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RECONNAISSANCE OF GROUND WATER IN THE WESTERN PART OF THE MOJAVE DESERT REGION, CALIFORNIA

By
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INTRODUCTION

PURPOSE AND SCOPE OF THIS PAPER

Interest in the cultural development of the Mojave Desert region of California has existed ever since completion of the first transcontinental railroad in 1869. Particularly since World War II, interest in the agricultural, industrial, military, and recreational potentialities of the area has greatly increased. Some parts of the region, such as Antelope Valley, are relatively well developed; other areas, such as Cuddeback and Superior Valleys, are virtually unchanged from the natural state.

Ground water is a vital resource in the development of the region, and there has been much speculation among geologists concerning Pleistocene and older drainage lines in the region. However, there are large areas where not only the older drainage lines but also the present source, occurrence, and movement of ground water are still unknown. To develop properly the water resources and to resolve many questions concerning the geologic history and structure of the region, knowledge of the source, occurrence, and movement of ground water in the region is necessary.

The purpose of this atlas is to summarize the progress of ground-water studies in the western part of the Mojave Desert region and to discuss areas where further study is necessary for an understanding of the source, occurrence, and movement of ground water.

EARLIER REPORTS ON THE REGION

Many geographic, geologic, and hydrologic reports have been written on the Mojave Desert region. The earliest significant general report is that of Fremont (1845), and the most comprehensive hydrologic report is that of Thompson (1929).

The geologic map of this report is generalized, in large part, after unpublished mapping made available by T. W. Dibblee, Jr., U. S. Geological Survey, and after earlier reports of the Geological Survey and of the California Division of Mines. No attempt was made to assemble here a complete list of references for the Mojave Desert region, but many pertinent reports were reviewed and are listed as references.

LOCATION, EXTENT, AND SUBDIVISIONS OF THE REGION

The term "Mojave Desert region" is a general one and does not refer to a well-defined physiographic province. Thompson (1929, p. 5) stated, "At present some confusion exists as to just what is included in the Mojave Desert." A review of the literature published since 1929 indicates no clarification regarding the boundaries of the Mojave Desert. In conformance with Thompson's usage (1929, p. 7), the term "Mojave Desert region" here refers only to a general location, as does the term "southern California."

The Mojave Desert region, as defined above, is part of the Basin and Range physiographic province of Fenneman (1931). That part of the Basin and Range province in California is subdivided into the Great Basin, the Salton Trough, and the Sonoran Desert sections (index map).

The Great Basin in southern California is that area east of the Sierra Nevada and north of the Garlock fault zone and its easterly projection to the California-Nevada State line. The Salton Trough is that area east of the coastal drainage area and, following Mendenhall (1909a, p. 11), west of the San Bernardino, Cottonwood, Chocolatta, and Cheesboro Mountains. The Sonoran Desert is south of the Great Basin and east of the Salton Trough.

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The western part of the Mojave Desert region of southern California (geologic map) lies south of the Tehachapi Mountains, east of the Sierra Nevada, and northeast of the San Andreas fault zone between lat 34°00' and 36°00' N. and long 116°30' and 119°00' W.; however, the generalized geologic units and principles of ground-water occurrence, source, and movement discussed for this area apply also to the entire Mojave Desert region.

GEOLOGY

FORMATIONS

For this atlas, the geologic formations of the Mojave Desert region are divided into four main groups based on age, distribution, and capacity to contain and yield water. The areal distribution of these groups, the consolidated rocks, the older alluvium and lacustrine deposits, the younger alluvium, and the younger lacustrine (playa) deposits, is shown on the geologic map, and their stratigraphic relations and lithologic character are discussed below.

Consolidated rocks.—The consolidated rocks are predominantly sedimentary, igneous, and metamorphic rocks of the pre-Tertiary basement complex and volcanic and sedimentary rocks of Tertiary age. In general, none of these rocks are significant sources of ground water, although small amounts may percolate through weathered and fractured zones.

The consolidated rocks surround the main valley areas and form the mountain-area catchment areas from which runoff, flowing onto the alluvial fans, contributes most of the recharge to the ground-water bodies. These rocks also form the sides and bottoms of the alluvium-filled structural basins which contain the main ground-water bodies of the valleys.

Older alluvium and lacustrine deposits.—The older alluvium, the principal water-bearing material, is composed of undeformed to moderately deformed lenticular deposits of unconsolidated to poorly indurated silt, sand, gravel, and boulders; locally it includes lacustrine deposits. The older lacustrine deposits are predominantly silt, silty clay, and clay interbedded locally with thin beds of impure limestone, calcareous sandstone, conglomerate, and sand. Some of the older lacustrine deposits are interbedded with the older alluvium. The thickness of these deposits, determined from well logs, ranges from zero near the margins of the basins to as much as 1,500 or 2,000 feet in the central parts of the basins. Where observed, the older alluvium and older lacustrine deposits unconformably overlie the consolidated rocks and are exposed in terraces along stream channels and washes. These deposits appear to be separated from the overlying younger alluvium and younger lacustrine deposits by an erosional unconformity. They are well exposed in the western part of Antelope Valley, along the Mojave River, and in Fremont, Indian Wells, and other valleys as shown on the geologic map. In these localities the older alluvium is compacted and is generally cemented by clay minerals formed from the weathering of the feldspar minerals. These deposits are generally considered to be early to middle Pleistocene in age, but the lowermost part may be late Tertiary in age.

The older lacustrine deposits locally contain coarse uncemented sand that yields large quantities of water; however, they are composed predominantly of silt and generally do not yield water freely to wells.

Younger alluvium.—The younger alluvium is composed of lenses of silt, sand, gravel, silt and gravel, sand and gravel, and boulders. These deposits overlie the older alluvium, the older lacustrine deposits, and the consolidated rocks. Well logs indicate that they range in thickness from 0 to 100 feet or more. They form a continuous and conformable sequence that probably spans an age range from late Pleistocene to Recent.

The younger alluvium is shown on the geologic map as a single sequence which, on larger scale maps, can be differentiated into several units. It was deposited largely by intermittent streams of low gradient or by distributaries from several coalescing fluvial fans. The younger alluvium is highly permeable and, where saturated, yields water freely to wells.

Younger lacustrine (playa) deposits.—The lowest parts of nearly all the closed desert basins are occupied by playas, or "dry lakes," most of which are nearly flat. These lakebeds are formed by the finest grained stream-borne materials, which are transported to the lowest parts of the basins by infrequent runoff.

The younger lacustrine deposits consist principally of clay or silt, thin lenses of sand, and a little gravel. Locally they include evaporites which, in a few places, are of sufficient thickness and extent to be of economic value. The playa deposits overlie the older alluvium and older lacustrine deposits along the margins they grade laterally into the younger alluvium. The thickness of these deposits ranges from 0 to 100 feet or more.

The playas are surfaces of active deposition; however, the playa deposits probably represent a continuous and conformable sequence of deposition from late Pleistocene to Recent time. The contact between the playa deposits and the older lacustrine deposits usually cannot be differentiated. Logs of typical wells that penetrate the playa deposits and underlying older lacustrine deposits are given by Pratt and Smith (1967) in their studies of Owens, China, Searles, and Panamint Lakes.

The clay and silt of the playa deposits are of low permeability, and, except for the scattered sand lenses, they generally are not a source of water.

The playas are differentiated on the geologic map according to whether they are of the dry, the moist, or the undetermined type. Because the nature of the playa is related to the occurrence, source, and movement of ground water, its significance is discussed in the ground-water section of this atlas.

GEOLOGIC STRUCTURE

The western part of the Mojave Desert region is characterized by numerous alluvium-filled intermontane basins. The principal structural controls in many of these basins are major faults which displace both the consolidated rocks and the alluvium. The two principal fault zones are the San Andreas, a northwestward-trending feature that has been traced from north of San Francisco to south of the Mexican border, a distance of about 1,000 miles; and the Garlock fault zone, a southwestward-trending fault zone which extends from its intersection with the San Andreas fault west of Lancaster, Calif., on the west almost to the Nevada-California State line on the east.

Between these two fault zones many northwestward-trending faults approximately parallel the San Andreas fault. Several of the most prominent are the Muroc, Helendale, Lockhart, and Gravel Hills faults, as shown on the geologic map. North of the Garlock fault, one of the principal structural features is the northward-trending Sierra Nevada fault, west of which the Sierra Nevada has been uplifted to an altitude of 14,450 feet above sea level. East of the fault the lowest altitude, in Death Valley, is about 280 feet below sea level.

Faulting that has resulted in significant displacement of the alluvial deposits has formed barriers that greatly impede or otherwise control the movement of ground water. On opposite sides of faults ground-water levels are locally displaced more than 300 feet.

GROUND WATER

Ground water may be defined as the water contained in pores, cracks, and other voids in the rocks and deposits below the water table. Ground water in any locality has as its ultimate source the precipitation that falls on the drainage area tributary to that locality. The lowest part of the valley is occupied by a playa that is one more than a small part of the precipitation that falls on any area of appreciable size. A large part may be intercepted by plant foliage after a storm and evaporated without having reached the land surface. Of the precipitation that does reach the land surface, and that does not immediately run off, part remains on the surface and is subject to evaporation, and part seeps into the soil to satisfy the moisture deficiency in the belt of soil water. From this shallow zone immediately below the land surface, water is discharged into the atmosphere by evaporation or is used by plants. Excess water, if any, can then percolate downward to the water table and recharge the ground-water body.

Ground water does not occur as "underground lakes" or "streams," except locally in areas of cavernous limestone or volcanic rocks. No such rocks are known to supply large quantities of water to wells in the Mojave Desert region. Except for minor amounts of water discharged by artesian wells drilled in fractured zones in the consolidated rocks, the principal sources of ground water in the Mojave Desert region are the unconsolidated alluvial deposits that occupy the lower parts of the valleys.

Not all the unconsolidated deposits are equally capable of yielding water to wells. For example, loose rounded well-sorted gravel and sand are more permeable than are clay, silt, cemented sand, cemented gravel, and compacted angular poorly sorted material. The yields of wells are dependent on the permeability and the saturated thickness of the deposits in which the wells are completed.

In most of the basins in the Mojave Desert region the water table lies at or near the base of the younger alluvium, and, because the younger alluvium is largely unsaturated, most of the water that is withdrawn comes from the underlying older alluvium.

The western part of the Mojave Desert region is characterized by many closed topographic basins of interior drainage and by a series of successively lower basins, the lowest unit of which receives all the surface drainage from the entire series. The closed basins and the lowermost unit of the closed series of basins, having no surface outlet, are sites of playas, or dry lakes, where water is accumulated and discharged by evaporation and transpiration. Some topographically closed basins are hydrologically connected with similar adjacent basins; there is also ground-water underflow from the highest to the lowest basins of the interconnected series, the lowest of which has no surface or subsurface outlet.

Under the natural conditions that prevailed before development by pumping, a state of equilibrium existed in which the natural discharge equaled natural recharge and ground-water storage changed only seasonally and with periods of dry and wet years. Ground-water pumping upsets this natural balance, and if pumpage plus the natural discharge exceeds recharge, ground water will be taken from storage and water levels will decline. If pumping is prolonged sufficiently, the natural discharge will be lessened and may eventually cease, and water levels will continue to decline. Water levels will stabilize at a lower level when pumping becomes uneconomical because of decreased well yields, high pumping costs, or deterioration of water quality.

In many of the ground-water basins in the western part of the Mojave Desert region, it is impractical or impossible to interrupt more than a small part of the natural discharge, and in most of the developed ground-water basins the annual withdrawal by pumping probably greatly exceeds the recharge. Most of the water pumped from wells in the western part of the region has been and will continue to be withdrawn from storage. Such withdrawal from storage, or "mining" of ground water, can be considered practical in these desert areas, however, because limiting the use of water either to the perennial yield[1] or to the natural recharge would not allow full utilization of this important natural resource of stored water. In this regard, Snyder (1955) gave an excellent discussion of the legal and economic implications for an area of large overdraft (Antelope Valley).

ANTELOPE AND FREMONT VALLEYS AREA

The area comprising Antelope and Fremont Valleys is a series of basins in which ground water, under natural conditions, moves downgradient from one basin to the other. Precipitation on the entire drainage area, but mainly on the San Gabriel Mountains to the south and the Tehachapi Mountains to the west, is the source of most natural ground-water recharge to the area. The relatively small part of the precipitation that percolates to ground water as recharge moves, in general, from the margins of Antelope Valley toward the south end of Rogers Lake, where most of the water goes into the cone of depression formed by pumping for irrigation. Some water moves northward beneath Piute Mountains and a narrow alluvium-filled slot in the consolidated rocks and continues toward Koehn Lake in Fremont Valley. Increments of recharge also move toward Koehn Lake from the Boron area and from the west side of Koehn Lake.

Ground water also moves eastward through Tehachapi Valley into the Chaffee area, where the Muroc fault acts as a barrier, impeding but not preventing further movement eastward into Fremont Valley. The water-level contours on opposite sides of the Muroc fault indicate a displacement of water level of approximately 320 feet. The average depth to water in wells south of the fault is about 200 feet below the land surface, whereas water levels immediately north of the fault average more than 500 feet below the land surface.

Under natural conditions, the depth to water beneath parts of Proctor Lake in Tehachapi Valley and beneath Rosamond, Buckhorn, and Rogers Lakes in Antelope Valley is less than 10 feet. In most of Antelope and Fremont Valleys the water is of a quality suitable for irrigation and domestic uses. However, because Koehn Lake is the "sink," or "sump," for the entire area, ground water is virtually at the land surface beneath this playa; and, because of the evaporation and transpiration of water in the vicinity of the playa, the concentration of chloride exceeds 14,000 ppm (parts per million) and the dissolved solids are as high as 28,000 ppm.

Antelope Valley is the largest area in the Mojave Desert region in which successful agricultural development has resulted almost exclusively from ground-water pumping for irrigation. Consequently, the problem of water-level decline in the central part of the valley due to heavy pumping has been studied in greater detail than that in other valleys.

In Antelope Valley the use of ground water for agricultural purposes dates to the early 1890's, when it was discovered that in the lower parts of the valley wells drilled 200 to 500 feet deep yielded flowing water artesian water. Ground water in place was used for irrigation. According to Thompson (1929, p. 20), it was reported that in 1890 about a hundred wells were in use in the valley. Johnson (1911, pl. 6) showed the locations of 353 wells in 1908, many of which were within an area of artesian flow. Thompson (1929, pl. 32b) at the completion of his fieldwork about 1929 reported data for 171 key water wells in Antelope Valley and estimated pumpage in the valley for the irrigation of 11,960 acres to be 35,100 acre-feet per year. In the period 1945–51 the land under irrigation increased from about 44,000 acres to about 70,000 acres, and the irrigated acreage may be larger at present (1959). During 1951–52 about 1,100 water wells of all types in the northeastern part of Antelope Valley were inventoried. Snyder (1955, p. 87) estimated that the net draft of ground water in Antelope Valley during 1951 was about 195,000 acre-feet. The water-level contours shown on the geologic map for Antelope Valley for the year 1954 show a considerable depression southeast of Rosamond Lake caused by the heavy pumping.

As the land most suitable for irrigation in the central part of Antelope Valley is still being developed agriculturally, the demand for water is increasing and many new wells are being drilled each year. Heavy ground-water withdrawals there decrease the amount of water locally available and cause the water levels to decline at an accelerated rate. This decline, in many cases, makes necessary the drilling of new wells or the deepening of old ones in order to maintain the previous supply. Increased annual use of water in this area only tends to aggravate the situation that now exists.

On the basis of data compiled by Snyder (1955, p. 87), it appears that overdraft in Antelope Valley, mainly a result of pumping for irrigation northeast of Lancaster, has existed at least since the early 1920's. It is estimated that the cumulative overdraft in the valley may have reached 1½ to 2 million acre-feet as of 1951 and probably exceeds that of any other ground-water basin in southern California. Some discharge still occurred in an area of artesian flow prior to 1954; however, during 1952–54 the uncapped wells flowed for less than 6 months a year and the discharge from flowing wells was negligible compared to the total discharge from pumping within the basin. All wells ceased to flow prior to 1955.

MOJAVE RIVER VALLEY AREA

The drainage area of the Mojave River valley area is one of the largest in the Mojave Desert region. It is irregularly shaped and extends from the southwestern part of San Bernardino County northeastward to Barstow and eastward to Soda Lake (outside mapped area), which is the "sink," or "sump," area of the Mojave River.

The Mojave River rises on the north side of the San Bernardino Mountains, where it is a perennial stream; however, within a short distance after it emerges onto the alluvial plain, the water infiltrates into the porous materials so that the river is entirely dry throughout much of its course for months and sometimes years at a time.

Ground water in the Mojave River valley generally moves northward through the alluvial deposits from areas of recharge in the Upper Mojave, the Apple and the Fifteenmile Valleys into the Middle Mojave Valley. In the Middle Mojave Valley ground water moves northeastward toward Barstow; however, west of Barstow an increment of ground water moves north and then west into Harper Valley. Under natural conditions ground water beneath most of Harper Valley is less than 10 feet below the land surface, and the playa is moist. Irrigation west of Harper Lake has created a large pumping depression centered beneath the irrigated area. (Stone, 1957, pl. 3.)

Cuddeback Valley is a closed topographic basin north of Harper Valley. Its playa is of the dry type, and a few water-level data suggest that ground water moves southward through a narrow tongue of alluvium into Harper Valley. Ground water in much of Cuddeback Valley is of poor quality and is not suitable for irrigation.

From Barstow ground water moves eastward through the Lower Mojave Valley and Afton Canyon toward Soda Lake (outside mapped area), which is a discharging playa east of the area shown on the geologic map. Both Troy and Coyote Lakes are moist playas, indicating that there is movement of ground water toward them. However, water beneath both these lakes is in hydraulic continuity with water beneath the Mojave River. Hence, the areas tributary to Coyote and Troy Lakes are also part of the Lower Mojave Valley area.

The agricultural, military, and urban development of parts of the Mojave River valley, including the areas of Harper, Coyote, and Troy Lakes, is based on the use of ground water. The area also has great potential for additional development. Frequently, during wet years, surface water in the river flows from the Lower Mojave Valley to Soda Lake and is wasted because the ground-water basin upstream remains full, and storage space is not available to accept available recharge. Full utilization of the water resources of the area will require much more study and analysis of the geology and hydrology of the areas than have been made to date.

EL MIRAGE VALLEY AREA

El Mirage Valley is a small area at the west-edge of the Upper Mojave Valley, east of Antelope Valley. The lowest part of the valley is occupied by a playa that appears to be of the dry type. The water level in one well at the west end of the playa in 1956 was about 18.8 feet below the land surface. One measurement in another well indicates that the depth to water beneath the playa in 1917 may have been as little as 16 or 17 feet below the land surface. According to Thompson (1929, p. 109), "This fact is believed to indicate that there is underground drainage from beneath the playa." However, the water-level contours, which were not available to Thompson, indicate a movement of water toward El Mirage Lake from all sides, suggesting that some evaporation from the playa occurs even though the depth to water is greater than 10 feet.

According to Thompson (1929, p. 125–126), in playas where the depth to water is more than 10 feet below land surface, the ground water is too far below the surface to be discharged by capillary rise and evaporation. According to Lee (1912, p. 53), evaporation from bare soil does not occur where the depth to water exceeds 7½ or 8 feet. However, preliminary studies by the author in several desert playas indicate that in playas having tight soils evaporation takes place from bare surfaces where the depth to water is greater than 15 or 20 feet. Evaporation from the bare soil may occur locally where the depth to water exceeds 40 feet, but additional studies are necessary to demonstrate quantitatively that ground water is able to discharge from bare playa surfaces where the depth to water in wells exceeds 15 feet.

LUCERNE, FRY, JOHNSON, AND MEANS VALLEYS AREA

Lucerne, Fry, Johnson, and Means Valleys are four closed topographic basins that occupy approximately 180 square miles along the north flank of the San Bernardino Mountains.

Lucerne Valley is the most highly developed of the four valleys; it had more than 450 wells in 1954. Many of the wells are 200 to 500 feet deep and are used for irrigation. The deepest well in the valley was drilled to a depth of 778 feet and bottomed in bedrock. The lowest part of the valley is occupied by a playa that is now borderline between a moist and a dry type. Under natural conditions ground water discharged from the surface of the playa; however, pumping of ground water for irrigation has lowered water levels in the valley so that evaporation from the surface may have ceased.

Fry and Johnson Valleys lie east of Lucerne Valley but occupy the same structural basin. The lowest part of Fry Valley is occupied by a playa of the dry type. The presence of the moist-type playa, Melville Lake, in the lowest part of Johnson Valley indicates that ground-water underflow from Fry Valley probably moves eastward toward the lake.

Means Valley, the easternmost of the areas considered, is occupied by a playa of the moist type. However, it is unlikely that there is ground-water underflow from Johnson Valley into Means Valley.

INDIAN WELLS AND SEARLES VALLEYS AREA

Indian Wells and Searles Valleys are two separate alluvium-filled valleys but are parts of the same drainage system. The maximum known thickness of the alluvium in Indian Wells Valley is 1,350 feet and of that in Searles Valley is 875 feet.

During the latter part of the Pleistocene epoch, Indian Wells and Searles Valleys were occupied by a single lake whose surface, at an altitude of about 2,265 feet, was about 640 feet above the present surface of Searles Lake and about 100 feet above the present surface of China Lake. At the close of Pleistocene time a gradual desiccation of Searles and China Lakes began, during which flow between the two lakes cut a low saddle in the Argus Mountains that drained China Lake into Searles Lake. As desiccation progressed, these two lakes became separated and eventually they dried up. The once-connecting channel is now partially filled with windblown sand.

China Lake now is a moist playa surrounded by a large area covered mainly with salt grass and pickleweed. Searles Lake also is a moist playa or swamp, and by virtue of underflow through the former surface-water channel it is the sink for all the drainage tributary to Indian Wells and Searles Valleys.

Ground water in Indian Wells Valley is derived mainly from precipitation on the Sierra Nevada. However, there is some underflow into the valley from the north through a narrow alluvium-filled channel, as well as recharge from precipitation on the Argus and El Paso Mountains and direct infiltration of precipitation on the valley floor.

Under natural conditions the ground water moved toward China Lake. The evapotranspiration in 1953 from the playa and surrounding moist land was estimated by the author at approximately 8,000 acre-feet, and in addition there was about 20 acre-feet of subsurface outflow into Salt Wells Valley, from which, in turn, a minor amount of very salty ground water was discharged as surface flow into Searles Valley.

Development of ground water in Indian Wells Valley has been extensive, and according to Lee (1912) many wells had been drilled in the valley prior to 1912. Thompson (1929) reported that as of 1919 about 800 acres was under cultivation. Pumpage in 1953 was about 2,800 acre-feet, and it increased progressively to about 10,000 acre-feet in 1959. Most of this water was pumped in the southern part of the valley. The effect of the pumping is reflected by the water-level contours on the geologic map, which show a pumping depression in the vicinity of Ridgecrest. Water levels in the northern part of the valley and the rate of evapotranspiration from China Lake closely approximate natural conditions. This fact indicates that a large part of the water pumped from the southern part of the valley has been withdrawn from storage. It is estimated that the upper 100 feet of saturated alluvium in the central part of the valley contains about 720,000 acre-feet of ground water in storage. Therefore, if wells are properly spaced it will be possible to pump ground water from storage at present rates for many tens of years without importation of water from outside sources.

Except for a few springs, there are no known supplies of potable ground water in Searles Valley. The water beneath Searles Lake is highly saline and has been pumped for many years as a source of potassium and other valuable salts. Virtually all the potable water used in Searles Valley is imported by pipeline from Indian Wells Valley.

PANAMINT VALLEY AREA

Panamint Valley, lying east of Searles Valley, is a long, narrow, north-northwestward-trending alluvium-filled valley whose physical features suggest that it is a graben, or downfaulted block. The maximum thickness of the sedimentary deposits in this basin is more than 995 feet (Pratt and Smith, 1967). The central and lowest part of the valley is the sink for the tributary drainage area and is occupied by a moist playa. There is a considerable growth of salt grass and pickleweed along the margins of the playa. Except at a few cattle ranches that are supplied with water by several springs along the east side of the valley, there is virtually no development of ground water in the area. The most detailed analysis to date of the geology and hydrology of Panamint Valley was made by Thompson (1929).

SUPERIOR VALLEY AREA

Superior Valley is a well-defined alluvium-filled topographic basin of interior drainage about 25 miles north of Barstow. The lowest part of the valley contains three separate small dry-type playas which are aligned nearly east-west across the valley. At one time, surface water probably flowed out the southwest corner of the valley through a canyon into Harper Valley. However, movement along small unmapped faults, which trend northwestward along the southwest border of the valley, and local deposition of alluvial-fan deposits have blocked the former surface outlet.

Granitic rocks compose the west margin and parts of the south and east margins of the valley. Basalt underlain by continental deposits of Tertiary age forms the southwest boundary. The northern part of the area is underlain almost entirely by continental deposits of Tertiary age.

The depth to water beneath most of the central part of the valley is between 87 and 110 feet below the land surface, and the quality of the water is suitable for irrigation. The water-level gradients in the valley are very low and, owing to a lack of precise determinations of land-surface altitudes at the wells, it is difficult to determine where ground water discharges from the valley. The available data suggest, however, that ground water may move beneath basalt flows along the southwest margin of the valley and may discharge into Harper Valley.

More than 100 persons lived in the valley during 1917–20, but during 1953–55 the southern part was uninhabited. The occupation of the northern part of the valley by a military reservation, the isolation of the area, lack of electric power, and distance to market contribute to the lack of irrigation development in the area.

CAMP IRWIN AREA

The Camp Irwin area includes the ground-water basins beneath Camp Irwin, Langford Lake, and Bicycle Lake. Camp Irwin overlies a ground-water basin filled with more than 500 feet of alluvium. The camp supply is derived from six wells drilled in the central part of the basin. As no playa occupies the central part of the basin, it is believed that ground water discharges from the Camp Irwin basin to the southeast by underflow into another alluvium-filled basin, the lowest part of which is occupied by Langford Lake, a dry-type playa. Ground water from Langford Valley, in turn, moves eastward by underflow into Cronise Valley, which is east of the area shown on the geologic map. One well drilled southwest of Langford Lake penetrated alluvium to a depth of 500 feet and was test pumped at 695 gpm (gallons per minute) with 158 feet of drawdown.

Bicycle basin lies immediately east of the Camp Irwin basin and is separated from it by a low divide of consolidated rock. The lowest part of Bicycle basin is occupied by Bicycle Lake, a dry-type playa. One well drilled north of Bicycle Lake penetrated alluvium to a depth of 444 feet and was test pumped at a rate of 710 gpm with a drawdown of 90 feet. A preliminary examination of the geology indicates that ground water moves north and east by underflow toward Red Pass Lake, a playa east of the area shown on the geologic map.

GRANITE MOUNTAINS AREA

South of the Garlock fault zone in the vicinity of the Granite Mountains, an extensive area is reserved for use by the military services. The area includes Randsburg Wash and Goldstone, Nelson, McKean, Drinkwater, and Leach Lakes.

Measurements of water level in two wells in Randsburg Wash indicate that ground water moves from west to east in that area. Moist ground east of Drinkwater Lake (east of area shown on the geologic map) indicates that ground water beneath the lake moves from west to east into another ground-water basin at a lower altitude. As no well data are available for the remainder of the area and as the geology shown is based on a very brief reconnaissance, the direction of ground-water movement as shown is speculative. All the playas in the area appear to be of the dry type, indicating that ground water discharges by underflow out of the area.

DEATH VALLEY AREA

The Death Valley area includes Death Valley, Wingate Pass, Lost Lake, and Owl Lake. The lowest point in Death Valley is 282 feet below sea level and is the lowest point not only in the Mojave Desert region but also in the United States. The central part of Death Valley is occupied by an extensive moist playa where water is at or near the land surface and is highly mineralized and not suitable for domestic or irrigation use. There are many springs in the area, however, some of which were described in detail by Thompson (1929).

Wingate Pass, Lost Lake, and Owl Lake are considered parts of the Death Valley area, but no ground-water data, except those given by Thompson (1929), are available for these areas at the present time. The source, occurrence, and movement of ground water in these areas, for all practical purposes, are unknown.

SUMMARY

Except for the monumental work of Thompson (1929), no comprehensive ground-water studies of the entire Mojave Desert region have been made. In many areas in the region the U. S. Geological Survey, in cooperation with the California Department of Water Resources, has conducted a continuing program of basic-data collection. Analysis, interpretation, and utilization of these data, however, have not progressed as fast as the water needs of the region. For the area north of the Garlock fault and east of Indian Wells Valley and for the Randsburg Wash-Granite Mountains area, virtually no ground-water data are available and none are being collected. For Antelope Valley many data, covering most of the valley, are available, but in relation to the intensive development of the area the study and analysis of the data are inadequate.

Because the rapidly expanding agricultural, urban, and industrial development in the Mojave Desert region is based for the most part on the mining of ground water, there exists for the entire Mojave Desert region a critical need for an accelerated and continuing program for collection of basic data, for detailed geologic studies with particular reference to ground water, and for studies of quantitative ground-water occurrence, source, and movement.

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[1] Perennial yield of a ground-water basin may be defined as the rate at which ground water can be withdrawn year after year without depleting the ground-water storage to such an extent that withdrawal at this rate is no longer feasible because of increased pumping costs or deterioration of water quality.

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HYDROLOGIC INVESTIGATIONS
ATLAS HA-31

PRELIMINARY MAP SHOWING VALLEY-FILL AREAS AND SOURCE, OCCURRENCE, AND MOVEMENT OF GROUND WATER IN THE WESTERN PART OF THE MOJAVE DESERT REGION, CALIFORNIA

By
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1962