WATER RESOURCES - RECONNAISSANCE SERIES

Report 43

WATER-RESOURCES APPRAISAL OF THE WARM SPRINGS-LEMMON VALLEY AREA, WASHOE COUNTY, NEVADA

By

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and

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Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

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FOREWORD

The program of reconnaissance water-resources studies was authorized by the 1960 Legislature to be carried on by the Department of Conservation and Natural Resources in cooperation with the U.S. Geological Survey.

This report is the 43d. report prepared by the staff of the Nevada District of the U.S. Geological Survey. These 43 reports describe the hydrology of 100 valleys.

The reconnaissance surveys make available pertinent hydrologic information of great and immediate value to many State and Federal agencies, the State cooperating agency, and the public. As development takes place in any area, demands for more detailed information will arise, and studies to supply such information will be undertaken. In the meantime, these reconnaissance studies are timely and adequately meet the immediate needs for information on the water resources of the areas covered by the reports.

Elmo J. DeRicco
Director

Department of Conservation and Natural Resources.

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WATER-RESOURCES APPRAISAL OF THE WARM SPRINGS-LEMMON VALLEY AREA, WASHOE COUNTY, NEVADA

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F. Eugene Rush and Patrick A. Glancy

SUMMARY

The report area, largely in western Nevada, lies north of the Truckee River, west of Pyramid Lake Valley, east of the Sierra Nevada, and south of Smoke Creek Desert. The area covers about 900 square miles and is composed of 11 valleys. Table 1 summarizes the hydrology of the valleys. Water is imported into Lemmon and Spanish Springs Valleys from the Truckee River near Reno. Each year an average of about 900 acre-feet is piped to Lemmon Valley and about 16,000 acre-feet is carried by the Orr Ditch to Spanish Springs Valley. Surface water is diverted from streams in most valleys for irrigation. Evapotranspiration losses account for most of the natural discharge in most valleys. Ground water in most valleys can be developed by pumping from wells in or near the areas of discharge.

This report also presents the concept of "transitional storage reserve," which is a measure of the amount of storage depletion necessary to attain a new equilibrium under the perennial-yield concept of ground-water development.

Table 1. -- Hydrologic summary

(All water quantities in acre-feet per year except where specifically noted)

	Hydrologic units (valleys)										
	Honey Lake	Newcomb Lake	Dry	Red Rock	Bedell Flat	Ante-Lope	Warm Springs	Cold Spring	Lemmon	Spanish Springs	Sun
Approximate growing season (days)	170	130	130	130	130	130	140	130	130	140	140
Valley area (sq mi)	235	7	82	43	53	17	250	31	96	73	10
Surficial drainage character	(a)	(a)	(b)	(b)	(b)	(a)	(b)	(a)	(a)	(a,b)	(b)
Surface-water runoff from mountains	4,000	400	7,500	2,600	3,000	600	14,000	1,400	5,400	1,500	<100
Ground-water recharge from precipitation	1,500	300	2,400	900	1,100	300	6,000	900	1,800	600	50
Preliminary estimate of perennial yield	10,000	200	1,000	1,000	300	150	3,000	500	1,500	1,000	25
Transitional storage reserve 1/	240,000	1,500	35,000	12,000	10,000	25,000	110,000	10,000	70,000	60,000	15,000
Present surface-and ground-water development	1,450	10	30	520	10	10	400	150	300	4,200	200

a. Internal drainage.

b. External drainage.

1. Total acre-feet.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

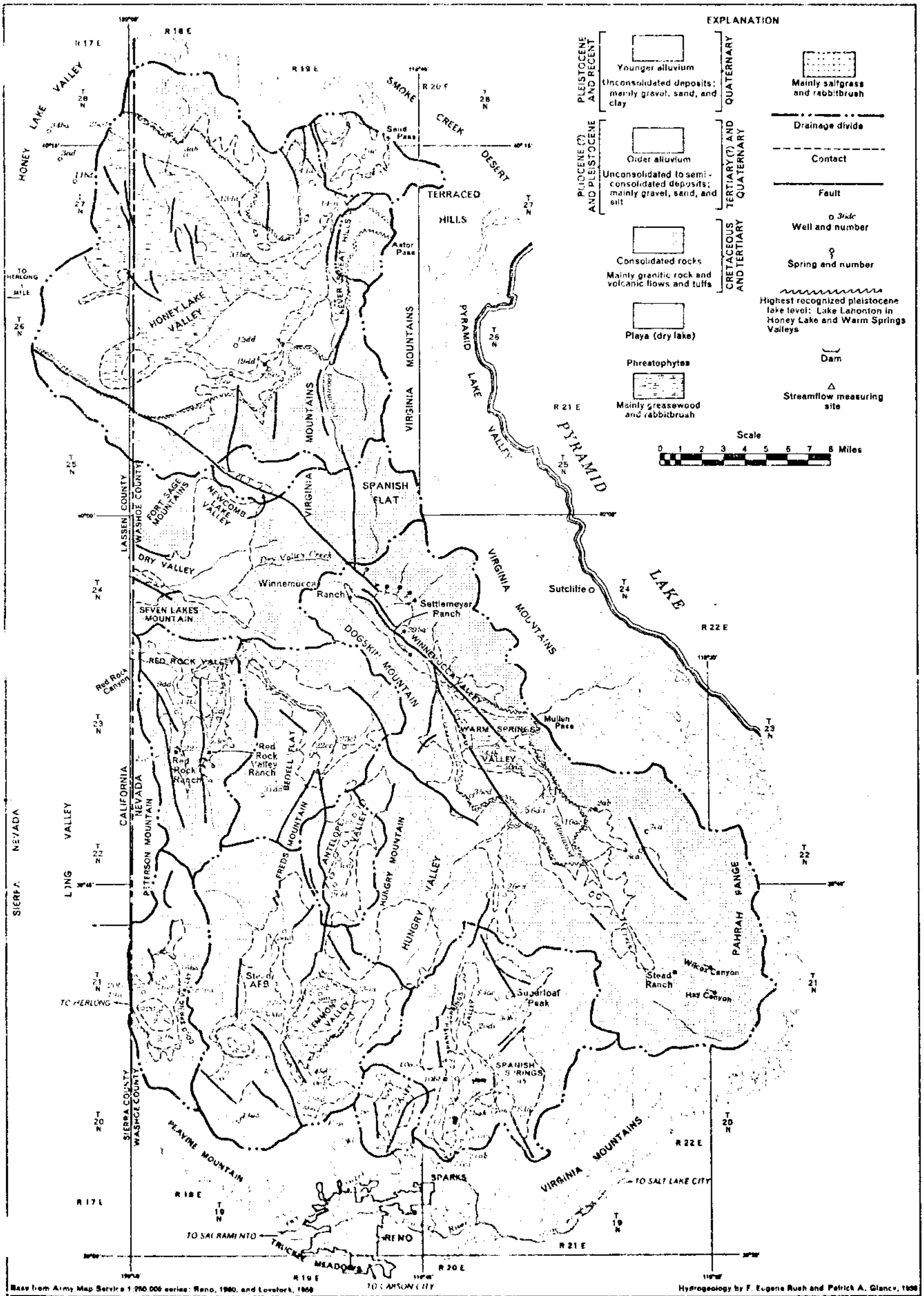

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE WARM SPRINGS-LEMMON VALLEY AREA, WASHOE COUNTY, NEVADA AND LASSEN COUNTY, CALIFORNIA

INTRODUCTION

Purpose and Scope of the Study

Ground-water development in Nevada has shown a substantial increase in recent years. Part of this increase is due to the effort to bring new land into cultivation and part to a rapidly increasing urban population. The increasing interest in ground-water development has created a substantial demand for information on ground-water resources throughout the State. Recognizing this need, the State Legislature enacted special legislation (Chap. 181, Statutes of 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. Subsequently, the studies were broadened to include pertinent streamflow and water-quality data. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the forty-third report prepared as part of the reconnaissance series (fig. 1).

The objectives of this report are to (1) appraise the source, occurrence, movement, and chemical quality of water in the area, (2) estimate average annual recharge to and discharge from the ground-water reservoir, (3) provide preliminary estimates of perennial yield and transitional storage reserve, and (4) evaluate the present and potential water development in the area.

The investigation was made under the general supervision of G. F. Worts, Jr., District Chief in charge of hydrologic studies by the Geological Survey in Nevada. The field work was done during a two-week period in July and August of 1966 and required about 10 man days.

Location and General Features

The area covered by this report is in extreme western Nevada and in a small, adjoining part of northeastern California, lying generally north of Reno and the Truckee River, west of Pyramid Lake Valley, and east of the Sierra Nevada, as shown in figure 1. The area covers about 910 square miles and is composed of 11 valleys, several of which have one or more named segments, and a small part of Long Valley, which is mostly in California. The valleys are shown on plate 1 and from north to south are: (1) Honey Lake Valley; the eastern part in Nevada, which is composed of three topographically closed segments; (2) Newcomb Lake Valley; (3) Dry Valley, including an eastern tributary called Spanish Flat; (4) Red Rock Valley; (5) Bedell Flat; (6) Antelope Valley; (7) Warm Springs Valley, including a northern part called Winnemucca Valley and a southwestern tributary called Hungry Valley; (8) Cold Spring Valley, also known as

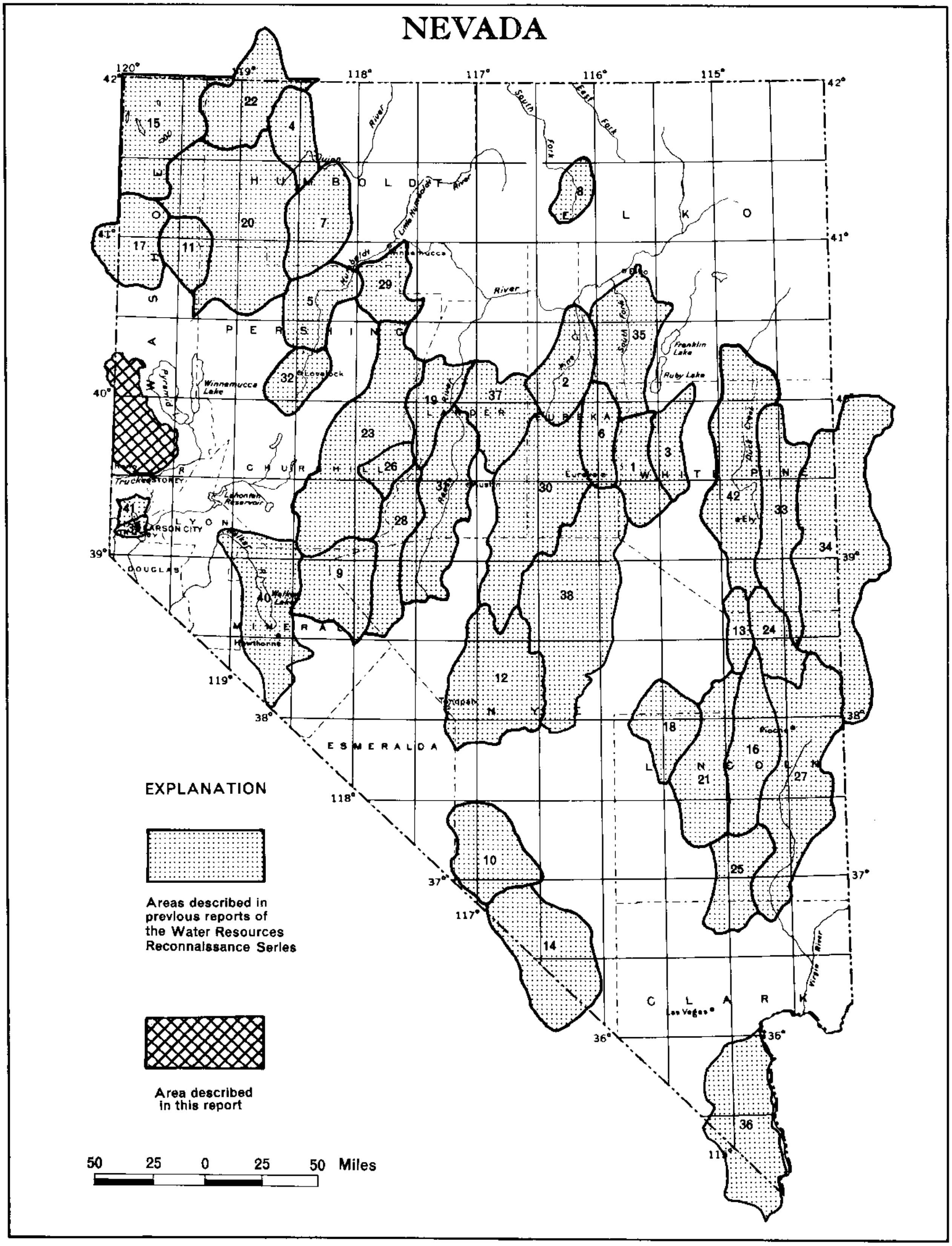

Figure 1.—Areas in Nevada described in previous reports of the Water Resources Reconnaissance Series and the area described in this report

Glider Valley; (9) Lemmon Valley, composed of two topographically closed unnamed segments--an eastern part and a western part containing Stead Air Force Base; (10) Spanish Springs Valley, composed of two unnamed segments-- a topographically closed northern part and a southern part which drains to Truckee River; and (11) Sun Valley which also drains to the Truckee River.

Access to the area is by State Route 33, and U.S. Route 395, both paved roads. Trails and graded roads give access to all the valleys.

For most of the area ranching is the basis of the economy. However, residential and industrial development is expanding outward from Reno in five valleys: Sun, Lemmon, Cold Spring, Warm Springs, and Spanish Springs Valleys. The estimated population of Sun and Lemmon Valleys is 2,000; of Cold Spring and Spanish Springs Valleys 200 and 300, respectively. The total population of the report area is estimated to be nearly 5,000. In the latter half of 1966, Stead Air Force Base ceased operation as a military facility. Part of it was taken over by the University of Nevada, part by commercial groups, and part by the City of Reno.

Previous Work

Fremont (1845) was the first explorer to publish a description of the region, traversing the nearby Smoke Creek Desert and Pyramid Lake Valley in 1843 and 1844. Later, Russell (1885) described the geologic history of Lake Lahontan, which in part occupied Honey Lake and Warm Springs Valleys. He described High Rock Spring and located Fish Springs, both in Honey Lake Valley. High Rock Spring was also described by Waring (1915) in his report on springs of California. He reports a measured flow of the spring, in 1909, of 525 gallons per minute and a temperature of 86°F.

The Corp of Engineers (1943) made a study of the sources of water for Reno Army Air Base (Stead Air Force Base, Lemmon Valley). It was recommended that the main supply of water for the base be obtained from the Truckee River. The ground-water supply system (two wells and a mine shaft) were considered inadequate. Robinson and Phoenix (1948) made a ground-water reconnaissance of Spanish Springs and Sun Valleys.

The California Department of Water Resources (1960, 1962) published ground-water quality and water-level data for that part of Honey Lake Valley in California. Later, interpretive reports of the water resources were published by that agency (California Dept. Water Resources, 1963) and by Hilton (1963).

Snyder and other (1964) compiled a map showing the extent of the Pleistocene lakes in the Great Basin, including those of the report area. William F. Guyton and Associates (written communication, 1964) prepared a report for Sierra Pacific Power Company describing the ground-water conditions in Spanish Springs Valley. Waring (1965) listed descriptions of the warm springs of the area and Horton (1964) showed them on a map. The hydrology of the adjoining area of Truckee Meadows was described by Cohen and Loeltz (1964). Gimlett (1967) presented the results of gravity studies made in Warm Springs Valley.

HYDROLOGIC ENVIRONMENT

Climate

The climate of the area is characterized by long winters having moderate to light snow on both the valley floors and the mountains. The summers are short with warm daytime temperatures and cool nights. Little precipitation except for occasional thunderstorms occurs in the summer.

Growing-season data have been computed for 5 stations, all within about 10 miles of the area but none of them in the report area. These data are summarized in table 2. The topography of the area favors the flow of heavy cold air toward the lower parts of the valleys during periods of little wind movement, resulting in temperature inversion during such periods. Doyle (altitude 4,300 feet), which lies at the bottom of a narrow valley, has the shortest average 28°F growing season--130 days. Sand Pass station, at Bonham Ranch (sec. 12, T. 28 N., R. 19 E.) on the western flank of Smoke Creek Desert, has the longest average 28°F growing season--169 days. It also has recorded the greatest variation of the stations, from 124 to 225 days, or a growing-season range of 101 days. Doyle has the shortest season recorded, 102 days. Spanish Springs, Sun, and Warm Springs Valleys probably have a growing season similar to that at Reno Airport, or an average of about 140 days. Honey Lake Valley growing season probably is as long as at the Sand Pass station (about 170 days), and the remainder of the valleys probably will have similar conditions as recorded at the Doyle station, or about 130 days.

Physiography and Drainage

The valleys of the area are structural depressions near the western margin of the Great Basin section of the Basin and Range physiographic province (Fenneman, 1931). The valleys generally are bounded by north-trending mountains and are partly filled with unconsolidated deposits derived from mountain erosion. Table 3 summarizes the physiographic and drainage features of the 11 valleys. The parts of Honey Lake Valley considered in this report are separated from the main part of the valley in California by a very low topographic divide as shown on plate 1. Because of low alluvial divides, the area of Honey Lake Valley considered in this report is composed of three topographically closed parts. The two parts of Lemmon and Spanish Springs Valleys are also separated by low alluvial divides.

In all the areas of internal drainage, playas have formed, including a small playa in the northern part of Spanish Springs Valley. The largest playa is in Honey Lake Valley, where much of the valley floor is covered by several playas.

Table 2.--Length of growing season between killing frosts that occur at 32°, 28°, and 24°F.

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

Station 1/	Period of record (years)	Minimum recorded (days) 32°F.	28°F.	24°F.	Maximum recorded (days) 32°F.	28°F.	24°F.	Average (days) 32°F.	28°F.	24°F.
Doyle	1948-55	35	102	141	123	154	200	95	130	169
Doyle 5 SSE	1957-65	104	132	139	134	191	238	121	152	182
Fernley	1950-52, 1955-65	112	125	144	181	191	222	141	161	187
Fleming Fish and Game	1961-65	99	117	158	119	183	201	109	136	181
Reno Airport	1948-65	57	107	121	150	167	204	106	140	166
Sand Pass	1920-25, 1927-31, 1934-41, 1948-62	98	124	124	176	225	274	137	169	198

1. See table 6 for station locations.

Table 3. -- Summary of physiography and drainage of the area

Valley; topography (See pl. 1)	Area (sq mi)	Type of surficial drainage	Adjoining mountains (altitude, in feet)	Valley floor (altitude, in feet)	Altitude of alluvium-consolidated rock contact (feet)	Average maximum relief (feet)
Honey Lake Valley; three topographically closed segments	235	internal	5,500-8,100	4,000	4,200-4,400	3,000
Newcomb Lake Valley; topographically closed	7	internal	6,000-8,000	5,150	5,200-5,300	1,500
Dry Valley, including Spanish Flat; drains to Long Valley in California	82	external	5,500-8,500	4,400-6,700	4,600-5,200	2,000
Red Rock Valley; drains to Long Valley in California	43	external	6,000-7,800	4,600-5,000	4,800-5,200	2,000
Bedell Flat; drains to Red Rock Valley	53	external	6,000-7,500	4,800-5,200	5,000-5,400	2,000
Antelope Valley; topographically closed	17	internal	5,800-7,200	5,100	5,300-5,400	1,400
Warm Springs Valley, including Winnemucca and Hungry Valleys; drains to Pyramid Lake	250	external	6,000-8,700	4,200-5,000	4,400-5,000	2,500
Cold Spring (Glider) Valley; topographically closed	31	internal	5,800-8,000	5,000	5,200	1,500
Lemmon Valley; two topographically closed segments	96	internal	6,000-8,300	4,900	5,100-5,400	2,000
Spanish Springs Valley; one topographically closed segment and one segment of external drainage to Truckee River 1/	73	internal and external	6,000-7,400	4,400-4,600	4,600-5,000	2,500
Sun Valley; drains to Truckee River	10	external	5,000-5,900	4,600-4,800	4,700-4,900	600

1. In the northern part of the valley an area generally north of a line extending west from Sugarloaf Peak has internal surface drainage to a small playa, as shown on plate 1.

No large perennial streams were observed in the area, except for the stream which drains from Spanish Springs Valley to Truckee Meadows. The other drainageways have flow only following intense storms or during periods of rapid snowmelt. The flow from Spanish Springs Valley is mostly excess water imported to the valley through the Orr Ditch (pl. 1).

Geologic Units and Structural Features

The geologic map is an extremely generalized presentation of the surficial distribution of the principal rock types in the area. The distribution and identification of the units on plate 1 are based principally on aerial-photograph interpretation and field checking at widely scattered points. The characteristics of the unit are given in table 4.

The volcanic rocks and associated shallow intrusions, such as andesite, dominate in the Virginia, Dogskin, and Seven Lakes Mountains, and those mountains to the north, as shown on plate 1. The mountains to the south and west are mostly underlain by granitic rocks.

Some parts of the area, shown as consolidated rocks on plate 1, are pediments--bedrock areas at the foot of mountains that are covered by a veneer of alluvium. Because the alluvial veneer is not only thin but generally unsaturated, these areas are hydrologically similar to the consolidated rock areas.

Many faults cut the consolidated rocks and the alluvium of the area. Most of the faults are marginal to the mountains and generally have a northwest orientation causing the structural trends of the area. Plate 1 shows those faults that cut the alluvium, the large faults that cut the consolidated rocks, and those that form boundaries between geologic units.

Table 4. -- Geologic units

	Geologic age		Geologic unit	Thickness (feet)	General character and extent	Water-bearing properties
QUATERNARY	Pleistocene and Recent	Valley fill	Younger alluvium	0-1,000±	Unconsolidated lenses of gravel, sand, and clay comprising stream and playa deposits.	Yields water to a few shallow domestic and stock wells where saturated. Yields are small.
TERTIARY (?) and QUATERNARY	Pliocene (?) and Pleistocene	Valley fill	Older alluvium	0-400±	Unconsolidated to semiconsolidated lenses of gravel, sand, and silt exposed principally marginal to the younger alluvium on the valley floor and on the apron. Also underlies younger alluvium. Playa deposits may be relatively thick, especially in Honey Lake Valley.	The younger and older alluvium together form the valley-fill reservoir, the principal source of water for wells. Most wells more than 50 feet deep obtain supply from older alluvium; yields vary greatly depending on construction, and depth of wells, and permeability of the deposits.
CRETACEOUS and TERTIARY			Consolidated -- rocks		Granitic rocks, volcanic flows and tuffs, composed of andesite and associated rock types. Exposed in the mountains, are at shallow depths in pediment areas and underlie the older alluvium at unknown depths.	Generally untapped by wells except for the southeastern part of Lemmon Valley. Yields to wells are variable but generally small to moderate. In Honey Lake Valley, volcanic rocks yield large amounts of water to springs.

CHARACTERISTICS OF THE VALLEY-FILL RESERVOIR

Extent and Boundaries

The younger and older alluvium of the valleys, as shown on plate 1, form the valley-fill reservoir and are the principal sources of ground water in the area. The maximum thickness of the reservoir in most valleys probably is at least 400 feet. In Sun Valley the reservoir, according to the logs in table 25, may have a maximum thickness of less than 200 feet. In Lemmon Valley it is at least 1,000 feet (table 25). Although consolidated rock reportedly has been encountered in wells at shallow depths, these wells were generally near the consolidated rock-alluvium contact where the alluvium is thin.

External hydraulic boundaries of the reservoirs are formed by the consolidated rocks (table 1 and pl. 1) which underlie the valley fill and form the mountains; all boundaries are leaky to varying degrees. The volcanic rocks, particularly basalt and scoria, may transmit moderate amounts of water in the Virginia Mountains to the adjoining valley-fill reservoirs by subsurface flow. Water probably leaks from the valley fill to consolidated rocks in Antelope and Lemmon Valleys and to some adjacent valley.

Recharge boundaries are formed by Orr Ditch, where it flows across the valley floor of Spanish Springs Valley and the few perennial streams. Flooded playas locally may also function as recharge boundaries.

The principal internal hydraulic boundaries are the faults passing through the valley-fill reservoirs. In Lemmon Valley, limited data indicate that two large faults probably affect the movement of water in the valley-fill reservoir. Three springs, in the southwest corner T. 21 N., R. 19 E., shown on plate 1, are on the southwestern, shallow-water side of the fault, which apparently is acting as a barrier, impeding the northeastward flow of ground water. The effectiveness of this and other barriers to ground-water flow probably cannot be determined until substantial ground-water development occurs.

Gross lithologic variations in the valley fill, such as playa deposits and old lake beds, also are hydraulic boundaries, although their subsurface location, extent, and effectiveness cannot be identified from available information.

Transmissibility and Storage Coefficients

Coefficient of transmissibility is a measure of capacity for ground water to flow in an aquifer system. The coefficient of storage in a heterogeneous valley-fill reservoir is a measure of the amount of water that will drain by gravity. When utilized together in certain types of mathematical models or analog models, the two coefficients can be used to define the distribution and amount of water-level decline that would result under certain conditions of pumping and boundary conditions.

Table 5 summarizes the tentative estimates of the coefficients of transmissibility of the ground-water reservoir of each area, based principally on the specific capacities (i.e. the yield of a well per unit of drawdown, expressed in gallons per minute per foot of drawdown) of a small number of existing wells, their diameters, and an estimated coefficient of storage of 0.1.

A valley-fill reservoir under long-term pumping conditions generally functions as an unconfined aquifer or water-bearing zone; under such conditions the coefficient of storage may be nearly equal to the specific yield. The coefficient of storage of the valley fill is computed from well logs to be at least 0.1, which is equivalent to a specific yield of 10 percent. Locally, the valley fill is lenticular, the silt and clay beds act as semiconfining layers, and water is under low and variable artesian head in the interbedded sand and gravel lenses.

Ground-Water Flow

Ground water, like surface water, moves from areas of higher head to areas of lower head. Unlike surface water, however, it generally moves very slowly, commonly at rates ranging from a fraction of a foot to several hundred feet per year, depending on permeability and hydraulic gradient.

In the several valleys, ground water moves from recharge areas in the mountains or on the alluvial apron to discharge areas in the valley lowlands. The principal discharge areas are where there is subsurface outflow, springs, and evapotranspiration.

Spanish Springs Valley has an internal surface-water drainage divide formed by a low alluvial ridge in the northern part of the valley. The alluvial divide probably has a negligible affect on ground-water movement in that valley, and all ground water in the northern part of the valley, except for a small amount discharged by evapotranspiration, flows southward to the discharge area.

The conditions are more complex in Lemmon Valley. An alluvial ridge divides the lowland into eastern and western segments. Further, several faults in the alluvium may impede ground-water flow. The principal area of natural ground-water discharge apparently is in and adjacent to the western playa, even though the eastern playa is about 40 feet lower. Water levels in the western segment have altitudes commonly between 4,950 and 4,960 feet, as indicated in table 24 of this report

Table 5. -- First approximations of the coefficient of transmissibility of the valley-fill reservoir[1]

Hydrologic unit	Range in the coefficient of transmissibility (gpm/ft)	Reference well in table 25
Honey Lake Valley	<100,000	26/19-29ba
Warm Springs Valley	<20,000	23/20-24db
Lemmon Valley	< 2,000 to 25,000	21/19-30dd 21/19-31cc
Spanish Springs Valley	3,000 to 30,000	20/20-3ca1 21/20-26dc
Other valleys	--	(insufficient data)

1. Based wholly on specific capacities of existing wells.

and data contained in a Corps of Engineers report (1943). The water table beneath the playa is within a few feet of the land surface and shallow in surrounding areas. The depth to water beneath the eastern playa is at least 15 feet or at an altitude no greater than about 4,900 feet. Thus, there is a potential gradient from west to east through the ridge between the playas. The faults undoubtedly impede ground-water flow, but data are not sufficient to demonstrate the effectiveness of the barriers to the movement of ground water. The alluvial ridge may be underlain at shallow depth by consolidated rocks. If so, they probably impede ground-water flow between the two valley segments.

Equilibrium Condition

Development of a hydrologic system commonly alters the surface-water and ground-water flow patterns, depth to water places of discharge, and in some cases the places of recharge. Flow of the larger creeks has been diverted for irrigation, locally causing higher heads where recharge occurs from the water spread on fields. Importation of water into Lemmon and Spanish Springs Valleys is a man-made source of potential ground-water recharge, altering the flow pattern and locally raising water levels. Pumping in parts of Lemmon, Sun, and Cold Spring Valleys has resulted in local lowering of water levels. Newcomb Lake, Dry, and Antelope Valleys, Bedell Flat, and to a lesser extent Red Rock, Warm Springs, and Honey Lake Valleys have had little development, and therefore are at or very near natural equilibrium conditions.

Table 6. -- Average annual precipitation at nine stations

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

Station	Location	Altitude (feet)	Period of record (years)	Average annual precipitation (inches)	Remarks
Doyle	7 mi. NW of Dry Valley	4,300	1923-55, 1960-65	10.10	In Long Valley
Doyle 5 SSE	4 mi. W of Dry Valley	4,385	1957-65	17.64	In Long Valley
Fernley	11 mi. SE of Warm Springs Valley	4,150	1870-1915, 1947-51, 1954-65	4.96	
Long Valley	1 mi. W of Cold Spring valley	5,060	1960-65	12.39	
Reno	3 mi. S of Sun Valley	4,432	1870-1942	7.19	
Reno AP	4 mi. S of Sun Valley	4,404	1937-65	7.23	
Sand Pass	6 mi. NE of Honey Lake valley	3,900	1914-32, 1934-62	6.43	In Smoke Creek Desert
Vinton	10 mi. W of Red Rock Valley	4,945	1950-65	13.54	In Sierra Valley
Wendel	10 mi. NE of Herlong	4,035	1959, 1962-65	6.83	In Honey Lake Valley, Calif.

INFLOW TO THE VALLEY-FILL RESERVOIR

Inflow to the valley-fill reservoir is from precipitation, runoff, imported water from outside the area, and from inflow of ground water through consolidated rock and alluvium. Each of these elements of inflow is discussed in the following sections.

Precipitation

Precipitation, falling as rain or snow, is the principal source of water entering the hydrologic systems of the area. Air masses moving into the area from the west generally lose much of their moisture in the Sierra Nevada, as can be seen from the data in table 6. As a result the mountains and valley floors of the area are subarid to arid, being in the rain shadow of the Sierra Nevada. Most of the precipitation falls in the winter and spring as snow; the largest amounts are at the highest altitudes. During the late spring and summer the precipitation is usually in the form of local thundershowers. June through September are the driest months, during which period the average rainfall is less than half an inch per month at Doyle, Sand Pass, and Reno Airport.

The precipitation pattern in Nevada is related principally to the topography (Hardman, 1936); the stations at the highest altitudes generally receive more precipitation than those at lower altitudes. However, this general relation may be considerably modified by local conditions. The valley floors of the area generally receive less than [illegible] inches of precipitation per year.

Precipitation data have been recorded for Reno or Reno Airport since 1870. These data plus those for the Sierraville, California station, which is 20 miles west of Cold Spring Valley in the Sierra Nevada, are used to identify the long-term variations in the annual precipitation and to identify drought periods. Four droughts are indicated: 1870-87, 1923-36, 1946-49, and 1959-61.

Estimates of average precipitation are summarized by altitude zones for the area in table 8. The estimates are based on the precipitation-altitude relation shown by Hardman's (1936) map, as revised in 1964.

Surface Water

By D. O. Moore

Runoff from the mountains to the valley floors is the principal source of surface water in the area. To a lesser extent, precipitation on the apron and valley floor produces runoff, but then only locally following intense storms. In most of the valleys some runoff flows to the lower parts of the valleys and ponds on playas in closed valleys or flows from the valleys that have external drainage (table 3). This section discusses the runoff from the mountains--the amount of surface water crossing the edge of the valley-fill reservoir.

Runoff occurs following intense storms and during periods of rapid snowmelt. To a lesser extent, runoff occurs as small, springfed perennial streams mostly on the west flank of the Virginia Mountains. The amount of runoff that reaches the surface of the valley-fill reservoirs from the mountains cannot be computed directly because of the absence of streamflow data. Therefore, methods devised by Riggs and Moore (1965) for estimating the altitude-runoff relations in areas where few or no data are available, and a method now being developed by Walter Langbein of the U.S. Geological Survey that is based on stream-channel geometry, are used to estimate runoff in the Warm Springs-Lemmon Valley area. The estimated average annual runoff at edges of the valley-fill reservoirs is summarized in table 7. Most of the streamflow generally occurs in the late winter and early spring.

Observations were made of streamflow during the last week of August and the first week of September 1966. Other than springfed creeks, no creeks were observed to have flow greater than 5 gpm (gallons per minute). The spring flow is discussed in a later section.

Most of the runoff is absorbed by the unsaturated alluvium underlying the washes. Some of this absorbed water percolates downward to the water table and recharges the groundwater reservoir, but most usually is held in the soil where it subsequently is discharged by evapotranspiration. Some of the runoff flows to the lower parts of the valleys during the growing season and is used for irrigating crop lands.

Recharge from Precipitation

On the valley floors where precipitation is small, little water infiltrates directly into the ground-water reservoir. Much of the precipitation is evaporated before and after infiltration and some adds to soil moisture. Greater precipitation in the mountains provides most of the recharge; the water reaches the ground-water reservoir by infiltration of

Table 7.--Estimated average annual runoff

Valley	Runoff area (acres)		Estimated average annual runoff (acre-feet)	
Honey Lake Valley:				
northern mountains	4,600		200	
southern mountains	20,900		3,900	
Total (rounded)		25,500		4,000
Newcomb Lake Valley		4,800		400
Dry Valley		38,300		7,500
Red Rock Valley		18,600		2,600
Bedell Flat		31,500		3,000
Antelope Valley		11,100		600
Warm Springs Valley:				
west of Highway 33	52,900		8,000	
east of Highway 33	45,900		6,000	
Total		98,800		14,000
Cold Spring Valley		14,700		1,400
Lemmon Valley		56,400		5,400
Spanish Springs Valley		18,600		1,500
Sun Valley		2,200		<100

runoff on the alluvial apron and the valley floor and some by lateral underflow from the consolidated rocks.

A method described by Eakin and other (1951, p. 79-81) is used to estimate the average annual recharge from precipitation. The method assumes that a percentage of the average annual precipitation becomes ground-water recharge. The estimated average annual recharge for the 11 valleys and that part of Long Valley in Nevada listed in table 8 ranges from about 1 percent to about 7.5 percent of the estimated total precipitation. A range of 3 to 7 percent is typical of the amounts usually calculated by this method for the desert basins of Nevada. Thus, the estimated recharge for Honey Lake, Antelope, Spanish Springs, and Sun Valleys, which is less than 3 percent of the estimated precipitation, may be somewhat low.

The average annual ground-water recharge from precipitation to Spanish Springs Valley is estimated to be about 600 acre-feet (table 8) and is in close agreement with the 500 acre-feet determined by Robinson and Phoenix (1948). The recharge for the Nevada part of Long Valley flows into California where it is discharged.

Subsurface Inflow

Ground water enters Red Rock and Honey Lake Valleys by subsurface inflow (underflow) from adjacent upgradient areas. Flow may occur through consolidated rocks and alluvium; however, evaluation of inflow through consolidated rocks by direct methods is difficult and is not attempted here.

To compute the underflow the equation $Q = 0.00112TIW$, is used: where $\underline{Q}$ is the quantity of underflow, in acre-feet per year; $\underline{T}$ is the coefficient of transmissibility, in gallons per day per foot, of the alluvial fill; $\underline{I}$ is the gradient of the water surface, in feet per mile; $\underline{W}$ is the effective flow width, in miles; and 0.00112 is a factor to convert gallons per day to acre-feet per year.

Underflow enters Red Rock Valley from Bedell Flat. The flow occurs through the valley fill in the narrow canyon connecting the two areas. Using the following estimated values: T= 25,000 gpd per ft, I= 80 feet per mile, and W= 0.08 mile (about 400 feet), the underflow to Red Rock Valley is estimated to be somewhat less than 200 acre-feet per year.

Underflow enters the part of Honey Lake Valley included in this report from the western part of Honey Lake Valley that is entirely in California. The underflow occurs through the broad alluvial divide that forms the western boundary of the part of Honey Lake Valley included in this report (pl. 1).

Table 8.--Estimated average annual precipitation and ground-water recharge

Altitude zone (feet)	Area (acres)	Estimated annual precipitation			Estimated recharge	
		Range (inches)	Average (feet)	Average (acre-feet)	Assumed percentage of: precipitation:	(acre-feet per year)
HONEY LAKE VALLEY						
Above 7,000	2,340	15-20	1.5	3,500	15	530
6,000-7,000	7,020	12-15	1.1	7,700	7	540
5,000-6,000	16,100	8-12	.8	13,000	3	390
Below 5,000	125,000	8-	.5	62,000	minor	--
Total (rounded)	150,000			a86,000		b1,500
NEWCOMB LAKE VALLEY						
Above 7,000	460	15-20	1.5	740	15	100
6,000-7,000	1,240	12-15	1.1	1,400	7	100
5,000-6,000	3,090	8-12	.8	2,500	3	70
Total (rounded)	4,790			4,500		300
DRY VALLEY						
Above 7,000	4,250	15-20	1.5	6,400	15	960
6,000-7,000	12,300	12-15	1.1	14,000	7	970
5,000-6,000	21,700	8-12	.8	17,000	3	510
4,000-5,000	14,000	8-	.5	7,000	minor	--
Total (rounded)	52,200			44,000		2,400

Table 8.--continued

Altitude zone (feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average (feet)	Estimated annual precipitation: Average (acre-feet)	Estimated recharge: Assumed percentage of precipitation	Estimated recharge: (acre-feet per year)
RED ROCK VALLEY						
Above 7,000	1,400	15-20	1.5	2,100	15	320
6,000-7,000	4,210	12-15	1.1	4,600	7	320
5,000-6,000	13,000	8-12	.8	1,000	3	300
Below 5,000	8,700	8-	.5	4,400	minor	--
Total (rounded)	27,300			12,000		900
BEDELL FLAT						
Above 7,000	410	15-20	1.5	620	15	90
6,000-7,000	5,050	12-15	1.1	5,600	7	400
5,000-6,000	26,000	8-12	.8	21,000	3	630
Below 5,000	2,340	8-	.5	1,200	minor	--
Total (rounded)	33,800			28,000		1,100
ANTELOPE VALLEY						
Above 7,000	60	15-20	1.5	90	15	10
6,000-7,000	620	12-15	1.1	700	7	50
5,000-6,000	10,400	12-	.8	8,400	3	250
Total (rounded)	11,100			9,000		300

Table 8.-- continued

Altitude zone (feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Averages (feet)	Averages (acre-feet)	Estimated recharge: Assumed percentage of precipitation	(acre-feet per year)
			WARM SPRINGS VALLEY			
Above 8,000	1,950)	15-20	1.5	18,000	15	2,700
7,000-8,000	10,000)					
6,000-7,000	27,000	12-15	1.1	30,000	7	2,100
5,000-6,000	60,100	8-12	.8	48,000	3	1,400
Below 5,000	60,800	8-	.5	30,000	minor	--
Total (rounded)	159,800			130,000		6,000
			COLD SPRING VALLEY			
Above 7,000	850	15-20	1.5	1,300	15	200
6,000-7,000	3,970	12-15	1.1	4,400	7	310
Below 6,000	15,000	12-	.8	12,000	3	360
Total (rounded)	19,800			18,000		900
			LEMMON VALLEY			
Above 8,000	130)	15-20	1.5	2,600	15	390
7,000-8,000	1,580)					
6,000-7,000	5,230	12-15	1.1	5,800	7	410
5,000-6,000	44,200	8-12	.8	35,000	3	1,000
Below 5,000	10,100	8-	.5	5,100	minor	--
Total (rounded)	61,200			48,000		1,800

Table 8.--continued

Altitude zone (feet)	Area (acres)	Estimated annual precipitation			Estimated recharge	
		Range (inches)	Average (feet)	Average (acre-feet)	Assumed percentage of precipitation	(acre-feet per year)
			SPANISH SPRINGS VALLEY			
Above 7,000	310	15-20	1.5	460	15	70
6,000-7,000	2,090	12-15	1.1	2,300	7	160
5,000-6,000	16,200	8-12	.8	13,000	3	400
Below 5,000	28,000	8-	.5	14,000	minor	--
Total (rounded)	46,600			30,000		600
			SUN VALLEY			
Above 5,000	2,210	8-12	.8	1,800	3	50
Below 5,000	4,120	5-8	.5	2,100	minor	--
Total (rounded)	6,330			4,000		50
			LONG VALLEY 1/			
Above 7,000	1,440	15-20	1.5	2,200	15	330
6,000-7,000	3,540	12-15	1.1	3,900	7	270
5,000-6,000	2,420	8-12	.8	1,900	3	60
Below 5,000	530	8-	.5	260	minor	--
Total (rounded)	7,930			8,000		700

1. Nevada part only.
a. Of this amount, 2,000 acre-feet occurs in California.
b. Of this amount, 100 acre-feet occurs in California.

Russell (1885, p. 55, 56) described Honey Lake, which is about 10 miles west of the report area, as a playa lake, sometimes becoming completely dry. The lake is generally very shallow, with an average only about 18 inches according to Russell. The altitude of Honey Lake and probably the water table, as determined from the topographic map, is about 3,985 feet. On the large playa 15 miles east in the report area, well 26/18-13dd has a water-level altitude of about 3,960 feet, or about 25 feet lower. The water-surface gradient between the two reference points would average about 2 feet per mile, indicating underflow eastward. The width of the valley fill in the underflow area ranges from 7 to 14 miles, but subsurface inflow from the mountains on the north and south of the valley reduces the effective width of eastward underflow to an estimated average of about 5 miles. Using the above assumed values and an average coefficient of transmissibility of 50,000 gpd per ft, the average annual underflow, as computed by the above equation, is nearly 600 acre-feet.

Imported Water

Stead Air Force Base, Lemmon Valley

Water is imported from the Truckee River to Lemmon Valley by pipeline for use at Stead Air Force Base, where it is the principal source of water supply. Importations for the period 1956-66 are shown in table 9, and ranged from 260 to 1,280 acre-feet per year. Records prior to 1956 were not available at the base.

Table 10 shows the use and probable disposition of imported and pumped water at Stead Air Force Base. The release of the Air Force Base to State and commercial interests in July 1966 may result in a change in the average annual importation and pumpage.

Spanish Springs Valley

Water is conveyed by gravity from the Truckee River to Spanish Springs Valley by means of the Orr Ditch (also called the Spanish Springs Valley ditch), which encircles about 3,600 acres of the valley floor. For the years 1956-65, but excluding 1959 and 1963 because of incomplete records, the diversion to the Orr Ditch averaged 31,500 acre-feet per year (records supplied by Claude Dukes, Federal Court Watermaster). Diversions for individual years ranged from 29,000 to about 39,000 acre-feet

Because of diversions and leakage along the unlined Orr Ditch, the flow reaching Spanish Springs Valley is less than the turn-out from the Truckee River. In the summer and fall 1966, measurements were made by the U.S. Geological Survey at a point near where the ditch enters Spanish Springs Valley and

Table 9.--Importation of water to Lemmon Valley from Truckee River for use at Stead Air Force Base

(Records from Stead Air Force Base)

Year	Imported (acre-feet)	Year	Imported (acre-feet)
1956	260	1962	1,130
1957	290	1963	1,140
1958	500	1964	1,280
1959	940	1965	1,110
1960	1,080	1966	a 480
1961	1,060		
Average annual (rounded)			900

a. Imported for first half of year.

Table 10.--Summary of water use at Stead Air Force Base, Lemmon Valley

(Quantities rounded)

	Acre-feet per year
WATER SUPPLIED:	
Average importation of water, 1956-66 (from table 9)	900
Average well pumpage, 1956-66[1]	100
Total average annual water supplied, 1956-66	1,000
DISPOSITION OF THE WATER:	
Ground-water recharge due to irrigation of golf course and lawns and to infiltration of sewage effluent (assume 30 percent of above water supply)	300
Water consumed by evaporation, transpiration of irrigated areas, of sewage effluent, and by domestic and military uses (assume 70 percent of above water supply)	700
Total water consumed or recharged, 1956-66	1,000

1. Records from Stead Air Force Base.

where outflow leaves the valley. Table 11 summarizes the inflow and outflow of the imported water and indicates that about 7,000 acre-feet per year is consumed annually in the valley. This water is consumed by crops, phreatophytes, evaporation from storage ponds, and subsurface outflow as described under outflow.

Table 11.--Summary of estimated inflow to Spanish Springs Valley in Orr Ditch and the subsequent outflow

Date	Diversion rate into Orr Ditch 1/ (cfs)	Measured flow rate near valley 2/ (cfs)	Flow as part of diversion (percent)	Measured outflow from valley in ditch 3/ (cfs)	Measured outflow as part of diversion (percent)
8- 5-66	84	68	81	24	29
8-19-66	84	63	75	36	43
8-26-66	84	62	74	21	25
11-2-66	41	25	61	10	24
Average (rounded)			75		30

Budget for Orr Ditch water

	Acre-feet per year
Average annual diversion into Orr Ditch	31,500
Approximate average annual flow at measuring site: 31,500 acre-feet x 75 percent . . . .(1)	24,000
Approximate diversion to 22-inch pipeline between measuring site and where ditch enters Spanish Springs Valley . . . .(2)	a8,000
Approximate flow into Spanish Springs Valley . . . . . .(1)-(2)=(3)	16,000
Approximate outflow in ditch from Spanish Springs Valley to Truckee Meadows = 31,500 acre-feet x 30 percent . . . .(4)	9,000
Average annual flow consumed in Spanish Springs Valley .(3)-(4)=(5)	b7,000

1. High rates of diversion are made during the growing season, or from about mid-March to October. Measurements by Federal Court Watermaster.

2. Flow measured in NW¼, sec. 34, T. 20 N., R. 20 E., by U.S. Geological Survey.

3. Outflow measured in SW¼, sec. 27, T. 20 N., R. 20 E., by U.S. Geological Survey.

a. Computed from data supplied by J. L. Raffetto (oral commun., 1966).

b. Owing to limited data this quantity is only approximate.

OUTFLOW FROM THE VALLEY-FILL RESERVOIR

The principal types of outflow from the valley-fill reservoir are surface-water outflow, evaporation of runoff reaching the playas, evapotranspiration in areas of shallow ground water, spring discharge, subsurface ground-water outflow, and irrigation. Each type of discharge as it pertains to the 11 valleys of the study area is discussed in the following several sections.

Surface-Water Outflow in Streams

By D. O. Moore

During the infrequent periods of large runoff, surface water flows out of the valleys having external surficial drainage (table 3) to downstream areas. A method developed by Walter Langbein, used in computing runoff, was also used to estimate outflow of streams from all drained valleys, except for Spanish Springs Valley. In Spanish Springs Valley, the outflow estimate is based on four measurements of flow made in the summer and fall of 1966 at the valley outlet (table 11). Table 12 lists the estimated average annual outflow of streams for the several valleys. The annual variations in outflow from these valleys are not known, because no gages have been maintained to monitor them. During most years the outflow probably is small (except for Spanish Springs Valley, the discharge from which is largely derived from imported irrigation water), and during a few years large amounts flow out, reflecting the general pattern of precipitation.

Playa Flooding and Evaporation

During periods of large runoff, water flows to playas (dry lakes) in the valleys having internal drainage (table 3). Most of the ponded water evaporates, but some may infiltrate the fine-grained playa deposits to recharge the ground-water reservoir. No data are available to determine the average annual evaporation of water from flooded playas. The authors have developed some impressions of the extent of playa flooding by talking to residents of the area. This information is summarized in table 13.

Evapotranspiration

Phreatophytes, plants that extend roots to the water table and draw upon ground water, utilize and discharge by transpiration large amounts of water in the area. In northwestern Nevada, the most common phreatophytes are greasewood, rabbitbrush, and saltgrass. Other less abundant species are willow and saltcedar. In the mountain canyons some of the common phreatophytes are cottonwood, aspen, and wildrose. In this area,

Table 12.--Estimated outflow of streams from valleys having external drainage [1/]

Valley	Stream or canyon	Location	Estimated average annual outflow (acre-feet)
Dry Valley	Dry Valley Creek[2/]	24/18-8c	4,000
Red Rock Valley	Red Rock Canyon	24/18-32b	1,000
Bedell Flat	Unnamed creek	24/19-31c	70
Warm Springs Valley	Mullen Creek	23/21-17b	70
Spanish Springs Valley	Unnamed creek	20/20-27c	a 9,000
Sun Valley	Unnamed creek	20/20-30c	20

1. No streams drain from Honey Lake, Newcomb Lake, Antelope, Cold Spring, or Lemmon Valleys.

2. At State line.

a. From table 11.

Table 13.--Playa flooding and evaporation[1]

Valley	Playa: number	Playa: area (acres)	Generalized flooding characteristics	Evaporation quantity compared to the estimated average annual runoff [2]
Honey Lake Valley	6	9,300	Large playa partly flooded each year for short period of time.	Small
Newcomb Lake Valley	1	115	Partly flooded in most years.	Large
Antelope Valley	2	40	Flooded in many years.	Moderate
Cold Spring Valley	1	1,150	Partly flooded in most years, sometimes to depths of 2 or 3 feet.	Large
Lemmon Valley	2	1,300	Western playa partly flooded in most years; eastern playa rarely flooded.	Small
Spanish Springs Valley[3]	1	50	Flooded in some years.	Small

1. No playas were identified in Dry, Red Rock, Warm Springs, and Sun Valleys, or in Bedell Flat.

2. See table 7.

3. Northern segment of valley.

the discharge of the phreatophytes found in the mountains is small and is not considered in the hydrologic budget. Table 14 summarizes the discharge by evapotranspiration from phreatophyte areas and evaporation from playas.

Evapotranspiration rates used are based on rates of consumption of ground water in other areas as described by Lee (1912), White (1932), and Young and Blaney (1942). Test holes were augered on the playas of Honey Lake, Cold Spring, and Lemmon Valleys (wells 26/18-13dd, 21/18-20cd, 21/18-28bb, and 21/19-27ca, table 24) to obtain information on depth to water and water quality. These water-level data were used to estimate the rate of evaporation from the playas in these three valleys. Because of large depths to water beneath the playas of Antelope Valley, about 77 feet, no ground water evaporates from them.

Where the phreatophytes cover a sufficient area to map at a scale of 1:250,000, they are shown on plate 1. In general, areas less than about a quarter of a mile wide could not be shown on plate 1. These include Bedell Flat and Cold Spring, Sun, and Spanish Springs Valleys.

Springs used for Irrigation

Many small springs are found in the area; however, most occur in the mountains. These springs have a combined net discharge that is a minor part of the hydrologic budget. Therefore, they were not considered in the ground-water budget for each valley. The two small springs at the south end of Sun Valley (Robinson and Phoenix, 1948) are included in this group.

Several moderate-sized springs and two large springs, which occur at or near the consolidated rock-alluvium contact, are used for irrigation. Table 15 lists these springs, their flow, and how they are utilized. For the area, adequately irrigated crops consume 1.5 to about 2 feet of water, depending on the length of growing season and the crop (Houston, 1950). The flow of these larger springs, when not utilized for irrigation, generally percolates back into the ground downslope from their outlets and recharges the ground-water reservoir at shallow depths, or is consumed by evapotranspiration. Commonly, phreatophytes grow in this shallow-water area, but this discharge associated with the springs is small and is included in the other estimates of discharge.

Fish Springs (26/19-19dd) reportedly has a natural flow of 1,600 gpm (2,600 acre-feet per year). When a nearby irrigation well (26/19-29ba) is being pumped an average of 90 days each year at 2,000 gpm, the flow of the spring reportedly is reduced to about 400 gpm due to interference. Under present condition of well interference and schedule of well use, the spring has an annual flow of about 2,100 acre-feet per year. Of this amount, 270 acre-feet is consumed by irrigated crops (table

Table 14.--Estimated evapotranspiration of ground water

Principal phreatophyte	Area (acres)	Density (percent)	Depth to water (feet)	Estimated ground-water discharge: Rate (acre-feet per acre)	Estimated ground-water discharge: (acre-feet per year)
HONEY LAKE VALLEY					
Mixture of greasewood, rabbitbrush, and big sage	41,000	5-25	10-50	.2	8,200
Playa	9,300	--	5-15	.1	930
Total (rounded)	50,000				a 9,000
NEWCOMB LAKE VALLEY					
Mixture of rabbitbrush and big sage	225	20	10-50	.2	50
Saltgrass 1/	65	--	3-10	.5	30
Playa	115	--	2-3	.4	50
Total (rounded)	400				130
DRY VALLEY					
Mixture of greasewood, rabbitbrush, and saltgrass	280	25	5-50	.3	80
RED ROCK VALLEY					
Do.	2,100	25	5-50	.3	630
BEDELL FLAT					
Saltgrass 2/	20	--	2-10	.4	8
Very wet meadow 2/	10	--	0-2	2.5	25
Total (rounded)	30				30
ANTELOPE VALLEY					
None	0				0
WARM SPRINGS VALLEY					
Mixture of greasewood, rabbitbrush, and big sage	5,700	20	10-50	.2	1,100
Mixture of saltgrass and rabbitbrush	500	--	0-10	.5	250
Meadowgrass	100	--	0-5	1.0	100
Total (Rounded)	6,300				1,500

Table 14.--continued

Principal phreatophyte	Area (acres)	Density (percent)	Depth to water (feet)	Estimated ground-water discharge: Rate (acre-feet per acre)	Estimated ground-water discharge: (acre-feet per year)
		COLD SPRING VALLEY			
Mixture of greasewood, saltgrass, and rabbitbrush[2]	40	20	5-50	.3	10
Playa	1,150	--	5-10	.1	120
Total (rounded)	1,200				130
		LEMMON VALLEY			
Mixture of greasewood and rabbitbrush	5,400	20	15-50	.2	1,100
Playa[3]	400	--	0-10	.1	40
Total (rounded)	5,800				1,200
		SPANISH SPRINGS VALLEY			
Saltgrass and meadow-grass [2]	1,100	--	5-10	.5	550
Tule and saltgrass[2]	150	--	1-5	1.5	220
Greasewood[2]	600	20	10-50	.2	120
Playa	50	--	5-15	.1	<10
Total (rounded)	1,900				b 900
		SUN VALLEY			
Meadow, wet[2]	2	--	0-10	1.0	c 2

1. Not shown as a separate unit on plate 1.

2. Area too small to show on plate 1; see text.

3. Playa discharge is limited to the western playa, because the depth to water beneath the eastern playa is greater than 15 feet, which is too great for any significant amount of evaporation from the playa to occur.

a. Of this amount about 2,000 acre-feet occurs in California.

b. Robinson and Phoenix (1948) listed a phreatophyte discharge of 3,000 acre-feet per year, because they mapped a large part of the area, listed in table 19 (irrigated by the Orr Ditch), as ground-water discharge area.

c. Same as reported by Robinson and Phoenix (1948).

Table 15.--Springs used for irrigation[1/]

Valley	Name	Location	Flow (gpm)	Crop	Area (acres)	Estimated average annual consumption (acre-feet)
Honey Lake Valley	Fish Springs	26/19-19dd	a 400	Alfalfa, grass	400	b 270
	High Rock Spring	28/17-25cd	500	Alfalfa, grass	200	320
Total (rounded)						600
Red Rock Valley	Tunnel Spring	23/18-21dc	200	Grass	200	c 160
	Red Rock Valley Ranch spring complex	At ranch	250	Alfalfa	100	b 60
Total						220
Warm Springs Valley	Winnemucca Ranch spring complex	At ranch	--	Grass, alfalfa	200	c 200
	Stead Ranch spring complex	At ranch	--	Grass, alfalfa rye	60	d 30
	Settlemeyer Ranch spring	24/20-29ba	75-100	Grass, alfalfa	80	c 80
Total (rounded)						300
Spanish Springs Valley	Spanish Springs	Under pond at 20/20-12a	(unknown)	Mostly grass	--	(e)

1. No springs used for significant amounts of irrigation in Newcomb Lake, Dry, Antelope, Cold Spring, Lemmon, and Sun Valleys and Bedell Flat.

a. Well 26/19-29ba pumped at 2,000 gpm during irrigation season, reducing normal flow of 1,600 gpm or 2,600 acre-feet per year.

b. Used to supplement well pumpage.

c. Supplemented by snowmelt when available.

d. Used to supplement snowmelt or other surface-water flow.

e. Flow mixes with water from Orr Ditch (table 10).

15), about 700 acre-feet is estimated to percolate back to the ground-water system, and about 1,100 acre·feet is assumed to be discharged by evaporation from ponding areas and evapotranspiration from wet soil in vegetated areas.

Subsurface Outflow

Ground water discharges from some of the valleys by subsurface outflow (underflow). Flow may occur through consolidated rocks and alluvium; however, evaluation of outflow through consolidated rocks by direct methods, like inflow, is difficult to estimate and is not attempted here.

To compute the quantity of subsurface outflow through alluvium, the same equation was used as in the "Subsurface Inflow" section of the report. Table 16 lists the values used in the computations as well as the estimated average annual subsurface outflow through alluvium.

For most valleys, outflow occurs through alluvium in a consolidated-rock narrows where a creek or wash drains the valley. The effective flow width assumed in the computations in most cases is the alluvial-fill width in the narrows, measured at land surface.

Development

Irrigation for Pumpage and Domestic Use

In a few valleys, wells are pumped to irrigate cropland. In all cases, well water is used in conjunction with other sources of water supply. Table 17 summarizes the net amount of water pumped from wells for irrigation. In Warm Springs and Spanish Springs Valleys, North American Aviation Inc. has constructed several wells for industrial supply. About 27 acre-feet was pumped by them in Warm Springs Valley and none in Spanish Springs Valley in 1966. Assuming that much of the used water infiltrates and returns to ground-water storage, the net draft in Warm Springs Valley is estimated to have been about 15 acre-feet in 1966.

In general, small amounts of water are diverted from springs and withdrawn from wells for both domestic and stock use. The exceptions are Lemmon and Sun Valleys where larger amounts are withdrawn by wells for domestic use. Table 18 summarizes the use for each valley. Most of the discharge in Sun Valley is by domestic pumping where observation well data (table 25) indicate that water levels are generally declining. The average rate of decline observed in five wells ranges from 0.5 foot to 0.2 foot per year since 1948. However, observation well 20/20-30da, in the outflow gap, shows no net change since it was first measured in 1948.

Table 16.--Subsurface outflow through alluvium

Valley[1/]	Outflow location	Assumed coefficient of transmissibility (gpd per ft)	Estimated ground-water gradient (feet per mile)	Flow width (miles)	Estimated average annual outflow (acre-feet)
Dry	At State line	50,000	20	2	2,200
Red Rock	24/18-32b	--	--	--	Minor
Bedell Flat	24/19-31c	25,000	80	.07	a <200
Warm Springs	23/21-17b	20,000	20	.4	200
Spanish Springs	20/20-27c	30,000	30	.1	b 100
Sun	20/20-30c	25,000	50	.02	About 25

1. No subsurface outflow through alluvium was identified for Honey Lake, Newcomb Lake, Antelope, Cold Spring, or Lemmon Valleys.

a. Outflow is to Red Rock Valley (p.   ).

b. Cohen and Loeltz (1964, p.23) compute an outflow of 150 acre-feet per year.

Table 17.--Summary of irrigation pumpage from wells[1]

Valley	Name	Location	Crop	Area (acres)	Pumping rate (gpm)	Estimated average consumption (acre-feet per year)
Honey Lake	Fish Spring Ranch	26/19-29ba	Alfalfa, grass	400	2,000	a 500
Red Rock	Red Rock Valley Ranch[2]	23/18-23cd	Alfalfa	100	--	b 200
Cold Spring	--	21/18-33bc	Grass	100	--	c Minor
Spanish Springs	--	20/20-12ca	Grass	(d)	flowing 100	100

1. No pumpage for irrigation in Newcomb Lake, Dry, Antelope, Warm Springs, Lemmon, and Sun Valleys and Bedell Flat.

2. Ranch has constructed a second irrigation well, but reported it will not be used until the growing season of 1967.

a. Supplemented by spring flow.

b. Supplemented by stream diversions and spring flow.

c. Used to supplement stream diversions.

d. Flow mixes with water from Orr Ditch (table 19).

Table 18.--Domestic and stock water derived from wells and springs

Valley	Estimated population	Estimated average annual domestic consumption1/ (acre-feet)	Estimated average annual stock consumption2/ (acre-feet)	Estimated total average annual consumption (acre-feet)
Honey Lake	25	<10	< 50	50
Newcomb Lake	0	0	< 10	10
Dry	0	0	< 10	10
Red Rock	10	<10	< 20	20
Bedell Flat	0	0	< 10	10
Antelope	0	0	< 10	10
Warm Springs	25	<10	< 20	25
Cold Spring	200	20	< 10	30
Lemmon	a 2,000	a 200	< 20	b 300
Spanish Springs	300	30	< 20	40
Sun	2,000	c 200	< 10	200

1. Based on an estimated average rural to suburban consumption rate of 100 gallons per day per person.

2. Based on an estimated use by range cattle of 6 gallons per day.

a. Number does not include Stead Air Force Base.

b. Number includes 70 acre-feet of well water consumed on Stead Air Force Base; based on a 70 percent consumption of the 100 acre-feet pumped (table 10).

c. Robinson and Phoenix (1948) described pumpage as negligible. Increase due to population growth since 1948.

Stream Diversions for Irrigation

A few creeks are diverted to fields for irrigation in several of the valleys in the report area. Most of the water is derived from snowmelt, and has maximum flow in the late spring. Table 19 summarizes the irrigation in each valley.

Table 19.--Consumption of streamflow by irrigation[1]

Valley	Stream or canyon	Crop	Location	Area (acres)	Estimated average net consumption (acre-feet per year)	
Honey Lake	Cottonwood Creek	Alfalfa	26/19-14b	120		a 300
Dry	Dry Valley Creek	Grass	24/19-3d	15		20
Red Rock	Unnamed Creek	Grass	Red Rock Ranch (T.23N., R.19E.)	200	b 40	
	Unnamed creek	Alfalfa	Red Rock Valley Ranch (T.23N., R.19E.)	100	b 40	
Total						80
Warm Springs	Unnamed creek	Grass, alfalfa	Settlemeyer Ranch (T. 24N., R.20E.)	80	b 50	
	Wilcox and Hay Canyons	Grass, alfalfa, rye	Stead Ranch (T.21N,R.22E.)	60	a 60	
	Unnamed creek	Grass, alfalfa	Winnemucca Ranch (T.24N., R.20E.)	200	b 70	
Total						180
Cold Spring	Unnamed creek	Grass	21/18-33b	100		100
Spanish Springs	Orr Ditch (Truckee River)	Mostly grass	T. 20 N., R. 20 E.	c 1,700		a 4,000

1. No large stream diversions for irrigation are made in either Newcomb Lake, Antelope, Lemmon, and Sun Valleys or Bedell Flat.

a. Supplemented by ground-water sources.

b. Used to supplement ground-water sources.

c. Robinson and Phoenix (1948) mapped 1,500 acres of cropped and cultivated land, about 1,100 acres of which was considered to be irrigated by water from the Orr Ditch.

GROUND-WATER BUDGET

For natural conditions and over the long term, ground-water inflow to and outflow from an aquifer are about equal. Thus, the purpose of preparing a ground-water budget is to compare the estimates of natural inflow and outflow for each valley, determine the magnitude of the errors in the two estimates, and select a value that hopefully represents both the inflow and outflow. This value in turn is used in a following section of the report to estimate the perennial yield of each valley. Table 20 shows the budget and the reconnaissance value selected to represent inflow and outflow.

The largest imbalance, 9,000 acre-feet per year, is for Honey Lake Valley. The imbalance probably is due to the small estimate of recharge (table 8) being in error; the estimate of outflow is considered to be more accurate. The recharge to the valley-fill reservoir by underflow from consolidated rocks at springs 26/19-19dd and 28/17-25cd is at least equal to their combined natural flow of about 2,100 gpm (table 15) or 3,400 acre-feet per year. Either a larger proportion of precipitation becomes recharge than that shown in table 8, or there is an unaccounted-for routing of subsurface flow through the consolidated rocks to the valley-fill reservoir. The subsurface flow would probably originate beyond the topographic boundaries of Honey Lake Valley as defined in this report.

The large imbalance of 4,000 acre-feet per year for Warm Springs Valley probably is due largely to less recharge than that shown in table 8. The valley is the farthest east in the area, and the precipitation may be less than that computed or some of the precipitation that infiltrates the consolidated rocks of the mountains may flow northward through the rocks to Honey Lake Valley. The imbalance of 900 acre-feet per year for Bedell Flat may also be due to less recharge than that shown in table 8. However, it also could be caused by underflow westward through the volcanic rocks to Red Rock Valley, which is 200 feet lower in altitude, or north-westward to Dry Valley, which is 400 feet lower.

Other areas having appreciable imbalances are Antelope and Cold Spring Valleys. Antelope Valley, which has no observed natural discharge, may discharge southward to Lemmon Valley (200 feet lower) through a narrow alluvial fill, through consolidated rocks or both, northward to Bedell Flat (300 feet lower) through consolidated rocks, or eastward to Warm Springs Valley (900 feet lower), also through consolidated rocks. For Cold Spring Valley the imbalance could be due to errors in the assumptions used to estimate inflow and outflow, or to subsurface outflow westward through alluvium or consolidated rocks or both, to the southern end of Long Valley, which is about the same altitude.

Table 20.--Preliminary ground-water budget for natural conditions

(All estimates in acre-feet per year and rounded)

Valley	Estimated natural inflow (tables 8 and 10, p. 20, 26) (1)	Estimated natural outflow (tables 14-16, p. 33, 35, 37) (2)	Imbalance (1)-(2)	Reconnaissance value selected for inflow and outflow
Honey Lake Valley	a 2,000	b 11,000	-9,000	b 10,000
Newcomb Lake Valley	300	130	170	200
Dry Valley	2,400	2,300	100	2,300
Red Rock Valley	1,100	850	250	1,000
Bedell Flat	1,100	250	900	700
Antelope Valley	300	0	300	300
Warm Springs Valley	6,000	2,000	4,000	3,000
Cold Spring Valley	900	130	770	500
Lemmon Valley	2,100	1,200	900	c 1,500
Spanish Springs Valley	> 600	> 1,000	-400	c 1,000
Sun Valley	50	25	25	50

a. Of this amount, about 100 acre-feet is recharge in California.

b. Of this amount, about 2,000 acre-feet is in California.

c. This estimate for natural conditions must be considered together with the substantial amount of imported water.

CHEMICAL QUALITY OF THE WATER

Samples of well, spring, and ditch water were collected and analyzed in seven of the valleys to make a generalized appraisal of the suitability of the ground and surface water for agricultural and domestic use and to help define the relation of quality to the hydrologic system. These analyses are listed in table 21.

Relation to the Hydrologic System

The water of best chemical quality generally has had a minimum time of contact with the rocks and soil. In the hydrogeologic environment of this area, the surface water flowing in the mountain streams and on the alluvial apron is generally low in mineral content. The surface water that wastes to the playas and ponds, in time, can be expected to become poor in quality by the processes of concentration by evaporation and solution of the salts from the soil of the playas.

As ground water flows from the source area to the discharge area it generally increases in dissolved-solids content. At the discharge areas where water is evaporated or transpired by plants, much of the mineral matter is deposited in the soil or remains in the shallow ground water, and causes an increase in the mineral concentration of the water. However, at depth below some areas, better quality of water can be found.

Generally the shallow ground water in the alluvium has a temperature near the average annual air temperature of the area, which is approximately 50° to 60°F. Water temperatures appreciably higher than this may indicate high thermal gradients or relatively deep water circulation, or both. Ground water occurring under such conditions may reach boiling; however, the highest temperature observed in the area, 86°F., was at spring 28/17-25cd in Honey Lake Valley.

Suitability for Agricultural Use

According to the Salinity Laboratory Staff, U.S. Department of Agriculture (1954, p. 69), the most significant factors with regard to the chemical suitability of water for irrigation are: (1) dissolved-solids content, (2) the relative proportion of sodium to calcium and magnesium, (3) the concentrations of elements and compounds that are toxic to plants, and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium. Dissolved-solids content commonly is expressed as "salinity hazard," the relative proportion of sodium to calcium and magnesium as "alkali hazard," and the relative bicarbonate concentration as "residual sodium carbonate" or RSC. No analysis was made for boron or the other toxic elements.

Table 21.--Chemical analyses of water from selected sources[1]

[Field analyses by the U.S. Geological Survey, except as indicated]

Location	Date of collection	Source type	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus Potassium (K)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulfate (SO_4)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Salinity hazard[2]	Alkalinity hazard[2]	RSC[2]	Water type	Rock source
				Parts per million (upper number), equivalents per million (lower number)										Some factors affecting irrigation quality[2]				
HONEY LAKE VALLEY																		
26/18-13dd	8-24-66	Well	66	--	--	--	--	--	--	--	--	8,920	--	Very high	--	--	--	Alluvium
26/18-25ac	7-27-66	Well	--	40 0.20	2.9 0.24	67 2.91	144 2.36	22 0.62	18 0.37	22	0	303	7.9	Medium	Low	Marginal	Sodium bicarbonate	Alluvium
26/19-19dd	7-27-66	Spring	73	3.0 0.15	3.0 0.25	78 3.39	179 2.93	18 0.51	17 0.35	20	0	328	8.0	Medium	Low	Not suitable	Sodium bicarbonate	Volcanic
26/19-29ba	8-23-66	Well	--	6.4 0.32	3.4 0.28	60 2.61	155 2.54	12 0.34	16 0.33	30	0	287	8.0	Medium	Low	Marginal	Sodium bicarbonate	Volcanic
27/17-3ad[3]	8-23-66	Well	67	5.6 0.28	10 0.84	393 17.1	593 9.7	233 6.57	74 1.54	56	0	1,560	8.4	High	Very high	Not suitable	Sodium bicarbonate	Alluvium
27/19-31ba	8-24-66	Well	--	53 2.64	49 4.03	1,810 78.7	224 3.67	2,010 56.7	1,200 25.0	334	150	7,720	7.8	Very high	Very high	Safe	Sodium chloride	Alluvium
28/17-25cd	8-23-66	Spring	86	5.6 0.28	0.5 0.04	55 2.41	124 2.03	13 0.37	16 0.33	16	0	253	8.1	Medium	Low	Marginal	Sodium bicarbonate	Volcanic
RED ROCK VALLEY																		
23/18-21dc	7-29-66	Spring	--	19 0.95	2.6 0.21	19 0.82	96 1.57	5.6 0.16	12 0.25	58	0	152	7.6	Low	Low	Safe	Mixed bicarbonate	Granitic
23/18-22cc	7-29-66	Spring	--	12 0.60	4.9 0.40	18 0.79	92 1.51	5.6 0.16	6.0 0.12	50	0	139	7.9	Low	Low	Safe	Mixed bicarbonate	Granitic
WARM SPRINGS VALLEY																		
22/21-2cb	7-27-66	Spring	--	38 1.90	2.2 0.18	35 1.50	136 2.23	20 0.56	38 0.79	104	0	319	7.9	Medium	Low	Safe	Mixed bicarbonate	Volcanic
COLD SPRING VALLEY																		
21/18-20ba	7-26-66	Well	--	23 1.15	12 1.01	11 0.49	124 2.03	13 0.37	12 0.25	108	7	276	7.8	Medium	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
21/18-20cd	8-22-66	Well	69	--	--	--	--	--	--	--	--	3,410	--	Very high	--	--	--	Alluvium
21/18-28bb	8-22-66	Well	70	--	--	--	--	--	--	--	--	15,000	--	Very high	--	--	--	Alluvium
LEMMON VALLEY																		
20/19-10db	7-26-66	Well	--	47 2.35	21 1.73	21 0.91	261 4.28	11 0.31	19 0.40	204	0	419	7.9	Medium	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
20/19-12bc[4]	1961	Well	63	39 1.95	14 1.15	67 2.92	156 2.56	12 0.34	69 1.44	134	--	--	--	Medium	Low	Safe	Mixed	Alluvium
20/19-16ba	7-25-66	Well	--	43 2.15	22 1.79	34 1.47	207 3.39	30 0.85	56 1.17	197	28	499	8.0	Medium	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
21/18-25ad1	7-26-66	Well	--	46 2.30	14 1.14	22 0.96	168 2.75	17 0.48	56 1.17	172	35	398	8.2	Medium	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
21/19-22bb	7-26-66	Well	--	20 1.00	10 0.84	29 1.26	120 1.97	6.6 0.19	45 0.94	92	0	280	7.8	Medium	Low	Safe	Mixed bicarbonate	Alluvium
21/19-23aa	7-26-66	Well	58	42 2.10	13 1.10	42 1.81	220 3.61	25 0.71	33 0.69	160	0	450	8.1	Medium	Low	Safe	Mixed bicarbonate	Alluvium
21/19-30dd	7-25-66	Well	62	9.3 0.46	1.2 0.10	58 2.51	112 1.84	17 0.48	36 0.75	28	0	273	7.9	Medium	Low	Marginal	Sodium bicarbonate	Alluvium
SPANISH SPRINGS VALLEY																		
20/30-2cb[4,5]	10-20-42	Well	--	152 7.60	46 3.78	66 2.75	395 6.48	57 1.61	281 5.86	649	--	--	--	High	Low	Safe	Mixed	Alluvium
20/20-10ab	7-27-66	Well	--	23 1.15	9.1 0.75	32 1.40	152 2.49	13 0.37	21 0.44	95	0	314	7.7	Medium	Low	Safe	Mixed bicarbonate	Alluvium
20/20-12db	7-27-66	Well	--	13 0.65	10 0.79	63 2.75	160 2.62	23 0.65	44 0.92	72	0	403	7.8	Medium	Low	Safe	Sodium bicarbonate	Alluvium
20/20-15ab[4,5]	11-12-43	Well	--	50 2.50	12 0.99	9 0.39	154 2.52	18 0.51	56 1.17	175	--	--	--	Medium	Low	Safe	Calcium bicarbonate	Alluvium
20/20-21aa	7-27-66	Well	--	63 3.14	49 4.03	125 5.45	144 2.36	48 1.35	428 8.91	359	241	1,150	7.9	High	Low	Safe	Mixed sulfate	Alluvium
20/20-27cd[4,5,6]	1946	Well	--	85 4.25	25 2.06	263 11.4	-- --	25 0.70	380 7.92	315	--	--	--	High	Low	--	--	Alluvium
20/20-27cd	7-27-66	Ditch	--	19 0.95	7.9 0.65	37 1.59	136 2.23	8.0 0.23	35 0.73	80	0	266	7.7	Medium	Low	Safe	Mixed bicarbonate	--
20/20-32ac	7-27-66	Orr Ditch	--	13 0.65	5.2 0.43	8 0.34	72 1.18	5.0 0.14	4.8 0.10	54	0	117	7.6	Low	Low	Safe	Mixed bicarbonate	--
21/20-24ac	7-27-66	Well	--	40 2.00	12 0.96	21 0.91	192 3.15	14 0.39	16 0.33	148	0	334	8.0	Medium	Low	Safe	Calcium bicarbonate	Alluvium
21/20-26dc[4,5]	9-12-41	Well	--	48 2.40	10 0.82	26 1.13	151 2.48	30 0.85	49 1.02	161	--	--	--	Medium	Low	Safe	Calcium bicarbonate	Alluvium
SUN VALLEY																		
20/20-18dc[4,5]	8-14-47	Well	--	36 1.80	Tr. Tr.	68 2.95	244 4.00	10 0.28	28 0.58	90	--	--	--	Medium	Low	Not suitable	Mixed bicarbonate	Alluvium
20/20-19dc[4,5]	5-15-47	Well	--	162 8.10	18 1.47	70 3.09	248 4.07	18 0.51	240 5.00	329	--	--	--	--	Low	Safe	Mixed	Alluvium

1. No water samples were collected in Newcomb Lake, Dry, and Antelope Valleys and Bedell Flat.

2. Descriptive terms are for water applied to good soils requiring little or no leaching and having favorable drainage characteristics.

3. Carbonate (CO_3), 11 ppm (0.37 epm).

4. Dissolved solids: Wells 20/20-2cb, 744 ppm; 20/20-15ab, 355 ppm; 20/20-27cd1, 946 ppm; 21/20-26dc, 290 ppm; 20/20-18dc, 320 ppm; 20/20-19dc, 630 ppm; 20/19-12bc, 357 ppm.

5. Analysis by the University of Nevada, Department of Food and Drugs.

6. Carbonate (CO_3), 46 ppm (1.53 epm).

The streamflow resulting from snowmelt during the spring of the year is low in dissolved material. This water is excellent for irrigation in all valleys.

According to the data in table 21, half of the samples from Honey Lake Valley generally were not suitable for long-term use for irrigation with usual practices. These ground-water sources were widely scattered and were from consolidated rocks and alluvium. For Spanish Springs Valley, of the 10 samples listed, three had high salinity hazards; two of the three were from wells near the Orr Ditch on the west side of the valley, and one from a well near the gap through which excess water drains from the valley. The surface-water outflow, as sampled nearby, was generally of good quality for irrigation. One of the two samples from Sun Valley was not suitable as to residual sodium carbonate (RSC). All other samples were either good or marginal in quality.

Suitability for Domestic and Public-Supply Use

The U.S. Public Health Service (1962) formulated drinking-water standards which have been endorsed by the American Water Works Association as minimum standards for all public water supplies. These standards are used as a basis in evaluating the water samples in this report. Only chemical characteristics will be evaluated in relation to the data listed in table 21. Bacteriological, physical, and radiological quality also affect the potability of water, but are not considered. Evaluation of potability of the supply from a water system, can be obtained from the Nevada Department of Health and Welfare, Bureau of Environmental Health, Reno.

The U.S. Public Health Service recommends the following maximum limits of concentration: chloride, 250 ppm; sulfate, 250 ppm; and dissolved solids, 500 ppm; 1,000 ppm is permissible. Specific conductance is a measure of dissolved solids. The relation is

$$\text{Specific conductance} \times \text{factor A} \approx \text{Dissolved solids (ppm)}.$$

The factor A has a value ranging from 0.5 to 1.0 (Hem, 1958, p. 40) and commonly is about two-thirds. Therefore, a water having a specific conductance of 750 micromhos might have a dissolved-solids content of 500 ppm, or water having a specific conductance of 1,500 micromhos might have a dissolved—solids content of 1,000 ppm (the maximum permissible).

Accordingly, the samples from well 27/19-31ba in Honey Lake Valley, wells 20/20-21aa, 20/20-2cb, and 20/20-27cd in Spanish Springs Valley, and well 20/20-19dc in Sun Valley should not be used for a source of drinking water, if other more suitable supplies are or can be made available. (See footnotes to table 21.) All other samples were suitable for the constituents tested.

For Lemmon Valley, the Corps of Engineers (1943) report that well 21/19-30dd produced good quality water but at a small pumping rate. Wells 21/19-31cc and 20/18-24ab (the mine shaft) yielded a larger amount of water, but the mineralization of the water was considered excessive for public-supply use.

Ground water at shallow depths adjacent to and beneath the playas is commonly unsuitable for human consumption. However, it has been found in some valleys of Nevada that the mineral content decreases with depth. Therefore, it may be possible to obtain potable water even in these areas if wells are drilled to sufficient depth, usually more than 300 feet below the water level.

THE AVAILABLE WATER SUPPLY

By G. F. Worts, Jr.

Sources of Supply

The available ground-water supply of the 11 valleys in the Warm Springs-Lemmon Valley area consists of two interrelated entities: (1) the perennial yield, or the maximum amount of natural discharge that economically can be salvaged over the long term by pumping; and (2) the transitional storage reserve (defined on p.50). The natural ground-water supply in Spanish Springs and Lemmon Valleys is greatly augmented by the water imported from the Truckee River. In addition, the pumped ground-water supply in most valleys is augmented by diversions from springs and streams (tables 15 and 19).

Perennial Yield

The estimated perennial yield of each of the 11 valleys in the study area is shown in table 22. For Honey Lake, Newcomb Lake, Red Rock, Warm Springs, Cold Spring,, Lemmon, and Spanish Springs Valleys, from which little (in relation to total discharge) or no ground-water outflow occurs, most of the natural discharge could be salvaged by properly located wells in or near the areas of natural discharge. Therefore the estimated perennial yield of these valleys is about the same as the "inflow and outflow" column in table 20.

For Bedell Flat and Dry, Antelope, and Sun Valleys, from which substantial subsurface ground-water outflow occurs in relation to the supply available, the amount of salvable discharge is difficult to determine. The possibility of salvaging all or part of the outflow through alluvium by pumping is dependent on its thickness in the narrows where the underflow occurs. If the fill is thin, the outflow in effect is moving over a consolidated-rock "spillway"; most of the outflow could be salvaged by drawing down the water levels below the outlet altitude. On the other hand, if the subsurface outflow is through a thick section of valley fill in the narrows, then only a moderate part of the outflow could be salvaged by pumping within the valley. In addition, Bedell Flat and Antelope Valley probably have subsurface outflow through consolidated rocks to adjacent valleys. For the purposes of this reconnaissance it is assumed that the subsurface geohydrologic controls might permit salvage of half the outflow.

With regard to the development in 1966, the estimated net pumpage of 200 acre-feet in Sun Valley (table 22) exceeded the estimated yield by 175 acre-feet. In all other valleys the pumpage is less than the estimated perennial yield.

Table 22.--Estimated perennial yield

(Compiled by F. E. Rush)

Valley	Estimated perennial yield[1] (acre-feet)	Remarks
Honey Lake Valley[2]	a 10,000	Assumes salvage of all discharge
Newcomb Lake Valley	200	Do.
Dry Valley	1,000	Assumes salvage of nearly half the outflow through alluvium
Red Rock Valley	1,000	Assumes salvage of all discharge
Bedell Flat	300	Assumes salvage of about half the outflow through alluvium
Antelope Valley	150	Assumes salvage of half the outflow, probably through consolidated rocks
Warm Springs Valley	3,000	Assumes salvage of all discharge
Cold Spring Valley	500	Do.
Lemmon Valley	b 1,500	Do.
Spanish Springs Valley	c 1,000	Do.
Sun Valley	25	Assumes salvage of half the outflow through alluvium

1. Salvable ground-water discharge, based on estimates in table 20.

2. Only that part of Honey Lake Valley considered in this report and shown on plate 1.

a. Of this amount, about 2,000 acre-feet is in California.

b. In addition, about 900 acre-feet per year is imported (table 9).

c. In addition, about 16,000 acre-feet per year is imported (table 11).

Transitional Storage Reserve

Transitional storage reserve is here defined as the quantity of water in storage in a particular ground-water reservoir that can be extracted and beneficially used during the transition period between equilibrium conditions in a state of nature and new equilibrium conditions under the perennial-yield concept of ground-water development. In the arid environment of the Great Basin, the transitional storage reserve of such a reservoir is the amount of stored water available for withdrawal by pumping during the nonequilibrium period of development, or period of lowering water levels. Obviously, transitional storage reserve is a specific part of the total ground-water resource that can be taken from storage; it is water that is available in addition to the recharge.

Most pertinent is the fact that no ground-water source can be developed without causing storage depletion. The magnitude of depletion varies directly with the distance of development from any recharge and discharge boundaries in the ground-water system. Few desert valleys have well-defined recharge boundaries, such as live streams or lakes; many, however, have well-defined discharge boundaries, such as areas of evapotranspiration.

To compute the transitional storage reserve of the 11 valleys in the report area, several assumptions are made: (1) wells would be strategically situated in, near, and around the areas of natural discharge so that these natural losses could be reduced (subsurface outflow) or stopped (evapotranspiration losses) with a minimum of water-level drawdown in pumped wells; (2) a perennial water level 50 feet below land surface would curtail virtually all evapotranspiration losses from ground water; (3) over the long term, pumping would cause a moderately uniform depletion of storage throughout most of the valley fill (excluding semi-isolated tributary areas), except in the playa deposits (mostly clay) where the transmissibility and storage coefficients are small; (4) the specific yield of the valley fill is 10 percent; (5) the water levels are within the range of economic pumping lift for the intended use; (6) the development would have little or no effect on adjacent valleys or areas; and (7) the water is of suitable chemical quality for the intended use.

Table 23 presents the preliminary estimates of transitional storage reserve in the Warm Springs-Lemmon Valley area computed on the basis of the above assumptions. For each of the 11 areas the estimated storage depletion is the product of the area beneath which depletion can be expected to occur, the average thickness of the valley fill to be dewatered, and the specific yield.

Table 23.--Preliminary estimates of transitional storage reserve

(Compiled by F. E. Rush)

Valley	Area of depletion (acres) (1)	Dewatered thickness (feet) (2)	Transitional storage reserve (acre-feet) (1) x (2) x 0.1
Honey Lake Valley	a 60,000	40	b 240,000
Newcomb Lake Valley	300	50	1,500
Dry Valley	c 7,000	50	35,000
Red Rock Valley	d 3,000	40	12,000
Bedell Flat	e 2,000	50	10,000
Antelope Valley	5,000	50	25,000
Warm Springs Valley	f 27,000	40	110,000
Cold Spring Valley	2,800	40	11,000
Lemmon Valley	g 18,000	40	72,000
Spanish Springs Valley	15,000	40	60,000
Sun Valley	3,000	50	15,000

a. Area does not include sec. 11, T. 27 N., R. 19 E. and all alluvial area northeast.

b. Of this amount, about 70,000 acre-feet is in California.

c. Area does not include T. 25 N., R. 18 E.

d. Area limited to eastern half of valley.

e. Area limited to sec. 9, T. 23 N., R. 19 E., and all alluvial area northwest.

f. Area does not include Winnemucca Valley and T. 21 N., Rs. 21 and 22 E.

g. Area does not include T. 22 N., R. 19 E., and sec. 19, T. 21 N., R. 20 E. and all alluvial area south.

In Sun Valley, lowering ground-water levels to salvage natural ground-water discharge would also increase infiltration of imported water. This would increase ground-water recharge but would decrease the surface-water outflow to Truckee Meadows.

Sample Computation of Ground-Water Supply

Transitional storage reserve generally provides a substantial amount of water in addition to the perennial yield. During the transition period the salvage of natural discharge increases from none at the time pumping starts to the maximum rate of salvage (the perennial yield) at the time pumping has fully depleted the transitional storage reserve. The general equation to express this relation is:

$$\text{Annual pumpage} = \text{Rate of depletion of transitional storage reserve} + \text{Rate of salvage of natural discharge during depletion period}$$

Assuming a uniform rate of storage depletion and uniform rate of increase in salvage of natural discharge, the annual pumpage (Q) and the time in years (t) during which depletion takes place can be approximated from equation (1):

$$Q = \frac{\text{Transitional storage reserve}}{t} + \frac{\text{Perennial yield}}{2} \quad . . (1)$$

This basic equation, of course, could be modified to allow for changing rates of storage depletion and salvage of natural discharge. The equation, however, is not valid for pumping rates less than the perennial yield.

Using equation (1) and the estimates for Honey Lake Valley as an example (transitional storage reserve 240,000 acre-feet, table 23; perennial yield 10,000 acre-feet, table 22) and using a pumping rate (Q) equal in quantity to perennial yield, in accordance with the general intent of Nevada water law, the time (t) to deplete the transitional storage reserve is computed to be about 50 years.

At the end of that time, the transitional storage reserve would be exhausted, subject to the assumptions given in the preceding section.

What is not shown by the example is that in the first year virtually all the pumpage would be supplied from storage, and very little, if any, would be supplied from natural discharge. On the other hand, during the last year of the period selected nearly all the pumpage would be derived from the salvage of natural discharge and virtually none from the storage reserve.

During the period of depletion the ground-water flow net would be substantially modified. The estimated recharge of 10,000 acre-feet per year that originally flowed from around the sides of the valley to areas of natural discharge would ultimately flow directly to the pumping wells.

To meet the needs of an emergency or other special purpose requiring ground-water pumpage in excess of the perennial yield for specified periods of time, the transitional storage reserve would be depleted at a more rapid rate than in the example given. The above equation can be used to compute the time required to exhaust the storage reserve for any selected pumping rate in excess of the perennial yield. However, once the transitional storage reserve was exhausted, the pumping rate should be reduced to the perennial yield as soon thereafter as possible. Pumpage in excess of the perennial yield would result in an overdraft, and pumping lifts would continue to increase and stored water would continue to be depleted until some undesired result occurred.

FUTURE SUPPLY

Most if not all the economically available surface water is appropriated for use. Because of this, most additional water for consumption in the future will have to be from ground-water sources or imported from outside the area.

Cold Spring, Lemmon, Spanish Springs, and Sun Valleys, being close to Reno and Sparks, will undoubtedly experience additional development as the economy and population of the area grow. The form of economic growth in these valleys probably will be residential and industrial, with a corresponding decrease in the importance of ranching. With continued growth, ultimately the small perennial yields will be exceeded (exceeded in 1966 in Sun Valley) and water levels will decline as ground water in storage is consumed. Water is now being piped to Lemmon Valley because of the generally low well yields and reportedly will be piped to Sun Valley starting in the summer of 1967. This method of supply may ultimately have to be used in other valleys as water consumption expands.

Very few large-capacity wells have been drilled in the report area. Accordingly, the possibility of obtaining large well yields throughout the area cannot be predicted. Variation probably will be found within each valley and between valleys. Because of the uncertainty, test drilling and test pumping should precede any attempt to obtain a large ground-water supply.

PROPOSALS FOR ADDITIONAL STUDIES

1. To define the quantity and distribution of outflow of streams from Dry, Red Rock, and Spanish Springs Valleys, gages should be installed at the outflow points.

2. To determine the quantity and distribution of inflow of water to Spanish Springs Valley in the Orr Ditch, a gage should be installed where the ditch enters the valley.

3. Because of the possibility of overdraft in other valleys near Reno where considerable development is expected to occur, additional, more detailed studies might be considered within the next 10 years.

NUMBERING SYSTEM FOR HYDROLOGIC SITES

The numbering system for hydrologic sites in this report is based on the rectangular subdivision of the public lands, referenced to the Mount Diablo base line and meridian. It consists of three units: the first is the township north of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; the third unit, separated from the second by a dash, designates the section number. The section number is followed by a letter that indicates the quarter section and quarter -quarter section, the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. For example, well 26/19-29ba is the well recorded in the NE¼NW¼ sec 29, T. 26 N., R. 19 E., Mount Diablo base line and meridian.

Because of the limitation of space, wells and springs are identified on plate 1 only by the section number, quarter section and quarter-quarter section letters. Township and range numbers are shown along the margins of the area on plate 1.

SELECTED WELL DATA AND LOGS

Selected well data are listed in table 24; selected drillers' logs of wells are listed in table 25. Most of the data and logs are from the files of the Nevada State Engineer. Data in table 24 were selected to include most wells in Honey Lake, Red Rock, Antelope, Warm Springs, and Spanish Springs Valleys and Bedell Flat. In Cold Spring, Lemmon, and Sun Valleys, which have about 50, 200, and 400 wells, respectively, only a few wells were selected and shown on plate 1. They generally are representative of the other wells in the valleys. No data were available for wells in Dry and Newcomb Lake Valleys.

Table 25 contains logs of a few wells in each valley except Dry and Newcomb Lake Valleys. Their locations also are shown on plate 1.

Table [illegible].--Selected wells data

Use. P, public supply, D, domestic, U, unused, Ir, irrigation, S, stock, In, industrial T, test hole

State log number. Log number in the files of the State Engineer

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number
								Date	Depth (feet)	
				HONEY LAKE VALLEY						
26/18-13dd	U.S. Geological Survey	1966	15	2	T	---	3,973	8-24-66	12.89	--
-25ac	Lime Rock Well	---	---	---	S	---	3,977	8-23-66	flowing	--
26/19-29ba	Fish Springs Ranch	1954	400	12	Ir	2000/31	4,010	1954	23	2508
27/17-3ad	Honey Lake Cemetery	---	---	6	S	---	4,010	8-23-66	26.08	--
-11bd	---	---	---	---	U	---	4,004	--	19	--
27/18-3ab	Turn of the Road Well	---	---	6	S	---	4,110	8-23-66	150.95	--
-5cc	High Rock Well	---	176	8	S	---	4,005	8-23-66	14.71	--
-13dd	Flanigan Well	---	312	6	S	7/50	4,061	8-23-66	102.11	--
27/19-1ac	Bonham Well	---	---	6	S	---	4,045	8-23-66	30.91	--
-4da	Mission Peak Well	---	390	6	S	---	4,300	9-13-66	300.71	--
-14ca	Double Check Well	---	---	8	S	---	4,005	8-23-66	40.59	--
-31ba	Gertrude Milne	1954	210	8	D	---	3,995	8-24-66	35	2558
28/17-34ba	--	---	---	6	U	---	4,025	8-23-66	18.71	--
				RED ROCK VALLEY						
23/13-9dd	Red Rock Ranch	1950	135	6	S	6/42	5,000	1950	7	1267
-14ad	Red Rock Valley Ranch	1947	277	---	S	11/12	4,761	12- 5-63	16.58	120
-14bb	Red Rock Valley Ranch	1966	700	---	Ir	2100/---	4,750	8- 1-66	flowing	---

Table 24.--continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement Date	Water-level measurement Depth (feet)	State log number
				BEDELL FLAT						
22/19-4da	U.S. Bureau of Land Management	1958	390	6	S	5 [illegible]	5,160	1958	300	4030
23/19-23cb	Harold R. Kellenbarger	1954	60	6	D	10/5	5,050	1954	44	2631
-31dd	Chapman Dickinson	1944	70	6	S	10/15	5,400	1944	12	123
				ANTELOPE VALLEY						
22/19-1cb	Chapman Dickinson	1947	218	6	S	5/--	5,237	1947 7-30-66	175 178.91	101
-14cd	---	---	--	8	U	--	5,150	7-30-66	76.60	--
-26bb	Chapman Dickinson	1946	90	---	S	20/15	5,110	1946	56.	118
				WARM SPRINGS VALLEY						
22/20-25da	North American Aviation, Inc.	1959	500	10	In	162/160 250/203	4,640	1959	71	4549
22/21-6da	North American Aviation, Inc.	1962	500	24,12	In	175/151	4,330	1962	93	6984
-10ac	Monte Cristo Ranch	1948	200	6	D,S	10/--	4,410	11-25-63	105.±	718
22/22-7ca	North American Aviation, Inc.	1962	500	12,10	In	--	5,050	1962	20.33	6684
-18ca	A.M. & F.M. Crosby & J.F. Burke	1948	161	6	S	10	4,840	11-18-48	32.88	719
23/20-24db	North American Aviation, Inc.	1963	200	8	In	145/11	4,210	1963	9	7985
-35cd	North American Aviation, Inc.	1963	400	8	In	--	4,360	1963	115	7983
23/21-30dd	---	---	20	48	U	--	4,240	5-19-48	13.35	--

Table 24.--continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number
								Date	Depth (feet)	
				COLD SPRING VALLEY						
21/18-16bd	Donnell Richard	1964	250	12	Ir	---	5,070	1964	40	8072
-16cb	---	---	165	8	U	---	5,065	7-26-66	39.00	--
-19aa	Raymond Dahmer	1963	80	8	D	40/15	5,120	1963	25	6974
-20	U.S. Geological Survey	1966	7	2	T	---	5,030	8-22-66	5.42	--
-21ba	---	---	---	14	U	---	5,040	7-26-66	5.35	--
-28bb	U.S. Geological Survey	1966	7	2	T	---	5,030	8-22-66	5.02	--
				LEMMON VALLEY						
20/18-1cc	L.C. Trail	1958	200	6	D	±10/--	5,160	1958	90	4874
-24ab	Stead Air Force Base Mine shaft	---	386	--	P,U	264/321	6,300	8-4-43	274	--
20/19-4bd	VIP, Inc.	1962	177.5	20	P	125/---	5,000	1962	52	7891
-4cb	---	---	---	6	D	---	5,000	7-26-66	52.12	--
-8aa	Western Capital Development Co.	1962	414	8	P	300/--	5,060	1962	55	6878
-10db	Arnold Smith	---	---	---	D	---	5,090	7-26-66	27.61	--
-15bd	C & R Trailer Park	1963	408	8	P	200/160 300/192	5,130	1963	125	7534
-15dc	Memory Gardens, Inc.	1952	205	8	Ir	400/25	5,190	1952	120	2008
21/18-25ad	H. Bowman	---	74	6	D	---	4,980	7-26-66	16.28	--
-36dc	J.C. Faretto & Son	1946	115	16	Ir	30/21	4,970	1946	6	127
21/19-5aa	Chapman Dickinson	1944	300	6	S	5	5,140	7-26-66	123.22	124
-10dd	Jerome Powers	1961	108	6	D	15/30	5,080	1961	48	6223
-27ca	U.S. Geological Survey	1966	15	2	T	---	4,920	8-22-66	dry	--
-22ba	Albert J. Clanton	1962	102	6	D	25/45	4,930	1962	22	6904
-30dd	Stead Air Force Base no. 1	1942	706	24,12	P	117/327	4,985	1942	35	--
-31cc	Stead Air Force Base no. 2	1942	1,170	24,12	P	499/217	4,980	12-22-42	22.5	--
-33bb	---	---	---	8	U	---	4,965	8-22-66	11.02	--
-34cc	LeCaer	1963	254	10	D	---	4,950	1963	19	7075

Table 24.--continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement: Date	Water-level measurement: Depth (feet)	State log number
				SPANISH SPRINGS VALLEY						
20/20-2cb	Gaspari Brothers	1942	117	6	D	20(?)	4,480	4-14-48	5.34	7730
-3ca	E.A. Becker	1963	848	26	U	500/140	4,540	1963	54	7343
-10ab	Gun Club	1949	360	6	P	50/63	4,490	1-26-49	22.60	--
-10bb	James E. Stead	1951	424	12 10	D	---	4,560	1951	55	1878
-12ca	G. Windfield	---	100	--	Ir D S	100/---	4,480	4-27-48	flowing	--
-15ab	James Stead	---	600	6	D	---	4,468	4-27-48	14.22	--
-21aa	Oasis Mobile Estates	1964	580	10	P	150/---	4,520	1964	85	7848
-21ab	Oasis Mobile Estates	1961	210	8	P	100/47	4,520	1961	85	6882
-27cd	---	1948	35	6	D	---	4,420	4-26-48	4.95	--
20/21-18dd	U.S. Bureau of Land Management	1953	96	8	S	--	4,550	1953	65	2292
21/20-26dc	North American Aviation, Inc. Spanish Springs Valley, no. 1	1957	821	22,10	In	640/28	4,540	7-28-66	63.51	4888
21/21-30ba	Gaspari Bros. Windmill	---	160	6	S	---	4,750	4-26-48	123.82	--
				SUN VALLEY						
20/20-18aa	R.E. Hahn	1948	170	6	D	---	4,800	6-30-48	35.90	--
-18da	Mel Meyer	---	96	8	D	---	4,720	8- -47	30	--
-18dc	C. MacBride	---	137	8	D	---	4,720	1947	97	--
-19ad	Anders	1949	---	12	U	---	4,670	6- 7-49	23.48	--
								10- 5-59	25.13	
								9-28-65	29.50	
-19dc	Ken Rogers	---	26	48	D	---	4,650	8- 5-48	18.74	--
								10- 5-59	20.48	
								9-28-66	dry	
-30ab	Frank Nelson	1947	61	6	D	---	4,630	2- 2-48	17.89	--
								10- 5-59	20.35	
								3- 4-65	22.30	

Table 24.--continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement		State log number
								Date	Depth (feet)	
			SUN VALLEY (continued)							
20/20-30da	M.A. Morley	--	12	48	D	--	4,600	6-30-48	6.02	--
								10- 5-59	10.97	
								3-24-66	5.10	
								9-28-66	9.36	

Table 25.--Selected well logs

Material	Thickness (feet)	Depth (feet)
HONEY LAKE VALLEY		
26/19-29ba		
Soil	5	5
Sand	25	30
Sand and boulders	10	40
Clay, yellow	10	50
Boulders	3	53
Clay, yellow	2	55
Sand and boulders	5	60
Sand, hard	25	85
Sand, hard, and boulders	10	95
Rock, black lava	80	175
Rock, brown lava	62	237
Conglomerate, lava	80	317
Rock, very hard, black lava	8	325
Rock, soft, broken lava	75	400
27/18-5cc		
Sand	6	6
Gravel and boulders	3	9
Gravel	6	15
Sand	24	39
Gravel and boulders	3	42
Sand	36	78
Gravel	7	85
Sand	11	96
Gravel and boulders	11	107
Clay, yellow	10	117
Rock	40	157
Sand	2	159
Gravel and boulders	16	175
27/19-4da		
Soil and sand	12	12
Clay	35	47
Clay and boulders	63	110
Clay, hard, gravel, and boulders	245	355
Lava	35	390
27/19-31ba		
Soil	5	5
Clay, sandy, yellow	33	38
Sand, black	19	57
Boulders and gravel	13	70
Clay, yellow	18	88
Clay, blue	49	137
Clay, hard, blue	38	175
Lava rock, black	24	199
Lava rock, soft, black	9	208
Lava rock, very hard, black	2	210
RED ROCK VALLEY		
23/18-9dd		
Sand, very fine to medium, with yellow clay	18	18
Sand, fine to medium, with yellow clay and a few rocks, water	1	19
Sand, soft, fine, with yellow clay	20	39
Sand, loose, fine to medium, water	1	40
Sand, fine to medium, with yellow, red clay	31	71
Clay, yellow	2	73
Sand, fine to medium, and some coarse sand, water	1	74
Clay, white, with fine to medium sand	9	83
Clay, hard, sticky, yellow, with fine sand	10	93
Sand, heaving, fine to medium, with clay, water	25	118
Granite, soft, with seams of fine to medium, heaving, water-bearing sand	17	135

Table 25.--continued

Material	Thickness (feet)	Depth (feet)
RED ROCK VALLEY (continued)		
23/18-14ad		
Soil, sandy	2	2
Sand, gray	26	28
Sand; water	1	29
Sand, granitic, brown, with a slight mixture of clay, water-bearing, fine, light micaceous sands about every 10 or 12 feet	131	160
Clay, blue, mixed with granitic sand, a water strata of fine, light, micaceous, granitic sand about every 10 or 12 feet	117	277
BEDELL FLAT		
23/19-22cc		
Clay	5	5
Clay, sandy	13	18
Gravel	2	20
Clay, sandy	12	32
Gravel	3	35
Clay	27	62
Clay, sandy	6	68
Gravel	4	72
Clay	33	105
Clay, sandy	3	108
Gravel	4	112
Clay	33	145
Gravel	3	148
Clay, sandy	22	170
Clay	16	186
Sand	4	190
Clay	17	207
Sand	17	224

Material	Thickness (feet)	Depth (feet)
ANTELOPE VALLEY		
22/19-1cb		
Soil, granitic, sandy, loamy	1	1
Sand, granitic	9	10
Sand with yellow clay	20	30
Rocks, granitic, and sand with yellow clay	5	35
Sand with red clay	15	50
Sand, fine, and silt	15	65
Sand with gray clay	25	90
Sand with gray clay and many granitic rocks	70	160
Sand and granite boulders	10	170
Sand with a bluish clay	17	187
Sand and boulders	8	195
Sand, granitic, coarse, white; water	1	196
Sand, hard packed, fine, with gray clay	3	199
Sand, coarse	1	200
Sand, fine, gray, with gray clay	5	205
Sand, coarse, water	1	206
Sand, fine, gray, with gray clay	4	210
Sand, coarse, water	1	211
Sand, fine, gray, with gray clay	5	216
Sand, coarse	1	217
Sand, fine, gray, and hard granite rocks with gray clay	1	218
22/19-26bb		
Soil, sandy, loamy	2	2
Sand, granitic, fine, very hard packed, gray; water 78-90 feet	88	90

Table 25.--continued

WARM SPRINGS VALLEY

22/20-25da

Material	Thickness (feet)	Depth (feet)
Clay	73	73
Sand	4	77
Clay	15	92
Sand	2	94
Clay	26	120
Sand	70	190
Sand and clay	3	193
Sand	14	207
Sand and clay	14	221
Sand, clay, and rock	7	228
Sand	21	249
Rock	3	252
Sand and clay	3	255
Sand	24	279
Sand, clay, and rock	32	311
Rock	12	323
Clay, blue, and rock	16	339
Chalk	4	343
Rock, white	109	452
Rock, hard, white	16	468
Rock, hard, blue	32	500

22/21-6da

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Gravel	2	8
Conglomerate, clay, and gravel	97	105
Sand, medium	15	120
Clay, yellow	65	185
Sand	45	230
Clay	104	334
Sand and clay	23	357
Sand, medium	8	365
Clay, blue	135	500

23/20-35cd

Material	Thickness (feet)	Depth (feet)
Sand and gravel	70	70
Clay, sandy	80	150
Clay streaks with gravel	60	210
Gravel and white sand; water	140	350
Sand, fine, and clay	50	400

COLD SPRING VALLEY

21/18-16bd

Material	Thickness (feet)	Depth (feet)
Sand with light clay silt	53	53
Sand, fine; water	6	59
Clay, brown	12	71
Sand, loose, and gravel	114	185
Clay, yellow	6	191
Gravel, cemented	7	198
Clay, brown	5	203
Sand, tight, and gravel	17	220
Gravel, cemented	6	226
Clay	4	230
Sand and gravel	16	246
Clay, brown	4	250

LEMMON VALLEY

20/19-8aa

Material	Thickness (feet)	Depth (feet)
Soil and cobbles	4	4
Clay, brown	12	16
Clay, sandy with boulders	47	63
Clay and cobbles with gravel lense	51	114
Sand and gravel	4	118
Clay, sandy, brown	39	157
Granite, decomposed, hard	12	169
Granite, decomposed, and clay	75	244
Granite, decomposed, and red rock	23	267
Rock, solid, red	12	279
Clay, brown	25	304
Clay and rock	10	314
Clay, sandy, and rock	44	358
Clay, sandy	28	386
Conglomerate; water	6	392
Clay, sandy	3	395
Conglomerate, broken, water	11	406
Sand, coarse, water	2	408
Clay, brown, with small gravel	6	414

Table 25.--continued

LEMMON VALLEY--continued

20/19-12bc

Material	Thickness (feet)	Depth (feet)
Lithology unknown	104	104
Sand, fine gravel, and yellow clay	16	120
Sand, gravel, and a few boulders	18	138
Boulders	10	148
Clay and boulders	14	162
Gravel and sand	16	178
Clay, sandy	16	194
Sand and gravel	10	204
Clay and gravel streaks	49	253
Gravel	17	270
Clay	5	275
Gravel and sand	7	282
Boulders	4	286
Boulders, hard, and clay streaks	9	295
Boulders, hard, and clay	4	299
Sand, gravel, and clay	10	309
Clay and boulders	8	317
Sand and gravel	11	328
Clay and boulders	2	330
Sand and gravel	16	346
Clay and boulders	2	348
Sand, gravel, and clay breaks	5	353
Gravel, sandy	22	375
Clay and boulders	3	378
Sand and gravel	24	402
Clay and boulders	2	404
Clay, sandy, and boulders	11	415
Sand and some gravel	23	438
Clay, sandy, and boulders	16	454
Sand and gravel	12	466
Clay, sandy, blue	2	468
Sand and gravel	25	493
Sand, broken	4	497
Shale	6	503
Gravel, sand, and clay	19	522
Shale, hard, sandy	41	563
Sand, hard, and gravel	12	575
Shale, sandy, blue	8	583
Sand and shale breaks	34	617
Boulders	1	618
Sand, hard, cemented, and gravel	8	626
Rock	1	627
Sand and broken clay	28	655
Clay, sandy	9	664
Sand and broken clay	48	712
Sand and clay	10	722
Clay, sandy, and sand	31	753

21/19-30dd

Material	Thickness (feet)	Depth (feet)
Clay and gravel	15	15
Sand, granitic	130	145
Clay	11	156
Sand, granitic, partly cemented	31	187
Clay and sand	95	282
Sand, granitic, hard, tight	52	334
Gravel and clay, alternating layers	192	526
Shale(?)	5	531
Gravel	40	571
Shale and clay	5	576
Gravel with 2 feet of clay	55	631
Gravel and clay	45	676
Gravel	25	701
Clay	5	706

21/19-31cc

Material	Thickness (feet)	Depth (feet)
Clay	352	352
Gravel	28	380
Clay	69	449
Sand and gravel	38	487
Clay	116	603
Gravel, loose	24	627
Clay, firm	11	638
Gravel	12	650
Clay	74	724
Sand and gravel, loose	77	801
Clay	113	914
Gravel and clay, alternating layers	23	937
Clay	48	985
Gravel	18	1003
Clay	52	1055
Shale(?), hard	115	1170

Table 25. continued

SPANISH SPRINGS VALLEY

20/20-3ca

Material	Thickness (feet)	Depth (feet)
Granite, decomposed	45	45
Granite, boulders, decomposed	15	60
Granite, boulders, decomposed, and some blue clay	20	80
Clay, sandy, blue	10	90
Rocks, sand, clay	10	100
Sand, blue clay	5	105
Sand, blue clay, and some boulders	5	110
Sand, blue clay, and some gravel	375	485
Sand, very fine, and blue clay	5	490
Clay, blue	10	500
Sand, fine, and blue clay	165	665
Clay, blue, and medium sand	105	770
Sand, coarse, and minor streaks of blue clay	50	820
Sand, coarse, clay streaks and boulders	15	835
Boulders, clay, and sand (hard drilling)	5	840
Boulders, sand, and minor clay	8	848

20/20-15ab

Material	Thickness (feet)	Depth (feet)
Clay, yellow to gray, interbedded with fine sand	300	300
Lava capping	50	350
Clay and sand	220	570
Gravel	30	600

20/20-21ab

Material	Thickness (feet)	Depth (feet)
Clay, brown, and alluvial rock	81	81
Rock, brown	6	87
Clay, yellow	59	146
Rock, broken, gray, water	7	153
Sand, black, and gravel, water	5	158
Rock, hard, black, water	21	179
Sand, water	2	181
Rock, shelf	5	186
Sand, water	2	188
Rock, hard and soft, black, water	8	196
Clay, sandy, yellow	3	199
Clay, blue	11	210

21/20-36cc

Material	Thickness (feet)	Depth (feet)
Alluvium	17	17
Sand, coarse	21	38
Clay, brown	16	54
Sand, coarse	31	85
Clay, silty	10	95
Sand, coarse	27	122
Clay and sand, alternating layers	33	155
Clay, mostly	67	222
Sand and clay, alternating layers	27	249
Clay, mostly	74	323
Sand, mostly	37	360
Clay, brown	33	393
Sand and clay, alternating layers	74	467
Siltstone, gray	41	508
Sand and siltstone	20	528
Sand, coarse	66	594
Sand and siltstone alternating layers	134	728
Sand	34	762
Siltstone, gray	12	774
Sand	47	821

SUN VALLEY

20/20-18aa

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Hardpan	4	7
Gravel	8	15
Clay, sandy, brown	72	87
Gravel, medium, water	7	94
Clay, sandy	46	140
Gravel, small, water	6	146
Sandstone	8	154
Gravel, cemented	8	162
Rock, hard	8	170

20/20-1[illegible]da

Material	Thickness (feet)	Depth (feet)
Topsoil	2	2
Hardpan	4	6
Granite, decomposed	14	20
Clay, sandy, and sand	15	35
Clay	25	60
Sand, water-bearing, coarse	26	86
Clay	10	96

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9	Gabbs
10	Sarcobatus and Oasis
11	Hualapai Flat
12	Ralston and Stonecabin
13	Cave
14	Amargosa
15	Long, Surprise
	Massacre Lake, Coleman
	Mosquito, Guano
	Boulder
16	Dry Lake and Delamar
17	Duck Lake
18	Garden and Coal
19	Middle Reese and Antelope
20	Black Rock Desert
	Granite Basin, Summit Lake
	High Rock Lake
21	Pahranagat and Pahroc
22	Pueblo, Continental Lake
	Virgin, Gridley Lake
23	Dixie, Stingaree
	Fairview, Pleasant
	Eastgate, Jersey
	Cowkick
24	Lake
25	Coyote Spring
	Kane Spring
	Muddy River Springs
26	Edwards Creek
27	Lower Meadow, Patterson
	Spring (near Panaca) - Panaca
	Eagle, Clover
	Dry
28	Smith Creek and Ione
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	Pleasant
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38	Little Smoky
	Hot Creek, Little Fish Lake
39	Eagle Valley, (Ormsby Count
40	Walker Lake Area, Whiskey Flat, Rawhide Flats (Mineral, Lyon, Churchill Counties)
41	Washoe Valley
42	Steptoe Valley (White Pine and Elko Counties)
43	Warm Springs-Lemmon Valley area (Washoe County)

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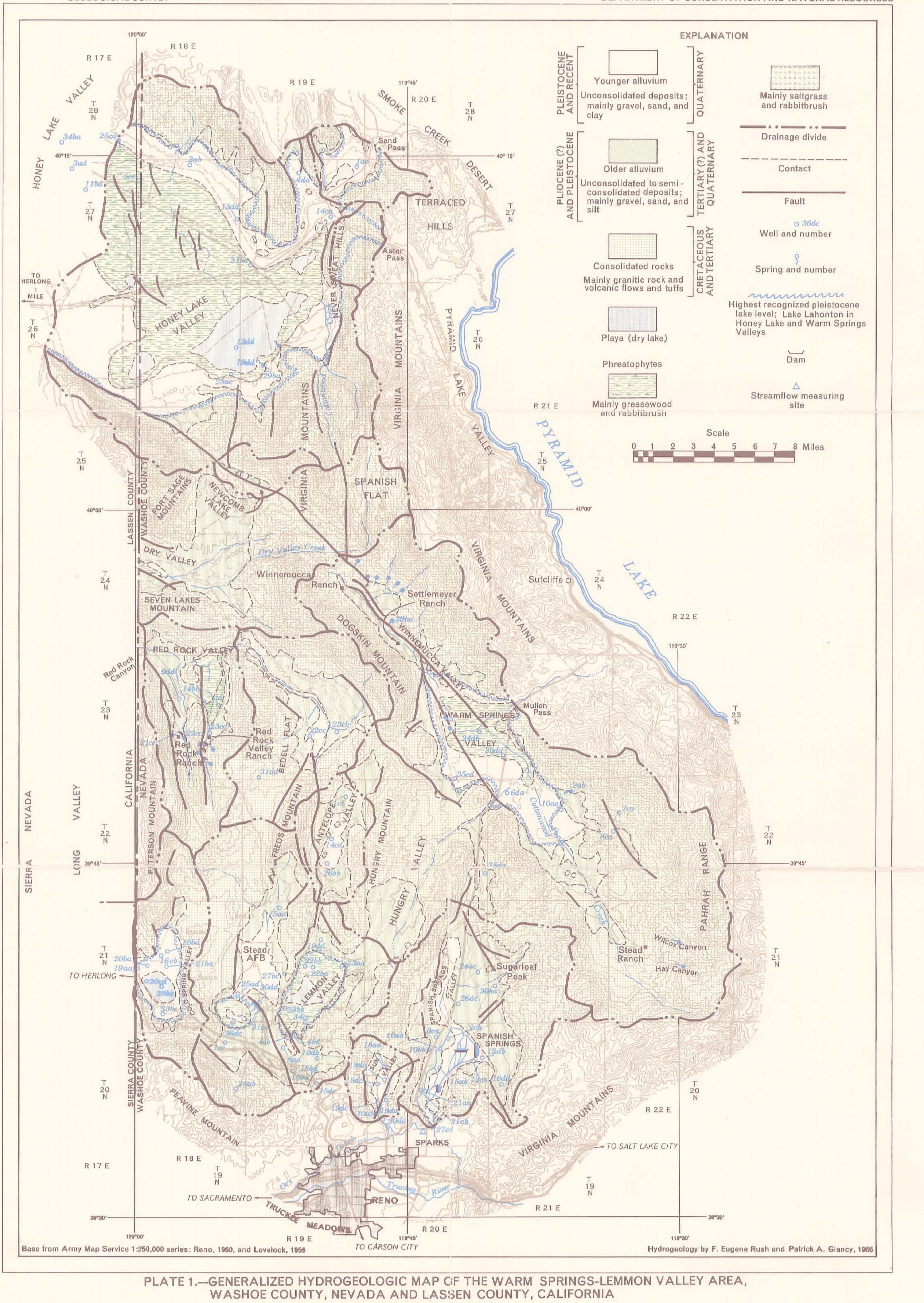

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE WARM SPRINGS-LEMMON VALLEY AREA, WASHOE COUNTY, NEVADA AND LASSEN COUNTY, CALIFORNIA