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WATER RESOURCES BULLETIN NO. 13

GEOLOGY AND GROUND-WATER RESOURCES OF BUENA VISTA VALLEY, PERSHING COUNTY, NEVADA

By O. J. LOELTZ and D. A. PHOENIX

WITH A STATEMENT ON

RECONNAISSANCE LAND CLASSIFICATION OF BUENA VISTA VALLEY, PERSHING COUNTY, NEVADA

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Prepared cooperatively by the
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FOREWORD

This report is the thirteenth in the series of Nevada Water Resources Bulletins prepared by the U. S. Geological Survey in cooperation with the office of State Engineer.

Buena Vista Valley is a typical Nevada valley which has a limited water supply in relation to arable lands. The report indicates an average annual recharge of about 10,000 acre-feet per year which will be sufficient to irrigate approximately 3,000 acres of land. Continued work such as the measuring of wells, pumping tests and inventories of ground-water withdrawals will be carried on as the valley develops agriculturally so that at a later date a more detailed analysis can be made as to the average annual recharge to the valley.

In general, the cooperative ground-water program consists of individual studies of the various ground-water basins throughout the State, thus enabling us to ascertain the approximate amount of ground water that can be developed; a continuing follow-up study of these basins as ground water is developed, and the maintenance of a state-wide network of observation wells.

At the present time studies are being made in ten valleys heretofore unreported upon. In addition, due to the very rapid development within the Las Vegas Basin, a ground-water study is now being made which will supplement the study reported in Bulletin No. 5.

The future development of Nevada will depend to a large extent upon being able to fully utilize and protect our renewable ground-water resources. The necessity of continuing this cooperative program with the U. S. Geological Survey must not be minimized.

Hugh A. Shamberger

State Engineer.

April 28, 1955

GEOLOGY AND GROUND-WATER RESOURCES OF BUENA VISTA VALLEY, PERSHING COUNTY, NEVADA

BY

O. J. LOELTZ AND D. A. PHOENIX

ABSTRACT

Buena Vista Valley, in west-central Nevada, is a typical intermontane basin of the Great Basin section of the Basin and Range province. It is bounded on the west by the northern echelon of the Humboldt Range and on the east by the lower lying East and Stillwater Ranges. Most of the 800 square miles within its borders drains to a playa at the south end of the valley.

The bordering mountains are composed of great thicknesses of sedimentary and volcanic rocks of Paleozoic and Triassic age which have been strongly deformed. These are intruded by Upper Jurassic(?) plutonic rocks. Tertiary lava flows, erupted after a long period of erosion, cap the older rocks. Large-scale normal faulting contemporaneous with and later than this vulcanism is responsible for the present-day relief. Sediments of Tertiary and Quaternary (Pleistocene) age compose the valley fill.

In the consolidated rocks of the mountains ground water commonly occurs in joints and along bedding-plane fractures and fault zones. Therefore it seems probable that only small quantities of water can be developed from these rocks. The best prospects for obtaining large supplies of water lie in the sand and gravel aquifers underlying the alluvial apron, for although the lake and playa deposits in the central part of the valley may contain the greater part of the total ground-water supply they are ordinarily so fine grained that it is impractical to develop water from them at reasonably large rates.

Precipitation on the drainage basin is the source of recharge to the ground-water reservoir. The average recharge is estimated to be about 10,000 acre-feet per year and appears to be in balance with the average annual discharge. Most of the discharge is by evapotranspiration, the average annual discharge by springs and wells being only about 200 acre-feet each.

Most of the samples of water that were analyzed were classified as excellent to good for irrigation and, except for being hard, as excellent for domestic use. However, a sample of water containing about 12,000 parts per million of dissolved solids was collected

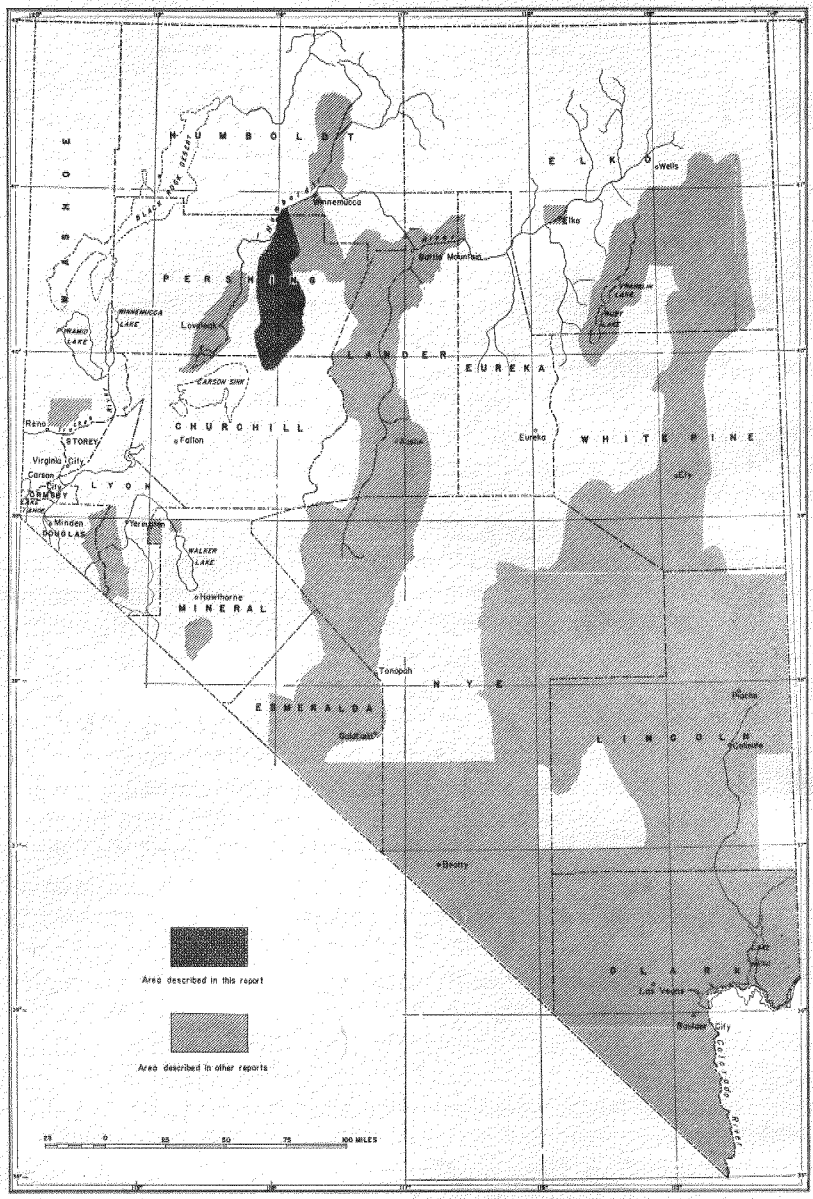

Figure 1.—Map of Nevada showing areas covered by other ground-water reports and by the present report.

from one well. Ground water satisfactory for irrigation and domestic use underlies much of the alluvial apron fronting the bordering mountains.

The potential agricultural lands are mostly on the lower slopes of the large alluvial fans and almost entirely on the west side of the valley. About 4,500 acres of Class I land are considered suitable for agricultural development by use of irrigation wells. An additional 5,000 acres of Class II land are capable of reclamation but the water supply is probably too limited for extensive development of this land.

INTRODUCTION

Purpose and Scope of the Investigation

This investigation of the geology and ground-water resources of Buena Vista Valley is part of the state-wide program under the direction of the U. S. Geological Survey in cooperation with the State Engineer of Nevada for evaluating the ground-water resources of the State. The U. S. Geological Survey is represented in the joint program by O. J. Loeltz, District Engineer for the Ground Water Branch in Nevada; and the State, by Hugh A. Shamberger, State Engineer.

The geologic portion of the report describes the general geologic features and discusses the water-bearing properties of the rocks. The ground-water portion includes a discussion of the occurrence and movement of ground water and gives estimates of average annual recharge and discharge. It includes also a brief discussion of the suitability of water for irrigation on the basis of chemical analysis of representative samples. Tables at the end of the report list data pertinent to selected wells and springs in the valley.

Field work was done in the fall of 1947 by D. A. Phoenix, geologist. Additional field work was done in later years by T. W. Robinson, engineer, and by O. J. Loeltz, who wrote the bulk of the report. Field work was completed in September 1953.

Geographical Sketch

Buena Vista Valley is in Pershing County, in west-central Nevada. (See fig. 1.) The maximum length between its drainage boundaries is about 55 miles and the maximum width about 22 miles. Its area is about 800 square miles. It is bounded on the west by the Humboldt Range and on the east by the connected East and Stillwater Ranges. Low-lying spurs of these ranges form the north and south boundaries.

State Highway 50, a gravel-surfaced road along the west side

of the northern half of the valley, joins U. S. Highway 40 at two points. One junction near Oreana, in the valley of the Humboldt River, is reached by crossing the Humboldt Range via a pass at the upper end of Spring Valley, and the other junction, near Mill City about 30 miles farther up the Humboldt River, is reached by passing through a small canyon in the foothills at the north end of the valley. The Southern Pacific Railroad offers shipping facilities at both junction points. There are few other surfaced roads in the valley, although there is an extensive network of fair-weather roads and trails.

There are no towns in the valley. The center of habitation is the once-thriving mining camp of Unionville in Big Canyon on the east flank of the Humboldt Range. The county seat is Lovelock, a thriving community in the valley of the Humboldt River about 12 miles south of Oreana, or about 37 miles by highway from Unionville.

The raising of livestock is the principal means of livelihood. Considerable hay is raised by irrigating fields and meadows with water diverted from streams heading in the Humboldt Range. Irrigation by pumping ground water has been significant for only a few years. Mining is but a minor activity.

Historical Sketch

The early settlers of Buena Vista Valley were miners drawn to the area by the discovery of rich mineral deposits. Silver, gold, lead, antimony, and quicksilver were mined in the Humboldt Range. Much of the gold in Big, Cottonwood, Spring, and American Canyons, which drain the east flank of the Humboldt Range, was recovered by placer mining. Unionville, in Big Canyon, was founded in 1861. It was the center of activity and until 1873 was the county seat of Humboldt County. The population of the town in its best days was variously estimated at 600 to 1,500 (Thompson and West, 1881). The early residents of Lovelock report that between the years 1884 and 1895 there were almost 3,000 Chinese engaged in placer mining in the canyons (Vanderburg, 1936).

Because of the then long distance to the railroad and outside communities, the demand for local foodstuffs was great. Consequently, orchards and gardens were planted in Big Canyon, and hay, grain, and livestock were raised in the valley. Although local farms undoubtedly furnished much of the perishable food, it is doubtful if the population was entirely independent of outside produce.

Today, only a few of the original adobe buildings of Unionville remain and the Chinese population has disappeared.

Numbering System for Wells and Springs

The number assigned to a well or spring in this report both identifies and locates the well or spring. The number is based on the Bureau of Land Management system of land division. A typical number consists of three units. The first is the township number north of the Mount Diablo base. The second unit, separated from the first by a slant, is the range number east of the Mount Diablo meridian. The third unit, separated by a dash, is the section number. This is followed by an uppercase letter to denote the quarter section in which the well or spring is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter sections. Finally, the consecutive numbers beginning with 1 show the order in which the well or spring was recorded in the quarter section. For example, the number 30/35–32D2 designates the second well recorded in the SE¼ sec. 32, T. 30 N., R. 35 E., Mount Diablo base and meridian.

On plate 1 only that part of the number designating the quarter section and the order in which the well or spring was recorded in the quarter section is shown. The section number can be ascertained from the corresponding section number in T. 26 N., R. 33 E. Township and range numbers are shown on the edges of the plate.

CLIMATE

The climate of Buena Vista Valley is arid to semiarid. Precipitation on the valley floor probably averages about 6 inches annually. However, in the bordering mountains, especially on the higher slopes, precipitation is much greater, and near the highest peaks it may exceed 15 inches. Most of the precipitation in the mountains occurs as snow during the winter months, but occasionally considerable precipitation is received from heavy rains in the spring or fall.

A climatological station was maintained in the valley from 1940 to 1947 during which time precipitation and temperature data were recorded at an airfield known as Humboldt Field in the SW¼ sec. 27, T. 26 N., R. 34 E. The station was abandoned in 1947 when the airfield was deactivated.

Table 1 (p. 12) contains the available precipitation data for this station, as compiled by the U. S. Weather Bureau.

During the 7-year period of record, the annual precipitation

TABLE I

Precipitation, in inches, during the period 1940–1947, at Humboldt Field station, Pershing County, Nevada, from records of U. S. Weather Bureau

(Altitude 4,160 feet; location, SW¼ sec. 27, T. 26 N., R. 34 E.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	3.10	1.35	0.81	0.69	0.27	0.50	0.02	*	0.80	1.52	0.57	1.95	11.58
1941	.81	.69	.24	1.45	.24	1.58	.37	1.10	.32	1.58	.65	1.07	10.10
1942	.86	.54	.64	.96	1.07	.30	.00	*	.10	.02	.43	.63	5.55
1943	1.32	.51	1.18	.20	.48	.91	.18	*	*	1.23	.34	.39	6.74
1944	.55	3.25	.18	.74	.43	1.27	*	.00	.41	.67	1.56	.21	9.27
1945	.56	1.64	1.13	.05	.63	.77	.06	.24	.02	.68	.18	.60	6.56
1946	.01	.17	1.03	*	.98	*	.86	*	.26	1.78	1.04	.50	6.63
1947	.08	.21	.44	.43	.27	.15	.00	*	.04	.47	----	----	----

*Trace.

averaged 8.06 inches. However, a 7-year period of record ordinarily is much too short to reliably indicate average climatic conditions. In order to ascertain what the long-term record might be, it is necessary to make use of a climatological station outside the valley. The climatological station at Imlay, in sec. 9, T. 32 N., R. 43 E., appears most suitable for this purpose. It is in the valley of the Humboldt River about 5 miles west of the point where State Highway 50, which leaves the north end of Buena Vista Valley, joins U. S. Highway 40. Its altitude of 4,209 feet compares favorably with the altitude of the lower parts of Buena Vista Valley. Although the climate at this station is undoubtedly influenced somewhat by the Humboldt Range, it should nevertheless give an indication of the climate at comparable altitudes in Buena Vista Valley. Table 2 lists the normal monthly precipitation at Imlay based on 79 years of record through 1951.

TABLE 2

Normal monthly and annual precipitation at Imlay, Pershing County, Nevada, from records of U. S. Weather Bureau

(Altitude 4,209 feet; 79 years of record through 1951)

Month	Normal (inches)	Normal (percentage)	Month	Normal (inches)	Normal (percentage)
January	0.66	11.8	July	0.11	2.0
February	.66	11.8	August	.55	2.7
March	.50	9.0	September	.26	4.7
April	.52	9.3	October	.49	8.8
May	.69	12.4	November	.45	8.1
June	.39	7.0	December	.69	12.4
			Annual	5.57	100.0

The average annual precipitation of 5.57 inches at Imlay for the 79-year period of record is considerably less than the average of 8.06 inches for the Humboldt Field station for the years 1940–1946. Although precipitation data at Imlay for the years 1940–1946 is incomplete, it appears that the average annual precipitation for the 7-year period was about 7.3 inches, or 1.7 inches greater than the 79-year normal. It seems reasonable to assume, therefore, that the average annual precipitation at Humboldt Field station is probably between 6 and 7 inches and that this rate of precipitation approximates the average annual precipitation in the lower lying parts of Buena Vista Valley.

Table 3 lists the available data regarding killing frosts at the Humboldt Field station.

TABLE 3

Killing frosts at Humboldt Field station, Pershing County, Nevada, 1941–1947, from records of U. S. Weather Bureau

(Altitude 4,160 feet; location, SW¼ sec. 27, T. 26 N., R. 34 E.)

Year	Last in spring	First in fall
1941	June 26	September 12
1942	June 13*	August 18*
1943	June 4*	October 12*
1944	May 25*	September 15*
1945	June 15*	September 19*
1946	May 31*	September 17*
1947	May 11	September 19

*No frost reported; last date in spring and first in fall are those having a temperature of 32°F or lower.

According to the data in the table the average growing season for the 7-year period of record is 103 days. However, the actual growing season is probably a week or two more than the record indicates, inasmuch as frosts often were not reported, thus making it necessary to assume that a killing frost occurred on the last day in the spring and the first day in the fall that a temperature reading of 32°F or below was observed. At Imlay, the average growing season for the same 7-year period based on a somewhat incomplete record is about 132 days, and based on 23 years of record prior to 1940 is about 125 days. It seems probable, therefore, that the average growing season in Buena Vista Valley is between 105 and 115 days.

Based on 36 years of record through 1951 the mean annual temperature at Imlay is about 50°F; the average January temperature is 27.6°F; and the average July temperature, 74.8°F. Temperature extremes range from —35° to 110°F. Similar data are not available for Buena Vista Valley. However, it is believed that during the colder months the temperatures in the lower parts of Buena Vista Valley generally are somewhat lower than the temperatures at Imlay and that during the summer months the temperatures are comparable.

PHYSIOGRAPHY AND DRAINAGE

Buena Vista Valley lies in the Great Basin section of the Basin and Range province, which is characterized by a series of northerly trending mountain ranges and intermontane valleys filled with detrital material from the adjacent mountains.

The valley is a typical intermontane basin. The sinuous trend of the bordering mountains causes the north-trending axis of the valley to resemble an elongated "S". An alluvial divide near the north end of the valley diverts about one-sixth of the drainage to the valley of the Humboldt River. This minor drainage passes through a small canyon in the foothills at the north end of the

Humboldt Range. Runoff from the major part of the basin periodically reaches a large playa in the southern part of the valley where it evaporates.

The valley is bounded on the west by the northern part of the Humboldt Range. Crest altitudes are generally about 9,000 feet above mean sea level, or about 5,000 feet above the playa at the south end of the valley. The crest reaches a maximum altitude of 9,835 feet at Star Peak near the north end of the range. About 14 miles south of Star Peak the crest drops rather abruptly to about 6,200 feet, forming a pass over which State Highway 50 has been built. South of the pass the crest rises to about 7,500 feet, reaching a high point at Buffalo Mountain, 8,196 feet above mean sea level.

A northerly trending range of mountains, broken by intervening passes, borders the east side of the valley. McKinney Pass, about due east of the center of the playa in the south end of the valley, separates the range into two parts. The part north of the pass is named the East Range and the part south of the pass, the Stillwater Range.

The East Range has an altitude of 7,430 feet at Dun Glen Peak, about 2 miles beyond the northern limit of plate 1. The crest then drops to somewhat lower altitudes toward the south, reaching a low point of about 6,000 feet at Natchez Pass, a low divide 7 miles south of Dun Glen Peak. Eleven miles south of Natchez Pass the range crest peaks at an altitude of 8,263 feet. The unnamed peak is 14 miles east of Star Peak, the highest peak of the Humboldt Range. The alluvial divide which separates Buena Vista Valley into two drainage basins lies between these two peaks. South of the unnamed peak the range crest is generally at lower altitudes. However, at a point about 19 miles farther south the crest rises rapidly to the summit of Granite Mountain, 8,461 feet above sea level. Four miles south of Granite Mountain, at McKinney Pass, the altitude of the crest drops to about 5,500 feet.

As previously stated, the Stillwater Range lies south of the pass. It trends south for about 12 miles and then swings southwestward. Crest altitudes are about 7,000 feet. A low-lying spur from this range projects northwestward to join low hills extending southward from the Humboldt Range, thus forming the southern boundary of the drainage basin.

Several perennial streams head in the Humboldt Range on the west side of the valley. Star, Coyote, and Big Canyons normally carry water throughout the year. Cottonwood Canyon and Spring

Valley likewise have perennial streams, although the flow of the streams in late summer and fall is generally negligible. American Canyon is usually dry, although springs near the head of the canyon discharge a small amount of water that probably enters Buena Vista Valley as underflow.

The west flank of the East and Stillwater Ranges which forms the east boundary of the valley is dissected by many canyons. Most of the canyons are normally dry. However, during a few months in the spring and for a short time after an occasional severe summer thunderstorm, they may carry considerable water.

Over a long period of years the streams heading in the bordering mountains have built up extensive coalescing alluvial fans that extend as much as 5 miles from the mouths of the canyons toward the axis of the valley.

Well defined wave-cut terraces have been eroded on the midslopes of the alluvial fans. These terraces are evidence that the valley was flooded by a lake which was, without a doubt, at one time an arm of Lake Lahontan, an extensive Quaternary lake that covered much of northwest Nevada. Well preserved beach terraces in Lovelock Valley to the west of Buena Vista Valley indicate that the high-water stage of Lake Lahontan was at an elevation of slightly more than 4,400 feet (Robinson, 1946, p. 11). Inasmuch as the lowest barrier between Buena Vista and Lovelock Valleys has an altitude of about 4,120 feet, the lake in Buena Vista Valley must have been part of Lake Lahontan, at least while Lake Lahontan was at its higher stages.

Some of the most prominent shorelines are shown on plate 1. The highest well defined shorelines had altitudes ranging from 4,340 to 4,360 feet, as determined by altimeter readings.

Points at which prominent shorelines were noted and the respective altitudes are as follows:

Location	Feet above sea level
SW¼ sec. 17, T. 29 N., R. 35 E.	4,360
SW¼ sec. 29, T. 29 N., R. 35 E.	4,360
NW¼ sec. 11, T. 29 N., R. 36 E.	4,340
SE¼ sec. 20, T. 30 N., R. 35 E.	4,350

In addition, a prominent wave-cut niche was observed in volcanic rock in the NW¼ sec. 14, T. 26 N., R. 34 E., at an altitude of 4,360 feet. These highest prominent shorelines are at about the same altitude as the crest of the low hills enclosing the south end of Buena Vista Valley. This suggests that the hills may have acted as a control for the stage of the lake. The lake, thus maintained at this stage for relatively long periods of time, was able to develop the more prominent shoreline features.

Possible shoreline features noted at elevations above 4,400 feet indicate that the Humboldt Range was at one time completely surrounded by Lake Lahontan. One such feature was noted just east of well 31/35–16C1. Here the alluvial apron of the East Range slopes gently westward to a line several hundred feet east of the well and then drops abruptly about 10 feet to a plain that is almost flat in an east-west direction. The altitude of the land surface at the well, as determined from altimeter readings, is about 4,410 feet above mean sea level. Other breaks in the slope of the alluvial apron were noted farther north. Another possible lake feature was noted near the highest point along the axis of the valley near the north end of T. 31 N., R. 35 E., where according to the topographic map of the Lovelock quadrangle, Nevada, the altitude is 4,414 feet. A possible lake feature here is a plain of fine sediments a mile or more wide bordered on the east and west by gently sloping alluvial aprons which at many places along the border drop abruptly 3 feet or more to the plain. The abrupt drops are believed to be former shorelines.

Paul F. Kerr, as cited by Jenney (1935, p. 69–70), also concluded that the Humboldt Range, although mapped by Russell (1885) as a peninsula, was in reality an island during the highest stage of Lake Lahontan.

The lake had a maximum depth of about 400 feet in Buena Vista Valley. As Lake Lahontan began to recede, the Humboldt Range was no longer isolated from the East Range but connected to it by the alluvial divide east of Star Peak. As Lake Lahontan receded still more, the connection between the Buena Vista arm and the main lake became narrower and less deep until eventually it ceased to exist and a separate lake was created in Buena Vista Valley. This lake was probably less than 75 feet deep. Its complete desiccation has exposed the large lake plain in the south end of the valley.

GEOLOGY

The geology of parts of the Humboldt Range has been described by Louderback (1904), Knopf (1924), and Jenney (1935), and the geology of the East and Stillwater Ranges by Ferguson, Muller, and Roberts (1951).

Briefly stated, the mountains are composed of a great thickness of sedimentary and volcanic rocks of Paleozoic and Triassic age which are strongly deformed and whose mutual relationships are difficult to ascertain. These are intruded by Upper Jurassic(?) plutonic rocks which are believed to be contemporaneous with the Sierra Nevada batholith. Tertiary lava flows, which erupted after

a long period of erosion, overlie the older rocks. Large-scale normal faulting contemporaneous with and later than this vulcanism is directly or indirectly responsible for the relief of the mountains today. The valley fill is composed of sediments of Tertiary and Quaternary (Pleistocene) age.

Water-Bearing Characteristics of the Rocks

The water-bearing characteristics of the rocks in the mountains are known only as revealed by the underground exploration for minerals. To date no large supplies of water have been found, although a number of mines have encountered water.

PERMIAN ROCKS

Koipato formation.—The oldest rocks exposed in the central Humboldt Range are a group of Permian volcanic rocks referred to as the Koipato formation, which consists of a mixture of flows and pyroclastic rocks some 6,000 feet thick, overlain by some 5,000 feet of rhyolite. Rhyolite tuff and flows 3,000 to 4,000 feet thick complete the sequence.

Because of the generally low permeability of these rocks the prospects of obtaining water from them are poor. However, it is possible that small supplies may be developed locally in favorable locations such as openings in fractured zones.

TRIASSIC ROCKS

Star Peak formation.—The Star Peak formation is composed of a generally dark-gray massive limestone about 2,000 feet thick and is probably present along the entire length of the Humboldt Range. There is no evidence to indicate that the limestone of the Star Peak formation has cavernous zones that might act as good aquifers. However, some water was encountered in fractured and brecciated limestone in the Pershing and the Montgomery quicksilver mines. In the Pershing mine the water level was about 100 feet below the portal of the No. 3 adit, or about 4,300 feet above sea level. In the Montgomery mine the water level in 1942 was 80 feet below the portal of the adit or about 4,131 feet above sea level. (Bailey and Phoenix, 1944.)

JURASSIC AND CRETACEOUS ROCKS

The Jurassic and Cretaceous rocks are igneous intrusives. They consist principally of diorite, aplite, granite porphyry, and granite. It is very improbable that a satisfactory supply of water can be developed in these rocks.

TERTIARY ROCKS

Truckee formation.—Continental sediments of the Truckee formation of Miocene age are not exposed in Buena Vista Valley, but they have been described in nearby localities (Louderback, 1904, p. 301). Typically they consist of fine-grained and varicolored lake and playa deposits, olive and terra-cotta silts, and white diatomite and volcanic ash. This formation is usually exposed along the flanks of the ranges where the sediments are tilted, faulted, and often overlain unconformably by basalt flows. Valleyward the lake sediments and basalt flows are covered by alluvium or lake deposits.

It is probable that Miocene sediments of the Truckee formation underlie the valley fill at depth. Wells penetrating sediments thought to represent the Truckee formation ordinarily yield water at low to moderate rates.

Alluvial-cone deposits of Pliocene(?) age.—Coarse detrital material containing boulders and fragments of the Koipato and Star Peak formations has been deposited at the base of the Humboldt Range. Knopf (1924, p. 41) described this material as alluvial-cone debris "laid down at a time when the nearby country was of considerable relief and the streams that flowed from it were of great carrying power—in short, the alluvial deposits are the cones that were built up at the mouths of the canyons that indented the escarpment of a youthful fault-block range." The deposits are more than 500 feet thick and are overlain by basalt flows. Jenney (1935, p. 57) correlates the formation of the alluvial-cone detritus with a period of stability which followed the initial uplift of the northern Humboldt Range relative to the basins and the southern block. Inasmuch as the streams transporting this alluvial detritus had great carrying power, it is probable that some of the coarse sediments were eventually deposited some distance from the north block of the Humboldt Range, thus forming fair to good aquifers in the valley fill on the west side of the valley. Elsewhere, the Pliocene deposits of the valley fill are probably finer grained and thus poorer aquifers.

Basalt.—Basalt flows locally lie unconformably on an erosion surface on Triassic limestone at the east side of the Humboldt Range from American Canyon to the south end of the range. Knopf (1924, p. 37) found that basalt flows also overlie Pliocene(?) alluvial-fan deposits in the vicinity of Black Knob, and Louderback (1904, p. 301) found basalt unconformably overlying the Truckee formation of Miocene age in the southern part of the

Humboldt Range south of Buena Vista Valley. North of American Canyon, only scattered outcrops have been noted on the eastern slope of the range.

Cameron (1939, p. 588–590) noted that just below the mouth of Cottonwood Canyon basalt crops out as a small isolated knob in the alluvial-fan gravels. The top of the knob slopes gently southeastward but there was no definite indication of the attitude of the flow. Farther north, at Santa Clara Canyon, he noted basalt and trachyte tuff in contact with trachyte porphyry dipping toward the valley at about 20°.

Muller (1951) shows that similar basalt flows are widespread on the east slope of the East Range, extending southward from a line about east of Sulphur Canyon to a line about east of McClure Canyon, and that basalt flows also cap the crest of the Stillwater Range south of Logan Canyon.

The texture of the rocks varies considerably. Generally, the basalt is described as being highly vesicular. However, Knopf (1924, p. 37) describes the basalt from Little Black Knob, which is less than a mile east of Black Knob, as compact and nonporphyritic. Muller (1951) indicates that the texture of the mapped basalt in the East Range and Stillwater Range varies from scoriaceous and ropy to massive.

In view of the eastern dip of the flows on the east flank of the Humboldt Range the possibility exists that basalt flows may be encountered beneath the floor of the valley, especially in the southern part of the basin. If these flows are sufficiently jointed they might form good aquifers.

QUATERNARY ROCKS

Older Quaternary(?) deposits.—Older alluvial deposits floor some of the highland basins of the bordering mountains and undoubtedly underlie the floor of Buena Vista Valley. The age of the deposits is not known but they are believed to have been deposited during a period of stability between periods of Basin and Range faulting.

These older alluvial deposits have been explored by wells to a depth of 161 feet in Spring Valley, a typical highland basin in the Humboldt Range about opposite the center of Buena Vista Valley. Four gravel strata were encountered in well 29/34–34D1, none of which was more than 7 feet thick. The intervening material consisted of mixed sand and clay, or red or yellow clay. The gravel strata were 15 to 20, 83 to 87, 115 to 122, and 154 to 161 feet below the land surface. According to the driller's log the well

flowed 48 gallons per minute when completed in November 1947.

Well 29/34–34D2, which is 136 feet deep, penetrated more clay than did well 29/34–34D1. The driller reported a flow of 3 or 4 gallons per minute upon completion of the well in April 1948. In July 1949, after the well had been pumped about 4 hours it was yielding about 150 gallons per minute and the water level was 69 feet below the land surface. A specific capacity in the neighborhood of 2 gallons per minute per foot of drawdown is thus indicated.

The yield of these two wells suggests that the alluvium in Spring Valley does not contain aquifers of high permeability. The water in both wells is warm, suggesting the possibility that it has circulated deeply along a fault zone, which may be a northward extension of the major fault zone paralleling the east side of the crest of the range mapped by Knopf (1924, pl. 1).

Alluvium.—Quaternary alluvial-fan debris extends outward from the mouths of the canyons toward the valley floor as much as 5 miles. Many of the fans have coalesced to form an undulating alluvial apron along the range fronts.

Near the mouths of the canyons the sediments generally are poorly sorted and are not good aquifers. At the mouth of Spring Valley ground water being discharged from the sides of excavations made during dredging operations was coming from small local gravel lenses.

Three exploration holes, 160, 169, and 170 feet deep, were drilled about 300 yards below the mouth of American Canyon in 1947 by the Yuba Consolidated Goldfield Placer Co. of San Francisco. The materials penetrated were gravel and cobbles mixed with clay. No water was encountered.

The middle and lower slopes of the alluvial fans are more likely to be underlain by good aquifers because the larger particles have had an opportunity to become rounded and better assorted, and much of the finer material kept in suspension has been carried on to the lower parts of the valley.

The middle and lower slopes of the alluvial apron fronting the Humboldt Range have been prospected for water by means of several rather widely separated wells. Well 30/35–5C1, drilled to a depth of 302 feet, encountered gravel and clay strata to a depth of 290 feet, below which a water-bearing stratum of gravel and sand was logged by the driller. The gravel penetrated by this well generally was poorly sorted. Although a satisfactory drawdown measurement was not made, it is estimated that the well yields

about 10 gallons per minute per foot of drawdown when pumped at the rate of about 350 gallons per minute.

Well 30/35–21B2, somewhat lower on the alluvial fan, penetrated alternating strata of gravel, sand, and clay throughout its entire depth of 374 feet. Evidently, some of the sand and gravel strata must be fairly well sorted and relatively free of silt and clay, because the well yielded about 32 gallons per minute per foot of drawdown when tested on June 30, 1950. The well had been pumping continuously for several days prior to the determinations of yield and drawdown.

Farther valleyward the sediments become increasingly finer grained. For example, the log of well 33/35–27A1, which was drilled to a depth of 615 feet, showed an appreciable increase in the percentage of sand, silt, and clay as compared to the percentage of these sediments in the wells previously described.

Thus the water-bearing characteristics of the alluvial-fan deposits vary greatly. It is impossible to predict with certainty whether good aquifers underlie any particular location. However, as a general rule, the better aquifers are usually found in fans built up by the larger streams and in a belt lying between the midpoint and the toe of the fan.

Lake and playa deposits.—An undetermined thickness of fine-grained deposits underlie the playa in the southern half of Buena Vista Valley. Well 30/35–26B2, which was jetted to a depth of about 500 feet, reportedly penetrated mostly fine-grained material. The log of well 30/35–27A1, drilled to a depth of 615 feet, also indicates that a large percentage of the sediments were fine grained. The yield of the well upon completion as reported by the driller was 450 gallons per minute with a drawdown of 125 feet. This gives a specific capacity of about 3.6 gallons per minute per foot of drawdown for a relatively short period of pumping. At Humboldt Field well 26/34–34B1, drilled to a depth of 400 feet, reportedly penetrated only fine-grained material. Undoubtedly a large part of the sediments penetrated by these wells were deposited during the Pleistocene epoch on the bottom of Lake Lahontan.

Much of the fringe area of the bare playa of the lake plain in the southern part of Buena Vista Valley is covered by sand dunes of Recent age. They have formed mostly near the east and south margins of the playa and probably are in large part lake sediments reworked by the prevailing winds. Alkali salts, the product of many years of evaporation, mantle part of the playa.

Because of the generally fine grain of the sediments composing the deposits underlying the lake plain and playa, wells drilled in

these sediments can be expected to provide only small to moderate yields. In and around the playa the chemical quality of the water has been impaired by solution of the alkali salts that have accumulated in the sediments.

GROUND WATER

Principles of Occurrence

Meinzer (1923a, 1923b) described the occurrence of ground water in the United States and outlined the principles of ground-water hydrology. The following discussion is adapted in large part from his reports.

The rocks of the earth's crust contain numerous open spaces, called voids or interstices, that may be the receptacles of water. Most rocks have minute openings or voids and a few have large openings, such as joints and caverns. When rocks are capable of transmitting water under pressure they are said to be permeable.

Ordinarily below a certain level permeable rocks are saturated with water under hydrostatic pressure and are said to be in the "zone of saturation." The permeable rocks that lie above the zone of saturation are in the "zone of aeration."

The water table is the upper surface of the zone of saturation, except where that surface is formed by an impermeable body. In the zone of aeration immediately above the water table is the capillary fringe. The very small voids in the rocks in this fringe may be completely filled with water but the larger voids are only partially filled. Molecular forces instead of gravitational forces control the movement of water. Therefore, some of the water may be available to plants whose roots penetrate the capillary fringe, but none of the water is available to wells. Ordinarily the thickness of the capillary fringe is dependent on the size of the voids in the sediments. In coarse sands and gravel the thickness may be only a small fraction of a foot whereas in clay it may be 8 feet or more.

Above the capillary fringe is the intermediate or vadose zone. In this zone water not retained by the soil moves toward the water table. Ordinarily the larger voids in this zone are filled with air, although under unusual conditions practically all the voids may be filled with water. In some localities where the water table is near the land surface, the vadose zone may be entirely absent; in other areas it may have a thickness of several hundred feet. At the top of the zone of aeration is the belt of soil water. It lies just below the land surface and holds water by molecular attraction. The thickness of the belt is governed by the size of the voids and

the thickness of the soil. The soil zone usually has to be moistened beyond field capacity before appreciable amounts of water can percolate downward to the water table.

If an impermeable body forms the upper surface of the zone of saturation there is no water table and the water is said to occur under confined or artesian conditions. The imaginary surface to which the water would rise were it free to do so is called the piezometric surface. The height to which the water level in a tightly cased well rises indicates the position of the piezometric surface at that point. If the position of the piezometric surface is determined at a sufficient number of points it is possible by interpolation to draw contours on the piezometric surface and thus determine its position and shape.

Water in the zone of saturation, whether it occurs under water-table or under artesian conditions, moves under the influence of gravity to a point of lesser head. Ordinarily then, the water moves normal to contour lines drawn on the water table or piezometric surface. In alluvial-fan material the rate of movement is much slower than is popularly supposed. It is probable that most of the water moves down the slope of the piezometric surface at a rate considerably less than 50 feet per day. In fine silt and clay the rate of movement may be less than a foot a year. Nevertheless, the water is continually moving toward some point of discharge, be it a spring, stream, or body of surface water, an area of evaporation or transpiration, or a well or other artificial structure.

Under natural conditions and over a long period of time the amount of water entering the zone of saturation is balanced by a like amount discharged from it. However, neither the rate of replenishment nor the rate of discharge is uniform. Consequently, the water table or piezometric surface rises or falls as the amount of ground water in storage increases or decreases.

Artificial withdrawals of water, such as discharge of water by wells, diverts water that otherwise would be discharged by natural means. To the extent that artificial withdrawals are not balanced by a decrease in the natural discharge or by an increase in the natural recharge, or a combination of the two, the artificial withdrawals must be obtained from water in storage in the ground-water reservoir, with a consequent lowering of the water table or piezometric surface.

Occurrence

The rocks of the mountains enclosing Buena Vista Valley and the sediments of the valley fill both contain ground water.

The ground water in the consolidated rocks of the mountains commonly occurs in joints, and along bedding-plane fractures and fault zones. These joints appear to be fairly open and quite numerous and widespread, particularly near the axes of folds judging from field examination of several outcrops, but where encountered below the zone of weathering in mine workings the joints generally are very small. Consequently, it is believed that in most places only small quantities of water can be developed from joints in the consolidated rocks.

In the vicinity of faults, fracturing becomes more pronounced, both on the surface and underground. Inasmuch as fault zones may extend to great depths and can be traced for miles along the land surface, they afford a much better opportunity for the collection and transmission of ground water than do the joints and bedding-plane fractures. A fault zone in the Humboldt Range is believed to pass across the head of South American Canyon, American Canyon, and Spring Valley. Eight springs were noted along its trace in a distance of 4 miles.

Sediments of the valley fill contain large quantities of ground water. That which is most easily obtainable for development is contained in the sand and gravel aquifers underlying the alluvial apron and the valley floor. The greater part of the total supply, however, probably is contained in fine-grained sediments such as silt and clay from which it is difficult if not impractical to develop water at reasonably large rates.

Inventory

In a closed basin the annual recharge plus or minus the change in storage equals the annual discharge. Over a long period of time the average amount of water in storage is more or less constant, thereby making the change in storage negligible. This makes for a very simple ground-water equation—namely that ground-water recharge equals ground-water discharge. By far the greater portion of Buena Vista Valley—that is, the portion south of the drainage divide east of Star Peak ranch—can be considered a closed basin. Consequently, any quantitative study of ground water can be based on the fact that the average long-term recharge to the ground-water reservoir is balanced by the long-term discharge from the reservoir. Unfortunately, the hydrologic data on which such estimates must necessarily be based are meager, especially data regarding precipitation and runoff. Therefore, estimates of the recharge to and discharge from the ground-water

reservoir should be considered as indicating the order of magnitude of the recharge or discharge rather than giving these quantities within close limits.

RECHARGE

The ground-water reservoir is recharged principally by the infiltration of water from streams as they cross the alluvial fans and by infiltration of precipitation on these fans. Some recharge also results from the downward percolation of irrigation water, infiltration of precipitation on the floor of the valley, and possibly upward and lateral percolation of water from the consolidated rocks below the valley fill. The principal source of the recharge is precipitation within the drainage basin. Hardman (1936) compiled a map showing precipitation by zones for the State of Nevada. It furnishes the best available data upon which to base an estimate of the amount and distribution of the average annual precipitation within the valley. The amount and distribution of precipitation above the bedrock-alluvium contact is significant in that most of the recharge to the ground-water reservoir is derived from the infiltration of runoff resulting from precipitation above that contact. A comparison of the precipitation map with the Lovelock and Sonoma Range topographic maps prepared by the U. S. Geological Survey indicates that between the altitudes of 5,500 and 6,500 feet the average annual precipitation is between 8 and 12 inches, and that between altitudes of 6,500 feet and those of the highest peaks the average annual precipitation ranges from 12 to 15 inches. If the area of each zone is multiplied by the average rate of precipitation for the zone, and the quantities thus obtained are summed, an indication of the probable total annual precipitation for the areas lying above the bedrock-alluvium contact is obtained. The total precipitation south of the alluvial divide at the Star Creek ranch thus computed is 117,400 acre-feet. However, only a small part of this total recharges the ground-water reservoir. The greater part of the precipitation evaporates directly or is transpired and therefore does not even contribute to the runoff of the streams. A study of the relationship between total precipitation and stream runoff for the Martin Creek drainage basin in Paradise Valley some 80 miles north of the center of Buena Vista Valley indicated that an average of about 9 inches of precipitation annually was used to satisfy evapotranspiration requirements in mountains having altitudes comparable to those in Buena Vista Valley. If 9 inches of precipitation is deducted from the total precipitation, the probable annual runoff is indicated to be in the neighborhood of 24,500 acre-feet. This method

of computing precipitation and runoff further indicates that about 11,000 acre-feet or almost half the runoff originates in the Humboldt Range and that about two-thirds of the 11,000 acre-feet of runoff is from that portion of the range lying between the Star Creek drainage on the north and the Spring Valley drainage on the south.

Studies of the relationship between runoff and recharge to the ground-water reservoir in Paradise Valley, north of Winnemucca, and Grass Valley, immediately east of Buena Vista Valley, indicate that the recharge to the ground-water reservoir probably does not exceed 40 percent of the estimated runoff at the bedrock-alluvium contact. Considering the apparent opportunity for infiltration of runoff, it seems improbable that the percentage would be any larger for Buena Vista Valley. Accordingly, using the estimated runoff of 24,500 acre-feet, the average annual recharge to the ground-water reservoir probably is about 10,000 acre-feet.

The fallability of the above method must be recognized. The method is based in large part on the assumption that the altitude-precipitation relationship is the same over the entire drainage basin. It has been long recognized that this assumption is not always valid; that many other factors besides altitude affect precipitation. The relationships between precipitation and runoff and between runoff and recharge to the ground-water reservoir likewise are not well known. The assumed relationships were necessarily based on very meager data. However, in spite of these shortcomings, it is believed that the figure of 10,000 acre-feet as the average annual recharge obtained by the above method is at least of the correct order of magnitude.

DISCHARGE

Discharge from the ground-water reservoir is effected largely by evaporation and by transpiration of native vegetation. Discharge by evaporation takes place in areas where the water table, or the capillary fringe above it, reaches the land surface. Discharge by transpiration occurs mainly in areas where the native vegetation consists of phreatophytes—that is, water-loving plants that habitually obtain their water supply from the water table or the capillary fringe above it. Some water is discharged also by springs and seeps and by withdrawals from wells and is ultimately evaporated or transpired.

Evapotranspiration.—The principal area of discharge of ground water by evaporation and transpiration is indicated on plate 1. It includes the lower part of the floor of the valley and, locally, the

lower parts of some of the alluvial fans. The amount of water that is transpired from the vegetated part of the area depends on many factors, principally the species of plant, its density of growth, and the depth to water. A breakdown of these three factors was made in the field within limits justified by the reconnaissance type of investigation.

Greasewood, with an association of saltgrass, rye grass, rabbitbrush, and buffalo berry, transpires considerable ground water. Sagebrush and shadscale also were sometimes associated with greasewood, although they are not phreatophytes. For convenience in discussion, the areas where greasewood is dominant but where there is an association of other plants will be called the greasewood areas. On plate 1, the evapotranspiration areas are shown by two different symbols. The denser symbol indicates areas where the density of growth averages 80 percent or more of that of the densest stands observed growing under the most favorable conditions in the valley. Areas of such growth were noted in secs. 25, 26, 35, and 36, T. 30 N., R. 35 E.

The depth to water in these areas probably ranges from 8 to 30 feet below the land surface. On the basis of the work of White (1932), it is estimated that the average annual rate of use of water by the plants in these areas is 2 acre-inches per acre. Thus the total amount of water discharged annually from the 49,350 acres of 80 plus percent density that were mapped is computed to be about 8,000 acre-feet.

Lying within the area of luxuriant phreatophytes and adjacent to the northern end of the playa is a tract of greasewood and associated vegetation that is quite sparse. In some places the vegetation is interspersed with barren alkali-covered soil and sandy areas. The density of the plants is estimated to be about 50 percent of the optimum density in the valley. The depth to water probably ranges from 3 to 8 feet below the land surface. Because of the fineness of the soil, the capillary fringe undoubtedly extends to the land surface in some parts of the area and thus ground water is discharged by direct evaporation also. On the basis of White's work (1932) in Escalante Valley, Utah, it is estimated that the combined discharge by evaporation and transpiration from the 11,840 acres of this type that were mapped probably amounts to about 3 acre-inches per acre annually, or about 3,000 acre-feet.

The south-central part of the valley is a playa, a part of which generally is covered by surface water in the spring of the year.

The surface water coming onto the playa from small streams sometimes entrenches itself in the silt and clay sediments to form rivulets which later coalesce and form thin sheets of water, especially over the northern part of the playa. This water seldom remains for any length of time. Most of it evaporates as surface water but a small part may percolate downward to the water table.

Discharge from the ground-water reservoir beneath the playa is largely by evaporation from those areas where the capillary fringe reaches the land surface. The sediments underlying the playa are fine grained and, therefore, the capillary fringe may extend to the land surface even though the water table may be 5 feet or more below the playa. However, the rate of evaporation will vary considerably, depending on the depth to the water table and the time of the year, although some evaporation probably takes place throughout the year. Alkali encrustations, locally as much as 2 or 3 inches thick, may lower the rate of evaporation considerably. It is believed that the average annual rate of discharge from about 9,000 acres of the playa where the water table is less than 4 feet below the surface is about 2 acre-inches per acre. In addition to this acreage there is some 30,000 acres of barren playa where the depth to water probably exceeds 4 feet. It is believed that the amount of water discharged annually from the ground-water reservoir beneath this acreage is negligible.

The estimated annual discharge from the ground-water reservoir in 1947 is summarized in table 4.

TABLE 4

Estimated annual discharge of ground water in 1947, in acre-feet, by transpiration and evaporation in the lower part of Buena Vista Valley, Pershing County, Nevada.

Vegetation type	Area (acres)	Estimated discharge (acre-feet)
Greasewood, rabbitbrush, saltgrass, shadscale, etc.	49,350	8,000
Near optimum density of growth for valley.		
Depth to water, 8 to 30 feet.		
Average rate of use, 2 acre-inches per acre per year.		
Greasewood, rabbitbrush, saltgrass, shadscale, etc.	11,840	3,000
Some barren alkali spots.		
About 50 percent of optimum density of growth in the valley.		
Depth to water, 4 to 8 feet.		
Average rate of use, 3 acre-inches per acre per year.		
Bare playa	9,000	1,500
Periodically covered with water, locally alkali encrustations 2 to 3 inches thick.		
Depth to water, 1 to 4 feet.		
Average rate of evaporation, 2 acre-inches per acre per year.		
Total discharge by transpiration and evaporation (approximate)		12,500

Springs.—Ground water is also discharged by springs. Most of the many springs in the mountains discharge ground water from fractures and faults in the consolidated rocks. Their flows are small and are reported to fluctuate with the seasons. The water is utilized extensively by stockmen and miners.

There are also many springs in the lower parts of the basin, most of which occur along and below the shoreline of ancient Lake Lahontan. They are believed to discharge water from the ground-water reservoir of the valley fill. Buffalo Springs, in sec. 2, T. 27 N., R. 35 E., is a well-known spring of this type. It was an early stopping place on the old emigrant trail through Buena Vista Valley but now serves only as a watering site for stock. The discharge of the springs is about 3 gallons per minute.

At least half a dozen springs and numerous seeps occur below the shoreline of Lake Lahontan east of Unionville Canyon. The discharge of the individual spring is small, probably about 1 or 2 gallons per minute. However, seeps and springs arise in an area about a mile long and several hundred yards wide. Luxuriant native vegetation in this area also discharges ground water that otherwise would appear as seeps and springs.

The only known hot spring in the valley is Kyle Hot Springs in sec. 12, T. 29 N., R. 36 E. It is on the upper slope of the alluvial apron fronting the west side of the East Range. A low mound of siliceous sinter about 150 yards in diameter marks the site. Only one natural outlet exists at the present time, although there is evidence of other older outlets that were abandoned and have since filled with rubble. There is no visible discharge, but only a circular pool 6 feet in diameter whose surface is 5 feet below the general land surface. Small amounts of siliceous sinter and sulfur are being deposited around the margin of the pool and the odor of hydrogen sulfide gas is noticeable. The temperature of the water several feet below the surface of the pool was 159°F. The analysis of the water (table 7) shows that it is highly mineralized. Because of the concentration and kinds of minerals the water probably would not be suitable for growing many types of plants. In sufficient quantity it may also act as a purgative for livestock and human beings.

In the past the spring was utilized as a health resort by a few people from Lovelock and other communities. Today, only four small wooden buildings, two of which were evidently steam rooms built over shafts dug to the hot water, attest to the popularity of the site in former years. The water discharged by the spring probably originates from consolidated rocks underlying the valley

fill and therefore probably does not represent discharge from the principal ground-water reservoir.

Wells.—The amount of ground water discharged from wells for domestic and stock use is estimated to be less than 100 acre-feet per year. The discharge of ground water by pumping for irrigation is also small. Prior to 1950 the annual discharge probably was less than 200 acre-feet. In 1950 the discharge was estimated at 835 acre-feet; in 1951, at 550 acre-feet; in 1952, at 140 acre-feet; and in 1953, at 50 acre-feet. The low pumpage during 1952 and 1953 was due in part to the fact that there was an adequate supply of surface water.

SUMMARY

The average annual recharge to the ground-water reservoir was estimated to be about 10,000 acre-feet. The average annual discharge from the ground-water reservoir by evapotranspiration was estimated conservatively to be about 12,500 acre-feet. The discharge by springs and seeps probably is less than 200 acre-feet and the discharge by wells has averaged less than 200 acre-feet, and these amounts, in part, are included in the total of 12,500 acre-feet given above. The total discharge from the ground-water reservoir thus appears to be between 12,500 and 13,000 acre-feet, or about 2,500 to 3,000 acre-feet more than the estimated recharge. Theoretically, in view of the relatively small artificial withdrawals the average annual recharge and the average annual discharge should be about equal. The failure of the two estimates to agree more closely probably is due principally to the lack of adequate data on precipitation and evapotranspiration. In view of the unrefined methods that necessarily were used in arriving at the estimates, it is believed the agreement between the estimates is reasonably close.

Fluctuation of Water Levels

In the discussion of the principles of occurrence of ground water (see pp. 23, 24) it was pointed out that the amount of ground water in storage is not constant, owing to variation in the rates of recharge and discharge. The resulting changes in the volume of water in storage cause corresponding changes in the stage of the water table or piezometric surface, which for all practical purposes can be determined by measurements of the change of water level in wells.

In order to obtain an indication of the changes in ground-water storage in the basin, periodic measurements of water levels were made in representative wells. Periodic measurements were begun

in well 30/35–4C1 on November 10, 1947, and in well 30/35–27B1 on January 7, 1948. (See table 9.) In addition, two or three water-level measurements were made in each of about a dozen other wells during the 1947–1953 period. These measurements are listed in table 8.

The measurements of water level that are available show that there is considerable variation in the magnitude and character of the fluctuations in different parts of the valley. The water level in well 30/35–4C1 evidently rises 7 feet or more during the irrigation season as a result of recharge from infiltration of excess irrigation water and streamflow from Coyote Canyon and adjacent canyons. Evidence for this is the general rise of water level during the irrigation season and after periods of abnormally high precipitation such as occurred during the latter part of 1950 and 1951 and during the summer of 1952.

The average annual magnitude of the water-level fluctuations in well 30/35–27B1 is considerably less than in well 30/35–4C1, probably because it is neither in an irrigated area nor in an area where the ground-water reservoir receives appreciable recharge by downward percolation of water from streams. The water level in this well showed a practically persistent decline from the time the well was drilled in January 1948 until sometime after March 1950. The decline was slightly more than 5 feet during this 4-year period. Measurements were not resumed until March 1952, so the pattern of the water-level fluctuations during the 2-year period for which no record is available is not known. The persistent decline of water levels noted for several years after the well was drilled probably was caused by a combination of factors. Leakage between strata because of a differential in head of the water in them appears to be one possibility that might have caused a significant part of the decline. According to the driller's log the first water was encountered 35 feet below the land surface. Shortly after the well was completed the water level was about 22 feet below the land surface. Thus there is an indication of an artesian head of at least 13 feet. The driller's log further states that the space between the drill hole and the casing was filled with gravel and that the casing was perforated between depths of 25 and 100 feet. Under these conditions leakage is almost a certainty. The decrease in the rate of decline with time lends additional support to the theory that leakage between strata is primarily responsible for the decline. In spite of this probable leakage, however, the trend of water levels in 1952 and 1953 was upward, probably as

a result of the above-normal precipitation received during the latter part of 1951 and during the summer of 1952.

The few measurements of water level in well 30/35–21B2 indicate that withdrawals from the well for irrigation cause no appreciable permanent lowering of the water level. Measurements of water levels in other wells likewise indicate that withdrawals of ground water have caused little, if any, permanent lowering of the water table or piezometric surface.

Chemical Quality of Water

GENERAL CHARACTER

Natural waters vary greatly in the composition and the concentration of dissolved constituents and, therefore, in their suitability for various uses. The maximum allowable concentration of one or more constituents for many industrial uses other than cooling is usually so small that most ground water must be treated to bring the concentration of dissolved minerals within desirable limits.

The desirable limits of concentration of various constituents for domestic purposes generally are less stringent. In many areas ground water, therefore, needs little if any treatment in order to be chemically suitable for domestic use. The limitations for irrigation as proposed by different investigators vary somewhat; however, except for boron and percent sodium, the limitations are less restrictive than for most industrial and domestic uses. Generally it has not been economically feasible to treat a ground-water supply in order to make it suitable for irrigation.

WATER FOR INDUSTRIAL USE

The allowable limit for one or more of the chemical constituents of water used for processing goods or products is usually so small that for many industrial uses partial treatment probably would be required for all the ground water in Buena Vista Valley. It appears that water requiring a minimum amount of treatment occurs beneath the alluvial fans built out from the canyons of the larger streams heading in the Humboldt Range. For example, the water from well 30/35–21B2 is the least mineralized of the samples of water for which analyses are available. (See table 7.) Except for being hard, the water probably would be satisfactory for many industrial uses. If and when water is needed for industrial use, the special requirements of the particular type of industry will need to be considered in determining whether a given water supply is or can be made satisfactory.

In areas where there is little movement of ground water and in areas where ground water is discharged naturally by evapotranspiration, the concentration of chemical constituents usually is moderate to high, and treatment, if feasible, would be more expensive. It is believed that much of the ground water underlying the alkali flat and areas adjacent thereto is mineralized to such an extent that it would not be feasible to treat the water to make it suitable for most industrial uses.

WATER FOR DOMESTIC USE

The desirable limits of concentration of various chemical constituents of water to be used for domestic purposes vary with the particular use to be made of the water. The U. S. Public Health Service has specified the following limits for drinking water used on interstate carriers, and for public supplies in general:

Constituent	Maximum (parts per million)
Iron and manganese (sum)	0.3
Magnesium	125
Sulfate	250
Fluoride	1.5
Chloride	250
Dissolved solids	(1,000 permitted) 500

The above limits serve as a general guide in determining the suitability of a water for human consumption. Waters containing constituents considerably in excess of these limits have been drunk for years without apparent ill effect by people whose systems have developed a tolerance for the higher concentrations.

No fixed limits have been set for the maximum hardness acceptable for domestic use. Calcium and magnesium, the principal constituents in water causing hardness, use up soap by forming sticky curds. These curds are difficult to remove from the hair, skin, glassware, enamelware, and textiles. It is evident, therefore, that a water having little or no hardness is desirable for washing and laundry. For general domestic use, water having a hardness in excess of 100 to 150 parts per million is considered hard, and treatment to reduce the hardness is desirable if not always practical. However, the use of modern-day detergents may overcome many of the difficulties experienced with soap.

All the samples of water for which analyses are available (see table 7) are hard to the extent that considerable quantities of soap will be consumed for washing and laundering. However, several of the waters that were analyzed are chemically excellent for drinking.

Whether or not the supplies that were sampled are satisfactory

for human consumption as to bacteria was not determined, although there is no reason to doubt that safe supplies have been and can be developed in most places.

WATER FOR IRRIGATION

The biggest demand for ground water has been and probably will continue to be for irrigation. The limits of various chemical constituents for irrigation water as proposed by different investigators vary somewhat. However, the criteria generally used in determining the suitability of a water for irrigation are: (1) the total concentration of chemical constituents, (2) the percent sodium, and (3) the concentration of boron.

Total concentration of constituents.—The fact that most natural waters contain inorganic salts that ionize and thus permit passage of an electric current has led to the practice of obtaining an indication of the concentration of chemical constituents by measuring the electrical conductivity of a solution. The conductivity is usually expressed in micromhos/cm at 25°C or EC $\times$ 10^6 at 25°C, both of which have the same numerical value.

A fair relationship between the electrical conductivity and the total cations or anions in a solution, expressed as equivalents per million, has been observed. For approximate values it can be assumed that EC $\times$ 10^6 at 25°C divided by 100 equals the sum of the cations or anions expressed as equivalents per million.

A fair relationship also exists between the electrical conductivity and the concentration of dissolved solids expressed in parts per million. Multiplying the electrical conductivity expressed as EC $\times$ 10^6 at 25°C by 0.6 gives an indication of the dissolved solids in parts per million for much of the ground water in Buena Vista Valley.

Percent sodium.—Sodium, calcium, and magnesium are the three principal cations in most natural waters. Calcium and magnesium are essential to plant nutrition and beneficial to the soil. Sodium, though probably essential in small quantities, if present in large quantities may impair the growth of plants and be detrimental to the soil. Where sodium is the predominant cation it may cause the soil to deflocculate or "run together" and become sticky and impermeable when wet. Upon drying, the soil becomes hard and brittle and large cracks appear. So called "slick spots" may develop in irrigated fields, and black alkali—sodium carbonate—may be formed.

It appears that the adverse effect on the soil is related more

closely to the ratio of sodium to the total cations than to the absolute concentration of sodium. Therefore, in determining the suitability of a water for irrigation, the concentration of sodium is usually expressed as a percentage of the total cations, all the cations being expressed in equivalents per million. For all practical purposes, "total cations" is represented by the total for calcium, magnesium, and sodium. Equivalents per million for calcium, magnesium, and sodium may be obtained by dividing the parts per million of these cations by 20, 12.2, and 23, respectively. The percent sodium is 100 times the equivalents per million of sodium divided by the sum of the equivalents per million of calcium, magnesium, and sodium. This assumes that potassium is negligible, which is generally true so far as this computation is concerned.

Boron.—In the concentrations ordinarily found in irrigation waters boron has no detrimental effect on soils. However, although some boron is essential to plant growth, concentrations only slightly above optimum can be exceedingly toxic. Scofield (1935) has proposed the following limits for boron:

TABLE 5

Permissible limits for boron of several classes of irrigation water.

Classes of Water		Sensitive crops (ppm)	Semitolerant crops (ppm)	Tolerant crops (ppm)
Rating	Grade			
1.	Excellent	<0.33	<0.67	<1.00
2.	Good	0.33–0.67	0.67–1.33	1.00–2.00
3.	Permissible	0.67–1.00	1.33–2.00	2.00–3.00
4.	Doubtful	1.00–1.25	2.00–2.50	3.00–3.75
5.	Unsuitable	>1.25	>2.50	>3.75

In determining the suitability of a water for irrigation the kind of crop to be irrigated must also be considered. Eaton (1935) has grouped crops according to their tolerance to boron. Some of the crops for which relative tolerances to boron have been listed are shown in the following table.

TABLE 6

Relative tolerances of crop plants to boron

(In each group the plants first named are considered to be more sensitive than those that follow)

Sensitive	Semitolerant	Tolerant
Apricot	Lima bean	Carrot
Peach	Sweet potato	Lettuce
Cherry	Bell pepper	Cabbage
Grape	Pumpkin	Turnip
Apple	Tomato	Onion
Pear	Oat	Broadbean
Plum	Milo	Alfalfa
Navy bean	Corn	Garden beet
	Wheat	Sugar beet
	Barley	Asparagus
	Field pea	
	Radish	
	Potato	

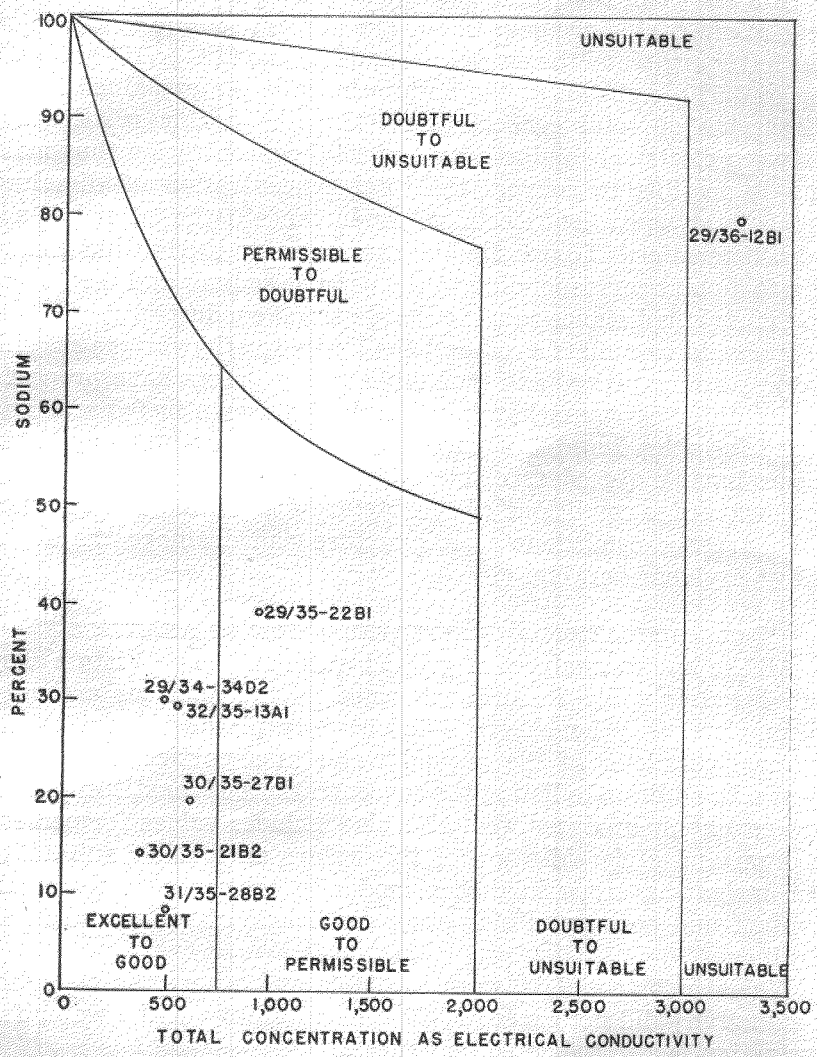

Figure 2.—Diagram for use in interpreting the chemical analysis of an irrigation water.

Classes of water.—Wilcox (1948) proposed the use of a diagram for classifying waters for irrigation with respect to the total concentration of dissolved solids and the percent sodium. Figure 2 is such a diagram. Five classifications of water ranging from excellent to unsuitable are delineated. The percent sodium is shown on the left margin and the electrical conductivity ($EC \times 10^6$ at 25°C) up to 3,500 is shown at the bottom margin. As explained in the discussion of total concentration, there is a fair relationship between electrical conductivity and total concentration thus making it possible to convert the total concentration of dissolved solids to an equivalent electrical conductance if the latter has not been determined. To use the diagram move up the left-hand margin to a point corresponding to the percent sodium and then move to the right a distance equal to the electrical conductivity.

It should be remembered that the limits for the various classifications are empirical and that other investigators have proposed limits differing somewhat from the limits shown in figure 2 and listed in tables 5 and 6. Figure 2 sets limits for water applied to crops having a moderate tolerance for dissolved salts growing under average conditions of soil texture and drainage. For other than average conditions of soil texture and drainage the limits may vary considerably.

CLASSIFICATION AND INTERPRETATION OF ANALYSES

All the known analyses of ground water in Buena Vista Valley are listed in table 7. Although some of the analyses are very incomplete, they have been listed as they provide a clue to the general character of the ground water at a particular site and depth. In addition to listing the concentrations of constituents that are commonly analyzed, the table also includes values for percent sodium and a classification of the waters as to their suitability for irrigating crops having a moderate tolerance to total salt content and boron under average conditions of soil texture and drainage.

Where sufficient data were available and where the electrical conductivity did not exceed 3,500, the suitability of the water for irrigation is also indicated on figure 2.

Water from well 26/34–27C1 had the highest concentration of dissolved solids. Four samples of water obtained from various depths in this well were analyzed in October 1934 as part of a reconnaissance investigation made by the U. S. Geological Survey at the request of the U. S. Department of Commerce to determine

TABLE 7

Chemical analyses and classification of waters in Buena Vista Valley, Pershing County, Nev.

Classification for irrigation: E, excellent; G, good; P, permissible; D, doubtful; U, unsuitable.

Analyst: A, University of Nevada, Agricultural Experiment Station; B, University of Nevada, Department of Food and Drugs; C, Geological Survey, U. S. Department of the Interior.

Remarks: C, cold water; H, hot water. *Reported.

Analyses in parts per million except conductance, pH, and percent sodium.

Well or spring number and location	Depth (feet)	Temperature (°F)	Date collected	Specific conductance (Micromhos at 25°C)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	pH	Percent sodium	Classification for irrigation	Analyst	Remarks
26/34–27C1	*400	----	10–17–34	----	12,000	----	----	----	488	101	3,370		49	2,380	4,570	----	----	----	1,640	1,600	----	82	U	C	
26/36–19C1	100	----	11– 6–51	4,090	2,500	39	0.22	0.00	325	234	200	20	104	473	1,160	0.2	0.5	0.24	1,770	1,690	7.3	19	U	C	
29/34–34D2	136	75	5–15–52	463	271	20	.05	.00	50	9.3	33	1.3	210	23	29	.1	2.0	.18	163	0	7.4	30	E	C	
29/35–22B1	23	----	5–15–52	936	583	36	.06	.00	92	17	90	1.3	356	83	77	.3	11	.41	300	8	7.5	39	G	C	
29/36–12B1	----	----	1935	----	----	14	----	----	120	22	649		550	153	844	----	----	3.9	390	0	----	----	U	A	C
	----	----	1935	----	----	15	----	----	88	23	596		526	59	794	----	----	3.6	315	0	----	----	U	A	H
	----	159	3–25–46	----	1,970	53	Tr	----	96	20	574		512	59	770	----	----	----	323	0	----	79	U	B	H
–32D1	56	----	11–30–47	3,680	2,580	----	----	----	----	----	----	----	390	----	858	----	----	----	----	----	----	----	U	A	
30/35–4C1	46	----	11–30–47	770	539	----	----	----	----	----	----	----	473	----	17	----	----	.00	----	----	----	----	G	A	
–21B2	374	59	5–15–52	369	219	16	.04	.00	49	11	13	.9	192	23	9	.1	2.0	.13	168	10	7.8	14	E	C	
–27B1	100	56	5–15–52	612	366	17	.05	.09	77	16	30	1.0	246	61	37	.1	6.0	.14	258	56	7.5	20	E	C	
–35A1	23	----	11–30–47	769	538	----	----	----	----	----	----	----	235	----	115	----	----	.18	----	----	----	----	G	A	
31/35–28B2	----	53	5–15–52	500	301	16	.04	.00	74	13	10	.9	228	33	16	.1	26	.10	238	51	7.5	8	E	C	
32/35–13A1	101	55	5–15–52	532	296	11	.04	.00	48	14	34	1.9	113	55	76	.2	.3	.10	178	85	7.6	29	E	C	

the possibility of obtaining a satisfactory water supply for Humboldt Field. All four samples were practically identical. Each contained more than 11,000 parts per million of dissolved solids, a concentration considered too high to warrant treatment to make the water suitable for domestic use. According to the available information, salty water was reported to have been encountered between depths of 120 and 140 feet when the well was drilled. The stratum containing salty water was underlain by a stratum of blue clay 12 feet thick. Nothing definite is known of the material encountered below this depth other than that a stratum supposedly containing fresh water was encountered between depths of 160 and 200 feet. The airport manager and the caretaker of a nearby quicksilver mine both are reported to have stated that they drank the water bailed from the lower stratum when the well was being drilled and that it was "good fresh water." Sometime after completion of the well, however, water bailed from it was salty. In view of these reports, and of reports that the construction of the well was such that the upper stratum was not sealed from the lower stratum, it was concluded that salty water from the upper stratum probably was contaminating the lower-lying fresh water. It was recommended therefore that the well be properly plugged and that another well be drilled at a distance of 500 feet or more from the existing well in the direction of maximum increase in slope of the water table. It was believed that by effectively sealing off the upper stratum of salty water a satisfactory domestic supply could be obtained if the proposed well were drilled to a depth of about 200 feet.

Efforts during the present investigation to obtain information as to whether the proposed well was ever drilled were unsuccessful.

On the basis of the high mineral content of the water encountered in the well at Humboldt Field it seems probable that water of similar mineral content will be found locally elsewhere in the valley. However, water having a concentration of several thousand parts per million of dissolved solids is likely to be more widespread, probably underlying much of the lower part of the valley, especially those areas where there is little movement of ground water. The analyses of water from wells 26/36–19C1 and 29/36–32D1 are probably typical of the types of water underlying these areas. A further reason for believing that water that is at least moderately to highly mineralized may be encountered is that the geologic history of the sediments of the valley fill undoubtedly is

very similar to the geologic history of the fill in Lovelock Valley, which is immediately west of Buena Vista Valley. Both valleys were occupied by Quaternary Lake Lahontan and presumably contain lake sediments of similar chemical composition. Robinson (1946, p. 16) states that ground water from both shallow and deep wells in the southern part of Lovelock Valley is rather highly mineralized. In order to obtain a ground-water supply suitable for municipal use, the city of Lovelock found it expedient to develop a well field rather high on the alluvial apron fronting the west side of the Humboldt Range opposite Spring Valley, about 15 miles north of Lovelock.

The water from Kyle Hot Springs, 29/36–12B1, also is rather highly mineralized. According to the classification used in this report it would be unsuitable as an industrial, domestic, or irrigation supply. The boron content of this water is much greater than that of any of the other waters that were analyzed and is large enough to be toxic to most plants.

The other samples that were analyzed were classified as excellent to good for irrigation, and except for being hard would be considered good for domestic use.

It is believed that ground water satisfactory for irrigation underlies much of the alluvial apron fronting the bordering mountains, ordinarily at sites somewhat above the lower edge of the apron. Water of satisfactory quality may underlie areas of lower elevation where there is significant movement of ground water toward areas of natural discharge. This movement of ground water helps to flush away or dissolve many soluble salts that originally may have been deposited with the sediments.

Ordinarily, however, the mineral content of the ground water increases as the water moves toward the lower parts of the valley, especially in areas where the rate of movement is relatively slow.

Present Development

Some of the ground water discharged by springs is utilized for domestic use and for watering stock. However, the greater part of the discharge by springs and seeps supports the growth of native vegetation, some of which is suitable for stock feed, but most of which has little or no economic value.

There are about 50 wells in the valley, data for 32 of which are given in table 8 at the end of this report. Most of the wells were constructed in order to obtain satisfactory and adequate supplies of water for domestic use or for watering stock. However, several

wells have been drilled to obtain water for irrigation, usually a supplemental supply for lands irrigated by surface water.

Well 30/35–32D2, drilled some 20 years ago, is one of the earliest wells of this type. On June 27, 1950, the yield of the well was measured as 375 gallons per minute after the well had been pumping at a uniform rate for about 1½ hours. The lift was 56 feet; the drawdown 22 feet; and the temperature of the water, 59°F. The well was used in 1950 and 1951 to irrigate alfalfa, grain, and potatoes.

Well 30/35–5C1 was drilled in 1947 to a depth of 302 feet. The well was being pumped at the rate of about 165 gallons per minute on July 19, 1949. According to an airgage the lift was about 148 feet. The nonpumping level as reported on the driller's log was 135 feet below the land surface. Thus the drawdown was about 13 feet. The construction of the well was such that it was impractical to obtain a water-level measurement by means of a steel tape or electric sounder. The temperature of the water was 53°F at the time the discharge measurement was made. A larger pumping unit was installed at a later date with a consequent increase in the rate of discharge. The required power is supplied by a diesel engine. The well furnishes a supplemental supply of water to lands normally irrigated with surface water. Alfalfa is the principal crop.

Well 30/35–21B2 was completed in February 1950 to a depth of 374 feet. On June 30, 1950, after the well had been pumped continuously for several days, the discharge was 1,400 gallons per minute. The pumping level was 68 feet below the land surface, and the temperature of the water was 59°F. The nonpumping level was about 24 feet below land surface. The specific capacity of the well at the time the measurements were made thus was about 32 gallons per minute per foot of drawdown. In 1950 and 1951 much new land was irrigated, principally by the furrow method. Because considerable difficulty was experienced in controlling erosion, an extensive sprinkling system was installed in 1952. There is promise that sprinkling might solve the problem.

The three wells just discussed are the only wells from which significant quantities of water have been pumped for irrigation. Several other attempts have been made to obtain a supply suitable for irrigation, but to date the owners of the wells have not used them for that purpose.

Wells 29/34–34D1 and –34D2 were drilled in 1947 and 1948 respectively in an effort to obtain water for mining and domestic

use. In 1949 a deep-well turbine pump was installed on well 29/34–34D2. The well was pumped about 10 hours a day during most of the summer. On July 19, 1949, the discharge of the well was estimated at about 150 gallons per minute after it had been pumping several hours. The pumping level was 69 feet below the land surface and the temperature of the water was 74°F. The well ordinarily flows about 10 gallons per minute at the land surface, so the specific capacity of the well was in the neighborhood of 2 gallons per minute per foot of drawdown. The well has not been pumped since 1949, but along with well 29/34–34D1 has been allowed to flow to waste. The combined flow of the wells ordinarily is less than 15 gallons per minute.

Potential Development

When water is artificially withdrawn from a ground-water reservoir the balance between recharge and discharge under natural conditions is disturbed. The result is a lowering of the water table or piezometric surface. The lowering is greatest at the point of withdrawal and lessens with increasing distance from it. This depression in the piezometric surface is commonly referred to as a cone of depression. The cone of depression continues to grow in depth and areal extent as long as water is being withdrawn from storage. Water levels cease lowering only when the amount of the artificial withdrawal is balanced by an increase in the amount of the average annual recharge, a decrease in the amount of the average annual discharge, or a combination of the two.

The maximum rate at which water can be artificially withdrawn from Buena Vista Valley without causing a continual lowering of water levels that eventually will deplete the ground-water reservoir is therefore limited to the average annual recharge or discharge. Only to the extent that the average annual recharge can be increased by artificial means, such as water spreading on recharge areas or the introduction of water into wells or sumps, can the potential safe withdrawal exceed the average annual recharge, which earlier in this report was estimated to be about 10,000 acre-feet.

However, there are many factors that would make it impractical to withdraw water at this rate indefinitely. To stabilize water levels at this rate of withdrawal would necessitate the stopping of all natural discharge from the ground-water reservoir as it occurs today. Inasmuch as practically all the natural discharge now occurs by evaporation from the land surface or by

transpiration of native water-loving plants, it would be necessary to lower the water level sufficiently at all points to prevent these processes. Such natural discharge would be almost wholly eliminated if a minimum depth to water of about 50 feet could be maintained in areas where phreatophytes might grow and about 15 feet in areas where evaporation from the soil might otherwise occur.

To attain and maintain this position of the water level would necessitate artificial withdrawals at many points in the valley if the withdrawals were to be made with minimum lifts. However, because of the limitations imposed by soil conditions, topography, and the quality of the water, the areas where it is economically feasible to withdraw water artificially are but a fraction of the areas where withdrawals would be needed. Furthermore, withdrawals from fewer areas would require increased pumping lifts, the increase being dependent on the size of the area beneath which the water level would have to be lowered to the required minimum depth.

It thus appears impractical to stop all natural discharge from the ground-water reservoir. Also, in order to sustain an agricultural development, a part of the water would have to be permitted to move to the playa in order to avoid a harmful accumulation of salt in the agricultural areas. Consequently, if there is to be any hope that ground-water levels eventually will stop lowering before they reach a stage where it is uneconomical to withdraw the water by pumping, the average annual withdrawal must be limited to the amount of natural discharge that can be diverted to wells. In view of the relationships between areas of recharge and discharge, the present and probable future depths to water beneath lands suitable for agricultural development, and the deterioration in chemical quality of the water that might result from artificial withdrawals, it is estimated that perhaps about half the present natural discharge eventually could be economically diverted to wells and pumped for irrigation or other uses. Thus, if the average annual withdrawals could be kept in the neighborhood of 5,000 acre-feet, obtained from reasonably widespread wells, the economy of the area, insofar as it depends on water, should be on a sound basis.

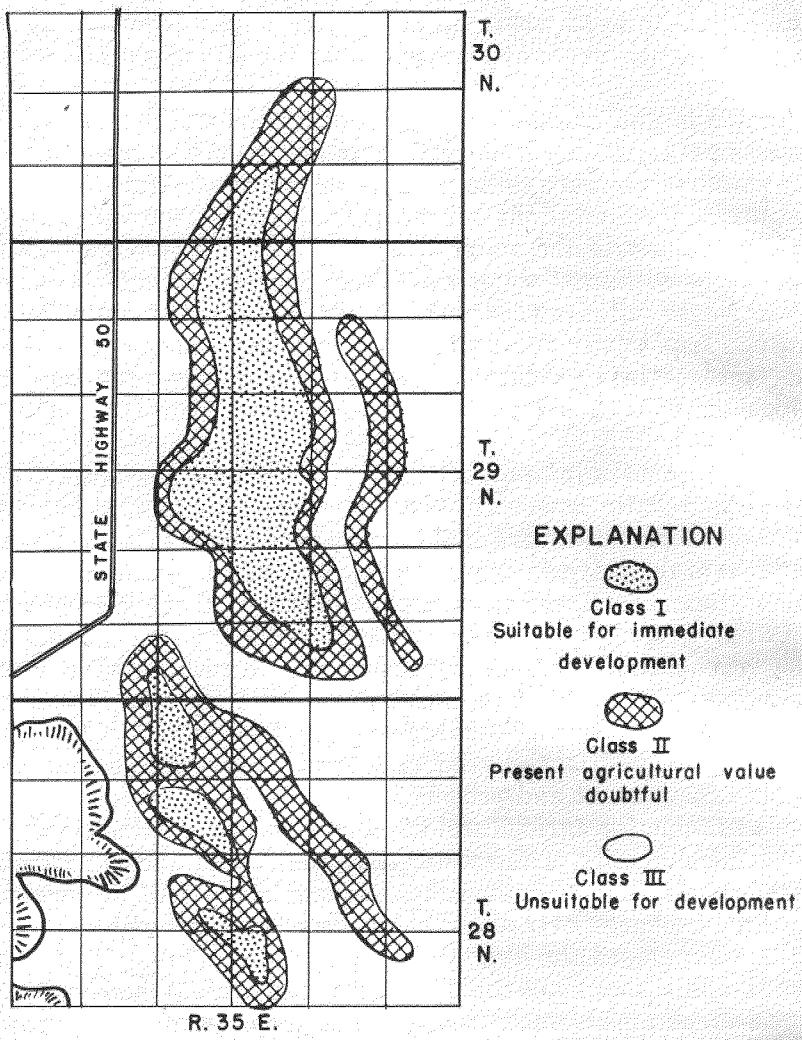

Figure 3.—Map of part of Buena Vista Valley, Pershing County, Nevada, showing reconnaissance land classification.

RECONNAISSANCE LAND CLASSIFICATION OF BUENA VISTA VALLEY, PERSHING COUNTY, NEVADA

By HOWARD G. MASON[1]

Buena Vista Valley is in eastern Pershing County. The potential agricultural lands in the valley are about 30 miles northeast of Lovelock and 10 to 20 miles south of Mill City. These lands are most readily accessible from State Highway 50 leaving U. S. Highway 40 a short distance west of Mill City.

The altitude of the valley floor is about 4,200 feet. The climate at this elevation and latitude will permit the production of cereal grains, two cuttings of alfalfa, clover, grasses, and hardy vegetables and fruits. Temperatures and precipitation should be about the same as at Winnemucca, where the mean temperature is 28°F in January and 74°F in July, and the average annual precipitation is about 5 inches.

The potential agricultural lands in this valley are mostly on the lower slopes of large alluvial fans. For the most part they have been affected but little, if at all, by inundation and deposition of lake sediments or by the accumulation of salts resulting from the evaporation of lake waters. The upper soil horizons consist mainly of medium- to fine-textured alluvial material washed down from the mountains to the west. The land surface is fairly smooth but much of it slopes a little too steeply for ordinary irrigation methods except when used with great care. The development of good agricultural land is limited almost entirely to the upper west side of the valley, in Ts. 29 and 30 N., R. 35 E., as indicated by figure 3.

A reconnaissance-type survey was made of the lands in the valley that lie within a reasonable pumping lift from the ground-water supply, that seemed free from excessive quantities of soluble salts, and that had surface conditions favorable for irrigation development. This area was classified on the basis of soil texture and profile, topography, present and probable future drainage conditions, and presence or absence of harmful mineral salts. About 4,500 acres of land considered to be suitable for immediate development were placed in Class I. Over 5,000 acres of land with weakness in one or more of the factors listed above but still capable of reclamation were placed in Class II. It appears unlikely that there will be more water available than can serve the Class I

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lands. No development of Class II lands seems feasible at this time.

Buena Vista Valley seems to be one of the more desirable areas in the northern part of the State for early development by pumping ground water. It is only a short distance over an all-season road from U. S. Highway 40. It has a considerable area of good soil. The growing season is somewhat longer than in most of the northern valleys.

The surrounding area is devoted to grazing cattle and sheep, supplemented by a minimum amount of winter feeding for maintenance of the breeding herds. An additional area in forage crops would permit more efficient use of the ranges and production of higher value animals. Another possibility is the production of seed crops which may be somewhat safer from frost damage here than in some other northern Nevada valleys.

TABLE 8—*Continued*

Record of wells in Buena Vista Valley, Pershing County, Nevada
(Location of wells is shown on pl. 1)

Type of well: Dg, dug; Dr, drilled; B, bored.
***Reported; †See remarks column.**

Use of water: D, domestic; I, irrigation; M, mining; N, unused; O, observation; S, stock.

Well number and location	Owner	Type of well and year completed	Diameter (inches)	Depth (feet)	Measuring Point: Above (+) or below (−) land-surface (feet)	Measuring Point: Description	Depth to water level below measuring point (feet)	Date	Use	Temperature (°F)	Remarks
30/35–27B1	Neil Talcott	Dr, 1947	8	100	—	Top of casing	22.51	1– 7–48	O, S	—	Log.
								5–12–52		56	Analysis.
–27C1	Neil Talcott	Dg	†	12	0.0	Top of wood cribbing	6.68	11– 9–47	S	—	Opening, 4 by 5 feet.
–32D1	G. D. Brown	Dg	†	27	+0.8	Top of 8- by 8-inch pipe clamp	15.85	11–10–47	S	—	Opening, 4 by 4 feet.
–32D2	G. D. Brown	Dr, 1930	14	98	+0.1	Top of casing	34.00	6–20–50	D, I	59	Pumping 375 gallons per minute with 22-foot drawdown after 1½ hours of pumping.
							36.23	8–29–51			
–35A1	Neil Talcott	Dg	†	23	—	Top of wood platform	12.58	11–30–47	S	—	Opening, 3 by 3 feet.
31/35–15C1	Theodore Belzarena	Dr, 1946	6	—	0.0	Top of casing	96.60	11–10–47	S	56	
–27C1	Theodore Belzarena	Dr, 1952	6	120	—	Land surface	70	1–11–52	S	—	Log.
–28B1	Theodore Belzarena	Dr	6	—	—		—	5–15–52	D, S	53	Analysis.
–28B2	Theodore Belzarena	Dr	—	—	—	Land surface	110	—	—	—	Log.
–34B1	Gallio Bros.	Dg	6	41	+0.2	Top of wood platform	33.87	11–10–47	S	—	
							33.36	9–18–53			
32/35–13A1	Gallio Bros.	Dr, 1930	8	101	+0.8	Bottom edge of pump base	52.85	11– 8–51	S	57	
							52.78	5–15–52	—	55	Analysis.
–34A1	U. S. Bureau of Land Management	Dr	6	89	+0.6	Top of wood platform	77.78	11–12–47	S	56	
							76.90	8–29–51			
							76.95	5–15–52			
32/36–6B1	Theodore Belzarena	Dr, 1949	6	132	0.0	Land surface	70	10– –49	S	—	Log.

TABLE 8

Record of wells in Buena Vista Valley, Pershing County, Nevada

(Location of wells is shown on pl. 1)

Type of well: Dg, dug; Dr, drilled; B, bored.
***Reported; †See remarks column.**

Use of water: D, domestic; I, irrigation; M, mining; N, unused; O, observation; S, stock.

Well number and location	Owner	Type of well and year completed	Diameter (inches)	Depth (feet)	Measuring Point: Above (+) or below (—) land-surface (feet)	Measuring Point: Description	Depth to water level below measuring point (feet)	Date	Use	Temperature (°F)	Remarks
26/34–27C1	U. S. Department of Commerce	Dr, 1934?	6	*400	0.0	Land surface	95.5	10–17–34	D	—	Analysis. Salt water stratum reported from 120–140 feet which supposedly contaminated fresh water stratum from 160–200 feet.
					—6.0	Top of casing	89.42	11– 6–51	N		
26/36–19C1	U. S. Bureau of Land Management	Dr, 1938	6	100	+0.7	Top of 6- by 8-inch pipe clamp	90.3	11– 6–51	S	—	Analysis.
28/35–2A1	U. S. Bureau of Land Management	Dg	—	14	+0.5	Top of 2-inch plank cover	9.77	11–12–47	S	—	Well penetrates fine silt.
–14A1	G. D. Brown	Dg	20	16	+1.0	Top of casing	8.19	11– 9–47	S	—	
							7.80	11– 7–51			
							9.00	10–21–53			Mill down 15 minutes.
29/34–34D1	Southwest Dredging Co.	Dr, 1947	6	157	—		†	11– –47	M	—	Log; mining company official reported measured flow as 48 gallons per minute when drilled.
							†	3–19–50	N	72	Flow, 6 gallons per minute from pipe 1.5 feet above land surface.
							†	11– 9–51	N	72	Flow, 4 gallons per minute from pipe 1.5 feet above land surface.
–34D2	Southwest Dredging Co.	Dr, 1948	13	136	—		†	7–19–49	M	75	Log; analysis; pumping about 150 gallons per minute; pumping level, 69 feet below land surface; nonpumping level above land surface.
							†	3–10–50	N	75	Flow estimated at 10 gallons per minute at land surface.
29/35–14B1	G. D. Brown	Dg	8	20	+0.5	Top of wood platform	9.64	11–10–47	S	—	Well penetrates fine silt.
							8.92	4–23–48			
–22B1	G. D. Brown	Dg	12	23	+0.2	Top of wood platform	18.51	11–10–47	S	53	Analysis.
							16.20	11– 9–51			Mill down 20 minutes.
29/36–16B1	U. S. Bureau of Land Management	Dr	6	76	+1.0	Top of casing	32.72	11–10–47	S	—	
							33.15	11– 7–51		59	Mill down 15 minutes.
–32D1	U. S. Bureau of Land Management	Dr, 1946	8	56	+0.4	Top of pipe joint	10.13	11–10–47	S	—	Water has salty taste.
30/35–4C1	Gallio Bros.	Dg	†	46	+1.5	Top of wood platform	39.06	11–10–47	O, S	—	Analysis; opening 4 by 4 feet.
–5C1	Gallio Bros.	Dr, 1947	8	302	—	Land surface	*135	12– 9–47	I	—	Log.
								7–19–49		53	Pumping about 160 gallons per minute; drawdown probably 5 feet or more.
–14B1	Gallio Bros.	Dg	48	24	+1.3	Top of wood platform	19.25	11–11–47	N	—	
–21B1	O. L. Sheppard	Dr	6	53	0.0	Top of casing	20.47	11–10–47	N	—	Log.
–21B2	O. L. Sheppard	Dr, 1950	12	374	+0.3	Top of casing	24.66	3–19–50	I	—	Log; analysis.
								6–30–50		59	Pumping 1,400 gallons per minute; pumping level 68 feet below land surface.
–21D1	O. L. Sheppard	Dg	†	25	0.0	Top of wood platform	19.47	11–11–47	S	—	Opening, 4 by 4 feet.
							20.19	11– 7–51	N		
–26B1	Neil Talcott	Dg	†	20	0.0	Top of wood platform	16.87	11– 9–47	S	—	Opening, 5 by 5 feet.
–26B2	Neil Talcott	Dr, 1927	3	*500	—		—	—	—	—	Reported materials penetrated consisted predominantly of lake clays and silts. A few small gravel strata were encountered. Well abandoned shortly after drilling.
–27A1	Neil Talcott	Dr, 1951	12	615	+0.7	Top of opening in pump base	17.22	8–30–51	—	—	Log; driller reports well pumped 450 gallons per minute with 108-foot drawdown after initial development.
							17.59	10–21–53			

TABLE 9

Measurement of water levels in wells in Buena Vista Valley, Pershing County, Nevada, 1947–1953

30/35–4C1. Gallio Bros. Dug stock well, 4- by 4-foot opening, depth 46 feet. Equipped with lift pump and windmill. Measuring point, top of wood platform, 1.5 feet above land surface.

Water level, in feet below measuring point, 1947–1953

Date	Water level	Date	Water level	Date	Water level
Nov. 10, 1947	39.06	Sept. 13, 1949	*40.45	Mar. 28, 1952	*38.30
June 18, 1948	31.74	Mar. 19, 1950	40.90	Sept. 9	*25.76
Sept. 13	39.10	Sept. 16	39.75	Mar. 17, 1953	35.20
Mar. 14, 1949	*41.05	Mar. 29, 1951	†33.50	Sept. 18	33.95
July 19	34.47	Aug. 29	‡36.90		

*Windmill shut down 10 minutes prior to measurement.
†Irrigation of field adjacent to well recently completed.
‡Pumping.

30/35–21B2. O. L. Sheppard. Drilled irrigation well, diameter 12 inches, depth 374 feet. Equipped with deep-well turbine pump and diesel engine. Measuring point, top of casing, 0.3 foot above land surface. Water levels, in feet below measuring point: Mar. 19, 1950, 24.66; Nov. 8, 1951, 25.74; Mar. 28, 1952, 25.44.

30/35–27B1. Neil Talcott. Drilled stock well, diameter 8 inches, depth 100 feet. Equipped with lift pump and windmill. Measuring point, top of casing, 0.6 foot above land surface.

Water level, in feet below measuring point, 1948–1953

Date	Water level	Date	Water level	Date	Water level
Jan. 7, 1948	22.51	Mar. 14, 1949	26.72	Sept. 9, 1952	28.10
Jan. 27	23.83	July 19	26.71	Mar. 17, 1953	27.93
Apr. 23	24.42	Sept. 13	27.03	Sept. 18	27.50
June 18	24.77	Mar. 19, 1950	27.98		
Sept. 13	25.62	Mar. 29, 1952	28.78		

TABLE 10

Logs of wells and other pertinent well data, Buena Vista Valley, Pershing County, Nevada

29/34–34D1. Southwest Dredging Co. Mining-supply well; casing diameter, 6 inches to 151 feet; uncased 151 to 161 feet; perforated from 140 to 151 feet with ⅜- by 3-inch slots. First artesian water at 83 feet; measured flow, 48 gallons per minute when completed. Drilled by Henry L. Nelson, Lovelock, Nevada. Completed to 120 feet, July 1, 1947; to 161 feet, November 1, 1947. Driller's log.

Material	Thickness (feet)	Depth (feet)
Silt and broken rock	15	15
Gravel (surface water)	5	20
Clay, yellow, and rock	63	83
Gravel (first artesian water; estimated flow, 20 gallons per minute)	4	87
Clay, yellow, and rock	28	115
Sand and gravel, loose (estimated flow about 60 gallons per minute)	5	120
Gravel, fine, and sand	2	122
Sand and clay, reddish	2	124
Sand, gravel, and clay, white	18	142
Clay, reddish	3	145
Clay, red; sand and gravel	7	152
Sand, gravel, and clay, red	2	154
Sand and gravel (large increase of artesian flow)	7	161

Note by driller—Drill hole below 151 feet abandoned because formation caved.

TABLE 10—*Continued*

29/34–34D2. Southwest Dredging Co. Mining-supply well; casing diameter, 13 inches to 136 feet; perforated from 46 to 131 feet with ¼- by 6-inch slots. First water at 48 feet; flowed 3 or 4 gallons per minute when completed. Drilled by Henry L. Nelson, Lovelock, Nevada. Completed April 8, 1948. Driller's log.

Material	Thickness (feet)	Depth (feet)
Clay, heavy, and rock, fine	47	47
Gravel and clay (water at 48 feet)	18	65
Clay, heavy; some gravel	17	82
Gravel and clay (water)	2	84
Clay strata alternating with sand and fine gravel (some water)	11	95
Gravel and clay	10	105?
Clay	3	108?
Clay and gravel, alternating strata (some water)	17	125?
Decomposed formation, very hard	16	141?

Note—Depth of formation below 95 feet may be 5 feet less than shown because of discrepancies between depths computed from thickness of formations and depths shown in driller's log.

30/35–5C1. Gallio Bros. Irrigation and domestic well; original depth 175 feet. Casing diameter, 8 inches; casing not perforated. First water at 160 feet; static level at 135 feet. Drilled by Harden and Co., Boise, Idaho, November 24, 1947.

Well deepened to 302 feet, July 1, 1948 by Mel Meyer, Reno, Nevada. Casing diameter, 8 inches to 255 feet; uncased 255 to 302 feet; perforated at one-foot intervals with ½- by 2½-inch slots, about 12 slots per round; static level at 145 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay and gravel intermingled	157	160
Gravel (water)	15	175
Clay, white, and gravel	115	290
Gravel and sand (water)	12	302

30/35–21B1. O. L. Sheppard. Abandoned well about 10 feet north of well 30/35–21B2; casing diameter, 6 inches to 75 feet; uncased 75 to 94 feet; perforated from 57 to 75 feet with ⅛- by 6-inch slots. Static level at 20 feet. Drilled in 1947 by Henry L. Nelson, Lovelock, Nevada. Driller's log.

Material	Thickness (feet)	Depth (feet)
Topsoil, rock	20	20
Clay and rock (some water)	32	52
Gravel and sand (water)	5	57
Gravel and clay	18	75
Rock and clay	5	80
Clay	14	94

TABLE 10—*Continued*

30/35–21B2. O. L. Sheppard. Irrigation well; casing diameter, 14 inches to 170 feet; 12 inches to 354 feet; uncased 354 to 374 feet; perforated from 46 to 48, 55 to 89, 100 to 118, 151 to 154, 160 to 168, 197 to 204, 331 to 345 feet with ½- by 3½-inch slots, 10 slots per round, and usually a 12-inch spacing between rounds. First water at 84 feet; static level at 22 feet. Drilled by Star Well Drilling and Pump Co., Yuba City, California. Completed February 6, 1950. Driller's log.

Material	Thickness (feet)	Depth (feet)
Topsoil	4	4
Clay, hard, and gravel	6	10
Clay, yellow, soft	2	12
Gravel, dry	4	16
Clay, yellow	30	46
Sand and gravel	2	48
Clay, yellow	7	55
Gravel	29	84
Sand and gravel	34	118
Gravel, cemented, and clay	2	120
Gravel, coarse, and clay	9	129
Clay, yellow, sticky	12	141
Clay and gravel	10	151
Gravel, coarse, possibly cemented	3	154
Clay, yellow	6	160
Sand and gravel	8	168
Sand and gravel, some clay	2	170
Clay and gravel	27	197
Sand, loose, and gravel	7	204
Rock and clay	43	247
Clay, yellow, sticky	19	266
Clay and gravel	8	274
Clay, yellow, sticky	16	290
Clay and gravel	41	331
Sand and gravel	7	338
Sandstone, very hard	1	339
Clay and gravel	30	369
Gravel and sand	5	374

30/35–27A1. Neil F. Talcott. Irrigation well; casing diameter, 12 inches to 350 feet; 6 inches to 615 feet; perforated from 110 to 615 feet with ¼- by 2-inch slots. First water at 32 feet; static level at 17 feet. Drilled by John Champion, Reno, Nevada. Completed March 10, 1951. Driller's log.

Material	Thickness (feet)	Depth (feet)
Clay	16	16
Gravel, loose	5	21
Clay	11	32
Gravel, fine (water)	5	37
Clay, with hard ribs	56	93
Clay, sticky	26	119
Clay, cemented, and pea gravel	5	124
Clay, sticky	6	130
Clay and gravel	16	146
Sandstone rib	3	149
Clay and sandstone ribs	30	179
Clay and gravel	69	248
Clay, sticky	10	258
Clay and gravel	27	285
Sandstone	5	290
Gravel (water)	5	295
Clay, sticky	9	304
Clay and gravel	33	337
Sand, firm	3	340
Clay, sandy	7	347
Sandstone	9	356
Sand and gravel, loose	3	359
Clay, sticky	104	463
Sand, cemented	40	503
Clay, sticky	80	583
Sand, clay, and gravel	13	596
Sandstone	9	605
Sand, fine	2	607
Sandstone	3	610
Clay	5	615

Note by driller—Well yielded 450 gallons per minute with 125-foot lift after development.

TABLE 10—*Continued*

30/35–27B1. Neil F. Talcott. Stock well; casing diameter 8 inches to 100 feet; perforated from 25 to 100 feet with ⅛- by 6-inch slots. First water at 35 feet; static level at 23 feet. Drilled by Henry L. Nelson, Lovelock, Nevada. Completed January 1948. Driller's log.

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Clay	15	20
Rock	2	22
Gravel	13	35
Clay	10	45
Rock (water)	5	50
Sand and clay	25	75
Sand (water)	10	85
Gravel (water)	5	90
Clay	10	100

31/35–27C1. Theodore Belzarena. Stock well; casing diameter, 6 inches to 120 feet; perforated from 80 to 120 feet with ⅛- by 3-inch slots. First water at 78 feet; static level at 70 feet. Drilled by Glenn McNinch, Winnemucca, Nevada. Completed January 11, 1952. Driller's log.

Material	Thickness (feet)	Depth (feet)
Topsoil	4	4
Gravel, cemented	33	37
Clay	41	78
Gravel (water)	8	86
Clay	29	115
Gravel (water)	5	120

31/35–28B2. Theodore Belzarena. Domestic and stock well; casing diameter, 6 inches to 153 feet; perforated from 119 to 153 feet with ⅛-inch slots. First water at 112 feet; static level at 110 feet. Drilled by Claude R. Keener, Winnemucca, Nevada. Completed December 22, 1948. Driller's log.

Material	Thickness (feet)	Depth (feet)
Boulders, gravel, and clay	53	53
Clay and gravel	59	112
Gravel and clay	41	153

Note by driller—Bailing 30 gallons per minute caused a drawdown of 5 feet.

32/36–6B1. Theodore Belzarena. Stock well; casing diameter, 6 inches to 132 feet; perforated from 60 to 132 feet with ⅛-inch slots. First water at 70 feet; static level at 51 feet. Drilled by Claude R. Keener, Winnemucca, Nevada. Completed October 1, 1949. Driller's log.

Material	Thickness (feet)	Depth (feet)
Burden	5	5
Clay	65	70
Clay and gravel	62	132

Note by driller—Bailing at 15 gallons per minute caused a drawdown of 16 feet.

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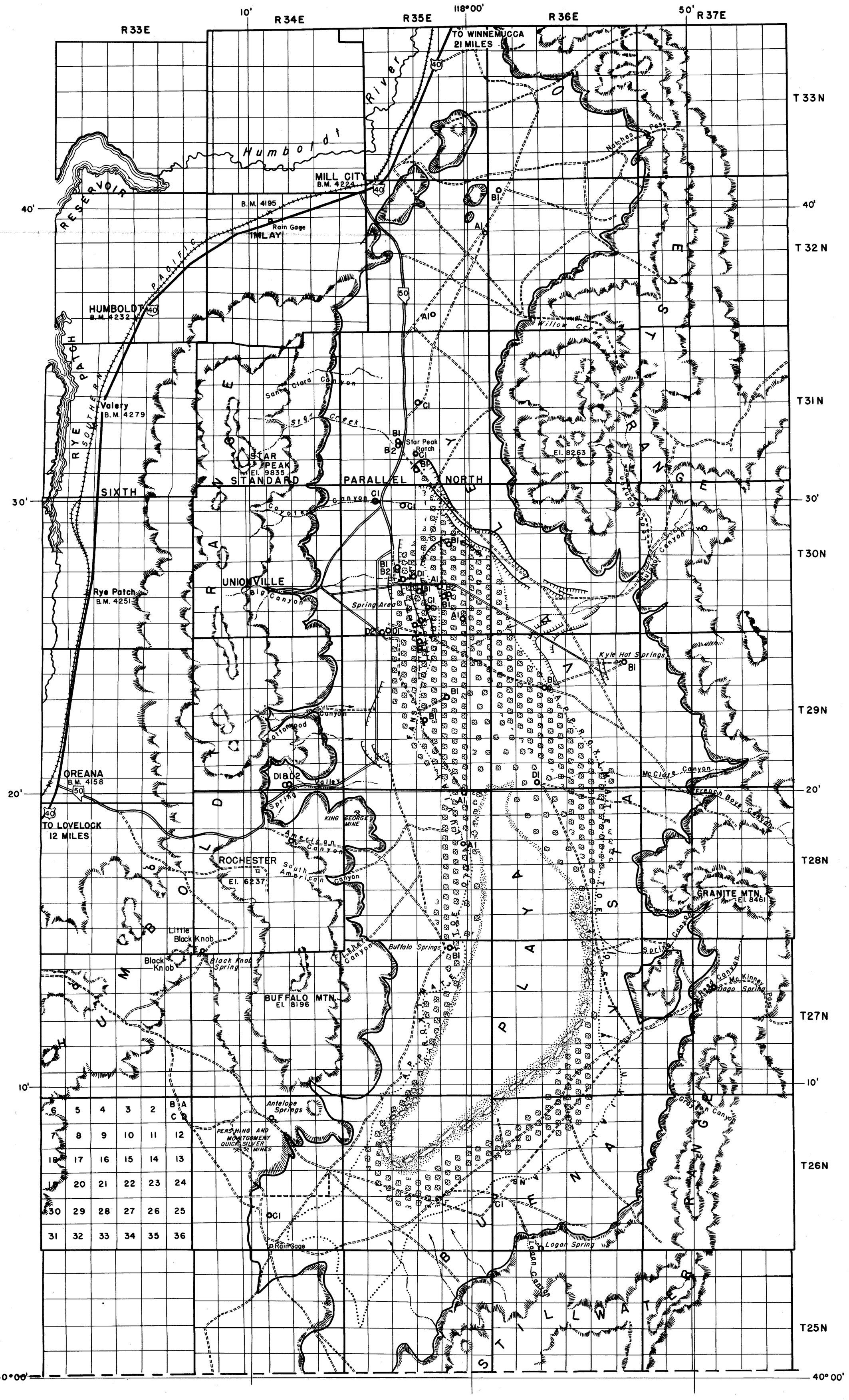

EXPLANATION

Lake terrace

Sand dune area

Well

Boundary between bedrock and unconsolidated sediments

Transpiration area

Spring

Base compiled from U. S. Geological Survey maps and Bureau of Land Management map

MAP OF BUENA VISTA VALLEY, PERSHING COUNTY, NEVADA

Showing general geologic and hydrologic features, location of wells and springs, and area of transpiration

September 1953

Scale
1 0 1 2 3 4 5 MILES