Ground-Water Reconnaissance of Winnemucca Lake Valley Pershing and Washoe Counties Nevada

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1539-C

Prepared in cooperation with the State of Nevada, Department of Conservation and Natural Resources

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By C. P. ZONES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GROUND-WATER RECONNAISSANCE OF WINNEMUCCA LAKE VALLEY, PERSHING AND WASHOE COUNTIES, NEVADA

By C. P. Zones

ABSTRACT

Winnemucca Lake Valley is an intermontane valley in western Nevada. The valley trends north and is bordered on the east by the Nightingale Mountains and the Selenite Range and on the west by the Lake Range. The mountains were uplifted and tilted eastward as a result of faulting along their west sides.

Material eroded from the mountains has accumulated in the valley. In the northern part of the valley older alluvium of Quaternary age is exposed in alluvial fans—large ones at the base of the Selenite Range and small ones at the base of the Lake Range. Elsewhere in the valley the material of the piedmont slopes has been reworked by currents and waves of Lake Lahontan into beach terraces and gravel spits. Younger sediments deposited in Winnemucca Lake overlie the sediments of Lake Lahontan downslope from the base of the piedmont.

Winnemucca Lake was dry about 1840, began to fill shortly thereafter, and then contained water until about 1945. In 1882 the lake had a maximum depth of 87 feet. Exposed sediments deposited in Winnemucca Lake consist largely of clay and silt, except at the south end of the valley, where coarse sand and gravel mantle the surface.

The sediments of Winnemucca Lake are generally nearly impermeable. On the other hand, the coarse-grained sediments of the Lake Lahontan shore features may transmit water readily, if they occur within the zone of saturation. The older alluvium exposed in fans at the north end of the valley may yield moderate quantities of water to wells under favorable conditions, but the depth to ground water probably is greater than 100 feet.

Ground water in the valley is recharged mainly from precipitation that runs off from the bordering mountain ranges. Lesser amounts of recharge are received by ground-water inflow through a gap at the south end of the valley, and from precipitation on the valley floor.

Ground water is discharged by direct evaporation from the large mud flat that occupies most of the valley floor, by springs, and by transpiration by phreatophytes. From crude estimates of the average annual recharge and discharge it is concluded that the ground-water supply of the valley is about 5,000 to 10,000 acre-feet per year.

Ground water beneath the valley floor is highly mineralized. Even though wells drilled into the material underlying the piedmont slopes may tap water

of good chemical quality, large withdrawals from such wells on a long-term basis may reverse the hydraulic gradient and cause water of poor chemical quality to move from the central part of the valley to the pumped wells.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation of ground-water conditions in Winnemucca Lake Valley is part of the cooperative program of the U.S. Geological Survey and the Nevada Department of Conservation and Natural Resources for evaluating the ground-water resources of the State.

The purposes of the present study are: (a) to determine the sources of recharge, the occurrence and movement, and the areas of discharge of ground water, (b) to estimate the average annual recharge to the ground-water reservoir, (c) to determine the chemical quality of the ground water, and (d) to determine the more favorable areas for the development of ground-water supplies. Because the piezometric surface is less than 5 feet below the land surface in much of the central—or low-lying—part of the area, direct evaporation from the capillary fringe is an important part of the ground-water discharge. Consequently, much of the field work was directed toward obtaining data that would permit the construction of a detailed map showing the depths to the water table. For this purpose about 60 wells were either augered or dug or piezometer tubes were driven. The field work was done during June, July, and August 1959. G. Davis, G. Frazier, and C. Tobey, nearby residents, were employed for several weeks to assist with the field work.

The investigation was made by the Ground Water Branch, U.S. Geological Survey, under the supervision of O. J. Loeltz, district engineer in charge of ground-water studies in Nevada.

LOCATION AND EXTENT OF THE AREA

Winnemucca Lake Valley is in west-central Nevada in Pershing and Washoe Counties (fig. 1). The valley, which trends north, is bordered by the Lake Range on the west and by the Nightingale Mountains and Selenite Range on the east. (See fig. 2)

The valley is about 35 miles long and averages 12 miles wide. The area underlain by alluvium, lake deposits, and sand dunes is about 165 square miles.

Access to the valley is by Nevada Highway 34, a paved road along the west side of the valley. A gravel and dirt road follows a route along the east side of the valley.

The western part of the valley is within the Pyramid Lake Indian Reservation; the eastern part, within the Winnemucca Migratory Bird Refuge. There are no communities in the valley and only one family lives there.

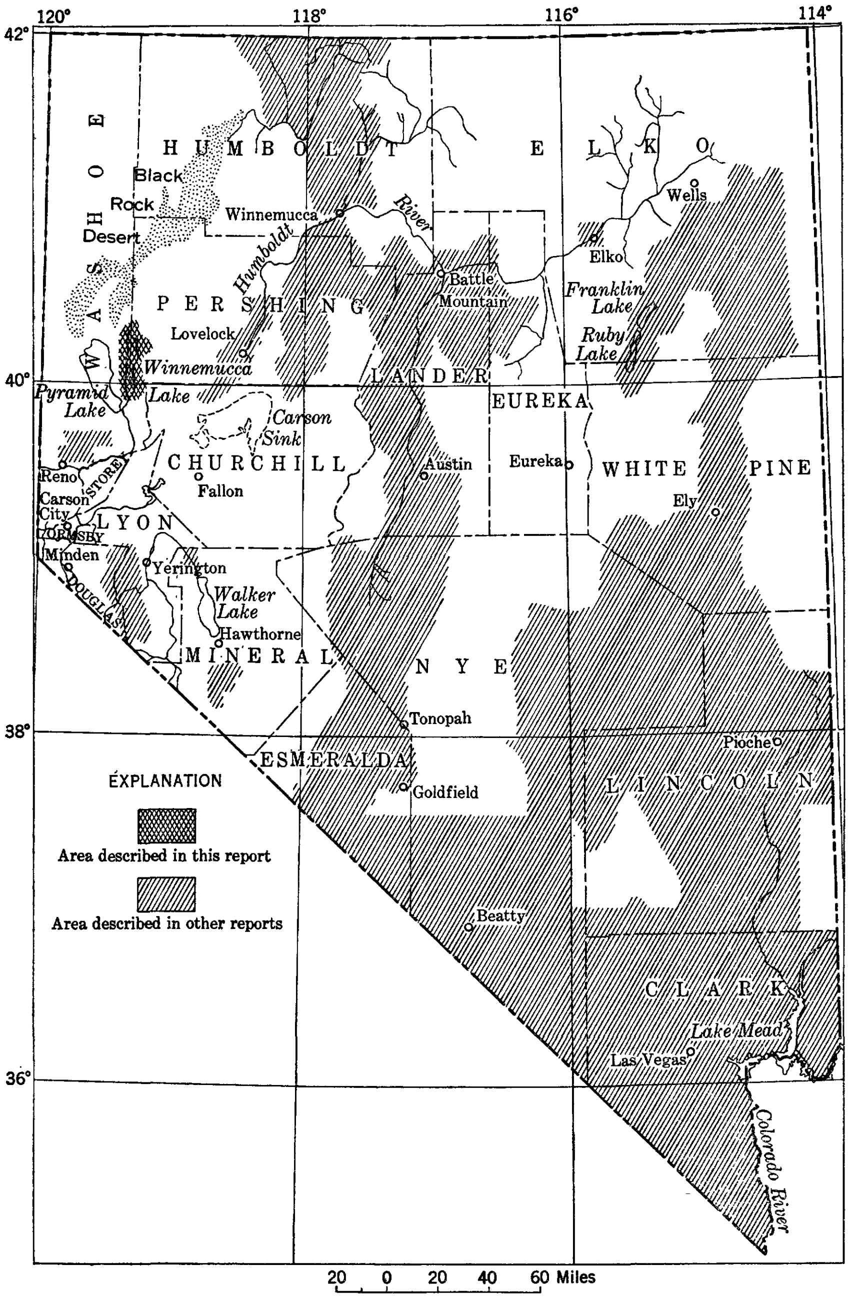

Figure 1.—Map of Nevada showing areas covered by previous ground-water reports and by the present report.

The nearest towns are Nixon, 5 miles south of the valley, and Empire and Gerlach, 10 and 15 miles, respectively, north of the valley. The three communities have a combined population of only a few hundred people. Nixon, within the Pyramid Lake Indian Reservation, is a community of small farms. Empire is a mining community most of whose inhabitants work for the U.S. Gypsum Company. Gerlach is on the Western Pacific Railroad, and many of its residents are employed by the railroad.

PREVIOUS INVESTIGATIONS

A reconnaissance of Winnemucca Lake Valley was first made by members of the Fortieth Parallel Survey in 1867 (King, 1878).

Russell (1885) made a more thorough study of the area. His studies show that Winnemucca Lake Valley was once occupied by an arm of Lake Lahontan whose shore features and sediments are still plainly evident.

Hardman and Venstrom (1941) reviewed the late history of Winnemucca Lake, seeking to determine the probable causes of the changes in the level and volume of the lake.

CLIMATE

Long-term precipitation and temperature records are available for the U.S. Weather Bureau stations at Empire, 10 miles north of the valley, and at Sand Pass, 25 miles west of the north end of the valley. The normal monthly and annual precipitation and temperature at each station are given below. Both stations are at elevations comparable to that of the floor of Winnemucca Lake Valley—about 3,800 feet above sea level. Probably the climate at these stations is typical of the valley.

Normal monthly and annual precipitation at Empire, Washoe County, Nev. (From records of U.S. Weather Bureau; length of record, 43 years through 1957)

Month	Precipitation (inches)	Month	Precipitation (inches)
January	0.62	August	0.13
February	.68	September	.25
March	.45	October	.45
April	.35	November	.48
May	.56	December	.65
June	.46		
July	.17	Annual	5.25

Normal monthly and annual precipitation at Sand Pass, Washoe County, Nev. (From records of U.S. Weather Bureau; length of record, 43 years through 1958)

Month	Precipitation (inches)	Month	Precipitation (inches)
January	1.01	ugust	0.07
February	.80	September	.19
March	.53	October	.45
April	.47	November	.61
May	.50	December	1.23
June	.49		
July	.18	Annual	6.53

Normal monthly and annual temperature at Empire, Washoe County, Nev. (From records of U.S. Weather Bureau; length of record, 41 years through 1956)

Month	Temperature (° F)	Month	Temperature (° F)
January	28.3	August	73.1
February	34.8	September	63.9
March	42.2	October	52.1
April	50.0	November	39.7
May	58.0	December	31.4
June	66.1		
July	75.5	Annual	51.3

Normal monthly and annual temperature at Sand Pass, Washoe County, Nev. (From records of U.S. Weather Bureau; length of record, 38 years through 1957)

Month	Temperature (° F)	Month	Temperature (° F)
January	29.8	August	72.0
February	36.0	September	63.6
March	43.0	October	53.0
April	50.5	November	40.3
May	58.4	December	32.6
June	65.9		
July	74.5	Annual	51.6

The annual precipitation recorded at Sand Pass is 6.53 inches, and at Empire, 5.25 inches. Most of the precipitation occurs during the winter months, largely as snow. At higher elevations the snow cover may last for several weeks, or months. Precipitation during the sum-

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mer months is very slight. During August, the driest month, the normal amount of precipitation recorded at Sand Pass is only 0.07 inch, and at Empire, only 0.13 inch. According to local residents, much of the summer precipitation in Winnemucca Lake Valley occurs during cloudbursts, chiefly along the east side of the valley.

Although no data are available concerning the rate of evaporation in Winnemucca Lake Valley, the rate is probably comparable to that at Lahontan Reservoir, 50 miles to the southeast. The U.S. Bureau of Reclamation estimates that the average annual evaporation from the surface of Lahontan Reservoir is about 54 inches.

The normal annual temperature is 51.6° F at Sand Pass and 51.3° F at Empire. The lowest normal monthly temperatures are recorded in January (29.8° F at Sand Pass and 28.3° F at Empire); the highest in July (74.5° F at Sand Pass and 75.5° F at Empire). Temperatures of 100° F or higher are common in the summer months, but in the winter the temperature may drop below 0° F, although such low temperatures ordinarily are recorded only a few days each year. Daily fluctuations in temperature are as much as 50° F during the summer, but more commonly range from 30° to 40° F. The daily fluctuations generally range from about 20° to 30° F during the winter.

LANDFORMS AND DRAINAGE

The north-trending ranges at the east and west sides of Winnemucca Lake Valley are fault-block mountains which rise more than 4,000 feet above the valley floor to altitudes of 8,000 feet. Each range has been faulted on its west side and tilted to the east. The steep western slope of the Nightingale Mountains is cut by V-shaped canyons separated by sharp-crested spurs that end abruptly in steep, triangular facets. The facets probably represent a fault trace that has been only slightly subdued by erosion.

The gentler dip slope of the Lake Range, which borders the west side of the valley, is in marked contrast to the steep western face of the Nightingale Mountains and the Selenite Range.

The alluvial or piedmont slopes that border the ranges have average gradients of about 100 feet per mile. The slopes consist of rubble that has been eroded from the mountain ranges and deposited at their base by streams. At the extreme north end of the valley, the rubble forms alluvial fans—large ones at the base of the high Selenite Range, and small ones at the base of the low-lying Lake Range. The piedmont slope of the Selenite Range is an apron of coalescing alluvial fans which extends outward about 2 miles from the base of the range. The smaller fans at the base of the Lake Range extend outward less than 1 mile. The alluvial fans are traversed by ephemeral streams that are dissecting them, probably as a result of the lowering of the base level of the streams following the dessication of Lake Lahontan, or because of downcutting of the consolidated rocks above the apexes of the fans.

Elsewhere in the valley the material of the piedmont slopes has been reworked by waves and currents of Lake Lahontan of Pleistocene age, which has resulted in the formation of numerous beach terraces and spits. The spits are especially well developed on the west side of the valley, where their average length is about 1 mile. Domes and pinnacles of tufa are common on the piedmont slopes.

The edge of the valley floor is marked by an abrupt decrease in gradient of the alluvial slopes. The more gently sloping valley floor, which was the bed of Winnemucca Lake before the lake dried up in 1945, is a nearly featureless area, completely devoid of vegetation except for a few small areas of greasewood, saltbush, and saltgrass. Most of the surface is covered by a thin crust of salt or by a white efflorescence. There is a discontinuous belt of sand dunes along the east, north, and south sides of the valley floor.

A channel in the gap at the south end of the valley (south of the area shown on fig. 2) formerly discharged water that overflowed from Pyramid Lake into the valley, but now it carries only excess irrigation water and some groundwater effluent from the Nixon area.

There are no perennial streams in the valley. The normally dry stream courses carry water only during and for a short time after storms.

HISTORICAL FLUCTUATIONS IN THE LEVEL OF WINNEMUCCA LAKE

Pyramid Lake, west of Winnemucca Lake Valley, and Winnemucca Lake both received most of their water supply from the Truckee River, which bifurcated at a point about 4 miles southwest of Winnemucca Lake Valley. The main stem of the Truckee flowed, and still flows, into Pyramid Lake. A narrow channel, known as Mud Lake Slough, carried the overflow of Pyramid Lake into Winnemucca Lake.

Hardman and Venstrom (1941) summarize the changes in the lake levels since the middle of the last century. Winnemucca Lake was dry or nearly dry in 1840 and remained relatively low until about 1860. The volume of water in the lake increased rapidly from 1862 to 1871 and decreased slightly from 1882 to 1889. In 1882 the lake had a maximum depth of 87 feet. The 1889–90 period was very wet and the lake level rose sharply. The climate continued to be moist until about 1917, and consequently the level of the lake was high. The level declined after 1917 and, according to local residents, the lake became dry in 1945 and has remained dry to date.

Owing to large upstream withdrawals of water from the Truckee River, even the level of Pyramid Lake is declining rapidly. Its level is now about 40 feet below Mud Lake Slough.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTER

FORMATIONS OF TERTIARY AGE AND OLDER

The consolidated rocks of the bordering mountain ranges consist of volcanic rocks of Tertiary age and older igneous, sedimentary, and metamorphic rocks. In general, these consolidated rocks probably do not transmit appreciable quantities of water. A well in consolidated rocks ordinarily will yield water in significant quantities only if it penetrates fracture zones, open joints or bedding planes, or porous zones, such as may occur between lava flows.

OLDER ALLUVIUM

Older alluvium of Quaternary pre-Lake Lahontan age is exposed at the north end of the valley above an elevation of approximately 4,400 feet, and extends northward to the drainage divide between Winnemucca Lake Valley and the valley to the north. The alluvium occurs as large coalescing fans at the base of the Selenite Range and as smaller ones at the base of the Lake Range. Only a dry drainage channel separates the opposing fans. The exposed sediments, which are poorly sorted, range in size from clay to boulders several feet in diameter.

The water-bearing character of the older alluvium varies widely, depending on the conditions existing at a particular site at the time the alluvium was deposited. Large perennial streams deposit material that is better sorted than that deposited by ephemeral streams. Characteristically, alluvial fans contain the coarsest, most angular, and most poorly sorted material at the apexes. Material at the toe of a fan is generally less angular and better sorted, and as a rule the average size of the rock fragments is smaller. This relationship between grain size and sorting and distance from the source area is only a general one, because of the nature of the streams that deposit the fan material. During periods of high runoff, a stream may deposit large boulders at the toe of the fan, and a few days later the stream may be so small that it can transport only the finest rock particles. This produces a characteristic irregularity in the nature and water-bearing property of alluvial-fan deposits.

Alluvian of pre-Lake Lahontan age is undoubtedly buried beneath younger deposits throughout most of the valley. Its depth of burial is probably several hundred feet at the center of the valley, but it may be considerably less beneath the piedmont.

DEPOSITS OF LAKE LAHONTAN

Deposits of Lake Lahontan are exposed in a continuous band around the more recent sediments that occupy the central part of the valley. The exposures consist largely of shoreline and near-shore deposits, such as beaches, bars, and spits. Bedded clay, sand, and gravel are exposed in the sides of the canyon through which Mud Lake Slough enters the valley. Tufa occurs in isolated domes and pinnacles that range from less than a foot to a few tens of feet in height, and as a coating on rock outcrops. Numerous fragments of tufa, ranging in size from a fraction of an inch to somewhat more than 1 foot in diameter, occur throughout the area.

The surficial and near-surface sand and gravel deposits are generally unconsolidated, but locally they are cemented to form conglomerate or breccia. In most of the exposures the sand and gravel appear to be well sorted and the individual grains are fairly well rounded.

The character of the Lake Lahontan sediments beneath the more recent sediments of Winnemucca Lake is not known, but it is almost certain that they are largely fine grained and probably would not yield water freely to wells.

The sand and gravel deposits that fringe the valley probably are highly permeable and, if they occur below the zone of saturation, may yield water freely to wells. However, the maximum thickness of these coarse-grained deposits may be only a few tens of feet.

SEDIMENTS OF POST-LAKE LAHONTAN AGE

Sediments of post-Lake Lahontan age include those deposited in Winnemucca Lake, dune sand, and small alluvial-fan deposits.

The sediments deposited in Winnemucca Lake underlie most of the valley floor. These sediments were explored to a depth of only a few feet. In general, the surficial material of about the southern tenth of the valley floor consists largely of coarse sand and gravel. Northward it grades to fine sand, silt, and finally, clay. The coarse-grained deposits are generally less than 3 or 4 feet thick and are underlain by at least 2 feet of interbedded clay, silt, and sand. It is possible that more sand and gravel beds are present at depth.

Most of the surficial sediments of Winnemucca Lake consist of clay and silt, covered by a thin crust of salt or a white efflorescence. The clay and silt normally are brown near the surface, but the color is green or greenish-blue a few inches above the water table. At about the level of the water table the clay and silt are jet black and have a strong odor of hydrogen sulfide. The association of black clay and silt with the zone of saturation is general throughout the area of the valley floor.

Locally, the clay is interbedded with thin hard layers of coarse-grained, cemented material, and, near the periphery of the mud flat, with beds of coarser material and a few thin beds that consist almost entirely of shells of ostracodes.

The permeability of the upper few feet of sediments is extremely low. In many areas water entering the shallow wells that were constructed during the investigation did not attain a static level until several hours after the well was completed. This was true even for wells in the southern part of the valley, except where sand or gravel were in the zone of saturation.

The dune sand throughout much of the area is very permeable, but the sand is above the zone of ground-water saturation. Perched water may occur near the base of the sand for a brief period following a rain or snow melt but no perennial supplies can be obtained from the dune sand.

Similarly, the small alluvial-fan deposits and talus are above the zone of saturation and contain no permanent ground-water supplies.

GROUND WATER

OCCURRENCE AND MOVEMENT

Ground water occurs both in the consolidated rocks of the mountain ranges and in the unconsolidated and consolidated rocks that occupy the intermontane basin. Ground water in the mountain ranges normally occurs in appreciable quantities only in joints and fractures or in relatively uncommon porous beds. In contrast the unconsolidated rocks of the valley fill are saturated with water almost to the level of the valley floor.

The depth to water beneath the valley fill is greatest near the mountains, where it may be more than 100 feet, and least in the central part of the valley where beneath several thousand acres it is only a fraction of a foot, and locally the water table intersects the land surface.

The slope of the water table is away from areas of ground-water recharge toward areas of discharge; that is, from the edge of the valley toward the central part. The gradient of the water table roughly parallels the slope of the former bed of Winnemucca Lake. Ground water moving toward the center of the valley from the north and south has a gradient of about 10 feet per mile. In the area where Winnemucca Lake was narrowest, about midway between the north and south ends of the valley, ground water moves toward the center of the valley from the east and west at a hydraulic gradient of more than 20 feet per mile.

RECHARGE

Nearly all the ground-water recharge to the valley originates as precipitation on the mountain ranges within the drainage basin. Additional minor sources of recharge are precipitation on the sediments of the valley fill and surface and subsurface inflow from Mud Lake Slough.

PRECIPITATION ON THE MOUNTAIN RANGES

A map compiled by Hardman (1936) shows approximately the precipitation zones, in Nevada, estimated mainly on the basis of elevation, type of vegetative cover, and data from precipitation stations. In general, the valley floors are in the zones that receive the least precipitation and the higher mountains are in the zones that receive the greatest amounts. Hardman shows that the floor of Winnemucca Lake Valley and the piedmont slopes are in the 5- to 8-inch precipitation zone, the lower elevations of the mountain ranges are in the 8- to 12-inch zone, and the intermediate and highest elevations of the Lake Range and Nightingale Mountains are in the 12- to 15-inch zone. The precipitation is greater only on the highest parts of the Selenite Range, where the average annual amount is 15 to 20 inches. The total average annual precipitation in each zone is equal to the average annual precipitation in that zone multiplied by the area of the zone. On this basis, the total average annual precipitation in the mountains within the drainage divide is estimated at about 50,000 acre-feet in the 8- to 12-inch zone, 38,000 acre-feet in the 12- to 15-inch zone, and 2,000 acre-feet in the 15- to 20-inch zone, or a total of about 90,000 acre-feet. Because the precipitation map is only approximate and in detail may have large inaccuracies, the estimate of 90,000 acre-feet that is based on the map may likewise be inaccurate.

Only a small part of the total precipitation on the mountain ranges reaches stream courses. Most of the moisture returns to the atmosphere almost immediately through evaporation, or enters the zone of soil moisture and subsequently is transpired or evaporated. A study of the relationship between precipitation and runoff in the Martin Creek drainage area of Paradise Valley (Loeltz, Phoenix, and Robinson, 1949, p. 35), about 100 miles northeast of Winnemucca Lake Valley, indicated that the yearly evapotranspiration requirement in the Martin Creek drainage area is about 9 inches of precipitation. Assuming that the yearly evapotranspiration requirement in Winnemucca Lake Valley is the same, the average amount available for runoff is equal to the amount by which the average precipitation exceeds 9 inches. From these assumptions the average annual runoff is estimated to be 19,000 acre-feet.

A study of the relationship between runoff and recharge to the ground-water reservoir in Paradise Valley (Loeltz, Phoenix, and Robinson) indicates that about 40 percent of the runoff in that area ultimately recharges the ground-water reservoir.

The opportunity for infiltration of runoff into the valley fill may be greater in Winnemucca Lake Valley than in Paradise Valley because most of the streams in the former area traverse the coarse-grained well-sorted Lake Lahontan sediments that underlie much of the piedmont slope. Therefore, the average annual recharge from precipitation and runoff is estimated to be at least 40 percent of the estimated average annual runoff of 19,000 acre-feet, or about 8,000 acre-feet.

PRECIPITATION ON THE VALLEY FLOOR AND PIEDMONT SLOPES

Direct precipitation on the valley floor and piedmont slopes is 5 to 8 inches per year. Ordinarily, this is not enough to satisfy evapotranspiration requirements, and little, if any, of the precipitation infiltrates into the ground-water reservoir. But in areas that are mantled with highly porous material and that have only a sparse covering of vegetation, a high percentage of the precipitation may recharge the ground-water reservoir. There are several such favorable areas in the valley: the extensive area of sand dunes; the uncemented sand and gravel deposits at the south end of the former bed of Winnemucca Lake; and the numerous spits, beaches, and bars. Direct precipitation on these areas may contribute several hundred acre-feet of recharge annually. In addition, a small amount of recharge probably takes place where the water table is only a fraction of a foot beneath the valley floor.

INFLOW FROM MUD LAKE SLOUGH

Mud Lake Slough carries some of the excess irrigation water from the Nixon area and also may carry effluent ground water into the south end of Winnemucca Lake Valley. Much, if not all, of the water is transpired by cottonwood trees that grow along the slough. Water in the slough flows at an average rate of only a few gallons per minute at the south end of the gap which separates Winnemucca Lake Valley and the valley occupied by Pyramid Lake. The rate of flow is governed largely by the amount of excess irrigation water that enters the slough. During the nongrowing season, the flow is only 5 to 10 gallons per minute; during the growing season it is about 100 gallons per minute. Normally there is no water in the slough at the north end of the gap, although there may be some underflow.

The amount of recharge from this source is not known but probably is no more than a few hundred acre-feet per year.

DISCHARGE

Ground water is discharged from the valley by direct evaporation from the water table and from the capillary fringe, by transpiration of plants, and by springs.

EVAPORATION FROM THE WATER TABLE AND FROM THE CAPILLARY FRINGE

Direct evaporation from the water table and from the capillary fringe above it takes place in a large area of the former bed of Winnemucca Lake. Because the area is large and the amount of ground water evaporated is correspondingly large, a detailed map showing the depth to the water table was prepared. (See fig. 2.) The map is based largely on data obtained by digging or boring about 60 wells, but also in part on the appearance of the land surface.

The depth to water is greater than 5 feet in the southern and northern parts and along the eastern side of the former lake bed. Generally, the depth to water is progressively less toward the central part of the area. Locally, differences in depth to water in the northeastern part of the mud flat are clearly due to irregularities in the land surface, but they may also result from a change in the gradient of the water table.

A layer of salt on the land surface, such as exists in the mud flat of Winnemucca Lake Valley, lowers the rate of evaporation from the capillary fringe. Besides, salt in the soil tends to break down the granular structure of the soil and make it less permeable thus impeding the upward capillary movement of water. T. W. Robinson (written communication, 1959) describes two experiments made to determine the rate of evaporation from the capillary fringe in areas of saline mud. One experiment was made near Ogden, Utah; the other in Death Valley, Calif. The data obtained from the experiments were inconclusive, but they suggest that the rate of evaporation from the capillary fringe in saline muds is very small compared to the rate of evaporation of ground water from nonsaline soils.

AREA IN WHICH THE DEPTH TO THE WATER TABLE IS MORE THAN 5 FEET

The depth to water is more than 5 feet and generally less than 10 feet below the land surface at the north and south ends of the valley and along most of the eastern edge of the mud flat. The surficial material at the south end of the valley consists largely of a layer of coarse gravel and sand ranging from a few inches to a few feet in thickness. The capillary fringe does not rise to the surface, hence evaporation is negligible. The surface of most of the rest of the area is covered with a white, saline efflorescence, indicating that there is some evaporation from the capillary fringe. The underlying material is predominantly clay and silt. Although the surface was dry during the summer of 1959, the underlying material only a few inches below the surface was damp throughout much of the area. Evaporation from this area may be only a few hundred acre-feet annually.

AREA IN WHICH THE DEPTH TO THE WATER TABLE IS 2 TO 5 FEET

The area in which the water table is 2 to 5 feet below the land surface is generally covered with a very rough and jagged crust about ¼-inch thick which consists of clay and silt particles loosely cemented by salt. A paper-thin layer of salt covers the crust. Where the water table is less than 3 feet below the surface the crust is wet, but where the depth to the water table is greater than 3 feet, the crust is dry, although the soil beneath it is damp. The crust is traversed by numerous cracks, which form polygons several feet wide. The crust arches upward at the cracks, forming ridges several inches to more than a foot high. These ridges may be due to lateral expansion of the crust caused by the growth of individual salt crystals. The crust is underlain by clay and silt. Although the area includes about 11,300 acres, the average annual evaporation is probably no more than several hundred acre-feet, because the crust greatly retards evaporation.

AREA IN WHICH THE DEPTH TO THE WATER TABLE IS LESS THAN 2 FEET

The area in which the depth to water is less than 2 feet occupies about 7,200 acres, chiefly near the central part of the mud flat. It includes 1,600 acres where the water table is at or near the land surface. In the rest of the area, the surface is muddy and is underlain by green, gray, or black clay. A paper-thin crust of salt overlies the mud and probably prevents the rate of evaporation from exceeding several hundred acre-feet per year.

AREA IN WHICH THE WATER TABLE IS AT OR NEAR THE SURFACE

Ground water is virtually at the land surface over about 1,600 acres that include the nearly flat central part of the valley, numerous abandoned stream channels, and other depressions outside the main area. Owing to the inaccessibility of the area, detailed observations were made at only three points at the edge of the main area. General observations were made from a low-flying airplane. Nearly all the area appears to be covered with a light pink to deep red salt crust. In July 1959 numerous small pools of water covered about 1 percent of the area.

A sample of the salt crust collected from the eastern edge of the area consists of a porous ¼-inch-thick aggregate of small salt cubes. Under the crust at this locality is a very soft black mud that has a strong odor of hydrogen sulfide. Probably the crust and underlying mud are typical of the area.

The origin of the salt crystals is not known. They may form as water evaporates from the shallow water table, but more probably they are deposited from water that occasionally occupies the area during the winter and early spring when the precipitation and runoff reach a maximum. The crystals are highly soluble and would dissolve if covered with fresh water, and be deposited again when the standing water evaporates.

It is difficult to estimate the rate of evaporation in this area. However, because the water table is essentially at the surface and the salt crust is very porous, the annual rate of evaporation may be on the order of a few thousand acre-feet.

PHREATOPHYTES

Greasewood, saltbush, and saltgrass are the main phreatophytes (plants which send their roots to the water table or to the capillary fringe above it) in the valley. They grow in several areas which are generally just outside the edge of the mud flat. The greasewood and associated saltbush grow where the estimated depth to water ranges from 1 to 40 feet. Their density is only about 10 percent of optimum density. The saltgrass grows in areas where the water table is between about 1 and 10 feet below the land surface. Its density is less than 50 percent of optimum density.

The total area covered by phreatophytes is about 5,200 acres, of which 4,700 acres is covered by greasewood and saltbush and 500 acres by saltgrass. It is estimated, on the basis of work by White (1932) in Escalante Valley, Utah, that the greasewood and associated saltbush transpire about 700 acre-feet of ground water annually, and the saltgrass about 500 acre-feet.

SPRINGS AND SEEPS

Numerous springs and seeps annually discharge a total of about 2,000 acre-feet of ground water. The springs occur chiefly along a line that roughly parallels the bedrock-alluvium contact at the west side of the valley. (See fig. 2 for the location of the larger springs.) Each spring generally discharges only a trickle of water, but one (locality 3), in T. 27 N., R. 23 E., discharges about 50 gpm. A spring (locality 5) at the eastern edge of the mud flat in T. 26 N., R. 24 E., discharges at the rate of about 100 gpm. This is the only large spring that issues from the fine-grained sediments in the west-central part of the mud flat. Although it is difficult to determine the total discharge of the many small springs, an estimate of 2,000 acre-feet per year is a crude measure of the total spring discharge in the valley.

GROUND-WATER INVENTORY

In a ground-water basin, such as Winnemucca Lake Valley, under natural conditions the average annual recharge is equal to the average annual discharge. Ground-water recharge is estimated to average about 8,000 acre-feet per year.

Ground-water discharge by evaporation from the water table and the capillary fringe cannot be determined accurately owing to a lack of data, but it probably is several thousand acre-feet per year. The estimated discharge by phreatophytes is about 1,200 acre-feet per year, and discharge by springs (most of the water later being evaporated or transpired), about 2,000 acre-feet per year. These crude estimates suggest a figure for the average annual discharge from the ground-water reservoir of about the same order of magnitude as that for the average annual recharge. Probably the average annual increment to ground water in Winnemucca Lake Valley is 5,000 to 10,000 acre-feet.

CHEMICAL QUALITY OF THE GROUND WATER

Chemical analyses of water from 2 springs, 1 shallow well, and 1 test boring are given in table 1. In addition to the data given in the table the specific conductance was determined for samples from two shallow test borings—one (locality 6) at the south end of the valley in T. 25 N., R. 23 E. and the other (locality 7) in the north-central part in T. 27 N., R. 23 E. The specific conductance of the sample from the test boring in the south was 36,000 micromhos per centimeter at 25° C; that of the sample from the other test boring, where the water table is only about 1½ feet below the surface, was 150,000 micromhos per centimeter at 25° C. These determinations indicate that the ground water is very saline, especially in the central part of the valley.

A sample from a spring (locality 3) in T. 27 N., R. 23 E., contains only 189 ppm (parts per million) of dissolved solids, and although the water is of a sodium bicarbonate type it is suitable for irrigation except for certain sodium and boron-sensitive crops, according to standards established by Wilcox (1955). It is satisfactory for domestic use.

The other three samples analyzed were collected from a shallow well (locality 1) in T. 25 N., R. 23 E., a test boring (locality 2) in T. 26 N., R. 23 E., and a spring (locality 4) in T. 27 N., R. 23 E., on the west side of the valley floor. They are highly mineralized and are not satisfactory either for irrigation or domestic use. Sodium and chloride are the predominant ions, although the sample from the spring at locality 4 also contains a proportionately large amount of bicarbonate ion.

The chemical analyses and the determinations of specific conductance, although of samples from few localities indicate that ground water beneath the valley floor in large part is highly mineralized. The high degree of mineralization undoubtedly is due in part to the saline material in the sediments of the valley fill, but also to the concentration of salts at or near the land surface as a result of evaporation of ground water from the capillary fringe.

Samples of water could not be obtained from deep wells; therefore, it is not known whether water at depth is less mineralized than the water in the shallow zones. In many ground-water basins of internal drainage the water at a depth of several hundred feet is of better chemical quality than that at shallow depth.

DEVELOPMENT OF GROUND WATER

Water is being pumped from only one stock well (locality 1) in the southeastern part of the valley floor. In addition, water from the

TABLE 1.—*Chemical analyses of water in Winnemucca Lake Valley, Pershing and Washoe Counties, Nev.*

[Analyses by U.S. Geological Survey. Source of sample: S, spring; T, test boring; W, well; Carbonate (CO_3), Phosphate (PO_4), Lithium (Li), Strontium (Sr), Aluminum (Al); 0.00 ppm unless indicated otherwise in "Remarks" column]

Locality number	Location	Source of sample	Depth of well (feet)	Date collected	Specific conductance (micromhos at 25° C)	Dissolved solids (ppm)	Constituents (ppm)											Hardness as $CaCO_3$		pH	Remarks
							Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Total	Noncarbonate		
1.	T. 25 N., R. 23 E.	W	11½	6-17-59	17,200	11,100	11	0.26	4.2	4.5	4,350	744	918	5,290	2.8	5.1	8.8	29	0	8.7	CO_3, 128; PO_4, 2.7; Li, 0.2; Sr, 8.0
2.	T. 26 N., R. 23 E.	T	2	6-24-59	7,010	4,340	14	.10	2.8	3.3	1,700	708	305	1,790	1.9	5.8	5.3	20	0	9.3	CO_3, 159; PO_4, 1.8; Li, 0.2; Sr, 4.0; Al, 1.2
3.	T. 27 N., R. 23 E.	S	......	6-18-59	241	189	69	.16	14	2.3	31	97	12	9	.3	2.6	.42	44	0	7.8	PO_4, 0.1; Sr, 0.3
4.	T. 27 N., R. 23 E.	S	......	6-22-59	3,670	2,220	38	.23	23	3.3	849	744	149	775	2.9	4.1	3.4	70	0	7.5	PO_4, 2.0; Sr, 2.1

spring at locality 3 is used to irrigate a garden and for domestic supply.

Moderate supplies of water probably could be obtained from wells drilled into saturated zones in the coarse-grained Lake Lahontan sediments that underlie the piedmont slopes. The older alluvial-fan deposits at the base of the Selenite Range may yield moderate quantities of water to wells drilled near the toe of the fans, but the depth to water may be more than 200 feet.

The presence of coarse sand and gravel on the surface at the southern part of the valley floor suggests that similar material may be present at depth. Although the deposits may be very permeable and transmit water readily, the quality of the water may be unsatisfactory for most purposes.

It is doubtful that large amounts of ground water can be withdrawn from the sediments of the valley fill on a perennial basis without causing a deterioration in the quality of the ground water in the vicinity of the pumped wells. Although wells drilled in the material underlying the piedmont slopes may strike water of good chemical quality, large withdrawals from such wells over a long period might result in a reversal of the natural gradient of the water table, eventually allowing the highly mineralized ground water in the central part of the valley to move laterally toward the wells and contaminate them.

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