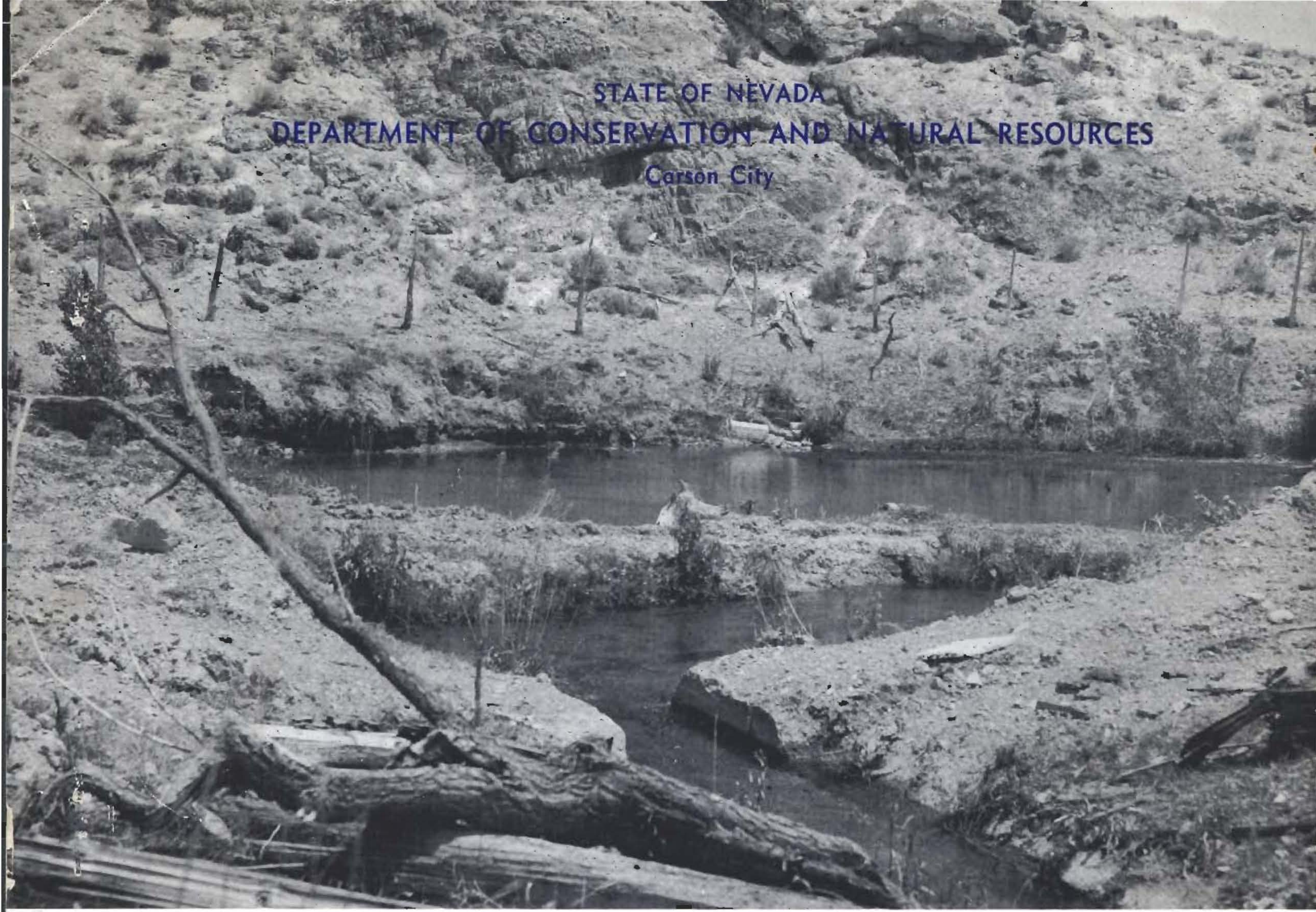
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of Hiko Spring

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES
REPORT 21

GROUND–WATER APPRAISAL OF PAHRANAGAT AND PAHROC VALLEYS, LINCOLN AND NYE COUNTIES, NEVADA

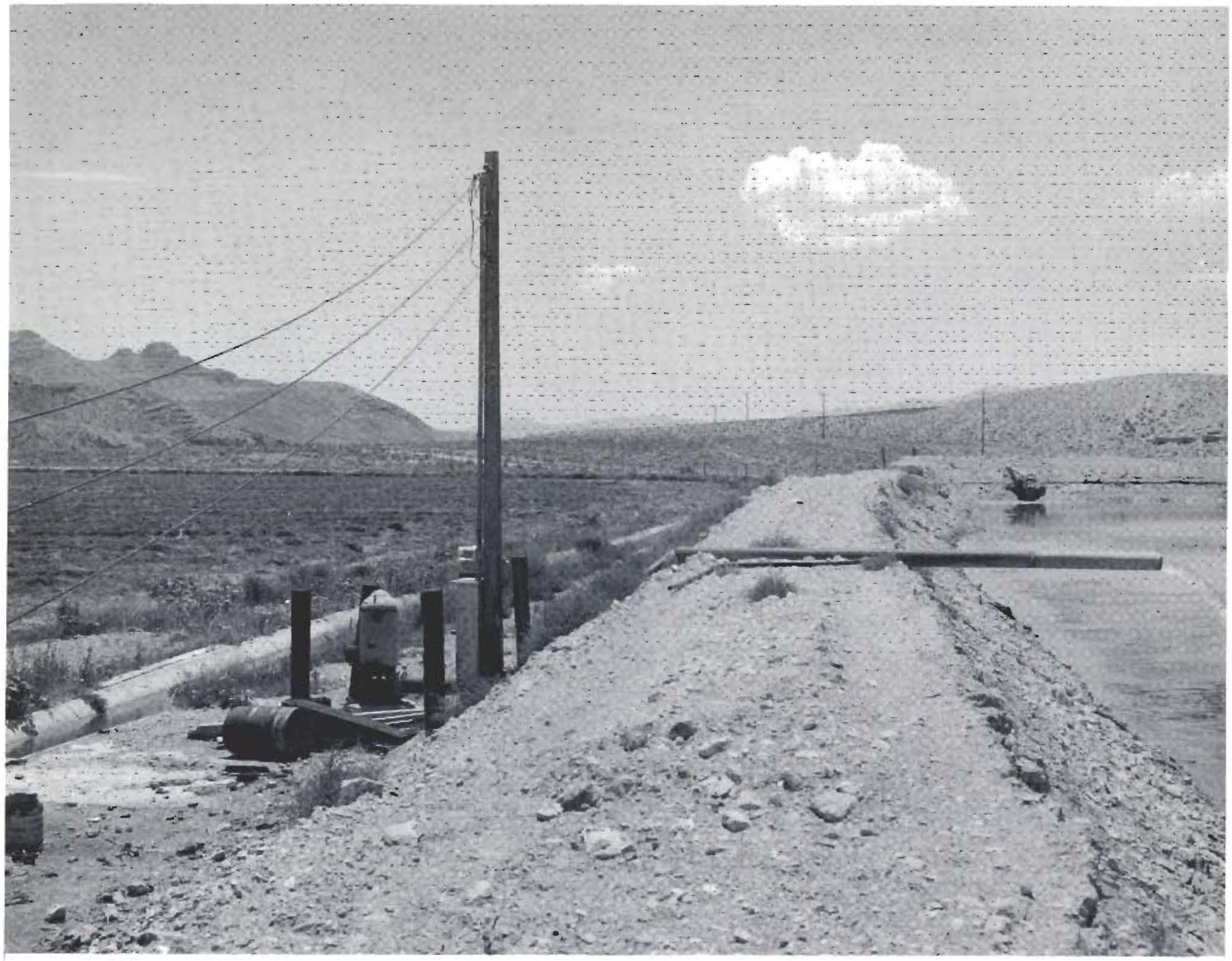
By

THOMAS E. EAKIN
Geologist

PRICE $1.00

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

OCTOBER 1963



View of irrigation well 45/60-2al, about 2½ miles north of Hiko Spring. Well is pumping an estimated 1,000 gallons a minute into reservoir from which water is carried in concrete lined ditches, one of which is shown at left of well, to field at left side of photograph.

COVER PHOTOGRAPH

View of Hiko Spring in northern Pahranagat Valley. A discharge of 5.36 cfs. was measured on June 17, 1963, the longtime discharge may average about 6 cfs. Ground water issues from the bottom of pool and at far side of pool where a concrete box was installed. At the time of picture essentially all of the discharge was diverted through ditch in foreground. Note limestone bedrock exposures in hillside just beyond spring pool.

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FOREWORD

This report, the 21st in the series of reconnaissance ground-water studies which were initiated by action of the legislature in 1960, deals with the underground water resources of Pahranagat and Pahroc Valleys in Lincoln and Nye Counties, Nevada. The ground-water resources of some twenty-six valleys have been appraised in these twenty-one reports.

The present appraisal was made by Thomas E. Eakin, geologist, U. S. Geological Survey.

These reconnaissance ground-water resources studies make available pertinent information of great value to many State and Federal agencies. As development takes place in any area, demands for more detailed information will arise and studies to supply such information will be undertaken. In the meantime these reconnaissance type studies are timely and adequately meet the immediate needs for information on the ground-water resources of the areas on which reports are prepared.

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

October, 1963.

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GROUND-WATER APPRAISAL OF PAHRANAGAT AND PAHROC VALLEYS, LINCOLN AND NYE COUNTIES, NEVADA

by

Thomas E. Eakin

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SUMMARY

The results of this reconnaissance indicate that on the order of 28,000 acre-feet of ground water is discharged annually from Pahranagat Valley by evapotranspiration (natural and artificial processes). Of the total amount at least 25,000 acre-feet per year is largely from Hiko, Crystal, and Ash Springs. Most of the pumpage of about 2,000 acre-feet per year is from four wells at the north end of the valley, where the water provides the full irrigation requirements for approximately 300 acres of land. The remaining pumped water is used for domestic and stock supply, and a small amount of local irrigation.

The natural recharge from precipitation within the defined limits of Pahranagat Valley is estimated to be only 1,800 acre-feet per year. This estimate of recharge is roughly one-fourteenth of the estimated natural discharge, indicating that most of the ground water in Pahranagat Valley is derived from beyond the drainage area of the valley. In addition, potential hydraulic gradients, geologic environment, and water-quality data also indicate that ground-water recharge to Pahranagat Valley is derived from adjacent valleys; these include Garden and Coal Valleys to the northwest, White River and Cave Valleys to the north, and Dry Lake and Delamar Valleys to the northeast and east, and possibly others. Thus, ground water discharged as springs from the carbonate rocks in Pahranagat Valley is part of a regional ground-water system.

Present development of ground water in Pahranagat Valley is using nearly all of the natural spring discharge of about 25,000 acre-feet per year. Further development of ground water is possible by additional pumping from the ground-water reservoir in the valley fill. Maintenance of this additional pumping would depend in part on the extent to which water from the springs infiltrates to the ground-water reservoir along the distribution system and irrigated areas. Use of water recycled in this way would provide a means of increasing the irrigated acreage.

As the ground water, both spring discharge and underflow, moves southward, its dissolved-solids content increases owing to evapotranspiration

and the solution of minerals from the soils. Consequently the chemical concentration is increased, eventually to an amount that it may become unsuitable for some or most uses.

In contrast to the large amount of ground water discharging from land surface in Pahranagat Valley, very little is discharged in Pahroc Valley. Ground-water recharge from precipitation within the valley, which is estimated to be about 2, 200 acre-feet per year, largely is discharged as underflow from the valley. Ground-water levels in a few wells at the north end of the Pahroc Valley, along the White River channel, are 250 feet below land surface or less. Southward the depth to water increases substantially. In the central part of the valley the depth to water is on the order of 1, 000 feet, and at the south end of Pahroc Valley the depth to water is on the order of 350 feet.

Use of ground water in Pahroc Valley now is limited to supplying stock requirements. For most of the valley the depth to water probably is too great to provide low-cost water supplies.

INTRODUCTION

Ground-water development in Nevada has shown a substantial increase in recent years. Part of the increased development is due to the effort to bring new land into cultivation, part is due to the effort to supplement surface-water supplies, and part is due to the general increased demands for water. In any case, as efforts to develop ground water increase, there is a corresponding increase in demand for information on the ground-water resources throughout the State.

Recognizing this need, the State Legislature enacted special legislation (Chapt. 181, Stats, 1960) for beginning a series of reconnaissance studies of the 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 emphasis of the reconnaissance studies is to provide as quickly as possible a general appraisal of the ground-water resources in particular valleys or areas where information is urgently needed. Ultimately, ground-water information will be available for practically all valleys of the State, at least at a reconnaissance level. For this reason each study is limited severely in time, field work for each area generally averaging about two weeks.

The Department of Conservation and Natural Resources has established a special report series to expedite publication of the results of the reconnaissance studies. Figure 1 shows the areas for which reports have been published in this series. The titles of previous reports published in the series are given at the end of this report. This report is the twenty-first in the Reconnaissance Series.

The purpose of the Reconnaissance Series is to provide a general appraisal of the ground-water resources of virtually all valleys of the State for public information, and to provide a preliminary estimate of the amount of ground-water development that the areas might sustain on a perennial basis as an initial guide to possible requirements for administration of the areas under the State ground-water law.

The scope of this report is limited to a general description of some of the physical conditions of Pahranagat and Pahroc Valleys, including observations of the interrelations of climate, geology, and hydrology as they affect ground-water resources. Movement of ground water between valleys is discussed, preliminary estimates of the average annual recharge to and discharge from the ground-water reservoir in the valleys are included.

Acknowledgements:

The author wishes to express his appreciation to Howard Ness for field assistance in this study. Residents of the area were most kind and helpful in providing information. Special acknowledgement is due Mr. L. Wadsworth for taking much time and effort in providing information which was most valuable in the preparation of this report.

Location and General Features:

Pahranagat and Pahroc Valleys are largely in west-central Lincoln County, although the northwest part of Pahroc Valley extends a few miles into Nye County (See Pl. 1 and Fig. 4). They lie within an area bounded by lat. 37°17' and 38°20' N., and long 114°45' and 115°25' W. Pahranagat Valley adjoins Pahroc Valley on the south; together they extend about 82 miles in a north-south direction and about 30 miles in an east-west direction. Local residents refer to the valley north of Pahranagat Valley as White River. However, the name Pahroc is used in this report to distinguish it from the area more generally known as White River Valley that lies north of Pahroc Valley. The areas within the drainage divide are about 790 and 510 square miles for Pahranagat and Pahroc Valleys, respectively.

U.S. Highway 93 passes through the Pahranagat Valley from Crystal Springs southward. It connects the valley with Las Vegas about 100 miles to the south, Caliente about 45 miles to the east, and Ely about 125 miles to the north. State Highway 25, extends west from Crystal Springs, connects with U.S. Highway 6 and Tonopah about 150 miles west. State Highway 38, largely a gravel and graded road, extends northward from Crystal Springs through the length of Pahroc Valley and connects with

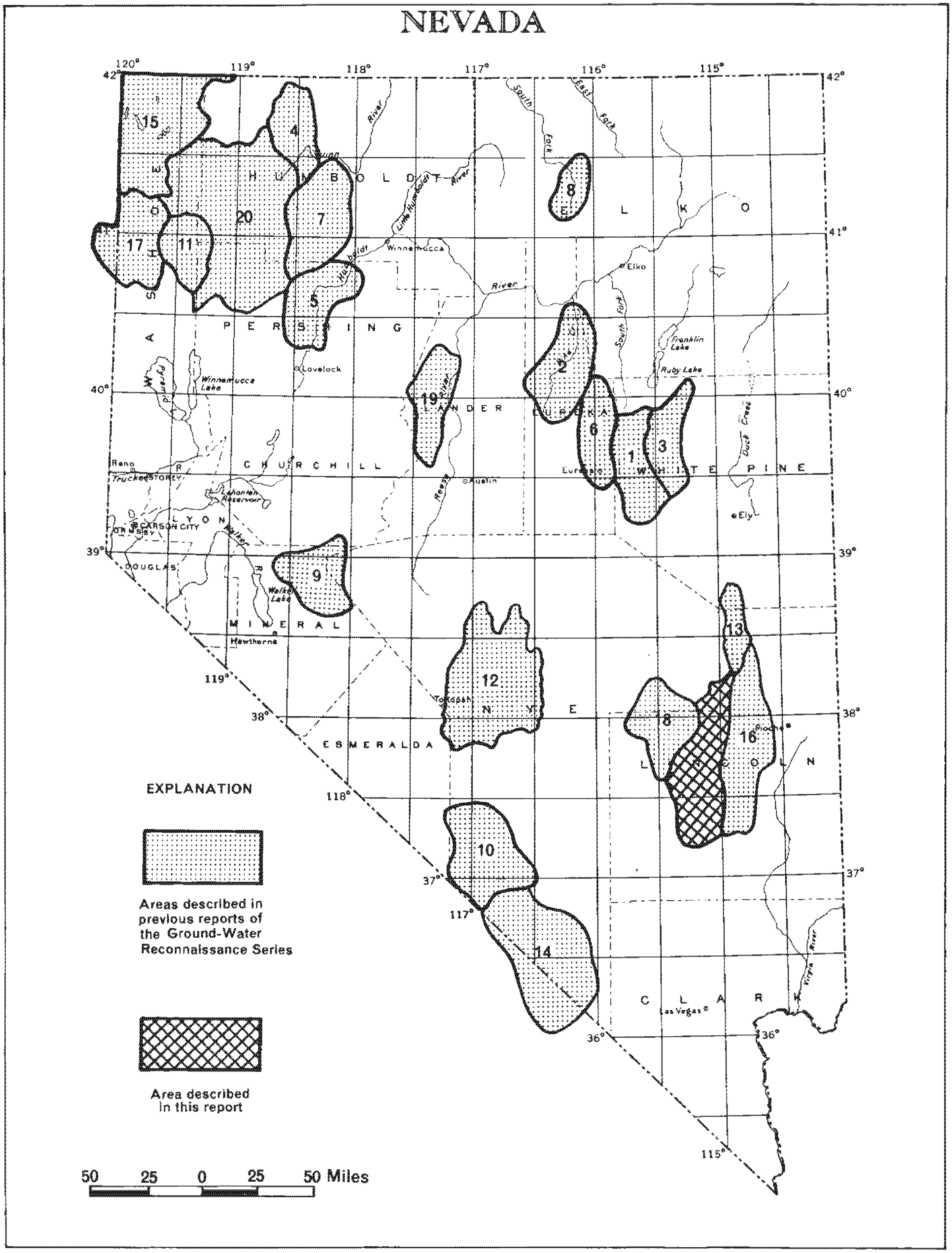

FIGURE 1. Map of Nevada showing areas described in previous reports of the Ground-Water Reconnaissance Series and the area described in this report

U.S. Highway 6 in White River Valley, about 120 miles north of Crystal Springs.

Pahranagat Valley is a center of dairy farming and extensive range livestock activity developed around several springs that collectively discharge about 35 cfs (cubic feet per second). Most of Pahranagat Valley and all of Pahroc Valley are used for livestock range. Full use of Pahroc Valley for livestock range has been handicapped by inadequate distribution of watering points.

Climate:

The climate of the lowlands of Pahranagat and Pahroc Valleys is semiarid. Precipitation and humidity ordinarily are low and summer temperatures and evaporation rates are high. Precipitation is irregularly distributed within the valleys but generally is least on the valley floors and greatest in the mountains. Snow is common in the mountains during the winter, and localized storms provide most of the summer precipitation. The daily and seasonal range in temperature is large.

Records of precipitation at Alamo have been kept since about 1921, although records for some years were incomplete. The average monthly and annual precipitation at Alamo for the period 1931-60 is listed in table 1. Records for Adaven, about 40 miles northwest of Crystal Springs, and Caliente for the same period also are listed for general reference. Location of the stations is shown in figure 4.

Figure 2 shows graphs of the cumulative departures from average annual precipitation at the three stations for the period 1948-60, which is the longest period of concurrent records at the stations; cumulative departure from average annual precipitation for the period 1919-62 at Adaven, the station with the longest continuous record, also is shown. Downward trends of the graph indicate a year or succession of years when precipitation was below average. Precipitation generally was below average at Adaven in 1922-29, 1941-44, and 1946-53, and generally above average in 1934-41. Additionally above average precipitation occurred in 2 successive years in 1945-46, 1954-55, and 1957-58. Somewhat similar characteristics occurred at all three stations in these years. The graph for Adaven for the 44 years shows that successive years of above and below average precipitation are irregular in duration and frequency--a characteristic well known to residents in the region.

Table 2 lists temperature data at Adaven, Alamo, and Caliente for the period 1931-60. Maximum and minimum temperatures recorded are: at Adaven, 100°F. on July 18, 1959 and July 19, 1960, and -20°F. on January 9, 1937; at Alamo, 115°F. on August 11, 1940, and -9°F. on January 9, 1937; and at Caliente, 109°F. on June 22, 1948, and -31°F. on January 9, 1937.

Table 1.--Summary of precipitation at Adaven, Alamo, and Caliente, Nevada

(from published records of the U.S. Weather Bureau)

(Average monthly and annual precipitation, in inches, (1931-61)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Adaven	1.51	1.57	1.43	1.17	.75	.51	.95	1.02	.61	.97	.85	1.27	12.67
Alamo	.70	.68	.68	.57	.45	.15	.73	.77	.32	.43	.43	.60	6.60
Caliente	.83	.79	.85	.70	.56	.39	.76	.92	.49	.89	.75	.86	8.79

Annual precipitation, in inches, (1931-61)

Year	Adaven	Alamo	Caliente	Year	Adaven	Alamo	Caliente
1931	15.92	9.60	9.49	1947	6.51	--	7.47
1932	10.44	9.68	11.61	1948	8.99	2.75	5.23
1933	12.66	7.29	8.16	1949	11.67	6.09	10.03
1934	9.28	3.01	7.14	1950	7.79	5.32	2.92
1935	12.79	5.58	9.43	1951	9.49	4.89	10.15
1936	16.82	8.97	11.60	1952	15.77	6.88	11.52
1937	12.74	6.30	6.84	1953	6.83	1.98	4.66
1938	21.32	11.15	--	1954	16.09	5.96	9.31
1939	16.94	7.42	9.41	1955	19.09	5.65	7.13
1940	9.65	6.16	7.49	1956	4.42	1.23	4.78
1941	23.55	14.91	18.73	1957	14.24	7.43	10.88
1942	5.19	2.94	6.63	1958	16.42	6.47	8.13
1943	14.98	--	11.70	1959	8.45	4.42	4.83
1944	8.71	--	7.96	1960	11.59	6.02	9.77
1945	17.43	10.65	11.60	1961	12.47	3.63	8.80
1946	14.28	--	12.36				

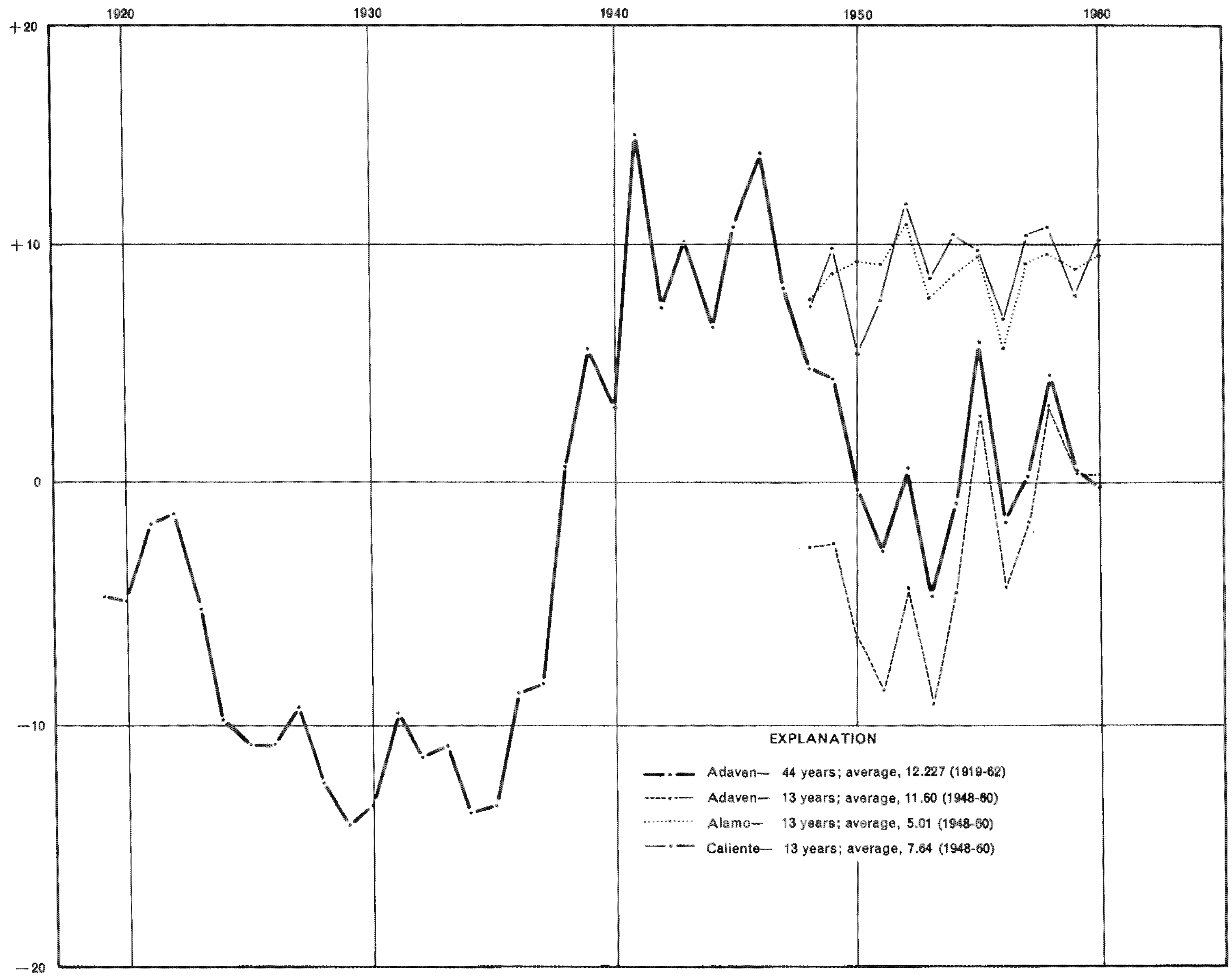

Figure 2.—Graphs of cumulative departure from average annual precipitation at Adaven for the period 1919-62, and for Adaven, Alamo, and Caliente for the period 1948-60.

Table 2. -- Average monthly and annual temperature, in degrees Fahrenheit, at Adaven, Alamo, and Caliente, Nevada, 1931-60

(from published records of the U. S. Weather Bureau)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Adaven	29.1	31.4	37.6	46.2	53.8	62.6	70.2	68.3	61.8	50.4	39.1	32.5	48.6
Alamo	36.6	41.1	47.2	56.1	62.9	71.9	79.2	76.9	69.7	58.6	46.8	39.3	57.1
Caliente	30.4	36.0	43.7	52.2	60.2	68.5	75.9	73.9	65.9	54.1	41.5	33.5	52.9

Low humidity and high temperature and wind movement result in high evaporation rates. Pan-evaporation data recorded at Caliente since 1956 are listed in table 3. The evaporation station at Caliente is the nearest to Pahranagat and Pahroc Valleys. These data are considered to be only generally indicative of evaporation in Pahranagat and Pahroc Valleys. As suggested by the record at Caliente, evaporation from May through September accounts for most of the annual total evaporation, and seasonal evaporation averages about 50 inches for the period of record.

Table 3. -- Pan evaporation, in inches, at Caliente, Nevada, 1956-62

(from published records of the U. S. Weather Bureau)

Year	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1956			7.42	[b]12.55	11.10	10.86	8.07	[b]4.65	2.05
1957	3.97	6.76	6.33	10.66	11.45	[b]11.60	7.54		
1958		[b]6.39	9.35	11.99	12.39	11.73	7.56	5.00	
1959		7.56	9.59	11.89	11.71	10.10	7.18		
1960			9.78	10.94	11.16	10.87	7.34	4.06	
1961		7.19	9.40	12.07	11.06	7.90	6.68	[b]4.07	
1962		7.93	8.27	10.93	11.52	11.41	7.50	4.53	

b. Adjusted to full month by Weather Bureau.

Houston (1950, p. 19), lists the average growing season in Pahranagat Valley as 167 days. However, the growing season in Pahranagat and Pahroc Valleys varies from year to year and with location within the valleys. The present area of irrigation in Pahranagat Valley is designated as being in the Pahranagat Zone by Hardman and Mason (1949, p. 14). They characterize the zone as follows: "Occasional winter temperatures in this zone are too low for many of the tender plants grown in the Las Vegas Zone. Three to four cuttings of alfalfa are obtained and late maturing varieties are grown. Most of the cropland, about 6,500 acres, is located in Pahranagat Valley and the Beatty area. The distance to markets and the demand for feed used in connection with livestock production on the large contiguous areas of pasture and range have tended to limit production to forage crops."

In recent years the U.S. Weather Bureau records list freeze data rather than killing frosts; the dates are listed for the occurrence of the last spring minimum and the first fall minimum for temperatures of 32°F. or below, 28°F. or below, 24°F. or below, 20°F. or below, and 16°F. or below. From these data, the number of days between the last spring minimum and the first fall minimum occurrence for the respective temperature groups are given. The following tabulation lists the number of days for three of the temperature groups recorded at Adaven, Alamo, and Caliente for the period 1952-61.

Number of days between the last spring minimum temperature and the first fall minimum temperature for Adaven, Alamo, and Caliente, for the period 1952-61

	32°F or below			28°F or below			24°F or below		
Year	Adaven	Alamo	Caliente	Adaven	Alamo	Caliente	Adaven	Alamo	Caliente
1952	147	177	183	213	212	208	222	227	227
1953	118	117	122	148	150	144	151	208	191
1954	126	219	151	136	230	206	176	257	210
1955	126	141	137	126	178	178	183	208	186
1956	150	134	151	163	183	--	193	202	204
1957	133	163	138	155	169	162	168	238	227
1958	135	173	134	177	176	152	179	222	191
1959	130	151	135	134	184	150	197	228	200
1960	138	144	141	164	164	189	198	198	205
1961	129	129	136	156	156	179	188	188	183
Average	133	154	142	157	180	174	186	217	202

Because of the gradual increase in altitude and latitude to the north, the growing season in Pahroc Valley probably is somewhat shorter than in Pahranagat Valley. The somewhat shorter periods for Adaven and Caliente, shown in the freeze data above, may be somewhat indicative of the growing season in Pahroc Valley.

Physiography and Drainage:

Pahranagat and Pahroc Valleys are segments of a topographic trough that includes White River Valley on the north and Coyote Springs Valley and Moapa Valley on the south (Fig. 4). The ancestral White River flowed in this trough in late Pleistocene time, some 10, 000 years ago, when it was a tributary of the Virgin and Colorado Rivers. Under present climatic conditions, however, streamflow in segments of the White River and tributary channels only occurs for short intervals after high-intensity storms. The present-day lowland of Pahranagat and Pahroc Valleys are the former flood plain of the White River and forms the topographic axis of the two valleys. The valley floor slopes southward from an altitude of about 5, 100 feet in T. 4 N., R. 61 E. near the north end of Pahroc Valley, to an altitude of about 3, 120 feet at Maynard Lake in the gap at the south end of Pahranagat Valley. The altitude decreases about 1, 900 feet in approximately 80 miles, which indicates an average gradient of about 24 feet per mile. However, the gradient is not uniform; it is steeper in and downstream from the several gaps that occur in the valleys, such as at the north end of Pahranagat Valley where the average gradient is about 50 feet per mile. In the segments upstream from the gaps the gradient is less, such as in Pahroc Valley several miles above the gap in T. 1 S., R. 62 E. (projected), where the gradient averages about 18 feet per mile.

The channel of the Pleistocene White River is incised throughout the length of Pahroc and Pahranagat Valleys. In those segments of the valleys underlain by sedimentary deposits the bluffs bordering the flood plain of the White River commonly are 50 feet high or more. In the gaps, where the river cut into volcanic rocks, the bluffs are several hundred feet high. For example, the bluffs in the Maynard Lake gap at the south end of Pahranagat Valley are about 400 feet high.

Numerous dry channels are graded and tributary to the channel of the White River. These probably were formed principally at the time of the formation of the White River channel in Pleistocene time. Subsequently in Recent time small fans have developed at the mouths of the tributary channels and have modified the former flood plain of the White River.

The Seaman and Pahranagat Ranges bound the area on the west. A series of low hills at the south end of the Pahranagat Range connects with the north end of the Sheep Range and forms the southern boundary of Pahranagat Valley. The Pahroc Range generally borders the valleys on the east. On the north the Pahroc Range merges with the southern extension of the Ely and Egan Ranges. On the south the Pahroc Range merges with the Hiko Range, which connects through a line of low hills with the Delamar Range to the southeast.

The north end of Pahroc Valley is arbitrarily separated from White River Valley by a line drawn through a series of hills between the north end of the Seaman Range and the south end of the Egan Range. The south end of Pahranagat Valley is defined by hills connecting the north end of the Sheep and Delamar Ranges. A gap through these hills is occupied by Maynard Lake.

Pahranagat and Pahroc Valleys are arbitrarily divided at the gap about eight miles north of Hiko.

Mt. Irish, altitude 8,741 feet, at the north end of the Pahranagat Range is the highest point in the areas. Big Timber Mountain, altitude about 8,650 feet, near the north end of the Seaman Range, is the next highest peak in the area. Crest altitudes of the mountains bordering Pahranagat and Pahroc Valleys are above 7,000 feet for about 8 miles in the northern Seaman Range, 13 miles in the Pahranagat Range, and about 4 miles in the southern Pahroc or Hiko Range. Elsewhere the crests are lower.

GENERAL GEOLOGY

The following discussion of geology is based largely on a reconnaissance geologic map of Lincoln County prepared by Tschanz and Pampeyan (1961) and on a reconnaissance geologic map of northern part of Pahroc Valley in Nye County by C. M. Tschanz (written communication, 1963).

Kellog (1960, p. 189) in his study of the southern Egan Range noted that about 80 percent of the rocks in the Paleozoic section, which is about 30,000 feet thick, is limestone and dolomite. The southern end of the Egan Range terminates near the north end of Pahroc Valley. Reso and Croneis (1959) described a maximum thickness of 6,048 feet of Devonian rocks in the Pahranagat Range. Of these, carbonate (limestone and dolomite) rocks comprise a thickness of 5,588 feet. For comparison, the Devonian rocks of the Paleozoic section, described by Kellog (1960) in the southern Egan Range, are about 5,450 feet thick. Of this thickness, nearly 95 percent was carbonate rocks. Tschanz (1960, p. 198) indicates that the total thickness of these rocks may not be as great in Pahranagat and Pahroc Valleys, it is presumed that the total thickness of these rocks and the proportion of carbonate rocks underlying Pahranagat and Pahroc Valleys is similar to that in the areas to the east and north.

In this report, the rocks of Pahranagat and Pahroc Valleys are divided into two major groups, and further, each group is divided into two units. The distribution of the four units is shown on plate 1. The Paleozoic carbonate rocks have been identified as one unit of the bedrock group because of their significance in the ground-water hydrology of the region. The second unit of the bedrock group includes Paleozoic shale, sandstone, quartzite, and conglomerate, and Tertiary volcanic rocks composed chiefly of welded tuff, but including tuff, lava flows, and some sedimentary units.

The second group of rocks is designated valley fill and is divided into two units--older and younger valley fill. The older unit consists of unconsolidated to partly consolidated silt, sand, and gravel derived from adjacent highland areas, but includes some rocks of volcanic origin. It ranges in age from Tertiary to Quaternary. The unit was deposited largely under subaerial and lacustrine environments. Although data are not available to determine the maximum thickness of the unit, it probably is at least several hundred feet thick and may exceed a thousand feet.

The younger valley fill includes clay, silt, sand, and gravel of late Quaternary age and occurs along the White River channel and a few tributary channels. Obviously, recent deposits along numerous channels are of Recent age, although these are not shown on pl. 1. As defined, the maximum thickness of younger valley fill probably is about 200 feet along the White River channel. The valley fill probably is underlain by bedrock similar to that exposed in the mountains.

Water-Bearing Properties of the Rocks:

The rocks of Paleozoic age generally have had their primary permeability, that is, permeability at the time of deposition, considerably reduced by consolidation, cementation, or other alteration. However, because they subsequently have been fractured repeatedly by folding and faulting, secondary openings have developed through which some ground water is transmitted. Further, the fractures or joints in the Paleozoic carbonate rocks locally have been enlarged by solution as water moved through them. Solution openings developed near sources of recharge where carbon dioxide carried by rain water penetrated the rocks, or where organic and other acids derived from decaying vegetation and other sources were carried by water into contact with the carbonate rocks. Solution openings are not necessarily restricted to the vicinity of present day recharge areas and outcrops of these rocks. Rather, they may occur wherever the requisite conditions have occurred anytime since the deposition of the carbonate rocks. The principal significance of solution openings is that they greatly facilitate movement of ground water through carbonate rocks.

That the existing fractures or solution openings have extensive hydraulic connection throughout the area is demonstrated by the regional hydrology. In the absence of detailed information, it is presumed that ground-water movement through carbonate rocks in this region occurs through both fractures and solution openings. Certainly, the large quantity of ground water issuing from fractures and solution openings, such as those at Ash, Crystal, and Hiko Springs in Pahranagat Valley, is a dramatic demonstration that ground water moves through Paleozoic carbonate rocks in this region of Nevada.

The Paleozoic clastic rocks and the Tertiary volcanic and clastic rocks exposed in the mountains generally have little primary permeability. Secondary fractures probably are the principal means by which limited amounts of ground water are transmitted through these rock. Favorably disposed fractures probably provide the network of openings through which water moves and is discharged at small springs in the mountains, and which yield a few gallons per minute to wells penetrating these rocks. Under favorable conditions the distribution of fractures in welded tuff, lava flows, or Paleozoic clastic rocks may permit the development of moderate yields of water from wells. However, these occurrences are likely to be so localized that the odds of a well encountering them are very small indeed.

The partly consolidated fine-grained deposits of the older valley fill probably would yield water slowly to wells. Locally either fractures or gravel and sand beds may yield water freely. The tunnel by which Brownie Spring (pl. 2) was developed is excavated largely, if not entirely, in conglomerate in the older valley fill. A considerable amount of water drips from the roof of the tunnel, indicating that the water is moving relatively freely in the conglomerate in this locality. The spring discharges one-half to one cfs.

Most of the unconsolidated sand and gravel of the younger valley fill is capable of transmitting ground water freely, as is demonstrated by several large-capacity wells in northern Pahranagat Valley. However, much of the valley fill apparently is composed of deposits of fine sand and silt that have relatively low permeability and, where saturated, transmit water much more slowly than coarse sand and gravel. Younger valley-fill deposits in Pahranagat Valley commonly provide adequate supplies of water for domestic and stock purposes, even to wells that only penetrate the upper few feet of saturated deposits. The depth to water in most of Pahroc Valley apparently is below the younger valley fill and most of the successful wells probably are developed in the older valley fill.

GROUND-WATER APPRAISAL

Occurrence and Movement of Ground Water:

The occurrence of ground water in Pahranagat and Pahroc Valleys is one of contrast. The depth to ground water in most of Pahroc Valley is generally more than 200 feet. In Pahranagat Valley, however, the depth to water along the White River channel from the vicinity of Hiko Springs to Maynard Lake is at or within a few feet of land surface. Northward from Hiko along the lowland the depth to water increases; at the north end of Pahroc Valley it apparently is on the order of 250 feet or more. In most of Pahranagat Valley the younger valley fill along the White River channel is saturated to or nearly to land surface. Toward the mountains the depth to water increases.

Water-level control in wells is meager but suggests that the slope of the water table is toward the White River channel. For example, the depth to water in well 5S/60-6c1 is about 380 feet, or at an altitude of about 4,025 feet (pl. 1). This indicates a water-level gradient of roughly 70 feet per mile eastward toward Frenchy Lake. Similarly, the reported depth to water in well 4S/61-15a1 in Sixmile Basin is about 670 feet, or at an altitude of about 4,000 (pl. 1 and fig. 4). This indicates an average gradient of about 22 feet per mile westward toward Hiko Spring or about 30 feet per mile southwestward toward Frenchy Lake.

In Pahroc Valley the depth to water in most places is below the bottom of the younger valley fill. Locally in the north end of the valley, where several stock wells are located, the water table is in the younger valley fill. It is inferred that at least part of the older valley fill is saturated, based on the depth to water of 255 feet in well 3N/60-33a1 in northern Pahroc Valley and the reported depth to water of about 350 feet in well 2S/61-23dl in southern Pahroc Valley (figs. 3 and 4).

Ground water also is stored and transmitted in the Paleozoic carbonate rocks beneath the valley fill. Hiko, Crystal, and Ash Springs issue from the Paleozoic carbonate rocks and play a dominant roll in the eonomy of the Pahranagat Valley. The magnitude of the combined discharge, averaging about 35 cfs, is far in excess of the amount that might be supplied by recharge from precipitation within the defined surficial area of the valley. This indicates that much of the ground water discharged by the springs is derived from beyond the drainage divide of the valley, a condition long recognized by the residents of the area. Thus, the hydrologic system, of which Pahranagat and Pahroc Valleys are a part, may be considered an open system -- that is, it extends beyond the limits of the valleys. To examine this feature further it is convenient first to identify a closed hydrologic system.

In typical hydrologically closed valleys in the Great Basin, ground water is derived largely from precipitation in the mountains enclosing the valley and moves toward the central part of the valley. In or adjacent to the topographically lowest part of a hydrologically closed valley, the water table, or upper surface of the zone of saturation, is at or within a few feet of land surface. Where the water table is close to land surface, ground water is discharged naturally by evaporation from the soil or from free-water surfaces and is transpired by plants (phreatophytes) that obtain most of their water from the zone of saturation or overlying capillary fringe.

Under long-term conditions and prior to development, in a hydrologically closed ground-water system average annual recharge to the ground-water reservoir equals average annual discharge. However, if a ground-water system in a topographically closed valley is hydrologically open, recharge derived from precipitation in the valley may be more or less than the natural discharge by evapotranspiration within the valley. Where the long-term recharge derived from precipitation within the valley is more than the long-term discharge in the valley, ground water must be discharging from the valley by underflow to an area or areas of lower hydraulic head. Conversely, where the long-term recharge derived from precipitation within the valley is less than the long-term discharge in the valley, recharge must be entering the valley by underflow from an area or areas beyond the topographic divide having a higher hydraulic head.

In addition to hydraulic head potentials, the hydrologic properties of the rocks affect the movement of ground water. Where bedrock in the mountains enclosing a topographically closed valley is relatively impermeable, ground water normally is part of a closed hydrologic system. Where the bedrock is at least locally permeable, the ground-water system may be hydrologically open.

The chemical quality of the ground water is another factor that may be an aid in evalutaing the nature of a ground-water system. Ordinarily, the concentration of chemical constituents shows considerable variation in different parts of a ground-water system. Generally, the concentration is least in recharge areas and greatest in natural-discharge areas. Despite the normal variations that may be expected in the chemical constituents in ground water in a given system, the character and concentration of one or more constitutents may aid in identifying whether or not the system is closed.

In summary, closed or open ground-water systems may be identified by potential hydraulic gradients between the reference valley and adjacent valleys, by the relation of recharge to discharge within the valley, by the water-bearing character of geologic formations, including modifications by structural deformation, and by the chemical quality of the ground water.

Potential hydraulic gradients suggest that the source of the water discharged by the principal springs in Pahranagat Valley is beyond the surficial drainage divides of the valley. From north to south, the altitude of Hiko Spring (cover photograph) is about 3,890 feet and that of Crystal Springs is about 3,805 feet. Thus, a southward hydraulic gradient is indicated. This is consistent with the generally southward gradient of the White River channel. It is inferred that the principal source of ground water issuing from the springs is generally from areas to the north, although some probably is supplied from the northeast and northwest.

Figure 3 shows an approximate water-level profile in the valley fill along the White River channel from about the north end of Pahroc Valley to Hiko Springs. The control is not as good as might be desired but is sufficient to show that the hydraulic gradient slopes southward through Pahroc Valley. The profile is drawn on water levels in the valley fill, and therefore probably is not identical to the profile that exists in the underlying Paleozoic carbonate rocks along the same section.

The steep gradient at the north end of the profile is interpreted to represent a loss in head due to part of the ground water locally moving from the valley fill into the underlying Paleozoic carbonate rocks, which are believed to have a higher transmissibility. If this is correct, then the water-level profile for ground water in the Paleozoic carbonate rocks would be somewhat lower in altitude than the one shown in figure 3.

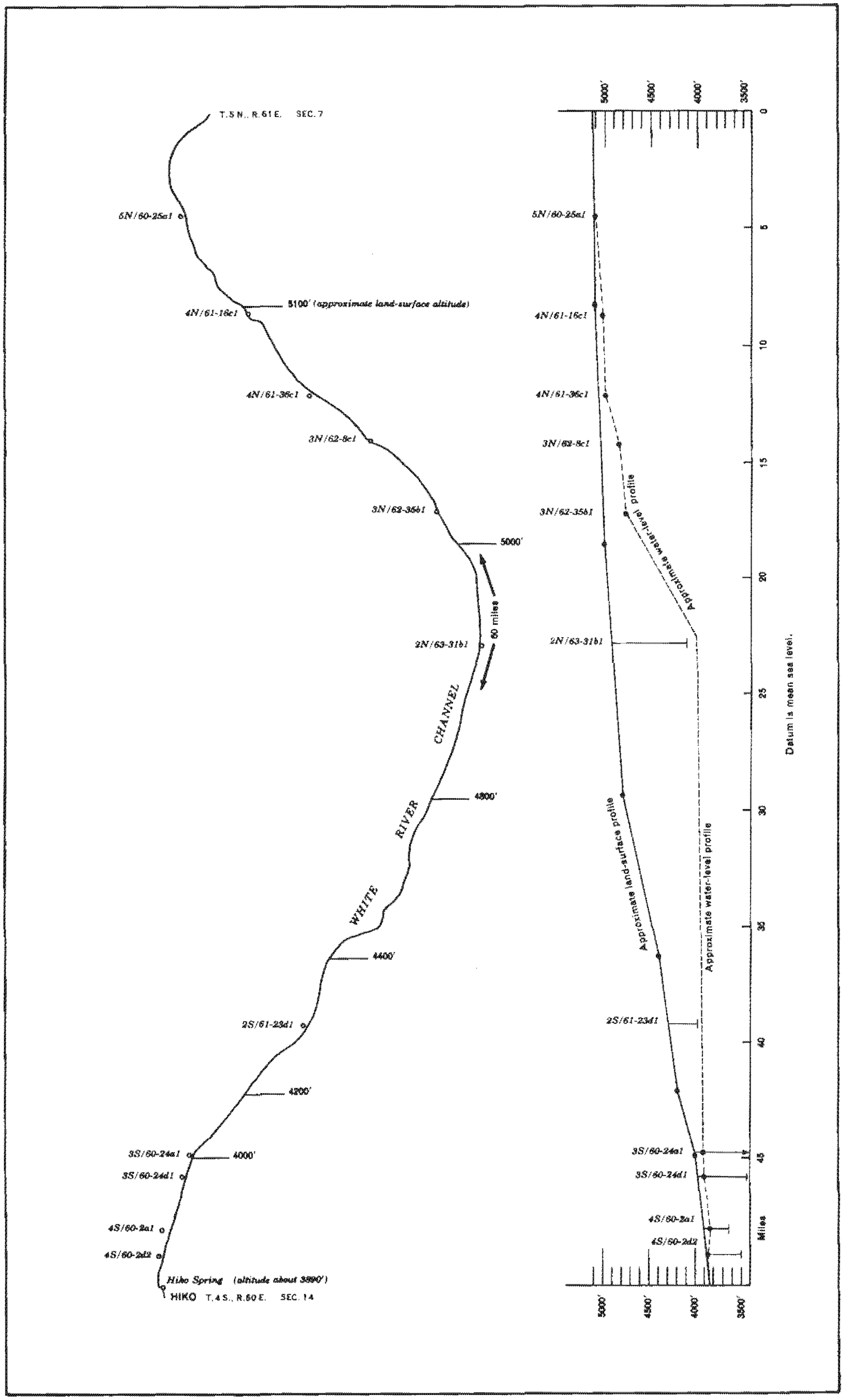

Figure 3.—Sketch of water-level profile along White River Channel, north from Hiko Spring.

To the northeast and east the lowest known water levels also are higher than the altitude of the springs in Pahranagat Valley. Figure 4 shows locations of selected wells and the approximate altitude of water levels in Dry Lake and Delamar Valleys. Here, too, water levels are those for wells developed in the valley fill. Also it is likely that the hydraulic head of ground water in the carbonate rocks underlying the valley fill in these valleys may be somewhat lower than that in the valley fill in the same location. Eakin (1963) concluded that gradients were favorable for the movement of ground water from Dry Lake and Delamar Valley toward Pahranagat Valley or southward.

To the northwest the lowest known water levels also are higher than the altitude of the springs. Figure 4 shows the location of selected wells and the approximate altitude of water levels in Garden Valley. The location of a dry well in upper Seaman Wash also is shown and indicates that the water-level altitude in the Tertiary volcanic rocks at that locality is lower than about 4,500 feet. The water-level altitudes shown for Garden Valley in figure 4 also represent the water table in the valley fill. It is inferred that the water levels in the carbonate rocks at those points are at somewhat lower altitudes. Thus, based on the potential hydraulic gradients, ground water probably moves from the northwest, north, and northeast toward the principal carbonate springs in Pahranagat Valley.

Ground-water discharge from Pahranagat Valley is many times the estimated recharge of 1,800 acre-feet a year from precipitation within the defined surficial tributary area of the valley (table 4). Most of the discharge is from the carbonate springs, which is on the order of 25,000 acre-feet a year. The substantially greater discharge over the estimated recharge thus supports the concept that the source of much of the ground water in Pahranagat Valley is derived from beyond the valley limits. In contrast, Pahroc Valley has an insignificant amount of ground-water discharge from springs or by evapotranspiration in areas of shallow water table. The estimated recharge from precipitation within the drainage area of Pahroc Valley as defined is only about 2,200 acre-feet a year (table 4) and is much greater than the discharge by springs or evapotranspiration. To the extent that the estimated recharge from local precipitation is of the correct order of magnitude, part of the ground water discharged from Pahroc Valley apparently occurs by underflow along the White River channel at the south end of Pahroc Valley; the larger part may occur as underflow southward in the Paleozoic carbonate rocks.

The capability of the Paleozoic carbonate rocks to transmit ground water in quantity has been discussed by Eakin (1962, 1963a, 1963b). Drilling at the Nevada Test Site, some 60 miles southwest of Alamo, has shown that the Paleozoic carbonate rocks commonly transmit ground water more readily than the Paleozoic clastic rocks and Tertiary tuff (Winograd, 1962, p. 110). Thus, the Paleozoic carbonate rocks probably afford the best opportunity for ground-water movement between valleys. It should be recognized, however, that ground water is transmitted largely through fractures or solution openings in the Paleozoic carbonate rocks. Potential lateral movement of ground water through the carbonate rocks for distances of many miles is favored by the

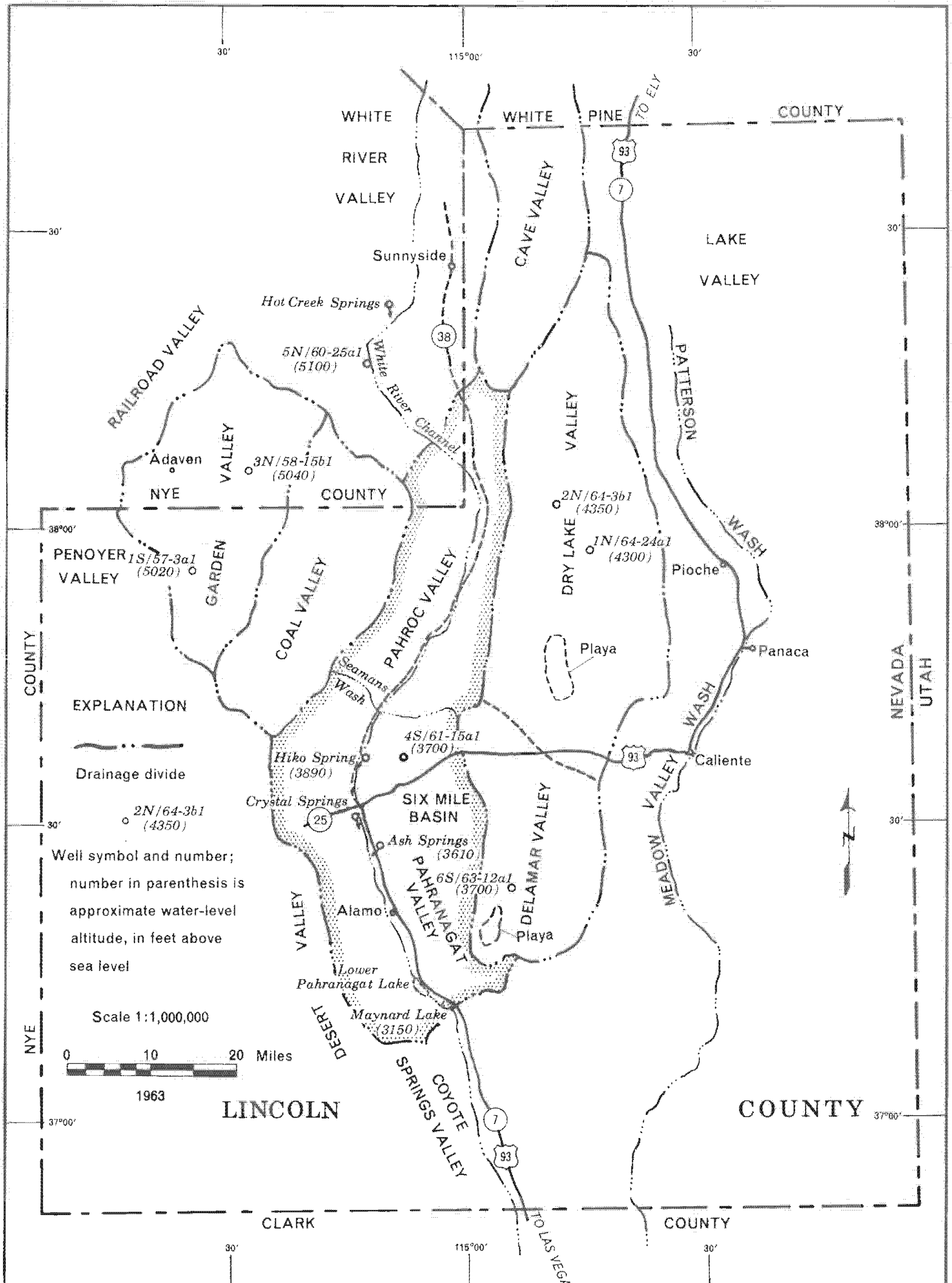

FIGURE 4. Sketch map showing relation of Pahranagat and Pahroc Valleys to adjacent, areas

relatively high proportion of carbonate rocks in the Paleozoic section, which is on the order of 30,000 feet thick. Several periods of faulting and erosion provided the mechanism for the development of extensive systems of fractures and solution openings. Although faulting may offset or separate individual carbonate formations, it very likely may provide connection with other carbonate formations and thus result in hydraulic continuity over considerable distances.

With respect to chemical quality, which is further discussed beyond, the analyses show that the water from Hiko, Crystal, and Ash Springs is low in dissolved-solids content, about 300 ppm (parts per million), is of a calcium-magnesium bicarbonate type, having a typical calcium-magnesium ratio for water from carbonate rocks. All these features are favorable to support the inference that the water discharging from the springs probably in large part has been transmitted through carbonate rocks.

In Pahranagat Valley ground water discharged from the carbonate rocks through the principal springs and to some extent by subsurface seepage into the valley-fill deposits are sufficient to maintain ground-water levels in these deposits at or near land surface in the lower parts of the valley from the vicinity of Hiko Spring southward to Maynard Lake. Ground water in the younger valley fill in this area provides all or most of the water withdrawn by the wells in this section of the valley.

The quantity of ground water presently withdrawn by wells in this area generally has little effect on water levels, except temporarily and adjacent to pumped wells. However, water-level fluctuations do occur from natural causes and from the effects of different routing arrangements for conveying the spring flow through the valley.

Figure 5 shows hydrographs of water levels for eight wells in Pahranagat Valley. For some wells, measurements have been made since about 1946. As there normally have been only one or two measurements a year, detailed fluctuations are not identified. The effects of pumping for irrigation north of Hiko Spring are illustrated generally by the hydrographs for wells 4S/60-2a1, 4S/60-2d1, and 4S/60-2d2. The nearly 60-foot decline in water level in well 4S/60-2a1 (photograph 2) is largely the result of pumping from that well since 1948. The decline indicates that much of the water withdrawn from that well has apparently come from ground water in storage adjacent to the well.

The hydrograph for well 4S/60-2d1 (now destroyed) shows the drawdown interference effect of pumping nearby irrigation well 4S/60-2d2, particularly in 1951 and 1952. For the period of record, water levels in both wells have declined 5 to 10 feet as a result of pumping one or both wells.

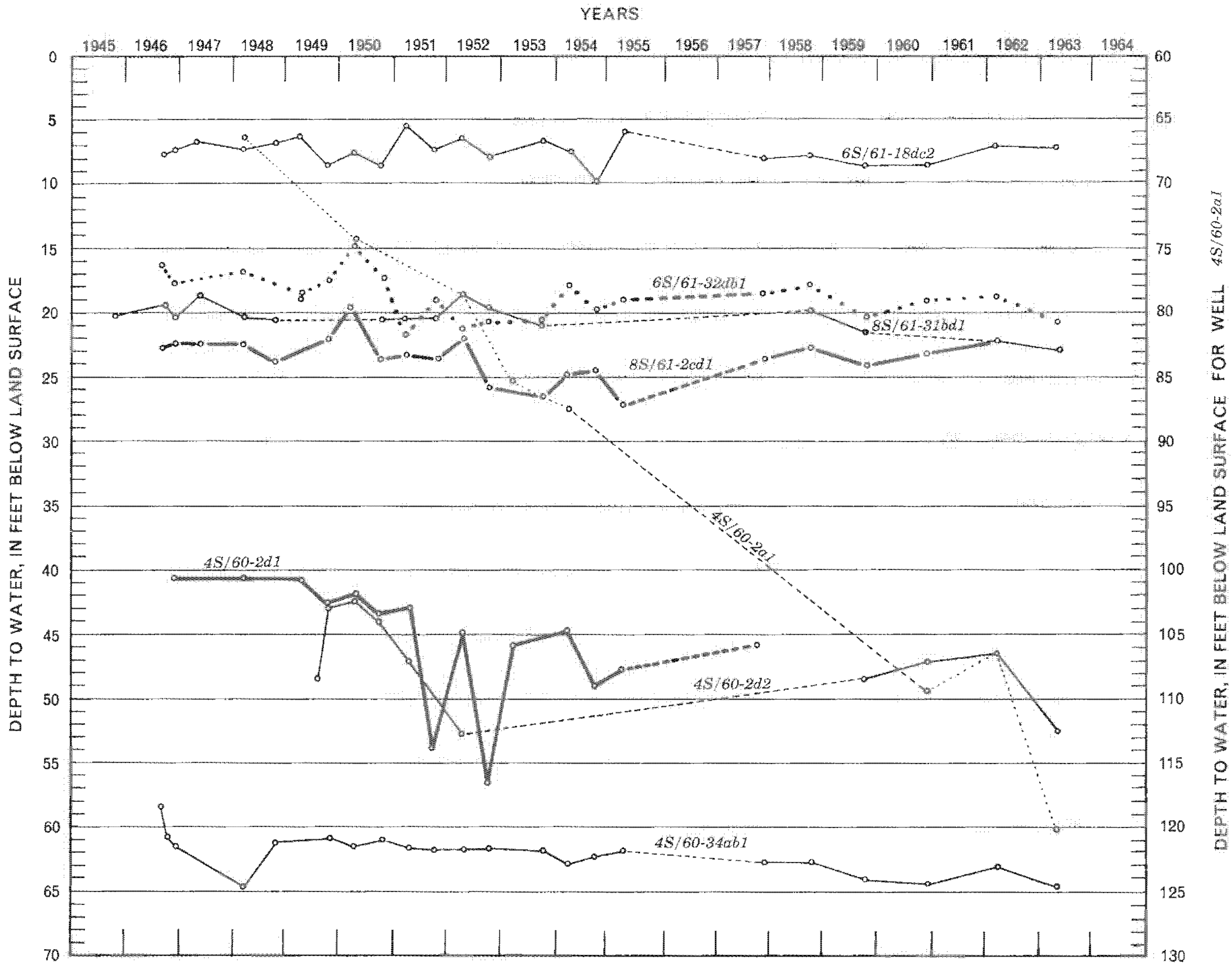

Figure 5.—Hydrographs for eight wells in Pahranagat Valley, Lincoln County, Nevada

Annual water-level fluctuations in the other five wells probably are caused largely by evapotranspiration, recharge from spring flow in ditches and irrigated fields, and local recharge from precipitation. In general, ground-water levels in the younger valley fill southward from Hiko Spring has been affected only slightly by pumping from wells in the last 15 years. North of Hiko Spring, where the amount of ground-water pumpage for irrigation was larger, water-level declines resulted from removal of water from storage.

Estimated Average Annual Recharge:

The average annual recharge to the ground-water reservoir is estimated as a percentage of the average annual precipitation within the valley (Eakin and others, 1951, p. 79-81). A brief description of the method follows: Zones in which the average precipitation ranges between specified limits are delineated on a map, and a percentage of the precipitation is assigned to each zone which represents the assumed average recharge from the average precipitation in that zone. The degree of reliability of the estimate so obtained, of course, depends on the degree to which the values approximate the actual precipitation in the several zones and the degree to which the assumed percentages represent the actual proportion of recharge to ground water. Neither of these factors is known precisely enough to assume a high degree of reliability of the recharge estimate 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 the actual long-term average annual recharge.

The precipitation map of Nevada (Hardman and Mason, 1949, p. 10) has been adjusted (Hardman, oral communication, 1962) to the improved topographic base maps (scale 1:250,000) now available for the whole State. The base map for plate 1 of this report was prepared from the same series of topographic maps. The several zones of precipitation applicable to Pahranagat and Pahroc Valleys are: The boundary between the zones of less than 8 inches and 8 to 12 inches of precipitation was delineated at the 6,000-foot contour; between 8 to 12 inches and 12 to 15 inches, at the 7,000-foot contour; between 12 to 15 inches and more than 15 inches at the 8,000-foot contour.

The average precipitation used for the respective zones, beginning with the zone of 8 to 12 inches of precipitation, is 10 inches (0.83 foot), 13.5 inches (1.12 feet), and 17.5 inches (1.46 feet).

The percentages of the average precipitation assumed to represent recharge for each zone are: less than 8 inches, 0; 8 to 12 inches, 3 percent; 12 to 15 inches, 7 percent; and 15 to 20 inches, 15 percent.

Table 4 summarizes the computation of recharge for Pahranagat and Pahroc Valleys. The recharge (column 5) for each zone is obtained by multiplying the figures in columns 2, 3, and 4. Thus, for the zone of 12 to 15 inches of precipitation in Pahranagat Valley the computed recharge is 10,000 (acres) times 1.12 (feet) times .07 (7 percent), which is about 800 acre-feet.

The estimated total average annual recharge derived from precipitation within the drainage basins is 1, 800 acre-feet in Pahranagat Valley and 2, 200 acre-feet in Pahroc Valley.

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

Pahranagat Valley

Precipitation zone (inches)	Approximate area of zone (acres)	Average annual precipitation (feet)	Percent recharged	Estimated recharge (acre-feet) (2 x 3 x 4 ÷ 100)
15+	500	1.46	15	100
12-15	10, 000	1. 12	7	800
8-12	37, 000	.83	3	900
8-	459, 000	--	--	--
	507, 000 (about 790 sq. mi.)		Estimated average annual recharge (rounded)	1, 800

Pahroc Valley

Precipitation zone (inches)	Approximate area of zone (acres)	Average annual precipitation (feet)	Percent recharged	Estimated recharge (acre-feet) (2 x 3 x 4 ÷ 100)
15+	600	1.46	15	150
12-15	8, 400	1. 12	7	650
8-12	56, 000	.83	3	1, 400
8-	263, 000	--	--	--
	328, 000 (about 510 sq. mi.)		Estimated average annual recharge (rounded)	2, 200

Estimated Average Annual Discharge:

A relatively large amount of ground water is discharged from Pahranagat Valley by the natural processes of evaporation and transpiration. A minor amount of subsurface outflow may occur through the valley fill in the gap at Maynard Lake--the southern end of Pahranagat Valley. A large amount of ground water may discharge through Paleozoic carbonate rocks at the south end of the valley toward areas of lower head, although the proportion derived from the Pahranagat and Pahroc Valley drainage areas cannot be identified at this time.

Ground water discharged from Pahranagat Valley by evapotranspiration can be estimated roughly by evaluating the amount evaporated from the lakes, which are largely sustained by ground water, and the amount lost in the area of evapotranspiration. According to the record at Caliente, seasonal pan evaporation averages about 50 inches. Pan evaporation in Pahranagat Valley probably is somewhat greater than at Caliente. This is supported by the fact that Alamo is nearly 1,000 feet lower in altitude. Furthermore, Houston (1950, p. 19) indicates that on the average the growing season at Alamo is about 10 days longer.

To obtain a directly applicable rate of average annual evaporation from lakes would require a detailed study and rigorous analysis for the area of concern. However, a rough approximation may be obtained by using the rate indicated by Kohler, Nordenson, and Baker (1959, pl. 2), which is based on a study of nation-wide data for the period 1946-55.

The rate so indicated is about 58 inches, a little more than 4.8 feet a year. In a general way, this value is reasonable when compared to the evaporation record at Caliente. The pan record is seasonal. Further, although lake evaporation commonly is only about 70 percent of pan evaporation at the same locality, the Pahranagat Valley lakes are generally shallow and conditions favor relatively high evaporation rates.

The areas of the four lakes, Hiko, Frenchy, Upper Pahranagat, and Lower Pahranagat, undoubtedly vary widely during the season and from year to year. These variations may be due partly to natural fluctuation of supply but more probably are the result in changes in patterns of handling water by the users. For example, for the last few years Lower Pahranagat Lake has been virtually dry; but at the same time the average surface area of Upper Pahranagat Lake has increased. It may be, however, that the combined area of the lakes in the past averaged about 1,000 acres. This is close to the 953 acres estimated in 1958 by the U.S. Soil Conservation Service (D. J. Johnson, oral communication, June 1963). Based on the assumptions of an average lake area of about 1,000 acres and an annual evaporation rate of 4.8 feet, the average annual evaporation would be on the order of 5,000 acre-feet a year.

Additionally, there are about 8,000 acres in the valley lowland south of Hiko Spring. Of this amount it is estimated that beneath about 6,000 acres water is generally at or very near land surface resulting from applied irrigation water or high water table or a combination thereof. An evapotranspiration of 3 feet per year may be a reasonable approximation of the rate of loss from this area, which suggests a loss of about 18,000 acre-feet per year from the 6,000 acre area. Beneath the remaining 2,000 acres, the depth to water below land surface is somewhat greater. An evapotranspiration rate of 1.0 foot per year is assigned as a reasonable rate of loss, which suggests an annual loss of roughly 2,000 acre-feet per year. The combined loss by evapotranspiration from irrigated land and phreatophyte areas thus may be the order of 20,000 acre-feet per year, which together with the 5,000 acre-feet per year evaporation from the lake areas, gives a combined average annual evapotranspiration loss of about 25,000 acre-feet. It is emphasized that this estimate is a rough approximation and obviously is only as accurate as the assumptions. A more refined estimate of evapotranspiration loss would require a detailed field study over a considerable period of time.

As a check against the estimated losses by evapotranspiration, most of the natural ground water discharged within Pahranagat Valley may be evaluated by summing the discharge of the principal springs which probably supply most of the water evaporated and transpired on the valley floor. Continuous records of the discharge of Hiko, Crystal, Ash, and Brownie Springs are not available to demonstrate adequately the magnitude and variations of their discharge. However, some data are available. Carpenter (1915, p. 56) estimated that the discharge of Hiko Springs was 9 cfs, Crystal Springs 7 cfs, and Ash Springs was 20 cfs--a total of 36 cfs. The discharge of the springs as reported in the State Engineer Biennial Report for 1934-36 (1936, p. 60) was Hiko, 6.57 cfs, Crystal, 9.96 cfs, and Ash 19.34 cfs--a total of 35.88 cfs. In the State Engineer Biennial Report for 1940-42 (p. 48-50) it is reported that the discharge of Hiko Springs, 6.52 cfs, and of Crystal Springs, 9.68 cfs, were relatively constant and the sum of flow in four ditches from Ash Springs was 15.55 cfs. The sum of the discharge for the three springs at that time was 31.75 cfs, although it is not known whether the total flow of Ash Springs was measured. In the State Engineer Biennial Report for 1943-44 (1944, p. 25-26) the indicated discharge of Hiko Springs was about 6.4 cfs, of Crystal Springs about 9.5 cfs, and of Ash Springs 17.35 cfs.

Of the three springs, there is some indication that Ash Springs may be somewhat more variable than in the other two, as is indicated by the reported increase of 1.2 cfs on July 4, 1943. On June 17, 1963, measurements of Hiko, Crystal, and Ash Springs were 5.36, 11.84, and 17.0 cfs, respectively, or a total of 34.2 cfs. From the above information it would seem that a discharge of about 35 cfs might be assumed as a reasonable average for these three springs together with Brownie Spring, which has an estimated discharge of one-half to one cfs. An average discharge of 35 cfs is equivalent to an annual discharge of about 25,000 acre-feet, which is the same as estimated discharge by evapotranspiration. Despite the exact agreement of the two figures, it is likely that the spring discharge is not a complete measure of the discharge from the carbonate rocks. In all probability, additional discharge occurs by upward leakage from the carbonate rocks to the overlying younger valley fill. Thus, the exact agreement is more apparent than real.

Artificial withdrawals of ground water by pumping are estimated as follows: The domestic and stock use of water from most of the wells implies a relatively small annual withdrawal, probably not more than a few hundred acre-feet a year. A few wells, however, are used for irrigation. Most of these are north of Hiko, where four are being used solely for irrigation supply. The combined reported pumping rates are about 4,000 gpm (gallons per minute). Observation suggests that the normal pumping rates may be considerably less. For well 4S/60-2a1 a rough measurement indicates that the discharge is about 1,000 gpm in contrast to the reported rate of 1,800 gpm. It may be that the reported rate is the capacity of the well rather than the normal pumping rate. Assuming that the combined pumping rate may be more nearly 2,500 gpm and that the wells are pumped an average of 150 days, the seasonal pumpage would be approximately 1,500 acre-feet.

According to Houston (1950, p. 21, 23) irrigation requirements of water for alfalfa and small grains are about 28 inches (about 2.3 feet) and 14 inches (about 1.25 feet) respectively in the study area. If about 100 acres are in alfalfa and 200 acres are in grain, the water requirements would be nearly 500 acre-feet for the season. This is much less than the amount estimated from the generalized pumpage information.

At best the seasonal pumpage can be estimated only roughly and for the present purposes it is assumed that seasonal pumpage is on the order of 1,000 acre-feet. Actual pumpage for irrigation from these wells may be somewhat greater or less. Of the remaining wells used in whole or part for irrigation, the reported yields and apparent acreages irrigated suggest that annual pumpage probably does not exceed a few hundred acre-feet.

In summary, pumpage from wells in Pahranagat Valley in 1963 probably was about 2,000 acre-feet for all purposes.

Natural discharge of ground water by evapotranspiration in Pahroc Valley is small and is limited to areas adjacent to the few springs in the mountains, in small mountain washes where perched ground water may occur as underflow, and at the north end of the valley where the water level might be shallow enough to supply some of the water requirements to vegetation along the White River. The quantity of ground water lost by evapotranspiration in Pahroc Valley may be no more than a few tens or hundreds of acre-feet a year.

Pumpage in Pahroc Valley also is small and is limited to a few wells at the north end of the valley to provide water for stock. The total pumpage in 1963 probably was less than a hundred acre-feet.

Perennial Yield:

The perennial yield of a ground-water system is the upper limit of the amount of water than can be withdrawn economically from the system for an indefinite period of time without causing a permanent and continuing depletion of ground water in storage and without causing a deterioration of the quality of water. It is limited ultimately by the amount of natural discharge of suitable quality that can be salvaged for beneficial use from the ground-water system. The average recharge derived from precipitation and streams and from underflow into a valley are measures of the natural inflow to the ground-water system. The average discharge by evapotranspiration, discharge to streams flowing from the valley, and underflow from the valley are measures of the natural discharge from the ground-water system.

In Pahranagat Valley the estimated natural discharge from the valley by evapotranspiration is on the order of 25,000 acre-feet per year. This does not include the water that may be discharged from the south end of the valley by underflow through the carbonate rocks. Recharge by precipitation within the valley is estimated to be only about 1,800 acre-feet per year (table 4). Thus, the source of virtually all the natural discharge from the valley fill is from basins up-gradient and hydrologically interconnected with Pahranagat Valley. These include White River, Cave, Dry Lake, Delamar, Pahroc, Garden, and Coal Valleys and possibly other valleys in upgradient positions.

Because little development has occurred in these valleys, as yet no depletion in natural discharge has occurred in Pahranagat Valley. However, although most of these valleys are several tens of miles distant, substantial development in them in time might intercept some of the supply now reaching Pahranagat Valley. The result, of course, would be a decrease in the natural discharge. If it is assumed that all the evapotranspiration loss can be salvaged for beneficial use, the perennial yield of Pahranagat Valley can be related to present and future patterns of development as follows: (1) Under the existing conditions of development in the gross ground-water system, the yield of Pahranagat Valley would be at least 25,000 acre-feet per year; and (2) under future conditions, if substantial development in upgradient valleys intercepts underflow supplying the springs in Pahranagat Valley, the yield of Pahranagat Valley could be expected to decrease--the magnitude of the decrease would be directly proportional to the magnitude of the water intercepted; the time that it would take for the effects to reach Pahranagat Valley would be inversely proportional to the distance.

With regard to the present pattern of use, the magnitude of the discharge from Hiko, Ash, and Crystal Springs is one of the dominant features in Pahranagat Valley. In the areas where these springs occur and the water is utilized, some of the water returns to the ground-water reservoir and subsequently is discharged from the reservoir by evapotranspiration or other means. In effect this is a natural re-cycling of the ground water, and thus at least some of the water may be used two or more times; once when the water first is discharged from the springs and later when waste water from higher situated irrigated areas is used in lower situated areas. This may be repeated as many times as the physical situation permits and may be limited by the extent to which water quality deteriorates through re-use until finally it becomes unsuitable for the intended use. Additionally as the spring water is distributed through ditches and on irrigated fields, part of the spring discharge returns to the ground-water reservoir from which it can be withdrawn by wells.

In a manner somewhat similar to that described above for reuse of the spring discharge, ground water from the valley fill also could be re-used. Generally, the proportion of ground water that is returned to the ground-water reservoir after being pumped and used would tend to be of somewhat poorer chemical quality. Under a long-continued operation involving return of pumped ground water to the ground-water reservoir the quality of the pumped water may be severely deteriorated.

Certainly a large proportion of the water discharged from the springs is used to some extent. However, part of the discharge from the springs goes into the ground-water reservoir during and after being distributed and used for irrigation. If development from wells resulted in a substantial lowering of water levels in the lowland areas, a larger proportion of the water now consumed by phreatophytes would be salvaged for beneficial use.

As for Pahroc Valley, the perennial yield could be limited to the estimated recharge from precipitation within the valley of 2,200 acre-feet per year. On the other hand, Pahroc Valley also is part of the regional ground-water system contained in the carbonate rocks, and therefore development could affect the supply now reaching Pahranagat Valley, as already described. Moreover, some of the water in Pahroc Valley is moving southward through the alluvial fill to Pahranagat Valley, and development in these deposits could affect the supply reaching downstream areas.

Ground Water in Storage:

The amount of ground water stored in the valley fill and underlying carbonate rocks in Pahranagat and Pahroc Valleys is substantial. The large volume of ground water in storage provides a reserve for maintaining an adequate supply for pumping during protracted periods of drought or for temporary periods of high demand under emergency conditions. This reserve, in effect, increases the reliability of ground water as a dependable source of supply and is an important asset in semiarid regions where surface-water supplies vary widely from year to year.

The magnitude of the stored ground water in Pahranagat Valley may be illustrated by the following calculation: The surface area of the lowlands from the latitude of Hiko Springs to the latitude of Lower Pahranagat Lake is about 8,000 acres. This area overlies a substantial thickness of saturated sedimentary deposits. If a value of 15 percent is assumed as the specific yield (drainable pore space) of the saturated deposits, then about 120,000 acre-feet of water are stored in the upper 100 feet of saturated valley fill.

This volume of water is roughly five times the estimated average annual discharge.

A moderate reduction of stored water beneath the lowland part of Pahranagat Valley would be beneficial in that the drainage of water-logged and high water-table lands would be improved. Further, the lowered water levels would result in decreased evapotranspiration loss and in effect would increase the amount of ground water available for development.

Chemical Quality:

The chemical quality of the water in most ground-water systems in Nevada varies considerably from place to place. In recharge areas the chemical concentration of the water normally is very low. However, as the ground water moves through the system to discharge areas it comes into contact with soluble rock materials for long periods of time. 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, by the time the water is in contact with the rocks, and by the temperature and pressure in the ground-water system.

Ground water discharged at the land surface commonly is subjected to the processes of evapotranspiration, and the dissolved-solids content of the remaining water is increased. The water comes in contact with soluble materials in the soils over which it flows and the chemical composition may be altered by ion exchange or the total concentrations may be increased. When applied to irrigated fields to which soil amendments or fertilizer has been added, there also is an opportunity for the chemical concentration of the water to be increased.

In Pahranagat Valley, the large spring discharge used for irrigation, the shallow water table, and the fact that the area of ground-water discharge by evapotranspiration includes the area of irrigation, all combine to produce an environment wherein the chemical concentration and character of ground water generally is variable from place to place and with time.

Table 5 lists several analyses that illustrate some of the variations. As may be noted, the successive analyses for Hiko, Crystal, and Ash Springs indicate considerable uniformity of chemical constituents and concentration with time. Much of the variation actually indicated by the analyses probably results from different analytical techniques used and variations in the actual points at which the samples were taken. In contrast the concentration of the Lower Pahranagat Lake varies rather widely with time. This characteristic is to be expected where a high rate of evaporation is operative more or less uniformally from year to year and the inflow is variable due to diversion and evapotranspiration losses between the lake and the supplying springs. It may be expected, too, that there commonly would be a tendency for some increase in concentration in the irrigation ditches as the water moves southward, at least during the summer period of high evaporation rates.

Table 5.--Chemical analyses, in equivalents per million, (epm) of water from selected wells, lakes and springs in Pahranagat Valley, Nevada

Location	Name	Date of collection	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B) ppm	Dissolved solid (residue at 180°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Non-carbonate	SAR	RSC	Specific conductance (micromhos at 25°C)	pH
4S/60	Hiko Springs	11-15-12	-	-	2.60	1.97	0.96	-	4.46	-	0.75	0.31	-	-	-	-	-	-	0.63	0.89	596	-
4S/60	Hiko Springs	2-25-44	-	-	2.25	2.13	0.74	-	4.39	-	.50	.25	-	-	-	-	-	-	.50	.01	512	-
4S/60	Hiko Springs	6- 4-44	-	-	2.40	1.90	1.30	-	4.60	0	.74	.30	-	-	0.21	-	-	-	.89	.30	511	-
4S/60-22	Orifice of Spring Hiko Springs	3-10-62	80	33	2.20	1.92	1.26	0.18	4.26	0	.75	.31	0.03	0.02	.01	-	206	0	.88	.14	494	8.0
4S/60	Hiko Lake	6-21-39	-	-	4.20	1.88	10.83	-	10.00	0	5.23	1.69	-	-	-	-	-	-	6.23	3.92	1824	-
5S/60-10	Crystal Springs	11-16-12	-	-	2.65	1.88	.83	-	4.28	-	.77	.31	-	-	-	-	-	-	.55	0.00	577	-
5S/60-10	Crystal Springs	3-11-35	-	-	2.75	1.88	1.61	-	4.48	-	.27	1.94	-	-	-	-	-	-	1.12	0.00	671	-
5S/60	Crystal Springs	4-25-44	-	-	2.20	2.00	.71	-	4.20	0	.46	.25	-	-	-	-	-	-	.49	0.00	491	-
5S/60	Crystal Springs	6- 4-44	-	-	2.30	1.96	1.10	-	4.40	0	.71	.25	-	-	.05	-	-	-	.75	.14	488	-
5S/60-10a	Upper orifice of Crystal Springs	3-10-62	82	31	2.30	1.82	1.04	.14	3.97	0	.71	.28	.15	.01	.01	-	206	8	.72	0.00	481	7.2
5S/60	Crystal Springs	4-15-63	81	31	2.25	1.93	1.00	.13	4.46	0	.56	.23	.03	.02	.2	277	223	0	.69	.28	-	8.0
5S/60-36	Ash Spring	11-16-12	-	-	2.45	1.06	1.96	.36	4.24	0	.96	.31	-	-	-	-	-	-	1.48	.73	624	-
5S/60	Ash Spring	3-11-35	-	-	2.70	.82	2.05	-	4.33	-	.85	.39	-	-	-	-	-	-	1.16	.81	614	-
	Ash Spring Diversion point	9-13-39	-	-	2.88	2.00	1.49	-	5.12	0	.90	.35	-	-	-	-	-	-	.96	.24	693	-
5S/60	Ash Spring	4-25-44	-	-	2.25	1.48	.91	-	4.11	-	.38	.25	-	-	-	-	-	-	1.88	.38	473	-
5S/60	Ash Spring	6- 4-44	-	-	2.32	1.59	1.30	-	4.20	0	.72	.30	-	-	.37	-	-	-	.65	.29	480	-
	Outlet of Pool	3- 9-62	88	31	1.95	1.49	1.39	.17	3.79	0	.71	.27	.03	.02	.1	-	172	0	1.06	.35	443	8.1
7S/61	Alamo Town Well	3-11-35	-	-	3.60	3.93	4.35	-	7.48	-	3.17	1.18	-	-	-	-	-	-	2.24	0.00	1242	-
7S/61	Alamo Town Well	9-22-44	-	-	2.80	1.15	6.35	-	6.80	.57	2.12	.79	-	-	-	-	-	-	4.53	2.85	1111	-
7S/61	H. Frebner Farmstead (Well)	1942	-	-	3.65	2.54	7.70	-	8.90	-	3.48	1.60	-	-	.98	-	-	-	4.40	1.71	1250	-
8S/61	Upper Pahranagat	4-25-44	-	-	2.50	4.00	2.48	-	6.40	0	1.93	.65	-	-	-	-	-	-	1.37	0.00	898	-
8S/61	Upper Pahranagat	6- 4-44	-	-	1.42	1.05	7.10	-	5.00	.80	2.92	.85	-	-	.39	-	-	-	6.48	2.53	947	-
8S/61	Upper Pahranagat	9-14-44	-	-	2.13	5.97	13.00	-	9.80	1.00	6.98	3.32	-	-	.71	-	-	-	3.24	1.70	1775	-
8S/61	Lower Pahranagat	11-21-12	-	-	.90	11.39	35.35	-	13.15	4.70	22.62	7.15	-	-	-	-	-	-	12.24	.86	4647	-
8S/61	Lower Pahranagat	4-25-44	-	-	2.34	8.00	8.52	-	11.64	0.10	4.81	2.48	-	-	-	-	-	-	3.75	1.30	1902	-
8S/61	Lower Pahranagat	6- 4-44	-	-	1.01	2.21	20.40	-	8.95	2.70	9.01	3.00	-	-	.87	-	-	-	16.06	5.73	1751	-
8S/61	Maynard Lake Outlet	3-20-37	-	-	2.92	7.76	16.65	3.29	-	9.14	10.84	4.11	-	-	-	-	-	-	7.30	0.00	2655	-

Chemical data for ground water in the younger valley fill beneath the lowlands of Pahranagat Valley probably are not fully definitive of the chemical variations that may occur. In a general way, however, the chemical concentration of the ground water in the valley fill should tend to be relatively low but greater than that of the spring water where it discharges from the carbonate rocks. Inflow to the younger valley fill from the Pahranagat Range to the west also may be of relatively low chemical concentration. Generally however, as the ground water moves southward beneath the lowlands the chemical concentration should tend to increase as it moves through the deposits and as it mixes with re-cycled irrigation water that has been partly concentrated by evapotranspiration.

The chemical concentration of water from Hiko, Crystal, and Ash Springs is relatively low as indicated by the specific conductance. The specific conductance determined for samples collected in March 1962 at the three springs ranged from 443 for Ash Springs to 494 for Hiko Spring. These values are roughly equivalent to about 300 parts per million of dissolved solids. The water from the three springs is of a calcium-magnesium-bicarbonate type. Their irrigation class is C2-S1 according to the classification of the Salinity Laboratory of the U.S. Department of Agriculture (1954, p. 79). That is, C2 indicates a medium-salinity water which can be used if moderate leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. The S1 identification indicates a low-sodium water which can be used for irrigation on almost all soils with little danger of harmful levels of exchangeable sodium.

As indicated previously, the chemical concentration of the water tends to increase as the water from the springs moves southward due largely to evapotranspiration enroute. Thus, water in Lower Pahranagat Lake, according to the analyses in 1912 and 1944, ranged from C4+-S4 to C3-S1. The chemical character of the water at intermediate points is governed to a large extent by the routes of travel of the water. Minimum rate of deterioration would be expected for water that traveled directly through a ditch from the springs to the lower lake with little or no modification by seepage gain to that flow. On the other hand, maximum rate of deterioration between the springs and lower lake would be expected for water that had been reused for irrigation several times, or had entered the ground-water reservoir in the valley fill and returned as seepage to the drain ditches perhaps several times.

The chemical concentration of ground water in the valley fill is represented by only three analyses in table 5 and are from wells in or adjacent to Alamo. Specific conductance is in the range of 1,100 to 1,250. This is somewhat more than twice that of the springs but substantially less than that of the analysis for lower Pahranagat Lake. Apparently the chemical quality has been satisfactory for public supply as the supply has been used for many years.

Development:

The major ground-water development in Pahranagat Valley is dependent upon the discharge of the several large springs in the area. The ready availability of the water required very little development work in the early history of the valley. The effort to increase agricultural production included bringing additional land under irrigation, which necessitated the construction of minor control works at Hiko, Crystal, and Ash Springs to permit diversion of their flows into ditches and a ditch system to convey the water to points of use or disposal. In more recent years sections of the high-line ditches have been lined to reduce seepage loss. Drainage ditches have been constructed which to some extent has reduced water-logged areas. The pattern is such that water applied for irrigation and waste water from irrigation tends to maintain the level of ground water at or near the surface in the topographically lower parts of the lowland area southward from Hiko Springs, especially in the vicinity of the several lakes.

The water of the springs was adjudicated by Court Decree issued October 14, 1929, following a series of proceedings beginning December 8, 1919, when several users of the supply initiated a request for adjudication. The following is quoted from the Nevada State Engineer's report for the biennium 1929-30 (1931, p. 32);

"The Pahranagat Lake stream system is located in Lincoln County, from Hiko southerly in Pahranagat Lake, the town of Alamo being situated near the center of the system:

"December 8, 1919--Several of the water users diverting water for irrigation purposes from this source of supply petitioned the State Engineer to initiated adjudication proceedings to determine the relative rights of the various water users.

"July 27, 1921--The State Engineer issued order initiating proceedings for the determination of the relative rights to the waters of Pahranagat and Maynard Lakes and their tributaries.

"September 8, 1921, to May 27, 1922--Proofs of appropriation of water, maps, plans and surveys filed by water users with the State Engineer.

"1925--Abstract of Claims completed and filed by State Engineer in his office.

"October 1, 1925--Preliminary Order of Determination completed by State Engineer and filed in his office.

"January 25, 1926--Abstract of Claims and Preliminary Order of Determination open for inspection for twenty-day period.

"March 4, 1926--Last-day objections to the Preliminary Order of Determination would be received by State Engineer's office.

"April 21, 1926--Order of Determination filed by State Engineer in his office.

"March 10, 1927--Order of Determination filed by State Engineer with the Clerk of the District Court, Pioche, Nevada.

"June 21, 1927--Hearing held by Honorable Wm. E. Orr, Judge of the Tenth Judicial District Court of the State of Nevada.

"October 14, 1929--Decree issued by the above court.

"November 1, 1929--Certificates of Proof of Appropriation of Water issued by the State Engineer to the respective water users as set forth by the decree of October 14, 1929."

Covered by the decree were 3,018.05 acres of harvest land and 1,953.57 acres of diversified pasture land, or a total acreage of 4,971.62 acres. Duty of water was set at a rate of 1 cfs per 100 acres.

The acreage and crop type apparently varies to some extent from year to year. One example of the type and acreage of crops is given in the Nevada State Engineer Biennial Report for 1934-36 (1936, p. 60), as follows:

Corn	379.5
Milo maize	45.0
Alfalfa	1140.4
Wild hay	529.0
Orchard	43.0
Truck vegetables	75.75
Irrigated pasture	950.10
Wheat	46.0
Barley	170.0
Oats	50.0
Potatoes	12.50

The organization of the Alamo Irrigation Company (1922) and subsequently Ash Springs Irrigation and Hiko Irrigation Companies (1949) resulted in improvement in distribution practices. Much work has been done in lining ditches and installation of diversion works. With all the work that has been done additional improvements could be made to afford greater control of water losses and water-logged areas. The nature of such improvements depend, however, upon the cost to benefit involved and the degree to which changes in the basis of the economy might be desired by the community.

Ground water developed by wells has long provided water for domestic and stock purposes in Pahranagat Valley. Plate 2 shows the location and tables 6, 7, and 8 give information concerning most of the wells in the valley lowland. The location of other wells in Pahranagat and Pahroc Valleys are shown on plate 1.

The domestic and stock use of water from most of the wells now requires a relatively small annual withdrawal, probably not more than several hundred acre-feet a year. Throughout the valley at least 25 wells have been drilled with the expectation of their being used for irrigation. Commonly yields or pumping lifts or a combination thereof have not been satisfactory for the intended purpose. Yields of as much as 1,800 gallons a minute have been reported, but more typical yields are on the order of a few hundred gallons a minute. Of the larger yields, seemingly the quantity has been obtained by relatively large drawdowns. Many of these wells are used now for domestic or stock purposes, a number are unused, and some have been destroyed. A few wells, however, are used for irrigation. Most of these are in Pahranagat Valley, north of Hiko. Here four wells are being used as sole irrigation supply. Seasonal pumpage apparently is on the order of 1,000 acre-feet. Of the remaining wells used in whole or part for irrigation, the reported yields and apparent acreages irrigated suggest that annual pumpage probably does not exceed a few hundred acre-feet. Total pumpage from wells in Pahranagat Valley in 1963 probably did not exceed about 2,000 acre-feet per year for all purposes.

Pumpage in Pahroc Valley presently is restricted to small withdrawals for stock supply from the few wells at the north end of the valley. It probably does not exceed a few tens of acre-feet per year.

Potential Development.--Additional development of ground water in Pahranagat Valley is possible. Several thousand acre-feet a year might be developed from the valley fill southward from Hiko Springs. Moderate pumping of ground water from the fill probably would have little effect on the discharge of the principal springs whose flow is adjudicated. Depending upon the location of wells, the lowering of water levels could induce additional water to seep into the valley fill from ditches now conveying water from the springs, or could cause some reduction of water-logging. However, locally the chemical quality of the ground water in the valley fill may not be suitable for irrigation use.

PROPOSALS FOR ADDITIONAL GROUND-WATER STUDIES

In compliance with the request of Hugh A. Shamberger, Director, Department of Conservation and Natural Resources, State of Nevada, suggestions for special studies are listed below to obtain needed basic data and a better understanding of the factors that influence or control ground water in Pahranagat and Pahroc Valleys and similar areas in Nevada. These proposed studies are separate from the usual areal investigations, which commonly are needed after the development of ground water in a given area has become substantial.

1. Monitoring the discharge of Hiko, Crystal, and Ash Springs involves the installation of recording devices for the continuous measurement of the total discharge of these springs. Data so obtained would be of considerable value to the users of the spring flow and possibly would assist them in determining the potential value of further improvements in the handling of the water that they may wish to consider.

Additionally the hydrologic value of such data would be substantial. Analysis of well-controlled data of the spring discharge would result in a much better understanding of the system of which they are a part. Variations in total discharge that may occur over periods of several years, might permit evaluation and correlation with antecedant climatic conditions. Should this be determinable with a high degree of reliability, the discharge might then be forecast to the potential benefit for local use.

2. Collection of data and analysis of the routing, use, and loss by evapotranspiration of the ground water in Pahranagat Valley would show more clearly the degree to which the water is re-cycled and reused from the points of discharge at the springs to the areas of final discharge from the valley by evapotranspiration processes. As a companion to the first proposed special study, this study in Pahranagat Valley could provide much valuable data on the details required for the evaluation of perennial yield as affected by development of this type. Resultant information could be of much value to local residents as a part of their considerations of further utilization of ground water in the valley. The information and data undoubtedly would be of additional illustrative value for preliminary application in other areas of the State having similar hydrologic conditions.

DESIGNATION OF WELLS

In this report the number assigned to a well is both an identification number and a location number. It is referenced to the Mount Diablo base line and meridian established by the General Land Office.

A typical number consists of three units. The first unit designates the township; "N" after the number identifies the township as north of the Mount Diablo base line; "S" after the number identifies the township as south of the Mount Diablo base line. The second unit, a number separated by a slant line from the first, is the range 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 lower case letter, which designates the quarter section, this letter may be followed by another letter which designates the quarter-quarter section, and finally, a number designating 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 or quarter-quarter of the section.

Table 6.--Records of selected wells in Pahranagat Valley, Lincoln County, Nevada.

Well number and location: See page for description of numbering system.
Depth of wells: reported.
Altitude: Land surface above mean sea level. Altitude given in whole feet are interpolated from topographic maps.
Measuring point: Above land surface: L, Land surface; Tc, top of casing, Ep, entry point.

Water level: in feet and tenths if measured by U.S.G.S.; in feet only if reported.
Yield: m, measured by U.S.G.S.; other drawdowns are reported.
Status or use: Ir, irrigation; P, public supply; Obs. observation D, domestic; U, unused; S, stock; C, construction.

Well number and location	Owner	Year completed	Depth (feet)	Diameter (inches)	Depth (feet)	Perforated zone (feet)	Altitude (feet)	Meas. Point: Description	Meas. Point: Height (feet)	Water level: Above(+) or below land surface (feet)	Water level: Date	Yield (gpm)	Drawdown (feet)	Status or use
3S-60-24a1	C. Stewart	1951	1157	8 5/8	143	-	4,000	Ep	.5	187.5	4- 1-63	400	-	Ir
3S/60-25a1	C. Stewart	1951	563	12	563	128-563	4,000	Ep	1.5	140.83	3-25-52	900	-	Ir
4S/60-1b2	M. K. Stewart	1943	250	10	85(?)	-	-	Tc	0.0	59.58	12-17-46	200	-	U
4S/60-2a1	M. K. Stewart	1948	340	10	-	-	-	Tc	1	106.11	2-25-62	1800	-	Obs
4S/60-2a2	M. K. Stewart	1949	403	12	385	0-385	3,915	Ep	-	-	-	-	-	-
4S/60-2d1	M. K. Stewart	1942	130	10	80±	-	-	Tc	.25	47.40	3-24-55	-	-	Ir, Obs
4S/60-2d2	M. K. Stewart	1949	471	12	-	-	3,905	Ep	1.5	50.7	4- 1-63	600	-	Ir, Obs
4S/60-11a1	M. K. Stewart	1948	105	10	-	-	-	-	-	29.72	2-19-48	-	-	U
4S/60-11a2	M. K. Stewart	1948	120	10	-	-	-	-	-	dry to 30	6- 3-63	-	-	U
4S/60-14bb1	K. Whipple	1960	400	12	400	65-400	3,900	-	-	47.00	9-30-60	700	-	Ir
4S/60-23cb1	Nevada Fish and Game	1949	100	8	68	24- 68	3,860	Tc	-	24	5- 7-49	383	-	D
4S/60-23cb2	Nevada Fish and Game	1954	67	14	67	20- 67	3,860	Tc	-1.5	22.0	4- 1-63	383	47	Ir
4S/60-34ab1	W. U. Schofield	1946	-	10	96	60-96	3,870	Tc	1.3	64.3	4- 1-63	-	-	Obs
4S/60-34ad1	M. F. Schofield	-	112	4	112	94-112	3,830	Tc	-14	24.8	4- 2-63	-	-	Obs, D
4S/60-34ad2	M. F. Schofield	-	-	8	-	-	3,840	Tc	LSD	49.15	4- 1-63	-	-	Ir
4S/60-34ad3	W. U. Schofield	-	66	6	-	-	3,850	Tc	4.9	25.8	4- 2-63	-	-	D
4S/61-15a1	- -	-	670+	6	-	-	4,375	Tc	-	6.70	-	-	-	S
5S/60-6c1	SCS stock well	-	404	4	395	-	-	-	-	382	-	10to15	-	-
5S/60-10ba1	Unknown	?	200	5	-	-	-	Tc	-	64.01	9-15-53	-	-	Obs
5S/60-14cb1	Stewart	-	64.5	6	44	20- 44	-	Tc	.6	8.12	12- 7-60	-	-	Obs
5S/60-14bc2	Stewart	1957	100	8	100	36-100	-	-	-	19	10- 9-57	-	-	D
5S/60-24bc1	Mrs. Wright	-	25	6	-	-	-	Ep	0	12.83	2-19-48	-	-	D
6S/61-7ca1	M. V. Burns	-	-	6	-	-	3,555	Tc	1	12.9	4- 2-63	12	-	Obs, S
6S/61-7ca2	M. V. Burns	-	16	dug	-	-	-	-	-	12	8-14-46	-	-	U
6S/61-18dc1	G. Whipple	-	16	dug	-	-	-	-	-	-	-	-	-	-
6S/61-18dc2	Whipple	-	41	6	-	-	3,550	Tc	1.7	6.9	4- 2-63	-	-	Obs
6S/61-29cc1	Highway Dept.	-	192	6	-	-	3,510	Ep	0	15.5	4- 2-63	-	-	Obs, D
6S/61-29cc2	Don Anders	-	16	6	-	-	3,507	Tc	7.6	12.6	4- 3-63	-	-	D
6S/61-30aa1	M. Steele	-	-	6	-	-	3,530	Tc	1.7	9.0	4- 3-63	-	-	D
6S/61-30a1	L. Nelson	1953	46	8	46	30- 46	3,544	Tc	.5	19.8	4- 3-63	-	-	D
6S/61-30dd1	L. E. Wadsworth	-	39	6	-	-	-	Tc	2.5	15.10	9- 8-54	-	-	Obs
6S/61-32ac1	E. Higbee	1945	44	6	44	31- 44	3,502	Tc	.5	22.9	4- 4-63	-	-	D
6S/61-32ba1	C. Foremaster	1949	64	6	64	50- 64	-	-	-	16	5- 49	10	-	D
6S/61-32cc1	W. Stewart	1944	63	4	-	-	-	Ep	.2	10.10	9-21-45	-	-	D
6S/61-32cd1	Alamo Irr. Co.	1954	97	8	82	8- 82	3,445	Tc	1.6	4.40	4- 4-63	225	-	D
6S/61-32cd2	Alamo Irr. Co.	1954	160	12	100	12-100	3,450	Tc	.0	9.4	4- 4-63	-	-	D
6S/61-32db1	K. Buffham	-	57	6	-	-	3,499	Ep	.5	21.4	4- 4-63	200	-	Obs
6S/61-32dc1	M. Bunker	1945	65	6	61	28- 61	-	-	-	9.04	9-30-48	-	-	Obs
6S/61-32dc2	M. Bunker	1950	44	10	44	28- 44	-	-	-	22	2-23-50	-	-	D
6S/61-32dd1	H. Nothey	1962	185	8	60	36- 56	3,472	Tc	-	51.7	4- 3-63	120	-	D
7S/61-5ac1	Unknown	1963	-	8	-	-	3,460	Tc	+3	17.53	4- 5-63	-	-	U
7S/61-5ad1	C. Holliday	-	-	2	-	-	3,465	Tc	+3	11.2	4- 3-63	-	-	D
7S/61-5ad2	C. Holliday	-	30	4x6	-	-	-	Ep	4	7.31	2-18-48	-	-	D
7S/61-5cc1	City of Alamo	1935	64	6	58	-	-	-	-	30	8-13-46	-	-	P
7S/61-5cc2	City of Alamo	1941	80	6	65	55- 65	-	-	-	30	8-13-46	60	-	P
7S/61-5cc3	Alamo WaterCo.	1961	-	8	-	-	3,480	Tc	LSD	35.9	4- 3-63	-	-	D
7S/61-5cd1	J. Richards	-	dug	dug	-	-	-	Tc	+2	13.50	3-24-55	-	-	D, Obs
7S/61-5dc1	H. Frehner	-	-	6	-	-	-	Tc	+2.9	13.42	3-24-55	-	-	D, Obs
7S/61-8ac1	J. Wright	1954	70	8	70	10- 70	-	-	-	7	12-15-54	-	-	S
7S/61-8ca1	M. K. Stewart	1954	52	10	51	45- 51	-	-	-	12	2-27-50	-	-	D

Table 6.-- (continued.)

Well number and location	Owner	Year com- pleted	Depth (feet)	Dia- meter (inches)	Depth (feet)	Perfor- ated zone (feet)	Altitude	Meas. Point De- scrip- tion	Meas. Point Height (feet)	Water level Above(+) or below land surface (feet)	Water level Date	Yield (gpm)	Draw- down (feet)	Status or use
7S/61-8dc1	L. M. Erckenbeck	1949	44	6 3/4	44	21- 44	-	-	-	16	5-14-49	12	4	D
7S/61-16bb1	M. Erckenbeck	-	30	-	-	-	-	-	-	26	8-12-46	-	-	S
7S/61-16bb2	Stewart	1959	70	8	68	30- 70	3,442	Tc	.5	27.0	4- 5-63	60	-	D,S
7S/61-17aa1	M. Erckenbeck	1946	25	4x4	-	-	-	-	LSD	19.20	12-17-46	-	-	D,S
7S/61-17aa2	Stewart	-	-	6	-	-	3,432	Tc	LSD	16.15	4- 4-63	-	-	D
7S/61-21aa1	F. Lamb	1944	70	4	70	35- 70	-	Tc	-3	8.08	2-18-47	-	-	D,S,Obs
7S/61-21aa2	R. Mills	1948	225	8	20	-	3,408	Tc	+2	8.02	9- 8-54	50	0	D,Obs
7S/61-21ac1	F. Lamb	1952	40	10	40	20- 40	3,437	Tc	-3	15.6	4- 4-63	-	-	D
8S/61-2bc1	Well-Stewart Const. Co.	1962	350	12	320	120-320	3,344	Ep	0	12.9	4- 5-63	800	-	C
8S/61-2cb1	F. Lamb	1947	92	10	-	-	-	Ep	.8	21.92	2-25-62	500	-	Ir,Obs
8S/61-10ad1	J. A. Hall	-	69	6	69	59- 69	3,337	Tc	-6	25.00	4- 5-63	18	-	D,S,Obs
8S/61-11bd1	B. Gorman	1947	60	7½	60.5	-	3,345	-	.5	9.08	2- 8-49	-	-	Ir,Obs
8S/61-24dc1	B. Grieves	-	-	4x4	-	-	-	Ep	.3	3.67	2-25-62	-	-	Obs, D
8S/62-31bd1	J. Richard	1944	66	10	-	-	-	Tc	+2.2	22.65	5-10-63	-	-	Obs

Thus, well number 6S/61-29cc1 indicates that this well was the first well recorded in the southwest quarter of the southwest quarter of sec. 29, T. 6 S., R. 61 E.

Wells on plate 1 are identified only by the section number, quarter-section letter, and quarter-quarter section letter and serial number. The township in which the well is located can be ascertained by the township and range numbers shown on the margin of plate 1. For example, well 6S/61-29cc1 is shown on plate 1 as 29cc1 and is within the rectangle designated as T. 6 S., R. 61 E. On plate 2, the full townships are not shown, but appropriate identification is given on the margins.

Table 7. -- Records of selected wells in Pahroc Valley, Lincoln County, Nevada.

2S/60-1d1. Owner not determined. Drilled well; depth 500 feet; casing diameter 6 inches. Dry well.

2S/61-23d1. Owner, Mr. Stewart. Proposed irrigation well; depth 302± feet; casing diameter 12 inches. Dry well.

2N/63-31b1. Owner, Bureau of Land Management. Drilled well; depth reported 800 feet; casing none, hole 8 inches in diameter. Dry well.

3N/62-8c1. Owner, Bureau of Land Management. Esplin well. Drilled stock well; depth unknown; casing diameter 8 inches. Equipped with gasoline engine and jack pump. Measuring point top of casing which is 1.0 foot above land surface. Depth to water below measuring point 217.5 feet, May 1, 1963.

3N/62-35b1. Owner, Bureau of Land Management. White River well No. 2. Drilled stock well; depth unknown; casing diameter 6 inches. Not equipped. Measuring point top of collar in 6-inch casing which is 1.0 foot above land surface. Depth to water below measuring point, 252.80 feet, May 8, 1963.

4N/61-16d1. Owner, John Uhalde. Drilled stock well; casing diameter 8 inches. Equipped with gasoline engine and gear jack pump. Measuring point top of casing which is about at land surface. Depth to water below measuring point 84 feet, May 10, 1963.

4N/61-27a1. Owner, Mr. Griswald. Lower Griswald well. Drilled stock well. Windmill powered.

4N/61-36c1. Owner, Bureau of Land Management. White River well No. 1. Drilled stock well; depth unknown; casing diameter 9 inches. Equipped with turbine pump and gasoline engine. Reported depth to water 90 feet.

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Table 8.--Drillers' logs of selected wells in Pahranagat Valley, Lincoln County, Nevada.

(The well logs contained herein were obtained from the office of the Nevada State Engineer, Carson City, Nevada. The terminology of the logs has been slightly modified for uniformity and clarification).

3S/60-24a1 C. Stewart

Material	Thickness (feet)	Depth (feet)
Soil	60	60
Boulders and clay	120	180
Gravel, water	45	225
Gravel and clay, brown and red	320	545
Gravel, water	30	575
Gravel and clay	582	1157
Total depth		1157

3S/60-24d1 C. Stewart

Material	Thickness (feet)	Depth (feet)
Soil	57	57
Gravel	12	69
Gravel and "red beds"	71	140
Gravel, and sand, water	63	203
Gravel	20	223
"Shell"	2	225
Gravel, sand, and clay	50	275
Gravel and "red beds"	100	375
Sand	25	400
Gravel, clay	103	503
Gravel, water	60	563
Total depth		563

4S/60-2a1 M. K. Stewart

Material	Thickness (feet)	Depth (feet)
Soil	15	15
Gravel, cemented	57	72
Sand and clay	168	240
Gravel	2	242
Sand, gravel and with thin gravel layers	98	340
Total depth		340

4S/60-2a2 M. K. Stewart

Material	Thickness (feet)	Depth (feet)
Soil, sandy	12	12
Gravel, cemented	71	83
Gravel, water	12	95
Gravel, clay	8	103
Gravel, water	7	110
Sand, red-brown; clay	90	200
Gravel, hard	8	208
Sand, gravel, clay	7	215
Gravel and clay	149	364
Gravel, water	31	395
Clay and gravel	8	403
Total depth		403

4S/60-2d2 M. K. Stewart

Material	Thickness (feet)	Depth (feet)
Soil, sandy	40	40
Gravel	2	42
Clay, sandy	16	58
Gravel, water	7	65
Gravel and clay	7	72
Sand, gravel; water	6	78
Gravel, sand, some clay	44	122
Sand, gravel and clay	246	368
Gravel and clay, silty	20	388
Gravel, sand	8	396
Gravel, sand and clay silty	29	425
"Rock", black and gray lenses of clay, white and sand	20	445
"Rock", hard, black and gray	5	450
Clay, sandy, white	4	454
"Rock", hard, black	3	457
Clay, sandy, white	4	461
"Rock", hard, black	3	464
Clay, sandy, white	2	466
"Rock", cherty hard, black and white	5	471
Total depth		471

Table 8.--(continued)

Material	Thick-ness (feet)	Depth (feet)
4S/60-11a2 M. K. Stewart		
Gravel, cemented	20	20
Clay, sandy	100	120
Total depth		120
4S/60-14bb1 K. Whipple		
Soil	5	5
Gravel	26	31
Sand, cemented	5	36
Gravel, cemented	29	65
Clay and gravel	30	95
Gravel, cemented	305	400
Total depth		400
4S/60-23cb1 Nevada Fish and Game		
Gravel	15	15
Clay	5	20
Gravel	11	31
Clay	1	32
Sand, coarse	7	39
Gravel	3	42
Clay, gray	7	49
"Hardpan", gravel cemented	2	51
Gravel and sand	11	62
Gravel with some clay	23	85
Clay, red	15	100
Total depth		100
5S/60-14bc2 Stewart		
Gravel	20	20
Clay, sandy	28	48
Gravel	48	96
Clay	4	100
Total depth		100
6S/61-29cc1 Highway Dept.		
Soil	1	1
Sand, coarse	7	8
"Loam"	1	9
Sand, coarse	9	18
Conglomerate, sandy	2	20
Clay	1	21
"Loam"	2	23
Quicksand, coarse, water	5	28
"Loam"	3	31
Quicksand, water	1	32
"Loam", sandy	6	38
Clay	151	189
Sand, water	3	192
Total depth		192
6S/61-30ba1 L. Nelson		
Sand and gravel	40	40
Clay	6	46
Total depth		46
6S/61-32cd2 Alamo Irrigation Co.		
Soil	5	5
Gravel	5	10
Sand and gravel	15	25
Clay, blue	25	50
Sand, fine	10	60
Sand and gravel, coarse	5	65
Sand, fine	10	75
Gravel and sand	10	85
Sand and clay	5	90
Clay	15	105
Clay, sandy	55	160
Total depth		160
6S/61-32dd1 Howard Nothey		
Sand and gravel	45	45
Sand, cemented	10	55
Clay, yellow	61	116
Sand and stratified clay	69	185
Total depth		185

Table 8.--(continued)

Material	Thick-ness (feet)	Depth (feet)
7S/61-8ca1 M. K. Stewart		
Sand, gravel, and some boulders	15	15
Sand, fine	15	30
Sand, coarse	3	33
Sand	12	45
Clay, orange	2	47
Gravel and sand	5	52
Total depth		52
7S/61-21aa2 R. Mills		
Soil	3	3
Sand and gravel	7	10
Sand and clay	215	225
Total depth		225
8S/61-2bc1 Well-Stewart Const. Co.		
Sand	35	35
Gravel	1	36
Sand	20	56
Gravel	2	58
Clay, sandy, blue	62	120
Gravel, cemented	230	350
Total depth		350
8S/62-31bd1 John Richard		
Soil	1	1
Silt	19	20
Sand, very fine in layers and sand, coarse and gravel	40	60
Conglomerate, cemented	25	85
Total depth		85

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