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STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

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WATER RESOURCES BULLETIN No. 12

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CONTRIBUTIONS
TO THE
HYDROLOGY OF EASTERN NEVADA

Papers by
T. E. EAKIN, G. B. MAXEY, T. W. ROBINSON,
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Prepared cooperatively by the
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187

TABLE OF CONTENTS

FOREWORD

This bulletin contains reconnaissance reports on ground-water conditions in several valleys in the eastern part of Nevada that have been studied and reported upon by the U. S. Geological Survey under the cooperative program with the State Engineer of Nevada. (See Fig. 1, following page.)

While these reports are purely of a reconnaissance nature, they form a basis for proper understanding of the occurrence, source, movement, and disposal of ground water in the respective basins. Estimates are included on the amount of water that may potentially be developed in each valley and therefore add much to our knowledge of our water resources.

Very little ground-water development has so far been made in the valleys covered by this bulletin. The demand for food and forage will become more acute as time passes, and we anticipate that many of the arid valleys in our State will eventually be developed to their full potential.

We are indebted to the University of Nevada Agricultural Experiment Station for their splendid cooperation in assigning Howard Mason, Agricultural Economist, to the task of making reconnaissance land classification studies included in some of the reports contained in this bulletin. We also wish to express our appreciation for the valuable assistance of the U. S. Bureau of Land Management, U. S. Soil Conservation Service, and the Nevada State Department of Highways.

The cooperative program is under the supervision of Hugh A. Shamberger, Assistant State Engineer of Nevada, and Thomas W. Robinson, District Engineer, Ground Water Branch, U. S. Geological Survey.

ALFRED MERRITT SMITH,
State Engineer.

May 4, 1951.

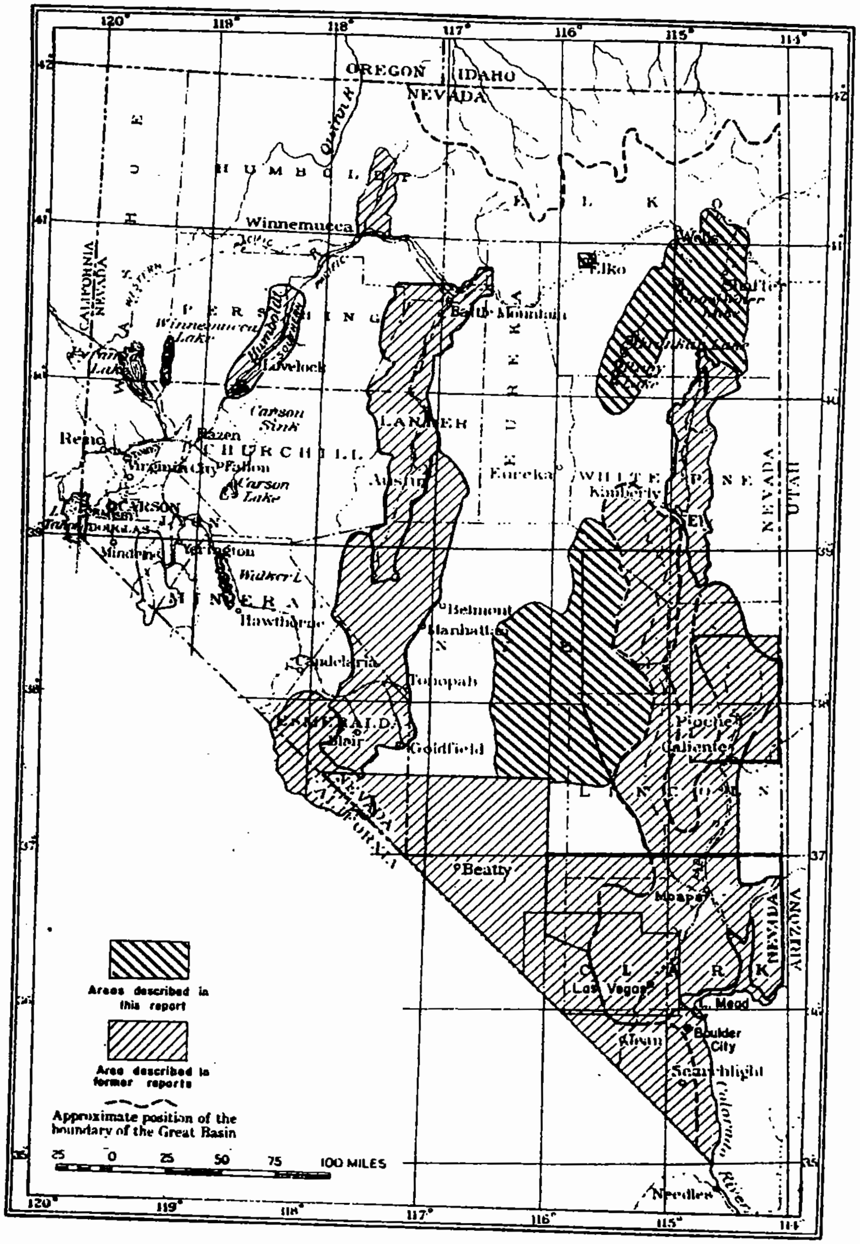

FIGURE 1. Map of Nevada showing areas covered by published ground-water reports and by the present report.

ABSTRACTS

GROUND WATER IN GOSHUTE-ANTELOPE VALLEY, ELKO COUNTY, NEVADA

By T. E. Eakin and G. B. Maxey, *Geologists*, and T. W. Robinson, *Engineer*,
U. S. Geological Survey

Goshute-Antelope Valley occupies an intermontane depression in southeast Elko County, Nevada. The Pequop Mountains which form the west boundary of the valley separate it from the adjacent Independence Valley. The crest altitudes of the mountains commonly range from 7,000 to 8,000 feet above sea level, but exceed 10,000 feet in the north-central part. The Goshute Mountains and Toana Range form the east boundary of the valley. The crest altitude is about 8,000 feet above sea level for about 30 miles along the central part of the mountains.

Most of the valley is used for grazing but a relatively small acreage is irrigated east and southeast of Johnson Springs and also about 4 miles northwest of Decoy. Some of the residents are employed by the Western Pacific Railroad, Southern Pacific Company and the Nevada Northern Railroad for maintenance and operation of the respective railroads that pass through the valley. The highway station at Oasis has a small permanent population that serves travelers on U. S. Highway 40.

The main purpose of this reconnaissance investigation was to study the source, occurrence, movement and disposal of ground water, and to obtain an estimate of the annual amount of ground water that might be developed by wells.

Available precipitation records suggest that precipitation on the floor of the valley may average about 8 inches a year. The frost-free or growing season is inferred to be about 100 days on the basis of apparent similarity with the record in Clover Valley about 25 miles west of Shafter.

A few short steep streams discharge water during the spring runoff from the adjacent flanks of the mountains bordering the valley.

The principal water-bearing beds probably are in the unconsolidated sediments underlying the alluvial apron and valley floor. These generally occur as beds of sand and gravel, but the continuity and areal extent cannot be defined because of relatively little information from well logs. Interbedded with the water-bearing beds are deposits of fine-grained sediments.

Information available from a 251-foot railroad supply well at Shafter indicates that water was obtained between the depth of 117 and 251 feet. According to the reported log the water is derived from zones of gravel and possibly limestone. The yield of this well has been reported to be as much as 1,000 gallons a minute.

The principal source of ground water in Goshute-Antelope Valley is from precipitation on the adjacent flanks of the mountains bordering the west and east sides of the valley. Much of the precipitation is lost by evaporation and transpiration before it reaches the ground-water reservoir. Reconnaissance methods of estimating the ground-water recharge and discharge indicate that both the average annual recharge and discharge is about 10,000 acre-feet. Under extensive development about one-fourth of this amount could be recovered by wells. Withdrawals by wells at the time of this investigation were rather small in aggregate but supplied stock, domestic, irrigation and railroad requirements. The areal extent of the valley fill is very large and consequently a very large quantity of ground water is in storage. Assuming a specific yield of 10 percent, there would be about 36,000 acre-feet of water in storage for each foot in the upper part of the saturated sediments. Thus a relatively large amount of water is available from storage for use during protracted periods of drought or for temporary periods of large withdrawals.

The report includes a discussion of the general geology as it relates to ground water, the results of four chemical analyses, and a table of records of wells in the valley. The general geologic and hydrologic data are shown on Plate 1. Tables of climatologic data are given, as is a brief discussion of the vegetation and soils.

GROUND WATER IN THE VICINITY OF ELKO, NEVADA

By J. C. Fredericks, *Geologist*, and O. J. Loeltz, *Engineer*,
U. S. Geological Survey

Elko, lying in the valley of the Humboldt River, is the county seat of Elko County. In 1940 it had a population of 4,094. The municipal water supply is obtained from a well field at the northeast edge of the city and from a group of springs in Kittridge Canyon about 6 miles northwest of Elko. An increase in annual pumpage from 269 million gallons in 1937 to about 408 million gallons in 1946 taxed the existing facilities to a point where the city deemed it advisable to augment the municipal supply. The present study was made to determine the most favorable area for future ground-water development.

The Elko Basin lies between the River Range on the northwest and the Elko Range on the southeast. The altitude of the crest of the River Range is generally about 7,000 feet, and of the Elko Range somewhat less than 7,000 feet. The Humboldt River entering the basin from the northeast has built a narrow, nearly flat flood plain ranging from a quarter of a mile to nearly three-quarters of a mile wide, at an altitude of about 5,000 feet above sea level.

The average annual precipitation at Elko based on 75 years of record is 9.68 inches. The mean annual temperature is 46° F.

The rocks in the vicinity of Elko range in age from Paleozoic limestones and quartzites to surficial Quaternary alluvial deposits. Tertiary alluvial and lacustrine deposits are the most favorable for developing large supplies for the city. The series of rocks, called the Humboldt formation, may be several thousand feet thick. The logs of wells penetrating 400 to 600 feet of the Humboldt formation near Elko indicate that the water-bearing beds consist of sand and/or gravel and are generally lenticular and of limited areal extent. They commonly contain considerable fine sand and silt which materially reduce the permeability of the beds. The Humboldt formation is recharged principally by water from the Humboldt River, and by infiltration of runoff from the adjacent mountain ranges. Recharge appears to be considerably in excess of withdrawals by pumping. Although water is encountered in the Quaternary alluvial deposits at shallow depth in the flood plain of the Humboldt River, the yield of wells penetrating these deposits probably would not be adequate for augmenting the municipal supply.

Five city wells tap the Humboldt formation. The water, under artesian head, rises to within 20 to 40 feet of the land surface. Yields range from 204 to 751 gallons per minute, and specific capacities range from 3.9 to 12.6 gallons per minute per foot of drawdown. Warm to hot water, or mud, has been encountered at depths less than 500 feet in some parts of the area. The thermal water is believed to have a common source with the Elko Hot Springs that arise 1 mile southwest of Elko. Water in the Humboldt formation generally is only moderately mineralized and is suitable for domestic use.

An average transmissibility of about 40,000 gallons per day per foot and a coefficient of storage of about 0.001 was determined for the formations penetrated by the city wells. Assumed pumping schedules for a hypothetical well field penetrating an ideal formation having hydrologic characteristics similar to the formation penetrated by the city wells indicate significant changes in interference effects between wells with changes in pumping schedules. The simultaneous pumping of adjacent wells increased interference effects 40 percent over the interference resulting from pumping alternate wells.

The most favorable area for future ground-water development is northeast of Elko, along the Humboldt River plain. New wells should be drilled at least 1,500 feet and preferably 2,000 feet apart from any existing well in order to minimize interference effects.

Included in the report is a table of monthly and annual pumpage from 1937 to 1946, data on the performance of the city wells, drillers' logs, chemical analyses of water from five wells, and a table containing pertinent data for 14 wells. Illustrations include maps of the area showing general geology, and location of wells and springs; and a graph showing the theoretical relation between lowering of the water level, time after pumping begins, and distances from the pumped well.

GROUND WATER IN RUBY VALLEY, ELKO AND WHITE PINE COUNTIES, NEVADA

By T. E. Eakin and G. B. Maxey, *Geologists, U. S. Geological Survey*

Ruby Valley is a north-south trending valley largely in the south-central part of Elko County but with a small segment extending south into White Pine County, Nevada.

The principal mountains which border the valley are the Ruby Mountains on the west and the East Humboldt Range on the north and northeast. The crest of these mountains range in altitude from about 8,000 to 11,000 feet above sea level and may average nearly 10,000 feet. The mountains which border other parts of the valley have substantially lower altitudes. The floor of Ruby Valley has an altitude of approximately 6,000 feet.

The principal activity in the valley is raising livestock and some forage. Mining operations are limited and intermittent. The population is limited to residents on several ranches which are distributed along the west, north, and northwest sides of the valley. Gravel roads connect most of the ranches. Wells, the nearest town, is about 40 miles north from the northeast part of the valley.

The main purpose of this reconnaissance investigation was to study the source, occurrence, movement and disposal of ground water, and to obtain an estimate of the annual amount of ground water that might be recovered by wells.

Weather records indicate that precipitation averages 10 to 12 inches per year on the floor of the valley. Snow survey records suggest that precipitation in the mountains is relatively heavy and locally may exceed 35 inches a year. The frost-free or growing season has ranged from a minimum of 68 days to a maximum of 151 days during 8 years of record from 1940–1948.

Franklin River, which drains the mountains at the north end of the valley, is perennial at least to sec. 11, T. 33 N., R. 60 E., and during the spring runoff ordinarily discharges into the north end of Franklin Lake. Many short streams, which drain the east flank of the Ruby Mountains, are perennial to the upper part of the alluvial apron.

The principal water-bearing beds are in the alluvial apron and the younger unconsolidated deposits underlying the floor of the valley. These generally occur as beds of sand or sand and gravel, but the continuity and areal extent cannot be defined because of relatively little information from well logs. The water-bearing beds are interbedded with deposits of relatively fine sediments frequently approximating silty fine sand. The consolidated and igneous rocks of the mountains are relatively impermeable and act as a barrier to the movement of ground water with local exceptions—that is, solution openings in limestone. These openings form a conduit system and may supply water to springs such as that of Cave Creek. Water so transmitted in bedrock may also supply water directly to the ground-water reservoir in the valley fill.

The principal source of ground water is from precipitation on the adjacent flanks of the Ruby Mountains and East Humboldt Range, but lesser amounts are supplied from the mountain areas along the east and south sides of Ruby Valley. Much of the precipitation is lost by evaporation and transpiration before it reaches the ground-water reservoir. A reconnaissance method of estimating average annual ground-water recharge from precipitation indicates that the annual increment is about 68,000 acre-feet. Ground water moves underground toward the lowest parts of the valley where it is discharged by phreatophyte vegetation, evaporation from Ruby and Franklin Lakes, and evaporation from soil.

Much of the ground water supplied to Ruby Lake supports the lake which is used as a wildlife refuge. For this reason potential ground-water withdrawals have been considered primarily for the northern part of the valley—that is, the northern part of Franklin Lake. In this area the average annual ground-water discharge, largely by phreatophytes, is estimated to be about 37,000 acre-feet. Under extensive ground-water development possibly one-half of the natural discharge could be recovered by wells. Present well discharge is used for stock and domestic purposes.

The report includes: A discussion of the general geology as it relates to ground water; the information obtained by drilling a test well; analyses of water from two water-bearing zones in the test well and one for Sulphur Hot Springs; a table of records of wells in the valley. The general geologic and hydrologic data are shown on Plate 2, tables summarizing climatologic data are given, and the vegetation and soils are briefly discussed from information obtained by Howard G. Mason, Agricultural Economist, University of Nevada Agricultural Experiment Station.

GROUND WATER IN CLOVER AND INDEPENDENCE VALLEYS, ELKO COUNTY, NEVADA

By T. E. Eakin and G. B. Maxey, *Geologists, U. S. Geological Survey*

Clover and Independence Valleys are north-south trending valleys in the south-central part of Elko County. Clover Valley lies adjacent to and northeast of Ruby Valley, and Independence Valley adjoins Clover Valley on the east. Under conditions of favorable runoff, surface water in Clover Valley could enter the playa area of Independence Valley through a poorly defined drainage way several miles south of Tobar.

The East Humboldt Range is the principal range that borders Clover Valley on the west. The crest altitude of the range averages somewhat more than 10,000 feet above sea level for a distance of 10 miles. Spruce Mountain at the south end of the valley has a peak altitude of 11,041 feet above sea level. However, the altitude diminishes rapidly from this point. The mountains which border other parts of the valley have substantially lower altitudes. A narrow alluvial divide forms the north boundary of the valley.

The most prominent mountains which border Independence Valley are the Pequop Mountains along the east margin. The crest altitude commonly ranges from 7,000 to 8,000 feet above sea level, but exceeds 10,000 feet in the north-central part of the range. Elsewhere the highest parts of the enclosing mountains and divides probably nowhere exceed 8,000 feet above sea level and ordinarily are less than 7,000 feet.

The principal activity in the valleys is raising livestock and forage. This activity is confined to several ranches along the west side of Clover Valley.

Other than at the ranches, the only residents are those at the Western Pacific railroad station at Jasper and Ventosa in Independence Valley and Tobar and Boaz in Clover Valley. U. S. Highway 93 traverses Clover Valley from north to south more or less along the west side of the valley; gravel-surfaced roads are conveniently located for use by the valley residents; and trails make most parts of the valleys accessible in dry weather.

The main purpose of this reconnaissance investigation was to study the source, occurrence, movement and disposal of ground water and to obtain an estimate of the annual amount of ground water that might be recovered by wells.

Weather records at Clover Valley station for a 39-year period ending in 1933 indicate an annual precipitation of 13.22 inches. This station was on the lower west side slope of Clover Valley and therefore the record probably reflects a somewhat higher precipitation than falls on the valley floor. The frost-free or growing season for a 27-year period ending 1932 at the Clover Valley station averaged about 100 days and ranged from 64 days in 1918 to 149 days in 1910.

Many short streams drain the east flank of the East Humboldt Range and several are perennial to the upper part of the alluvial apron. Ordinarily a substantial part of the runoff is used for irrigation at the several ranches.

The principal water-bearing beds are in the lower parts of the alluvial apron and the younger unconsolidated deposits underlying the floor of the valley. These generally occur as beds of sand and gravel, interbedded with finer sediments, but their continuity and areal extent have not been defined because of lack of well logs.

The bedrock of the mountains is relatively impermeable and acts as a barrier to ground-water movement with local exceptions—that is, solution openings in limestone. These openings may form a conduit system that supplies water to springs such as the spring in the NE$\frac{1}{4}$, sec. 30, T. 36 N., R. 62 E. and probably

Warm Spring in the SE¼, sec. 12, T. 33 N., R. 61 E. Such a conduit system could also supply water directly to the ground-water reservoir in the valley fill.

The principal source of ground water is from precipitation on the east flank of the East Humboldt Range for Clover Valley and the west flank of the Pequop Mountains for Independence Valley, but lesser amounts are supplied from the other mountain areas bordering the valleys. Much of the precipitation is lost by evaporation or transpiration before it reaches the ground-water reservoir. A reconnaissance method of estimating average annual ground-water recharge from precipitation indicates an annual increment of about 21,000 acre-feet for Clover Valley and about 9,000 acre-feet for Independence Valley. Ground water moves toward the lower parts of the valleys where it is discharged by transpiration, or evaporation from soil and free-water surfaces.

Estimates of the average annual ground-water discharge suggest that about 19,000 acre-feet are discharged from Clover Valley and about 9,500 acre-feet from Independence Valley.

Under extensive ground-water development possibly one-half of the natural discharge could be recovered by wells in Clover Valley and about one-fifth of the natural discharge from Independence Valley. Most of the existing wells are used to supply stock and domestic requirements. The discharge from the springs s used principally for irrigation.

The report includes: A discussion of the general geology as t relates to ground water; the information obtained by drilling test well in Clover Valley; analyses of water from Warm Spring 33/61-12D1) and from four zones in the test well (35/62-27B1); nd tables of records of wells in Clover and Independence Valleys.

The general geologic and hydrologic features are shown on Plate 3. Tables summarizing climatologic data are given and the egetation and soils of Clover Valley are discussed briefly on he basis of information obtained in a field reconnaissance by Howard G. Mason, Agricultural Economist, University of Nevada gricultural Experiment Station.

GROUND WATER IN RAILROAD, HOT CREEK, REVEILLE, KAWICH, AND PENOYER VALLEYS, NYE, LINCOLN AND WHITE PINE COUNTIES, NEVADA

By G. B. MAXEY and T. E. EAKIN, *Geologists, U. S. Geological Survey*

This report describes a region of alternate valleys and moun- in ranges covering about 5,570 square miles in the central part the Great Basin in east-central Nevada. Railroad Valley has interior drainage and Hot Creek and Reveille Valleys are tributary to it. Kawich and Penoyer Valleys are separate closed basins. In general, the valleys and ranges trend northward. The sparse population is engaged principally in raising livestock but there is some supplemental farming. Mining operations are limited to a few scattered localities. The principal ranches are adjacent to springs, or creeks supplied by springs. Wells are used primarily to supply stock on the range, but they supply some domestic requirements also.

The main purpose of this reconnaissance investigation was to study the source, occurrence, movement, and disposal of ground water and to obtain an estimate of the annual amount of ground water that might be recovered by wells.

The principal water-bearing beds are the more permeable sand and gravel deposits of the Tertiary and Quaternary valley fill. Several wells drilled in the lower part of Railroad Valley and a few in Hot Creek Valley have yielded water under sufficient artesian pressure to flow at the land surface. The maximum reported yield for a flowing well is 480 gallons a minute, but most wells flow less than 100 gallons a minute.

Ground water in the valleys is recharged principally by rain water and snow melt from the adjacent mountains. Discharge of ground water in the region ultimately is by evaporation and transpiration. In Railroad Valley, the estimated average annual discharge of ground water, including the discharge from Hot Creek and Reveille Valley, is about 50,000 acre-feet. The average recharge of course is the same. In Penoyer and Kawich Valleys the estimated average annual recharge to and discharge from ground water are only a few thousand acre-feet each.

Big Warm Spring at Duckwater in the northwestern part of Railroad Valley is the largest spring in the region, having a discharge that may average about 14 second-feet. It and some small nearby springs are used for irrigation on several ranches, but a considerable part of the annual flow of the springs is discharged to the southeast beyond the irrigated area. Of this "waste" water a part infiltrates to the main ground-water reservoir in Railroad Valley.

The report contains climatological data, data on the discharge of certain springs and of Current Creek, and the logs of several relatively deep wells not previously published.

A reconnaissance report on land classification by Howard G. Mason of the Nevada Agricultural Experiment Station is included.

DESIGNATION OF WELLS AND SPRINGS

Wells and springs are designated by a single numbering system used in all five reports of Bulletin 12. The number assigned to a well or spring in these reports is both an identification and location number. It is based on the Mt. Diablo base and meridian network of surveys established by the General Land Office.

A typical number usually consists of three units. The first unit is the township number north of Mt. Diablo base unless some of the townships in a valley or group of valleys comprising a unit of this bulletin are south of the Mt. Diablo base, in which case the township number in that unit is followed by the letter N or S to designate the township number north or south, respectively, of the Mt. Diablo base. The second unit, separated from the first by a slant, is the range number east of Mt. Diablo meridian. The third unit, separated from the second by a dash, is the number of the section in the township. The section number is followed by a letter, which designates the quarter section and finally, a number designating the order in which the well or spring was recorded in that quarter section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section.

Thus, well number 33/66-32A2 indicates this well was the second well recorded in the NE¼ of section 32, T. 33 N., R. 66 E., Mt. Diablo base and meridian. If the area covered by a report includes wells on both sides of the Mt. Diablo base the well number is modified as follows: Well number 3S/54-13D1 indicates the first well recorded in the SE¼ sec. 13, T. 3 S., R. 54 E., and well number 5N/54-32C1 designates the first well recorded in he SW¼ sec. 32, T. 5 N., R. 54 E.

Owing to space limitation wells and springs on Plates 1 and 4 nd Figures 2 and 3 are identified only by section number, a etter showing the quarter section, and a number showing the rder in which it was recorded in the quarter section. On Plates , 3, and 5, section numbers for wells are not given but they can e determined by noting the corresponding section number shown or T. 5 N., R. 55 E., Plate 5. Township and range numbers re shown on the edges of the plates.

STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

GROUND WATER IN GOSHUTE-ANTELOPE VALLEY, ELKO COUNTY, NEVADA

By T. E. EAKIN and G. B. MAXEY, Geologists, and T. W. ROBINSON, Engineer,
U. S. Geological Survey

Prepared cooperatively by the
UNITED STATES GEOLOGICAL SURVEY
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CONTENTS

ILLUSTRATIONS

GROUND WATER IN GOSHUTE-ANTELOPE VALLEY, ELKO COUNTY, NEVADA

By T. E. Eakin and G. B. Maxey, *Geologists*, and T. W. Robinson, *Engineer, U. S. Geological Survey.*

INTRODUCTION

The area included in this report is in eastern Elko County some 20 miles west of the Nevada-Utah State line between latitudes 40°08′ and 41°09′ north and longitudes 114°14′ and 114°48′ west (see pl. 1).

Goshute Valley occupies the northern part of this area, an intermontane depression, from the vicinity of Cobre on the north to Shafter on the south. Antelope Valley extends from Shafter southward and adjoins Spring Valley in White Pine County. For this report it is defined to extend to a low alluvial divide about at the south boundary of Elko County. A tongue of the valley extends southwest from Dolly Varden siding to within 2 miles of Currie, where it is connected with Steptoe Valley by a narrow gap in the bedrock. The total drainage area is about 1,230 square miles.

The valleys are reasonably accessible by road. U. S. Highway 50 crosses Antelope Valley near the south end. U. S. Highway 40 crosses the central part of Goshute Valley. Fairly good dry-weather roads extend along the east and west sides of the valley and connect with U. S. Highways 40 and 50.

The Southern Pacific Railroad crosses the extreme north end of the valley at Cobre. The Western Pacific Railroad crosses the valley and goes through Shafter. The Nevada Northern Railroad extends south from Cobre through Shafter and leaves the valley at Currie.

The population of the valley probably does not exceed 200. The only populated places are the railroad stations of Shafter and Cobre, the highway station of Oasis, and several ranches, only two of which have permanent residents.

Most of the valley area is grazing land, but small acreages are irrigated from surface runoff in the southwest part of T. 33 N., R. 66 E., by pumping from a well situated approximately in sec. 33, T. 35 N., R. 66 E., and from Johnson Springs, approximately in sec. 33, T 36 N., R. 66 E.

Previous work by the U. S. Geological Survey in this area includes a reconnaissance in 1946 by H. V. Peterson to locate stock wells in Goshute Valley and adjacent areas, and an investigation in 1942–1943 by P. E. Dennis of Johnson Springs and vicinity for a water supply for the Army Air Base at Wendover, Utah.

The present report is based on field work in May and June, 1948. Field data on essentially all the wells in the area were obtained and a reconnaissance of the geology and hydrology was made. Some additional office work was necessary to obtain other pertinent data.

CLIMATE

The climate of the valley is arid to semiarid and characterized by low precipitation, low humidity, and high evaporation, and a large temperature range both daily and seasonally. Precipitation is least on the valley floor and greatest in the higher parts of the mountains.

The only precipitation record within the area is a short, broken record for Otego. These and the other climatological data are from records of the U. S. Weather Bureau.

Average monthly and annual precipitation at *Otego, Elko County
(Broken record, period 1877–1887)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.96	1.18	0.70	1.22	0.66	0.38	0.21	0.38	0.25	0.65	0.51	1.01	8.11

*Location and altitude uncertain.

The annual precipitation at Otego during the period of record ranged from 1.85 inches in 1880 to 13.32 inches in 1884.

A longer record is available at Toano, just west of Cobre. There the period of record was from 1870 to 1905. The annual precipitation ranged from 1.80 inches in 1881 to 20.38 inches in 1891. As the altitude of Toano (5,975 feet above sea level) is about 300 to 400 feet greater than that of the floor of Goshute-Antelope Valley, the precipitation may be slightly greater also. The following table summarizes the precipitation at Toano:

Average monthly and annual precipitation at Toano, Elko County
(Record broken)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.92	0.85	0.87	0.81	0.92	0.66	0.28	0.22	0.25	0.44	0.64	1.30	8.16

No temperature records are available for the valley. However, Clover Valley station, about 25 miles west of Shafter, is believed representative. The temperature data are summarized below:

Temperature at Clover Valley, Elko County. Altitude 5,800 feet.

	Jan.	Feb.	Mar.	Apr.	May	June
Average*	24.6	29.3	35.7	44.3	51.0	59.4
Average minimum*	12.3	17.9	23.1	29.2	35.3	42.3
Average maximum*	36.8	40.8	48.3	59.4	66.6	76.4

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average*	67.2	65.8	57.5	47.0	36.7	26.3	45.4
Average minimum*	49.3	47.6	39.3	30.1	21.9	13.6	30.2
Average maximum*	85.2	83.9	75.7	63.8	51.6	39.0	60.6

*Temperature in degrees Fahrenheit; period of record 27 years, ending in 1930.

The record of the frost-free period at Clover Valley is also believed to approximate that of Goshute-Antelope Valley. At Clover Valley the frost-free period has ranged from 149 days in 1910 to 64 days in 1918 and has averaged about 100 days for the 22-year period ending in 1930. Thus, the growing season in Goshute-Antelope Valley is short and is suitable only for the production of hay and other frost-resistant or rapidly maturing crops.

VEGETATION AND SOILS

The vegetation* on the floor of Goshute-Antelope Valley, according to Soil Conservation Service maps, includes big greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), big sagebrush (*Artemisia tridentata*), white sage (*Eurotia lanata*), big rabbit brush (*Chrysothamnus sp.*), and mixed grasses and other members typical of the Northern Desert Shrub plant association.

The soils in the potential area of irrigation with ground water, although locally somewhat heavy and alkaline, appear to be suitable for crops commonly grown in eastern Nevada. These soils, however, may require treatment for continued crop production.

PHYSIOGRAPHY AND DRAINAGE

Goshute-Antelope Valley of this report lies within the Great Basin section of the Basin and Range physiographic province. It occupies a structural trough elongated in a general north-south direction. In its south part the valley is separated into southwest- and southeast-trending tongues separated by the Antelope Range. The valley is about 70 miles long and the valley floor averages 8 to 10 miles in width. The lowest part of the valley is nearly flat in both east-west and north-south directions. This is indicated in part by a level line along the Nevada Northern Railroad where, for a distance of 22 miles between Dolly Varden siding and Shafter, there is an altitude differential of only 10

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*See list of references at end of report.

feet. The altitude of the valley floor is about 5,600 feet above sea level.

The valley is bounded on the east by the Goshute Mountains to the south and the Toano Range to the north. The Pequop Mountains bound the valley on the west. The north end of the valley is terminated by a mountain mass extending southward and merging with the Pequop Mountains and the Toano Range in low passes. A low range of hills connects the Pequop Mountains with the Antelope Mountains to the south, and a low alluvial divide connects the Antelope Mountains with the Goshute Mountains.

The summit altitude of the Pequop Mountains commonly ranges between 7,000 and 8,000 feet above sea level but exceeds 10,000 feet westward from Johnson Springs. In the Toano-Goshute Range, the summit altitude is somewhat above 8,000 feet from a point about east of Shafter to a point about 5 miles north of U. S. Highway 50. Elsewhere the mountains are lower.

Intermittent streams drain the flanks of these mountains adjacent to the valley. Some surface discharge may occasionally enter the valley near Currie from Steptoe Valley. There is no surface discharge from the Goshute-Antelope Valley.

GENERAL GEOLOGY

The oldest rocks in the area are exposed in the mountains surrounding the valley. They consist of limestones and associated sedimentary rocks of Paleozoic age. Quartz monzonite of Mesozoic(?) age is intrusive into the Paleozoic sedimentary rocks in the north part of the Antelope Range (the Dolly Varden Mountains), in Silver Zone (Middle Zone) Pass of the Toano Range, and in the White Horse district of the Goshute Range (Hill, 1916). The Paleozoic and Mesozoic(?) rocks are overlain unconformably by Tertiary(?) lava flows of two periods of extrusion. Most of the valley fill is of Tertiary age and is believed to consist primarily of lacustrine sediments together with marginal alluvial-fan deposits (see log of well 34/67-6A1 in well table). Deposits of Pleistocene age are of minor importance but appear to form a thin lacustrine mantle on the valley floor. They occur most prominently in the forms of beaches, bars, spits, and other shore features on the lower parts of the alluvial fans. Deposits of Recent age appear to be very minor. A tentative geologic history is given below:

1. Deposition of limestone and associated sediments of Paleozoic age.

2. Quartz monzonite intrusion accompanied by folding and faulting (Mesozoic(?) age).
3. Erosion. The debris resulting from this erosion may have been minor, covered by later deposits, or it may have been removed from the area.
4. Extrusion of andesitic lava flows and associated ejectamenta of early(?) Tertiary age.
5. Faulting, involving the flow rocks.
6. Erosion in the mountains. Detritus from this erosion possibly related to lower member of Humboldt formation as defined by Sharp (1939).
7. Extrusion of rhyolitic lava of Tertiary age (contemporaneous(?) with the Humboldt formation as defined by Sharp (1939)).
8. Faulting and tilting involving rhyolitic flow rocks.
9. Erosion in mountains. Deposition of bulk of valley fill, predominantly lacustrine sediments with marginal alluvial fans; of Tertiary age but probably also of early Pleistocene age. (Related in part(?) to upper member of Humboldt formation as defined by Sharp (1939).)
10. Development of lake during late Pleistocene time. Two prominent shore lines and several minor shore lines developed during stages of the lake. Deposition primarily as lake-shore features.
11. Desiccation of the Pleistocene lake.
12. Minor erosion and deposition in Recent time.

GROUND WATER

The chief source of the ground water in Goshute-Antelope Valley is precipitation within the valley and on the adjacent flanks of the mountains. A small amount of water may enter the valley occasionally from Steptoe Valley.

Most of the valley floor and marginal alluvial fans has an average annual precipitation of about 8 inches, which probably does not contribute materially to the ground-water reservoir. Thus, essentially all of the contribution to the ground water is derived from precipitation on the flanks of the mountains adjacent to the valley floor.

Ground water occurs in the zone of saturation below the water table in the valley fill and in the bedrock. However, it has been obtained by wells only in the permeable sands and gravels of the valley fill. The bedrock has not been tested by wells to determine whether suitable bedrock aquifers occur in this area.

The ground water is recharged largely by surface flow from the mountain canyons that percolates into the valley fill in the alluvial-fan areas at the edges of the mountains. The slope and movement of the ground water within the central part of the valley fill have not been determined accurately. Available data indicate that the water table is nearly flat. For example, the "highway" well (28/68-8D1) has a water-level altitude of about 5,575 feet; well 31/66-30A1 has a water-level altitude of about 5,565 feet, and the railroad wells at Shafter (34/67-6A1, 2) have water-level altitudes of about 5,560 feet. These wells are spaced about 20 miles apart. Thus, in general, slow northerly movement of ground water in the valley fill is indicated. The character of the bedrock across the north end of the valley is not favorable for underflow out of the valley; thus the water is discharged largely or entirely by evaporation and transpiration by plants.

The depth to water is least in a narrow strip lying 2 to 5 miles west of the road between Shafter and Oasis. Over most of this area, topographically the lowest in the valley, the depth to water is 15 to 20 feet below the land surface and the water table is at its lowest altitude in the valley. The water table rises eastward and southward but the land surface rises even more rapidly, so that the depth to water increases; for example, it is 64 feet in well 32/67-24C1 and 101 feet in well 29/67-1A1. The 25- and 50-foot depth-to-water contours are shown approximately on plate 1.

ESTIMATED ANNUAL INCREMENT TO GROUND WATER

The average annual increment to ground water can be estimated as a percentage of the total precipitation within the drainage basin of Goshute-Antelope Valley. The best available basis from which to estimate total precipitation is the "Precipitation map of Nevada" showing areas of assumed equal rainfall, prepared in 1936, under the supervision of George Hardman, by the Nevada Agricultural Experiment Station. On this map precipitation is shown by zones of precipitation of less than 5 inches, 5 to 8 inches, 8 to 12 inches, 12 to 15 inches, 15 to 20 inches, and over 20 inches.

Preliminary recharge studies in east-central Nevada, in which estimates of ground-water discharge by natural losses were made for 13 valleys, indicate the approximate recharge in terms of percentage of the precipitation. The rainfall was estimated for each valley, using the rainfall map as a basis. The recharge percentages were balanced by trial and error against the estimates of discharge by natural losses in the 13 valleys. Lack of agreement in the recharge and discharge estimates for any one valley probably results primarily from insufficient detailed control for the precipitation map. The percentages derived agree reasonably well with those obtained in the Las Vegas Valley, Nevada, and the Roswell Basin, New Mexico, particularly for the zones of higher precipitation. The estimates are as follows: No significant ground-water recharge is believed to occur in the zones having precipitation of less than 8 inches. In the 8- to 12-inch zone the recharge may be about 3 percent of the precipitation; in the 12- to 15-inch zone, about 7 percent; in the 15- to 20-inch zone, about 15 percent; and in the zone having over 20 inches, about 25 percent.

For Goshute-Antelope Valley the percentage of recharge from precipitation in the 8- to 12-inch zone was reduced from 3 percent to 1 percent. This was largely because of the relatively great depth to the water table and because of the lack of collecting drainageways in the area included by the zone. Thus, there is a greater opportunity for loss of water by evaporation and transpiration by plants.

The areas of each zone of precipitation in the Goshute-Antelope Valley were determined by planimeter. The data pertinent to the estimate of recharge from precipitation are summarized in the following table:

Estimated average annual recharge from precipitation in Goshute-Antelope Valley, by zones

Precipitation (inches)	Area of zone (acres)	Percentage of recharge	Recharge (acre-feet)
8-12	340,000	1	2,800
12-15	89,000	7	7,000
15-20	2,800	15	600
Total			10,400

ESTIMATED AVERAGE ANNUAL DISCHARGE OF GROUND WATER

Discharge of ground water from Goshute-Antelope Valley is accomplished by pumpage from railroad wells; one irrigation well; and several stock wells; by spring flow, the water being disposed of eventually by evaporation and transpiration; and by natural discharge by evaporation and transpiration. Discharge by underground outflow is believed to be negligible. A summary of discharge is given in the following table:

Estimated annual discharge of ground water from Goshute-Antelope Valley

Method of discharge	Annual discharge (acre-feet)
Johnson Spring (26/66-29D1)—	
Discharge estimated at 1,500 gpm (3.3 sec.-ft.)	*2,400
Dolly Varden Spring (28/67-9A1)—	
Discharge estimated at 50 gpm (0.1 sec.-ft.)	*75
Railroad wells (34/66-6A1, 2)—	
Reported pumping rate 400 gpm for -A1, and 900 gpm for -A2. Estimate very rough	150
Irrigation well (35/66-33C1)—	
Pumping rate about 450 gpm. 60± acres irrigated; estimated duty 3½ feet	200
Evaporation and transpiration—	
About 107,000 acres, predominantly of greasewood vegetation, estimated average use about 0.03-foot. Depth to water along the outer margin of the area may be as much as 80 feet	3,200
About 16,000 acres where depth to water is 25 feet or less; includes greasewood, giant rabbit brush, and associated plants. Estimated average use about 0.25-foot	4,000
Discharge of miscellaneous small springs and stock pumping	*50
Total	10,075

It should be emphasized that only a part of the discharge can be salvaged perennially by pumping, because the recharge occurs over a widespread area whereas the area in which pumping for irrigation may be feasible is small and is distant from much of the recharge area. Adequate data are not available for estimating the recoverable part of the discharge, but an estimate of one-fourth, or about 2,500 acre-feet, seems reasonable.

STORAGE

A large amount of ground water is stored in the valley fill of Goshute-Antelope Valley. The magnitude of this storage is indicated by the following: The valley fill has an area of approximately 360,000 acres; assuming an average specific yield (the ratio of the volume of water a rock will yield by gravity to the total volume of the rock, expressed as a percentage) of 10 percent for the valley fill, the ground-water revervoir could yield about 36,000 acre-feet for every foot of lowering of the water table over the entire area of the valley fill. Of course, it is not possible to lower the water table uniformly by means of pumping, but the estimate serves to show that a relatively large volume

of ground water is available in storage for maintaining an adequate water supply for pumping during protracted periods of drought or for temporary periods of high pumping rates such as were required a few years ago for the military bases and industrial projects. However, the perennial yield is limited by the average annual recharge, only a part of which can be recovered practicably, as stated previously.

The actual amount of ground-water storage in the Goshute-Antelope Valley cannot be determined until after substantial well development has been made. It may then be possible to evaluate the specific yield of the valley fill by analysis of pumpage and water-level data.

DEVELOPMENT

Throughout most of Goshute-Antelope Valley the depth to water is greater than in other areas of ground-water irrigation in eastern Nevada. However, two areas in which the depth to water is 25 feet or less should be suitable for irrigation development. Here, if wells having a specific capacity (yield in gallons per minute per foot of drawdown) of 20 or more can be obtained, an adequate water supply for irrigation would be available with a moderate pumping lift.

The principal area includes perhaps 10,000 acres lying in a strip parallel to and about 2 to 5 miles west of the graded road between Shafter and Oasis. Some of the discharge from Johnson Springs is utilized for irrigation of native meadow in secs. 28 and 33, T. 36 N., R. 66 E. Irrigation by pumping was in progress (June 1948) on about 60 acres in sec. 33, T. 35 N., R. 66 E. The only data available on the performance of the well irrigating this tract are the discharge (estimated at 450 gallons per minute) and the static water level (about 20 feet below land surface). The construction of the well makes it difficult to get good data on the pumping lift, but some useful information could be obtained by determining the cost of pumping.

The second area includes about 6,000 acres in an irregular strip extending from a point about 1 mile west of Decoy to about 1 mile north of Flowery Lake. Here well 33/66-32A2 (with a 4-inch centrifugal pump) has been used to some extent for irrigation but is now used principally for stock watering. The reported yield of this well is 350 to 400 gallons per minute.

The average permeability of the water-bearing sediments of the valley fill is believed to be relatively low, because lake sediments constitute the bulk of the valley fill. However, local areas are known to be underlain by water-bearing sediments capable

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*A part of the spring water is discharged by evaporation and transpiration near the springs and where it is used for irrigation. This part is not included in the estimates given for evaporation and transpiration. The remainder of the spring water returns to the ground-water reservoir and is discharged later by evaporation and transpiration. This part is included in the estimates for evaporation and transpiration. The figures for evaporation and transpiration and thus total discharge are high by the amount of spring water that returns to the water table and is discharged later, but data are not available for computing this amount.

of yielding water in quantities sufficient for irrigation, as indicated by the following three wells in the north part of the valley:

The irrigation well in sec. 33, T. 35 N., R. 66 E., pumps about 450 gallons per minute; the railroad wells at Shafter (34/67-6A1 and 6A2) are reported to pump 400 and 900 gallons per minute, respectively. Well 34/67-6A1 is reported to have yielded 204 gallons per minute with a drawdown of 6 feet (specific capacity of 36 gallons per foot of drawdown). It is also reported to have yielded 1,000 gallons per minute with a drawdown of 7 feet 2 inches (specific capacity of 139 gallons per foot of drawdown). It is not certain which of these figures is more nearly correct, but even the smaller figure shows an adequate specific capacity for irrigation wells where the water table is not far beneath the land surface.

QUALITY OF WATER

The chemical character of the ground water in Goshute-Antelope Valley, as indicated by four analyses, shows considerable variation.

Chemical analyses of ground water from four localities in Goshute-Antelope Valley*
(Parts per million)

	No. 1 12-10-42	No. 2 1-29-43	No. 3 1-29-43	No. 4 1-29-43
Silica (SiO_2)	64	45	11	15
Iron (Fe)	....	0	0	0
Calcium (Ca)	64	36	43	44
Magnesium (Mg)	36	40	15	18
Sodium (Na)	192	373	8.3	10
Chloride (Cl)	204	287	11	13
Sulfate (SO_4)	240	355	13	15
Nitrate (NO_3)	....	0	0	0
Fluoride (F)	1.05	1.7	.2	.1
pH	7.6	7.5	7.5	7.35
Bicarbonate alkalinity (as $CaCO_3$)	186	322	160	172
Carbonate alkalinity (as $CaCO_3$)	....	6.0	7.0	3.0
Hardness (as $CaCO_3$)	307	252	168	182
Volatile and organic matter	....	125	30	34
Dissolved solids	941	1,380	191	217
Percent sodium†	58	77	10	11

*From data compiled by P. E. Dennis during an investigation for a water supply for Wendover Army Air Base, Utah, April 1943.
†Computed.

1. **Well 34/67-6A1.** Western Pacific Railroad well at Shafter, Nevada.
2. **Well 34/67-16D1.** Utah Construction Co. (U. C. Land and Cattle Co.) well about 3 miles southeast of Shafter.
3. **Large spring at Johnson Ranch (Johnson Springs).**

4. Small spring on Johnson Ranch, about half a mile northeast of Johnson Springs.

In general, the water in the central part of the valley is of relatively poor quality (analyses 1 and 2) whereas in the marginal areas it is probably of better quality. In localized areas of relatively large annual recharge the ground water is of excellent quality (analyses 3 and 4). Additional chemical analyses of ground water in various parts of the valley would better define the areal distribution of water of different quality.

Within the central part of the valley, the water from water-bearing zones of different depths is also variable. The water from well 34/67-6A1 (analysis 1) probably is more or less representative of the deeper zones and that of well 34/67-16D1 (analysis 2) may be representative of the shallow water-bearing zones.

Magistad and Christiansen (1944, pp. 8, 9) have given tentative standards for irrigation waters, but indicate that consideration should be given to the characteristics of the type of soil and the soil solution in evaluating the effect of a given chemical composition of the water on a given soil.

Standards for irrigation waters

Water class	Conductance (micromhos at 25° C.)	Salt Content Total (p.p.m.)	Salt Content Per acre-foot (tons)	Sodium[1] (percent)	Boron (p.p.m.)
Class 1[2]	<1,000	<700	<1	<60	<0.5
Class 2[3]	1,000–3,000	700–2,000	1–3	60–75	.5–2.0
Class 3[4]	>3,000	>2,000	>3	>75	>2.0

[1] The percentage of sodium is calculated from analytical results expressed in milligram equivalents per kilogram. These results are obtained by dividing the parts per million of sodium, calcium, and magnesium by 23, 20, and 12.24, respectively; then 100 times the milligram equivalents of sodium is divided by the sum of the milligram equivalents of sodium, calcium, and magnesium. In milligram equivalents $\frac{100\,Na}{Na+Ca+Mg}$ = percentage of sodium.

[2] Excellent to good, suitable for most plants under most conditions.

[3] Good to injurious, probably harmful to the more sensitive crops.

[4] Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant. If a water falls in Class 3 on any basis, i. e., conductance, salt content, percentage of sodium, or boron content, it should be classed as unsuitable under most conditions. Should the salts present be largely sulfates, the values for salt content in each class can be raised 50 percent.

The available analyses do not include determination of conductance or of boron. However, comparison of the sodium percent in the analysis of the water from well 34/67-16D1 (analysis 2) indicates unsuitability under most conditions. Water from well 34/67-6A1 (analysis 1) is near the upper limit of percent sodium for Class 1, but is probably suitable in general. The water from the two springs (analysis 3 and 4) apparently is satisfactory.

The water from well 34/67-16D1 (analysis 2) is too high in sulfate, dissolved solids, and fluoride to meet the drinking-water standards set by the Public Health Service Reports (1946). The water from well 34/67-6A1 (analysis 1) apparently is satisfactory for all constituents but approaches the upper limits of the drinking-water standards for sulfate and dissolved solids. The two other analyses indicate that the two springs on the Johnson Ranch yield water that is satisfactory so far as mineral quality is concerned.

CONCLUSIONS

Additional analyses of water from wells and springs distributed throughout Goshute-Antelope Valley are needed in order to give a complete over-all picture of the chemical character of the ground water.

Goshute-Antelope Valley has a very large ground-water storage capacity in comparison to the estimated annual recharge. This, together with the apparent lack of underflow from the valley, may make the area satisfactory for studies of storage capacity and specific yield of valley-fill sediments.

It would be worth while to study consumptive use of ground water by greasewood (*Sarcobatus vermiculatus*) in the Goshute-Antelope Valley. As greasewood grows where the depth to water ranges from 15 feet to as much as 80 feet or more, such a study would determine whether a measurable draft on ground water by greasewood occurs throughout this depth range. Data on the draft of ground water in this depth range are practically nonexistent.

The depth of drilling for irrigation or other large-capacity wells may range from 150 to perhaps 300 feet, depending on the permeability and depth of the water-bearing zones in the particular area to be drilled. In drilling wells each substantial water-bearing zone should be tested; and the wells should be adequately constructed and developed to obtain water efficiently from all potential water-bearing zones.

The following wells appear to be suitable for the periodic observation of water-level fluctuations that are needed to provide basic data on the effects of existing and future ground-water developments:

28/68-8D1. Well is located on slope of fan from Goshute Range; unused; not locally affected by evaporation and transpiration; accessibility, excellent.

32/66-33D1. Well is located on lower slope of fan; unused; little effect from evaporation and transpiration; accessibility, poor in wet weather.

34/66-8A1. Well is along margin of area of transpiration by plants; may also be somewhat affected by irrigation-well pumping; unused; accessibility, poor in wet weather. It would be preferable to obtain or put in another well in the same general area for similar information on water-level fluctuation.

34/67-6A2. Railroad supply well; measurements would be affected by pumping from the well itself and from well 34/67-6A1; accessibility, fair in wet weather. It might be possible to test these two wells to obtain information on the transmissibility and storage capacity of the water-bearing sediments in this part of the valley.

34/67-16D1. Well located on valley floor; little effect from transpiration; used for stock watering; accessibility, poor in wet weather.

WELL DATA

(For explanation of numbering system see page 16.)

28/68-8D1. "Highway" well. Public domain. Drilled, 6-inch casing; cylinder pump; used for stock. Depth to water, 98.95 feet below measuring point, top of casing, 0.5 foot above average land surface, June 25, 1948.

29/67-1A1. "Itcaina" well. Public domain. Dug, 48-inch wood cribbing; depth 113.5 feet below average land surface; cylinder pump; used for stock. Depth to water, 101.02 feet below measuring point, top of 4- by 4-inch sill on crib, 3.0 feet above average land surface, June 25, 1948.

31/66-30A1. Unknown. Dug, diameter and depth unknown; no pump; unused. Depth to water, 52.50 feet below measuring point, top of 1-inch pipe or sucker rod intake, 1.0-foot above land surface, May 21, 1948.

31/67-26D1. Shafter well No. 4. U. C. Land and Cattle Co. Drilled, 6-inch casing; cylinder pump; used for stock and domestic. Depth to water, 79.58 feet below measuring point, top of casing, land surface, June 25, 1948.

32/66-33D1. Milum(?). Drilled, 8-inch casing; depth, 55 feet; no pump; unused. Depth to water, 46.46 feet below measuring point, top of 3- by 6-inch wood cribbing at land surface and 3.5 feet above top of casing, May 21, 1948.

32/66-33D2. Milum(?). Drilled, 6-inch casing; depth, 110± feet; unused. Depth to water, 37.36 feet below measuring point, top of vertical 4- by 6-inch wood tie which is at land surface and 11.7 feet above top of casing, May 21, 1948.

32/67-24C1. Shafter well No. 3. U. C. Land and Cattle Co. Dug, diameter (?); depth 73± feet; cylinder pump; used for stock. Depth to water, 63.91 feet below measuring point, top of iron plate covering over well, 3.0 feet above average land surface, June 25, 1948.

33/66-32A1. Griswold. Drilled, 18-inch casing; depth, 42 feet; cylinder pump, windmill; used for stock. Depth to water, 25.96 feet below measuring point, bottom of pump base, at land surface, May 21, 1948.

33/66-32A2. Griswold. Drilled, 18-inch casing; depth 51 feet; 4-inch centrifugal pump; gasoline engine; reported yield 350–400 gallons per minute; used for stock. Reported depth to water, 26 feet.

33/67-26A1. Shafter well No. 2. U. C. Land and Cattle Co. Dug, diameter(?); depth, 65 feet; cylinder pump; used for stock. Depth to water, 54.93 feet below measuring point, top of 8- by 8-inch wood tie cover on well, 2.0 feet above average land surface, June 25, 1948.

34/66-8A1. Unknown. Diameter and depth, unknown; hand pump; unused. Depth to water 19 feet below measuring point, bottom of pump base, at land surface, June 25, 1948.

34/67-6A1. "Old" well. Western Pacific Railroad Co. Drilled, 1925; depth, 251 feet; casing diameter 14- to 12-inch: perforated 117 to 250 feet. Turbine pump, diesel engine, 37.5 hp. Yield: 204 gallons per minute with a 6-foot drawdown (on graphic log dated November 6, 1925); 1,000 gallons per minute, drawdown 7 feet 2 inches (reported in letter from P. E. Dennis to J. J. Duggan, dated January 27, 1943); and 400 gallons per minute, drawdown unknown (reported by pump operator May 21, 1948). Depth to water, 23.51 feet below measuring point, top of casing, 4.0 feet below land surface, May 21,

1948. Following is the log of the well, furnished by the Western Pacific Railroad Co.

Material	Thickness (feet)	Depth (feet)
Clay, yellow	23	23
Clay, blue, little sand	17	40
Clay, yellow	10	50
Clay, hard	10	60
Clay, hard, fine gravel	8	68
Clay, yellow	27	95
Clay and gravel	9	104
Clay, gravel, and sand	9	113
Gravel, cemented, very hard	10	123
Gravel, cemented, light	37	160
Limestone	5	165
"Rock dust" and limestone, white	20	185
Clay, light, sandy, some water	41	226
Clay and sandy clay	25	251
Total depth	----	251

34/67-6A2. "New" well. Western Pacific Railroad Co. Drilled, 16-inch casing; depth, 250 feet; turbine pump; gasoline engine; reported yield, 900 gallons per minute; railroad. Depth to water, 22.88 feet below measuring point, top of casing, 4.5 feet below land surface, May 21, 1948.

34/67-16D1. Shafter well No. 1. U. C. Land and Cattle Co. Dug, diameter(?); depth, 58 feet; cylinder pump; gasoline engine and windmill; used for stock. Depth to water, 46.57 feet below measuring point, top of iron plate well cover, 2.5 feet above average land surface, June 25, 1948.

35/66-33C1. Kern Packing Company(?). Drilled, depth unknown; turbine pump; tractor engine with power take-off. Yield, 450 gallons per minute. Depth to water below land surface 20 feet (estimated).

36/66-2C1. Oasis station. Drilled well; water level 225 feet below land surface (reported).

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STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

GROUND WATER IN THE VICINITY OF ELKO, NEVADA

By J. C. FREDERICKS, Geologist, and O. J. LOELTZ, Engineer,
U. S. Geological Survey

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CONTENTS

TABLES

Tables

ILLUSTRATIONS

GROUND WATER IN THE VICINITY OF ELKO, NEVADA

By J. C. Fredericks, *Geologist*, and O. J. Loeltz, *Engineer*,
U. S. Geological Survey.

INTRODUCTION

The city of Elko is located in the valley of the Humboldt River, in Elko County, northeastern Nevada, about 300 miles east of Reno, and about 240 miles west of Salt Lake City, Utah, on U. S. Highway 40. The Southern Pacific and Western Pacific Railroads pass through Elko in following the natural thoroughfare of the Humboldt River Valley. Elko is the county seat and supply center for the stock-raising and mining activities of Elko County. The population of Elko in 1940, reported in the 16th Census of the United States, was 4,094. The present population is probably slightly greater than in 1940.

The present city water supply is from two ground-water sources. The principal source is a group of five wells in the city well field at the northeast edge of the city. (See Fig. 2.) The other source is a group of springs located about six miles northwest of Elko in the upper reaches of Kittridge Canyon. These springs have been developed by tunnels driven horizontally into a consolidated conglomerate formation at the spring site. The springs discharge at a fairly uniform rate of about 200,000 gallons per day, and the water flows by gravity through a pipe line to City Reservoir No. 1 (capacity, 294,000 gallons) ; the overflow from reservoir No. 1 going to reservoir No. 2 (capacity, 555,000 gallons). The city wells discharge into reservoir No. 2 through a common pipeline. Reservoir No. 2 feeds the city mains while reservoir No. 1 is reserved as storage for fire protection. Both reservoirs are approximately 125 feet above the general elevation of the city.

During 1946, and a few earlier years, the summer peak demand of the city and the Southern Pacific and Western Pacific railroads, which are supplied by the city, has been as much as 1,750,000 gallons per day. As the result of this peak demand there are periods of exceptionally heavy draft on the city wells during the summer months.

The pumpage of water for use by the city and railroads has increased steadily during the 9½-year period (January 1937 through July 1946) for which records are available. During this

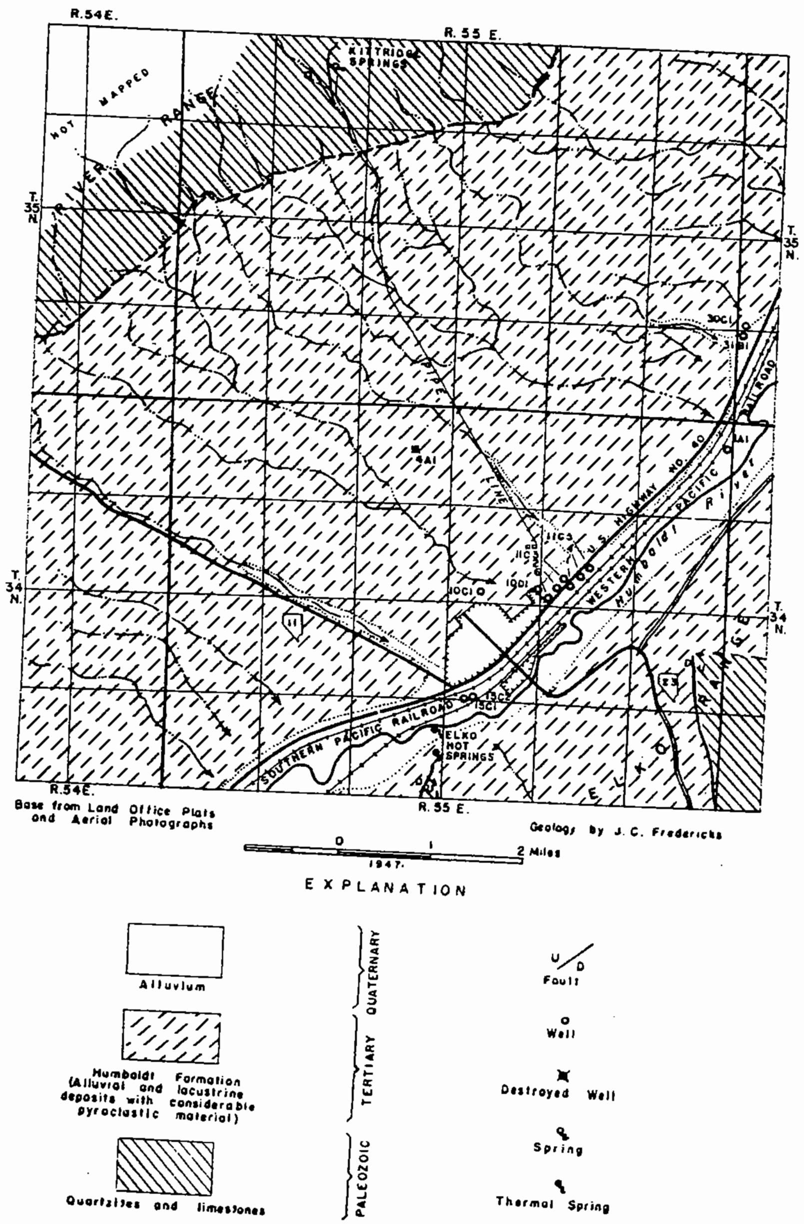

FIGURE 2. Map of Elko area, Nevada, showing general geology and location of wells and springs.

period the pumpage increased from 269 million gallons in 1937 to a maximum of about 408 million gallons in 1944, or more than 50 percent. It dropped slightly in 1945, but partial records for 1946 indicate the maximum of 408 million gallons may have been exceeded in that year.

The table that follows gives the total monthly and annual pumpage for the period of record (January 1937 through July 1946), based on the hours of operation of each well, and the average discharge for each well. The average discharge for each well is based upon the best available data of discharge over the period of record. The average rates of discharge used to compute monthly and annual pumpage are as follows:

Well No.	Discharge g.p.m.
9	250
10	480
11	300
12	630
14	620

The discharge rate for each well is not constant, but varies as the result of interference effects, fluctuations in water level, and changes in back pressure, depending upon whether there is individual or combined discharge into the reservoir pipe line by one or more wells. To ease the draft on the existing wells, caused by the heavy peak load and the increasing demand, the city is planning to drill additional wells.

In order to estimate the total amount of water used the amount of water supplied by the springs in Kittridge Canyon must be added to the amount shown in Table 1. These springs have a nearly constant flow of 200,000 gallons a day. However, during the period of record the pipe line to the City Reservoir No. 1 was not always functioning due to leaks and breaks in the line. Hence, the amount of water contributed from this source is not known exactly.

The purpose of this report is to record the ground-water conditions in the vicinity of Elko, and suggest the most favorable area for future ground-water development.

TABLE 1

Total monthly and annual pumpage in millions of gallons from wells of the City of Elko, 1937–1946

Month	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Jan.	20.77	23.06	18.71	20.05	22.46	27.62	23.86	29.00	32.58	30.64
Feb.	15.47	21.55	18.15	16.60	20.29	24.71	24.57	26.69	25.39	25.46
Mar.	16.55	18.33	19.54	19.21	22.90	25.90	25.47	28.71	22.07	26.60
Apr.	16.07	20.18	23.17	22.35	20.96	26.45	30.08	27.14	23.55	33.18
May	19.52	24.13	28.10	30.64	31.87	26.54	34.27	39.90	31.27	37.81
June	20.62	29.63	33.41	33.62	28.85	34.86	35.62	28.43	32.78	50.15
July	32.10	34.37	35.92	39.01	41.35	46.60	47.42	47.57	47.41	53.07
Aug.	34.92	32.42	36.39	39.50	34.51	48.04	46.83	51.08	47.15	
Sept.	29.27	29.08	29.04	27.13	29.76	37.14	43.33	40.58	38.31	
Oct.	22.04	21.34	22.26	20.17	24.35	24.96	25.75	30.45	31.90	
Nov.	20.41	20.51	21.29	19.69	24.36	22.18	22.33	25.98	28.68	
Dec.	20.93	20.63	19.58	22.96	23.59	24.15	24.64	32.30	29.43	
The year	268.67	295.23	306.16	310.93	325.25	369.15	384.17	407.83	390.52	

GENERAL TOPOGRAPHIC FEATURES

In the vicinity of Elko the Humboldt River courses through a trough-like basin between two roughly parallel elongated mountain masses, the River Range lying to the northwest, and the Elko Range lying to the southeast. The basin ranges in width from 7 to 9 miles with the lowest part of the basin lying near the base of the Elko Range.

The Humboldt River flows through the Elko Basin from the northeast to the southwest with a relatively flat gradient of 7 to 10 feet per mile.

The alluvial and lacustrine sediments deposited in the Elko Basin have been dissected by the Humboldt River and its tributary drainage to form a unique topographic pattern. Northwest of the Humboldt River a series of roughly parallel ridges with a northwest trend extend 5 to 7 miles to the steep front of the River Range. These ridges have short steep scarps on the southwest slope 100 to 200 feet high, and gentle slopes a quarter of a mile to half a mile long on the northeast slope. This series of ridges is prominently developed for a distance of at least 15 miles.

The Humboldt River through down cutting and later deposition has built a narrow, nearly flat flood plain ranging from a quarter of a mile to three-quarters of a mile in width. In the process the low ridges, or spurs, were truncated, and in many places well developed river terraces were formed.

Southeast of the Humboldt River the ridge type of topography is well developed only in local areas. The crest of the Elko Range is 1 to 2 miles from the Humboldt River, and only the longer streams have been able to erode typical ridges in the lacustrine and alluvial sediments which crop out between the Humboldt River plain and the crest of the Elko Range.

The elevation of the river plain immediately southeast of Elko is about 5,025 feet. To the northwest, the even-crested River Range rises to an elevation of about 7,000 feet, with a few peaks reaching 7,400 feet. South of Elko, the summit of the Elko Range is approximately 6,200 feet, but rises to 7,000 feet about 10 miles to the northeast near the end of the range.

CLIMATE

The average annual precipitation at Elko, according to a 75-year record by the U. S. Weather Bureau, is 9.68 inches. The precipitation from year to year may vary widely. The least recorded during the 75-year period was 0.94 of an inch, in 1872, and the greatest was 18.94 inches, in 1904.

Average monthly precipitation figures for the same length of record show that the greatest amount of precipitation falls in the winter months of December (1.02 inches), January (1.37 inches), February (1.16 inches), and March (0.96 inch). The least amount of precipitation falls in the summer months of July (0.41 inch), August (0.32 inch), and September (0.42 inch).

The annual mean temperature at Elko, based on a 47-year record by the U. S. Weather Bureau, is 46.0° F. The coldest temperature recorded during this period was —43° F. on January 21, 1937, and the hottest temperature was 107° F.

There are no records of precipitation in the adjacent Elko and River ranges but undoubtedly it is greater than at Elko. As the River Range receives greater snowfall than the Elko Range the greatest runoff into the basin may be expected from the northwest.

GENERAL GEOLOGY

The rocks of the Elko area may be divided into three general groups. (See Fig. 2.) These are: (1) The older rocks, Paleozoic limestones and quartzites which crop out in the River and Elko ranges; (2) Tertiary alluvial and lacustrine sediments with interbedded pyroclastic materials, which partially fill the basin between the two ranges; and in addition Tertiary lavas which in some parts of the area are interbedded with, or rest upon, the Tertiary alluvial and lacustrine deposits; (3) surficial Quaternary alluvial deposits which underlie the plain of the Humboldt River and the channels of its tributary drainage.

In general the Paleozoic limestones and quartzites, and the Tertiary lavas, do not contain good water-bearing beds. Locally ground water is discharged from seeps and springs which occur at favorable locations along fractures and crushed zones in these rocks. Since the Paleozoic limestones and quartzites, and the

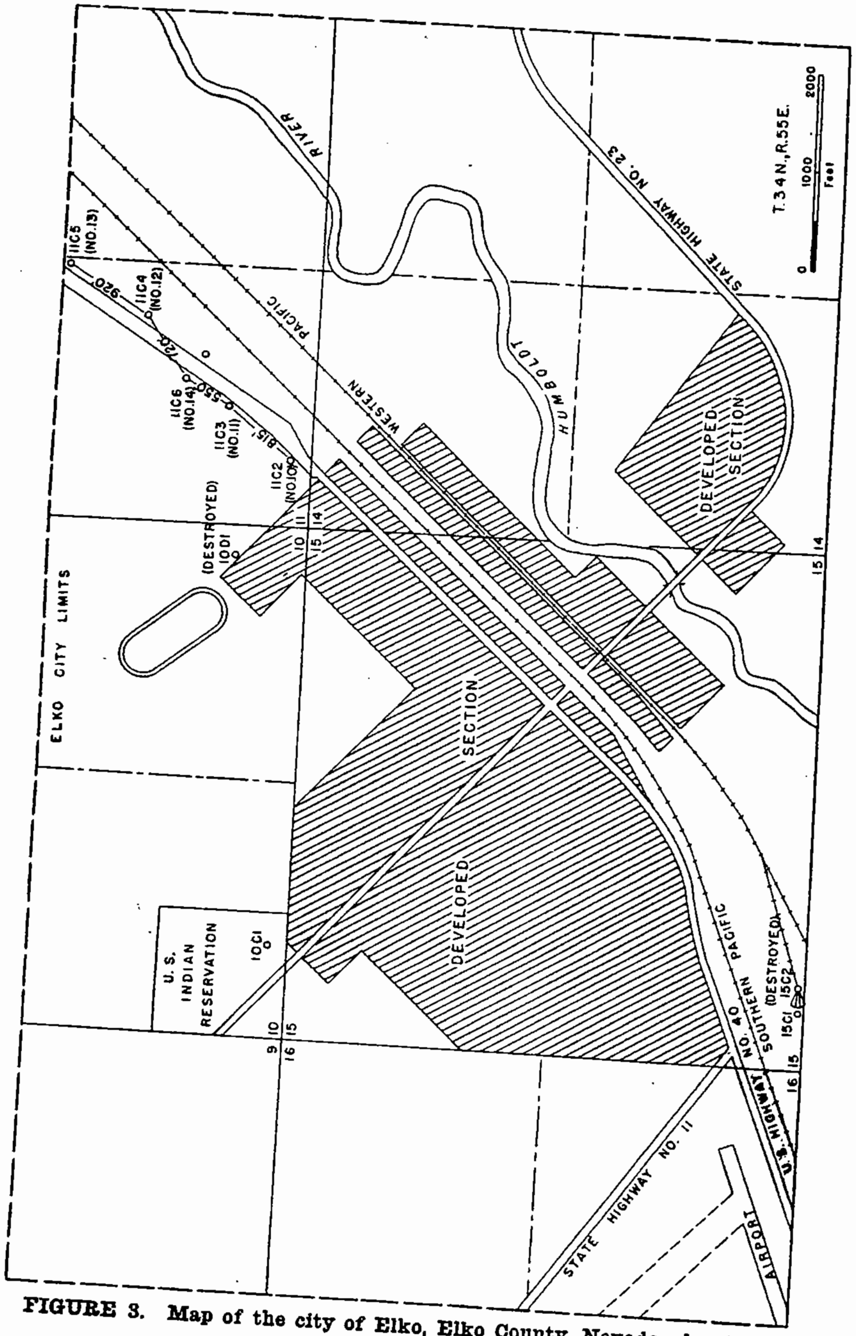

FIGURE 3. Map of the city of Elko, Elko County, Nevada, showing location of wells.

Tertiary lavas, are not favorable for the development of additional water for the city, they will not be discussed further.

In the Elko Basin the Quaternary alluvial sediments were deposited, for the most part, directly on the Tertiary alluvial and lacustrine deposits, and since the Quaternary sediments consist chiefly of re-worked Tertiary deposits, and consequently are similar to the Tertiary rocks, it is generally difficult to establish the contact between the two series of rocks from descriptions in drillers' logs. The base of the Quaternary deposits is not exposed in the area of greatest deposition (in the vicinity of the Humboldt River plain) but it is believed that these deposits are not more than 75 feet thick.

Ground water is obtained from shallow wells in the Quaternary alluvial deposits but the yield of individual wells is not large.

The Tertiary alluvial and lacustrine deposits contain much good water-bearing material and are the prime source of ground water in the Elko area. Consequently, the geology of this series of rocks will be discussed in greater detail.

HUMBOLDT FORMATION

During the Tertiary period Elko Basin was the site of deposition of a relatively thick series of alluvial and lacustrine sediments with considerable interbedded pyroclastic material. R. P. Sharp* (1939) has discussed this series of rocks and included them in the Humboldt formation which he redefined. The identification of animal and plant remains indicate that the Humboldt formation was deposited during late Miocene, and possibly early Pliocene time.

In the vicinity of Elko, on the flanks of the River and Elko ranges, the Humboldt formation is observed to rest unconformably on the late Paleozoic limestones and quartzites.

Sharp (1939) has described the section of his Humboldt formation exposed along Huntington Creek about 12 miles south of Elko and suggests that this be considered the type section. He has divided the formation into three members as follows:

"Lower Member"

"The lower member is composed of shale, oil shale, fresh-water limestone, sandstone, and conglomerate. Oil shale and limestone beds identify this member. In places the limestone and oil shale grade laterally into mudstone, sandstone, and conglomerate, and

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*See list of references at end of report.

the member loses its distinctiveness. The lower member is 800-1,000 feet thick at places of maximum thicknesses but is missing or indeterminate at other places."

"Middle Member"

"The middle member is characterized by rhyolitic tuff and ash. Tuff and ash beds are found throughout the formation, but they are particularly abundant in the middle member. A single outcrop of ash or tuff does not identify this member, but a thickness of a hundred feet or so of associated tuff and ash beds is distinctive within the writer's experience. Volcanic activity of an explosive nature seems to have been at a peak at this time. The middle member has a maximum measured thickness of 1,300 feet."

"Upper Member"

"The upper members consists of fine conglomerate, sandstone, mudstone, siltstone, and shale beds. Mudstone and shale are abundant near the top. The conglomerate is distinguished by a large proportion of quartzite and granitic pebbles, compared to the number composed of limestone. This member is identified by its great thicknesses of mudstone and shale, and the relative paucity of conglomerate beds. The maximum measured thickness of the upper member is 3,600 feet, although it may be much thicker, for the top of the formation is not known." The aggregate thickness of these members is about 5,800 feet.

The thickness of the Humboldt deposits in the Elko Basin is not known, but an oil-test well located about two miles north of Elko penetrated more than 3,200 feet of material which undoubtedly can be identified as Humboldt. (See well 34/55-4A1, Table 3.)

The Humboldt formation has a general southeast dip of 10 to 15 degrees in the central part of the basin, but near the margins the structure of the formation is complicated by local folding and faulting.

The drillers' logs of the city of Elko wells (see Table 3) indicate that the 400 to 600 feet of the Humboldt formation penetrated by these wells is comparable to part of the upper member of the formation described by Sharp (1939). The individual beds are generally lenticular and of limited areal extent. There are few clean beds of gravel and sand. Water-bearing sand and/or gravel beds generally contain considerable amounts of fine sand, and silt, which materially reduce their permeability.

GROUND WATER

In the vicinity of Elko, ground water occurs in the Humboldt formation and the Quaternary alluvial deposits of the Humboldt River plain. The water-bearing materials in these deposits receive recharge from two main sources; (1) water from the Humboldt River which percolates through the river deposits into the Humboldt formation, and (2) runoff from the adjacent mountain ranges, particularly the River Range. It is believed that a large part of the runoff reaches the central part of the basin as underflow as the majority of the streams that rise on the flanks of the mountains flow to the Humboldt River for only a short time in the spring, and generally sink into the exposed Humboldt formation before reaching the Humboldt River. Direct precipitation on the land surface may be considered as a minor source of recharge. Although no data are available, it appears that the ground-water recharge is considerably in excess of the relatively small pumping withdrawals in the vicinity of Elko.

WATER TABLE

The water table in the plain of the Humboldt River is near the surface. In 1922 a series of shallow test wells were dug for the city of Elko in sec. 11, T. 34 N., R. 55 E. These wells were between 20 and 30 feet deep, and most of them encountered the water table about 15 feet below ground. The yield of these wells was reported to be small, and no further consideration has been given to the possibility of obtaining a municipal water supply from shallow wells in the Quaternary alluvial deposits.

Many of the widely spaced ranches along the Humboldt River plain obtain an adequate water supply for stock and domestic use from shallow water-table wells but the withdrawals are small.

WATER-BEARING BEDS IN THE HUMBOLDT FORMATION

In the Humboldt formation water occurs in poorly sorted sand and gravel beds of limited areal extent. These lenticular beds appear to be imperfectly interconnected as shown by the fluctuations of water levels in wells near a pumping well.

In the vicinity of Elko, which is near the axis of the lowest part of the Elko Basin, ground water in the Humboldt formation is under artesian pressure and rises in wells to within 20 to 40 feet of the land surface.

The table that follows summarizes pertinent data on the performance of five wells that draw water from the Humboldt formation in the vicinity of Elko. With the exception of well No. 13 the data for discharge and drawdown were obtained by special pumping tests during November and December 1946.

TABLE 2

Data on the performance of five wells that draw water from the Humboldt formation in the vicinity of Elko, Nevada

Well number	Owner	Reported depth of well, in feet	Discharge, in gallons per minute	Drawdown of water level, in feet	Specific capacity of well, gallons per minute per foot of drawdown
34/55–11C2	City of Elko (No. 10)	400	480	63	7.6
34/55–11C4	City of Elko (No. 12)	570	630	85.5	7.4
34/55–11C5[1]	City of Elko (No. 13)	495	751	70	10.7
34/55–11C6	City of Elko (No. 14)	488	620	49	12.6
35/56–31B1	Nevada School of Industry	243	204	52.2	3.9

[1] From typewritten report by E. G. Thorum, consulting engineer to the city of Elko, January 1946.

In evaluating the data presented in Table 2, it is necessary to note that there is some question regarding the perforations in well 34/55-11C4 (City of Elko No. 12). The Water Department of the city of Elko reports that the casing in this well was perforated in place and there is some doubt as to whether all cuts penetrated through the casing.

Although the amount of data available is insufficient to draw definite conclusions, it may be noted first that all of the wells have relatively low specific capacities, and second, disregarding well 34/55-11C4, which reportedly may not have very effective perforations, specific capacity apparently increases with depth. This is to be expected inasmuch as the number of water-bearing beds penetrated in the Humboldt formation increases with depth.

The specific capacity of well 35/56-31B1, which is 243 feet deep, is 3.9 gallons per minute per foot of drawdown. This well penetrates only 22 feet of water-bearing material (see log, Table 3), and it is possible the specific capacity could be increased by deepening the well and penetrating additional water-bearing beds.

The specific capacity of future wells drilled to comparable depths into the Humboldt formation could probably be increased appreciably by altering the present type of well construction. It is believed that if well screens with the proper size openings were substituted for perforated casing opposite water-bearing beds, the specific capacity of a well could be increased due to the increase in percentage of openings to the well, and the development of a natural gravel pack around the well. The net result of this type of construction would be to decrease the lift for the same discharge, or increase the discharge for the same lift. In either case the amount of energy required to pump a given amount of water would be decreased in direct proportion to the increased efficiency of the well.

TEMPERATURE OF THE GROUND WATER

About 1 mile southwest of Elko in the SE¼ sec. 21, T. 34 N., R. 55 E., there are several hot springs, known as the Elko Hot Springs, discharging from openings in sedimentary rocks which are probably of the same age as the lower part of the Humboldt formation. These springs are supplied by hot waters ascending from depth along fractures associated with an immediately adjacent north-south fault. (See Fig. 2.) Temperature of the water in the springs ranges from 150 to 190 degrees Fahrenheit.

Several of the wells drilled in the vicinity of Elko have encountered warm to hot water, or mud, at various depths. (See Table 3.) These thermal waters and the hot springs probably have a common source. Well 34/55-15C1, drilled by the Western Pacific Railway Company in 1911 at their roundhouse, encountered a supply of "warm water" between 345 and 360 feet which flowed at the surface at the rate of 7 gallons per minute. Another well, 34/55-15C2, was drilled about 50 feet away from that well and encountered "hot caving mud" at a depth of 280 feet.

The city of Elko drilled a well, 34/55-10D1, near the old city camp grounds. It is reported that a supply of cool water was encountered between a depth of 390 to 400 feet, and "hot mud" was penetrated at a depth of 425 feet.

The temperature of water pumped from well No. 12 of the city of Elko (34/55-11C4), which is 570 feet deep, is 75° Fahrenheit. City of Elko No. 14 (34/55-11C6), which is 720 feet southwest of the city well No. 12 and 488 feet deep, discharges water with a temperature of 66° Fahrenheit. The 75° temperature of water from city well No. 12 indicates abnormal temperature conditions at depth.

It is apparent, from the cases cited above, that situations and depths at which warm to hot water, or mud, may be encountered in wells are variable in the Elko area. The drilling record of well 34/55-10D1, mentioned above, indicates that temperatures may increase abruptly at depth, and in drilling a new well care should be taken to carefully record, at frequent intervals, the bottom-hole temperatures as drilling progresses.

QUALITY OF GROUND WATER

Well 34/55-1A1 is a shallow water-table well dug in the river deposits of the Humboldt River plain. The analysis of water from this well (see Table 4) shows this water to be moderately mineralized and suitable for domestic use. In local areas along the Humboldt River plain the high alkali content of the soil has made water from shallow wells unfit for domestic use.

Analyses of water from wells pumping from the Humboldt formation (see Table 4) show considerable range in the amount of various chemical constituents. Total solids range from 269 parts per million for well 34/55-11C4, to 451 parts per million for well 34/55-11C2. Although the waters from wells pumping from the Humboldt formation differ in chemical analysis, they are in general only moderately mineralized. The water in all wells is suitable for domestic use.

ANALYSIS OF PUMPING-TEST DATA

The following discussion is a summary of the analysis of pumping-test data for the municipal wells of the city of Elko.

Water-level and well-discharge data were collected December 9–11, 1946, to determine the hydrologic characteristics of the formations penetrated by the city wells. (See Fig. 3 for location of wells.) Knowing these hydrologic characteristics it is possible to predict the drawdown, or lowering of the water level in a well, caused by pumping in a nearby well. It is also possible to predict the changes in water level that would occur by varying the distance between pumped wells and by changes in pumping schedules.

The hydrologic characteristics of a formation are conveniently expressed by the coefficients of permeability, transmissibility, and storage. The field coefficient of permeability has been defined by Wenzel (1942) as: "the number of gallons of water a day that percolates under prevailing conditions through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow) for each foot of thickness of the bed, and for each foot per mile of hydraulic gradient." The coefficient of transmissibility, according to Theis (1935), is the product of the field coefficient of permeability and the thickness of the saturated portion of the aquifer. The coefficient of storage is defined by Theis (1938) as the volume of water measured in cubic feet, released from storage in each column of the aquifer having a base 1 foot square and a height equal to the thickness of the aquifer, when the water table or other piezometric surface is lowered 1 foot.

Coefficients of transmissibility and storage were determined from the data obtained December 9–11. The range in the values of the coefficient of transmissibility for individual wells was quite large. Most of the differences in coefficients of transmissibility

are probably caused by differences in the depths of the wells, some wells failing to penetrate all the aquifers, and by the absence of perforations in the casing opposite each of the saturated water-bearing beds. Nevertheless, when all the data obtained are taken into account it was found that a coefficient of transmissibility of 40,000 gallons per day per foot (0.0618 cubic feet per second per foot) and a coefficient of storage of 0.001 gave values that checked the observed data very well. These coefficients were, therefore, used for the preparation of Figure 4, and for all computations of fluctuations in water level resulting from changes in well spacing and changes in pumping schedules.

Figure 4 is a graphical representation of interference effects in an ideal formation having water-bearing properties and hydrologic characteristics similar to those of the formations penetrated by the city wells. Specifically it shows the effect of pumping a well at a steady rate of 1 cubic foot per second, or about 450 gallons per minute, for varying periods of time on the water level in wells 500, 1,000, 1,500, and 2,000 feet distant. The effects are directly proportional to the rate of pumping so that the effect for any other rate of pumping is obtained merely by multiplying the effect shown on the graph by the ratio of the actual rate at which the well is pumped to the arbitrarily chosen rate of 450 gallons per minute.

The amount of the lowering of the water level that will have occurred at the end of any pumping period also can be read directly from the graph when the well has been pumped at the rate of 450 gallons per minute. For example, at the end of 8 hours of pumping the water level in a well 500 feet distant from the pumped well would be lowered 3.6 feet; 1,000 feet distant, 1.9 feet; 2,000 feet distant, 0.7 foot, etc.

When interference effects occur, more energy is required to pump a given amount of water, since the amount of lift is increased. The additional energy may be determined by multiplying each increment of interference by the time during which it occurs, summing the products, and then multiplying the sum by the weight of water in pounds pumped during the period interference took place. If the amount of interference is measured in feet, the product will be energy in foot-pounds, which can readily be converted to kilowatt-hours.

Using the above method it was found that the interference caused by pumping a well steadily for 8 hours was about 5 times larger in a well 720 feet distant, than in a well 1,600 feet distant. Applied to the existing city wells it indicates that the

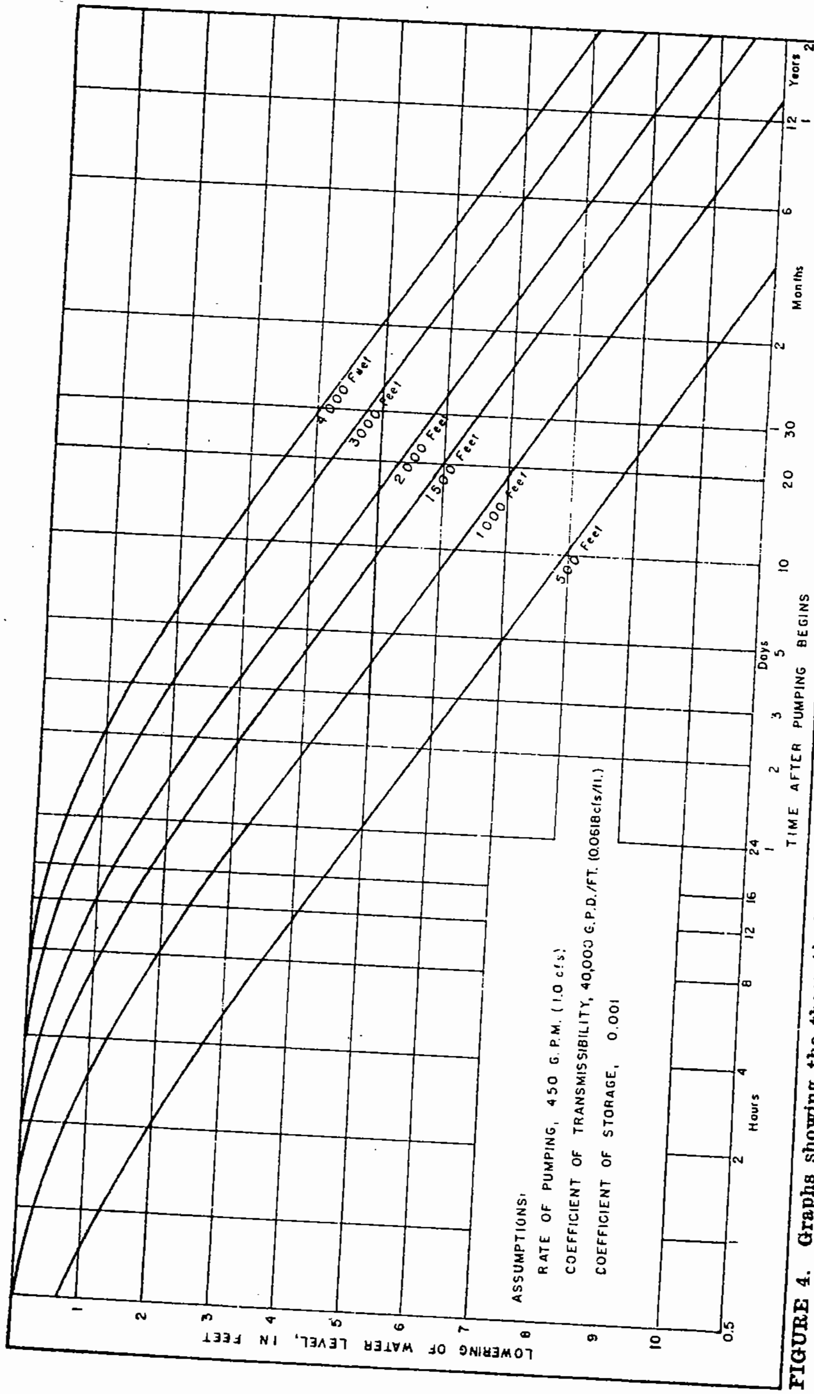

FIGURE 4. Graphs showing the theoretical relation between lowering of the water level, time after pumping begins, and distances from the pumped well.

interference resulting from well No. 14 pumping 8 hours is about 5 times larger in well No. 12 than in well No. 13. However, the ratio of the interference decreases with time so that if the well were pumped 16 hours instead of 8 hours the ratio would be about 3.2 to 1.

The interference in well No. 12 caused by pumping well No. 14, 16 hours was computed to be almost 3 times the interference caused by pumping well No. 14 only 8 hours. The ratio of the interference effect in well No. 13 caused by pumping well No. 14, 16 hours instead of 8 was about 44 to 1. It is to be noted that interference effects are not directly proportional to the length of the pumping period but rather increase at a faster rate.

To show how interference effects might vary with pumping schedules, computations were made assuming the following conditions: The well field was to consist of four wells on line with the same spacing (see Fig. 3) between wells as the city of Elko field. The rate of discharge from each well was assumed to be 450 gallons per minute. The values used in the computations were obtained from Figure 4, which shows interference effects similar to those observed in the formations penetrated by the city wells.

According to Pumping Schedule "A," wells No. 12 and 14 were to be pumped simultaneously for 8 hours, after which the pumps were to be shut off and wells No. 10 and 13 pumped simultaneously for 8 hours. Pumping Schedule "B" consisted of pumping wells No. 10 and 13 simultaneously for 8 hours, shutting the pumps off, and then pumping wells No. 12 and 14 simultaneously for 8 hours. Pumping Schedule "C" consisted of pumping wells No. 10 and 12 simultaneously for 8 hours, shutting the pumps off, and then pumping wells No. 13 and 14 simultaneously 8 hours. According to Schedule "D" wells No. 13 and 14 were to be pumped simultaneously for 8 hours after which the pumps were to be stopped and wells No. 10 and 12 pumped simultaneously for 8 hours. The interference effects at the end of 16 hours operation for Pumping Schedules "A" and "B" were the same as were the interference effects for Pumping Schedules "C" and "D." However, the interference effects under Schedules "A" and "B" were about 40 percent greater than the interference under Schedules "C" and "D." Thus, it made no difference whether wells No. 10 and 13 were pumped the first or the second 8-hour period. Likewise, it made no difference whether wells No. 10 and 12 were pumped the first or the second 8-hour period. There was a difference, however, between simultaneous operation of adjacent wells as compared with simultaneous operation of alternate wells.

In the examples cited above the interference effects of simultaneous pumping of adjacent wells is about 40 percent greater than simultaneous pumping of alternate wells.

Interference effects can be reduced by increasing the spacing between wells. This may be shown by the following example: The well field was assumed to consist of five wells on a straight line, spaced 500 feet apart, and tapping an aquifer with hydrologic characteristics similar to the aquifer tapped by the city of Elko wells. If all of the wells were pumped continuously at a constant rate of 450 gallons per minute each, the extra lift at the end of one year due to interference was computed to range from 42.1 feet for the end wells to 46.7 feet for the middle well. If spaced 1,000 feet apart, the extra lift would range from 35.1 to 39.6 feet; if spaced 1,500 feet apart, it would range from 31.0 to 35.5 feet; and if spaced 2,000 feet apart, it would range from 28.2 to 32.6 feet. For each additional 500 feet of spacing between wells, therefore, the maximum extra lift caused by interference is reduced by 7.1, 4.1, and 2.9 feet, respectively. Thus, at the end of a year the maximum difference in lift for 500-foot spacing and 2,000-foot spacing would be 14.1 feet or about 30 percent. A given increase in spacing is most effective in decreasing interference where the wells are closely spaced. As may be seen from the above example the advantage to be gained by increasing the spacing between wells from 1,000 to 1,500 feet is greater than the advantage to be gained by increasing the spacing from 1,500 to 2,000 feet.

It is suggested that any new wells be drilled at least 1,500 and preferably 2,000 feet from the nearest existing well. This would permit the simultaneous pumping of all wells so spaced without excessive interference.

Wells spaced too closely are always uneconomical. If the wells are pumped simultaneously additional energy is required to pump a given amount of water, due to the increased lift resulting from interference. If only alternate wells are pumped in order to increase spacing between pumped wells and decrease interference approximately twice the number of wells are required. On the one hand energy requirements, and consequently costs, are increased, and on the other hand capital expenditures are increased.

MOST FAVORABLE AREAS FOR FUTURE GROUND-WATER DEVELOPMENT

It has been shown that the best source of ground water in the vicinity of Elko is the Humboldt formation. It is desirable to tap the water-bearing beds of this formation in the area receiving maximum recharge. In the Elko Basin the area receiving maximum ground-water recharge follows the Humboldt River plain. Northwest and southeast of the river, surface water and ground water follow the natural gradient and move toward the lower level of the Humboldt River plain.

Although the favorable ground-water recharge conditions near the trough of the Humboldt River plain extend several miles northeast and southwest of Elko, it is not considered advisable to drill within one or two miles southwest of Elko inasmuch as the records of well 34/55-15C1, and well 34/55-15C2, indicate undesirable thermal conditions in that area.

The most favorable area for future ground-water development then, is to the northeast of Elko, near, or on, the Humboldt River plain. As previously mentioned any future wells should be properly spaced to reduce interference effects due to pumping, and care should be taken to check bottom temperatures while drilling to avoid warm or hot water at depth.

SUMMARY

The best source of ground water in the vicinity of Elko is the Humboldt formation. The ground water occurs in lenticular gravel and sand beds which are poorly interconnected. There is adequate recharge to the water-bearing beds of the Humboldt formation from (1) the Humboldt River and its tributary drainage, and (2) runoff in the Elko Basin and the adjacent mountain ranges which reaches the area receiving maximum recharge chiefly as ground-water underflow. The area receiving maximum recharge is roughly coextensive with the Humboldt River plain.

In the vicinity of Elko, wells drilled to a depth of 400–600 feet have an average specific capacity of about 10 gallons per minute per foot of drawdown and yield between 500 and 750 gallons per minute. If well screens are used in construction of future wells, specific capacities would undoubtedly be increased over those obtained in present wells.

The quality of water from wells tapping the water-bearing beds of the Humboldt formation is suitable for domestic use.

Data from well 34/55-15C1, and well 34/55-15C2, indicate that wells drilled in the Humboldt formation, southwest of Elko, probably will encounter warm to hot water. This thermal water, and the hot water being discharged from Elko Hot Springs, 1 mile southwest of Elko, probably have a common source.

The most favorable area for future ground-water development in the vicinity of Elko is to the northeast of Elko, along the Humboldt River plain. Any wells drilled in this area should be spaced at least 1,500 to 2,000 feet apart in order to minimize the interference effects of pumping. Bottom temperatures should be recorded at frequent intervals as drilling progresses in order to avoid penetrating deposits which have abnormal temperatures.

The analysis of pumping test data for the wells of the city of Elko shows that the amount of energy required to pump ground water to the surface can be reduced by considering the spacing of the wells and by using the proper pumping schedule for the battery of city wells.

TABLES

The three tables that follow give the data that have been collected for representative wells in the vicinity of Elko. In tabular form are given drillers' logs of wells, mineral analyses of well water, and well records. For explanation of numbering system of wells and springs, see page 16.

TABLE 3

Drillers' logs of wells in the vicinity of Elko, Nevada

34/55-4A1. Owner unknown. Abandoned oil-test well.

Material	Thickness (feet)	Depth (feet)
Gray lime and shale	600	600
Brown shale	108	708
Shale and white sand	57	765
Sandy blue shale	26	791
Brown shale	17	808
Blue shale	2	810
Brown shale	76	886
Blue shale	4	890
Brown sandstone	28	918
Brown lime and shale	25	943
Dark red shale	16	959
Gray sand rock	32	991
White sand rock	11	1,002
Dark brown sand	28	1,030
Gray sand	57	1,087
Dark clay	17	1,104
Dark paraffin shale	258	1,362
Blue shale	365	1,727
White lime, sand shale	*	*

*Remainder of log not available, well reported to have been drilled to a depth greater than 3,200 feet.

34/55-10D1. City of Elko. (Old city well No. 13, destroyed.) Diameter 16-inch outer surface casing to 48 feet, 14-inch inner casing to 404 feet. This well penetrated a cold water supply between 390 and 400 feet but encountered hot mud at 425 feet. The hot mud invaded the casing and the well was abandoned.

Material	Thickness (feet)	Depth (feet)
Top soil	12	12
Conglomerate	10	22
Sandy clay	3	25
Conglomerate	7	32
Coarse gravel—water	4	36
Sandy clay	29	65
Gravel	1	66
Sandy clay and boulders	20	86
Gravel	3	89
Cement gravel	21	110
Sandy clay	16	126
Cement gravel	2	128
Clay with sand and gravel	24	152
Cement gravel, not very tight	6	158
Sandy clay	64	222
Cemented coarse gravel, might be water	5	227
Sandy clay	13	240
Soft sandy clay	5	245
Cement gravel, hard	42	287
Sand	1	288
Sandy clay	37	325
Thin layers gravel and clay	5	330
Sandy clay, soft in spots	40	370
Sand and gravel—water	12	382
Cement gravel	3	385
Sandy clay	5	390
Sand and gravel—water	3	393
Sandy clay	2	395
Sand and gravel—water	5	400
Total depth	---	400

34/55-11C1. City of Elko. (City Well No. 9.) Diameter 12 inches to 50 feet, 10-inch inside 12-inch casing from surface to 148 feet. Ten-inch casing perforated full length.

Material	Thickness (feet)	Depth (feet)
Soil	7	7
Clay	1	8
Hardpan	1	9
Clay	3	12
Sand and gravel	6	18
Boulders mixed with clay	5	23
Clay	12	35
Clay	101	136
Pea gravel to sand*	2	138
Clay	8	146
Gravel, diameter one inch, to sand	2	148
Clay	15	163
Total depth	---	163

*Water rose to within 12 feet of land surface.

34/55-11C2. City of Elko. (City Well No. 10.) Diameter 12 inches. Gravel packed well.

Material	Thickness (feet)	Depth (feet)
Surface soil	10	10
Cemented rock and large rock, little water	20	30
Cemented rock, spots of large rock—water	10	40
Shale, yellow (very tight and tough)	55	95
Sand, little clay, rock, little gravel—water	25	120
Sandy, little clay, carries water	125	245
Sandy, clay-packed loose spots, carry water	25	270
Sandy clay (loose) some water	5	275
Shale (very hard)	5	280
Sandy, little clay, loose spots, carries water	30	310
Sandy clay (packed)	50	360
Sandy clay, loose spots, carry some water	35	395
Sandy clay (hard)	5	400
Total depth	---	400

34/55-11C3. City of Elko. (City Well No. 11.) Drilled to 278 feet in 1936, deepened to 403 feet in 1938. Diameter 16 inches to 43 feet, 12 inches to 262 feet, no record of casing from 262 to 403 feet.

Material	Thickness (feet)	Depth (feet)
Clay	12	12
Dry gravel	3	15
Clay	6	21
Fine gravel—water	6	27
Clay cemented gravel	3	30
Sandy clay	17	47
Sand and fine gravel—water	8	55
Clay cemented gravel	147	202
Fine gravel—water	2	204
Sandy clay	16	220
Fine gravel	1	221
Sandy clay	5	226
Fine gravel—water	2	228
Clay cemented gravel	7	235
Fine gravel—water	2	237
Clay cemented gravel	41	278
Sandy clay	12	290
Sand stratas	10	300
Sandy clay	40	340
Gravel—water	1	341
Clay	21	362
Gravel—water	0.5	362.5
Clay	27.5	390
Gravel—water	6	396
Clay	2	398
Gravel	1	399
Clay	4	403
Total depth	....	403

34/55-11C4. City of Elko. (City Well No. 12.) Diameter 15-inch casing set at 42 feet, 12-inch casing set at 395 feet, 10-inch casing from 391 to 535 feet. 15-inch casing not perforated, 12-inch casing perforated at all gravel and sand stratas, 10-inch casing perforated in 8 rows, ⅛-inch by 6-inch slots.

Material	Thickness (feet)	Depth (feet)
Top soil	15	15
Dry gravel	4	19
Cement sand and gravel, clay cement	8	27
Soft sandy clay	18	45
Hard sandy clay	5	50
Sand and fine gravel—water	5	55
Sandy clay	2	57
Sand and fine gravel—water	17	74
Sandy clay	14	88
Hard cement gravel—some free gravel	5	93
Sandy clay	71	164
Hard clay, cemented gravel	10	174
Sandy clay	3	177
Free gravel	7	184
Sticky clay	3	187
Sandy clay	12	199
Free gravel	6	205
Sandy clay	16	221
Hard cemented sand and gravel	17	238
Hard clay	5	243
Soft clay	4	247
Cement gravel	3	250
Clay	12	262
Cement gravel	5	267
Sandy clay	43	310
Cement gravel	5	315
Sandy clay	2	317
Free gravel	4	321
Clay	18	339
Cemented sand and gravel	5	344
Sandy clay	49	393
Cement gravel	7	400
Sandy clay	70	470
Clay cemented gravel	10	480
Sandy clay	11	491
Free gravel	1	492
Sandy clay	10	502
Clay cemented gravel	8	510
Sandy clay	15	525
Clay cemented gravel	18	543
Clay and sandy clay	27	570
Total depth	....	570

34/55-11C5. City of Elko. (City Well No. 13.) Diameter 16-inch outer surface casing and 12-inch inner casing.

Material	Thickness (feet)	Depth (feet)
Clay, yellow	29	29
Gravel—water	7	36
Clay, yellow	45	81
Gravel	1	82
Clay, yellow	11	93
Clay, yellow and gravel	5	98
Gravel	2	100
Clay, yellow and gravel	14	114
Gravel	16	130
Clay, yellow	2	132
Gravel	23	155
Clay, yellow	16	171
Gravel	2	173
Clay, yellow	8	181
Gravel	1	182
Clay, yellow	17	199
Gravel	2	201
Clay, yellow and gravel	34	235
Sandy yellow clay	36	271
Gravel	3	274
Clay, yellow	10	284
Gravel	3	287
Clay, yellow	21	308
Clay, yellow and sandy	18	326
Gravel	2	328
Sand and clay-thin layers	20	348
Clay, yellow	14	362
Gravel and clay mixed	18	380
Gravel	4	384
Sandy clay	40	424
Gravel	2	426
Sandy clay	29	455
Clay, sticky	5	460
Sand, (little clay)	12	472
Sandy clay	13	485
Gravel and clay	10	495
Total depth	....	495

34/55-11C6. City of Elko. (City Well No. 14.) Diameter 15½-inch outer surface casing set at 53 feet, 12½-inch casing to 487 feet. 12½-inch casing perforated from 50 to 487 feet.

Material	Thickness (feet)	Depth (feet)
Surface soil	2	2
Clay	4	6
Sand and gravel	2	8
Sandy clay	10	18
Coarse gravel—water	6	24
Sandy clay	23	47
Clay	7	54
Coarse sand and gravel interlayed with clay. Thin strata of clay, sand, and gravel, with sand and gravel carrying much water. Water increases with depth. Temperature 55° F.	66	120
Free fine brown sand	3	123
Sand and clay, clay predominates	55	178
Free fine brown sand	3	181
(Same as 54 to 120 foot section) Temperature 55° F.	134	315
Free fine brown sand, quicksand nature	5	320
Sand, gravel, and clay. Sand and gravel strata carrying much water. Temperature 55° F.	165	485
No record	3	488
Total depth	....	488

34/55-15C1. Western Pacific Railroad Company. Diameter 11⅝-inch casing set at 240 feet, 9⅝-inch casing from the surface to 340 feet. 9⅝-inch casing perforated from 280 to 340 feet. This well encountered warm water between 345 and 360 feet which flowed at the surface at the rate of 7 gallons per minute.

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Gravel	3	9
Yellow clay	103	112
Light green clay, or conglomerate	68	180
Dark green clay or shale	68	248
Light green clay	48	296
Lava, tough and sticky	33	329
Conglomerate and shale	20	349
Hard rock in an altered state	21	370
Black bitumen shale	8	378
Total depth	....	378

34/55-15C2. Western Pacific Railroad Company. Diameter 10-inch surface casing set at 40 feet, open hole from 40 to 281 feet. Well abandoned and filled when hot caving material entered the hole.

Material	Thickness (feet)	Depth (feet)
Volcanic sand and ash, caving ground, strong sulphur odor	192	192
Gravel, volcanic sand and ash	62	254
Volcanic sand, fine gravel, hot caving ground	14	268
Volcanic sand and ash, no water	13	281
Total depth	....	281

35/56-30C1. Nevada School of Industry. (Owner's Well No. 1.) Diameter 6 inches. Casing perforated from 122 to 162 and 202 to 237 feet.

Material	Thickness (feet)	Depth (feet)
Conglomerate	14	14
Gravel	3	17
Conglomerate	22	39
Cemented sand	2	41
Clay with gravel	4	45
Hard conglomerate	6	51
Clay	3	54
Gravel—some water	1	55
Yellow clay	10	65
Blue clay	39	104
Yellow sandy clay	28	132
Gravel (water rose to 81 feet)	3	135
Clay	15	150
Gravel	1	151
Clay, gravel	8	159
Cemented sand and fine gravel	6	165
Clay, streaks of gravel	18	183
Clay	16	199
Clay and gravel	2	201
Clay	22	223
Gravel	2	225
Clay	3	228
Gravel, fine	1	229
Clay	4	233
Gravel	4	237
Clay	13	250
Total depth	....	250

35/56-31B1. Nevada School of Industry. Diameter 12 inches. Perforated from 85 to 99 and 200 to 240 feet.

Material	Thickness (feet)	Depth (feet)
River deposit	10	10
Green clay	40	50
Deep blue clay	35	85
Coarse gravel (first water)	14	99
Yellow clay, some small stratas of sandy formations, but very little	125	224
Coarse gravel	8	232
Yellow clay	8	240
Total depth	—	240

TABLE 4

Analyses of water from wells in the vicinity of Elko, Nevada

(Analyses by Public Service Division, University of Nevada, under the direction of Wayne B. Adams, Commissioner, Department of Food and Drugs. Analyses in parts per million)

Well number	Owner	Date of collection	Temperature °F	Total solids	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na and K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)
34/55-1A1[1]	Dressi Bros.	11- 5-46	50	369	38	62	20	37	0	281	40	25	230	237
34/55-11C2[2]	City of Elko (No. 10)	6- 2-37	64	451	70	68	20	40	Tr.	251	79	53	206	252
34/55-11C4[2]	City of Elko (No. 12)	12-23-46	75	269	81	36	12	20	3	139	27	25	113	139
34/55-11C6[2]	City of Elko (No. 14)	12-23-46	66	358	71	56	18	19	9	162	54	36	133	214
35/56-31B1[2]	Nevada School of Industry	11- 5-46	60	273	50	40	13	27	0	151	26	28	124	153

All the above samples show only traces of iron and aluminum.

[1] Shallow water-table well, drawing from water-bearing beds in the Quaternary alluvium.

[2] Well drawing from water-bearing beds in the Humboldt formation.

TABLE 5

Hydrologic data for wells in the vicinity of Elko, Nevada

(Use of water—D, Domestic; Irr., Irrigation; N, None; P, Public Service; R, Railroad)

Well number	Owner	Type (Dr, Drilled)	Year completed	Depth in feet	Diameter in inches	Water Level: Feet below land-surface datum	Water Level: Date of measurement	Use	Remarks
34/55-1A1	Dressi Bros.	Dug	-------	12.5	72-72	10.06	10-22-46	D	Analysis.
34/55-4A1		Dr.	-------	3200+	6	flowing	1923	N	Log; abandoned oil test well.
34/55-10C1	U. S. Dept. of Interior, Bureau of Indian Affairs	Dr.	1937 -------	245 -------	8 -------	83.83 83.77	10-22-46 12-11-46	D	
34/55-10D1	City of Elko (Old No. 13)	Dr.	1940	425	16-14	-------	-------	N	Log; encountered hot mud at 425 feet, well abandoned and destroyed.
34/55-11C1	City of Elko (No. 9)	Dr.	1924 -------	148 -------	12-10 -------	41.19 35.37	8-15-46 10-22-46	N	Log; yield in 1924, 290 g.p.m. Abandoned.
34/55-11C2	City of Elko (No. 10)	Dr.	1927	400	-------	38.0	12-10-46	P, R	Log; Analysis; yield in 1946, 500 g.p.m. Pump test.
34/55-11C3	City of Elko (No. 11)	Dr.	1938	403	16-12	34.5	12-10-46	P, R	Log; well not used in December 1946 sucks air when pumped at 250-300 g.p.m.
34/55-11C4	City of Elko (No. 12)	Dr.	1937	570	15-12-10	37.0	12-10-46	P, R	Analysis; log; pump test, measured yield 630 g.p.m. in December 1946.
34/55-11C5	City of Elko (No. 13)	Dr.	1945 ------- -------	495 ------- -------	16-12 ------- -------	39.7 41.95 38.35	11-14-45 6-11-46 10-22-46	P, R	Log; pump being installed in December 1946. Reported yield 750 g.p.m.
34/55-11C6	City of Elko (No. 14)	Dr.	1942	488	15½-12½	34.5	12-10-46	P, R	Analysis; log; pump test; measured yield 600 g.p.m. in December 1946.
34/55-15C1	Western Pacific Railway	Dr.	1911	378	11⅝-9⅝	flowing	1911	N	Log; well abandoned and destroyed. Flow 7 g.p.m.; warm water.
34/55-15C2	Western Pacific Railway	Dr.	1924	281	10	-------	-------	N	Log; well abandoned and destroyed when hot caving material entered the drill hole.
35/56-30C1	Nevada School of Industry	Dr.	1930	250	6	-------	-------	D	Log.
35/56-31B1	Nevada School of Industry	Dr.	-------	243	12	31	12-11-46	Irr.	Analysis; log.

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STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

GROUND WATER IN RUBY VALLEY, ELKO AND WHITE PINE COUNTIES, NEVADA

By T. E. EAKIN and G. B. MAXEY, Geologists,
U. S. Geological Survey

Prepared cooperatively by the
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CONTENTS

ILLUSTRATIONS

TABLES

GROUND WATER IN RUBY VALLEY, ELKO AND WHITE PINE COUNTIES, NEVADA

By T. E. Eakin and G. B. Maxey, *Geologists, U. S. Geological Survey.*

INTRODUCTION

Since July 1, 1945, the United States Geological Survey, Ground Water Branch, has been cooperating with the State Engineer of Nevada in a State-wide study of the ground-water resources. The potential ground-water supplies have been evaluated by ground-water basins, which ordinarily coincide with valley units in the State.

The present report is based on about 2 weeks of field work during the summer of 1948 and a similar period of work in June 1949. That in 1949 was devoted largely to the location and drilling of a test well. Most of the well information was collected and a field reconnaissance of the general geologic and hydrologic conditions was made in 1948. Chemical analyses were made of samples of water from Sulphur Hot Springs and two water-bearing zones in the test well. Several wells were selected for periodic measurement in accordance with the State-wide observation-well program. In addition, a soils reconnaissance of the valley floor was made in 1948 by Howard G. Mason, Agricultural Economist, of the Nevada Agricultural Experiment Station. The investigation has been under the general supervision of T. W. Robinson, District Engineer in Nevada, for the Ground Water Branch, U. S. Geological Survey.

The writers appreciate the critical review of this report by their colleagues in the Geological Survey.

LOCATION AND GENERAL FEATURES OF THE AREA

Ruby Valley, in the south-central part of Elko County and the northwestern part of White Pine County, Nevada, 40 miles south-southwest of Wells, lies in the area between about latitudes 40° and 41° N., and between longitudes 115°05′ and 115°35′ W. The southernmost part of the valley extends about 15 miles into White Pine County.

The valley lies immediately east of the Ruby Mountains. Ruby Mountains merge on the north with the East Humboldt Range which forms the northeast boundary of the valley. A low, nearly continuous bedrock ridge bounds the east side of the valley and connects with Ruby Mountains closing the south end of the valley. This ridge, in part, is known as the Valley Mountain. Ruby

Valley is about 70 miles long and from 3 to 20 miles wide and has a total drainage area of about 1,000 square miles (see pl. 2).

The valley is readily accessible under most weather conditions by gravel-surfaced roads. State Highway 11, connecting with U. S. Highway 93 in Clover Valley, enters the valley from the northeast, extends north along the east side of the valley, and thence out of the valley through Secret Pass, joining U. S. Highway 40 at Halleck. The gravel-surfaced road along the west side of the valley extends southward from the junction with State Highway 11 near Secret Pass and joins U. S. Highway 50 about 35 miles west of Ely. Another gravel-surfaced road extends from State Highway 11 southwestward across the valley and connects with the gravel-surfaced road along the west side of the valley. Numerous other roads and trails make other parts of the valley accessible in good weather.

The rural population is distributed at a number of ranches around the west, north, and northeast sides of the valley.

The principal industry of the valley is raising livestock, with a substantial acreage of meadow hay and a small acreage of domestic crops grown for feed.

Previous reports of the U. S. Geological Survey that give information on Ruby Valley include a memorandum report on ground water by Taylor (1940) and a bulletin by Hill (1916) that has some incidental references to the valley. Several reports by Sharp (1938, 1939, 1940) contain information on geology, structure, and geomorphology of this and the adjacent area to the west. The Halleck quadrangle covers the northern part of Ruby Valley and the Jiggs quadrangle covers a part of the area west of Ruby Lake.

PHYSIOGRAPHY AND DRAINAGE

Ruby Valley is in the Great Basin section of the Basin and Range physiographic province. It occupies an elongate structural basin which trends about N. 20° E. The lowest part of the valley in the vicinity of Ruby and Franklin Lakes is about 5,950 feet above sea level. The altitude of the valley floor increases northward from Franklin Lake to about 6,100 feet above sea level in sec. 11, T. 33 N., R. 60 E. In this 20-mile segment the average slope is about 7½ feet a mile. Numerous Pleistocene lake features, which include beaches, bars, spits and lake stands, are prominent along the north and east sides of the valley below an altitude of 6,100 feet. A bar form divides Ruby and Franklin Lakes.

Ruby Mountains, along the west side of the valley, rise abruptly from the valley floor to summit altitudes averaging about 10,000 feet above sea level within a distance of 1 to 3 miles. Several of the peaks have altitudes in excess of 11,000 feet. Considerable Pleistocene glaciation occurred in the Ruby Mountains and East Humboldt Range (Sharp, 1938).

The part of the west flank of the East Humboldt Range that drains to Ruby Valley has summit altitudes of about 8,000 feet at the south to about 11,000 feet at the north. This flank is less bold than the east flank of the Ruby Mountains but still has relatively steep slopes.

Many of the streams draining the east flank of the Ruby Mountains are perennial in the canyons and along the upper parts of the alluvial slopes. The Franklin River, which is perennial to about sec. 11, T. 33 N., R. 60 E., is supplied principally by runoff from the East Humboldt Range.

Sharp (1940, p. 355), in his discussion of the geomorphology of the two ranges, states:

> The west side of the southern projection of the East Humboldt Mountains, the west flank of the Valley Mountains, and most of the east flank of the Ruby Mountains are bordered by alluvial-covered slopes which do not have the undulatory cross section parallel to the mountain front which typifies a piedmont slope formed by coalescing alluvial fans. The reasonable interpretation is that these slopes are actualy debris-mantled pediments. In a few places, notably just south of Sharps Creek, streams cutting through this alluvial mantle have exposed a gently sloping surface cut on pre-Tertiary rocks. The alluvial cover is not over 20 feet thick. Elsewhere, isolated knobs of pre-Tertiary rocks project through the alluvial mantle, substantiating the postulate that the alluvium actually rests on a surface cut on pre-Tertiary rocks.
>
> The pediment on the east flank of the Ruby Mountains is uncovered and dissected between Smithers Creek and Battle Creek. This surface is cut on the pre-Tertiary limestone and intrusives which compose the mountain block.

This is a rather different geologic condition than that commonly found in other valleys studied in eastern Nevada, where alluvial fans of considerable thickness are found marginal to the valley floors.

CLIMATE

The climate of Ruby Valley is arid to semiarid and is characterized by low precipitation on the valley floor, low humidity, high rate of evaporation, and a wide range in temperature seasonal and daily. Precipitation increases generally with altitude in the adjacent Ruby Mountains and East Humboldt Range.

Precipitation in the higher parts of these mountains ranks closely with other areas of heavy precipitation in Nevada and may locally exceed 35 inches a year. Precipitation on the valley floor may average between 10 and 12 inches a year.

Records of precipitation, available for two stations in the valley at the base of the Ruby Mountains and for two stations east and north of the valley, are shown in Table 1. Table 2 shows the average annual water content of snow at 16 snow courses in the Ruby Mountains as of about March 1 and April 1. It may be noted that these records show a definite increase in precipitation with altitude.

The growing or frost-free season in Ruby Valley is relatively short and generally suited to growing only rapidly maturing or frost-resistant crops. The only record of the growing season within the valley is that at the Ruby Lake station, which for the 8 years ending in 1948 has averaged 107 days. The minimum of 68 days occurred in 1945, and the maximum of 151 days occurred in 1947. Although this record is of short term, it compares approximately with the longer but not overlapping record of adjacent Clover Valley. The growing season at Clover Valley averaged about 100 days for the 27-year period ending in 1932, with a maximum of 149 days in 1910 and a minimum of 64 days in 1918.

TABLE 1

Average monthly and annual precipitation, in inches, at four stations in and near Ruby Valley, Nevada

(Weather Bureau records)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arthur[1]	1.80	1.83	1.46	1.54	1.49	1.05	0.65	0.57	0.74	1.27	1.27	1.54	15.21
Ruby Lake[2]	.92	1.04	1.42	1.32	1.06	1.19	.48	.46	.72	1.26	1.10	1.45	12.42
Clover Valley[3]	1.91	1.87	1.31	1.09	1.30	.71	.46	.61	.59	.77	1.31	1.29	13.22
Wells[4]	1.28	1.12	1.20	.80	.98	.70	.33	.25	.31	.73	.88	1.14	9.72

[1] Altitude, 6,500 feet; location, sec. 27, T. 34 N., R. 60 E. Period of record, 44 years, 1894–1948 (no record 1899–1909, inclusive).
[2] Altitude, 6,012 feet; location, sec. 24, T. 27 N., R. 57 E. Period of record, 9 years, 1940–1948 (broken in 1944).
[3] Altitude, 5,800 feet; location, sec. 12, T. 33 N., R. 61 E.(?). Period of record, 39 years, 1894–1932 (broken in 1894, 1897, and 1898).
[4] Altitude, 5,633 feet; location, sec. 10(?), T. 37 N., R. 62 E. Period of record, 59 years, 1870–1948 (no record 1916–1935, inclusive).

TABLE 2

Average annual water content of snow, in inches, in the Ruby Mountains, Nevada*

Name of snow course	Location Sec.	Location T.	Location R.	Altitude	Period of record (March) (years)	Average water content in March (inches)	Period of record (April) (years)	Average water content in April (inches)
Lower Trout Creek	28	37 N.	61 E.	6,900	12	5.9	3	1.9
Upper Trout Creek	4	36	61	8,500	13	19.6	3	30.2
Dorsey Basin	28	35	60	8,100	17	10.8	7	16.1
Ryan Ranch	1	34	59	5,800	17	2.0	7	0.6
Dry Creek	5	34	60	6,500	15	5.5	7	3.9
Lamoille No. 1	15	32	58	7,100	23	9.3	17	9.9
Lamoille No. 2	14	32	58	7,200	22	9.4	20	10.4
Lamoille No. 3	24	32	58	7,700	14	12.1	14	13.8
Lamoille No. 4	19	32	59	8,000	8	16.6	8	19.1
Lamoille No. 5	31	32	59	7,800	14	23.1	11	26.8
Green Mountain	23	29	57	8,000	14	12.9	7	14.0
Harrison Pass No. 1	9	28	57	6,600	20	5.4	12	5.2
Harrison Pass No. 2	16	28	57	7,400	19	5.7	7	4.8
Corral Canyon	27	28	57	8,500	14	14.3	7	19.5
Cave Creek	25	27	57	7,000	7	13.9	8	13.4
Hager Canyon	34	27	57	8,500	8	16.4	8	18.8

*Houston, Clyde, and Ghiglieri, Gloria, Summary of snow surveys in Nevada, 1910 through 1948: U. S. Dept. Agr., Soil Cons. Service, Div. Irr. and Water Cons., Reno, Nev., July 1948.

VEGETATION AND SOILS

The native vegetation on the floor of Ruby Valley includes big greasewood (*Sarcobatus vermiculatus*), big rabbitbush (*Chrysothamnus nauseosus*), sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), white sage (*Eurotia lanata*), saltgrass (*Distichlis spicata*), and mixed grasses and other members of the Northern Desert Shrub plant association.

The soils along the axis of the valley have been classed* in general as slightly productive semisink or playa gray soil, medium-textured but locally heavy and alkaline. The soils along the west and north sides are predominantly meadow soil, and are dark in color, of medium texture, highly productive, and moisture retentive.

Several thousand acres in Ruby Valley within the area of potential ground-water development were included by Mason during his field reconnaissance, September 30, 1948, in Class I soils—those deemed rather definitely suitable for development—and in Class II soils—those considered generally less suitable for development than Class I, but usable with reclamation.

Class I land occupies about 6,500 acres in three areas of Ruby Valley. The largest area, about 3,700 acres on the east side of Franklin River, is from ¼ to 1½ miles wide and extends from sec. 1, T. 33 N., R. 60 E., to about sec. 15, T. 32 N., R. 60 E. Here, most of the soil is of terrace or alluvial-fan type of medium texture, with a lime hardpan. Along the western part of this strip the soils are commonly 3 feet or more deep, but probably thin up the slope to the east. The vegetation consists of sagebrush and grass. The size of the sagebrush is an indication of the degree of productivity of the soil—that is, the larger the size of the sagebrush, the greater the productivity.

The second area of Class I land, about 2,000 acres, lies in parts of secs. 11, 12, 13, 14, 15, 22, and 24, T. 31 N., R. 59 E., and sec. 7, T. 31 N., R. 60 E. The soils in this area are classed as alluvial-fan type, and are brownish gray medium-textured, permeable, and moderately to highly productive. The vegetation is sagebrush and grass. The size of the sagebrush is an indication of the degree of productivity.

The third area, about 800 acres, lies in parts of secs. 19, 20, 29, and 30, T. 30 N., R. 59 E. The soils are similar to those in the second area.

Approximately 12,000 to 15,000 acres of Class II land lie principally west of Franklin River in parts of Tps. 31, 32, and 33 N., R. 60 E. Smaller areas are indicated west of Franklin Lake in T. 30 N., R. 59 E., and at the south end of Franklin Lake in T. 28 N., R. 58 E.

The soils of Class II land in Ruby Valley are derived almost entirely from basin sediments, developed under arid conditions, and are subject to periodic flooding and ground-water discharge. Nearly all of this type are on the border line in alkali content. Some of this soil adjacent to Franklin River has been considerably modified by frequent and heavy flooding. This phase of the class is the more desirable and is identified by its darker color, more granular structure, and heavy vegetative growth. Reclamation problems increase with the alkali content, and much of the Class II land would require long and persistent treatment.

GENERAL GEOLOGY

The oldest rocks, consisting of Paleozoic limestone, dolomite, and lesser amounts of sandstone and shale, crop out in the Ruby Mountains and East Humboldt Range. These rocks have been altered in varying degrees by intrusive granite and associated rocks of early Tertiary or late Mesozoic age. Erosion of the mountains yielded a large volume of detritus which was deposited during the Tertiary period in the adjacent valleys, under subaerial and lacustrine conditions. Sharp (1939b) described these deposits, considered them of late Miocene or early Pliocene age, and included them in the Humboldt formation. These in turn are unconformably overlain locally by volcanic flows, breccias, and tuffs of Pliocene(?) age. Pleistocene deposits overlie the sedimentary rocks of the Humboldt formation in Ruby Valley. In general, these are believed to be coarser in texture, less consolidated, and more permeable than the upper part of the Humboldt formation, as indicated by the sand and gravel in the upper 174 feet of the U. S. Geological Survey test well (32/60-29C1). (See pp. 86, 87.) Other Pleistocene deposits consist of glacial materials that occur low on the flanks of the mountains, terrace gravels, and numerous lake-shore beaches, bars, and spits on the floor of the valley. Deposits of Recent age are relatively minor.

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*Data on vegetation and soils based on a field reconnaissance Sept. 30, 1948, by Howard G. Mason, Agricultural Economist, Agr. Exper. Sta., Reno, Nev., and "Physical conditions and forage resources maps of Elko County, Nev.": Soil Cons. Service, U. S. Dept. Agr., and cooperating agencies.

p (1 , p.) summarized the rock sequence as follows:

Age	Formation	Lithology	Thickness (feet)
Quaternary	Drift, gravels, alluvium	Pediment and terrace gravels, glacial drift, recent alluvium	5–150
Pliocene (?)	Pliocene (?) lava	Pyroxene andesite and olivine-pyroxene basalt flows, breccia, and tuff	200–400
Unconformity			
Miocene	Humboldt formation	Breccia, fanglomerate, conglomerate, sandstone, mudstone shale, oil shale, limestone, ash, tuff, and interbedded rhyolite flows (Rhyolite not known to crop out in area of this report)	5,800
Early Tertiary or Late Mesozoic	Binary granite Porphyritic granite	Binary granite, porphyritic granite, pegmatite. (Igneous rocks intruded into Paleozoic rocks)	
Unconformity			
Carboniferous	Undifferentiated Carboniferous	Massive limestone, siliceous conglomerate quartzite	+? 4,000
	Mississippian (?)	Massive cherty crinoidal limestone	300
Devonian	Upper Devils Gate formation	Platy arenaceous and argillaceous limestone	300
	Lower Devils Gate formation	Dark gray, well-bedded, fossiliferous limestone	900
Silurian	Nevada formation	Gray, bedded, laminated and mottled dolomite	1,900
	Lone Mountain formation	Massive white dolomite	1,350
Unconformity			
Ordovician	Pogonip Limestone	Gray, massive, cherty limestone; platy, argillaceous limestone; shale and limy quartzite near the top	3,650
Unconformity			
Cambrian	Upper Cambrian	Thin-bedded limestone, argillaceous limestone, limy argillite and arenaceous beds	3,550
	Middle Cambrian	Thin-bedded arenaceous and argillaceous limestone	3,100
	Prospect Mountain quartzite	Massive quartzite	1,400
		Base not exposed	

NOTE: The Paleozoic section is from Plate 1 of:
Sharp, R. P., 1942, Stratigraphy and structure of the southern Ruby Mountain, Nevada: Geol. Soc. America Bull., vol. 53, pp. 647–690.
The post Paleozoic section is from Figure 3, Sharp, R. P., 1939, Basin-Range structure of the Ruby-East Humboldt Range, Northeastern Nevada: Geol. Soc. America Bull., vol. 50, pp. 881–920.

The following tentative geologic history is adapted largely from the published work of Sharp:

1. Deposition of Paleozoic limestone, dolomite, sandstone, and some shale.
2. Folding, with minor faulting, probably accompanied by granitic intrusions in early Tertiary or late Mesozoic time.
3. Erosion of the high areas and deposition in the basins.
4. Faulting during the latter part of the deposition of the Humboldt formation in the basins.
5. Faulting and deposition during post-Humboldt time.
6. Extrusion of lava flows and deposition of related sediments during Pliocene (?) time.
7. Faulting, involves post-Pliocene (?) lava flows.
8. Continued erosion and deposition extending into late Pleistocene time with the development of a relatively narrow pediment marginal to the valley floor. Concurrently, the formation, in whole or in part, of a Pleistocene lake with several shore lines developed locally, representing various levels of the lake.
9. Desiccation of the lake.
10. Erosion and deposition in Recent time.

WATER-BEARING PROPERTIES OF THE ROCKS

The Paleozoic rocks in general are of low permeability, but secondary joints, fractures, and solution channels may locally transmit large quantities of water. Thus Cave Creek, which issues from a limestone cave, has an average discharge that may be of the magnitude of 3 or 4 second-feet. Whether similar openings in the Paleozoic rocks occur beneath the valley fill is not known. However, as only a few springs issue from such channels in the exposed bedrock, there is little probability of encountering these openings by wells.

The intrusive rocks are exposed in the mountains and can carry water only in fractures, joints, or deeply weathered zones. In Ruby Valley, the conditions are not generally favorable for obtaining water from these rocks.

The older part of the valley fill (Humboldt formation) may locally contain beds or lenses of permeable deposits along the west, north, and northeast sides of the valley. No wells are known to have penetrated these deposits in the marginal parts of the valley. However, the upper part of the older valley fill has been tested for water under artesian pressure in the central part of the valley. It is reported by Mr. Duval, who had well 30/60-18A1 drilled to a depth of 510 feet, that blue clay was encountered in the interval between 120 and 510 feet. This suggests that suitable aquifers do not occur in the upper part of the older valley fill in the vicinity of this well.

The younger valley-fill deposits in the same well are reported to be principally sand and gravel to a depth of 120 feet. In the test well, 32/60-29C1, the depth of the younger valley-fill deposits is about 174 feet. The permeability of these deposits is believed to be greater than that of the older valley fill and the Paleozoic be k. W e these deposits have an adequate saturated thickness and permeability, moderate quantities of water can be transmitted to wells of good construction.

The pediment, where exposed, is cut on limestone and intrusive bedrock along the west side of Ruby Valley, and is overlain, in part, by a thin mantle of younger alluvium. If the pediment extends farther east beneath the lower alluvial slopes, the saturated part of the younger valley fill may be thin in this segment of the valley.

Similarly, the pediment cut on the older valley fill (Humboldt formation) along the east and northeast sides of the valley may occur at shallow depths, thereby minimizing the thickness of the younger valley fill in this area.

GROUND WATER

GENERAL CONDITIONS

The source of ground water in Ruby Valley is precipitation within the drainage basin. Precipitation on the flanks of the Ruby Mountains and the East Humboldt Range adjacent to Ruby Valley supplies most of the recharge to the ground-water reservoir. The other surrounding mountains are low and receive materially less precipitation. That on the valley floor is largely evaporated or transpired by the vegetation before it can penetrate to the water table.

Ground water occurs below the zone of saturation in the valley fill and in the underlying bedrock. However, it has been obtained only in the valley fill, and primarily in the younger fill deposits. There are only a few wells in the valley at present. Consequently, adequate information as to the distribution and potential yield of water-bearing beds in the valley-fill deposits in various parts of the valley will be obtained only by the drilling of additional wells.

Ground-water recharge occurs principally on the upper parts of the adjoining alluvial-covered slopes and the flanks of the mountains. From there it moves into the lower parts of the valley. The slope of the water table conforms in general to the slope of the land surface but ordinarily has a lesser gradient. Thus, the slope of the water table is toward Ruby and Franklin Lakes at all times except, perhaps, when surface runoff to the lakes may raise the lake level temporarily and reverse the water-table gradient in a narrow segment marginal to the lakes.

Ground water is discharged by transpiration of vegetation and by evaporation from soil and free-water surfaces. The valley is a closed basin, and the possibility of underflow out of it is remote.

The depth to water ordinarily is less than 10 feet in the floor of the valley and along the lower alluvial slopes to the west and north. The depth generally increases toward the margins of the valley because of the increased surface slope. Thus, at well 30/60-18A1, on the valley floor, the depth to water is about 13 feet, and at well 30/61-7D1, about 6 miles east, it is about 98 feet. It has been reported (Taylor 1940) that water levels in stock-water sumps rose 2.5 feet during the spring of 1939. Measurements in observation wells since 1948 suggest that the annual range in average water level may be 3 to 5 feet.

An annual fluctuation of this magnitude in the lower parts of the valley suggests that the annual increment to the ground water may represent a considerable percentage of the available storage. It also may indicate that the annual recharge is comparatively large if the assumption is correct that the younger valley-fill deposits transmit water freely.

Gravity-type springs and seeps commonly issue from the lower parts of the alluvial slopes along the west margin of the valley in the vicinity of Ruby and Franklin Lakes. A large number of such springs on the west side of Ruby Lake supply a substantial part of the annual contribution to the lake. A lesser number of gravity springs west of Franklin Lake are largely utilized in supplying part of the water requirements for irrigated meadow land in the area.

Sulphur Hot Springs, in NE¼NE¼ sec. 11, T. 31 N., R. 59 E., issues from several pools. These pools are on a mound built by deposition of minerals from the water of the spring. The temperature of the water is 162° F. at a depth of 5 feet below the surface of the main pool. It appears probable that the water supplying these springs rises in openings adjacent to a fault.

Taylor (1940) mentions that similar springs were reported on the east side of the valley and somewhat south of the latitude of Sulphur Hot Springs.

The warm springs in sec. 2, T. 27 N., R. 58 E., along the northeast margin of Ruby Lake, issue from valley fill a short distance from the bedrock outcrop. It is possible that these are the springs to which Taylor refers.

ESTIMATED AVERAGE ANNUAL RECHARGE

The average annual recharge to the ground-water reservoir can be estimated as a percentage of the total precipitation within ura e ba of Ruby Valley. The best available basis on which to estimate the total precipitation is the "Precipitation map of Nevada," prepared in 1936 under the supervision of George Hardman, by the Nevada Agricultural Experiment Station. This map shows areas of assumed equal precipitation by zones of less than 5 inches, 5 to 8 inches, 8 to 12 inches, 12 to 15 inches, 15 to 20 inches, and more than 20 inches.

Preliminary studies in east-central Nevada, in which estimates of ground-water discharge by natural losses were made for 13 valleys, indicate the approximate recharge in terms of percentage of the precipitation. The precipitation was estimated for each valley, the rainfall map being used as a basis. The recharge percentages were balanced by trial and error against the estimates of discharge by natural losses in the 13 valleys. Lack of agreement in the recharge and discharge estimates for any one valley probably results from insufficiently detailed control for the precipitation map, and for density and distribution of native vegetation or for other reasons. The recharge percentages derived agree reasonably well for those obtained in Las Vegas Valley, Nevada (Maxey and Jameson, 1948), and Roswell Basin, New Mexico (Fielder and Nye, 1933), particularly in areas of higher precipitation. The estimates are as follows: No significant ground-water recharge is believed to occur in the zones having precipitation of less than 8 inches; in the 8- to 12-inch zone the recharge may be about 3 percent of the precipitation; in the 12- to 15-inch zone, about 7 percent; in the 15- to 20-inch zones, about 15 percent; and in the over-20-inch zone, about 25 percent.

TABLE 3

Estimated average annual ground-water recharge from precipitation in Ruby Valley, Nevada

AREA NORTH OF FRANKLIN LAKE

Precipitation zone (inches)	Area of zone (acres)	Percentage of recharge	Approximate recharge (acre-feet)
8–12	135,000	3	3,400
12–15	33,900	7	2,700
15–20	53,100	15	11,600
Over 20	38,400	25	20,000
Estimated recharge			37,700

AREA SOUTH OF NORTH END OF FRANKLIN LAKE

Precipitation zone (inches)	Area of zone (acres)	Percentage of recharge	Approximate recharge (acre-feet)
8–12	237,400	3	5,900
12–15	92,200	7	7,300
15–20	29,400	15	6,400
Over 20	20,500	25	10,700
Estimated recharge			30,300
Estimated total recharge, Ruby Valley			68,000

The zones of precipitation were transferred from the "Precipitation map" to the base map of this report and the areas determined by planimeter. The 5- to 8-inch zone shown on the "Precipitation map" was included in the 8- to 12-inch zone in Ruby Valley because it is believed to more nearly approximate the local conditions. Also, the average precipitation for the over-20-inch zone was assumed to be 25 inches because of the relatively heavy precipitation in the Ruby Mountains and the East Humboldt Range. In order to consider potential development, the estimates have been divided into two areas—north and south of the south line of T. 30 N., or roughly north and south of the north end of Franklin Lake. The data pertinent to the estimates of recharge from precipitation are summarized in Table 3.

The estimated 68,000 acre-feet of average annual recharge to the ground-water reservoir is relatively high compared to other valleys of similar area in eastern Nevada. However, the Ruby Mountains and the East Humboldt Range receive some of the heaviest precipitation in the State. This precipitation, together with the steep slopes in the higher parts of the mountains, favors a high-percentage runoff to the area of recharge and tends to qualitatively support the estimate.

ESTIMATED AVERAGE ANNUAL DISCHARGE

Ground water is discharged by transpiration of phreatophyte vegetation, evaporation from the soil and, in part, from Ruby and Franklin Lakes, by springs, and by stock and domestic wells. As essentially all of the water discharged from springs is finally utilized by vegetation or is evaporated, it is included in the estimates of discharge by transpiration and evaporation. The amount of ground water withdrawn by stock and domestic wells is relatively small and is not included in the estimate of discharge.

The average annual discharge of ground water from Ruby Valley is estimated to be about 68,000 acre-feet of which a little over 50 percent is discharged in the area north of Franklin Lake (see Table 4). The area from which ground-water discharge occurs is approximately 143,000 acres as indicated by the field reconnaissance.

The scope of this investigation did not permit any detailed studies of evapo-transpiration rates in Ruby Valley, therefore, estimates of the rates of evapo-transpiration are based on data obtained from studies by Lee (1912), and White (1932) in the Great Basin and adapted to Ruby Valley. These compare reasonably with consumptive use estimates by Piper, Robinson, and for the Harney Basin, Oregon. It should be recognized, however, that the accuracy of the estimate is limited to the degree of validity of transferring experimental data from areas considerably removed from Ruby Valley as modified for local conditions.

TABLE 4

Estimated annual discharge of ground water, in acre-feet, by transpiration and evaporation in Ruby Valley, Nevada

AREA NORTH OF FRANKLIN LAKE

Method of discharge	Acres	Approximate discharge (acre-feet)
Saltgrass, big rabbitbrush (Individually predominant or mixed) Average density; average depth to water, 4 feet. Estimated average consumptive use, 0.7 foot.	41,000	28,700
Greasewood, big rabbitbrush, shadscale, saltgrass Moderate density; depth to water, 5 to 10 feet.: Estimated average consumptive use, 0.3 foot.	19,000	5,700
Irrigated meadow Irrigated principally by surface water. Estimated ground-water consumptive use, 0.25 foot.	12,000	3,000
Estimated ground-water discharge		37,400

AREA SOUTH OF NORTH END OF FRANKLIN LAKE

Method of discharge	Acres	Approximate discharge (acre-feet)
Saltgrass, big rabbitbrush (Individually predominant or mixed) Average density; average depth to water, 4 feet. Estimated average consumptive use, 0.7 foot.	14,700	10,300
Greasewood, big rabbitbrush, shadscale Low to moderate density; depth to water, 5 to 40 feet. Estimated average consumptive use, 0.2 foot.	24,500	4,900
Evaporation from Ruby and Franklin Lakes, and transpiration from marsh vegetation Ruby Lake—22,000 acres; estimated 4-foot evaporation, partly supplied by ground water. Franklin Lake—10,000 acres; evaporation substantially less than from Ruby Lake as lake frequently goes dry. Probably not less than 15,000 acre-feet of the total loss by evapo-transpiration is supplied by ground water.	....	15,000
Estimated ground-water discharge		30,200
Estimated total ground-water discharge from Ruby Valley		68,000

Estimates of both discharge and recharge could be made with more assurance if they were based upon data on rates of discharge and recharge which were obtained experimentally in the valley or in one or more areas within the State of Nevada.

It should be noted that the estimated losses from Ruby and Franklin Lakes are considered a minimum. On the basis of a 4-foot annual evaporation from Ruby Lake, and the fact that surface runoff supplies most of the water to the lake, the amount of stream discharge would have to be considerably higher than it appears to be. This suggests that ground-water recharge in the upper parts of the alluvial slopes west of Ruby Lake is greater than elsewhere.

If this is true, then the contribution to Ruby Lake by discharge from the gravity springs along the west margin may be substantially greater than the amount used in the estimate.

DEVELOPMENT

The area of potential ground-water development lies north of Franklin Lake. In this area the estimated average annual recharge and discharge is about 37,000 acre-feet. Of this, possibly no more than about one-half can be recovered annually by wells under present conditions.

Ground-water development in the northern part of Ruby Valley, if limited to about one-half of the annual amount discharged under natural conditions, should not have much effect on Ruby Lake, as most of the recharge to the lake is supplied from the Ruby Mountains immediately to the west. Such development would be 10 miles or more away, and the lowering of water level by pumping probably would not greatly change the gradient toward the lake.

As Ruby Lake is a wildlife refuge, it is assumed that the water in the lake and the surface runoff and springs supplying the lake will not be utilized for other purposes. However, limited irrigation development might be feasible without material effect on the lake level.

QUALITY

The chemical composition of water from one hot spring and two water-bearing zones in the Geological Survey test well (32/60-29C1) is shown in Table 5. The analyses were made by the Salt Lake City laboratory of the U. S. Geological Survey, Quality of Water Branch.

The analyses indicate that, except for the fluoride content of the water from Sulphur Hot Spring, the water sampled is satisfactory for domestic uses when compared to the limits recommended by the U. S. Public Health Service (1942) for drinking water used on interstate carriers.

Water from the spring probably would cause mottled enamel if used regularly for drinking by young children during the period of calcification or formation of their teeth. The water from the two water-bearing zones of the test well was not analyzed for fluoride content.

Magistad and Christiansen (1944, pp. 8–9) have given tentative standards for irrigation waters, but they indicate that consideration should be given to the characteristics of the type of soil and the soil solution in evaluating the effect of water of a particular chemical composition on a given soil.

Water class	Conductance (micromhos at 25° C.)	Salt Content: Total (p.p.m.)	Salt Content: Per acre-foot (tons)	Sodium[1] (percent)	Boron (p.p.m.)
Class 1[2]	<1,000	<700	<1	<60	<0.5
Class 2[3]	1,000–3,000	700–2,000	1–3	60–75	.5–2.0
Class 3[4]	>3,000	>2,000	>3	>75	>2.0

[1] The percentage of sodium is calculated from analytical results expressed in milligram equivalents per kilogram. These results are obtained by dividing the parts per million of sodium, calcium, and magnesium by 23, 20, and 12.24, respectively; then 100 times the milligram equivalents of sodium is divided by the sum of the milligram equivalents of sodium, calcium, and magnesium. In milligram equivalents

$$\frac{100\ Na}{Na+Ca+Mg} = \text{percentage of sodium.}$$

[2] Excellent to good, suitable for most plants under most conditions.

[3] Good to injurious, probably harmful to the more sensitive crops.

[4] Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant. If a water falls in Class 3 on any basis, i. e., conductance, salt content, percentage of sodium, or boron content, it should be classed as unsuitable under most conditions. Should the salts present be largely sulfates, the values for salt content in each class can be raised 50 percent.

Comparison of the analyses with the tentative standards indicates that the water from the hot spring and the deep zone of the well falls in Class 3 on the basis of the percentage of sodium, and probably would be unsatisfactory as the sole irrigation supply for most crops.

TABLE 5

Chemical analyses of water from one hot spring and two water-bearing zones in the U. S. Geological Survey test well in Ruby Valley, Nevada[1]

(Analyses by Salt Lake City Laboratory, Quality of Water Branch, U. S. Geological Survey)

(Parts per million)

	Sulphur Hot Spring	Test well (32/60-29C1) (depth 82 ft.)	Test well (32/60-29C1) (depth 202 ft.)	Limits recommended by U. S. Pub. Health Service
Silica (SiO_2)	72	29	133	
Iron (Fe)	....	....	....	0.3
Calcium (Ca)	18	24	2.0	
Magnesium (Mg)	5.8	5.4	1.1	125
Sodium and potassium (Na & K)	106	14	133	
Bicarbonate (HCO_3)	242	124	246	
Sulfate (SO_4)	59	5.6	56	250
Chloride (Cl)	12	2.5	27	250
Fluoride (F)	8.0	....	....	1.5
Nitrate (NO_3)	0.5	0.9	0.1	
Boron (B)	0.04	0.00		
Dissolved solids	400	142	473	1,000
Hardness as $CaCO_3$: Total	69	82	10	
Noncarbonate	0	0	0	
Specific conductance (micromhos at 25° C.)	660	211	662	
Percent sodium	77	27	97	

[1] Samples collected June 1949 by R. C. Perry, U. S. Geological Survey.

The water from the deep zone of the test well is similar in character to that of Sulphur Hot Spring. However, there is a greater amount of sodium and potassium and a lesser amount of calcium and magnesium, which suggests that there has been a degree of base exchange. Further, it is noted that the silica content of the water from the deep zone is substantially greater than that of the hot-spring water. The similarity of the two waters suggests subsurface leakage of hot-spring type water into permeable zones of the valley fill, at least in the vicinity of the test well. As the area, or areas, of water of this type have not been delimited, it would be desirable to have chemical analyses made of water from the deeper wells to determine suitability for their contemplated use.

RESULTS OF DRILLING OF THE U. S. GEOLOGICAL SURVEY TEST WELL IN RUBY VALLEY, NEVADA

In June 1949, a test well was drilled in the northern part of the valley under the supervision of the U. S. Geological Survey. The cost of drilling, testing, and completing the well was financed by cooperative funds. The purpose of such drilling was to obtain geologic and hydrologic information on the sediments penetrated, and also to determine the chemical quality of the ground water.

The well, 32/60-29C1, on land owned by the Federal Government, is nearly 200 feet north of the center line of the gravel road that crosses the valley floor near the west line of sec. 29, T. 32 N., R. 60 E. The land-surface altitude in this vicinity is about 6,000 feet, as shown on the Halleck quadrangle.

The well was drilled with a cable-tool rig to a depth of 202 feet and cased with 6-inch steel casing to a depth of 137 feet. The casing was not perforated and the water level in the well represents the head of the water-bearing zone between 145 and 174 feet below land surface (see p. 89). It is approximately 4 feet above the unconfined water table. In order to compare fluctuations of water level in the deeper zone with that of the water table in the immediate vicinity, a 1½-inch galvanized pipe with a well point was driven along the outside of the 6-inch casing to a depth of about 15 feet below land surface. Thus, comparison of the water levels in the two wells are readily made.

Periodic water-level measurements will be made in these two wells as a part of the State-wide observation-well program.

The log of the test well, in Table 6, is based on samples of material collected during drilling. In general, the material encountered was gravelly silt and soil from the surface to 6 feet; loose, fine sand to medium gravel from 6 to 20 feet; coarse to medium sand, with varying amounts of fine sand, silt, or gravel, from 20 to 65 feet; coarse sand with fine to medium sand from 65 to 70 feet and from 78 to 82 feet, with fine and medium sand with silt and layers of coarse sand in the interval between 70 to 78 feet; fine to coarse sand and silt, generally in thin layers, from 82 to 145 feet; coarse sand to medium gravel from 145 to 157 feet and

, wi ne t ediu and between 157 and 161 feet; and fine to coarse sand from 174 to 202 feet.

TABLE 6

Log of the U. S. Geological Survey test well, 32/60–29C1, in Ruby Valley, Nev.

Location: SW¼ sec. 29, T. 32 N., R. 60 E. In Ruby Valley about 2 miles west of Franklin River crossing and nearly 200 feet north of gravel road that connects State Highway 11 with the west-side road. Owner, U. S. Geological Survey. Driller, C. N. Robertson. Depth, 202 feet, diameter, 6 inches. Unperforated to 137 feet, open hole from 137 to 202 feet. Log from samples collected during drilling by the U. S. Geological Survey. Some samples taken where there was open-hole drilling may be partly modified by admixture of material caved from above the zone sampled.

Material	Thickness (feet)	Depth (feet)
Soil and gravelly silt	6	6
Sand, coarse, with lesser amounts of fine sand to medium gravel (Coarse sand, 60%[1]; medium gravel, 15%; fine gravel, 10%; medium sand, 10%; and fine sand, 5%. Subangular particles, loosely consolidated. Grains largely quartz with some feldspar and ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)[2]	14	20
Sand, medium, with lesser amounts of silt to medium gravel (Medium sand, 50%; coarse sand, 20%; fine sand, 18%; fine gravel, 8%; medium gravel, 2%; and silt, 2%. Angular to subangular particles, loosely consolidated. Grains largely quartz and feldspar with very little mica and ferromagnesian minerals. Color, greenish yellow to pale olive [10Y7/2].)	7	27
Sand, medium and coarse, with fine sand (Coarse sand, 30%; medium sand, 30%; fine sand, 28%; medium gravel, 5%; fine gravel, 5%; and silt, 2%. Subangular particles, loosely consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	8	35
Silt and fine sand, with medium to coarse sand (Silt, 35%; fine sand, 30%; medium sand, 20%; coarse sand, 10%; and medium gravel, 5%. Subangular particles, loosely consolidated. Grains largely quartz and feldspar. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	40
Sand, coarse to fine, with gravel and some silt (Fine to medium gravel, 30%; medium sand, 25%; coarse sand, 20%; fine sand, 15%; and silt, 10%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, moderate yellow to light olive brown [5Y6/6].)	8	48
Sand, coarse to medium gravel, with medium to fine sand (Coarse sand, 60%; fine to medium gravel, 25%; medium sand, 10%; and fine sand, 5%. Angular to subangular particles, lightly consolidated. Grains largely quartz and white and pink feldspar, with some mica and ferromagnesian minerals. Color, pale greenish yellow to pale olive [10Y7/2].)	2	50
Sand, coarse to fine, with some silt (Coarse sand, 40%; medium sand, 25%; fine sand, 25%; fine gravel, 5%; and silt, 5%. Subangular particles, lightly consolidated. Grains largely quartz, feldspar, and some ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	15	65
Sand, coarse, with medium to fine sand (Coarse sand, 65%; medium sand, 20%; fine sand, 10%; and fine gravel, 5%. Angular to subangular particles, lightly consolidated. Grains largely quartz and white, gray, and pink feldspar. Color, pale greenish yellow to pale olive [10Y7/2].)	5	70
Sand, fine and medium, with some coarse sand, silt, and clay (Fine sand, 45%; medium sand, 30%; coarse sand, 15%; silt, 5%; clay, 4%; and fine gravel, 1%. Subangular particles, lightly consolidated. Grains largely quartz, feldspar, and muscovite mica. Color, pale greenish yellow to pale olive [10Y7/2].)	8	78

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[1] All samples contain small amounts of calcium carbonate. Percentages of grain sizes were obtained by visual inspection and, therefore, are relative within a given sample and only approximate between different samples. Grain sizes are according to a scale—coarse gravel is greater than 6 millimeters, medium gravel from 4 to 6 millimeters, fine gravel from 2 to 4 millimeters, coarse sand from ½ to 2 millimeters, medium sand from ¼ to ½ millimeter, fine sand from ⅛ to ¼ millimeter, and silt less than ⅛ millimeter.

[2] Numbers indicate a specific color as defined in the Rock Color Chart system, National Research Council, 1948.

TABLE 6—*Continued.*

Material	Thickness (feet)	Depth (feet)
Sand, coarse, with medium to fine sand and fine gravel (Coarse sand, 60%; medium sand, 20%; fine gravel, 10%; and fine sand, 10%. Angular to subangular particles, lightly consolidated. Grains largely quartz, white and pink feldspar, and green ferromagnesian minerals. Color, greenish yellow to pale olive [10Y7/2].)	4	82
Sand, medium and fine, coarse sand, and a little fine gravel and silt (Medium sand, 35%; fine sand, 33%; coarse sand, 25%; fine gravel, 5%; and silt, 2%. Subangular to subrounded particles, lightly consolidated. Color, dusky yellow [5Y6/4].)	9	91
Sand, medium, coarse, and fine (Medium sand, 40%; coarse sand, 30%; fine sand, 25%; and fine gravel, 5%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar, with some ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	9	100
Sand, coarse and medium, with fine sand and silt (Coarse sand, 40%; medium sand, 40%; fine sand, 18% and silt, 2%. Subangular to subrounded particles, lightly consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	10	110
Sand, coarse and medium, with fine sand, a little fine gravel, and silt (Coarse sand, 35%; medium sand, 35%; fine sand, 22%; fine gravel, 5%; and silt, 3%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow [5Y6/4].)	5	115
Sand, fine with coarse and medium sand, and a little silt (Fine sand, 42%; coarse sand, 30%; medium sand, 25%; silt, 2%; and fine gravel, 1%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to light olive gray [5Y5/3].)	5	120
Sand, coarse, with medium and fine sand, and a little fine gravel (Coarse sand, 45%; medium sand, 30%; fine sand, 20%; and fine gravel, 5%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	125
Sand, coarse and medium, with some fine sand and fine gravel (Coarse sand, 45%; medium sand, 40%; fine sand, 8%; fine gravel, 6%; and medium gravel, 1%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar, with few ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	10	135
Sand, coarse, with medium to fine sand (Coarse sand, 45%; medium sand, 30%; and fine sand, 25%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to light olive brown [5Y5/5].)	5	140
Sand, medium, coarse sand, and fine sand (Medium sand, 50%; coarse sand, 35%; and fine sand, 15%. Subangular to subrounded particles, lightly consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	145
Gravel, fine to medium, with coarse sand, and a little coarse gravel and medium sand (Fine gravel, 40%; medium gravel, 30%; coarse sand, 20%; coarse gravel, 5%; and medium sand, 5%. Subangular to subrounded particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow [5Y6/4].)	6	151
Sand, coarse, with medium to fine sand (Coarse sand, 80%; medium sand, 15%; and fine sand, 5%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, grayish yellow to dusky yellow [5Y7/4].)	6	157
Sand, medium to fine, with some coarse sand and silt (Medium sand, 50%; fine sand, 35%; coarse sand, 10%; and silt, 5%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, moderate yellow to light olive brown [5Y6/6].)	4	161
Sand, coarse, with medium sand, some fine sand, and fine gravel (Coarse sand, 60%; medium sand, 25%; fine sand, 10%; and fine gravel, 5%. Subangular particles, lightly consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	9	170
Sand, coarse, with medium sand and some fine sand (Coarse sand, 60%; medium sand, 30%; fine sand, 8%; and fine gravel, 2%. Subangular particles, lightly consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	4	174
Sand, medium, with fine and coarse sand (Medium sand, 50%; fine sand, 25%; coarse sand, 24%; and fine gravel, 1%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, moderate yellow to light olive brown [5Y6/6].)	6	180

TABL —Continued

Material	Thickness (feet)	Depth (feet)
Sand, fine to coarse (Fine sand, 40%; medium sand, 30%; and coarse sand, 30%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to moderate olive brown [5Y5/4].)	3	183
Sand, fine, with medium and coarse sand (Fine sand, 50%; medium sand, 30%; and coarse sand, 20%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, moderate yellow to light olive brown [5Y6/6].)	2	185
Sand, coarse and medium, with fine sand (Coarse sand, 45%; medium sand, 35%; fine sand, 18%; and fine gravel, 2%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	190
Sand, fine and medium, with some coarse sand (Fine sand, 50%; medium sand, 40%; and coarse sand, 10%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	195
Sand, coarse and coarse gravel, with some medium to fine sand and medium to fine gravel "Slumped" sample—probably from 145- to 151-foot zone. (Coarse sand, 30%; coarse gravel, 25%; medium sand, 20%; fine gravel, 15%; medium gravel, 5%; and fine sand, 5%. Subangular to subrounded particles, lightly consolidated. Grains largely quartz, feldspar, and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	at	198
Sand, coarse and medium with fine sand (Coarse sand, 40%; medium sand, 35%; fine sand, 20% and fine gravel, 5%. Subangular particles, lightly consolidated. Grains largely quartz and feldspar with few ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	7	202
Total depth	....	202

Supplemental information obtained by R. C. Perry, geologist, U. S. Geological Survey, during drilling is summarized below:

While drilling from 6 to 40 feet (depths are referred to land surface) the casing was maintained near the bottom of the hole to reduce the tendency of the loose sediments to "heave" into the hole. After the casing was driven to the bottom of the hole at 60 feet, bailing about 50 gallons in 2½ minutes lowered the water level almost to the bottom of the hole. The hole was then drilled to 65 feet and was left overnight. The following morning it was still essentially dry and water was added to facilitate drilling. When the hole was down to 75 feet the casing was driven from 60 to 71¾ feet and the hole was still comparatively dry. Drilling was continued to slightly below 78 feet at which depth the water level began to rise. At a depth of 80 feet the water level had risen to 25.18 feet, and 30 minutes later it stood at 11.29 feet. Drilling was then continued to 82 feet, with the casing at 71¾ feet. The sand from 78 to 82 feet was tested by bailer at the rate of 36 gallons per minute for 15 minutes, at the end of which time the drawdown was 6.7 feet. Within 10 minutes the water level recovered to 6.00 feet, which was 5.29 feet above the level prior to bailing. The bailing test obviously developed this zone to some extent as the rate of recovery indicates. However, the water level prior to the test was not stabilized and may have risen to the same level had sufficient time been allowed. A water sample was taken from this zone for chemical analysis and the results are shown in Table 5.

With the casing maintained at 71¾ feet, drilling was continued to 110 feet. The casing was then driven to 94¾ feet. Drilling was continued to 136 feet, during which time the water level was depressed 25 to 40 feet (indicating practically no water yield from the materials in the interval from 95 to 135 feet). The casing was then driven to 116 feet, after which drilling was continued. At about 145 feet the hole was cleaned out and the water level rose from about 23.5 feet to 8.56 feet, 20 minutes after cleaning. The following morning the well was cleaned out again and in 15 minutes the water level rose to 6.80 feet. After drilling to 154 feet, with the casing at 116 feet, the water level stood at 6.47 feet. The casing was then driven to 137 feet. When the drilling depth was 181 feet the water level was at 6.00 feet after standing overnight.

At 200 feet, with the casing at 137 feet, the well was cleaned out and after a short interval was tested by bailer at 25 gallons per minute for 28 minutes. At the end of the test the water level was at 11.00 feet but it recovered to 6.37 feet in 8 minutes. Shortly afterward a second test was run, during which the bailing rate of 39 gallons per minute was maintained for 14 minutes. A drawdown of 9.6 feet resulted. After the test the water level recovered to 4.02 feet in 1 hour and 50 minutes. During this test the well filled in 10 feet to 190 feet; this was cleaned out and the well was drilled to 202 feet. Within 30 minutes after cleaning the water level had recovered to 4.06 feet. A water sample was taken for chemical analysis near the end of this test, and the results are shown in Table 5. The zones tested by bailing were those from 145 to 157 feet and 161 to 174 feet.

As indicated by the test drilling, three general water-bearing zones were encountered—from 6 to 20 feet, 78 to 82 feet, and 145 to 174 feet. The materials penetrated to 174 feet are believed to represent deposits belonging to the younger valley fill, and those between 174 feet and the bottom of the well (202 feet) to the upper part of the Humboldt formation. This is largely predicated on the assumption that the deformation which terminated deposition of the Humboldt formation resulted in deposition in restricted basins and, in the Ruby Valley test well, may be represented by the sand and gravel interval between 145 and 174 feet. The rocks exposed in Ruby Mountains are the same types as those that have supplied detritus to Ruby Valley since at least upper Humboldt time, and there probably is not a sufficient [illegible] mineralogical ratios to separate the younger valley fill from the upper Humboldt formation on this basis with the information from only one well. Although it is recognized that the full thickness of the younger valley fill may not have been penetrated by the test well, the available information suggests that the base may be at about 174 feet below the surface at the test-well site. Of the three water-bearing zones encountered, the lowest (145 to 174 feet) appears most suitable for development at this locality. The log indicates that 24 feet of the zone contains water-bearing sand and gravel. The sand logged in this interval is principally coarse with some gravel having fragments as large as 6 millimeters. With proper development, this, or similar zones, should be capable of yielding moderate quantities of water through wells. It seems likely that the "slumped" sample obtained at 198 feet was derived from the 145- to 174-foot zone. If this is correct, this sample represents, in part, material as it occurs naturally and not that which has been broken by the drill bit. It may be noted that water in the 145- to 174-foot zone is under artesian head sufficient to raise the water level in the well to about 2 to 4 feet above the water table, although not enough to raise it above land surface at the test-well site.

To develop moderate to large quantities of water by drilled wells from the 6- to 20-foot zone would be difficult because of the poor consolidation of the sediments and the tendency to "heave" into the well. This zone may be more favorable for development in other localities.

The 78- to 82-foot zone probably would not be satisfactory for development of more than moderate yields, largely because of its limited thickness. A substantially greater thickness of this zone in other localities would be more favorable for potential development.

SUMMARY

The following summarizes the principal items of this reconnaissance of Ruby Valley:

1. Of the average annual increment to the ground-water reservoir, derived chiefly from precipitation on the Ruby Mountains and the East Humboldt Range, perhaps about 20,000 acre-feet may be recovered annually by wells under full development in the area north of Franklin Lake.
2. The permeable sand and gravel of the younger valley fill may generally be the most satisfactory for obtaining moderate to large yields by wells, as indicated in part by the results of the drilling of a test well in sec. 29, T. 32 N., R. 60 E.
3. The soils in the area of potential development, where free from alkali, are suited for irrigated pasture and the production of domestic hay in a long-time rotation with grain or other row crops adapted to the climate of the valley. In a field reconnaissance by H. G. Mason, of the University of Nevada Agricultural Experiment Station, about 6,500 acres of Class I land—definitely suitable for development—and 12,000 to 15,000 acres of Class II land—less suitable for development, but useable with reclamation—were indicated in the potential area of ground-water development.
4. The frost-free or growing season in the valley is relatively short, and may average 100 days.

TABLE 7

Record of wells in Ruby Valley, Nev.

25/57-3D1. U. S. Fish and Wildlife Service. Unused, dug well; depth, 13 feet; diameter, 48 inches. Equipped with bucket and chain, hand-operated. Measuring point. top of 2- by 4-inch wood sill, northeast corner, 0.5 foot above land surface. Depth to water, below measuring point, 5.21 feet, July 8, 1948.

26/58-10A1. Unknown. Unused, drilled well; depth, 59 feet; diameter, 8¼ inches; steel casing. Measuring point, top of casing, 1.5 feet above land surface. Depth to water, below measuring point, 28.50 feet, July 8, 1948.

28/59-9C1. Ruby Valley well No. 1. Stock, dug well; depth, 44 feet; diameter, 48 inches square; wood cribbing. Equipped with a cylinder pump driven by gasoline engine. Measuring point, top of 2- by 12-inch sill, west side, at land surface. Depth to water, below measuring point, 37.27 feet, July 7, 1948.

30/60-18A1. R. Duval. Stock, drilled well; reported depth, 510 feet; diameter, 4 inches; steel casing reported to 180 feet. Reported log, gravel to 120 feet, blue clay 120 to 510 feet. Equipped with cylinder pump driven by windmill and gasoline engine. Measuring point, top of collar on 4-inch casing, 1.0 foot above land surface. Depth to water, below measuring point, 19.75 feet, December 8, 1939 (by G. H. Taylor), and 14.10 feet, August 26, 1948.

30/61-7D1. Unknown. Stock, dug well; depth, 130± feet; diameter, 72 inches square; wood cribbing. Equipped with a cylinder pump driven by a gasoline engine. Measuring point, top of 8- by 8-inch pump support, 2.0 feet above land surface. Depth to water, below measuring point, 100.78 feet, June 29, 1948.

31/60-4A1. Unknown. Stock, drilled well; depth, 20± feet; diameter, 8 inches; steel casing. Equipped with a cylinder pump driven by a windmill. Measuring point, top of casing, 1.0 foot above land surface. Depth to water, below measuring point, 6.79 feet, June 30, 1948.

31/60-4D1. Division of Grazing. Stock sump. Depth to water, below land surface, 7.1 feet, March 31, 1939. (Data from report by G. H. Taylor.)

31/60-7C1. Unknown. Unused, dug well; depth, 9 feet; diameter, 24 by 48 inches; stone curbing. Equipped with cylinder pump, hand-operated. Measuring point, top of rock sill, southeast corner, at land surface. Depth to water, below measuring point, 8.53 feet, July 7, 1948.

31/60-16C1. Unknown. Stock, drilled well; depth, 35 feet; diameter, 8 inches; steel casing. Equipped with cylinder pump driven by windmill. Measuring point, top of casing, 0.5 foot above land surface. Depth to water, below measuring point, 9.27 feet, June 30, 1948.

31/60-21C1. Division of Grazing. Stock sump. Depth to water, below land surface, 8.7 feet, March 31, 1939. (Data from report by G. H. Taylor.)

32/60-29C1. U. S. Geological Survey. Test and observation well; depth, 202 feet; diameter, 6 inches; steel casing. No equipment. Measuring point, top edge of 1-inch hole in steel plate on casing, 0.7 foot above land surface. Depth to water, below measuring point, 3.45 feet, June 10, 1949; 4.26 feet, July 19, 1949; 5.08 feet, September 15, 1949; and 5.03 feet, December 21, 1949.

32/60-29C2. U. S. Geological Survey. Observation well; depth, 15 feet; diameter, 1½ inches. Measuring point, top of 1½-inch galvanized iron pipe, 2.05 feet above land surface. Depth to water, below measuring point, 6.18 feet, June 10, 1949; 9.00 feet, September 15, 1949; and 8.90 feet, December 21, 1949.

32/60-27B1. Division of Grazing. Stock sump. Depth to water, below land surface, 5.9 feet, March 31, 1939. (Data from report by G. H. Taylor.)

32/60-29B1. Sharp and Smith well. Stock, bored well; reported depth 15 to 18 feet. Measuring point, top of plank cover, at land surface. Depth to water, below measuring point, 6.30 feet, December 8, 1939 (by G. H. Taylor); 4.78 feet, June 30, 1948.

33/60-1C1. Unknown. Stock, drilled well; depth 30± feet; diameter, 4 inches; steel casing. Equipped with cylinder pump operated by hand and windmill. Measuring point, top of casing, at land surface. Depth to water, below measuring point, 4.62 feet, June 29, 1948.

33/60-13C1. Unknown. Stock, drilled well; depth, 18 feet; diameter, 4 inches; steel casing. Equipped with cylinder pump operated by hand and windmill. Measuring point, top of casing, 0.5 foot above land surface. Depth to water, below measuring point, 9.92 feet, June 29, 1948.

33/60-21A1. "Old Ruby City deep well." Unused; reported depth, 60 to 100 feet. Depth to water, below land surface, 13.0 feet, December 7, 1939 (by G. H. Taylor).

33/60-25A1. Division of Grazing. Stock sump. Depth to water, below land surface, 9.0 feet, June 6, 1939. (Data from report by G. H. Taylor.)

33/60-29A1. Unknown. Unused, dug well; depth, 8.5 feet; diameter, 36 inches. Windmill stands over well, no pump. Measuring point, top of 8- by 8-inch cover, 0.5 foot above land surface. Depth to water, below measuring point, 7.68 feet, June 30, 1948.

33/60-35D1. Earl Wright (?). Stock, dug well; diameter, 14 inches. Equipped with cylinder pump and windmill. Measuring point, top of steel-barrel casing, at land surface. Depth to water, below measuring point, 5.70 feet, June 29, 1948.

33/60-35D2. Earl Wright. Unused, drilled well; reported depth, 275 feet; measured depth, 10.5± feet; diameter, 4 inches. Equipped with cylinder pump, no engine. Measuring point, top of casing, 2.0 feet above land surface. Depth to water, below measuring point, 11.25 feet, December 8, 1939 (by G. H. Taylor), 7.02 feet June 29, 1948.

34/60-36A1. Earl Wright. Dug well; depth, 18 feet; diameter, 3± feet; reported depth to water, below land surface, 9± feet, 1939. (Data from report by G. H. Taylor.)

34/60-36B1. R. Duval. Stock, dug well; reported depth, 25 feet; diameter, 18 inches; tin casing. Equipped with cylinder pump operated by hand and windmill. Measuring point, top of casing, at land surface. Depth to water, below measuring point, 5.64 feet, August 26, 1948.

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STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

GROUND WATER IN CLOVER AND INDEPENDENCE VALLEYS, ELKO COUNTY, NEVADA

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CONTENTS

ILLUSTRATIONS

TABLES

GROUND WATER IN
CLOVER AND INDEPENDENCE VALLEYS, ELKO COUNTY, NEVADA

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(September 1950)

INTRODUCTION

Since July 1, 1945, the United States Geological Survey, Ground Water Branch, has been cooperating with the State Engineer of Nevada in a State-wide study of ground-water resources. The resulting reports cover the various ground-water basins, which ordinarily coincide with valley units.

The present report is based on reconnaissance field work during the summer of 1948 and drilling operations in May 1949, at which time the U. S. Geological Survey test well (35/62-27B1) was drilled. During the 1948 period essentially all available well and spring information was collected, and a field reconnaissance of the general geologic and hydrologic conditions was made. A water sample was collected from the Warm Spring in SE¼ sec. 12, T. 33 N., R. 62 E., and other samples were collected from four zones in the test well. They were analyzed by the Salt Lake City laboratory of the U. S. Geological Survey, Quality of Water Branch. A field reconnaissance of soil conditions was made by Howard G. Mason, Agricultural Economist, Nevada Agricultural Experiment Station, Reno, Nevada.

LOCATION AND GENERAL FEATURES

Clover and Independence Valleys are in the south-central part of Elko County, Nevada. They lie between north latitudes 40°33′ and 41°15′ and west longitudes 114°35′ and 115°7′. The north end of Clover Valley is about 5 miles south of the town of Wells, and from here the valley extends southward for about 35 miles. Independence Valley lies adjacent to and east of Clover Valley. The south end of Independence Valley is at about the same latitude as the south end of Clover Valley and extends northward about 48 miles. The combined drainage area of the two valleys is about 975 square miles. (See pl. 3.)

The East Humboldt Range and its low-lying southern extension, the south end of which is named Valley Mountain, form the west margin of the area; Spruce Mountain and the low east-west-trending ridges extending from it bound the area on the south; the Pequop Mountains are on the east; and an irregular topographic high composed of bedrock and alluvial fill limits the area on the north. In years of heavy runoff, discharge from Clover Valley to Independence Valley may occur in a poorly developed drainage way eastward through sec. 27, T. 34 N., R. 63 E.

U. S. Highway 93 traverses the full length of Clover Valley, and U. S. Highway 40 crosses the northern part of Independence Valley. Both highways pass through the town of Wells. State Highway 11 leaves U. S. Highway 93 about 3¼ miles south of Warm Spring and trends southwestward into Ruby Valley. Numerous roads and trails traverse most of the valley-lowland area. In part these roads are gravel-surfaced and are satisfactory for travel except under wet-weather conditions.

The Western Pacific Railroad crosses the valleys in a general northwest-southeast direction. It enters Independence Valley near Jasper on the east and leaves Clover Valley at the north end several miles south of Wells. The Southern Pacific Railroad skirts the north end of Independence Valley.

The principal industry in the two valleys is raising livestock.

The population of Clover Valley includes residents of several ranches along its west side and fewer residents at the railroad stations of Tobar and Boaz. The population of Independence Valley, with the exception of one ranch, and possibly temporary residents at Sonar, is limited to the residents at the railroad stations of Jasper, Ventosa, Moor, and Fenelon.

Previous reports that cover parts of the area include those by Hill (1916) and several by Sharp (1938, 1939, 1940);* the latter author gives much information on the geology, structure, and geomorphology of the Ruby-East Humboldt Ranges.

PHYSIOGRAPHY AND DRAINAGE

Clover and Independence Valleys are in the Great Basin section of the Basin and Range physiographic province. Each occupies an elongate structural basin which trends about north-south. Snow Water Lake is a low area in Clover Valley, and on the Halleck quadrangle topographic map the lake is indicated as a little less than 5,600 feet above sea level. The lake area receives drainage from the western, southern, and southeastern parts of Clover Valley. Drainage from the northern part of Clover Valley may enter Independence Valley in years of heavy precipitation and favorable runoff conditions. However, this is unusual and generally runoff from the mountains replenishes the groundwater reservoir or is lost by evaporation and transpiration within the valley. As surface drainage can move from Clover to Independence Valley, Independence Valley must be the lower of the two. However, from field observation, it appears that the lowest part of each valley differs little from the other in altitude. The two valleys together form a closed basin.

Surficial topography in the lower parts of the valleys formed during the Pleistocene consist primarily of beach features—beaches, bars, and spits. Some of the marginal beach features are slightly modified by stream erosion. Dune topography occurs in places in the vicinity of Snow Water Lake.

The East Humboldt Range, along the west side of Clover Valley, is the principal mountain range in the area. The crest altitude for about 10 miles along the central part of this range averages somewhat more than 10,000 feet above sea level, with several peaks in excess of 11,000 feet.

The altitude of Spruce Mountain, at the south end of the area, is 11,041 feet at its highest point. However, the altitude diminishes rapidly from this point. The crest of the northward extension from Spruce Mountain, Chase Spring Mountains, which in part divides the two valleys, probably averages somewhat less than 8,000 feet above sea level.

The summit altitude of the Pequop Mountains, along the east side of Independence Valley, commonly ranges from 7,000 to 8,000 feet above sea level, but it exceeds 10,000 feet in the north-central part of the range.

Elsewhere the highest parts of the enclosing mountains and divides probably nowhere exceed 8,000 feet above sea level and ordinarily are less than 7,000 feet.

Streams draining the mountain areas are short and steep. Perennial streams occur only along the East Humboldt Range, and these are dissipated by the time they reach the lower alluvial slopes.

Sharp (1940), in discussing the alluvial slopes along the east side of the East Humboldt Range, suggests that the upper half of these slopes is a debris-mantled pediment cut on the Humboldt formation and that a pediment at the south end of the East Humboldt Range is cut on Paleozoic rocks and Pliocene(?) lavas. The physical characteristics of the present surface in the northeastern part of Clover Valley (north from Tobar) also suggest that a pediment cut on the Humboldt formation may underlie the

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*See list of references at end of report.

surface at shallow depth. The presence of such pediment surfaces suggests that post-Humboldt deposits are relatively thin in the central part of the valley.

CLIMATE

The climate of Clover and Independence Valleys is arid to semi-arid and is characterized by low precipitation on the valley floor, low humidity, high rate of evaporation, and a wide range in temperature, both seasonal and daily.

Precipitation increases generally with altitude in the adjacent mountains. The higher parts of the East Humboldt Range rank closely with other areas of heavy precipitation in Nevada and locally the precipitation may exceed 35 inches.

Precipitation on the floor of Clover Valley probably ranges from 5 to 12 inches a year, and on the floor of Independence Valley, from 5 to 8 inches.

Records of precipitation are available for three stations: Clover Valley, Fenelon, and Wells. The data are from records of the U. S. Weather Bureau, and the locations of the stations are given in Table 1.

TABLE 1

Average monthly and annual precipitation, in inches, at three stations in and near Clover and Independence Valleys, Nevada

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Clover Valley (Warm Spring)[1]	1.91	1.87	1.31	1.09	1.30	0.71	0.46	0.61	0.59	0.77	1.31	1.29	13.22
Fenelon[2]	1.18	1.09	1.33	.70	.90	.40	.15	.36	.35	.66	.75	1.37	9.24
Wells[3]	1.28	1.12	1.20	.80	.98	.70	.33	.25	.31	.73	.88	1.14	9.72

[1] Altitude, 5,800 feet. Location, sec. 12, T. 33 N., R. 61 E.(?). Period of record, 39 years, 1894–1933 (broken in 1894, 97, and 98.)

[2] Altitude, 6,128 feet. Location, sec. 5, T. 38 N., R. 65 E. Period of record, 18 years, 1888–1907 (broken record).

[3] Altitude, 5,633 feet. Location, sec. 10(?), T. 37 N., R. 62 E. Period of record, 59 years, 1870–1949 (no record 1915 to 1935).

The frost-free or growing season, as indicated by the record for Clover Valley station, is relatively short and generally suited only to early maturing or frost-resistant crops. The record at Clover Valley for the 27-year period ending in 1932 showed an average of about 100 days between the last killing frost in spring and the first killing frost in autumn, with a minimum of 64 days in 1918, and a maximum of 149 days in 1910.

VEGETATION AND SOILS

The native vegetation* on the floor of Clover and Independence Valleys include big greasewood (*Sarcobatus vermiculatus*), big rabbitbrush (*Chrysothamnus nauseosus*), sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), white sage (*Eurotia lanata*), saltgrass (*Distichlis spicata*), mixed grasses, and other members of the Northern Desert Shrub plant association. Substantial acreages of meadow hay and small acreages of alfalfa are grown for livestock feed in Clover Valley.

Mason indicated in his reconnaissance of Clover Valley about 6,000 acres of Class I land, which he defines as soils deemed definitely suitable for development. Most of these soils are alluvial deposits of outwash or modified basin deposits of Recent age. They are medium-textured, permeable, free from alkali, and highly productive, and surface slopes of 3 percent or less. The vegetation is meadow or upland grasses, sagebrush, or rabbitbrush. The soils occur along the lower slopes on the west side of Clover Valley, northward from Snow Water Lake, and also in the lower parts of the drainage system that passes about 2 miles to the west of Tobar and extends to a point about 4 miles south of Tobar.

Mason also indicated a substantial acreage of Class II land—soils considered generally less suitable for development than Class I land—north and northwest of Snow Water Lake. This land generally lies lower than Class I land and is marginal to it. These soils are derived almost entirely from basin sediments and have developed under arid conditions, but they are subject to periodic flooding and ground-water discharge. The soils in their common phase are of grayish color and medium-fine texture, are alkaline, and support a moderately light growth of sagebrush, greasewood, shadscale, and some grasses. The presence of greasewood, shadscale, or saltgrass is evidence of soil conditions unfavorable for agriculture. Most of the soils of this phase would be difficult to reclaim and if brought under irrigation would likely vary in productivity from spot to spot for a long time. However, about 5,000 acres of the total indicated might be usable—principally in the central part of T. 34 N., R. 62 E. and in parts of secs. 32–34, T. 35 N., R. 62 E. A modified phase of Class II soil is present west and northwest of Tobar. There modification has resulted from frequent and heavy flooding prior to diversion of water for irrigation of the higher lands. It is identified by its darker color, more granular texture, and heavy vegetative growth. This phase is more desirable than the common phase of the Class II land. It occurs in parts of secs. 10, 14, 23, 24, 25, and 26, T. 35 N., R. 62 E., and may include about 2,000 acres.

Thus, in Clover Valley about 6,000 acres of Class I land and about 7,000 acres of usable Class II land were indicated in the reconnaissance by Mason.

Soils in the central part of Independence Valley are predominantly either gray, heavy-textured, alkaline, unproductive playa soil, subject to flooding, or semisink (playa) soil, gray, heavy-textured, alkaline and slightly productive. Only small acreages around the margin of the valley might be suitable for development with considerable reclamation.

GENERAL GEOLOGY

The oldest rocks exposed in this area are Paleozoic limestone, dolomite, quartzite, and some shale. In part these were metamorphosed during late Mesozoic or early Tertiary time by intrusion of granitic and associated rocks. The intrusive rocks are exposed over a large area on the east flank of the East Humboldt Range.

Faulting occurred in several periods, beginning in early upper Miocene(?) time (Sharp, 1939b, p. 915). Erosion of the mountains yielded the large volume of sediments deposited in the adjacent valleys. Most of these sediments were laid down under subaerial and lacustrine conditions prior to Pleistocene time.

Pleistocene deposits in the western part of Clover Valley are believed to contain a moderate proportion of sand and gravel. In the central and eastern parts of the valley and over most of the floor of Independence Valley the deposits may be predominantly clay or silty sand. Other surficial Pleistocene deposits consist of glacial debris, low on the flanks of the East Humboldt Range and lake-shore deposits in the form of beaches, bars, and spits. Deposits of Recent age are of relatively minor importance.

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*Data on vegetation and soils based on a field reconnaisance Sept. 30, 1948, by Howard G. Mason, Agricultural Economist, Agr. Exper. Sta., Reno, Nev., and "Physical conditions and forage resources maps of Elko County, Nev.": Soil Cons. Service, U. S. Dept. Agr., and cooperating agencies.

The generalized rock sequence has been summarized by Sharp (1939b, p. 887) in a columnar section, which follows.

Age	Formation	Lithology	Thickness (feet)
Quaternary	Drift, gravels, alluvium	Pediment and terrace gravels, glacial drift, recent alluvium	5–150
Pliocene (?)	Pliocene (?) lava	Pyroxene andesite and olivine-pyroxene basalt flows, breccia, and tuff	200–400
Unconformity			
Miocene	Humboldt formation	Breccia, fanglomerate, conglomerate, sandstone, mudstone shale, oil shale, limestone, ash, tuff, and interbedded rhyolite flows	5,800
		(Rhyolite not known to crop out in area of this report)	
Early Tertiary or Late Mesozoic	Binary granite Porphyritic granite	Binary granite, porphyritic granite, pegmatite. (Igneous rocks intruded into Paleozoic rocks)	
Unconformity			
Carboniferous	Undifferentiated Carboniferous	Massive limestone, siliceous conglomerate quartzite	+? 4,000
	Mississippian (?)	Massive cherty crinoidal limestone	300
Devonian	Upper Devils Gate formation	Platy arenaceous and argillaceous limestone	300
	Lower Devils Gate formation	Dark gray, well-bedded, fossiliferous limestone	900
	Nevada formation	Gray, bedded, laminated and mottled dolomite	1,900
Silurian	Lone Mountain formation	Massive white dolomite	1,350
Unconformity			
Ordovician	Pogonip Limestone	Gray, massive, cherty limestone; platy, argillaceous limestone; shale and limy quartzite near the top	3,650
Unconformity			
Cambrian	Upper Cambrian	Thin-bedded limestone, argillaceous limestone, limy argillite and aranaceous beds	3,550
	Middle Cambrian	Thin-bedded arenaceous and argillaceous limestone	3,100
	Prospect Mountain quartzite	Massive quartzite	1,400
		Base not exposed	

NOTE: The Paleozoic section is from Plate 1 of: Sharp, R. P., 1942, Stratigraphy and structure of the southern Ruby Mountain, Nevada: Geol. Soc. America Bull., vol. 53, pp. 647–690.

The post Paleozoic section is from Figure 3, Sharp, R. P., 1939, Basin-Range structure of the Ruby-East Humboldt Range, Northeastern Nevada: Geol. Soc. America Bull., vol. 50, pp. 881–920.

WATER-BEARING PROPERTIES OF THE ROCKS

Most of the Paleozoic rocks are of low permeability. However, secondary faults, fractures, joints, and solution channels may locally transmit substantial quantities of water.

Water from several of the springs that issue from alluvium near outcrops of Paleozoic bedrock in the area is believed transmitted through solution channels or fractures in the bedrock. The distribution and probable infrequency of the fractures or solution channels beneath the valley fill are not favorable for obtaining large-capacity wells in the bedrock.

The older valley fill (Humboldt formation) in Clover Valley may locally contain beds or lenses of permeable deposits, particularly along the west margin adjacent to the East Humboldt Range. Well 35/62-26A1, an oil test well, reportedly was drilled to a depth of 600 feet, but no log is available. This well is reported to have encountered water under sufficient pressure to flow at the land surface. However, the U. S. Geological Survey test well (35/62-27B1), about 1¼ miles west of this well, did not encounter any water under sufficient pressure to flow within 286 feet of the land surface.

The maximum thickness of the younger valley fill (post-Humboldt) is not known. However, in the U. S. Geological Survey test well it may be 110 or 155 feet thick, as discussed on page 116. The permeability of the coarser sediments of the younger valley fill is inferred to be greater than that of the older valley fill because the younger strata have undergone less consolidation.

The pediment cut on Paleozoic and Pliocene (?) bedrock along the southeast flank of the East Humboldt Range, if extensive and at relatively shallow depth, may effectively reduce the saturated thickness of the valley fill beneath the lower alluvial slopes. Likewise, the suggested pediment (p. 101) cut on the older valley fill (Humboldt formation) along the northeast side of Clover Valley may occur at shallow depth. Here the younger valley fill may be above the water table and water would necessarily be drawn from the older valley fill. Low yields to wells in the older valley fill would be expected from the inferred low average permeability of these deposits. The logs of the Western Pacific Railroad wells at Tobar and the reported low yields tend to bear out this inference.

GROUND WATER

CLOVER VALLEY

General Conditions

Ground water in Clover Valley is derived principally from precipitation on the east flank of the East Humboldt Range, and to a lesser extent from precipitation on the north side of Spruce Mountain, the west flank of the Chase Spring Mountains, and the high area bordering the northeastern part of the valley.

Ground water occurs below the water table—the upper surface of the zone of saturation—in the valley fill and underlying bedrock. However, it has been developed only in the upper part of the valley fill; the lower part has not been prospected for water.

Recharge to ground water occurs in the marginal parts of the [illegible] in the bedrock of the mountains. From the areas of recharge, ground water moves toward the valley, usually in conformance with the general slope of the land surface.

The information available indicates that in the central, western, and northwestern parts of Clover Valley the depth to water is generally less than 15 feet and in most places is less than 10 feet. Here ground water is discharged by transpiration of vegetation and by evaporation from soil and from temporary free-water surfaces.

Gravity-type springs or seeps issue from the lower alluvial slopes along the west side of Clover Valley. These are utilized largely for supplemental irrigation of meadowland.

Warm Spring, in SE¼ sec. 12, T. 33 N., R. 61 E., which issues from alluvium, probably is largely controlled by conduits in the underlying Paleozoic bedrock. The discharge at the impounding dam immediately below the spring was estimated to be between 4 and 5 second-feet in 1948. Several weir measurements made in 1912 at the ranch house several hundred yards downstream indicated a discharge of 5.84 second-feet. This higher rate of discharge may have been due, in part, to water rising along the channel between the impounding dam and the weir location. The temperature of the water at one of the discharge outlets of the pool was 65° F. The water is used largely for irrigation of meadowland.

Another spring, in the NE¼ sec. 30, T. 36 N., R. 62 E., issues at a limestone-alluvial contact and discharges into a large pool. The discharge of this spring approximates 1 second-foot. The water is used for irrigation of meadowland.

The potential yield from water-bearing zones in the valley fill has not been tested by wells. However, it is reported that one of the stock-watering pits (about a 500-square-foot area extending a few feet below the water table) yielded possibly 1 second-foot without much lowering of the water level. This suggests that the sand and gravel deposits in the younger valley fill locally may be moderately to highly permeable.

Estimated Average Annual Ground-Water Recharge

The average annual recharge to the ground-water reservoir can be estimated as a percentage of the total precipitation within the drainage basin of Clover Valley.

The basis for such estimates is the "Precipitation map of Nevada" showing areas of assumed equal rainfall, prepared in 1936 under the supervision of George Hardman by the Nevada Agricultural Experiment Station. On this map are shown zones of precipitation of less than 5 inches, of 5 to 8 inches, 8 to 12 inches, 12 to 15 inches, 15 to 20 inches, and more than 20 inches. These zones were transferred to the base map, from which the area of each zone was determined by planimeter. The data pertinent to the estimate are summarized in Table 2.

As indicated by preliminary recharge studies in east-central Nevada (Eakin, Maxey, Robinson, 1949; Maxey and Eakin, 1949), zones of precipitation of less than 8 inches are considered not to recharge the ground-water reservoir significantly; for the 8- to 12-inch zone the recharge may be 3 percent; 12- to 15-inch zone, 7 percent; 15- to 20-inch zone, 15 percent; and over 20-inch zone, 25 percent.

TABLE 2

Estimated average annual ground-water recharge from precipitation in Clover Valley, Nevada

Precipitation zone (inches)	Area of zone (acres)	Percentage of recharge	Recharge (approximate) (acre-feet)
8–12	[1]195,300	3	2,900
12–15	51,300	7	4,000
15–20	25,900	15	5,700
Over 20[2]	15,600	25	8,100
Total (order of magnitude)	....	....	20,700

[1] About 40 percent of this area shown on the "Precipitation map of Nevada" is believed to be actually in the 5- to 8-inch zone. Recharge is therefore considered only for the remaining 60 percent of the area indicated.

[2] Average precipitation for this zone assumed to be 25 inches.

Estimated Average Annual Ground-Water Discharge

Ground water is discharged from Clover Valley by transpiration of vegetation, by evaporation from soil or free-water surfaces, by springs, and by domestic, stock, and irrigation wells. Although underflow from Clover Valley to Independence Valley is possible, it is believed to be very small because of the low water-level gradient and low permeability of the sediments in the segment between the two valleys. Essentially all the water from springs is finally discharged from the valley by transpiration and evaporation, and is accounted for in the estimates of these losses. Discharge from wells at present constitutes but a small percentage of the total discharge and, therefore, is not included in the estimate of discharge. A summary of the ground-water discharge is given in Table 3.

BLE

Estimated annual discharge of ground water, in acre-feet, by transpiration and evaporation in Clover Valley, Nevada

Discharge area and rate of discharge	Area (acres)	Discharge (acre-feet)
Greasewood, big rabbitbrush, saltgrass, and shadscale Moderate density. Depth to water 5 to 15 feet. Estimated rate of discharge, 0.3 foot per year.	45,000	13,500
Irrigated meadow Irrigated principally by surface runoff. Depth to water less than 10 feet. Estimated rate of discharge from ground water, 0.25 foot per year.	10,200	2,500
Snow Water Lake Dry much of the time. Estimated annual evaporation, 1 foot, of which about 0.6 foot is supplied from ground water.	5,000	3,000
Total (order of magnitude)	......	19,000

Of the total estimated average annual discharge from the ground-water reservoir in Clover Valley, it is believed practicable to salvage about 10,000 acre-feet annually by pumping from wells. Most of this amount could be developed in the area of the Class I and Class II soils indicated by Mason in his reconnaissance.

INDEPENDENCE VALLEY

General Conditions

Ground water in Independence Valley is derived principally from precipitation on the west flank of the Pequop Mountains and, to a lesser extent, from precipitation on the east flank of the Chase Spring Mountains, the mountains bordering the south end of the valley, and the mountains bordering the northwestern part of the valley.

Ground water has been obtained only from the upper part of the valley fill; the lower part has not been prospected for water.

Recharge to ground water occurs in the marginal parts of the valley fill and, to some extent, in the bedrock of the mountains. From the areas of recharge, ground water moves toward the lower parts of the valley. The slope of the water table ordinarily conforms with the general slope of the land surface.

The depth to water in the central and southern parts of Independence Valley is generally less than 25 feet, and in most places less than 15 feet. Here ground water is discharged by transpiration of vegetation, and by evaporation from soil and, to a small extent, from free-water surfaces.

Gravity-type springs or seeps of small discharge occur locally along the lower alluvial slopes of the Chase Spring Mountains and the Pequop Mountains.

Ralph's Warm Springs are in secs. 28 and 33, T. 36 N., R. 64 E. The water issues from several pools and seeps along a nearly 1-mile segment of the lower part of the alluvial slope. They probably are related to conduits in the underlying limestone bedrock but may be controlled, in part, by faulting beneath the valley fill. The temperature of the water is 65° F. at one of the pool outlets. The total discharge is not known, but it supports an extensive area of native meadow.

The only indication of the yield to wells from the water-bearing zones in Independence Valley is a pumping test at Ventosa well (34/63-1A1) of the Western Pacific Railroad. During September 1945, this well was pumped at the rate of 68 and 64 gallons per minute, respectively, for a 9-hour and a 7-hour period. The yield in 1948 is reported to be only about 30 gallons per minute after several hours of pumping.

Estimated Average Annual Ground-Water Recharge

The average annual recharge to the ground-water reservoir can be estimated as a percentage of the total precipitation within the drainage basin of Independence Valley according to the method described for Clover Valley. The data pertinent to the estimate are given in Table 4.

TABLE 4

Estimated average annual ground-water recharge from precipitation in Independence Valley, Nevada

Precipitation zone (inches)	Area of zone (acres)	Percentage of recharge	Recharge (approximate) (acre-feet)
8–12	[1]285,000	3	4,300
12–15	44,000	7	3,500
15–20	7,000	15	1,500
Total (order of magnitude)	....	---	9,300

[1] About 40 percent of this area shown on the "Precipitation map of Nevada" is believed to be actually in the 5- to 8-inch zone. Recharge is therefore considered only for the remaining 60 percent of the area indicated.

Estimated Average Annual Ground-Water Discharge

Ground water is discharged from Independence Valley by transpiration, evaporation, springs, and stock, domestic, and railroad wells. Water from springs is finally discharged by transpiration and evaporation, and is accounted for in the estimates of these losses. The total discharge from wells at present is very small and is not included in the estimate of discharge. A summary of the ground-water discharge is given in Table 5.

TABLE 5

Estimated annual discharge of ground water, in acre-feet, by transpiration and evaporation in Independence Valley, Nevada

Discharge area and rate of discharge	Area (acres)	Discharge (acre-feet)
Greasewood, shadscale, big rabbitbrush, and salt grass. Low density growth. Depth to water, 5 to 25 feet. Estimated rate of discharge, 0.1 foot per year.	85,000	8,500
Meadowland. Moderate density. Irrigated primarily by spring discharge. Estimated rate of discharge, 0.5 foot per year.	2,000	1,000
Total (order of magnitude)		**9,500**

Of the total estimated discharge from the ground-water reservoir in Independence Valley it is believed practicable to salvage about 2,000 acre-feet annually by pumping from wells. As most of the recharge to the ground-water reservoir appears to be along a 30-mile segment on the east and south sides of the valley, the most effective development of ground water would result from wide spacing of wells along this segment.

CHEMICAL QUALITY

Water samples were collected from Warm Spring (33/61-12D1) and from four zones in the U. S. Geological Survey test well (35/62-27B1). These samples were analyzed for mineral content by the Salt Lake City Laboratory of the U. S. Geological Survey, Quality of Water Branch. The results are shown in Table 6.

TABLE 6

Chemical analyses of water from Warm Spring and from four water-bearing zones in the U. S. Geological Survey test well in Clover Valley, Nevada

Constituents (Parts per million)	Warm Spring (33/61-12D1)	U. S. Geological Survey Test Well 35/62-27B1				Limits recommended by U. S. Public Health Service
		18- to 23-foot zone	40- to 43-foot zone	122- to 132-foot zone	107- to 212-foot zone	
Silica (SiO_2)	35	34	40	23	15	
Iron (Fe)	...	...	...	...	...	0.3
Calcium (Ca)	52	24	...	...	31	
Magnesium (Mg)	20	3.4	...	...	4.6	125
Sodium and potassium (Na + K)	63	47	...	...	26	
Bicarbonate (HCO_3)	334	144	108	192	144	
Sulfate (SO_4)	39	28	9.5	17	20	250
Chloride (Cl)	23	20	14	8	10	250
Fluoride (F)	1.0	.4	...	...	...	1.5
Nitrate (NO_3)	.8	2.1	.3	.8	.1	
Boron (B)	.10	.01	.00	.03		
Dissolved solids: ppm	398	230	...	...	178	1,000
Hardness as $CaCO_3$: Total	212	74	...	...	96	
Noncarbonate	0	0	...	...	0	
Specific conductance (Micromhos at 25° C.)	640	348	227	342	286	
Percent sodium	39	55	...	...	37	

The analyses indicate that the water is satisfactory when compared to the limits recommended by the U. S. Public Health Service for drinking water used on interstate carriers.

Magistad and Christiansen (1944, pp. 8, 9) have given tentative standards for irrigation waters, but they indicate that consideration should be given to the characteristics of the type of soil and the soil solution in evaluating the effect of water of a given chemical composition on a given soil.

Standards for irrigation waters

Water class	Conductance (micromhos at 25° C.)	SALT CONTENT		Sodium[1] (percent)	Boron (p.p.m.)
		Total (p.p.m.)	Per acre-foot (tons)		
Class 1[2]	<1,000	<700	<1	<60	<0.5
Class 2[3]	1,000–3,000	700–2,000	1–3	60–75	.5–2.0
Class 3[4]	>3,000	>2,000	>3	>75	>2.0

[1] The percentage of sodium is calculated from analytical results expressed in milligram equivalents per kilogram. These results are obtained by dividing the parts per million of sodium, calcium, and magnesium by 23, 20, and 12.24, respectively; then 100 times the milligram equivalents of sodium is divided by the sum of the milligram equivalents of sodium, calcium, and magnesium. In milligram equivalents $\frac{100\ \mathrm{Na}}{\mathrm{Na}+\mathrm{Ca}+\mathrm{Mg}}$ = percentage of sodium.

[2] Excellent to good, suitable for most plants under most conditions.

[3] Good to injurious, probably harmful to the more sensitive crops.

[4] Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant. If a water falls in Class 3 on any basis, i. e., conductance, salt content, percentage of sodium, or boron content, it should be classed as unsuitable under most conditions. Should the salts present be largely sulfates, the values for salt content in each class can be raised 50 percent.

Comparison of the analyses with these standards indicates that the water from the four zones in the well and from the Warm Spring are in Class I for all constituents for which standards have been listed.

It seems likely that ground water of good quality can be obtained generally along the west and north sides of Clover Valley. From experience in other closed valleys in Nevada some and probably considerable deterioration of quality may be expected in the lowest part of the valley, which is in the vicinity of Snow Water Lake.

On the same basis it would be expected that ground water along the marginal parts of Independence Valley would be of better quality than that in the playa area in the lowest part of the valley. If water is developed in either the vicinity of Snow Water Lake (Clover Valley) or the playa area of Independence Valley, it will be desirable to have chemical analyses made to determine its suitability for the contemplated use.

RESULTS OF DRILLING THE U. S. GEOLOGICAL SURVEY TEST WELL IN CLOVER VALLEY, NEVADA

In May 1949 a test well was drilled in the northern part of Clover Valley under the direction of the U. S. Geological Survey. The cost of drilling, testing, and completing the well was financed by cooperative funds. The purpose of such drilling was to obtain geologic and hydrologic information on the sediments penetrated and to determine the chemical character of the ground water encountered.

The well is on land owned by the State of Nevada, on the right-of-way east of U. S. Highway 93, about 15 miles south of Wells and about 3½ miles west of the Western Pacific Railroad station at Tobar.

The well was drilled with a cable-tool rig to a depth of 286 feet and was cased to a depth of 197 feet with 6-inch casing. The casing is not perforated, and the water level is representative of water-bearing zones in the interval between 197 and 286 feet. A companion observation well penetrates the sediments to a depth of 15 feet. The water levels in the two wells are approximately equal. Periodic measurements will be made in the wells as a part of the State-wide observation-well program.

The log of the test well, as shown in Table 7, is based on samples of material obtained during drilling operations. In general, the material encountered was fine- to coarse-grained sand with lesser amounts of silt and gravel. Forty-eight samples were taken from this 286-foot well. The average of all the samples contained about 9 percent silt, 43 percent fine- to medium-grained sand, 45 percent coarse-grained sand and fine gravel, and 3 percent medium or coarse gravel. Most samples ranged in grain size from silt to fine gravel. No materials recovered were larger than about half an inch in diameter.

Sediments having such poor sorting ordinarily are not highly permeable and do not yield large quantities of water to drilled wells. However, some zones appear capable of development, the more promising of which are those in the intervals from 40 to 43 feet, 74 to 80 feet, 145 to 155 feet, and 185 to 190 feet. Of these, the 145- to 155-foot zone is believed to be the most suitable for development. The sediments in the vicinity of the test well probably are finer-grained on the average than would be expected at equivalent depths a mile or more west of the well. If this inference is correct, wells drilled to the west should encounter more productive water-bearing zones than those penetrated by the test well. The physical character of the materials encountered suggest that satisfactory yields are not likely to be obtained by wells of ordinary construction in the vicinity of the test well, and possibly in the lower parts of the valley. It is believed that the most efficient development of water in this area can be obtained through a well properly screened or gravel-packed, or both.

The mineralogical character of the younger valley fill and the upper part of the Humboldt formation is essentially the same because both had the source of their materials in the East Humboldt Range. Therefore, a separation on a mineralogical basis is not believed to be possible.

The first 110 feet of materials penetrated by the well may represent the thickness of the younger valley fill in this locality. Between 110 feet and the bottom of the well, at 286 feet, the materials are believed to be a part of the Humboldt formation. Although not entirely certain, the assumed break at about 110 feet is based on the difference of drilling characteristics above and below that level. The common characteristic of the sediments above 110 feet is the extremely "loose" condition, which permitted frequent "heaving" of the sand into the casing.

One other possible break between the younger valley fill and the Humboldt formation is at 155 feet. Here the break is predicated on the assumption that the coarse-grained sand and gravel in the interval between 145 and 155 feet represents a change in conditions of deposition. The deformation that terminated the deposition of the Humboldt formation initiated a period of deposition in restricted basins. Under these conditions the coarse material in the 145- to 155-foot interval would represent the initial deposits of the restricted basins.

Of the several water-bearing zones encountered by the test well it seems likely that the zone between 145 and 155 feet may be the most favorable for development. If this zone actually represents the base of the younger valley fill, the postulation may be made that the zone would be at a shallower depth, and possibly thicker, between the well and the lower alluvial slopes of the East Humboldt Range.

TABLE 7

Log of the U. S. Geological Survey test well, 35/62–27B1, in Clover Valley, Nev.

Location: NE¼NW¼ sec. 27, T. 35 N., R. 62 E. In Clover Valley about 15 miles south of the town of Wells, on the right-of-way east of U. S. Highway 93, and at the only bend in the highway for several miles in either direction, just south of a trail leading east from the highway to the railroad station of Tobar. **Owner:** U. S. Geological Survey. Driller, C. N. Robertson. Depth 286 feet; 6-inch casing to 197 feet (not perforated), and open hole from 197 to 286 feet. Log from samples collected by R. C. Perry, geologist, U. S. Geological Survey. Some samples taken where open-hole drilling was in progress may contain material "spalled off" from above the zone sampled.

TABLE 7—*Continued.*

Material	Thickness (feet)	Depth (feet)
Soil and silty gravel	18	18
Sand, coarse, with medium to fine sand and fine gravel (Coarse sand, 40%[1]; medium sand, 25%; fine sand, 19%; fine gravel, 15%; silt, 1%. Angular to subangular particles, loosely consolidated. Grains, largely quartz and feldspar, with small amounts of mica and other ferromagnesian minerals. Color, light to moderate olive brown [5Y5/5].)[2]	5	23
Sand, coarse to medium, with fine gravel and silt (Coarse sand, 45%; medium sand, 30%; fine gravel, 15%; fine sand, 10%. Angular to subangular particles, unconsolidated. Grains, largely quartz, feldspar, with small amounts of mica and other ferromagnesian minerals. Color, pale greenish yellow to pale olive [10Y7/2].)	5	28
Sand, fine to coarse, with silt (Fine sand, 35%; medium sand, 30%; coarse sand, 20%; silt, 15%. Subangular particles, loosely consolidated. Grains, mostly quartz and feldspar, with minor amounts of ferromagnesian minerals. Color, light to moderate olive brown [5Y5/5].)	12	40
Sand, coarse, with medium sand, fine gravel, and fine sand (Coarse sand, 55%; medium sand, 20%; fine gravel, 14%; fine sand, 10%; silt, 1%. Subangular particles, unconsolidated. Grains, chiefly quartz and feldspar, with minor amounts of ferromagnesian minerals. Color, pale greenish yellow to pale olive [10Y7/2].)	3	43
Sand, coarse to fine (Coarse sand, 45%; medium sand, 30%; fine sand, 22%; fine gravel, 2%; silt, 1%. Angular to subangular particles, unconsolidated. Grains, largely quartz, feldspar, and small amounts of muscovite mica. Color, pale greenish yellow to pale olive [10Y7/2].)	2	45
Sand, fine and medium with silt and coarse sand (Fine sand, 35%; medium sand, 30%; silt, 20%; coarse sand, 15%. Subangular particles, loosely consolidated. Grains, largely quartz, feldspar, and minor amounts of ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	2	47
Silt, with fine to medium sand and some coarse sand (Silt, 32%; fine sand, 25%; medium sand, 25%; coarse sand, 15%; fine gravel, 3%. Subangular particles, moderately consolidated. Larger particles entirely quartz and feldspar. Color, pale to grayish olive [10Y5/2].)	2	49
Sand, medium, with coarse sand and fine sand (Medium sand, 40%; coarse sand, 25%; fine sand, 20%; silt, 13%; fine gravel, 2%. Subangular particles, loosely consolidated. Grains, largely quartz, feldspar, mica, and small amount of other ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	3	52
Sand, coarse to fine (Coarse sand, 35%; medium sand, 30%; fine sand, 22%; silt, 10%; fine gravel, 3%. Subangular particles, loosely consolidated. Grains, quartz, feldspar, and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	4	56
Sand, coarse and medium, with fine gravel and fine sand (Coarse sand, 35%; medium sand, 30%; fine gravel, 23%; fine sand, 10%; silt, 2%. Subangular particles, moderately consolidated. Grains, largely quartz and feldspar, with some ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	4	60
Gravel, fine and coarse sand, with medium and fine sand (Fine gravel, 30%; coarse sand, 30%; medium sand, 20%; fine sand, 19%; silt, 1%. Subangular particles, loosely consolidated. Grains, largely quartz, white and pink feldspar, and small amounts of ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	2	62
Sand, coarse, with medium sand, fine gravel, and fine sand (Coarse sand, 55%; medium sand, 23%; fine sand, 18%; silt, 2%; fine gravel, 2%. Subangular particles, unconsolidated. Grains, chiefly quartz, white and pink feldspar, and some ferromagnesian minerals. Color, pale olive [10Y6/2].)	8	70
Sand, coarse to medium, with fine gravel and fine sand (Coarse sand, 40%; medium sand, 30%; fine gravel, 15%; fine sand, 14%; silt, 1%. Subangular grains, unconsolidated. Grains, quartz, feldspar, and ferromagnesian minerals. Color, pale to grayish olive [10Y5/2].)	4	74

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[1] All samples contain small amounts of calcium carbonate. Percentages of grain sizes were obtained by visual inspection and, therefore, are relative within a given sample and only approximate between different samples. Grain sizes are according to scale—coarse gravel is greater than 6 millimeters, medium gravel from 4 to 6 millimeters, fine gravel from 2 to 4 millimeters, coarse sand from ½ to 2 millimeters, medium sand from ¼ to ½ millimeter, fine sand from ⅛ to ¼ millimeter, and silt less than ⅛ millimeter.

[2] Colors are based on the Rock Color Chart system, National Research Council, 1948.

TABLE 7—*Continued.*

Material	Thickness (feet)	Depth (feet)
Gravel, fine to medium with coarse to medium sand (Fine gravel, 40%; medium gravel, 30%; coarse sand, 15%; medium sand, 10%; fine sand, 4%; silt, 1%. Subangular particles, unconsolidated. Grains, quartz, feldspar, and abundant ferromagnesian minerals. Color, pale to grayish olive [10Y5/2].)	4	78
Gravel, medium, to fine sand (Coarse sand, 30%; medium sand, 20%; fine gravel, 20%; medium gravel, 20%; fine sand, 10%. Subangular particles, unconsolidated. Grains, largely quartz and feldspar, with some ferromagnesian minerals. Color, pale to grayish olive [10Y5/2].)	2	80
Sand, coarse, with medium to fine sand (Coarse sand, 65%; medium sand, 20%; fine sand, 13%; silt, 2%. Subangular particles, unconsolidated. Grains, quartz, white and gray feldspar, with some ferromagnesian minerals. Color, pale olive [10Y6/2].)	8	88
Sand, coarse, with fine gravel and medium sand (Coarse sand, 55%; medium sand, 20%; fine gravel, 20%; fine sand, 4%; silt, 1%. Subangular particles, unconsolidated. Grains, quartz, feldspar, and some ferromagnesian minerals. Color, light olive brown [5Y5/6].)	7	95
Sand, coarse, with fine gravel and medium to fine sand (Coarse sand, 35%; medium sand, 25%; fine gravel, 20%; fine sand, 18%; silt, 2%. Subangular particles, unconsolidated. Grains, largely quartz and feldspar, with mica and other ferromagnesian minerals. Color, pale to grayish olive [10Y5/2].)	10	105
Sand, coarse to fine (Medium sand, 35%; coarse sand, 30%; fine sand, 25%; silt, 8%; fine gravel, 2%. Subangular particles, loosely consolidated. Grains, largely quartz and feldspar, with some ferromagnesian minerals. Color, light olive brown [5Y5/6].)	2	107
Sand, coarse, with fine gravel and medium to fine sand (Coarse sand, 40%; fine gravel, 25%; medium sand, 20%; fine sand, 14%; silt, 1%. Subangular particles, moderately consolidated. Grains, largely quartz, white and gray feldspar, and minor amounts of ferromagnesian minerals. Color pale to grayish olive [10Y5/2].)	5	112
Sand, coarse, with fine gravel and medium to fine sand (Coarse sand, 50%; medium sand, 20%; fine gravel, 20%; fine sand, 10%. Subangular grains, lightly consolidated. Particles largely quartz, feldspar, mica, and other ferromagnesian minerals. Color, pale to grayish olive [10Y5/2].)	8	120
Gravel, fine, to fine sand, with silt and clay (Coarse sand, 35%; medium sand, 25%; fine gravel, 20%; fine sand, 18%; silt, 2%. Subangular particles, moderately consolidated with clay. Grains, quartz, feldspar, with some mica and other ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	2	122
Sand, coarse, with medium to fine sand and fine gravel (Coarse sand, 45%; medium sand, 25%; fine sand, 15%; fine gravel, 15%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and abundant ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	6	128
Gravel, fine, with coarse sand, little medium to fine sand (Fine gravel, 60%; coarse sand, 30%; medium sand, 5%; fine sand, 4%; silt, 1%. Subangular particles, unconsolidated. Grains, largely quartz, feldspar, and some ferromagnesian minerals. Color, grayish olive [10Y4/2].)	4	132
Sand, fine to coarse, with some silt (Fine sand, 35%; coarse sand, 30%; medium sand, 25%; silt, 10%. Subangular particles, moderately consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	6	138
Gravel, medium, to fine sand with little silt (Medium gravel, 25%; fine gravel, 20%; coarse sand, 20%; medium sand, 15%; fine sand, 15%; silt, 5%. Subangular particles, moderately consolidated. Grains, largely quartz, white and pink feldspar, and ferromagnesian minerals. Color, grayish yellow to dusky yellow [5Y7/4].)	7	145
Gravel, coarse, to fine sand (Fine gravel, 25%; medium gravel, 20%; coarse sand, 20%; coarse gravel, 15%; medium sand, 10%; fine sand, 9%; silt, 1%. Subangular particles, loosely consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	10	155
Sand, coarse, with fine gravel and medium sand, and little silt (Coarse sand, 55%; fine gravel, 20%; medium sand, 20%; fine sand, 5%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and about 30% hornblende. Color, grayish olive [10Y4/2].)	9	164

TABLE 7—*Continued.*

Material	Thickness (feet)	Depth (feet)
Silt, clayey, with fine to coarse sand (Silt, 50%; fine sand, 20%; medium sand, 15%; coarse sand; 10%; fine gravel, 5%. Larger particles subangular to angular, firmly consolidated with clay binder. Larger grains consist of quartz, feldspar, and ferromagnesian minerals. Color, moderate greenish yellow to pale olive [10Y7/3].)	6	170
No sample	5	175
Sand, coarse, with medium to fine sand, and some fine to medium gravel (Coarse sand, 40%; medium gravel, 5%; medium sand, 25%; fine sand, 18%; fine gravel, 10%; silt, 2%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	10	185
Gravel, medium, to medium and fine sand (Coarse sand, 30%; fine gravel, 25%; medium sand, 20%; medium gravel, 15%; fine sand, 9%; silt, 1%. Subangular to angular particles, very loosely consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	5	190
Gravel, medium, to silt (Fine gravel, 25%; medium gravel, 20%; medium sand, 15%; fine sand, 15%; silt, 15%; coarse sand, 10%. Subangular particles, moderately consolidated. Grains, largely quartz and feldspar, with minor amounts of mica and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	5	195
Sand, coarse, with medium to fine sand (Coarse sand, 50%; medium sand, 25%; fine sand, 20%; silt, 3%; fine gravel, 2%. Subangular to subrounded particles, lightly consolidated. Grains, largely quartz, feldspar, and minor amounts of mica and ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	5	200
Sand, coarse to fine (Coarse sand, 40%; medium sand, 30%; fine sand, 25%; fine gravel, 3%; silt, 2%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and minor amounts of mica and ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	6	206
Sand, coarse to fine, with little silt and fine gravel (Coarse sand, 25%; fine sand, 25%; medium sand, 20%; silt, 15%; fine gravel, 12%; medium gravel, 3%. Subangular to subrounded particles, moderately consolidated. Grains, largely quartz, feldspar, and some ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	6	212
Sand, medium and fine, with coarse sand and silt (Medium sand, 30%; fine sand, 30%; coarse sand, 20%; silt, 18%; fine gravel, 2%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	13	225
Sand, fine and medium, with silt and coarse sand (Fine sand, 35%; medium sand, 30%; silt, 19%; coarse sand, 15%; fine gravel, 1%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and minor amounts of ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	5	230
Silt, with some fine sand (Silt, 78%; fine sand, 15%; medium sand, 5%; coarse sand, 2%. Larger particles subangular, moderately consolidated. Grains, largely quartz with minor amounts of ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	1	231
Sand, coarse, with medium sand to silt (drilling difficult) (Coarse sand, 40%; medium sand, 20%; fine sand, 20%; silt, 19%; fine gravel, 1%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	6	237
Sand, fine to coarse, with silt (Fine sand, 30%; medium sand, 25%; coarse sand, 25%; silt, 19%; fine gravel, 1%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	8	245
Sand, fine and medium, with silt and coarse sand (Fine sand, 30%; medium sand, 25%; silt, 20%; coarse sand, 20%; fine gravel, 5%. Subangular particles, lightly consolidated. Grains, largely quartz, feldspar, and minor amounts of ferromagnesian minerals. Color, dusky yellow to light olive brown [5Y5/5].)	9	254
Sand, coarse to fine (Coarse sand, 40%; medium sand, 30%; fine sand, 25%; fine gravel, 3%; silt, 2%. Subangular to subrounded particles, lightly consolidated. Grains, largely quartz, white and pink feldspar, and minor amounts of ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	8	262

TABLE 7—*Continued.*

Material	Thickness (feet)	Depth (feet)
Gravel, fine, to fine sand (Coarse sand, 30%; fine gravel, 25%; fine sand, 24%; medium sand, 20%; silt, 1%. Subangular particles, lightly consolidated. Grains, largely quartz, white and pink feldspar, and minor amounts of ferromagnesian minerals. Color, dusky yellow [5Y6/4].)	7	269
Sand, coarse, with some medium and fine sand (Coarse sand, 55%; medium sand, 20%; fine sand, 19%; fine gravel, 5%; silt, 1%. Subangular to subrounded particles, lightly consolidated. Grains, largely quartz, white and pink feldspar, and minor amounts of ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	6	275
Sand, coarse, with fine and medium sand (Coarse sand, 40%; fine sand, 28%; medium sand, 25%; fine gravel, 5%; silt, 2%. Subangular particles, lightly consolidated. Grains, largely quartz and feldspar, with mica and ferromagnesian minerals. Color, moderate yellow to light olive brown [5Y6/6].)	6	281
Sand, coarse to fine, with little silt (Coarse sand, 40%; medium sand, 25%; fine sand, 20%; silt, 10%; fine gravel, 5%. Subangular particles, lightly consolidated. Grains, largely quartz and feldspar, with ferromagnesian minerals. Color, dusky yellow to moderate olive brown [5Y5/4].)	5	286
Total depth	....	286

Supplemental information was obtained during drilling operations by R. C. Perry, geologist, U. S. Geological Survey, and is summarized below (depths are referred to land surface):

When hole was slightly deeper than 18 feet, water was measured at 11.3 feet, and 1 hour later it was 9.4 feet. Water sample of the 18- to 23-foot zone was taken at this depth. When hole depth was 43 to 45 feet, depth to water was 23.45 feet and water yield was small. Casing was maintained at the bottom of the hole. Water sample of the 40- to 43-foot zone was then collected. Material was added to the hole to reduce tendency for sand to "heave" into casing. At 49 feet, brown sand was very loose. When hole was 53½ feet deep the casing was at 50¾ feet, and the water at 19.75 feet. When the hole was 66 feet deep, the casing was at 62½ feet and water at 27.46 feet, and the hole had filled in 20 feet to 46 feet with loose brown sand. The casing was maintained at 62½ feet and, after being cleaned out, the hole was carried to 75 feet; at this time the depth to water was 10.25 feet. Difficulty with sand heaving into the casing was encountered intermittently until the casing was carried to 111 feet. Below 111 feet open-hole drilling was possible. When the hole was 112 feet, the depth to water was 31.64 feet after drilling was stopped in late afternoon. The following morning the depth to water was 15.70 feet.

While drilling in "hard clay" with gravel pebbles, between 120 and 122 feet, the water level began to rise; in 1½ minutes water started flowing over the casing in small quantity. At slightly below 122 feet the tools were pulled out and well was bailed. Withdrawal of about 150 gallons in 7 minutes lowered the water level to 28.78 feet. In 20 minutes the water level recovered to 16.10 feet. Subsequently, a 15-minute bailing test was run at the rate of 20 gallons per minute. The water level at the end of the test was 42.27 feet—a drawdown of about 26 feet. In 30 minutes the water level had recovered to 19.6 feet. The indicated specific capacity was less than 1 gallon per minute per foot of drawdown. A water sample of the 122- to 132-foot zone was collected near the end of this bailing test. Drilling was carried to 125 feet and the casing was driven from 111 to 125 feet. The depth to water was 21.10 feet when drilling operations were stopped for the day. The following morning the water level was 23.39 feet. Drilling was continued to 155 feet and the casing was carried to 132 feet. With the hole at 155 feet the depth to water was 15.0 feet. With the casing maintained at 132 feet, the depth to water was 21.77 feet when the hole was at 170 feet, and 18.53 feet when the hole was at 187 feet. It is probable that these water levels were not entirely stabilized. Drilling was carried to 212 feet and the casing driven to 197 feet. The depth to water was then 16.55 feet. A 20-minute bailing test was run. With a bailing rate of 25 gallons per minute the water level was drawn down to 31.64 feet at the end of the test. A water sample of the 197- to 212-foot zone was collected during the latter part of this test. The hole was then drilled from 212 to 215 feet. One hour after the bailing test the depth to water was 11.99 feet. Forty-five minutes later the depth to water was 11.20 feet. With the casing maintained at 197 feet, drilling was continued. Drilling was hard between 231 and 237 feet. When the depth of the hole was 255 feet the depth to water was 13.51 feet. Drilling was stopped at 286 feet, the casing was maintained at 197 feet, and the depth to water was 12.62 feet on May 24, 1949; the depth to water was 9.35 feet on May 31.

TABLE 8

Record of wells in Clover and Independence Valleys, Nevada

CLOVER VALLEY

31/62-3A1. Owner, unknown. "Deep" well. Stock, dug well, depth 141 feet, cross section diameter 30 by 36 inches, wood-cribbed; equipped with a cylinder pump and gasoline engine. Measuring point, top of 8- by 8-inch wood tie, which is 1.5 feet above land surface. Depth to water below measuring point, 131.25 feet, August 24, 1948.

32/63-21B1. Owner, unknown. "R. H." well. Stock, dug well, cross section diameter 48 by 48 inches. Equipped with a cylinder pump and gasoline engine. Depth to water below land surface, 135± feet.

33/63-28B1. Owner, unknown. Stock, drilled well, depth 66 feet, diameter 6 inches, steel casing; equipped with a cylinder pump and windmill. Measuring point, top of casing, which is 0.5 foot below land surface. Depth to water below measuring point, 46.60 feet, August 24, 1948.

34/61-12A1. J. L. Vandiver and J. S. Badt. Domestic, drilled well, depth 195 feet, diameter 6 inches, steel casing. Drilled September 1948. Water level reported 13 feet below surface when hole was 60 feet deep or less, 20 feet below surface when 63 feet deep. Bailing test (depth 25 to 60 feet) 1,500 gallons per hour with a drawdown of 15± feet, bailing test (depth 195 feet) 1,500 gallons per hour with a drawdown of 15± feet. Log of well:

Material	Thickness (feet)	Depth (feet)
Sand, fine, little clay	25	25
Gravel, fine, sandy	35	60
Gravel, hard, fine, sandy	3	63
Gravel, some coarse, sand, little clay	132	195
Total depth	—	195

34/62-14B1. J. P. Wallman. Stock, drilled well, depth 35 feet, diameter 6¼ inches. Reported depth to water 15 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Hardpan"	5	5
Clay and gravel, gray	13	18
Sand and gravel; water	17	35
Total depth	—	35

34/63-21A1. Leslie Davis. Unused dug well, diameter 9 feet, concrete cribbed. Measuring point, top of concrete cribbing, west side, which is at land surface. Depth to water below measuring point, 12.58 feet, August 25, 1948.

35/62-26A1. Lloyd Higley. (Formerly O'Neil oil test.) Unused drilled well, reported depth 600 feet, diameter 8¼ inches, steel casing. Reported to have flowed a large amount from aquifer at 160 or 260 feet. Measuring point, top of casing, which is 1.0 foot above land surface. Depth to water below measuring point, 8.44 feet, August 25, 1948.

35/62-26A2. Lloyd Higley. Irrigation, dug well, depth 10 feet, cross section diameter 6 by 7 feet, wood tie cribbing. Equipped with 2-inch centrifugal pump and 2½-horsepower gasoline engine. Reported yield, 75 to 100 gallons per minute. Measuring point, top of 8- by 8-inch wood cribbing, west side, which is at land surface. Depth to water below measuring point, 7.72 feet, August 25, 1948.

35/62-26C1. J. P. Wallman. Stock, drilled well, depth 38 feet, diameter 6¼ inches. Reported depth to water 15 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Hardpan"	15	15
Sand and gravel, brown, loose; water	23	38
Total depth	—	38

35/62-27B1. U. S. Geological Survey. Test and observation, drilled well, depth 286 feet, diameter 6 inches, cased to 197 feet. Casing not perforated. Measuring point, top of 1-inch hole in plate on 6-inch casing, which is 0.45 foot above land surface. Depth to water below measuring point, 1949: 9.35 feet, May 31; 8.89 feet, June 23; 9.22 feet, July 19; 9.84 feet, August 25; 10.08 feet, September 14; and 10.23 feet, December 21.

35/62-27B2. U. S. Geological Survey. Observation well, depth 15 feet, diameter 1 inch. Measuring point, top of 1-inch iron pipe, which is 0.45 foot above land surface. Depth to water below measuring point, 1949: 9.41 feet, June 8; 9.12 feet, July 19; 9.70 feet, August 25; 10.00 feet, September 14; and 10.22 feet, December 21.

35/62-28A1. J. P. Wallman. Stock, drilled well, depth 41 feet, diameter 6¼ inches. Equipped with windmill and cylinder pump. Measuring point, top of 6¼-inch casing, which is 0.6 foot above land surface. Depth to water below measuring point, 1949: 11.49 feet, May 4; 11.64 feet, September 14. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Hardpan"	15	15
Sand and gravel, loose; water	26	41
Total depth	—	41

35/63-20C1. Western Pacific Railroad. "Old" well at Tobar. Domestic and railroad, drilled well, depth 130 feet, diameter 4 inches, steel casing to 126 feet. Equipped with a cylinder pump and gasoline engine. Reported pumping rate 9 gallons per minute; pumpage about 20,000 gallons per month.

Material	Thickness (feet)	Depth (feet)
Gravel, cemented	22	22
Clay	34	56
Quicksand; water	1	57
Clay and gravel	66	123
Gravel; water	4	127
Clay and "hardpan"	3	130
Total depth	—	130

35/63-20C2. Western Pacific Railroad. "New" well at Tobar. Railroad, drilled well. reported depth 132 feet, diameter 6 inches, steel casing. Drilled August 1948; bailing test, about 24 gallons per minute with little effect on water level. No equipment at time of this report. Measuring point, top of casing, which is 0.5 foot above land surface. Depth to water below measuring point, 57.40 feet, August 25, 1948.

Material	Thickness (feet)	Depth (feet)
Gravel	10	10
Gravel and clay, yellow	50	60
Gravel	10	70
Gravel and clay, yellow	12	82
Sand	3	85
Gravel and clay	23	108
Sand	8	116
Gravel and clay	16	132
Total depth	—	132

36/61-36A1. K. C. Ranch. Unused dug well, depth 23 feet, diameter 48 inches. Measuring point, top of 8- by 8-inch timber cover, which is 0.5 foot above land surface. Depth to water below measuring point, 5.55 feet, July 7, 1948.

INDEPENDENCE VALLEY

32/64-4B1. Griswold(?). Domestic and stock, dug well, depth and diameter unknown. Well caved around pump column, but pumps water readily. Water estimated about 10 feet below land surface.

32/64-4B2. Griswold(?). Stock, drilled well, depth 60 feet, diameter 4 inches, steel casing. Equipped with cylinder pump, no engine. Measuring point, top of casing, which is at land surface. Depth to water below measuring point, 27.38 feet, August 24, 1948.

32/65-6C1. Owner, unknown. Stock, drilled well, diameter 6 inches, steel casing. Equipped with cylinder pump and gasoline engine. Measuring point, top of casing, which is at land surface. Depth to water below measuring point, 120.75 feet, August 24, 1948.

33/65-10D1. (Unsurveyed.) Jasper well. Stock. Equipped with a cylinder pump and gasoline engine. Could not measure.

34/63-1A1. Western Pacific Railroad. Ventosa well. Railroad, drilled well, depth 320 feet, diameter 11⅝ inches, steel casing to 315 feet. Drilled 1908(?). Test pumped September 1945, 37,000 gallons in 9 hours, and 27,000 gallons in 7 hours. Present yield reported to have decreased to less than 2,000 gallons per hour after several hours of pumping. Log of well:

Material	Thickness (feet)	Depth (feet)
Clay	60	60
Sand and gravel; water at 210 feet	150	210
Sand	85	295
Gravel, cemented	25	320
Total depth	—	320

34/65-29C1. (Unsurveyed.) Western Pacific Railroad. Sonar well. Unused bored well, depth 108 feet, cased to hardpan at 86 feet. Bored in 1931. Log of well:

Material	Thickness (feet)	Depth (feet)
Clay	14	14
Sand, fine, white	5	19
Clay, sandy	7	26
Sand, hard-packed; water	12	38
Clay	30	68
"Quicksand"; very little water	2	70
Clay, sandy, or packed sand	10	80
Clay	26	106
"Quicksand"; very little water	2	108
Total depth	....	108

36/65-6C1. Owner, unknown. Domestic and stock, dug well. Equipped with a cylinder pump and windmill. Depth to bedrock reported at 56 to 69 feet (bottom of well). Water level reported 56± feet below land surface.

SUMMARY

The following summarizes pertinent items of this reconnaissance on Clover and Independence Valleys:

1. The amount of ground water that it may be practicable to recover annually is estimated to be about 10,000 acre-feet in Clover Valley and about 2,000 acre-feet in Independence Valley.

2. Shallow wells of a "pit" type may prove satisfactory for irrigation use in the area north and northwest of Snow Water Lake in Clover Valley.

3. Potential yields of ground water from relatively deep water-bearing zones in the valley fill in Clover Valley have not been thoroughly explored. The U. S. Geological Survey test well (35/62-27B1) encountered several relatively thin water-bearing zones from which small to moderate supplies could be developed.

The reported pumping rate of the 320-foot railroad well at Ventosa in Independence Valley suggests that conditions are not favorable for deep wells to produce large yields in the central part of Independence Valley. More permeable water-bearing zones might be expected in the marginal portions of Independence Valley but no data are available.

4. About 6,000 acres of Class I land, suitable for development, and about 7,000 acres of Class II land, less suitable for development, are indicated by soil reconnaissance in Clover Valley. Only small acreages may be developed locally in Independence Valley.

5. The frost-free or growing season in Clover and Independence Valleys is relatively short, averaging about 100 days.

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STATE OF NEVADA
OFFICE OF THE STATE ENGINEER

GROUND WATER IN RAILROAD, HOT CREEK, REVEILLE, KAWICH, AND PENOYER VALLEYS, NYE, LINCOLN, AND WHITE PINE COUNTIES, NEVADA

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CONTENTS

ILLUSTRATIONS

TABLES

GROUND WATER IN RAILROAD, HOT CREEK, REVEILLE, KAWICH, AND PENOYER VALLEYS, NYE, LINCOLN, AND WHITE PINE COUNTIES, NEVADA

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(November 1950)

INTRODUCTION

Since July 1, 1945, the United States Geological Survey, Ground Water Branch, in cooperation with the State Engineer of Nevada, has been engaged in a survey of the ground-water resources of Nevada. The State is represented in the joint program by Hugh A. Shamberger, Assistant State Engineer, and the work is under the direction of Thomas W. Robinson, District Engineer of the Ground Water Branch in Nevada. The studies and reports are of two general types—one of a more or less detailed character for areas in which ground water is moderately or extensively developed, and the other of a reconnaissance type where little ground-water development has taken place. This is a reconnaissance report.

Field studies of the general geologic and hydrologic conditions in the region covered by this report were made in the spring of 1948. During this time most of the known wells and springs were visited and basic hydrologic data were obtained. Logs and data for wells drilled between July 1, 1947, and December 31, 1949, obtained from the files of the State Engineer, are included in the report.

The purpose of the study was: (1) To determine the approximate order of magnitude of the average annual recharge to and discharge from the ground-water reservoirs, (2) to estimate the approximate fraction of the annual increment that might be available for development, and (3) a general consideration of the quality of the ground water.

LOCATION AND CULTURAL FEATURES OF THE AREA

The region described in this report includes about 5,570 square miles in the northeastern part of Nye County, the northwest corner of Lincoln County, and the southwestern part of White Pine County in east-central Nevada, between 115°15′ and 116°30′ west longitude and 37°15′ and 39°15′ north latitude. The population is sparse, there being no towns. The principal industries are livestock raising and some mining. Some farming is carried on in connection with the livestock industry. The principal trade centers are Tonopah, about 50 miles west, Eureka, about 40 miles north, Ely, about 60 miles northeast, and Caliente, about 70 miles east of the region. Ely and Caliente also serve as the principal shipping points. The region is accessible by automobile. U. S. Highway 6 enters it from the east at Currant Summit, crosses it diagonally in a southwesterly direction, and leaves it a few miles southwest of Warm Springs in Hot Creek Valley. Also, Nevada State Highway 25 crosses the southern part of the region, and Nevada State Highway 20 connects U. S. Highway 6 at Currant with U. S. Highway 50 near Eureka. Numerous dry-weather roads and trails connect the most important points within the region.

PHYSIOGRAPHY AND DRAINAGE

The region is near the central part of the Great Basin section of the Basin and Range physiographic province. It has the typical characteristics of the Great Basin—elongate valleys partly filled with unconsolidated and poorly consolidated alluvial and lacustrine deposits. The valleys lie between narrow, northward-trending mountains composed of well-consolidated sedimentary and igneous rocks.

The region contains five valleys, Railroad, Hot Creek, Reveille, Kawich, and Penoyer, which are separated from each other and from adjacent regions by relatively high northward-trending mountain ranges (7,000 to 11,000 feet above sea level). Hot Creek and Reveille Valleys drain eastward through low passes into Railroad Valley, whereas Railroad, Kawich, and Penoyer Valleys are basins with interior drainage. (See Pl. 1.)

The area of the five valleys below an altitude of 6,000 feet is about 2,580 square miles. Railroad Valley contains 1,370 square miles or about half of this area, Hot Creek and Reveille Valleys together contain about 605 square miles, Kawich Valley has about 160 square miles, and Penoyer Valley about 445 square miles. The lowest part of the region is the playa area in the north-central part of Railroad Valley. There the altitude averages about 4,760 feet above sea level.

The White Pine, Horse, Grant, Quinn Canyon, Worthington, and Timpahute Ranges bound the region on the east and southeast. The White Pine Range at the north and the Grant Range lying east of the central part of Railroad Valley are the highest of these ranges. They reach altitudes of more than 11,000 feet, and average about 9,000 feet above sea level, which is from 4,000 to 5,000 feet above the valley floor. The crests of Hot Creek and Kawich Ranges bounding the west side of the region probably do not average more than about 8,000 feet above sea level, but they contain peaks as high as 9,500 feet. The Pancake Range bounds the northern and northwestern parts of the region. A low-lying southward-trending spur of this range, and farther south the Reveille Range, separate Railroad and Hot Creek Valleys. The south side of the region is bounded by the Belted and Timpahute Ranges, the crests of which reach altitudes as high as 9,000 feet but average about 7,500 feet above sea level. A northward extension of the Belted Range bounds the southwest end of Penoyer Valley. Kawich and Penoyer Valleys are separated from Railroad Valley by the south end of Quinn Canyon Range.

Railroad, Kawich, and Penoyer Valleys contain large playas near the central parts of the valleys, in addition to the alluvial aprons adjacent to the mountains. As a result, there are three local physiographic provinces within the region: (1) The highlands—areas of erosion, characterized by steep slopes much dissected and composed commonly of well-indurated bedrock; (2) the alluvial apron—ordinarily a province of deposition, but also an area eroded and dissected in many places, with slopes ranging from 5° to 18°, and composed of unconsolidated or poorly consolidated, irregular alluvial and lacustrine beds which commonly dip toward the axes of the valleys; and (3) the valley lowlands—areas of deposition, nearly level and underlain by thick predominantly fine grained alluvial and lacustrine deposits. The third province is not present in Hot Creek and Reveille Valleys. The contact of the highland and alluvial-apron provinces roughly approximates the 6,000-foot contour shown on Plate 1. The contact of the alluvial apron and the valley lowland is ordinarily marked by a shore line or perimeter of the playas.

Wave-cut shore-line terraces, offshore bars and spits, and beaches built in lakes that existed during Pleistocene time are especially prominent along the margins of the lower part of Railroad Valley from the latitude of Currant to as far south as Nyala. No prominent lake-cut features were observed in the other valleys but it is likely that Penoyer and Kawich Valleys also were occupied by shallow, more or less ephemeral Pleistocene lakes.

The only perennial streams in the region are Currant and Duckwater Creeks in the northern part of Railroad Valley and Hot Creek in the northwest corner of Hot Creek Valley. The other streams are intermittent except for short reaches in the mountains, and water runs in their channels only during the spring runoff or during torrential storms.

Currant Creek heads high on the east slopes of the White Pine Mountains and flows southward for about 10 miles. It then flows westward through a deep gorge in the southern part of the range and over the alluvial apron toward the playa in the north-central part of Railroad Valley. According to reports from the Office of the State Engineer, Currant Creek discharges 10 to 15 second-feet of water during the spring. However, for short periods during the spring runoff the discharge may be as much as 25 second-feet. During the period of low flow, from about July to March, the discharge of the creek ranges from 3 to 5 second-feet. (See Tables 2 and 3.) The flow of the creek during this period is maintained by the discharge of springs in the deep gorge through which the creek passes. Above the gorge the stream is generally dry during this period.

Duckwater Creek rises in the northwest corner of Railroad Valley. Its source is a group of springs in the vicinity of the Duckwater Indian Reservation. (See Tables 4A and 4B.) The two largest springs in this group are known as Big Warm Spring and Little Warm Spring. The creek flows south and when its flow along the upper reaches of the creek is not completely used for irrigation it discharges into the playa. Big Warm Spring, the principal source of Duckwater Creek, has an average discharge of about 14 second-feet.

Hot Creek rises in the Hot Creek and Monitor Ranges northwest of Hot Creek Valley and flows southeastward toward Twin Springs in the east-central part of the valley. The discharge from the creek is used for irrigation along its course, and during the irrigation season it never flows farther south than U. S. Highway 6 in the central part of Hot Creek Valley. During the non-irrigation season and in the winter months the flow may reach Twin Springs and mingle with the flow of those springs.

CLIMATE

The climate in the area of the report is arid to semiarid, for the precipitation is scant, the relative humidity is low, and the evaporation is high. The daily and seasonal temperature range is unusually wide. Snow may fall on the valley lowlands during any month from October to April and on the mountains during any month from September to June. Strong winds are common in the valleys throughout the year. The frost-free growing period, as indicated by U. S. Weather Bureau records, ranges from a maximum of 130 days to a minimum of 90 days at Currant (5-year period of record, 1942–1946), and from 194 to 144 days at Rattlesnake (5-year period of record, 1942–1947, exclusive of 1946). It appears likely that the length of the growing period in most parts of the region will more closely approximate the Currant record because the conditions at Currant more closely resemble those of the lower parts of the valleys.

Precipitation records of the U. S. Weather Bureau for short periods are available from four stations in Hot Creek and Railroad Valleys. A summary of these records showing the monthly and annual average precipitation is given in Table 1. The annual precipitation at Currant has ranged from 3.01 inches to 12.52 inches during the period of record (1942–1947); at Tybo from 6.33 inches to 13.90 inches between 1892 and 1901; and at Rattlesnake from 1.27 to 6.44 inches between 1942 and 1947.

A map showing the annual precipitation in Nevada by zones (Hardman, 1936)* indicates that precipitation varies greatly with elevation, the higher areas receiving more precipitation. According to this map, only small areas on the highest parts of White Pine and Grant Ranges receive precipitation exceeding 20 inches a year. Large areas in the lower parts of the valley, approximately beneath the 6,000-foot contour, receive 8 inches or less of precipitation annually.

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*See list of references at end of report.

TABLE 1

Average monthly and annual precipitation, in inches, at four climatological stations in Railroad and Hot Creek Valleys, Nevada

(Weather Bureau records)

Station and location	Years of record	Altitude (feet)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Currant (Sec. 8, T. 10 N., R. 58 E.)	6	5,183	0.28	0.34	1.17	0.95	0.34	0.45	0.12	0.59	0.36	0.90	0.73	0.44	7.14
Morey (T. 9 N., R. 51 E.)[1]	5	7,384	1.29	1.04	3.74	1.12	1.86	.34	.84	1.03	.65	.90	2.00	.17	14.98
Rattlesnake (T. 7 N., R. 52 E.)[1]	6	5,913	.15	.14	.33	.39	.24	.16	.19	.29	.29	.48	.53	.44	3.63
Tybo (T. 6 N., R. 50 E.)[1]	13	6,500	1.19	1.12	1.20	.61	1.14	.10	.55	1.24	.33	.55	.43	.86	9.32

[1] Unsurveyed.

VEGETATION AND SOILS

The higher areas in the region, which range from 6,000 to 10,000 feet in altitude, are commonly covered by a vigorous growth of juniper and piñon pine associated with sagebrush, blackbrush, little rabbitbrush, and other typical members of the Northern Desert Shrub plant association. The alluvial apron and the valley floor are commonly covered by sagebrush, little rabbitbrush, and associated shrubs and grasses, except in places where the water table is near the land surface. The only large areas of valley floor in which the water table is shallow are in the north-central part of Railroad Valley and in the vicinity of Twin Springs in Hot Creek Valley. Common phreatophytes such as rabbitbrush, saltgrass, and greasewood grow in abundance in these areas.

A reconnaissance of the soils in the region, except in Kawich and Reveille Valleys, by Howard G. Mason, Agricultural Economist of the Nevada Agricultural Experiment Station, was made during the early summer of 1948. The results of this study are given in the following letter:

NEVADA AGRICULTURAL EXPERIMENT STATION
RENO, NEVADA, July 8, 1948.

MR. ALFRED MERRITT SMITH, *State Engineer, Carson City, Nevada.*

DEAR MR. SMITH: I should like to present for your consideration the following observations on agricultural land resources in Railroad, Hot Creek, and Penoyer Valleys.

I visited Railroad Valley with Mr. Eakin on May 25, at which time we made a circuit of that part of the valley which lies south of Highway 6. On July 1, with Mr. Maxey, I looked at the rest of Railroad Valley, which is estimated to have water development possibilities. We also inspected Hot Creek and Penoyer Valleys.

In Railroad Valley I saw only two areas of land which appeared at all promising. One of about 300 acres, is on the east side of the Valley about 27 miles south of Currant and a mile or two north of Troy (Irwin) Creek. This tract lies well for irrigation and has a deep fine sandy loam soil which appears to be free from harmful amounts of alkali.

The other body of land which appeared possibly feasible of development extends from Highway 6 northerly and westerly through the middle of T. 10 N., R. 57 E. The area is only a few hundred yards wide along the highway and probably extends only a short distance south. The potential agricultural land is identified by a mixed vegetation of big sagebrush and rabbitbrush, and where it reaches the highway, by growth of volunteer sweetclover in the borrow pit. The limits of the area to the north were not determined and may include a gross of several thousand acres. There is a small tract of cultivated land within this area; which has several acres of alfalfa, poplar and willow trees, and several common perennial weed species growing on it. No occurrence of excessive alkali was noted on the cultivated land. The place has had little care recently and the condition of the trees, the alfalfa, and the absence of annual weeds indicates that there has been no irrigation this season.

The soil in this area is deep and of fine texture. Where free from alkali it may be highly productive. However, it appears to be near the borderline for alkali and much reclamation would probably not be feasible.

Development of this area should be preceded by an intensive survey of salinity in both the surface soil and the subsoil.

Over the rest of Railroad Valley, within the assumed limits of economic lift for irrigation, there appears to me to be very little opportunity for agricultural development because of the lack of suitable land. My hypothesis for this condition is that the lands at the lower levels were heavily impregnated with salts by the receding lake and since desiccation there has been too little precipitation for salt removal. There has also been very little development of alluvial soil in this part of the valley since the disappearance of the lake. If it should ever become economically feasible to lift water 75 to 100 feet in this area, lands higher up off the valley floor and charged with less alkali would begin to come into the picture.

In Hot Creek Valley an area in T. 4 N., R. 50 E., just east of Warm Springs, was inspected. The land in this vicinity appears to be satisfactory for agriculture except for its light texture and gravelly subsoil. The land would not be permanently productive without special conservation practices, including periodic application of mineral fertilizer. Water requirements would be high and efficient application would be difficult and costly as it probably would involve surface pipe or sprinkler installation.

The potential area in Penoyer Valley is covered by an almost pure stand of greasewood. There is little or no understory of annual or perennial plants between the greasewood clumps. This indicates a very narrow range in adaptability to plant growth—also, even if a few of the most tolerant crop plants could be grown, it would probably be necessary to irrigate very frequently in order to satisfy their water requirements under the existing soil conditions. I consider the possibilities for development in this area to be relatively unfavorable.

I hope these notes on soil resources in the three valleys visited will satisfy the immediate purposes of the cooperative investigations you are conducting.

Very respectively,
(Signed) HOWARD G. MASON,
Agricultural Economist.

GENERAL GEOLOGY AND WATER-BEARING PROPERTIES OF THE ROCKS

The rocks of the region are divided into two general groups on the basis of their age, origin, occurrence, and influence on the occurrence and movement of ground water. These groups are: (1) The older sedimentary and igneous rocks in the mountains and foothills, and (2) the alluvial deposits and lake beds of the valleys.

The older sedimentary and igneous rocks are not known to have been studied and mapped in detail anywhere within the region. The results of several investigations of widely separated mining districts have been published (Ball, 1907; Hill, 1916; Ferguson, 1933; Kirk, 1933) and reveal, to some extent, the general nature of the older rocks. These and similar rocks were also examined by the authors during brief reconnaissance studies in this and adjacent regions. The following summary is based upon available published reports and these studies.

The older sedimentary rocks range in age from Cambrian to Carboniferous, and possibly Permian, and include great thicknesses of limestone with lesser amounts of dolomite, quartzite, and shale. Most of the limestone beds are not cavernous. All the sedimentary rocks are moderately to greatly disturbed by faulting and folding and well-jointed sections are common in both the calcareous and clastic sediments.

The older sedimentary clastics are commonly well-consolidated and therefore relatively impermeable. Only when these rocks are jointed are they capable of transmitting appreciable quantities of ground water. Only a few beds of limestone in the mountain areas were noted to be even moderately cavernous. Therefore, the limestone beds are also relatively impermeable unless they have been jointed by structural movement. A localized system of conduits in limestone may be capable of transmitting a substantial quantity of water. It is believed that the discharge of Big Warm Spring near Duckwater represents the outlet for such a conduit system. In general, however, the older sedimentary and igneous rocks in the region are not important water-bearing beds and commonly act as barriers to ground-water movement.

The igneous rocks are commonly extrusive and in some areas there are large deposits of ejectamenta such as scoria, volcanic ash, and pumice. Small areas of intrusive rocks also are present in the White Pine and Grant Ranges. The most extension period of volcanism was probably during the middle Tertiary, but some of the igneous rocks may have been extruded before that time and undoubtedly some of the lavas of the Pancake Range are of Pleistocene or Recent age. The igneous rocks are relatively impermeable and transmit water only where they are jointed or fractured.

The alluvial deposits of the valley fill contain the most important water-bearing beds in the region. They are composed of unconsolidated and poorly consolidated gravel, sand, silt, and clay that are interbedded with lacustrine sand, silt, and clay. The alluvial deposits form the alluvial apron and much of the valley fill in the central parts of the valleys, whereas the lacustrine deposits are commonly found interbedded with the alluvial materials in the lower parts of the valleys. The contact of the alluvial deposits and the older consolidated rocks averages about 6,500 feet above sea level, but in many places, especially in the larger canyons in the mountains, outcrops of the alluvial deposits are found at altitudes as high as 7,500 feet. Locally, the contact is considerably lower in the vicinity of spurs of bedrock that jut into the valley from the mountains and in the interfan areas on the alluvial apron.

Outcrops where the physical characteristics of the alluvial deposits may be observed are numerous along the upper parts of the alluvial apron. There the deposits consist of unconsolidated boulder, cobble, and gravel beds with minor quantities of sand interbedded with a few thin lenses of silt. Outcrops are fewer farther down on the alluvial apron and, although the sediments near the surface of the toe of the apron appear to be finer-grained, little is known concerning the nature of the sediments at depth, except where logs of wells drilled in this part of the apron have been recorded. Wells logs are available from well-drilling operations by the Railroad Valley Saline Co. and the Fish and Wildlife Service, U. S. Department of the Interior (formerly the Biological Survey), in the north-central part of Railroad Valley. These wells were drilled in the valley lowlands about 75 to 150 feet below the uppermost lake-built features and are lower than the present toe of the alluvial apron. The logs of these wells are given at the end of this report. They show that the materials of the valley fill are predominantly fine-grained in the central part of the valley with a little gravel and fine-grained sand in thin beds.

The valley fill ranges in thickness from a feather edge to at least 1,204 feet, the depth of the deepest known well (8N/56-2D1) in the area, and may be considerably thicker. In one well (7N/56-3C1) basalt, which may be bedrock, was encountered at 794 feet. The character of the deposits underlying the alluvial apron is in part indicated by the log of well 3N/54-5C1.

The water-bearing properties of the valley-fill deposits, as indicated by the physical character of the sediments, are favorable for the development of considerable quantities of water, especially in the area above the toe of the alluvial apron. Locally, however, as in the northeastern part of T. 3 N., R. 54 E., bedrock may underlie the surface of the alluvial apron at depths of only a few tens of feet. The alluvial sand and gravel are permeable and capable of transmitting large quantities of water. The interbedded lacustrine deposits are relatively impermeable and thus act as confining beds that hold the ground water under pressure in the deposits of coarser and more permeable materials. Thus, water under artesian pressure is found in Railroad Valley and may possibly be present in Penoyer Valley.

GROUND WATER

SPRINGS

Large springs provide most of the water now used for irrigation in the region. The most important of these are the springs in the vicinity of Duckwater, which are the source of Duckwater Creek, and the springs in Currant Creek Canyon, the base supply of Currant Creek. The reported discharge of Currant Creek usually ranges from 10 to 15 second-feet during the spring runoff to 3 to 5 second-feet during the period of low flow, as shown in Tables 2 and 3. The discharge during the low-flow period is approximately the discharge of the springs.

The discharge of Duckwater Creek is supplied largely from

Big Warm Spring. Records of discharge of Big Warm Spring, shown in Tables 4A and 4B, indicate an average discharge of about 14 second-feet. Table 5 shows the discharge of Duckwater Creek at a point about 2 miles downstream from Big Warm Spring. Diversions from the creek, and some inflow from small springs, affect the recorded discharge of Duckwater Creek. According to records in the Office of the State Engineer, total irrigation diversions of the waters from the springs at Duckwater amount to 20 to 25 second-feet. This is possible because of a large re-use of water and return flow along the creek. Other well-known springs that supply minor quantities of water for irrigation, domestic, and stock use are listed in Table 6.

TABLE 2

Daily discharge, in second-feet, of Currant Creek at Cazier's ranch near Currant, Nevada

(Data from U. S. Geological Survey Water-Supply Papers 360, 390, 410, 440, 460, and 570)

Location: In sec. 25, T. 11 N., R. 58 E., at Cazier's ranch, about 2½ miles below inflow from Cazier's reservoir and about 2 miles above Currant Post Office. The flow is somewhat affected by regulation of discharge from Cazier's reservoir. Total discharge for year ending September 30, 1915, was 5,430 acre-feet, and for year ending September 30, 1917, was 4,650 acre-feet.

1913

Date	May	June	July	Aug.	Sept.	Date	May	June	July	Aug.	Sept.
1	----	8.8	6.0	3.7	6.0	17	5.6	8.4	4.8	3.5	3.5
2	----	8.8	6.5	4.4	11.	18	6.8	7.8	4.8	1.1	3.5
3	----	12.	6.1	4.8	2.6	19	6.0	7.8	4.8	1.9	3.3
4	----	14.	5.1	5.1	2.9	20	5.4	6.8	5.4	2.2	3.5
5	4.0	11.	5.8	4.8	3.1	21	6.0	6.5	5.4	2.6	3.1
6	3.2	12.	5.8	3.5	3.1	22	6.1	6.8	5.4	2.4	3.1
7	3.5	11.	5.8	3.3	3.1	23	6.8	6.8	5.4	5.0	3.1
8	3.3	10.	5.1	3.5	3.5	24	7.8	6.5	4.8	5.0	3.5
9	3.3	10.	5.8	3.3	3.7	25	8.4	6.8	4.8	5.0	3.5
10	4.0	10.	4.7	3.5	3.3	26	8.4	6.1	4.8	4.8	3.3
11	5.1	12.	4.4	3.3	3.5	27	8.4	6.1	4.8	3.7	3.3
12	5.1	11.	4.0	3.3	3.1	28	10.	6.0	4.4	3.7	3.5
13	4.5	11.	5.1	3.5	3.3	29	10.	6.0	4.0	2.9	3.3
14	5.4	11.	4.8	4.0	3.3	30	7.8	6.5	4.4	2.9	3.7
15	5.1	11.	5.0	3.5	3.3	31	6.8	----	4.0	5.1	----
16	5.1	9.3	4.0	3.5	3.3	Total runoff (acre-feet)					1,600

1914

Date	May	June	July	Aug.	Sept.	Date	May	June	July	Aug.	Sept.
1	----	16.8	11.5	7.6	4.8	17	----	15.0	9.5	6.6	3.6
2	----	16.8	10.5	7.6	4.8	18	----	16.8	8.9	6.6	3.6
3	----	16.8	10.5	7.6	4.8	19	----	15.0	8.9	6.2	3.6
4	----	16.8	10.5	7.6	4.8	20	----	16.8	8.9	5.7	3.6
5	----	16.8	10.5	7.6	4.8	21	----	15.0	8.9	5.7	3.6
6	----	15.7	10.5	7.6	4.8	22	----	15.0	8.5	5.7	3.6
7	----	14.6	10.5	7.6	4.8	23	----	14.6	8.5	5.7	3.6
8	----	12.5	11.5	7.6	4.8	24	----	14.6	8.5	5.7	3.6
9	----	11.5	11.5	7.6	4.8	25	14.6	14.6	8.5	5.7	3.6
10	----	12.5	11.5	7.0	4.8	26	14.6	13.6	8.5	5.2	3.6
11	----	13.6	11.5	7.0	4.2	27	14.6	13.6	8.5	4.8	3.6
12	----	14.6	11.5	7.0	4.2	28	14.6	12.5	8.5	4.8	3.6
13	----	15.0	11.5	7.0	4.2	29	16.8	11.5	8.5	4.8	3.6
14	----	15.7	11.5	6.6	3.6	30	17.9	11.5	8.1	4.8	3.6
15	----	15.0	9.5	6.6	3.6	31	16.8	----	7.6	4.8	----
16	----	16.8	9.5	6.6	3.6	Total runoff (acre-feet)					2,330

TABLE 2—*Continued.*

1914–1915

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	3.6	5.6	5.6	5.6	5.6	5.6	5.6	24.0	14.0	12.0	5.6	5.6
2	3.6	5.6	5.6	5.6	5.6	5.6	5.6	22.	14.	12.	5.6	5.6
3	3.6	5.6	5.6	5.6	5.6	5.6	5.6	22.	12.	12.	5.6	5.6
4	3.6	5.6	5.6	5.6	5.6	5.6	5.6	22.	12.	12.	5.6	5.6
5	4.8	5.6	5.6	5.6	5.6	5.6	5.6	21.	12.	12.	5.6	5.2
6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	19.	12.	12.	5.6	4.7
7	5.6	5.6	5.6	5.6	5.6	5.6	5.6	18.	12.	12.	5.6	4.2
8	5.6	5.6	5.6	5.6	5.6	5.6	5.6	18.	12.	11.	5.6	4.2
9	5.6	5.6	5.6	5.6	5.6	5.6	5.6	16.	14.	10.	5.6	4.2
10	5.6	5.6	5.6	5.6	5.6	5.6	5.6	15.	13.	10.	5.6	4.1
11	5.6	5.6	5.6	5.6	5.6	5.6	5.6	15.	12.	9.0	5.6	4.0
12	5.6	5.6	5.6	5.6	5.6	5.6	5.6	12.	12.	9.0	5.6	3.9
13	5.6	5.6	5.6	5.6	5.6	5.6	5.6	12.	12.	10.	5.6	3.9
14	5.6	5.6	5.6	5.6	5.6	5.6	7.2	12.	12.	10.	5.6	3.8
15	5.6	5.6	5.6	5.6	5.6	5.6	8.1	12.	12.	9.0	5.6	3.7
16	5.6	5.6	5.6	5.6	5.6	5.6	9.0	12.	12.	9.0	6.4	3.6
17	5.6	5.6	5.6	5.6	5.6	5.6	9.0	11.	14.	10.	9.0	3.5
18	5.7	5.6	5.6	5.6	5.6	5.6	12.	21.	14.	9.0	8.1	3.4
19	5.7	5.6	5.6	5.6	5.6	5.6	12.	21.	12.	9.0	7.2	3.4
20	5.8	5.6	5.6	5.6	5.6	5.6	12.	21.	12.	8.1	7.2	3.3
21	5.8	5.6	5.6	5.6	5.6	5.6	12.	14.	10.	8.1	7.2	3.2
22	5.9	5.6	5.6	5.6	5.6	5.6	13.	12.	10.	8.1	6.4	3.1
23	5.9	5.6	5.6	5.6	5.6	5.6	16.	12.	10.	8.1	5.6	3.0
24	6.0	5.6	5.6	5.6	5.6	5.6	16.	12.	10.	8.1	5.6	2.9
25	6.0	5.6	5.6	5.6	5.6	5.6	16.	11.	10.	8.1	5.6	2.8
26	6.1	5.6	5.6	5.6	5.6	5.6	16.	11.	10.	8.1	5.6	2.8
27	5.6	5.6	5.6	5.6	5.6	5.6	15.	10.	10.	8.1	5.6	2.7
28	5.6	5.6	5.6	5.6	5.6	5.6	16.	10.	10.	7.2	5.6	2.6
29	5.6	5.6	5.6	5.6	----	5.6	20.	10.	10.	6.4	5.6	5.0
30	5.6	5.6	5.6	5.6	----	5.6	24.	10.	12.	5.6	5.6	5.0
31	5.6	----	5.6	5.6	----	5.6	----	12.	----	5.6	5.6	
Total runoff (acre-feet)												5,430

1915–1916

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	5	5	5	5	4	4	----	----	----	11	8	5
2	5	5	5	----	4	4	----	----	----	11	8	5
3	5	5	5	----	4	4.	----	----	----	11	8	5
4	5	5	5	----	4	4	----	----	----	12	7	5
5	5	5	5	----	4	4	----	----	----	13	7	5
6	5	5	5	----	4	4	----	----	----	13	7	5
7	5	5	5	----	4	4	----	----	----	12	7	5
8	5	5	5	----	4	5	----	----	----	12	7	5
9	5	5	5	----	4	5	----	----	----	12	7	5
10	4	5	5	----	4	6	----	----	----	12	7	5
11	4	5	5	----	4	10	----	----	----	14	7	5
12	4	5	5	----	4	13	----	----	----	9	7	5
13	4	5	5	----	4	12	----	----	----	9	7	5
14	4	5	5	----	4	14	----	----	----	9	7	5
15	4	5	5	----	4	16	----	----	----	9	7	5
16	4	5	5	4	4	16	----	----	----	9	7	5
17	4	5	5	4	4	17	----	----	----	9	7	5
18	4	5	5	4	4	19	----	----	----	9	7	5
19	4	5	5	4	4	20	----	----	----	9	7	5
20	4	5	5	4	4	23	----	----	----	9	7	6
21	5	5	5	4	4	----	----	----	----	9	7	6
22	5	5	5	4	4	----	----	----	----	9	7	6
23	5	5	5	4	4	----	----	----	----	9	6	6
24	5	5	5	4	4	----	----	----	11	9	6	6
25	5	5	5	4	4	----	----	----	11	9	6	6
26	5	5	5	4	4	----	----	----	11	9	6	6
27	5	5	5	4	4	----	----	----	11	9	6	6
28	5	5	5	4	4	----	----	----	11	9	5	6
29	5	5	5	4	4	----	----	----	11	8	5	6
30	5	5	5	4	----	----	----	----	11	8	5	6
31	5	----	5	4	----	----	----	----	----	8	5	

NOTE—Gauge washed out on March 20—no records until June 24.

TABLE 2—*Continued.*

1916–1917

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	6	6	6	6	6	4	4	4	7	10	6	6
2	6	6	6	6	6	4	4	4	6	10	6	6
3	6	6	6	6	6	4	4	4	6	10	6	6
4	6	6	6	6	6	4	4	4	6	10	6	6
5	6	6	6	6	6	4	4	4	6	10	6	6
6	6	6	6	6	6	4	4	4	6	10	6	6
7	6	6	6	6	6	4	4	5	6	10	6	6
8	6	6	6	6	6	4	4	5	8	10	6	6
9	6	6	6	6	6	4	4	5	8	10	6	6
10	6	6	6	6	6	4	4	5	8	9	6	6
11	6	6	6	6	6	4	4	7	8	8	6	6
12	6	6	6	6	6	4	4	9	9	8	6	6
13	6	6	6	6	6	4	4	8	9	7	6	6
14	6	6	6	6	6	4	4	10	11	7	6	6
15	6	6	6	6	6	4	4	15	13	6	6	6
16	6	6	6	6	6	4	4	12	16	6	6	6
17	6	6	6	6	6	4	4	12	15	8	6	6
18	6	6	6	6	4	4	4	12	15	8	6	6
19	6	6	6	6	4	4	4	12	15	8	6	6
20	6	6	6	6	4	4	4	12	14	8	6	6
21	6	6	6	6	4	4	4	12	14	8	6	6
22	6	6	6	6	4	4	4	12	14	7	6	6
23	6	6	6	6	4	4	4	10	12	6	6	6
24	6	6	6	6	4	4	4	14	11	6	6	6
25	6	6	6	6	4	4	4	24	11	6	6	6
26	6	6	6	6	4	4	4	15	11	6	6	6
27	6	6	6	6	4	4	4	14	10	6	6	6
28	6	6	6	6	4	4	4	13	11	6	6	6
29	6	6	6	6	----	4	4	11	11	6	6	6
30	6	6	6	6	----	4	4	10	11	6	6	6
31	6	—	6	6	----	4	----	9	----	6	6	
Total runoff (acre-feet)												4,650

1923

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
1	----	1	1	4	10	16	8	7
2	----	1	1	4	13	15	12	7
3	----	1	1	4	10	15	12	7
4	----	1	*3	4	13	13	12	7
5	----	1	*3	4	14	16	12	7
6	----	1	*3	4	15	15	10	7
7	----	1	*3	5	16	15	10	7
8	----	1	*3	5	21	15	10	5
9	----	1	*3	5	21	13	10	5
10	----	1	*3	5	20	13	10	5
11	----	1	*3	5	18	13	10	5
12	----	1	*3	5	17	13	9	5
13	----	1	*3	5	11	13	9	7
14	----	1	*3	5	11	13	9	5
15	----	1	*3	6	10	13	9	5
16	----	1	*3	7	12	12	9	5
17	----	1	*3	8	12	10	9	5
18	----	1	4	8	15	10	9	5
19	----	1	4	8	15	10	9	5
20	----	1	4	8	15	9	9	5
21	1	1	4	8	16	8	8	5
22	1	1	4	10	15	8	8	5
23	1	1	4	10	15	8	8	5
24	1	1	4	10	15	8	8	5
25	1	1	4	10	16	8	8	5
26	1	1	4	10	16	9	8	5
27	1	1	4	10	15	9	8	5
28	1	1	4	10	15	9	8	5
29	1	----	4	10	13	9	8	5
30	1	----	4	10	15	8	8	5
31	1	----	4	----	18	----	8	5
Total runoff (acre-feet)								3,060

*Estimated.

Miscellaneous discharge measurements of Currant Creek at Cazier's ranch gauging site:

April 29, 1922	21.2 second-feet
June 4, 1922	15.8 second-feet
June 18, 1929	4.0 second-feet

TABLE 3

Daily discharge, in second-feet, of Currant Creek at Ranger Station near Currant, Nevada, for the period May 6 to August 31, 1913

(Data from U. S. Geological Survey Water-Supply Paper 360)

Location: About 4½ miles above Currant Post Office and about 1 mile above the Ranger Station. The flow is affected by storage changes in Cazier's reservoir (off channel) a short distance above the station.

Date	May	June	July	Aug.	Date	May	June	July	Aug.
1	------	6.5	3.6	0.4	17	4.5	5.4	0.8	0.4
2	------	7.6	3.4	.4	18	5.4	5.4	.4	.4
3	------	6.5	3.0	.4	19	6.5	4.5	.4	.4
4	------	6.5	2.6	.4	20	6.5	5.4	.8	.2
5	------	6.5	2.2	.4	21	5.4	5.4	.4	.2
6	2.1	5.4	1.7	.4	22	5.4	4.5	.4	.2
7	2.5	4.5	2.2	.4	23	6.5	5.4	.8	.4
8	2.9	5.4	1.7	.4	24	7.6	6.5	.8	.4
9	3.6	4.5	1.7	.4	25	9.0	5.4	.8	.8
10	3.6	4.5	1.7	.4	26	9.0	4.5	1.2	.4
11	4.5	4.5	1.7	.4	27	7.6	4.5	.4	1.7
12	3.6	4.5	1.2	.2	28	8.8	3.6	.8	1.2
13	4.0	5.4	1.2	.4	29	10.	3.6	.8	1.2
14	4.5	5.4	1.2	.4	30	7.6	3.6	.8	.8
15	5.4	4.5	.8	.4	31	6.5	----	.4	.8
16	4.5	5.4	.8	.4	Total runoff (acre-feet)				711

TABLE 4A

Average monthly discharge, in second-feet, of Big Warm Spring near Duckwater, Nevada, for year ending September 30, 1916

(Data from U. S. Geological Survey Water-Supply Paper 440)

Location: About 300 yards below spring, about 1 mile south of Duckwater.

Month	Discharge	Month	Discharge
October	13.3	April	14.1
November	13.5	May	14.4
December	13.5	June	14.4
January	13.5	July	14.5
February	13.5	August	14.6
March	13.5	September	14.6

Average discharge 14.0

TABLE 4B

Miscellaneous measurements of discharge, in second-feet, of Big Warm Spring near Duckwater, Nevada

(Compiled from records in office of the State Engineer)

Date	Discharge (second-feet)	Remarks
April 6, 1912	16.51	In channel between Warm Spring and works of control.
October 15, 1913	11.9	Immediately downstream from swamp diversion.
September 22, 1914	13.38	At Tognoni's weir.
September 8, 1915	13.2	In channel between spring pool and Tognoni's diversion.
November 21	13.6	Gate to swamp open, 1.0 second-foot leakage through Tognoni's gate.
May 5, 1916	14.3	Do
May 6	14.4	Do (?)
June 25	14.4	Do (?)
August 25	14.6	Do (?)
Dicharge for year ending September 30, 1916, 10,100 acre-feet.		
April 30, 1922	13.6	At former gaging station.
September 10, 1929	14.13	Near (?) spring outlet.
September 13	14.10	Do
May 10, 1937	12.76	At gates at outlet from spring pool.
June 6	14.66	Do (?)
June 7	12.52	Do (?)
June 15	14.22	Do (?)
June 19	14.10	Do (?)
July 3	14.38	Do (?)
September 11	13.27	Do
October 15	12.96	Do
November 1	13.72	Do
May 19, 1938	14.70	Do
May 30	14.51	Do
June 21	14.18	Do
July 21	14.74	Do
August 23	13.77	Do
September 22	13.59	Do

Daily discharge, in second-feet, of Duckwater Creek near Duckwater, Nevada

(Data from U. S. Geological Survey Water-Supply Paper 440)

Location: In T. 12 N., R. 56 E., 200 feet below old stone building, 1½ miles below Duckwater, 2 miles by channel below Big Warm Spring. The flow is affected by a few small(?) ditches diverting water from creek above gage.

1915–1916

Date	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	......	8.9	4.4	6.2	8.4	10.0	9.3	9.5	9.5	7.7	7.6	7.2	8.1
2	......	8.8	4.5	6.4	8.4	9.7	9.3	9.5	9.5	7.6	7.6	7.2	8.1
3	......	8.9	4.5	6.4	8.4	9.5	9.3	9.5	9.5	7.6	7.6	7.2	8.1
4	......	9.0	4.5	6.5	8.4	9.5	9.3	9.5	9.5	7.6	7.4	7.2	8.1
5	......	9.2	4.5	6.7	8.4	9.1	9.3	9.5	9.5	7.6	7.4	7.2	8.1
6	......	9.3	4.5	6.9	8.4	9.5	9.1	9.5	9.5	7.4	7.4	7.4	7.9
7	11.3	9.4	4.5	7.0	8.4	9.5	9.1	9.5	9.5	7.4	7.4	7.4	7.9
8	11.2	9.5	4.7	7.0	8.6	9.5	9.1	9.5	9.3	7.4	7.4	7.4	7.7
9	11.2	6.9	4.8	7.2	8.6	9.7	9.1	9.5	9.3	7.4	7.4	7.4	7.7
10	11.2	4.3	5.0	7.2	8.6	9.7	9.3	9.7	9.3	7.4	7.4	7.2	7.7
11	9.3	4.3	5.1	7.4	8.6	9.8	9.3	9.7	9.3	7.4	7.4	7.7	7.7
12	9.8	4.3	5.3	7.4	8.8	9.5	9.3	9.7	9.1	7.4	7.4	8.1	7.6
13	10.2	4.1	5.4	7.4	8.6	9.5	9.5	9.5	9.1	7.4	7.4	8.1	7.6
14	10.6	4.1	5.4	7.6	8.8	9.8	9.5	9.5	9.1	7.4	7.4	8.1	7.6
15	10.3	4.1	5.6	7.6	8.9	9.1	9.5	9.5	9.1	7.4	7.4	8.1	7.4
16	10.0	4.1	5.6	7.6	8.9	8.9	9.5	9.7	9.1	7.4	7.4	8.1	7.4
17	9.8	4.1	5.6	7.6	10.	8.8	9.5	9.8	9.1	7.4	7.4	8.1	7.3
18	9.5	4.0	5.7	7.6	10.	8.8	9.5	9.8	8.5	7.4	7.4	8.1	7.1
19	9.5	3.9	5.7	7.6	9.5	8.8	9.5	9.8	8.1	7.4	7.2	8.1	7.0
20	9.5	3.9	5.9	7.6	9.1	8.8	9.5	10.	7.9	7.4	7.2	8.1	6.9
21	9.5	3.8	5.9	7.7	8.9	8.8	9.5	10.	7.9	7.4	7.2	8.1	6.7
22	9.5	3.7	6.1	7.9	9.1	8.8	9.5	9.8	7.9	7.6	7.2	8.1	6.7
23	9.3	3.7	6.1	8.1	9.3	8.8	9.5	9.8	7.9	7.6	7.2	8.1	6.7
24	9.3	3.8	6.2	8.1	9.8	8.8	9.5	9.8	7.9	7.6	7.4	8.1	6.5
25	9.3	3.9	6.2	8.1	10.	8.9	9.5	9.8	7.9	7.4	7.4	8.1	6.5
26	9.3	4.0	6.2	7.9	10.	9.1	9.5	9.8	7.7	7.6	7.4	8.1	6.4
27	9.3	4.1	6.2	7.9	9.8	9.1	9.5	9.8	7.7	7.6	7.2	8.1	6.2
28	9.1	4.2	6.2	7.9	9.8	9.1	9.5	9.7	7.7	7.6	7.2	8.1	6.2
29	9.1	4.3	6.2	8.1	10.	9.1	9.5	9.5	7.7	7.6	7.2	8.1	6.2
30	8.9	4.4	6.2	8.1	10.	....	9.5	9.5	7.7	7.6	7.2	8.1	6.1
31	....	4.4	....	8.1	10.	....	9.5	....	7.7	....	7.2	8.1	
Total runoff (acre-feet)													5,700

NOTE—Daily discharge interpolated for several short periods during year.

1917

Date	May	June	July	Aug.	Sept.	Oct.
1	....	5.9	8.9	7.4	8.4	4.1
2	....	5.9	8.9	8.4	8.4	4.1
3	....	5.9	8.9	8.8	8.4	4.1
4	....	5.9	8.8	8.8	8.4	4.0
5	....	5.9	8.2	8.8	8.6	3.8
6	....	5.9	8.2	8.8	8.6	3.7
7	....	6.1	8.6	8.8	8.2	3.0
8	....	6.1	8.6	8.6	7.7	2.9
9	....	6.1	8.4	8.8	7.7	2.2
10	....	6.1	8.6	9.3	7.6	2.2
11	....	6.5	8.4	9.1	7.6	2.2
12	....	6.9	8.2	8.9	7.6	2.1
13	....	7.0	8.2	8.9	7.2	2.1
14	....	7.0	8.4	8.8	7.0	2.1
15	....	7.2	8.6	8.8	6.9	2.1
16	....	7.2	8.6	8.8	7.0	
17	....	7.2	8.4	8.8	7.0	
18	....	7.2	8.4	8.8	6.9	
19	....	7.2	8.4	8.9	6.9	
20	....	7.4	8.4	8.8	6.7	
21	....	7.9	8.6	8.8	6.7	
22	7.4	8.8	8.6	8.6	6.7	
23	7.0	9.3	8.4	8.6	6.7	
24	6.1	9.3	8.9	8.6	6.7	
25	5.9	9.1	8.8	8.4	6.7	
26	5.9	8.2	8.8	8.4	6.7	
27	....	7.9	9.3	8.6	6.2	
28	....	8.6	7.7	8.4	4.7	
29	....	8.4	7.7	8.4	4.1	
30	....	8.6	7.6	8.4	4.1	
31	....	....	7.4	8.4		
Total runoff (acre-feet)						1,990

TABLE 6

Record of well-known springs in Railroad, Hot Creek, and Reveille Valleys, Nevada

Number and location	Name and owner		Temperature (°F.)	Discharge: Date of measurement	Discharge: Gallons per minut
	RAILROAD VALLEY				
6N/57-5A1	Willow Springs[1]		60	2/ 7/34	30
7N/55-16	Chimney Springs[1]		130-160	2/ 7/34	95
7N/57-28A1	Bullwhacker Spring[1]		59	2/ 7/34	10
8N/55-15C1	Lockes Hot Spring[1]	Titus Bros.	95	2/ 7/34	200
8N/55-15C2	Lockes Stockyard Spring[1]	Titus Bros.	93	2/ 7/34	600
8N/55-15C3	Lockes Big Spring[1]	Titus Bros.	99	2/ 7/34	900
8N/55-15C4	Reynold's Spring[1]	Titus Bros.		2/ 7/34	300
8N/56-14	Kate Spring[2]		72	1/24/35	14
8N/57-11D1	Blue Eagle Springs[1]	Howard Sharp, et al.	82	2/ 7/34	1,800
	Blue Eagle Springs[2]	Howard Sharp, et al.	...	1/23/35	1,385
	Blue Eagle Springs[3]	Howard Sharp, et al.		2/13/48	2,270
8N/57-27C1	Butterfield Springs[2]		64	1/24/35	227
8N/57-34	Bacon Spring[2]		57	2/ 7/34	2
11N/59-21	Currant Creek Springs		Cool	See tables 2 and 3	
12N/56-5	Little Warm Spring		Warm		
13N/56-32	Big Warm Spring		Warm	See tables 4A and B	
15N/57-33C1	Green Spring[4]	Mrs. B. R. Holstead	63	4/29/48	675
	HOT CREEK VALLEY				
4N/50-20B1	Warm Spring		Boiling	....	Small
8N/51	Hot Creek Springs		Warm		
	REVEILLE VALLEY				
1N/50-4A1	Eden Creek Springs	Fallini Bros.	Cool	....	Small

[1] Measured by F. W. Millard and G. A. Waring.

[2] Measured by F. W. Millard and Son.

[3] Measured by G. B. Maxey, T. E. Eakin, and R. W. Millard.

[4] Estimated by G. B. Maxey.

Most of the springs along the east side of Railroad Valley issue from the valley alluvium near the toe of the alluvial apron on the periphery of the playa. They are probably gravity springs and most of the water that issues from them comes to the surface along the outcrop area of the relatively permeable water-bearing beds that overlie impermeable beds in the alluvial deposits. Butterfield Springs is an example of this type of spring.

Other springs, such as Duckwater, Lockes, Hot Creek, and Warm Springs, issue from or in the vicinity of Paleozoic sedimentary rocks and Tertiary and Quaternary extrusive rocks. All these springs discharge warm or hot water, which may indicate either that some or all of the water circulates to considerable depth beneath the land surface or that there is a high geothermal gradient in the region. The latter condition is probable because in some places, especially in the hills west and southwest of Lockes Springs, volcanism occurred in Pleistocene and possibly Recent time.

RAILROAD VALLEY

The source of essentially all the ground water in Railroad Valley is precipitation falling within the drainage boundaries enclosing it and its tributary valleys, Hot Creek and Reveille. The greater part of the precipitation that enters the ground-water reservoir is believed to fall on that part of the drainage basin at an altitude exceeding 6,000 feet, because the precipitation at lower altitudes is 8 inches or less, and is probably lost by evaporation and transpiration before it can percolate to the water table. Much of the water from precipitation at the higher altitudes also is discharged by evaporation and transpiration and some of it runs off, especially during floods and the melting season, and is lost by evaporation from the playas. The remainder of the water, which percolates deeply into the soil mantle and rocks of the highlands and the gravels of the alluvial apron, moves downward into the ground-water reservoir. There it is stored until the level of the ground water in the reservoir is raised sufficiently to allow losses by natural discharge—by springs, or by evaporation, or by transpiration by phreatophytes. Thus, the ground-water level is high in the marshy playa in the central part of Railroad Valley from about 1 mile north of U. S. Highway 6 to about the latitude of Nyala. Large quantities of ground water are discharged by evaporation and transpiration from this playa.

The basin formed by Railroad Valley and the tributary Hot Creek and Reveille Valleys is a closed basin having interior drainage. There is no evidence of discharge of ground water as underflow from it. Thus, the only way in which ground water can be discharged is by evaporation and transpiration.

Under natural conditions the ground water in a closed basin is in hydrologic balance—that is, the average annual recharge is equal to the average annual discharge. Data are available for an estimate of both the recharge and discharge. Although not exact, they are believed sufficiently accurate to show the magnitude of the recharge and discharge.

The average annual discharge may be estimated approximately by use of transpiration and evaporation rates determined from studies in somewhat similar areas in the Great Basin and in other parts of the southwestern United States. Saltgrass, greasewood, and rabbitbrush are the three predominant phreatophytes growing in Railroad Valley. In addition, much water is transpired from several small areas of native meadow grasses and from small tracts of alfalfa and other irrigated crops. Studies by Lee (1912) and White (1932) afford a basis for estimating the annual rate of loss from saltgrass, greasewood, and rabbitbrush areas. The annual rate of evapo-transpiration loss from native meadow and alfalfa has been studied or estimated by Piper, Robinson, and Park (1939); Blaney, Taylor, and Young (1930); and Young and Blaney (1942). The rates of use of water by the various phreatophytes determined or used in these studies have been adapted for this area with consideration of depth to water and plant density and size. The rate of use by saltgrass is estimated to average about ½ foot a year, by greasewood and rabbitbrush, about ⅓ foot a year, and by irrigated meadow grasses and alfalfa, about 1¼ feet a year.

The area in Railroad Valley in which the water table is 15 feet or less below land surface includes about 96,000 acres. Saltgrass, greasewood, and rabbitbrush grow in about half of this area. Thus, about 24,000 acre-feet may be discharged annually by the saltgrass, and about 16,000 acre-feet by greasewood and rabbitbrush. Additionally, an area of about 8,000 acres of land along Duckwater Creek, Currant Creek, and the margin of the playa is covered by meadow grasses and other irrigated crops. The evapo-transpiration losses in these places are estimated to be about 10,000 acre-feet annually. Therefore, the total annual loss of water by evapo-transpiration from Railroad Valley is estimated to be on the order of magnitude of 50,000 acre-feet.

It is possible to estimate the total annual increment of ground water to Railroad Valley by determining the amount of precipitation within the drainage boundaries that annually enters the ground-water reservoir. As Reveille Valley drains into Railroad Valley and only negligible amounts of ground water are discharged from it by evaporation and transpiration, precipitation in its drainage basin is included in the following discussion. Hot Creek Valley also drains into Railroad Valley, but precipitation in its drainage basin is not included in the following calculation. A simpler and more accurate method of estimating its contribution to the ground-water reservoir in Railroad Valley is described in the following pages.

According to the zonal precipitation map of Nevada (Hardman, 1936), the annual precipitation in each zone above the 5- to 8-inch zone and the area of each zone in Railroad and Reveille Valleys are as shown in Table 7. Also shown in the table are the estimated percentages of total precipitation that enters the ground-water reservoir. These estimated percentages are based on preliminary studies in 15 valleys in east-central Nevada. They were determined by trial-and-error balancing of recharge estimates based on them against estimates of discharge in each valley. The final column in the table shows the estimated annual increment to the ground-water reservoir furnished by each zone and the estimated total increment.

TABLE 7

Estimated average annual ground-water recharge, by zones, from precipitation in Railroad Valley, Nevada

Precipitation zone (inches)	Area of zone (acres)	Total precipitation in zone (acre-feet)	Percentage of recharge	Approximate recharge (acre-feet)
8–12	618,500	515,400	3	15,500
12–15	165,100	185,700	7	13,000
15–20	66,000	96,200	15	14,400
Over 20	16,600	29,900	25	7,500
Total				50,400

Hot Creek Valley drains into Railroad Valley through a channel in a narrow gap in the mountains east of Twin Springs. Part of this surface water is lost by evaporation and transpiration but possibly as much as 0.5 second-foot percolates deeply into the gravels and thus recharges the ground-water reservoir in Railroad Valley. Possibly as much as 1 second-foot of water passes through this gap as underflow into Railroad Valley. Therefore, probably as much as 1,100 acre-feet of water from

Hot Creek Valley annually recharges the ground-water reservoir in Railroad Valley.

The total annual increment to the ground water in Railroad Valley, as estimated by the precipitation and underflow method, is therefore about 51,500 acre-feet of water. This estimate closely approximates the discharge estimate of 50,000 acre-feet determined by the evapo-transpiration method.

Only about 10,000 acre-feet of water in Railroad Valley was put to beneficial use in 1948. However, not all the remaining water can be used for irrigation, owing to the lack of arable land. Not more than 2,000 or 3,000 acres, largely land that must be reclaimed, is available for cultivation, according to the reconnaissance soil survey. Most of this land lies in an area where flowing artesian wells may be expected. One such well (10N/57-32B1) already has been drilled near the central part of the area. Assuming the maximum acreage of arable land in Railroad Valley to be 3,000 acres and the duty of water to be 4 feet a year, the total expected use of ground water might be about 12,000 acre-feet, an amount easily available without exceeding the safe yield of the ground-water reservoir. A large part of the remaining water now lost by natural discharge would be available for uses other than irrigation.

Wells

The information obtained from deep drilling in the lower part of Railroad Valley indicates that flowing wells can be developed in some places although yields may be variable from well to well. Data for well 6N/56-5B1 (Pl. 5) indicate that a flow ranging from 180 to 300 gallons per minute was developed in zones between 174 and 412 feet below land surface, and that drilling water was lost at depths of 735 to 745 feet. To the north wells in T. 7 N., R. 56 E., were reported to yield no flowing water, to a depth as great as 990½ feet in well 7N/56-22A1. Wells in T. 8 N., Rs. 55 to 57 E., developed flowing water at a rate ranging from 50 to 230 gallons per minute at depths to as much as 969 feet. The depths of wells in these townships range from 120 feet in 8N/57-14A1 to 1,204 feet in 8N/56-2D1. Two wells in the southern part of T. 9 N., R. 56 E., developed flows ranging from 46 to about 100 gallons per minute. Two other wells in T. 10 N., R. 57 E., developed flows, one of which (10N/57-32B1) was reported to be 480 gallons per minute.

This information allows certain generalizations:

(1) Much of the area in T. 7 N. is underlain by a thick section of clay containing very little sand, from which it is doubtful that satisfactory flowing wells can be developed.

(2) In the northern part of T. 6 N., R. 56 E., and possibly farther south, a moderate proportion of sand will probably yield water to wells of good construction, although "dry" sand may take water, as in the zone between 735 to 745 feet in well 6N/56-5B1.

(3) In parts of Tps. 8 and 9 N., Rs. 56 and 57 E., moderate yield may be developed by utilizing several water-bearing zones.

(4) The yield of well 10N/57-32B1 suggests that good yields are possible in the southwestern part of T. 10 N., R. 57 E., and perhaps in the southeastern part of T. 10 N., R. 56 E., if one or more zones of sand and gravel are encountered.

Chemical Quality

Analyses of water from two springs and one well in Railroad Valley are shown in Table 8. These analyses were made in 1912 by S. C. Dinsmore, of the Nevada Agricultural Experiment Station, and were published in U. S. Geological Survey Water-Supply Paper 365.

TABLE 8

Chemical analyses of water from three localities in Railroad Valley, Nevada

Constituents (parts per million)	Duckwater Creek at Irwin's ranch	Blue Eagle Spring (8N/57-11D1)	Railroad Valley Saline Co. well (8N/56-2D1)
Silica (SiO_2)	36	17	83
Iron (Fe)	.1	.6	1.7
Calcium (Ca)	72	80	26
Magnesium (Mg)	43	24	8.9
Sodium and potassium (Na + K)	69	30	69
Carbonate (CO_3)	.0	.0	.0
Bicarbonate (HCO_3)	414	385	223
Sulfate (SO_4)	127	34	5.7
Chloride (Cl)	25	10	45
Nitrate (NO_3)	1.6	.0	3
Dissolved solids: ppm	590	465	421
Total hardness (as $CaCO_3$)	356	300	100
Percent sodium[1]	30	18	60

[1]Computed by G. B. Maxey.

Magistad and Christiansen (1944) have given tentative standards for irrigation waters, but they indicate that consideration should be given to the characteristics of the type of soil and the soil solution in evaluating the effect of water of a given chemical composition on a given soil.

Standards for irrigation waters

Water class	Conductance (micromhos at 25° C.)	Salt Content: Total (p.p.m.)	Salt Content: Per acre-foot (tons)	Sodium[1] (percent)	Boron (p.p.m.)
Class 1[2]	<1,000	<700	<1	<60	<0.5
Class 2[3]	1,000–3,000	700–2,000	1–3	60–75	.5–2.0
Class 3[4]	>3,000	>2,000	>3	>75	>2.0

[1] The percentage of sodium is calculated from analytical results expressed in milligram equivalents per kilogram. These results are obtained by dividing the parts per million of sodium, calcium, and magnesium by 23.20, and 12.24, respectively; then 100 times the milligram equivalents of sodium is divided by the sum of the milligram equivalents of sodium, calcium, and magnesium. In milligram equivalents $\frac{100\ Na}{Na+Ca+Mg}$ = percentage of sodium.

[2] Excellent to good, suitable for most plants under most conditions.

[3] Good to injurious, probably harmful to the more sensitive crops.

[4] Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant. If a water falls in class 3 on any basis, i. e., conductance, salt content, percentage of sodium, or boron content, it should be classed as unsuitable under most conditions. Should the salts present be largely sulfates, the values for salt content in each class can be raised 50 percent.

The available analyses do not include determination of boron. However, the water from Railroad Valley Saline Co. well would be placed in Class 2 on the basis of the percent sodium and may be unsuitable for irrigation when used on the heavy saline soils that occur in the lower part of the valley. The waters from Duckwater Creek and from Blue Eagle Spring are in Class 1, on the basis of percent sodium and dissolved solids.

The analysis of water from Duckwater Creek indicates that it is satisfactory for domestic use. The water from Blue Eagle Spring and from the Railroad Valley Saline Co. well would not be satisfactory for domestic use if untreated, because of the indicated high iron content. An iron concentration in excess of about 0.3 part per million causes staining and is therefore undesirable. The water could be made suitable for domestic use by aerating and filtering to remove most of the iron.

HOT CREEK VALLEY

The source of most of the ground water in Hot Creek Valley, as in Railroad Valley, is precipitation within the drainage boundaries of the valley. After the water from precipitation has percolated into the ground it moves toward the lower part of the valley where it is discharged by underflow and stream flow in the gap southeast of Twin Springs, and by evapo-transpiration in the vicinity of Twin Springs and from irrigated lands along Hot Creek. As conditions in Hot Creek Valley are similar to those in Railroad Valley, it is possible to estimate the amount of ground water annually available for development by the same method that was used in that valley.

The quantity of water discharged from Hot Creek Valley by surface flow and underflow through the gap east of Twin Springs and entering the ground-water reservoir of Railroad Valley is about 1.5 second-feet or 1,100 acre-feet per year, as previously estimated (pp. 151, 152).

In the vicinity of Twin Springs and Hot Creek Springs and adjacent to Hot Creek south of U. S. Highway 6 there is an estimated 7,000 acres from which water is discharged. The vegetation in this area consists largely of native meadow grasses but includes areas of saltgrass, rabbitbrush, and greasewood. Nearly all of the water discharged by evapo-transpiration in this area is ground water. The amount of ground water so discharged is believed not to exceed 9,000 acre-feet.

The total discharge of Hot Creek Valley is the sum of the stream flow and underflow out of the valley plus the evapo-transpiration loss, or about 10,000 acre-feet of water annually.

The average annual increment to the ground-water reservoir estimated by the precipitation method previously described (p. 151) is on the order of magnitude of 10,600 acre-feet of water.

The amount of water in the valley utilized annually for irrigation and livestock probably never exceeds 2,500 acre-feet. Although much of the remaining 7,500 acre-feet of water that is being lost by natural discharge should be available for development, such development does not appear to be feasible under existing economic conditions. Little is known concerning the ability of the water-bearing materials to yield water, as only a few wells have been drilled in the valley. Most of them are shallow and are in places that are not suitable for pumping for irrigation. Thus, their records are not necessarily indicative of ground-water conditions in the potential irrigation areas. It is possible that satisfactory irrigation wells could be constructed in the vicinity of the tract of land mentioned by Mason (page 138) in his report on soil conditions. It is estimated that as much as 5,000 acre-feet of ground water could be developed from wells in the valley.

REVEILLE VALLEY

The geologic, hydrologic, and topographic conditions indicate that only a small amount of ground water is available for development in Reveille Valley. The available evidence indicates that ground water in the valley may drain southeastward into Railroad Valley and northward into Hot Creek Valley. The depth to water probably is not less than 100 feet in the valley proper. The only areas of transpiration observed were very small ones adjacent to small springs in or near the mountains.

KAWICH VALLEY

Only the northern part of Kawich Valley was visited during the reconnaissance studies on which this report is based. Kawich Valley is essentially an isolated ground-water basin enclosed by low mountains, with the exception of an alluvial divide at the north end which rises about 400 feet above a playa in the central part of the valley. Residents of the region report that possibly three wells have been drilled near the central part of the valley to depths of as much as 350 feet without yielding water. A small amount of water might be developed on the alluvial apron, but the pumping lift would be high. It appears likely that Kawich Valley is similar to Reveille Valley in having little ground water available for development.

PENOYER VALLEY

Penoyer Valley, known by some residents of Lincoln County as Sand Springs Valley, is an isolated ground-water basin containing a small transpiration area covered largely by greasewood. The water level within the transpiration area appears to be no closer to the land surface than 10 feet and may be as much as 20 feet. Ground water has been pumped to supply mining and milling operations in the east-central part of the valley, and to supply stock with drinking water. The estimated annual increment of water to the ground-water reservoir, based on the precipitation method of calculation, is about 13,500 acre-feet. This estimate is probably high because the annual increment, as estimated by the natural-discharge method, is only about 6,400 acre-feet of water. As indicated by Mason's report on the soils, there is probably no land in the valley within economic reach of ground water that may be cultivated profitably. However, it is estimated that as much as 3,000 acre-feet of water might be available for development.

SUMMARY

The principal source of ground water is precipitation within the drainage boundaries of the several valleys included in this report.

Railroad Valley receives some contribution from its tributary valleys, Hot Creek and Reveille. The average annual recharge to and discharge from the ground-water reservoir in Railroad Valley are estimated to be about 50,000 acre-feet. From this, beneficial use is made of an estimated 10,000 acre-feet. It is probable that an additional 10,000 to 15,000 acre-feet could be developed readily. Wells have developed water under sufficient pressure to flow at the land surface in T. 6 N., R. 56 E., Tps. 8 and 9 N., Rs. 56 and 57 E., and T. 10 N., R. 57 E.

The quality of ground water in Railroad Valley, as shown by three analyses, is generally satisfactory for most uses in the marginal parts of the valley but may be unsatisfactory for some uses locally in the lowest part of the valley.

In Hot Creek Valley, possibly as much as 5,000 acre-feet now lost by natural discharge may be available annually for development.

Possibly 3,000 acre-feet of ground water is available for development in Penoyer Valley. No ground water appears to be available for irrigation development in Reveille Valley, and probably very little is available in Kawich Valley.

No analyses are available for ground water in Hot Creek, Reveille, Kawich, or Penoyer Valleys.

On the basis of the soils reconnaissance by Howard G. Mason, Agricultural Economist, Nevada Agricultural Experiment Station, 2,000 to 3,000 acres of land in T. 10 N., R. 57 E., in Railroad Valley may be suitable for irrigation development.

In Hot Creek Valley a part of T. 4 N., R. 50 E., may also be suitable for development. However, the light texture of the soil and the gravelly subsoil probably would require certain amendments and the soil would have a high water requirement.

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TABLE 9

Records of well data in Railroad, Hot Creek, and Penoyer Valleys, Nevada

RAILROAD VALLEY

1N/53-8B1. Fallini Bros. Owner's designation, "Fred's well." Dug stock well, equipped with windmill, gasoline motor, and cylinder pump, diameter 48 inches, depth 110 feet. Yields brackish water. Water level reported by owner to be 80 feet below land surface on May 5, 1948.

1N/53-27B1. Fallini Bros. Drilled stock well, diameter 6 inches, depth 200 feet. Casing to 195 feet, perforations ⅛- by 3-inch slots from 175 to 190 feet. Depth to water 180(?) feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Silt	20	20
Sand and gravel	60	80
Clay	10	90
Gravel	10	100
Sand, fine	20	120
Silt	25	145
Sand, fine	10	155
Clay, sandy	25	180
Sand and gravel. Water	20	200
Total depth	....	200

3N/52-3D1 (unsurveyed). Public Domain (Fallini Bros.). Dug stock and domestic well, now unused and unequipped, diameter 42 inches, depth 27.5 feet. Measuring point, bottom of top 1-inch plank of sill at land surface. Water level, 24.35 feet below measuring point, April 24, 1948.

3N/54-5C1. H. N. Sharp. Drilled stock well, diameter 6 to 4 inches, depth 325 feet. Casing perforations ⅛- by 2-inch slots between 285 and 325 feet; 177 feet of 6-inch casing, and 160 feet of 4-inch casing. Reported depth to water 265 feet. Log from records of J. D. Hill, driller.

Material	Thickness (feet)	Depth (feet)
Rock and sand	175	175
"Solid rock" (extrusive (?) rock)	40	215
Silt	85	300
Sand. Water	5	305
Clay	15	320
Sand. Water	5	325
Total depth	....	325

4N/54-17C1. A. F. Bordoli. Drilled stock well, diameter 5 inches, depth 150 feet. Casing perforations ⅛- by 2-inch slots from 130 to 140 feet, 5-inch casing to 148–9 feet. Reported depth to water 130 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Dirt," sand and gravel	130	130
Sand and gravel. Water	2	132
Silt	16	148
Sand and gravel. Water	2	150
Total depth	....	150

5N/54-32C1. A. F. Bordoli. Drilled stock(?) well, diameter 5 inches, depth 110 feet. Casing perforations ⅛- by 2-inch slots from 85 to 105 feet, 5-inch casing to 107–110 feet. Reported depth to water 80 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Dirt," sand and gravel	90	90
Sand and gravel. Water	2	92
Silt	13	105
Sand and gravel. Water	5	110
Total depth	—	110

TABLE 9—*Continued.*

5N/56-30B1. Sheldon Lamb. Drilled test well, unused and unequipped, diameter 3 inches (steel casing), depth 175 feet (reported). Measuring point, top of flange on casing at land surface. Water level, 4.17 feet below measuring point, April 24, 1948.

6N/56-5B1. U. S. Fish and Wildlife Service. "Old well No. 7." Drilled, diameter 6 inches, depth 745 feet. Flow 180–300 gallons per minute. Temperature of water 65° F. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, sandy, and clean sand, alternating	95	95
Sand, fine, dark-colored	13	108
Clay, sandy, and clean sand, alternating	66	174
Sand, coarse. Strong artesian flow, increasing toward bottom. (Smells of hydrogen sulphide)	8	182
Clay, sandy	14	196
Sand with thin layers of sandy clay	16	212
Sand	14	226
Clay, hard, sandy	4	230
Sand, coarse. Strong artesian flow	4	234
Clay, hard, sandy	7	241
Clay, sandy, and clean sand, alternating	45	286
Sand, fine	11	297
Clay, sandy, and clean sand, alternating	8	305
Sand. Strong artesian flow	5	310
Clay, hard, sandy	16	326
Sand. Strong artesian flow	20	346
Clay, sandy, and coarse sand, alternating	31	377
Sand, fine. Strong artesian flow	9	386
Clay, sandy, and clean sand, alternating	14	400
Sand, coarse. Very strong artesian flow	12	412
Clay, sandy, and clean sand, alternating	18	430
Sand, very fine	12	442
Sand, fine, with thin layers of sandy clay	32	474
Clay, sandy	6	480
Clay, sandy, and coarse sand, alternating	38	518
Clay, sandy; harder and less sandy in upper part	22	540
Sand, clean; apparently partly cemented	28	568
Sand, fine; not cemented	17	585
Sand, coarse; partly cemented	4	589
Sand, fine; not cemented	11	600
Sand, coarse; partly cemented	12	612
Sand, coarse; partly cemented with occasional layers of sandy clay	19	631
Sand, fine	15	646
Sand, with very thin layers of sandy clay	12	658
Sand, coarse; partly cemented with very thin layers of sandy clay	10	668
Clay, sandy, and coarse sand, alternating	22	690
Clay, sandy, with occasional thin layers of coarse sand	22	712
Sand, with occasional thin layers of coarse sand	23	735
Sand, coarse. Drill water lost	10	745
Total depth	—	745

7N/56-1D1. U. S. Fish and Wildlife Service. "Old well No. 3." Drilled, depth 770 feet. Flow 1½ gallons per minute. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, gray	15	15
Mud, black	23	38
Clay, tough, gray	52	90
Clay, black mixed, with gray clay alternating	40	130
Clay, gray	25	155
Clay, gray, with a little sand	5	160
Clay, gray	15	175
Clay, mixed black and gray	89	264
Clay, sticky, lead-colored	3	267
Clay, gray and black, alternating	10	277
Clay, lead-colored	6	283
Clay, gray and black, alternating	17	300
Clay, gray	16	316
Clay, mixed gray and black, probably alternating	16	332
Clay, light- and dark-gray, alternating	8	340
Clay, gray	15	355
Clay, mixed light- and dark-gray	5	360
Clay, gray	36	396
Clay, soft, black	19	415
Clay, gray	5	420
Clay, light- and dark-gray, alternating	10	430

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, tough, black	4	434
Clay, gray, cemented with calcite or gaylussite, probably the latter	2	436
Clay, gray	49	485
Clay, gritty, gray, containing small portions of sand	15	500
Clay, soft, gray	5	505
Clay, hard, light-gray, somewhat sandy in lower portion	15	520
Clay, mixed gray and black	40	560
Clay, mixed gray and black, small proportion of sand	15	575
Clay, gray	22	597
Clay, gray with some sand and a few calcite crystals	3	600
Clay, tough, gray	16	616
Clay, gray, with numerous calcite crystals	36	652
Clay, light-gray, not sticky	5	657
Clay, sticky, gray, changing to black in lower portion	23	680
Clay, black, changing to gray in lower portion	7	687
Clay, gray, containing some rhyolitic sand	15	702
Clay, black, somewhat saline, containing calcite crystals. Trace of sodium carbonate	6	708
Clay, gradual transition to sandy, gray	12	720
Clay, gray, with less sand	35	755
Clay, gray, sandy, with proportion of sand increasing toward bottom	15	770
Total depth	....	770

7N/56-3C1. U. S. Fish and Wildlife Service. "Old well No. 5." Drilled, depth 795 feet. Small flow of saline water reported. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, gray	10	10
Clay, black	66	76
Clay, gritty, black	15	91
Clay, black (smells of hydrogen sulphide in upper part)	52	143
Clay, mixed gray and black	22	165
Mud, gritty, black	11	176
Clay, black, with small admixture of gray clay at about 210 feet	95	271
Clay, black, with calcite crystals, some grit	29	300
Clay, mixed gray and black, with calcite crystals	20	320
Clay, black, with calcite crystals	13	333
Clay, gray	11	344
Clay, black, with calcite crystals in lower part	41	385
Clay, gray, with some sand and calcite crystals	135	520
Clay, sandy, gray with partly cemented layers	29	549
Clay, sandy, gray	121	670
Clay, less sandy, gray	27	697
Clay, sandy, gray	46	743
Clay, sandy, gray	51	794
Basalt (rock), impossible to penetrate	1	795
Total depth	....	795

7N/56-11B1. U. S. Fish and Wildlife Service. "Old Well No. 2." Drilled, depth 841 feet. Reported no water. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, brown	2½	2½
Clay, gray	19½	22
Mud, soft, black	22	44
Clay, gray	8	52
Mud, black	3	55
Clay, gray	1	56
Mud, black	13	69
Clay, dark-gray	16	85
Mud, black	28	113
Clay, gray	1	114
Mud, black	7	121
Clay, gray	7	128
Mud, black	8	136
Clay, gray	13	149
Clay, hard, black	2	151
Clay, black and gray, alternating thin layers	18	169
Clay, soft, black and brown, alternating thin layers	4	173
Clay, stiff, gray	18	191
Clay, soft, black and gray	4	195
Clay, hard, black and gray, slightly saline	37	232
Mud, hard, black	9	241
Clay, gray	10	251
Clay, gray, cemented with small proportion of a calcareous cement, probably calcite	7	258

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, gray	14	272
Clay, cemented, gray	7	279
Clay, soft, black	1	280
Clay, cemented, black	8	288
Clay, soft, black and gray	2	290
Clay, cemented, black	7	297
Clay, soft, gray and black	4	301
Clay, cemented, black	3	304
Clay, gray	2	306
Clay, soft, white	10	316
Clay, hard, probably cemented	44	360
Clay, gray and black, probably alternate layers	34	394
Clay, hard, black	28	422
Clay, hard, gray	4	426
Clay, cemented, black	3	429
Clay, hard, black	34	463
Clay, light-gray and brown	12	475
Clay, cemented, black	12	487
Clay, black	5	492
Clay, cemented, black	14	506
Clay, hard-gray	11	517
Ash, volcanic; 2-inch stratum, hard, rhyolitic	....	517
Clay, hard, gray	12	529
Ash, volcanic; thin stratum, rhyolitic	....	529
Clay, gray and black	21	550
Clay, cemented, black	6	556
Clay, soft, white and brown	11	567
Clay, stiff, white and brown	15	582
Clay, soft, white and brown	57	639
Clay, light-gray, with occasional cemented streaks	14	653
Clay, hard, light-brown, partly cemented	6	659
Clay, tough, gray	20	679
Clay, soft, gray	3	682
Clay, hard, brown, somewhat saline	2	684
Clay, tough, gray	34	718
Clay, gray, with crystals of gaylussite and carrying many hard layers cemented with gaylussite	47	765
Clay, gray, with the proportion of gaylussite crystals increasing downward	16	781
Gaylussite, crystalline	9	790
Gaylussite, crystalline; rapid alternations and many hard layers cemented with gaylussite	4	794
Gaylussite, crystalline	5	799
Gaylussite, crystalline, with occasional layers of gray clay carrying gaylussite crystals	42	841
Total depth	....	841

7N/56-11C1. U. S. Fish and Wildlife Service. "Old well No. 4." Drilled, depth 762 feet. Reported no water. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, gray	9	9
Clay, very hard, gray	1	10
Clay, gray, darker toward bottom	15	25
Clay, sandy, gray	2	27
Clay, black	14	41
Clay, mixed gray and black; probably alternations	21	62
Clay, black	5	67
Clay, mixed black and gray	11	78
Clay, gray	10	88
Clay, black, slightly gritty	4	92
Clay, black, with faint odor of hydrogen sulphide	3	95
Clay, black; no grit	29	124
Clay, black, dark-gray	5	129
Clay, black, with some gray in lower portion	13	142
Clay, mixed black and gray, somewhat gritty	3	145
Clay, mixed gray and black	10	155
Clay, mixed gray and black, somewhat gritty	21	176
Clay, gray	21	197
Clay, soft, black	5	202
Clay, gray	8	210
Clay, mixed gray and black	20	230
Clay, black	10	240
Clay, mixed gray and black	20	260
Clay, black	4	264
Clay, mixed gray and black	41	305
Clay, soft, black	7	312
Clay, black, somewhat sandy	6	318
Clay, black	37	355

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, gray	5	360
Clay, mixed gray and black	22	382
Clay, soft, black, slightly saline	4	386
Clay, black	25	411
Clay, mixed gray and black	19	430
Clay, gray, somewhat variable in color; contains hard streaks	98	528
Clay, mixed gray and black	7	535
Clay, gray, variable in color and hardness	37	572
Clay, mixed gray and black	65	637
Clay, mixed gray and black, with occasional gritty layers	52	689
Clay, mixed gray and black, with occasional cemented layers	3	692
Clay, mixed gray and black	24	716
Clay, mixed gray and black, with scattered gaylussite crystals; gaylussite more plentiful toward bottom	46	762
Total depth	....	762

7N/56-22A1. U. S. Fish and Wildlife Service. "Old well No. 6." Drilled, depth 990½ feet. Reported no water. Log from records of F. W. Millard and Son.

Material	Thickness (feet)	Depth (feet)
Clay, gray	29	29
Clay, lead-colored	56	85
Clay, black; slightly salty in upper part	70	155
Clay, tough, gray	15	170
Clay, black; 6-inch layer cemented with calcite or gaylussite	....	170
Clay, gray; slightly saline	30	200
Clay, mixed gray and black	20	220
Clay, soft, black	80	300
Clay, mixed gray and black; probably alternations	5	305
Clay, mixed gray and black, with grit and calcite crystals	285	590
Clay, gray; calcite crystals	60	650
Clay, gray, with occasional thin cemented layers	25	675
Clay, gray, with little grit. No calcite crystals	47	722
Clay, gray, with grit and calcite crystals	48	770
Clay, gray, with grit, slightly saline to taste	26	796
Clay, gray, with grit and gaylussite crystals	44	840
Clay, gray, with gaylussite crystals present, but less plentiful than above	60	900
Clay, gray, with gaylussite crystals	6	906
Gaylussite, solid crystalline	83	989
Gaylussite, solid crystalline, too hard to penetrate with rotary drilling	1½	990½
Total depth	....	990½

8N/55-24A1. U. S. Fish and Wildlife Service. "New well No. 1." Drilled, diameter 8 inches to 41 feet, 6 inches to 493 feet, open hole to 107 feet, depth 600 feet. Casing perforations 128-135, 148-153, 155-160, 190-200, 210-220, 237-243, 245-250, 275-280, 285-292, 298-303, 320-325, 340-345, and 370-375 feet. Temperature 68° F. before perforating and 66° F. after perforating. Flow 55 to 115 gallons per minute. Data from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, white	18	18
Clay, blue. Surface water at 27 feet	18	36
Sand and clay, blue	1	37
Clay, gray, water strata at 38 feet. Artesian water at 55 feet	18	55
Clay, blue. Artesian water at 82 feet; flow 2 gallons per minute	45	100
Clay, gray, tough	34	134
Sand, cemented. Artesian water; flow 7 gallons per minute	2	136
Clay, gray	26	162
Clay, gray. Artesian water at 155 to 165 feet; flow 20 gallons per minute	4	166
Clay, gray	28	194
Sand, black. Artesian water; flow 15 gallons per minute	6	200
Clay, gray	16	216
Clay, gray, and fine sand. Artesian water	4	220
Clay, gray	17	237
Clay, gray and black sand	3	240
Clay, gray. Artesian water at 250 feet	20	260
Clay, gray, and gravel	5	265
Sand, blue	10	275
Clay, gray	13	288
Sand, blue. Artesian water at 285 to 290 feet; flow 50 gallons per minute	2	290

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, gray, mixed with sand	35	325
Clay, gray, and sand. Sulphurated hydrogen at 358 feet	50	375
Gravel	5	380
Clay, blue, sand and gravel	5	385
Clay, blue	10	395
Clay, blue, fine gravel and sand	55	450
Clay, blue	10	460
Clay, gray	5	465
Clay, blue	20	485
Clay, gray	35	520
Clay, yellow	30	550
Clay, yellow, and very little sand	15	565
Clay, lead-colored, coarse sand, and some gravel	4	569
Clay, yellow, some gravel and coarse rock	5	574
Clay, yellow, sand and gravel. Artesian water; flow 41 gallons per minute; temperature 68° F.	23	597
Clay, yellow	3	600
Total depth	....	600

8N/56-2B1. U. S. Fish and Wildlife Service. "New well No. 4." Drilled, diameter 6 inches to 4 inches, depth 430 feet. Casing perforations ⅛ by 5 inches per foot staggered around casing, 173-178, 205-210, 220-225, 258-263, 269-274, 300-305, 308-313, and 365-370 feet. Flow 158 to 175 gallons per minute. Temperature 58° F. Data from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, blue, black	30	30
Clay, blue	20	50
Clay, gray	60	110
Clay, gray, and little gravel	5	115
Clay, gray, sandy	32	147
Clay, gray, and little gravel	7	154
Clay, gray, sandy	41	195
Clay, gray, sandy, and little gravel	5	200
Clay, gray, sandy	5	205
Clay, gray, sandy, and little gravel	10	215
Clay, gray, sandy	15	230
Clay, yellowish-gray, sandy	10	240
Clay, gray, and sand	5	245
NOTE—Log of formation 245 to 427 feet is not reliable. Because of 4-inch perforated casing that was used to case the hole below the 168-foot level, sand ran through the perforations, diluting all samples.		
Clay, gray, and sand	30	275
Sand, fine	10	285
Clay, gray; sand ran through perforations in all samples	55	340
Clay, gray, and sand; gravel and sand strata at 350 feet	10	350
Clay, gray, and sand	20	370
Sand strata and gravel	1	371
Sand and clay; flow of water washes out clay, leaving samples of sand only	56	427
Sand strata with gray clay	3	430
Total depth	....	430

8N/56-2D1. Railroad Valley Saline Co. Well No. 1. ("Old well No. 1" U. S. Fish and Wildlife Service?) Drilled, diameter 10 inches, depth 1,204 feet. Flow 206 to 231 gallons per minute. Temperature 67° F. Log from U. S. Geological Survey Water-Supply Paper 365, pp. 76-78.

Material	Thickness (feet)	Depth (feet)
Sand with occasional clay layers	32	32
Quicksand	71	103
Clay and quicksand, alternating. Artesian water, especially at 128 feet	29	132
Clay, white, small seams fine gravel or coarse quicksand	4	136
Clay, heavy	42	178
Quicksand. Artesian water	36	214
Clay and sand, layers 1 to 10 feet thick, alternating. Artesian water in sands, especially at 220 and 250 feet	71	285
Sand, coarser in upper part. Pebbles 3 to 4 inches in diameter at 285 feet. Artesian water	20	305
Clay, tough	31	336
Quicksand with some clay and small gravel. Artesian water	4	340
Clay with occasional streaks of quicksand	25	365
Quicksand with very small streaks of clay. Artesian water	10	375

Material	Thickness (feet)	Depth (feet)
Clay, tough, gray	15	330
Quicksand. Small artesian flow	1	331
Clay, tough, gray	27	418
Quicksand. Small artesian flow	1	419
Clay, brown	10	429
Quicksand. Small artesian flow	1	430
Clay, brown in upper part, changing to gray in lower	30	460
Quicksand. Artesian water	1	461
Clay, blue-green, with white layer at top	9	470
Quicksand. Artesian water	1	471
Clay, lead-colored	7	478
Sand, very fine	1	479
Clay, white and blue-green	21	500
Clay, blue-green, with some coarse sand	4	504
Clay, white and blue-green	15	519
Quicksand. Artesian water smelling of sulphured hydrogen	1	520
Clay, gray, with occasional sand streaks. Small artesian flows in sand. All smell of sulphured hydrogen	9	529
Clay, gray	4	533
Quicksand, very fine	1	534
Clay, blue-green	5	539
Quicksand, some light-colored clay and some coarse gravel. Strong artesian flow	2	541
Clay, yellowish, white, and blue-green	19	560
Quicksand. Artesian flow	1	561
Clay, blue-green and white	25	586
Quicksand. Artesian flow (small)	1	587
Clay	9	596
Sand and clay, alternating proportion of sand increasing downward. Small artesian flow at 605 feet	13	609
Clay, whiter in upper part	28	637
Quicksand	1	638
Clay, tough, white and greenish in color	38	676
Quicksand. Small artesian flow	1	677
Clay and sand, alternating	3	680
Clay, white	11	691
Clay and sand, alternating	9	700
Clay, brownish at top	19	719
Sand	1	720
Clay, brownish	18	738
Clay and quicksand, mixed. Some coarse gravel. Very small artesian flow	8	746
Clay, tough, brownish	13	759
Sand alternating with tough brownish clay. Very small artesian flows in sand	12	771
Clay, tough, brownish	14	785
Quicksand. Artesian flow	1	786
Clay	4	790
Clay, sandy streak. Small artesian flow	1	791
Clay, brownish	7	798
Clay and sand, alternating	7	805
Clay, hard and brown in lower part	11	816
Quicksand and gravel. Artesian water	6	822
Clay, hard, white	2	824
Clay and sand alternating every 2 to 6 inches. Proportion of clay increases with depth. Strong artesian flows in all sand strata	22	846
Clay, brownish	4	850
Sand and gravel	5	855
Clay and sand, rapidly alternating	10	865
Clay, gray	11	876
Gravel, coarse. Artesian water	2	878
Sand, fine	4	882
Clay and sand, alternating	17	899
Clay, gray	9	908
Sand and gravel. Strong artesian flow	16	924
Clay, light-gray	10	934
Sand, fine	7	941
Clay, gray	4	945
Sand	2	947
Clay, yellow on top, gray below	20	967
Sand and gravel. Small artesian flow	2	969
Clay, brown, a little sandy in upper part	33	1,002
Sand, fine, dry	1	1,003
Clay, hard, brown	46	1,049
Clay, brown, with a few thin streaks of sand. Sand probably dry	36	1,085
Clay, tough, brown. Very thin sand streak at 1,131 feet. Dry	46	1,131
Clay, brown	9	1,140
Sand cemented by calcium carbonate and gaylussite	4	1,144
Clay, gray	21	1,165
Clay and sand, rapidly alternating	10	1,175
Sand cemented by calcium carbonate. Characteristic lake-deposited tufa	15	1,190
Clay, brownish, with occasional very thin sand streaks	11	1,201
Bottom of hole in quicksand	....	1,204
Total depth	....	1,204

8N/56-3A1. U. S. Fish and Wildlife Service. "New well No. 3." Drilled, diameter 6 inches, depth 550 feet. Casing perforations, 185-190, 206-211, 217-222, 250-255, 270-275, 290-295, 310-315, and 360-365 feet. Flow 110 to 125 gallons per minute. Temperature 58° F. Data from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, blue. Surface water at 10 feet	20	20
Clay, gray	15	35
Clay, blue	30	65
Clay, gray, with some gravel	10	75
Clay, gray, and sand with particles of cap rock	30	105
Clay, gray, cap rock and trace of water gravel	5	110
Clay, gray, and sand	5	115
Clay, gray	45	160
Clay, gray, and some sand	25	185
Clay, gray, and some gravel	20	205
Clay, gray, and sand	20	225
Clay, gray, sand and gravel	3	228
Sand and gravel with some clay. Artesian water. Flow 12 gallons per minute	7	235
Clay, yellow. Gas at 247 feet	12	247
Sample washed out	10	257
Sand and clay. Very small flow at 263 feet	9	266
Sand and gravel, little clay. Small flow at 266 feet	1	267
Clay, white, and sand	3	270
Clay, gray, sand and gravel	5	275
Sand and gravel	4	279
Clay, sticky, and some sand	8	287
Clay and coarse sand	8	295
Sand, fine	10	305
Sand, coarse	10	315
Sand, fine, and some gravel. Artesian water; flow 63 gallons per minute; temperature 57° F.	5	320
No sample	13	333
Clay, gray	15	348
Clay, sticky, white, with some sand	10	358
Clay, sandy, white	9	367
Sand and gravel. Artesian water at 371 feet; flow 55 gallons per minute; temperature 58° F.	11	378
Clay, white, and sand	12	390
Clay, gray, with some sand	15	405
Clay, gray	10	415
Clay, gray, and some sand	45	460
Sand	5	465
Sand and some clay	5	470
Clay, sandy, gray. Artesian water; flow 32 gallons per minute; temperature 58° F.	17	487
Clay, gray	33	520
Clay, gray, sand and gravel	15	535
Clay, greenish-gray, sand and gravel, gravel strata 537 to 538 feet	3	538
Clay, gray, sand and gravel	12	550
Total depth	....	550

8N/57-4A1. U. S. Fish and Wildlife Service. "New well No. 6." Drilled, diameter 6 inches, depth 635 feet. Casing perforations, 360-365, 510-515, and 530-535 feet. Flow 110 to 125 gallons per minute. Temperature 66° F. Data from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, blue, sandy	40	40
Clay, blue-gray, sandy	25	65
Clay, gray, sandy	125	190
Clay, tough, gray	30	220
Clay, gray, and fine sand	20	240
Clay, blue-gray, sandy	5	245
Clay, gray, sandy	25	270
Clay, blue-gray, sandy	15	285
Clay, black, sandy. Smells of hydrogen sulphide (H_2S)	15	300
Clay, gray, sandy	60	360
Clay, light-blue, and sand	5	365
Sand	5	370
Clay, blue, sandy	45	415

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, gray, and sand	5	420
Clay, blue-green, sandy	55	475
Clay, gray, sandy	30	505
Clay, blue-gray, sandy	5	510
Clay, blue, and black sand. Small artesian flow at 517 feet	7	517
Clay, sticky, blue, and little sand	18	535
Clay, blue, sandy, and some gravel	7	542
Clay, blue, and black sand	3	545
Clay, gray, sandy	25	570
Clay, hard sandy strata	5	575
Clay, gray, sandy. Sand strata 590 to 592 feet. Artesian water. Flow 90 gallons per minute	60	635
Total depth	—	635

8N/57-14A1. H. N. Sharp. Drilled domestic well, diameter 5 inches, depth 120 feet. 118 feet of 5-inch casing, perforations ⅛- by 2-inch slots between 50 and 98 feet. Flow 50± gallons per minute. Log from records of J. D. Hill, driller.

Material	Thickness (feet)	Depth (feet)
"Mud"	10	10
Clay	5	15
Sand and gravel. Water	20	35
Clay	7	42
Sand. Water	3	45
Clay	5	50
Sand. Water	1	51
Clay	7	58
Sand. Water	1	59
Clay	4	63
Sand. Water	1	64
Clay	4	68
Sand. Water	10	78
Clay	7	85
Sand. Water	3	88
Clay	6	94
Sand. Water	1	95
Clay	2	97
Sand. Water	2	99
Clay	6	105
Sand. Water	2	107
Clay	5	112
Sand. Water	1	113
Clay	5	118
Sand. Water	2	120
Total depth	—	120

9N/56-28B1 (tentative). Harvey Titus. Drilled stock well, diameter 6 inches, depth 70 feet. Casing perforations ⅛- by 2-inch slots from 35 to 50 feet; 6-inch casing to 59 feet. Depth to water 40 (?) feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Clay, sandy	40	40
Sand. Water	1	41
Clay, sandy	8	49
Sand. Water	2	51
Silt	19	70
Total depth	—	70

9N/56-34C1. U. S. Fish and Wildlife Service. "New well No. 2." Drilled, diameter 6 inches, depth 700 feet. No artesian flows developed during drilling. However, when casing was pulled it parted at 172½ feet, resulting in an initial flow of 190 gallons per minute which gradually reduced to about 100 gallons per minute. Temperature of water 58° F. Log from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, blue. Surface water at 10 feet	15	15
Clay, dark-blue	5	20
Clay, gray	23	43
Clay, yellow	43	86
Clay, yellow, and "sandstone"	11	97
Clay, gray	5	102

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Clay, blue	5	107
Clay, blue, and gravel	5	112
Clay, yellow, and gravel	5	117
Clay and sand. 100 feet of water in casing	5	122
Clay, gray, sandy	53	175
Sand, gray	20	195
Clay, gray	15	210
Clay and gravel	12	222
Clay and gravel, also "bedrock capping"	8	230
Clay and gravel	5	235
Gravel	5	240
Clay, yellow, and gravel	32	272
Gravel	10	282
Clay and gravel	33	315
Quicksand and gravel	10	325
Gravel and black sand	7	332
Quicksand and gravel	3	335
Sand and gravel	13	348
Clay, gray, and gravel	10	358
Sand and fine gravel	2	360
Clay, gray, and sand, alternating	104	464
Clay and gravel	4	468
Clay, gray, and sand	12	480
Clay, yellow, and sand	20	500
Clay, gray, and sand, alternating	35	535
Clay, yellow	50	585
Clay and sand, alternating	35	620
Clay, yellow, and gravel in streaks (dry)	13	633
Clay, yellow	22	655
Clay, blue and yellow	5	660
Clay, gumbo, with some pea gravel	4	664
Clay and sand with some gravel	1	665
Clay, yellow	35	700
Total depth	—	700

9N/56-35C1. U. S. Fish and Wildlife Service. "New well No. 5." Drilled, diameter 6 inches, depth 550 feet. Casing perforations 123-126, 130-132, 148-149, 152-154, 158-160, 190-193, 196-200, 220-225, 250-253, 260-263, 270-272, 302-307, 320-325, 337-339, 341-343, 350-353, 370-373, 420-425, 432-437, 450-455, and 478-483 feet. Flow 46 to 51 gallons per minute. Temperature 61° F. Data from files of U. S. Bureau of Biological Survey.

Material	Thickness (feet)	Depth (feet)
Clay, blue	20	20
Clay, gray, and some pea gravel	10	30
Clay, gray, sandy	40	70
Clay, gray, sandy, and some pea gravel	10	80
Clay, gray, sandy	10	90
Sand	5	95
Clay, gray	30	125
Sand, black. Small artesian flow 130 to 131 feet	5	130
Clay, gray, sandy	20	150
Clay, gray, sandy, and sand. Artesian flow at 158 feet	8	158
No sample. Mudding off sand strata and driving casing	12	170
Clay, gray, sandy	20	190
Sand. Artesian water 193 to 195 feet	5	195
Sand. Artesian water at 200 feet	5	200
Clay, grayish brown, and sand	15	215
Clay and sand, sand at 224 feet. Artesian water	10	225
Clay, gray, sandy	10	235
Clay, gray, sandy, and little gravel	10	245
Clay, gray, sandy	15	260
Sand. Small artesian flow	3	263
Clay, brown, and fine sand	4	267
Sand. Artesian water; flow 17 gallons per minute	8	275
Clay, gray, and fine sand	13	288
Sand, quicksand at 294 feet	6	294
Sand and clay	6	300
Sand, coarse. Artesian water 305 to 307 feet; flow 48 gallons per minute	8	308
Clay, gray, sandy	12	320
Clay, gray, sandy, and coarse sand. Small artesian flow 326 to 327 feet	7	327
Clay, gray, and gravel	13	340
Gravel. Small artesian flow	2	342
Clay and gravel. Artesian flow at 352 feet	10	352
Clay, sticky, and gravel	8	360
Clay, sticky, and fine sand	60	420

TABLE 9—*Continued.*

Material	Thickness (feet)	Depth (feet)
Gravel. Artesian water; flow 41 gallons per minute	5	425
Clay, gray, and sand	10	435
Gravel. Small artesian flow	2	437
Clay, gray, sandy	16	453
Sand. Artesian water; flow 12 gallons per minute	2	455
Clay, gray, sandy	30	485
Clay, gray, sandy; coarse sand and fine gravel. Artesian water; flow 12 gallons per minute	10	495
Clay, gray; sand and gravel	10	505
Clay, white	5	510
Clay, gray, sandy	30	540
Clay, gray, sandy, and gravel. Gravel at 550 feet. Small artesian flow	10	550
Total depth	....	550

9N/59-5C1. William Blackeye. Locally known as "Calloway well." Dug domestic and stock well, equipped with gasoline motor and cylinder pump, diameter 40 inches (steel casing), depth 40 feet. Measuring point, top of inner lip of concrete cribbing, 0.5 foot above land surface. Water level 37.62 feet below measuring point, April 18, 1948.

10N/57-30C1. Unknown. Dug unused well, diameter 48 inches, depth 15 feet. Measuring point, top of 2- by 4-inch wood sill which is 2.5 feet above land surface. Water level 13.77 feet below measuring point, July 1, 1948.

10N/57-31C1. Railroad Valley Land and Water Co. (?). "Drill hole No. 2." Carey Act withdrawal list No. 47, E. L. Fletcher, applicant. Drilled, depth 445 feet. Log from applicant's field notes and general description of proposed plan of irrigation.

Material	Thickness (feet)	Depth (feet)
Soil	15	15
Gravel	1	16
Quicksand	24	40
Gravel. Water	6	46
Clay, with streaks of gravel	44	90
Sand and gravel	15	105
Clay	30	135
Gravel	5	140
Clay	50	190
Sand	10	200
Sand and clay, alternating	10	210
Sand	7	217
Clay	17	234
Sand. Small artesian flow	2	236
Clay	2	238
Sand and clay, alternating	7	245
Sand	12	257
Clay	13	270
Sand	2	272
Clay	8	280
Sand. Water rose almost to surface	3	283
Clay with thin sand streaks	15	298
Sand, fine	5	303
Clay, brown	6	309
Sand, fine	3	312
Clay, brown	7	319
Sand, fine	3	322
Clay, brown	2	324
Sand	4	328
Clay, brown	14	342
Sand	8	350
Clay	26	376
Sand and clay	3	379
Clay, brown	55	434
Quicksand	6	440
Quicksand and gravel	5	445
Total depth	....	445

TABLE 9—*Continued.*

10N/57-32B1. Railroad Valley Land and Water Co. (?). "Drill hole No. 1." Carey Act withdrawal list No. 47, E. L. Fletcher, applicant. Gib Campbell, owner (?). Drilled, diameter 6 inches, depth 348 feet. Flow 110 to 480 gallons per minute. Temperature 61½° F. Log from applicant's field notes and general description of proposed plan of irrigation.

Material	Thickness (feet)	Depth (feet)
Soil	16	16
Sand and gravel. Abundant water	6	22
Clay	39	61
Gravel, compact. Abundant water	9	70
Clay	8	78
Gravel, cemented, hard. No water	6	84
Clay	7	91
Sand, loose. Very little water	3	94
Clay, sandy	7	101
Clay	8	109
Clay, sandy, hard	4	113
Sand, coarse, hard. Very little water	4	117
Clay, sandy	5	122
Gravel. Very little water	1	123
Clay	17	140
Clay, very hard	2	142
Sand, cemented	1	143
Gravel, coarse, cemented. No water	2	145
Clay, very hard	1	146
Sand, cemented	2	148
Clay	8	156
Sand	2	158
Clay, hard	4	162
Sand and gravel. Very little water	1	163
Clay, very hard	22	185
Clay, hard, and lake tufa, alternating	7	192
Tufa, very hard	6	198
Tufa, softer	4	202
Tufa	4	206
Gravel, thin	1	207
Clay and tufa, alternating	6	213
Tufa, very hard	1	214
Boulder	1	215
Clay and tufa, alternating	8	223
Clay, very hard	10	233
Sand, cemented, hard	1	234
Clay, cemented, hard	11	245
Gravel. Flow 8 gallons per minute	1	246
Clay, cemented, hard	5	251
Clay	17	268
Clay, white, tough	10	278
Gravel, cemented	6	284
Clay	21	305
Clay, cemented, very hard	1	306
Clay	41	347
Sand and gravel. Flow over 400 gallons per minute	1	348
Total depth	....	348

11N/57-16A1. Bureau of Land Management. Owner's designation, "Bull Creek well No. 1." Drilled stock well, equipped with windmill and cylinder pump, diameter 6 inches (steel casing), depth unknown. Measuring point, top of casing 0.5 foot above land surface. Water level 175.44 feet below measuring point, April 25, 1948.

15N/57-19A1. Bureau of Land Management. Drilled stock well, equipped with windmill and cylinder pump, diameter 6 inches (steel casing), depth 221 feet. Measuring point, top of casing, 1.0 foot above land surface. Water level 205.86 feet below measuring point, April 29, 1948.

HOT CREEK VALLEY

3N/50-15A1 (tentative). Fallini Bros. "Charlie's" well. Drilled stock well, diameter 6 inches, depth 320 feet. Six-inch casing to 320 feet, perforations ⅛- by 2-inch slots from 290 to 310 feet. Reported depth to water 280 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
"Dirt," sand and gravel	280	280
Silt	10	290
Sand and gravel. Water	2	292
Silt	18	310
Clay	5	315
Sand and gravel. Water	5	320
Total depth	----	320

4N/51-14D1 (tentative). Fallini Bros. Drilled stock well, diameter 6 inches, depth 210 feet. Casing to 210 feet, perforations ⅛- by 2-inch slots from 40 to 180 feet. Flow 50 gallons per minute reported. Driller's log.

Material	Thickness (feet)	Depth (feet)
Clay	40	40
Sand	5	45
Clay	5	50
Sand and gravel. Water	60	110
Sand. Water (?)	100	210
Total depth	—	210

5N/50-24A1. Fallini Bros. Dug stock well, equipped with windmill, gasoline motor, and cylinder pump, diameter 48 inches (wood cribbing), depth 52± feet. Measuring point, top of 8- by 8-inch timber at top of wood crib, 1.5 feet above land surface. Water level in feet, below measuring point, 1948: January 6, 38.18; April 24, 38.54.

6N/50-18D1 (tentative). Constant Vener. At mouth of Tybo Canyon. Drilled stock well, diameter 6 inches, depth 216 feet. Six-inch casing to 90 feet, no perforations. Reported depth to water 90 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Sand and gravel	85	85
Shale	131	216
Total depth	—	216

6N/50-24B1 (tentative). Constant Vener. About 7 miles east of Tybo Canyon. Drilled stock well, diameter 6 inches, depth 220 feet. Six-inch casing to 220 feet, no perforations. Reported depth to water 185 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Soil	10	10
Sand and gravel	195	205
Gravel. Water	3	208
Clay	2	210
Sand and gravel	10	220
Total depth	---	220

6N/50-~~34~~B1 (tentative). Constant Vener. About 3 miles west of U. S. Highway 6, along Tybo road. Drilled stock well, diameter 6 inches, depth 205 feet. Six-inch casing to 205 feet, no perforations (?). Reported depth to water 170 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Sand and gravel	160	165
Clay	10	175
Sand and gravel	3	178
Clay	20	198
Sand and gravel	7	205
Total depth	....	205

8N/50-31D1. Joseph Williams. Drilled domestic well, diameter 6 inches, depth 180 feet. Casing to 180 feet, perforations ⅛- by 2-inch slots from 150 to 170 feet. Depth to water 150 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Gravel, cemented	145	145
Silt	15	160
Sand. Water	1	161
Silt	14	175
Sand and gravel. Water	5	180
Total depth	----	180

8N/50-34C1. Joseph Williams. Drilled stock well, diameter 5 inches, depth 155 feet. Casing to 155 feet, perforations ⅛- by 2-inch slots from 120 to 145 feet. Depth to water 110 feet. Driller's log.

Material	Thickness (feet)	Depth (feet)
Clay and silt	20	20
Sand and gravel	60	80
Silt	45	125
Sand	1	126
Clay	4	130
Sand	25	155
Total depth	----	155

PENOYER VALLEY

3S/54-13D1. Unknown. Drilled stock well, equipped with gasoline motor and cylinder pump, diameter 6 inches (steel casing), depth 165± feet. Measuring point, top of iron cover on casing at land surface. Water level 141.91 feet below measuring point, July 1, 1948.

3S/55-6A1. Unknown. Dug and drilled stock well, equipped with wooden windmill and cylinder pump, diameter 8 inches (steel casing), depth (drilled well) 20 feet. Measuring point, top of collar on casing, 4.0 feet below land surface. Water level 14.75 feet below measuring point, May 5, 1948.