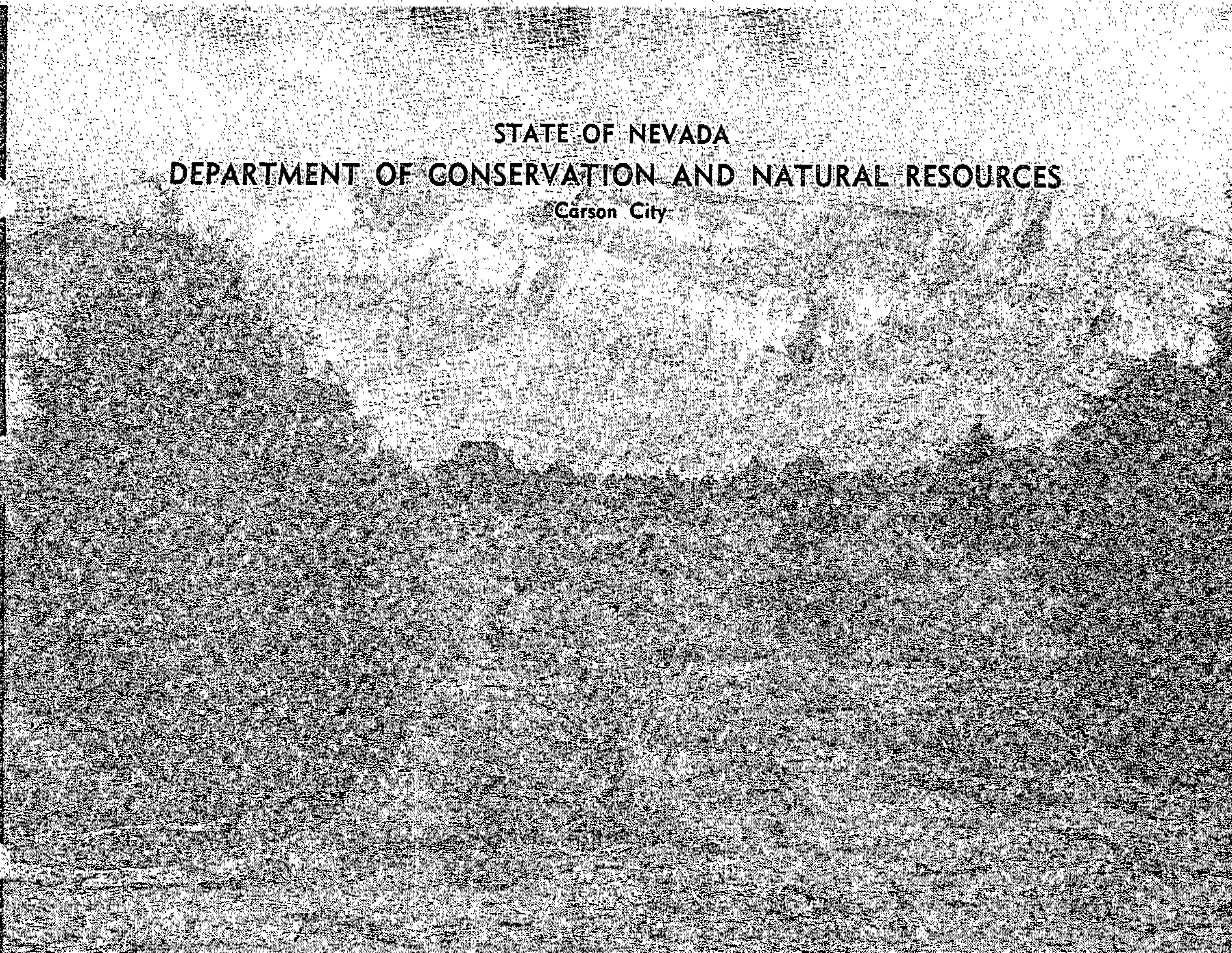
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of part of Schell Creek Range

GROUND-WATER RESOURCES – RECONNAISSANCE SERIES
REPORT 13

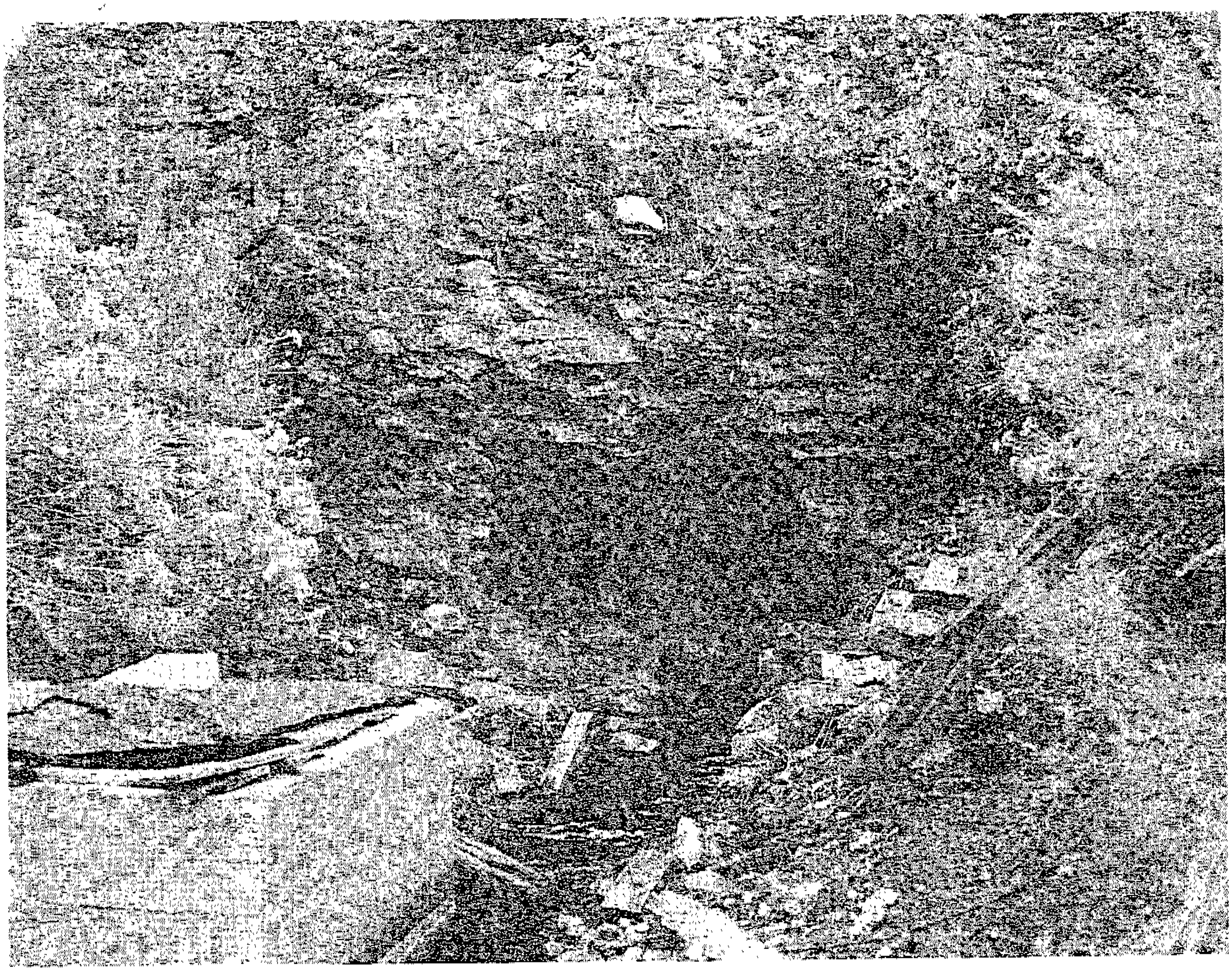
GROUND–WATER APPRAISAL OF CAVE VALLEY IN LINCOLN AND WHITE PINE COUNTIES, NEVADA

By
THOMAS E. EAKIN
Geologist

Price $1.00

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

DECEMBER 1962



SPRING NEAR GARDNER RANCH

View southeast of spring SW$\frac{1}{4}$NE$\frac{1}{4}$, sec. 16, T. 9 N., R. 64 E., about $\frac{1}{4}$ mile east of Gardner Ranch. Spring discharge estimated to be less than 10 gallons per minute, October 1962. Spring has been "developed" by cleaning out natural opening in Paleozoic (Cambrian) limestone, which crops out in an isolated hill north and east of Gardner Ranch.

COVER PHOTOGRAPH

View northeast of Schell Creek Range north of Patterson Pass. Bold cliffs are composed largely of Paleozoic (Cambrian) carbonate rocks. Thick and extensive Paleozoic carbonate rocks afford favorable conditions for ground-water recharge where they are exposed in the mountains. Ground water moves through fractures and solution openings. Paleozoic carbonate rocks supply many of the larger springs in eastern Nevada, and also provide a means for ground water to move from one valley to another where hydraulic gradients are favorable.

GROUND-WATER RESOURCES - RECONNAISSANCE SERIES

Report 8

GROUND-WATER APPRAISAL OF INDEPENDENCE VALLEY, WESTERN ELKO COUNTY, NEVADA

by

Thomas E. Eakin,
Geologist

Prepared Cooperatively
by the

Geological Survey
U. S. Department of the Interior

May
1962

GROUND-WATER RESOURCES - RECONNAISSANCE SERIES

Report 13

GROUND-WATER APPRAISAL OF CAVE VALLEY IN LINCOLN AND WHITE PINE COUNTIES, NEVADA

by

Thomas E. Eakin

Prepared cooperatively by the

Geological Survey

U. S. Department of the Interior

1962

FOREWORD

This report, No. 13 in the reconnaissance ground-water series, covers Cave Valley in Lincoln and White Pine Counties, and considers the problem of inter-valley movement of ground water. Mr. Thomas E. Eakin, Geologist with the U. S. Geological Survey who made this study and report, suggests that information accumulated as a result of ground-water investigations in Nevada seemingly indicates that the Paleozoic carbonate rocks control the ground-water hydrology in many areas in eastern and southern Nevada.

Mr. Eakin points out that apparently one regional unit of this type is associated with the White River system which extends from north of the latitude of Ely to the vicinity of Muddy River Springs near Moapa, a distance of more than 200 miles. Available information suggests the interbasin movement of ground water through bedrock, largely Paleozoic carbonate rocks, may involve Long, Jakes, White River, Cave, Dry Lake, Delamar, Garden, Coal, Pahranagat, Kane Springs, and possibly Penoyer, and Desert Valleys in the White River regional system.

I feel that we should definitely start studies of the interbasin movement of ground water in the various regional systems. Such studies will take years to develop answers but may at some future time make possible the optimum use of all of our ground water resources.

Studies such as this one indicate the desirability and necessity of ground-water studies in all of the valleys in Nevada. We hope that during the next biennium we can increase this reconnaissance ground water report program.

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

January, 1963.

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ILLUSTRATIONS

TABLES

GROUND-WATER APPRAISAL OF CAVE VALLEY IN LINCOLN AND WHITE PINE COUNTIES, NEVADA

by

Thomas E. Eakin

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SUMMARY

The results of this reconnaissance indicate that the average annual ground-water recharge may be on the order of 14,000 acre-feet. This estimate cannot be checked directly against an estimate of ground-water discharge as apparently a substantial part of the average annual discharge leaves Cave Valley by subsurface underflow west, southwest or south principally through Paleozoic carbonate rocks. Ground water discharged by evapotranspiration from Cave Valley probably is not more than a few hundred acre-feet a year. Therefore by difference, discharge by subsurface underflow may closely approach the estimated average annual ground-water recharge.

The perennial yield could be substantially larger than the few hundred acre-feet a year estimated as discharged by evapotranspiration. This would be possible through partial interception of ground water that is contained in the valley fill. Interception probably could be accomplished best by development along the main channel of the valley and its tributaries northward from T. 8 N. The magnitude of the perennial yield cannot be estimated, as it would depend largely on the distribution of and amount pumped from wells, the permeability of the water-bearing zones, and the proportion of total recharge that passes through the valley fill in the vicinity of the well development.

Ground water in storage in Cave Valley is substantial and is estimated to be about 1,000,000 acre-feet in the upper 100-feet of saturated valley fill beneath a 100,000-acre area in the lower part of the valley.

The most favorable area for ground-water development appears to be along the main channel of the valley and its principal tributaries in T. 9 N. and the south half of T. 10 N., where the depth to water is relatively shallow. Elsewhere moderate yields might be obtained along the lower part of the alluvial apron northward from the playa. However, in most areas of the alluvial apron, the non-pumping depth to water commonly may be 300 or more feet.

INTRODUCTION

The development of ground water in Nevada has shown a substantial increase in recent years. Part of this increase is due to the effort to bring new land into cultivation. The increasing interest in ground-water development has created a substantial demand for information of 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. For this reason each study is limited severely in time, field work for each area generally averaging about two weeks.

Additionally, 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. A list of the titles of previous reports published in the series is given at the end of this report. The present report is the thirteenth in the reconnaissance series. It describes the physical conditions of Cave Valley and includes observations of the interrelation of climate, geology, and hydrology as they affect ground-water resources. It includes also a preliminary estimate of the average annual recharge to and discharge from the ground-water reservoir.

The investigation was made under the general direction of G.F.Worts, Jr. District Chief, Water Resources Division, U.S. Geological Survey. Some of the well data were supplied by C. T. Snyder, Water Resources Division, and were obtained as part of the soil and moisture conservation program of the U.S. Geological Survey.

Location and General Features

Cave Valley, in eastern Nevada, lies within an area enclosed by lat 38°15' and 38°51' N. and long 114°43' and 114°58' W. The north end of the valley is about 30 miles south of Ely, Nevada. North-trending Cave Valley is about 41 miles long and has a maximum width, between drainage divides, of about 13 miles in the latitude of Mount Grafton (pl. 1). The valley as defined has an area of about 365 square miles.

Improved roads provide access to the north end of the valley from southern Steptoe Valley. Additionally, access to the valley may be attained

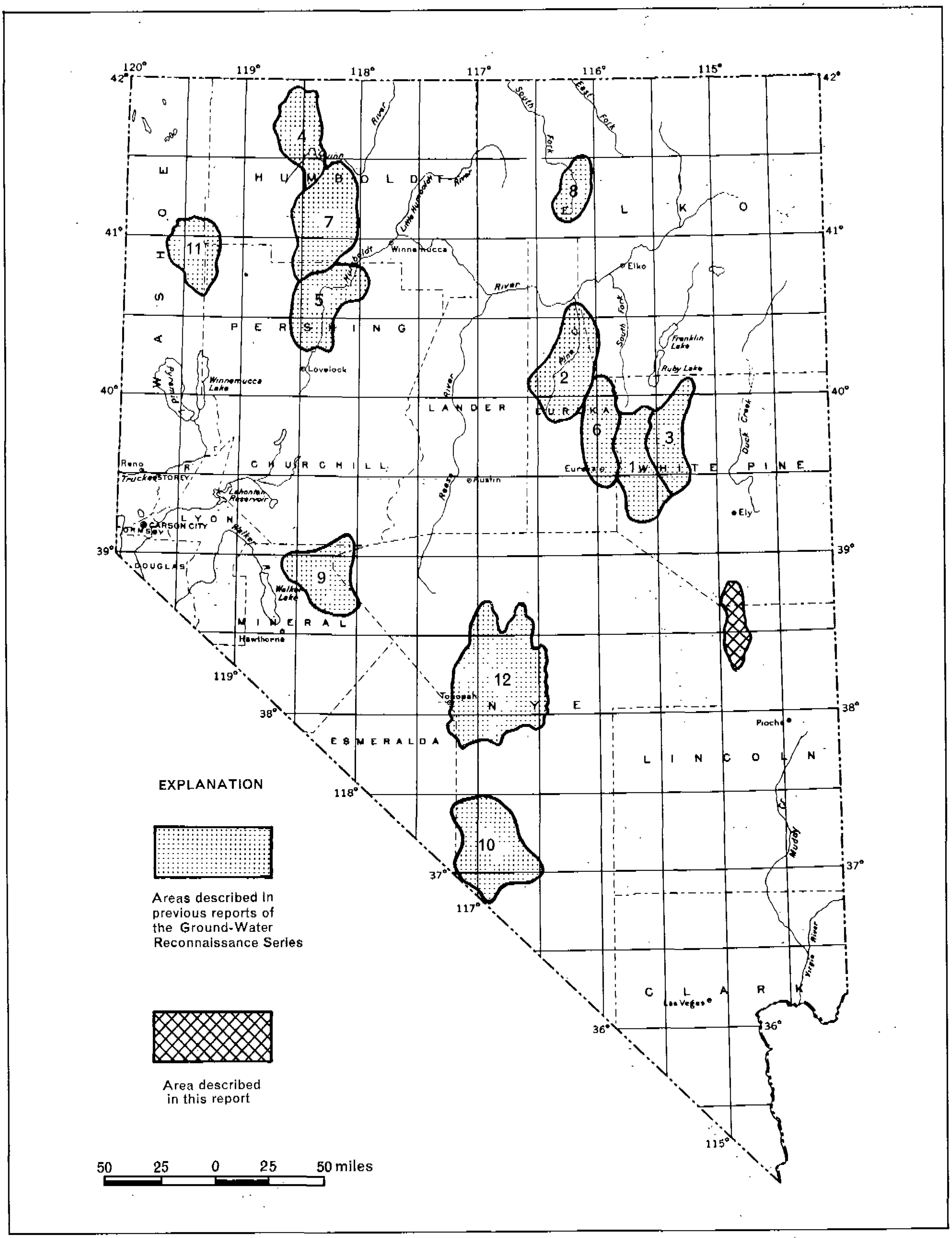

Figure 1. **MAP OF NEVADA**
showing areas described in previous reports of the ground water reconnaissance series and the area described in this report.

through Patterson Pass from the east and principally through Shingle Pass from the west. Unimproved trails permit general access to principal points in the valley during good weather.

Cave Valley is used for livestock range. Several ranches are in the northern part of the valley; however, they are occupied only for short periods during the year.

Climate

The climate of eastern Nevada is semi-arid in the valleys and sub-humid to humid in the higher mountains. In the valleys, precipitation and humidity are generally low and summer temperatures and evaporation rates are high. Precipitation is irregularly distributed but generally is least on the valley floor and greatest in the mountains. Winter precipitation occurs largely as snow distributed through several months. Summer precipitation commonly occurs as localized thundershowers. The daily and seasonal range in temperature is relatively large, and the growing season is relatively short.

Precipitation has not been recorded in Cave Valley. An approximate indication of precipitation in Cave Valley may be obtained from the U.S. Weather Bureau precipitation records for Ely airport and Kimberly, about 30 miles north of Cave Valley. (See table 1.)

Table 1.--Average monthly and annual precipitation at Ely airport and Kimberly for period of record

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

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Ely 1/	.64	.57	.92	.96	.88	.61	.57	.48	.59	.70	.59	.55	8.06
Kimberly 2/	1.55	1.49	1.55	1.32	1.07	.66	.90	.83	.68	.89	.84	1.51	13.30

1/ Altitude 6,257 feet. Location Sec. 35, T. 17 N., R. 63 E. Period of record, 23 years, 1939-1961 (continuing).

2/ Altitude 7,230 feet. Location Sec. 8, T. 16 N., R. 62 E. Period of record, 27 years, 1931-58.

The maximum recorded annual precipitation has been 13.52 and 19.95 at Ely and Kimberly, respectively. The minimum recorded annual precipitation has been 5.22 and 7.82 at Ely and Kimberly, respectively. It is inferred that the range and distribution of precipitation at Ely airport and Kimberly are broadly representative of precipitation in Cave Valley.

The average growing season in Cave Valley has not been determined, but a crude approximation may be obtained by reference to a nearby area. Houston (1950, p. 6) states that the average growing season at McGill, in Steptoe Valley, is about 119 days (May 26 to September 22). Killing-frost conditions vary with the type of crop. Weather Bureau records beginning in 1948 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 the following temperature groups; 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. Table 2 lists the number of days between the last spring minimum and the first fall minimum for the first three of these groups at Ely airport and McGill during the 10-year period ending 1961.

Table 2.--Number of days between the last spring minimum and the first fall minimum for Ely airport and McGill during the 10-year period 1952-61

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

	32°F or below		28°F or below		24°F or below	
	Ely airport	McGill	Ely airport	McGill	Ely airport	McGill
1952	88	150	88	204	188	216
1953	70	117	90	--	128	191
1954	97	114	97	174	124	178
1955	7*	116	114	141	143	183
1956	86	137	130	164	153	194
1957	75	121	96	136	139	151
1958	91	120	112	151	172	180
1959	53	120	113	126	130	130
1960	63	90	63	93	96	143
1961	133	113	118	139	141	141

*The record shows frost on June 30 and July 7, but no frost during the succeeding 72 days to September 17th.

The topography of Cave Valley favors the flow of heavy cold air toward the lower parts of the valley during periods of little or no wind movement. Therefore, the length of the growing season, although relatively short because of the latitude and because of the rather high altitude of the valley floor, undoubtedly varies considerably from one locality to another depending upon the pattern of flow of cold air currents. This may be illustrated, in part, by a comparison of the records of temperature at the climatological stations at Ely and McGill. The station at McGill is on the alluvial apron along the east side of Steptoe Valley. It is 250 to 300 feet above the axis of the valley. The station at the Ely airport, although only about 80 feet lower than the McGill station, is near the topographic low of the valley in that latitude.

The 10-year average number of days between temperatures of 32°F or below, is 121 days at McGill and 72 days at Ely airport; 28°F. or below, 133 days at McGill and 100 days at Ely airport; and for 24°F. or below, about 176 days at McGill and 140 days at Ely airport. Thus, the average growing season at McGill apparently averages 36 to 49 days more than at Ely airport. Similar local variations may be expected in Cave Valley.

On the basis of altitude and topographic environment it would appear that the conditions controlling minimum temperature in the lower parts of Cave Valley are more nearly comparable with those at Ely airport than with those at McGill.

Physiography and Drainage

Cave Valley is a topographically closed valley in the central part of the Great Basin section of the Basin and Range physiographic province of Fenneman (1931, p. 328). It is a north-trending valley bounded on the west by the Egan Range and on the east by the Schell Creek and Ely Ranges. The Ely Range trends south-southwest from the Schell Creek Range and closes the south end of the valley by merging with the Egan Range in a low bedrock divide. The Egan and Ely Ranges terminate a few miles south of Cave Valley. A low alluvial divide separates the north end of Cave Valley from Steptoe Valley.

The lowest part of Cave Valley is at the playa, altitude 6,000 feet, near the south end of the valley. The highest point in the adjacent mountains is Mount Grafton, altitude 10,993 feet, in the Schell Creek Range. Accordingly, the maximum relief in the area is about 5,000 feet.

North of Patterson Pass for a distance of about 8 miles, the crest of the Schell Creek Range (cover photograph) is above an altitude of 9,000 feet. The crest of the Egan Range in this latitude generally is lower, although it has three peaks which reach an altitude of more than 9,000 feet. The altitude of the unnamed peak south of Shingle Pass is 9,861 feet.

The principal drainage in the valley lowlands is southward toward the playa. The main drainage channel contains streamflow only during the spring runoff or for short periods after high intensity storms. North of the playa the

gradient along the main channel is about 50 feet per mile. The gradient increases northward and, in the latitude of Mount Grafton, is about 80 feet per mile. Between the mountains and lower parts of the valley gradients on the alluvial apron commonly range from 100 to 300 feet per mile. In the mountains erosion has produced steep sided canyons, and stream-channel gradients commonly are more than 300 feet per mile.

In late Pleistocene time a lake occupied the lower part of Cave Valley. Beaches, bars, and spits locally are prominent adjacent to the playa. Several shore lines were noted at an altitude of about 6,100 feet. An inspection of aerial photographs and topographic map indicates that the maximum altitude of the lake was not more than about 6,100 feet; therefore, it is unlikely that the lake overflowed into White River Valley to the south. The dissection of the main channel and its tributaries in the valley lowlands probably occurred at the time of the late Pleistocene lake when there was more runoff than under present climatic conditions.

GENERAL GEOLOGY

A reconnaissance geologic map of Lincoln County (Tschanz and Pampeyan, 1961), which includes most of Cave Valley, is available as a result of the cooperative program between the U.S. Geological Survey and the Nevada Bureau of Mines. Other geologic reports are available for areas adjacent to Cave Valley. Most of these stem from interest in oil and mineral exploration or development in eastern Nevada. Among those of particular pertinence to Cave Valley are reports by Kellog (1960) and Tschanz (1960). Additionally, several other papers published in the "Guidebook to the Geology of East-central Nevada" (1960) provide useful information.

The rocks of Cave Valley have been divided into two general groups, bedrock in the mountains and valley fill in the lowlands, and further into four major units. The distribution of the four units is shown on plate 1.

The bedrock includes Paleozoic carbonate and clastic rocks and Tertiary volcanic and sedimentary rocks. These crop out in the mountains and underlie the valley fill.

The valley fill includes deposits ranging in age from Tertiary to Quaternary and consists of younger unconsolidated clay, silt, sand, and gravel, which has been eroded from the surrounding mountains, and older partly consolidated pyroclastic deposits of welded tuffs, and sedimentary deposits. The subsurface lithology and water-bearing properties of the rocks are not known. However, it is inferred that the sediments of Quaternary age were deposited under subaerial and lacustrine environments. The rocks of Tertiary age underlying the Quaternary deposits are believed to be similar in character to the Tertiary rocks exposed in the mountains.

Bedrock in the Mountains

Paleozoic rocks in the Egan Range have a maximum thickness of more than 30,000 feet, according to Kellog (1960, p. 189). He indicates that Paleozoic rocks include about 5 percent quartz sandstone, about 15 percent shale, and about 80 percent carbonate rocks. Kellog (1960, pl. 2) indicates a maximum thickness of more than 9,000 feet of Tertiary rocks, of which about one-half comprise the Sheep Pass Formation of Winfrey (1958), of Eocene age. The Tertiary rocks include conglomerate, sandstone, siltstone, clay, and some fresh-water limestone. They also include volcanic tuffaceous deposits, welded tuff, and lava flows.

Most of the formations described by Kellog in the Egan Range also occur in the Schell Creek and Ely Ranges in the latitude of Cave Valley.

The Paleozoic and Tertiary rocks that crop out in the mountains have been deformed substantially by faulting. Because of differences in their hydrologic properties, the bedrock shown on plate 1 is divided into two units, those in which Paleozoic carbonate rocks predominate, and those in which clastic or volcanic rocks predominate.

Valley Fill

The valley fill shown on plate 1 is divided into two units: older unconsolidated to partly consolidated sedimentary deposits of late Tertiary and Quaternary age, and unconsolidated clay, silt, sand, and gravel of late Quaternary age. The valley fill, of which both the older and the younger units are exposed at land surface, was deposited partly under subaerial and partly under lacustrine conditions.

Water-Bearing Properties of the Rocks

The rocks of Paleozoic age generally have had their primary permeability substantially reduced, if not wholly eliminated, by consolidation or alteration. However, because they have been substantially fractured, some of these rocks locally may contain secondary openings through which water may be transmitted to some degree. Further, joints in carbonate rocks may be enlarged from solution by water moving through them.

Inspection of the Paleozoic rocks shows considerable fracturing and the cave and spring openings (see photograph on inside cover) near the Gardner Ranch attest to the development of solution conduits in the Paleozoic carbonate rocks. The occurrence and movement of ground water in carbonate rocks are further identified by the many springs issuing from or adjacent to those rocks in eastern Nevada. As many of these springs, such as Hot Creek and Lund in nearby White River valley, discharge relatively large quantities of water, it is further indicated that carbonate rocks locally may transmit substantial quantities of ground water.

The Tertiary volcanic rocks and older Tertiary sedimentary deposits exposed in the mountains are moderately consolidated. Although there may be some interstitial permeability probably much of the limited amount of water transmitted is through fractures. In general it is believed that the capability of the Tertiary rocks to transmit water is relatively low.

The unconsolidated sand and gravel deposits of Quaternary age are capable of transmitting ground water freely. However, the finer sand, silt, and clay have low permeability and transmit water slowly. These deposits occupy a large volume and have a relatively high porosity. Thus, where saturated, the Quaternary deposits contain a large volume of water in storage.

GROUND-WATER APPRAISAL

General Conditions

Most of the ground water in Cave Valley is derived from precipitation within the drainage area of the valley. Some of the precipitation on the upper parts of the alluvial apron percolates downward to the ground-water reservoir in the valley fill, but most of the recharge results from runoff in the mountains or percolation into the bedrock of the mountains and then lateral movement to the valley fill. Ground water in the valley fill moves from the areas of recharge in the northern part of the valley generally southward toward the playa.

In typical valleys in Nevada, most of the ground water is discharged naturally by evaporation and transpiration where the water table is at or near land surface. The principal means of natural ground-water discharge are transpiration by salt grass, native meadow grasses, rabbitbrush, greasewood, and other phreatophytes and evaporation from free-water surfaces and through the soil where the water table is shallow. Under ordinary conditions the area of principal evapotranspiration is in the topographically low part of the valley.

The water table is at shallow depth along the main channel and adjacent tributary channels from the middle of T. 9 N. into the northern part of T. 10 N. Here the depth to water may be nearly at land surface, as indicated by the 2-foot depth to water in well 9/63-1a1. The depth to water increases northward and is about 20 feet below land surface in well 10/63-25a1. At the playa, however, in the vicinity of T. 6 N., which is the lowest part of Cave Valley and where the principal area of natural discharge of ground water ordinarily would be found, the depth to water is substantial.

No wells were found in the immediate vicinity of the playa. However, the reported depth to water in well 7/63-15c1 and the measured depth to water in well 8/64-30c1 are both about 330 feet below land surface, and water-level altitudes are about 5,850 and 5,700, respectively. The indicated gradient of the water table between the two wells is about that of the land surface, or about 30 feet per mile. This gradient cannot be projected toward the playa because it is an apparent gradient only and the actual direction of the water-table gradient in this area is not known. It does indicate, however, that the depth to

water beneath the playa is substantial and may be on the order of 300 feet. This depth to water virtually precludes any significant amount of ground-water discharge from the ground-water reservoir in this area.

Most of the ground water must be discharged from Cave Valley by underflow through bedrock. This conclusion is based on a comparison of the magnitude of recharge to the valley and the magnitude of discharge by evapotranspiration from the valley in parts of Tps. 9 and 10 N., as discussed in subsequent sections of this report.

In this area the Paleozoic carbonate rocks offer the most favorable conditions for ground-water movement between topographically closed valleys (cover photograph). Springs, such as Lund and Hot Creek Springs in adjacent White River Valley, for example, discharge from carbonate rocks. Indeed, springs discharging from or adjacent to Paleozoic carbonate rocks in this part of Nevada are commonplace. Thus, although much is unknown about the role of Paleozoic rocks in the ground-water hydrology of this area, it is evident that these rocks to large degree control the movement of ground water in this part of the State.

The discharge of ground water through bedrock from Cave Valley is not sufficient to drain completely the valley fill. Indeed, available data permit only a generalization of the system. However, on the basis of information of the few stock wells developed in the valley fill, it is evident that at least limited supplies can be obtained from the more permeable zones in the zone of saturation in the valley fill.

If the Paleozoic rocks are capable of transmitting ground-water discharge from Cave Valley by underflow, the inference is that ground-water recharge to the valley also could be accomplished by a similar mechanism. Ground water in Cave Valley occurs at a minimum known altitude of about 5,700 feet; lower water-level altitudes occur in parts of White River Valley to the west and southwest and in Dry Lake Valley to the south. Higher water-level altitudes occur in the valley fill in the northern part of Geyser (Lake) Valley to the east and Steptoe Valley to the north. Thus, based on the difference in water-level altitudes in the several valleys, the potential direction of ground-water discharge from Cave Valley is limited to the south and west.

By a similar line of reasoning it could be postulated that ground water is recharged to Cave Valley from Steptoe and Geyser Valleys. However, the principal recharge from precipitation in Cave Valley is derived from the Egan and Schell Creek Ranges, which bound the east and west sides of the valley, and most of this recharge occurs north of T. 7 N. The area of recharge probably is an area of a relative high water level compared to the ground-water levels in the adjacent valleys. Thus, it is inferred that the water-level altitudes beneath the mountains in this part of Cave Valley are sufficiently high to form a hydraulic divide and thus, to preclude ground-water underflow from Steptoe and Geyser Valleys to Cave Valley. This contrasts with the south end of Cave Valley where the mountains are much lower and recharge from

precipitation is small to negligible; thus, an hydraulic barrier to underflow through the Paleozoic carbonate rocks from the valley probably does not exist.

The above discussion of the regional ground-water system in the carbonate rocks in the vicinity of Cave Valley is greatly simplified. However, the system actually has a much greater complexity. For example, locally there are perched ground-water bodies which tend to obscure the regional system to some extent. Thus, many of the small springs issuing in the mountains probably are related to perched ground-water bodies and do not reflect the position of the regional ground-water system in that locality. Indeed, it is not unlikely that the ground-water system in the valley fill in the vicinity of Cave Valley playa might appropriately be classified as semiperched with respect to the underlying regional ground-water system in the bedrock.

Estimated Average Annual Recharge

The average annual recharge to the ground-water reservoir may be 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 probable average recharge from the average annual precipitation on that zone. The degree of reliability of the estimate so obtained, of course, is related to the degree to which the values approximate the actual precipitation, and the degree to which the assumed percentages represent the actual percentage of recharge. Neither of these factors is known precisely enough to assure a high degree of reliability for any one valley. However, the method has proved useful for reconnaissance estimates, and experience suggests that in many areas the estimates probably are relatively close to the actual long-time average annual recharge.

The precipitation map of Nevada (Hardman and Mason, 1949, p. 10) has been modified by Hardman (oral communication, 1962) in part to adjust to recent topographic base maps for the region. This is the same base used for plate 1 of this report. Five precipitation zones were selected: the boundary between the zones of less than 8 inches and 8 to 12 inches 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 15 to 20 inches at the 8,000-foot contour; between 15 to 20 inches and more than 20 inches at the 9,000-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 feet), 13.5 inches (1.12 feet), 17.5 inches (1.46 feet), and 21 inches (1.75 feet).

The recharge estimates as a percentage of the average precipitation for each zone are: less than 8 inches, 0; 8 to 12 inches, 3 percent; 12 to 15 inches, 7 percent; 15 to 20 inches, 15 percent; and more than 20 inches, 25 percent.

Table 3 summarizes the computation of recharge. The approximate recharge (column 5) for each zone is obtained by multiplying the figures in columns 2, 3, and 4. Thus, for the zone receiving more than 20 inches of precipitation, the computed recharge is 3,500 acres x 1.75 feet x 0.25 (25 percent) = about 1,500 acre-feet. The estimated average annual recharge to the ground-water reservoir in Cave Valley is about 14,000 acre-feet.

Table 3.--Estimated average annual ground-water recharge from precipitation in Cave Valley

(1) Precipitation zone (inches)	(2) Approximate area of zone (acres)	(3) Average annual precipitation (feet)	(4) Percent recharged	Estimated recharge (acre-feet) (2 x 3 x 4 ÷ 100)
20+	3,500	1.75	25	1,500
15 to 20	19,500	1.46	15	4,300
12 to 15	69,000	1.12	7	5,400
8 to 12	114,000	.83	3	2,800
8-	29,000	--	-	--
	235,000	Estimated average annual recharge (rounded)		14,000

Estimated Average Annual Discharge

Some ground water is discharged from Cave Valley by transpiration of water-loving vegetation (phreatophytes) and by evaporation along stream channels and a smaller amount is discharged from wells. However, most ground-water discharge from the valley probably is by underflow through bedrock to the west, southwest, or south. The quantity of this underflow could not be estimated directly, because the hydrologic and geologic data are inadequate. However, an indirect estimate of the average annual underflow from Cave Valley can be made, based on the fundamental concept that over the long term, assuming no change in storage, recharge must equal discharge.

Ground-water discharge by evapotranspiration probably does not exceed a few hundred acre-feet a year. Evapotranspiration of ground water is limited to the area along the main drainage channel in the valley fill in Tps. 9 and 10 N.

adjacent tributary channels, and along channels in the upper parts of the alluvial apron where the water table is at shallow depth, such as in the vicinity of stock wells 9/62-1a1 and 10/63-25a1, and to the spring areas in sec. 9, T. 9 N., R. 64 E. and near the Gardner Ranch. Pumpage from stock wells probably does not exceed 100 acre-feet a year. Thus, the estimated average annual discharge of ground water by evapotranspiration and pumpage from wells is not more than several hundred acre-feet. In contrast, the estimated average annual recharge to ground water is about 14,000 acre-feet (table 3). If the values of recharge and discharge are of the correct magnitude, then by difference the discharge of ground water by underflow through the bedrock is only several hundred acre-feet less than the 14,000 acre-feet estimated for annual recharge.

Inasmuch as the estimate of discharge is based on the estimate of recharge, the estimated discharge in no way provides an independent check on the accuracy of the estimate of recharge.

Perennial Yield

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

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

The apparent substantial ground-water underflow out of Cave Valley further complicates the evaluation of perennial yield. Pumping from wells might not salvage much of this discharge unless the wells were drilled so as to intercept the discharge or unless pumping resulted in the removal of a substantial part of the ground water in storage in the valley fill. To accomplish the required lowering of water levels in the valley fill, pumping lifts

probably would have to be considerably in excess of present economic pumping lifts for irrigation.

However, to the extent that ground water occurs in the valley fill, development is possible in Cave Valley. On a perennial basis the amount would be limited to the ground water actually recharging the permeable water-yielding zones in the valley fill and in which the depth to water is shallow enough to pump economically. The rate at which ground water in Cave Valley could be pumped perennially under the above conditions is not known but may not exceed a few thousand acre-feet per year. The extent to which the yield could be increased above this amount is related largely to the amount of underflow from the valley that could be salvaged. In any event, assuming that all natural discharge could be salvaged, the yield could not exceed the average annual recharge on a continuing basis.

Storage

A considerable amount of ground water is stored in the valley fill in Cave Valley. It is many times the volume of the average annual recharge to the ground-water reservoir. The magnitude of this stored ground water may be estimated by the following calculation: The surface area of the valley fill below the 7,000-foot contour is a little more than 143,000 acres. If it is assumed that only about 100,000 acres overlies a reasonably thick section of valley fill that is saturated, and if a value of 10 percent is assumed as the specific yield (drainable pore space) of the saturated deposits, then about 10,000 acre-feet of water is in storage for each foot of saturated valley fill. Thus, the amount of water in storage in the upper 100 feet of saturated valley fill would be about 70 times the estimated average annual recharge to the ground-water reservoir. Because the depth to water commonly may be 300 feet or more in this part of the valley, pumping in quantity from this area probably would not be economically feasible for most uses.

The principal point to be recognized is that the 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.

Chemical Quality

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

pressure in the ground-water system.

No samples of water were collected for chemical analysis, and as a matter of fact there are not yet sufficient sampling points available in Cave Valley to determine the general chemical character of the ground water in the various parts of the valley. On the basis of the general chemical character of water associated with Paleozoic limestone and dolomite rocks elsewhere in eastern Nevada, the ground water in Cave Valley, at least in the marginal parts of the valley fill adjacent to the area of recharge, probably is a calcium-magnesium bicarbonate type and probably slightly to moderately mineralized. To the writer's knowledge, no serious effort to raise crops by irrigation has been attempted in Cave Valley, but should an attempt be made, the water developed for irrigation should be analyzed to determine its chemical suitability for the proposed crop.

Development

Ground water presently is used to a minor extent for stock supplies in Cave Valley, and well 9/63-1a1 is equipped with a small turbine pump. Water from this well may have been used to a limited extent for the irrigation of native meadow grasses. The volume of water discharged from wells and springs probably is less than 100 acre-feet a year. Although data are not available to indicate where moderate-to large-capacity wells might be developed, yields of a few hundred gallons a minute probably could be developed along the principal channel and its tributaries in the latitude of T. 9 N., and the southern part of T. 10 N. Initial efforts to develop ground water in Cave Valley might well take advantage of the shallow depth to water in this area; that is, carefully constructed wells or infiltration systems may result in development of moderate supplies at a reasonable cost.

Moderate supplies also might be developed locally in the middle segment of the alluvial apron on both sides of the main channel north of the playa, although the water-yielding character of the water-bearing zones is not known. Adjacent to principal canyons ground water may locally be within 100 feet of land surface, but for much of the alluvial apron and in the immediate vicinity of the playa the water table probably is in excess of 200 feet. Before extensive development is attempted, it would seem prudent to put in one or more test holes in favorable localities to determine whether moderate to large supplies can be obtained from wells.

PROPOSALS FOR ADDITIONAL GROUND-WATER STUDIES

In compliance with the request of Hugh A. Shamberger, Director, Nevada Department of Conservation and Natural Resources, the special studies listed below are suggested as necessary for obtaining basic data for a better understanding of the factors that influence or control ground water in Cave Valley and other areas in Nevada. These studies are separate from the normal areal investigations that commonly are needed after development of ground water in a given valley becomes substantial.

1. An investigation of the geologic and hydrologic factors that control the discharge of ground water from the valley fill into the bedrock and out of the drainage basin of Cave Valley should be made. This study probably would have substantial value to the State in that the knowledge and understanding gained from a study in this valley could be applied to other areas where similar physical conditions exist.

Information has been accumulating during the course of ground-water investigations in Nevada which strongly suggest that the Paleozoic carbonate rocks control the ground-water hydrology in many areas in eastern and southern Nevada.

Apparently one regional unit of this type is associated with the White River system which extends from north of the latitude of Ely to the vicinity of Muddy River Springs near Moapa--a distance of more than 200 miles. Present information suggests that interbasin movement of ground water through bedrock, largely Paleozoic carbonate rocks, may involve Long, Jakes, White River, Cave, Dry Lake, Delamar, Garden, Coal, Pahranagat, Kane Springs, and possibly Penoyer and Desert Valleys in the White River regional system.

The desirability of a full definition of the character of this system will be of increasing economic value in future years. Because the cost of obtaining a full definition of this system would be substantial, it would be prudent to examine the system in successive steps to obtain maximum information at a minimum cost. The first step includes a reconnaissance examination of the valleys that comprise the overall system. This step, or phase, is currently in progress. The next step is an evaluation of the overall system, based on information collected during the reconnaissance studies. The conclusions of the second study would provide the basis for specific proposals for future studies.

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 is the township north 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, 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 of the section.

Wells on plate 1 are identified only by the section number, quarter-section letter, and serial number. The township in which the well is located can be ascertained by the township and range numbers shown on the margin of plate 1. For example, well 7/63-15c1 is shown on plate 1 as 15c1 and is within the rectangle designated as T. 7 N., R. 63 E.

Table 4.--Records of selected wells in Cave Valley, Lincoln and White Pine Counties, Nevada.

7/63-15c1. Owner, Bureau of Land Management. Sawmill well. Drilled stock well; depth 385 feet, casing diameter 6 inches. Equipped with cylinder pump and windmill. Reported depth to water below measuring point 300 feet.

8/64-30c1. Owner, M. Urrutia. Drilled stock well; depth unknown, casing diameter 6 inches. Equipped with cylinder pump and windmill. Measuring point, top of casing which is 1.5 feet above land surface. Depth to water below measuring point 332.4 feet, April 22, 1960, and 330.48 feet, October 16, 1962.

9/63-1a1. Owner not determined. Dug well, 3- b 3-foot wood cribbing. Equipped with 4-inch turbine pump. Depth to water 2 feet below land surface, October 16, 1962.

10/63-25a1. Owner, M. Urrutia. Drilled stock well; depth 20 feet. Equipped with cylinder pump and windmill. Measuring point, top of well cover which is at land surface. Depth to water below measuring point 17.8 feet, July 15, 1958, and 19.6 feet, October 16, 1962.

REFERENCES CITED

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

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill, 534 p.

Hardman, George, and Mason, Howard G., 1949, Irrigated lands of Nevada: Nevada Univ. Agr. St. Bull. 183, 57 p.

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

Kellog, Harold E., 1960, Geology of the southern Egan Range, Nevada: Intermountain Assoc. of Petroleum Geologists, Guidebook to the geology of east central Nevada, p. 189-97.

Tschanz, Charles M., 1960, Geology of northern Lincoln County, Nevada: Intermountain Assoc. of Petroleum Geologists, Guidebook to the geology of east central Nevada, p. 198-208.

Tschanz, C. M., and Pampeyan, E. H., 1961, Preliminary geologic map of Lincoln County, Nevada: U.S. Geological Survey Mineral Inv. Field Studies Map MF-206.

Winfrey, W. M., Jr., 1958, Stratigraphy, correlation, and oil potential of the Sheep Pass formation, east-central Nevada: Am. Assoc. Petroleum Geologists Rocky Mtn. Sec., Geol. Record, 8th Ann. Mtg., p. 77-82.

COOPERATIVE PUBLICATIONS

Report No.

1. Ground-Water Appraisal of Newark Valley, White Pine County, Nevada.
   Dec. 1960 By Thomas E. Eakin

2. Ground-Water Appraisal of Pine Valley, Eureka and Elko Counties, Nevada.
   Jan. 1961 By Thomas E. Eakin

3. Ground-Water Appraisal of Long Valley, White Pine and Elko Counties, Nevada.
   June 1961 By Thomas E. Eakin

4. Ground-Water Resources of Pine Forest Valley, Humboldt County, Nevada.
   Jan. 1962 By William C. Sinclair

5. Ground-Water Appraisal of the Imlay Area, Humboldt River Basin, Pershing County, Nevada.
   Feb. 1962 By Thomas E. Eakin

6. Ground-Water Appraisal of Diamond Valley, Eureka and Elko Counties, Nevada.
   Feb. 1962 By Thomas E. Eakin

7. Ground-Water Resources of Desert Valley, Humboldt County, Nevada.
   April 1962 By William C. Sinclair

8. Ground-Water Appraisal of Independence Valley, Western Elko County, Nevada.
   May 1962 By Thomas E. Eakin

9. Ground-Water Appraisal of Gabbs Valley, Mineral and Nye Counties, Nevada.
   June 1962 By Thomas E. Eakin

10. Ground-Water Appraisal of Sarcobatus Flat and Oasis Valley, Nye County, Nevada.
    Oct. 1962 By Glenn T. Malmberg and Thomas E. Eakin

11. Ground-Water Resources of Hualapai Flat, Washoe, Pershing, and Humboldt Counties, Nevada.
    Oct. 1962 By William C. Sinclair

12. Ground-Water Appraisal of Ralston and Stonecabin Valleys, Nye County, Nevada.
    Oct. 1962 By Thomas E. Eakin

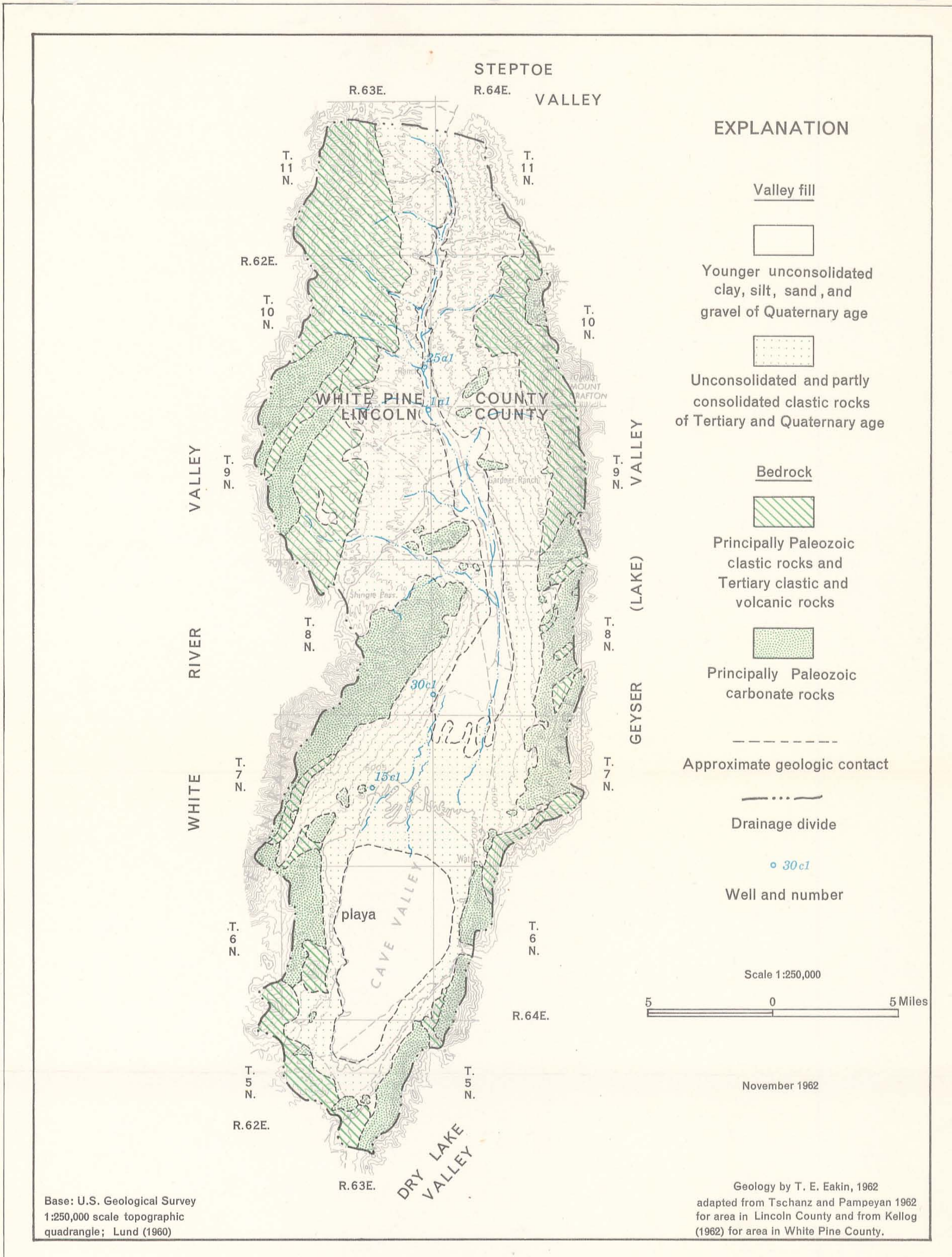

PLATE 1. MAP OF CAVE VALLEY IN LINCOLN AND WHITE PINE COUNTIES, NEVADA
SHOWING AREAS OF BEDROCK, VALLEY FILL, AND LOCATION OF WELLS.