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DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
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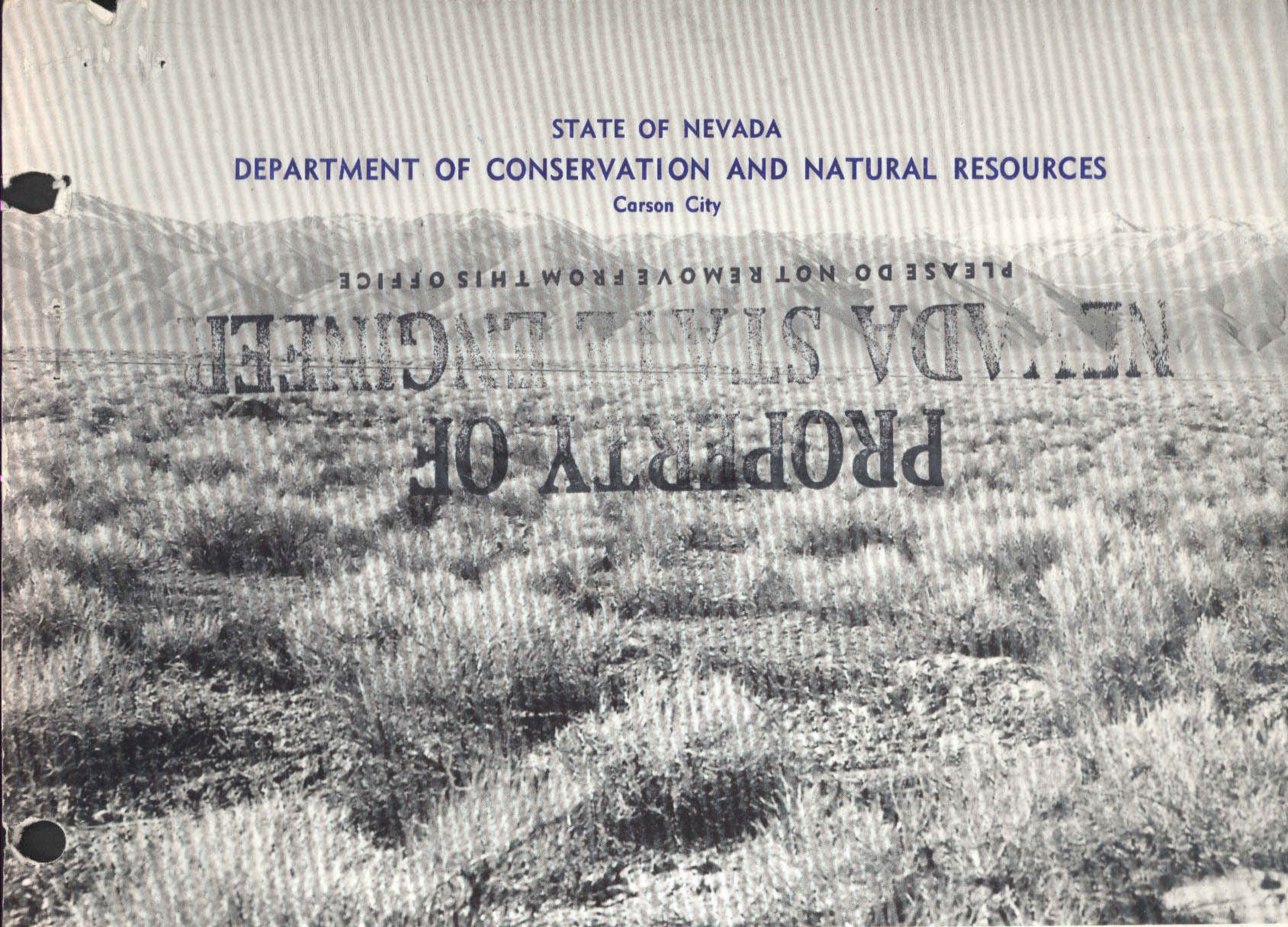

GROUND-WATER RESOURCES - RECONNAISSANCE SERIES
REPORT 4

GROUND-WATER RESOURCES OF PINE FOREST VALLEY, HUMBOLDT COUNTY

By
WILLIAM C. SINCLAIR,
Geologist

Price $1.00

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

JANUARY 1962

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January 1962

FOREWORD

This reconnaissance report on the ground-water resources of Pine Forest Valley in Humboldt County, is the fourth report in a series of such reports authorized by the 1960 Legislature. The preceeding reports cover Newark Valley, White Pine County; Pine Valley, Eureka and Elko Counties; and Long Valley in White Pine and Elko Counties. Several other such reports are now in process of review including Diamond Valley, Eureka County; Gabbs Valley, Mineral County; Independence Valley, Elko County; Imlay Area, Humboldt River Basin in Pershing County; and Desert Valley in Humboldt and Pershing Counties, all of which should be in printed form by July 1, 1962.

During 1961 the first report under an information series was issued. This report by O. J. Loeltz, Engineer, and G. T. Malmberg, Geologist, covered the ground-water situation in Nevada in 1960.

The reconnaissance ground-water surveys are conducted under a cooperative program between the State Department of Conservation and Natural Resources and the United States Geological Survey. They are designed to give information on the ground-water resources in areas where there is a lack of such information. They are not intended to take the place of the more detailed cooperative ground-water surveys under the regular ground-water program which has been in progress since 1946.

It is intended to continue these studies until all of the major basins in the State have been covered, either by detailed, semi-detailed, or reconnaissance studies.

Hugh A. Shamberger, Director
Department of Conservation
and Natural Resources

January 3, 1962.

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GROUND-WATER RESOURCES OF PINE FOREST VALLEY

HUMBOLDT COUNTY, NEVADA

By William C. Sinclair

ABSTRACT

Pine Forest Valley is an intermontane valley in the Great Basin section of the Basin and Range physiographic province. The valley is drained by the Quinn River. The climate is arid to semiarid; precipitation on the floor of the valley is less than 6 inches annually.

The valley is bordered by mountain ranges composed principally of granodiorite and volcanic rocks. The mountains were uplifted by faulting and tilting during the latter part of the Tertiary period. Material eroded from the uplands has filled the intermontane basin of the valley with at least 700 feet of alluvium, including lake and stream sediments. The amount of ground water stored in the upper few hundred feet of valley fill is estimated at about 18,000 acre-feet per foot of thickness of saturated sediments.

The ground-water reservoir is recharged by streams that drain the bordering mountain ranges. Ground water moves from the areas of recharge toward the axis of the valley and thence southwestward. About 2,700 acre-feet of ground water is discharged by underflow each year to the Black Rock Desert, but under natural conditions most of the ground-water discharge, about 11,000 acre-feet per year, is transpired by plants that send their roots to the water table or to the capillary fringe above it. A minor amount of ground water, about 200 acre-feet per year, is discharged by thermal springs. The total average annual ground-water discharge, under natural conditions, is equal to the average annual recharge and is estimated to range from 10,000 to 15,000 acre-feet per year.

The ground water is generally suitable for irrigation and domestic use. The principal exception is water from thermal springs which is unsuitable for irrigating most crops because of the high sodium content.

Although desirable, it may not be practical to intercept by wells and use consumptively all the ground water that is now being discharged by evapotranspiration. The perennial yield, the amount of natural discharge by phreatophytes, and underflow that can be salvaged for beneficial use probably does not exceed 10,000 to 15,000 acre-feet. Gross pumpage in 1960 was only about 3,000 acre-feet.

INTRODUCTION

This report is one of a series of reconnaissance studies of the valleys of northwestern Nevada (fig. 1). These studies are made by the U. S. Geological Survey in cooperation with the Department of Conservation and Natural Resources, State of Nevada, and are part of a statewide study to evaluate the ground-water resources of Nevada.

The purposes of this study of Pine Forest Valley are: (1) To determine the nature and extent of the aquifers; (2) to evaluate the occurrence and movement of ground water, including the sources of recharge and areas of discharge; (3) to estimate the average annual recharge to the aquifers; (4) to estimate the quantity of ground water that can be developed perennially; and (5) to determine the chemical quality of the ground water and its suitability for irrigation and domestic use.

Pine Forest Valley is only sparsely populated. The nearest communities are Winnemucca, about 60 miles to the southeast, and Denio, about 10 miles to the north. Winnemucca has a population of 3,453 according to the 1960 census. Denio is a local supply center for the ranches in the area. The economy of the valley is based on ranching and the irrigation of about 3,000 acres of cultivated land.

The valley is traversed by Nevada Highway 8A which connects Winnemucca with Denio and northwestern Nevada.

The fieldwork for this report was done during parts of October and November 1960. It consists of a study of the physiographic features of the area and of the water-bearing character of the geologic units, an inventory of the wells and springs, and the mapping of vegetation that consumes ground water.

The assistance provided by residents of the area in the form of information regarding wells, springs, and local irrigation practices is gratefully acknowledged.

Location and Extent of the Area

Pine Forest Valley is in north-central Humboldt County. The valley is the northernmost extension of the Black Rock Desert and is bounded by the Pine Forest Range on the west and the Bilk Creek Range on the east. The coalescence of the two ranges in a low alluvial saddle forms the northern boundary of the valley. The Quinn River enters the valley from the southeast through a gap between the Jackson Mountains and the Bilk Creek Range. It flows northwest toward the center of the valley, then swings southwestward along the west side of the Jackson Mountains, into the Black Rock Desert.

Pine Forest Valley has an area of about 500 square miles. The main part of the valley floor trends south, principally in R. 31 E., and is about 25 miles long and 6 miles wide. A smaller part lies within the gap between the

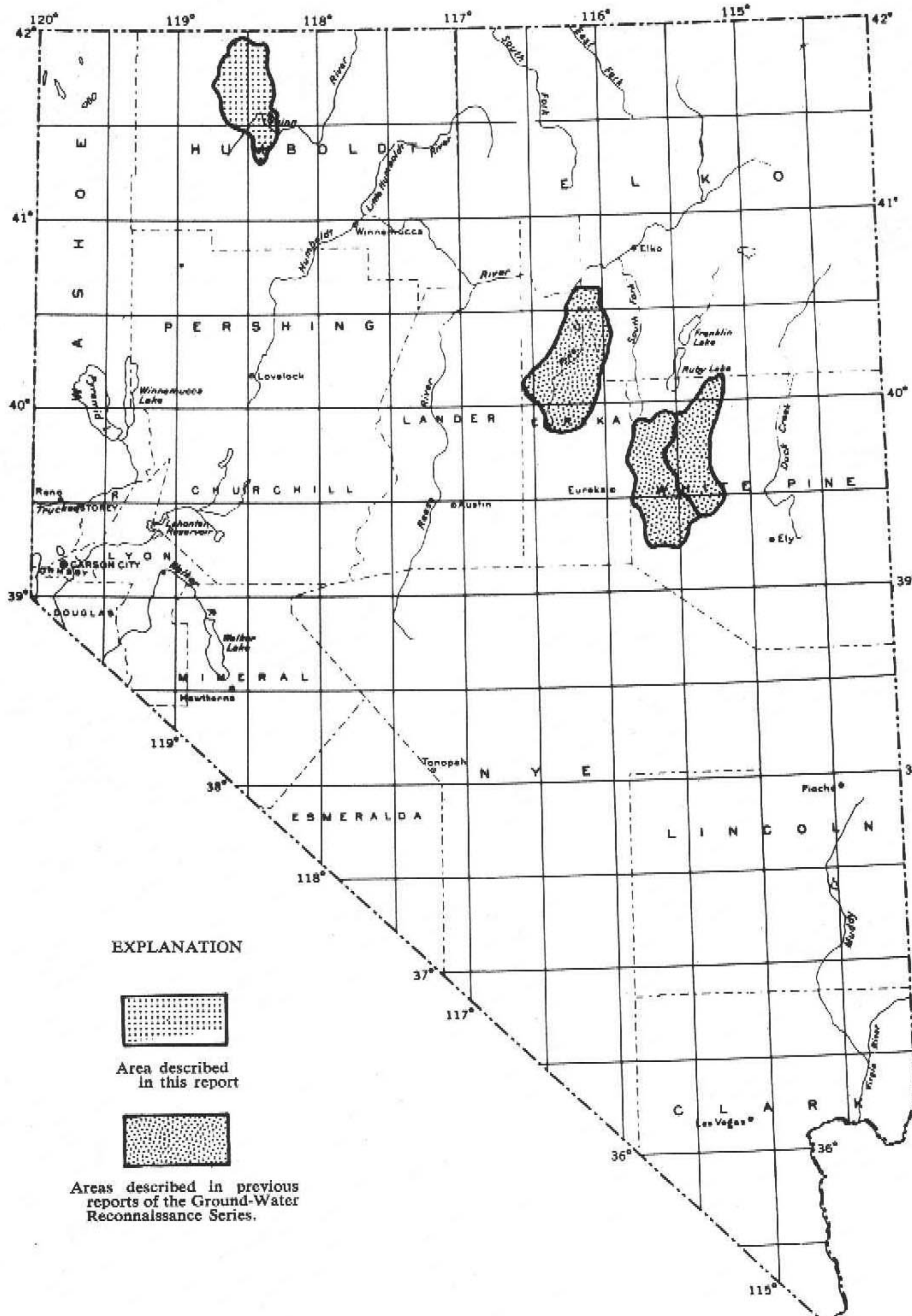

Figure 1.—Map of Nevada showing areas described in previous reports of the Ground-Water Reconnaissance Series and in this report.

Jackson Mountains and the Bilk Creek Range, and is almost completely separated from the main valley by a north-trending ridge along the west edge of T. 43 N., R. 32 E. This part of the valley trends northwest and is 10 miles long and about 4 miles wide.

Numbering System for Wells and Springs

The well-numbering system used in this report indicates the location of the wells within the rectangular subdivisions of the public lands referenced to the Mount Diablo meridian and base line. The first two segments of a well number designate the township and range; the third segment is the number of the section followed by a letter which designates the quarter section in which the well or spring is located. Following the letter a number indicates the order in which the well or spring was recorded within the subdivision. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section. For example, well number 46/30-13A1 designates the first well recorded in the NE 1/4 sec. 13, T. 46 N., R. 30 E., Mount Diablo base and meridian.

Plate I shows the location of wells and springs in the valley. The available data on the wells and springs are listed in table 2. The results of chemical analyses of water from the thermal springs and selected wells are in table 3.

GEOGRAPHIC FEATURES

Landforms and Drainage

Pine Forest Valley is in the Great Basin section of the Basin and Range physiographic province. The Great Basin is an area of alternating mountain ranges and valleys which generally trend nearly north. The mountain ranges commonly are 50 to 70 miles long and 6 to 15 miles wide. The valleys have approximately the same dimensions. The crests of the mountain ranges ordinarily are 3,000 to 5,000 feet above the valley floors and 7,000 to 10,000 feet above sea level. Typically, a range is a faulted and tilted block.

The intermontane valleys are characteristically closed alluvium-filled basins, although some valleys are interconnected by drainage channels. Playas, or "dry lakes", are present in most of the valleys and receive runoff from the mountain ranges. Pine Forest Valley differs from the typical valley of the Great Basin in that it is not closed and has no playa. Runoff from the valley discharges into the Quinn River, which in turn flows southwestward to the playas of the Black Rock Desert where it evaporates.

Mountains

The Bilk Creek Range, which borders the east side of the valley, consists mostly of lava flows of Tertiary age to which a gentle eastward dip of 10° to 15° has been imparted by faulting and tilting of the mountain block. The crest ranges from about 1,000 feet above the valley floor at the southern end of the valley to about 3,000 feet above the floor near the northern end.

Along the west side of the valley, the Pine Forest Range rises rather abruptly above the valley floor. At both the southern and northern ends the crest is about 3,000 feet above the valley floor but near the middle of the range at Duffer Peak, altitude 9,500 feet, the crest is about 5,400 feet above the valley floor. This range is composed predominantly of granodiorite but also contains some volcanic and sedimentary rocks, especially at the southern end.

The Jackson Mountains, a complex of metamorphic and volcanic rocks, rise to about 4,500 feet above the valley floor at their northern end in a north-facing amphitheater whose west limb extends as a low spur toward the center of the valley.

Piedmont Slopes and Valley Floor

Piedmont slopes consist of coalescing alluvial fans that form a continuous apron around the mountain ranges and merge almost imperceptibly into the valley floor. These slopes range in width from less than half a mile at the south end of the valley to several miles at the north end.

The valley floor is the relatively flat area downslope from the alluvial fans. It has an area of approximately 200 square miles, or about 70 percent of the total area of alluvium. The gradient of the main part of the valley is generally southward and ranges from more than 50 feet per mile at the north end of the valley to about 8 feet per mile at the south end. That part of the valley floor which lies in the gap between the Jackson Mountains and the Bilk Creek Range is nearly level.

Streams

Many of the streams that drain the mountain ranges are ephermeral. Most of the smaller stream courses carry water only during and after storms, but some also carry water for a few months during late winter and spring.

Meager flow characterizes most of the streams draining the Bilk Creek Range. This range is composed largely of volcanic rocks that are jointed and broken to form a porous surface, and thus most of the precipitation on the range infiltrates to the ground-water reservoir rather than moving overland.

The Bilk Creek-Quinn River drainageway is the major stream system in the valley. Bilk Creek, which drains about 50 square miles, is incised deeply into the Bilk Creek Range. The flow of this stream is perennial but flashy in nature and, reportedly, during the spring runoff it overflows the 2,000 acre-foot capacity reservoir in sec. 4, T. 43 N., R. 32 E., which is used by the Quinn River Crossing Ranch to control the flow of Bilk Creek below the reservoir for irrigation.

The canyons along the east flank of the Pine Forest Range broaden into alluvial basins in their upper reaches. The streams in this area are fed by seepage from the mantle of alluvium which acts as a regulator, absorbing water from snowmelt and rain and discharging it into the canyons as seeps and springs. Most of these streams, therefore, are perennial in their upper reaches, but the water sinks into the alluvium of the piedmont slope and few of the streams reach the valley floor except during periods of high runoff.

Several stream channels are incised in the main valley floor. Most notable of these is the channel of the Quinn River which is dry throughout most of the year. In the winter, however, when evapotranspiration requirements are less and precipitation is somewhat greater, the water table rises and the Quinn River drains the valley southwestward to the Black Rock Desert at a gradient of about 8 feet per mile. The gradient of the Quinn River above the confluence with Bilk Creek is less than 2 feet per mile. The flow of water is negligible in this reach of the river, except during periods of extremely high runoff.

Climate

The climate of the valley ranges from arid to semiarid. The precipitation and humidity are low and summer temperatures and evaporation rates are high. Precipitation is irregular in areal distribution but generally is least on the valley floor and greatest on the highest parts of the mountains. The range in temperature is large, both daily and seasonally. The growing season is short.

Figure 2, based on records from the U. S. Weather Bureau station at Quinn River Crossing Ranch, shows the average monthly precipitation and average monthly temperatures for a 26-year period ending in 1950, and the average of the monthly high and of the monthly low temperatures for a 5-year period ending 1950.

Recorded temperatures range from a maximum of 105°F to a minimum of -34°F. Although freezing temperatures have been recorded every month of the year, the average date of the last killing frost in the spring is June 20, and that of the first killing frost in the fall is September 5; thus the average growing season has 77 days (U. S. Department of Agriculture, 1941, p. 979). However, the U.S. Weather Bureau station (altitude 4,087 feet) is only 50 feet above the lowest part of the valley and, because cold air commonly flows into the low parts of a valley during periods of little or no wind movement, the station records probably show somewhat lower temperatures than generally occur in other parts of the valley. Thus, a somewhat longer growing season may prevail along the piedmont slopes and the higher parts of the valley floor.

The average annual precipitation for the 26-year period of record is 5.6 inches. Most of this occurs during the winter as snow. Ordinarily the snow on the valley floor melts in a few days, but at the higher elevations it may remain for several weeks or months. The summers are notably dry. Usually, precipitation is only a small fraction of an inch during July and August, the driest

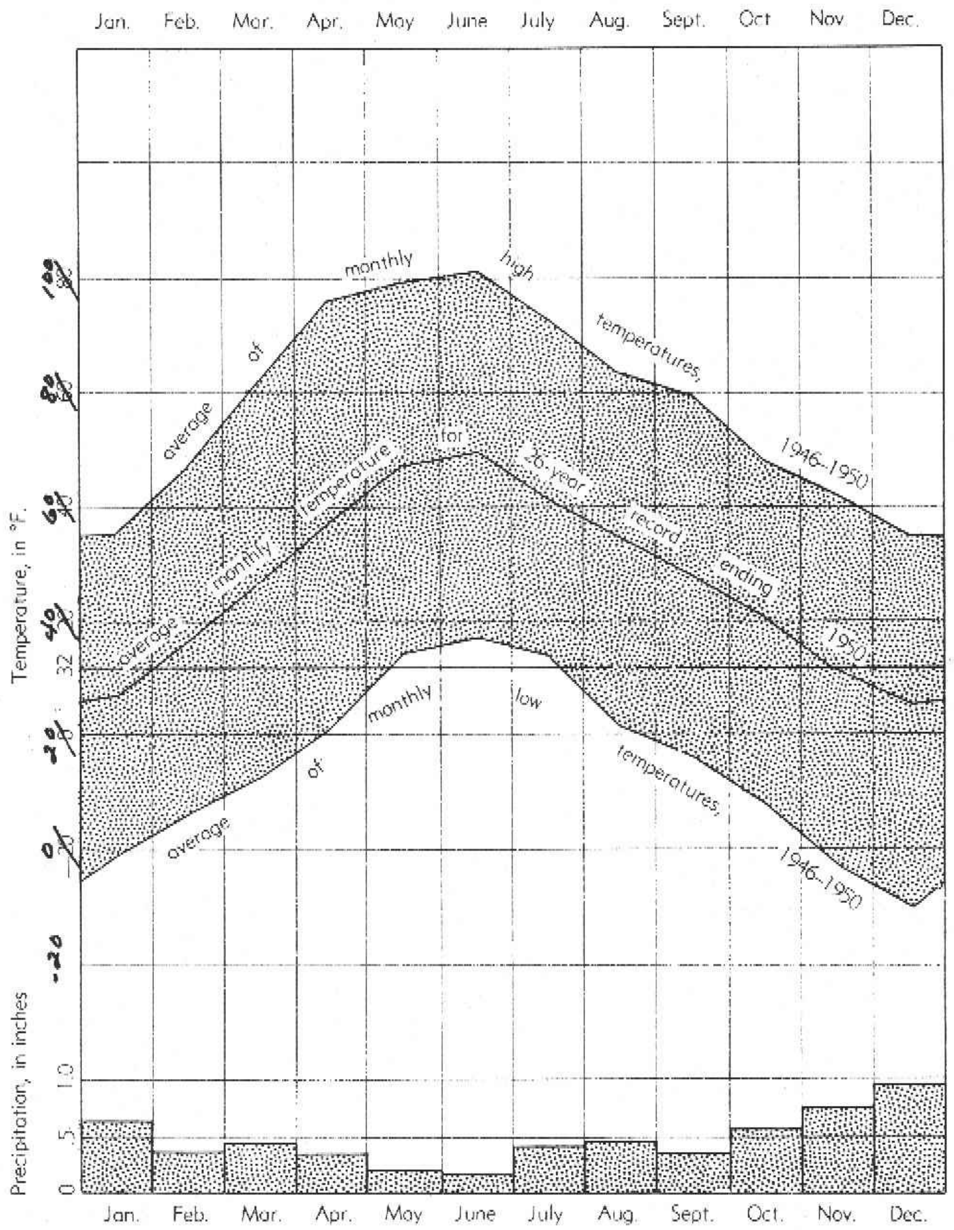

Figure 2. Average monthly precipitation and temperature for a 26-year period ending 1950, and average of the monthly high and the monthly low temperatures for a 5-year period ending 1950 at the U. S. Weather Bureau station at Quinn River Crossing Ranch.

months, and in some years there is no precipitation during these months. The evaporation rate from a free-water surface, based on data from Weather Bureau records in the State, is estimated to be about 4 feet per year, or more than 8 times the precipitation.

GEOLOGY

Previous Investigations

The geology of Humboldt County has been mapped by Ronald Willden (1961). The bedrock-alluvium contact and the distribution of the younger and the older alluvium, as shown on figure 2, are taken from Willden's map.

Summary of Late Cenozoic History

The present topography of Pine Forest Valley and the surrounding mountain ranges began to take form during the latter part of the Tertiary period. At that time, the country rock, composed of granodiorite of Cretaceous and Tertiary age and various volcanic rocks of Tertiary age, was broken and tilted by extensive faulting which continued into the Pleistocene epoch.

Erosion of the uplifted mountain blocks has partly filled the valley with alluvium. The maximum thickness of the alluvium is unknown, but on the basis of the log of well 43/32-20C1, the alluvium is at least 700 feet thick and in the central parts of the valley is composed, in large part, of lake sediments.

The Quinn River probably has occupied its present course, perhaps intermittently, since late Tertiary time. The present course may have been determined by the regional faulting or the river may have existed before the mountain ranges were uplifted to their present form. If the river predates the mountain ranges, downcutting by the river kept pace with the uplifting of the mountains, carving the gaps through which the river now flows. In either sequence of events alternating uplift and downcutting imply the formation of lakes behind the temporary barriers and alternate drowning and rejuvenation of the river. The types of sediments would vary in response to the changes in environment.

The climatic fluctuations of the Pleistocene epoch resulted in a series of lakes which intermittently covered a large part of western Nevada. The most recent of these, Lake Lahontan, attained a maximum depth of about 350 feet in Pine Forest Valley. To a large extent, the present valley floor is underlain by lake sediments and represents the configuration of the ancient lake bottom. Many stages and fluctuations of Lake Lahontan are recorded in these sediments and in the shoreline features, such as beaches and spits, which terrace the surrounding hillsides.

The processes of erosion and deposition have resulted only in minor changes since the last withdrawal of Lake Lahontan.

PHYSICAL CHARACTER AND WATER-BEARING PROPERTIES OF THE ROCKS

Bedrock

The volcanic rocks are mainly basalt and andesite and are characterized by closely spaced columnar jointing. Weathering causes the columns to break down into cobble-size pieces. Much of the surface of the Bilk Creek Range is littered with the resulting coarse rubble which permits much of the precipitation to infiltrate rapidly to considerable depths below the land surface and, eventually, to the ground-water reservoir.

Joints in the granodiorite of the Pine Forest Range, on the other hand, are generally quite widely spaced, and the rock is dense and impermeable. Deep infiltration is thus negligible. However, the granodiorite is mantled by the products of its own weathering which are capable of retaining a considerable volume of water. The available snowmelt and rainfall runs off only after the mantle becomes saturated.

Movement of ground water in the consolidated rocks of the mountain ranges is largely through joints and other secondary openings and in porous zones between lava flows. Although the total volume of water moving through bedrock may be quite large, as it is assumed to be in the Bilk Creek Range, the success of a well penetrating the bedrock is dependent on its tapping enough of the secondary water-bearing zones to yield the required amount of water. The chances of intercepting a sufficient number of water-bearing zones are generally so poor that the consolidated bedrock, whether in the mountains or buried beneath the valley fill, probably will not yield large amounts of water to wells.

Valley Fill

The valley fill is composed of rock debris which has been eroded from the surrounding mountains. It includes an unknown thickness of unconsolidated material, comprising the older and younger alluvium, which are composed mainly of stream deposits and lake sediments. These alluvial deposits form the principal source of ground water in the valley. Alluvium is unconsolidated water-laid rock debris ranging in size from boulders to clay. Where it contains well-sorted sand or gravel it may yield moderate to large amounts of water to wells.

Older Alluvium

Deposits of older alluvium form the piedmont slopes along the flanks of the mountains and the low divide at the northern end of the valley (plate 1). Also it underlies younger alluvium beneath much of the floor of the valley where it is composed principally of lake sediments.

During periods between high lake stages, some of the alluvium was deposited in the lower parts of the valley. These deposits, to some extent, were reworked and sorted by the advancing waters of a later highwater stage which subsequently covered them with silt and clay. These reworked layers of alluvium are generally moderately permeable, and may yield moderate to large amounts of water to properly constructed wells.

The major streams probably have followed their present courses throughout much of the history of the valley; thus, stream-laid deposits of permeable sand and gravel may be present at various depth within the valley fill.

Well 42/31-11B1 on the bank of the Quinn River was drilled to a depth of 352 feet. Although no log is available, this well, which flows 170 gpm (gallons per minute) at the surface and has been pumped at a rate of 2,400 gpm with a drawdown of 52 feet, probably taps permeable material of older river deposits. Overlying deposits of lake clay may form the confining layer responsible for the artesian condition.

Younger Alluvium

The younger alluvium is composed mainly of lake sediments which were deposited in Lake Lahontan and some stream deposits of post-Lahontan age. The contact between the older and younger alluvium shown on plate 1 is drawn at the highest shoreline of Lake Lahontan. The younger alluvium is predominantly silt and clay, which are deep-lake deposits, separated by layers of sand and gravel, which are principally stream deposits and reworked alluvium that accumulated during shallow stages of the lakes and periods of emergence of the land surface. The sand and gravel strata are the most important aquifers in the section of lake sediments. Their occurrence, although probably widespread, generally is obscured by overlying sediments. One exception is the large gravel spit which trends north through secs. 30 and 31, T. 43 N., R. 32 E. Well 43/32-30A2, which was drilled near the toe of this spit, yielded 1,600 gpm with a drawdown of 40 feet (table 1), indicating a specific capacity of about 40 gpm/ft. The confluence of Bilk Creek and the Quinn River nearby suggests that stream, as well as lake currents, may have had a part in depositing and reworking the sand and gravel now underlying the area.

GROUND WATER

Occurrence and Movement

Most of the available ground water in Pine Forest Valley occurs in the unconsolidated sediments of the valley fill. Where the valley fill consists of fine-grained material, such as silt and clay, or of poorly sorted alluvium, the permeability is low and only small yields can be expected from wells. In contrast, strata of well-sorted sand and gravel have moderate to high permeabilities and will yield water readily to wells.

Ground water occurs in the valley either under water-table or artesian conditions. Under water-table conditions the water stands in the well at about the same altitude at which it was first found. Under artesian conditions, the water is under pressure and rises in wells to above the bottom of the relatively impermeable stratum that acts as the confining bed. If the water is under sufficient pressure to flow at the land surface, as at well 42/31-11B1, the well is called a flowing artesian well.

The lake sediments of the valley fill form an excellent environment for artesian conditions because they are composed of alternating layers of permeable and relatively impermeable materials and because the recharge to them is from the margins of the valley, which are at slightly higher elevations than most of the valley floor. However, none of the wells drilled to date have high artesian heads, and the only flowing well in the valley, 42/31-11B1, is below the average level of the valley floor.

Ground water flows in the direction of lower head just as surface water does. The movement, however, is much slower. Ground water generally moves from recharge areas in the mountains and piedmont slopes toward the axis of the valley where a considerable part of it is discharged by evapotranspiration. That which is not discharged within the valley moves southwestward as underflow toward the Black Rock Desert.

The gradient of the water table in the main part of the valley is southwestward at about 8 feet per mile, whereas the gradient of the water table in that part of the valley between the Jackson Mountains and the Bilk Creek Range is northward at less than 2 feet per mile. The latter gradient is reduced and possibly even locally reversed during the summer by the spreading of irrigation water in the vicinity of the Quinn River Crossing Ranch.

Recharge

The ultimate source of recharge to the ground-water reservoir of Pine Forest Valley, except for a minor amount of underflow from the upper reaches of the Quinn River, is the precipitation on the alluvial fans and the mountains that border the valley.

The average annual precipitation within the drainage area can be estimated from a map showing precipitation zones in Nevada (Hardman, 1936). The total annual precipitation within the Pine Forest Valley drainage basin, on the basis of Hardman's map, as modified by subsequent data, is about 260,000 acre-feet. This figure was derived by subdividing the drainage basin of the valley into precipitation zones and multiplying the area of each zone by the average precipitation within the zone, as tabulated below:

Precipitation zone (inches)	Altitude of zone (feet)	Area of zone (acres)	Precipitation (acre-feet per year rounded)	Percent recharge	Approximate recharge (acre-feet per year rounded)
15-20	above 7,500	3,200	5,000	15	700
12-15	6,000-7,500	58,900	66,000	7	5,000
8-12	4,400-6,000	151,000	126,000	3	4,000
less than 8	below 4,400	129,200	65,000	0	0
Total (rounded)			260,000		10,000

Only a small part of the total precipitation ever reaches the ground-water reservoir in the valley. Most of it is transpired and evaporated. Part of the remainder runs off immediately and part infiltrates into the rocks of the mountain ranges and the alluvial fans from which it eventually moves directly into the valley fill or surfaces along the stream courses and at springs. Further loss by evaporation and transpiration takes place along the stream courses.

The "percent recharge" figures in the above table takes into account these losses and were determined empirically by Eakin (1951) from studies in eastern Nevada. Assuming these factors to be valid in Pine Forest Valley, the total recharge to the ground-water reservoir is on the order of 10,000 acre-feet per year.

Recharge by underflow through the gap between the Jackson Mountains and the Bilk Creek Range is estimated to be between 200 and 300 acre-feet per year.

Discharge

Ground water is discharged from the valley by evaporation, transpiration, springs, pumping, and underflow from the south end of the valley to the Black Rock Desert.

Evaporation and Transpiration

Evaporation from the ground-water reservoir occurs where the capillary fringe reaches or is near the land surface. The capillary fringe ordinarily reaches the land surface where the depth to the water table is only a few feet below the surface. In Pine Forest Valley, the areas where the water table is near enough to the surface for a significant amount of evaporation to take place are quite limited, although, no doubt, a small amount of ground water is discharged in this manner.

Transpiration, on the other hand, accounts for most of the natural discharge in the valley. Large quantities of ground water are transpired by plants, known as phreatophytes, whose roots descend to the water table or to the capillary fringe above it. Greasewood is the most common phreatophyte in the valley; others are saltgrass, ryegrass, rabbitbrush, pickleweed, willows, and associated wild rose and buckbrush. In addition, about 3,000 acres of meadow grass and alfalfa are sustained in part by flood irrigation and in part by the ground-water reservoir.

The phreatophytes are mainly in the south end of the valley, where the depth to water is less than about 30 feet, and are thickest along the channel of the Quinn River (Plate 1). A few small, isolated areas of phreatophytes also thrive at the mouths of some of the canyons.

The phreatophytes have been grouped on the basis of the dominant species and water use, into (1) greasewood, which includes rabbitbrush and some shadscale, commonly not a phreatophyte; (2) grasses, native and subirrigated; and (3) willow.

The estimated rate of use of ground water by phreatophytes used in this study is based largely on work done by White (1932, p. 28-93) in Escalante Valley, Utah, and on more recent investigations by Young and Blaney (1942, p. 41-246). The following table summarizes the estimate of discharge of ground water by phreatophytes:

Predominant phreatophyte type	Area (acres)	Depth to water (feet)	Estimated rate of use of ground water (feet per year)	Estimated discharge by evapotranspiration (acre-feet per year)
Greasewood	45,000	10-30	0.2	9,000
Grasses				
Native	1,000	5	1	1,000+
Subirrigated	3,000	5	1	[a] 3,000
Willow	[b] 200	20	5	1,000
			Total	14,000

[a] About 50 percent of irrigation water, or 3,000 acre-feet per year, is supplied by streamflow. Remainder, or estimated 1 foot per acre per year, supplied from ground water.

[b] Includes many areas, principally near mouths of canyons, too small to delineate on plate 1.

Springs

Five thermal springs, whose temperatures range from 70°F to 163°F, issue from the alluvium of the valley floor. Except for springs 44/31-4A1 and also 43/30-25D1 which flow about 50 gpm, the discharges are small, ranging from about 1 to 10 gpm. Their combined discharge is somewhat less than 200 acre-feet per year. These springs are probably associated with fault zones which provide paths along which ground water, heated at depth, and therefore less dense, can rise to the surface. Probably all of the water from the small springs is lost by evaporation and transpiration; but a small amount of the discharge of the two largest springs may be returned to the ground-water reservoir.

Springs and seeps of the gravity type are common in the surrounding mountains, particularly the Pine Forest Range. These occur in places where the water table intersects the land surface, commonly at the heads of canyons, and are the source of many of the small streams which drain the mountains. Most of the water discharged by these springs is either lost by evaporation and transpiration near the spring sites or along the stream channel; only a small part persists as streamflow, a fraction of which may return to the ground-water reservoir as seepage from streams.

Pumpage

Withdrawal of ground water by pumping for irrigation, stock, and domestic use amounted to about 3,000 acre-feet in 1960. Most of this was used to supplement water from Bilk and Happy Creeks for the irrigation of pasture and hay fields.

Underflow to the Black Rock Desert

An estimated 2 1/2 million gallons per day, or about 2,700 acre-feet of ground water per year, is discharged to Black Rock Desert. This estimate is based on the gradient of the water table, the coefficient of transmissibility [1/], and the width of the aquifer, according to the following relationship: Underflow, in gallons per day, equals the coefficient of transmissibility, in gallons per day per foot, times the gradient in feet per mile, times the width in miles. The gradient of the water table in the area of underflow to the Black Rock Desert, as shown by the contours on Plate 1, averages about 8 feet per mile. The width

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1/ The coefficient of transmissibility is defined as the number of gallons of water per day, at the prevailing temperature, that will move through a vertical strip of the aquifer 1 foot wide and having a height equal to the thickness of the aquifer under a hydraulic gradient of 100 percent. The coefficient of transmissibility also may be defined as the average field permeability of the rock material multiplied by the thickness of the aquifer, in feet.

of the aquifer, which is assumed to be bounded on the east and west by relatively impermeable bedrock, is about 6 miles. The coefficient of transmissibility, as determined by a test of well 42/31-11B1, is about 50,000 gallons per day per foot. The computed underflow therefore is: Underflow = 50,000 x 8 x 6 = about 2 1/2 million gallons per day, or about 2,700 acre-feet per year. Although this well probably taps stream deposits of the older alluvium which may not be representative of the entire width of the underflow area, the estimate of 2,700 acre-feet per year for underflow probably still is reasonable.

In addition, some ground water also discharges to the Black Rock Desert. The seasonal rise of the water table during the winter months, which is due mainly to the decreased discharge of ground water by evapotranspiration, causes ground water to discharge into the channel of the Quinn River. Ice conditions permitting, this water runs off to the Black Rock Desert. The amount of water discharged in this manner is probably negligible, on the order of 200 to 300 acre-feet per year.

Ground-Water Inventory

Under natural conditions the average annual recharge to Pine Forest Valley equals the average annual discharge from the valley. Temporary extremes of drought or flood are compensated for by changes of ground water in storage. Because pumping has not appreciably affected the equilibrium of the system, the estimated recharge should be about equal to the estimated natural discharge.

The following table shows estimates of recharge and discharge under virgin, or pre-development, conditions. The estimate for discharge by evapotranspiration does not include the losses from subirrigated fields (p. 12).

	(Acre-feet)	Text reference (page)
Estimate of average annual recharge	10,000	10
Estimate of average annual discharge by:		
Evapotranspiration	11,000	11
Underflow to Black Rock Desert	2,700	12
Discharge into the Quinn River	200	13
Springs	200	12
Total (rounded)	14,000	

Exact agreement of the estimates of average annual recharge and average annual discharge is not to be expected because of the crude methods that were used in estimating the various elements of recharge and discharge. Although the estimates of recharge and discharge differ somewhat, they are of about the same magnitude and probably are within the general range of the actual values.

Perennial Yield

The perennial yield is the maximum rate at which water can be withdrawn from a ground-water system for an indefinite period of time without permanently depleting the supply. It is ultimately limited by the amount of water available to the system through recharge.

The net amount of ground water that can be pumped perennially in Pine Forest Valley without causing a continuing decline in ground-water levels is limited to the amount of natural discharge that can be salvaged. The allowable gross pumpage may exceed the net withdrawal to the extent that some of the ground water returns to the ground-water reservoir and is suitable for reuse. The actual perennial yield of the valley can be determined only after several years of extensive development.

Ground Water in Storage

The amount of recoverable ground water in storage in the valley fill of Pine Forest Valley is many times the average annual recharge. An estimate of the magnitude of the recoverable water in storage can be obtained by computing the amount of ground water that will drain from the sediments for each foot of lowering of water level in the valley fill. A value of 10 percent is considered to be a reasonable estimate of the amount of water by volume that will drain from the sediments. The drainable unconsolidated sediments are estimated to include almost all the valley fill, which has an area of about 180,000 acres.

The recoverable ground water from storage as a result of lower water levels would thus be about 18,000 acre-feet per foot of lowering--somewhat more than the estimated average annual recharge. If water levels were lowered 100 feet, the amount of water supplied from storage would roughtly equal the total recharge for 100 years. Thus the amount of water that could be developed by pumping from storage is very large. Because it would be replenished only in part, however, the practice of pumping from storage constitutes mining and offers no hope for developing ground water on a perennial basis.

CHEMICAL QUALITY OF GROUND WATER

The chemical constituents in ground water are acquired by the solution of minerals from the materials through which the water percolates. In general, the dissolved solids content of the water is determined by the solubility of the rock or soil, the area and duration of contact, and other factors such as pressure and temperature.

Water for Irrigation

The suitability of water for irrigation may be evaluated on the basis of the salinity hazard, the sodium (alkali) hazard, and the concentration of bicarbonate, boron, and other ions (Wilcox, 1955, p. 7-12).

Salinity Hazard

The salinity hazard depends on the concentration of dissolved solids. It is normally measured in terms of the electrical conductivity, or specific conductance, of the water, expressed as micromhos per centimeter at 25°C. The electrical conductivity is an approximate measure of the total ionized chemical constituents of the water. Wilcox (1955, p. 7) divides water into four classes with respect to its conductivity. The dividing points between the four classes are at 250, 750, and 2,250 micromhos (see fig. 3). Water of low conductivity generally is more suitable for irrigation than water of high conductivity. Wilcox provides the following classification of irrigation water with respect to salinity hazard:

1. "Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

2. "Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

3. "High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

4. "Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances."

Sodium (alkali) hazard

The sodium, or alkali, hazard is indicated by the sodium-adsorption-ratio (SAR), which may be defined by the formula

$$SAR = \frac{Na+}{\sqrt{\frac{Ca++ + Mg++}{2}}}$$

in which concentrations are expressed in equivalents per million. If the proportion of sodium among the cations is high, the alkali hazard is high; but if calcium and magnesium predominate, the alkali hazard is low. Wilcox classifies irrigation water, with respect to sodium hazard, as follows:

1. "Low sodium water (S1) can be used for irrigation on almost all soils

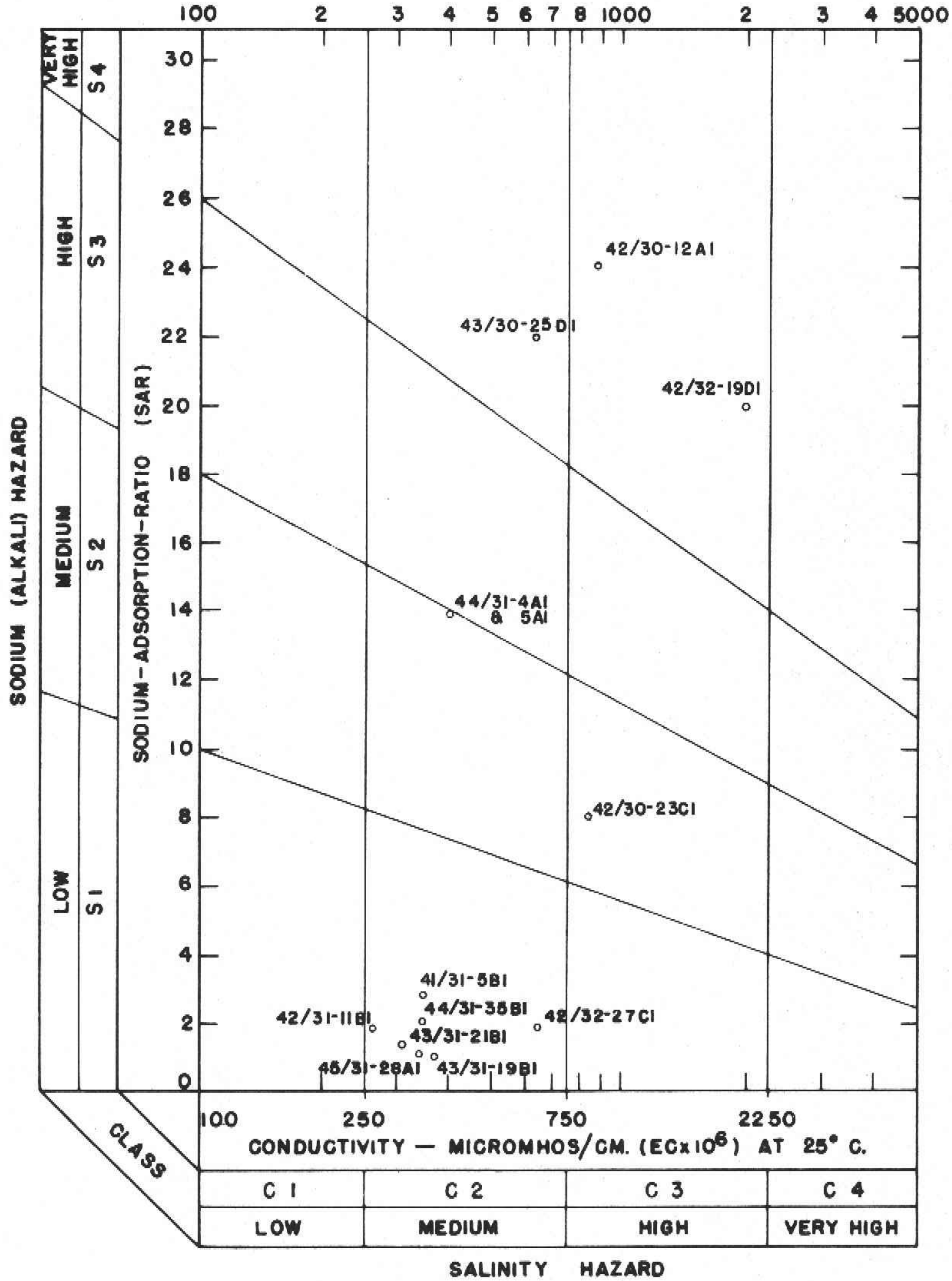

Figure 3. Classification of irrigation water on the basis of conductivity and sodium-adsorption ratio.

with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops * * * may accumulate injurious concentrations of sodium.

2. "Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, expecially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

3. "High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions.

4. "Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except under special circumstances."

Bicarbonate ion

Residual sodium carbonate (RSC), which may be defined by the formula $RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$, in which concentrations are expressed in equivalents per million, is a measure of the hazard involved in the use of high-bicarbonate water. If residual sodium carbonate is greater than 2.5 epm (equivalents per million), the water is not suitable for irrigation. The water is marginal if the residual sodium carbonate is between 1.25 and 2.5 epm, and is probably safe if the residual sodium carbonate is less than 1.25 epm (U.S. Salinity Laboratory Staff, p. 81).

Boron

Nearly all natural water contains boron in amounts that range from a trace to several parts per million. Although boron in small amounts is essential to plant growth, it is toxic at concentrations slightly higher than the optimum. Scofield (1936, p. 286) proposed limits for boron in irrigation water, depending on the sensitivity of the crops to be irrigated. In general, boron in excess of 3 ppm (parts per million) is injurious to most crops.

Classification and Interpretation of Analyses

The results of chemical analyses of water from 11 wells and 5 thermal springs are given in table 3. The salinity and alkali hazards of all the samples that were analyzed are plotted on a diagram proposed by Wilcox for the classification of irrigation water (fig. 3). On the basis of this diagram and the residual sodium carbonate column in table 3, all the water, except that from the thermal springs and well 42/30-23A1, can be used safely for the irrigation of most crops. Water from springs 44/31-4A1, and 5A1, and well 42/30-23A1 is marginal and might be used under special conditions. Water from the other thermal springs probably will not be satisfactory for irrigating most crops.

Water from the thermal springs is somewhat more saline than the country water and is characterized by very low calcium and magnesium content. The two thermal springs in the northern part of the valley, 44/31-4A1 and 5A1, are dominantly sodium-sulfate water whereas the others are high in sodium-bicarbonate.

Only one small thermal spring yielded water that contained boron in excess of the limit of 2.5 ppm set by Scofield (1936, p. 286). This was spring 42/30-1D1, near the edge of the valley floor in the southwestern part of the valley, whose boron content was 3.9 ppm. The boron content of all the other water that was analyzed was not detrimental for any of the crops likely to be grown in the valley.

Water for Domestic Use

Most of the water from wells in Pine Forest Valley is within the limits prescribed for drinking water by the U. S. Public Health Service (1946). The notable exception to this is the high concentration of fluoride in well 44/31-35B1. All the thermal springs yield water having objectionable amounts of fluoride.

Temperature

The temperature of water from wells sampled in Pine Forest Valley ranged from 51° to 61° F and averaged about 58° F, with the exception of the temperature of the water from well 42/31-11B1 which was 75° F. The chemical analysis of this water shows no relation to other thermal water in the valley but is typical of the country water.

CONCLUSIONS

The most important aquifers in Pine Forest Valley are the sand and gravel deposits buried within the less permeable fine-grained sediments of the valley fill. An extensive test-drilling program would be needed to define these aquifers, particularly in the central part of the valley where the surface geology gives no indication of what may be expected at depth. Without such a program the location and extent of these aquifers will have to be determined as new wells are drilled. In addition to the occurrence of favorable water-bearing zones, success in obtaining wells that will yield large volumes of water depends, to a large extent, on proper well construction and development.

The average annual recharge to and the average annual discharge from Pine Forest Valley are each on the order of 10,000 to 15,000 acre-feet.

Recoverable ground water in storage in the valley amounts to about 18,000 acre-feet per foot of saturated sediments. Although it is desirable that some water be removed from storage to achieve optimum development of the ground-water reservoir, an economy based on depletion of stored water would necessarily be limited in time. On a long-term basis, therefore, the net pumpage draft should not exceed the perennial yield.

Chemical analyses indicate that most of the water in the valley is suitable for irrigation and domestic use.

This appraisal of the ground-water resources of Pine Forest Valley is based on a limited amount of data. A more detailed appraisal of the ground-water resources can be obtained by a program of continued periodic inventories of pumpage correlated with water-level measurements and chemical analyses of water from wells at selected sites in the valley. Such a program would supply the necessary information for the development and management of the water resources of Pine Forest Valley.

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Table 1. - - Yield, drawdown, and specific capacity of wells in Pine Forest Valley, Humboldt County, Nev.

Well number and location	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per foot of drawdown) 1/
45/31-19A1	10	20	0.5
43/32-20A1	1,100	95	12
43/32-20C1	3,100	97	32
43/32-29B1	3,600	97	37
43/32-30A2	1,600	40	40
42/30-23C1	25	6	4.2
42/31-11B1	2,400	48	50
41/32-2A1	2,250	32	70

1/ Computed from yield and drawdown data contained in drillers' reports to the State Engineer of Nevada.

Table 2.--Record of wells and springs in Pine Forest Valley, Humboldt County, Nev.
Use of water: D, domestic; I, irrigation; S., stock.
Water level: M, measured; R, reported.
Altitude: Determined from altimeter readings, rounded to nearest 5 feet.

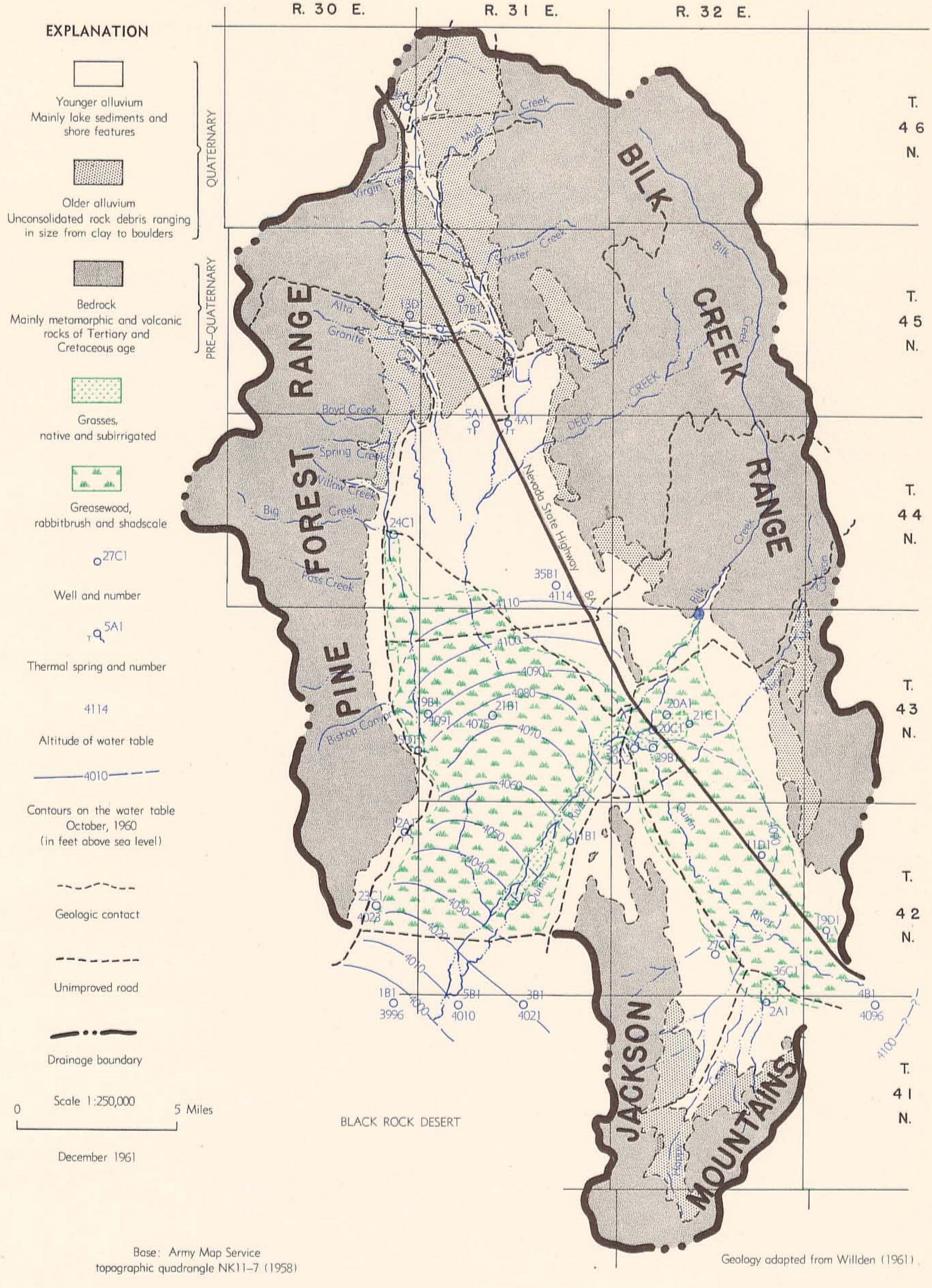
Well or spring number and location (See Fig. 2.)	Owner	Date drilled	Diameter (inches)	Depth (feet)	Depth of main aquifers (feet)	Measuring point: Altitude (feet)	Measuring point: Above land surface (feet)	Measuring point	Water level: Below measuring point (feet)	Water level: M or R	Water level: Date	Use	Remarks
46/30-13A1	Quinn River Crossing Ranch	9-55	8	194	191-194	--	1.5	Top of casing	113.9	M	10- 1-60	S	Chemical analysis
45/30-13D1	Big Creek Ranch	5-51	8	80	25-38	--	--	--	18	R	5- 51	D	
45/31-17B1	--	--	--	161	--	--	0	Top of soil drum	130.9	M	9-20-60	S	Chemical analysis
45/31-19A1	Nevada Highway Department	2-56	6	230	193-227	--	--	--	195	R	2-18-56	D	
45/31-28A1	--	--	6	123	--	--	.5	Top of casing	90.7	M	10- 5-60	S	Chemical analysis
44/30-24C1	Big Creek Ranch	--	--	40	--	--	0	Hole in pump base	20.5	M	10- 5-60	D	
44/31-4A1	--	--	--	--	--	--	--	--	--	--	--	S	Thermal Springs; flow about 50 gpm. Chemical analysis
44/31-5A1	--	--	--	--	--	--	--	--	--	--	--	S	Thermal spring; flow about 5 gpm. Chemical analysis
44/31-35B1	U.S. Bureau of Land Management	--	--	--	--	4,195	.5	Top of oil drum	81	M	10- 4-60	S	Chemical analysis
43/30-25D1	--	--	--	--	--	--	--	--	--	--	--	S	Thermal spring; flow about 40 gpm. Chemical analysis
43/31-19B1	Harold Woodward	1931	--	25	--	4,100	2	Concrete pump base	10.2	M	10- 8-60	S	Chemical analysis
43/31-21B1	U.S. Bureau of Land Management	--	8	33	--	4,090	.5	Top of casing	14.1	M	10- 8-60	S	Chemical analysis
43/32-20A1	Quinn River Crossing Ranch	3-51	14	925	348-925	--	--	--	--	--	--	I	
43/32-20C1	Quinn River Crossing Ranch	--	16	706	300-706	--	--	--	--	--	--	I	
43/32-21C1	Quinn River Crossing Ranch	10-57	6	75	61-75	4,120	1	Top of casing	32.1	M	9-30-60	S	
43/32-29B1	Quinn River Crossing Ranch	5-60	16	700	110-190	--	--	--	13	R	5-20-60	I	
43/32-30A1	Quinn River Crossing Ranch	3-51	8	60	15-20	--	--	--	15	R	3- -51	--	
43/32-30A2	Quinn River Crossing Ranch	3-51	16	395	60-120	--	--	--	--	--	--	I	
42/30-12A1	--	--	--	--	--	--	--	--	--	--	--	--	Thermal springs; flow 1-2 gpm. Chemical analysis
42/30-23C1	U.S. Bureau of Land Management	10-58	6	128	117-125	4,055	1	Top of casing	32.9	M	9-30-60	S	Chemical analysis
42/31-11B1	Quinn River Crossing Ranch	8-55	17	352	55-120	4,055	3	Top of casing	+4.6	R	8-30-55	I	Flows about 170 gpm Chemical analysis
42/32-11D1	--	8-49	8	--	--	--	1	Top of casing	25.7	M	6- 2-61	--	Not used
42/32-19D1	--	--	--	--	--	--	--	--	--	--	--	S	Thermal springs; flow about 5 gpm. Chemical analysis
42/32-27C1	--	--	--	--	--	--	--	--	--	--	--	S	Chemical analysis
42/32-36C1	Happy Creek Ranch	--	--	65	--	--	--	--	--	--	--	D	Chemical analysis
41/30-1B1	U.S. Bureau of Land Management	--	6	57	--	4,055	1	Top of casing	57.1	M	9-30-60	S	
41/31-3B1	U.S. Bureau of Land Management	--	6	--	--	4,040	1	Top of casing	17.7	M	9-30-60	S	
41/31-5B1	U.S. Bureau of Land Management	--	6	78	--	4,030	1	Top of casing	20.3	M	10-8-60	S	Chemical analysis
41/32-2A1	Happy Creek Ranch	8-54	16	202	142-202	4,130	0	Pump base	38	M	9-30-60	I	Water level measured by airline
41/33-4B1	--	--	6	--	--	4,100	0	Top of casing	2.6	M	11- 7-60	S	Not used

Table 3.--Chemical analyses of ground water in Pine Forest Valley, Humboldt County, Nev.

[Analyses by U.S. Geological Survey unless otherwise stated. Constituents in parts per million. For information on classification for irrigation, see Fig. 3 and p. [illegible].]

Well or spring number	Date collected	Temperature (°F)	Specific conductance (micromhos at 25°C)	Dissolved solids (ppm) residue at 180°C	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)-(epm)	Classification for irrigation	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Hardness non-carbonate	pH
46/30-13A1	10- 1-60	55	[a] 209																			
45/31-17B1	9-20-60	57	[a] 339																			
45/31-28A1	10- 5-60	59	338	239	1.3	0.10	C2S1	39	28	7.5	30	5.8	0	128	26	26	0.2	3.5	0.08	100	0	7.7
44/31-4A1	10- 7-60	136	401	324	14	1.99	C2S2	84	2.4	.5	91	2.0	39	52	64	14	7.9	.1	.26	8	0	9.3
44/31-5A1	10- 7-60	163	398	344	14	2.16	C2S2	84	3.2	.0	90	2.3	41	58	46	12	8.0	.2	.21	8	0	9.3
44/31-35B1	10- 4-60	61	354	262	2.1	.57	C2S1	54	26	4.4	45	3.8	0	136	40	21	2.0	.7	.16	83	0	7.6
43/30-25D1	10- 8-60	158	636	470	22	3.94	C2S4	83	3.2	.0	146	3.7	16	218	76	6.0	8.9	.3	.41	8	0	8.7
43/31-19B1	10- 8-60	55	367	272	1.6	.51	C2S1	57	33	6.3	39	3.6	0	164	44	15	.2	.1	.10	109	0	7.7
43/31-21B1	10- 8-60	53	315	241	1.5	.54	C2S1	55	26	5.8	33	3.0	0	140	31	17	1.0	.3	.06	88	0	7.6
42/30-12A1	10- 8-60	104	883	660	24	5.82	C3S4	125	3.2	1.5	210	6.2	7	358	67	54	14	1.2	2.9	14	0	8.3
42/30-23C1	11- 9-60	--	845	--	7.7	2.66	C3S2	--	21	5.7	153	11	0	255	--	66	--	--	--	76	0	8.1
42/31-11B1	10- 8-60	75	259	244	2.0	.63	C2S1	65	18	2.4	34	4.8	0	104	25	15	.6	.8	.11	54	0	7.7
42/32-19D1	10- 7-60	70	1,900	1,290	20	13.54	C3S4	51	30	6.3	455	9.9	0	948	204	69	9.8	.4	1.3	100	0	8.1
42/32-27C1	10- 7-60	55	648	436	2.0	0	C2S1	57	41	17	76	7.1	0	204	91	56	.4	1.7	.19	171	4	7.6
42/32-36C1	9-30-60	51	[a] 172																			
41/31-5B1	10- 8-60	56	345	250	2.4	1.16	C2S1	49	20	4.6	47	8.2	0	156	22	23	.4	.9	.13	70	0	7.6

[a] Field test.



Base: Army Map Service topographic quadrangle NK11-7 (1958)

Geology adapted from Willden (1961)

PLATE 1. GENERALIZED GEOLOGIC AND HYDROLOGIC MAP OF PINE FOREST VALLEY, HUMBOLDT COUNTY, NEVADA