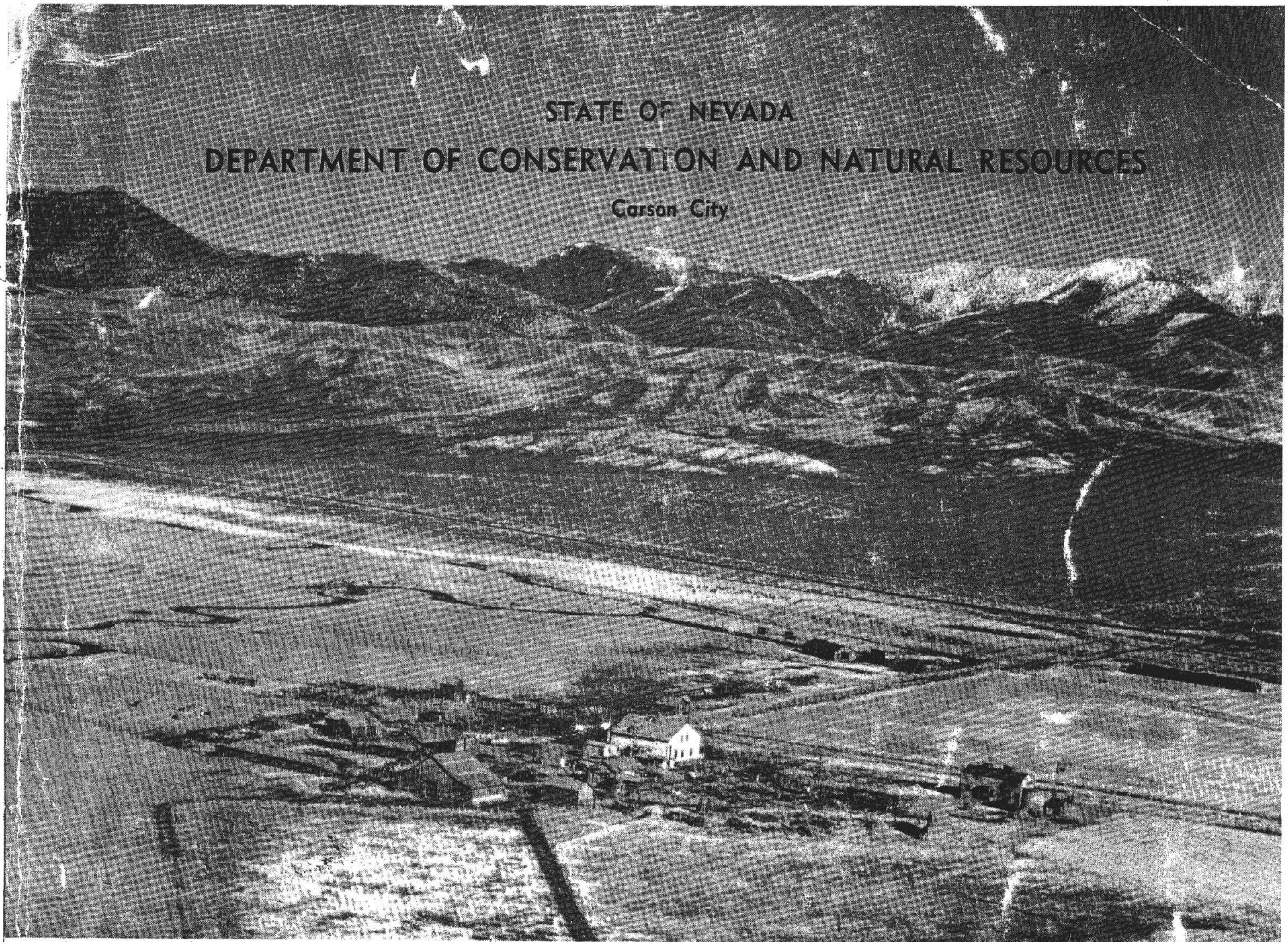


Pine Valley—View of Pine Mountain and Piñon Range

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES

REPORT 2

GROUND-WATER APPRAISAL OF PINE VALLEY
EUREKA AND ELKO COUNTIES, NEVADA

By

THOMAS E. EAKIN

Geologist

Price $1.00

Prepared Cooperatively by the

Geological Survey, U. S. Department of Interior

JANUARY 1961

VIEW OF NORTH PART OF PINE VALLEY

View to the north taken from about the south line of Sec. 29, T. 30 N., R. 52 E. shows the valley lowland northward from the J. Tomera ranch. Note the reduced width of the lowland in the middle distance and the amount of dissection of valley fill adjacent to the lowland. State Highway 20 borders the right side of the pasture land.

COVER PHOTOGRAPH

View from about the south quarter of Sec. 20, T. 30 N., R. 52 E. to the northeast showing Pine Mountain in left background and the northern part of the Piñon Range in the right background. Evans Flat in middle distance, a part of the valley upland, is a high-level pediment. Valley lowland is in the foreground. W. R. Rand ranch in lower center is the location of the weather station in Pine Valley.

GROUND-WATER RESOURCES--RECONNAISSANCE SERIES

Report 2

GROUND-WATER APPRAISAL OF PINE VALLEY EUREKA AND ELKO COUNTIES, NEVADA

By Thomas E. Eakin

Prepared Cooperatively

by the

Geological Survey

U. S. Department of the Interior

January 1961

FOREWORD

A special series of reconnaissance surveys of the ground-water resources of the state, authorized by the 1960 Legislature, has been in progress for the past six months. This program, conducted under the supervision of the State Department of Conservation and Natural Resources in cooperation with the United States Geological Survey, is designed to give information on the possibilities for development of ground-water in areas where such information is not available. It does not include areas covered, or planned to be covered, by the surveys conducted under the regular cooperative ground-water program.

The following report on a reconnaissance appraisal of the ground-water resources of Pine Valley is the second in this series. The first report, covering Newark Valley was issued in December 1960. Similar reports on other areas will be issued this calendar year.

The reports on Newark Valley and Pine Valley confirm our previously expressed opinion that this series of reconnaissance ground-water surveys will be of great value to our state.

HUGH A. SHAMBERGER
Director
Department of Conservation
and Natural Resources

January 1961.

CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER APPRAISAL OF PINE VALLEY, EUREKA AND ELKO COUNTIES, NEVADA

by
Thomas E. Eakin

SUMMARY

The results of this reconnaissance indicate that the average annual ground-water discharge from Pine Valley by natural processes is on the order of 24,000 acre-feet. The estimate is believed to be reasonable and appears to be compatible with information developed for other valleys of Nevada where more extensive studies have been made. The estimate of discharge provides an initial guide of the amount of ground water that may be developed in Pine Valley. This estimate can be refined at such time as a great many more data are available. Substantial development in the valley would provide a means of obtaining a part of the necessary data, and additional data could be obtained at such time as an intensive investigation was economically warranted.

The estimate of average annual ground-water recharge, based on precipitation and altitude zones, is about twice the estimate for discharge. This estimate of recharge was compared to another estimate obtained by using the "9-inch base" method, which was developed for the investigation in Paradise Valley, Humboldt County, and reasonable agreement was obtained. However, the latter method indicated runoff onto the valley fill much in excess of actual streamflow as estimated from the acreage under irrigation and records of runoff at the Pine Creek gaging station at the mouth of Pine Valley. The estimate of average annual recharge to the ground-water reservoir is not used for this valley as a measure of the perennial yield, because it is believed that the actual precipitation probably is less than is shown on the precipitation map of Nevada. Occasionally there are substantial differences in a given valley between the estimate of discharge and the estimate of recharge from precipitation. Generally, however, the method of estimating recharge from precipitation appears to be fairly reliable. The fact that a substantial difference occurs in the Pine Valley estimate shows the need for making a special study of the amount and the distribution of precipitation and the factors that control precipitation in Pine Valley. Many of the findings of such a study would have application throughout the entire State.

The amount of ground water in storage has been estimated to be on the order of 20,000 acre-feet per foot of saturated thickness in the valley fill within a 200,000 acre-area. This amount, which is equivalent to more than 80 percent of the estimated average annual discharge, is indicative of the very large amount of ground water in reserve for maintaining pumping withdrawals during protracted periods of drought.

Data are not available at this time to describe the chemical quality of ground water in Pine Valley. However, the fact that ground water discharged from springs and into Pine Creek has been used successfully for many years in

the valley suggests that the water is suitable at least for the crops currently grown in the area. Chemical analyses of water are needed to provide information as to the suitability of a water for new crops that might be grown and for furthering knowledge of the ground-water hydrology of Pine Valley.

Development of ground water by wells was begun several years ago with a successful irrigation well on the JD Ranch in the southern part of the valley. Deficient water supply in the last two years stimulated interest in irrigation wells in the northern part of Pine Valley. Initially, several wells were unsuccessful with respect to desired yield and drawdown. However, in the latter part of 1960, improved construction techniques resulted in the completion of an irrigation well capable of yielding more than 3,000 gpm (gallons per minute) on the Rand Ranch, and of another well which was tested at more than 2,000 gpm. The wells are about 6 miles apart, in the valley lowland along Pine Creek, and are 400 to 550 feet deep. The valley lowland probably is favorable generally for ground-water development by wells 400 to 600 feet deep. The above-mentioned wells demonstrate that wells of moderate to large capacity can be obtained by means of sound construction and development techniques.

INTRODUCTION

Ground-water development has shown a large increase in Nevada in recent years. Much attention has been given to bringing new land into cultivation through the use of ground-water supplies. The increasing interest in the development of ground water has created a substantial demand for information on ground-water resources throughout the State.

Recognizing this need, the State Legislature enacted special legislation (Chap. 181, Stats. 1960) for beginning a series of reconnaissance studies of ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U. S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources.

Interest in ground-water resources currently includes many areas and is extending to additional areas almost continuously. Thus, the objective of the studies is to provide a general appraisal of the ground-water resources in particular areas where information is urgently needed as quickly as possible. For this reason each reconnaissance study is severely limited in time. For example, most of the field work for this report was completed within a period of about 2 weeks during September and October 1960.

The Department of Conservation and Natural Resources has established a special report series to expedite publication of the results of these reconnaissance studies.

This report is the second in the reconnaissance series. It describes the physical conditions of Pine Valley and includes observations and evaluations of the interrelation of climate, geology, and hydrology as they affect ground-water resources. It includes also a preliminary estimate of the average annual recharge to and discharge from the ground-water reserv oir.

The investigation was made under the admininstrative supervision of Omar J. Loeltz, District Engineer in charge of ground-water studies in Nevada. The writer wishes to acknowledge his appreciation of the personnel of the district office for constructive discussions and review of the report, all of which have been most helpful.

Location and General Features

Pine Valley is principally in the north-central part of Eureka County, although the eastern side of the valley north of about the latitude of Bruffey Canyon is in the southwestern part of Elko County. In this report Garden and Denay Valleys at the south end of the area under discussion are included as parts of Pine Valley.

The valley extends about 55 miles southward from the Humboldt River nea Palisade. Its maximum width is about 30 miles, and is at the latitude of Mount Tenabo. Alpha Ranch, in the southern part of the valley, is about 35 miles north-northwest of Eureka. The north end of the valley is about 10 miles southwest of

Carlin and about 30 miles southwest of Elko. Pine Creek drains the valley and flows northward to Humboldt River.

Mining formerly was important to the economy of the area. Most of the production came from the Buckhorn, Cortez, and Safford districts on the west flank of the Cortez Mountains. However, the Mineral Hill district in the south end of Pine Valley is reported by Couch and Carpenter (1943, p. 60) to have yielded silver, lead, gold, copper, and zinc valued at $1,714,037.

In the early 1950's exploration for oil received widespread attention in Nevada. Lintz (1957, p. 42) reports that the Eureka Oil Co., during the period 1951 to March 1953, drilled 7 wells and started an 8th in or near sec. 11, T. 27 N., R. 52 E. No information has been released concerning the wells, but Lintz (1957, p. 42) indicates that generally the wells were drilled to about 600 feet, although one was as much as 1,500 feet deep. As of October 1960, additional drilling for oil was in progress. These wells are near the long-known oil seep at the mouth of Bruffey Canyon.

An oil test in sec. 6, T. 26 N., R. 51 E., reportedly was drilled to a depth of 3,500 feet or more. In August 1960, efforts were being made to bring the well into production from a reported oil show believed to be at a depth between 2,100 and 2,200 feet.

Ranching and farming have provided the economic base for Pine Valley for many years. In the early days, dairy farming was a prominent activity in the north end of the valley. However, most ranching operations now are devoted to raising livestock. A number of ranches, some rather large, are distributed along the main creeks of the valley. The population of the valley probably does not exceed 200.

Nevada State Highway 20, a paved road, traverses the length of the valley and connects with Carlin to the northeast and Eureka to the southeast. The Eureka-Nevada railroad (abandoned) provided a rail connection between Eureka and the east-west transcontinental rail routes in the valley of Humboldt River. Numerous roads and trails provide reasonably good access to most parts of the valley, at least during good weather.

Climate

The climate of north-central Nevada is characterized by low precipitation and humidity and high summer temperatures and rates of evaporation. Precipitation is very irregular in areal distribution but generally is least on the floors of the valleys and greatest in the highest parts of the mountains. Winter precipitation generally occurs as snow. Summer preciptiation usually occurs as localized showers. The temperature range is large both daily and seasonally. The growing season is relatively short.

Records of precipitation and temperature are available for the Weather Bureau climatological station at Elko, which is about 35 miles northeast of Pine Valley. The period of record is 90 years--one of the longest records in Nevada.

The normal monthly and annual precipitation is given in table 1, part a. Table 1, part b, lists the annual precipitation for the period 1946-59.

The published records show that the maximum recorded annual precipitation at Elko was 18.94 inches in 1904 and the maximum monthly precipitation was 6.00 inches in January 1903. Maximums for other months exceed 3 inches for all months except July, September, and October. Precipitation for the period 1986 to 1904, inclusive, averaged about 14.15 inches a year, substantially above the long-time average.

The minimum annual precipitation was 0.94 inch in 1872. The annual precipitation was less than 6 inches every year during the period 1870-83 and averaged only 4.13 inches. Precipitation has been zero several times in the months of June, July, and August.

For general comparison, precipitation during the 9-year period 1951-59, averaged only 7.83 inches.

Table 1. Summary of precipitation at Elko, Nev.

a. -- Long-term mean monthly and annual precipitation, in inches (1871-1959)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1.07	0.95	0.69	0.93	0.95	0.70	0.37	0.29	0.39	0.81	0.93	1.05	9.13

b. -- Annual precipitation, in inches (1946-59)

Year	Ppt	Year	Ppt	Year	Ppt
1946	14.09	1951	7.97	1956	10.04
1947	7.23	1952	7.28	1957	10.10
1948	5.31	1953	7.04	1958	6.40
1949	7.10	1954	6.58	1959	5.51
1950	14.60	1955	9.52		

A station was established recently at the Rand Ranch in Pine Valley, (see cover photograph). The record for this station, after several years, should be a valuable reference for the northern part of the valley. Monthly and annual records of precipitation and temperature at this station during 1957-60 are listed in table 2. During this period, the monthly precipitation ranged from a trace in November 1959 and June and September 1960 to 2.50 inches in May 1957. The temperature has ranged from 103° F, July 25, 1960, to -21° F, January 4, 1960.

The growing season is relatively short. Houston (1950, p. 14-15) shows an average growing season of 120 days (May 26 to September 23) for the middle Humboldt River area at Battle Mountain; 103 days (June 1 to September 12) for the upper Humboldt River area at Elko; and 117 days (May 29 to September 23) for Lamoille Valley at Lamoille. The respective reference altitudes are 4,500, 5,100, and 6,000 feet above sea level. On the basis of these data the average growing season in Pine Valley is estimated to be between 100 and 110 days.

A temperature of 32° F does not necessarily result in a killing frost. Because killing-frost conditions vary with crop type, the Weather Bureau records, in recent years, lists freeze data--the last spring minimum and the first fall minimum--for temperatures of 32°F or below, 28°F or below, 24°F or below, and 16°F or below. Freeze data published by the Weather Bureau for the Rand Ranch station are as follows:

	Number of days between temperatures of:			
	32°F or below	28°F or below	24°F or below	20°F or below
1957	27	51	---	---
1958	2	100	128	146
1959	1	9	60	121

Table 2. --Record of precipitation and temperature for period 1957 to 1960, Rand Ranch, Pine Valley

a. --Precipitation, in inches

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1957	0.50	0.54	1.99	1.07	2.50	1.10	0.08	0.06	0.48	0.93	1.09	0.67	11.01
1958	1.01	1.64	1.29	.32	.48	.75	.06	.61	.25	.01	.40	.83	7.65
1959	.81	.55	.57	.37	.90	.71	.61	.47	2.44	.09	T	.61	8.13
1960	.56	.93	1.07	1.57	.58	T	.21	.19	T	.33			

b. --Mean monthly temperature, in degrees Fahrenheit

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1957	--	--	--	--	--	58.7	63.8	61.8	54.4	43.5	30.3	29.4	
1958	27.0	37.5	33.3	40.4	53.7	58.5	63.5	67.3	54.5	45.2	34.4	32.3	45.6
1959	31.4	29.0	35.7	44.1	46.4	60.3	65.8	62.1	54.0	46.0	33.8	21.0	44.2
1960	19.2	27.7	39.8	43.3	49.0	60.3	--	--	--	44.2			

The Rand Ranch record of freeze data obviously is too short to represent the long-term average number of days between particular freezing temperatures. However, it does indicate that the period increases as the reference temperature is decreased. One readily may infer that the average growing season is not a single period, but is variable depending upon the particular crop as well as temper ature. The ranchers of the region qualitatively recognize this relationship. However, with good records of freeze data it may be possible to identify additional crops that could be grown successfully in the area.

Physiography and Drainage

Pine Valley is an intermontane valley elongate in a northerly direction, and is tributary to Humboldt River. It is a general hydrologic and drainage unit that includes Garden and Denay Valleys at its southern end. As so defined, it extends from Henderson Summit on the south to Humboldt River on the north--a distance of about 55 miles. Its maximum width is about 30 miles in the latitude of Mount Tenabo. The total area is about 1,000 square miles.

The Roberts Mountains at the south end of the valley are the highest in the area. Roberts Creek Mountain, altitude 10,133 feet above sea level, is the highest point.

The Sulphur Spring Range and its northern extension, the Pinyon Range, form the eastern boundary of the valley. Much of the crest altitude along the eastern side of the valley is between 7,000 and 8,000 feet above sea level. Pine Mountain, altitude 8,285 feet, is prominent in the northern part of the range, (see cover photograph). The highest point, an unnamed peak in the Pinyon Range, is 8,736 feet above sea level. The north end of the Simpson Park Mountains forms the southwestern boundary of the valley. Alluvial divides form topographic highs connecting the Simpson Park Mountains with the Roberts Mountains to the southeast and the Cortez Mountains to the northwest.

The Cortez Mountains form the western boundary of the valley. The altitude of the crest gradually increases from about 6,000 feet above sea level at the north end of the range to over 8,000 feet at the south end. Mount Tenabo, altitude 9,162 feet, is the highest peak.

The altitude of the floor of the valley gradually increases southward from somewhat less than 4,840 feet at Humboldt River to about 5,800 feet near Alpha Ranch on Henderson Creek. The average gradient is about 25 feet per mile.

Physiographically, Pine Valley can be divided into three parts--the mountain highlands, the valley upland, and the valley lowland, (see cover and photograph 6). The mountain highlands essentially coincide with the area of bedrock shown on plate 1.

The Sulphur Spring and Pinyon Ranges and the Roberts Mountains along the east and south sides of the valley, are areas of erosion and are characterized by steep gradients, deeply incised canyons, and relatively bold relief. They are underlain to a large extent by limestone and dolomite of Paleozoic age. The Cortez Mountains along the west side of the valley also are areas of erosion. However, the general surface slopes to the east or southeast and approximates the dip of the underlying volcanic lavas. The canyons that dissect the eastern slope of the Cortez Mountains are steep sided, and commonly the highland surfaces between them are comparatively smooth.

The valley upland and valley lowland are underlain by valley-fill deposits of Tertiary to Recent age. The valley upland comprises two pediment surfaces referred to by Regnier (1960, p. 1203-1204) and, locally, lower hills which are eroded remnants derived from those surfaces. The valley upland is characterized by surfaces that dip gently toward the axis of the valley, are relatively smooth, and commonly are veneered by gravel which overlies comparatively fine-grained sediments of Tertiary age, (see photograph 2). The slope of the upland surfaces ranges from about 100 to 300 feet per mile and averages about 200 feet per mile. After the deposition of the bulk of the valley fill, erosion developed an extensive high-level pediment surface. Partial dissection of this pediment resulted in the development of a lower level pediment which also might be referred to as a stream eroded terrace. Subsequent downcutting developed the large main drainage-ways. Most of these events took place in late Pleistocene time.

The valley lowland comprises the lower lying parts of the main drainage-ways of Pine, Henderson, Denay, and Horse Creeks and their principal tributaries. The gradient of the axial part of the valley lowland from about the middle of T. 27 N., R. 51 E., is about 16 feet per mile northward toward Humboldt River. The gradient of the lower lying parts of the Henderson, Denay, and Horse Creek segments may average about 20 feet per mile. Sections of the valley lowland along tributary drainageways have steeper gradients as the mountain fronts are approached.

Present-day runoff is small. Substantial flows occur in some years from the spring snow melt and for short periods of a few hours from cloudbursts. The low flow of perennial segments of streams or creeks is supplied by ground-water discharge, principally through springs. For example, Pine Creek, the principal stream in the valley, is maintained largely by the 4 to 5 cfs (cubic feet per second discharged from hot springs in the NW 1/4 sec. 12, T. 28 N., R. 52 E. (see photograph 5).

Present-day streams have rather small but well-defined channels in the valley lowland. The part of Pine Creek north of the Slagowski Ranch, locally, is incised as much as 15 feet where it crosses the lower part of recent alluvial fans. There is another good example of this downcutting in sec. 32, T. 31 N., R. 52 E., just south of Ferdelford Creek. However, for much of its length, Pine Creek is cut a few feet or less into the floor of the valley lowland. In fact, in man areas in the southern part of the valley lowland, overland runoff merely flows across brush-covered topographic lows.

Streamflow Records

A recording stream-gaging station was maintained on Pine Creek from January 1, 1946, through September 1958 at a point below all diversions in the NW 1/4 SE 1/4 sec. 1, T. 31 N., R. 51 E. Prior to that time, many discharge measurements and staff-gage readings had been made from November 1902 through December 1904 and from February 1912 through September 1914. Table 3 shows the monthly discharge, in acre-feet, of Pine Creek for the period January 1946 through September 1958, as compiled from published records of the U. S. Geological Survey. (See Water-Supply Papers 1314, p. 377; 1214, p. 202; 1244, p. 196; 1284, p. 180; 1344, p. 197; 1394, p. 187; 1444, p. 186; 1514, p. 185; and 1564, p. 196). The record indicates that the average annual stream discharge from Pine Valley is about 8,400 acre-feet.

Because of the geology and topography of the north end of the valley, ground water discharges to the stream channel in the lower reaches of Pine Creek. However, data are not available to define precisely the proportion of the total discharge of Pine Creek that is derived from ground-water discharge. A preliminary estimate is that more than 50 percent of the average annual streamflow, about 5,000 acre-feet, may be supplied by ground-water discharge.

Table 3.--Monthly and annual flow, in acre-feet, of Pine Creek near Palisade

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water year
1946	--	--	--	1,240	3,530	4,310	6,450	1,720	993	801	231	422	19,700
1947	1,190	1,200	1,130	758	1,740	1,010	443	165	132	13	26	53	7,860
1948	336	774	805	924	887	979	506	101	35	14	13	21	5,440
1949	318	645	738	676	584	2,190	2,800	808	200	41	52	58	9,110
1950	373	662	585	647	942	1,040	1,470	688	209	102	22	53	6,790
1951	280	917	1,770	1,510	3,390	1,680	751	299	110	37	63	42	10,850
1952	431	706	625	552	847	4,580	16,010	4,400	281	143	76	163	28,810
1953	446	730	648	952	720	741	271	20	11	5.2	11	46	4,600
1954	266	514	517	471	780	576	135	17	22	12	3.4	74	3,390
1955	282	486	564	404	416	1,270	284	12	4.8	0.2	126	22	3,870
1956	170	331	931	1,650	793	3,790	1,260	566	148	9.5	12	79	9,740
1957	335	441	591	442	662	852	480	203	84	5.8	17	108	4,220
1958	410	593	608	683	966	1,200	1,890	11	10	8.5	9.1	7.7	6,400
Average	407	667	793	806	1,060	1,660	2,190	608	104	33	36	60	8,420

GENERAL GEOLOGY

On the basis of their general relation to ground water and their topography, the rocks of Pine Valley may be divided into two gross units, the bedrock and the valley fill.

The bedrock includes rocks of Paleozoic age, consisting principally of limestone, dolomite, and quartzite; intrusive rocks of probable Late Cretaceous or early Tertiary age; and related lavas and pyroclastic rocks of early Tertiary (?) age. These rocks crop out in the mountain areas surrounding Pine Valley and underlie the valley fill.

The valley fill includes sediments that range in age from early Tertiary to Recent. The valley fill has a maximum thickness of several thousand feet. The rock types are diverse; they include conglomerate, sandstone, vitric tuff, and pyroclastics and lesser amounts of limestone, diatomite, and lava flows.

Bedrock in the Mountains

The formations of Paleozoic age in the Roberts Mountains at the south end of the valley have been studied by Merriam and Anderson (1941). Extensive studies of the Eureka area about 30 miles southeast of the Roberts Mountains by Nolan (1943) and by Nolan, Merriam, and Williams (1956) provide valuable background information on the Paleozoic stratigraphy. Carlisle, Murphy, Nelson, and Winterer (1957) discuss the Devonian stratigraphy of the Sulphur Springs and Pinyon Ranges. Carlisle and Nelson (1955) briefly discuss the Paleozoic stratigraphy of the Mineral Hill region. Fads (1960) recently reported on the Permian stratigraphy at Carlin Canyon. Further investigations of the bedrock in the Cortez Mountains are in progress by personnel of the U. S. Geological Survey. Reeves and Shawe (1956, p. 1779) discussed the geology of the bedrock in the northern part of the Cortez Mountains. Emmons (1910, p. 95-110) gave brief descriptions of the geology in the several mining districts in the mountains bordering Pine Valley. He reports that Ordovician limestone is intruded by grandodiorite in the Buckhorn District; that Tenabo Peak is composed of limestone of Paleozoic age; that quartzite is intruded by granitic rocks and porphyries; that limestones of Paleozoic age are cut by altered dikes in the Mineral Hill district; and that the country rock (bedrock) includes diorite, vesicular andesites, and diorite porphyries, all of which are probably related to centers of volcanism of Tertiary age.

An oil test was drilled in 1956 in the NW 1/4 sec. 6, T. 26 N., R. 51 E., along Henderson Creek and about 2 miles south of the Knight Ranch. Reportedly the well was drilled to a depth of about 3,500 feet. It was reported also that surface casing was set to a depth of 800 to 900 feet, which suggests that the surface of the bedrock may lie at that depth at this site.

Valley Fill

The valley fill in the northern part of Pine Valley has been studied in some detail by Regnier (1960). The dissection of the fill in late Quarternary time provides numerous exposures which greatly facilitate the study of the Cenozoic geology and history of the area, (see photograph 2). A more complete knowledge of the Cenozoic geology and history will be valuable for a better under standing of ground-water conditions in Pine Valley. It also will be an important key in unraveling the Cenozoic geology, structure, and history of the Humboldt River drainage basin. Further, the knowledge is important economically because the occurrence and movement of ground water are controlled to a very large extent by the nature of the Cenozoic deposits.

Regnier (1960, p. 1191) gives the following outline of the Cenozoic stratigraphy. These new formation names are those used by Regnier and are not necessarily those of the U. S. Geological Survey.

Age	Formation [Nomenclature of Regnier, 1960]	Lithology	Thickness (feet)
Late Pleistocene to Recent	Alluvium	Pediment gravel and deposits of the present streams. Also welded tuff	30
Erosional unconformity			
Middle Pliocene to middle Pleistocene	Hay Ranch formation	Fanglomerate, conglomerate, sandstone, clay, and limestone. Some vitric tuff mostly, altered to zeolite. . .	Possibly several thousand feet
Early Pliocene	Carlin formation	Tuffaceous sandstone and conglomerate, vitric tuff, shale, limestone, and diatomite. (Not present in Pine Valley)	600+
Late Miocene or early Pliocene	Palisade Canyon rhyolite		500
Slight angular unconformity			
Late Miocene	Raine Ranch formation	Lapilli tuff, volcanic breccia, lava flows, vitric tuff, diatomaceous shale, and limestone	2,000
Slight angular unconformity			

Age	Formation [Nomenclature of Regnier, 1960]	Lithology	Thickness (feet)
Late Oligocene(?) or early Miocene (?)	Safford Canyon formation	Tuffs, tuffaceous conglomerate, and sandstone	700
	Flight angular unconformity		
Oligocene (?)	Rand Ranch formation	Sandstone and conglomerate	1,700
	Erosional unconformity		
Early Tertiary (?)	Volcanic rocks of the Cortez Mountains	Two sequences of flows and pyroclastic rocks separated by angular unconformity	3,500+

Geologic History

The geologic history of an area is useful to portray events that bear on the interpretation of the occurrence and movement of ground water.

For the Pine Valley area, Regnier's study (1960) of the geology and history of the valley fill provides greater detail than is usually available for valleys of Nevada. Therefore, the following nomenclature and tentative history are adapted largely from Regnier (1960, p. 1204, 1205).

1. Deposition of many thousands of feet of limestone, dolomite, sandstone (later altered to quartzite) and shale, of Paleozoic age. Involves complex history of sedimentation, erosion, folding, and faulting which is discussed by Nolan (1943), Nolan, Merriam, and Williams (1956), and others.

2. Extrusion of older volcanic rocks in Late Cretaceous to early Tertiary (Paleocene?) time.

3. Folding and intrusion of diorite and grandiorite in Eocene (?) time.

4. Erosion and formation of younger volcanic rocks in Oligocene (?) time.

5. Deformation (folding, faulting, or both) and deposition of Rand Ranch formation in Oligocene (?) time.

6. Faulting, involving tilting of Cortez Mountains and deposition of Safford Canyon formation, in late Oligocene(?) and early Miocene(?) time.

7. Renewed faulting and additional tilting of Cortez Mountains, continued erosion, and resultant deposition of lower member of the Raine Ranch formation in late Miocene time.

8. Basin and Range faulting, involving movement along fault on west side of Pinyon Range, in late Miocene time.

9. Extrusion of Palisade Canyon rhyolite in late Miocene time.

10. Warping or folding of Palisade Canyon rhyolite; erosion, and deposition of Carlin formation in nearby Carlin basin and other lowland areas in early Pliocene time.

11. Renewed faulting along west side of Pinyon Range and Cortez Mountains, erosion, and deposition of Hay Ranch formation in middle Pliocene and middle Pleistocene time.

12. Dominantly erosion in late Pleistocene to Recent time, involving:

    a. Development of upper pediment--for example, Evans Flat, 700 feet above grade of Pine Creek.

    b. Downtilting of high-level pediment.

    c. Development of lower partial pediment, 120 feet above grade of Pine Creek.

    d. Downcutting in present main drainageway of Pine Creek.

    e. Partial filling of main drainageway of Pine Creek.

    f. Minor downcutting of younger fill, forming present channel of Pine creek.

Water-Bearing Properties of the Rocks

The oldest rocks in the area are of Paleozoic age and are exposed principally in the mountains along the east and south sides of the valley. They consist chiefly of limestone and dolomite, and lesser amounts of quartzite and shale. Consolidated rocks of this type usually have a low primary permeability--that is, openings present at the time of deposition are small or have been filled up. However, the rocks have been substantially faulted, folded, and weathered and otherwise altered; they locally contain many secondary openings, mainly joints.

These fractures, which locally have been enlarged by solution, have created substantial permeability in some of the limestone and dolomite. At least locally, this secondary permeability may be quite important with respect to the movement of ground water in the bedrock. The occurrence of several important springs alined adjacent to the contact of the bedrock and valley fill strongly suggest that secondary permeability in the bedrock is important in Pine Valley. Hot springs in sec. 12, T. 28 N., R. 52 E., having an estimated discharge of 4 to 5 cfs, are the largest of this type. Other examples of springs having discharges of about half a cubic foot per second are Austin and Edwards springs in sec. 23, T. 27 N., R. 52 E. Springs of this type are found principally on the east side of Pine Valley.

In many areas the Paleozoic rocks underlie the valley fill at substantial depths. Locally, at least, they should be capable of transmitting ground water. However, data are not available to identify the degree to which ground water could be developed from these rocks by wells on the valley floor.

The early Tertiary volcanic lavas, which are exposed principally in the Cortez Mountains, commonly are fractured to some extent. The resultant secondary permeability allows limited movement of ground water in them. Several small springs on the east flank of the Cortez Mountains discharge ground water from the volcanic rocks.

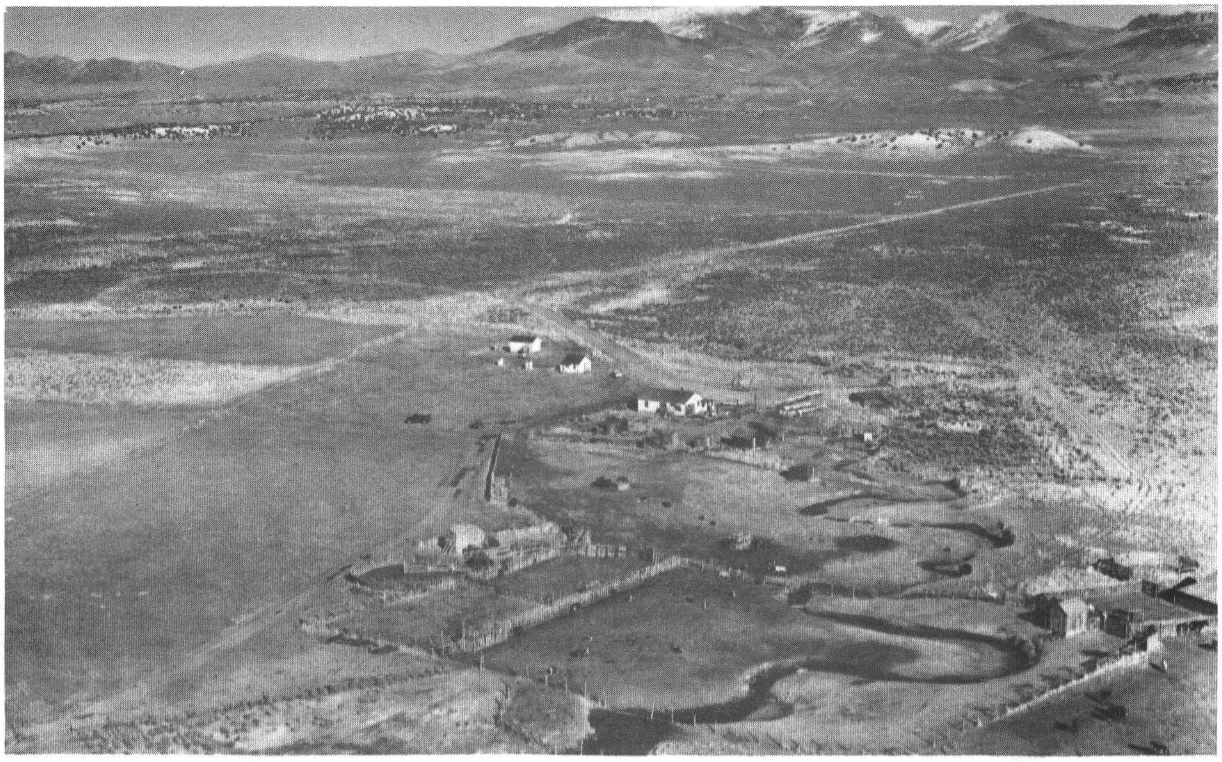
The Tertiary and Quaternary formations that compose the valley fill in Pine Valley span a nearly complete range of sedimentary and pyroclastic rock types, and also include some extrusive lavas. Although Tertiary formations of the valley fill differ considerably in their capacity for storing ground water, collectively they contain a large volume of ground water in storage.

A large part of the valley fill probably has a relatively low permeability and therefore will not yield water readily to wells. However, the valley fill also contains sand and gravel strata which locally are sufficiently permeable to yield water freely to adequately constructed wells. Examples of these strata are the sand and gravel water-bearing zones in the lower parts of irrigation wells 30/52-29A1, 29/52-29B1, and 25/50-1D1.[1/] (See also photographs 3 and 4). Water-bearing sand and gravel, such as these, may be encountered in various locations and depths in the valley fill of Tertiary age. Present knowledge, however, does not permit delineation of the areal and vertical extent of specific sand and gravel units. Several wells, which have proved unsatisfactory with respect to desired yields, have been drilled in the last 2 years within a few miles of the successful irrigation wells mentioned above. In part, it may be that suitable water-bearing zones were not penetrated within the depth drilled at the respective sites.

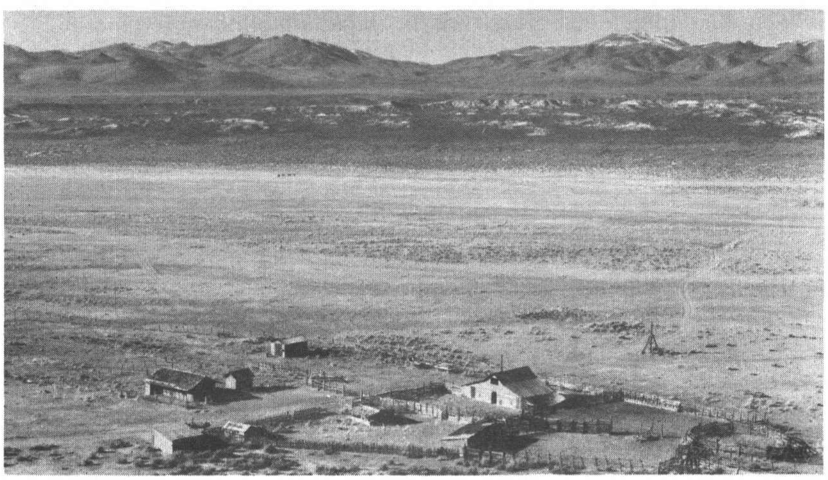
Sediments of Quaternary age are composed of silt, sand, and gravel derived from the bedrock and from reworked sediments of the valley fill of

---

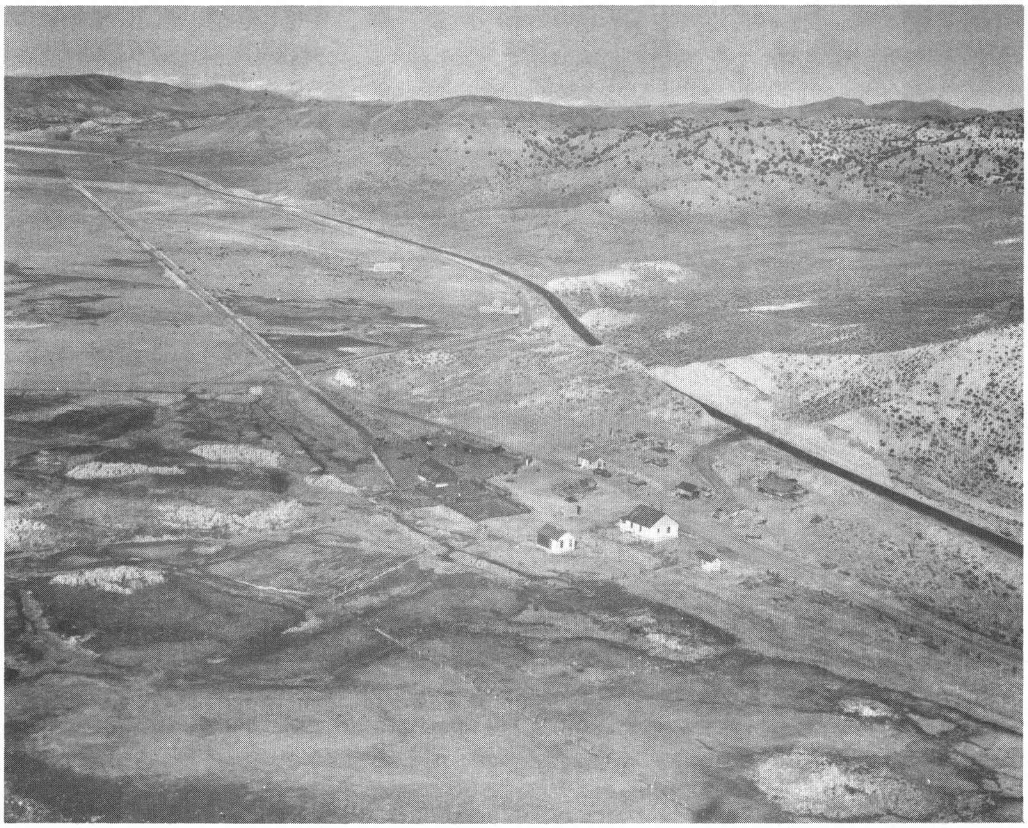
1/ The well-numbering system is described in the section "Designation of Wells."



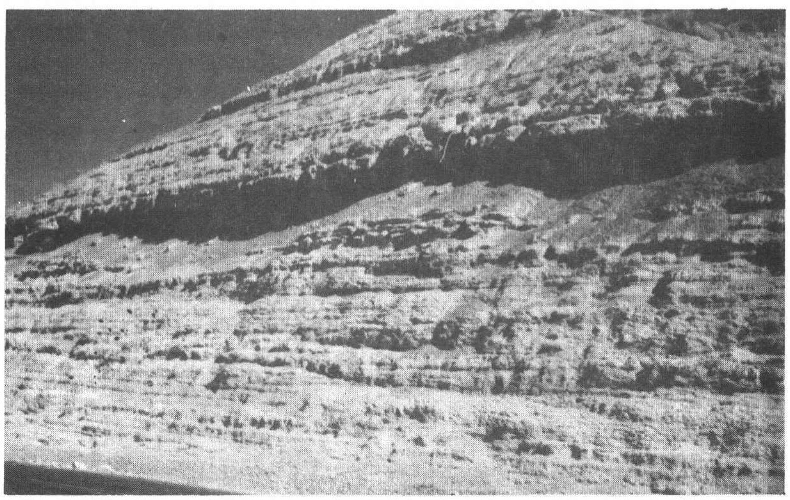
Photograph 5. View from about the east line of Sec. 17, T. 28 N., R. 52 E. to the northeast showing Hot Creek at the F. Slagowski ranch. Hot Creek is supplied from hot springs to the right of the picture about 3 miles east of the ranch. The discharge of the hot springs is 4 to 5 cubic feet per second.



Photograph 6. View from about Sec. 30, T. 27 N., R. 51 E. to the northwest. Knight ranch is at bottom of photograph. Valley lowland is in foreground. The dissected margin of the valley upland is beyond the valley lowland. The crest of the Cortez Mountains forms the skyline.



Photograph 3. View to northeast showing seep area in the valley lowland at the B. Tomera ranch. Seep area on left side and bottom of photograph is due, in part, to the constriction of the valley lowland by the hill of older valley fill in upper right side of the photograph. The road cut at upper right edge of photograph is shown in detail in photograph 4.



Photograph 4. View of road cut on east side of State Highway 20 near entrance to B. Tomera ranch. Most of roadcut is formed of fine grained sediments of the Hay Ranch formation. The two dark shadow bands mark the location of beds of loose gravel 1 to 3 feet thick. Gravel of this type, where below the zone of saturation, would yield water readily to wells. If such beds were sufficiently thick, large-capacity wells could be obtained.

Tertiary age. These contain ground water principally beneath the valley lowland. The records of several wells drilled along Pine Creek, and at the JD Ranch on Henderson Creek, suggest that relatively permeable sand and gravel commonly occur at depths of less than about 100 feet. These water-bearing zones probably are in sediments of Quaternary age.

GROUND-WATER APPRAISAL

General Conditions

Ground water in Pine Valley is presumed to originate largely or entirely in precipitation within the drainage basin. Precipitation on the flanks of the Sulphur Spring and Pinyon Ranges and the Roberts Mountains, and to a lesser extent the Cortez and Simpson Park Mountains, undoubtedly supplies most of the recharge to the ground-water reservoir. Precipitation on the valley fill apparently is effective in recharging the ground-water reservoir principally when the resulting runoff concentrates along sections of the valley lowland that are favorable for the downward percolation of water.

The valley fill is the principal ground-water reservoir. Some water occurs also in bedrock where continuity of openings permits. Locally, some ground water is perched, or held up, by relatively impermeable rock units in the upper parts of the valley fill. Small seep areas, or areas of phreatophytes, above the regional water table are evidence of this perched ground water.

Ground water is discharged by evapotranspiration, springs and seeps (see photograph 3) and discharge into Pine Creek, and to a minor extent by underflow from the north end of the valley. Water from springs along the margins of the valley fill is used largely for irrigation or is wasted so that ultimately it is transpired by vegetation or evaporated. Transpiration by meadow grasses, greasewood, rabbitbrush, salt grasses, willows, and other phreatophytes, together with direct evaporation where the water table is at or near the land surface, are the principal means of discharge of ground water from the valley. Most of this discharge occurs in the valley lowland.

The water table generally is 0 to 5 feet below the land surface along Pine Creek from about the Slagowski Ranch (T. 28 N., R. 52 E.) northward to the mouth of the valley. South of T. 28 N., R. 52 E., as far as the southwestern part of T. 26 N., R. 52 E., the depth to water increases somewhat along Pine Creek and its extension, Horse Creek, and may average about 10 feet below the land surface. Water is within a few feet of the land surface from the lower part of Garden Valley to a short distance south of the JD Ranch. From a point about 1 1/2 miles south of the ranch, where the water level is about 10 feet below the land surface, the depth to water along Garden Valley increases somewhat for a few miles. However, in the vicinity of the Alpha Ranch it again is relatively shallow. The depth to water commonly is 10 feet or less in the lower parts of other drainageways tributary to the principal creeks but increases toward the mountains, except where this relationship is modified by ground water discharged from springs near the contact of bedrock and valley fill.

The amount of ground water in storage in the valley fill is substantial and is many times the volume that is annually recharged to and discharged from the valley fill.

Estimated Average Annual Recharge

An estimate may be made of the average annual recharge to the ground-water reservoir as a percentage of the average annual precipitation within the valley. The general method is described in an earlier report (Eakin and others, 1951, p. 79-90). Briefly, it is as follows: Zones in which the precipitation ranges between specified limits are delineated on a map and a percentage is assigned to each zone which represents the probable average recharge from the average annual precipitation on that zone. The degree of reliability of the estimate so obtained is, of course, related to the degree to which the values approximate the actual precipitation and the degree to which the assumed percentages represent the actual percentages of recharge. Neither of these factors is known precisely enough to assure a high degree of reliability for any one valley. However, the method has proved useful for reconnaissance estimates, and experience suggests that in many areas the estimates probably are relatively close to actual long-time average annual recharge.

The precipitation map of Nevada (Hardman 1949, p. 10) was recently modified for Pine Valley by Hardman (written communication, 1960) on the same base map used for plate 1.

The modified map shows the zone of 8 to 12 inches of precipitation to be below the 6,000-foot contour; the zone of 12 to 15 inches of precipitation, between the 6,000- and 7,000-foot contours; the zone of 15 to 20 inches of precipitation, between the 7,000- and 8,000-foot contours; and the zone of more than 20 inches of precipitation, above the 8,000-foot contour.

The average precipitation assumed for the respective zones, beginning with the zone of 8 to 12 inches of precipitation, is 10 inches (0.83 ft.), 13.5 inches (1.12 ft.), 17.5 inches (1.46 ft.) and 21 inches (1.75 ft.).

The recharge estimated as a percentage of the average precipitation for each zone is as follows: 8 to 12 inches, 3 percent; 12 to 15 inches, 7 percent; 15 to 20 inches, 15 percent; and over 20 inches, 25 percent.

Table 4 summarizes the computation. The approximate average annual recharge, in acre-feet (column 5), for the zone of 15 to 20 inches of precipitation is obtained by multiplying the area of the zone (column 2) times the average precipitation (column 3) times the percent recharge (column 4) divided by 100, and rounding the product. Thus, for the 15- to 20-inch precipitation zone: 64,000 x 1.46 x 15 ÷ 100 = (about) 14,000 acre-feet. Estimates of the recharge for the other zones are computed in a similar manner.

The average annual recharge from precipitation, as shown in table 4, is estimated to be on the order of 46,000 acre-feet. This is nearly twice the estimated discharge of 24,000 acre-feet, which is discussed in a subsequent section. In previous studies of most other valleys the divergence between the estimated recharge and discharge has been comparatively small. The specific reason or reasons for the large divergence between these estimates in the present study is not yet known.

Table 4.--Estimated average annual ground-water recharge from precipitation in Pine Valley

(1) Precipitation Zone (inches)	(2) Approximate acreage of zone	(3) Average annual precipitation (feet)	(4) Percent recharge	(5) Approximate recharge (acre-feet) (2x3x4÷100)
20+	11,000	1.75	25	4,800
15-20	64,000	1.46	15	14,000
12-15	256,000	1.12	7	20,000
8-12	307,000	0.83	3	7,700
				(45,500)
Estimated average annual recharge (rounded)				46,000

To examine further the possible recharge from precipitation, a method for evaluating the amount of water available for recharge as used by Loeltz, Phoenix, and Robinson (1949, p. 34-36) was tried for Pine Valley. In applying this method, only the precipitation zones above the 6,000-foot contour are used because that contour approximately coincides with the contact of bedrock and the alluvium. It is assumed that about 9 inches of precipitation is needed to satisfy evapotranspiration requirements in the bedrock drainage area. Precipitation in excess of this amount in the bedrock drainage area is assumed to be available for streamflow to the valley fill, a part of which, presumably, will recharge the ground-water reservoir.

The total area in Pine Valley above the 6,000-foot contour is about 330,000 acres. The average precipitation over this area, as computed by summing the precipitation in the three higher zones of precipitation, is 1.21 feet. Nine inches of precipitation over the area is equivalent to about 248,000 acre-feet. Subtracting the 248,000 acre-feet from total precipitation of about 400,000 acre-feet gives a value of about 152,000 acre-feet which presumably is available for ground-water recharge. In the Paradise Valley study, it was estimated that probably about one-third of the amount of water available for recharge actually reached the ground-water reservoir. On this same basis, recharge to the ground-water reservoir in Pine Valley would be approximately 50,000 acre-feet a year. This is in reasonable agreement with the value derived by the percentage method of estimating recharge (table 4). However, this method gives values for the amount of water "available" for runoff from the bedrock drainage area that are considerably higher than one would estimate on the basis of acreage in Pine Valley that is irrigated by surface water. To illustrate, in Paradise Valley it was estimated by Loeltz, Phoenix, and Robinson (1949, p. 38-39) that about 20,000 acres was irrigated during years of average runoff and that the average runoff was about 70,500 acre-feet. On the same basis an average available runoff of 152,000 acre-feet would irrigate more than 40,000 acres in Pine Valley. However, the average acreage under irrigation in Pine Valley is far less, probably less than 7,000 acres.

Observations made during this study indicate that most of the available surface water is being utilized for irrigation. Thus it appears that the average "available" runoff, as computed by the 9-inch-base method, is substantially larger than the actual runoff. Because of the large discrepancies between values computed on the basis of precipitation estimates and values based on actual use of water and other conditions in the valley, the need for a special study of the recharge factors in Pine Valley is apparent and is the subject of a recommendation in the latter part of this report. For this report, principal weight is given to the estimate of ground-water discharge as a measure of the perennial yield of Pine Valley.

Estimated Average Annual Discharge

Ground water is discharged ultimately from Pine Valley by transpiration of water-loving vegetation (phreatophytes), by evaporation from soil and free-water surfaces, and to a lesser extent by surface and underground flow from the north end of the valley. Discharge by springs and wells within the valley is eventually discharged from the valley by the above methods. Stock and domestic consumption is a relatively minor quantity. Thus, an estimate of natural discharge of ground water may be made by evaluating the amount of ground water tha is transpired and evaporated, and that which is discharged from the valley by surface and underground flow. Table 5 summarizes the estimates of discharge from Pine Valley by evapotranspiration, streamflow, and ground-water underflow from the valley.

Several investigators have made studies of evapotranspiration by certain types of phyreatophytes. The studies of Lee (1912) and White (1932), made in the Great Basin, and Young and Blaney (1942), made in southern California, form the basis for the estimates used in reconnaissance studies in Nevada.

The areas of phreatophytes were roughly outlined by field reconnaissance and by interpolating from data on the Palisade and Pine Valley quadrangles of the Northeastern Nevada Cooperative Land-Use Studies (1941?), which cover the valley north of the middle of T. 26 N.

Rates of ground-water use were assigned on the basis of principal species of phreatophytes, approximate average density, and depth to water table.

Table 5. -- Estimated average annual ground-water discharge from Pine Valley

Process of ground-water discharge	Area (acres)	Approximate discharg (acre-feet per year)
Evapotranspiration:		
(a) Meadow and pasture [1/]	6,850	8,000
(b) Native vegetation [2/]	26,600	9,100
(c) "Correction" for below-average conditions [3/]		2,000
Discharge to Pine Creek (rising water)		5,000
Underflow from mouth of Pine Valley		300
		(24,400)
Estimated average annual discharge (rounded)		24,000

1/ Mixed meadow grasses, depth to water, 0 to 5 feet below land surface. Actual totals of acreage and discharge are summations of numerous small tracts, and discharge estimates in which the rate of ground water use generally was estimated at either 1.0 foot or 1.25 feet per year. Meadow and pasture land is irrigated largely by spring discharge and shallow ground water. Irrigation from overland runoff is not included.

2/ Includes greasewood, rabbitbrush, salt grass, willows, and possibly other phreatophytes in varying proportion, density generally moderate to low, depth to water ranging from a few to about 20 feet. Actual discharge and acreage totals are summations of numerous tracts, and discharge estimates are separated for convenience in developing total estimate. Estimated rates of use for individual tracts ranged from 0.1 to 0.5 foot, depending on average depth to water and density.

3/ Estimates of evapotranspiration were made on basis of existing below-average water-supply conditions. The value assigned to "correct" evapotranspiration to a long-term average is made only in recognition of the fact that the present discharge by evapotranspiration probably is below the long-time average by a significant amount, perhaps on the order of 10 to 15 percent.

Residents in the valley report that the last 2 years were very dry, and these reports are supported by the fact that several attempts were made during this period to develop irrigation wells to augment the present water supplies for the ranches in the lower part of Pine Valley. Also, the poor condition of phreatophyte growth observed, especially south of T. 28 N., is indicative of a below-average water supply for the last year or two.

Other things being equal, the rate of ground-water use by phreatophytes decreases with increasing depth to water. Where the depth to water fluctuates in a range that is less than 10 feet below the land surface, the rate of ground-water use by phreatophytes will decrease substantially if the average water table is lowered 2 or 3 feet. On this basis, the estimate of phreatophyte discharge shown in table 5 may be as much as several thousand acre-feet too low to represent the long-time average discharge by this process. Therefore, a value of 2,000 acre-feet is shown to "correct" the estimate to a long-term basis. This value is qualitative only and is intended to illustrate that the present phreatophyte discharge is below the long-term average by a significant amount. However, it is doubtful that the present (1960) annual deficiency in phreatophyte discharge is less than several hundred or more than several thousand acre-feet below the long-term average.

The flow of Pine Creek, the record of which was given in a preceding section, is composed of both direct runoff and ground-water discharge. Data are not available to define precisely the contribution of ground water to the total flow as recorded for Pine Creek. However, a rough estimate may be made on the basis of an average runoff hydrograph of Pine Creek and a knowledge of the physical conditions in the lower reach of Pine Creek.

The average monthly discharge, in acre-feet, of Pine Creek at the mouth of Pine Valley for the 12 complete water years 1947-58 is tabulated below:

Oct.	407	Feb.	1,060	June	104
Nov.	667	Mar.	1,660	July	33
Dec.	793	Apr.	2,190	Aug.	36
Jan.	806	May	608	Sept.	60

If a hydrograph is constructed using these figures, a peak is shown for the months February through May, which is assumed to be the result of direct runoff. It may be assumed further that the discharge in the remaining months is essentially the result of ground-water discharge. Then by sketching a smooth curve through the months February through May, controlled by the curve defined for the other months, the average contribution of ground-water discharge to the recorded flow of Pine Creek for the period of record would be about 5,500 acre-feet a year.

A more conservative estimate can be made if it is assumed that part of the flow of Pine Creek during the months October through January also resulted from direct runoff. For example, if it were assumed that 20 percent of the runoff during October through January were direct runoff, the estimated ground-water contribution would be about 4,400 acre-feet a year for the period. For the purpose of this report it is assumed that 5,000 acre-feet a year is the approximate ground-water contribution to the recorded average annual flow of Pine Creek at the gaging station. Further refinement of the contribution of ground water to the flow of Pine Creek would require considerably more data and field control.

Ground-water underflow, or subsurface outflow, from the mouth of Pine Valley is limited by the relatively narrow cross-sectional area through which it takes place. The formula $Q = 0.00112TIW$ provides the basis for computation, where Q = quantity of underflow, 0.00112 converts gallons per day to acre-feet per year, T = transmissibility[1/] of the water-bearing deposits, I = ground-water gradient, and W = the width of the section through which ground water moves. The terms are given in the following units: Q, in acre-feet per year; T, in gallons per day per foot times 0.00112; I, in feet per mile; and W, in miles.

Recent fill deposits are less than 100 feet wide in the vicinity of the gaging station. Some underflow may occur in the older valley-fill deposits, but the total width through which ground water is moving down-valley probably would not exceed 0.5 mile. A transmissibility of 100,000 gallons per day per foot probably is a reasonable value for this section. The hydraulic gradient is about constant and parallel to the land surface, which averages about 5 feet per mile. Substituting these figures in the formula, $Q = 0.00112 \times 100,000 \times 5 \times 0.5$, a value of less than 300 acre-feet per year is obtained for ground-water underflow from Pine Valley.

The estimates of ground-water discharge by evapotranspiration, discharge into Pine Creek, and underflow from the mouth of Pine Valley indicate that the long-term average annual discharge from Pine Valley is about 24,000 acre-feet.

Perennial Yield

The perennial yield of the ground-water system is ultimately limited by the average annual recharge and discharge circulating into and out of the system. It is the upper limit of the amount of water that can be withdrawn for an indefinite period of time from a ground-water system without permanent depletion. The average recharge from precipitation and the average discharge by evapotranspiration, discharge to streams, and underflow from a valley are measures of the natural inflow to and outflow from the ground-water system.

1/ The transmissibility may be expressed in terms of gallons per day, at the prevailing ground-water temperature, through a strip of aquifer 1 foot wide extending the full height of the aquifer under unit hydraulic gradient, or through a section of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

In an estimate of perennial yield, consideration should be given to the effects that ground-water development by wells may have on the natural circulation of the ground-water system. Development by wells may, or may not, induce recharge in addition to that received under natural conditions. Part of the water discharged by wells may re-enter the ground-water reservoir by downward percolation, especially if the water is used for irrigation. Ground water discharged by wells usually is offset eventually by a reduction of the natural discharge. In practice, however, it is difficult for well discharge to offset the natural discharge fully, except when the water table has been lowered to a level that eliminates both underground outflow and transpiration in the natural area of discharge. The complexities of the numerous pertinent factors are such that, in effect, specific determination of perennial yield of a valley requires a very extensive investigation based in part on data that can be obtained economically only after there has been substantial development of ground water for several years.

As an initial guide for the development of Pine Valley, the preliminary estimate of ground-water discharge, previously discussed, may be used. Thus, the estimate of discharge of 24,000 acre-feet per year, as determined in this brief reconnaissance, is also considered the preliminary estimate of the perennial yield of Pine Valley. The crude data and assumed values used in the estimate make it apparent that the actual perennial yield of the natural ground-water system may be several thousand acre-feet a year more or less than this estimate.

Storage

A large amount of ground water is stored in the valley fill in Pine Valley. It is many times the volume of the annual ground-water recharge and discharge. Some concept of the magnitude of the ground water in storage may be obtained by the following calculation: The surface area of the valley fill lying below the 6,000-foot contour is approximately 300,000 acres. If it is assumed that only two-thirds of this, or 200,000 acres, is the surface area in which the valley fill is saturated, and if a value of 10 percent is assumed as the specific yield (drainable pore space) of the saturated sediments, then about 20,000 acre-feet of ground water is theoretically available from storage for each saturated foot of thickness of valley fill. This is equivalent to slightly more than 80 percent of the estimated annual ground-water discharge. On this basis, the amount in storage in a 100-foot-thick section of the saturated valley fill would be equal to about 80 times the natural annual discharge from the ground-water reservoir.

In addition to the water in the valley fill, there is an unknown amount of ground water stored in the bedrock. Thus, it is evident that the total amount of ground water in storage is many times the average annual recharge to and discharge from the ground-water system in Pine Valley. The water so stored provides a reserve for maintaining an adequate supply for pumping during protracted periods of drought or for limited periods of high demand under emergency conditions. This reserve further increases the reliability of ground water as a dependable source of irrigation supply and is an important asset in semiarid regions where surface-water supplies are widely variable from year to year.

Quality

The chemical quality of the water in most ground-water systems in Nevada commonly varies considerably. In the areas of recharge the chemical concentration of the water normally is very low. However, as the ground water moves through the system to the areas of discharge it is in contact with rock materials which have different solubilities. The extent to which the water dissolves chemical constituents from the rock materials is governed in large part by the solubility, volume, and distribution of the rock materials, the time it is in contact with the rocks, and the temperature and pressure in the ground-water system.

No samples of water were collected for chemical analysis, and as a matter of fact, there are not yet sufficient sampling points available in Pine Valley to determine the general chemical character of the ground water in the various parts of the valley. Determination of the chemical quality of water from existing wells and springs could provide information that would be helpful in planning a detailed chemical study in the future.

Many of the springs have supplied water for irrigation of meadows and pastures with apparent success for many years. However, this does not assure that the quality of ground water is satisfactory for irrigation at all locations in the valley. With the increasing use of ground water from wells it will be desirable to have chemical analyses made to determine the suitability of the water for its intended use. This information is needed especially if the cultivation of new types of crops is contemplated.

Development

Springs have supplied dry-season water for irrigation probably from the beginning of agricultural development in the valley. The hot springs in sec. 12, T. 28 N., R. 52 E., discharge 4 to 5 second-feet of water which is used to meet irrigation requirements or which maintains the flow of Pine Creek. Ground water also discharges into the channel of Pine Creek in its lower reaches. Springs at the JD Ranch and on or near most of the ranches near the margins of the valley fill further emphasize the importance of ground water in the agricultural development of Pine Valley.

The development of ground water for irrigation by wells has been stimulated in recent years by deficient runoff. However, earlier attempts to develop ground water for irrigation by wells were made. One of the earliest attempts was the drilling of a 300-foot-deep well on the Slagowski Ranch in about 1918. Reportedly the well flowed for some time, but caving subsequently cut off the flow.

About 1940 well 29/52-4B1 was drilled on the Bailey Ranch to a depth of 900 feet. This venture for obtaining a flowing well was unsuccessful and no information is available about the log or the well construction. However, it is possible that water-bearing zones were penetrated which did not have enough artesian head to cause the water to flow at the land surface. The present depth to water, about 43 feet below the land surface, seems to be below the level of unconfined water in the vicinity. This suggests that the well is cut off from the deeper water-bearing zones, as most other deep wells in the lower part of the valley have water levels that are somewhat above the level of the shallow unconfined ground water.

In the early 1950's a successful irrigation well, 25/50-1D1, was drilled to a depth of 400 feet on the JD Ranch. The principal water-bearing zone was reported to be 20 to 120 feet below the land surface. Several other zones also were reported, the deepest of which was 330 to 400 feet below the land surface. The yield of this well, as reported by Mr. S. Damele, is about 1,100 gpm (gallons per minute) at the start of the irrigation season but decreases with continued pumping. Reported information suggests that the specific capacity[1/] of the well may be on the order of 25 gpm per foot of drawdown.

Well 25/50-28B1 was drilled along Denay Creek in 1952, and is reported to have been drilled to a depth of 126 feet. Sand and gravel strata, 30 to 50 feet below the land surface, reportedly form the principal water-bearing zone. Mr. Damele estimated that the well yields 600 to 700 gpm. The well is equipped with a centrifugal pump, and therefore the drawdown probably is limited to about 20 feet. This suggests a specific capacity of 30 to 35 gpm per foot of drawdown. Irrigation well 24/49-26B1 was drilled to a depth of 100 feet on the Tonkin Ranch. Water-bearing sand and gravel were reported for most of the depth of the well. The yield of the well is not known.

In 1958 a well was drilled to a depth of 170 feet for irrigation on the Alpha Ranch in sec. 35, T. 25 N., R. 51 E. It was unsuccessful, the yield reportedly being only 100 gpm with an 80-foot drawdown. A water-bearing zone of gravel between 27 and 65 feet was reported.

In the last 2 years several wells were drilled in Tps. 28-30 N., R. 52 E., for the purpose of obtaining irrigation supplies. The first few, however, were unsuccessful. Well 28/52-22C1 was drilled to a depth of 300 feet. Little information on the materials penetrated or on the construction of the well is available, although reportedly some water-bearing zones were penetrated. Mr. Slagowski, the owner, reported that the well flowed 15 to 20 gpm when completed, but this yield was not sufficient for irrigation. When the well was visited in October 1960, a flow of 1 to 2 gpm was observed.

Well 20/52-22D1 was drilled to a depth of 360 feet. A pumping rate of about 100 gpm with a drawdown of 140 feet was reported by the owner, Mr. H. Bailey, when the well was tested on completion--a specific capacity of 0.7 gpm per foot of drawdown.

Several wells were drilled on the Hay Ranch in an attempt to develop large yields for irrigation. Well 29/52-9C1 was drilled to 116 feet. Mr. J. Pieretti,

---

1/ The number of gallons per minute a well yields per foot of drawdown due to artificial withdrawal.

the owner, reported that gravel apparently was penetrated between 27 and 42 feet and between 60 and 70 feet. The well reportedly was test pumped at 400 gpm with a 78-foot drawdown and at 325 gpm with a 60-foot drawdown, indicating that the specific capacity is roughly 5 gpm per foot of drawdown. Well 29/52-9C2, which is 70 feet deep, was test pumped at about 300 gpm with a large drawdown. Well 29/52-21B1 was drilled to a depth of 336 feet in late 1959. Prior to test pumping, the well flowed about 50 gpm, according to the owner. When test pumped, the well yielded a reported 600 gpm with a drawdown of 170 to 180 feet. Additional perforations were made in the well casing, and on a second test a pumping rate of 1,200 gpm with a drawdown of 150 feet was obtained. The latter test indicates that the specific capacity is about 8 gpm per foot of drawdown. The nonpumping depth to water after the additional perforations were made was about 2 feet below the land surface.

The specific capacities for the above group of wells did little to build confidence that satisfactory yields from wells for irrigation could be obtained in the valley. However, in the summer of 1960 well 30/52-29A1 was drilled to a depth of 400 feet, improved drilling techniques being used. Mr. W. R. Rand, the owner, reported that this well was tested at about 3,600 gpm with a drawdown of 82 feet. The specific capacity of more than 40 gpm per foot of drawdown is the largest for the valley. Obviously, the yield is very satisfactory for irrigation.

In the fall of 1960, well 29/52-29B1 was drilled to a depth of more than 500 feet. Prior to the completion of development and testing, it appeared that a yield of more than 2,000 gpm could be obtained from the well with adequate permanent pumping equipment.

These two latest wells demonstrate that it is possible to obtain wells of moderate to large capacity in Pine Valley. The available information on wells and the geology of Pine Valley suggests that the improved construction methods used on the latest wells have been an important factor in their success. In other words, the geology and the occurrence of ground water are favorable for the development of irrigation water by pumping from wells. However, success depends also on good well design, construction, and development. A short general discussion of well construction is presented in the appendix.

Recommendations for Additional Ground-Water Studies

In compliance with the request of Mr. Hugh A. Shamberger, Director, Department of Conservation and Natural Resources, State of Nevada, suggestions for special studies that are listed below are recommended for obtaining needed basic data and for a better understanding of the factors that influence or control ground water in Pine Valley and similar areas in Nevada. These studies are separate from the normal areal investigations that commonly are needed after the development of ground-water in a given area becomes substantial.

1. A detailed investigation of the geomorphology of Pine Valley, with emphasis on late Cenozoic events. A fairly satisfactory study of the Cenozoic geology is available as a basis for the investigation. The geomorphology should be studied in detail to improve understanding of the geologic events that influence or control the occurrence and movement of ground water, not only in Pine Valley but in other parts of the Humboldt River drainage system. For example, the dominantly erosional environment that existed in Pine Valley in the latter part of its geologic history must have a close relation to events in the lower Humboldt River where the environment was largely one of deposition. The study should be of considerable value to the study of the lower Humboldt River currently being sponsored by the Department of Conservation and Natural Resources.

2. A detailed investigation of the hydrology of Pine Creek from Hot Creek to the north end of the valley. This study would emphasize the effect of ground water on the flow of Pine Creek. It would include factors related to the diversion of water from Pine Creek for irrigation. The study would be directed toward the determination of the ground-water outflow from Pine Valley. As foreseen at this time, the study would include geochemical investigations, series of seepage measurements, and studies of water-level fluctuations and gradients, as well as studies of the discharge of ground water by phreatophytes and evaporation.

Should ground-water development by wells become substantial in Pine Valley, this study also would prove of considerable value in evaluating the effect of that development on the existing pattern of surface flow from the valley.

3. Study of factors affecting recharge from precipitation. Although the method that has been used for estimating ground-water recharge from precipitation generally has been satisfactory for reconnaissance estimates, it is recognized that the result for any particular valley may be substantially different from actual conditions. For example, the estimate of recharge to Pine Valley by the precipitation method, when compared to the estimated discharge, is high. For these reconnaissance studies the use of independent methods for estimating the recharge and discharge usually provides a means of checking against too great an error in either method and usually helps to define, within more accurate limits, the estimate of perennial yield. However, as development increases toward optimum conditions in the different valleys, it will be necessary to devise more accurate methods of evaluating recharge. Such a study for Pine Valley might be postponed until a general detailed ground-water investigation is required. However, the development of more accurate methods at an early date would be of value not only

for Pine Valley but for possible application to other valleys where estimates of recharge are needed. More data on the amount and areal distribution of precipitation are greatly needed.

The scope and intensity of the proposed study could be adapted, within limits, to the availability of personnel and funds. At least two lines of attack might be used. One might be to concentrate efforts on several small drainage units whose geology, topography, and orientation were different. The other approach would emphasize the relation of rates of precipitation to change in altitude. Also, a grid of precipitation storage gages might be established in Pine Valley to provide data on areal distribution. If possible both lines of approach might be pursued simultaneously for correlation. Along with adequate data on the distribution and amounts of precipitation, additional data on runoff from the various drainage units should be determined. The combined data then could be used in studies of the physical conditions of recharge. Although this would be a substantial investigation, it is believed that the results would provide a much stronger base for understanding the factors affecting ground-water recharge, and therefore would furnish the necessary information for estimating more accurately the recharge to the valley.

DESIGNATION OF WELLS

Wells and springs in this report are designated by a single numbering system. The number assigned to a well or spring is both an identification and a location number. It is based on the Mount Diablo base line 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 the Mount Diablo base line. The second unit, separated from the first by a slant, is the range number east of the Mount 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 capital letter, which designates the quarter section; and finally, a number designates the order in which the well was recorded in the quarter section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section.

Thus, well number 29/52-21B1 indicates that this well was the first well recorded in the NW 1/4 sec. 21, T. 29 N., R. 52 E.

Owing to limitation of space, wells on plate 1 are identified only by the section number, quarter-section letter, and serial number. The township in which the well is located can be ascertained by the township and range numbers shown in the margin of plate 1. For example, well 29/52-21B1 is shown on plate 1 by 21B1 and is within T. 29 N., R. 52 E.

Table 6.--Records of selected wells in Pine Valley

23 1/2/49-1C1. Owner, S. Damele. Drilled, irrigation well, depth 125 feet, casing diameter 6 inches to 21 1/2 feet, open hole below. In spring area, reported flow 1 c.f.s. (cubic feet per second) Driller's log:

Material	Thickness (feet)	Depth (feet)
Mud, soil	4	4
Sandstone, hard, gray "capping"	16	20
Clay, sandy, soft in gray and brown streaks - water	22	42
Clay, sandy, tight, yellow	38	80
Clay, coarse, sandy, loose, yellow - water	15	95
Sandstone, tight, gray	27	122
Sandstone, tight, brown - water	3	125
Total depth		125

24/29-26B1. Owner, S. Damele. Drilled, irrigation well, depth 100 feet, casing diameter 10 inches, gravel-packed. Reported perforations 3/16- by 2-inch from 6 to 100 feet. Driller's log:

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Sand and gravel	24	30
Red rock	3	33
Sand	37	70
Gravel	30	100
	Total depth	100

25/49-7A1. Owner, E. Bauman and Sons, "Bauman" well. Drilled, stock well, depth 259.5 feet, casing diameter 6 inches. Equipped with cylinder pump and windmill. Reported depth to water 194 feet. Driller's log:

Material	Thickness (feet)	Depth (feet)
Top soil	6	6
Rock and clay	9	15
Clay and rock	37	52
Coarse rock and clay	3	55
Clay, sandy, brown	20	75
Clay, sandy, fine, brown	20	95
Clay, sandy, brown	69	164
Clay, sandy, brown	30	194
Sand - water	10	204
Clay, sand, and gravel	47	251
Sand and gravel, clay - water	8.5	259.5
	Total depth	259.5

25/50-1D1. Owner, S. Damele. At JD Ranch. Drilled, irrigation well, depth 400 feet, casing diameter 16 inches to 60 feet; 14 inches to 300 feet; and 8 inches to 396 feet; gravel-packed, slot-perforated 20 to 400 feet. Equipped with turbine pump and diesel engine. Reported yield 1,100 gallons a minute which decreases on continued pumping. Driller's log:

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Clay, yellow	14	20
Sand and gravel	100	120
Clay, yellow	20	140
Sand and gravel	90 1/	250 1/
Clay, yellow	10	260
Sand and gravel	105	365
Clay, yellow	15	380
Sand	20	400
	Total depth	400

25/50-28B1. Owner, S. Damele. Drilled, irrigation well, depth 126 feet, diameter 16 inches, gravel-packed, slot-perforated 20 to 100 feet. Equipped with centrifugal pump. Pumping rate reported 600 to 700 gallons a minute. Measuring point, top of 16-inch casing. Depth to water below measuring point, 7.64 feet on October 20, 1960. Driller's log:

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, yellow	7	10
Shale, blue	20	30
Sand and gravel	20	50
Clay, yellow	76	126
	Total depth	126

25/51-5A1. Owner, Eureka Land and Livestock Co. Drilled, stock well, depth 147 feet, casing diameter 6 inches, slot-perforated 80 to 145 feet. Equipped with a cylinder pump and windmill. Reported depth to water 75 feet. Driller's log:

Material	Thickness (feet)	Depth (feet)
Cemented gravel	25	25
Silt	120	145
Sand and gravel	2	147
	Total depth	147

1/ Thickness and depth as reported. It is uncertain which figure is in error.

25/51-35B1. Owner, Eureka Land and Livestock Co. Drilled well, depth 170 feet, casing diameter 12 inches to 69 feet, open hole below, perforated 0 to 67 feet. Reported test pumped 100 gallons a minute with 80-foot drawdown. Depth to water reported 27 feet. Driller's log:

Material	Thickness (feet)	Depth (feet)
Clay, yellow	27	27
Gravel	38	65
Shale, sandy	102	167
"Lime" hard, gray	3	170
	Total depth	170

26/51-6B1. Lessor, Last Frontier Oil Co. "Oil test" well. Reportedly drilled to about 3,500 feet. Surface casing to 800 to 900 feet, which may indicate the bottom of the valley fill. A water-bearing zone was reported at 1,200 or 1,250 feet which flowed at land surface slightly, but was mudded-off during initial drilling.

28/52-22C1. Owner, F. Slagowski. Drilled well, depth 300 feet, casing diameter 14 inches, slot-perforated at unknown intervals. Owner reports initial flow of 15 to 20 gallons a minute from a depth of about 80 feet. Flow, 1 to 2 gallons a minute on October 19, 1960. Insufficient yield for irrigation. No driller's log available.

29/52-4B1. Owner, H. Bailey. Test well exploring for flowing water of adequate volume for irrigation. Drilled, unused well, depth 900 feet, casing diameter 6 inches. Measuring point, top of collar on casing. Depth to water below measuring point 44.89 feet on October 20, 1960. Well apparently plugged.

29/52-9C1. Owner, J. Pieretti. Drilled well, depth 116 feet, casing diameter 14 inches to 110 feet. Test pumped 400 gallons a minute with a drawdown of 78 feet, and 325 gallons a minute with a drawdown of 60 feet. Unused, insufficient for irrigation requirements. Measuring point top of casing. Depth to water below measuring point, 4.72 on October 19, 1960. No driller's log available.

29/52-9C2. Owner, J. Pieretti. Drilled, unused well, depth 70 feet, casing diameter 14 inches. Test pumped at about 300 gallons a minute with large drawdown. Depth to water ab out 4 feet. No driller's log available.

29/52-21B1. Owner, J. Pieretti. Drilled, unused well, depth 336 feet, casing diameter 14 inches, gravel-packed, slot-perforated 180 to 336 feet, subsequently additional perforations between 115 and 336 feet reported. Test pumped at 600 gallons a minute with a drawdown of 170 to 180 feet (length of pump column). After further perforation, a test pumping rate of about 1,200 gallons a minute with a drawdown of 150 feet was obtained. Measuring point, top of casing. Depth to water below measuring point, 2.81 feet on October 19, 1960. No driller's log available.

29/52-33D1. Dodge Construction Co. Drilled well, depth 225 feet, casing diameter 6 inches, perforated 20 to 200 feet. Unequipped. Formerly used for highway construction. Measuring point, top of collar on casing. Depth to water below measuring point, 20.88 feet on October 18, 1960. Driller's log:

Material	Thickness (feet)	Depth (feet)
Clay	35	35
Sand and gravel	2	37
Clay, blue	138	175
Sand and gravel	1	176
Clay, blue	48	224
Sand and gravel	1	225
	Total depth	225

30/52-29A1. Owner, W. R. Rand. Drilled, irrigation well, completion depth 400 feet, casing diameter 16 inches, gravel-packed, factory perforated 50 to 400 feet with 1/8- x 1 1/2-inch slots. Equipped with turbine pump and diesel engine. Estimated permanent pumping rate 3,000 gallons a minute with a drawdown of 79 feet. Test pumped, reportedly, at about 3,600 gallons a minute with a drawdown of 82 feet. Measuring point, top of casing. Depth to water below measuring point 9.06 feet on October 18, 1960. Driller's log of test hole at same location:

Material	Thickness (feet)	Depth (feet)
Surface (soil)	2	2
Clay	16	18
Gravel, loose - water	27	45
Boulders	23	68
Clay	7	75
Boulders, hard	9	84
Clay and boulders with small layers of gravel	57	141
Clay, yellow, with small layers of sand	117	258
Gravel	8	266
Clay, yellow, with small layers of sand and gravel	32	298
Gravel and boulders	20	318
Clay, yellow, and boulders	50	368
Gravel, cemented	10	378
Gravel, loose	14	392
Clay, hard	19	411
	Total depth	411

30/52-33D1. Owner, H. Bailey. Drilled, unused well, depth 360 feet, casing diameter 16 inches. Reportedly perforated below 180 feet. Test pumped at reported 100 gallons a minute with a drawdown of 140 feet. Measuring point, top of casing. Depth to water below measuring point, 41.83 feet on October 20, 1960. No driller's log available.

31/52-29A1. Owner, J. Tomera. Dug, domestic well, depth 35 feet, 3- by 3-feet in cross section. Equipped with cylinder and hand pump. Reported depth to water about 32 feet in October 1960.

REFERENCES CITED

Carlisle, Donald E., Murphy, M.A., Nelson, C. A., and Winterer, E. L., 1957, Devonian stratigraphy of Sulphur Springs and Pinyon Ranges, Nev.: Am.Assoc. Petroleum Geologists Bull., v. 41, no. 10, p. 2175-2192.

Carlisle, Donald E., and Nelson, C. A., 1955, Paleozoic stratigraphy of the Mineral Hill region: Geol. Soc. America Bull., v. 66, p. 1645-1646.

Couch, B. F., and Carpenter, Jay A., 1943, Nevada's metal and mineral production: Nevada Univ. Bull., Geol. Mining Ser. 38, 159 p.

Eakin, Thomas E., and others, 1951, Contributions to the hydrology of eastern Nevada: Nevada State Engineer, Water Resources Bull. 12, 171 p.

Emmons, W. H., 1910, A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada: U.S. Geol. Survey Bull. 408, 130 p.

Fads, Thos. G., 1960, Permian stratigraphy at Carlin Canyon, Nev.: Am. Assoc. Petroleum Geologists Bull., v. 44, no. 10, p. 1692-1703.

Hardman, George, and Mason, Howard G., 1949, Irrigated lands in Nevada: Nevada Univ. Agr. Expt. Sta. Bull., 183, 57 p.

Houston, Clyde E., 1950, Consumptive use of irrigation water by crops in Nevada: Nevada Univ. Agr. Expt. Sta. and Div. Irrigation and Water Conserv., Soil Conserv. Service, U.S. Dept. Agriculture Bull. 185, 27 p.

Lee, C. H., 1912, An intensive study of the water resources of a part of Owens Valley, California: U.S. Geol. Survey Water-Supply Paper 294, 135 p.

Lintz, Joseph, Jr., 1957, Nevada oil and gas drilling data, 1906-1953: Nevada Bur. Mines Bull. 52, 80 p. (Formerly Nevada Univ. Bull., Geol. Mining Ser.)

Loeltz, Omar J., Phoenix, David A., and Robinson, Thomas W., 1949, Ground water in Paradise Valley, Humboldt County, Nevada: Nevada State Engineer, Water Resources Bull. 10, 61 p.

Merriam, C. W., and Anderson, C. A., 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geol. Soc. America Bull, v. 53, p. 1675-1728.

Nolan, Thomas B., 1943, The Basin and Range province in Utah, Nevada, and California: U. S. Geol. Survey Prof. Paper 197-D, p. 141-196.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U. S. Geol. Survey Prof. Paper 276, 71 p.

Reeves, R. G., and Shawe, F. R., 1956, Geology and iron-ore deposits of the northern part of the Cortez Mountains, Eureka County, Nevada /abs./: Geol. Soc. America Bull., v. 67, p. 1779.

Regnier, Jerome, 1960, Cenozoic geology in the vicinity of Carlin, Nevada: Geol. Soc. America Bull, v. 71, no. 8, p. 1189-1210.

Soil Conservation Service 1941(?), Northwest Nevada cooperative land use studies /maps/, Palisade and Pine Valley quadrangles: U. S. Dept. Agriculture.

White, Walter N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U. S. Geol. Survey Water-Supply Paper 659-A, p. 1-105.

Young, Arthur A., and Blaney, Harry F., 1942, Use of water by native vegetation: California Dept. Public Works, Div. Water Resources Bull. 50, 154 p.

Appendix--Construction of Wells

Several wells drilled in Pine Valley have been unsuccessful in developing adequate water supplies for irrigation. Unsuccessful wells may result from one or more causes. If these causes are recognized, it may then be possible, by applying appropriate corrective measures, to reduce the percentage of failures in future drilling.

A well involves three principal factors--the water-bearing character of the aquifer, the well construction, and the pumping equipment. If any of these is inadequate for the purpose, the well will not be satisfactory. For any particular location the physical character of the water-bearing zone, or zones, usually cannot be changed significantly; but change to improve the drilling procedures, well construction and development, and pumping equipment can result in improved performance of the well. Some of the controlling factors are discussed in the following paragraphs:

Water-bearing zones.--Most wells of moderate to large capacity in Nevada obtain their water from water-bearing zones in the valley fill. The general nature of the deposition of the valley fill is such that single units of sand, or sand and gravel aquifers, are limited in both horizontal and vertical extent. Thus, a single unit seldom occurs at the same stratigraphic or depth interval in a group of wells in a particular township, and often does not occur in adjacent wells only a few hundred feet apart. Typically, however, in a given area water-bearing units will be found somewhere within a given depth zone. For example, it may be found that the water-bearing zones of a group of wells in an area generally occur at depths of 10 to 100 feet and 300 to 400 feet below the land surface. That is, wells of the group have tapped water-bearing zones somewhere within the two indicated depth intervals, although any two wells may not have water-bearing zones at precisely the same depths. There would be a reasonable expectancy that future wells also would encounter water-bearing zones in these depth intervals in the same general area.

For proper design of a new well it is necessary to know the depth, thickness, and hydraulic character of the water-bearing zone, or zones, beneath the site. It is desirable also to know the chemical character of the water in the water-bearing zones, as it bears on the design of the well. The water-yielding character of an aquifer is dependent, in large part, on its permeability. 1/ In well-sorted materials, permeability may range from a few gallons per day per square foot for silt sizes to several thousand gallons a day per square foot for a coarse gravel. This seemingly simple relationship is complicated in Nevada, because most water-bearing zones in the valley fill are not well sorted but rather

---

1/ The coefficient of permeability may be expressed as the number of gallons a day that will move through a cross section of one square foot of the water-bearing zone under unit hydraulic gradient, at 60°F (standard, or laboratory, coefficient) or at the prevailing temperature (field coefficient).

are heterogeneous mixtures of silt and sand, sand and gravel, and even silt, sand, and gravel. Further, because of the wide range in sorting and roundness of the particles, one zone composed of sand and gravel may have a moderate permeability, whereas another zone of sand and gravel may have a high permeability. It is very desirable, therefore, to know the character of the water-bearing zones beneath the site of a proposed well. Formation samples can be collected during drilling, and laboratory tests can be made to provide part of the information.

Well construction.--The information on the water-bearing zones that is obtained during drilling provides the basis of design and completion of the well. The thickness and depths of the water-bearing zones and analyses of samples obtained from the several zones permit determination of the intervals at which the casing should be perforated. The mechanical (particle-size) analyses provide the basis for determining the size of the perforations. The number of perforations per unit of casing, however, must be governed not only by the number needed to obtain the desired yield but also by the structural strength of the casing

If the casing perforations are too large, sand and gravel may continue to enter the well after the permanent pumping equipment is installed, and may result in a serious reduction of yield and permanent damage to the pump. If the perforations are too few, or too small, the yield of the well will not equal the ability of the aquifer to transmit water to the well. Excessively large entrance losses--loss of head as the water moves through the perforations into the well from the aquifer--result from too few or too small perforations. Machine-cut perforations ordinarily give the best results because the size of the perforation is well controlled and the cut is smooth. However, this procedure is not readily applicable to the cable-tool method. Perforations made by acetylene torch often are satisfactory for wells tapping coarse material but may result in limited yield. The uncertainty of the size and pattern of cuts made by a Mills knife tends to favor limiting its use to coarse-grained deposits.

Gravel packing is the practice of placing gravel in the annular space between the well casing and the natural materials of the water-bearing zone. Its purpose is to provide a permeable transition material between the well and the water-bearing zone. To the extent that properly sized gravel is used and is satisfactorily emplaced, gravel packing may be quite useful in obtaining larger yields from wells. Whether or not gravel-packing is desirable should be determined on the basis of the grain-size distribution of the water-bearing zone.

After the casing has been installed, the well should be developed; that is, pumping and surging, or other means, should be used to clean out fine-grained materials adjacent to the well. If there is a reasonably good grain-size distribution of the particles forming the aquifer, good development may result in a natural gravel-pack around the well by removing the finer grains of the natural deposits. Good development also removes any fine material, such as drilling mud, that is in the hole as a result of drilling operations. The objective of development is to obtain a smooth hydraulic continuity between the water-bearing zone and the well so that entrance losses, and hence drawdown, will be minimized, and the finer grained material will be stabilized and thus will not come into the well after the permanent pump is operating.

Pumping equipment.--After the well has been developed and information has been obtained about the hydraulic character of the water-bearing zone of the well, the next step is to determine the most efficient pump design for the well. Proper selection of pumping equipment takes into account the range in lift that is expected, the desired pumping rate, the diameter of the well, and where important, the chemical quality of the water. Accurate information on these items will permit pump manufacturers or distributors to offer the equipment they feel is best suited to supply the owner's requirements.

A properly designed, constructed, developed, and equipped well is not likely to be the cheapest in initial cost, but it is the more economical in operating cost and as a long-term investment.

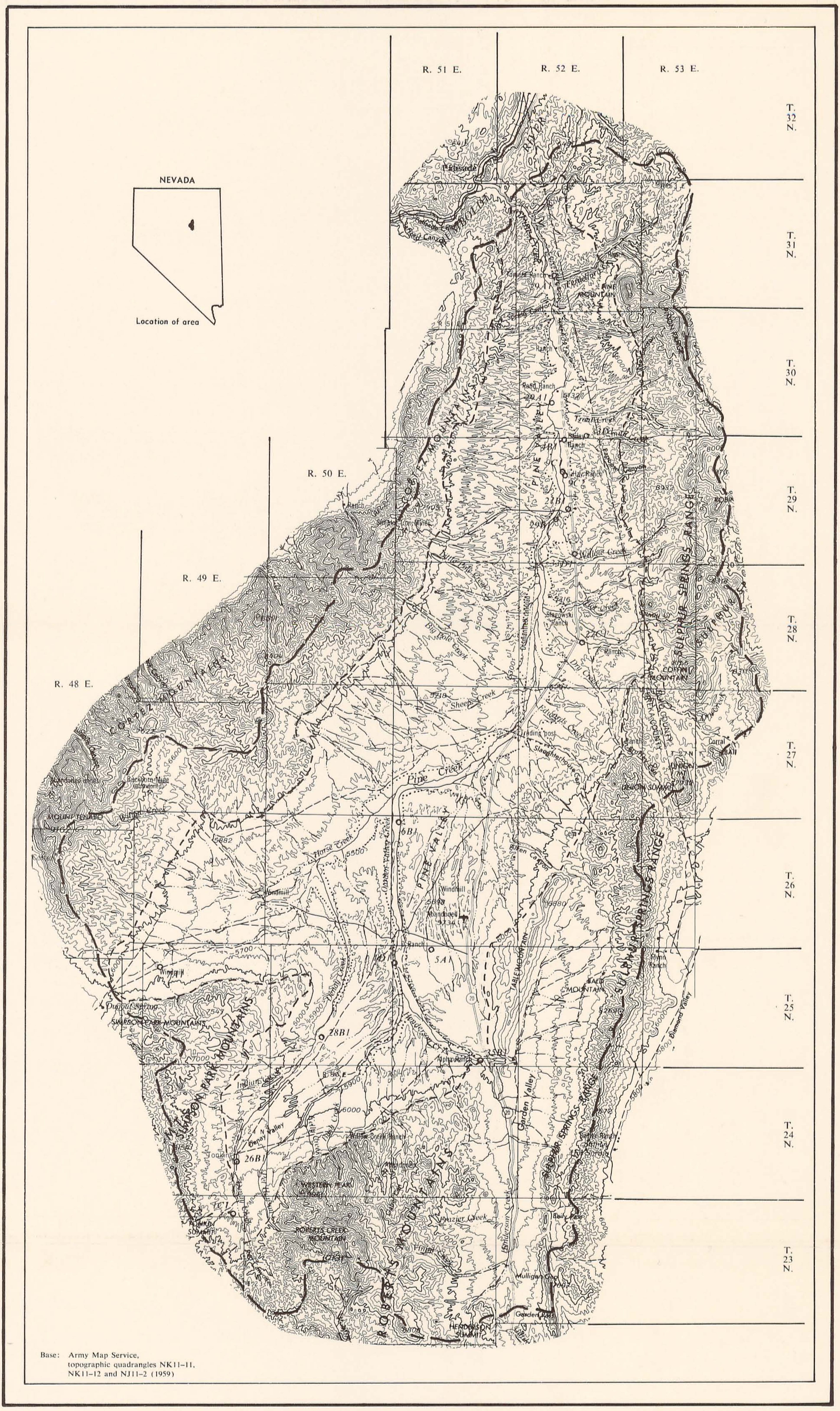


PLATE 1. MAP OF PINE VALLEY, EUREKA AND ELKO COUNTIES, NEVADA,

SHOWING AREAS OF BEDROCK AND VALLEY FILL, AND LOCATIONS OF WELLS

EXPLANATION

Drainage divide

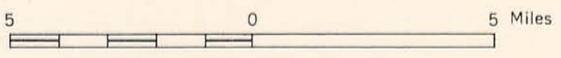
Contact between valley upland and valley lowland (approximate)

Contact between valley fill and bedrock (approximate)

29A1

Well

Scale 1:250,000



January

1961