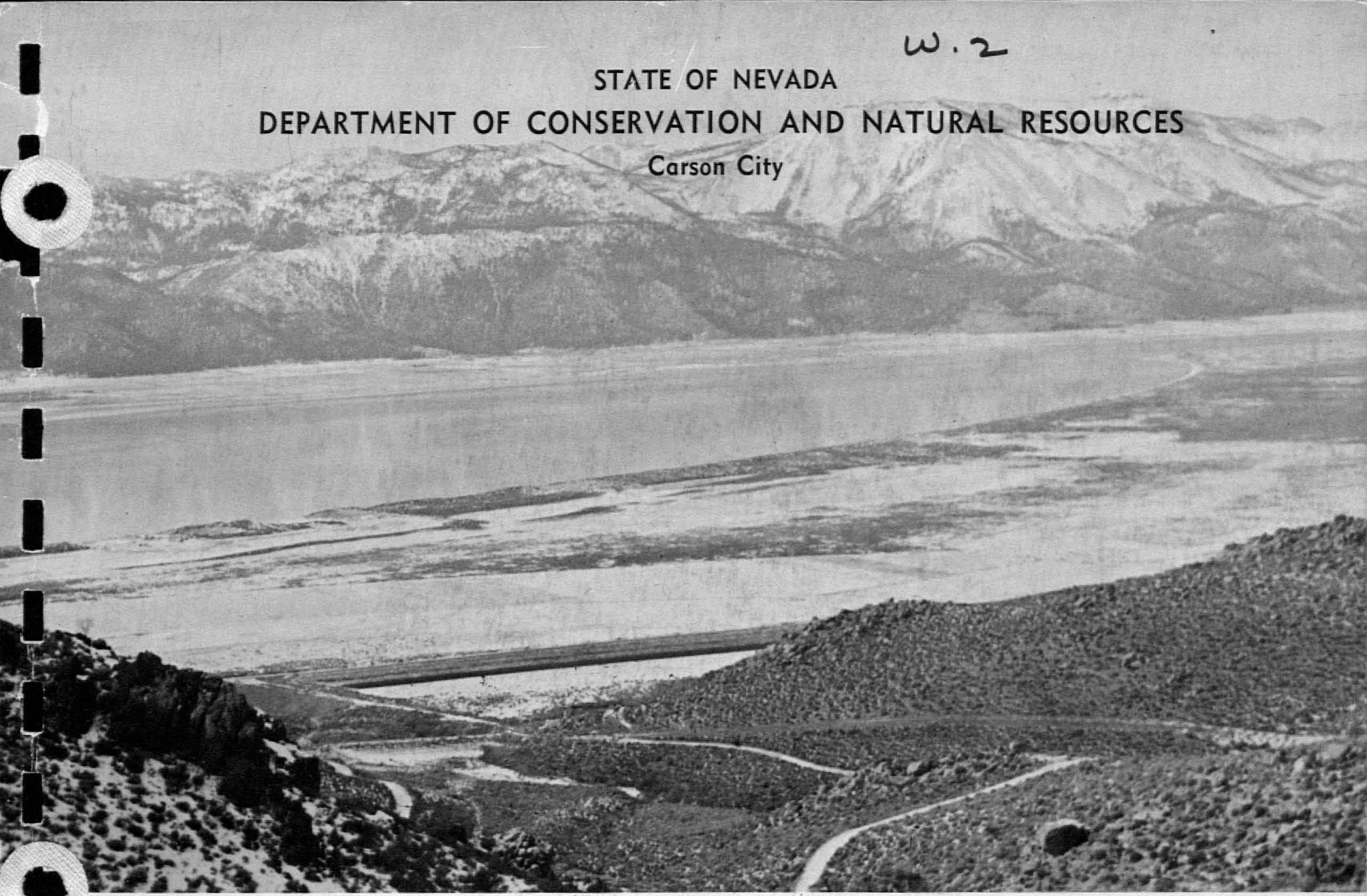
W. 2

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of Washoe Valley looking northwest toward Slide Mountain.

WATER RESOURCES-RECONNAISSANCE SERIES

REPORT 41

WATER-RESOURCES APPRAISAL OF WASHOE VALLEY, NEVADA

By

F. Eugene Rush

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

APRIL 1967

WATER RESOURCES - RECONNAISSANCE SERIES

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by F. Eugene Rush

SUMMARY

Washoe Valley is an 84-square mile basin in western Nevada between Reno and Carson City. About 270,000 acre-feet of ground water is stored in the upper 100 feet of saturated valley fill. On the average, an additional 20,000 acre-feet of water is stored in Washoe and Little Washoe Lakes, which cover much of the valley floor. The total estimated average annual inflow to the basin is 33,000 acre-feet, of which 23,000 acre-feet is by runoff, principally from the high-precipitation areas of the Carson Range of the Sierra Nevada. The other sources of inflow are precipitation directly on the lake areas, surface-water importation to the basin, and subsurface inflow across the consolidated rock-valley-fill contact.

The estimated average annual outflow from the basin is 31,000 acre-feet. The evaporation from Washoe and Little Washoe Lakes is estimated to account for about 14,000 acre-feet of this total. Irrigation from surface-water sources consumes nearly 6,000 acre-feet per year and ground-water losses by phreatophytes are nearly 9,000 acre-feet per year. About 600 acre-feet of surface water was exported in 1965 for use in public-supply systems at Virginia City and Carson City. The estimated net pumpage from irrigation, stock, and domestic wells was 1,000 acre-feet in that year. Field analyses of water samples indicate that the water in the valley is generally suitable for irrigation, domestic, and stock uses. Ground water is hard on the east side of the valley and for the most part soft to moderately hard on the west side.

The yield of the system is estimated to range between 15,000 and 25,000 acre-feet per year, depending on how the water resources are developed. Although the economy of the valley is principally ranching, residential development is increasing rapidly as the general population of the Reno-Carson City region grows. Therefore, it is important that scientific water management be practiced; because there is a strong interrelation between surface and ground water of the valley, the development of either will strongly affect the other.

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 an increase in 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, Stats, 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. 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-first report prepared as part of the reconnaissance series (fig. 1).

Objectives of this report are to (1) appraise the source, occurrence, movement, storage, and chemical quality of water in the area, (2) estimate average annual recharge to and discharge from the ground-water reservoir, (3) provide a preliminary estimate of the system yield, and (4) evaluate present and potential water development in the area. The system yield of the valley was determined for the present conditions of development.

Field work for this study required about 10 man-days in the fall of 1965 and the spring of 1966.

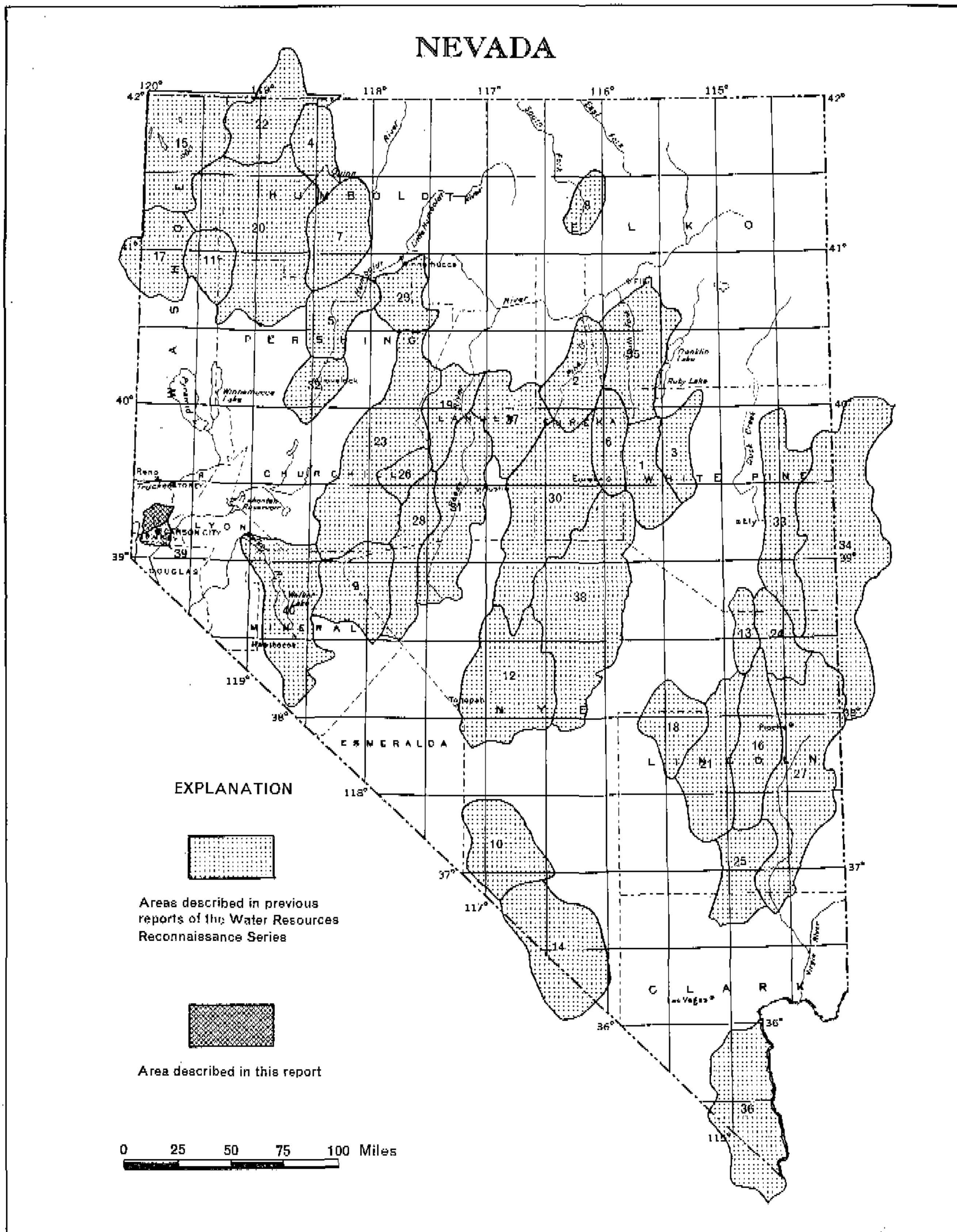

Figure 1.—Area described in this report and others in previous reports of the Water Resources—Reconnaissance Series

Location and General Features

Washoe Valley is in western Nevada (fig. 1), between the adjacent communities of Reno and Carson City, and is a small, well watered area. The large runoff from the Sierra Nevada is carried by several creeks which extend from the mountains and flow across the flat valley floor. Some runoff is diverted and utilized for irrigation of cropland, the remainder flows to Washoe and Little Washoe Lakes, which occupy much of the valley floor. During high lake stages, water from the lakes drains northward from the valley in Steamboat Creek through a narrow canyon cut deeply into consolidated rocks. Steamboat Creek discharges into the Truckee River east of Reno (fig. 1).

Other principal streams in the area are Ophir and Franktown Creeks. Smaller streams include Winters, Musgrove, and Big Canyon Creeks.

The basin is roughly triangular (pl. 1) and occupies 84 square miles. Principal access is by U. S. Highway 395, which extends through the valley and connects Reno, 14 miles north, and Carson City 4 miles south. State Highway 27 extends westward from U. S. Highway 395, crossing the Carson Range of the Sierra Nevada in the northwest corner of the basin, to the Lake Tahoe basin at Incline Village (not shown on pl. 1). A paved road extends along the east side of the valley and provides access to the growing residential area of New Washoe City, northeast of Washoe Lake.

The economy of the valley is basically ranching with much of the valley floor not occupied by lake used for hay and pasture, but residential development is expanding in three major areas: at the northern end of the valley (Washoe City), northeast of Washoe Lake (New Washoe City), and at the southern end of the valley near Lakeview Summit. The estimated population in 1966 was about 1,000.

HYDROLOGIC ENVIRONMENT

Landforms

Washoe Valley is a structural depression along the western margin of the Great Basin section of the Basin and Range physiographic province (Fenneman, 1931). The valley is bounded by two mountain ranges, the tree-covered Carson Range of the Sierra Nevada on the west and the sage-covered Virginia Range on the east. Within the drainage area the Carson Range crests at an altitude of about 9,000 feet; the Virginia Range generally reaches an altitude of from 6,000 to 7,500 feet. Low spurs from the two ranges join at Lakeview Summit but at the north end of the valley, Steamboat Creek separates the two ranges. The altitude of Lakeview Summit is 5,163 feet and that of Washoe Hill, about 3/4 of a mile east of Steamboat Creek, is about 5,100 feet.

The valley floor is broad and flat (altitude, 5,019 to 5,200 feet) and abruptly joins the foot of the Carson Range on the west. As previously mentioned, nearly a fourth of the valley floor is occupied by Washoe and Little Washoe Lakes which at medium- to low-water levels are separated by a swampy area, but at high water stages form a single body of water. The outlet from Little Washoe Lake to Steamboat Creek is several feet above the bed (bottom) of Washoe Lake, which prevents the lakes from being entirely drained by the creek. On the east side of the valley, the valley floor and mountains are separated by a poorly developed alluvial apron or intermediate slope which is narrow where present, usually less than a quarter-mile wide. On the east side of the valley, the valley floor has a slope of about 80 feet per mile, the alluvial apron about 300 feet per mile.

Geologic Units and Structural Features

The principal geologic units in Washoe Valley are shown on plate 1 and are described in table 1. The description of the general character and extent of the units is based principally on the geologic maps of Thompson and White (1964), Moore (1961), and Thompson (1956). A major modification is made in the classification and extent of younger and older alluvium, which form the principal ground-water reservoir in the valley.

Faults that form geologic unit boundaries or occur in the alluvium are shown on plate 1. These structural features may effect the flow of ground water. Two faults cut the alluvium, one in the southwest part of the valley near the west shore of Washoe Lake, the other near Washoe City at the north end of the valley. The escarpment formed by the fault in the southwest part of the valley has a maximum height of about 30 feet a quarter-mile north of where it crosses U. S. Highway 395. The escarpment of the other fault is about 20 feet high. Older alluvium is exposed on the upthrown side of each fault.

Historical Sketch

The first settler in Washoe Valley built a cabin at Franktown (site was in NW$\frac{1}{4}$, sec. 10, T. 16 N., R. 19 E.) in 1852. During the following decade many more settlers came to the valley. In 1861 Washoe City (pl. 1) was founded, Ophir Mill was built (SW$\frac{1}{4}$, sec. 35, T. 17 N., R. 19 E.), and Dall Mill was built at Franktown to process

Table 1.--Geologic units in Washoe Valley

Geologic age			Geologic unit	Thickness (feet)	General character and extent	Water-bearing properties
QUATERNARY	Recent and Pleistocene	Unconsolidated deposits	Younger alluvium	0-50±	Unconsolidated lenses of gravel, sand, and silt comprising stream, lake, and swamp deposits and sand dunes along the eastern shore of Washoe Lake	Yields water to a few shallow domestic and stock wells. Yields are small
QUATERNARY	Recent and Pleistocene	Unconsolidated deposits	Landslide deposits	0-200±	Unconsolidated deposits of granitic rubble and sand southeast of Slide Mountain in the Ophir Creek area of the Carson Range	Not tapped by wells. Probably would yield small amounts of water to wells where saturated
QUATERNARY	Pleistocene	Unconsolidated deposits	Glacial deposits	0-100±	Unconsolidated boulders, gravel, and sand; largely morainal deposits on high mountain slopes west and north of Slide Mountain in the Carson Range	May be tapped by a few wells of ski lodges. Probably would yield small to moderate amounts of water to wells where saturated
QUATERNARY	Pleistocene	Unconsolidated deposits	Older alluvium	0-500±	Semiconsolidated to unconsolidated lenses of gravel, sand, and silt exposed principally in the northeastern part of the valley and buried at shallow depth beneath younger alluvium. In the southwestern part of the valley, it is chiefly disintegrated granitic debris	Most wells more than 50 feet deep obtain supply from older alluvium; yields range from a few gallons per minute for small diameter wells to more than 2,000 gpm in a few large-diameter wells

Table 1.--Geologic units in Washoe Valley--continued

	Geologic age		Geologic unit	Thickness (feet)	General character and extent	Water-bearing properties
TERTIARY	--	Consolidated rocks	Volcanic rocks	--	Lava flows and intrusions, chiefly andesite and basalt. Locally overlie principally granitic rocks in the Carson and Virginia Ranges	Not tapped by wells. Virtually no interstitial permeability. Probably would yield small amounts of water to wells where saturated
CRETACEOUS	--	Consolidated rocks	Granitic rocks	--	Mostly light gray granodiorite; includes small areas of quartz monzonite, aplite, and pegmatite. Dominant rock in the Carson Range; less abundant in the Virginia Range	Not tapped by wells; supply water to springs marginal to the valley fill. Probably would not yield much water to wells
TRIASSIC(?)	--	Consolidated rocks	Metamorphic rocks	--	Mostly argillite, slate, hornfels, and schists; northeast of Washoe Valley and metamorphosed basalts and andesites east of Washoe Lake	Not tapped by wells; transmit small amounts of water along bedding planes and in fracture zones. Probably would yield small amounts of water to wells

ore from Virginia City. Washoe City grew rapidly, becoming the county seat of newly-organized Washoe County. A mile-long bridge (east of Ophir Mill site in sec. 35 and 36, T. 17 N., R. 19 E.) was constructed for wagons carrying ore from the Ophir Mine on the Comstock to Ophir Mill and lumber on the return trip.

In 1862 Sandy and Eilley Bowers built Bowers Mansion, which is now a popular Washoe County park; their wealth was from mining on the Comstock. By 1865, Washoe City had three mills and a population of 2,000. However, by 1869 the community was in economic decline; the county seat was moved to Reno in 1870. In 1872 the Virginia and Truckee Railroad was completed through Washoe Valley, near the present alignment of U. S. Highway 395.

As Virginia City grew, the local water supply became inadequate. As a result, work was started in 1872 on a diversion system to carry water from the Carson Range to the Comstock. Water was diverted from Hobart Creek (SW$\frac{1}{4}$, sec. 32, T. 16 N., R. 19 E.) through a 21-mile long flume and pipeline system. In 1875 the system was extended to the west side of the Carson Range by a 4,000-foot tunnel (sec. 25, T. 16 N., R. 18 E. and sec. 30, T. 16 N., R. 19 E.); Hobart Reservoir (NE$\frac{1}{4}$, sec. 5, T. 15 N., R. 19 E.) was also built. Water was diverted from Marlette Lake (sec. 12, T. 15 N., R. 18 E.) by flume to the tunnel and to the reservoir. Another flume, 8 miles long, was constructed northward from the west end of the tunnel to divert creeks on the western slope of the range. The third pipe was added to the flume and pipe line system in 1887. These pipes extended from their inlet in the NW$\frac{1}{4}$, sec. 3, T. 15 N., R. 19 E., across Lake View Summit, to their outlet in the SW$\frac{1}{4}$, sec. 15. T. 16 N., R. 20 E. The water system is still in use and is owned by the State of Nevada. The tunnel has caved in so the principal diversions are now made from Marlette Lake to Hobart Reservoir by a pipeline (not shown on plate 1). All flumes have long since been replaced by pipelines.

Climate

The climate of Washoe Valley is characterized by long winters with moderate amounts of snow on the valley floor and large accumulations in the mountains. The summers are short with warm daytime temperatures and cool nights. Little precipitation occurs in the summer except for occasional thunderstorms.

Temperature data have been recorded at four stations near Washoe Valley; growing-season data are summarized in table 2 for these stations. The topography of the area favors the flow of heavy cold air toward the lower parts of the valley during periods of little wind movement, minimizing the normal effect of altitude on temperature. The highest of these stations, Marlette Lake, and the lowest, Carson City (fig. 1), have nearly the same average length of growing season, both near 140 days for a 28°F killing frost. On the floor of Washoe Valley, the length of the 28°F growing season is estimated to average about 120 days.

Table 2.--Length of growing season between killing frosts

[Summarized from published records of the U.S. Weather Bureau]

Station 1/	Altitude (feet)	Period of record (years)	Minimum recorded (days)			Maximum recorded (days)			Average (days)		
			32°F	28°F	24°F	32°F	28°F	24°F	32°F	28°F	24°F
Mount Rose Highway Station	7,360	1960-62	63	118	144	120	122	178	92	121	157
Carson City	4,675	1924-64	62	89	141	167	192	223	122	142	177
Marlette Lake	8,000	1931-44, 1949-51	85	90	114	141	172	181	111	137	156
Virginia City	6,002	1951-60	102	140	176	152	198	237	135	164	203

1. None of these stations is in Washoe Valley.

VALLEY-FILL RESERVOIR

Extent and Boundaries

Older and younger alluvium of the valley, as shown on plate 1, form the valley-fill reservoir, which is the principal source of ground water in Washoe Valley. The valley-fill reservoir is about 8 miles long, 3 to 5 miles wide, and underlies an area of about 18,000 acres. The reservoir in most places probably is at least 500 feet thick. Although bedrock reportedly has been encountered in wells at shallower depths, these wells were near the bedrock-alluvium contact.

External hydraulic boundaries are formed by the consolidated rocks (table 1 and pl. 1) which underlie and form the sides of the valley-fill reservoir. The lateral boundaries are leaky to varying degrees. The volcanic rocks, particularly the basalt and scoria in the Virginia Range, may contribute moderate amounts of the recharge from the Virginia Range to the valley-fill reservoir by subsurface flow. Steamboat Creek, which drains Little Washoe Lake, flows through a narrow steep-walled canyon that is cut to a depth of about 150 feet into volcanic rocks. At creek level, the canyon is generally less than 50 feet wide. Northward leakage through the volcanic rocks to Pleasant Valley probably is minor.

Recharge boundaries are formed by the live-stream segments of all streams where they flow across the valley floor to Washoe and Little Washoe Lakes and by the lakes themselves. Flow in the streams usually crosses the valley floor in the winter and spring. Most streams become dry in the summer and fall, largely because of diversions along the mountain front.

The principal internal hydraulic boundaries are the faults passing northward on the west side of Washoe Lake and at Washoe City, as shown on plate 1. The extent to which these barriers impede ground-water flow probably will not be determined until substantial ground-water development occurs.

Transmissibility and Storage Coefficients

The coefficient of transmissibility is a measure of the resistance to ground-water flow in an aquifer or reservoir system. The coefficient of storage in a heterogeneous valley-fill reservoir is a measure of the amount of downward drainage of water through sediments as water levels are drawn down by pumping. When utilized together in certain types of mathematical models or simulated in electrical models, the two coefficients define the hydraulic diffusivity of the system; or in simpler terms, can be used to describe the distribution and amount of water-level decline that would result under certain conditions of pumping and boundary conditions.

Two widely separated large-diameter wells have specific capacities of 36 and 73 gpm per foot (gallons per minute per foot of drawdown), suggesting transmissibilities of 50,000 to 150,000 gpd (gallons per day) per foot (approximated by use of the Thiem (1906) formula). These wells, 16/19-3cd and 16/20-17ac, are 225 and 475 feet deep, respectively. Other large-diameter wells have been disappointing producers, some never being utilized. Many domestic wells reportedly have small yields too (table 10). Some reasons for the wide range in well yields may be: (1) an equally wide range in the water-yielding properties of the valley fill from one place to another, which could be attributed to the distribution of disintegrated granitic debris; (2) most water production seems to be derived from sand lenses, which require special techniques in well construction and development to obtain an acceptable well; and (3) most wells are less than 200 feet deep, suggesting that a considerable thickness of valley fill must be penetrated to obtain large well yields.

The coefficient of storage, which over the long term may be nearly equal to the specific yield of the valley fill, is computed from well logs to be about 0.15, or about equivalent to a specific yield of 15 percent. Beds composing the valley fill are lenticular. Silt lenses act as semiconfining beds. As a result, flowing wells are obtained over much of the area west of Washoe Lake. However, under long-term pumping, all these deposits would drain slowly and artesian head, sufficient to cause flow, would gradually be lost.

Ground Water in Storage

Recoverable ground water in storage is that part of the water moving through the valley-fill reservoir that will drain by gravity in response to pumping. Under native conditions the amount of stored ground water remains nearly constant. The long-term balance between recharge and discharge, which controls changes of ground water in storage, probably has been disturbed only slightly by the diversions of surface and ground water.

Recoverable ground water in storage is the product of the specific yield, the area of the ground-water reservoir, and the selected saturated thickness of the alluvium. Specific yield of a rock or soil is the ratio of (1) the volume of water which the ground-water reservoir will yield by gravity to (2) the reservoir volume. This ratio is stated as a percentage. In Washoe Valley, the average specific yield of the alluvium (the ground-water reservoir) probably is about 15 percent. The selected thickness is the uppermost 100 feet of saturated alluvium.

Using the surface area of the valley-fill reservoir, the estimated recoverable ground water in storage is the area of about 18,000 acres times the selected depth of 100 feet times the drainable volume of 15 percent, which is about 270,000 acre-feet. Figure 2 shows that nearly all this water is available for development at shallow depths, especially on the west side of Washoe Lake.

Surface Water in Storage

Water stored in Washoe and Little Washoe Lakes can be considered rejected ground-water recharge and impounded runoff from flash floods. If the valley fill were not fully or nearly fully saturated, much of the water in the lakes and streams would infiltrate.

The area and volume of the two lakes fluctuate, depending to a great extent on the amount of precipitation and runoff in the basin. In the spring of 1966, following several years of above-average precipitation, the maximum lake size of about 5,600 acres was reached. This supposedly is the maximum area that would be expected under native conditions, because a small dam on Steamboat Creek at the north end of the valley (pl. 1) is designed not to raise the maximum lake-storage level. The

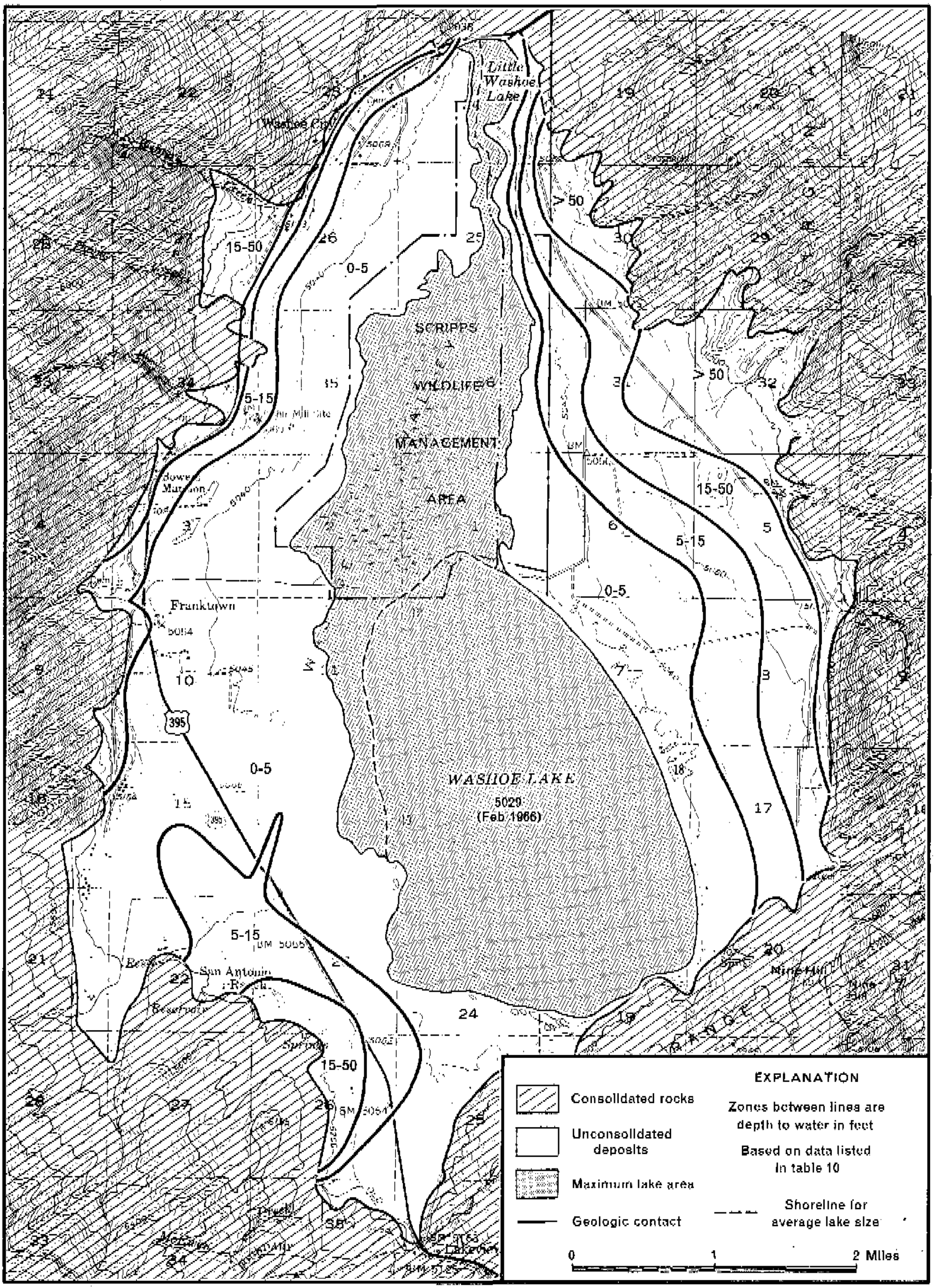

Figure 2.—Generalized depth to ground-water, October 1965

spillway of the dam is at an altitude of 5,029 feet. The bottom of the channel of Steamboat Creek just above the dam is at an altitude of about 5,022 feet. Outflow is regulated through openings in the dam below the spillway. Under existing conditions, the lakes at their maximum size as controlled by a spillway altitude of 5,029 feet, have a combined volume of about 35,000 acre-feet, as shown in figure 3 and a maximum depth of about 11 feet. Plate 1 shows the lakes at maximum size and as a single body of water because the swamp which separates the lakes into two bodies of water at lower stages is submerged. The dashed line shows the approximate average extent of the lakes.

Local residents report that both Washoe and Little Washoe Lakes were dry in 1932 and 1934, and remained very small until 1938. Other low lake levels probably occurred in 1915, 1950, and 1961, following droughts. Washoe and Little Washoe Lakes in 1950 covered about 3,400 and 70 acres, respectively. Taking into consideration irrigation withdrawals, the average size of Washoe Lake is estimated to be about 4,000 acres with a volume of about 20,000 acre-feet; and for Little Washoe Lake, an area of about 100 acres and a volume of about 400 acre-feet.

Figure 3 shows recorded water-surface altitudes and the approximate amount of stored water in Washoe and Little Washoe Lakes for the period 1963-66. During 1965 and early 1966, the water-surface altitudes of Washoe and Little Washoe Lakes were nearly the same, because the intervening swamp was inundated. During 1963 and 1964 the lakes were lower and more isolated hydrologically. Effects of regulated outflow to Steamboat Creek are indicated in the late summer by the rapid and more extensive lowering of Little Washoe Lake than Washoe Lake.

During the short period of record shown on figure 3, the volume of stored water in the lakes has ranged from about 7,000 acre-feet in November 1964 to about 35,000 acre-feet in January and February 1966.

Ground-Water Flow

Ground-water flow in the valley-fill reservoir is from the areas of recharge toward areas of discharge. The configuration of the ground-water surface is shown by the water-level contours on figure 4. Direction of flow is at right angles to the contours and from higher to lower levels.

The water-level contours show that ground water is moving generally away from the foot of the Carson and Virginia Ranges, where streams lose water by infiltration to the valley-fill reservoir, toward Washoe Lake. The steep gradients, as indicated locally by close spacing of contours on the southwest side of the valley, probably are caused by a combination of moderately large recharge and low transmissibility. Several irrigation wells in this area have low yields and large drawdowns.

The Equilibrium Condition

Water-level contours in figure 3 presumably have changed little from natural conditions as a result of man's activities in Washoe Valley. Man has diverted the flow principally from Franktown and Ophir Creeks for irrigation and Hobart Creek for public-supply water. Spreading water on the fields has resulted locally in slightly higher heads in the reservoir system than originally existed. On the other hand, pumping has been small and probably has depleted the system only slightly. Accordingly, the valley-fill reservoir is functioning under near natural conditions, and the system over the long term is in a near equilibrium condition.

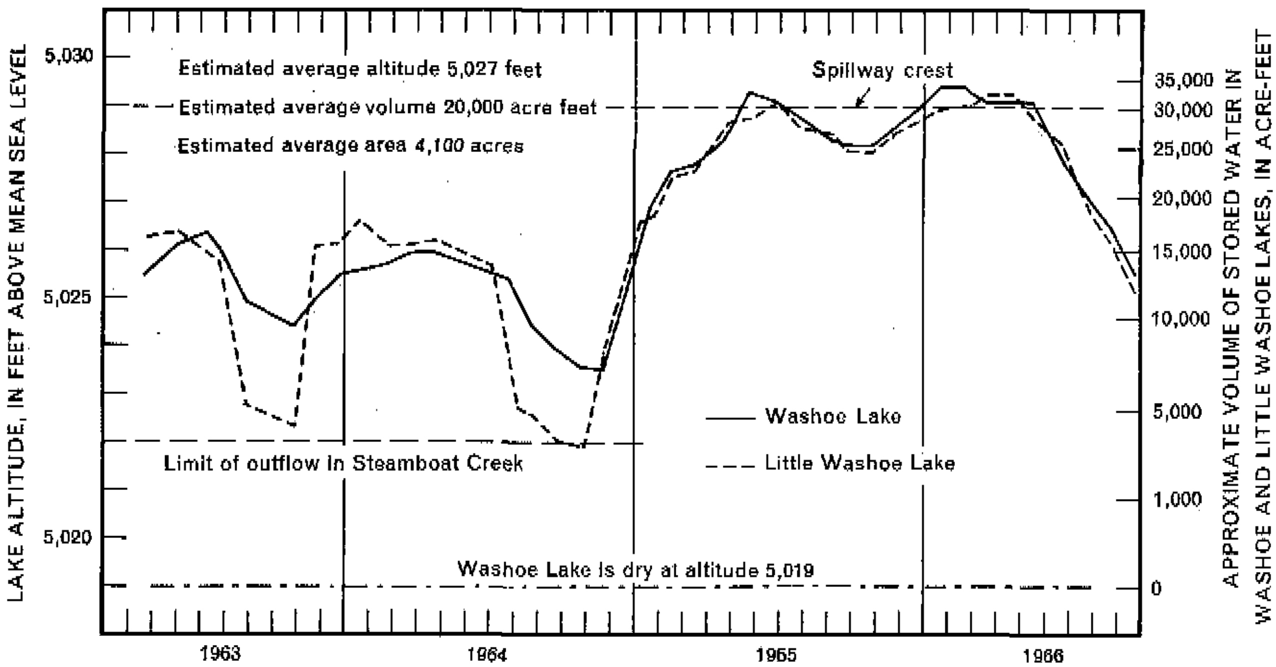

Figure 3.—Water-surface altitude and volume of Washoe and Little Washoe Lakes

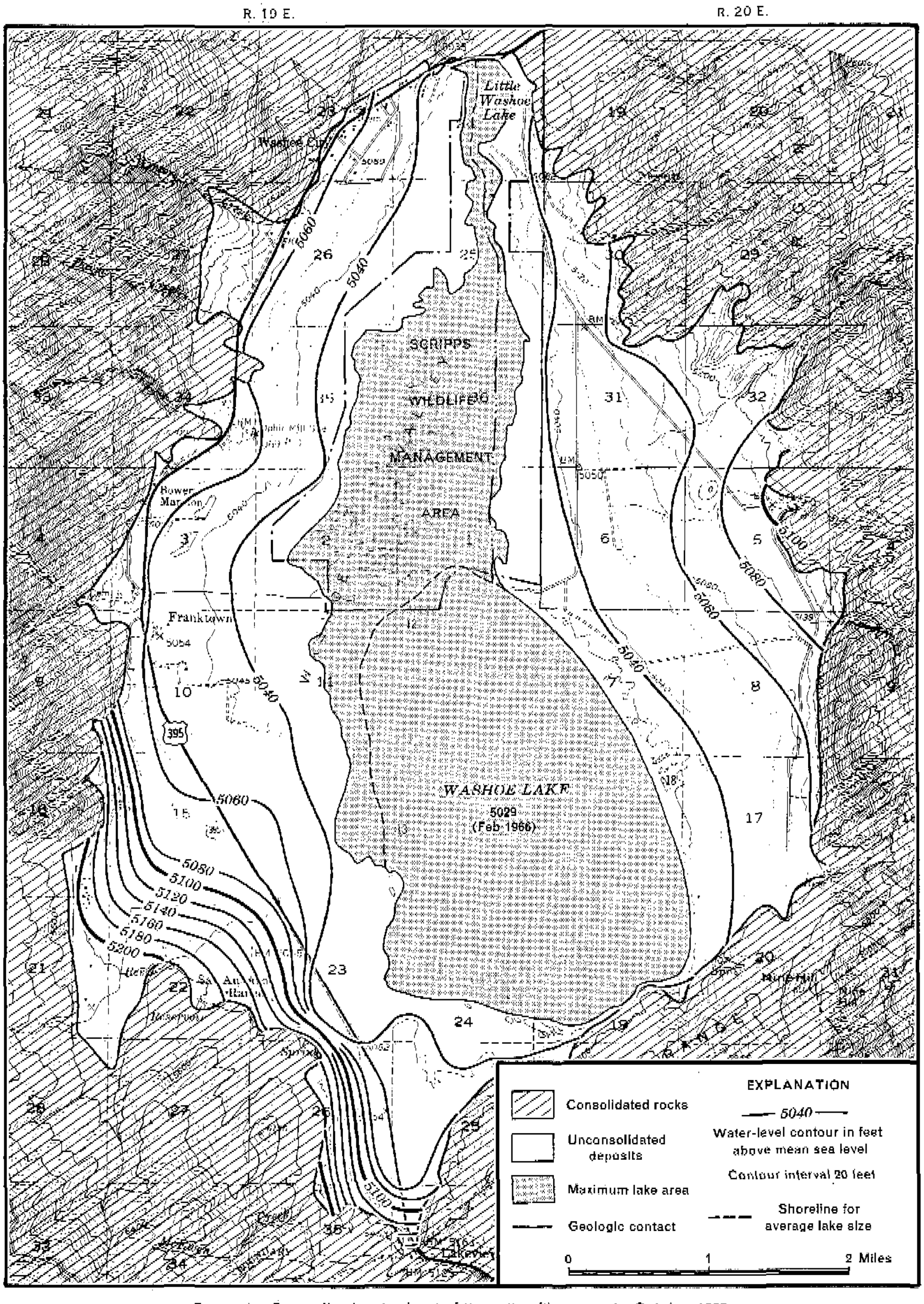

Figure 4.—Generalized water-level of the valley-fill reservoir, October 1965

INFLOW TO THE VALLEY-FILL RESERVOIR

Inflow to the valley-fill reservoir is estimated by reconnasissance techniques developed by the Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. The components of inflow are summarized in table 7, which shows that the estimated total average annual inflow is 33,000 acre-feet.

Precipitation

Precipitation falling as rain or snow is the principal source of water entering the hydrologic system of Washoe Valley. Air masses moving into the area from the west generally lose much of their moisture in the Sierra Nevada. As a result the Carson Range of the Sierra Nevada is humid and the floor of Washoe Valley and the Virginia Range, being in the rain shadow of the Sierra Nevada, are subarid to arid. Most precipitation falls in the winter and early spring as snow. The largest amounts fall at the higher altitudes. During late spring and summer precipitation is light at all altitudes and usually is in the form of rain during thundershowers. (fig. 5).

The precipitation pattern in Nevada is related principally to topography (Hardman, 1936). Stations at the highest altitudes generally receive more precipitation than those at lower altitudes. However, as shown in figure 6, this general relation may be considerably modified by local conditions. Virginia City is assumed to receive less precipitation than typical for its altitude and location because of the rain shadow caused by Mt. Davidson which rises on the west side of the community.

On table 3 precipitation is summarized by altitude zones for the Carson Range, Virginia Range, and the floor of Washoe Valley. The estimates are based on the curves shown in figure 6. The estimated average annual precipitation on the drainage basin is 87,000 acre-feet.

Precipitation that falls onto Washoe and Little Washoe Lakes is a direct contribution to surface-water storage. The estimated average annual precipitation on the lakes is about one foot. As determined earlier, the estimated average lake area is about 4,000 acres. Therefore, the direct contribution to the lake by precipitation averages about 4,000 acre-feet per year.

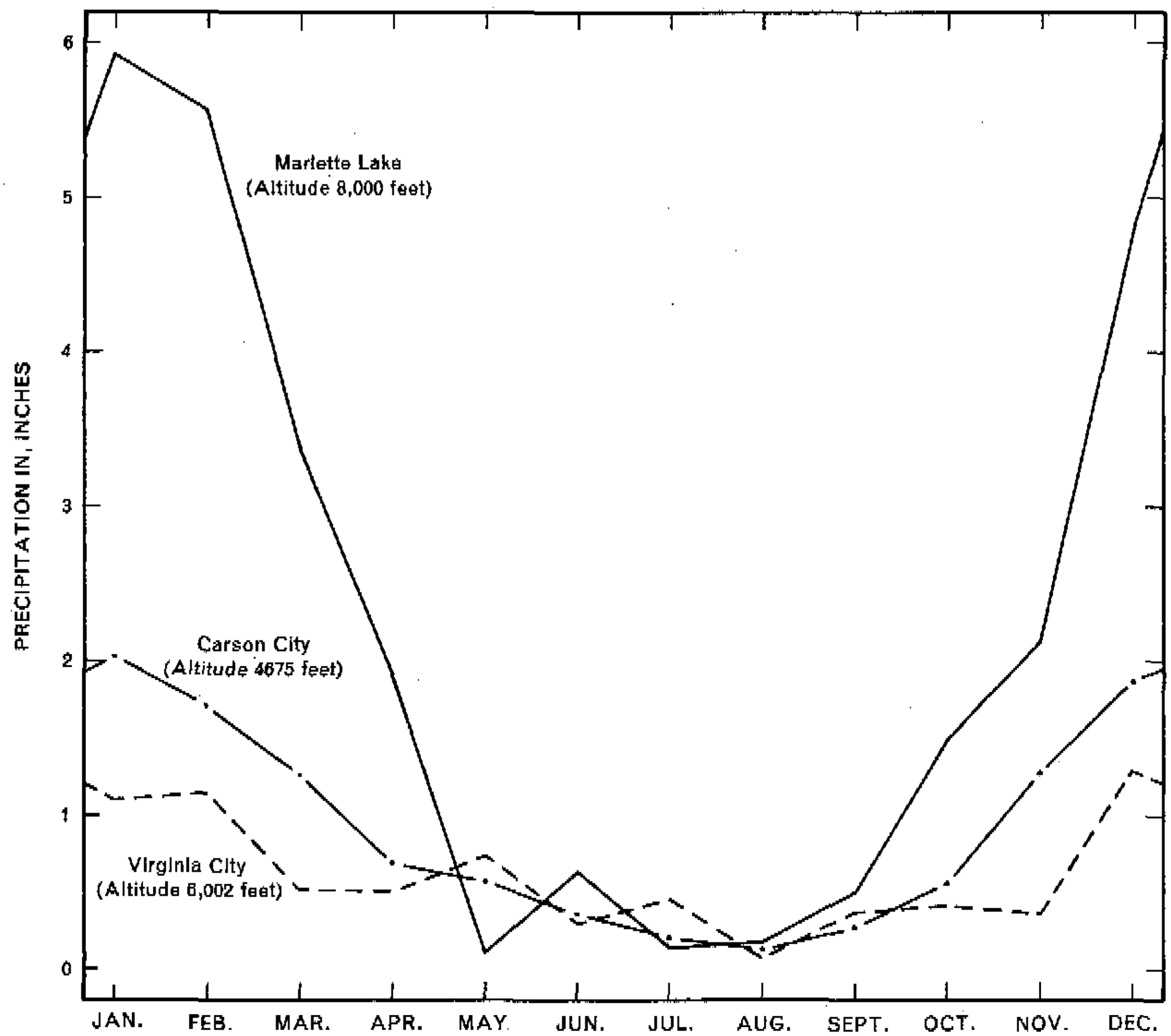

Figure 5.—Average monthly precipitation at Marlette Lake, Carson City, and Virginia City

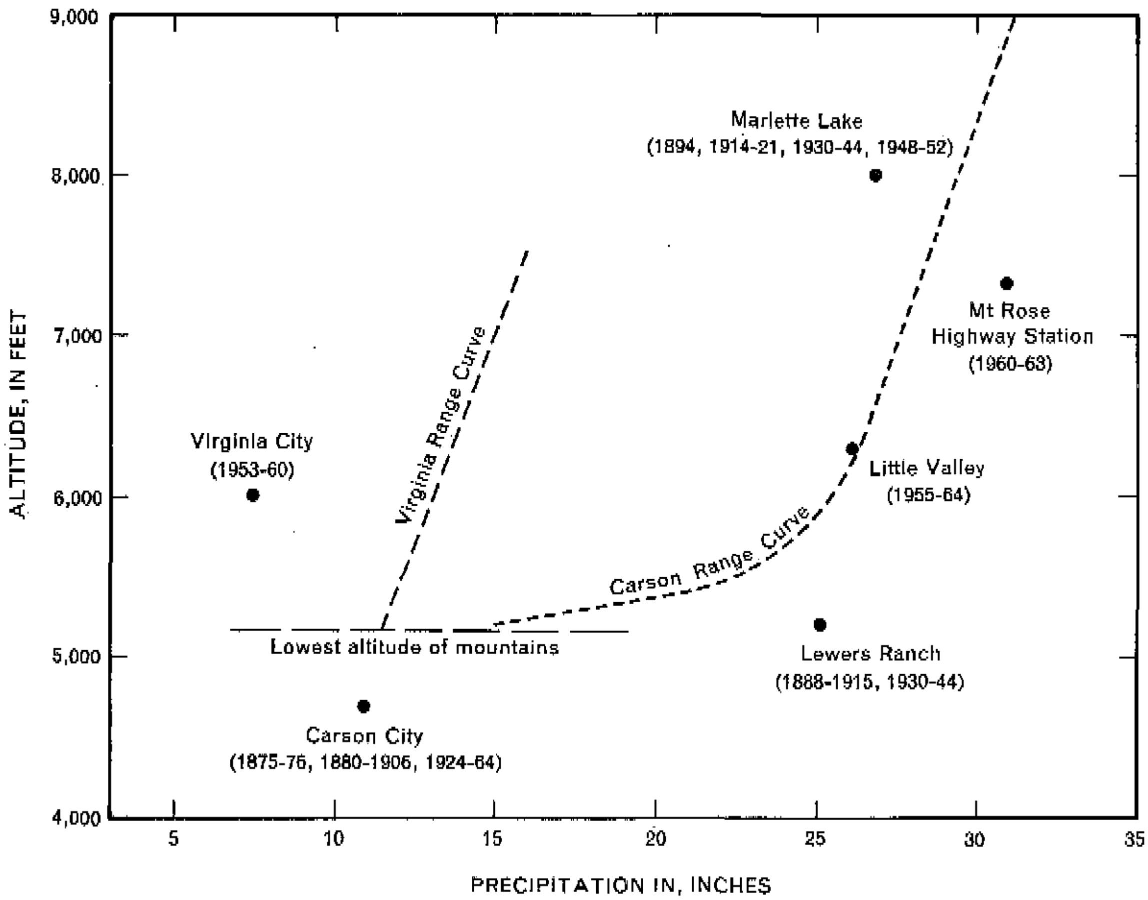

Figure 6.—Relation of altitude to precipitation

Ground-Water Recharge

Little precipitation directly infiltrates into the ground-water reservoir on the valley floor where precipitation is small. Greater precipitation in the mountains provides most of the recharge. Water that reaches the ground-water reservoir does so by seepage loss from streams on the valley floor and by underflow from the consolidated rocks. Much precipitation is evaporated before and after infiltration and some adds to soil moisture.

A method described by Eakin and others (1951, p. 79-81) is used to estimate the potential recharge in this report. The method assumes that a percentage of the average annual precipitation may recharge the ground-water reservoir. Because of the large runoff from the Carson Range, the valley-fill reservoir in many places is saturated to or very near the land surface, especially near where streams cross the valley floor. Because of this, room for stream recharge is limited, not by the small amount of precipitation as is the case in most of Nevada, but by limited local storage space in the valley-fill reservoir. As a result, most of the computed ground-water recharge is rejected at the land surface; some may enter ground-water storage for a very short period of time. Although a small part of this rejected water is utilized for irrigation, most flows in the creeks to Washoe and Little Washoe Lakes as runoff.

Table 3 shows the values used to estimate precipitation and potential ground-water recharge in Washoe Valley. The estimated potential recharge of 15,000 acre-feet per year is about 17 percent of the estimated total precipitation. This percentage is more than three times the amount usually found by this method for the desert basins of Nevada, and is accounted for by the unusually heavy precipitation in the Carson Range--one of the wettest areas in the State. As can be computed from the table, nearly 90 percent of the estimated potential recharge is from the Carson Range.

Table 3.--Estimated average annual precipitation and potential annual ground-water recharge

Precipitation zones (altitude in feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average (feet)	Estimated annual precipitation: Average (acre-feet)	Estimated potential recharge from precipitation: Percentage of precipitation	Estimated potential recharge from precipitation: Acre-feet per year
		CARSON RANGE OF THE SIERRA NEVADA				
9,000 - 9,700	800	more than 32	2.8	2,200		
8,000 - 9,000	4,930	30 - 32	2.6	13,000		
7,000 - 8,000	5,320	28 - 30	2.4	13,000	25	11,000
6,000 - 7,000	7,750	25 - 28	2.2	17,000		
5,200 - 6,000	5,100	15 - 25	1.7	8,700	20	1,700
Subtotal (rounded)	23,900			54,000		13,000
		VIRGINIA RANGE				
7,000 - 7,500	710	15 - 20	1.5	1,100	15	160
6,000 - 7,000	3,700	12 - 15	1.1	12,000	7	840
5,200 - 6,000	7,140					
Subtotal (rounded)	11,550			13,000		1,000
		VALLEY FLOOR				
5,028 - 5,200	a14,200	12 - 15	1.1	16,000	7	1,100
Total (rounded)	49,650			87,000		15,000

a. Excludes average area of Washoe and Little Washoe Lakes (4,000 acres). Precipitation on lake area directly enters surface-water storage.

Runoff

by D. O. Moore and J. E. Parkes

Most runoff in Washoe Valley is in Franktown and Ophir Creeks, both of which drain the eastern slope of the Carson Range. A gaging station was maintained on Franktown Creek during the years 1948-55, and its location is shown on plate 1. The average annual discharge for the period was 10,060 acre-feet with water being both diverted to and from the stream above the gage (U.S. Geol. Survey, 1963). In 1964 periodic measurements of streamflow were made on several creeks in the valley. The measurements are shown in table 4; the measuring sites on plate 1.

Surface-water inflow to the valley floor has been estimated using a method described by Eakin, Moore, and Everett (1965) and Riggs and Moore (1965). The record for Franktown Creek was used as a guide for correlating the flow in five of the larger ungaged streams listed in table 4. An altitude-runoff relation developed during the study of Statewide runoff (Lamke and Moore, 1965) also was used in this study. Table 5 shows the estimated surface-water inflow to the valley floor.

Table 4.--Streamflow measurements, 1964[1]

[Streamflow in cubic feet per second]

Stream	May 11, 12	June 18, 19	July 23	Aug. 24	Sept. 21, 22	Nov. 23
McClellan Peak tributary	0	0	0	0	--	0
Jumbo Creek	E 0.12	.15	.05	.02	E .075	.15
Virginia Range tributary (17/20-31d)	0	0	0	0	0	0
Virginia Range tributary (17/20-30b)	0	0	0	0	0	--
Steamboat Creek	0	0	0	0	0	0
Unnamed creek at Washoe City	E .03	1.00	.06	0	.02	.12
Winters Creek	1.28	.61	.28	.33	.24	.49
Davis Creek	.79	.36	.05	.005	.03	.39
Ophir Creek	15.0	13.1	4.42	2.27	3.02	4.26
Franktown Creek	20.6	5.04	1.69	1.27	1.56	2.80
Musgrove Canyon Creek	1.00	.41	.06	.04	.05	.43
Big Canyon Creek	1.00	.054	--	E .42	.54	.31
McEwen Creek	.68	.39	.08	0	.06	.26

1. Flow values preceded by an E were estimated.

Table 5.--Estimated average annual runoff

Areas	Acres	Percentage of runoff area	Estimated runoff: Acre-feet per year	Estimated runoff: Percent of total runoff
Carson Range	23,900	48	20,000	87
Virginia Range	11,550	23	1,500	7
Valley floor	a14,200	29	a 1,300	6
Total (rounded)	49,650	100	23,000	100

a. Precipitation directly onto lake area is assumed to go entirely to lake storage and is not included.

Importation of Water

Surface water is diverted into the valley from two areas of the Carson Range, as shown on plate 1: the North Creek headwater area (a 2-square-mile area northwest of Incline Lake) and the Browns Creek-Galena Creek drainage area (which adjoins Washoe Valley on the north). Diversions are made from North Creek to Ophir Creek and from Galena and Browns Creeks to Joy Lake and to Little Washoe Lake by ditches. The annual diversions have not been measured, but for the purposes of this report the average annual diversion from North Creek, as based on available information from water users, and George Hardman (oral communication), of the Nevada Department of Conservation and Natural Resources may be on the order of 2,000 acre-feet; diversion from Galena and Browns Creeks also may be on the order of 2,000 acre-feet per year. Therefore, the total estimated average annual importation of surface water probably is about 4,000 acre-feet. No ground water is imported into the basin.

Underflow

In Washoe Valley, no means are available to measure directly the amount of ground-water underflow moving from the consolidated rocks to the valley-fill reservoir. The fracture and joint characteristics of the consolidated rocks underlying the mountains suggest, that small amounts of underflow do enter the valley-fill. Worts and Malmberg (1967) estimated an underflow of about 1,000 acre-feet per year for Eagle Valley. Because of the similarities in rock types and length of the mountain fronts, the average annual underflow to the valley-fill reservoir is assumed to be on the same order of magnitude, or about 1,000 acre-feet.

OUTFLOW FROM THE VALLEY-FILL RESERVOIR

The major components of outflow are evaporation from Washoe and Little Washoe Lakes, evapotranspiration and stream diversions for irrigation. The estimated average annual outflow is about 31,000 acre-feet per year (table 7). Figure 7 is a land-status map showing the maximum and average lake areas, phreatophyte areas, and irrigated and unirrigated lands of the valley floor.

Surface Water

Evaporation from Lakes

Evaporation from Washoe and Little Washoe Lakes is the largest element of outflow in Washoe Valley. The estimate is based on rates determined by Kohler and others (1959, pl. 2) for the United States. According to their map, an annual average of about 3.5 feet of water evaporates from free-water surfaces in Washoe Valley. The volume of total evaporation fluctuates principally because the lake size fluctuates. As estimated in an earlier section, the average lake area is about 4,000 acres. Therefore, the estimated average annual evaporation is about 14,000 acre-feet.

Outflow from the Valley

In 1863 or 1864 a small wooden dam was constructed on Steamboat Creek about 50 yards north of U. S. Highway 395, as shown on plate 1. In 1889 it was replaced by a box-like rock and concrete structure. The dam is used to regulate the flow from Little Washoe Lake to the creek. However, during years of low lake level, when lake levels are below an altitude of 5,022 feet, water can not be diverted by gravity from Little Washoe Lake. Downstream water users report that during the late part of the irrigation season for a period of about 5 weeks, an average flow of about 10 cfs is allowed to pass the dam for irrigation in Pleasant Valley and Truckee Meadows. The 5-week flow reportedly averages about 600 acre-feet.

During periods of high lake level, as the spring of 1966 shown in figure 3, water flowed over the spillway. This unregulated overflow has not been measured, but during years of high lake levels, it probably ranges up to a few thousand acre-feet. During most years there is no overflow. The estimated average annual overflow is about 300 to 400 acre-feet. Therefore, the estimated total average annual surface-water outflow from the valley is on the order of 1,000 acre-feet per year.

Diversions for Irrigation

In Washoe Valley, about 4,200 acres are irrigated; of this amount, about 600 acres is irrigated by water from Washoe Lake, the remainder, about 3,600 acres, by diversions from creeks and supplemental irrigation-well pumpage.

Diversions from lakes.--As previously described, controlled releases from Little Washoe Lake through Steamboat Creek are utilized for irrigation downstream from Washoe Valley. In addition, water is pumped from Washoe Lake to irrigate pasture and hay land. The water is pumped from a canal which has been cut southward from the south shore of Washoe Lake in the SW$\frac{1}{4}$ sec. 19, T. 16 N., R. 70 E., as shown on plate 1. A pump lifts water from the canal to a ditch which carries water to the

Table 6.--Estimated average annual evapotranspiration of ground water

[Phreatophyte areas shown in figure 7]

Phreatophyte	Location	Area (acres)	Depth to water (feet)	Evapotranspiration[1] Acre-feet per acre	Evapotranspiration[1] Acre-feet (rounded)
Chiefly swamp grass and other vegetation	Area inundated during maximum lake size and excluding area of average lake size	1,500	0-2	2.5	3,800
Chiefly a mixture of meadow-grass, rabbitbrush, and big sage	Marginal to eastern lake shore and area adjoining Washoe City on east and southeast as shown in figure 7	1,600	2-10	1.0	1,600
Chiefly meadowgrass	Areas southeast of Franktown and west of Washoe Lake	1,300	2-5	1.0	1,300
Various hay crops	Most of the irrigated land as shown in figure 7	3,500	2-5	.5	a 1,800
Total (rounded)					8,500

1. Includes nongrowing season losses in very shallow ground-water areas.

a. Natural subirrigation of crop lands by ground water in same areas where surface-water diversions and pumpage are used to irrigate crops. Usually occurs in late spring and early summer when water levels are shallow.

southwest where it is used to irrigate about 600 acres in parts of secs. 19, 24, 25, and 30. The estimated net pumpage is about 1,000 acre-feet per year.

Diversions from creeks.--Diversions are made from McEwen, Big Canyon, Musgrove, Franktown, Ophir, Davis, Winters, and Jumbo Creeks. The most complex diversions are on Ophir Creek. From Ophir Creek, flow is diverted southward to Franktown Creek at Upper Price Lake. About 2 miles farther down Ophir Creek, one of two ditches extends northeast to Davis Creek, the other carries water to irrigate land in secs. 34 and 35, T. 17 N., R. 19 E. One-eighth mile farther downstream a ditch carries water to irrigate land in secs. 2 and 3, T. 16 N., R. 19 E. A $2\frac{1}{2}$-inch diameter pipe also extends from the latter ditch to a nearby house for domestic use. From Ophir Creek, about 100 feet east of U. S. Highway 395, water is diverted to land in parts of the above-mentioned sections by two ditches. About half a mile east of U. S. Highway 395 the last diversion on Ophir Creek is to two ditches for flood irrigation in parts of $N\frac{1}{2}$, sec. 2, T. 16 N., R. 19 E. and $S\frac{1}{2}$, sec. 35, T. 17 N., R. 19 E. Only the larger diversion ditches are shown on plate 1.

Streamflow, supplemented by irrigation-well pumping, is used to irrigate about 3,600 acres of cropland on the valley floor, as shown by figure 7. During the irrigation season, May through September, about 1.5 acre-feet per acre is estimated to be consumed by the crops. This is a net figure and excludes the amount of water used from precipitation and by subirrigation of ground water (table 6). The average annual consumption from diverted streamflow is estimated to be about 5,400 acre-feet minus the well pumpage (p. 20), or about 4,600 acre-feet. Much more water than this is diverted, but most of it seeps to the water table or runs off the fields and reenters the creeks; in either case it is not being consumed by the crops.

Water Export

Export of water by the State-owned Marlette Water System from Hobart Creek in the headwater area of Franktown Creek and therefore from Washoe Valley, (pl. 1) for public-supply purposes was about 600 acre-feet in 1964 and 575 acre-feet in 1965. Of these totals, about 425 acre-feet went to Eagle Valley; the remainder to Virginia City (Worts and Malmberg, 1967).

Ground Water

Evapotranspiration

In shallow ground-water areas, ground water is discharged by evaporation from the soil and water use by plants that root to the water table. Plants that tap the ground-water reservoir are called phreatophytes. In Washoe Valley, figure 7 shows that phreatophytes grow along the eastern shore of Washoe and Little Washoe Lakes and on most of the valley floor west of the lakes. The principal phreatophytes are swamp vegetation, meadowgrass, rabbitbrush, and crops during period when they are not irrigated and where their roots reach the water table. The swamp area is that area shown in figure 7 as inundated during maximum lake stage but adjacent to the lake area at average or low stages. Table 6 summarizes the estimated evapotranspiration of ground water from these areas. The rates used are based on work done in other areas by Lee (1912), White (1932), and Young and Blaney (1942).

Irrigation by Wells

As indicated in the surface-water irrigation section, wells are pumped to supplement diversions from creeks when flow is inadequate. This usually occurs in the late summer. In 1965, five large-diameter irrigation wells (table 10) were pumped, four of the wells are on the west side of Washoe Lake and one well (16/20-17ac) is on the southeast side of the lake. Well inventory indicates that in 1964 and 1965, the gross pumpage averaged about 1,200 acre-feet per year, and supplied supplemental water to about 1,800 acres. Of this amount, it is assumed that about one-third percolated back to the water table or flowed from the fields and returned to ditches. The remainder, about 800 acre-feet per year, was consumed by crops.

Domestic and Stock Pumpage

Ground water is pumped from wells for domestic and stock-watering use. No consolidated water systems operate in the valley. For a rural population of possibly 1,000 plus 500 to 1,000 head of dairy and range cattle the total water pumped probably did not exceed 300 acre-feet in 1965. Some of the water used to irrigate lawns or flows to septic systems seeps downward and recharges the valley-fill reservoir. Therefore, the estimated net pumping draft on the valley-fill reservoir to meet these needs was about 200 acre-feet.

Springs

Many small springs are along the margin of the mountains, as shown on plate 1, and issue from consolidated rocks. They support small nearby areas of phreatophytes, such as willow, cottonwood, and rabbitbrush, are diverted for irrigation, or seep back to the water table. The largest spring probably is at Bowers Mansion (16/19-3ba, pl. 1); it reportedly flows about 75 gpm of water at 128°F. Fish Hatchery Spring (16/19-27a) has a reported flow of about 50 gpm; all other springs are smaller. The estimated combined flow of the springs shown on plate 1 is 300 acre-feet per year. Because some of their flow seeps back to the water table, their net discharge is estimated to be about 200 acre-feet per year.

Additional smaller springs, such as 16/19-23dc and 16/19-26ab, are along the foot of the Carson Range of the Sierra Nevada, but their presence is masked by the generally wet conditions caused by high runoff. Because discharge from these smaller springs is utilized in irrigation and consumed by phreatophytes the use is included in the discharge by these means.

Subsurface Outflow

Subsurface outflow to Pleasant Valley through the few feet of alluvium in the canyon of Steamboat Creek is minor. Because no springs were found issuing from the consolidated rocks in Pleasant Valley on the north side of Washoe Hill, it is assumed that subsurface flow through them also is minor.

Eagle Valley to the south is about 400 feet lower than Washoe Valley. Although the net head potential for southward outflow through the Virginia Range exists, the water-level contours on figure 4 show northward movement of ground water rather than any southward flow. Moreover, the granitic rocks separating the two valleys (about 1 mile at the narrowest point at Lakeview Summit) greatly reduces the possibility of any intervalley flow.

WATER BUDGET FOR THE VALLEY-FILL RESERVOIR

Over the long term and for native conditions inflow to and outflow from the valley are equal. Accordingly, a water budget for native conditions expresses the quantity of water flow in a hydrologic system under equilibrium conditions. The water budget generally is designed to bring together and compare the estimates of inflow and outflow to determine the magnitude of error in the estimates. A budget that balances reasonably well lends credence to the individual elements of inflow and outflow, which are depended upon by those concerned with water development and management.

For Washoe Valley equilibrium conditions existed up to the time that man began to develop the area for mining and agriculture. Surface-water diversions from the principal streams began about 100 years ago and have continued to date. Diversions, importation, and exportation of water have modified the natural condition only to a small extent. The principal changes have been the increase in surface-water storage in and evaporation losses from Washoe and Little Washoe Lakes due to the construction of a small dam at their outlet, the importation of water, and pumping of wells which may be decreasing slightly the amount of ground water in storage.

In previous sections, various elements of inflow and outflow have been evaluated for 1965 conditions and are summarized in table 7. Estimates of inflow and outflow lack closure by only 2,000 acre-feet, or 6 percent, which may be caused by: (1) unidentified outflow elements, or (2) errors inherent in assumptions made in estimating various elements of the water budget, or both.

Table 7.--Water budget for 1965 conditions

(Most values estimated, as described in text)

	1965 conditions (acre-feet per year)
ESTIMATED INFLOW:	
Runoff (table 5)	23,000
Precipitation on lakes (P. 12)	4,000
Surface-water import from outside the basin[1] (P. 12)	4,000
Precipitation on valley floor (table 3)	1,100
Ground-water inflow across consolidated rock-valley-fill contact (P. 18)	1,000
Total (1)	33,000
ESTIMATED OUTFLOW:	
Surface water:	
Evaporation from lakes (P. 19)	14,000
Outflow from valley (P. 19)	1,000
Diversions from lakes (P. 19)	1,000
Diversions from creeks (P. 21)	4,600
Export of water[2] (P. 21)	600
Subtotal (rounded)	21,000
Ground water:	
Evapotranspiration (table 6)	8,500
Pumpage for irrigation (P. 22)	800
Domestic and stock pumpage (P. 22)	200
Spring discharge (P. 22)	200
Subsurface outflow (P. 22)	minor
Subtotal (rounded)	10,000
Total (2)	31,000
IMBALANCE, excess of inflow over outflow (1) - (2)	2,000

1. From North, Browns, and Galena Creeks.
2. Through the Marlette Water System.

CHEMICAL QUALITY OF WATER

As part of the present study, 31 water samples were field analyzed to make a general appraisal of the suitability of the water for domestic and agricultural use and to define the general chemical quality of the water. Sampling sites were chosen to be representative of conditions throughout the valley. The field analyses are listed in table 8. An additional five samples of surface water were analyzed for specific conductance only. They are listed in table 9.

Samples were analyzed for the principal anions and cations, except sodium and potassium, which were computed by difference. Boron, fluoride, iron, and nitrate were not determined, although they are important ions affecting the suitability of water for irrigation and domestic use.

For agricultural use the surface and ground waters are medium to low in salinity and alkalinity hazards and generally safe in residual sodium carbonate (RSC), as classified by the Salinity Laboratory (U.S. Department of Agriculture, 1954). These are quality factors related to the suitability of water for irrigation.

Except for unknown concentrations of minor constituents, such as fluoride, iron, and nitrate, the surface and ground waters are mineralogically suitable for domestic use, as defined by the U. S. Public Health Service (1962). Iron is a problem in some wells throughout the valley. Figure 8 shows the distribution of hardness of ground water in the valley. The distribution of ground water by specific conductance is shown in figure 9. Specific conductance is an approximate measure of the dissolved-mineral content of water. The relation may be defined as

$$(\text{Specific conductance}) \times A = \text{Dissolved solids}$$

where specific conductance is measured in micromhos at 25°C and dissolved solids in parts per million (ppm). For Washoe Valley, A probably has a value between 0.55 and 0.75.

If any doubts exist as to the potability of a water source, arrangements for analysis should be made with the Nevada Department of Health.

Table 8.--Field chemical analyses, in parts per million and equivalents per million, of water from selected sources

[Analyses by the U.S. Geological Survey]

Hardness: 0-60 ppm, soft; 61-120 ppm, moderately hard; 121-180 ppm, hard; and over 180 ppm, very hard.

Location	Date of collection	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K) 1/	Bicarbonate (HCO_3)	Carbonate (CO_3)	Chloride (Cl)	Sulfate (SO_4)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Irrigation quality: Salinity hazard	Irrigation quality: Alkalinity hazard	Irrigation quality: RSC	Water type	Rock source
WELLS																		
16/19- 3bc1	10-12-65	75	19	3.3	16	103	0	3.8	6.0	61	0	171	7.8	Low	Low	Safe	Mixed bicarbonate	Granitic rocks
			0.95	0.27	0.70	1.69	0.00	0.11	0.12									
3cd	4-12-66	--	6.1	4.9	29	100	0	2.6	11	35	0	186	7.9	Low	Low	Safe	Sodium bicarbonate	Alluvium
			0.30	0.40	1.24	1.64	0.00	0.07	0.23									
10ba1	10-11-65	62	22	0.7	15	86	1	4.4	12	58	0	161	8.4	Low	Low	Safe	Mixed bicarbonate	Alluvium
			1.10	0.06	0.65	1.41	0.03	0.12	0.25									
10bc	10-11-65	67	12	3.2	25	89	0	4.8	16	43	0	125	8.0	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.60	0.26	1.07	1.46	0.00	0.14	0.33									
11cc	10-11-65	56	9.5	1.8	20	80	0	1.0	6.4	31	0	129	8.0	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.47	0.15	0.85	1.31	0.00	0.03	0.13									
14bc	4- 3-66	--	12	11	2.1	89	0	1.6	4.6	76	3	139	8.1	Low	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
			0.60	0.92	0.09	1.46	0.00	0.05	0.10									
15bd	4-12-66	59	2.6	8.1	16	76	0	5.2	4.9	40	0	121	7.6	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.13	0.67	0.70	1.25	0.00	0.15	0.10									
22bd	10- 7-65	57	16	4.4	15	92	0	4.2	8.8	58	0	157	7.6	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.80	0.36	0.65	1.51	0.00	0.12	0.18									
23cc	10- 7-65	54	17	5.2	18	109	0	4.2	7.2	64	0	178	7.9	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.85	0.43	0.78	1.79	0.00	0.12	0.15									
23dd	10-12-65	59	18	4.6	23	128	0	2.8	5.7	64	0	220	7.8	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.90	0.38	1.01	2.10	0.00	0.08	0.11									
26ab	10- 7-65	53	14	1.0	29	90	0	3.4	22	39	0	149	7.7	Low	Low	Safe	Mixed bicarbonate	Volcanic rocks
			0.70	0.08	1.26	1.48	0.00	0.10	0.46									
26dc	10- 6-65	57	22	5.1	8.7	84	0	8.0	14	76	7	220	7.6	Low	Low	Safe	Calcium bicarbonate	Volcanic rocks
			1.10	0.42	0.38	1.38	0.00	0.23	0.29									
26dd	10- 6-65	55	17	5.5	15	82	0	6.8	20	65	0	184	7.7	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.85	0.45	0.65	1.34	0.00	0.19	0.42									
35db	10- 5-65	53	21	5.7	20	122	0	2.4	16	76	0	193	8.2	Low	Low	Safe	Mixed bicarbonate	Granitic rocks
			1.05	0.47	0.88	2.00	0.00	0.07	0.33									
16/20- 5ac	10-13-65	59	41	8.4	24	164	0	5.6	44	137	3	329	7.9	Medium	Low	Safe	Mixed bicarbonate	Alluvium
			2.05	0.69	1.03	2.69	0.00	0.16	0.92									
5cc	1-13-66	--	38	15	12	162	5	5.0	33	156	15	332	8.5	Medium	Low	Safe	Calcium-magnesium bicarbonate	Alluvium
			1.90	1.22	0.54	2.66	0.17	0.14	0.69									
6bb	1-13-66	54	27	21	28	216	16	1.2	9.1	154	0	366	8.6	Medium	Low	Safe	Mixed bicarbonate	Alluvium
			1.35	1.73	1.21	3.54	0.53	0.03	0.19									
6ca	1-13-66	55	11	16	14	135	0	2.0	11	94	0	231	8.2	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.55	1.33	0.62	2.21	0.00	0.06	0.23									
17/19-23dc	10-12-65	61	31	17	27	230	0	7.2	8.4	148	0	355	8.1	Medium	Low	Safe	Mixed bicarbonate	Alluvium
			1.55	1.41	1.18	3.77	0.00	0.20	0.17									
24bc	10-13-65	57	69	27	50	372	0	25	48	283	0	609	8.2	Medium	Low	Marginal	Mixed bicarbonate	Alluvium
			3.44	2.21	2.16	6.10	0.00	0.71	1.00									
25ad	1-14-66	--	32	14	6.2	144	0	6.8	24	139	21	299	8.7	Medium	Low	Safe	Mixed bicarbonate	Alluvium
			1.60	1.18	0.27	2.36	0.00	0.19	0.50									
30bc	5-30-61	43	2.2	0.0	5.0	11	0	1.8	3.0	6	0	29	5.3	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.11	0.00	0.21	0.18	0.00	0.05	0.06									
34da	10-12-65	60	23	4.3	12	113	0	1.6	6.8	75	0	190	7.8	Low	Low	Safe	Calcium bicarbonate	Alluvium
			1.15	0.35	0.54	1.85	0.00	0.05	0.14									
17/20-31ac1	1-14-66	--	17	6.2	10	70	1	4.6	24	68	9	186	8.4	Low	Low	Safe	Mixed bicarbonate	Alluvium
			0.85	0.51	0.43	1.15	0.03	0.13	0.50									
WASHOE AND LITTLE WASHOE LAKES																		
16/19- 1dc	4- 1-66	58	35	23	42	264	12	11	20	181	0	477	8.5	Medium	Low	Safe	Mixed bicarbonate	- -
			1.75	1.87	1.84	4.33	0.40	0.31	0.42									
23da	4- 3-66	--	37	30	30	268	12	12	22	214	0	477	8.6	Medium	Low	Safe	Mixed bicarbonate	- -
			1.85	2.43	1.31	4.39	0.40	0.34	0.46									
16/20-20bc	4- 1-66	57	36	16	57	283	4	12	22	154	0	477	8.4	Medium	Low	Marginal	Mixed bicarbonate	- -
			1.80	1.28	2.49	4.64	0.13	0.34	0.46									
SPRINGS																		
16/19- 3ba	4-12-66	128	2.7	.4	49	78	4	6.6	33	8	0	236	8.7	Low	Low	Safe	Sodium bicarbonate	Granitic rocks
			0.13	0.03	2.13	1.28	0.13	0.19	0.69									
21aa	10- 7-65	54	13	3.3	14	83	0	2.0	4.4	46	0	130	7.9	Low	Low	Safe	Mixed bicarbonate	Granitic rocks
			0.65	0.27	0.59	1.36	0.00	0.06	0.09									
21ad	10- 7-65	62	15	1.3	16	73	4	1.8	7.6	43	0	126	8.5	Low	Low	Safe	Mixed bicarbonate	Granitic rocks
			0.75	0.11	0.68	1.20	0.13	0.05	0.16									
16/20-17aa	1-14-66	42	37	16	13	137	7	8.2	48	158	34	332	8.4	Low	Medium	Safe	Mixed bicarbonate	Granitic rocks
			1.85	1.31	0.55	2.25	0.23	0.23	1.00									

1. Computed by difference.

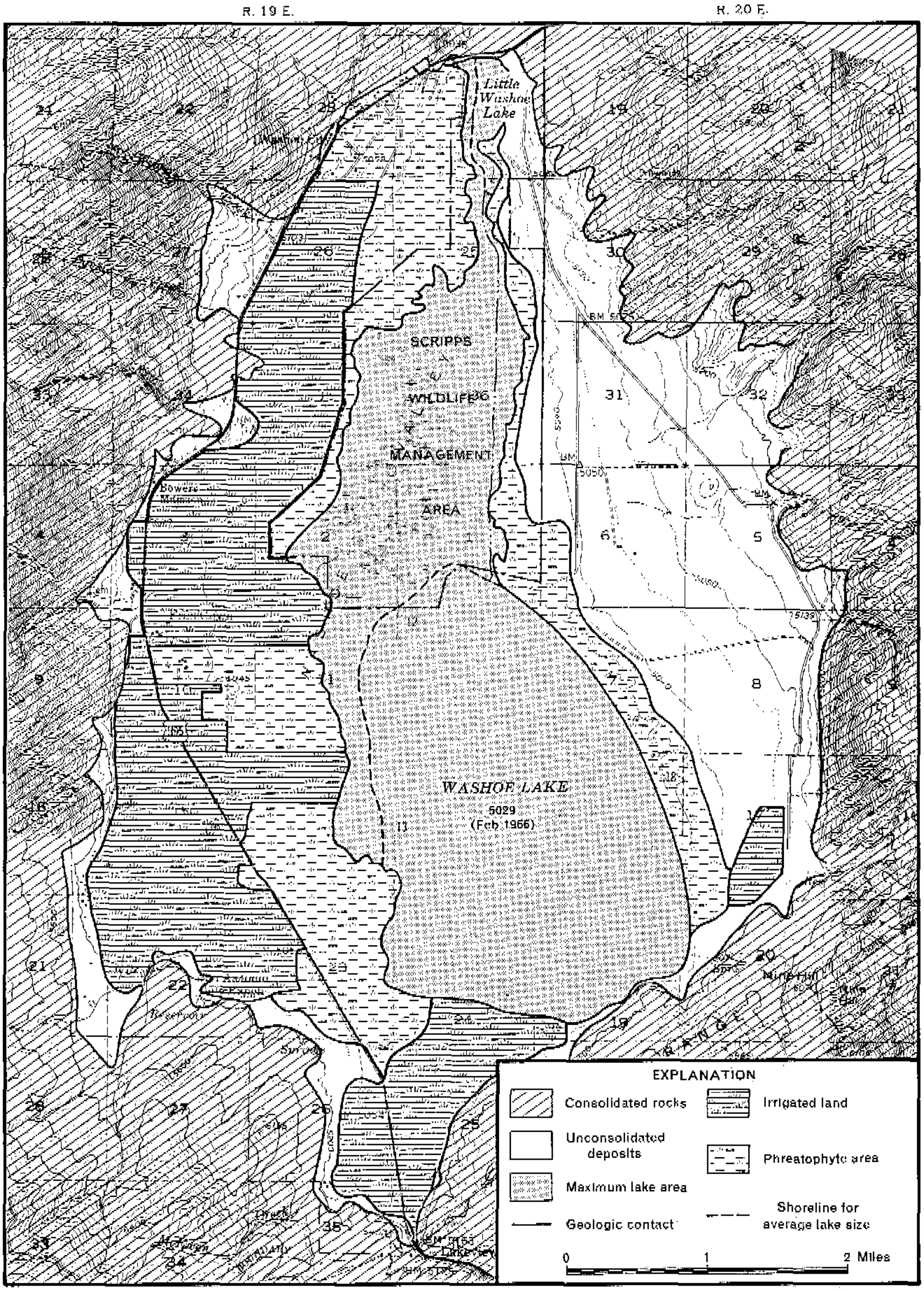

Figure 7.—Generalized land-status of the valley floor, April 1966

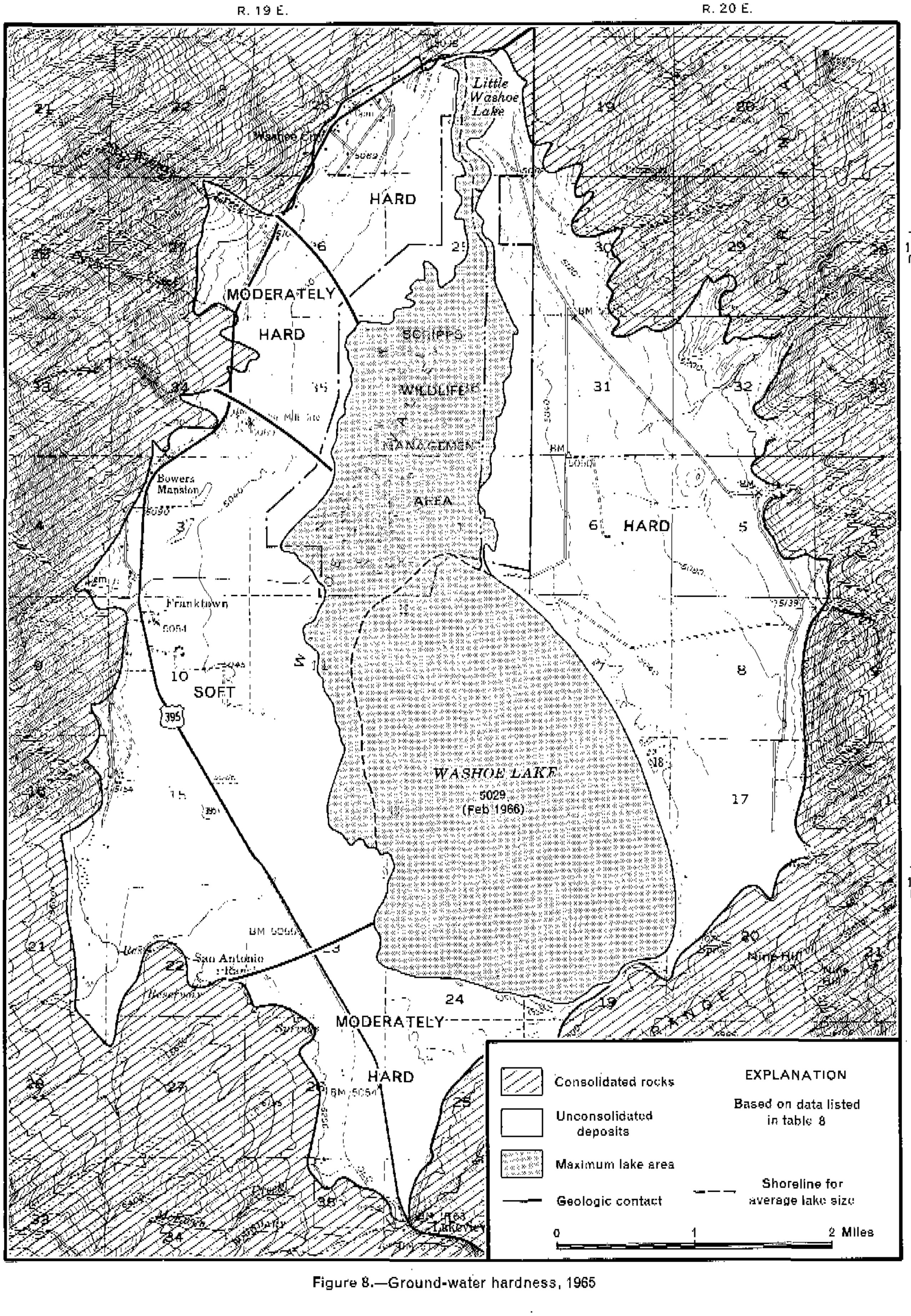

Figure 8.—Ground-water hardness, 1965

Table 9.--Specific conductance of selected surface-water samples

Location	Date	Source	Temperature (°F)	Specific conductance (Micromhos at 25°C)
16/19-3cc	5- 4-66	Franktown Creek	64	70
11ad	4-10-66	Washoe Lake	64	446
22ca	5- 4-66	Musgrove Creek	63	146
17/19-24ba	4-10-66	Little Washoe Lake	65	a 374
34dc	5- 4-66	Ophir Creek	64	46

a. This value is lower than those for other samples from Washoe and Little Washoe Lakes (this table and table 8) because lower-conductance water was being diverted to Little Washoe Lake near the sampling site.

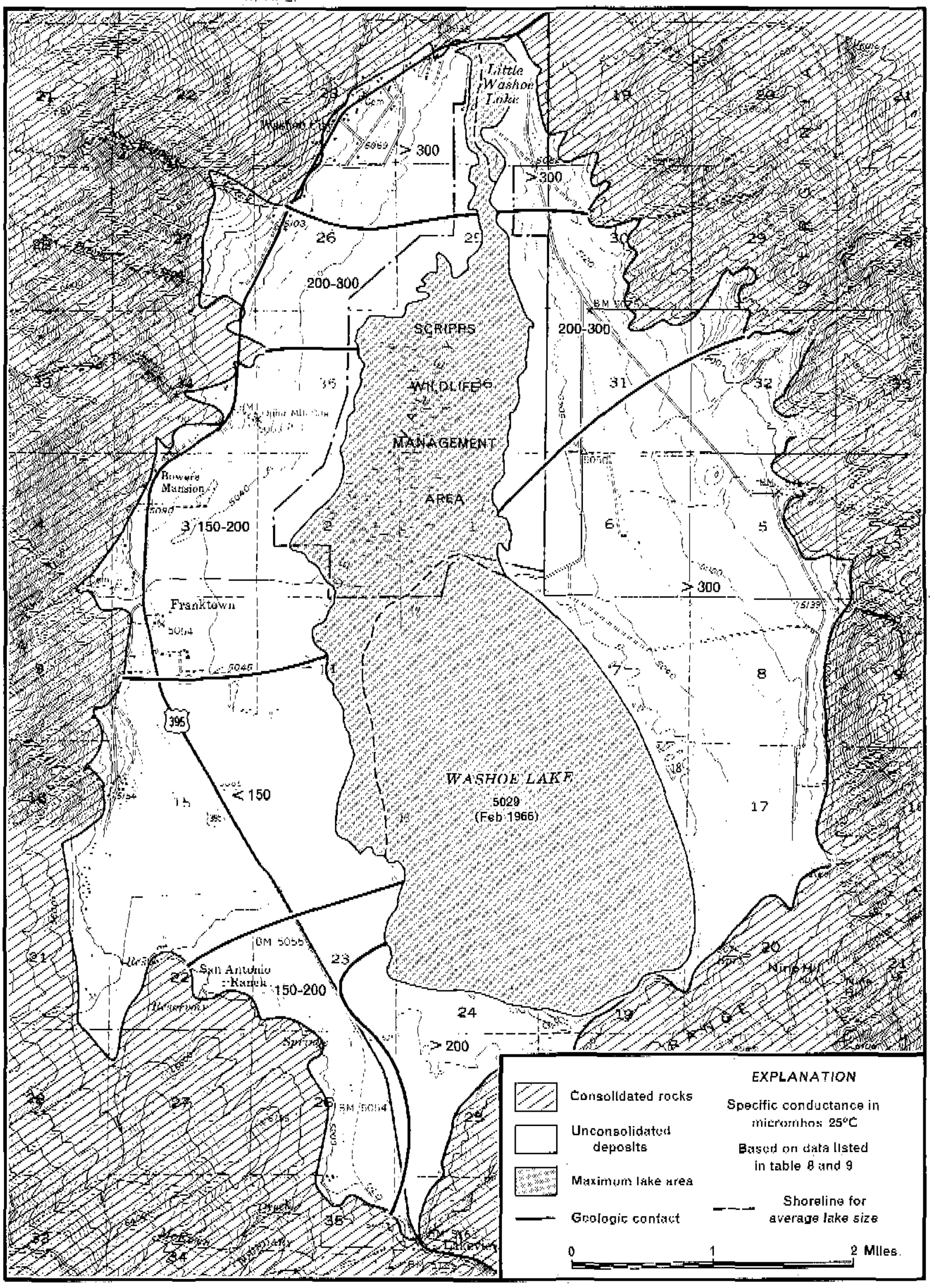

Figure 9.—Generalized distribution of specific conductance of ground-water, 1965

SYSTEM YIELD

The yield of a hydrologic system has been defined as the maximum amount of surface and ground water of suitable chemical quality that can be obtained economically each year from sources within the system for an indefinite period of time (Worts and Malmberg, 1967). The system yield can not be more than the inflow to or outflow from the system; it ultimately is limited to the maximum amount of surface-water, ground-water, and water-vapor outflow that can be salvaged economically each year for beneficial use.

For Washoe Valley the predevelopment conditions of the hydrologic system have been modified by the following principal changes: (1) construction of a dam at the outlet of Little Washoe Lake, causing a substantial reduction of outflow in Steamboat Creek and increasing substantially the average volumes and areas of Washoe and Little Washoe Lakes; (2) import of streamflow from North, Brown, and Galena Creeks; (3) export of streamflow through the Marlette Water System; and (4) diversion of streamflow from streams and lakes to fields on the valley floor. These changes in the native conditions have existed for nearly 100 years and probably will continue for many years. Therefore, the following estimate of the system yield will be for the modified conditions as identified above.

For 1965 conditions, diversions from lakes and creeks, pumpage, export of water, and most of the outflow from the valley are being put to beneficial use--a total of about 8,000 acre-feet (table 7). The estimated average annual evapotranspiration (9,000 acre-feet) in areas of phreatophytes and evaporation from Washoe and Little Washoe Lakes (14,000 acre-feet) constitute virtually all the remaining outflow--a total of about 23,000 acre-feet (table 7). By replacing most of the phreatophytes with beneficial vegetation where land and soil conditions permit, but excluding the 1,500 acres that is inundated between average and full lake stage (table 6), about half, or roughly 4,000 acre-feet per year, probably could be salvaged for beneficial use.

Washoe and Little Washoe are becoming increasingly valuable for their recreational and wildlife-management (Scripps Wildlife Management Area) uses. The problem of whether these uses are worth the large average evaporation losses, which amount to nearly 50 percent of the total water crop, is beyond the scope of this study. However, under this arrangement of operating the lakes at medium to high lake stage, the system yield could be only about 15,000 acre-feet per year, if the evaporation losses on Washoe and Little Washoe Lakes average as much as 14,000 acre-feet per year.

On the other hand, if irrigation or other large uses are considered more pertinent to the economy of the area, the lakes could be utilized as regulating reservoirs from which water could be withdrawn for use in the surrounding areas. The cyclic range in lake stage, then, might be from dry or nearly dry to medium levels, in which case the evaporation losses might average only 7,000 acre-feet per year. Under such a plan of operation the system yield could be as much as 25,000 acre-feet per year. Obviously, such a water use would have an adverse effect on the 2,700-acre wildlife management area and on fishing, boating, and other recreational uses. Moreover, during part of the time, water would have to be pumped into Steamboat Creek to meet present downstream irrigation rights.

Thus, this reconnaissance suggests that, depending upon how Washoe Valley is developed and managed, the system yield ranges between 15,000 and 25,000 acre-feet per year.

FUTURE SUPPLY

For the past 100 years Washoe Valley's economy has been dominated by mining and agriculture. However, in the first half of the present decade (1960-70) the population of the valley has grown and an increased amount of land transformed to residential development. As Carson City and Reno continue to grow in population, Washoe Valley may lose agricultural importance and could become an important residential and recreational area. This transition will have an important effect on the water use in the valley.

Streamflow

Most of the streamflow is now utilized for agriculture. If irrigated land is converted to residential development, water previously used for irrigation of cropland will become available for domestic, commercial, and recreational use. The streams of the Carson Range provide most of the inflow to the valley floor and could be developed further for public-supply systems.

Pumping from Wells

Figure 2 shows large areas where the depth to water below land surface is less than 5 feet. Such areas are considered waterlogged. Wells pumped in these areas would lower the water table, salvaging much water now wasted by evapotranspiration and making the areas more suitable for irrigation or residential development.

The Lakes

With the continued expansion of recreational activity, perhaps one of the best uses of the stored water in Washoe and Little Washoe Lakes would be for recreation. The lake area has high potential for park development, fishing, hunting, and boating. Its continued use as a wildlife-management area would also require that the lakes be maintained at medium to high stages.

Because a strong interrelation exists between ground and surface water in the valley, the development of either will strongly affect the quantity and quality of the other. This consideration points up the need for long-range planning of residential and agricultural development and the associated water use.

WELL RECORDS

Location Numbering System

The numbering system for wells and springs and other hydrologic sites in this report is based on the rectangular subdivision of public lands, referenced to the Mount Diablo base line and meridian. The number consists of three units: The first is the township north of the base line; the second, separated from the first by a slant, is the range east of the meridian; and the third, separated from the second by a dash, designates the section number. The two letters following the section number indicate the quarter-quarter section (40-acres); the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters of each subdivision of the section. A number following the final letter indicates that more than one well was located in the quarter-quarter section. For example, well 16/19-3ba, assigned to a well at Bower's Mansion, designates that the well is the only well identified in the NE¼NW¼ sec. 3, T. 16 N., R. 19 E., Mount Diable base line and meridian.

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

Selected Data

A rough field inspection suggests that a total of 250 residences are in Washoe Valley, each having a well and septic system. Table 10 includes information on about 50 wells, which generally are representative of the depth and type of the other wells in the valley. Well locations are shown on plate 1. Drillers' logs for many wells are available. Table 11 includes 10 of these, selected to provide areal and depth representation. Their locations also are shown on plate 1.

Table 10.--Data of selected wells

Use: P, public supply; D, domestic; U, unused; I, irrigation; S, stock
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)	
16/19-3ba	Bower's Mansion	--	--	6	P	--	5,080	10-11-65	11.11	--
3bc1	Charles A. Steen	1963	239	6	D	88/63	5,160	10-11-65	29.13	6989
3bc2	Do.	1963	996	6,4	U	--	5,160	--	--	6990
3cd	R. Raymond	1959	475	14	I	4100/56	5,050	4-20-66	Flowing 50 gpm	4820
10aa	R. Raymond	1950	138	6	U	--	5,035	10-11-65	Flowing 10 gpm	1466
10ad	(Unknown)	--	--	4	U	--	5,040	10-11-65	Flowing 5 gpm	--
10ba1	Robison Realty	--	--	6	U	--	5,055	10-11-65	4.43	--
10ba2	Flying "ME" Ranch	--	--	12	U	--	5,055	10-11-65	8.56	--
10cb	(Unknown)	--	--	14	I	--	5,100	--	--	--
11cc	(Unknown)	--	--	3	U	--	5,035	10-11-65	Flowing	--
14bc	A. H. Cliff	1960	162	6	S	300/75	5,045	10-11-65	Flowing 3 gpm	5048
14cd	F. Crouse	--	90	6	D	--	5,050	10-12-65	7.30	--

Table 10.--Data of selected wells--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
16/19-15bc	A. H. Cliff	1950	131	6	D	30	5,160	7-14-50	4	--
15bd	Do.	1962	500	14	I	1200/140	5,060	10-11-65	Flowing 10 gpm	8310
15ca	James Lathrop	--	450	14	U	--	5,085	10-11-65	9.87	--
16da	Do.	1949	115	6	D	3/56	5,200	4-29-49	4.10	881
16dd	R. G. Miller Washoe Pine Ranch	1952	235	6	D,S	18/25	5,190	10- 6-65	1.23	2051
21ad	Henry Heidenreich	--	--	6	D	--	5,200	10- 6-65	Flowing 0.5 gpm	--
22bd	Lightning "W" Ranch	1963	622	10	I	800/145	5,200	10- 6-65	1.31	7306
22da	Do.	1965	590	--	I	(untested)	5,150	--	--	--
22dc	Do.	1964	122	8	D	25	5,200	--	--	7617
23cc	(Unknown)	--	130	6	U	--	5,180	10- 5-65	26.96	--
23db	Claude Hansen	1962	70	6	D	20/30	5,040	10- 5-65	10.53	6762
25ba	Frank List (windmill)	--	100	6	S	--	5,060	10-13-65	+ 0.9	--
26ab	(Unknown)	--	130	8	D	--	5,170	10-13-65	19.72	--
26dc	Hugh Shamberger	1960	156	8	D	30	5,160	10-13-65	14.87	6049
26dd	Jerry Freeman	1961	84	6	D	--	5,060	10-13-65	Flowing	6571

Table 10.--Data of selected wells--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
16/19-35ab	List Ranch	--	--	6	S	--	5,180	10-13-65	.10	--
35db	R. A. Petty	1964	155	6	D	9/72	5,250	11-30-63	33	8187
36bb	J. Savage Construction Co.	1965	--	8	D	--	5,070	--	--	--
36bc	Cecil Laird	1960	170	10	D	20/77	5,170	7-19-59	3	5043
16/20-5ac	Mrs. C. Maloff	--	80	8	D	--	5,150	10-13-65	49.60	--
5cc	Mr. Williams	1954	242	6	D	20	5,075	5- 3-54	1	2681
6aa	Ed. Heidenreich	--	83	6	D	--	5,085	10-13-65	39.34	--
6ab	Robert Kobman	1964	83	6	D	32	5,080	4-30-64	46	7851
6ba	M. Stecker	--	87	6	D	--	5,055	1-13-66	10.87	--
6ca	L. Warner	--	--	6	D	--	5,045	1-13-66	Flowing 0.5 gpm	--
6dd	Ruth Mitchel	--	66	6	D	--	5,070	1-13-66	22.25	--
17ac	John Whitehead and Henry Heidenreich	1957	225	14	I	2000/55	5,060	10-13-65	13.43	4028
17da	Mrs. James Greil	--	--	10	U	--	5,120	1-13-66	55.79	--
17/19-23ad	R. Edelen	--	70	6	D	--	5,075	10-13-65	12.46	--
23d	J. W. Giles	--	--	6	D	--	5,070	10-13-65	5.20	--

Table 10.--Data of selected wells--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
17/19-23dc	Bill Payne	1958	76	6	D	15/50	5,080	10-11-65	19.36	4336
24bc	N. Walthers	--	--	6	D	--	5,040	10-13-65	12.69	--
25ad	Robert Price	1964	92	6	D	5/80	5,075	10-11-65	39.89	8232
26aa	James Ross	1959	120	6	D	20/58	5,050	10-11-65	Flowing 1.5 gpm	4754
34aa	Richard R. Hood	--	--	6	D	--	5,075	10-13-65	16.26	--
34da	E. M. Gibbs	1963	63	6	D	--	5,085	10-13-65	16.87	8063
17/20-30cc	(Unknown)	--	--	6	U	--	5,065	10-11-65	27.29	--
31ac1	James S. Tyzbir	--	--	6	D	--	5,080	1-13-66	34.33	--
31ac2	Don Penrod	1964	317	6	D	13/9	5,100	--	--	7766
31ba	(Unknown)	--	--	6	U	--	5,070	1-13-66	13.06	--
31da	L. Burlingham	--	--	6	D	--	5,130	1-13-66	85.86	--

Table 11.--Drillers' logs of selected wells

Material	Thickness (feet)	Depth (feet)
16/19-15bd		
Topsoil	5	5
Soil, sandy	37	42
Sand and gravel	218	260
Clay, sandy, blue	140	400
Clay, blue	50	450
Sand, gravel, and boulders	50	500
16/19-22bd		
Sand	5	5
Gravel, pea	5	10
Sand, cemented	80	90
Basalt and granite (decomposed?)	110	200
Granite (decomposed?)	120	320
Basalt, hard (decomposed?)	80	400
Basalt and shell granite (decomposed?)	100	500
Sand	50	550
Clay streaks and hard sand	15	565
Basalt and granite	57	622
16/19-26dc		
Sand	43	43
Clay, yellow	32	75
Rock, red	5	80
Sand, hard	4	84
Rock, red	55	139
Gravel, fine, red and gray	13	152
Rock	1	153
Rock, broken	3	156
16/19-35db		
Topsoil	6	6
Rock, brittle, broken	½	6½
Rock, weathered, solid	5½	12
Rock, broken	9	21
Rock, brown, weathered	29	50
Clay, sandy, hard, gray	6	56
Sandstone, weathered, gray	11	67
Rock, hard, gray	9	76
Rock, black, water-bearing	9	85
Rock, gray-green, broken	22	107
Rock, black, broken	12	119
Rock, hard, gray, water-bearing	36	155

Material	Thick-ness (feet)	Depth (feet)
16/19-36bc		
Topsoil	6	6
Sand and clay	14	20
Clay	25	45
Sand	3	48
Clay and rock (weathered?)	20	68
Rock (weathered?)	12	80
Clay and rock	20	100
Rock	70	170
16/20-5cc		
Old well	90	90
Sand, water-bearing	30	120
Clay, sandy	80	200
Sand	42	242
16/20-17ac		
Soil, sandy	12	12
Sand, fine	18	30
Gravel	8	38
Sand, coarse	22	60
Gravel and boulders	15	75
Clay, sandy	45	120
Clay, yellow	45	165
Sand and pea gravel	35	200
Granite, decomposed	25	225

Material	Thick-ness (feet)	Depth (feet)
17/19-23dc		
Topsoil	2	2
Clay and sand	22	24
Sand	3	27
Clay	19	46
Sand, water-bearing	30	76
17/19-25ad		
Sand	5	5
Sand, coarse, hard	25	30
Sand, fine, and clay	15	45
Clay, sandy	23	68
Sand, coarse	20	88
Clay and gravel	4	92
17/20-31ac2		
Topsoil	4	4
Sand, white, silty	6	10
Clay, yellow, silty	20	30
Sand and silt	5	35
Granite, decomposed	55	90
Granite rock, solid and fractured	139	229
Granite, weathered and clay	7	236
Sand and some clay	2	238
Granite, decomposed	20	258
Granite, hard	6	264
Granite, decomposed	50	314
Sand, clean, water-bearing	3	317

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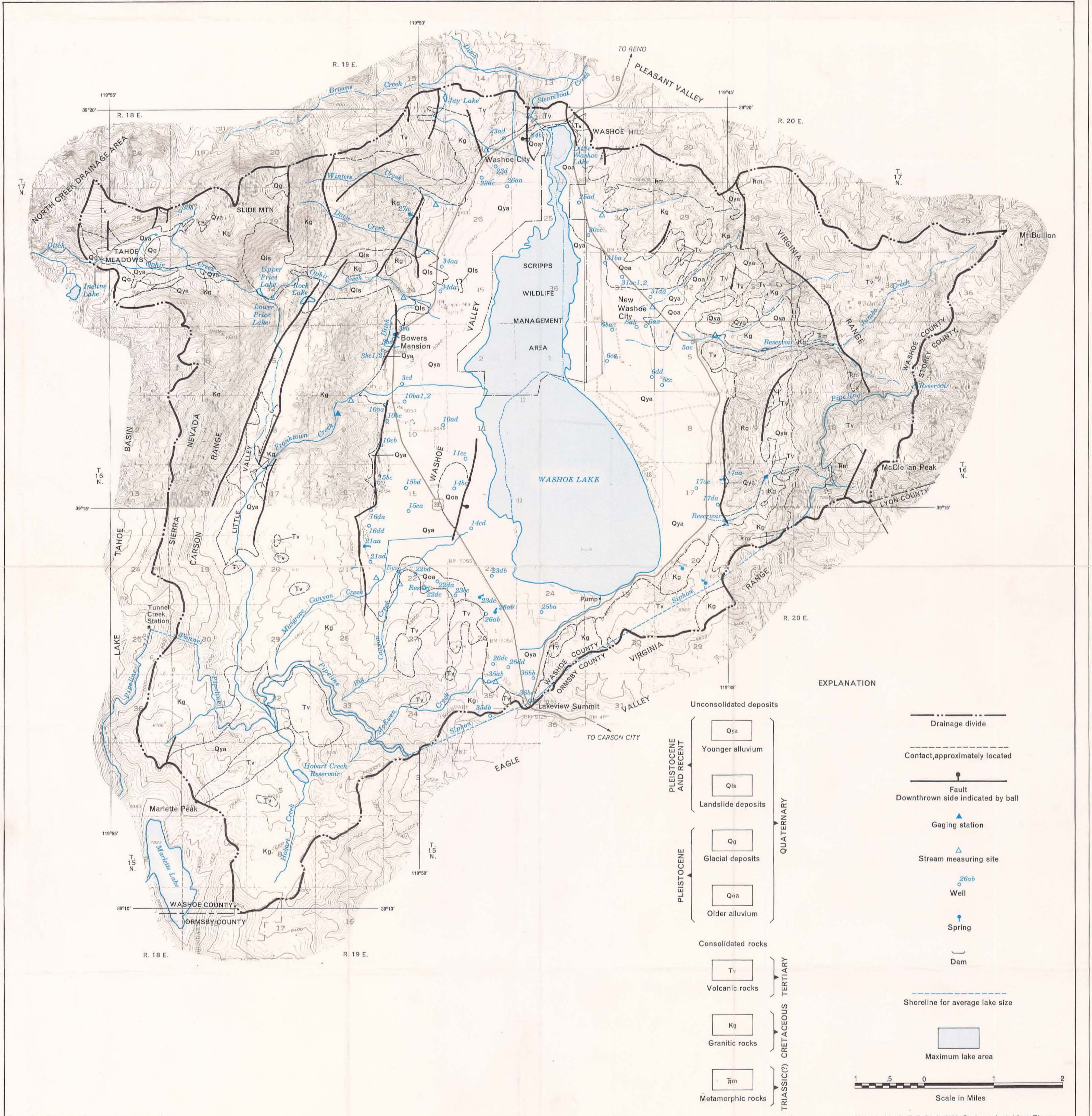
40	Walker Lake	
	Rawhide Flats	
	Whisky Flat	

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
STATE OF NEVADA



Base: U.S. Geological Survey 1:62,500 topographic quadrangles; Mt Rose, Virginia City, Carson City, and Dayton

Hydrogeology by F. E. Rush, 1966; Geology adapted from Thompson and White (1964), Moore (1961), and Thompson (1951)

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF WASHOE VALLEY, WASHOE COUNTY, NEVADA