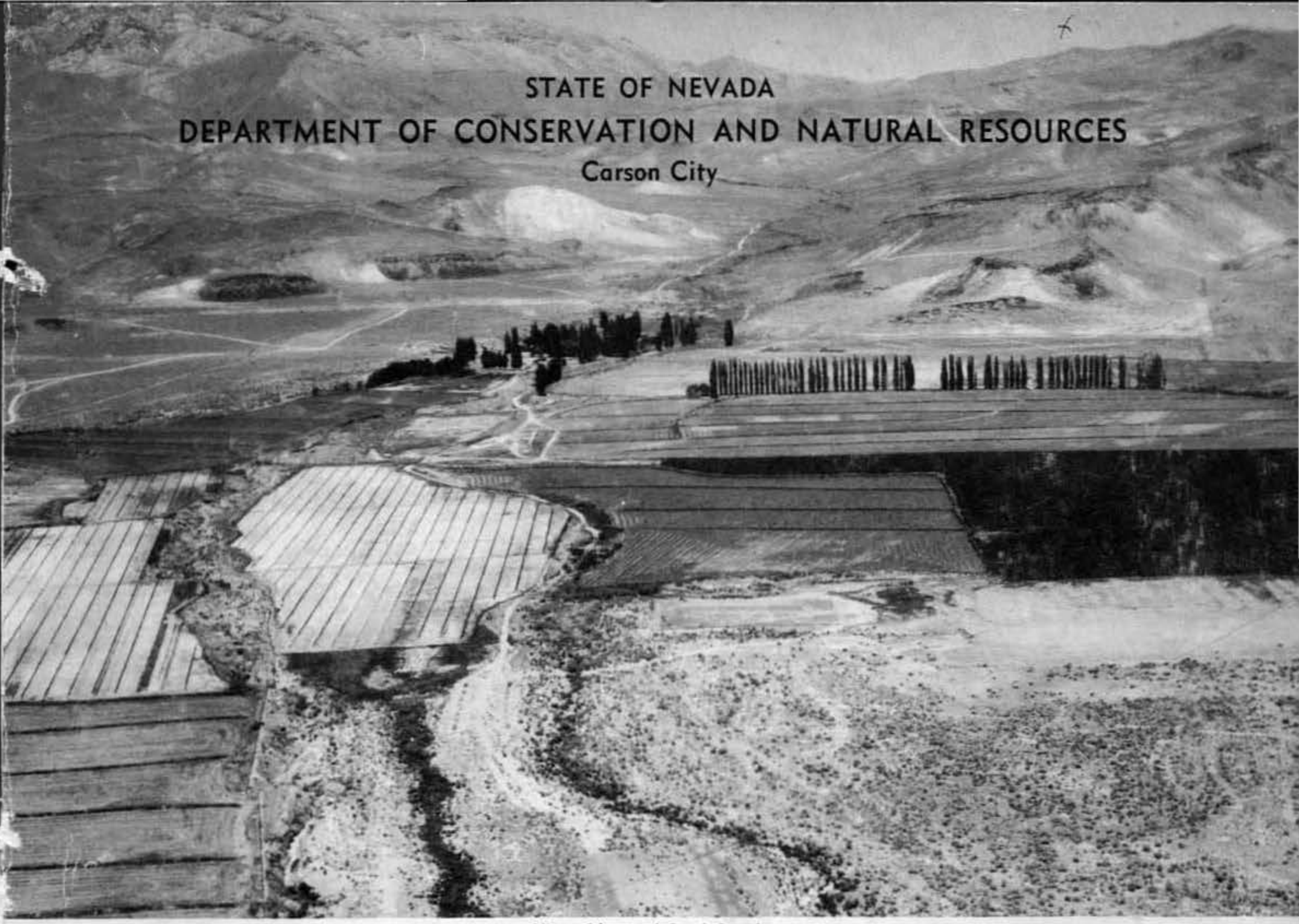
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of Leonard Creek Ranch

GROUND-WATER RESOURCES–RECONNAISSANCE SERIES
REPORT 20

GROUND–WATER APPRAISAL OF THE BLACK ROCK DESERT AREA NORTHWESTERN NEVADA

By
WILLIAM C. SINCLAIR
Geologist

Price $1.00

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

OCTOBER 1963

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FOREWORD

This reconnaissance appraisal of the ground-water resources of the Black Rock Desert area in northwestern Nevada is the 20th in this series of reports. Under this program, which was initiated following legislative action in 1960, reports on the ground-water resources of some 23 Nevada valleys have been made.

The present report, entitled, "Ground-Water Appraisal of the Black Rock Desert Area, Northwestern Nevada", was prepared by William C. Sinclair, Geologist, U. S. Geological Survey.

The Black Rock Desert area, as defined in this report, differs somewhat from the valleys discussed in previous reports. The area is very large with some 9 tributary basins adjoining the extensive playa of Black Rock Desert. The estimated combined annual recharge of all the tributary basins amounts to nearly 44,000 acre-feet, but recovery of much of this total may be difficult. Water which enters into the ground water under the central playa probably will be of poor quality for irrigation. The development of good producing wells in the old lake sediments underlying the central playa appears doubtful. Also, the soils on the playa are unsuitable for crop production.

The report points out that the best opportunities for the development of good yielding wells in areas where good soils are situated lies along the toes of the alluvial slopes, where the main streams debouch from the mountains. These areas are dispersed around Black Rock Desert and separated by wide areas of mountains and desert. Transportation of materials and farm products, both to and from the farms, will be a major problem in the development of these areas.

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

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

October 1963

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ILLUSTRATIONS

GROUND-WATER APPRAISAL OF THE BLACK ROCK DESERT AREA

NORTHWESTERN NEVADA

by

William C. Sinclair

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SUMMARY

The Black Rock Desert is one of the major structural basins in Nevada. The valley floor is the sink, or discharge area, for runoff and ground-water underflow from the surrounding watershed, which covers about 2, 600 square miles in Humboldt, Pershing, and Washoe Counties, and for the Quinn River which rises in Oregon, about 150 river miles northeast of the sink.

Mining and the manufacture of gypsum products are the principal industries in the area along with sheep and cattle ranching. The cultivation of forage-type crops in conjunction with the ranching operations is also becoming a significant part of the local economy. In this, ground water is being used increasingly to supplement irrigation by streamflow.

The Black Rock Desert has a wide, extremely flat valley floor grading from a large playa, into relatively steep alluvial slopes which flank the surrounding mountainsides. The valley floor is underlain by silt and clay to an unknown depth. Near the edges of the basin, thin layers of sand and gravel are interfingered with the less permeable silt and clay. The sand and gravel layers together with the alluvium flanking the mountainsides constitute the principal ground-water aquifers in the area.

The lake deposits which underlie the valley floor and playa contain an abundance of evaporite minerals which are easily taken into solution by the ground water as it moves from the surrounding upland areas of recharge toward the central part of the basin. The development of ground-water supplies of chemical quality suitable for irrigation or domestic use, therefore, requires that wells be drilled along the perimeter of the basin to intercept the relatively fresh ground water. Even so, encroachment of the saline water beneath the playa may limit the draft from the freshwater aquifers.

Estimates of average annual recharge to the ground-water reservoirs of eight sub-watersheds in the Black Rock Desert area range from 2, 000 to 13, 000 acre-feet. These estimates suggest an order of magnitude for the perennial yield of the sub-watersheds and constitute a more reasonable

management tool than an estimate of the total perennial yield for the entire Black Rock Desert.

Although no direct estimates were made of evaporation and transpiration losses from areas of shallow ground water on the floor of Black Rock Desert, the size of the areas involved suggest that the total may be in the range of 10, 000 to 30, 000 acre-feet per year.

INTRODUCTION

Location and Extent of the Area:

The Black Rock Desert covers an area of about 2, 600 square miles in parts of Humboldt, Pershing, and Washoe Counties, Nevada (fig. 1). The area described in this report also includes the High Rock Lake and Summit Lake drainage basins; an additional 800 and 50 square miles, respectively. These two watersheds, formerly tributary to the Black Rock Desert, were closed by landslides which impounded the drainage to form the two lakes.

In addition to the natural watershed boundaries (pl. 1), the area covered in this report does not extend beyond the vicinity of Gerlach, at the southwest corner of the area, where the Black Rock, San Emidio, and Smoke Creek Deserts come together; it is limited on the northeast by the Leonard Creek Ranch Road. Pine Forest Valley, a northward extension and tributary of the Black Rock Desert, lies north of the road and was described in report 4 of this series.

The Black Rock basin is a structural depression, bounded on the east and west, and bisected in part, by north-trending fault-block mountains. The valley floor therefore, is somewhat U-shaped and is noted for its large area, about 700 square miles, of extremely low local relief, generally less than 10 feet. The Black Rock Desert is the sink, or discharge area, for the waters of the Quinn River, which rises in Oregon about 150 river miles northeast of the sink, and of other smaller streams tributary to the basin. The Quinn River enters the area from the northeast, Mud Meadow Creek from the northwest. When the streamflow is sufficient to reach the valley floor, a lake is formed on the playa in the area southwest of Black Rock Point.

The shipment of gypsum products from a quarry and mill near Empire, about 8 miles south of Gerlach, makes the town of Gerlach an important stop on the Western Pacific Railroad, which crosses the southern edge of the Black Rock Desert. The gypsum plant is the largest economic development in the area. Aside from placer gold operations at Mandalay Springs, Rabbithole, and Placeritas, and the sulfur mine at Sulphur, all of which are conducted on a very small scale, the rest of the area is devoted to the raising of sheep, cattle, and feed crops.

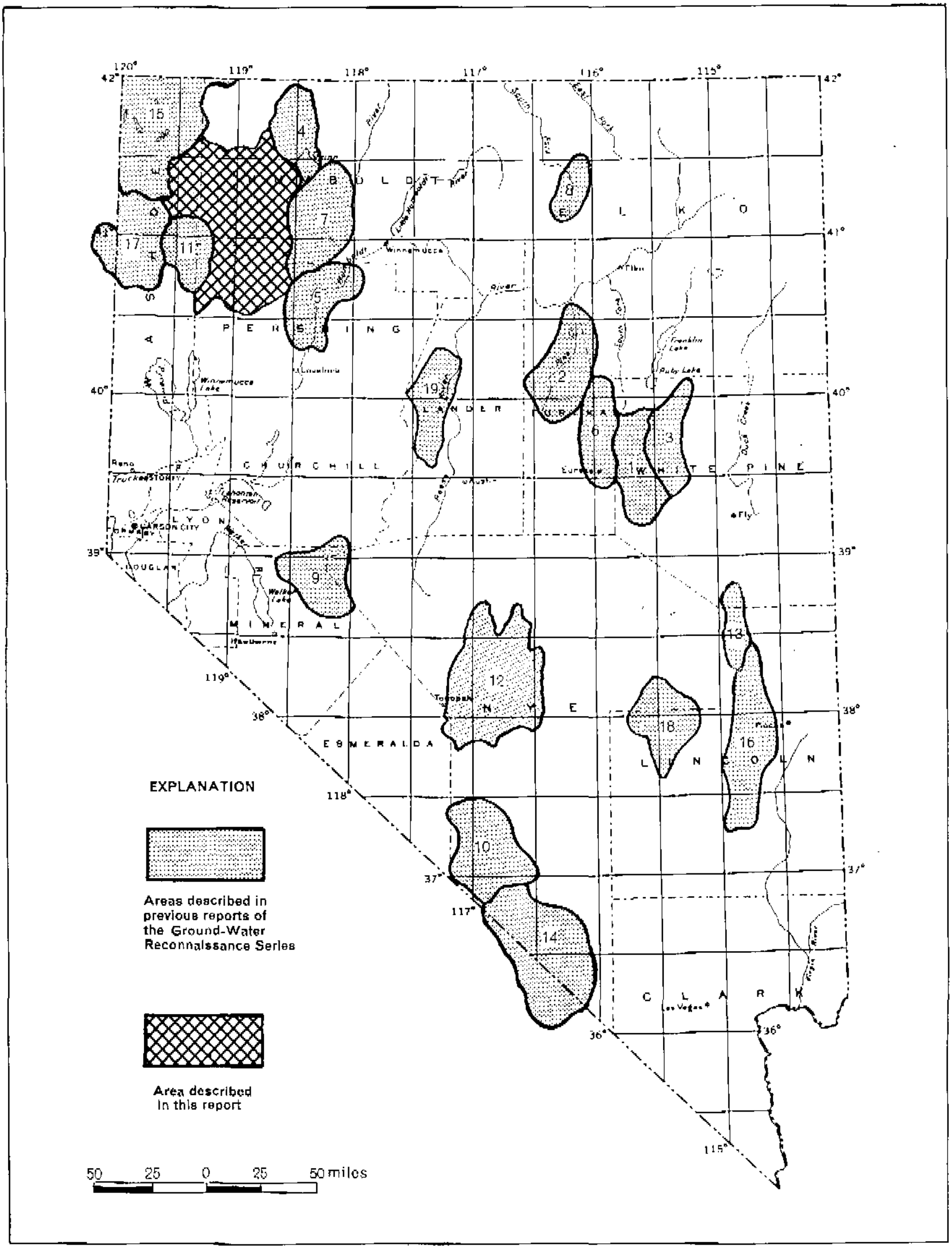


Figure 1. Map of Nevada showing areas described in previous reports of the ground-water reconnaissance series and the area described in this report

The population of the Gerlach-Empire metropolitan area is approximately 1,000. The population of the remainder of the region may total 200, although the influx of seasonal ranch help and Indian families to the Summit Lake Indian Reservation may increase this figure during the summer.

Although both Gerlach and Empire have a general store, the main trading center for the region is Reno, about 110 miles south of Gerlach. State Route 34 is paved from Gerlach south to U. S. 40. North of Gerlach it is gravel, usually well maintained, and trends northward about 84 miles to Vya and a junction with secondary roads to Oregon and California. State Route 81 is also paved through part of the 55 miles from Gerlach to the California state line, and to Cedarville, 25 miles beyond.

Graded gravel roads connect Sulphur with Winnemucca, 56 miles east, and Lovelock, 64 miles south. A graded road enters the region from highway 8A at Quinn River crossing and connects Leonard Creek, Battle Creek, and Pahute Meadows ranches with nearby towns. The gravel roads mentioned above are usually passable with a relative degree of comfort and confidence by passenger car. Other roads and trails in the area, some of which are shown on Plate 1, are best attempted by pickup truck, and in many cases, only with four-wheel drive vehicles.

Purpose and Scope of the Investigation:

This report is the 20th in a series of reconnaissance studies of the valleys of 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 purpose of this study is: (1) to determine the nature and extent of the aquifers; (2) to determine the occurrence and movement of ground water, including the areas of recharge and areas of discharge; (3) to determine the sources of recharge and 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 its chemical quality and suitability for irrigation and domestic use.

The field work for this report was done at intervals during the period January 1960 to May 1963, and represents a total of about 30 days. It consisted of a brief 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 collection of samples of water for chemical analysis.

The assistance provided by residents of the areas in supplying information about wells and springs is gratefully acknowledged. Information from the files of the Winnemucca Grazing District Office of the U. S. Bureau of Land Management and data collected by the General Hydrology Branch of the U. S. Geological Survey as part of a stock-well site study were also of value in this study.

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 section number 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 33/23-24d1 designates the first well recorded in the SE 1/4 sec. 24, T. 33 N., R. 23 E., Mount Diablo base and meridian. In unsurveyed areas the land grid has been arbitrarily extended from the nearest reference corner, and well location numbers assigned accordingly.

Plate 1 shows the locations of many of the wells and springs in the area included in this report. The available data for the wells are listed in tables 2 and 4, and for selected springs in table 3. The chemical analyses of water from selected springs and wells are shown in table 5.

PREVIOUS INVESTIGATIONS

A preliminary geologic map of Humboldt County by Ronald Willden was published in 1961. The geologic units shown in plate 1 are based largely on that map. The geology of the Jackson Mountains was studied in some detail by Willden (1962).

The late Pleistocene history of the Black Rock Desert is, to a great extent, the history of Lake Lahontan, which was studied in detail by Russell (1885) and, more recently, by Morrison (1961).

GEOGRAPHIC FEATURES

Northwestern Nevada is typically a sagebrush desert. North-trending mountain ranges separate desert basins which characteristically have no drainage outlet under the present semiarid climate. The relief of the area is the result of vertical displacement of large mountain blocks by faulting, and to their subsequent sculpture by erosion. The valleys generally are underlain by the downfaulted blocks. They are the catchment areas for the streamflow from the surrounding mountains and have been filled, commonly to great thicknesses, with rock debris eroded from the mountains.

Mountains:

The Black Rock Range stands at an altitude of 8,631 feet, about 4,700 feet above the desert floor, near the northern border of the watershed. It tapers southward to a narrow ridge extending into the center of the basin and to within about 10 miles of the south edge of the desert floor. Along the northern border of the drainage basin the Black Rock Range coalesces with the High Rock Lake area on the west and the Pine Forest Range on the east.

Although the major stream courses in the High Rock Lake drainage are deeply entrenched, the upland topography is relatively subdued, rising to occasional peaks at altitudes of about 7,000 feet.

From High Rock Lake southward, the Calico Mountains border the western edge of the desert, rising to an altitude of 8,491 feet at Division Peak, then decreasing in altitude southward, and finally dipping beneath the alluvium of the valley fill. A low ridge of metamorphic rocks trends northeast from the Granite Range to within about a mile of the southern terminus of the Calico Mountains. Between the two a low alluvial divide, covered with hummocks of wind-blown silt, separates the Black Rock Desert from Hualapai Flat, a small valley which was described in report 11 of this series (Sinclair, 1962b).

The Granite Range rises abruptly from the desert floor north of Gerlach and trends northwestward for about 15 miles, attaining an altitude of 9,056 feet at Granite Peak. Granite Basin, a small valley on the south end of the Granite Range, drains to the Black Rock Desert through Bowen Creek.

South of the Granite Range the Black Rock Desert merges with the San Emidio Desert, then, through a narrow gap north of the Fox Mountains, with the Smoke Creek Desert (pl. 1).

The Selenite Range trends northward along the east side of the San Emidio Desert then curves northeastward to form a part of the south edge of the Black Rock Desert. This and several other northeast-trending ridges form the southern boundary of the Black Rock drainage. The topography in the southern watershed is relatively subdued. Although the Seven Troughs Range rises to peaks of 7,782 and 7,552 feet, the altitudes of most of the other ridges in this area are about 6,500 feet or less.

The eastern edge of the desert is bordered by the Jackson Mountains whose ragged crest is generally above 7,000 feet in altitude. King Lear Peak, the highest point in the range, rises to an altitude of 8,910 feet, roughly 5,000 feet above the desert floor.

The northern end of the Jackson Mountains lies about 5 miles east of the south end of the Pine Forest Range. The Black Rock Desert is open to the north here, receiving occasional runoff via the Quinn River as well as ground-water underflow from Pine Forest Valley.

Piedmont Slopes and Desert Floor:

Rock debris eroded from the mountains, carried downslope by gravity, streamflow, and storm runoff and deposited in the valley, is generally termed alluvium. Alluvium begins to collect, generally in cone or fan-shaped deposits, at the mouths of canyons or other places where the stream gradient and sediment-carrying capacity is sharply reduced. In time, these fans extend well out into the valley and along the flanks of the mountains until they coalesce and form a continuous slope of alluvium, considerably less steep than the mountain fronts and decreasing in slope until they merge, imperceptibly, with the level desert floor.

The alluvial slopes flanking the mountains around Black Rock Desert are relatively narrow and steep. The stoping action of waves and currents in the lakes, which have occupied the basin in times past, has nibbled back the lower slope of the alluvial apron, steepening the upper slope and removing the fine particles for redeposition in the relatively still, deep waters toward the center of the basin. Most of the desert floor is underlain by dense saline clay, deposited in the many lakes which have occupied the basin intermittently since it first began to form.

A well drilled to a depth of 1,500 feet, 4 1/2 miles north of Trego on the desert floor, penetrated clay throughout the entire depth. Occasionally the clay was reported as "sandy", "fossiliferous", or "marly". No identification of the fossils was made in the log of this well, which is on file at the office of the State Engineer (log No. 3929, Pershing County); it is not known how much of the geologic time scale is represented in this 1,500-foot section. It seems probable, however, that the downthrown fault blocks underlying the Black Rock Desert have been subsiding, relative to the surrounding mountains, at least since mid-Tertiary time; an interval of about 25 million years.

The most remarkable feature of the Black Rock Desert is the desert floor itself. A playa, utterly flat and devoid of any vegetation, occupies about 150 square miles. During the winter months and for a few days following infrequent summer storms, the playa becomes a sea of mud. The standing water is generally only a few inches deep but may extend over many square miles. As winter advances into spring, the water evaporates and the mud dries to a hard clay surface crazed with polygonal desiccation fissures and white with the efflorescence of minerals precipitated from the saline water. The salts are soon dissipated, along with loose clay particles, by the winds which constantly sweep, unhendered, across the level expanse of desert floor.

The wind, in fact, is the most important erosional force presently at work in the Black Rock Desert. The flatness of the desert floor is due largely to the planning action of the playa lakes as they are swept about by the wind. The presence of the water table just beneath the desert floor is another controlling factor, providing a base level which limits the effect of wind action as an erosional agent.

An additional 550 square miles of valley floor surrounds the playa and extends eastward to Sulphur and northward to Soldier Meadows along the west side of the Black Rock Range and to Pine Forest Valley along the east side. The land rises gradually northward at a rate of about 7 feet per mile, west of the Black Rock Range and about 2 feet per mile in the eastern arm, toward Pine Forest Valley.

This area is covered with a sparse growth of salt-tolerant bush. A dense pattern of incipient drainage lines has become incised a few inches or feet into the desert floor, channelling the meager runoff toward the main course of the Quinn River or to one of the many small playas, impounded by minor surface irregularities in the valley floor. The local relief is rarely more than a few feet. The drainage channels are sharply, though not deeply, incised in the areas underlain by silt and clay. Elsewhere the surface is irregular and usually soft, being composed of ridges and hummocks of wind-flown silt, so that travel, by any method, is generally difficult.

Sand is notably lacking in the Black Rock Desert, although a few dunes, stabilized by vegetation, occur along the west flank of the Black Rock Range north of Double Hot Spring and to a lesser extent in an area north of Sulphur. Most of the material composing the valley floor is silt or clay.

Drainage:

Most of the streams draining the mountains surrounding the Black Rock Desert are relatively short, their profiles are irregular, and their canyons generally narrow and steep sided. The streams are fed principally by snowmelt and storm runoff. Their flow, therefore, is ephemeral, occurring during the spring and early summer. As summer progresses, the snowpack in the mountains is depleted, the headwaters of the streams decrease or go dry, and the decreased flow is insufficient to reach the valley floor, owing to seepage into the alluvium flanking the mountains and losses of water to the vegetation growing along the stream channels. Flow in the perennial streams, then, is limited to the middle reaches which are sustained by the discharge of ground water from bedrock and alluvium farther upstream.

Some of the streams carry sufficient flow during flood periods for their channels to have become incised in the valley floor. The most notable of these are the channels of the Quinn River. The gradient of the Quinn River in the Black Rock Desert is somewhat less than 2 feet per mile. As a result of the extremely low gradient the Quinn River has developed several meandering, braided channels.

Throughout most of the year these channels are dry, and occasional pools of standing water are formed where the channel bottom lies below the water table. In the winter, however, when precipitation is somewhat greater and losses to evapotranspiration are less, the water table rises until it intersects the channels of the Quinn River, which then becomes a drain carrying the effluent ground water toward the playa in the southwest quadrant of the valley floor.

The drainage which presently terminates in High Rock Lake was formerly tributary to the Black Rock Desert through Willow Creek. A landslide, at what is now the head of Willow Creek Canyon, blocked this drainage, impounding the waters of High Rock Lake. In pluvial times the lake rose until it spilled into Fly Creek, a few miles north of the former outlet. Under the present climatic conditions the lake is generally several feet below the col at the head of Fly Creek, and sometimes dries up completely in late summer or early fall.

A debris slide forms the present drainage divide between Summit Lake and Soldier Meadows Creek. Slight fluctuations in lake level are indicated by the faint shorelines which border the lake just a few feet above its present level, but there is no evidence that Summit Lake overflowed during late pluvial times. The fact that no evidence of significantly higher lake stages was noted in the Summit Lake Basin suggests that the debris slide is relatively recent, and probably occurred after the pluvial period had ended. Evaporation from the lake's surface, and perhaps some seepage through the debris and buried stream gravels into the head of Soldier Meadows Creek, is sufficient discharge to balance the inflow to the lake under the present climatic conditions.

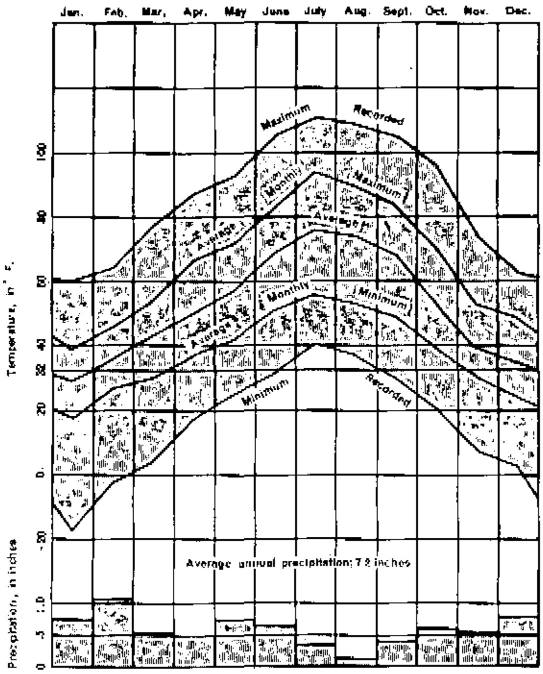
Climate:

The rainfall of northwestern Nevada is governed largely by the seasonal migration of storm centers which move inland from the Pacific Coast in the winter. During the summer months of July, August, and September, less than one tenth of the total annual precipitation occurs, as illustrated by the graphs in figure 2. Topography exerts considerable control on precipitation, and the high mountains of California intercept much of the moist Pacific air that moves inland from the storm centers. The Black Rock Desert lies to leeward of these mountains along the major storm tracks and therefore has a relatively arid climate.

As the eastward moving air masses are forced upward by a mountain range, the decrease in pressure and temperature causes precipitation. Most of this precipitation occurs on the western flank of the range. As the air mass moves down the eastern flank it is warming and dry. This is well illustrated by the Granite Range whose highest peaks seem to rake moisture from clouds which ordinarily drift on across the Black Rock Desert usually without further precipitation.

Although the annual precipitation may be as much as 15 to 20 inches along the crests of some of the higher ranges surrounding the Black Rock Desert, the valley floor itself probably receives somewhat less than 6 inches per year, as indicated in the graphs compiled from U. S. Weather Bureau data for stations at Gerlach, Sulphur, Quinn River Crossing Ranch and Leonard Creek Ranch (fig. 2). These graphs also give an indication of the range of temperature and length of the average growing season.

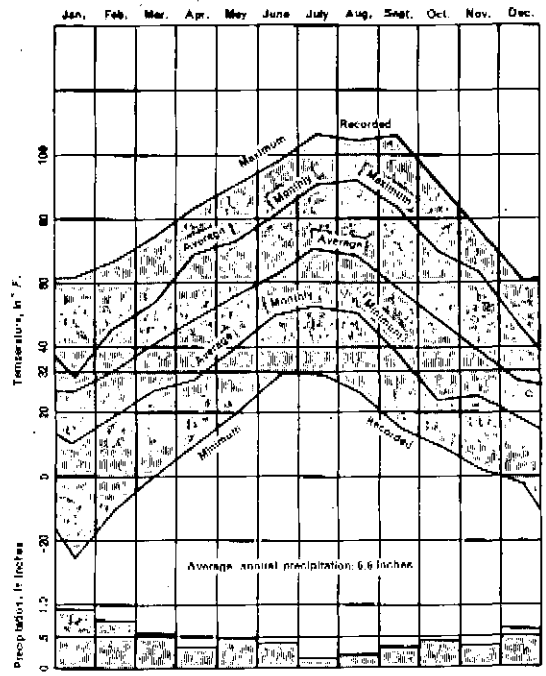
The rate of evaporation from a free water surface in the area is about 50 inches a year, according to Kohler, Nordenson, and Baker (1959, pl. 2). This rate of evaporation is roughly 8 times the annual precipitation on the valley floor.



LEONARD CREEK RANCH

Altitude 4,226

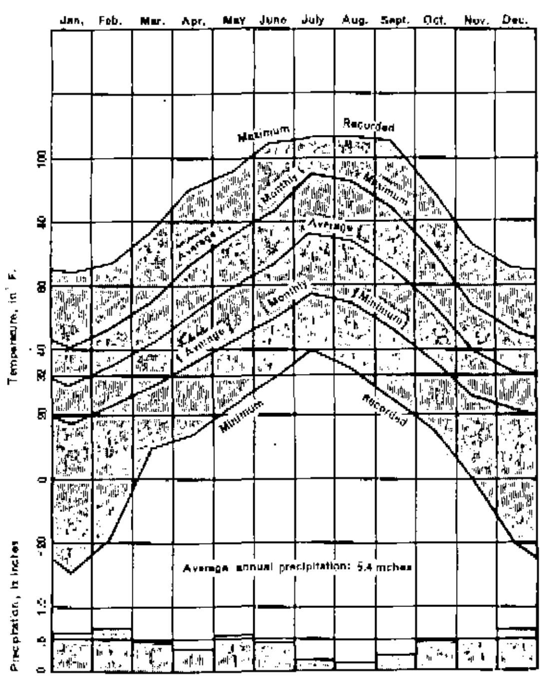
Average monthly precipitation and temperature data for the period 1955-1962.



QUINN RIVER CROSSING RANCH

Altitude 4,087

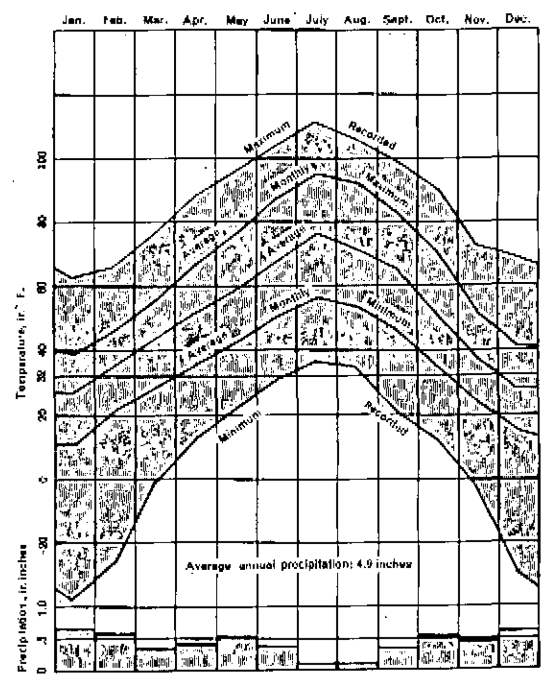
Average monthly precipitation and temperature for a 28-year period ending 1950, and average monthly temperature data for a 2-year period ending 1950.



GERLACH

Altitude 3,980

Average monthly precipitation for a 40-year period, and average monthly temperature data for the period 1931-1952.



SULPHUR

Altitude 4,044

Average monthly precipitation for the periods 1916-1945, 1949-1952.
Average monthly temperature data for the periods 1922-1924, 1927, 1930-1941, 1943.

Figure 2.—Graphs illustrating the climatic conditions at the U. S. Weather Bureau stations at Gerlach, Leonard Creek Ranch, Quinn River Crossing Ranch and Sulphur.

PHYSICAL CHARACTER AND WATER-BEARING PROPERTIES OF THE ROCKS

Hydrologic Setting:

The present topography of the region and the present hydrologic setting began to take form during the middle part of the Tertiary Period. At that time, and continuing well into the Pleistocene Epoch, the country rock was disrupted by vertical movement along an extensive system of faults; the present basins were downfaulted and mountain ranges uplifted with respect to one another. The vertical displacement along the major range-front faults was even greater than the present relief would indicate. Erosional debris from the uplifted areas has partly filled the basins with an unknown thickness of alluvial, stream, and lake deposits. The thickness of the unconsolidated material in the Black Rock Desert may be on the order of several thousand feet.

The Pleistocene Epoch was characterized by worldwide climatic changes which resulted in the formation of lakes in many of the undrained basins of Nevada. The most recent of these, Lake Lahontan, intermittently covered a large part of western Nevada and attained a maximum altitude of about 4,380 feet. In the Black Rock Desert, which was a major arm of Lake Lahontan more than 400 feet deep, the many stages and fluctuations of the lake are recorded in the shoreline features which terrace the surrounding mountainsides.

Bedrock:

Black Rock, a small steep hill at the south end of the Black Rock Range, is composed of Permian marine and volcanic rocks; the westermost exposure of fossilerous Permian strata known in the State (Gianella and Larson, 1960). The Jackson Mountains are largely composed of Permian and older rocks, named the Happy Creek Volcanic Series by Willden (1962). Intrusive masses, mainly granodiorite, occur in many of the surrounding mountains and are probably Cretaceous or Tertiary in age. Various sedimentary and metamorphic rocks, ranging in age from Permian to Pleistocene, also occur in the mountains of the Black Rock Desert, but in general volcanic rocks predominate. In the area north and west of Black Rock the terrane is composed almost exclusively of a thick section of volcanic flow rocks intercalated with tuff and lake beds of Tertiary age.

The movement of ground water in the consolidated rocks of the mountain ranges is largely through joints and other secondary openings and in permeable 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 volcanic terrane of the High Rock Lake Region, 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 channes 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, is not considered a dependable source of water for large-capacity wells.

Alluvium:

Alluvial fans coalesce to form the piedmont slopes which flank the mountains surrounding the Black Rock Desert. This alluvium has been deposited largely by mudflow and flood waters because of the flashy nature of the streams. As a result, it is composed of poorly sorted rock particles ranging in size from clay to boulders. The alluvium ranges in age from mid-Tertiary to Recent.

The permeability of alluvium, although much greater than that of bedrock, is generally low to moderate, depending on the size and degree of sorting of the rock particles. Layers and lenses of well-sorted sand and gravel are found at various levels within the alluvium. These are best developed off the mouths of the canyons where streamflow has sorted the particles according to size and weight, carrying the finest particles farthest out toward the center of the basin.

Wells penetrating a sufficient saturated thickness of alluvium may yield moderate to large volumes of water, but along the alluvial slopes the depth to water may be on the order of 100 feet or more; pumping lifts are even greater.

Lake Deposits:

The alluvium mantling the mountainsides has been reworked extensively by wave action in the lakes which have filled the basin to various levels throughout much of its history. The winowing action on the waves removed much of the fine material from the shores leaving beaches and bars of well-sorted sand and gravel ringing the basin at several elevations, both above and below the present valley floor. In the central part of the basin the valley floor is underlain by silt and clay deposited in the relatively still, deep parts of the former lakes. As previously mentioned (p. 6), the section of clay underlying the central part of the desert floor is at least 1, 500 feet thick and probably is much more. The lake deposits probably range in age from Pliocene to Recent.

Around the margins of the basin the thick clay and silt sections are separated by relatively thin layers and lenses of sand and gravel, which are principally stream deposits and reworked alluvium that accumulated during shallow stages of the lakes and periods of desiccation. These sheets of sand and gravel, though thin, may be quite extensive and probably constitute the most important aquifers in the basin. They are best developed along the edges of the basin and thin basinward as they interfinger with the silt and clay, eventually pinching out altogether.

GROUND WATER

Occurrence and Movement:

Most of the available ground water occurs in the unconsolidated deposits of the alluvium, or valley fill. Ground water also occurs in the consolidated rocks of the mountains. Moving through fractures in the rock, ground water sometimes appears at the surface to form a spring or, more commonly, discharges into the alluvium at some distance beneath the land surface. As previously mentioned, however, the bedrock is generally not a source of water for large-capacity wells.

Ground water, like surface water, always moves downgradient toward the area of lowest head. The alluvial aquifers in the Black Rock Desert are recharged along the piedmont slopes at elevations several hundred feet above the valley floor. The ground water then percolates downgradient toward the center of the basin where it is discharged to the atmosphere either by evaporation from the land surface or transpiration by the greasewood and other salt-tolerant plants which cover most of the valley floor.

The horizontal permeability of lake deposits, and to a lesser degree of alluvium, is generally greater than the vertical permeability. This is due primarily to the modes of deposition which have resulted in relatively thin but extensive layers of permeable sand and gravel overlain by layers of relatively impermeable silt and clay. This sequence is repeated many times, each member sloping from the margins of the basin toward the center, resulting in many thin artesian aquifers interbedded with less permeable confining layers. Upward leakage occurs through the confining layers, and ground water is discharged at the land surface by evaporation and transpiration.

Recharge:

Precipitation is the ultimate source of recharge to the ground-water reservoir of the Black Rock Desert. In addition to recharge from precipitation within the area defined on plate 1, some ground water enters the basin by underflow from beyond the surface drainage divides and along the course of the Quinn River.

The approximate amount of precipitation within the drainage area each year can be estimated from a map showing precipitation zones in Nevada (Hardman, 1936). Although the average annual precipitation is less than 6 inches on the valley floor (p. 8), precipitation increases with altitude, as described by Hardman and Mason (1949), and the entire drainage basin can be subdivided into precipitation zones based on aspect vegetation and altitude, as shown in table 1. Some areas, although high, lack the relief which generates precipitation in the mountain watersheds. The High Rock Lake drainage lies 6,000 to 7,000 feet above sea level. The topography is gently rolling desert plateau, for the most part, and the aspect vegetation suggests that the average precipitation probably is within the range of 8 to 12 inches per year, despite the altitude.

The amount of precipitation which infiltrates to the ground-water reservoir is determined largely by the vegetation, soil cover, and geology of the area. In areas of very little precipitation, such as the valley floor, all, or nearly all, the available moisture may be lost to evapotranspiration.

Seepage from streams crossing the alluvium of the piedmont slopes is generally an important source of recharge. The streambeds are composed of permeable gravel and the piedmont surface is generally well above the regional water table. Rapid infiltration is possible under these circumstances.

Recharge in the mountains is determined largely by the geology, soil types, and vegetal cover. The permeability of most of the consolidated rocks is relatively low; but secondary openings, such as along bedding planes, joints, and fractures are important avenues of infiltration. The manner in which the various rock types weather has a considerable effect on the recharge potential. A mantle of coarse rock debris retards the runoff from precipitation and snow-melt and permits the water to infiltrate. Once beneath the land surface the water may percolate into the bedrock, or, in the case of less permeable rock types, move downward, through the alluvium, along the surface of the bedrock. Springs and seeps occur where the mantle thins or the bedrock surface out-crops, and are the source of the base flow of many of the small streams draining the mountains.

The percentage of precipitation that recharges the ground-water reservoir, even under favorable conditions, is small, and the percentage for a given amount of precipitation varies considerably with the terrane. A detailed determination of the percentage of precipitation that infiltrates to the water table is impossible. The estimates of ground-water recharge from precipitation shown in table 1 are based on percentages determined empirically by Eakin and others (1951) from studies in eastern Nevada and may be in the proper order of magnitude for the Black Rock Desert area.

These estimates are made to facilitate management of the ground-water resources by the State Engineer, in accordance with the Nevada Water Law, which states in part that the withdrawal of ground water be limited to the "reasonable lowering of the static water level".

Table 1.--Estimated precipitation and recharge to the ground-water reservoirs of the Black Rock Desert area.

Drainage Area	Precipitation zone (inches)	Altitude of zone (feet)	Area of zone (acres) (rounded)	Precipitation (acre-feet per year) (rounded)	Per-cent re-charged	Estimate of recharge (acre-feet per year, rounded)
Watershed South of Western Pac. Railroad	8-12	above 5,500	78,000	65,000	3	2,000
TOTAL						2,000
Jackson Mts.	15-20	above 7,000	3,900	5,700	15	800
	12-15	6,000-7,000	16,500	18,500	7	1,300
	8-12	5,000-6,000	54,700	45,500	3	1,300
TOTAL						3,400
Pine Forest Range	15-20	above 7,000	7,560	11,000	15	1,600
	12-15	6,000-7,000	15,900	17,900	7	1,200
	8-12	5,000-6,000	27,300	22,700	3	700
TOTAL						3,500
East side of Black Rock Range	15-20	above 7,000	8,500	12,400	15	1,800
	12-15	6,000-7,000	35,900	40,300	7	2,800
	8-12	5,000-6,000	26,300	21,900	3	600
TOTAL						5,000
West arm of Black Rock Desert (W. side Black Rock Range & Calico Mtns)	15-20	above 7,000	8,500	12,400	15	1,800
	12-15	6,000-7,000	53,200	59,800	7	4,200
	8-12	5,000-6,000	70,200	58,400	3	1,700
TOTAL						8,000
Granite Basin (Bowen Creek drainage)	15-20	above 7,000	1,100	1,600	15	200
	12-15	6,000-7,000	1,000	11,300	7	800
	8-12	5,000-6,000	3,900	32,500	3	1,000
TOTAL						2,000
High Rock Lake (drainage)	8-12	6,000-7,000+	525,000	435,000	3	13,000
TOTAL						13,000
Summit Lake (drainage)	15-20	above 7,000	10,400	15,300	15	2,300
	12-15	below 7,000	24,400	27,400	7	1,900
TOTAL						4,200

Unlike many of the smaller basins in Nevada, the estimate of total recharge to the Black Rock Desert is not a useful management tool. The areas presently being developed and the areas having potential for development lie along the margins of the basin, separated from one another by great expanses of lake deposits which contain saline ground water. Thus, the development of a given area is dependent on the recharge within its immediate watershed and the amount of fresh water available from storage locally. In most areas development will not affect the available ground-water supply in another part of the basin. The estimates of recharge in table 1, therefore, have been made on the basis of individual areas which are divided by reason of geology, physiography, and hydrology into isolated hydrologic units.

In addition to direct recharge from precipitation, some ground water enters the Black Rock Desert by ground-water underflow, or inflow. In the study of the ground-water resources of Pine Forest Valley (Sinclair, 1962a), it was estimated that about 2,700 acre-feet of ground water per year moves southward into the Black Rock Desert. Ground water is also entering the desert from Hualapai Flat (Sinclair, 1962b), but the amount is considered to be small. Some ground water may also be moving from the High Rock Lake region into Soldier Meadows, and the west arm of the Black Rock Desert.

Discharge:

Ground water is discharged to the surface by springs, seeps, and pumping from wells. It is returned to the atmosphere by evaporation from the land surface and by transpiration through plants.

Springs: Springs and seeps are common in the mountains surrounding the Black Rock Desert and the principal springs are shown on plate 1. They are principally the gravity type, occurring where the land surface intercepts the water table or where infiltrating ground water encounters an impermeable rock stratum and is forced laterally to the surface.

Artesian springs issue from the lake deposits in the vicinity of the Wheeler Ranch and northward. Many artesian wells in this area are also flowing unchecked, their discharge being used for flood irrigation and watering stock.

Thermal springs, whose temperatures range from warm to boiling, issue from the desert floor in several areas. These springs are probably associated with recent movement along fault zones, which provide paths along which ground water, heated at depth, can rise to the surface.

Water from the thermal springs is commonly highly mineralized due to its high temperature, which is conductive to chemical reaction with the environment and to its history of deep circulation. Most of the thermal water is derived from the same ultimate source as all ground water--precipitation. Thus it is unnecessary and, in most cases, unreasonable to postulate that all the thermal spring water originates beyond the watershed or from magma deep within the earth's crust.

Pumpage: Withdrawal of ground water to supplement surface irrigation is becoming increasingly common in Nevada. Several large-capacity wells have been developed at the Leonard Creek Ranch in the past few years. A number of flowing wells in the vicinity of the Wheeler Ranch are used for irrigation, in addition to one large-capacity pumped well. The Garret Ranch, along the southern edge of the desert, also has several flowing artesian wells whose water ranges in temperature from 68°F to 125°F. The amount of ground water presently being discharged by wells in the Black Rock Desert, however, is still a minor part of the total amount in the hydrologic regimen.

Underflow: An alluvial gap, about a mile in width, connects Smoke Creek Desert with the San Emidio Desert, which in turn merges with the Black Rock Desert at Gerlach. The altitude of the water table within the three basins is so nearly equal that interbasin movement of ground water by underflow probably is negligible.

Evaporation: In addition to storm runoff reaching the valley floor, much of the water evaporated from the playa is effluent ground water drained to the playa during the winter months by the Quinn River and Mud Meadow Creek. Ground water is discharged to the atmosphere by evaporation in areas where the capillary fringe above the water table intersects the land surface. The loss of water by evaporation decreases rapidly with increasing depth to the water table. In clay the rate of evaporation is presumed to be very slight below a depth of a few feet. The mud cracks which cover most of the playa surface, however, may serve to facilitate evaporation of water from greater depths. These cracks have been observed to extend as much as 4 feet below the surface in areas where they were only a fraction of an inch wide at the surface and formed polygons less than 6 inches across. The giant desiccation fissures, described by Willden and Mabey (1961) along the northwest edge of the playa, are generally a foot or more in width, forming polygonal blocks with edges from 100 to 250 feet long. Tough irregularities in the fissure walls limit visual estimates of their depth to a few feet, the size of their surface features suggest that these giant fissures extend to considerable depth. During the large runoff of February 1962, the area of giant fissures was completely inundated. When the water had evaporated it was found that the cracks had closed, apparently by swelling of the wetted clay rather than by filling.

In August 1962 the depth to water beneath the playa was nowhere greater than 10 feet as shown in plate 1. In addition, pools of standing water in the channels of the Quinn River and Mud Meadow Creek indicate an extremely shallow water table throughout much of the central part of both arms of the valley floor. The total area of desert floor where the depth to water probably was less than 10 feet might be on the order of 250 square miles, or roughly 150,000 acres.

The area of the floor of Black Rock Desert beneath which water levels are less than 5 feet may be as much as 200,000 acres.

If an average of only half an inch of evaporation occurs each year, the discharge might be on the order of 5,000 to 10,000 acre-feet per year. Although the ground-water discharge by evaporation can not be computed accurately, it nevertheless is a major component of the hydrologic regimen of the Black Rock Desert.

Transpiration: Evaporation and transpiration account for all of the natural discharge of ground water from the Black Rock Desert watershed. 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. Typically, these plants grow along the foot of the piedmont slopes where the land surface comes within root range of the water table. Greasewood is the most common phreatophyte in the region, and the presence of certain species is generally an indication that the water table is within about 30 feet, or less, of the land surface. The greasewood gives way, basinward, to the more shallow-rooted, salt-tolerant plants, such as rabbitbrush, saltgrass, and various saltbushes which dwindle in density and vigor toward the center of the valley floor until they are unable to grow in the barren, saline ground of the playa.

In other reports of this series an estimate of the discharge of ground water by transpiration has been made by assuming a water-use factor for the phreatophytes and mapping their areas. In the Black Rock Desert, however, the lack of knowledge on depth to water and the inaccessibility of much of the lowland areas made direct estimates of water use by plant types beyond the scope of this study. However, the annual use may be on the same order of magnitude as the evaporation (see below).

In the High Rock Lake drainage, phreatophyte vegetation covers an estimated 4,000 acres along Cottonwood Creek, in Smokey Canyon, and in the immediate vicinity of the lake. The total discharge from these areas by transpiration may be within the range of 500 to 1,000 acre-feet per year. Small clumps and stringers of phreatophytes surrounding the countless springs in the uplands and growing along the many dry stream courses probably account for most of the discharge of ground water from the High Rock Lake drainage. The area of High Rock Lake ranges from nothing to as much as 1,000 acres. Evaporation from the lake surface varies accordingly but probably does not exceed 3,000 acre-feet per year.

Phreatophyte vegetation in the Summit Lake watershed is limited to the immediate vicinity of the upland springs and stream courses. As previously mentioned, recharge to the basin is probably balanced by evaporation from the lake surface and, to a minor extent, underflow through the rock debris which forms the southern drainage divide.

Perennial Yield:

The development and use of the ground-water resources of Nevada is predicated on the State Water Law, which states that the rate of ground-water withdrawal from a basin be limited to the "reasonable lowering of the static water level" (Hutchins, 1955, p. 61). Accordingly, the perennial yield is now the limiting factor in any permanent or long-range development of the ground-water resources of Nevada.

The perennial yield of a ground-water reservoir may be defined as the amount of water that can be pumped, or otherwise diverted from the reservoir, without causing an excessive depletion of the stored water. In other terms, perennial yield is the amount of water that can be salvaged from natural discharge, and is ultimately limited to the amount of recharge to the reservoir.

The estimates of recharge to the individual watersheds in the Black Rock Desert area (table 1) are considered to be a preliminary guide to the reasonable development of the areas. The poor quality of water beneath the playa of Black Rock Desert and the meager data on well yields and quality of water around the margins of the valley preclude an estimate of the yield of this major part of the area. Each subarea that is developed for irrigation adjacent to the playa must be evaluated on the basis of the quality of water, well yields, and suitability of the soils for irrigation. If water levels are drawn down substantially, water of poor quality may in time move laterally into the wells from beneath the playa.

In pumping ground water from storage, as must be done in the early stages of development, periodic samples of water for chemical analysis should be obtained along with measurements of the water level. Ideally, this might include drilling observation wells basinward from the area of development so that any reversal of gradient of the water table could be detected early and pumpage decreased to prevent the intrusion of saline water. Thereafter, pumpage should be limited to the amount of fresh ground water that can be intercepted as it moves basinward from the upland areas of recharge.

The perennial yield of the basins in the Black Rock Desert area can be determined more accurately only after several years of development have been closely observed and much additional data have been collected and evaluated. The pumpage from a basin may exceed the average annual recharge to the extent that some of the applied water returns to the ground-water reservoir. Also, in the early stages of development, some ground water must be removed from storage in order to induce ground-water movement toward the pumping wells. In the final analysis, however, the perennial yield of these basins will be determined largely by the amount of natural discharge that can be salvaged or diverted to beneficial use.

Ground Water in Storage:

Large volumes of water saturate the unconsolidated deposits underlying the floor of the Black Rock Desert. Where these deposits are fine-grained, as beneath the playa, the water is not available to wells, and in general the water is not chemically suitable for most uses. Laterally away from the playa, coarse-grained deposits within the alluvium may yield as much as 20 percent water by volume. This is the water that is generally available to wells and relatively low in mineral content.

The amount of fresh water in stroage in the aquifers of the Black Rock Desert area was not determined in this study. It seems likely, however, that the volume of fresh water available for development in the upper 100 feet of saturated deposits is many times the average annual recharge estimated for each of the subareas listed in table 1.

CHEMICAL QUALITY OF THE GROUND WATER

In addition to sediments carried in suspension by the streams tributary to the Black Rock Desert, large amounts of dissolved minerals were carried basinward in solution, having been leached from the rocks of the surrounding mountains. The dissolved minerals were precipitated when the water evaporated from the lake, and were intermixed with the silt and clay which has been gradually filling the central part of the basin.

Most of the chemical constituents in ground water are acquired by the solution of minerals in the material 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 moves slowly through fine-grained material, and silt and clay usually are susceptible to ion exchange with the percolating water, because of their chemical composition and large surface area. The rapid movement of water through gravel aquifers, on the other hand, coupled with the chemical stability of most pebbles, provides less opportunity for significant changes of water quality within the aquifer.

In general, ground water in the Black Rock Desert is relatively fresh along the margins of the basin, close to the areas of recharge, but becomes saline as it moves through the mineralized deposits toward the center of the basin. Clean sand and gravel aquifers may contain relatively fresh water, even though interbedded with saline clays.

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, which can be measured in general terms by the specific conductance of the water, expressed as micromhos per centimeter at 25°C. Water of low conductivity is generally more suitable for irrigation than water of high conductivity.

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. An SAR in excess of about 10, or less where specific conductance is high, probably will present a sodium hazard in the fine-textured soils of the Black Rock Desert.

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 probably is 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:

Chemical analyses were made of water from 10 wells and 6 springs in the Black Rock Desert. The results of these analyses are listed in table 5. 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). Geochemical interpretation of the analyses is also aided by the diagrams illustrating the general chemical character of the ground water. These are drawn by plotting the concentrations of six key ions, in equivalents per million, and connecting the plotted points (Stiff, 1951).

Both illustrations show a wide range in the quality of the water in the basin. The ground water is characteristically a sodium-bicarbonate type, but water from the flowing wells at the Garrett Ranch (33/25-10b4) contains mainly sodium chloride, as does water from Great Boiling Spring near Gerlach. Several other analyses show mixtures of these two types of water: Coyote Spring (34/25-16d1) about a mile north of the Garrett Ranch;

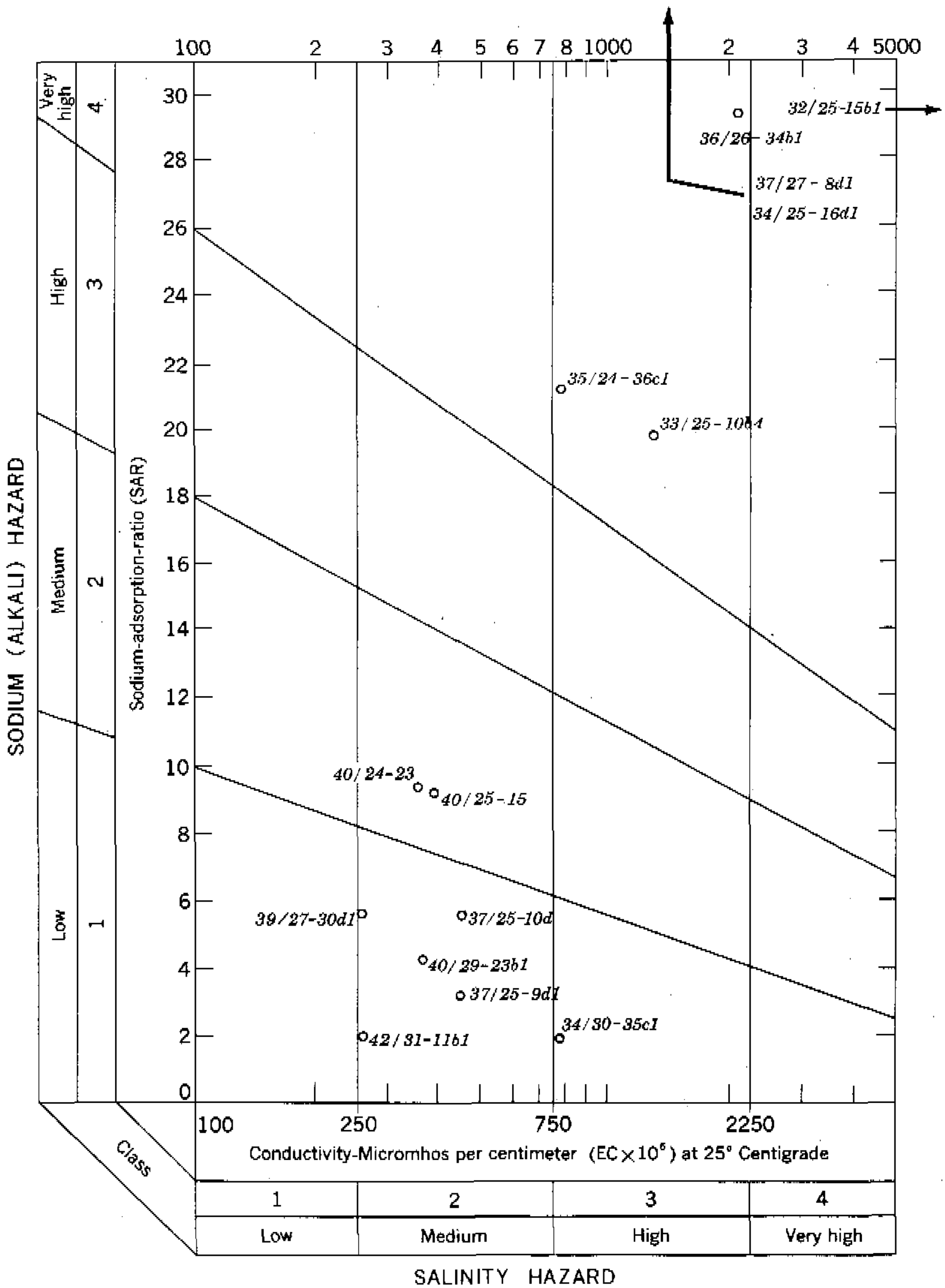


Figure 3.—Classification of irrigation water based on conductivity and sodium-adsorption ratio.

Well 33/23-26d1, at the edge of the playa near the mouth of Bowen Creek; and well 37/27-8d1, at the edge of the valley floor on the east side of the Black Rock Range.

The salinity and alkali hazards of nearly all the water sampled, as shown in table 5, indicate that most of the water is marginal for irrigation, particularly if used with the fine-grained, high-sodium soils which are so prevalent in the Black Rock Desert. Forage-type crops are grown almost exclusively in the region, and these are relatively tolerant to the salinity of the irrigation water. Even so, the quality of the water and its chemical reaction with the crops and soils will continue to be a limiting factor in the development of ground water for irrigation.

Water for Domestic Use:

Much of the water in the Black Rock Desert, although soft, is unsatisfactory for domestic use due to the high dissolved-solids content. The occurrence of fluoride in excess of the 1.5 ppm optimum suggested by the U.S. Public Health Service (1962) is common in the saline water and may be a hazard to health.

Water for Gerlach is piped 10 1/2 and 7 1/2 miles from Garden and Granite Springs, respectively, in the Granite Range northwest of town. Water is imported by rail for domestic use in Sulphur. Most of the ranch headquarters are near the mouths of canyons where streamflow supplies fresh water for domestic use.

CONCLUSIONS

The potential for agricultural development throughout most of the Black Rock Desert is limited by the arid climate, the steepness of the alluvial slopes flanking the mountainsides, and the salinity of the soils and water.

Most of the ground water in storage beneath and near the playa is unsuitable for domestic or irrigation use. The development of a supply of ground water of good quality, therefore, requires that wells be drilled near the lower edge of the alluvial slopes so that fresh ground water may be intercepted before it comes in contact with the mineralized deposits near the playa.

The few areas presently under cultivation, or having a potential for development, are relatively small and are separated from one another by ridges of bedrock or wide expanses of desert. The effect of ground-water development, or overdevelopment, in one area on the ground-water regimen in another area, therefore, would be negligible.

The perennial yield of any of the subareas may be on the order of magnitude shown for recharge in table 1, or may range from 2,000 to 13,000 acre-feet. However, the yield will depend largely on the location of wells and the manner in which they are pumped. On the floor of Black Rock Desert pumping in moderate amounts from several properly spaced wells, rather than from one large-capacity well, may be necessary to intercept the fresh ground water that is moving basinward and to avoid excessive drawdown and the resultant encroachment of saline ground water.

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Table 2.--Records of wells in the Black Rock Desert area, Nevada

Use of water: D, domestic; I, irrigation; S, stock; T, test.
Water level and temperature: M, measured; R, reported.

						Water level			Measuring point			
Well number and location	Owner	Date drilled	Diameter (inches)	Depth (inches)	Depth of main aquifers (feet)	Below measuring point (feet)	M or R	Date	Above land surface (feet)	Description	Use	Remarks
42/30-32d1	--	--	6	--	--	49.36	M	4-14-60	1	Top of casing	S	--
42/30-35a1	Bureau of Land Management	--	6	57	--	57.05	M	9-30-60	1	Top of casing	S	--
41/23- 1d1	Bureau of Land Management	6-55	8	98	--	43	R	6- -55	-	--	S	--
41/28-11a1	Leonard Creek Ranch	--	16	335	97-330	69	R	5- -60	-	--	-	--
41/28-11d1	Leonard Creek Ranch	4-51	16	420	15-38	15	R	4- -51	-	--	I	--
41/28-12c1	Leonard Creek Ranch	--	6	77	52-77	28	R	10-14-57	-	--	-	--
41/28-23c1	Leonard Creek Ranch	10-57	6	53	41-53	11	R	10-17-57	-	--	S	--
41/31- 3b1	--	--	6	--	--	17.66	M	9-30-60	1	Top of casing	S	--
41/31-4b1	Bureau of Land Management	--	6	78	--	20.27	M	10- 8-60	1	Top of casing	S	--
41/31- 5b1	Bureau of Land Management	--	6	78	--	20.3	M	10- 8-60	1	Top of casing	S	Chemical analysis, 55.5°F, M
41/31-28b1	Deer Creek Ranch	--	-	--	--	--	-	--	-	--	D,S	--
40/26-20d1	Bureau of Reclamation	11-56	6	300	190-215	100	R	11-15-56	-	--	-	67°F
40/27- 2c1	Battle Creek Ranch	5-52	8	70	60-70	--	-	--	-	--	D	65°F
40/27-14a1	Battle Creek Ranch	1953	6	62	40-62	--	-	--	-	--	-	--
40/27-23b1	Bureau of Land Management	--	6	--	--	39.97	M	5-12-60	0	Top of casing	S	--
40/31- 5a1	Bill Delong	--	6	--	--	10	R	11- 8-60	-	--	-	--
37/20-13a1	Bureau of Land Management	--	6	107	--	7.5	R	--	-	Top of casing	-	--
37/25- 9d1	Wheeler Ranch	1-51	14	1012	--	57.94	M	4-13-60	0	Hole in pump base	I	--
37/25-10c1	Wheeler Ranch	10-47	8	490	--	4	R	12-11-47	1	Top of casing	-	--
37/25-10d1	--	--	-	--	--	--	-	--	-	--	-	Chemical analysis, 97°F, M
37/25-11b1	Wheeler Ranch	10-47	8	287	--	35+	R	10-26-47	-	--	-	--
37/25-11b2	Wheeler Ranch	2-51	10	303	--	--	-	--	-	--	-	103°F, R
37/25-13c1	Jackson Bros.	1930	4	120	--	--	-	--	-	--	S,T	--
37/25-26a1	Jackson	--	5	--	--	29	M	11- 9-50	-	--	S,I	72°F, M
37/25-26c1	Jackson	--	4	200	--	--	-	--	-	--	I	78°F, M
37/27- 8d1	Bureau of Land Management	--	-	--	--	--	-	--	-	--	S	Chemical analysis, 60.5°F, M
37/30-6b1	Bureau of Land Management	--	-	--	--	--	-	--	-	--	S	--
36/25-16d1	Grover C. Jackson	1946	-	50	--	+6	R	--	-	--	-	62°F, M
36/29- 2c1	--	--	6	--	--	78.54	M	6-15-60	2	Top of casing	S	--
36/29- 3d1	Bureau of Land Management	--	-	--	--	100+	R	--	-	--	S	--
35/24-36c1	Edwin Van Riper	--	6	96	96	--	-	--	-	--	S,I	Chemical analysis, 60°F, M
35/25-33a1	W. W. Irwin	4-48	4	144	--	35	R	4-11-48	-	--	-	60°F, quality objectionable, R
35/30-17a1	Bob Wigle	--	6	--	--	2	M	3-25-63	2	Tie crib	D	50°F, M
34/29-28c1	Ben Constance	--	16	200	--	--	-	--	-	--	D,In	--
34/30-35c1	Maude well	--	3'x6'	35	--	20.85	M	3-25-63	0	Tie crib	D,In	--
33/23-24d1	--	--	4	72	--	1.90	M	6-15-60	0	Top of 2x4 block	S	--
33/23-26d1	Fred Vogel	--	-	--	--	--	R	4- 9-42	-	--	D,S	Chemical analysis
33/25-10a1	Garrett Ranch	--	-	--	--	--	-	--	-	--	S	125°F, M
33/25-10b1	Garrett Ranch	--	6	130	129-130	--	-	--	-	--	I	68°F, M
33/25-10b2	Garrett Ranch	--	2	90	--	--	-	--	-	--	D	108°F, M
33/25-10b3	Garrett Ranch	--	6	90	--	--	-	--	-	--	I	104°F, M
33/25-10b4	Garrett Ranch	1924	6	125	125	--	-	--	-	--	I	Chemical analysis, 92°F, M
33/29- 5d1	Federal Uranium	3-57	10	85	33-38	18	R	3-15-57	-	--	D	--
33/29- 8b1	Federal Uranium	4-57	10	400	153-157	30	R	4-19-57	-	--	D	--
33/29-34b1	Federal Uranium	5-57	6	168	55-60	52	R	5-24-57	-	--	D	--
32/29- 1a1	Placeritas	--	-	60	--	--	-	--	-	--	In	--

Table 3. -- Selected springs in the Black Rock Desert

Use of water: B, bathing; D, domestic; I, irrigation; Ind., industrial; S, stock.

Spring number	Name	Estimated discharge (gpm)	Use	Temperature (°F)	Remarks
40/25-23	Soldier Meadows	-	I, S	-	Chem. Anal., many springs and seeps.
40/28-29	Pinto Mountain	50	S	Boiling	Chem. Anal.
39/27-30dl	Cain	5	S	74	Chem. Anal.
38/25-34	--	100	I, S	-	About 10 separate pools
37/29-27bl	Macfarlanes' bathhouse	5	D, S	170	--
36/26-4bl	Double hot	250	I, S	Boiling	--
36/26-34bl	Black Rock	50	I, S	136	Chem. Anal.
35/24-35dl	Lost	5	S	--	--
35/25-35bl	Sulphur	-	Ind.	-	--
35/30-9dl	Mandalay	-	-	56	Area of shallow water table; seeps
34/25-16dl	Coyote	1	-	60	Spring mound on playa
34/25-31bl	--	35	I	Hot	--
32/23-15bl	Great Boiling	200	B	Boiling	Chem. Anal.

Table 4.--Drillers' logs of wells in the Black Rock Desert area.

	Thickness (feet)	Depth (feet)
41/23-1d1		
Casing perforated 70' to 98'		
Bentonite and gravel	16	16
Sandstone	59	75
Rock, broken; water	23	98
41/28-11a1		
Casing perforated 100' to 330'; 1/2" x 2"		
Soil	5	5
Clay, brown	9	14
Sand and gravel	36	50
Gravel, cemented	45	95
Clay, brown	10	105
Gravel and sand	15	120
Clay, brown	5	125
Gravel and sand	15	140
Gravel and clay	15	155
Sand and gravel	7	162
Cemented	20	182
Gravel and clay mix	19	201
Gravel and sand	43	244
Cemented	16	260
Gravel and clay mix	10	270
Sand and gravel	18	288
Clay	4	292
Sand and gravel	8	300
Gravel and clay mix	16	316
Pinch clay	4	320
Sand and gravel	5	325
Pinch clay	10	335
Sand and gravel	5	340

	Thickness (feet)	Depth (feet)
41/28-11d1		
Casing perforated 106' to 392'; 3/16"		
Topsoil	10	10
Gravel, coarse	28	38
Clay and gravel	54	92
Gravel, loose sand	106	198
Clay and gravel	128	326
Gravel, coarse	66	392
Clay	28	420
Gravel	--	--
41/28-12c1		
Casing perforated 40' to 75'; 3/16" x 6" torch cuts		
Topsoil	7	7
Clay, hardpan	7	14
Clay, gravelly	17	31
Sand, fine; water	7	38
Clay, sandy	14	52
Sand and gravel	25	77
41/28-23c1		
Casing perforated 30' to 50"; 3/16" x 6" torch cuts		
Topsoil, sandy clay	12	12
Clay, sticky bentonite	3	15
Sand, water seep	3	18
Clay, sandy	23	41
Sand and gravel	12	53
40/26-20d1		
Casing perforated 135' to 210'		
Topsoil	3	3
Tuff, bluish	187	190
Volcanic rock, porous	25	215
Volcanic rock, broken soft	85	300

Table 4 (continued)

	Thickness (feet)	Depth (feet)
40/27-2cl		
Casing perforated 30' to 70'; 1/4" x 3"		
Gravel	48	48
Clay	10	58
Sand and gravel	12	70
40/27-14al		
Hardpan	10	10
Clay	30	40
Sand, gravel; water	22	62
37/25-9dl		
Sand, top soil	3	3
Gravel	4	7
Sand	11	18
Clay, red; gravel	12	30
Clay, red; sand	8	38
Clay, brown; gravel	18	56
Clay, brown; sand	6	62
Clay, yellow; gravel	6	68
Gravel, sand, and water	8	76
Clay, red; gravel	26	102
Clay, red; sand	6	108
Clay, red; gravel	26	134
Gravel, sand, water	2	136
Clay, brown; gravel	20	156
Clay, gray	6	162
Clay, red; gravel	28	190
Clay, gray	6	196
Clay, red; gravel	45	241
Clay, gray	11	252
Clay, red; gravel	25	277
Clay, brownish white, sandy	15	292
Clay, red, sandy	41	333
Clay, brown; sand	9	342
Clay, white; gravel and sand	15	357
Clay, white; sand	53	410
37/25-9dl (continued)		
Clay, gray; sand	13	423
Clay, red; rock	2	425
Clay, gray; sand	17	442
Clay, redish white; rock	4	446
Clay, gray; sand	21	457
Clay, white, sugary	2	469
Sand, gray; clay	36	505
Sand, brown, coarse; clay	8	513
Clay, white; sand	9	522
Clay, white	24	546
Clay, blue	6"	546'6"
Clay, white; sand	5'6"	552
Rock, white	3	555
Clay, white	6	561
Clay, white; sand	8	569
Clay, gray, hard	9	578
Sand, white; rock	7	585
Clay, white, hard	12	597
Clay, gray	11	608
Clay, gray; sand	22	630
Clay, white	22	652
Clay, gray	5	657
Rock, red	7	664
Clay, gray	8	672
Clay, white	36	708
Clay, gray	27	735
Clay, gray, hard	17	752
Clay, white	11	763
Rock, pink	13	776
Clay, brown, hard	25	801
Clay, white	7	808
Clay, brown	9	817
Clay, gray	8	825
Clay, brown	7	832
Clay, gray	6	838
Clay, brown	8	846
Clay, blue	6	852
Clay, blue	1	853
Clay, brown	8	861
Clay, gray	11	872
Clay, brown	7	879

Table 4 (continued)

	Thickness (feet)	Depth (feet)
37/25-9dl (continued)		
Clay, white	8	887
Clay, brown	10	897
Clay, gray	10	907
Clay, blue	6	913
Sand, brown	5	918
Rock, black	56	974
Rock, whitish gray	38	1012
37/25-10dl		
Gravel, sandy	10	10
Clay, yellow; sand	10	20
Clay, black; water strata	10	30
Sand, black; yellow clay; small gravel	10	40
Clay, yellow; sand and small gravel	10	50
Clay, yellow; fine sand	10	60
Clay, yellow, soft	10	70
Clay, yellow, soft; sand and small gravel	10	80
Clay, rusty, soft	10	90
"Small stratas of clay", pea-sized gravel	20	110
Gravel, course; sand; water strata	5	115
Gravel stratas; soft brown to yellow clay; water	7	122
"Small stratas of yellow, pink, light green clays"	11	133
"Small clay stratas, water gravel stratas 2' thick"	7	140
Gravel stratas, cemented very hard	5	145
Gravel and soft stratas of pink clay, small	5	150
Clay, pink; gravel	10	160
Clay, pink; gravel	8	168
Clay, pink	2	170
Clay; pink; gravel	10	180
Clay, white; "artesian hot water indications"	26	206
"Small stratas, pink, green and white clays"	4	210
Clay, pink	3	213
Clay, pink; gravel	17	230
Clay, pink; sand and gravel	16	246
Clays, pink and dark green, hard	2	248
Gravel, cemented, very hard white quartz	24	272
Gravel, very hard white quartz mixed	8	280
Gravel, very hard white quartz mixed	15	295
Clay, brown and pink	5	300
"White hot water clays"	20	320

(continued)

Table 4 (continued)

	Thickness (feet)	Depth (feet)
37/25-10d1 (continued)		
"2" to 3" stratas of rust brown and gray clays, with quartz"	10	330
Clays, white gray; white quartz sands; water strata; sand	10	340
Clays, rusty brown; white quartz; loss of mud; water strata	60	400
Sands, brown, cemented, hard	10	410
Clay, white and gray; loss of mud; water strata	20	430
Quartz, white, cemented; or solid strata	10	440
"Alternate white and brown clay stratas, small ones"	10	450
Clay, brown; quartz sands; water strata	10	460
Clay, brown; quartz sands; water strata	30	490
37/25-11b1		
Silt, black; yellow clay	20	20
Hardpan and yellow clay	20	40
"soft whitish hot water clay"	33	73
Gravel, small; sand and clay	4	77
Clay, brown and yellow, hard	5	82
Gravel, coarse	4	86
Clay, blue, hard	4	90
Clay, blue, soft	5	95
Clay, blue, soft gummy	9	104
Clay, blue; 1/2" gravel	4	108
Clay, blue; heavy large gravel	2	110
Clays, sandy cream and blue; large gravel	10	120
Gravel and blue clay	40	160
Clay, blue	5	165
Clay, blue; gravel	2	167
Clay, blue	2	169
Clay, white to yellow; gravel, "hot water clay deposits"	21	190
Sand and gravel, no clay	8	198
Clay, blue	2	200
Clay, blue; fine sand	20	220
"Small stratas of white and green clays"	8	228
Clay, yellowish white; "hot water deposits"	22	250
Limestone, white, hard; "hot water lime"	3	253
Clay, white; quartz, some red gravel	12	265
"Terrific loss of drilling mud, level dropped 20', well began flowing before rods could be pulled. Flowing 212 gpm. Static head is in excess of 35', small volume. It is hard to determine exactly where the flows are originating.	2	267

Table 4. (continued)

	Thickness (feet)	Depth (feet)
37/29-11b2		
Mud, black	16	16
Clay, gray, sandy; some water	18	34
Clay, white	18	52
Clay, blue	2	54
Sand, black; water	4	58
Clay, white	19	77
Sand, brown; water	4	81
Clay, blue	8	89
Sand, brown; water	7	96
Clay, brown	8	104
Sand, brown	9	113
Clay, brown	8	121
Clay, blue	35	156
Sand, brown	2	158
Clay, yellow	4	162
Clay, blue	12	174
Sand, brown	6	180
Clay, white; sand	3	183
35/25-33a1		
Casing perforated 134' to 144' 1/4" x 6"		
"Fine granite sands"	20	20
Sand, coarse, and clay	5	25
Gravel and clay, cemented	5	30
Gravel and hard pink clay	64	94
Clay, pink, soft	6	100
Clay, sand, and fine gravel	10	110
Clay, pink, medium soft	10	120
"Small hard and soft strata alternate"	14	134
Gravel, small loss of mud	1	135
Clay, pink, hard	1	136
Gravel, medium loss, small amount of water	4	140
Clay, sand, hardpan	4	144
33/29-5d1		
Top soil	15	15
Clay, yellow	18	33
Gravel; water	5	38
Clay, blue	14	52
Shale, brown	11	63
Gravel; water	3	66
Shale, brown	11	77
Clay, gray	8	85
33/29-8b1		
Casing perforated 30' to 164' 1/4" x 3"		
Top soil	15	15
Clay, yellow	18	33
Gravel; water	5	38
Clay, blue	14	52
Shale, brown	11	63
Gravel	3	66
Shale, brown	11	77
Shale, blue; gravel	20	97
Clay, gray, sandy	56	153
Gravel, quartz	4	157
Clay, brown, sandy	6	163
Clay, gray, sandy	25	188
Clay, brown	4	192
Clay, dark brown	18	210
Clay, light brown	32	242
Hardpan and shale	20	262
Clay, light gray	13	275
Clay, brown	53	328
Clay, gray	48	376
Clay, brown	14	390
Clay, gray	10	400

Table 4 (continued)

	Thickness (feet)	Depth (feet)
33/29-34b1		
Casing perforated 50' to 108' 1/8" x 3"		
Clay, sandy	7	7
Gravel and clay	8	15
Gravel, large; clay	40	55
Sandstone, soft	5	60
Clay, sandy	7	67
Gravel, cemented	63	130
Gravel, cemented; boulders	34	164
Rock, gray, solid	4	168

Table 5.--Chemical analyses, in parts per million, of ground water in the Black Rock Desert Area

(Analyses by U.S. Geological Survey)

Well or spring	Date of collection	Temperature °F	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 $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Calcium magnesium	Specific conductance (Micromhos at 25°C)	Dissolved solids residue at 180°C	Sodium-adsorption-ration (SAR)	Residual sodium carbonate (RSC) in equivalents per million	pH	Remarks
42/31-11b1	10- 8-60	75	65	18	2.4	34	4.8	0	104	25	15	0.6	0.8	0.11	0	54	259	244	2.0	0.63	7.7	- -
40/24-23	5- 6-61	-	65	2.4	1.5	76	0	0	96	39	21	12	.5	.82	0	12	357	272	9.5	1.32	7.6	Soldier Meadows warm Springs
40/27-23b1	5- 3-61	60	79	11	2.4	63	11	0	151	21	28	.4	.8	.17	0	37	376	290	4.2	1.63	7.8	- -
40/28-29	?	212	-	-	-	-	-	0	420	126	159	-	-	-	-	-	-	1043	-	-	-	Pinto Mtn. Hot Spring
39/17-30d1	5- 6-61	74	34	6.4	.2	55	.6	0	120	15	11	.3	.3	.32	0	17	264	186	5.8	1.75	8.2	Cain Spring
37/25-9d1?	6-14-61	-	84	18	6.9	66	5.4	-	148	32	42	1.2	0	-	0	74	451	-	3.3	.55	7.3	- -
37/25-10d1	6-14-61	97	79	9.6	2.8	78	11	-	165	38	28	1.8	0	-	0	35	446	-	5.8	1.29	7.8	- -
37/27-8d1	5- 3-61	60	70	11	5.6	786	15	0	1150	95	500	3.9	1.1	7.9	0	50	3280	2070	48.3	17.84	8.2	- -
36/26-34b1	5- 3-61	136	62	18	1.9	486	13	0	902	130	155	8.9	.2	2.8	0	52	2050	1330	29.3	13.84	7.9	Black Rock Hot Spring
35/24-36c1	1-13-62	60	64	3.2	1.2	168	10	19	257	47	58	1.4	.1	.5	0	13	766	499	21.0	3.95	8.7	- -
34/25-16d1	5- 3-61	-	58	12	19	1160	15	0	1210	5.8	1170	1.5	1.1	4.5	0	109	5150	3060	49.3	17.74	7.8	Coyote Spring
34/30-35c1	6-11-61	60	26	62	14	72	.8	-	165	66	111	.3	.2	-	78	214	767	-	2.0	0	7.3	- -
33/23-26d1	4- 9-45	-	44	-	-	305	-	48	361	79	160	-	-	-	-	-	-	795	-	-	-	- -
33/25-10b1	9- 2-47	68	101	15	4	272	-	14	88	163	272	-	-	-	-	58	-	880	15.6	.30	-	- -
33/25-10b4	6-12-61	92	94	13	.6	272	8.4	-	93	156	278	2.9	.2	-	0	35	1410	-	19.9	.86	7.4	- -
32/25-15b1	5- 7-40	-	135	102	26	1476	-	0	227	353	2016	-	-	-	-	362	-	4135	29.6	0	-	Great Boiling Spring

PREVIOUSLY PUBLISHED REPORTS OF THE GROUND-WATER RESOURCES - RECONNAISSANCE SERIES

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Report No.	
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Report No.

14. Ground-Water Resources of Amargosa Desert, Nevada-California. March 1963, by George E. Walker and Thomas E. Eakin.

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16. Ground-Water Appraisal of Dry Lake and Delamar Valleys, Lincoln County, Nevada. May 1963, by Thomas E. Eakin.

17. Ground-Water Appraisal of Duck Lake Valley, Washoe County, Nevada. June 1963, by William C. Sinclair.

18. Ground-Water Appraisal of Garden and Coal Valleys, Lincoln and Nye Counties, Nevada. July 1963, by Thomas E. Eakin.

19. Ground-Water Appraisal of Antelope and Middle Reese River Valleys, Lander County, Nevada. September 1963 by E. G. Crosthwaite.

United States Department of Interior
Geological Survey

Department of Conservation and Natural Resources
State of Nevada

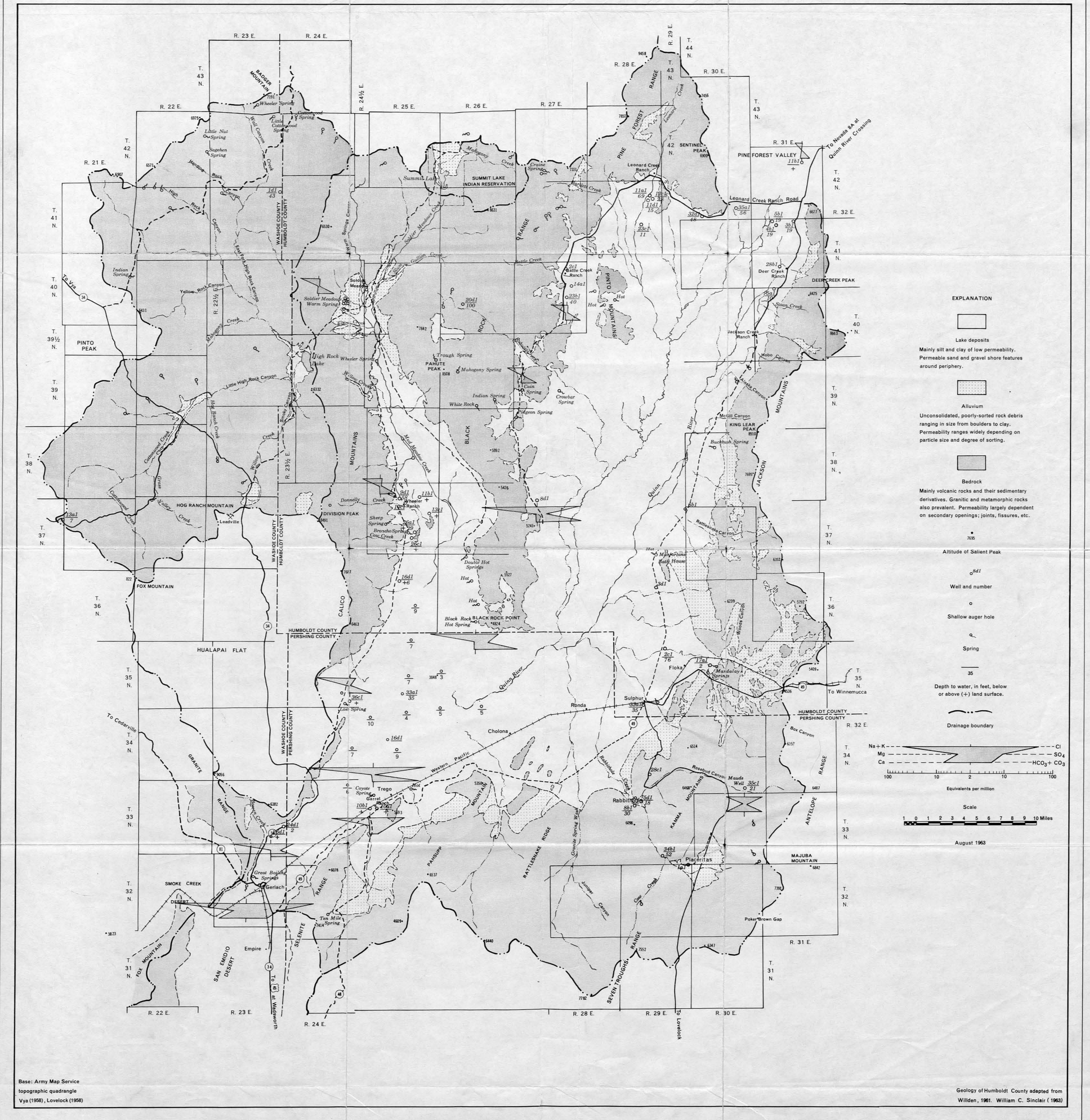
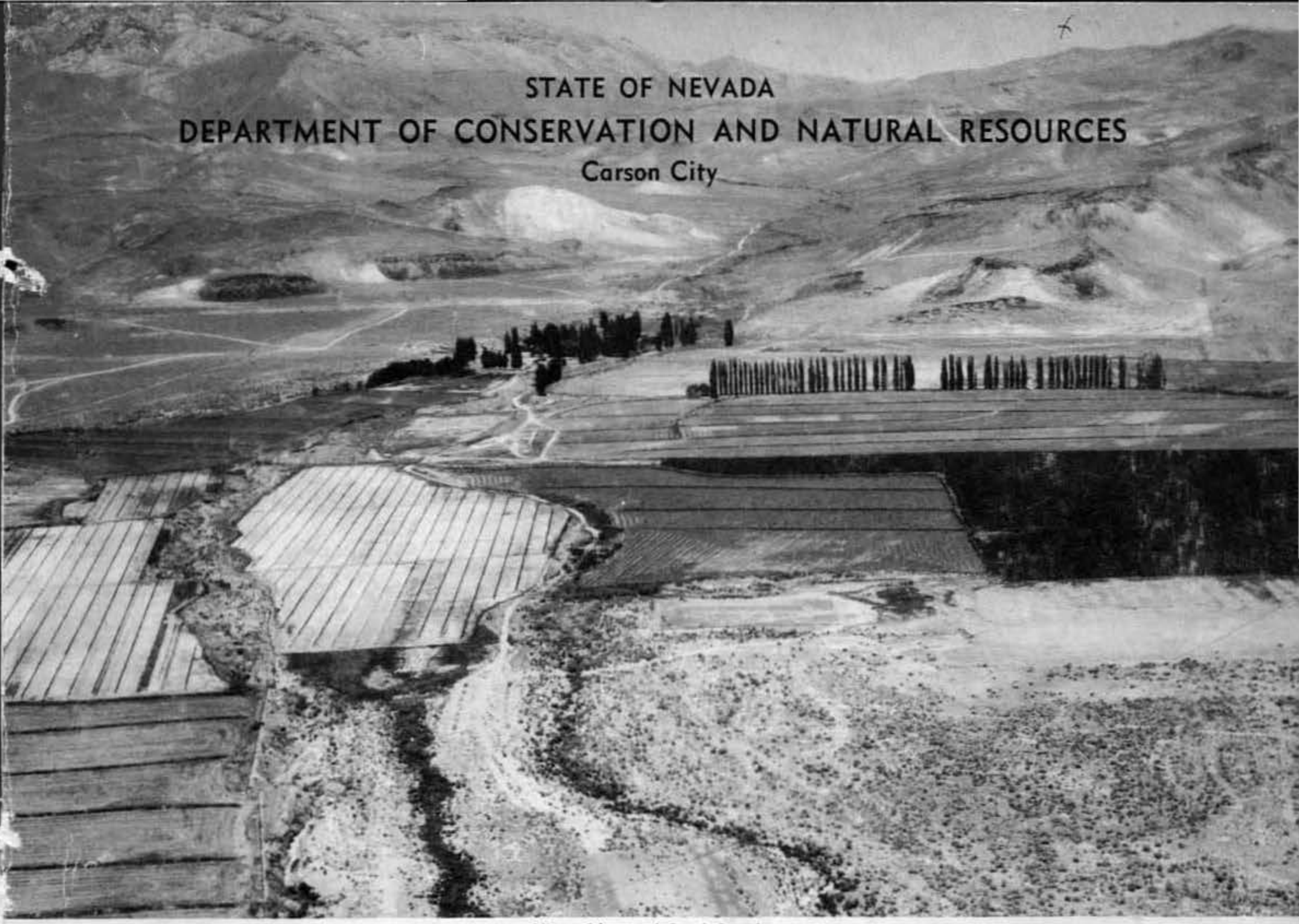


Plate 1.—Generalized Geologic and Hydrologic Map of the Black Rock Desert area, Northwestern Nevada

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Carson City



View of Leonard Creek Ranch

GROUND-WATER RESOURCES–RECONNAISSANCE SERIES
REPORT 20

GROUND–WATER APPRAISAL OF THE BLACK ROCK DESERT AREA NORTHWESTERN NEVADA

By
WILLIAM C. SINCLAIR
Geologist

Price $1.00

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

OCTOBER 1963

GROUND-WATER RESOURCES--RECONNAISSANCE SERIES

Report 20

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October, 1963

FOREWORD

This reconnaissance appraisal of the ground-water resources of the Black Rock Desert area in northwestern Nevada is the 20th in this series of reports. Under this program, which was initiated following legislative action in 1960, reports on the ground-water resources of some 23 Nevada valleys have been made.

The present report, entitled, "Ground-Water Appraisal of the Black Rock Desert Area, Northwestern Nevada", was prepared by William C. Sinclair, Geologist, U. S. Geological Survey.

The Black Rock Desert area, as defined in this report, differs somewhat from the valleys discussed in previous reports. The area is very large with some 9 tributary basins adjoining the extensive playa of Black Rock Desert. The estimated combined annual recharge of all the tributary basins amounts to nearly 44,000 acre-feet, but recovery of much of this total may be difficult. Water which enters into the ground water under the central playa probably will be of poor quality for irrigation. The development of good producing wells in the old lake sediments underlying the central playa appears doubtful. Also, the soils on the playa are unsuitable for crop production.

The report points out that the best opportunities for the development of good yielding wells in areas where good soils are situated lies along the toes of the alluvial slopes, where the main streams debouch from the mountains. These areas are dispersed around Black Rock Desert and separated by wide areas of mountains and desert. Transportation of materials and farm products, both to and from the farms, will be a major problem in the development of these areas.

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

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

October 1963

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ILLUSTRATIONS

GROUND-WATER APPRAISAL OF THE BLACK ROCK DESERT AREA

NORTHWESTERN NEVADA

by

William C. Sinclair

*****

SUMMARY

The Black Rock Desert is one of the major structural basins in Nevada. The valley floor is the sink, or discharge area, for runoff and ground-water underflow from the surrounding watershed, which covers about 2,600 square miles in Humboldt, Pershing, and Washoe Counties, and for the Quinn River which rises in Oregon, about 150 river miles northeast of the sink.

Mining and the manufacture of gypsum products are the principal industries in the area along with sheep and cattle ranching. The cultivation of forage-type crops in conjunction with the ranching operations is also becoming a significant part of the local economy. In this, ground water is being used increasingly to supplement irrigation by streamflow.

The Black Rock Desert has a wide, extremely flat valley floor grading from a large playa, into relatively steep alluvial slopes which flank the surrounding mountainsides. The valley floor is underlain by silt and clay to an unknown depth. Near the edges of the basin, thin layers of sand and gravel are interfingered with the less permeable silt and clay. The sand and gravel layers together with the alluvium flanking the mountainsides constitute the principal ground-water aquifers in the area.

The lake deposits which underlie the valley floor and playa contain an abundance of evaporite minerals which are easily taken into solution by the ground water as it moves from the surrounding upland areas of recharge toward the central part of the basin. The development of ground-water supplies of chemical quality suitable for irrigation or domestic use, therefore, requires that wells be drilled along the perimeter of the basin to intercept the relatively fresh ground water. Even so, encroachment of the saline water beneath the playa may limit the draft from the freshwater aquifers.

Estimates of average annual recharge to the ground-water reservoirs of eight sub-watersheds in the Black Rock Desert area range from 2,000 to 13,000 acre-feet. These estimates suggest an order of magnitude for the perennial yield of the sub-watersheds and constitute a more reasonable

management tool than an estimate of the total perennial yield for the entire Black Rock Desert.

Although no direct estimates were made of evaporation and transpiration losses from areas of shallow ground water on the floor of Black Rock Desert, the size of the areas involved suggest that the total may be in the range of 10,000 to 30,000 acre-feet per year.

INTRODUCTION

Location and Extent of the Area:

The Black Rock Desert covers an area of about 2,600 square miles in parts of Humboldt, Pershing, and Washoe Counties, Nevada (fig. 1). The area described in this report also includes the High Rock Lake and Summit Lake drainage basins; an additional 800 and 50 square miles, respectively. These two watersheds, formerly tributary to the Black Rock Desert, were closed by landslides which impounded the drainage to form the two lakes.

In addition to the natural watershed boundaries (pl. 1), the area covered in this report does not extend beyond the vicinity of Gerlach, at the southwest corner of the area, where the Black Rock, San Emidio, and Smoke Creek Deserts come together; it is limited on the northeast by the Leonard Creek Ranch Road. Pine Forest Valley, a northward extension and tributary of the Black Rock Desert, lies north of the road and was described in report 4 of this series.

The Black Rock basin is a structural depression, bounded on the east and west, and bisected in part, by north-trending fault-block mountains. The valley floor therefore, is somewhat U-shaped and is noted for its large area, about 700 square miles, of extremely low local relief, generally less than 10 feet. The Black Rock Desert is the sink, or discharge area, for the waters of the Quinn River, which rises in Oregon about 150 river miles northeast of the sink, and of other smaller streams tributary to the basin. The Quinn River enters the area from the northeast, Mud Meadow Creek from the northwest. When the streamflow is sufficient to reach the valley floor, a lake is formed on the playa in the area southwest of Black Rock Point.

The shipment of gypsum products from a quarry and mill near Empire, about 8 miles south of Gerlach, makes the town of Gerlach an important stop on the Western Pacific Railroad, which crosses the southern edge of the Black Rock Desert. The gypsum plant is the largest economic development in the area. Aside from placer gold operations at Mandalay Springs, Rabbithole, and Placeritas, and the sulfur mine at Sulphur, all of which are conducted on a very small scale, the rest of the area is devoted to the raising of sheep, cattle, and feed crops.

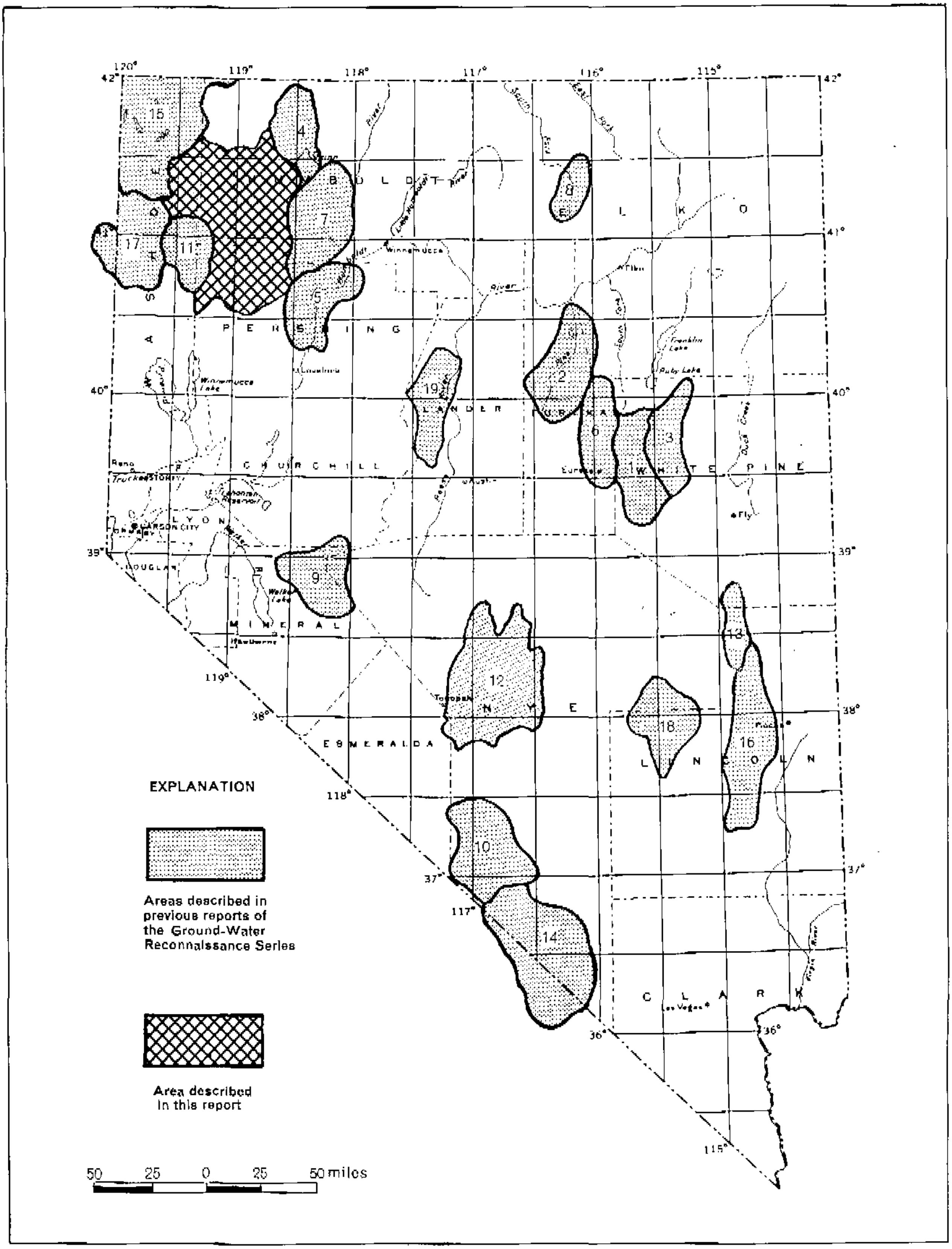


Figure 1. Map of Nevada showing areas described in previous reports of the ground-water reconnaissance series and the area described in this report

The population of the Gerlach-Empire metropolitan area is approximately 1,000. The population of the remainder of the region may total 200, although the influx of seasonal ranch help and Indian families to the Summit Lake Indian Reservation may increase this figure during the summer.

Although both Gerlach and Empire have a general store, the main trading center for the region is Reno, about 110 miles south of Gerlach. State Route 34 is paved from Gerlach south to U. S. 40. North of Gerlach it is gravel, usually well maintained, and trends northward about 84 miles to Vya and a junction with secondary roads to Oregon and California. State Route 81 is also paved through part of the 55 miles from Gerlach to the California state line, and to Cedarville, 25 miles beyond.

Graded gravel roads connect Sulphur with Winnemucca, 56 miles east, and Lovelock, 64 miles south. A graded road enters the region from highway 8A at Quinn River crossing and connects Leonard Creek, Battle Creek, and Pahute Meadows ranches with nearby towns. The gravel roads mentioned above are usually passable with a relative degree of comfort and confidence by passenger car. Other roads and trails in the area, some of which are shown on Plate 1, are best attempted by pickup truck, and in many cases, only with four-wheel drive vehicles.

Purpose and Scope of the Investigation:

This report is the 20th in a series of reconnaissance studies of the valleys of 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 purpose of this study is: (1) to determine the nature and extent of the aquifers; (2) to determine the occurrence and movement of ground water, including the areas of recharge and areas of discharge; (3) to determine the sources of recharge and 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 its chemical quality and suitability for irrigation and domestic use.

The field work for this report was done at intervals during the period January 1960 to May 1963, and represents a total of about 30 days. It consisted of a brief 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 collection of samples of water for chemical analysis.

The assistance provided by residents of the areas in supplying information about wells and springs is gratefully acknowledged. Information from the files of the Winnemucca Grazing District Office of the U. S. Bureau of Land Management and data collected by the General Hydrology Branch of the U. S. Geological Survey as part of a stock-well site study were also of value in this study.

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 section number 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 33/23-24d1 designates the first well recorded in the SE 1/4 sec. 24, T. 33 N., R. 23 E., Mount Diablo base and meridian. In unsurveyed areas the land grid has been arbitrarily extended from the nearest reference corner, and well location numbers assigned accordingly.

Plate 1 shows the locations of many of the wells and springs in the area included in this report. The available data for the wells are listed in tables 2 and 4, and for selected springs in table 3. The chemical analyses of water from selected springs and wells are shown in table 5.

PREVIOUS INVESTIGATIONS

A preliminary geologic map of Humboldt County by Ronald Willden was published in 1961. The geologic units shown in plate 1 are based largely on that map. The geology of the Jackson Mountains was studied in some detail by Willden (1962).

The late Pleistocene history of the Black Rock Desert is, to a great extent, the history of Lake Lahontan, which was studied in detail by Russell (1885) and, more recently, by Morrison (1961).

GEOGRAPHIC FEATURES

Northwestern Nevada is typically a sagebrush desert. North-trending mountain ranges separate desert basins which characteristically have no drainage outlet under the present semiarid climate. The relief of the area is the result of vertical displacement of large mountain blocks by faulting, and to their subsequent sculpture by erosion. The valleys generally are underlain by the downfaulted blocks. They are the catchment areas for the streamflow from the surrounding mountains and have been filled, commonly to great thicknesses, with rock debris eroded from the mountains.

Mountains:

The Black Rock Range stands at an altitude of 8,631 feet, about 4,700 feet above the desert floor, near the northern border of the watershed. It tapers southward to a narrow ridge extending into the center of the basin and to within about 10 miles of the south edge of the desert floor. Along the northern border of the drainage basin the Black Rock Range coalesces with the High Rock Lake area on the west and the Pine Forest Range on the east.

Although the major stream courses in the High Rock Lake drainage are deeply entrenched, the upland topography is relatively subdued, rising to occasional peaks at altitudes of about 7,000 feet.

From High Rock Lake southward, the Calico Mountains border the western edge of the desert, rising to an altitude of 8,491 feet at Division Peak, then decreasing in altitude southward, and finally dipping beneath the alluvium of the valley fill. A low ridge of metamorphic rocks trends northeast from the Granite Range to within about a mile of the southern terminus of the Calico Mountains. Between the two a low alluvial divide, covered with hummocks of wind-blown silt, separates the Black Rock Desert from Hualapai Flat, a small valley which was described in report 11 of this series (Sinclair, 1962b).

The Granite Range rises abruptly from the desert floor north of Gerlach and trends northwestward for about 15 miles, attaining an altitude of 9,056 feet at Granite Peak. Granite Basin, a small valley on the south end of the Granite Range, drains to the Black Rock Desert through Bowen Creek.

South of the Granite Range the Black Rock Desert merges with the San Emidio Desert, then, through a narrow gap north of the Fox Mountains, with the Smoke Creek Desert (pl. 1).

The Selenite Range trends northward along the east side of the San Emidio Desert then curves northeastward to form a part of the south edge of the Black Rock Desert. This and several other northeast-trending ridges form the southern boundary of the Black Rock drainage. The topography in the southern watershed is relatively subdued. Although the Seven Troughs Range rises to peaks of 7,782 and 7,552 feet, the altitudes of most of the other ridges in this area are about 6,500 feet or less.

The eastern edge of the desert is bordered by the Jackson Mountains whose ragged crest is generally above 7,000 feet in altitude. King Lear Peak, the highest point in the range, rises to an altitude of 8,910 feet, roughly 5,000 feet above the desert floor.

The northern end of the Jackson Mountains lies about 5 miles east of the south end of the Pine Forest Range. The Black Rock Desert is open to the north here, receiving occasional runoff via the Quinn River as well as ground-water underflow from Pine Forest Valley.

Piedmont Slopes and Desert Floor:

Rock debris eroded from the mountains, carried downslope by gravity, streamflow, and storm runoff and deposited in the valley, is generally termed alluvium. Alluvium begins to collect, generally in cone or fan-shaped deposits, at the mouths of canyons or other places where the stream gradient and sediment-carrying capacity is sharply reduced. In time, these fans extend well out into the valley and along the flanks of the mountains until they coalesce and form a continuous slope of alluvium, considerably less steep than the mountain fronts and decreasing in slope until they merge, imperceptibly, with the level desert floor.

The alluvial slopes flanking the mountains around Black Rock Desert are relatively narrow and steep. The stoping action of waves and currents in the lakes, which have occupied the basin in times past, has nibbled back the lower slope of the alluvial apron, steepening the upper slope and removing the fine particles for redeposition in the relatively still, deep waters toward the center of the basin. Most of the desert floor is underlain by dense saline clay, deposited in the many lakes which have occupied the basin intermittently since it first began to form.

A well drilled to a depth of 1,500 feet, 4 1/2 miles north of Trego on the desert floor, penetrated clay throughout the entire depth. Occasionally the clay was reported as "sandy", "fossiliferous", or "marly". No identification of the fossils was made in the log of this well, which is on file at the office of the State Engineer (log No. 3929, Pershing County); it is not known how much of the geologic time scale is represented in this 1,500-foot section. It seems probable, however, that the downthrown fault blocks underlying the Black Rock Desert have been subsiding, relative to the surrounding mountains, at least since mid-Tertiary time; an interval of about 25 million years.

The most remarkable feature of the Black Rock Desert is the desert floor itself. A playa, utterly flat and devoid of any vegetation, occupies about 150 square miles. During the winter months and for a few days following infrequent summer storms, the playa becomes a sea of mud. The standing water is generally only a few inches deep but may extend over many square miles. As winter advances into spring, the water evaporates and the mud dries to a hard clay surface crazed with polygonal desiccation fissures and white with the efflorescence of minerals precipitated from the saline water. The salts are soon dissipated, along with loose clay particles, by the winds which constantly sweep, unhendered, across the level expanse of desert floor.

The wind, in fact, is the most important erosional force presently at work in the Black Rock Desert. The flatness of the desert floor is due largely to the planning action of the playa lakes as they are swept about by the wind. The presence of the water table just beneath the desert floor is another controlling factor, providing a base level which limits the effect of wind action as an erosional agent.

An additional 550 square miles of valley floor surrounds the playa and extends eastward to Sulphur and northward to Soldier Meadows along the west side of the Black Rock Range and to Pine Forest Valley along the east side. The land rises gradually northward at a rate of about 7 feet per mile, west of the Black Rock Range and about 2 feet per mile in the eastern arm, toward Pine Forest Valley.

This area is covered with a sparse growth of salt-tolerant bush. A dense pattern of incipient drainage lines has become incised a few inches or feet into the desert floor, channelling the meager runoff toward the main course of the Quinn River or to one of the many small playas, impounded by minor surface irregularities in the valley floor. The local relief is rarely more than a few feet. The drainage channels are sharply, though not deeply, incised in the areas underlain by silt and clay. Elsewhere the surface is irregular and usually soft, being composed of ridges and hummocks of wind-flown silt, so that travel, by any method, is generally difficult.

Sand is notably lacking in the Black Rock Desert, although a few dunes, stabilized by vegetation, occur along the west flank of the Black Rock Range north of Double Hot Spring and to a lesser extent in an area north of Sulphur. Most of the material composing the valley floor is silt or clay.

Drainage:

Most of the streams draining the mountains surrounding the Black Rock Desert are relatively short, their profiles are irregular, and their canyons generally narrow and steep sided. The streams are fed principally by snowmelt and storm runoff. Their flow, therefore, is ephemeral, occurring during the spring and early summer. As summer progresses, the snow-pack in the mountains is depleted, the headwaters of the streams decrease or go dry, and the decreased flow is insufficient to reach the valley floor, owing to seepage into the alluvium flanking the mountains and losses of water to the vegetation growing along the stream channels. Flow in the perennial streams, then, is limited to the middle reaches which are sustained by the discharge of ground water from bedrock and alluvium farther upstream.

Some of the streams carry sufficient flow during flood periods for their channels to have become incised in the valley floor. The most notable of these are the channels of the Quinn River. The gradient of the Quinn River in the Black Rock Desert is somewhat less than 2 feet per mile. As a result of the extremely low gradient the Quinn River has developed several meandering, braided channels.

Throughout most of the year these channels are dry, and occasional pools of standing water are formed where the channel bottom lies below the water table. In the winter, however, when precipitation is somewhat greater and losses to evapotranspiration are less, the water table rises until it intersects the channels of the Quinn River, which then becomes a drain carrying the effluent ground water toward the playa in the southwest quadrant of the valley floor.

The drainage which presently terminates in High Rock Lake was formerly tributary to the Black Rock Desert through Willow Creek. A landslide, at what is now the head of Willow Creek Canyon, blocked this drainage, impounding the waters of High Rock Lake. In pluvial times the lake rose until it spilled into Fly Creek, a few miles north of the former outlet. Under the present climatic conditions the lake is generally several feet below the col at the head of Fly Creek, and sometimes dries up completely in late summer or early fall.

A debris slide forms the present drainage divide between Summit Lake and Soldier Meadows Creek. Slight fluctuations in lake level are indicated by the faint shorelines which border the lake just a few feet above its present level, but there is no evidence that Summit Lake overflowed during late pluvial times. The fact that no evidence of significantly higher lake stages was noted in the Summit Lake Basin suggests that the debris slide is relatively recent, and probably occurred after the pluvial period had ended. Evaporation from the lake's surface, and perhaps some seepage through the debris and buried stream gravels into the head of Soldier Meadows Creek, is sufficient discharge to balance the inflow to the lake under the present climatic conditions.

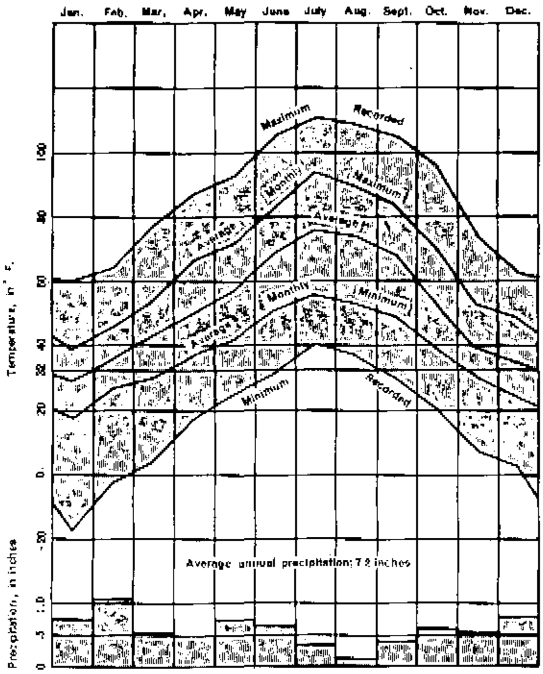
Climate:

The rainfall of northwestern Nevada is governed largely by the seasonal migration of storm centers which move inland from the Pacific Coast in the winter. During the summer months of July, August, and September, less than one tenth of the total annual precipitation occurs, as illustrated by the graphs in figure 2. Topography exerts considerable control on precipitation, and the high mountains of California intercept much of the moist Pacific air that moves inland from the storm centers. The Black Rock Desert lies to leeward of these mountains along the major storm tracks and therefore has a relatively arid climate.

As the eastward moving air masses are forced upward by a mountain range, the decrease in pressure and temperature causes precipitation. Most of this precipitation occurs on the western flank of the range. As the air mass moves down the eastern flank it is warming and dry. This is well illustrated by the Granite Range whose highest peaks seem to rake moisture from clouds which ordinarily drift on across the Black Rock Desert usually without further precipitation.

Although the annual precipitation may be as much as 15 to 20 inches along the crests of some of the higher ranges surrounding the Black Rock Desert, the valley floor itself probably receives somewhat less than 6 inches per year, as indicated in the graphs compiled from U. S. Weather Bureau data for stations at Gerlach, Sulphur, Quinn River Crossing Ranch and Leonard Creek Ranch (fig. 2). These graphs also give an indication of the range of temperature and length of the average growing season.

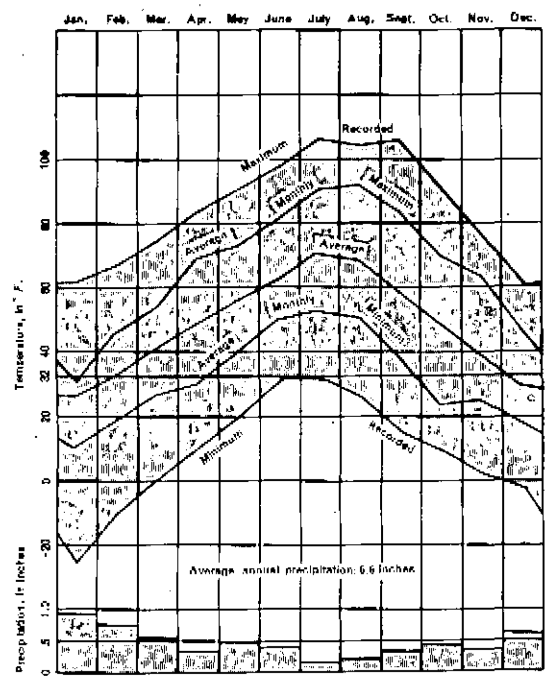
The rate of evaporation from a free water surface in the area is about 50 inches a year, according to Kohler, Nordenson, and Baker (1959, pl. 2). This rate of evaporation is roughly 8 times the annual precipitation on the valley floor.



LEONARD CREEK RANCH

Altitude 4,225

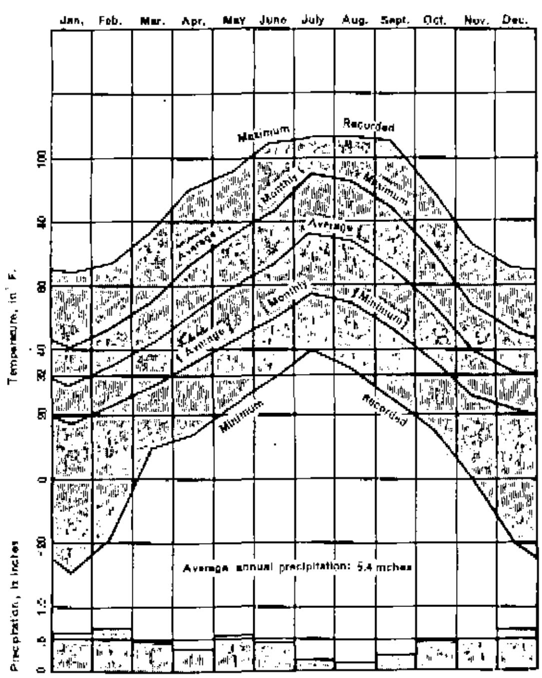
Average monthly precipitation and temperature data for the period 1955-1962.



QUINN RIVER CROSSING RANCH

Altitude 4,087

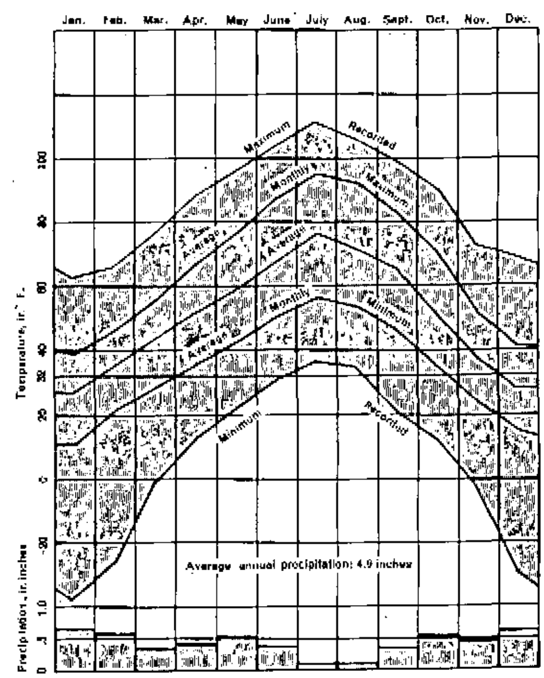
Average monthly precipitation and temperature for a 26-year period ending 1950, and average monthly temperature data for a 2-year period ending 1950.



GERLACH

Altitude 3,950

Average monthly precipitation for a 40-year period, and average monthly temperature data for the period 1931-1952.



SULPHUR

Altitude 4,044

Average monthly precipitation for the periods 1916-1945, 1949-1952.
Average monthly temperature data for the periods 1922-1924, 1927, 1930-1941, 1943.

Figure 2.—Graphs illustrating the climatic conditions at the U. S. Weather Bureau stations at Gerlach, Leonard Creek Ranch, Quinn River Crossing Ranch and Sulphur.

PHYSICAL CHARACTER AND WATER-BEARING PROPERTIES OF THE ROCKS

Hydrologic Setting:

The present topography of the region and the present hydrologic setting began to take form during the middle part of the Tertiary Period. At that time, and continuing well into the Pleistocene Epoch, the country rock was disrupted by vertical movement along an extensive system of faults; the present basins were downfaulted and mountain ranges uplifted with respect to one another. The vertical displacement along the major range-front faults was even greater than the present relief would indicate. Erosional debris from the uplifted areas has partly filled the basins with an unknown thickness of alluvial, stream, and lake deposits. The thickness of the unconsolidated material in the Black Rock Desert may be on the order of several thousand feet.

The Pleistocene Epoch was characterized by worldwide climatic changes which resulted in the formation of lakes in many of the undrained basins of Nevada. The most recent of these, Lake Lahontan, intermittently covered a large part of western Nevada and attained a maximum altitude of about 4,380 feet. In the Black Rock Desert, which was a major arm of Lake Lahontan more than 400 feet deep, the many stages and fluctuations of the lake are recorded in the shoreline features which terrace the surrounding mountainsides.

Bedrock:

Black Rock, a small steep hill at the south end of the Black Rock Range, is composed of Permian marine and volcanic rocks; the westermost exposure of fossilerous Permian strata known in the State (Gianella and Larson, 1960). The Jackson Mountains are largely composed of Permian and older rocks, named the Happy Creek Volcanic Series by Willden (1962). Intrusive masses, mainly granodiorite, occur in many of the surrounding mountains and are probably Cretaceous or Tertiary in age. Various sedimentary and metamorphic rocks, ranging in age from Permian to Pleistocene, also occur in the mountains of the Black Rock Desert, but in general volcanic rocks predominate. In the area north and west of Black Rock the terrane is composed almost exclusively of a thick section of volcanic flow rocks intercalated with tuff and lake beds of Tertiary age.

The movement of ground water in the consolidated rocks of the mountain ranges is largely through joints and other secondary openings and in permeable 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 volcanic terrane of the High Rock Lake Region, 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 channes 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, is not considered a dependable source of water for large-capacity wells.

Alluvium:

Alluvial fans coalesce to form the piedmont slopes which flank the mountains surrounding the Black Rock Desert. This alluvium has been deposited largely by mudflow and flood waters because of the flashy nature of the streams. As a result, it is composed of poorly sorted rock particles ranging in size from clay to boulders. The alluvium ranges in age from mid-Tertiary to Recent.

The permeability of alluvium, although much greater than that of bedrock, is generally low to moderate, depending on the size and degree of sorting of the rock particles. Layers and lenses of well-sorted sand and gravel are found at various levels within the alluvium. These are best developed off the mouths of the canyons where streamflow has sorted the particles according to size and weight, carrying the finest particles farthest out toward the center of the basin.

Wells penetrating a sufficient saturated thickness of alluvium may yield moderate to large volumes of water, but along the alluvial slopes the depth to water may be on the order of 100 feet or more; pumping lifts are even greater.

Lake Deposits:

The alluvium mantling the mountainsides has been reworked extensively by wave action in the lakes which have filled the basin to various levels throughout much of its history. The winowing action on the waves removed much of the fine material from the shores leaving beaches and bars of well-sorted sand and gravel ringing the basin at several elevations, both above and below the present valley floor. In the central part of the basin the valley floor is underlain by silt and clay deposited in the relatively still, deep parts of the former lakes. As previously mentioned (p. 6), the section of clay underlying the central part of the desert floor is at least 1, 500 feet thick and probably is much more. The lake deposits probably range in age from Pliocene to Recent.

Around the margins of the basin the thick clay and silt sections are separated by relatively thin layers and lenses of sand and gravel, which are principally stream deposits and reworked alluvium that accumulated during shallow stages of the lakes and periods of desiccation. These sheets of sand and gravel, though thin, may be quite extensive and probably constitute the most important aquifers in the basin. They are best developed along the edges of the basin and thin basinward as they interfinger with the silt and clay, eventually pinching out altogether.

GROUND WATER

Occurrence and Movement:

Most of the available ground water occurs in the unconsolidated deposits of the alluvium, or valley fill. Ground water also occurs in the consolidated rocks of the mountains. Moving through fractures in the rock, ground water sometimes appears at the surface to form a spring or, more commonly, discharges into the alluvium at some distance beneath the land surface. As previously mentioned, however, the bedrock is generally not a source of water for large-capacity wells.

Ground water, like surface water, always moves downgradient toward the area of lowest head. The alluvial aquifers in the Black Rock Desert are recharged along the piedmont slopes at elevations several hundred feet above the valley floor. The ground water then percolates downgradient toward the center of the basin where it is discharged to the atmosphere either by evaporation from the land surface or transpiration by the greasewood and other salt-tolerant plants which cover most of the valley floor.

The horizontal permeability of lake deposits, and to a lesser degree of alluvium, is generally greater than the vertical permeability. This is due primarily to the modes of deposition which have resulted in relatively thin but extensive layers of permeable sand and gravel overlain by layers of relatively impermeable silt and clay. This sequence is repeated many times, each member sloping from the margins of the basin toward the center, resulting in many thin artesian aquifers interbedded with less permeable confining layers. Upward leakage occurs through the confining layers, and ground water is discharged at the land surface by evaporation and transpiration.

Recharge:

Precipitation is the ultimate source of recharge to the ground-water reservoir of the Black Rock Desert. In addition to recharge from precipitation within the area defined on plate 1, some ground water enters the basin by underflow from beyond the surface drainage divides and along the course of the Quinn River.

The approximate amount of precipitation within the drainage area each year can be estimated from a map showing precipitation zones in Nevada (Hardman, 1936). Although the average annual precipitation is less than 6 inches on the valley floor (p. 8), precipitation increases with altitude, as described by Hardman and Mason (1949), and the entire drainage basin can be subdivided into precipitation zones based on aspect vegetation and altitude, as shown in table 1. Some areas, although high, lack the relief which generates precipitation in the mountain watersheds. The High Rock Lake drainage lies 6,000 to 7,000 feet above sea level. The topography is gently rolling desert plateau, for the most part, and the aspect vegetation suggests that the average precipitation probably is within the range of 8 to 12 inches per year, despite the altitude.

The amount of precipitation which infiltrates to the ground-water reservoir is determined largely by the vegetation, soil cover, and geology of the area. In areas of very little precipitation, such as the valley floor, all, or nearly all, the available moisture may be lost to evapotranspiration.

Seepage from streams crossing the alluvium of the piedmont slopes is generally an important source of recharge. The streambeds are composed of permeable gravel and the piedmont surface is generally well above the regional water table. Rapid infiltration is possible under these circumstances.

Recharge in the mountains is determined largely by the geology, soil types, and vegetal cover. The permeability of most of the consolidated rocks is relatively low; but secondary openings, such as along bedding planes, joints, and fractures are important avenues of infiltration. The manner in which the various rock types weather has a considerable effect on the recharge potential. A mantle of coarse rock debris retards the runoff from precipitation and snowmelt and permits the water to infiltrate. Once beneath the land surface the water may percolate into the bedrock, or, in the case of less permeable rock types, move downward, through the alluvium, along the surface of the bedrock. Springs and seeps occur where the mantle thins or the bedrock surface outcrops, and are the source of the base flow of many of the small streams draining the mountains.

The percentage of precipitation that recharges the ground-water reservoir, even under favorable conditions, is small, and the percentage for a given amount of precipitation varies considerably with the terrane. A detailed determination of the percentage of precipitation that infiltrates to the water table is impossible. The estimates of ground-water recharge from precipitation shown in table 1 are based on percentages determined empirically by Eakin and others (1951) from studies in eastern Nevada and may be in the proper order of magnitude for the Black Rock Desert area.

These estimates are made to facilitate management of the ground-water resources by the State Engineer, in accordance with the Nevada Water Law, which states in part that the withdrawal of ground water be limited to the "reasonable lowering of the static water level".

Table 1.--Estimated precipitation and recharge to the ground-water reservoirs of the Black Rock Desert area.

Drainage Area	Pre-cipita-tion zone (inches)	Altitude of zone (feet)	Area of zone (acres) (rounded)	Precipita-tion (acre-feet per year) (rounded)	Per-cent re-charged	Estimate of recharge (acre-feet per year, rounded)
Watershed South of Western Pac. Railroad	8-12	above 5,500	78,000	65,000	3	2,000
TOTAL						2,000
Jackson Mts.	15-20	above 7,000	3,900	5,700	15	800
	12-15	6,000-7,000	16,500	18,500	7	1,300
	8-12	5,000-6,000	54,700	45,500	3	1,300
TOTAL						3,400
Pine Forest Range	15-20	above 7,000	7,560	11,000	15	1,600
	12-15	6,000-7,000	15,900	17,900	7	1,200
	8-12	5,000-6,000	27,300	22,700	3	700
TOTAL						3,500
East side of	15-20	above 7,000	8,500	12,400	15	1,800
Black Rock	12-15	6,000-7,000	35,900	40,300	7	2,800
Range	8-12	5,000-6,000	26,300	21,900	3	600
TOTAL						5,000
West arm of Black Rock Desert	15-20	above 7,000	8,500	12,400	15	1,800
(W. side Black	12-15	6,000-7,000	53,200	59,800	7	4,200
Rock Range &	8-12	5,000-6,000	70,200	58,400	3	1,700
Calico Mtns)						
TOTAL						8,000
Granite Basin	15-20	above 7,000	1,100	1,600	15	200
(Bowen Creek	12-15	6,000-7,000	1,000	11,300	7	800
drainage)	8-12	5,000-6,000	3,900	32,500	3	1,000
TOTAL						2,000
High Rock Lake (drainage)	8-12	6,000-7,000+	525,000	435,000	3	13,000
TOTAL						13,000
Summit Lake	15-20	above 7,000	10,400	15,300	15	2,300
(drainage)	12-15	below 7,000	24,400	27,400	7	1,900
TOTAL						4,200

Unlike many of the smaller basins in Nevada, the estimate of total recharge to the Black Rock Desert is not a useful management tool. The areas presently being developed and the areas having potential for development lie along the margins of the basin, separated from one another by great expanses of lake deposits which contain saline ground water. Thus, the development of a given area is dependent on the recharge within its immediate watershed and the amount of fresh water available from storage locally. In most areas development will not affect the available ground-water supply in another part of the basin. The estimates of recharge in table 1, therefore, have been made on the basis of individual areas which are divided by reason of geology, physiography, and hydrology into isolated hydrologic units.

In addition to direct recharge from precipitation, some ground water enters the Black Rock Desert by ground-water underflow, or inflow. In the study of the ground-water resources of Pine Forest Valley (Sinclair, 1962a), it was estimated that about 2,700 acre-feet of ground water per year moves southward into the Black Rock Desert. Ground water is also entering the desert from Hualapai Flat (Sinclair, 1962b), but the amount is considered to be small. Some ground water may also be moving from the High Rock Lake region into Soldier Meadows, and the west arm of the Black Rock Desert.

Discharge:

Ground water is discharged to the surface by springs, seeps, and pumping from wells. It is returned to the atmosphere by evaporation from the land surface and by transpiration through plants.

Springs: Springs and seeps are common in the mountains surrounding the Black Rock Desert and the principal springs are shown on plate 1. They are principally the gravity type, occurring where the land surface intercepts the water table or where infiltrating ground water encounters an impermeable rock stratum and is forced laterally to the surface.

Artesian springs issue from the lake deposits in the vicinity of the Wheeler Ranch and northward. Many artesian wells in this area are also flowing unchecked, their discharge being used for flood irrigation and watering stock.

Thermal springs, whose temperatures range from warm to boiling, issue from the desert floor in several areas. These springs are probably associated with recent movement along fault zones, which provide paths along which ground water, heated at depth, can rise to the surface.

Water from the thermal springs is commonly highly mineralized due to its high temperature, which is conductive to chemical reaction with the environment and to its history of deep circulation. Most of the thermal water is derived from the same ultimate source as all ground water--precipitation. Thus it is unnecessary and, in most cases, unreasonable to postulate that all the thermal spring water originates beyond the watershed or from magma deep within the earth's crust.

Pumpage: Withdrawal of ground water to supplement surface irrigation is becoming increasingly common in Nevada. Several large-capacity wells have been developed at the Leonard Creek Ranch in the past few years. A number of flowing wells in the vicinity of the Wheeler Ranch are used for irrigation, in addition to one large-capacity pumped well. The Garret Ranch, along the southern edge of the desert, also has several flowing artesian wells whose water ranges in temperature from 68°F to 125°F. The amount of ground water presently being discharged by wells in the Black Rock Desert, however, is still a minor part of the total amount in the hydrologic regimen.

Underflow: An alluvial gap, about a mile in width, connects Smoke Creek Desert with the San Emidio Desert, which in turn merges with the Black Rock Desert at Gerlach. The altitude of the water table within the three basins is so nearly equal that interbasin movement of ground water by underflow probably is negligible.

Evaporation: In addition to storm runoff reaching the valley floor, much of the water evaporated from the playa is effluent ground water drained to the playa during the winter months by the Quinn River and Mud Meadow Creek. Ground water is discharged to the atmosphere by evaporation in areas where the capillary fringe above the water table intersects the land surface. The loss of water by evaporation decreases rapidly with increasing depth to the water table. In clay the rate of evaporation is presumed to be very slight below a depth of a few feet. The mud cracks which cover most of the playa surface, however, may serve to facilitate evaporation of water from greater depths. These cracks have been observed to extend as much as 4 feet below the surface in areas where they were only a fraction of an inch wide at the surface and formed polygons less than 6 inches across. The giant desiccation fissures, described by Willden and Mabey (1961) along the northwest edge of the playa, are generally a foot or more in width, forming polygonal blocks with edges from 100 to 250 feet long. Tough irregularities in the fissure walls limit visual estimates of their depth to a few feet, the size of their surface features suggest that these giant fissures extend to considerable depth. During the large runoff of February 1962, the area of giant fissures was completely inundated. When the water had evaporated it was found that the cracks had closed, apparently by swelling of the wetted clay rather than by filling.

In August 1962 the depth to water beneath the playa was nowhere greater than 10 feet as shown in plate 1. In addition, pools of standing water in the channels of the Quinn River and Mud Meadow Creek indicate an extremely shallow water table throughout much of the central part of both arms of the valley floor. The total area of desert floor where the depth to water probably was less than 10 feet might be on the order of 250 square miles, or roughly 150,000 acres.

The area of the floor of Black Rock Desert beneath which water levels are less than 5 feet may be as much as 200,000 acres.

If an average of only half an inch of evaporation occurs each year, the discharge might be on the order of 5,000 to 10,000 acre-feet per year. Although the ground-water discharge by evaporation can not be computed accurately, it nevertheless is a major component of the hydrologic regimen of the Black Rock Desert.

Transpiration: Evaporation and transpiration account for all of the natural discharge of ground water from the Black Rock Desert watershed. 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. Typically, these plants grow along the foot of the piedmont slopes where the land surface comes within root range of the water table. Greasewood is the most common phreatophyte in the region, and the presence of certain species is generally an indication that the water table is within about 30 feet, or less, of the land surface. The greasewood gives way, basinward, to the more shallow-rooted, salt-tolerant plants, such as rabbitbrush, saltgrass, and various saltbushes which dwindle in density and vigor toward the center of the valley floor until they are unable to grow in the barren, saline ground of the playa.

In other reports of this series an estimate of the discharge of ground water by transpiration has been made by assuming a water-use factor for the phreatophytes and mapping their areas. In the Black Rock Desert, however, the lack of knowledge on depth to water and the inaccessibility of much of the lowland areas made direct estimates of water use by plant types beyond the scope of this study. However, the annual use may be on the same order of magnitude as the evaporation (see below).

In the High Rock Lake drainage, phreatophyte vegetation covers an estimated 4,000 acres along Cottonwood Creek, in Smokey Canyon, and in the immediate vicinity of the lake. The total discharge from these areas by transpiration may be within the range of 500 to 1,000 acre-feet per year. Small clumps and stringers of phreatophytes surrounding the countless springs in the uplands and growing along the many dry stream courses probably account for most of the discharge of ground water from the High Rock Lake drainage. The area of High Rock Lake ranges from nothing to as much as 1,000 acres. Evaporation from the lake surface varies accordingly but probably does not exceed 3,000 acre-feet per year.

Phreatophyte vegetation in the Summit Lake watershed is limited to the immediate vicinity of the upland springs and stream courses. As previously mentioned, recharge to the basin is probably balanced by evaporation from the lake surface and, to a minor extent, underflow through the rock debris which forms the southern drainage divide.

Perennial Yield:

The development and use of the ground-water resources of Nevada is predicated on the State Water Law, which states that the rate of ground-water withdrawal from a basin be limited to the "reasonable lowering of the static water level" (Hutchins, 1955, p. 61). Accordingly, the perennial yield is now the limiting factor in any permanent or long-range development of the ground-water resources of Nevada.

The perennial yield of a ground-water reservoir may be defined as the amount of water that can be pumped, or otherwise diverted from the reservoir, without causing an excessive depletion of the stored water. In other terms, perennial yield is the amount of water that can be salvaged from natural discharge, and is ultimately limited to the amount of recharge to the reservoir.

The estimates of recharge to the individual watersheds in the Black Rock Desert area (table 1) are considered to be a preliminary guide to the reasonable development of the areas. The poor quality of water beneath the playa of Black Rock Desert and the meager data on well yields and quality of water around the margins of the valley preclude an estimate of the yield of this major part of the area. Each subarea that is developed for irrigation adjacent to the playa must be evaluated on the basis of the quality of water, well yields, and suitability of the soils for irrigation. If water levels are drawn down substantially, water of poor quality may in time move laterally into the wells from beneath the playa.

In pumping ground water from storage, as must be done in the early stages of development, periodic samples of water for chemical analysis should be obtained along with measurements of the water level. Ideally, this might include drilling observation wells basinward from the area of development so that any reversal of gradient of the water table could be detected early and pumpage decreased to prevent the intrusion of saline water. Thereafter, pumpage should be limited to the amount of fresh ground water that can be intercepted as it moves basinward from the upland areas of recharge.

The perennial yield of the basins in the Black Rock Desert area can be determined more accurately only after several years of development have been closely observed and much additional data have been collected and evaluated. The pumpage from a basin may exceed the average annual recharge to the extent that some of the applied water returns to the ground-water reservoir. Also, in the early stages of development, some ground water must be removed from storage in order to induce ground-water movement toward the pumping wells. In the final analysis, however, the perennial yield of these basins will be determined largely by the amount of natural discharge that can be salvaged or diverted to beneficial use.

Ground Water in Storage:

Large volumes of water saturate the unconsolidated deposits underlying the floor of the Black Rock Desert. Where these deposits are fine-grained, as beneath the playa, the water is not available to wells, and in general the water is not chemically suitable for most uses. Laterally away from the playa, coarse-grained deposits within the alluvium may yield as much as 20 percent water by volume. This is the water that is generally available to wells and relatively low in mineral content.

The amount of fresh water in stroage in the aquifers of the Black Rock Desert area was not determined in this study. It seems likely, however, that the volume of fresh water available for development in the upper 100 feet of saturated deposits is many times the average annual recharge estimated for each of the subareas listed in table 1.

CHEMICAL QUALITY OF THE GROUND WATER

In addition to sediments carried in suspension by the streams tributary to the Black Rock Desert, large amounts of dissolved minerals were carried basinward in solution, having been leached from the rocks of the surrounding mountains. The dissolved minerals were precipitated when the water evaporated from the lake, and were intermixed with the silt and clay which has been gradually filling the central part of the basin.

Most of the chemical constituents in ground water are acquired by the solution of minerals in the material 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 moves slowly through fine-grained material, and silt and clay usually are susceptible to ion exchange with the percolating water, because of their chemical composition and large surface area. The rapid movement of water through gravel aquifers, on the other hand, coupled with the chemical stability of most pebbles, provides less opportunity for significant changes of water quality within the aquifer.

In general, ground water in the Black Rock Desert is relatively fresh along the margins of the basin, close to the areas of recharge, but becomes saline as it moves through the mineralized deposits toward the center of the basin. Clean sand and gravel aquifers may contain relatively fresh water, even though interbedded with saline clays.

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, which can be measured in general terms by the specific conductance of the water, expressed as micromhos per centimeter at 25°C. Water of low conductivity is generally more suitable for irrigation than water of high conductivity.

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. An SAR in excess of about 10, or less where specific conductance is high, probably will present a sodium hazard in the fine-textured soils of the Black Rock Desert.

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 probably is 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:

Chemical analyses were made of water from 10 wells and 6 springs in the Black Rock Desert. The results of these analyses are listed in table 5. 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). Geochemical interpretation of the analyses is also aided by the diagrams illustrating the general chemical character of the ground water. These are drawn by plotting the concentrations of six key ions, in equivalents per million, and connecting the plotted points (Stiff, 1951).

Both illustrations show a wide range in the quality of the water in the basin. The ground water is characteristically a sodium-bicarbonate type, but water from the flowing wells at the Garrett Ranch (33/25-10b4) contains mainly sodium chloride, as does water from Great Boiling Spring near Gerlach. Several other analyses show mixtures of these two types of water: Coyote Spring (34/25-16d1) about a mile north of the Garrett Ranch;

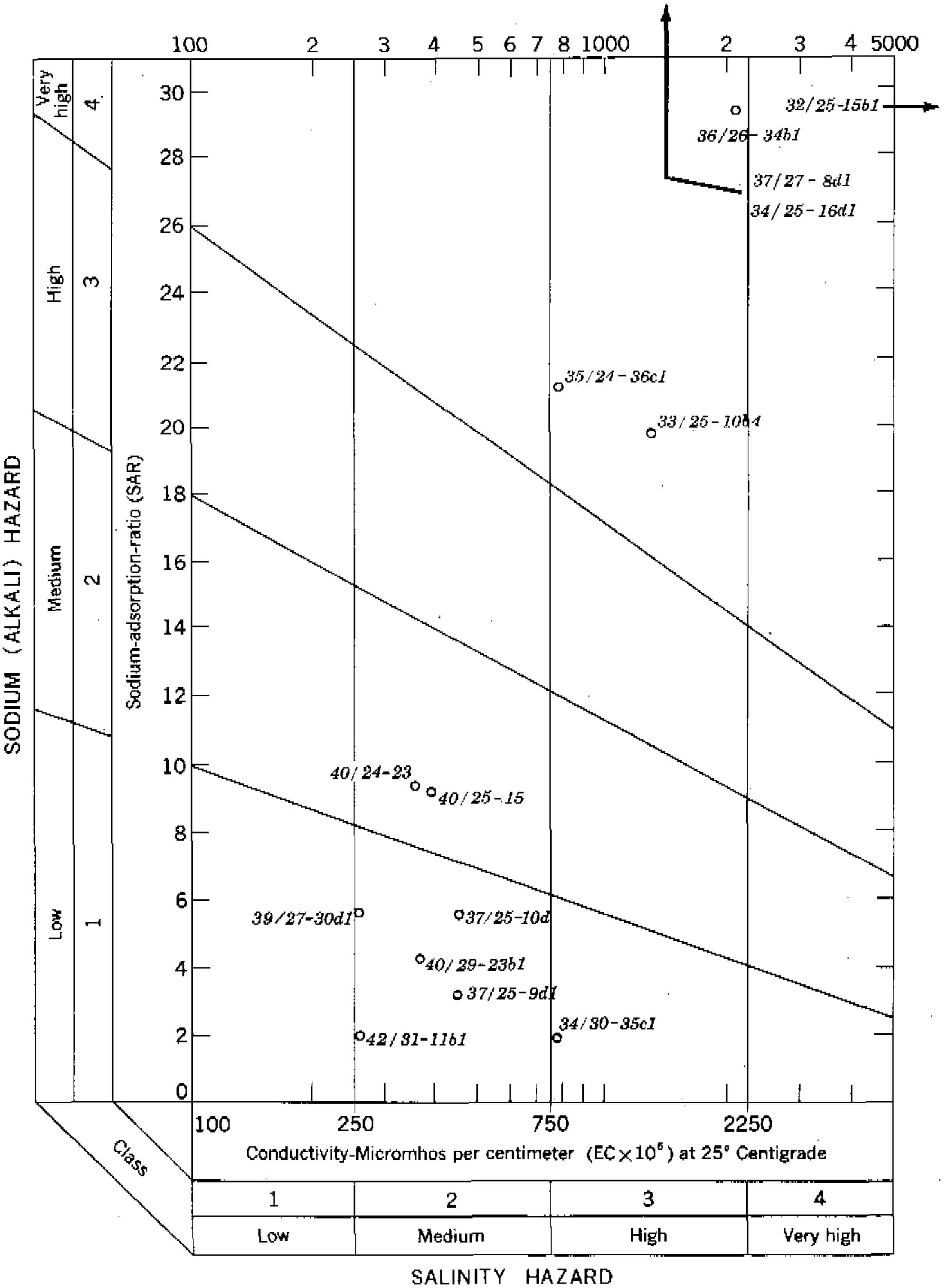


Figure 3.—Classification of irrigation water based on conductivity and sodium-adsorption ratio.

Well 33/23-26dl, at the edge of the playa near the mouth of Bowen Creek; and well 37/27-8dl, at the edge of the valley floor on the east side of the Black Rock Range.

The salinity and alkali hazards of nearly all the water sampled, as shown in table 5, indicate that most of the water is marginal for irrigation, particularly if used with the fine-grained, high-sodium soils which are so prevalent in the Black Rock Desert. Forage-type crops are grown almost exclusively in the region, and these are relatively tolerant to the salinity of the irrigation water. Even so, the quality of the water and its chemical reaction with the crops and soils will continue to be a limiting factor in the development of ground water for irrigation.

Water for Domestic Use:

Much of the water in the Black Rock Desert, although soft, is unsatisfactory for domestic use due to the high dissolved-solids content. The occurrence of fluoride in excess of the 1.5 ppm optimum suggested by the U.S. Public Health Service (1962) is common in the saline water and may be a hazard to health.

Water for Gerlach is piped 10 1/2 and 7 1/2 miles from Garden and Granite Springs, respectively, in the Granite Range northwest of town. Water is imported by rail for domestic use in Sulphur. Most of the ranch headquarters are near the mouths of canyons where streamflow supplies fresh water for domestic use.

CONCLUSIONS

The potential for agricultural development throughout most of the Black Rock Desert is limited by the arid climate, the steepness of the alluvial slopes flanking the mountainsides, and the salinity of the soils and water.

Most of the ground water in storage beneath and near the playa is unsuitable for domestic or irrigation use. The development of a supply of ground water of good quality, therefore, requires that wells be drilled near the lower edge of the alluvial slopes so that fresh ground water may be intercepted before it comes in contact with the mineralized deposits near the playa.

The few areas presently under cultivation, or having a potential for development, are relatively small and are separated from one another by ridges of bedrock or wide expanses of desert. The effect of ground-water development, or overdevelopment, in one area on the ground-water regimen in another area, therefore, would be negligible.

The perennial yield of any of the subareas may be on the order of magnitude shown for recharge in table 1, or may range from 2,000 to 13,000 acre-feet. However, the yield will depend largely on the location of wells and the manner in which they are pumped. On the floor of Black Rock Desert pumping in moderate amounts from several properly spaced wells, rather than from one large-capacity well, may be necessary to intercept the fresh ground water that is moving basinward and to avoid excessive drawdown and the resultant encroachment of saline ground water.

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Table 2.--Records of wells in the Black Rock Desert area, Nevada

Use of water: D, domestic; I, irrigation; S, stock; T, test.
Water level and temperature: M, measured; R, reported.

Well number and location	Owner	Date drilled	Diameter (inches)	Depth (inches)	Depth of main aquifers (feet)	Water level: Below measuring point (feet)	Water level: M or R	Water level: Date	Measuring point: Above land surface (feet)	Measuring point: Description	Use	Remarks
42/30-32d1	--	--	6	--	--	49.36	M	4-14-60	1	Top of casing	S	--
42/30-35a1	Bureau of Land Management	--	6	57	--	57.05	M	9-30-60	1	Top of casing	S	--
41/23- 1d1	Bureau of Land Management	6-55	8	98	--	43	R	6- -55	-	--	S	--
41/28-11a1	Leonard Creek Ranch	--	16	335	97-330	69	R	5- -60	-	--	-	--
41/28-11d1	Leonard Creek Ranch	4-51	16	420	15-38	15	R	4- -51	-	--	I	--
41/28-12c1	Leonard Creek Ranch	--	6	77	52-77	28	R	10-14-57	-	--	-	--
41/28-23c1	Leonard Creek Ranch	10-57	6	53	41-53	11	R	10-17-57	-	--	S	--
41/31- 3b1	--	--	6	--	--	17.66	M	9-30-60	1	Top of casing	S	--
41/31-4b1	Bureau of Land Management	--	6	78	--	20.27	M	10- 8-60	1	Top of casing	S	--
41/31- 5b1	Bureau of Land Management	--	6	78	--	20.3	M	10- 8-60	1	Top of casing	S	Chemical analysis, 55.5°F, M
41/31-28b1	Deer Creek Ranch	--	-	--	--	--	-	--	-	--	D,S	--
40/26-20d1	Bureau of Reclamation	11-56	6	300	190-215	100	R	11-15-56	-	--	-	67°F
40/27- 2c1	Battle Creek Ranch	5-52	8	70	60-70	--	-	--	-	--	D	65°F
40/27-14a1	Battle Creek Ranch	1953	6	62	40-62	--	-	--	-	--	-	--
40/27-23b1	Bureau of Land Management	--	6	--	--	39.97	M	5-12-60	0	Top of casing	S	--
40/31- 5a1	Bill Delong	--	6	--	--	10	R	11- 8-60	-	--	-	--
37/20-13a1	Bureau of Land Management	--	6	107	--	7.5	R	--	-	Top of casing	-	--
37/25- 9d1	Wheeler Ranch	1-51	14	1012	--	57.94	M	4-13-60	0	Hole in pump base	I	--
37/25-10c1	Wheeler Ranch	10-47	8	490	--	4	R	12-11-47	1	Top of casing	-	--
37/25-10d1	--	--	-	--	--	--	-	--	-	--	-	Chemical analysis, 97°F, M
37/25-11b1	Wheeler Ranch	10-47	8	287	--	35+	R	10-26-47	-	--	-	--
37/25-11b2	Wheeler Ranch	2-51	10	303	--	--	-	--	-	--	-	103°F, R
37/25-13c1	Jackson Bros.	1930	4	120	--	--	-	--	-	--	S,T	--
37/25-26a1	Jackson	--	5	--	--	29	M	11- 9-50	-	--	S,I	72°F, M
37/25-26c1	Jackson	--	4	200	--	--	-	--	-	--	I	78°F, M
37/27- 8d1	Bureau of Land Management	--	-	--	--	--	-	--	-	--	S	Chemical analysis, 60.5°F, M
37/30-6h1	Bureau of Land Management	--	-	--	--	--	-	--	-	--	S	--
36/25-16d1	Grover G. Jackson	1946	-	50	--	+6	R	--	-	--	-	62°F, M
36/29- 2c1	--	--	6	--	--	78.54	M	6-15-60	2	Top of casing	S	--
36/29- 3d1	Bureau of Land Management	--	-	--	--	100+	R	--	-	--	S	--
35/24-36c1	Edwin Van Riper	--	6	96	96	--	-	--	-	--	S,I	Chemical analysis, 60°F, M
35/25-33a1	W. W. Irwin	4-48	4	144	--	35	R	4-11-48	-	--	-	60°F, quality objectionable, R
35/30-17a1	Bob Wigle	--	6	--	--	2	M	3-25-63	2	Tie crib	D	50°F, M
34/29-28c1	Ben Constance	--	16	200	--	--	-	--	-	--	D,In	--
34/30-35c1	Maude well	--	3'x6'	35	--	20.85	M	3-25-63	0	Tie crib	D,In	--
33/23-24d1	--	--	4	72	--	1.90	M	6-15-60	0	Top of 2x4 block	S	--
33/23-26d1	Fred Vogel	--	-	--	--	--	R	4- 9-42	-	--	D,S	Chemical analysis
33/25-10a1	Garrett Ranch	--	-	--	--	--	-	--	-	--	S	125°F, M
33/25-10b1	Garrett Ranch	--	6	130	129-130	--	-	--	-	--	I	68°F, M
33/25-10b2	Garrett Ranch	--	2	90	--	--	-	--	-	--	D	108°F, M
33/25-10b3	Garrett Ranch	--	6	90	--	--	-	--	-	--	I	104°F, M
33/25-10b4	Garrett Ranch	1924	6	125	125	--	-	--	-	--	I	Chemical analysis, 92°F, M
33/29- 5d1	Federal Uranium	3-57	10	85	33-38	18	R	3-15-57	-	--	D	--
33/29- 8b1	Federal Uranium	4-57	10	400	153-157	30	R	4-19-57	-	--	D	--
33/29-34b1	Federal Uranium	5-57	6	168	55-60	52	R	5-24-57	-	--	D	--
32/29- 1a1	Placeritas	--	-	60	--	--	-	--	-	--	In	--

Table 3. -- Selected springs in the Black Rock Desert

Use of water: B, bathing; D, domestic; I, irrigation; Ind., industrial; S, stock.

Spring number	Name	Estimated discharge (gpm)	Use	Temperature (°F)	Remarks
40/25-23	Soldier Meadows	-	I, S	-	Chem. Anal., many springs and seeps.
40/28-29	Pinto Mountain	50	S	Boiling	Chem. Anal.
39/27-30dl	Cain	5	S	74	Chem. Anal.
38/25-34	--	100	I, S	-	About 10 separate pools
37/29-27bl	Macfarlanes' bathhouse	5	D, S	170	--
36/26-4bl	Double hot	250	I, S	Boiling	--
36/26-34bl	Black Rock	50	I, S	136	Chem. Anal.
35/24-35dl	Lost	5	S	--	--
35/25-35bl	Sulphur	-	Ind.	-	--
35/30-9dl	Mandalay	-	-	56	Area of shallow water table; seeps
34/25-16dl	Coyote	1	-	60	Spring mound on playa
34/25-31bl	--	35	I	Hot	--
32/23-15bl	Great Boiling	200	B	Boiling	Chem. Anal.

Table 4.--Drillers' logs of wells in the Black Rock Desert area.

	Thickness (feet)	Depth (feet)
41/23-1d1		
Casing perforated 70' to 98'		
Bentonite and gravel	16	16
Sandstone	59	75
Rock, broken; water	23	98
41/28-11a1		
Casing perforated 100' to 330'; 1/2" x 2"		
Soil	5	5
Clay, brown	9	14
Sand and gravel	36	50
Gravel, cemented	45	95
Clay, brown	10	105
Gravel and sand	15	120
Clay, brown	5	125
Gravel and sand	15	140
Gravel and clay	15	155
Sand and gravel	7	162
Cemented	20	182
Gravel and clay mix	19	201
Gravel and sand	43	244
Cemented	16	260
Gravel and clay mix	10	270
Sand and gravel	18	288
Clay	4	292
Sand and gravel	8	300
Gravel and clay mix	16	316
Pinch clay	4	320
Sand and gravel	5	325
Pinch clay	10	335
Sand and gravel	5	340
41/28-11d1		
Casing perforated 106' to 392'; 3/16"		
Topsoil	10	10
Gravel, coarse	28	38
Clay and gravel	54	92
Gravel, loose sand	106	198
Clay and gravel	128	326
Gravel, coarse	66	392
Clay	28	420
Gravel	--	--
41/28-12c1		
Casing perforated 40' to 75'; 3/16" x 6" torch cuts		
Topsoil	7	7
Clay, hardpan	7	14
Clay, gravelly	17	31
Sand, fine; water	7	38
Clay, sandy	14	52
Sand and gravel	25	77
41/28-23c1		
Casing perforated 30' to 50"; 3/16" x 6" torch cuts		
Topsoil, sandy clay	12	12
Clay, sticky bentonite	3	15
Sand, water seep	3	18
Clay, sandy	23	41
Sand and gravel	12	53
40/26-20d1		
Casing perforated 135' to 210'		
Topsoil	3	3
Tuff, bluish	187	190
Volcanic rock, porous	25	215
Volcanic rock, broken soft	85	300

Table 4 (continued)

	Thickness (feet)	Depth (feet)
40/27-2cl		
Casing perforated 30' to 70'; 1/4" x 3"		
Gravel	48	48
Clay	10	58
Sand and gravel	12	70
40/27-14al		
Hardpan	10	10
Clay	30	40
Sand, gravel; water	22	62
37/25-9dl		
Sand, top soil	3	3
Gravel	4	7
Sand	11	18
Clay, red; gravel	12	30
Clay, red; sand	8	38
Clay, brown; gravel	18	56
Clay, brown; sand	6	62
Clay, yellow; gravel	6	68
Gravel, sand, and water	8	76
Clay, red; gravel	26	102
Clay, red; sand	6	108
Clay, red; gravel	26	134
Gravel, sand, water	2	136
Clay, brown; gravel	20	156
Clay, gray	6	162
Clay, red; gravel	28	190
Clay, gray	6	196
Clay, red; gravel	45	241
Clay, gray	11	252
Clay, red; gravel	25	277
Clay, brownish white, sandy	15	292
Clay, red, sandy	41	333
Clay, brown; sand	9	342
Clay, white; gravel and sand	15	357
Clay, white; sand	53	410
37/25-9dl (continued)		
Clay, gray; sand	13	423
Clay, red; rock	2	425
Clay, gray; sand	17	442
Clay, redish white; rock	4	446
Clay, gray; sand	21	457
Clay, white, sugary	2	469
Sand, gray; clay	36	505
Sand, brown, coarse; clay	8	513
Clay, white; sand	9	522
Clay, white	24	546
Clay, blue	6"	546'6"
Clay, white; sand	5'6"	552
Rock, white	3	555
Clay, white	6	561
Clay, white; sand	8	569
Clay, gray, hard	9	578
Sand, white; rock	7	585
Clay, white, hard	12	597
Clay, gray	11	608
Clay, gray; sand	22	630
Clay, white	22	652
Clay, gray	5	657
Rock, red	7	664
Clay, gray	8	672
Clay, white	36	708
Clay, gray	27	735
Clay, gray, hard	17	752
Clay, white	11	763
Rock, pink	13	776
Clay, brown, hard	25	801
Clay, white	7	808
Clay, brown	9	817
Clay, gray	8	825
Clay, brown	7	832
Clay, gray	6	838
Clay, brown	8	846
Clay, blue	6	852
Clay, blue	1	853
Clay, brown	8	861
Clay, gray	11	872
Clay, brown	7	879

Table 4 (continued)

	Thick-ness (feet)	Depth (feet)
37/25-9dl (continued)		
Clay, white	8	887
Clay, brown	10	897
Clay, gray	10	907
Clay, blue	6	913
Sand, brown	5	918
Rock, black	56	974
Rock, whitish gray	38	1012
37/25-10dl		
Gravel, sandy	10	10
Clay, yellow; sand	10	20
Clay, black; water strata	10	30
Sand, black; yellow clay; small gravel	10	40
Clay, yellow; sand and small gravel	10	50
Clay, yellow; fine sand	10	60
Clay, yellow, soft	10	70
Clay, yellow, soft; sand and small gravel	10	80
Clay, rusty, soft	10	90
"Small stratas of clay", pea-sized gravel	20	110
Gravel, course; sand; water strata	5	115
Gravel stratas; soft brown to yellow clay; water	7	122
"Small stratas of yellow, pink, light green clays"	11	133
"Small clay stratas, water gravel stratas 2' thick"	7	140
Gravel stratas, cemented very hard	5	145
Gravel and soft stratas of pink clay, small	5	150
Clay, pink; gravel	10	160
Clay, pink; gravel	8	168
Clay, pink	2	170
Clay; pink; gravel	10	180
Clay, white; "artesian hot water indications"	26	206
"Small stratas, pink, green and white clays"	4	210
Clay, pink	3	213
Clay, pink; gravel	17	230
Clay, pink; sand and gravel	16	246
Clays, pink and dark green, hard	2	248
Gravel, cemented, very hard white quartz	24	272
Gravel, very hard white quartz mixed	8	280
Gravel, very hard white quartz mixed	15	295
Clay, brown and pink	5	300
"White hot water clays"	20	320

(continued)

Table 4 (continued)

	Thickness (feet)	Depth (feet)
37/25-10d1 (continued)		
"2" to 3" stratas of rust brown and gray clays, with quartz"	10	330
Clays, white gray; white quartz sands; water strata; sand	10	340
Clays, rusty brown; white quartz; loss of mud; water strata	60	400
Sands, brown, cemented, hard	10	410
Clay, white and gray; loss of mud; water strata	20	430
Quartz, white, cemented; or solid strata	10	440
"Alternate white and brown clay stratas, small ones"	10	450
Clay, brown; quartz sands; water strata	10	460
Clay, brown; quartz sands; water strata	30	490
37/25-11b1		
Silt, black; yellow clay	20	20
Hardpan and yellow clay	20	40
"soft whitish hot water clay"	33	73
Gravel, small; sand and clay	4	77
Clay, brown and yellow, hard	5	82
Gravel, coarse	4	86
Clay, blue, hard	4	90
Clay, blue, soft	5	95
Clay, blue, soft gummy	9	104
Clay, blue; 1/2" gravel	4	108
Clay, blue; heavy large gravel	2	110
Clays, sandy cream and blue; large gravel	10	120
Gravel and blue clay	40	160
Clay, blue	5	165
Clay, blue; gravel	2	167
Clay, blue	2	169
Clay, white to yellow; gravel, "hot water clay deposits"	21	190
Sand and gravel, no clay	8	198
Clay, blue	2	200
Clay, blue; fine sand	20	220
"Small stratas of white and green clays"	8	228
Clay, yellowish white; "hot water deposits"	22	250
Limestone, white, hard; "hot water lime"	3	253
Clay, white; quartz, some red gravel	12	265
"Terrific loss of drilling mud, level dropped 20', well began flowing before rods could be pulled. Flowing 212 gpm. Static head is in excess of 35', small volume. It is hard to determine exactly where the flows are originating.	2	267

Table 4. (continued)

	Thickness (feet)	Depth (feet)
37/29-11b2		
Mud, black	16	16
Clay, gray, sandy; some water	18	34
Clay, white	18	52
Clay, blue	2	54
Sand, black; water	4	58
Clay, white	19	77
Sand, brown; water	4	81
Clay, blue	8	89
Sand, brown; water	7	96
Clay, brown	8	104
Sand, brown	9	113
Clay, brown	8	121
Clay, blue	35	156
Sand, brown	2	158
Clay, yellow	4	162
Clay, blue	12	174
Sand, brown	6	180
Clay, white; sand	3	183
35/25-33a1		
Casing perforated 134' to 144' 1/4" x 6"		
"Fine granite sands"	20	20
Sand, coarse, and clay	5	25
Gravel and clay, cemented	5	30
Gravel and hard pink clay	64	94
Clay, pink, soft	6	100
Clay, sand, and fine gravel	10	110
Clay, pink, medium soft	10	120
"Small hard and soft strata alternate"	14	134
Gravel, small loss of mud	1	135
Clay, pink, hard	1	136
Gravel, medium loss, small amount of water	4	140
Clay, sand, hardpan	4	144

	Thickness (feet)	Depth (feet)
33/29-5d1		
Top soil	15	15
Clay, yellow	18	33
Gravel; water	5	38
Clay, blue	14	52
Shale, brown	11	63
Gravel; water	3	66
Shale, brown	11	77
Clay, gray	8	85
33/29-8b1		
Casing perforated 30' to 164' 1/4" x 3"		
Top soil	15	15
Clay, yellow	18	33
Gravel; water	5	38
Clay, blue	14	52
Shale, brown	11	63
Gravel	3	66
Shale, brown	11	77
Shale, blue; gravel	20	97
Clay, gray, sandy	56	153
Gravel, quartz	4	157
Clay, brown, sandy	6	163
Clay, gray, sandy	25	188
Clay, brown	4	192
Clay, dark brown	18	210
Clay, light brown	32	242
Hardpan and shale	20	262
Clay, light gray	13	275
Clay, brown	53	328
Clay, gray	48	376
Clay, brown	14	390
Clay, gray	10	400

Table 4 (continued)

	Thick-ness (feet)	Depth (feet)
33/29-34b1		
Casing perforated 50' to 108' 1/8" x 3"		
Clay, sandy	7	7
Gravel and clay	8	15
Gravel, large; clay	40	55
Sandstone, soft	5	60
Clay, sandy	7	67
Gravel, cemented	63	130
Gravel, cemented; boulders	34	164
Rock, gray, solid	4	168

Table 5.--Chemical analyses, in parts per million, of ground water in the Black Rock Desert Area

(Analyses by U.S. Geological Survey)

Well or spring	Date of collection	Temperature °F	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 $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Calcium magnesium	Specific conductance (Micromhos at 25°C)	Dissolved solids residue at 180°C	Sodium-adsorption-ration (SAR)	Residual sodium carbonate (RSC) in equivalents per million	pH	Remarks
42/31-11b1	10- 8-60	75	65	18	2.4	34	4.8	0	104	25	15	0.6	0.8	0.11	0	54	259	244	2.0	0.63	7.7	- -
40/24-23	5- 6-61	-	65	2.4	1.5	76	0	0	96	39	21	12	.5	.82	0	12	357	272	9.5	1.32	7.6	Soldier Meadows warm Springs
40/27-23b1	5- 3-61	60	79	11	2.4	63	11	0	151	21	28	.4	.8	.17	0	37	376	290	4.2	1.63	7.8	- -
40/28-29	?	212	-	-	-	-	-	0	420	126	159	-	-	-	-	-	-	1043	-	-	-	Pinto Mtn. Hot Spring
39/17-30d1	5- 6-61	74	34	6.4	.2	55	.6	0	120	15	11	.3	.3	.32	0	17	264	186	5.8	1.75	8.2	Cain Spring
37/25-9d1?	6-14-61	-	84	18	6.9	66	5.4	-	148	32	42	1.2	0	-	0	74	451	-	3.3	.55	7.3	- -
37/25-10d1	6-14-61	97	79	9.6	2.8	78	11	-	165	38	28	1.8	0	-	0	35	446	-	5.8	1.29	7.8	- -
37/27-8d1	5- 3-61	60	70	11	5.6	786	15	0	1150	95	500	3.9	1.1	7.9	0	50	3280	2070	48.3	17.84	8.2	- -
36/26-34b1	5- 3-61	136	62	18	1.9	486	13	0	902	130	155	8.9	.2	2.8	0	52	2050	1330	29.3	13.84	7.9	Black Rock Hot Spring
35/24-36c1	1-13-62	60	64	3.2	1.2	168	10	19	257	47	58	1.4	.1	.5	0	13	766	499	21.0	3.95	8.7	- -
34/25-16d1	5- 3-61	-	58	12	19	1160	15	0	1210	5.8	1170	1.5	1.1	4.5	0	109	5150	3060	49.3	17.74	7.8	Coyote Spring
34/30-35c1	6-11-61	60	26	62	14	72	.8	-	165	66	111	.3	.2	-	78	214	767	-	2.0	0	7.3	- -
33/23-26d1	4- 9-45	-	44	-	-	305	-	48	361	79	160	-	-	-	-	-	-	795	-	-	-	- -
33/25-10b1	9- 2-47	68	101	15	4	272	-	14	88	163	272	-	-	-	-	58	-	880	15.6	.30	-	- -
33/25-10b4	6-12-61	92	94	13	.6	272	8.4	-	93	156	278	2.9	.2	-	0	35	1410	-	19.9	.86	7.4	- -
32/25-15b1	5- 7-40	-	135	102	26	1476	-	0	227	353	2016	-	-	-	-	362	-	4135	29.6	0	-	Great Boiling Spring

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United States Department of Interior
Geological Survey

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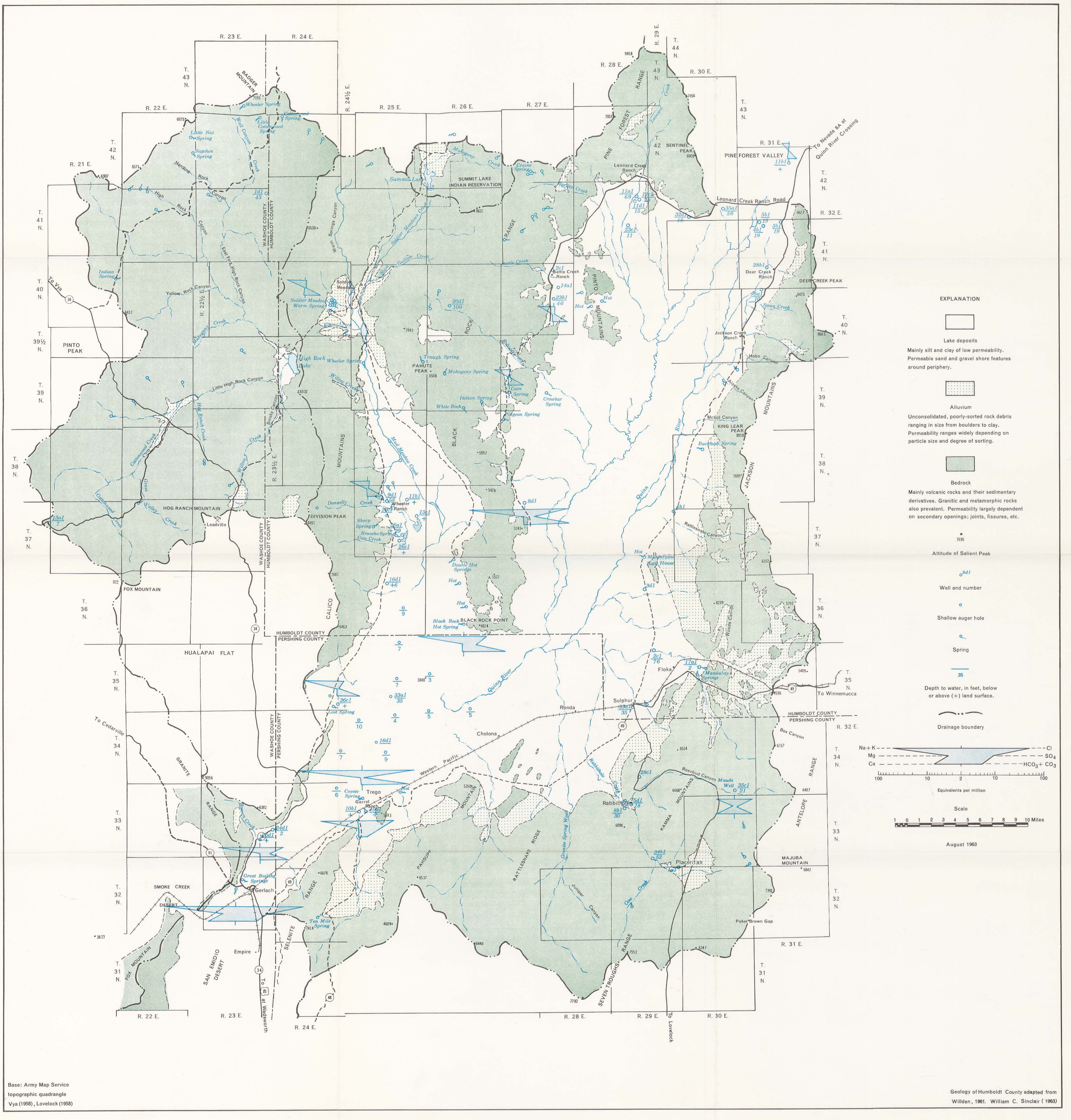

Plate 1.—Generalized Geologic and Hydrologic Map of the Black Rock Desert area, Northwestern Nevada