weather Bureau Climatic Summary for Nevada. The average annual minimum daily temperature for the same period of time at Sarcobatus is reported as 37.9°F and at Beatty as 31.1°F.

Table 1.--Monthly and annual precipitation for Sarcobatus and Beatty, Nev. 1951-60.

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

	Sarcobatus 1/											Beatty										
Month	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Aver-age	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Aver-age
January	.79	.51	.20	.40	.46	.00	1.04	.00	.16	.17	.37	.77	1.98	.04	1.30	.99	.02	.67	.15	.46	.70	.71
February	.09	.00	.00	.03	.00	.00	.16	.40	.22	.10	.10	.48	.02	.00	.68	.12	T	.61	1.12	.96	.47	.45
March	.23	.97	.00	.71	.00	.00	.41	.05	.00	.04	.24	.26	2.36	.15	.70	.00	.00	.29	.59	.00	.11	.45
April	.79	1.99	.26	.00	.27	.74	.18	.63	.00	.15	.50	.51	1.48	.02	.34	.14	1.25	.39	1.52	T	.13	.58
May	.00	.00	.18	.00	.24	.15	.85	.40	.00	.00	.18	.02	.00	.05	.00	1.04	.03	1.29	.45	T	.00	.29
June	.10	.00	.00	.30	.00	.00	.00	.00	.10	.00	.05	.00	.03	.00	.01	.00	.00	.17	.00	.07	.45	.07
July	.65	3.21	.63	1.25	.20	.46	.00	.00	.83	.00	.72	.05	.76	.12	.86	.04	.37	T	.00	.12	.09	.24
August	.00	T	.55	.00	1.12	.00	.30	.22	2.40	.00	.46	.00	.00	.11	T	1.40	.00	.00	.39	.10	.00	.20
September	.00	.40	.00	.12	.00	.16	.00	1.00	.30	.00	.20	[illegible]	.03	.00	.45	.00	.00	.06	.05	.69	.50	.18
October	.54	.00	.70	.00	.00	.00	.77	.49	.00	.00	.25	.32	.00	.12	.00	.00	T	.74	.51	.00	.38	.21
November	.02	.53	.00	.65	.00	.00	.87	.20	.00	1.63	.39	.00	.58	.18	1.66	.26	.00	.75	.40	.00	2.29	.61
December	.36	.57	.00	.60	.00	.00	.19	.00	.40	.00	.21	.19	1.07	.00	.89	.32	.00	.94	.00	.99	.00	.44
Annual	3.57	8.18	2.52	4.06	2.29	1.51	4.77	3.39	4.41	2.09	3.68	2.60	8.36	.79	6.89	4.31	1.67	5.91	5.18	3.39	5.12	4.42

1/ Highway Maintenance Station

Table 2.--Average monthly and annual temperatures Sarcobatus and Beatty, Nev., 1951-60.

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

Month	Sarcobatus 1/											Beatty										
	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Average	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Average
January	34.8	34.7	43.0	37.1	28.2	38.9	32.6	39.2	39.9	33.6	36.2	40.6	37.5	46.9	42.0	34.0	44.6	37.3	43.6	45.6	---	41.3
February	38.6	39.3	40.8	47.5	36.9	36.5	44.5	44.3	38.3	40.0	40.7	43.6	44.1	46.0	51.9	40.3	40.4	49.6	47.6	42.8	43.4	45.0
March	44.9	41.7	45.5	43.4	44.5	45.9	48.8	42.8	47.0	51.6	45.6	49.3	45.1	50.7	47.7	49.4	51.0	51.8	45.4	53.4	54.7	49.9
April	56.6	56.1	53.3	58.6	50.1	53.8	55.1	52.0	57.4	56.9	55.0	59.0	58.9	57.6	63.6	54.2	57.0	56.9	54.6	62.5	61.5	58.6
May	65.1	65.0	55.9	68.2	60.8	65.0	60.1	65.4	61.8	64.7	63.2	67.6	68.9	58.6	71.6	63.7	67.1	62.9	68.7	64.7	66.4	66.0
June	72.6	68.2	69.4	71.0	70.4	74.3	74.9	71.5	72.5	77.5	72.2	74.9	71.9	73.2	75.1	---	77.4	78.5	72.5	78.4	79.5	75.7
July	79.3	78.2	81.0	80.0	76.6	76.9	77.9	75.3	82.8	81.2	78.9	82.4	82.3	84.5	84.2	79.8	80.1	81.1	---	84.6	83.9	82.5
August	75.7	77.7	72.8	73.9	78.9	72.2	75.0	78.5	77.0	77.7	75.9	78.5	81.8	78.1	78.0	82.7	77.3	78.5	---	78.3	80.5	79.3
September	70.8	70.5	69.3	68.2	68.5	70.0	68.1	68.9	68.1	72.8	69.5	75.9	74.9	75.6	---	74.0	75.1	72.5	---	71.0	76.2	74.4
October	57.1	61.2	55.7	57.0	59.4	54.8	54.2	60.6	62.6	58.4	58.1	61.4	67.5	60.4	62.8	64.8	59.1	57.4	---	64.3	61.7	62.2
November	43.8	41.4	48.2	49.4	44.4	46.4	42.3	45.8	48.3	46.2	45.6	47.6	46.7	50.9	53.5	49.4	50.8	46.0	52.0	52.2	50.2	49.9
December	35.5	36.2	39.2	35.1	38.5	40.5	39.3	41.6	41.5	40.3	38.8	38.9	40.9	42.4	40.1	42.5	45.0	44.2	50.3	45.6	45.1	43.5
Annual	56.2	55.8	56.2	57.5	54.8	56.3	56.1	57.2	58.1	58.4	56.7	60.0	60.0	60.4	60.9	57.7	60.4	59.7	54.3	61.9	63.9	59.9

1/ Highway Maintenance Station

According to Houston (1950, p. 19) the average growing season at Beatty is 184 days, from April 26 to October 27. Variations from conditions at Beatty may be expected in the different parts of Sarcobatus Flat and Oasis Valley because of differences in altitude, topography, and exposure.

Physiography and Drainage:

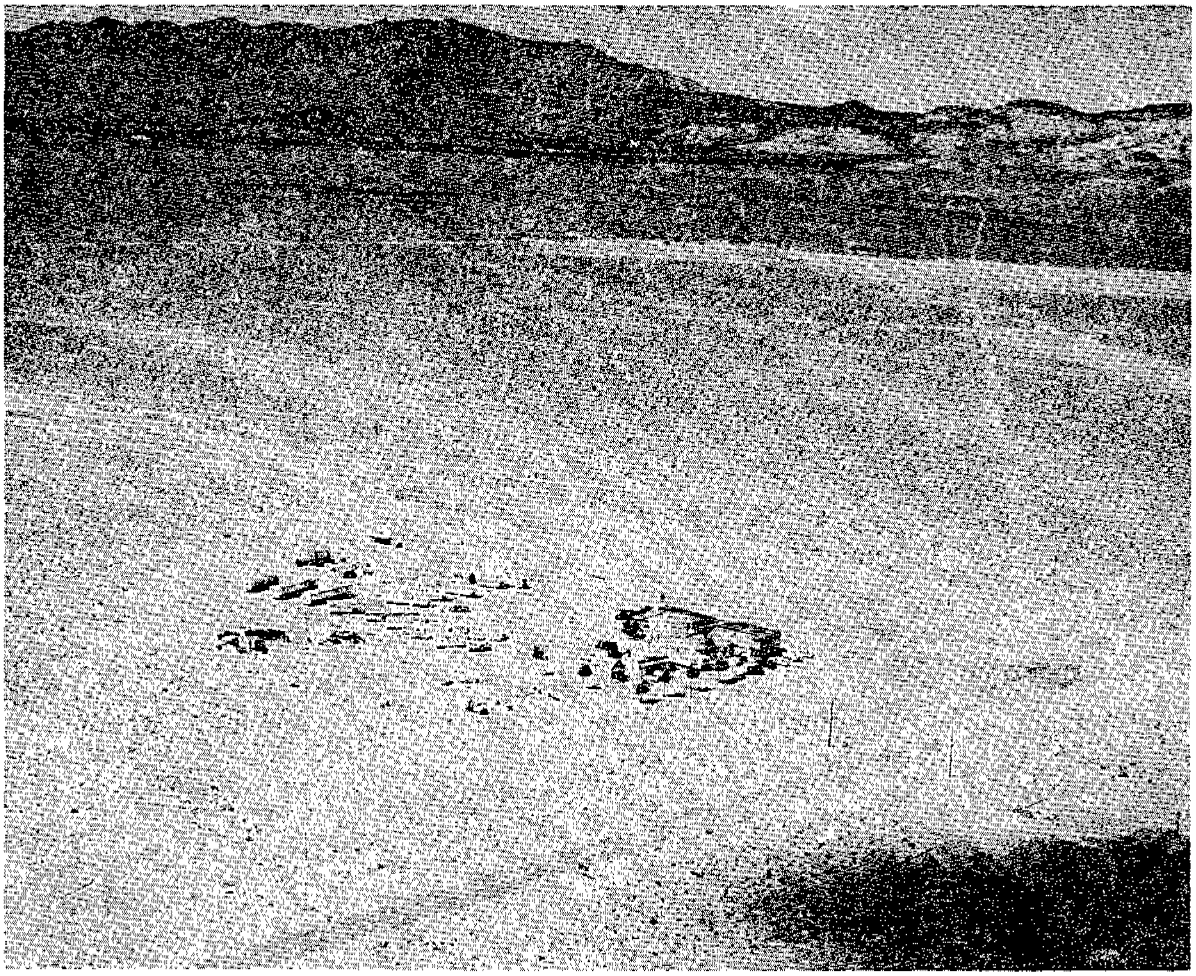
Sarcobatus Flat is a topographically closed valley except for an overflow channel entering the north end of the valley from Stonewall Flat (photograph 3). A large playa occupies the lowest part of the valley at an altitude of about 4,000 feet in the west-central part of Sarcobatus Flat. Two smaller playas occur about 5 miles southeast of the large playa. The small playas are at a slightly higher altitude than the large playa and drain toward the playa in the northwestern part of the valley, the gradient being a few tens of feet per mile. The gradient of the alluvial apron bordering the mountains is on the order of 200 to 300 feet per mile. Within the mountains, land-surface gradients are relatively steep and locally are more than 1,000 feet per mile.

No perennial streams flow into the valley. However, dry washes or canyong leading from the mountains indicate that there is occasional runoff to the playa.

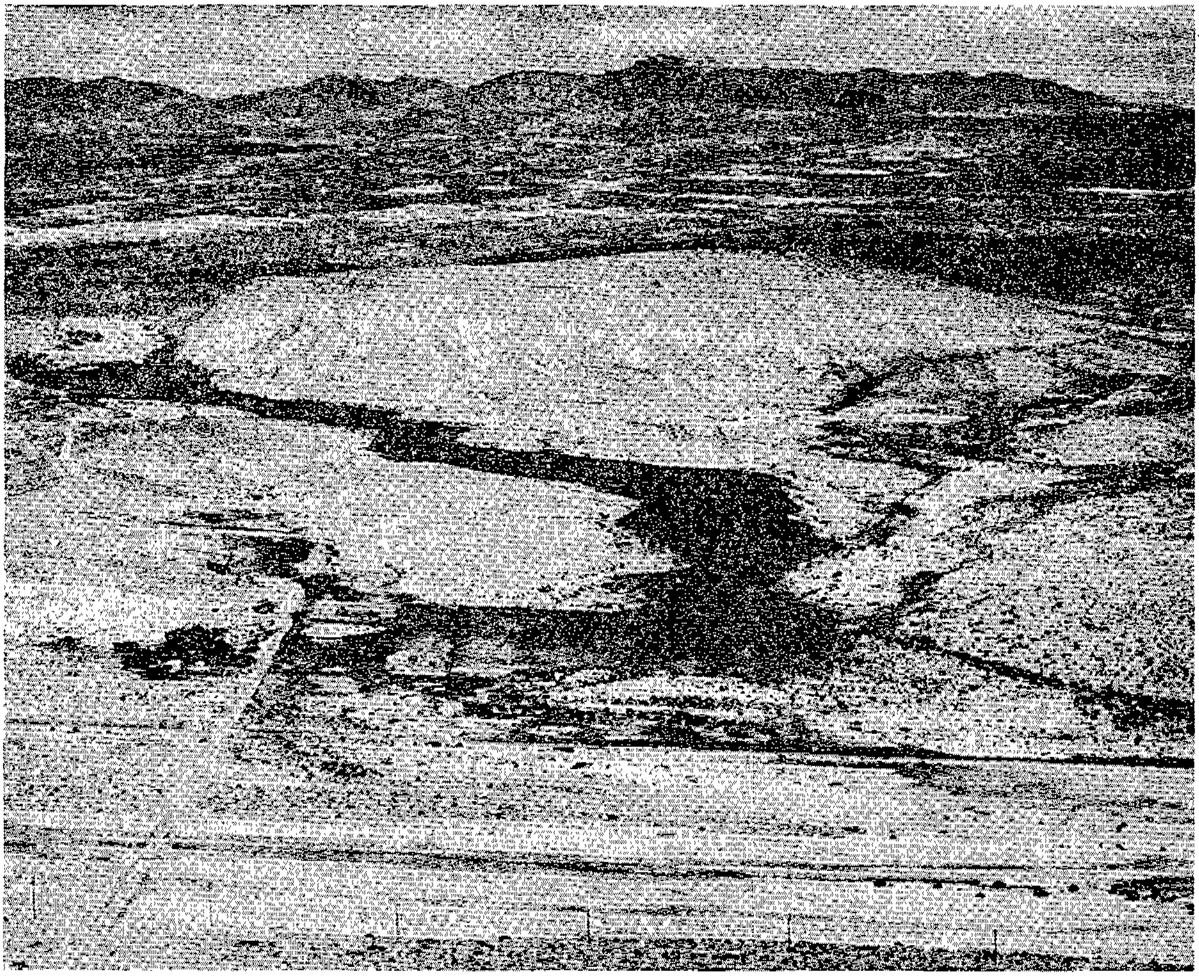
Although there is no surface-water outflow from Sarcobatus Flat under present conditions, streamflow in the geologic past may have discharged from the valley through a narrow gap in the mountains, west of Bonnie Clare, to Death Valley via Grapevine Canyon. The topographic divide at the gap is only a few tens of feet above the floor of the playa. A small amount of alluviation or structural uplift in this area may have formed the present topographic divide.

The large playa in the northwestern part of the valley can be divided into two dissimilar areas on the basis of differences in topographic expression, altitude, and soil characteristics. The western part of the playa is an irregularly shaped area about 2 square miles in extent and includes about 25 percent of the total playa area; it has a flat, compact, hard clay surface. This contrasts with the eastern part which commonly is covered by a white saline efflorescence and underlain by soft, fluffy silt and clay. The surface of the eastern part of the playa locally has minor relief resulting from flood runoff and subsequent wind action. The irregular surface of this part of the playa is about 10 to 15 feet higher in altitude than the western part. The boundary between the two parts of the playa is sharp.

In contrast to Sarcobatus Flat, surface water discharges from Oasis Valley through the Amargosa Narrows to the Amargosa Desert. Normally, however, the Amargosa River is an intermittent stream and has no sustained flow. Thirsty Canyon and its tributaries drain the high area in the northern and northeastern part of the valley between Quartz Mountain and Timber Mountain (photograph 4). That part of Oasis Valley south of Timber Mountain is drained by Beatty Wash. The principal drainage channels in Oasis Valley



Photograph 3. Aerial view to the northeast of Scottys Junction. U.S. Highway 95 crosses picture just beyond buildings, State Highway 72 starts at U.S. Highway 95 and trends southwest (to lower left corner of picture) to Scottys Castle and Death Valley. High point in skyline is Stonewall Mountain. Cluster of buildings in cleared area in middle distance lies adjacent to poorly defined channel which drains the north end of Sarcobatus Flat and rare surface flow from Stonewall Flat.



Photograph 4. Aerial view east of Goss Springs S11/47-10ab1 and irrigated area. Springs issue from Tertiary volcanic rocks. Timber Mountain is in central skyline. Dissected Tertiary rocks mantled by Quaternary alluvium lies between Timber Mountain and spring area. Drainage way of Amargosa River crosses from left to right just beyond pole line.

are incised into the Quaternary alluvium mantling the valley floor and in many places into the underlying Tertiary rocks. About 3 miles northeast of Beatty the Amargosa River is incised about 100 feet below the upland surface of the valley.

Much of the higher parts of Oasis Valley is underlain by Tertiary volcanic rocks that commonly dip at relatively low angles. Erosion of these rocks has resulted in a step-like pattern characterized by steep-walled canyons and relatively flat intervening surfaces.

Streamflow in Oasis Valley is limited to short periods following high-intensity precipitation and during the winter when evapotranspiration decreases and underflow to the Amargosa River increases. Throughout most of the year, however, the Amargosa River is an intermittent stream fed by many springs along the main channel of the Amargosa River between Springdale and Beatty.

GENERAL GEOLOGY

Ball (1907) made a reconnaissance geologic investigation of southwestern Nevada and southeastern California, which included the areas of Sarcobatus Flat and Oasis Valley. Several specific reports of mining areas in the vicinity of Beatty, including those of Ransome, Emmons, and Garrey (1910), Lincoln (1923), Bailey and Phoenix (1944), Thurston (1949), Kral (1951), and Brown (1954). Cornwall and Kleinhample (1961 a, b) studied the geology of the part of the project area south of latitude 37°00' N. Reconnaissance geologic mapping of Nye County currently is in progress under the cooperative program of the U.S. Geological Survey and the Nevada Bureau of Mines.

On the basis of topography and the occurrence of ground-water, the rocks of Sarcobatus Flat and Oasis Valley may be divided into two general groups--bedrock in the mountains and valley fill in the lowlands. The distribution of these units is shown on plates 1 and 3.

The bedrock includes Paleozoic limestone and dolomite and lesser amounts of shale and sandstone, and Tertiary volcanic rocks consisting principally of tuff or other pyroclastics, welded tuffs and flows. These rocks crop out in the mountains and underlie the valley fill.

The valley fill includes deposits that range in age from Tertiary to Quaternary and include rock debris which has been eroded from the surrounding mountains, and the pyroclastic deposits of tuff, welded tuff, and sedimentary deposits. Only a few drillers' logs are available and indicate the general character of the subsurface lithology and water-bearing properties of the upper part of the valley fill. The deposits of Quaternary age consist mostly of unconsolidated clay, silt, sand, and gravel. They were deposited under subaerial and lacustrine environments and were largely derived by erosion of the Tertiary rocks in the mountains. The rocks of Tertiary age underlying the Quaternary deposits are believed to be similar in character to the Tertiary rocks exposed in the mountains.

Bedrock in the Mountains:

The Paleozoic rocks in the Bare Mountain area probably are representative of the older rocks that crop out elsewhere in the area of this report. In the Bare Mountain area, Cornwall and Kleinhampl (1961a) briefly described 11 formations that collectively are more than 21,000 feet thick. The dominant rock types are limestone and dolomite and subordinate amounts of clastic rocks principally in the upper and lower parts of the Paleozoic section. Paleozoic rocks crop out to a smaller extent elsewhere in the area, such as in the Grapevine Mountains, at Stonewall Mountain, and in the vicinity of Tolicha Peak and Quartz Mountain. More limited exposures of these rocks probably occur elsewhere in the mountains.

Tertiary volcanic rocks are the dominant rock type exposed in the mountains bordering Sarcobatus Flat and Oasis Valley. In the Bare Mountain area, Cornwall and Kleinhampl (1961a) describe about 6,000 feet of Tertiary volcanic rocks, including lava flows, welded tuffs, tuffs, and other pyroclastics that range in composition from dacite to rhyolite but locally are basalt.

Ball (1907, p. 84 and 141) indicates that granitic intrusive rocks probably underlie Stonewall Mountain, Tolicha Peak, and Quartz Mountain, on the basis of granitic inclusions found locally in the Tertiary volcanic rocks.

The Tertiary and Paleozoic rocks have been considerably deformed. Cornwall and Kleinhampl (1961a) identify four principal periods of deformation in the structural history of the rocks in the Bare Mountain area:

"1. Folding, probably in middle or late Paleozoic time.

2. Intense thrust faulting and lateral faulting, probably in Mesozoic time.

3. Moderate thrusting and normal faulting in the middle or late Tertiary period.

4. Normal faulting from late Tertiary to Recent time."

It is likely that the rocks in the general area of Sarcobatus Flat and Oasis Valley had a similar structural history.

Valley Fill:

In Oasis Valley, physical conditions suggest that the Quaternary deposits have a maximum thickness of about 200 feet in the upland areas and perhaps only a few tens of feet beneath the flood plain of the Amargosa River. In Sarcobatus Flat there is no positive evidence of the maximum thickness of unconsolidated Quaternary deposits. However, logs of wells, a few miles south of Scottys Junction, suggest that these deposits are at least 200 to 300 feet thick. The Quaternary deposits generally wedge out toward the mountains.

Based on the Tertiary section described by Cornwall and Kleinhampl (1961), which is about 6,000 feet thick, the Tertiary rocks underlying in both valleys are inferred to be of substantial thickness. However, both the Tertiary and Quarternary rocks were deposited on irregular surfaces and therefore the thickness may vary considerably within short distances.

Water-Bearing Properties of the Rocks:

The character of the Paleozoic rocks reported by Cornwall and Kleinhampl (1961a) indicates that their permeability generally is low. However, some water undoubtedly is transmitted through fractures and other secondary openings.

Ground water also occurs in fractures in the Tertiary lava, welded tuff, and tuff, according to studies in the Yucca and Frenchman Flat areas (I. J. Winograd, written communication, 1961). The yield of wells developed in the Tertiary rocks is generally small, although where saturated a considerable amount of water may be stored in them. In the mountain areas of Sarcobatus Flat and Oasis Valley, ground water in the Tertiary rocks supplies a number of low-yield springs. Most of the spring discharge in Oasis Valley is derived from ground water moving through the Tertiary rocks. Saturated Tertiary rocks occurring beneath Quaternary deposits in the lower parts of the valleys probably would yield water to wells at low rates.

The saturated sand and gravel beds in the valley fill generally should yield water freely to wells. The fine-grained deposits contain a considerable amount of ground water in storage below the water table. In the lower parts of Sarcobatus Flat saturated Quaternary deposits undoubtedly are extensively distributed and may provide a valuable water supply. However, in Oasis Valley, physical conditions suggest that the bulk of the Quaternary deposits are largely above the zone of saturation.

GROUND-WATER APPRAISAL

General Conditions:

Virtually all the ground water that can be withdrawn economically from Sarcobatus Flat and Oasis Valley is in the valley fill. Ground water in these valleys is presumed to have originated partly from precipitation within the respective drainage basins of the two valleys and partly from underflow from adjacent valleys to the north and east.

The only precipitation that contributes to the recharge of the ground-water reservoir is that which infiltrates into the permeable deposits of the valley fill in excess of field capacity of the soil zone, or that which percolates into the bedrock in the mountains and eventually enters the ground-water reservoir of the valley fill.

Most of the precipitation on the valley floor is discharged by evaporation or is temporarily stored in the zone of soil moisture and subsequently evaporates or is transpired. Consequently, precipitation on the valley floor contributes little or no recharge to the ground-water reservoir. An unknown but perhaps considerable amount of recharge to Sarcobatus Flat and Oasis Valley may be derived from underflow through the Tertiary or Paleozoic bedrock beneath the topographic divide at the north and northeast sides of the two valleys. Ground water is stored largely in the valley fill and moves away from areas of recharge, which commonly are along the margin of the valley, toward areas of discharge.

The principal areas of natural discharge in Sarcobatus Flat are in and adjacent to the playa on the west side of the valley, and the principal area of discharge in Oasis Valley is along the flood plain of the Amargosa River.

Natural ground-water discharge results from transpiration by phreatophytes and evaporation from soil and free water surfaces where the water surface is at or near the land surface. Most of the discharge by evaporation and transpiration occurs adjacent to the main playa in Sarcobatus Flat and in the flood plain in Oasis Valley. Ground-water discharge probably occurs as underflow from Sarcobatus Flat and Oasis Valley through the alluvium forming the topographic divide at the head of Grapevine Canyon, the Amargosa Narrows, and to a lesser degree, through the underlying Paleozoic and Tertiary bedrock.

Virtually all ground water currently utilized in Oasis Valley issues from springs in the Tertiary and Quaternary deposits. Most of the springs issue from dissected alluvial-fan deposits in and adjacent to the flood plain of the Amargosa River or from fractures and bedding planes in poorly to highly indurated Tertiary tuff. Commonly the springs discharge from the valley floor or within several tens of feet above the valley floor along terraces or escarpments that form the low bluffs on either side of the Amargosa River flood plain. Springs and seep areas in the surrounding mountains occur where the land surface intersects the zone of saturation or a perched water body. Few springs exist in the mountains and most yield less than 5 gpm (gallons per minute).

Chemical Quality:

The chemical quality of the water in most ground-water systems in Nevada varies from place to place. In areas of recharge the dissolved-solids content normally is low. However, as the ground water moves through the system to the areas of discharge, it is in contact with rock materials which have different solubility. The extent to which water dissolves chemical constituents from the rock materials is governed largely by the solubility, volume, and distribution of the rock materials, the time the water is in contact with the rocks, and the temperature and pressure in the ground-water system.

For the present study, samples of water from 25 wells and springs in Sarcobatus Flat and Oasis Valleys were collected by the Geological Survey and analyzed by the Nevada Department of Health. Additionally, four samples were analyzed in 1956 by the Geological Survey. The analyses are listed in table 3. The chemical character of the analyses is shown diagramatically on plates 2 and 4.

The chemical analyses show the more important dissolved constituents and their concentrations in the water. On the basis of the chemical character indicated by the analyses, water can be classified as to its suitability for a variety of uses. For irrigation water some substances, such as calcium, magnesium, potassium, sulfate, and nitrate, are beneficial to plant growth, whereas others, such as sodium and chloride, may be detrimental to both soil and vegetation. Minor constituents, such as boron, also may affect plant growth. Likewise, the presence of excessive concentrations of major constitutents, such as magnesium, sodium, sulfate, and chloride, may have adverse affects in water for domestic use. Also small quantities of some substances, such as fluoride, nitrate, arsenic, iron, and manganese, in drinking water may have adverse physiological effects on humans or otherwise impart a quality unsuitable for domestic use. Therefore, it is essential to know the concentrations of the various constituents in solution in the water.

The range in concentration of several constituents, obtained from the analyses of water in Sarcobatus Flat and Oasis Valley and which are shown in table 3, are tabulated as follows:

Constituent	Range (in parts per million) Low	High
Calcium (Ca)	5	51
Magnesium (Mg)	0	13
Sodium plus potassium (Na + K)	57	489
Sodium (Na)	58	167
Potassium (K)	2	7.5
Bicarbonate plus carbonate (HCO_3+CO_3)	115	1150
Sulfate (SO_4)	14	121
Chloride (Cl)	16	118
Fluroide (F)	0.4	5
Nitrate (NO_3)	Trace	23

In the above tabulation, the high concentration commonly is on the order of 10 times the low for the constituents, suggesting some general relationship of increasing concentration with increase in total dissolved solids. It should not be expected, however, that this simple relationship would hold precisely for all analyses.

Generally the ground water of both valleys may be classified as a sodium-bicarbonate type. This type of ground water commonly is found in areas of Nevada underlain by Tertiary tuffaceous deposits.

Table 3.--Chemical analyses of springs and wells in Sarcobatus Flat and Oasis Valley

Location	Date of collection	Depth of well (feet)	Estimated spring discharge (gpm)	Temperature (°F)	Agency making analysis [a]	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium and Potassium (Na+K) [b]	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 105°C)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Approximate sodium adsorption ratio (SAR)	Approximate specific conductance (micromhos at 25°C) [c]	pH
						Chemical analyses in parts per million and in equivalents per million (equivalents per million in parenthesis)																		
S7/44-28bc1	3- 7-62	100	--	--	1	--	Neg.	51 (2.56)	3.0 (.25)	--	82 (3.55)	--	229 (3.76)	[d] --	48 (1.00)	53 (1.49)	2.7 (.14)	6.0 (.10)	564	140	0	3.0	800	7.6
S7/44-28cb1	3-13-62	203	--	72	1	--	Neg.	48 (2.40)	4.9 (.40)	--	123 (5.33)	--	266 (4.36)	--	106 (2.20)	54 (1.52)	2.7 (.14)	3.0 (.05)	560	140	0	4.5	800	7.9
S8/43-23a1	3-13-62	--	--	--	1	--	Neg.	38 (1.92)	11 (.88)	--	89 (3.88)	--	275 (4.52)	--	24 (.50)	59 (1.66)	1.8 (.09)	Tr	580	140	0	3.3	830	8.2
S8/44-12b1	3- 7-62	--	--	--	1	--	Tr	24 (1.20)	4.9 (.40)	--	489 (21.25)	--	1,150 (18.92)	--	29 (.60)	118 (3.33)	3.4 (.18)	Tr	1,408	80	0	23.8	2,000	7.9
S9/46-20a1	3-21-62	--	--	72	1	--	Neg.	18 (.90)	2.0 (.16)	--	149 (6.47)	--	212 (3.48)	--	67 (1.40)	87 (2.45)	3.2 (.17)	11 (.17)	568	52	0	9.0	810	8.2
S9/46-35a1	3-21-62	--	--	72	1	--	Neg.	11 (.56)	5.8 (.48)	--	87 (3.77)	--	155 (2.56)	--	24 (.50)	55 (1.55)	4.5 (.24)	12 (.20)	427	52	0	5.2	610	8.2
S10/47-14b1	3-14-62	--	50	72	1	--	Neg.	6.0 (.32)	1.0 (.08)	--	117 (5.10)	--	212 (3.48)	--	24 (.50)	54 (1.52)	3.8 (.20)	Tr	384	20	0	11.4	550	8.5
S10/47-27a1	3-14-62	6	--	58	1	--	Tr	24 (1.20)	2.0 (.16)	--	136 (5.92)	--	288 (4.72)	--	34 (.70)	66 (1.86)	3.7 (.19)	Neg.	712	68	0	7.2	1,000	8.0
S10/47-30c1	3-14-62	25	--	--	1	--	Neg.	29 (1.44)	4.9 (.40)	--	110 (4.77)	--	266 (4.36)	--	34 (.70)	49 (1.38)	1.5 (.08)	11 (.17)	412	92	0	5.0	590	7.9
S10/47-30d1	3-14-62	--	25	58	1	--	Neg.	27 (1.36)	4.9 (.40)	--	105 (4.58)	--	278 (4.56)	--	14 (.30)	48 (1.35)	3.2 (.17)	7.6 (.12)	477	88	0	4.9	680	8.1
S10/47-33a1	3-14-62	--	15	75	1	--	Neg.	24 (1.20)	.1 (.00)	--	127 (5.52)	--	275 (4.52)	--	14 (.30)	65 (1.83)	1.9 (.10)	4.0 (.06)	532	60	0	7.2	760	8.0
S11/45-22b1	3-15-62	--	1/4	--	1	--	Tr	42 (2.08)	9.8 (.80)	--	60 (2.60)	--	155 (2.56)	--	38 (.80)	68 (1.92)	.4 (.02)	12 (.20)	352	144	0	2.2	500	7.6
S11/46-26ca1	2-22-56	--	--	60	2	52	.22 (.01)	8.0 (.40)	1.0 (.08)	62 (2.70)	--	2.0 (.05)	131 (2.15)	0.0	22 (.46)	16 (.45)	.5 (.03)	6.7 (.11)	[e] 224	24	0	5.5	[f] 319	7.9
S11/46-26cb1	3-15-62	--	--	65	1	--	.08 (.00)	4.8 (.24)	2.9 (.24)	--	76 (3.31)	--	115 (1.88)	--	62 (1.30)	17 (.48)	.2 (.01)	8.5 (.14)	198	24	0	6.8	280	8.5
S11/46-26dc1	3-15-62	--	1-2	65	1	--	Neg.	8.0 (.40)	3.9 (.32)	--	64 (2.80)	--	139 (2.28)	--	24 (.50)	18 (.51)	.5 (.03)	14 (.23)	228	36	0	4.7	330	8.2
S11/47-4bb1	3-14-62	--	7	65	1	--	Neg.	27 (1.36)	4.9 (.40)	--	126 (5.49)	--	310 (5.08)	--	29 (.60)	52 (1.47)	2.2 (.12)	6.5 (.10)	532	88	0	5.9	760	8.4
S11/47-7dc1	2-22-62	--	--	--	2	55	.00	21 (1.05)	2.9 (.24)	58 (2.52)	--	3.0 (.08)	147 (2.41)	.0	27 (.56)	24 (.68)	.7 (.04)	12 (.20)	[e] 266	64	0	3.2	[f] 399	7.7

Table 3 .--Chemical analyses of springs and wells in Sarcobatus Flat and Oasis Valley--Continued

Location	Date of collection	Depth of well (feet)	Estimated spring discharge (gpm)	Temperature (°F)	Agency making analysis [a]	Chemical analyses in parts per million and in equivalents per million (equivalents per million in parentheses)																Approximate sodium adsorption ratio (SAR)	Approximate specific conductance (micromhos at 25°C) [c]	pH
						Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium and Potassium (Na+K) [b]	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3) [c]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 105°C)	Hardness as $CaCO_3$				
																				Calcium, Magnesium	Noncarbonate			
S11/47-9ac1	3-14-62	--	10	59	1	--	Neg.	24 (1.20)	5.8 (.48)	--	177 (7.70)	--	383 (6.29)	[d] --	34 (.70)	78 (2.20)	3.8 (.20)	Neg.	712	84	0	8.4	1,000	8.0
S11/47-10ab1	3-14-62	--	50-75	71	1	--	Neg.	19 (.96)	1.0 (.08)	--	90 (3.89)	--	188 (3.08)	--	24 (.50)	48 (1.35)	2.9 (.15)	Tr	413	52	0	5.4	590	8.3
S11/47-16dc1	2-22-56	--	5	100	2	65	.00	18 (.90)	.0	167 (7.26)	--	7.4 (.19)	256 (4.20	--	121 (2.52)	45 (1.27)	5.0 (.26)	.3 (.00)	[e] 535	45	0	11.1	[f] 821	7.9
S11/47-16dc1	3-14-62	--	--	97	1	--	Neg.	18 (.90)	.5 (.04)	--	144 (6.25)	--	266 (4.36)	--	72 (1.50)	48 (1.35)	4.2 (.22)	Neg.	526	48	0	9.1	750	7.9
S11/47-18aa1	3-14-62	--	2-3	69	1	--	Neg.	22 (1.12)	3.9 (.32)	--	57 (2.47)	--	151 (2.48)	--	14 (.30)	27 (.76)	.4 (.02)	23 (.37)	171	72	0	2.9	240	8.1
S11/47-21ac1	3-14-62	--	100	97	1	--	Neg.	27 (1.36)	3.9 (.32)	--	181 (7.88)	--	393 (6.44)	--	48 (1.00)	75 (2.12)	4.5 (.24)	Neg.	784	84	0	8.7	1,100	7.9
S11/47-28aa1	3-14-62	--	--	--	1	--	Neg.	40 (2.00)	4.9 (.40)	--	226 (9.81)	--	532 (8.72)	--	19 (.40)	108 (3.04)	1.2 (.07)	3.0 (.05)	1,071	120	0	8.9	1,500	8.1
S11/47-33ba1	3-14-62	--	25	88	1	--	Neg.	4.8 (.24)	.5 (.04)	--	96 (4.71)	--	176 (2.88)	--	34 (.70)	31 (.87)	4.1 (.22)	Neg.	330	14	0	12.2	470	8.4
S12/47-5ca1	2-22-56	--	100-200	76	2	68	--	14 (70)	1.9 (.16)	106 (4.61)	--	5.8 (.15)	194 (3.18)	0.0	69 (1.44)	27 (.76)	4.0 (.21)	.8 (.01)	[e] 368	43	0	7.4	[f] 552	8.2
S12/47-20bb1	3-16-62	--	--	64	1	--	Neg.	32 (1.60)	4.9 (.40)	--	184 (7.99)	--	400 (6.56)	--	48 (1.00)	86 (2.42)	4.5 (.24)	.3 (.00)	853	100	0	8.0	1,200	8.1

a 1, Nevada State Department of Health; 2, U.S. Geological Survey

b Calculated.

c Specific conductance computed by dividing the dissolved solids content by 0.7.

d Carbonate content not reported in samples analyzed by Nevada State Department of Health.

e Residue at 180°C.

f Specific conductance determined in laboratory.

Temperature:

Water samples obtained for this study indicate that the ground water in Sarcobatus Flat has a relatively uniform temperature of 72°F. Commonly the temperature of ground water in the upper part of a ground-water reservoir approximates the annual average air temperature in the area. However, the annual average air temperature at the Sarcobatus station is about 56°F. Thus the ground-water temperature is about 16°F higher than would be expected normally. The reason for this anomalously high ground-water temperature was not determined, but the regional hydrologic and geologic conditions are favorable for ground-water inflow from adjacent areas by relatively deep circulation through bedrock. An alternate reason might relate the higher temperature to a general above-normal temperature gradient of the rocks owing to volcanic or structural activity, but this would not seem to apply to two shallow wells in adjacent Oasis Valley. High temperatures have been observed locally at Hot Springs. Thermal water in Oasis Valley, to the extent observed, occurs only in close proximity to faults.

SARCOBATUS FLAT

Source, Occurrence, and Movement of Ground Water:

The principal ground-water reservoir in Sarcobatus Flat is in the valley fill deposits described on page ~~17~~ 9. Its maximum thickness generally is unknown but may be as much as several thousand feet. It has a surface area of about 380 square miles and extends from the base of the Grapevine Mountains on the west to the base of Pahute Mesa on the east, and from the base of Sawtooth Mountain in the south to Stonewall Mountain in the north. (See plate 1.)

Precipitation at the higher altitudes in the Sarcobatus drainage area is one of the main sources of recharge to the ground-water reservoir. Additional sources of recharge may occur from precipitation on the valley floor, seepage from bedrock, underflow from Stonewall Flat, and underflow from Gold Flat northeast of Pahute Mesa.

Only a small part of the precipitation within the drainage basin reaches the main ground-water body in the valley fill, however, because of large losses due to evaporation and transpiration. The only precipitation that contributes to the recharge of the ground-water reservoir is that which infiltrates into the permeable deposits of the valley fill in excess of the field capacity, or that which percolates into the bedrock in the mountains and eventually drains into the main ground-water reservoir in the valley fill. Additional minor quantities of the precipitation that flows toward the playa from storm runoff following infrequent thunderstorms may recharge the main ground-water body through shallow excavations or "tanks" dug along the margins of the playa for stock watering. Commonly, the bottom of these excavations is below the water table and therefore any surface runoff that may drain into these pits would contribute to the recharge of the ground-water reservoir. Because of the limited size and number of these pits, the low permeability of playa deposits in which they are constructed, and the infrequency of flood runoff to the playa, recharge from this source is considered to be insignificant.

Most wells in the valley penetrate only 200 to 300 feet into the zone of saturated deposits of the ground-water reservoir, and therefore the occurrence of water at greater depths in the ground-water reservoir is unknown. Permeable lenses of sand and gravel are the most productive aquifers of the ground-water reservoir. Commonly, these permeable deposits inter-finger with relatively impermeable lenses of silt and clay. Although silt and clay are highly porous, they yield little or no water to wells.

Water-bearing beds of sand and gravel in the valley fill occur at different depths, and a single well may penetrate several water-bearing strata. Within the depth penetrated by wells the aquifers usually have hydraulic continuity and a single water table probably is common to the area.

As indicated previously, water in the ground-water reservoir moves slowly from areas of recharge to areas of discharge. The recharge areas in Sarcobatus Flat are along the periphery of the drainage basin and the principal area of discharge is in the playa area. Accordingly, the water-level gradients in Sarcobatus Flat generally slope toward the main playa.

The altitude of the water table in the gap at the head of Grapevine Canyon, which is approximately 3,950 feet above mean sea level, is the lowest known water-table altitude in the valley. Approximately 7 miles northeast of the gap, the altitude of the water table is approximately 4,015 feet or about 70 feet higher than in the gap. The hydraulic gradient between these two points, therefore, is about 10 feet per mile. In the southeastern part of the valley at well S9/46-35a1, the altitude of the water table is approximately 4,000 feet above mean sea level, or about 55 feet higher than the water-level altitude near the gap. The gradient between these two points, which are about 20 miles apart, is about 2.5 feet per mile. From these examples it is inferred that the movement of water in the ground-water reservoir is toward Bonnie Clare. Data are insufficient to determine the direction of movement with any degree of certainity in the area west of Bonnie Clare. However, because virtually all ground-water discharge in Sarcobatus Flat is east of Bonnie Clare, the inferred westward sloping hydraulic gradient beneath the discharge area suggests that some ground-water underflow moves westward from Bonnie Clare toward the gap and probably through the gap to Grapevine Canyon.

The low mountain spurs that crop out on either side of the gap plunge beneath the alluvial fans that have coalesced in the gap to form the topographic divide. A small quantity of ground-water underflow probably moves to Grapevine Canyon through this alluvial debris and to a lesser extent through the underlying bedrock. Observed geologic and hydrologic conditions in the vicinity of the gap west of Bonnie Clare suggest that ground-water underflow from the valley probably is small.

Estimated Average Annual Recharge

The average annual recharge to the ground-water reservoir from precipitation within the drainage basin can be estimated as a percentage of the average annual precipitation within the basin. The average annual precipitation within the basin can be estimated from a generalized map showing the distribution of precipitation in Nevada (Hardman and Mason, 1949, p. 10). The map is divided into precipitation zones, based largely upon altitude and types of vegetation. In general, precipitation increases with altitude; the greater amount commonly occurring on the highest mountains. A comparison of the precipitation distribution map with recent topographic maps indicates that the precipitation zones suggested by Hardman coincide roughly with the topographic contours. The map suggests that in the area lying below 5,000 feet altitude the annual precipitation is less than 8 inches. At altitudes between 6,000 and 7,000 feet, annual precipitation ranges from 8 to 12 inches; from 7,000 to 8,000 feet the annual precipitation ranges from 12 to 15 inches; and at altitudes above 8,000 feet the annual precipitation ranges from 15 to 20 inches.

The total annual precipitation on each zone is computed by multiplying the average annual precipitation on each zone by the area of the zone. On the basis of these computations the average annual precipitation within Sarcobatus Flat is about 190,000 acre-feet.

Precipitation zone (inches)	Altitude of zone (inches)	Area of zone (acres)	Precipitation acre-feet per year (rounded)	Percent recharge	Approximate recharge acre-feet per year (rounded)
15 - 20	above 8,000	1,000	1,500	15	220
12 - 15	7,000-8,000	9,000	10,000	7	700
8 - 12	6,000-7,000	32,000	26,000	1	260
less than 8	below 6,000	500,000	150,000	0	0
Total (rounded)			190,000		1,200

The percentage of precipitation that recharges the ground-water reservoir in each precipitation zone shown in the above table is based on studies in eastern Nevada by Eakin and others (1951, p. 79-81). Based on the estimated percentage of precipitation recharging the ground-water reservoir as indicated by those studies, and insofar as the data are applicable to the study area, the estimated average annual recharge to Sarcobatus Flat is about 1,200 acre-feet.

Because there has been little ground-water development in Sarcobatus Flat, the ground-water reservoir is in approximate equilibrium; that is, the average annual recharge to the basin is equal to the average annual discharge from the basin. A comparison of the estimated average annual recharge computed from precipitation and the estimated average annual discharge (p. 16-17) indicate that discharge from the valley is considerably more than the computed recharge. If the reconnaissance estimates of discharge and recharge are reasonably good then it must be concluded that approximately 2,300 acre-feet of ground-water recharge to the ground-water reservoir is derived from underflow from tributary valleys.

Data are insufficient to determine if there is hydrologic continuity between Stonewall Flat, Gold Flat, and Sarcobatus Flat. The altitude of the water table is higher in these valleys than in Sarcobatus Flat, and therefore it is possible that underflow from these areas recharges the ground-water reservoir in Sarcobatus Flat. The drainage divide separating Sarcobatus Flat and Stonewall Flat is formed by a low alluvial divide about 2 miles wide between Stonewall Mountain and the Tertiary (?) basalt flows which form the drainage divide along the northern border of the study area. Numerous small exposures of basalt protrude above the alluvial deposits suggesting that the alluvial fill along the drainage divide between the two valleys may be relatively shallow. The water-level altitude of about 4,310 feet at Lida Junction in Stonewall Flat is about 365 feet below land surface. A projection of the water table from Lida Junction toward Sarcobatus Flat indicates that the depth to water below the surface of the gap would be at considerable depth and therefore it seems probable that little underflow would occur through the Quaternary deposits of the valley fill. Consequently any underflow from Stonewall Flat to Sarcobatus Flat probably occurs in the underlying Tertiary volcanic or Paleozoic carbonate rocks.

Recharge to the ground-water reservoir in Sarcobatus Flat also may result from underflow from Gold Flat through the Tertiary pyroclastic rocks forming Pahute Mesa. The altitude of the water table in Gold Flat is about 900 feet higher than in Sarcobatus Flat and the pyroclastic deposits that form Pahute Mesa are capable of transmitting water. Therefore, ground-water underflow from Gold Flat seems highly possible.

Estimated Average Annual Discharge:

Ground water is discharged from Sarcobatus Flat by natural and artificial methods. Natural discharge of ground water from the basin occurs principally by transpiration, evaporation, and underflow. Ground water discharged from wells within the valley presently represents only a small fraction of the natural discharge.

Transpiration: Transpiration by native vegetation constitutes practically the entire discharge from the ground-water reservoir. Ground-water discharge by transpiration occurs principally in the area surrounding the playa where the water table is within a few feet or tens of feet below the land surface. In the area surrounding the playa, the water table is near enough to the land surface to support vegetation known as phreatophytes. Phreatophytes obtain their perennial supply of water from the water table or the capillary fringe above it. The depth from which phreatophytes are capable of extracting water varies with different plant species. Generally, the roots of grasses do not extend more than a few feet below the land surface; however, plants such as greasewood may extend their roots to depths of 50 feet below land surface.

The quantity of ground water that is discharged by transpiration is dependent on the depth to water, the species of plant and their density, type of soil, climate, length of growing season and many other factors.

The dominant species of phreatophytes in Sarcobatus Flat is greasewood. Less abundant species include rabbitbrush, saltgrass, and ryegrass.

The phreatophytes in Sarcobatus Flat grow along the margin of the playa where the depth to water ranges from a few feet to about 40 feet, and averages about 20 feet. Within this area approximately 14,000 acres of phreatophytes were mapped (pl. 1). Most of the phreatophytes are along the north side of the playa where they occupy a band about 2 1/2 miles wide. Elsewhere around the playa, the phreatophyte area is less than a mile wide.

Estimates of ground-water discharge by phreatophytes in Sarcobatus Flat are based on studies of the consumptive use by phreatophytes in the Great Basin, by Lee (1912), White (1932), and studies by Young and Blaney (1942) in southern California. Based on the principal species of plant, approximate average areal density, the average depth to water, and the controlling climatic factors, the estimated annual rate of ground-water use by phreatophytes in Sarcobatus Flat is about 0.2 foot per year. At this rate of use, about 2,800 acre-feet of ground water is transpired annually by native vegetation.

Evaporation: Discharge of ground water by evaporation from the 9,000-acre playa may occur where the depth to ground water or the capillary fringe is near the land surface. The depth to the water table beneath the surface of the western part of the playa at the abandoned railroad stop at Bonnie Clare is about 5 feet. The depth to water in the eastern part of the playa locally may be as much as 20 feet, depending upon the local relief of the playa surface.

Discharge of ground water by evaporation from the western part of the playa probably is small despite the shallow depth to water, because of the compact nature of the clay and the possible occurrence of layers of hardpan that would tend to reduce the rate of evaporation from the capillary fringe. The rate of discharge by evaporation from the eastern part of the playa locally may be where the depth to water is within a few feet of land surface, but for the area as a whole the average rate of evaporation probably is small because the average depth to water probably is 10 to 15 feet. Accordingly, it is estimated that the average annual evaporation from the playa area probably does not exceed a few hundred acre-feet. Thus, total average annual discharge of ground water by transpiration and evaporation may be on the order of 3,000 acre-feet.

Underflow: Geologic and hydrologic conditions at the head of Grapevine Canyon and the adjacent area in Sarcobatus Flat strongly indicate that ground water may be discharged from Sarcobatus Flat through Grapevine Canyon by underflow through the alluvial fill and underlying bedrock in the narrow gap west of Bonnie Clare. From the head of Grapevine Canyon the hydraulic gradient of the water table slopes about 50 feet per mile toward the southwest. Ground-water underflow in Grapevine Canyon moves through the alluvial fill mantling the canyon floor or through the underlying bedrock toward Strainingers Spring near the mouth of Grapevine Canyon, where most of it is presumed to be discharged. If it is assumed that all or part of the spring discharge in Grapevine Canyon is supplied by ground-water underflow from Sarcobatus Flat, then an estimate of underflow can be made on the basis of spring discharge measurements. The combined discharge of the springs in Grapevine Canyon were reported by Ball (1907, p. 20) to be about 600,000 gallons per day or about 700 acre-feet per year. Part of the spring discharge, however, probably is derived from local recharge on tributary drainage areas adjacent to Grapevine Canyon. Based on the percentage of precipitation recharging the ground-water reservoir discussed on p. 15, approximately 200 acre-feet of the spring discharge probably resulted from precipitation in the mountains bordering Grapevine Canyon. Thus, the difference between the estimated discharge of the springs and the estimated recharge from precipitation is about 500 acre-feet and may represent the magnitude of ground-water underflow from Sarcobatus Flat, assuming that the above estimates reasonably reflect actual conditions.

Perennial Yield:

The perennial yield of the water-bearing deposits in Sarcobatus Flat is the rate at which water can be pumped from wells year after year without decreasing the storage to the point where the rate becomes economically unfeasible or the rate becomes physically impossible to maintain. It is ultimately limited by the amount of water available to the system through natural and artificial recharge an infiltration of any excess irrigation and waste water.

The net amount of water that can be pumped perennially is limited to the total natural discharge and underflow that can be diverted to wells, and the amount of water that infiltrates to the ground-water reservoir that can be salvaged and is suitable for reuse.

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 in 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 infiltration of excess irrigation water. Ground water discharged by wells usually is offset eventually by a reduction of the natural discharge. In practice, however, it is difficult to compensate fully for the discharge by wells by a decrease in the natural discharge, except when the water table has been lowered to a level that eliminates ground-water underflow from the basin and transpiration in the natural area of discharge. Ground-water underflow out of the drainage basin further complicates the evaluation of perennial yield. Pumping from wells might not salvage much of this discharge unless the wells were drilled in the vicinity of the gap west of Bonnie Clare so as to intercept any underflow that may discharge through Grapevine Canyon, or unless pumping results in the removal of a substantial part of the ground water in storage in the valley fill. 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 only after there has been substantial development of ground water for several years.

The estimated perennial yield that can be developed in Sarcobatus Flat, based on the assumption that nearly all of the natural discharge from the basin can be salvaged is limited to the average annual natural recharge to the ground-water reservoir, and is tentatively about 3, 500 acre-feet per year.

Storage Capacity:

A large quantity of ground water is stored in the valley fill in Sarcobatus Flat. The total volume is many times the average annual recharge to the system and probably represents an accumulation of water over a period of hundreds or thousands of years.

The total volume of valley fill that forms the principal ground-water reservoir is unknown because of the variation in the thickness of the valley fill resulting from variations in the surface of the underlying bedrock. The total volume of water that may be stored in the main ground-water reservoir in Sarcobatus Flat can not be computed from available information.

The magnitude of the total amount of recoverable ground water in storage may be obtained, however, by estimating the amount of water that will drain from the top foot of saturated sediments. The surface area of the valley fill is approximately 380 square miles or about 240, 000 acres. If the drainable pore space in the alluvium is assumed to be about 10 percent, which may be conservative, the volume of water that will drain from a given volume of alluvium by gravity is equal to approximately 0. 1 of the volume of the dewatered material; that is, for each hundred cubic feet of saturated sediments approximately 10 cubic feet of water will be released by gravity drainage. It can be computed that approximately 24, 000 acre-feet of water will drain from storage for each foot lowering of the water table. Accordingly, the amount of water in storage in the upper foot of saturated sedimentary deposits in the ground-water reservoir represents an accumulation of approximately 20 years of recharge estimated to be derived from precipitation within the drainage basin.

The recoverable stored water that could be developed by pumping is very large. Continued withdrawals of ground water from storage in excess of the yield, however, would result in declining water levels and a diminishing reserve of water in the ground-water reservoir, which in turn would restrict the development to a limited period of time.

A principal point to be recognized is that the volume of water in storage provides a reserve for maintaining a uniform annual supply for pumping independent of annual variations in recharge resulting from periods of above or below average precipitation.

Chemical Quality of Water:

The dissolved-solids content of ground water from six wells and one spring in Sarcobatus Flat ranges from 352 to 1,407 ppm (table 3). The maximum dissolved-solids content occurs in the shallow dug well (S8/44-11ba1) located in a topographically low area east of the playa. The depth to water is about 2 feet. As this is an area of discharge the dissolved-solids content would tend to be relatively high owing to concentration by evapotranspiration.

The dissolved-solids content of the samples from five wells averages about 540 ppm. The location of the wells from which these samples were collected suggests that they are reasonably representative of the general character of the ground water in the valley fill of Sarcobatus Flat. Plate 2 diagrammatically shows the chemical character of the several water samples in terms of their major constituents. The relatively high proportion of sodium + potassium and bicarbonate indicates that the ground water in Sarcobatus Flat generally is of a sodium-bicarbonate type.

The suitability of water for irrigation depends on many factors, including the chemical quality of the water, the physical character and the mineral content of the soil, drainage characteristics of the soil, irrigation practices, and many other related subjects. A method of classifying water for irrigation used by the U.S. Salinity Laboratory (1954) is based on the electrical conductivity, or more simply the specific conductance, of the water and the sodium-adsorption ratio (SAR). The electrical conductivity is an approximate measure of the concentration of the ionized constituents in the water, and the sodium-adsorption ratio is a measure of the adsorption of sodium by soil. Water of low conductivity and SAR value is more suitable for irrigation than water of high conductivity and SAR value.

By plotting the calculated value of the specific conductance at 25°C, and the sodium-adsorption ratio on a diagram shown in fig. 2, water can be classed as to its suitability for irrigation. The Salinity Laboratory of the U.S. Department of Agriculture (1954, p. 79) gives the following classification of irrigation water with respect to the salinity and sodium hazards.

1. Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

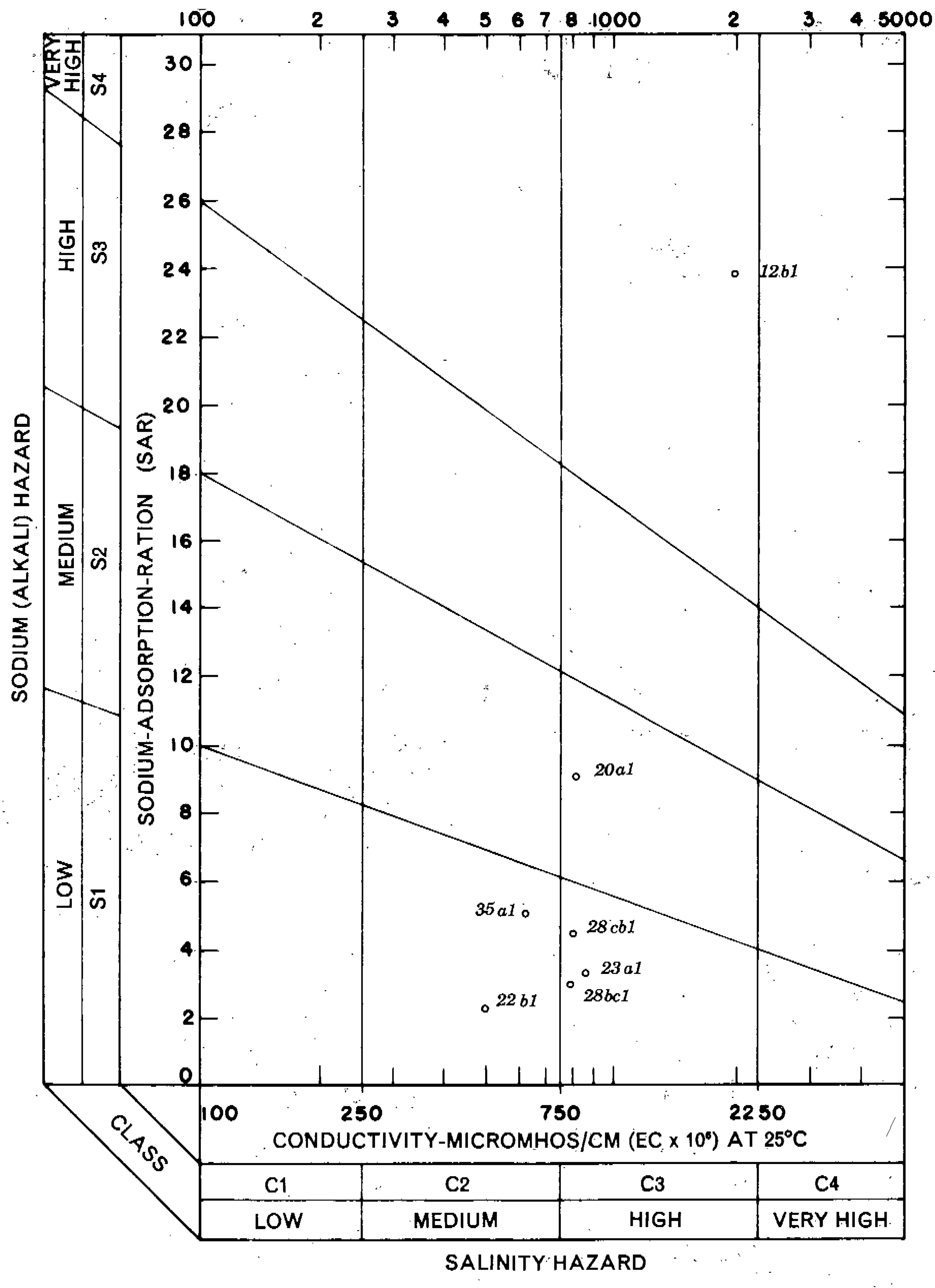


FIGURE 2.—— Approximate classification of irrigation water on the basis of computed conductivity and approximate sodium-adsorption ratio.

2. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

3. High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

4. Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances.

1. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stonefruit trees and avocados may accumulate injurious concentrations of sodium.

2. Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

3. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions.

4. Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except under special circumstances.

The classification of ground water from wells for irrigation given in fig. 2, although only approximate, indicates that moderate to extensive leaching will be required, depending on the drainage character of the soils. In some instances it may be necessary to plant crops having good salt tolerance, or special management may be required for salinity control.

Additional factors to be considered in classifying water for irrigation include the quantity of boron in solution and the residual sodium carbonate. In small quantities boron is necessary for proper plant nutrition, but in quantities of slightly more than 5 ppm, boron is extremely toxic. Boron was not analyzed in the samples collected during this study.

Residual sodium carbonate is a measure of the hazard that may be involved in the use of high bicarbonate water. Using Eaton's (1950) concept of "residual sodium carbonate" values (described in U.S. Department of Agriculture handbook, no. 60, 1954) for the analyses of water from the six wells sampled, ranged from 0.95 millequivalents per liter for the sample from well S7/44-28bc1 to 17.32 for the sample from well S8/44-12b1. Values for the other four samples ranged between 1.52 and 2.42. According to this method of calculation values greater than 2.5 are not suitable for irrigation purposes. Waters having values of 1.25 to 2.5 are marginal and those containing less than 1.25 are probably safe. On this basis four of the analyses indicate water that may be of marginal quality.

The foregoing discussion suggests that careful consideration should be given to the chemical quality of water intended for irrigation in Sarcobatus Flat.

Development:

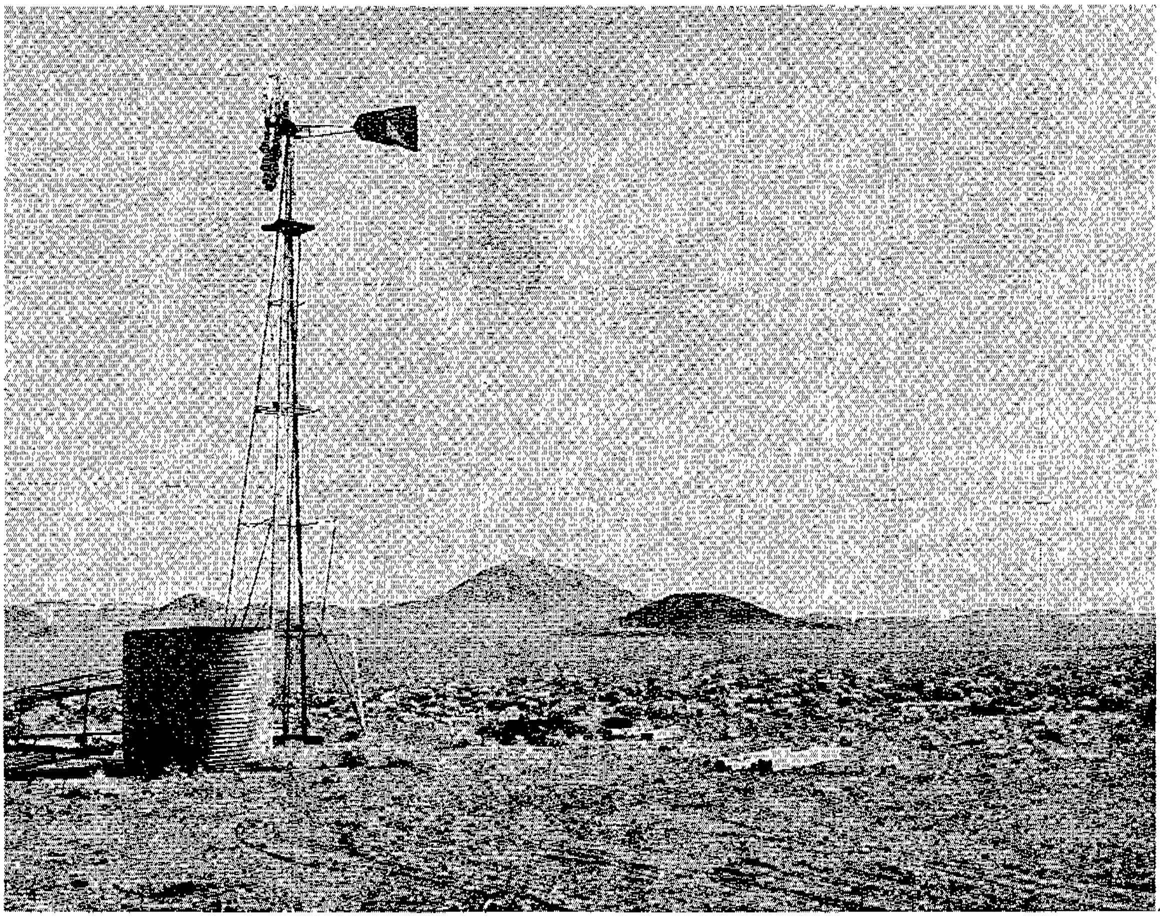
Pumpage of ground water in Sarcobatus Flat in 1961 was limited to several domestic and stock wells and two irrigation wells.

The total pumpage for domestic and stock use is estimated to be about 10 to 15 acre-feet per year. Ground water pumped for domestic use is limited to a bar, restaurant and service station, a highway maintainance station, and three homes. Three wells in the south end of the valley currently are being used for stock watering (photograph 5). These wells are equipped with windmills and under optimum conditions will pump but a few gallons per minute.

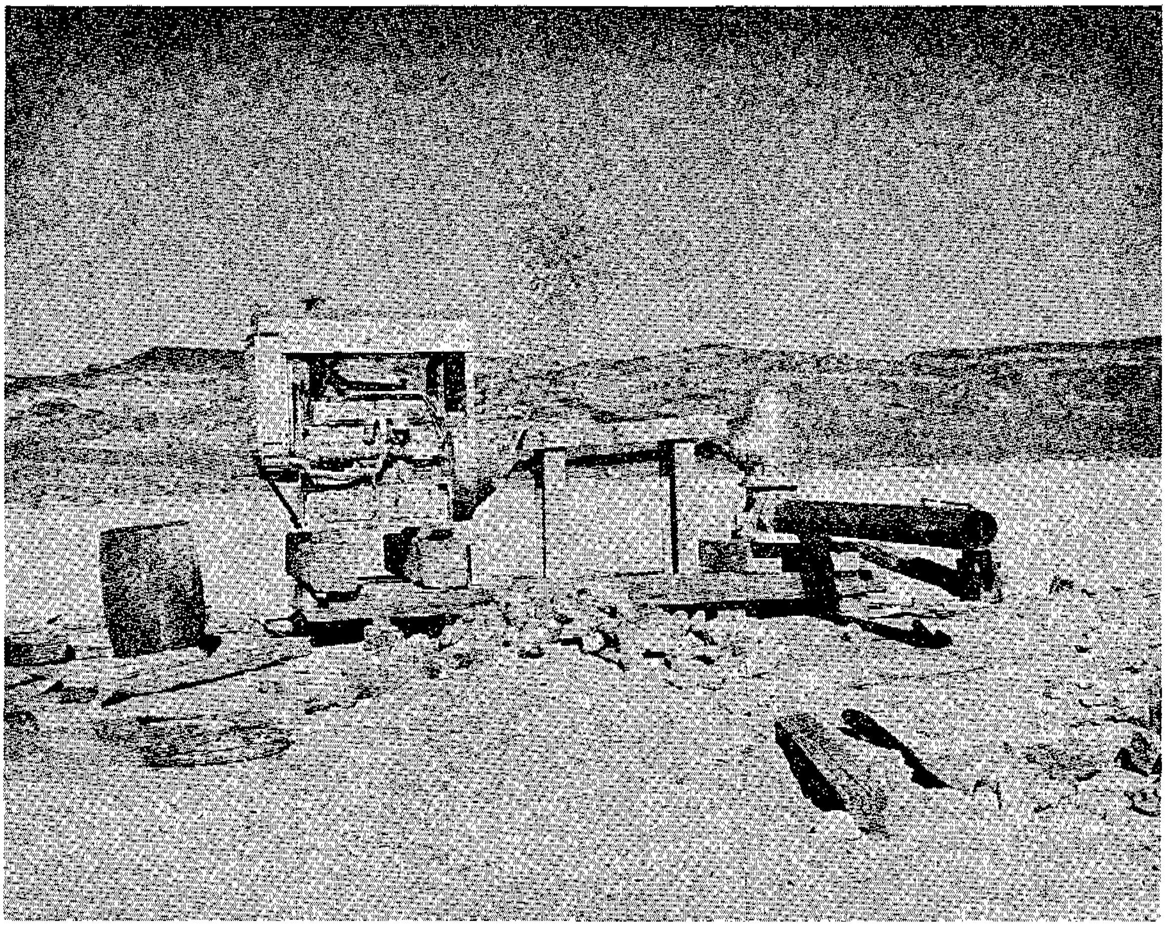
Pumpage of ground water for irrigation is small. During 1961, less than 25 acres of land were irrigated and probably less than 50 acre-feet of ground water was pumped. In sections 8 and 11, T. 8 S., R. 44 E., three large diameter irrigation wells recently were constructed and equipped with pumps (photograph 6). Approximately 120 acres of land adjacent to the wells has been cleared and leveled, and presumably will be placed in cultivation during the summer of 1962.

In 1961 the annual ground-water pumpage for all uses probably did not exceed 75 acre-feet. Within the next few years, however, production of ground water would be accelerated substantially, particularly if the present attempts at irrigation prove successful.

Summary of Ground-Water Discharge: The estimated total discharge from the ground-water reservoir includes natural and artificial discharge. Natural discharge by evapotranspiration is about 3,000 acre-feet and underflow from the valley is estimated to be about 500 acre-feet annually. Artificial discharge from the ground-water reservoir by pumpage probably does not exceed 75 acre-feet annually, thereby making the estimated total draft on the ground-water reservoir in Sarcobatus Flat about 3,500 acre-feet annually.



Photograph 5. View northeast of stockwell S9/46-35a1 about 2 miles north of the topographic divide between Sarcobatus Flat and Oasis Valley. Note recent volcanic cinder cone in background.



Photograph 6. View east of irrigation well S8/44-10 1, Sarcobatus Flat. The western margin of Pahute Mesa, in the background, forms the east boundary of Sarcobatus Flats. The banded rocks are of Tertiary age and principally include tuff and welded tuffs.

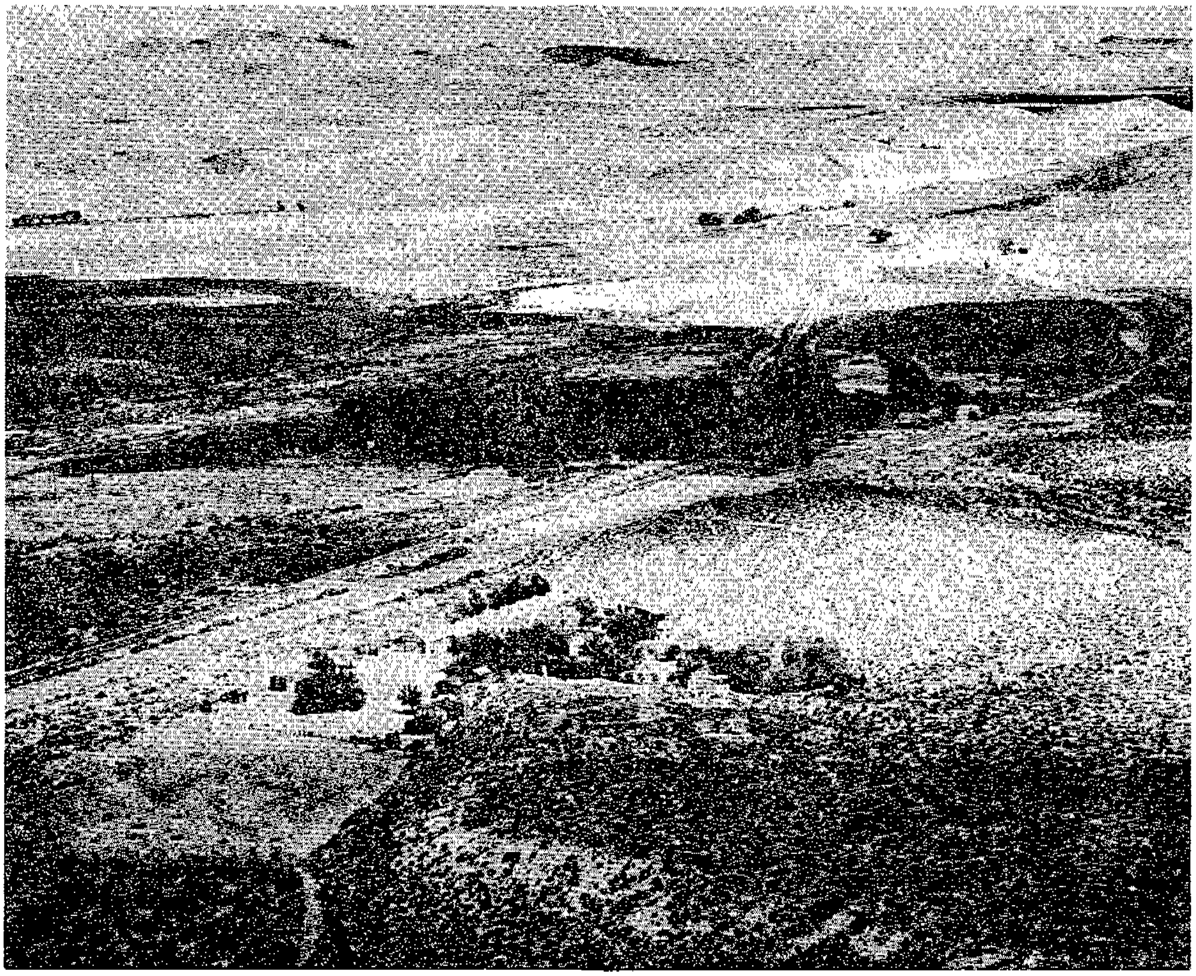
OASIS VALLEY

Source, Occurrence, and Movement of Ground Water:

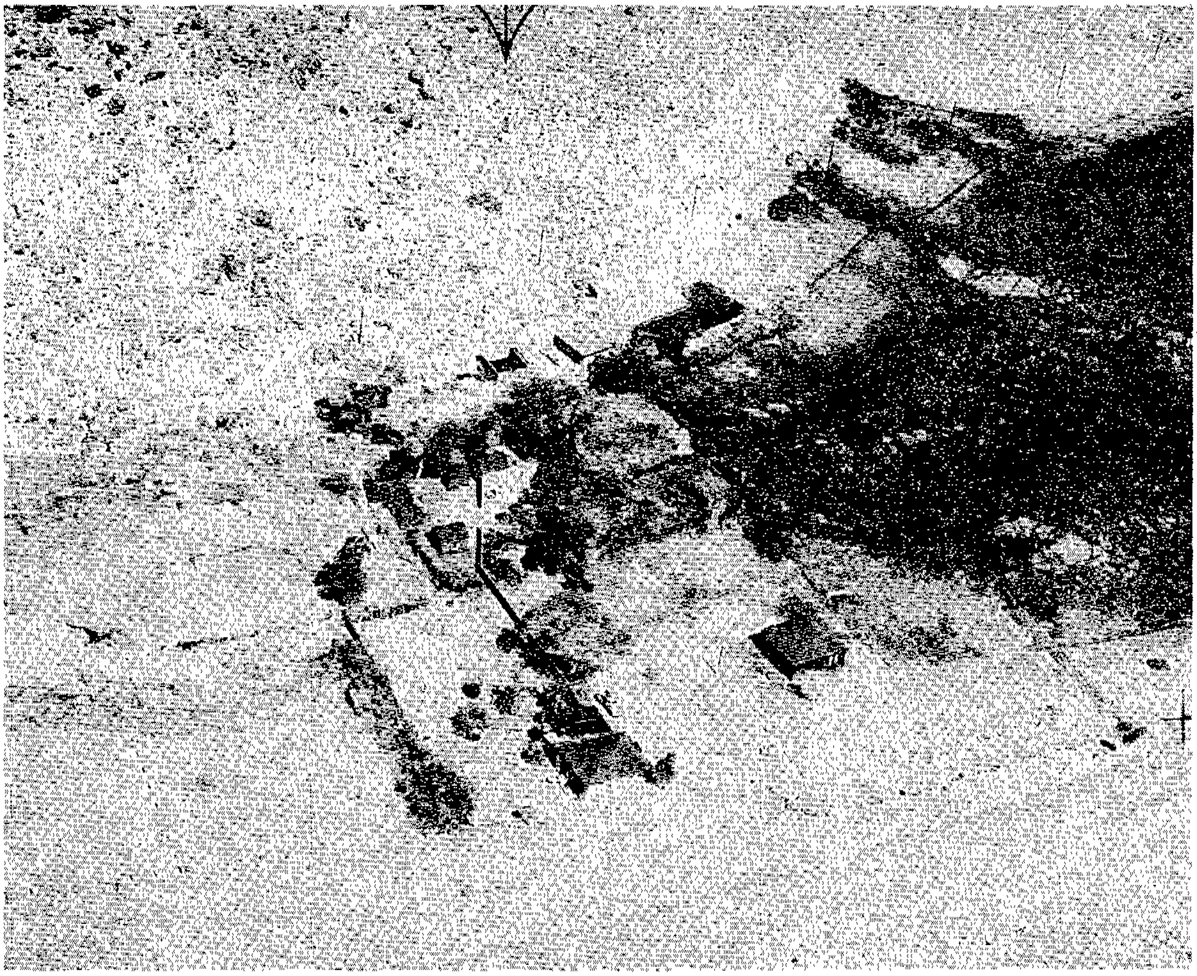
The valley fill constitutes the principal ground-water reservoir in Oasis Valley (pl. 3). Its thickness is not known but may be several thousand feet. The valley fill underlies an area of about 60 square miles or about 15 percent of Oasis Valley. Most of the area shown as valley fill on plate 3 is mantled by unconsolidated alluvial deposits of sand and gravel. The land surface of the area underlain by valley fill slopes at a low angle toward the Amargosa River. Drainageways have been incised into the unconsolidated deposits and locally have exposed the underlying Tertiary rocks. Most of the valley fill is composed of porous material capable of storing and transmitting water. Throughout Recent geologic history, infiltration of precipitation, streamflow, and underflow from adjacent valleys has saturated part of the porous material of the valley fill.

The principal areas of recharge from precipitation within Oasis Valley are adjacent to Black and Timber Mountains in the north and east parts of the valley, respectively. Some recharge also occurs in other topographically high areas, such as the Bullfrog Hills. Underflow through bedrock from areas beyond the drainage divide to the north and northeast of Oasis Valley apparently contributes a considerable proportion of the ground-water recharge to the valley.

Virtually all the ground-water development in Oasis Valley has been confined to the narrow strip of alluvial fill adjacent to the Amargosa River and its tributaries, south of the latitude of Springdale (photograph 7). The flood plain of the Amargosa River is a relatively flat surface of poor drainage. Along the main stem of the river the valley fill beneath the flood plain is saturated in most places to within a few feet of land surface. Away from the flood plain, the depth to water generally increases. The river, which is intermittent, is in a relatively narrow valley less than half a mile wide and has been incised into the alluvial fans that slope toward the river from either side of the valley. In areas where the cross-sectional area of the alluvial fill is decreased by relatively impermeable material which constricts the ground-water underflow through the alluvial fill, water is forced to the land surface. Commonly, these areas are identified by springs seeps, and swampy areas. Many springs issue from the well dissected alluvial-fan deposits on both sides of the flood plain of the Amargosa River. Many of these springs issue from the terraces, 20 to 50 feet above the valley floor, suggesting that much of the inflow from the tributary areas probably moves along the contact between the Quaternary alluvium and the underlying Tertiary rocks, or that it moves upward through joints or fractures in the underlying Tertiary rocks. Many of the springs are warm, suggesting that they probably are associated with deep ground-water circulation through joints and fractures in the underlying rocks (photograph 8). Many of the cooler springs probably are supplied by perched water moving along the contact between the Tertiary beds and alluvium.



Photograph 7. Aerial view to southeast of a part of Oasis Valley. Dark area in lower center of picture is Springdale. Ranches indicated by groups of trees lie in the main drainageway of Amargosa River. Springs occur at most ranches similarly located in Oasis Valley.



Photograph 8. Aerial view to southeast of Hot Springs in sec. 16, T. 11 S., R. 47 E., temperature, 97°F. Tertiary volcanic rocks crop out in hill in upper left of picture. Dark area at right is wet meadow supplied partly from Hot Springs and partly be surface and underflow along Amargosa River.

Ground water in Oasis Valley is both confined and unconfined. Flowing artesian water was developed in well S11/47-21ac2 on the west side of the Amargosa River. The well is of unknown depth and construction, is in a large spring area, and probably taps the spring system. Other artesian wells may be developed where ground-water inflow from the adjacent drainage areas becomes confined beneath lenses or layers of clay of the flood-plain deposits which undoubtedly interfinger with the alluvial fan deposits. Artesian water may also be encountered in deep wells penetrating the fractured volcanic rocks underlying the alluvial fill.

The movement of ground water in Oasis Valley can be inferred only in a general way because of the scarcity of existing ground-water data. In general, ground water moves from areas of recharge along the margins of the valley to areas of discharge. From the principal areas of recharge adjacent to Black and Timber Mountains ground water moves southwestward toward the Amargosa River, where most of it emerges as springs and seeps or moves as ground-water underflow beneath the Amargosa River flood plain toward the Amargosa Narrows. A limited quantity of ground-water underflow also moves toward the Amargosa River from the Bullfrog Hills.

Estimated Average Annual Recharge:

The average annual recharge to Oasis Valley is derived principally from precipitation on the slopes of the mountains within the drainage area shown in plate 2, and from ground-water inflow from the adjacent valleys north and east of Oasis Valley.

The average annual recharge to Oasis Valley from precipitation within the drainage basin is about 250 acre-feet, based on the estimated percentage of precipitation recharging the ground-water reservoir. The method of estimating recharge has been discussed previously (p. 15).

The estimate of ground-water inflow into Oasis Valley is derived by indirect methods and is based on the difference between the estimated average annual natural recharge from precipitation within the drainage basin and the estimated total ground-water discharge (p. 25-26). The validity of the estimates of natural recharge from precipitation and natural discharge are subject to the same limitations previously discussed. However, to the extent that they may reasonably represent actual conditions, the average ground-water inflow from the adjacent valleys to the north and east is estimated to be on the order of 1,800 acre-feet annually.

Gold Flat to the north of Oasis Valley seems to be a likely source of ground-water inflow through bedrock to Oasis Valley. The bedrock exposed in the mountains between the two areas is composed largely of Tertiary tuff and welded tuff. These in turn may be underlain by Paleozoic carbonate rocks. Deep test holes penetrating the Tertiary and Paleozoic rocks in adjacent valleys east of the study area have demonstrated that both the Tertiary and Paleozoic rocks are capable of transmitting substantial amounts of ground water. The lowest known water-level altitude in Gold Flat is about 4,900 feet, or about 650 feet higher than the northernmost spring in Thirsty Canyon in Oasis Valley. The distance between the spring and the area of minimum-water-level-altitude in Gold Flat is about 30 miles, and therefore if a hydraulic continuity exists between these two points, the gradient is on the order of 20 feet per mile. Consequently, it seems probable that some ground-water inflow is transmitted through bedrock from Gold Flat to Oasis Valley.

Estimated Average Annual Discharge:

Virtually all ground-water discharge from Oasis Valley is by evapotranspiration and ground-water underflow to Amargosa Desert. There are many small springs in Oasis Valley that discharge less than 50 gpm and several that discharge more. Notable among the larger springs are the Beatty Springs, which are currently being used as the municipal water supply for Beatty, an unnamed spring a few hundred yards north of the headquarters of the Rancho Trueba, Goss Springs, an unnamed spring at the Fleur-de-lis Ranch in S10/47-14B1, and another in the Amargosa Narrows about 2 miles south of Beatty. Except for the domestic and commercial use of water at Beatty and a limited amount of spring water used for irrigation, most of the spring flow in Oasis Valley is discharged or lost from the valley by evaporation and transpiration. That which is not discharged directly may infiltrate down to the main ground-water reservoir only to reappear farther downgradient as seeps or springs, or moves as underflow through the Amargosa Narrows to the Amargosa Desert, south of the study area.

Attempts at irrigation in Oasis Valley generally have been limited to small areas of Bermuda grass and salt grass meadows used for grazing. The high rate of evapotranspiration, the generally poor drainage characteristics of the soil, and the relatively high sodium-bicarbonate content in the water causes a pronounced increase in soil salinity that limits plants to those having a high salt tolerance. Irrigated and bare soil areas along the flood plain of the Amargosa River commonly are crusted by a salt efflorescence at the surface.

Transpiration and evaporation from spring pools and swamps accounts for most of the ground-water discharge in the valley. The principal areas of discharge by phreatophytes is along the flood plain of the Amargosa River and its tributaries, where the depth to water is within a few feet or tens of feet of the land surface. The principal species of phreatophytes in Oasis Valley include salt grass, Bermuda grass, greasewood, and salt bush; and in most of the spring pools and seep areas there are reeds and tules. There are approximately 3,800 acres of phreatophytes in Oasis Valley, commonly of low to moderate density. The average depth to water below the land surface in most of the phreatophyte areas is 6 to 10 feet. Evaporation locally from spring pools, swamps, and seep areas may be 5 to 6 feet annually. However, based on the type, density, and depth to water, the average rate of evapotranspiration is assumed to be about 0.5 foot annually. On the basis of phreatophyte and open-water acreage and the assumed rate of evapotranspiration, the natural discharge by native vegetation is estimated to average about 2,000 acre-feet annually.

Ground-water discharge by underflow through the Amargosa Narrows is a small percentage of the total natural discharge from Oasis Valley. Ground water moves as underflow from Oasis Valley through an unknown thickness of Recent alluvium in the bedrock gap at the Amargosa Narrows. The bedrock gap is approximately a quarter of a mile wide and a mile long. Surface runoff from Oasis Valley, following periods of heavy precipitation, follows the normally dry channel of the Amargosa River through the narrow bedrock gap. During most of the year, however, the river channel through the gap is dry, except for a large unnamed spring that discharges from the head of a ditch constructed near the southern end of the Amargosa Narrows. The spring discharges into the bottom of the ditch which intersects the water table 8 to 10 feet below land surface. The spring discharge is estimated to average about 100 gallons a minute or somewhat less than 200 acre-feet a year. In addition to the spring discharge, there is ground-water underflow through the alluvial fill mantling the floor of the Amargosa Narrows to the Amargosa Desert. Thus, the estimated average ground-water outflow from Oasis Valley probably is on the order of 400 acre-feet annually.

The estimated total average annual ground-water discharge from Oasis Valley by evapotranspiration and sub-surface outflow, then, is on the order of 2,400 acre-feet.

Chemical Quality:

One of the principal objectives of the ground-water study in Oasis Valley was to determine the chemical character of the ground water. The immediate purpose of this phase of the study was to evaluate the chemical quality of ground water for consideration of a possible alternative water supply for the town of Beatty.

The presence of fluoride in concentration of about 4 ppm of the municipal supply for the town of Beatty has caused dental fluorosis and discoloration in the teeth of children. A recent dental examination of school children in Beatty by officers of the Nevada Department of Health (W. W. White, oral communication, 1962) showed that 19 out of 20 children who lived in Beatty since birth were affected with dental fluorsis. In an effort to locate a different municipal water supply for Beatty, containing a fluoride concentration within acceptable limits of about 1.6 ppm, samples of ground water were obtained from wells and springs in Sarcobatus Flat and Oasis Valley by Mr. White and the authors to determine the chemical character of the ground water in the area. The distribution of the sampling sites and the fluoride concentration in the water at the different sampling sites is illustrated in plate 4. Records of the analyses are included in table 3.

The chemical analyses indicate that the ground water sampled in Oasis Valley east of the Amargosa River contains 1.9 ppm or more of fluoride. The only water samples that contained less than 1 ppm of fluoride were obtained from Indian and Crystal Springs.

The U. S. Public Health Service (1962, p. 2154) has placed limits on fluoride concentrations in drinking water which in part are based on the annual average maximum daily air temperature. The maximum upper limit for the concentration of fluoride for Sarcobatus Flat and Beatty, based on the annual average maximum daily air temperature of 73.7°F and 76.2°F, respectively, is 1.0 ppm.

The principal source of fluoride in the ground water in Oasis Valley probably is from chemical weathering of fluorite deposits in Paleozoic carbonate rocks in the Bare Mountain area east of Beatty and from the chemical decomposition of fluoride-bearing minerals in rocks of volcanic origin. Fluorite ore occurs in the Bare Mountain area as soft earthy deposits that weather readily. Although the solubility of fluorite is low, the abundance of the mineral in the consolidated and unconsolidated rocks of the area provides ample opportunity for leaching by water. Some fluoride in the ground water in Oasis Valley may be derived from fumarolic gasses or hydrothermal solutions which have altered the parent rock in the vicinity of some of the thermal springs, such as at Hot Springs (S11/47-16dc1).

Although the Bullfrog Hills are composed largely of volcanic rocks of mineral composition similar to the rocks east of the river, the fluoride content of ground water derived from precipitation on the Bullfrog Hills is much less than the fluoride content of ground water in the area east of the river. Indian Springs and Crystal Springs are near their source of recharge, and consequently the water discharged from the springs has been in contact with the sediments through which it moved for a limited time only. In contrast, most of the ground water beneath the flood plain of the Amargosa River probably originated as precipitation on Timber Mountain and Black Mountain, which are about 15 to 20 miles distant, or from underflow originating in Gold Flat, which is many more miles distant. Consequently ground water moving into Oasis Valley from the north and east has been in contact with the deposits for a considerably longer period of time than ground-water underflow from the Bullfrog Hills, thereby affording a greater opportunity to dissolve more minerals.

Maximum concentrations of fluoride of 5, 4.5, and 4.5 ppm, respectively, occur at thermal springs S11/47-16dc1 and S11/47-21ac1 and at unnamed spring, S12/47-20bb1, at the southern end of Oasis Valley in the Amargosa Narrows.

In the vicinity of the unnamed spring S10/47-14b1 in the northern part of the valley the fluoride concentration is about 3.8 ppm. As the ground water moves down the hydraulic gradient from this area toward Beatty, the fluoride concentration increases slightly. However, slight variations in the fluoride content probably are due to dilution by local recharge, to increased concentration resulting from evaporation, or from local hydrothermal activity.

Water from Indian and Crystal Springs has the lowest fluoride content (0.2 to 0.5 ppm) of the water sampled in Oasis Valley. Water from wells S11/47-28aa1 and S10/47-30c1, drilled near the base of the Bullfrog Hills, has a fluoride content of 1.2 and 1.5 ppm, respectively. Well S11/47-28aa1 is on the western edge of the flood plain of the Amargosa River near the mouth of Sober-Up-Gulch, which is the principal drainage on the eastern slope of the Bullfrog Hills. The low fluoride content of 1.2 ppm and the location of well S11/47-28aa1 suggest that the well may tap ground water that is derived partly from the drainage basin of Sober-Up-Gulch. Well S10/47-30c1 also is at the base of Bullfrog Hills and, although no water analysis is available, may be tapping ground water of low fluoride content recharged from precipitation on the Bullfrog Hills. The chemical analyses generally suggest that water of low fluoride content may occur in the alluvial-fan deposits at the mouths of the canyons draining the Bullfrog Hills on the west side of the Amargosa River flood plain. This generalization plus the low fluoride content in the water from Indian Springs suggest that ground water of suitable chemical quality may occur in the alluvial-fan deposits immediately north of Beatty.

Ground-Water Development:

The development of ground water in Oasis Valley has been confined largely to the development of springs. Only three wells were in use at the time of this investigation and supplied domestic needs for about 20 people.

The municipal water supply for Beatty is obtained from the Beatty Springs, which comprise of a group of six springs (S12/47-5ca1) that issue from the alluvial fill of the river flood plain about a mile north of town (pl. 4) The altitude of the spring orifices is about 3,370 feet, or about 80 feet higher than that altitude of most of Beatty. The springs discharge into concrete collection basins that drain directly into two 8-inch water mains that convey the water to the town of Beatty. Pressure in the system is maintained by gravity flow. Reportedly the springs discharge is about 100 to 200 gpm, although no measurement was made during this study. The magnitude of seasonal variations in the discharge from the springs is not known, but according to the owners of the springs, the discharge is noticeably less in the summer than in the winter. The smaller spring discharge during the period of peak demand in the summer has resulted in municipal water shortages during recent years.

Development of other springs in Oasis Valley usually is limited to cleaning and lowering the spring orifice and the construction of conveyance ditches from the spring to storage reservoirs and points of use. A dirt embankment has been constructed around spring S10/47-14b1 to impound the discharge and to provide sufficient head on the diversion works. It is common practice to release the water from these reservoirs through gate valves built into the dirt embankments.

The Hot Springs S11/47-16dc1 and S11/47-21aa have been developed for bathing. Improvements at the springs include bathing pools and related buildings and facilities.

Potential Development:

Although additional ground-water development in Oasis Valley probably could be accomplished effectively by the construction of wells, the ehcmical quality generally may present a greater problem than the quantity required. One of the best areas for development from the standpoint of quantity is along the flood plain of the Amargosa River where ground water is at shallow depths and moderate yields may be expected through properly constructed wells. However, the chemical quality of the water should be carefully considered, if it is to be used for domestic or irrigation purposes.

In terms of water for domestic or public supply, the fluoride content probably would be a problem. Based on this investigation, ground water sampled from the west side of the valley adjacent to the Bullfrog Hills appears to offer the minimum concentration of fluoride. However, the quantity of ground water derived from the Bullfrog Hills is limited to small amounts. For example, the drainage basin in which Indian Springs is located is small, and the altitude of the hills generally is less than 6,500 feet. Consequently, the annual precipitation on the basin is meager and the resulting recharge to the ground-water reservoir is small, perhaps on the order of 20 acre-feet per year. Therefore, if ground water of low-fluoride content can be developed from wells in the area immediately north of Beatty, the average annual quantity withdrawn necessarily will be limited if the water supply of low-fluoride content is to be maintained. The current annual demand for water for the town of Beatty exceeds the estimated annual rate of recharge from this drainage basin. Therefore, it is highly probable that pumpage would exceed the natural recharge to the ground-water reservoir, thus creating an overdraft on the system. Sufficient lowering of the water level in the lower part of the basin north of Beatty resulting from ground-water withdrawals will eventually reverse the natural hydraulic gradient, which is away from the mountains toward the Amargosa River, and thus induce inflow of water containing high fluoride content from the ground water beneath the flood plain of Amargosa River.

If pumpage equal to the present Beatty supply is pumped from wells drilled north of town, the supply of water of good chemical quality presumed to be in storage probably would be consumed in 10 years or less because of limited volume of usable ground water in storage. By reducing the use of low-fluoride water to that for human consumption, the supply of ground water from this basin probably could be maintained for many years.

Water of low-fluoride content is presumed to occur under similar conditions in an area approximately half a mile west of the Amargosa River near the base of Sober-Up-Gulch. The average annual recharge to the ground-water reservoir in the drainage area of Sober-Up-Gulch probably is about the same as recharge in the drainage basin of Indian Springs, or on the order of 20 acre-feet per year. However, the areal extent of the wash deposits in the gulch is considerably smaller, and therefore the storage capacity probably is smaller also. Thus, development of ground water for public supply would be subject to the same limitations, except that the volume of water of low-fluoride content in storage probably is less.

PROPOSALS FOR ADDITIONAL GROUND-WATER STUDIES

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

A detailed investigation of the oocurrence of fluoride in ground water in Nevada:

The occurrence of dental fluorosis in Beatty resulting from high fluoride content in the municipal water supply draws pointed attention to the need for a better knowledge of the occurrence of fluoride in water that may be used for public supply in all parts of Nevada. Much work has been done elsewhere in developing a sound understanding of the degree to which fluoride concentration in water may cause dental fluorosis. The problem in Nevada is to define clearly the extent and distribution of fluoride in the water of the State and why and under what conditions does it occur.

DESIGNATION OF WELLS AND SPRINGS

The wells and springs in this report are designated by a single numbering system. The number assigned to the well or spring 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, the initial "S" indicates that the township is south 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 S10/47-4dd1 indicates the first well recorded in the southeast quarter of the southeast quarter of sec. 4, T. 10 S., R. 47 E.

Owing to limitation of space, wells on plates 1 - 4 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 margins of the plates.

Table 4.--Records of selected wells in Sarcobatus Flat and Oasis Valley, Nye and Esmeralda Counties, Nev.

S7/44-21cd1. Owner Jim Daniels. Drilled irrigation and domestic well. Depth 375 feet. Equipped with turbine pump and diesel engine. Reported depth to water below measuring point 135 feet, October 26, 1961. Yield reported as 530 gpm with a drawdown of 20 feet.

S7/44-28bc1. Owner B. E. Riggs. Drilled domestic well. Depth 100 feet; casing diameter 6 inches. Equipped with a submersible pump. Reported depth to water below land surface 96 feet, October 1961.

S7/44-28cb1. Owner B. E. Riggs. Drilled irrigation well. Depth 203 feet; casing diameter 12 inches. Equipped with turbine pump and gas motor. Depth to water below land surface 94 feet, October 1961. Driller's log:

Material	Thickness (feet)	Depth (feet)
Loam - sandy	2	2
Sand and boulders	90	92
Sand and gravel, compacted	8	100
Clay, sandy	5	105
Boulders	21	126
Sand, coarse; small gravel	24	150
Boulders	25	175
Sand and gravel, conglomerate	28	203
Total depth		203

S7/44-34bb1. Owner Oscar Williams. Drilled irrigation well; depth 270 feet with a 15-inch casing perforated 73 to 270 feet with 3/16- by 7-inch perforations. Temperature of water 58°F. Measuring point, top of casing which is 0.5 foot above land surface. Depth to water below measuring point reported as 73 feet, June 6, 1958 and measured 75.48 feet February 8, 1962. Driller's log:

Material	Thickness (feet)	Depth (feet)
Alluvial volcanic	65	65
Gravel and rock	22	87
Gravel, rock, and clay	18	105
Gravel	4	109
Clay, brown	41	150
Gravel and rock	32	182
Rock, hard	4	186
Gravel	8	194
Clay and rock	16	210
Gravel, clean	4	214
Clay and rock	21	235
Volcanic formation contains small stratas of gravel	35	270
Total depth		270

S7/44-34ca1. Owner Oscar Williams. Drilled irrigation well; depth 223 feet; casing diameter 14 inches, perforated 0 to 50 feet. Depth to water below below land surface 64 feet, January 17, 1962. Driller's log:

Material	Thickness (feet)	Depth (feet)
Sand and gravel	38	38
Gravel, brown, sandy	8	46
Sand and gravel	18	64
Boulders	5	69
Sand and gravel	57	126
Clay, brown; sand and gravel	68	194
Boulders	2	196
Clay, gray	27	223
Total depth		223

S8/43-23a1. Owner not determined. Dug domestic well; diameter 4 by 6 feet. Equipped with cylinder pump. Measuring point, top of wood cribbing which is 3 feet above land surface. Depth to water below measuring point 28.54 feet, March 13, 1962.

S8/43-23bb1. Owner Lippencott Lead Co. Dug industrial well; diameter 4 by 6 feet. Depth to water below land surface 43.42 feet February 8, 1962.

S8/43-24bb1. Owner at Bonnie Clare. Dug well; diameter 30 inches. Measuring point top of casing which is 1.8 feet above land surface. Depth to water below measuring point 5.82 feet February 8, 1962.

S8/43-32b1. Owner not determined. Depth to water below measuring point 304 feet.

S8/44-2bb1. Owner Nevada State Highway Department. Drilled unused well; depth 94 feet, casing 10 inches.

S8/44-8aa1. Owner Don Terrell. Drilled domestic well; depth 600 feet, casing diameter 10 inches. Reported depth to water below land surface 38 feet July 1, 1960. Well destroyed. Driller's log:

Material	Thickness (feet)	Depth (feet)
Loam, sandy	4	4
Sand and small gravel	34	38
Boulders and medium gravel	17	55
Brown clay and gravel	345	400
Clay, gray; and opalite	50	450
Sand, fine; and gravel	40	490
Shale, gray	30	520
Clay shale, brown	80	600
Total depth		600
Well cemented		

S8/44-8aa2. Owner Don Terrell. Drilled irrigation well; depth 250 feet, casing diameter 14 inches. Equipped with turbine pump, reported yield 530 gpm with a drawdown of 40 feet. Reported depth to water below land surface 38 feet October 26, 1961; measured 36.17 feet February 8, 1962. Driller's log:

Material	Thickness (feet)	Depth (feet)
Loam, sandy	4	4
Sand and small gravel	34	38
Boulders and medium gravel	17	55
Clay, brown;gravel	195	250
Total depth		250

S8/44-10aa1. Owner Mrs. Leuello Wildeman. Drilled irrigation well; depth 260 feet; casing diameter 15 inches with 1/8- by 5-inch perforations. Temperature of water 64°F. Reported depth to water below land surface 22 feet, November 25, 1958, measured 15.45 feet, February 8, 1962. Driller's log:

Material	Thickness (feet)	Depth (feet)
Clay, hard, brown, saturated with water	10	10
Sand, silt, and soil, very soft	23	33
Rock, loose; sand, and gravel - water	6	39
Clay and rock	33	72
Gravel and sand - water	6	78
Clay, rocky, very tight	22	100
Rock, sand, and gravel	20	120
Conglomerate, very hard	68	188
Gravel and rock, loose formation - water	12	200
Rocky formation, very hard	40	240
Rock formation, solid	20	260
Total depth		260

S8/44-10ab1. Owner not determined. Drilled irrigation well; casing diameter 24 inches. Measuring point top of casing which is 0.5 foot above land surface. Depth to water below land surface 23.28 feet, February 8, 1962.

S8/44-11ba1. Owner not determined. Dug abandoned well; 4 by 6 feet. Measuring point below top of 6- by 8-inch timber which is 2.0 feet below land surface. Depth to water below measuring point measured 4 feet, October 26, 1961.

S8/44-12b1. Owner not determined. Drilled stock well; casing diameter 10 inches. Equipped with windmill. Measuring point, wood plank on top of well casing which is at land surface. Depth to water below measuring point 12.98 feet, October 26, 1961; 12.75 feet, February 8, 1962.

S8/44-12cd1. Owner Raymond Williams. Drilled irrigation well; depth 250 feet, casing diameter 14 inches. Measuring point top of casing which is 0.8 foot above land surface. Depth to water below land surface 15.06 feet, September 17, 1959; 17.82 feet February 8, 1962. Driller's log:

Material	Thickness (feet)	Depth (feet)
Loam, sandy	3 1/2	3 1/2
Clay, hard, lime	4 1/2	8
Sand and clay, brown	7	15
Boulders	4	19
Sand, coarse, and small gravel	47	66
Boulders	5	71
Sand, coarse; clay and small gravel	63	134
Boulders	6	140
Conglomerate, sand, and gravel	30	170
Boulders	3	173
Sand and gravel	31	204
Conglomerate, clay, boulders, and sand	46	250
Total depth		250

S9/45-29b1. Owner not determined. Dug well. Depth measured 19 feet, casing diameter 60 inches. Measuring point top of wood cribbing which is at land surface. Depth to water below land surface, dry at 19 feet, measured March 13, 1962.

S9/45-34c1. Owner Bureau of Land Management. Drilled stock well; casing diameter 10 inches. Equipped with cylinder pump with windmill and gasoline power. Measuring point top of collar on casing, which is 1 foot above land surface. Depth to water below land surface 61.40 feet March 13, 1962.

S9/46-20a1. Owner Bureau of Land Management. Drilled stock well; casing diameter 12 inches. Equipped with windmill. Measuring point plate on top of casing which is 0.25 foot above land surface. Depth to water below land surface 42.92 feet, October 26, 1961; 53.66 feet February 8, 1962.

S9/46-35a1. Owner Bureau of Land Management. Drilled stock well; casing diameter 10 inches. Equipped with windmill. Measuring point top of casing which is 1 foot above land surface. Depth to water below land surface 94.09 feet, October 26, 1961; 95.64 feet, February 8, 1962.

S10/47-27a1. Owner G. L. Coffer. Dug and drilled domestic well; depth 6 feet, casing diameter 6 inches. Equipped with centrifugal pump and gasoline engine. Temperature of water 58°F.

S10/47-30c1. Owner R. L. Gibson. Drilled domestic well; depth 25 feet. Equipped with windmill.

S11/47-28aa1. Owner Sid Whaley. Drilled domestic well; casing diameter 4 inches. Equipped with cylinder pump and gasoline engine and pump jack.

Table 5.--Records of selected springs in Sarcobatus Flat and Oasis Valley, Nye and Esmeralda Counties, Nev.

Location	Owner	Name of Spring	Use	Estimated discharge (gpm)	Date of measurement	Temperature	Chemical Analyses
S10/47-14b1	Fleur-de Lis Ranch	--	Irrigation	50	3-14-62	72	Yes
S10/47-30d1	Springdale Ranch	--	Domestic Stock	25	3-14-62	58	Yes
S10/47-33a1	Campbell	--	Irrigation	15	3-14-62	75	Yes
S11/45-22b1	Unknown	Currie Well	Stock	1/4	3-14-62	--	Yes
S11/46-26ca1	H. H. Heisler	Middle Indian Springs	Unused	--	--	60	Yes
S11/46-26cb1	H. H. Heisler	Upper Indian Springs	Unused	5	3-16-62	--	Yes
S11/46-26dc1	Unknown	Indian Springs	Stock	1-2	3-15-62	65	Yes
S11/47-4bb1	Unknown	Unnamed	Stock	7	3-14-62	65	Yes
S11/47-9ac1	Torrance	Unnamed	Domestic	10	3-14-62	59	Yes
S11/47-10ab1	Unknown	Goss Springs	Irrigation Stock	50-75	3-14-62	71	Yes
S11/47-16dc1	Roy Segers	Hot Springs	Bathing	5	3-14-62	97	Yes
S11/47-18aa1	L. M. Wheelwright	Crystal Springs	Domestic	2-3	3-14-62	69	Yes
S11/47-21ac1	Rancho Trueba	Unnamed	Irrigation Stock	100	3-14-62	97	Yes
S11/47-28aa2	Sidney Whaley	Ute Spring	Irrigation Domestic	--	--	--	No
S11/47-33ba1	Circle C Ranch	Unnamed	Domestic	25	3-14-62	88	Yes
S12/47-5ca1	Revert Bros.	Beatty Municipal Springs	Municipal	100	2-22-56	76	Yes
S12/47-20bb1	R. A. Fordham	Unnamed	Irrigation Domestic	--	--	--	No

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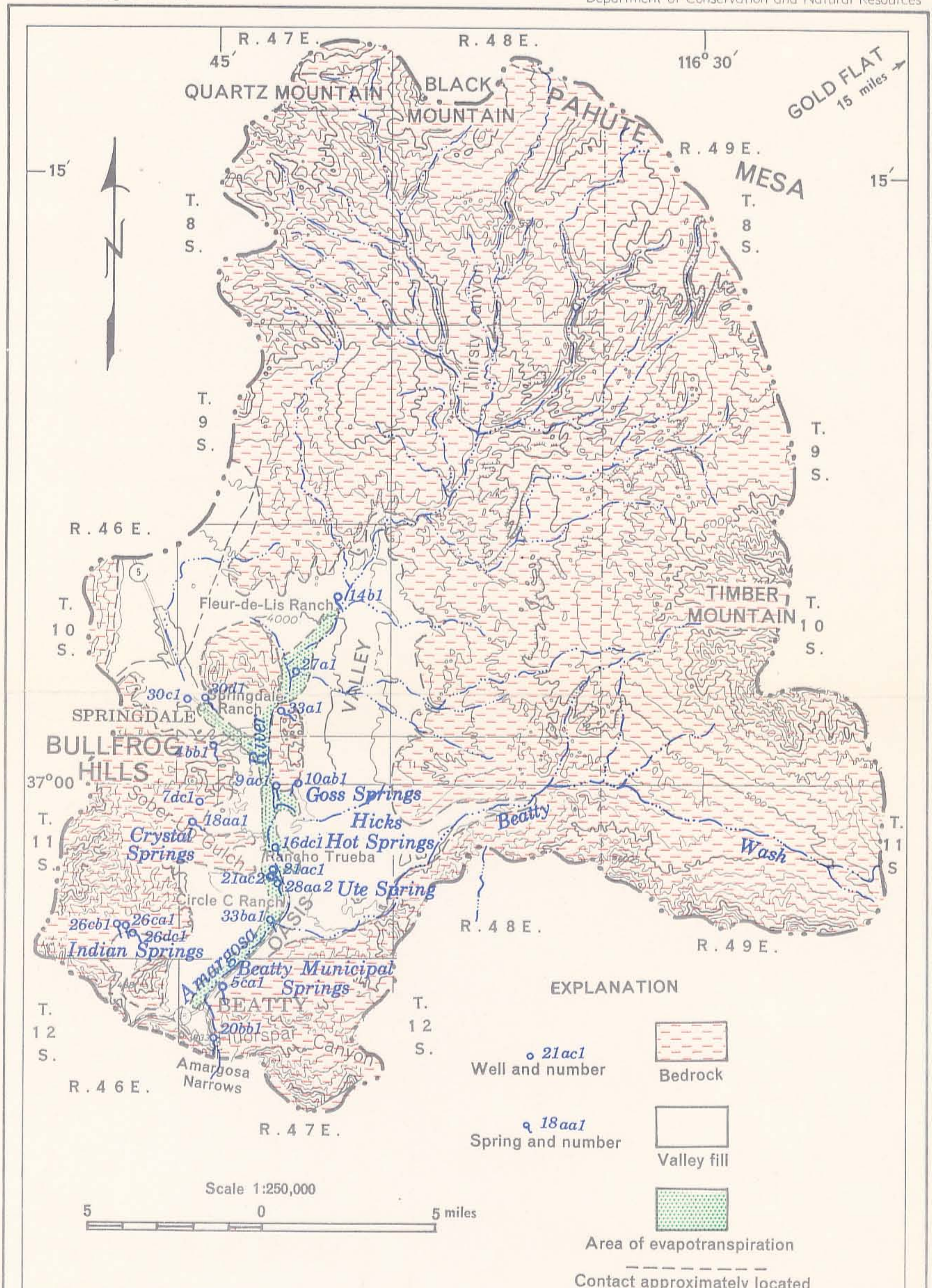

PLATE 3. GENERALIZED GEOLOGIC AND HYDROLOGIC MAP OF OASIS VALLEY, NYE COUNTY, NEVADA.

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State of Nevada
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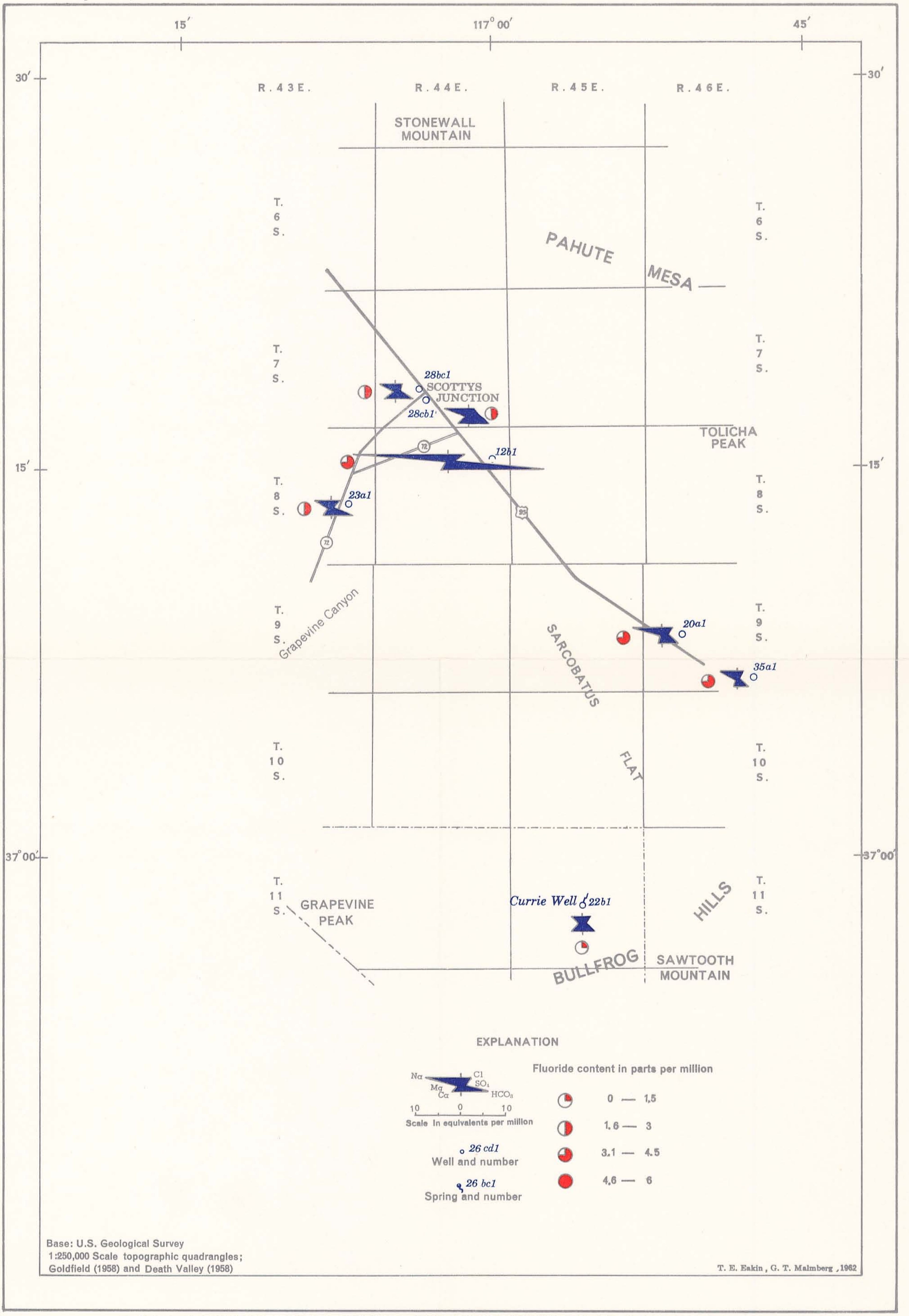

PLATE 2. DIAGRAMS SHOWING CHEMICAL QUALITY OF GROUND WATER IN SARCOBATUS FLAT

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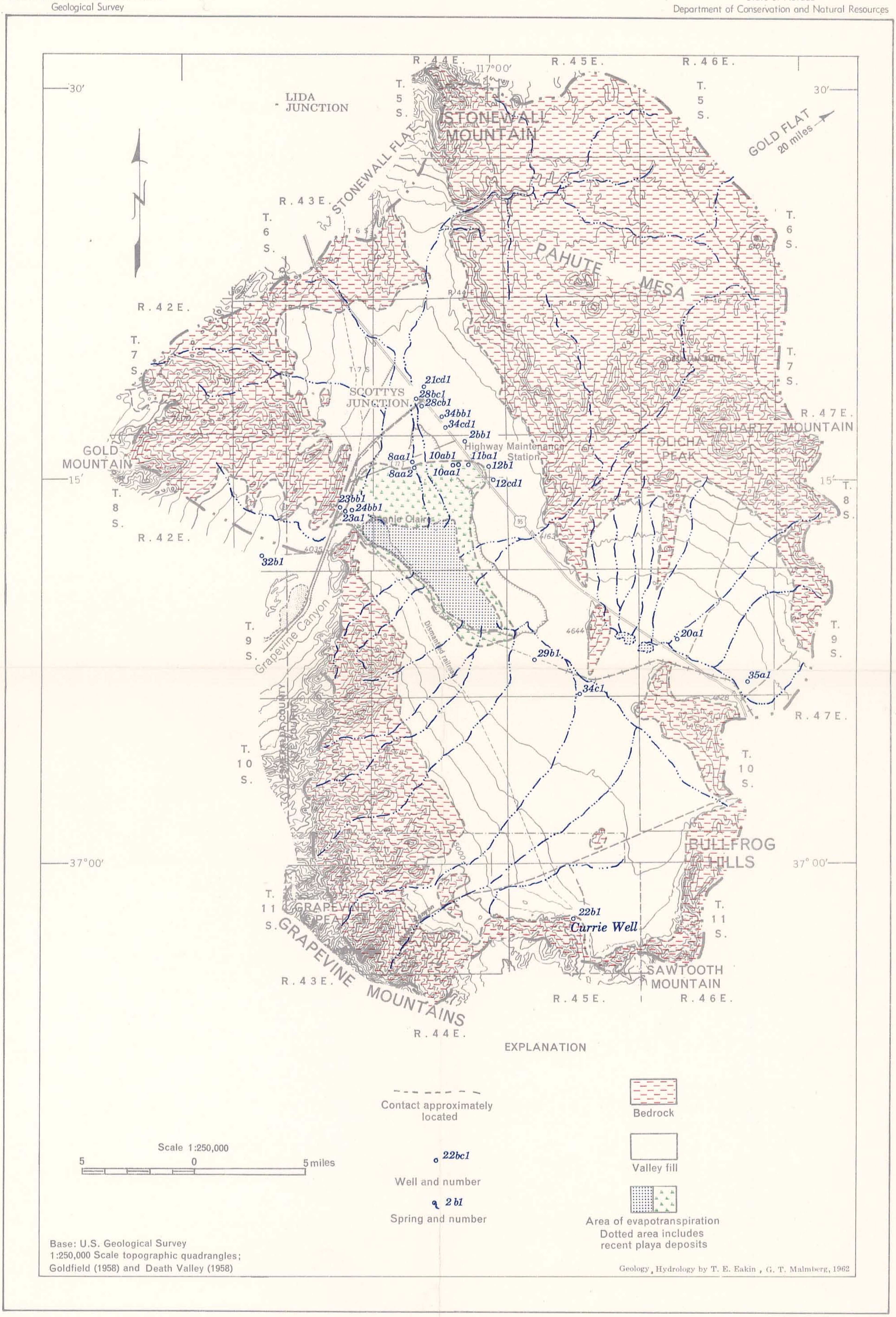

PLATE 1. GENERALIZED GEOLOGIC AND HYDROLOGIC MAP OF SARCOBATUS FLAT, NYE AND ESMERALDA COUNTIES, NEVADA.

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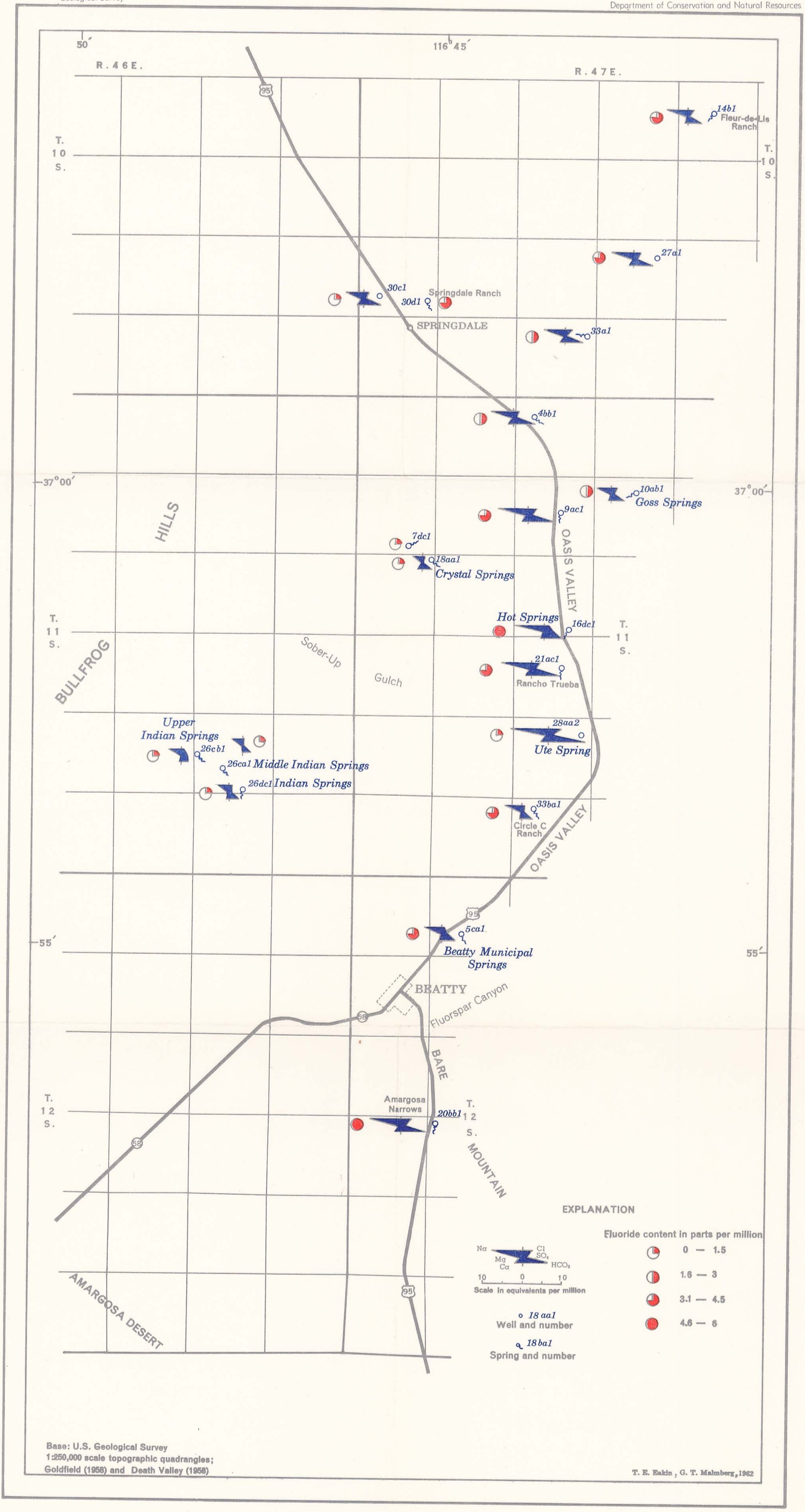

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