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U.S. DEPARTMENT OF THE NAVY

Geology and Ground-Water Appraisal of the Twentynine Palms Marine Corps Training Center, California

U.S. Geological Survey Open-File Report 98-167

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGY AND GROUND-WATER APPRAISAL OF THE TWENTYNINE PALMS MARINE CORPS TRAINING CENTER, CALIFORNIA

By F.S. Riley *and* G.F. Worts, Jr.

WITH A SECTION ON THE ESTIMATED RUNOFF IN PIPES CREEK

By Walter Hofmann

Open-File Report 98-167

Prepared in cooperation with the
U.S. DEPARTMENT OF THE NAVY

7407-03

Long Beach, California
December 1953
[Retyped 2001]

U.S. DEPARTMENT OF THE INTERIOR
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FOREWORD

This report originally was completed in 1953 by the U.S. Geological Survey (USGS) in cooperation with the U.S. Marine Corps, Department of the Navy, as an Administrative Report. The purpose of the report was to present to the Department of the Navy results of a detailed ground-water investigation of the main ground-water basins at a Marine Corps Training Center that was under construction. This training center has evolved into the Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California.

Administrative reports may not be cited or quoted or released to the public. However, this report contains valuable information on the geology and hydrology of the area that has important implications on the availability, source, and movement of ground water. For these reasons, and because of the importance of ground water to the MCAGCC and surrounding area, this report has been retyped for public release at this time.

In some respects, this report does not conform to current USGS editorial standards and it uses technical terms that are no longer used by the USGS. Also, as is common in reports produced for other Federal agencies, direct recommendations are given by the author. To avoid confusion, however, the report has been reproduced largely as originally written. Because reproducibles are not available, photocopies were made of the illustrations (some of which are of poor quality because of the deterioration of paper and ink); the photocopies were retouched and placed at the back of the report. It is our belief that these deficiencies are outweighed by the advantages to the public of making the information in this report available to potential users.

Michael V. Shulters
District Chief

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s or second-ft)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min or gpm)	0.06309	liter per second
inch (in)	2.54	centimeter
inch (in)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
yard (yd)	0.9144	meter

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

***Transmissivity*:** The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

ABBREVIATIONS

epm	equivalents per million
dd	drawdown
ppm	parts per million

GEOLOGY AND GROUND-WATER APPRAISAL OF THE TWENTYNINE PALMS MARINE CORPS TRAINING CENTER, CALIFORNIA

By F.S. Riley *and* G.F. Worts, Jr.

INTRODUCTION

Purpose and Scope of the Investigation

This is the second report by the U.S. Geological Survey pertaining to the development of a ground-water supply for the United States Marine Corps Training Center at Twentynine Palms, California. The first report (Riley and Worts, 1952 [2001]) presented the results of the geologic reconnaissance and test-drilling program that were undertaken as a part of the initial exploration for a ground-water supply. A reconnaissance hydrologic investigation by W.O. Wagner (1952), consulting engineer, constituted the remainder of the initial exploration.

On the basis of the geologic reconnaissance, the test drilling was largely concentrated in two ground-water basins, termed Deadman and Surprise Spring Basins. These were found to contain relatively large quantities of potable stored ground water that could readily be pumped from wells. Subsequently, three highly productive supply wells, each capable of delivering 1,500 gal/min (gallons per minute) with moderate drawdown, were drilled in these basins on sites suggested by the Geological Survey.

In order to evaluate further the water supply being developed, the Navy, in a letter dated September 3, 1952, from the Bureau of Yards and Docks to the Geological Survey, requested that the Survey investigate the ground-water conditions of the area in more detail during the 1953 fiscal year, with special reference to the Deadman, Surprise Spring, and Mesquite Basins. The program outlined in a letter dated June 25, 1952, from the Acting Director of the Geological Survey to the Bureau of Yards and Docks, was as follows: (1) Estimate the ground-water storage capacity of Deadman and Surprise Basins; (2) estimate, if possible, the amount of recharge to these basins; (3) report on the chemical quality of water in these basins; (4) begin a water-level measuring program in these basins and in Mesquite Basin; and (5) provide consultation and advice on matters relating to ground-water development and artificial recharge operations.

The collection of basic data required for this program has entailed primarily the following activities: Further geologic studies were undertaken to define more accurately the geologic framework of the ground-water basins. Virtually all wells in Mesquite, Deadman, and Surprise Spring Basins, as well as those in two other basins to the west along the lines of probable recharge, were canvassed to obtain data on the occurrence and use of ground water. In addition, most of the wells in and around the town of Twentynine Palms, and other selected wells, were canvassed to define the limits of Mesquite Basin and to determine the relations between waters in Mesquite Basin and those in adjacent basins.

Altitudes above sea level were determined for selected wells by carefully controlled barometric leveling in order that the altitude of the water table in the wells and the hydraulic gradient between wells might be ascertained. Periodic water-level measurements were made and automatic water-level recorders were operated on selected wells to reveal the nature and magnitude of water-level fluctuations.

Water samples were collected from numerous wells and analyzed to determine the chemical quality of the ground waters in the various basins. Pumping tests were conducted on the three new Navy supply wells to determine the specific capacity of the wells and, if possible, the coefficients of storage and transmissibility of the aquifers penetrated.

Thus, the scope of this report is virtually limited to the pertinent geology and hydrology of Mesquite, Deadman, and Surprise Spring Basins, and two smaller basins, Pipes and Reche Basins, to the west. The report describes the geologic features that define the limits of the ground-water basins and discusses the water-bearing properties of the geologic formations; it describes the occurrence, source, movement, and chemical character of ground water in the various basins; it includes a section on the runoff of Pipes Creek, prepared by Walter Hofmann of the Surface Water Branch of the Geological Survey; it estimates the magnitude of ground-water recharge and certain elements of the discharge; it discusses water-level fluctuations, with specific reference to effects produced by pumping in the Navy wells; and it estimates the ground-water storage capacity of Deadman and Surprise Spring Basins. In addition it presents certain data on the yields of the new Navy supply wells.

The geologic and ground-water phases of the investigation have been carried on by the Geological Survey, U.S. Department of the Interior, under the direction of A.N. Sayre, geologist in charge of the Ground Water Branch; and under the general supervision of J.F. Poland, district geologist in charge of ground-water investigations in California. The surface-water phase of the work has been carried on under the direction of J.V.B. Wells, engineer in charge of the Surface Water Branch; under the supervision of R.C. Briggs, district engineer in charge of surface-water work in California; and under the immediate supervision of W.M. Littlefield, engineer in charge of the Los Angeles area office.

Location and General Description of the Area

The area discussed in this report is west of the center and along the southern edge of San Bernardino County, California, in the southeastern part of the Mojave Desert. It constitutes about 90 percent of the area between 116°00′ and 116°30′ west longitude and between 34°05′ and 34°30′ north latitude, which is the area shown on plate 1 (at the end of report).

Geographically, the area is a broad moderately high eastward-sloping desert basin completely surrounded by mountains or upland areas. This area was termed the Twentynine Palms Basin in the first report and is so called herein. The dimensions of the basin average about 25 miles (mi) in a north–south direction and 20 mi in an east–west direction; the area is approximately 500 square miles (mi^2).

The town of Twentynine Palms, in the extreme southeast corner of the basin, is the largest community in the area. West of Twentynine Palms are several small but growing towns. The largest of these are Joshua Tree and Yucca Valley, 15 and 22 mi west of Twentynine Palms, respectively, and outside the area under study in this investigation (pl. 1).

Acknowledgments

The writers are grateful for the cooperation given by the many persons and several agencies who provided information and assistance in many phases of the investigation. The Twentynine Palms office of the National Park Service provided repeated assistance in making available maps and other data from their files. The San Bernardino County Flood Control District made available records of water-level measurements and chemical analyses. Mr. William B. Hatch, Surveyor, was of great assistance in providing records of water-level measurements, well logs, chemical analyses, spirit leveling data, and much valuable general information. In addition, Mr. Hatch's map of the Morongo to Twentynine Palms area, showing the public land grid and road net, was largely used to compile the base for the southern half of plate 1. Mr. O.J. Cones, constable at Twentynine Palms, provided valuable assistance in the initial reconnaissance by flying one of the writers over the project area in his personal aircraft and pointing out the location of isolated wells and certain general features of ground-water occurrence. Mr. Walter Reche provided useful information regarding the location and description of wells, the nature of subsurface materials, and the character and frequency of runoff in Pipes Wash and other washes in the northwestern part of the Twentynine Palms Basin.

GEOLOGY

The first report presented a geologic reconnaissance of the entire Twentynine Palms Basin. This report, in the following section, discusses the regional geology briefly with emphasis on the pertinent geologic features of the ground-water basins that are critical to the water supply of the Training Center. Certain subsurface geohydrologic data obtained in the drilling and pumping of the Navy test and supply wells are presented in the section on ground-water basins.

Landforms

Most of the area shown on plate 1 is occupied by the broad, irregular, detrital plain of the Twentynine Palms Basin, which slopes eastward from a maximum altitude of about 3,600 feet (ft) along the foot of the San Bernardino Mountains to a minimum of about 1,800 ft in the trough that contains Deadman and Mesquite Dry Lakes. The basin is nearly surrounded by mountain ranges of rugged aspect and considerable relief. To the west the San Bernardino Mountains rise to a maximum altitude of 11,485 ft at San Gorgonio peak; to the south the Little San Bernardino Mountains exceed 5,500 ft; to the east and northeast the Bullion Mountains attain altitudes of about 4,000 ft; and to the north an elevated badlands area, termed the Mud Hills, and several southeast-trending ridges, including Coffin Mountain and Deadeye Mountain, define a northern structural boundary whose altitude ranges from about 2,500 to about 4,000 ft.

The floor of the Twentynine Palms Basin is not a broadly concave alluvial plain extending around a central sink or playa that is characteristic of many structural basins in the Basin and Range Province of Southwestern United States. On the contrary, most of the central part of the Twentynine Palms Basin is a relatively high and moderately irregular area presently undergoing erosion. The playas and surrounding areas, which have been the sites of recent deposition, are limited to comparatively small areas distributed irregularly around the margins of the basin floor. The principal playas are Deadman, Mesquite, Emerson, Ames, and Coyote Dry Lakes (pl. 1). A number of isolated hills and buttes, which appear on the geologic map as patches of consolidated rock, protrude through the sediments of the basin floor. In addition, the southeast quadrant of the basin is traversed by a series of low, more or less north-trending ridges whose west-facing scarps are marked on plate 1 by the position of the generally north-trending fault lines. The center of the basin floor is crossed from east to west by a broad, low arch, extending from the Bullion Mountains to the Zeitz Mountains. Because this arch is oriented at nearly right angles to the trend of most topographic features in the area, it has been termed the "transverse arch."

The isolated buttes, the north-trending ridges, the transverse arch, and certain lesser features constitute localized topographic divides which split the over-all Twentynine Palms Basin into four major and three minor subbasins of interior surface drainage. Each of these closed basins, whose general drainage areas may be inferred from the pattern of ephemeral stream channels shown on plate 1, contains a playa or dry lake in its lowest part. During rare periods of heavy runoff, water accumulates on these playas to form temporary shallow lakes. The major drainage basins are those which drain to Coyote, Mesquite, Deadman, and Emerson Dry Lakes. The Emerson Dry Lake drainage basin is of particular interest because it includes the Pipes Creek drainage system whose watershed in the San Bernardino Mountains receives considerably more precipitation than the nearby desert areas. (See section "Estimated Runoff in Pipes Creek.") A small drainage basin in and immediately around the town of Twentynine Palms discharges in part to the unnamed playa, now largely covered by sand dunes, south of Mesquite Dry Lake but mostly to the head of a wash which ultimately drains to Dale Dry Lake 18 mi farther east. Two minor drainage basins immediately east of Copper Mountain drain to small playas which are forming against the western sides of two of the north-trending ridges (pl. 1).

Geologic Formations

For the purposes of this report the geologic formations in the area are grouped in two general categories: consolidated rocks and unconsolidated deposits. The consolidated rocks are exceedingly hard and impervious and are therefore virtually non-water-bearing. The unconsolidated deposits are porous and usually moderately permeable and hence are capable of storing and transmitting relatively large quantities of ground water.

Consolidated Rocks

Consolidated crystalline bedrock forms the mountains that surround the Twentynine Palms Basin and doubtless underlies the sediments exposed on the basin floor. In places the bedrock protrudes through the sediments as isolated buttes or mountains. The bedrock, or basement complex, is composed of two main rock units of different geologic age. The older is a complex series of igneous and metamorphic rocks and the younger is a granitic rock. Locally, flows of basalt cap hills in the western part of the basin. Because of the dense nature of these rocks, they are considered to be virtually non-water-bearing. Minor quantities of water contained in joints, fractures, and deeply weathered zones supply some water to springs and to a few domestic wells and probably locally supply a little water to the unconsolidated deposits.

Precambrian (?) Igneous and Metamorphic Complex

The oldest rocks in the area are igneous and metamorphic rocks described by Miller (1938, p. 418–438) as gabbro-diorite, gneiss, granite, and monzonitic porphyry (porphyritic monzonite according to modern usage), all of Precambrian age. The porphyry and the gneiss appear to be the most common in the areas examined. These rocks form most of the mountain masses surrounding and in the Twentynine Palms Basin. They compose the Bullion Mountains, parts of the San Bernardino Mountains and Little San Bernardino Mountains, and Fortynine Palms, Copper, Bartlett, Zeitz, Goat, Deadeye, and Coffin Mountains. Geologic mapping by Gardner (1940) in the area immediately north of the Twentynine Palms Basin suggests that parts of Miller's Precambrian complex, in particular some of the later intrusives, are of Mesozoic age. Locally, intrusive and metamorphic rocks different from those described by Miller but older than the Jurassic granite are included in this unit.

Jurassic Granitic Rock

The granitic rocks, which have intruded the Precambrian complex, have been described by Vaughn (1922, p. 365) as the Cactus granite and by Miller (1938, p. 438–443) as the White Tank quartz monzonite and assigned by both men to the Jurassic age. A late Jurassic or early Cretaceous age for the Cactus granite is generally accepted. The granite forms the north-central part of the Little San Bernardino Mountains and the southeastern end of the San Bernardino Mountains shown on plate 1. Small outcrops form parts of the hills near Giant Rock.

Quaternary Basalt

A third type of consolidated rock of limited extent and distribution is a series of basalt flows, 200 or more feet thick, which cap a group of mesas that rise 400 to 600 ft above the western edge of the Twentynine Palms Basin. The flows rest on a nearly flat erosional surface cut in part on late Tertiary deposits and in part on consolidated bedrock. Vaughn (1922, p. 384) assigned an early Quaternary age to these flows as well as to similar flows occurring on the desert floor north of the San Bernardino Mountains outside the area here considered. Some of these latter outcrops were observed by Gardner (1940, p. 288) and were mapped as Black Mountain basalt of Pliocene to Pleistocene age.

Unconsolidated Deposits

Unconsolidated continental deposits of considerable thickness underlie nearly all of the floor of Twentynine Palms Basin. Two main periods of deposition, separated by a long interval of erosion, are represented in the deposits of the basin. The older deposits, also referred to as late Tertiary continental deposits in the first report, are by far the thickest and most widespread of the unconsolidated materials (pl. 1). A comparatively thin veneer of younger alluvial deposits, Quaternary in age, locally mantles the old erosional surface cut in both the late Tertiary deposits and the ancient bedrock.

Late Tertiary Continental Deposits

Age, Character, and Extent

The areal extent of the late Tertiary continental deposits is shown on plate 1, and the general subsurface extent is shown on plates 2 and 3. Plate 2 shows the general character of the deposits from the San Bernardino Mountains on the west to the Bullion Mountains on the east. Plate 3 shows diagrammatically the extent of two principal units of the late Tertiary deposits from the Mud Hills on the north, across the transverse arch, to the vicinity of the town of Twentynine Palms on the south.

It has not been possible to determine closely the geologic age of the late Tertiary continental deposits. Fossil evidence is lacking and relations to other formations are not definitive within the area of the study. Deposits termed upper Pliocene or lower Quaternary by Vaughn (1922, p. 380) and overlain with slight angular unconformity by the Quaternary basalt are lithologically similar to some of the materials exposed around Twentynine Palms, in the Mud Hills, and elsewhere in the basin; their correlation, however, was not proved.

The lithologic characteristics of the older deposits are those generally associated with rather young deposits. That is, the unit as a whole is relatively soft, uncompacted, and a large part of it is relatively free from clay that is commonly formed by the decomposition of feldspar minerals. Structurally, however, a greater age for the deposit is indicated by its slight regional discordance with the present surface, its strong local deformation, and its large displacement by a number of major faults. On the basis of the exposures observed in the area, it is believed that the older sediments were deposited before the time of the so-called mid-Pleistocene crustal disturbances that raised the San Bernardino Mountains and probably the other surrounding ranges. The general physiographic and structural history of the Mojave Desert region, as interpreted by Reed (1933, p. 24–26, 200–203), Reed and Hollister (1936, p. 71–74), and others indicates that the deposits are almost certainly not older than late Miocene. Thus, a late Tertiary or possibly an early- to mid-Quaternary age is indicated for the older deposits. For the purposes of this report they are considered to be late Tertiary in age.

The late Tertiary deposits are fairly well exposed in low hills around Twentynine Palms, in an anticlinal hill immediately south of Copper Mountain, in the east end of the transverse arch between Deadman and Mesquite Dry Lakes, in a dissected area immediately south of Coffin Mountain, and in a hill about 2 mi southwest of test well 6. Most of these localities were very briefly described in the first report (Riley and Worts, 1952 [2001]). In addition, a few exposures of very limited extent were found elsewhere in the basin. All the exposures mentioned above are generally similar, being composed largely of poorly sorted medium to coarse arkosic sand, generally light reddish or grayish tan, locally cemented, and commonly containing numerous stringers of gravel. Beds of very fine generally micaceous silty sand and sandy silt and locally clay were found in most of the more extensive exposures although they usually constitute only a small percentage of the outcrops. Fine-grained materials, however, make up a considerable proportion of the deposits exposed in the transverse arch northwest of Mesquite Dry Lake.

By far the best and most extensive exposures of the late Tertiary deposits were observed in the Mud Hills northwest of Deadman Dry Lake. Uplift and deformation of the strata followed by extensive dissection have exposed a thick series of continental deposits whose general character is very similar to that of the other outcrop areas. In the southern part of the Mud Hills a stratigraphic section 790 ft thick was carefully measured across the northeast limb of a southeast-plunging anticline. The description of this section constituted table 3 in the first report and is incorporated in this report as table 1. Further investigation has shown that this section is directly overlain by at least 250 ft of medium to coarse sand and gravel, which are virtually indistinguishable in lithologic character from the 220-ft zone described as "sand, mostly medium to coarse..." shown in table 1. In addition, on the basis of measured dips and widths of outcrops scaled from aerial photographs, about 1,500 ft of deposits was found to underlie the measured section (table 1). The bottom is not exposed.

Thus, a total stratigraphic thickness of approximately 2,500 ft is known to be exposed in the Mud Hills. A detailed study of this total section reveals that it is divisible into an upper unit and lower unit. Most of the upper unit, which is about 1,000 ft thick, is shown in table 1, but only the upper 60 ft of the lower unit, which is roughly 1,500 ft thick, is shown in the table.

The upper unit is composed of roughly 60 percent coarse sand that is largely free of interstitial clay and probably moderately permeable. The remaining 40 percent is generally fine grained, ranging from very fine silty

Table 1. Stratigraphic section in late Tertiary continental deposits exposed in the Mud Hills, about 4.5 miles northwest of Deadman Lake
[ft, foot; in, inch]

Material	Thickness (ft)
Upper unit	
Silt, fine sandy, highly micaceous, pale olive green; and sand, very fine, micaceous, light tan; interbedded in 6- to 24-inch beds. Top not exposed	[1]22
Clay, silty, pistachio green	6
Sand, very fine, silty, biotitic, light yellow-tan	22
Sand, medium to coarse, angular to subangular, arkosic; and some gravel; light rusty brown; cemented in thin beds (1–6 in)	90
Sand, mostly medium to coarse, angular to subangular, arkosic, light rusty brown; fairly massive, somewhat cross-bedded, numerous 1- to 3-foot beds of cemented coarse sand and gravel; occasional beds of fine slightly silty sand, rather massive but with very thin laminar biotite concentrations	220
Sand, very fine, silty; and silt; some silty clay; highly biotitic, pale buff, soft to punky, all interbedded, 1- to 3-foot beds	120
Silt; silty clay; highly biotitic, light tannish gray, soft; and sand, very fine, silty, high biotitic, light yellowish tan, punky; all interbedded in 6- to 20-inch beds	135
Clay, mildly calcareous, light to dark tan, blocky, hard; contains thin stringers of fine sandy silt every 5 to 10 ft	55
Sand, very fine, silty, greenish yellow with limonite streaks	3
Clay, non-calcareous, very dark chocolate brown, very hard (ferruginous cement), blocky fracture	2
Clay, silty, high calcareous and gypsiferous with large selenite crystals; olive green, very hard, flocculent structure	6
Clay, somewhat silty, light chocolate brown, not hard, blocky structure	17
Lime, fairly hard, white	2
Silt, sandy, light rosy tan; and sand, fine to coarse, muddy, poorly sorted, angular to subangular, arkosic, light to dark tan; interbedded in 2- to 4-foot beds	30
Lower unit	
Sand, mostly coarse, some medium, very muddy, very poorly sorted, angular to subangular, arkosic, obscurely bedded, light tan to dark chocolate brown, rather hard; contains numerous stringers of fine to coarse gravel and a few boulders. Bottom not exposed	[2]60+
Total measured section	790

[1]Overlain by at least 250 ft of sand and gravel.
[2]Uppermost part of lower unit which totals roughly 1,500 ft in thickness.

sand to clay that is of low to very low permeability. The mineral constituents are arkosic and indicate a primarily granitic source area. Quartz, feldspar, and biotite predominate. The grains are generally angular and show effects of wind frosting and polishing. The feldspars show little weathering, and as a result there is comparatively little of the interstitial clay that would be produced by their weathering. This probably accounts in large measure for the loose porous texture that is characteristic of many of the outcrops of coarse sand.

The lower unit, a small part of which was described in table 1 as 60+ ft of "sand, mostly coarse, some medium, very muddy, very poorly sorted,...obscurely bedded,...numerous stringers of...gravel and a few boulders," is best exposed north of the measured section where it forms an extensive area of almost continuous moderately dipping outcrops, all of which exhibit lithologic characteristics sufficiently uniform and distinctive to warrant considering this section as a major stratigraphic unit. This unit differs from the upper unit primarily in being much more poorly sorted and more obscurely bedded, and in containing numerous metamorphic and volcanic fragments and much interstitial clay. The tight muddy appearance of this lower unit indicates that its permeability is probably low.

The considerable differences in lithology between the upper and lower units and the sudden change from coarse gravelly sand at the top of the lower unit to clay, silt, and marl at the bottom of the upper unit suggest a radical change in the sedimentary and possibly the structural regime. It is possible that the change at the contact between the two units also represents a disconformity, the direct evidence for which is masked by the inadequacy of the exposures.

The stratigraphic section exposed in the Mud Hills dips generally to the south beneath the northeast quadrant of the Twentynine Palms Basin suggesting that a thickness of deposits roughly equivalent to that in the Mud Hills may overlie the bedrock basement in the area between Surprise Spring and Mesquite Faults. Although considerable lateral variation in the deposits undoubtedly occurs, the major lithologic zones are readily recognizable across distances of as much as 5 mi in the Mud Hills suggesting that the general character of the section probably persists southward for some distance beneath the floor of the Twentynine Palms Basin (pl. 3). However, the similarity of different parts of the section, the absence of marker beds with distinctive characteristics, and the relatively small percentage of the total section penetrated by the individual test wells together prevent any but the most tentative stratigraphic correlation or structural interpretation based on the test-well logs. Nevertheless, the test-well logs do provide moderately detailed lithologic descriptions of the stratigraphic sections penetrated (table 4A in appendix). In general, the materials encountered are very similar to those of the coarse-grained zones of the upper unit exposed in the Mud Hills. Only test wells 1, 3, and 9 penetrated notable thicknesses of predominantly fine-grained deposits—mostly clay, silty clay, and silty fine sand. The materials logged in the other test wells are chiefly sand and gravel, although a considerable admixture of silt and clay is present in the upper 150 ft of test well 5 and from 600 to 800 ft in test well 8. Plate 3 shows diagrammatically the possible southward extent of the two units and the general manner in which the fine-grained deposits are bowed upward in the transverse arch.

Water-Bearing Properties

The late Tertiary continental deposits constitute the important water-bearing unit in the Twentynine Palms Basin. In Surprise Spring and Deadman Basins, most properly drilled and developed supply wells tapping these deposits have yields of 1,000 to 2,000 gal/min. The specific capacity of these wells ranges from about 20 to 40 gal/min per foot of drawdown, which, considering that the wells tap 500 to 600 ft of saturated materials, is only fair to fairly good.

During the development and test pumping of the new Navy supply wells, an attempt was made to estimate the hydrologic properties of the aquifers, principally the coefficients of storage and transmissibility[1]. However, because of the manner in which the test pumping had to be conducted in order to develop the wells properly, the

[1]Definitions: (1) Coefficient of storage may be defined as the volume of water that a unit decline of head releases from storage in a vertical prism of the aquifer of unit cross section; under water-table conditions (unconfined water) it is essentially equivalent to the specific yield; and (2) coefficient of transmissibility may be defined as the rate of flow of water in gallons per day through a vertical strip of an aquifer 1-ft wide and extending the full saturated height under a hydraulic gradient of 100 percent.

data obtained did not provide an adequate basis for determining coefficients of consistent magnitude. The additional water-level and pumpage data to be collected during the continuing program may provide a basis for estimating the coefficients.

If consistent and reasonable coefficients of storage could have been obtained for the two basins, the specific-yield values would have been useful in determining the storage capacity or at least in checking the empirical specific-yield values used. As is indicated in the section on ground-water storage capacity, the specific yield (equivalent in this case to the storage coefficient) was estimated by assigning values to the several types of deposits penetrated by wells and deriving a weighted average. On this basis, the specific yield of the saturated late Tertiary continental deposits to a depth of 100 ft was estimated to be about 13 percent, which is a high average for an older alluvial deposit.

Quaternary Alluvium

The Quaternary alluvium is composed largely of materials eroded from the presently existing mountain masses and to a lesser extent of reworked sediments derived from moderately elevated areas of late Tertiary continental deposits. There was a considerable period of erosion between the deposition of the later Tertiary deposits and the deposition of the Quaternary alluvium. During this period, a large volume of materials was transported out of the area. The Quaternary alluvium, which rests unconformably upon the late Tertiary deposits, presumably ranges in age from about mid-Pleistocene to Recent but is largely of late Pleistocene age. Extensive deposits of Quaternary alluvium are largely confined to alluvial fans and slopes along the mountain fronts, stream-channel deposits in the dry washes, and alluvial plains on the valley floors around the playas. Alluvial deposits characteristically grade from very coarse poorly sorted fanglomerates along the mountain fronts to fine sands and silts on the alluvial plains. It is believed that the alluvium is generally 50 to 150 ft thick.

Included with the Quaternary alluvium are local areas of dune sand. The most significant areas of dune sand are west and south of Mesquite Dry Lake, west of Deadman Dry Lake, along the east side of Pipes Wash, and on the west slopes of the Bullion Mountains.

For the most part the Quaternary alluvium appears to lie above the ground-water table in the areas under consideration. However, immediately west of Mesquite Fault near the playas, where the water table is near the surface, a considerable number of wells are obtaining at least part of their water directly from the younger deposits. The Quaternary alluvium is also believed to be an important water-bearing unit along the western edge of the Twentynine Palms Basin in and near Pipes Wash.

Quaternary Playa Sediments

The sediments underlying the playas consist largely of clay and silt deposited from shallow ephemeral lakes which have existed recurrently, probably ever since the late Pleistocene, when decreasing precipitation rendered surface streams incapable of maintaining their channels across areas of continuing localized uplift. Mesquite, Deadman, and Coyote Dry Lakes are apparently disrupted parts of a formerly well-integrated drainage system that drained most and perhaps all of the Twentynine Palms Basin during the late Pleistocene. Two main tributaries, one occupying the northwest-trending trough along the west side of the Bullion Mountains and the other the west-trending trough along the north side of the Little San Bernardino Mountains, apparently converged about 3 mi north of Twentynine Palms into a single stream that flowed eastward toward Dale Lake. Whether the ancestral Pipes Creek drainage was ever tributary to this system is not known, but on the basis principally of physiographic evidence, it probably has discharged a relatively large volume of materials into the Emerson Dry Lake trough for a considerable period of time. Therefore, it is likely that the Emerson Dry Lake playa sediments are relatively thick.

The playa clays are known from test borings to be 45 to 50 ft thick beneath Mesquite Dry Lake and are probably of the same order of thickness beneath Deadman and Coyote Dry Lakes. The playa sediments overlie unconformably the late Tertiary continental deposits and grade laterally into the Quaternary alluvium; they may overlie the alluvium locally.

Because of their very fine-grained texture, the Quaternary playa sediments are nearly impermeable, will permit only very minor infiltration of surface water, and will yield virtually no ground water to wells. For the same reason, they act as confining beds producing artesian pressure in underlying aquifers. Where the playa beds are slightly permeable and the water table is less than about 5 to 10 ft below the surface, capillary rise of ground water renders the playa surfaces moist and soft, and its subsequent evaporation leaves behind a deposit of the water's dissolved solids. A discharging playa surface of this type is present west of the Mesquite Fault on Mesquite Dry Lake.

Geologic Structure

The Twentynine Palms Basin constitutes the central part of a large structural trough, surrounded principally by fault-block mountains, that extends from Lucerne Valley to Dale Dry Lake. The structure of the basin, to which this discussion is limited, is dominated by extensive faulting and moderate to intense folding of the late Tertiary deposits. A knowledge of the geologic structure is particularly important to the study of ground-water conditions because many of the structural features, especially the major faults, act as barriers to the lateral movement of ground water and thereby in large part define the boundaries of ground-water basins.

Faults

The principal faults cutting the Tertiary deposits are shown on plates 1 and 2. Most of the more important faults are aligned in one of three main systems: northwest-trending, nearly north-trending, and west-trending. Most of the faults in the bedrock areas were examined in a cursory manner and only a few of them are shown on plate 1.

Northwest-Trending Fault System

The dominant fault system in the basin, as in the mountains to the north and east, trends in a generally northwesterly direction. The most important northwest-trending faults are described below in order from east to west.

The westernmost range of the Bullion Mountains is apparently an eastward tilted fault-block mountain, upthrown by several normal faults along its precipitous western face. The exact locations of these faults are concealed by alluvium. The eastern side of the range is a moderate slope on which easterly dipping Tertiary deposits overlie the bedrock in places almost to the crest of the ridge.

Several miles west of the Bullion Mountain scarp and nearly parallel to it, the Mesquite Fault has cut late Tertiary deposits. Direct topographic evidence of this fault is restricted to its southern end, where several ridges of late Tertiary sediments have been raised, perhaps comparatively recently, by uplift along its eastern side. Farther north where the fault crosses Mesquite Dry Lake the playa surface is relatively flat and virtually unaffected. Furthermore, the thicknesses of playa clays in two test holes on opposite sides of the fault are nearly the same, 45 ft on the east side and 49 ft on the western side, indicating little movement on this part of the fault since the playa began to form. At either end of Mesquite Dry Lake, and for 3 mi south of the playa, the location of the fault is strikingly shown by a line of demarcation between a heavily vegetated area to the west, where water levels are near or at land surface, and a nearly barren area to the east, where the depth to water is more than 200 ft. These sharply contrasting conditions demonstrate the effectiveness of the Mesquite Fault as a ground-water barrier. Between Mesquite and Deadman Dry Lakes the fault cannot be located by topography or vegetation, but its existence and approximate location are demonstrated by the fact that wells 2/9-19D1 and 2/8-11B1[2] contain water at moderate depths (88 and 35 ft, respectively), whereas well 2/8-13A1 was drilled to a depth of 155 ft without encountering the water table. Scattered mesquite bushes, and water levels in wells 3/8-34D1 and 3/8-17L1, indicate that the fault continues northward east of the wells probably along the west side of Deadman Dry Lake. The fault apparently diminishes northward and may be terminated against the fault that strikes about N. 60° W. in the southeastern part of the Mud Hills.

The Surprise Spring Fault may be readily traced from about 2 mi south of Surprise Spring northwesterly through Coffin Mountain and for some distance north beyond the limits of plate 1. The fault cuts the crystalline

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[2]See section entitled "Well-Numbering System," which precedes "References Cited."

bedrock, the late Tertiary deposits, and locally, as at Surprise Spring, thin veneers of Quaternary alluvium. The general topography and the dip of deformed strata near the fault indicate that through and immediately south of Coffin Mountain and for a distance of about 2 mi north and south of Surprise Spring the relative movement on the fault has been up on the west side. However, along the intervening reach the topography and the presence of a bedrock hill immediately east of the fault suggest localized uplift of the east side. A similar situation exists north of Coffin Mountain off the edge of plate 1. These alternate reversals in relative uplift suggest the presence of horizontal compressive forces acting along the strike of the fault to produce broad transverse folds whose crests approximately coincide across the fault in some places but alternate with troughs in others. The continuity of the fault trace and the generally greater elevation and folding of the area west of the fault constitute fragmentary but suggestive evidence for stronger compressive forces west of the fault, and a resulting horizontal component to the movement on the fault.

Striking natural evidence of the effectiveness of the Surprise Spring Fault as a ground-water barrier is provided by the flourishing mesquite and other vegetation at Surprise Spring. The main spring orifice has sanded in through neglect but is reported to have been located in the bottom of Surprise Spring Wash at the point where the channel intersects the fault trace. Topographically, this is the lowest point along the fault trace and constitutes a "spillway" over which ground water discharges to Deadman Basin.

The Emerson Fault is best defined in the northwest corner of the area where uplift along its western side has raised the crystalline bedrock to form Deadeye Mountain. In general, the fault has not visibly disrupted the recent alluvium deposited by Pipes Wash. However, the extension of the fault for a distance of about 7 mi southeast of Deadeye Mountain is indicated by a low ridge immediately northeast of well 3/6-4L2 and a sizable hill of northeasterly dipping Tertiary deposits 2 mi southwest of test well 6. A marked difference in water levels and water quality between wells in secs. 3 and 4, T. 3 N., R. 6 E. and other wells farther north demonstrates the existence of a ground-water barrier, presumably the Emerson Fault, between the two areas.

The Reche Fault extends along the northeast side of Reche Butte, which has been uplifted by movement on the fault, and continues southward past the Reche homestead, across Pipes Wash, and perhaps as far as the northwestern tip of the Zeitz Mountains. The fault is apparently recent and active, having disrupted along its northern portion all but the recent stream-channel deposits and dune sand. Although not mappable as a single trace it is believed that the fault zone extends southward past Zeitz Mountains and possibly to the Oasis Fault. Near Reche Butte the effectiveness of the fault as a ground-water barrier is demonstrated by the fact that the depth to water in well 2/6-6D1, immediately west of the fault, is approximately 36 ft, whereas a test hole in Pipes Wash just east of the fault is reported to have encountered no water although drilled to a depth of 150 ft.

Pipes Fault is about 3 mi west of the Reche Fault and is a major arcuate fault skirting the base of the San Bernardino Mountains and extending northwestward with increasing topographic expression, beyond the limits of plate 1. North of Saddlerock Wash, uplift along the west side of Pipes Fault has raised several low granite hills above the general surface. Intervening alluvium-covered areas are probably underlain by bedrock at shallow depth. South of Saddlerock Wash the fault assumes an almost north–south orientation and the topographic expression consists of a low west-facing scarp, becoming higher to the south, along which Quaternary alluvium has been disrupted and elevated on the east side of the fault. Thus, Pipes Fault is apparently of the rotational type, the hinge point being located just north of Saddlerock Wash.

If the apparent fault trace is extended to the south across an area of recent alluvium it is found to cross Pipes Wash at the west side of the granite outcrop through which Pipes Creek has cut a narrow throat at well 1N/5-2P1, long known as "The Windmill." Thus, it appears probable that this outcrop has been raised by movement along Pipes Fault. The bedrock exposed at the southern end and along the northern portion of this fault forms a barrier to ground-water movement. At the southern end this is corroborated by the relatively shallow water level in the windmill well. Along the intervening reach, where there are no evidences of shallow bedrock and no wells, the barrier effects of the fault, if any, cannot be determined.

North-Trending Fault System

Subsidiary to the main northwest-trending faults is a system of generally north-trending faults which are largely restricted to the southern part of the basin and characteristically die out toward the north or merge with the northwest-trending faults (pl. 1). From east to west the three most important north-trending faults are: (1) The Elkins Fault which butts against the Oasis Fault on the south and extends northward through Deadman Basin and appears to die out in the Mud Hills; (2) an unnamed fault which extends northward from Copper Mountain and merges with or truncates the southern end of Surprise Spring Fault; and (3) the Sand Hill Fault, which extends from Copper Mountain Valley northward and merges with the Emerson Fault.

The topographic expression of the north-trending faults consists of more or less continuous north-trending west-facing scarps and ridges, which decrease in height to the north and which appear to have comparatively recent uplift along their eastern sides. On the basis of water levels in a few scattered wells, it appears that the north-trending faults somewhat impede the movement of ground water but the barrier effects are not as great as those of the major northwest-trending faults.

West-Trending Fault System

One major west-trending fault is known to extend along the entire southern edge of the Twentynine Palms Basin and a second is inferred to do so. The existence of the southern fault, known as the Pinto Fault, has been inferred by other geologists in order to account for the uplift of bedrock along the northern front of the Little San Bernardino and Pinto Mountains. The Pinto Fault cannot be located accurately, except perhaps at the western end of Yucca Valley, because along most of the front it is covered by alluvial fans which postdate any movement on the fault. The fault is reported to constitute a ground-water barrier at the west end of Yucca Valley but is not known to do so elsewhere.

The Oasis Fault approximately parallels the inferred Pinto Fault about a mile to the north. Recent movement along most of its length has disrupted all but the youngest alluvial deposits and has left the fault trace sharply defined. Uplift along the north side of the fault has raised bedrock in contact with Tertiary and Quaternary sediments along the north side of Yucca Valley, at the southern end of Copper Mountain, and at the northeast side of Pinto Cove. The long narrow strip between the Pinto and Oasis Faults is a down-dropped block or graben whose apparent surface extent has been widened by erosion of the adjacent mountain fronts.

The Oasis Fault is known to be an effective ground-water barrier along most of its length. This is strikingly illustrated at the Twentynine Palms Oasis, from which the fault has been named. Here ground water moving northward out of Pinto Cove encounters the fault barrier and is forced to rise to the surface forming a line of springs and seeps almost a mile long. In 1952 and 1953 no water was seen at the surface by the writer. However, its presence at very shallow depth was indicated by the flourishing growth of phreatophytes. These included mesquite, arrow weed, saltgrass, willows, cottonwood trees, and of course, the native palms *(Neowashingtonia filifera)* that give the locality its name.

Another west-trending fault, termed the Bagley Fault by Marliave (1941), passes through the town of Twentynine Palms about half a mile north of the Oasis Fault. The fault plane is exposed in the cut north bank of a wash half a mile west of Adobe Road. The eastward extension and approximate location of the fault are indicated by the presence of a ground-water barrier as shown by differences in water levels in several wells. The westward extent of this fault is not well defined, but topographic evidence suggests that it extends to an intersection with the Oasis Fault about 3.8 mi west of Adobe Road (pl. 1).

Folds

Folding of the late Tertiary unconsolidated deposits is not of great importance in the development of the regional geologic structure. Locally, however, it is of considerable geologic and hydrologic significance. There are several areas, notably those west of Mesquite Dry Lake and west of Surprise Spring, where irregularities in topography suggest folding and warping, but exposures are not available to prove their existence.

Transverse Arch

The transverse arch, described in the section on landforms as a broad low nearly west-trending topographic high extending across the center of the basin floor, is shown by the exposures at its eastern end to be a structural arch or anticline composed of a generally fine-grained section of Tertiary deposits (pl. 3). At the west end at Zeitz

Mountains and possibly at relatively shallow depth farther east, the core of the arch is formed by bedrock. Water levels in wells north and south of the arch indicate that the structure forms a ground-water barrier that is at least moderately effective at the east end and strongly effective at the west end.

Folding in the Mud Hills

In the Mud Hills the late Tertiary deposits have been compressed into several southeast plunging and trending folds apparently caused by localized horizontal forces from the northeast and southwest. The dominant structural feature of the Mud Hills is a broad syncline that extends almost the whole length of the hill area. The syncline is adjoined on the southwest by a well-developed anticline, which is faulted along its axis and which is modified into a dome-like structure at its northwest end. To the northeast, the syncline is adjoined by a small tight anticline whose northeast limb is cut off by a subparallel fault (pl. 1).

Drag Folds

The shearing action along fault planes frequently drags the immediately adjacent sedimentary strata into sharp folds. For several feet or tens of feet on either side of the fault plane, bedding commonly is distorted to the extend of becoming virtually parallel to the fault. Because alluvial deposits are usually very much less permeable at high angles to their bedding than parallel to it, this steep tilting of the water-bearing strata would in itself create a considerable impediment to the lateral movement of ground water. In addition, the extremely short-radius folding requires a great deal of squeezing, stretching, and slipping in the sedimentary strata thereby altering the texture of the deposits so that their overall permeability is greatly reduced. Fine-grained clayey beds react plastically, being squeezed thin and smeared along the fault plane. Thus, the effects of drag folding appear capable of accounting for much of the pronounced hydrologic barrier effect encountered along the major faults.

ESTIMATED RUNOFF IN PIPES CREEK

By Walter Hofmann

Purpose

The purpose of this analysis is to derive an estimate of the annual runoff in Pipes Creek (also called Pipes Wash on the desert floor) and its principal tributaries. The runoff from this drainage area is believed to be one of the major sources of recharge to the Twentynine Palms Basin.

Description of the Drainage Area

The Pipes Creek drainage basin is a steep and rugged mountain area at the extreme eastern end of the San Bernardino Mountains. The outline of the basin, together with the principal landforms surrounding it, is shown on plate 4. The stream originates on the east slope of the 8,500- to 9,000-ft divide between the Great (desert) Basin and the Pacific Slope Basins, adjacent to the headwaters of the Santa Ana River. The basin is just eastward of the Cienaga Seca and Broom Flat, two well-known watering places in the higher San Bernardino Mountains. After flowing along an irregular but generally easterly course, Pipes Creek and its two principal tributaries of Burns and Antelope Creeks (plate 6) discharge onto the alluvial valley fill where most of the water is absorbed into the streambed deposits as recharge to ground-water storage. The flood runoff from these streams unites to flow past the well-known landmark—"The Windmill"—as a single stream. The infrequent flood runoff flows in a northerly direction after passing this old landmark and discharges into Ames and Emerson Dry Lakes.

It is the purpose of this analysis to estimate the runoff from the more mountainous areas of the basin tributary to the alluvial deposits which extend 5 to 6 mi upstream from "The Windmill."

Precipitation

Most of the precipitation in the more mountainous parts of the Pipes Creek drainage basin originates in the Pacific maritime air masses which develop over the Pacific Ocean. These eastward-moving air masses are funnelled up the deep west-trending valleys on the western slope of the San Bernardino Mountains, tributary to the Santa Ana River, to spill over the divide into the headwater of Pipes Creek. Because of the common origin, the precipitation distribution, characterized by wet winters and summer droughts, is similar to that found throughout the San Bernardino Mountains area. The first part of February is generally the middle of the rainy season with more than 85 percent of the precipitation occurring in the 6-month period of November through April. Past records have demonstrated that under certain circumstances the precipitation during individual storms may equal 70 to 90 percent of the mean annual value in such mountain areas as Pipes Creek.

East of the mountain area the mean annual precipitation decreases to less than 3 inches in such places as Bagdad where, under the conditions of continuous aridity, the monthly precipitation distribution differs from that in the mountain area. However, even in these arid areas most of the precipitation occurs in the winter months. Even so, the summer convectional storms in these arid regions have a pronounced but irregular influence on the annual precipitation.

The areal distribution of the mean annual precipitation over that part of the Mojave Desert extending north and east of the San Bernardino Mountains to Lucerne Valley, Bagdad, and Twentynine Palms, is shown on plate 5. From a maximum value of more than 45 inches in the San Bernardino Mountains, the mean annual precipitation decreases northward and eastward to a minimum of less than 3 inches in the Bagdad area.

The moisture-laden maritime air masses, after passing eastward through the upper valley area of the Santa Ana River Basin, flow over the divide yielding precipitation that ranges (mean annual value) from more than 25 inches (in.) at the divide to less than 7 in. at "The Windmill." This precipitation distribution was derived from earlier analyses made by Troxell (1948 and 1948a) and two very short records obtained at the Pipes Canyon and Kee ranches in the Pipes Creek drainage basin.

Runoff

The total drainage area of Pipes Creek above "The Windmill" is about 70 mi^2. However, the lower part of this area contributes little, if any, direct runoff to the stream because it consists chiefly of alluvial deposits which absorb most of the precipitation falling on the area. This runoff study, therefore, was confined to the 49 mi^2 of mountain area above these alluvial deposits. The main contributing area is shown (cross-hatched) on plate 6. Also shown on plate 6 are the stream systems of Pipes Creek and the adjacent drainage areas. From the isohyetal map presented as plate 5, the mean annual precipitation on the 49-square-mile main contributing area of Pipes Creek was determined to be about 12 in.

The annual runoff or recoverable water from this precipitation of 12 in. will depend largely on the absorption and retentive conditions of the mantle rock, the altitude, the natural water losses, and many other less important influences. On the basis of local experience, the mantle rock has been estimated to be among the least absorptive and retentive in the San Bernardino Mountain block. The optimum natural water losses within the Pipes Creek drainage basin are estimated as 21 in. on the basis of position, altitude, and mantle-rock characteristics (Troxell and Stafford, 1949).

The results of many years of observation of the runoff from mountain sections of southern California are shown on plate 7. These data consist of a series of curves which show the relationship between annual rainfall and runoff for different values of optimum natural water losses. Using the curves on plate 7, the estimated value of 21 in. as optimum natural water loss, and the previously determined value of 12 in. for the mean annual precipitation, a runoff of 0.8 in. over the area can be estimated. This is equivalent to a total runoff of about 2,000 acre-feet (acre-ft) for the 49-square-mile main contributing drainage area. Reasonable allowances for error in assumptions suggest limits of plus or minus 1,000 acre-ft, using the almost equally arid drainage areas of Cajon, Palm Canyon, and Deep Creeks as a guide.

On the basis of the annual runoff data from the adjacent Santa Ana River and nearby Deep Creek, it has been possible to distribute this mean annual runoff of 2,000 acre-ft to give the annual runoff between 1897 and 1952, as shown on plate 8. The available information on annual runoff of Palm Canyon and Snow Creeks in the San Jacinto Mountains has also been used to obtain this annual distribution. The lower part of this diagram gives the cumulative departures from the mean annual runoff, in percent, for the 1897–1951 period. Changes in trend of this cumulative curve denote the end of a dry period and the beginning of a wet period, or vice versa. On this basis the wet and dry periods have been identified and the average runoff for he periods indicated on the diagram. The mean annual runoff is dependent on the proper selection of these wet and dry sequences. These 55 years of record produce the estimated mean runoff for four basic periods, as indicated in table 2.

The maximum computed annual runoff during this 55-year period is believed to have occurred in the 1916 flood year whereas the minimum may have occurred in 1899. Table 3 gives the computed maximum and minimum annual runoff for periods ranging from 1 to 6 consecutive years.

The computed runoff for the period, representing the flow discharging from 49 mi^2 of the mountainous Pipes Creek area, is based on a bare minimum of evidence. For that reason, although the best estimate of the mean annual runoff from this area amounts to about 2,000 acre-ft, it is of course subject to the possibility of considerable error.

Only a part of this runoff passes through the confining channels of "The Windmill" landmark to discharge onto the desert as surface runoff. The residual part is absorbed into the streambed gravels to recharge the ground-water storage or to satisfy the natural water losses between this landmark and the mouths of the canyons.

In these areas of deficient precipitation practically all the runoff occurs over a period of a very few days each year. For example, it is estimated that on the average 50 percent of the runoff in Pipes Creek occurs in less than 0.5 percent of time or 1 day in 200, 66 percent occurs in less than 1.4 percent of time or 5 days in a year, and 85 percent occurs in less than 5 percent of the time or 5 days in 100. For this reason, an independent estimate of the storm runoff should give a fairly good indication of the mean annual runoff. Using the methods proposed by Troxell (1948) and the physical characteristics previously described, the storm runoff for Pipes Creek was computed and is given in table 4.

Table 2. Mean annual runoff, in acre-feet, of Pipes Creek for four basic periods

Period	Mean
1896–1922	2,300
1905–36	2,200
1922–43	1,600
1936–51	1,700
Average	2,000

Table 3. Maximum and minimum annual runoff, in acre-feet, of Pipes Creek for periods of 1 to 6 consecutive years

Length of period	Period	Average annual runoff	Departure from mean annual runoff (percent)
	Maximum		
1 year	1916	10,500	+425
2 years	1915–16	7,200	+260
3 years	1914–16	5,900	+195
4 years	1914–17	4,800	+140
5 years	1914–18	4,300	+115
6 years	1914–19	3,600	+80
	Minimum		
6 years	1946–51	290	–85
5 years	1898–1902	130	–94
4 years	1948–51	98	–95
3 years	1898–1900	61	–97
2 years	1899–1900	445	–98
1 year	1899	10	–99

Table 4. Maximum 5-day storm runoff, in acre-feet, of Pipes Creek

Recurrence interval in years	Volume
100	8,300
50	5,900
25	3,900
10	2,200
5	1,400
2	700
Mean annual	1,130

During the maximum 5-day period the runoff will range from 8,300 acre-ft for once in 100 years to 700 acre-ft for once in 2 years with a mean annual value of all storm periods having a recurrence of once a year or longer amounting to 1,130 acre-ft. The mean annual 5-day storm runoff can be converted to an approximate figure of mean annual runoff by dividing it by 0.66, the ratio of the 5-day runoff to the total annual runoff for Pipes Creek. This gives a mean annual runoff of 1,700 acre-ft, which is a reasonable check of the 2,000 acre-ft previously determined.

In the past 30 to 40 years the greatest flood runoff is believed to have occurred in the water years (ending Sept. 30) 1915–16 and 1937–38. During the flood periods of 1916 the peak discharge of Pipes Creek may have exceeded 6,000 second-ft (cubic feet per second) with a maximum daily discharge of 1,700 second-ft on the basis of the runoff in the adjacent Santa Ana River Basin and in nearby Deep Creek. In the March 1938 flood the peak may have been more than 3,000 second-ft with a maximum daily discharge of about 850 second-ft.

To summarize the above, it is estimated that a mean annual precipitation of 12 in. over the 49-square-mile main contributing area of Pipes Creek resulted in a mean annual runoff of 2,000 acre-ft, plus or minus 1,000 acre-ft, a possible error of 50 percent.

GROUND-WATER APPRAISAL

Source, Occurrence, and Movement of Ground Water

General Principals

The perennial supply of fresh water naturally available to any locality is ultimately limited by the amount of precipitation falling upon areas whose surface and underground drainage are tributary to that locality. It is never possible, of course, to collect for human use more than a small fraction of the precipitation that falls on an area of appreciable size. A considerable proportion may be caught by plant foliage and evaporated after a storm without ever reaching the land surface. Of the precipitation that does reach the land surface part seeps into the soil and part remains on the surface, initially filling shallow depressions and then running off in the network of rills, gullies, and stream channels that make up the surface drainage system. This surface water is subject to evaporation losses which are continuous except for short periods, usually during storms, when the overlying air is completely saturated. The water that infiltrates the soil must first make up the moisture deficiencies in the soil water zone, which is the shallow zone immediately below the surface, from which water is discharged into the atmosphere by soil evaporation and by the transpiration of plants. The residual water, if any, can then percolate downward to the water table and recharge the ground-water body. Surface streams provide maximum opportunities for infiltration, and their seepage losses frequently constitute the major ground-water recharge.

Ground water may be defined as the water contained in the pores, cracks, and other voids in the rocks that lie below the water table. Except in occasional large caves and caverns, found principally in limestone and lava flows, ground water does not occur as "underground streams" or "veins." On the contrary, it commonly exists as an extensive water body that permeates all the interstices of the porous rocks beneath the water table.

The yield of a properly constructed well is largely determined by the number, size, and arrangement of the water-filled interstices in the rocks surrounding the well. These three factors together determine the permeability of the rocks. Coarse-grained unconsolidated deposits, such as sand and gravel, contain numerous relatively large well-connected pores which make them highly permeable and usually copiously water bearing. However, fine-grained deposits, such as very fine sand and silt, contain much smaller pores which so restrict the movement of water that the permeability is vastly reduced. For this reason the permeability of clay is almost zero. Because of their low permeability, fine-grained rocks and deposits are usually considered non-water-bearing.

Consolidated crystalline rocks, such as granite, are nonporous and impermeable. They may, however, contain some water in crevices and fractures and in small pores produced by partial chemical decomposition of the rock in the zone of weathering. The quantities of water available from crystalline rocks may be adequate for small domestic supplies but are seldom of economic importance. Therefore, such rocks are commonly classified as being virtually non-water-bearing.

Ground water is nearly always in motion, impelled by gravitational forces to percolate slowly from points of highest head or water-table altitude, which are the sites of recharge, to points of lowest head, where it discharges naturally through springs and seeps, by evaporation from moist soil and discharging playa surfaces, and by transpiration of phreatophytes such as mesquite. The rate at which ground water percolates through the interstices of the saturated deposits depends on their permeability and the slope of the water table (the hydraulic gradient). At the same hydraulic gradient, the rate of movement through coarse sand and gravel will be on the order of several thousand times faster than through fine sandy silt. The quantity of water moving past a given line depends on the average rate of movement and the cross-sectional area of saturated deposits beneath that line. These relations are embodied in Darcy's law (Wenzel, 1942, p. 3–4) which in ground-water work is frequently expressed:

$$Q = PIA,$$

where

Q is the quantity of water discharged in a unit of time,
P is the permeability of the saturated deposits,
I is the hydraulic gradient, and
A is the cross-sectional area through which the water percolates.

Prior to their development by humans, nearly all ground-water basins are in a state of dynamic equilibrium. That is, the natural ground-water discharge to the atmosphere, to bodies of surface water, and by underflow to adjacent ground-water basins is equal to and dependent upon the natural recharge. Furthermore, the slope and configuration of the water table between the areas of recharge and discharge is more or less stable in a form that is precisely adjusted at all points to the permeability and cross-sectional area of the saturated zone and to the quantity of water supplied by the recharge. Where the major recharge is seasonal or sporadic, as is frequently the case, corresponding fluctuations are superimposed upon the mean position of the water table. These recharge "waves," representing increases in the water stored in the basin, move slowly downstream usually with rapidly decreasing amplitude. In a large ground-water basin in which storage capacity is vastly greater than the annual recharge, the recharge waves are quickly dissipated so that seasonal water-table fluctuations are at a minimum. It may also be noted that changes in discharge, accompanying, for example, the seasonal growth of phreatophytes and seasonal variations in evaporation, are likewise reflected by fluctuations in the water table.

For practical purposes the perennial yield available for development by pumping in arid regions is the amount of water that can be diverted or salvaged from the natural discharge without causing permanent chemical or other deterioration of the supply. In a relatively small ground-water basin where the average annual recharge is an appreciable percentage of the ground-water storage capacity, the artificial discharge by pumping must be kept within the limits of the perennial yield if the supply is not to be rapidly depleted.

However, under conditions commonly found in desert areas, a large ground-water basin may contain hundreds of times more water in storage than is brought in by the annual recharge. Under such conditions the ground water in storage, when withdrawn at a moderate rate in excess of the perennial yield, is a non-renewable resource which may be depleted, with due regard for conservation methods, if practical use is to be obtained from it. The rate of depletion, as shown by the regional decline of the water table, can usually be estimated according to the amount by which the annual pumpage exceeds the perennial yield. The maximum rate and ultimate extent of depletion that can be tolerated before pumping becomes impractical due to excessively lowered water levels are determined by economic considerations that are beyond the scope of this discussion.

Ground-Water Basins

The overall ground-water body contained in the deposits beneath the Twentynine Palms Basin is divided areally into several major and numerous minor ground-water basins by features of the geologic structure, principally the major faults. Although not entirely watertight, these faults greatly impede the movement of ground water causing it to accumulate in the ground-water basins behind the barriers, much as surface water backs up in the reservoir behind a dam. The very low permeability of the fault zones is believed to be caused in considerable measure by the compaction and extreme deformation of the water-bearing strata immediately adjacent to the faults. These processes were discussed in more detail in the preceding section on drag folds. Another process believed to be important in reducing the permeability of the faults is cementation of the fault zones by the deposition of carbonates, principally calcium carbonate, from rising ground water which, as pressure head decreases, releases carbon dioxide and causes the carbonates to precipitate.

Within a typical ground-water basin in this area, certain conditions of ground-water occurrence are more or less uniformly consistent. That is, except locally, the hydraulic gradient is approximately constant in each and is generally very low. Altitudes of the water level in wells throughout a typical basin cluster about a mean figure that differs notably from the average in adjacent basins. Thus, the water-table altitude descends in stair-step fashion through successive ground-water basins from the areas of recharge along the San Bernardino Mountains at the western edge of the Twentynine Palms Basin to areas of discharge, principally at Mesquite Dry Lake in the southeastern corner of the basin. (See pl. 2.) In addition, the chemical quality of the ground waters generally is relatively similar throughout a single basin but differs considerably from one basin to another. Sharp discontinuities in water-table altitudes, hydraulic gradient, and, in some cases, chemical character reveal or confirm the existence of geologic-barrier features that might otherwise remain concealed or conjectural.

Inasmuch as the ground-water movement through the Twentynine Palms Basin as a whole is largely in a state of dynamic equilibrium, the outflow from each basin across its downstream barrier must equal the inflow to the basin, except for minor recharge from streams or rain and evapotranspiration losses within the basin. From a consideration of Darcy's law it is apparent that if the quantity of water in motion remains virtually constant, a decrease in either the average permeability or the cross-sectional area of the saturated zone must produce a steepening of the hydraulic gradient. Where the gradient through a limited reach is steep relative to the gradients on either side, the presence of a hydrologic barrier is indicated and the boundary of a ground-water basin or subbasin is defined. Throughout the Twentynine Palms Basin the major fault zones, being very much less permeable than the adjacent formational materials, produce the most striking changes in gradient and the most sharply defined boundaries. However, other geologic phenomena, such as reduction of permeability by change in the character of the saturated deposits and restriction of the cross-sectional area by the presence of a buried ridge of bedrock, also cause local steepening of gradients and constitute basin boundaries.

A common means of showing the slope and configuration of the water table is by a water-level contour map, on which lines of equal water-level altitude are drawn at a convenient interval by interpolation between points of known water-level altitude. Throughout most of the Twentynine Palms Basin the slope of the water table is so gentle and the wells so far apart that water-level contours of required accuracy cannot be drawn on the strength of the meager data available. Therefore, water-table altitudes at key wells are shown on plate 1 together with water-level contours in the local area around Mesquite Dry Lake and in the eastern part of Surprise Spring Basin.

In the first report (Riley and Worts, 1952 [2001], p. 20–23), three ground-water basins, termed Surprise Spring, Deadman, and Mesquite Basins, were described as being of potential importance to the water supply of the Twentynine Palms Marine Corps Training Center. Old supply wells 1 and 2 are located in Mesquite Basin, old supply well 3 and new supply well 1A are in Deadman Basin, and new supply wells 2A an 3A are in Surprise Spring Basin. In the following section five basins are described—from west to east, Pipes and Reche Basins and the three described in the earlier report.

Pipes Basin

The highest water-level altitudes known to occur within the project area are found in wells tapping the Quaternary alluvium in the upper reaches of Pipes Wash, west of the granite outcrop at The Windmill (1N/5-2P1). The Quaternary alluvium upstream from the granite outcrop is very limited in areal extent (pl. 1) and probably does not exceed 150 ft in thickness. It is deposited in a channel cut for the most part into the granite that underlies the basalt mesas. Locally, however, the channel is cut into older (Tertiary?) deposits which overlie the granite but underlie the basalt. These older deposits may in some places extend deep enough to intersect the water table, in which case they would somewhat augment the local ground-water storage capacity of the alluvial deposits. In any case, however, the ground-water basin, herein termed the Pipes Basin, that contains these saturated deposits is very small and is limited in its eastern extent by Pipes Fault. The basin is hydrologically significant because it is the conduit that transmits virtually all the recharge from the mountain area of the basin west of plate 1 where Pipes Creek and other mountain streams discharge onto the alluvium, to the several basins east of Pipes Fault.

In addition to The Windmill well, Pipes Basin is tapped by wells 1N/5-10E1, 10G1, 19B1, and several shallow domestic wells farther to the west beyond the edge of the map (pl. 1). Of all these wells, an appreciable quantity of water is pumped from only 1N/5-19B1, the supply well for the village of Pioneertown.

The highest water-table altitudes in the basin occur, as would be expected, along its western edge against the bedrock mountain front. On the basis of land-surface altitudes interpolated from a contour map (U.S. Geological Survey San Gorgonio quadrangle, scale 1:125,000, contour interval 100 ft) the water table in the Quaternary alluvium attains a maximum observed altitude of roughly 4,500 ft. The water table in the Pioneertown well (1N/5-19B1) stands at about 3,900 ft. On the basis of barometric levels, the water table during the winter of 1952–53 in wells 1N/5-10E1, 10G1, and 2P1 stood 3,529, 3,495, and 3,447 ft, respectively, above sea level.

Throughout most of Pipes Basin the slope and configuration of the water table is largely controlled by and presumably closely parallels the slope and configuration of the underlying bedrock surface. For the most part the saturated thickness of the deposits in 1952 and 1953 was probably on the order of a few tens of feet. Depths to water in the wells in Pipes Basins shown on plate 1 range from 58 to 116 ft (table 1A in the appendix). Farther west, where the alluvium is locally very thin, depths to water of as little as 10 ft have been noted. At the east end of the basin the hydraulic gradient flattens markedly, changing from 94 ft per mile between wells 1N/5-10E1 and 10G1 to 52 ft per mile between wells 1N/5-10G1 and 2P1. In this lower reach the gradient is apparently controlled largely by the bedrock barrier immediately east of well 1N/5-2P1. Whether the total underflow through the upper reaches of Pipes Wash discharges into the main part of the Twentynine Palms Basin through the alluvium-filled bedrock throat at The Windmill well, or whether part escapes across the fault farther to the north or south cannot be determined from existing data.

Reche Basin

Reche Basin includes two and possibly more ill-defined basins contained between Reche Fault and its southern extension on the east, the Pipes Fault forming the common boundary between Reche and Pipes Basins on the west, Reche Butte on the north, and the bedrock hills west of Bartlett Mountains on the south. The lack of wells precludes the establishment of subbasin boundaries within the Reche Basin.

Very little is known of conditions of ground-water occurrence and movement for some distance east of the barrier at The Windmill. The nearest well is 1N/6-6E1, 1.9 mi to the east, which is the only source of data on ground-water occurrence in the southern part of Reche Basin. The land-surface altitude at the well is 3,482 ft and the depth to water in 1953 was 217 ft; the altitude of the water level was therefore 3,265 ft, or 182 ft lower than that in The Windmill well. Well 6E1 is 316 ft deep. According to the owner, the small pump, set 67 ft below the static water table, has a capacity of about 100 gal per hour. Approximately one hour's pumping at this rate drew the water level in the well down to the pump intake. The volume of water contained in 67 ft of the annular space between the 6-in. casing and the 2-in riser pipe was 90 gal. Thus, despite the considerable drawdown, the formational materials yielded only about 10 gal to the well during the one-hour period of pumping, indicating that the deposits tapped are of very low permeability or are not open to the well.

Because of the scarcity of data, the nature of ground-water movement through the southern part of Reche Basin is somewhat conjectural. There are two apparent components of movement which water escaping from Pipes Basin would be expected to take. One is east toward the lower water-table altitude in well 1N/6-6E1. From here ground water appears to move eastward out of Reche Basin across the southern extension of Reche Fault toward wells 1N/6-4Q1, 9Q1, and 10F1, which are in the Copper Mountain Valley area. These last three wells, less than a mile apart, had highly irregular and anomalous water-table altitudes, ranging from 2,889 to 2,701 ft, about 370 to 560 ft lower than at well 1N/6-6E1 (pl. 1). Their yields, furthermore, are very poor, being barely adequate for domestic supply. The log of well 1N/6-9Q1 shows a large percentage of clay (table 6A in the appendix). These facts, in conjunction with the apparent structural complexity of the area, suggest that these wells tap more or less isolated minor ground-water basins which are largely separated from the ground water in Reche Basin principally by structural features. Therefore, it is believed that only a small amount of the water is discharged from the southern part of the Reche Basin eastward between the Zeitz and Bartlett Mountains to the Copper Mountain Valley area. Furthermore, because well 1N/6-29H1 encountered the "blue shale" (probably decomposed bedrock) at 235 ft and was a dry hole, it is believed that there is virtually no movement either southward toward or northward from Yucca Valley (table 6A in the appendix).

The other apparent component of movement is northward toward the lower water table shown by water levels in wells around the Reche homestead in the northeast corner of section 1, T. 2 N., R. 5 E. The levels in these wells are about 530 and 350 ft lower than that in The Windmill well and in well 1N/6-6E1, respectively. The average hydraulic gradient between well 1N/6-6E1 and the wells at Reche's homestead, if assumed to be constant, is almost 60 ft per mile. A gradient of such steepness could perhaps be maintained in deposits of low permeability; however, the chemical quality of the water in well 6E1 is very different from that in both The Windmill well and well 2/5-1H1. On the basis of geologic, hydrologic, and geochemical data it is believed that well 6E1 taps older weathered deposits of late Tertiary age, whereas The Windmill well and 1H1 tap the Quaternary alluvium that is much more permeable. It is further believed that the deposits through which the ground water percolates in moving toward well 2/5-1H1 are largely the Quaternary alluvium. The relatively high water-table altitude in the southern part of the basin, despite the presence of permeable alluvial deposits tending to drain the water to the north, suggests the presence of either one or more hydrologic barriers between The Windmill well and well 2/5-1H1, or a relatively shallow bedrock floor that extends downstream from the granite outcrop at The Windmill well and supports the water table through this reach. If so, between The Windmill well and well 1H1 it is possible that locally the water level may be relatively close to land surface.

In the vicinity of the Reche homestead, wells 2/5-1G1, 1H1, 1H2, and 2/6-6D1 and 6D2 intersect the water table at altitudes ranging from 2,918 to 2,920 ft above sea level and at depths ranging from 36 to 95 ft below land surface. At well 2/6-7Q1, almost 2 mi to the south probably on or very close to the Reche Fault, the altitude of the water table is 2,912 ft, and the depth to water is 168 ft. The best-defined boundary of the basin containing these wells is the Reche Fault along its eastern side (pls. 1 and 2). As was mentioned, the northern boundary is formed by the bedrock of Reche Butte and shallow bedrock west of the butte.

Logs are not available for the wells in the northern part of Reche Basin. However, it is reported that well 2/6-6D2, drilled to a depth of 200 ft, encountered chiefly sand and gravel and had a yield of at least several hundred gallons per minute. Well 2/6-7Q1, 233 ft deep, is equipped with a 20-horsepower electrically driven turbine pump and is reported to have a good yield.

Ground water reaching the northeast part of Reche Basin discharges eastward across the Reche Fault. It is possible that the leakage across the fault is greatest through the younger less faulted channel deposits in Pipes Wash. The water-table altitude in well 2/6-7Q1 is 2,912 ft, which is 6 to 8 ft lower than those in wells 2/5-1G1, 1H1, and 1H2 and 2/6-6D1 and 6D2, suggesting that ground water may also be crossing the fault through Quaternary and late Tertiary deposits south of Pipes Wash.

Surprise Spring Basin

Surprise Spring Basin is delimited by Surprise Spring Fault on the east; Deadeye Mountain, bedrock near Giant Rock, and Reche Fault on the west; the probable fault trending west-northwest at Ames Dry Lake on the north; and the transverse arch on the south. As is indicated below, Emerson and Sand Hill Faults together form a hydrologic barrier within Surprise Spring Basin. Because there are no well data between Reche Fault and well 3/6-35N1, it is possible that minor barriers and basins exist in this local area. Thus, the overall extent of Surprise Spring Basin has not been materially altered from its original definition except for exclusion of the Emerson Dry Lake area north of the fault near Ames Dry Lake.

Ground water crossing Reche Fault enters the western part of Surprise Spring Basin and may be the principal direct recharge to the basin. Reports of infrequent flood flows in Pipes Wash reaching as far downstream as Emerson Dry Lake also suggest that an appreciable part of the recharge is supplied by seepage loss directly down from the wash surface. With regard to the ground-water movement, water discharging across Reche Fault might take either or both of two possible directions: eastward toward well 3/6-35N1 where the water-level altitude is

2,319 ft, about 600 ft lower than that in well 2/6-7Q1 in Reche Basin; or northwestward beneath Pipes Wash between Reche Butte and Spy Mountain, and thence northeastward toward Emerson Dry Lake. Available hydrologic and geologic data are insufficient to determine which course conveys the bulk of the recharge. Either course would supply recharge to the western part of Surprise Spring Basin.

The possibility of an appreciable thickness of unfaulted saturated late Tertiary deposits in the area between Sand Hill and Reche Faults and between Zeitz and Goat Mountains was recognized in the first report (Riley and Worts, 1952 [2001]). If this situation exists, the hydraulic gradient would be low through this reach and the depth to water would range from about 250 ft on the east to as much as 650 ft on the west. It is possible, however, that shallower bedrock supports a thin, more steeply sloping water body, or that one or more concealed faults create additional small basins through this reach. Under these circumstances the depths to water would be considerably less than those mentioned above.

All wells in Surprise Spring Basin, except perhaps some of those near Ames Dry Lake, obtain their water from the late Tertiary continental deposits. A generally coarse-grained stratigraphic section, consisting largely of sand and gravel, was penetrated in all the test and supply wells in Surprise Spring Basin, and the yields from these deposits were generally good. (See "Estimated Storage Capacity" section.) The detailed records of the pump tests and yield data on the test wells were given in the report by Wagner (1952).

The wells near Ames Dry Lake probably derive their water from the Quaternary alluvium and from the late Tertiary continental deposits. The gravel-packed former irrigation well 4/6-37H1, 150 ft deep, is reported to yield 1,000 gal/min with a 5-ft drawdown. Another former irrigation well 4/6-34E1, 163 ft deep, is reported to yield 900 gal/min.

The western part of Surprise Spring Basin is tapped by an unused domestic well, 3/6-35N1, which intersects the water table at a depth of 363 ft and altitude of 2,319 ft, and by wells 3/6-3N1, 4L1, 4L2, and 4P1, which intersect the water table at depths ranging from 75 to 93 ft and at altitudes of 2,323 to 2,330 ft (pl. 1). The altitudes of all these wells were determined by barometric traverses and may be subject to an error of a few feet.

The saturated materials tapped by well 3/6-35N1 are the late Tertiary continental deposits, whereas those tapped by wells 3/6-3N1, 4L1, 4L2, and 4P1, which are 140, 137, 76, and 132 ft deep, respectively, are probably in large part the Quaternary alluvium and in small part the late Tertiary deposits. The materials encountered in well 3N1 are reported by the driller to have consisted largely of medium to coarse sand and gravel, with some fine sand, and occasional beds of clay and silt, particularly in the upper part of the well. Well 4P1 was not equipped with a pump when visited but is reported to have yielded 270 gal/min. Well 4L1 had a deep-well turbine pump which produced a reported discharge of 900 gal/min for irrigation use.

The east part of Surprise Spring Basin is tapped by test wells 5, 6, 9, and 12; Navy supply wells 2A and 3A[3], two small domestic wells 3/7-35L1 and 35P1 at Surprise Spring, and irrigation and other wells 4/6-27C1, 27D1, 27F1, 27M1, 28R1, and 34E1 in the northwest corner of the basin, near Ames Dry Lake (pl. 1).

The altitude of wells in the vicinity of Surprise Spring and of test wells 6 and 9 was determined by spirit leveling. The altitudes of the water levels in 1953 ranged from 2,265 ft at test well 9 to 2,246 ft at supply well 3A, test well 5, and 3/7-35L1. The water-table altitude at supply well 2A was 2,251 and at test well 6 was 2,257 ft. Depths to water in these wells ranged from 250 ft below land surface in test well 9 to 2.4 ft above land surface in artesian well 3/7-35P1 at Surprise Spring.

The altitudes of wells near Ames Dry Lake were also determined by spirit leveling. In 1953 the altitudes of the water levels in wells 4/6-27D1, 27M1, 28R1, and 34E1 were between 2,259.5 and 2,260.9 ft (pl. 1), and the depths to water ranged from 59 ft in well 4/6-27C1 to 100 ft in well 28R1.

Thus, the water-level altitudes in wells indicate that at the north end of Surprise Spring Basin there is a drop in level of about 70 ft from west to east across Emerson Fault, and at the southern end of the basin there is a drop in level of about 55 ft between well 3/6-35N1 (barometric level) west of the Emerson and Sand Hill Faults and test well 9 (spirit level) east of the faults. Although the indicated displacement of water levels is considerable, the full

[3]See table 2A in the appendix for correlation of Navy well number with U.S. Geological Survey numbers.

effectiveness of the Emerson and Sand Hill Faults as a barrier is not known. Under the prevailing "static" conditions in 1953 and with the few wells available for measurement, the effect of pumping from one side of the barrier on water levels on the other side can not be determined. Furthermore, the meagerness of information precludes any statement as to where the water moves eastward across the barrier. The water-level altitude at test well 9, which is the highest east of the Sand Hill Fault, suggests that some recharge may be moving across the barrier where the Emerson and Sand Hill Faults appear to join. To the north, water may move across or through the Emerson Fault in the vicinity of Pipes Wash.

In the east part of Surprise Spring Basin the possible direction of ground-water movement is indicated by the dashed (uncertain) contours shown on plate 1. The position of the contours is based on the water-level altitudes in test wells 6, 9, and 12, supply well 2A, and wells 4/6-27M1, 28R1, and 34E1. These contours suggest that ground water is moving generally eastward away from the Emerson and Sand Hill Faults and is moving generally southeastward away from the Ames Dry Lake area toward Surprise Spring Fault. These data are insufficient to show the direction of movement east of test well 6. The position of the contours is controlled principally by the level at test well 9 which is west of a minor unnamed fault. If the unnamed fault forms a partial barrier to eastward movement, the water levels east of the fault might be 5 ft lower. Even a 5-ft differential would cause a marked change in the position of the contours and hence in the direction of ground-water movement. Until additional wells are drilled in the basin, it will not be possible to refine the contours.

Movement southeastward across the transverse arch is indicated by the water-level altitude in test well 11, which is 2,198 ft or about 50 ft lower than the levels in the vicinity of Surprise Spring, and also by the level in well 1N/8-6D1, which is 2,023 ft (barometric level) or about 175 ft lower than that in test well 11.

The concentration of phreatophytes in Surprise Spring Wash for several hundred feet downstream from the Surprise Spring Fault indicates that some water is spilling over the top of the fault through the Quaternary alluvium to Deadman Basin. Whether there is movement across the fault north and south of the spring is not definitely known. However, on the basis of knowledge that there is movement across the other major fault barriers in the area, it is believed that ground water also moves across Surprise Spring Fault in places other than at the spring. Thus, as was suggested above, movement from the Ames Dry Lake area may be southeastward to and across the Surprise Spring Fault north of Surprise Spring.

Deadman Basin

Deadman Basin lies on the east side of the Surprise Spring Fault, which thus forms its western boundary, and the Mesquite Fault forms the eastern boundary. To the north the folds and faults of the Mud Hills constitute a very effective boundary, and to the south the transverse arch effects a separation from Mesquite Basin farther north.

Deadman Basin, like Surprise Spring Basin, has been found to consist of two subbasins, although the difference in water-level altitudes between the two is not as great as in Surprise Spring Basin. The subdividing barrier is the Elkins Fault, which extends with diminishing magnitude northward from the Oasis Fault to the Mud Hills.

The west part of Deadman Basin is tapped only by test well 10, which intersects the water table at a depth of 189 ft and an altitude of 1,831, or 415 ft below the water table in test well 5 at Surprise Spring. The saturated materials penetrated in test well 10 are late Tertiary continental deposits consisting largely of fine to coarse sand and some gravel that yielded water readily to this well. In the absence of additional wells it cannot be definitely stated that the western part of Deadman Basin is not subdivided into more than one basin, in which case depths to water in the western part might be considerably less than the 415 ft indicated by the water-level differential between test wells 10 and 5. However, no evidence has been found to suggest a fault or other barrier feature between the Elkins Fault and the Surprise Spring Fault. Furthermore, because only this one well is west of Elkins Fault, it is not possible to determine the direction of ground-water movement. Hence, the principal area of ground-water inflow to Deadman Basin across Surprise Spring Fault cannot be determined.

The part of Deadman Basin east of the Elkins Fault is tapped by test wells 2, 3, and 8, old Navy supply well 3, new Navy supply well 1A, and unused domestic well 2/8-11B1 at the southeast corner of the basin. The altitude of the water table in 1953 is 1,803 ft (spirit levels) at test wells 2, 3, and 8; 1,804 ft (spirit levels) at supply well 1A; 1,799 ft (spirit levels) at old supply well 3; and about 1,797 ft (barometric traverse) at well 2/8-11B1. Depths to water ranged from 24 ft at old supply well 3 to 102 ft at new supply well 1A (table 1A in the appendix).

The saturated materials in the test and supply wells are the late Tertiary continental deposits. In test wells 2 and 8 and supply well 1A, all of which had good yields, the deposits consist largely of sand and gravel with occasional thin beds composed chiefly of silt and clay. A considerably increased proportion of fine-grained materials was encountered in test well 8 below 600 ft. According to the driller's log (table 5A in the appendix), old supply well 3 penetrated a predominantly fine-grained section but encountered several beds of clean sand and gravel which yielded good flow to the well. Test well 3 penetrated a fine-grained section, consisting primarily of silty sand and sandy clay, to a depth of 248 ft. From 248 ft to 512 ft the materials were logged as predominantly sand, with considerable gravel and occasional streaks of clay. Although perforated in the coarsest beds of the lower zone, the well had a poor yield. The sediments tapped by this well may constitute the lower, fine-grained part of the upper unit observed in the Mud Hills and the upper part of the underlying coarse but muddy unit, which in surface outcrops appears to be of low permeability.

The hydraulic gradients east of the Elkins Fault are so flat as to be almost negligible, and consequently indicated little more than a generally easterly to southeasterly movement of ground water, presumably at a very slow rate.

It is believed that the principal source of ground water in Deadman Basin is the subsurface flow across Surprise Spring Fault. After crossing the fault, water probably percolates precipitously downward toward a level on the order of that at test well 10, and then moves very slowly eastward. Water-level altitudes in test wells 10 and 8 indicate a drop in water-level altitudes of about 27 ft as ground water moves eastward across the Elkins Fault. With the "static" water-level conditions that existed in 1953, it is not possible to determine what the effectiveness of the fault barrier would be with lowered water levels. As the basin is pumped and more wells are drilled, it may be possible to determine the effectiveness of the barrier.

Water discharges from Deadman Basin primarily by subsurface flow across the transverse arch toward the lower water levels in Mesquite Basin to the southeast and by eastward leakage across the Mesquite Fault; a small amount is discharged by evapotranspiration along the western edge of Deadman Dry Lake.

Mesquite Basin

Mesquite Basin is separated from Deadman Basin by the transverse arch, which forms its northern boundary. The Mesquite Fault constitutes the eastern boundary; the southern boundary apparently consists of the Bagley and Chocolate Drop Faults together with a west-trending bedrock ridge that crops out in the northwest corner of sec. 30, T. 1 N., R. 9 E. and probably extends westward a mile or so at relatively shallow depths. Existing wells do not closely define the southwestern and the western boundaries. The altitudes of the water levels in wells 1N/8-9L1 and 21F1 are 1,860 and 1,872 ft, respectively, suggesting that these wells are separated from Mesquite Basin by a barrier. The geologic evidence shows that a northwest-trending monoclinal fold, perhaps associated with a fault, has raised bedrock above the bottom of the canyon in the southeast part of sec. 15, T. 1 N., R. 8 E. This fold appears to extend from near well 1N/8-9L1, southeastward to, or perhaps across, the Oasis Fault and may constitute the southwestern boundary of Mesquite Basin through this reach (pl. 1). North of well 9L1 the Elkins Fault defines the probable maximum western extent of Mesquite Basin.

The ground water of Mesquite Basin is tapped by old Navy supply wells 1 and 2, test well 1, and about 80 domestic wells, most of which are powered by windmills. The lowest determined water-table altitude is 1,763 ft measured in well 2/9-30P2 near the western edge of Mesquite Dry Lake. On the basis of water-level data obtained from a shallow test bore, the water levels beneath the playa west of the fault are slightly lower than in well 30P2. Most wells in the extensively developed southeastern part of the basin intersect the water table at altitudes between 1,775 an 1,770 ft above sea level.

Depths to water in Mesquite Basin range from a known maximum of 295 ft at 1N/9-29F1, to slightly above land surface in two flowing wells 2/9-30B1 and 30G1 located just west of the Mesquite Fault and northwest of Mesquite Dry Lake. Depths to water in the extensively developed area generally range between 25 and 50 ft.

Ground water in Mesquite Basin occurs in the late Tertiary continental deposits, the Quaternary alluvium, and the playa sediments. The approximate limits of appreciable thicknesses of Quaternary alluvium are shown on plate 1. Quaternary alluvium is known to be at least 50 ft thick in the lowest parts of the basin, but probably thins rapidly toward the west. Data from a few well logs and oral reports from drillers indicate that the Quaternary alluvium here consists largely of interbedded sand and silt, with some gravel and moderate amounts of clay. Little is known of the yields of the alluvium other than that quantities adequate for domestic use are usually obtained. Virtually no water is obtained from the playa deposits.

According to logs of old Navy supply wells 1 and 2 and test well 1, the late Tertiary continental deposits in the eastern part of Mesquite Basin consist primarily of rather thinly interbedded sand, silt, and clay, with occasional beds of coarse sand and gravel (tables 4A and 5A in the appendix). Test well 1 encountered a relatively fine-grained section and when tested had a yield of 190 gal/min with a 98-ft drawdown. Old supply well 2 encountered several beds of clean, coarse sand in the zone from 300 to 500 ft. These beds, though relatively thin, proved to be copiously water bearing and gave a yield of 376 gal/min with an 11-ft drawdown. Old supply well 1, only 0.7 mi to the southeast, penetrated a very similar and probably correlative section, including coarse sand from 390 to 495 ft, but has a yield of only 256 gal/min with a 41-ft drawdown. Thus, it appears that in Mesquite Basin widely varying yields may be obtained form the late Tertiary deposits.

The water-level contours on plate 1 show that water is moving toward the playa area from the northwest, west, south, and southeast. This in turn indicates that the source of ground-water recharge is by movement from Deadman Basin and several unnamed basins to the west and south—all on the west side of Mesquite Fault. The extremely flat hydraulic gradient in Deadman Basin and the water-level drop of 22 ft between well 2/8-11B1 in Deadman Basin and test well 1 in Mesquite Basin indicates that the ground-water movement may be restricted in crossing the transverse arch and that the amount of water entering Mesquite Basin from the northwest may be relatively small. However, at the southeast end of Surprise Spring Basin and at the southwest end of Deadman Basin, some ground-water leakage southward across the arch probably occurs.

Another source of ground water in Mesquite Basin is believed to be runoff from the Little San Bernardino Mountains to the south and southwest. Such runoff commonly seeps into the alluvial fans and stream-channel deposits immediately adjacent to the mountain front without ever reaching Mesquite Basin. From the small ground-water basins underlying these deposits the ground water then moves generally northward into Mesquite Basin across the Oasis, Bagley, and Chocolate Drop Fault barriers. During exceptionally heavy storms, however, large quantities of water flow through the major drainages shown on plate 1, across the boundaries of Mesquite Basin, and down to the playas. Under these circumstances appreciable recharge to Mesquite Basin probably occurs by direct seepage downward from the main stream channels and the numerous small distributaries that spread across the lower parts of the fans.

Considerable underflow is believed to enter Mesquite Basin from the southwest, although few wells are available to indicate accurately the nature of the movement. A generally eastward movement of ground water from Yucca Valley through Joshua Tree to Copper Mountain Valley is indicated by successively lower water-table altitudes from west to east, in a series of small ground-water basins not specifically studied in this investigation. Despite the continuous movement of water toward Coyote Dry Lake no natural discharge takes place in or around this playa. The depth to water in well 1N/7-15N1, at the western edge of the playa, is 184 ft, demonstrating conclusively that ground water is escaping this area, presumably by eastward movement around the south end of Copper Mountain and thence generally eastward through one or more minor basins and ultimately into Mesquite Basin.

Finally, some easterly movement probably takes place across the Elkins Fault (the western boundary of Mesquite Basin?) from small basins of higher water-surface altitudes, such as that indicated by well 1N/8-6D1, and in part from Surprise Spring and Deadman Basins.

Water that enters Mesquite Basin from the south across the Bagley Fault moves generally northwestward more or less parallel to the apparently highly impervious Mesquite Fault as far as the small unnamed playa and the head of the wash that drains eastward to Dale Lake. Geochemical data, discussed in the following section, suggest that little or none of this water moves north beyond the small playa. Here the ground water is discharged from the basin by evapotranspiration around the playa and by underflow eastward across the Mesquite Fault probably through the unfaulted or slightly faulted Quaternary alluvium. Water that enters Mesquite Basin from the southwest, west, and northwest moves generally toward Mesquite Dry Lake and the area of dense phreatophytes around the west side of the playa.

Relatively large quantities of water are discharged by the transpiration of mesquite and other phreatophytes, by evaporation from moist soil, and by escape from Mesquite Basin eastward across Mesquite Fault principally by movement through undisturbed or only slightly faulted Quaternary alluvium and by minor movement through the playa deposits that overlie the faulted Tertiary sediments. Water levels east of the fault are about 200 ft lower than in Mesquite Basin. Eastward, ground water moves through several ground-water basins and ultimately is returned to the atmosphere by evapotranspiration in and around Dale Dry Lake.

Ground-Water Recharge

Recharge from Streams

In the section "Estimated Runoff in Pipes Creek," it was estimated that the average annual runoff is on the order of 2,000 acre-ft per year and is probably within the limits of 1,000 and 3,000 acre-ft per year. It was also indicated that the other streams north of Pipes Creek do not contribute materially to the runoff to Twentynine Palms Basin. Because most of the runoff occurs during storms, probably the bulk of the stream discharge sinks into the deposits of Pipes Wash and recharges the several basins the wash traverses. Thus, as was previously described, most of the recharge so supplied moves generally eastward across Pipes, Reche, Surprise Spring, and Deadman Basins to Mesquite Basin. The fact that the highest water-level altitudes in the Twentynine Palms Basin are found in Pipes Wash and the lowest are found in Mesquite Basin, taken in conjunction with the data on ground-water movement and chemical quality, indicates conclusively that the principal source of recharge to Surprise Spring and Deadman Basins is derived from runoff in the San Bernardino Mountains.

As has been previously pointed out, the ultimate source of ground-water recharge is precipitation on areas overlying or tributary to the ground-water bodies in question. The magnitude of the total recharge is therefore related in a general way to the total precipitation, and in a desert basin is obviously small in comparison to that which can occur in a more humid area. Furthermore, if there are marked differences in precipitation intensity across a given desert basin, the general areas of maximum recharge within the basin are likely to coincide approximately with areas of maximum precipitation. The ioshyetal map of the Twentynine Palms area (pl. 5) shows that the heaviest precipitation occurs in the San Bernardino and Little San Bernardino Mountains, where the mean annual precipitation within the watershed of the Twentynine Palms Basin attains maximums of about 25 in. and about 10 in., respectively. Plate 5 also shows that the precipitation on the floor of the basin is very low, ranging from less than 4 in. to about 6 in., and further that no significant increase in precipitation is caused by the Bullion Mountains and other ranges around the northern and northeastern parts of the basin.

Inasmuch as the mean annual precipitation as distributed over the Twentynine Palms Basin is inadequate to satisfy the soil-moisture requirements, deep penetration and consequently ground-water recharge can occur only where surface waters are concentrated, as by runoff in stream channels, in quantities locally much larger than those provided by precipitation over the area as a whole. On the floor of the Twentynine Palms Basin, locally derived runoff is negligible except during the most violent storms because normal quantities of rainfall are absorbed into the sandy soil only to be returned to the atmosphere shortly thereafter by evapotranspiration. However, during heavy storms the steep rocky slopes of the surrounding mountains shed sufficient rainfall to cause raging torrents to pour down the rock-walled canyons out onto the alluvial deposits of the basin floor. These deposits, being generally very permeable, readily permit infiltration into the beds of the stream channels and washes.

During these very brief periods of large runoff, the quantity of water that seeps into the streambeds is much greater than that required to make up the soil-moisture deficiencies, and the excess percolates downward to recharge the ground-water body. The infiltration capacities of the channel deposits are great enough to permit the runoff from all but the heaviest storms to be completely absorbed so that none of the flow reaches the playas in the lowest parts of the basins. The runoff from most storms is largely absorbed near the mountain fronts, where the alluvium is commonly coarsest and most permeable. The infrequent but exceptionally heavy runoff flows far out across the desert floor and presumably contributes appreciable recharge to all the ground-water basins traversed by the flow.

From the considerations outlined above it is apparent that the average annual recharge to the Twentynine Palms Basin is virtually equal to the average annual runoff from the intermittent and ephemeral streams that drain its surrounding mountains. The only large mountain drainage area tributary to the system of interconnected ground-water basins that includes Surprise Spring and Deadman Basins is the drainage basin of Pipes Creek and its tributaries, on the eastern slope of the San Bernardino Mountains. Accordingly, the runoff of Pipes Creek, at the point where it discharges from its bedrock canyon onto the alluvium, constitutes by far the largest component of the recharge to this ground-water system.

Infiltration of Rain

The mean annual precipitation in the Twentynine Palms Basin ranges from less than about 4 in. along the east side to about 6 in. along the west side (pl. 5). This average annual precipitation, when normally distributed with respect to time, is insufficient to supply recharge to ground water. It is possible, however, that local cloudbursts might supply a very minor amount of recharge to the basins. However, it is believed that the amount so supplied is so local and so infrequent as to make the net basinwide effect negligible. Thus, for all practical purposes, the recharge by infiltration of rain is virtually eliminated as a source of ground-water recharge in the Twentynine Palms Basin.

Ground-Water Discharge

Ground water discharges naturally from the Twentynine Palms Basin to downgradient basins by underflow eastward across the Mesquite Fault ultimately reaching Dale Dry Lake, and discharges to the atmosphere by transpiration of phreatophytes and direct evaporation from moist soil. In recent years, a number of wells have been drilled and artificial discharge by pumping has gradually increased. Thus far, however, no significant irrigation or other large use has been made of the water, and the relatively small draft for domestic use and municipal supply has not seriously disturbed the naturally established equilibrium between recharge and discharge.

It is not possible to obtain an estimate of the total natural discharge that may serve as a close check on the estimated recharge from Pipes Creek and other minor sources principally because the underflow across Mesquite Fault can not be estimated on the basis of presently available data. The methods available for estimating natural discharge by evapotranspiration are limited and have been tested under conditions somewhat different than those in the Twentynine Palms Basin. Nevertheless, because the evapotranspiration forms a large part of the natural discharge, an attempt is made to determine its approximate magnitude.

Discharge by Evapotranspiration

In the Twentynine Palms Basin considerable natural discharge is effected by the transpiration of phreatophytes, which are plants that send long tap roots down as much as 40 or 50 ft to the water table or to the overlying capillary fringe and thereby draw their moisture supply directly from the ground-water reservoir. In this respect they differ notably from the xerophytes, such as cactus, creosote bush, and the Joshua tree, which depend on soil moisture and are biologically adapted to conserve as much water as possible. By far the most widespread phreatophyte in the basin is mesquite, but saltgrass, willows, cottonwoods, native palms, and other types are also represented locally.

Investigation on water use by phreatophytes in lower Safford Valley, Arizona (Gatewood, Robinson, and others, 1950, p. 195), determined that, under the conditions prevailing there, mesquite growing at maximum (100 percent) density annually consumed about 2.7 ft of ground water plus 0.6 ft of rainfall, or 3.3 ft total, where the depth to water was 10 ft. In most of the Twentynine Palms Basin mean temperatures are somewhat higher and mean relative humidity considerably lower than in Safford Valley, but in many places where phreatophytes grow the depth to water is more than 10 ft. An arbitrary figure of 3 acre-ft per acre (at 100-percent density) is used in this report to estimate the evapotranspiration. In order to estimate the transpiration loss from an area of mesquite, the size of the area and the areal density of the growth were determined from aerial photographs, and the vertical density was estimated by field observation. The product of these figures, the densities being expressed as percentages of the maximum, is in turn multiplied by 3 acre-ft per acre to obtain the annual transpiration loss.

Evaporation of water directly from discharging playa surfaces constitutes another form of natural discharge from the Twentynine Palms Basin. Such discharge may occur where the water table in the playa sediments is less than about 5 to 10 ft below the land surface. Capillary rise brings ground water to or nearly to the surface, whereupon it is evaporated, leaving its dissolved salts behind in the form of a puffy "alkali" crust. Natural discharge by transpiration of phreatophytes takes place in areas of shallow ground water in Pipes Basin, Reche Basin, Surprise Spring Basin, Deadman Basin, and Mesquite Basin, as well as at the Twentynine Palms oasis, south of the town of Twentynine Palms.

Intensive investigations in other desert basins have shown that the rate of evaporation from "discharging" playas is dependent on the interaction of a number of geologic, hydrologic, and climatologic variables whose quantitative determination is beyond the scope of the present investigation. However, on the basis of a general comparison of conditions in the Twentynine Palms Basin with those in areas closely studied, a rough approximation of ground-water discharge by evaporation is made. Ground-water discharge by evaporation from the soil occurs principally in Mesquite Basin.

Pipes and Reche Basins

In the north part of Pipes Basin, in the course of a brief reconnaissance survey, several sites of phreatophyte growth were noted. Occasional clumps of willow and cottonwood grow in the thin, rocky alluvium and decomposed granite of the upper part of the basin, and some sparse mesquite and willow grow in the wash northeast of well 1N/5-19B1. Because of the scarcity of wells, little is known of the depth to water and the occurrence and movement of ground water throughout much of Pipes Basin. It was therefore not feasible to evaluate the phreatophyte water use beyond saying that the total draft probably does not exceed 100 acre-ft per year.

In Pipes Wash just downstream from The Windmill, mesquite and willow grow sparsely in an area of about 40 acres. The volume density (percentage areal density multiplied by percentage vertical density) of this growth is probably not more than 5 percent. Hence, the annual water use by these plants is almost negligible, amounting in all probability to less than 10 acre-ft.

Surprise Spring Basin

Ground water discharges naturally in Surprise Spring Basin by transpiration, principally by mesquite, at Surprise Spring. This area of natural discharge consists of about 140 acres of mesquite, growing generally in rather dense clumps separated by considerable intervals of nearly barren sand. The overall areal density of the growth was determined to be about 25 percent and the vertical density was estimated at 75 percent. Therefore, the volume density is approximately 18 percent, which is equivalent to a growth of maximum density on an area of about 25 acres. Using the value of 3 acre-ft per acre for the annual transpiration of mesquite at maximum density, a figure of 75 acre-ft for the total annual transpiration of mesquite at Surprise Spring is obtained.

Inasmuch as the depth to water in most of the spring area is 10 to 25 ft there is probably little evaporation from the soil, and, except for the flow of well 3/7-35P1, which in 1952 amounted to about 15 acre-ft, the transpiration of mesquite is believed to be the principal discharge to the atmosphere from the area.

Deadman Basin

The area of evapotranspiration in Deadman Basin is not well defined. Mesquite grows in scattered clumps and clusters along the west side of Deadman Dry Lake where the depth to water ranges from about 15 to about 45 ft. Because the clumps are rather widely separated, the aggregate area of all the individual clumps was measured and this figure, which was determined to be 15 acres, was used as 100 percent areal density. The vertical density of these clumps was estimated to average 60 percent. Accordingly, the transpiration of mesquite in Deadman Basin is estimated at approximately 30 acre-ft annually. In view of the absence of "rising alkali" and the probable minimum depth to water of 15 ft, natural discharge by evaporation from the soil is thought to be negligible in Deadman Basin.

Mesquite Basin

Natural discharge by evapotranspiration takes place in Mesquite Basin throughout an area extending along the west side of the Mesquite Fault from the northern end of Mesquite Dry Lake southward for 5 mi and westward for 0.2 to 1.5 mi. The total area amounts to about 2,400 acres. Of this total, approximately 400 acres is barren discharging-playa area; approximately 340 acres is "rising alkali" soil, bearing considerable saltgrass and dense mesquite; and the remainder, 1,660 acres, is virtually dry soil supporting a moderate growth of mesquite. The average areal density of mesquite was determined to be about 10 percent and the average vertical density was estimated to be 75 percent, giving a volume density of about 7.5 percent. When applied to the total area of mesquite, 2,000 acres, this density percentage together with the estimated maximum annual transpiration figure of 3 acre-ft per acre give a value for transpiration by mesquite of approximately 450 acre-ft.

The depth to water in the playa sediments is on the order of 5 to 7 ft and nearly all of the 400 acres of playa surface are at least moderately discharging, as is evidenced by the puffy alkali encrusted on the surface. Work done by White (1932, p. 80 and fig. 26) in Utah indicates that the annual rate of discharge by evaporation from clay loams (similar to playa materials) where the depth to water is 5 to 7 ft is approximately 5 percent of the evaporation from an open-water surface. In the Twentynine Palms Basin where temperatures are higher than in Utah, the total evaporation would also be higher, but it is believed that the percentage would be virtually the same. On the basis of work by Blaney (1933, p. 23–24) on the Mojave River near Victorville, the evaporation rate from an open-water surface in the Twentynine Palms Basin is estimated to be approximately 5 to 6 ft per year. Thus, it is estimated that the rate of discharge from the playa surface at Mesquite Dry Lake is on the order of 0.3 acre-ft per acre per year. Therefore, this type of discharge probably amounts to roughly 100 acre-ft a year.

On this basis of data assembled by Blaney (1933, p. 50–53), the discharge from the 340 acres of seasonally moist soil, containing saltgrass and mesquite, is estimated to be about 1 ft per acre per year, exclusive of the mesquite transpiration which was included in the separated estimate indicated above. Accordingly, the evapotranspiration in these areas is estimated to be about 340 acre-ft a year. Thus, the total annual evapotranspiration in Mesquite Basin is roughly 900 or 1,000 acre-ft per year.

Total Evapotranspiration Loss

The total evapotranspiration loss in the Twentynine Palms Basin is the sum of the crude estimates derived above, which is roughly 1,100 or 1,200 acre-ft a year. This total is the discharge supplied by movement of ground water from all sources of recharge, which include not only Pipes Creek and lesser drainages in the San Bernardino Mountains but also the ephemeral streams along the northern front of the Little San Bernardino Mountains and other minor sources. The evapotranspiration losses related almost entirely to the recharge from the San Bernardino Mountains, principally from Pipes Creek include those from Pipes, Reche, Surprise Spring, and Deadman Basins, but only a part of that from Mesquite Basin where the remainder of the total loss is related to the recharge from the other sources.

In Mesquite Basin that part of the evapotranspiration loss attributable to the recharge from Pipes Creek cannot be estimated accurately. However, on the basis of the water-level contours, the relative size and character of the drainage areas, and the chemical character of the ground water, it is believed that approximately 50 percent, or roughly 500 acre-ft, of the loss in Mesquite Basin may be related to recharge from Pipes Creek. In this case, the total evapotranspiration loss, including that in Surprise Spring and Deadman Basins, related to the Pipes Creek recharge would be about 700 acre-ft a year, or about a third of the estimated annual recharge of 2,000 acre-ft. This suggests that the remaining two-thirds of the recharge is accounted for by ground-water discharge eastward across Mesquite Fault.

Discharge by Pumping

Artificial discharge of ground water by pumping takes place in all the major ground-water basins studied, but until the beginning of Navy pumping in Surprise Spring and Deadman Basins, the only pumpage of appreciable magnitude was in Mesquite Basin and in the northern part of Surprise Spring Basin just south of Ames Dry Lake where a recent irrigation development pumped considerable quantities of water for several years prior to the leasing of the irrigated lands by the Marine Corps. Estimates of pumpage in the various basins are for the most part based on a minimum of data and generally should not be considered more than crude approximations.

Pipes and Reche Basins

Pumpage in Pipes Basin is limited to the discharge of Pioneertown supply well 1N/5-19B1 and a few domestic wells which are used only occasionally. On the basis of the oral report of the operator, the total annual pumpage in 1952 and in prior years from supply well 1N/5-19B1 probably did not exceed 12 acre-ft. Total pumpage in Pipes Basin in 1952 was probably less than 20 acre-ft.

Pumpage in the Reche Basin in 1952 was derived entirely from wells 1N/6-6E1, 2/5-1H1, 2/6-6D1, and 2/6-7Q1. The water was used for household purposes, watering a few domestic animals, maintaining a swimming pool, and irrigating a few shade trees. In 1952 the total pumpage in Reche Basin was estimated to be about 3 acre-ft.

Surprise Spring and Deadman Basins

During and for some time prior to the present investigation, the only pumpage in Surprise Spring Basin was the irrigation development in the extreme northern part of the basin near Ames Dry Lake. Four high-capacity irrigation wells, 3/6-4L1, 4/6-27M1, 4/6-28R1, and 4/6-34E1, drilled in 1950 and 1951, reportedly were pumped at rates of 900, 1,000, 540, and 900 gal/min, respectively. High seepage and evaporation losses in the long ditches from the wells to the irrigated fields reportedly necessitated pumping most of these wells almost continuously during the growing season. Consequently, it is estimated that in 1952 at the height of development in this area, immediately prior to acquisition of the land for the training center, the pumpage was probably on the order of 2,000 acre-ft. The total draft from the Ames Dry Lake area in the years 1950–52 may have been about 3,000 acre-ft. For years prior to 1950, pumpage reportedly was small.

The only pumpage in the Surprise Spring area from the beginning of the investigation in January 1952 to June 30, 1953, was the quantity discharged during the development tests on the Navy test and supply wells. Most of the discharge on these tests was metered and totaled 37 acre-ft.

During the period of the investigation the only pumpage in Deadman Basin was the quantity discharged in the development tests of the Navy test and supply wells and the amount withdrawn from old supply well 3 to supply Marines on bivouac near Deadman Lake. The pumpage during the development tests totaled 22 acre-ft. The pumpage from old supply well 3 is not known but probably did not exceed 30 acre-ft.

Mesquite Basin

Mesquite Basin is tapped by about 70 domestic wells equipped with lift pumps or small-capacity jet pumps and 10 wells equipped with larger capacity turbine pumps. Eight of the wells equipped with small pumps and three of the wells equipped with turbines were apparently unused when visited during the investigation. The small domestic wells and most of the turbine-equipped wells generally supply an individual house with water for irrigating a few trees and shrubs and for general household uses other than cooking and drinking, for which purposes bottled water is generally used because of the excessive fluoride content of the native ground waters. The average annual pumpage from a domestic well of this type, on the basis of reported data from well owners, is commonly on the order of 0.2 to 0.3 acre-ft a year. Accordingly, the total annual pumpage from domestic wells in Mesquite Basin is believed to be roughly 10 to 20 acre-ft a year.

Wells 1N/9-17J1 and 17J2 at Smith's Ranch are equipped with turbine pumps and supply water to a small local distribution system. On the basis of information provided by the operator, the discharge from these wells was estimated to be 5 acre-ft in 1952.

By far the greatest pumpage in Mesquite Basin during the period of the investigation was that from old Navy supply wells 1 and 2, which were heavily pumped throughout 1952 and the first half of 1953 in order to provide water needed in the construction of the new training center. Despite the heavy draft neither of these wells was equipped with any means of measuring the rate or total quantity of discharge. Consequently, the pumpage from them can be only crudely estimated. Old supply well 1 was used to supply water to the living and office quarters of the construction crew and a small group of military personnel. The annual pumpage from old supply well 1 during 1952 is very roughly estimated at about 50 acre-ft a year. Old supply well 2 was equipped with a 600 gal/min pump and was heavily pumped to supply the water needed for construction at the site of the new facilities. On the basis of information supplied by the contractor, the total withdrawals from supply well 2 during 1952 are believed to have been on the order of 400 acre-ft.

The total of all pumping withdrawals from Mesquite Basin during 1952 was probably on the order of 500 acre-ft, of which about 90 percent was derived from old Navy supply wells 1 and 2. Although the pumping of old Navy supply wells 1 and 2 in 1952 caused an almost twentyfold increase over the pre-1952 withdrawals from Mesquite Basin, the estimated total pumpage of about 500 acre-ft in 1952 is still only about half of the estimated evapotranspiration loss of about 900 or 1,000 acre-ft.

Water-Level Fluctuations

In order to determine the nature and magnitude of water-level fluctuations in the several ground-water basins under investigation, periodic water-level measurements were made in about 50 observation wells; automatic water-level recorders were operated on 17 wells; and water-level records, dating back to 1940, were collected for Mesquite Basin from the San Bernardino County Flood Control District. The data collected on about 200 wells canvassed and water-level records on about 40 of those selected for observation wells are contained in tables 1A and 3A in the appendix.

Records of eight selected observation wells in Surprise Spring, Deadman, and Mesquite Basins have been prepared in hydrograph form and are shown on plates 9 and 10. These graphs illustrate the extent of pumping effects in the several basins and in the areas of shallow ground water show the seasonal effect of evapotranspiration. The graphs obtained from automatic water-level recorders show barometric fluctuations induced by changes in atmospheric pressure and daily effects caused by evapotranspiration.

Fluctuations Caused By Pumping

One of the principal purposes of the investigation was to determine the effect of pumping the Navy supply wells on water levels in wells in Mesquite Basin where the community of Twentynine Palms obtains a small part of its supply. In June 1953, there had been virtually no pumpage from the new supply wells in Surprise Spring and Deadman Basins. Accordingly, there is nothing to report regarding this relationship. However, old Navy supply wells 1 and 2 in Mesquite Basin were pumped nearly continuously during 1952 and part of 1953 while construction of the training center was in progress.

The graphs for observation wells in Mesquite Basin show that there was no local or regional decline in levels caused by pumping from these old Navy wells. However, the long-term graphs show a decline from 1940 to 1953 amounting to about 2 ft (pl. 10). The cause for this decline is not known, but it may be caused by the small pumpage for domestic use. It is more likely, however, that the decline is related to dryer climatic conditions during the period 1945–53 as compared to the wet period 1936–44. Continued measurements of observation wells over a period of years would be necessary to determine the effect of pumping in Surprise Springs and Deadman Basins on the water levels in Mesquite Basin.

In addition to showing short-term trends in regional water levels, the graphs for test wells 5 and 8 in Deadman and Surprise Spring Basins show the effect of test pumping the new supply wells (pl. 9). In Deadman Basin, pumping in supply well 1A for a period of 72 hours at rates up to 2,000 gal/min caused a maximum decline of only 0.7 ft in test well 8, about 2,400 ft away. In Surprise Spring Basin, pumping in supply well 2A for a period of 59 hours at rates up to 1,540 gal/min caused no decline in test well 12 (not shown on the graphs) about 4,000 ft away, and no decline in test well 5, about 4,000 ft away. Pumping in supply well 3A for a period of 59 hours at rates up to 1,800 gal/min caused a maximum decline of 1.2 ft in test well 5, about 1,400 ft away, but caused no decline in supply well 2A, about 2,600 ft away.

The results of these tests and related fluctuations in observation wells taken in conjunction with a 3-to-4-ft displacement of water levels across the small north-trending fault between supply wells 2A and 3A suggest that the fault may form a partial barrier to the eastward movement of ground water. Under "static" conditions existing up to June 1953, the hydrologic data suggested that the effectiveness of the barrier was poor. Continued pumpage from the supply wells and careful measurements of water levels in the supply and observations wells would show the effectiveness of this barrier.

The graphs for wells 1S/9-3D1 and 1N/9-32R1 show long-term declines of about 4 and 3 ft, respectively, in one of the small basins south of Mesquite Basin. These declines are probably due to the combined effects of pumping for city and domestic uses and reduced recharge during the dry period 1945–53. Because the altitudes of the water levels are higher than those in Mesquite Basin and because this small basin is separated from Mesquite Basin by fault barriers, the declines are not caused by pumpage in Mesquite Basin.

Fluctuations Caused by Evapotranspiration

Draft of ground water by phreatophytes, which depend on ground water for their supply, produces both seasonal and diurnal water-level fluctuations in response to seasonal and diurnal changes in the transpiration rate of the plants. Also, evaporation in areas of shallow ground water causes similar fluctuations. Collectively, they are termed water-level fluctuations caused by evapotranspiration.

Water-level records for wells in the area of evapotranspiration in Mesquite Basin show a progressive drawdown of the water level through most of the growing season and hot weather, followed by a recovery during late autumn, winter, and early spring, when the plants are largely dormant and evaporation losses are small. During the 13-month period of record, the lowest water level in well 2/9-30P2, in the area of considerable mesquite immediately west of Mesquite Dry Lake, was in November 1952, and was followed by a rise which amounted to 0.9 ft at its peak in April 1953 (pl. 9). Because this well is remote from any appreciable pumping and is unused, its observed fluctuations are believed to be due solely to evapotranspiration.

The hydrograph of well 1N/9-4E2, in the evapotranspiration area immediately south of Mesquite Dry Lake, closely parallels that of well 2/9-30P2 (pl. 9). The hydrograph obtained from an automatic water-level recorder operated on well 4N2 from July 11 to August 7, 1952, showed a diurnal fluctuation ranging from 0.01 to 0.03 ft. Peaks occurred at about 8 a.m., just before the morning sun caused the plants to begin to transpire heavily and troughs occurred at about 6 p.m., just before the waning of the sun caused the plants to reduce their draft on the ground-water body. No other types of fluctuations were detected in this well.

Barometric Fluctuations

In the areas remote from any pumping or evapotranspiration, the only types of fluctuations observed were barometric. All wells tapping the Tertiary deposits on which recorders were operated exhibited barometric fluctuations. The magnitude of the diurnal fluctuation ranged from 0.02 ft in test well 2 to 0.1 ft in test well 12. These fluctuations caused considerable difficulty in interpreting data obtained on observation wells during the test-pumping of the new supply wells. Frequently, near the end of the periods of pumping and recovery, the magnitude of the barometric fluctuations completely obscured the fluctuations due to pumping.

The interpretation of barometric fluctuations has a practical application in appraising the vertical permeability of water-bearing beds and especially in determining and eliminating the barometric fluctuation in individual water-level measurements made in conjunction with the test-pumping of supply wells and studies of fluctuations in areas of evapotranspiration.

Ground-Water Storage Capacity

Ground-water storage capacity may be defined as the reservoir space in a given volume of deposits; to be usable it must be capable of being drawn down for use. In areas of large recharge it must also be capable of being resaturated. In the Twentynine Palms Basin where the recharge is small, the principal concern is the amount of ground water that can be removed from storage for use. Accordingly, the storage within selected depth zones in Surprise Spring and Deadman Basins, where the supply wells are located, is critical with regard to the water supply of the training center.

Storage Units

In was pointed out in the "Ground-Water Basins" section that Surprise Spring and Deadman Basins were each divided into two subbasins by the Emerson–Sand Hill Fault and the Elkins Fault, respectively. In the event that the faults do form effective barriers to ground-water movement, the two basins are each here considered as having east and west parts. Thus, for the purposes of computing the storage capacity, four storage units have been selected, as follows: Surprise Spring Basin, east part and west part; and Deadman Basin, east part and west part.

The east part of Deadman Basin is limited in areal extent by Mesquite Fault on the east, the Elkins Fault on the west, an arbitrary line parallel to and about 0.5 mi north of the transverse arch on the south, and an arbitrary generally east-west line between secs. 6 and 7, T. 3 N., on the north (pl. 1). The west part of Deadman Basin is limited in extent by the Elkins Fault on the east, Surprise Spring Fault on the west, and by extensions of the two arbitrary lines established for the east part on the north and south.

The two arbitrary lines are shown on plate 1 and are used because of the uncertainty regarding the exact position of limiting features. It is possible that the southern boundary may extend to and even beyond the axis of the transverse arch; and the northern boundary, established on the south slope of the Mud Hills, probably would prove to be farther north. Thus, the limits of Deadman Basin are conservative. The areas of the two parts are nearly 16 mi^2 or about 10,000 acres for the east part and nearly 21 mi^2 or about 13,000 acres for the west part.

The east part of Surprise Spring Basin is limited in areal extent by Surprise Spring Fault on the east, Emerson and Sand Hill Faults on the west, by the west-northwest-trending fault on the south side of Ames Dry Lake and the foothills of the Coffin Mountains on the north, and by an arbitrary east-west line between secs. 11 and 14, T. 2 N., on the south. The west part of Surprise Spring Basin is limited by the Emerson and Sand Hill Faults on the east, by the bedrock hills near Giant Rock and an irregular line to the northwest and one to the south on the west and north, and by an irregular line largely in the north one-third of T. 2 N., R. 6 E. on the south (pl. 1).

Arbitrary lines again have been used to outline areas where the exact positions of limiting features are unknown. The western boundary of Surprise Spring Basin may extend beyond well 3/6-35N1 to Reche Fault; it may also extend west up Pipes Wash farther than shown. The southern boundary may extend farther south, but the consolidated rocks beneath the transverse arch may be at a shallow depth. Thus, the limits of Surprise Spring Basin are conservative. The areas of the two parts are about 41 mi^2 or about 26,000 acres for the east part and nearly 22 mi^2 or about 14,000 acres for the west part.

Depth Zone Used

The depth zone used in each of the storage units is selected as extending from the surface of the ground water down to a depth of 100 ft below this surface. The thickness of 100 ft so selected is readily within reach of the existing supply wells and is available at reasonable depth below land surface in selected topographically low areas of the basins.

Because the saturated thickness of the late Tertiary continental deposits, which contain virtually all the ground water in the four storage units, is known to be considerably in excess of 100 ft, for most of the area the selection of a depth zone 100 ft thick is a very conservative measure of the storage. If depths of wells and pumping lifts were of minor consideration, the depth zone could be doubled in some areas, such as those around Surprise Spring and near Deadman Dry Lake where depths to water are small.

Specific-Yield Values

The specific yield of a deposit is the ratio of (1) the volume of water which the deposit, when saturated, will yield by gravity to (2) the total volume of the deposit; specific yield is expressed quantitatively as a percentage. Thus, in order to estimate the ground-water storage capacity of the deposits in the four storage units by lowering the water level 100 ft below its present level, the specific yield of the saturated deposits must be determined.

The materials or deposits by the seven test and four supply wells in the upper 100 ft of the saturated section have been grouped into five general classes, each having relatively distinct hydrologic properties. Included in these properties are specific-yield values that are assigned to each of the five classes. Owing to the range in physical and hence hydrologic properties within each of the five general classes of material, the specific-yield values assigned are taken as the mean for each class.

Because the data provided by the brief test-pumping of the new supply wells were insufficient to derive coefficients of storage, it is necessary to assign specific-yield values to the five general classes of materials. The values are based on the results of several intensive field investigations in various parts of California. The most intensive of these was made by Eckis (1934) in the South Coastal Basin of the Los Angeles area. Another intensive study was made in the Mokelumne area in the northern part of the San Joaquin Valley by Piper, Gale, Thomas, and Robinson (1939). From these two sources, together with data from less detailed studies, specific-yield values have been selected which most closely represent the types of materials composing the late Tertiary deposits in Deadman and Surprise Spring Basins, as follows:

Material	Assigned specific yield (percent)
Sand, medium to very coarse, including some fine gravel, clean	20
Gravel and sand, fairly clean	15
Sand and silt, including tight sand, fine sand, and intermittently cemented gravel and sand	10
Sand, silt, and clay including sandy silt and some gravel and clay	7
Clay, including silty clay and some fine sandy clay, usually well compacted	1

Estimated Storage Capacity

The estimated ground-water storage capacity of the four storage units constituting Surprise Spring and Deadman Basins was computed as follows: (1) the areas of the four storage units were measured; (2) for each storage unit the volume of deposits was determined by multiplying the area in acres times the depth zone (thickness) of 100 ft. The volume so computed is given in acre-feet; (3) the logged materials in the test and supply wells were segregated into the five general types of material. The percentages of each type were multiplied by the assigned specific-yield values and added to determine the weighted average specific yield of the deposits in the 100-ft depth zone. For the west part of Surprise Spring Basin where no logs are available, the specific yield obtained for the east part was used; and (4) the estimated ground-water storage capacity for each of the four storage units was derived by multiplying the average specific yield of each times the total volumes of the saturated deposits in the 100-ft zone.

Because the areal extent of the storage units, the segregation of the types of material into the five general classes, and the specific-yield values assigned are believed to be conservative, the estimated storage capacity is also believed to be conservative. The estimated ground-water storage capacity for the four storage units constituting Surprise Spring and Deadman Basins is given in table 5.

As shown in table 5, the estimated total storage capacity of the two basins to a depth of 100 ft below the water level of 1953 is on the order of 800,000 acre-ft. This estimated total is approximately 400 times as much as the estimated annual recharge to the basins.

Table 5. Estimated ground-water storage capacity of the Surprise Spring and Deadman Basins

Storage unit	Area (acres)	Thickness (feet)	Total volume (acre-feet)	Specific yield (percent)	Storage capacity (acre-feet)	Percent of total storage
			Surprise Spring Basin			
East part	26,000	100	2,600,000	13	340,000	42
West part	14,000	100	1,400,000	[1]13	180,000	22
Subtotal					520,000	
			Deadman Basin			
East part	10,000	100	1,000,000	12	120,000	15
West part	13,000	100	1,300,000	13	170,000	21
Subtotal					290,000	
Total	63,000	100	6,300,000	13	810,000	100

[1]Estimated on basis of surface geology and log data in east part of Surprise Spring Basin.

With regard to the ground-water storage capacity below the 100-ft depth zone, a study of the materials tapped by the test and supply wells indicates that there is a slight decrease in the specific-yield values amounting to 2 to 3 percent. Hence, the specific yield for the deeper materials is on the order of 10 percent. In areas where water levels in the several basins are close to land surface, storage in addition to that in the 100-ft depth zone can be extracted for use. These areas are principally the east parts of Surprise Springs and Deadman Basins. Use of storage below the 100-ft zone in these areas would augment the storage capacity derived above.

Usable Storage Capacity

Of critical importance to the training center is whether all or part of the estimated storage capacity is usable. It is believed that with proper well spacing and location in all four storage units, most of the estimated storage could be pumped for use. In a few local areas, such as in the vicinity of test well 3 in Deadman Basin, there are sufficient fine-grained deposits to impede the downward drainage of ground water. Thus, the problem of utilizing the bulk of the storage is not one of areal drainage of ground water as the basins are pumped but one of areal distribution of wells over nearly 100 mi^2 overlying the storage units or basins.

Pumpage from new supply well 1A in the east part of Deadman Basin would not cause a uniform decline of water levels throughout the basin, nor would pumpage from new supply wells 2A and 3A in the east part of Surprise Spring Basin cause water levels to decline uniformly in this basin. Thus, in order to extract the bulk of the estimated storage, additional wells would have to be drilled, but there is no urgency in drilling the new wells. As storage is depleted in the vicinity of the existing new wells and as measurements of water level are continued in observation wells, studies of the data will provide a basis not only for determining the time when additional wells should be drilled but also for establishing the distance or spacing between the additional wells.

It is understood that the supply needed for the training center is not expected to exceed 3,000 acre-ft per year. The data in table 5 suggest that there is an average of about 8,000 acre-ft of ground-water storage to a depth of 100 ft below the 1953 water levels beneath each square mile of the basins. Thus, it is believed that the existing new supply wells should be able to supply the training center for a period of at least 5 years. It might be advisable to consider planning for additional supply wells within the next 3 to 5 years.

Relation of Storage to Reservation Boundaries

With regard to the lands that are outside the present military reservation but overlie the pertinent storage basins, the most critical are those at the south ends of Deadman Basin and the east part of Surprise Spring Basin. When additional supply wells are necessary, one of the areas most likely to be drilled is in Surprise Spring Wash upstream from the existing wells. Most of this area is south of the present reservation boundary. In order to protect the existing well fields and future additional wells in the basins it would be necessary for the Navy to acquire lands, or otherwise control the development of water in the north half of T. 2 N., R. 7 E., and those lands in the north halves of T. 2 N., Rs. 8 and 9 E., that are not already within the reservation.

A relatively large segment of the west part of Surprise Spring Basin is west of the present reservation boundary. The estimated storage capacity of this storage unit is about 170,000 acre-ft—roughly 20 percent of the total. It is understood that in the southern part, principally in T. 2 N., R. 6 E., there are numerous land patents and numerous applications on file with the Bureau of Land Management. For the north third of T. 2 N., R. 6 E. it would be worthwhile for the Navy to ascertain whether the Bureau of Land Management could permit entries but with a restriction on the type of desert entry or application whereby the use of water is limited to other than irrigation, industrial, or other heavy use. The water used for domestic purposes would be, or has been in other parts of the area, a very small amount. The southern two thirds of T. 2 N., R. 6 E. is not critical with regard to recharge or storage.

For the area north of T. 2 N., where it is understood that no lands have been opened for filing, if the storage is to be protected, it would be necessary to acquire, or control the development of water in: T. 3 N., R. 6 E., secs. 3 through 10, 15, 16, 22, 27, and 34; and T. 4 N., R. 6 E., secs. 19, 20, and 29 through 32.

Relation of Storage to Recharge

The reported requirements of not more than 3,000 acre-feet per year suggest that if the storage were properly and adequately developed over a period of years, there is a sufficient supply to meet the needs of the training center for at least 250 years, provided of course that there is no other substantial pumpage from Deadman and Surprise Spring Basins. On the other hand, the estimated recharge to the area is only slightly less than the yearly pumpage requirements.

In the recharge area, or area west of the storage units, the following lands overlie the most probable areas of recharge between Pipes Wash and the west part of Surprise Spring Basin: T. 1 N., R. 5 E., secs. 1 through 3; the east third of T. 2 N., R. 5 E.; T. 2 N., R. 6 E., secs. 6, 7, and 18; T. 3 N., R. 5 E., secs. 1, 2, 12, 13, 14, 23, 24, and 25; and T. 3 N., R. 6 E., sec. 31.

Regardless of the development of lands and water in the recharge area, which includes Pipes, Reche, and the small area west of Surprise Spring Basin, it would still be necessary for the Navy to drill additional supply wells in Deadman and Surprise Spring Basins over a period of years. The manner in which the basins are developed by the Navy for a water supply would not differ materially if the Navy acquired lands in the recharge area or if they were used by others for a water supply. Thus, the problem of acquiring lands in the recharge area resolves itself to the question of whether it is economically advisable to protect a supply for the years beginning after about 2200 A.D.

Chemical Character of Ground Water

All natural waters contain at least some dissolved solids. These are the salts that are dissolved in part by rain from atmospheric dust, and principally by surface and ground waters from the mineral and organic materials of the Earth's crust. The nature and concentration of the dissolved constituents in ground water, as revealed by analysis of samples from wells, define the chemical character of the water and in part determine its suitability for various uses. In addition, a study of the chemical character of the ground water may be of considerable assistance in determining the source and movement of the water and, inasmuch as the ground water is commonly in or approaching chemical equilibrium with its containing deposits, its character may be a useful tool in subsurface geologic studies.

With an exception of silica and iron, which may exist in colloidal form, nearly all the substances dissolved in the native ground waters of the Twentynine Palms Basin are ionic compounds (salts), made up of positively charges ions, termed cations, and negatively charged ions, termed anions. The major cations are calcium, magnesium, sodium, and potassium; the major anions are bicarbonate and carbonate, sulfate, and chloride.

Chemical-Character Diagrams

Analyses of water from all the Navy test and supply wells, together with selected wells in the pumping basins and source areas, are presented in table 7A in the appendix. Representative analyses are also plotted graphically on plates 11 and 12, which consist of diamond-shaped fields on which a single plotted point represents the percentages of the major chemical constituents in a given water sample.

In order to locate the point in the diamond-shaped field, the analytically determined weights of the ionic constituents, expressed in parts of ion per million parts of water (ppm), are first converted into chemically equivalent units that embody both the analytically determined weight of the ion and its chemical reactivity, that is, its capacity to combine with oppositely charged ions to form a salt. The values so obtained are termed the equivalents per million (epm) of the various constituents.

The equivalents per million of each cation are then expressed as a percentage of the sum of the equivalents per million of all the cations, and a similar computation is made for each of the anions. These percentages are termed the percentage reacting values of the various constituents and are the values represented by the point plotted on the graph. It should be noted that the point represents percentages only and does not indicate the absolute concentration of any of the constituents. Where desired, however, the total concentration of dissolved solids in the sample may be indicated on the graph by a circle whose center is the plotted point, and whose radius (or diameter) is a logarithmic function of the total dissolved solids, expressed in parts per million and plotted according to the scale of radii shown on plates 11 and 12.

Recharge Area

Ground water in the recharge area has a rather distinctive chemical character that is typical of source-area ground water in the Quaternary alluvium. Well 1N/5-22N1, drilled in decomposed granite in the foothills east of Pipes Basin, yields a calcium bicarbonate water; that is, calcium is the predominant cation and bicarbonate is the predominant anion, so that the analysis falls on the left-central part of the chemical-character diagram (pl. 11). The concentration of total dissolved solids in this water is 204 ppm. Many miles to the southeast in the vicinity of Twentynine Palms, recharge from the Little San Bernardino Mountains is of very similar quality, as is shown on plate 12 by the analyses of water from wells 1N/7-35D1, 1S/9-5A1, and 1N/9-32R1, whose total dissolved solids are 155, 123, and 138 ppm, respectively. The water from The Windmill, well 1N/5-2P1, in Pipes Creek shows a somewhat different character by virtue of an increase in sulfate, which may have been picked up from the Tertiary deposits exposed beneath the basalt in the middle of Pipes Basin.

The geochemical process initially most effective in changing the character of the source-type water as it moves downgradient is the phenomenon of cation exchange, also called base exchange, by means of which calcium ions in the water are exchanged for sodium ions loosely held in the molecular structure of clay particles. Thus, the ground water loses calcium and gains sodium and the clays gain calcium and lose sodium. Because calcium is the important "hardness" producing ion in the area, cation exchange constitutes a natural water-softening process. Changes in quality due to cation exchange are indicated on the chemical-character diagrams by a downgradient progression of the plotted points from the upper left to the lower right of the diagram. This process is well illustrated on plate 12 by the progressive changes between wells closest to the Little San Bernardino Mountain front and those a short distance to the north; for example, between well 1S/9-5A1, which yields a calcium bicarbonate water, and well 1N/9-32H1, which yields a sodium bicarbonate water.

The process of cation exchange is less well illustrated on plate 11 because of the scarcity of wells in the recharge area along the San Bernardino Mountain front. Nevertheless, the process may be recognized in general by the massing in the lower left part of the diagram of wells that are distant from the recharge area, and specifically by the progression in the plotted points representing water from wells 1N/5-2P1, 2/5-1H1, and 2/6-6D1. Some diversity in source or deposits tapped is suggested by the scattering of the analyses from Pipes and Reche Basins. For example, well 2/6-7Q1, in northern Reche Basin yields typical source-area calcium bicarbonate water, suggesting that most of the ground water feeding this particular well may be derived from a more local source than Pipes Creek, perhaps from Saddlerock Wash, which joins Pipes Wash a short distance from this well.

The examples of cation exchange cited in the preceding paragraphs are for wells that are believed to derive much or most of their water from the Quaternary alluvium. As water moves from the alluvium in the stream channels and along the mountain fronts into the older Tertiary deposits the process of cation exchange is apparently considerably hastened inasmuch as waters known or believed to be derived largely or wholly from the Tertiary deposits are generally rather soft, even a short distance downgradient from the areas of recharge and moderately hard water. Thus well 1N/6-6E1, only 1.7 mi east of and downgradient from well 1N/5-2P1, taps water that has exchanged nearly all of its calcium and is consequently exceedingly soft. The chemical character of this water is very similar to that in the southern part of Surprise Spring Basin and thus supports the geologic evidence that this well taps the Tertiary section. In addition, the change in character supports the hydrologic data regarding the eastward movement of ground water.

In the recharge area the ranges in concentration of critical constituents, in parts per million, are as follows: dissolved solids, 180 to 300; hardness 12 to 140; chloride 14 to 40; and fluoride, 0.3 to 1. Thus, the quality is wholly satisfactory for domestic use.

Surprise Spring Basin

Waters in the western part of Surprise Spring Basin differ from those in the recharge area principally in their diminished hardness and total concentration. Specifically, between well 2/6-7Q1 and test well 9, there is a reduction in the concentration of calcium and bicarbonate from 34 ppm to 10 ppm, and from 172 ppm to 81 ppm, respectively. These reductions are principally responsible for the decrease in hardness from 116 ppm to 34 ppm and the decrease in total dissolved solids from 233 ppm to 157 ppm.

Wells east of test well 9 in the southern part of Surprise Spring Basin tap water virtually similar to that at test well 9. No very significant trends in quality are apparent from west to east across the southern part of the basin. The wells in this area consistently yield a very soft sodium bicarbonate water, with the dissolved solids ranging between 196 ppm at new supply well 2A and 150 ppm at test well 5 and flowing well 3/7-35P1. The fluoride concentration is less than 1 ppm.

Well 3/6-4P1, in the northwestern part of Surprise Spring Basin, yields water generally similar to that of test well 9 although somewhat higher in calcium and bicarbonate. This similarity suggests that well 4P1 may derive most of its water from Tertiary deposits. However, wells 3/6-4L1 and 4L2, a very short distance farther north, tap a body of calcium bicarbonate water. This fact, in conjunction with an observed water-level difference of 7 ft between wells 3/6-4P1 and 3/6-4L1 and a much higher reported yield from well 4L1, suggests that wells 4L1 and 4L2 may possibly tap permeable Quaternary alluvium in an old buried channel of Pipes Wash that is conducting source area-type water from the recharge area.

The chemical character of the water tapped by test well 6 shows a marked divergence from the sodium bicarbonate type in the southern part of Surprise Spring Basin. The concentration of total dissolved solids is increased from 157 ppm at test well 9 to 444 ppm at test well 6 by an increase in the concentration of all ions except bicarbonate and carbonate, which remain virtually constant. Thus, the water from test well 6 is a sodium calcium chloride sulfate type that falls in the upper right part of the chemical-character diagram (pl. 11). Water of this type may be derived from antecedent low-concentration sodium bicarbonate waters of the type found in the western and southwestern parts of Surprise Spring Basin by the addition of sodium chloride and calcium sulfate and small amounts of calcium and magnesium chloride.

Near Ames Dry Lake, further addition of calcium, sodium, sulfate, and chloride would produce water of the character obtained from well 4/6-27M1 which, as its position on plate 11 shows, is very similar in type to that in test well 6 but has a total concentration of 909 ppm, more than twice the concentration at test well 6. The most probable sources of the calcium, sodium, sulfate, and chloride ions that are causing the increase in concentration are believed to be disseminated deposits of gypsum and common salt in the water-bearing Tertiary deposits tapped by test well 6 and well 4/6-27M1. Crystalline gypsum (selenite) in considerable quantities may be observed in various outcrops of the Tertiary deposits in the Mud Hills and presumably occurs beneath the floor of the basin in certain parts of the stratigraphic section.

The geologic structure and the log of test well 6 suggest that the Tertiary section dips gently northwestward between the Surprise Spring Fault and the Emerson Fault and thus brings successively higher parts of the section down into the upper part of the saturated zone. Accordingly, low concentration sodium bicarbonate water, apparently typical of the lower part of the Tertiary section west of the Emerson Fault, upon moving eastward across this fault near test well 9 and farther north may encounter for the first time a stratigraphically higher, finer grained (see log of test well 6 in table 4A in appendix), and more saline part of the Tertiary section from which it apparently dissolves appreciable amounts of salt and gypsum. The higher concentration at well 4/6-27M1 than that at test well 6 might result from a more saline part of the Tertiary section being tapped at well 27M1. The reasons for the decrease in concentration of ground waters between Ames Dry Lake and Surprise Spring can not be definitely resolved with the limited data available on the movement and chemical character of the ground water.

North of Surprise Spring Basin, three wells along the southern edge of Ames Dry Lake tap waters whose chemical characteristics are different from any south of the queried fault shown on plate 1. Well 4/6-27F1 contains a high-concentration (1,857 ppm of dissolved solids) sodium carbonate water having a pH of 9.7 and a fluoride content of 100 ppm. The well is drilled in the trace of a probable fault, and the peculiar character of the water suggests that some mineralized water may be rising from considerable depth in the fracture plane of the presumed fault. However, well 4/6-27D1, a short distance northeast of the fault yields a sodium chloride bicarbonate water with a total dissolved solids of only 523 ppm. Well 4/6-27C1, a dug well penetrating less than 4 ft below the water table, contains a sodium chloride sulfate water with a total concentration of 1,723 ppm. The reasons for the diverse chemical characteristics of the waters in these wells north of the probable fault are not known at this time. Although water levels across the probable fault do not indicate any appreciable barrier to ground-water movement, there is no indication from the chemical data that the water beneath Ames Dry Lake tends to move across the fault into Surprise Spring Basin. Whether this probable fault would form a barrier to ground-water movement if the water levels to the south were substantially lowered is not known; if it is an imperfect barrier, southward movement of poor quality water could occur.

In the southern part of Surprise Spring Basin the ranges in concentration of critical constituents, in parts per million, are as follows: dissolved solids, 150 to 196; hardness, 7 to 38; chloride, 12 to 29; and fluoride, 0.7 to 1. In supply wells 2A and 3A the concentrations are: dissolved solids, 196 and 172; hardness 38 and 30; chloride, 29 and 20; and fluoride, 0.8 and 1.0, respectively. Thus, these waters are of excellent quality for domestic use.

Deadman Basin

The chemical character of ground waters in Deadman Basin is notably different from that found in Surprise Spring Basin or in the recharge area to the west. The analyses of test wells 2, 3, 8, and 10, old supply well 3, and new supply well 1A fall in the right vertex of the chemical-character diagram (pl. 11), and indicate a sodium sulfate chloride water of reasonably consistent character ranging in dissolved solids from 683 to 1,040 ppm. Waters from test wells 2 and 8 and new supply well 1A, which tap very similar and probably correlative Tertiary sections of predominantly coarse sand and gravel, grouped closely on the diagram. Waters from test well 3 and old supply well 3, which penetrate similar generally fine-grained sections, likewise plot close together, but are displaced slightly from the others in the basin in the direction of higher percentage of sodium. Test well 10 in the western part of Deadman Basin is displaced slightly from the center of the group in the direction of a slight decrease in the percentage of sodium and a slight increase in the percentage of bicarbonate. The total concentration in test well 10, only 683 ppm, is appreciably less than in wells in the eastern part of Deadman Basin. These differences in chemical character between the western and eastern parts of Deadman Basin are not surprising in view of the displacement of the stratigraphic sections by relative uplift along the eastern side of Elkins Fault. Also, the analyses from test well 10 suggest that the quality in the west part of Deadman Basin is somewhat better than in the east part (table 7A in appendix).

The change in character of ground waters as they move from Surprise Spring to Deadman Basin cannot be explained on the basis of available data. To effect this change, the waters at Surprise Spring would have to undergo a fourfold-to-sevenfold increase in dissolved solids and change from a moderately bicarbonate type to a strongly sulfate type; the waters at Ames Lake, if moving southeastward to Deadman Basin, would have to undergo principally a change from a calcium to a sodium type water—the dissolved solids, although of somewhat different composition, remaining about constant. Thus, the study of water quality does not give any further information as to the sites of eastward ground-water movement across Surprise Spring Fault.

In Deadman as in Surprise Spring Basin the character of the ground water seems to be related principally to the position of the water-bearing deposits in the stratigraphic section. It is believed that the probable large-scale displacement on the Surprise Spring Fault has downdropped into the saturated zone tested in Deadman Basin a part of the Tertiary section that is considerably higher stratigraphically than the zone tested in Surprise Spring Basin. The section in Deadman Basin is tentatively believed to correlate generally with the uppermost part of the section measured in the Mud Hills, which was observed to contain beds whose surface outcrops became encrusted with an efflorescence of salts extracted from the sediments by leaching and evaporation of rainwater. These salts, if deposited in this part of the section believed to underlie the basin, might be the most probable source for the moderately high concentration of dissolved constituents in the ground waters of Deadman Basin.

The ground waters in Deadman Basin are the first thus far described that contain critical quantities of the fluoride ion. The quantities of fluoride in Surprise Spring Basin and basins upgradient do not appreciably exceed 1.0 ppm and are generally 0.6 to 0.8 ppm. However, in Deadman Basin they range from 1.5 ppm, which is the upper limit recommended by the U.S. Public Health Service for domestic use, in test well 8 to 4.5 ppm in old supply well 3. The source of the fluoride is not known. It, like the major constituents, may be associated principally with the stratigraphic section; however, there is fragmentary evidence that the fluoride may be in considerable part derived from the major fault zones.

In Deadman Basin the ranges in concentration of critical constituents, in parts per million, are as follows: Dissolved solids, 683 to 1,040; hardness, 62 to 160; chloride, 136 to 280 (test well 3); and fluoride, 1.5 to 4.5 (old supply well 3). In supply well 1A the concentrations are: dissolved solids, 1,040; hardness, 160 chloride, 188; and fluoride, 3.6. Thus, because of the high concentrations of dissolved solids and of fluoride, the waters in the east part of Deadman Basin are relatively poor for domestic use. However, if they are blended at a ratio of 1 part from Deadman Basin to 2 parts from Surprise Spring Basin, they would be satisfactory for training camp use.

Mesquite Basin and Vicinity

Ground waters derived from the late Tertiary deposits in the lower parts of the Mesquite Basin are generally very similar in chemical character to those in Deadman Basin, but are of a considerably lower total concentration, probably owing to more complete flushing of the sediments by the larger flow of ground water through Mesquite Basin, as is indicated by the high natural discharge around Mesquite Dry Lake. The water tapped by old supply well 2 is typical of this part of the basin, being a sodium sulfate type with a total concentration of 618 ppm and a fluoride content of 11 ppm. It is the very objectionably high fluoride content that renders waters in Mesquite Basin generally unsuitable for prolonged human consumption, particularly by children, whose developing teeth and bones may be seriously damaged.

As indicated on plate 12, the chemical character of waters in central, northern, and western Mesquite Basin is markedly different from that at the southeastern end of the basin (well 1N/9-27K1) and in the small basins south of Mesquite Basin. In the latter area the character ranges from the calcium bicarbonate source-area type to a sodium bicarbonate type of generally low concentration (130 to 250 ppm). In the southeastern part of Mesquite Basin, waters of this general type persist downgradient as far as the discharging area around the small playa, where they are apparently discharged from the basin by evapotranspiration and subsurface flow eastward across the Mesquite Fault.

The chemical character of the water in the northern part of Mesquite Basin, specifically in test well 1 and well 2/8-26J1, though very similar in type to that in Deadman Basin, reveals total concentrations of only 554 and 481 ppm, respectively, which is approximately 400 to 500 ppm less than those in the eastern part of Deadman Basin. These differences, however, do not cast doubt upon the existence of underflow from Deadman Basin to Mesquite Basin, because the directions of movement toward test well 1 and well 2/8-26J1, as indicated by the water-level contours and altitudes (pl. 1), are from the southern and southwesterly parts of Deadman Basin and probably from the small basins southeast of Surprise Spring Basin. The similarities in chemical type between the ground waters of Mesquite and Deadman Basins do suggest a similarity in the chemical characteristics of the containing sediments and the possibility of a general stratigraphic correlation between the basins.

The presently available chemical data cannot be used to evaluate the existence and magnitude of movement of low concentration water from Surprise Spring Basin southeast and subsequently east into Mesquite Basin because such water would be chemically modified substantially and probably beyond recognition in moving through different parts of the Tertiary section.

In old supply wells 1 and 2 the concentrations of critical constituents, in parts per million, are as follows: dissolved solids, 602 and 618; hardness, 92 and 94; chloride, 58 and 56; and fluoride, 7.5 and 11. In test well 1 the fluoride concentration was 8 ppm. The unusually high concentration of fluoride indicates that the water from these wells is unsuitable for training camp use, except possibly for short periods of time, and should definitely not be used for military housing projects were children or pregnant women are quartered.

SUMMARY AND CONCLUSIONS

This report, which is the second one prepared at the request of the Navy, presents basic and interpretive data that lead to certain conclusions regarding the water supply of the Twentynine Palms Marine Corps Training Center, California. Specifically, the following conclusions are related to the questions raised by the Navy with respect to the extent of the Surprise Spring and Deadman Basins, recharge to and storage in these basins, quality of ground waters, and further development of the basins for the water supply of the training center.

1. **Recharge.**—Virtually all the recharge to the Surprise Spring and Deadman Basins is supplied by runoff from Pipes Creek, only minor amounts being contributed by other small streams and virtually none by infiltration of rain. It is estimated by the Surface Water Branch of the Geological Survey that the average annual recharge to these basins supplied by Pipes Creek is about 2,000 acre-ft, subject to a possible error of 50 percent, or between 1,000 and 3,000 acre-ft.

The recharge takes place principally in Pipes Creek and occasionally in Reche Basin, by seepage loss from the stream during infrequent periods of high flow. The water moves in steplike fashion across a series of fault barriers, principally the Pipes and Reche Faults, to Surprise Spring Basin, and thence to Deadman and Mesquite Basins.

Lands outside the present reservation boundary overlying the most probable areas of recharge are as follows: T. 1 N., R. 5 E., secs. 1 through 3; the east third of T. 2 N., R. 5 E.; T. 2 N., R. 6 E., secs. 6, 7, and 18; T. 3 N., R. 5 E., secs 1, 12, 13, 14, 23, 24, and 25; and T. 3 N., R. 6 E., sec. 31. It is understood that a large part of the lands in Ts. 1 and 2 N. are either filed on or applied for. The ground-water development as of 1953 in the area of recharge is exceedingly small and therefore reduces by only a negligible amount the quantity of recharge moving eastward to Surprise Spring and Deadman Basins.

2. **Ground-water storage capacity.**—The estimate of ground-water storage capacity of Surprise Spring and Deadman Basins is based on the areal extent of the basins, the selection of a depth zone, and the derivation of a value for the specific yield of the deposits. The deposits composing the known ground-water reservoirs of Surprise Spring and Deadman Basins are the late Tertiary continental deposits tested to a depth of 800 ft.

Surprise Spring Basin is bounded on the east by the Surprise Spring Fault; on the west by consolidated rock near Giant Rock and by arbitrary lines to the northwest and south of Giant Rock; on the north by a fault near Ames Dry Lake and by the Coffin and Deadeye Mountains; and on the south by the transverse arch. The Emerson and

Sand Hill Faults form a barrier of known moderate effectiveness that divides the ground-water basin into two parts. The east part has an area of about 41 mi^2 and the west part, nearly 22 mi^2.

Deadman Basin is bounded on the east by the Mesquite Fault, on the west by the Surprise Spring Fault, on the south by the transverse arch, and on the north by the Mud Hills. The Elkins Fault forms a hydrologic barrier of known small-to-moderate effectiveness that divides the basin into two parts. The east part has an area of nearly 16 mi^2 and the west part, nearly 21 mi^2.

The depth zone selected for the storage computations in the basins is from the surface of the 1953 water level downward to 100 ft below the water level. In areas where the water level is close to the land surface the depth zone could be extended to a greater depth. A careful study of the deposits tapped by the wells within the 100-ft depth zone and the assignment of specific-yield values to the materials indicates that the average specific yield of the deposits is about 13 percent.

Thus, the total ground-water storage capacity of Surprise Spring and Deadman Basins, which is computed as the product of the area of about 100 mi^2, the thickness of the depth zone of 100 ft, and the specific yield of about 13 percent, is estimated to be about 800,000 acre-ft. Of this total, about 340,000 and 180,000 acre-ft are in the east and west parts of Surprise Spring Basin, respectively, and about 120,000 and 170,000 acre-ft are in the east and west parts of Deadman Basin, respectively. The estimated total storage in the 100-ft zone is approximately 400 times the estimated annual recharge, and if all recharge were intercepted before entering the basins, that storage would be sufficient to supply the training center at the reported maximum annual requirement of 3,000 acre-ft per year for a period of at least 250 years. Although not all the water in the 100-ft zone could be captured without an excessive number of wells and pipelines, the general lowering of the water table would cause ground water stored in surrounding basins to move into the dewatered area and so would increase the quantity subject to capture by feasible means.

In order to develop this storage, additional supply wells would have to be drilled over a period of many years. The existing new supply wells should be sufficient to meet the requirements of the training center for a period of at least 5 years; it is suggested that, to meet demands after that time, plans be considered for the construction of additional wells in the next 3 to 5 years. Continued records of pumpage and measurements of water level in supply and observation wells will be necessary not only to determine how soon additional supply wells will be needed but also to assist in the spacing of the wells.

With regard to lands overlying the basins that are outside the present reservation boundary, those at the south end of Deadman Basin and the south end of the east part of Surprise Spring Basin are critical with regard to the storage basins. In order to protect the existing well fields and future additional wells in the basins it would be necessary for the Navy to acquire, or otherwise control the development of water in, the north half of T. 2 N., R. 7 E., and those lands in the north halves of T. 2 N., Rs. 8 and 9 E., that are already within the reservation.

For the west part of Surprise Spring Basin, which is largely outside the reservation, it would be necessary to acquire or control the development of water in secs. 3 through 10, 15, 16, 22, 27, and 34, T. 3 N., R. 6 E.; and secs. 19, 20, and 29 through 32, T. 4 N., R. 6 E., where it is understood that the lands have not been opened for public filing, to protect the storage. In the north third of T. 2 N., R. 6 E., it is understood that numerous land patents and numerous filing applications have been made. For this area it would be worthwhile for the Navy to ascertain whether the Bureau of Land Management could permit entries but with a restriction on the type of water use, thereby limiting withdrawals principally to domestic use. The amount of water so withdrawn would be very small and would not reduce appreciably the storage in the basins. Similarly, if it were deemed advisable, the same arrangement could be considered for the public lands, previously described, in the recharge area.

3. **Recharge versus storage.**—A decision as to the advisability of acquiring the lands in the recharge area as a means of conserving and augmenting the available storage can be made only by the Navy. To assist the Navy in reaching that decision this report points out the magnitude of the estimated storage and annual recharge. Protection of the storage in the 100-ft zone in the lands outside the reservation by acquiring the lands or arranging with the Bureau of Land Management to restrict the use of ground water as described above should assure the

training center of a supply at an annual rate of withdrawal of 3,000 acre-ft a year for a period of at least 250 years. To acquire the lands composing the area of recharge would assure a perennial supply of 1,000 to 3,000 acre-ft per year, in addition to the stored water.

4. **Chemical character of ground water.**—The progressive change in character of ground water between the recharge area and Surprise Spring confirms the hydrologic data regarding the source of recharge and direction of ground-water movement. These waters generally contain less than 1.0 ppm of fluoride and less than 250 ppm of dissolved solids, and therefore are of excellent quality for camp supply. The recharge reaching the wells south of Ames Dry Lake has changed considerably in type; the water from the one well sampled contains 900 ppm of dissolved solids but only 1 ppm of fluoride. West of Emerson Fault the quality is very good. Thus, if the water in the local area south of Ames Dry Lake is blended with the water of excellent quality elsewhere in the basin, all the water in Surprise Spring Basin will be suitable for camp use.

The quality of ground water in Deadman Basin is considerably inferior to that in Surprise Spring Basin and of a different type. Because the analyses differ from those at Surprise Spring and at Ames Dry Lake, the chemical character cannot be used as a guide in determining where the bulk of the ground water moves eastward across the Surprise Spring Fault into Deadman Basin. In Deadman Basin the content of dissolved solids ranges from 700 to slightly more than 1,000 ppm, and the fluoride content generally ranges from 1.5 to 4.5 ppm. A blend of these waters at a rate of 1 part from Deadman Basin to 2 parts from Surprise Spring Basin would be satisfactory for camp use. Thus, if equal quantities of water were pumped from each of the three new supply wells, supply well 1A in Deadman Basin and supply wells 2A and 3A in Surprise Spring Basin, the resulting blend would contain about 470 ppm of dissolved solids and 1.8 ppm of fluoride.

5. **Development of the basin.**—In order to utilize most effectively the large volume of storage in Deadman and Surprise Spring Basins, future supply wells should be spaced so as to develop as much of the stored water between wells as possible, yet without excessive drawdown at the wells. Obviously, to effect such a spacing over the 100 mi^2 of the basins would necessitate many wells. For future development it is suggested that first consideration be given the following: In Deadman Basin, the placing of an additional well west of Elkins Fault and near the existing pipeline; in Surprise Spring Basin, the placing of one or two additional wells in Surprise Spring Wash upstream from existing supply well 2A.

Before an intelligent decision can be reached as to when to drill additional supply wells and what their spacing should be, it will be necessary to continue collecting records of pumpage and making water-level measurements in existing supply and observation wells to determine not only the rate of dewatering or storage depletion at the wells but also to provide information on the lateral extent of dewatering. In addition, if the relation of depletion in Deadman Basin to water levels in Mesquite Basin is to be established, and if the Navy plans to continue pumping old supply wells 1 and 2 in Mesquite Basin (these being matters of concern to the residents of Twentynine Palms), measurements of water levels in those two basins should be continued.

NAVY TEST AND SUPPLY WELLS

For the purpose of ascertaining the possibilities of obtaining a water supply for the training center from Surprise Spring and Deadman Basins, 10 test wells were drilled and tested for the Navy in 1952. The results of the test-drilling program were released in reports by Riley and Worts (1952 [2001]) and by Wagner (1952). On the basis of the favorable results obtained form the test-drilling program, three supply wells were drilled in 1953—well 1A in Deadman Basin and wells 2A and 3A in Surprise Spring Basin. In addition, there were three old wells, referred to as old supply wells 1, 2, and 3, already in existence at the start of the work. Wells 1 and 2 are in Mesquite Basin and well 3 is in Deadman Basin.

Summarized in table 6 are the pertinent data for all the Navy test and supply wells. These data include principally the tested capacity (not the maximum capacity), the drawdown, the specific capacity, and the concentrations of fluoride and dissolved solids.

Table 6. Summary of test- and supply-well data, Twentynine Palms Marine Corps Training Center
[ft, foot; gpm, gallon per minute; ppm, parts per million; dd, drawdown; °F, degrees Fahrenheit]

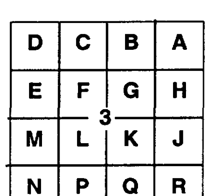
Well no.	Altitude of land surface[1] (ft)	Depth to water below land surface[1] (ft)	Altitude of water level (ft)	Tested capacity (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of dd)	Temper-ature (°F)	Quality	
								Fluoride (ppm)	Dissolved solids (ppm)
Mesquite Basin									
Supply well 1	1786.8	11.8	1775.0	256	41.0	6.2	77	7.5	602
Supply well 2	1779.2	5.5	1773.7	376	11.4	33.0	73	11.0	618
Test well 1	1856.2	80.2	1776.0	190	98.0	1.9	85	8.0	554
Deadman Basin									
Supply well 1A	1905.7	102.0	1803.7	2,000	61.5	31.5	79	3.6	1,040
Supply well 3	1823.9	24.5	1799.4	256	18.9	13.5	74	4.5	865
Test well 2	1845.7	43.0	1802.7	350	16.2	21.6	72	4.0	960
Test well 3	1850.4	46.9	1803.5	216	136.0	1.6	83	4.0	951
Test well 8	1890.9	87.5	1803.4	250	29.0	8.6	85	1.5	854
Test well 10	2020.2	189.4	1830.8	282	25.1	11.2	83	1.6	683
Surprise Spring Basin									
Supply well 2A	2355.3	104.7	2250.6	1,540	78.9	21.2	82	0.8	196
Supply well 3A	2300.9	54.4	2246.5	1,800	48.5	37.1	84	1.0	172
Test well 5	2272.1	25.4	2246.7	346	8.1	42.7	93	1.1	150
Test well 6	2403.7	146.7	2257.0	263	19.2	13.7	74	.3	444
Test well 9	2514.3	249.6	2264.7	262	8.6	30.5	78	.5	157
Test well 12	2442.2	188.7	2253.5	267	21.9	12.2	80	.7	174
South of Surprise Spring Basin									
Test well 11	2532.1	334.1	2198.0	76	54.5	1.4	96	1.1	166

[1]In 1952–53.

WELL-NUMBERING SYSTEM

The well-numbering system used in the Twentynine Palms Marine Corps Training Center investigation conforms to that used in virtually all ground-water investigations made by the Geological Survey in California. It has been adopted as official by the State Division of Water Resources and by the State Pollution Control Board throughout the State.

The wells are assigned numbers according to their location in the rectangular system for the subdivision of public land. For example, in the number 2/7-3B1, which was assigned to new supply well 2A in Surprise Spring Basin, the part of the number preceding the bar indicates the township (T. 2 N.), the part between the bar and the hyphen is the range (R. 7 E.), the number between the hyphen and the letter indicates the section (sec. 3), and the letter indicates the 40-acre subdivision of the section shown in the accompanying diagram.]



Within each 40-acre tract the wells are numbered serially as indicated by the final digit. Thus, well 2/7-3B1, is the first well to be listed in the NW 1/4 NE 1/4 sec. 3. Because the San Bernardino base line extends eastward across the south edge of the Twentynine Palms Basin, a few wells are south of the base line in T. 1 S. Accordingly, to avoid confusion, well numbers in T. 1 N. and T. 1 S. are prefixed by the symbols 1N and 1S, respectively; however, well numbers in townships to the north are prefixed by the symbols 2, 3 and 4. The entire area lies east of the San Bernardino meridian line; and therefore the range number is sufficient.

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APPENDIXES

Table 1A. Description of water wells, Twentynine Palms Basin, California

2A. Cross index of U.S. Navy well numbers and U.S. Geological Survey well numbers

3A. Records of water levels in observation wells, Twentynine Palms Basin, California

4A. Logs of U.S. Navy test wells

5A. Drillers' logs of U.S. Navy supply wells

6A. Drillers' logs of wells in the Twentynine Palms Basin, California

7A. Chemical analyses of water from wells in the TwentyninePalms Basin, California

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California

Other numbers: Well numbers consisting of a number, dash, number, and lower case letter (4-3b) are abbreviations of those assigned by the San Bernardino County Flood Control District. The complete number includes the portion shown above, prefixed by the township and range numbers as used in the Geological Survey well-numbering system. The U.S. Navy test and supply well numbers are indicated by the prefixes TW, denoting test well number, and SW, denoting supply well number.

Depth of well: Depths given in whole feet are reported or from drillers' logs; those given in feet and tenths were measured by the Geological Survey.

Type of pump and power: The first symbol indicates the type of pump as follows: L, lift; J, jet; S, submersible turbine; T, turbine. The second symbol indicates the type of power as follows: G, gasoline (or diesel) engine; H, hand operated; W, windmill; 15, electric motor rated at 15 horsepower.

Use of well: BS, Base supply; D, destroyed or dry; Dm, domestic; I, irrigation; Ob, observation well; PS, public supply; S, stock; T, test hole; and U, unused.

Altitude: Altitude given is the land-surface altitude or datum at the well; those in whole feet are barometric levels and those in feet and tenths are spirit levels.

Measuring point: Bnc, bottom of notch in casing; Bpb, bottom edge of pump base; Hc, hole in casing; Hpb, hole in pump base; Ls, land surface; Tap, top of well access pipe; Tb, top of board or timber cover or curbing; Tc, top of casing; Tcc, top of concrete curb; Tcv, top of casing cover; and Tpb, top of pump base. The suffix letters N, S, E, or W indicate the side north, south, east, or west, where measured. The distance of measuring point in feet and tenths above or below (–) land-surface datum is given in the column.

Water level: The water level is given in feet above (+) or below land-surface datum; measured depth to water is given in feet, tenths, and usually hundredths; and reported or approximate depth to water is given in whole feet.

Other data available: C, chemical analyses; L, log; and W, records of water levels. Most of these data are shown in tables 3A through 7A; the remainder are in the Geological Survey files.

[ft, foot; in, inch]

Well numbers		Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point		Water level		Other data available
Geological Survey	Other										(ft)	Depth (ft)	Date	
1S/9-3D1	3-2a	Mtn. View Estates				T	15	PS	2,075.4	Tpb	1.0	[a]89.80	11-20-52	C,W
5A1	5-1a	Beech			10	J	1	Dm	2,063.7	Tb	0.0	[a]74.16	2-2-40	C,W
												[a]75.14	4-10-46	
												[a]76.00	11-7-46	
												79.03	5-9-52	
1N/5-2P1					8	L	W	S	3,516	TcN	5.6	67.93	8-6-52	C
												69.00	2-11-53	
10E1					12	L	W	Dm	3,637	TcE	0.9	108.50	2-11-53	
10G1					8	L	W	Dm	3,608	TcS	2.5	116.44	2-11-53	
												115.58	5-2-53	
14J1		A. English		168	4	L	G	Dm	3,739	Ls	0.0	167	5-2-53	
14N1		R. Helfer		85	8	L		U		Ls	0.0	60	2-10-53	C
19B1		Pioneertown Corp.	1947	108	12	T	5	PS		TcN	1.7	58.88	2-10-53	C
22N1		R. Bennet		110	10	L	W	Dm						C

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	(ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/5-27D1		B. Burns	1948	208	12	L	W	Dm		Ls	0.0	75	2-10-53	
1N/6-4Q1	4-4a	J.W. Boldman		726	8	L	W	Dm	3,174	HcW	0.5	[b]501.1	2-13-53	C,W
												[a]472.79	5-25-53	
6E1		L.R. Rhoda		316	6	L	G	Dm	3,480	TcN	1.6	216.8	5-2-53	C
9Q1	9-4b	Mogle Bros.		570	16	L		U	3,214	TcN	0.0	391.6	2-13-53	L
10F1	10-2a	Olwell		315	8	L	W	Dm	3,127	Tcc	1.0	[a]256.00	3-13-51	C,W
												237.72	2-13-53	
25M1	25-3			512				PS	2,714.7			[a]408.0	5-28-41	C,W
28K1		Institute of Mentalphysics		260	10	T	10	Dm	2,927	BpbS	3.0	216.67	5-1-53	C
28L1	28-3	Do.			10	S	7.5	Dm	2,971.2	TcS	0.0	[a]216.83	5-28-41	W
												210.74	2-19-53	
29H1		Johnson		258				D				Dry		L
29R1		Lafferty		315	8	L	1.5	Dm	3,104			260	5-1-53	
1N/7-10D1		Tootle		268		L	G	Dm				213	2-12-53	C
14N1				450	12			U		TcN	1.0	184.15	2-13-52	
												184.02	12-16-52	
21J1		Crawford			8	L	W	Dm	2,470			260	5-28-41	C,W
26D1		Snyder		235	8	L		U		TcN	1.0	210.59	12-16-52	C
26P1		F. Pontius	1949	210		T	5	Dm				182	12-16-52	
28J1	28-4a				8	L		U	2,463.6	BncW	1.0	160.01	2-12-53	C,W
35D1		R.E. Sturdevant	1951	256	12	T	G	Dm		TcE	–1.0	182.14	2-18-53	C,L
1N/8-1A1				103.2	12	L	G	Dm		Hc	0.6	69.65	4-27-53	
1B1					8	L	W		1,903	BncE	0.4	124.06	4-27-53	W
1D1	1-2a	H.L. Cartwright	1934	212	8	L	W	Dm	1,949.2	BncS	1.8	[b]167.52	4-28-53	C,W

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/8-6D1		L.J. Rogers	1952	372	12	L	G	U	2,319	HpbS	1.0	295.9	2-19-53	L
9L1	9-3a				8	L	G	Dm	2,180.3	TcE	0.0	[a]320.70	1-7-41	C,W
												[a]320.70	5-28-41	
												320.85	7-9-52	
12G1	12-1a	W. Hockett	1931	420	12	L	G	Dm	1,972.7	TcN	1.0	196.02	4-28-52	C,W
21F1		G.R. Ruben	1945	356	10	L	G	Dm	2,171	TbN	1.4	298.9	11-25-52	
25R1				292				D				160	1937	C,L
26G1	26-1a	W. Schutze	1940	603	12	L	5	Dm	2,414.2	HpbW	1.0	[a]471.85	11-20-52	C,L,W
32C1		G.M. Graham	1947	295	8	L	G	Dm	2,430	Ls	0.0	245	1947	
36A1	36-1a	Mtn. Properties Water Co.		292		T		PS	2,129.7			[a]133.44	10-15-42	C,W
1N/9-4N1	SW 1	U.S. Navy	1941	500	14	T	G	BS	1,786.8	TapE	0.4	11.84	2-13-52	C,L,W
	4-3c													
4N2	4-3a	A. Krushat	1934	59.2	9			U	1,786.9	TcS	1.0	22.25	7-10-52	C,W
4N3	4-3b	Do.	1930	80	12			D	1,787			[a]30.44	3-4-41	W
5G1	SW 2	U.S. Navy	1941	500	14	T	75	BS	1,779.2	BpbN	0.6	5.48	2-13-52	C,L,W
5M1		A. Critchfield	1949	60	8	L	W	Dm	1,798	TbE	1.3	26.03	4-28-52	C,W
5M2		C.L. Toppen	1949	70	6	J	0.5	Dm						
5M3		J.W. Schopp	1948	80	8	L		Dm		TcW	1.0	27.75	7-9-52	
5Q1		W. Singleton		43		J	.5	Dm						C
5Q2		Do.		148	8	T	G	U	1,801	BpbN	1.2	27.22	4-29-52	C,W
5R1	5-4c	M. Elliott	1938	93.8	8	L		U	1,788.8	TcS	1.7	18.16	4-29-52	C,L,W
6D1	6-2a	Wilson			8	L	W	U		HcS	1.1	[a]61.89	4-12-46	
												[a]62.30	11-14-46	
												62.49	4-27-52	

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump	and power	Use	Altitude (ft)	Measuring point	(ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/9-6K1		E. Mason		61	2	L	H	U						
6N1		Bullard			8	L	W	Dm						
6P1					8	L	W	Dm						C
6R1	6-4a			65	8	L	W	Dm	1,820.1	Tcv	1.4	44.73	4-28-52	W
7E1	7-2a			160.9	8	L		U		TcW	0.9	[a]161.95	4-?-40	C
												Dry	4-28-52	
7G1	7-1b	Mabry			8	L	G	Dm	1,889			[a]112.42	4-?-40	
7H1	7-1a	P. Carson		10	8	L	W	Dm	1,843.3	TbS	0.0	68.50	4-29-52	C,W
8D1		Brown			8	L	W	Dm						
8D2	8-2b	Do.		42.3	44			U		TbW	0.5	42.7	4-29-52	C
8F1		Gouthier			8	L	W	Dm						C
8G1		N. Heely	1948	88	8	J	1	Dm		TcS	1.2	49.12	5-30-52	
8Q1		A.J. Lang	1940	92	8	L	W	Dm						
8R1		R. Markell		112	12	J	1	Dm		TcS	1.0	[b]49.09	5-1-52	
9A1					8	T	G	Dm						
9C1	9-2a	T.D. McMarlow		20.0	48			D		Tc		[a]26.45	4-1-40	C
												[a]26.45	4-11-46	
												[a]27.80	11-13-46	
												Dry	5-1-52	
9M1	9-3b	O. Taylor	1946	64.3	12			U	1,810	TcW	2.0	37.12	4-29-52	L,W
9M2	9-3a	Do.	1932	61.5	12			U	1,810.0	TcW	1.2	37.32	8-6-52	C,W
9N1		Matthiews		60.2	8	J	1	U		TcN	0.5	36.96	5-1-52	C
9Q1	9-4a	Stubbs		20		L	W	Dm	1,783	Tc		[a]16.48	11-13-46	C,W
10D1	10-2a	Taylor		301	8			U	1,815	TcE	1.0	272.90	5-7-52	C,W

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/9-12G1		Darling	1942	245	6			U						C
12G2	12-1b	Do.	1946	265	8	T	G	Dm	1,750± (from quad)	Tc		[a]210.26 [a]210.05	4-11-46 11-12-46	
13P1	13-3a	Brogdon			8	L	W	Dm	1,795±	TccE	0.5	260.17	5-7-52	C,W
14D1		Perkins	1950		8	L	G	Dm						
14D2		Keeffler	1949		12	L	W	U		Hc	2.0			
14M1	14-3a				8	L		U		HcS	1.0	208.76	5-7-52	C,W
15N1		Hamilton Sales Corp.	1950	312	12	T		PS						C
16D1		Whited	1933	96	12	L	W	Dm	1,812.9	Tb	1.0	38.80	5-1-52	C,W
16E1		E.W. Moseley	1940	108	8	J	0.25	Dm		TcE	1.5	41.43	5-1-52	
16E2		Joyce		120	8	J	1	Dm		TcW	2.6	40.61	5-1-52	
16H1				56.8	12			U		Tb	0.0	14.33	5-7-52	
16H2					30	L	G	U		TbE	0.5	13.51	5-7-52	
16H3		G. Michells	1948	153.9	12			U	1,777	TcW	0.4	8.76	5-7-52	C,W
16M1		S. Howland	1946	110	8	J		Dm		TcW	0.8	42.49	5-1-52	C
16N1					8			U		TcW	2.6	42.30	5-28-52	
16N2					8			U						
17C1		Jim Hill			48	L	W	Dm		TbS	1.0	74.49	4-29-52	C
17E1	17-2a	Barry		133	12	L	W	Dm	1,882.7	Tcv	0.5	107.56	4-29-52	C,W
17G1		J.A. Goddard	1937	85	8	L	W	Dm		TcW	1.0	61.12	4-29-52	
17H1					8	J		U		TcE	1.9	53.08	5-1-52	
17H2		Rx Acres			6	L	W	Dm		Tcv	1.0	52.24	5-1-52	
17H3					8	L	W	Dm		BncS	1.9	45.50	5-1-52	
17J1		W. Smith	1948	106	8	T	15	PS						C

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/9-17J2		Do.		85	8	5	2	PS						C
17J3		Do.		61.9	12			U		Tb	0.3	52.15	4-29-52	
18R1	19-1a				8	L	W	Dm		TbS	1.0	[a]137.52	4-12-46	C
												[a]137.48	4-11-46	
												137.54	4-29-52	
20A1		J. Williams			8	L	W	Dm		Tc	1.6	38.34	5-1-52	
20A2		R.W. Flickinger			6	J	0.5	Dm		TcN	2.1	44.45	5-1-52	
20J1		W.T. Ince		128	8	L	W	S						
20R1	20-4a	Bagley			8			D	2,009					C
21C1		O.J. Cones	1933	42	12			Dm						C
21D1		L. Halderman	1933	43	8	J		Dm						
21D2		R.A. Elleboudt		60	8	L	W	Dm		HcW	2.0	34.94	5-1-52	
21E1		H. Smith	1950	77	8	L	G	D		Hc	1.0	41.50	5-1-52	
												41.55	5-28-52	
												41.60	7-9-52	
												41.64	8-7-52	
												42.10	9-9-52	
21E2		H. Smith	1951	90	6	J		Dm	1,816	Tc	0.5	44.48	10-3-52	W
21J1		H. School				J	2	Dm		BpbN	1.6	63.55	5-7-52	C
21J2		L. Greenman		227	48	J	1	Dm		Tbs	2.0	64.04	5-7-52	C
22B1	22-1A	E. Schenck	1929	309	8	L	G	Dm		TcW	0.5	[a]267.64	4-11-46	C
												[a]267.61	11-12-46	
												267.20	5-7-52	
22C1	22-2g			59.7	8	L	G	U	1,804.4	TcS	0.5	33.61	5-7-52	W

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers		Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point		Water level		Other data available
Geological Survey	Other										(ft)	Depth (ft)	Date	
1N/9-22C2		G. Michells		50	12	L	W	Dm		TcN	2.0	41.60	5-7-52	
22C3		Do.		60	48	J	1.5	Dm						
22D1	22-2h	E. Michells			8	J		Dm						C,W
22E1	22-2a	W.B. Hatch			8	L	W	Dm	1,826.8	TbW	0.5	52.32	5-2-52	C,W
22E2	22-2f	R.G. Michells		64	40	J		Dm	1,815			[a]42.65	2-17-40	
												[a]39.25	4-1-40	
22E3	22-2c	R.G. Michells		75	12	L	G	Dm	1,815	TcE	–4.0	39.74	5-2-52	W
24G1		C. Gregory	1952		10			Dm						
26E1	26-2a			133.7	12			U	1,896.6	TccN	0.0	116.56	5-2-52	C,W
26F1					10	T	5	Dm						
26N1	26-3a	L. Jacobs	1936	162	8			U	1,932.4	TcE	2.0			C,W
27C1	27-2a	Wrubel		350		T	15	Dm						C,L,W
27C2	27-2a	Do.		165		L	W	Dm	1,867.8	TbS	0.4	82.26	5-2-52	C,W
27K1	27-4a	T. Hopkins	1936	165	12	L	G	Dm		HcW	1.0	[a]112.28	4-10-46	C
												[a]112.19	11-14-46	
												117.59	5-2-52	
27M1		J. Landon			8			U		TcN	0.5	114.29	5-7-52	
												114.42	5-28-52	
												114.48	7-9-52	
												114.52	8-6-52	
28B1	28-1a	C. Malory		180.6	8			U	1,947.9	TcE	1.0	[a]169.84	2-2-40	W
												[a]170.55	4-10-46	
												171.04	5-1-52	
28D1	28-2a							D	2,008					W

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/9-28R1	28-4a				6			D	1,922					W
29F1	29-2a	Adobe Hotel			10	L	G	U	2,079.4	Hc	0.7	[a]296.41	3-22-40	C
												[a]296.75	4-8-41	
												[a]305.40	4-16-46	
												295.1	11-26-52	
29R1	29-4a			121				D	1,991			[a]103.00	10-4-41	C,W
30K1	30-4b	W.A. Nicolson		171	8			U	2,120.5	TcW	0.5	139.44	12-3-52	C,L,W
30Q1	30-4c	Mission Inn		120	8			U		TcN	3.4	[a]102.94	11-8-46	C
												102.28	12-4-52	
												101.82	2-18-53	
31A1		R. Abell	1936	112	8	L	1.5	Dm		BpbE	1.5	98.70	12-4-52	C
31A2		R. Scriven	1950	117	8	L		Dm				77	1950	C
31C1	31-2a	Abell Water Co.		305	14	T	15	PS	2,103.0	Tc	1.0	[a]106.73	11-7-46	C,L,W
31H1		Do.	1953	350	12	T	25	PS		TapN	1.0	93.5	5-1953	C,L
												[b]97.45	9-10-53	
32F1	32-2a				8	L		U		TcN	0.0	[a]64.04	4-10-46	C
												[a]64.29	11-7-46	
												66.35	11-26-52	
32G1		C.F. Lekstrum	1938	84	8	L		U		TcN	0.6	61.59	11-26-52	
32G2		W.L. Mayo	1940	75	8	L	G	Dm				55	1940	
32G3		G. Macklin		85	8	L	W	Dm		TcN	0.6	43.67	12-3-52	
32G4		T.J. Ford	1946	84	8	J	0.25	Dm						
32G5	32-1c	J.S. Petersen	1933	71	8	L	W	Dm		TcS	1.0	[a]40.90	4-10-46	C
												[a]40.70	11-7-46	
												43.10	12-3-52	

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
1N/9-32H1	32-1b	Sullivan			48				2,006			[a]17.20	10-15-42	C,W
32H2	32-1d	N.S. Hughes		125	8	L	G	U		BpbE	0.7	102.67	11-26-52	C,W
32H3		H.G. Legg	1947	52	8	J	0.5	Dm		Tb	0.0	31.42	12-3-52	
32K1		F. Brockman		60		J	0.5	Dm						
32R1	32-4d	Earenfight		75	8	L	W	Dm	2,045.9	Tb	0.9	59.24	5-9-52	C,W
33F1		Twentynine Palms Inn		60	8			U				Flowing		C
33F2		Do.		175	12			U				Flowing		
33F3	33-2a	Do.	1939	285	12	T	10	PS				Flowing		C,L,W
33H1	33-1a	U.S. Park Service	1900	16	32				1,961.2	TcN	0.9	0.84	5-9-52	W
34A1	34-1a	Keaton			8	L	W	Dm		TcS	1.0	152.54	5-7-52	C,W
35F1	35-2a	Watson		253	12	L	W	Dm	1,971.6	HcN	0.6	130.94	5-9-52	C,L,W
35N1	35-3a		1935	244.2	12			U	2,079	TcN	1.0	103.44	5-9-52	C,L,W
2/5-1G1		W. Reche	1953		18			U	3,015	Tc	5.0	94.75	9-11-53	
1H1		Do.	1940	85	5	L	W	Dm,S	2,920			60		C
1H2		Do.	1949	84	8			U	2,983	TcW	0.8	64.51	10-25-52	
												64.87	2-25-53	
												64.78	9-11-53	
2/6-6D1		G. Van Tassel	1943	60	8	L	W	S	2,954	TcS	1.0	36.22	2-25-53	C
									2918			36.21	9-11-53	
6D2		Do.		200	8			U	2,959	TcN	1.0	39.51	2-6-53	
									2920			39.86	2-25-53	
												39.57	6-25-53	
7Q1		G. Belfield		233		T	20	Dm	3,080	Ls	0.0	168		C
12R1				194.0		T			2,912	Ls	0.0	Dry	1-28-53	

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers		Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump and power		Use	Altitude (ft)	Measuring point		Water level		Other data available
Geological Survey	Other										(ft)	Depth (ft)	Date	
2/7-2C1	TW 5	U.S. Navy	1952	400	10			Ob	2,272.1	TcN	2.2	25.41	6-25-53	C,L,W
3A1	SW 3A	Do.	1953	[c]560	16	T	G	BS	2,300.9	TapE	1.7	54.41	6-25-53	C,L,W
3B1	SW 2A	Do.	1953	[c]700	16	T	G	BS	2,355.8	TapN	1.5	104.68	1-10-53	C,L,W
4H1	TW 12	Do.	1952	500	10			Ob	2,442.2	TcN	2.6	188.72	10-2-52	C,L,W
2/7-14K1	TW 11	Do.	1952	644	10			Ob	2,532.1	TcW	2.0	334.1	10-2-52	C,L
												334.49	2-19-53	
												334.58	5-30-53	
2/8-11B1		Stites		64.6	12			U	1,833	Hc	0.0	35.52	4-26-52	C,W
13A1		G.W. Shutes	1946	154.3	10			D		TcE	3.1	Dry	4-26-52	
24H1	TW 1	U.S. Navy	1952	320	10			Ob	1,856.2	TcN	2.7	80.19	5-28-52	C,L,W
26J1	26-4a	B. Stubbs	1932	185	8	T	G	Dm	1,938	BpbS	0.5	155.37	4-27-52	C,W
2/9-19D1		C.B. Woodrow	1950	146	6			U	1,860±	TcE	1.6	88.34	4-26-52	
19N1		H.A. Porter	1950	136	8	L	W	Dm		TcW	0.9	86.15	4-27-52	L
19N2		W.D. Deller			8	L	W	Dm		TbW	0.3	60.78	4-27-52	
19N3	19-3a	Do.		77.8	8	L		U	1,833.8	TcE	0.5	68.90	4-27-52	C,W
30B1		C.B. Woodrow	1937	40	6	L	H	Dm		Ls	0.0	Flowing	4-26-52	C
30B2				18.9	48			D		TcN	0.0	Dry	4-27-52	
30D1		Steward		56.0	8	L	W	U		BncE	0.0	45.54	4-27-52	
30G1				7.9	10			U		Hc	0.8	Flowing	4-26-52	C
30K1		R.E. Jones	1951	48	8	L	W	Dm						
30K2		Do.	1950	35	6			U		TcE	0.5	16.87	4-29-52	
30P1		E.R. Camp	1951	77	8	L	G	Dm						
30P2		E. Ball	1936	55.8	8			U	1,790	TcN	2.6	27.38	4-27-52	W
31E1	31-2b	Meyer			8	L	W	Dm	1,830	Tcc		[a]59.85	4-12-46	C,W

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump	and power	Use	Altitude (ft)	Measuring point	(ft)	Water level: Depth (ft)	Water level: Date	Other data available
2/9-31N1	31-3a	Johnson			8			D				[a]62.20	4-12-46	C
												[a]62.36	11-14-46	
												Dry	4-27-52	
31Q1		J. Meggs	1952	31	8	L	W	Dm		TcE	0.4	15.25	4-29-52	
31R1		J. Haworth	1947	36	8	L	W	Dm		TcN	0.6	16.04	4-29-52	
32E1				13.8	12			U		TcN	2.4	6.72	4-29-52	
												6.23	8-6-52	
32N1				15.6	8	L		U		TcS	0.0	6.25	4-29-52	C
												7.09	5-28-52	
												7.98	7-9-52	
												8.46	8-6-52	
3/6-3N1		F.B. Mullen		133.9	14			U	2,419	TcS	1.3	95.28	5-8-52	
												93.19	2-24-53	
4L1		C.W. Alvord	1950	137	16	T	G	I	2,406	BpbW	0.5	83.07	1-29-53	C
4L2		Do.	1951	76	26			T		Tc	1.0	74.95	5-8-52	C
4P1		Gentry	1946	132	6			U	2,408	TcN	1.0	80.05	5-8-52	C
												77.95	1-29-53	
35N1					9	L	G	U	2,682	TcN	0.8	363.10	1-27-53	
3/7-13N1	TW 10	U.S. Navy	1952	501	10			Ob	2,020.2	Tc	1.0	189.39	10-30-52	C,L,W
18D1	TW 6	Do.	1952	449	10			Ob	2,403.7	TcS	1.0	146.75	7-8-52	C,L,W
												146.80	11-10-52	
												146.66	2-22-53	
31E1	TW 9	Do.	1952	430.0	10			Ob	2,514.3	TcN	1.7	249.96	7-8-52	C,L,W
												249.90	1-26-53	
												249.55	5-30-53	

See footnotes at end of table.

Table 1A. Descriptions of water wells, Twentynine Palms Basin, California—Continued

Well numbers: Geological Survey	Well numbers: Other	Owner or user	Year drilled	Depth (ft)	Diameter (in)	Type of pump	and power	Use	Altitude (ft)	Measuring point	Measuring point (ft)	Water level: Depth (ft)	Water level: Date	Other data available
3/7-35L1		Do.		36.0	9			U	2,259.6	TcS	–4.2	13.51	7-8-52	W
35P1		Do.			3			U	2,244.5	TcE	3.9	+2.45	5-30-53	C,W
3/8-17L1	TW 3	Do.	1952	512	10			Ob	1,850.4	TcE	1.0	46.87	5-29-53	C,L,W
29C1	TW 8	Do.	1952	800	10			Ob	1,890.9	TcN	2.9	87.52	5-30-53	C,L,W
29L1	SW 1A	Do.	1952	[c]600	16	T	G	BS	1,905.7	TapE	1.7	102.02	5-30-53	C,L,W
33B1	TW 2	Do.	1952	526	10			Ob	1,845.7	TcN	0.7	42.95	5-29-53	C,L,W
34D1	SW 3	Do.	1943	400	12			BS	1,823.9	TcN	0.5	24.46	4-26-52	C,L
4/5-13R1				54.9	48			U	2,299	TbN	0.0	41.10	11-1-53	C
4/6/18F1			1953	39.1				T	2,292	Ls	0.0	Dry		L
27C1			1915	63.1				U		TbN	3.0	59.33	5-8-52	C
												59.28	1-29-53	
27D1		C.W. Alvord	1946	80.2	6			U	2,328.0	TcS	1.6	68.47	4-30-52	C
												68.49	1-29-53	
27F1		C.E. Crumb		182.3	8			U		TcS	1.1	70.55	5-8-52	C
												72.97	1-29-53	
4/6-27M1		C.E. Crumb	1951	150	16	T	G	I	2,344.8	TcS	1.0	83.88	1-29-53	C
28R1		H. Higgins	1951	150	14	T	G	I	2,360.0	TcN	1.0	100.13	5-8-52	
												99.11	1-29-53	
34E1		L.F. Mullen	1951	163	14	T	G	I	2,358.3	Tc	0.5	99.01	´5-8-52	
												98.27	2-24-53	
5/6-31N1				40.0	6			D	2,294			Dry	1-11-53	

[a] By San Bernardino County Flood Control District.
[b] Pumping measurement.
[c] Pilot hole drilled to 800 ft.

Table 2A. Cross index of U.S. Navy well numbers and U.S. Geological Survey well numbers

[U.S. Navy number: SW, supply well; TW, test well]

U.S. Navy number	USGS number	Ground-water basin
	Supply wells	
SW 1	1N/9-4N1	Mesquite
SW 2	5G1	Do.
SW 3	3/8-34D1	Deadman
SW 1A	3/8-29L1	Deadman
SW 2A	2/7-3B1	Surprise Spring
SW 3A	3A1	Do.
	Test wells	
TW 1	2/8-24H1	Mesquite
TW 2	3/8-33B1	Deadman
TW 3	17L1	Do.
TW 5	2/7-2C1	Surprise Spring
TW 6	3/7-18D1	Do.
TW 8	3/8-29C1	Deadman
TW 9	3/7-31E1	Surprise Spring
TW 10	13N1	Deadman
TW 11	2/7-14K1	Unnamed
TW 12	4H1	Surprise Spring

USGS number	U.S. Navy number	Ground-water basin
1N/9-4N1	SW 1	Mesquite
5G1	SW 2	Do.
2/7-2C1	TW 5	Surprise Spring
3A1	SW 3A	Do.
3B1	SW 2A	Do.
4H1	TW 12	Do.
2/7-14K1	TW 11	Unnamed
2/8-24H1	TW 1	Mesquite
3/7-13N1	TW 10	Deadman
18D1	TW 6	Surprise Spring
31E1	TW 9	Do.
3/9-17L1	TW 3	Deadman
29C1	TW 8	Do.
29L1	SW 1A	Do.
33B1	TW 2	Do.
34D1	SW 3	Do.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California

[Records prior to May 1952 are by the San Bernardino County Flood Control District; records beginning May 1952 are by the U.S. Geological Survey, except as indicated by footnote [a], which denotes records by San Bernardino County Flood Control District. Water levels are in feet above (+) or below land surface datum. ft, feet.]

Date	Water level	Date	Water level	Date	Water level
		Well 1S/9-3D1. Altitude 2,075.4 ft			
1939		**1941—Continued**		**1948**	
Dec. 6	86.29	Mar. 4	86.41	Apr. 6	88.78
		Apr. 8	86.41	Nov. 15	88.47
1940		June 1	86.43		
Jan. 16	86.32	Aug. 1	86.47	**1949**	
Feb. 2	86.33	Oct. 1	86.49	Apr. 27	88.56
17	86.32	Dec. 15	86.45	Nov. 17	88.92
Apr. 1	86.35				
May 3	86.34	**1942**		**1950**	
June 3	86.37	Feb. 16	86.48	Apr. 11	92.66
27	86.41	Aug. 1	86.53	Nov. 7	94.26
Aug. 1	86.39	Oct. 15	86.57		
Sept. 6	86.44			**1951**	
Oct. 11	86.43	**1946**		Mar. 14	89.10
Nov. 4	86.43	Apr. 16	[b]88.50	Nov. 14	92.87
Dec. 6	86.45	Nov. 7	87.58		
				1952	
1941		**1947**		Nov. 20	89.80
Jan. 7	86.42	Apr. 11	87.61		
Feb. 9	86.41	Nov. 17	88.25		
		Well 1N/8-1B1. Altitude 1,903 ft			
1952		**1952—Continued**		**1953**	
Apr. 27	124.06	Aug. 6	[c]127.09	Jan. 26	124.45
May 28	124.08	Oct. 4	124.30	Feb. 20	[b]124.40
July 9	124.12			Mar. 27	124.46

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 1N/8-12G1. Altitude 1,972.7 ft					
1940		**1942**		**1950**	
May 3	194.85	Feb. 16	194.94	Apr. 14	196.02
June 27	194.77	Aug. 1	194.94		
Aug. 1	194.80	Oct. 15	195.03	**1951**	
Sept. 6	194.85			Nov. 15	202.76
Oct. 11	194.91	**1946**			
Nov. 4	194.86	Apr. 12	195.49	**1952**	
				Apr. 28	[e]196.02
1941		**1947**		May 28	[b]196.92
Jan. 7	194.91	Apr. 11	195.61	July 9	[c]196.65
Feb. 9	194.76	Nov. 21	195.84	Aug. 7	196.02
Mar. 4	194.89			Oct. 4	196.2
Apr. 8	194.88	**1948**			
June 1	194.89	Apr. 9	194.96	**1953**	
Aug. 1	194.83	Nov. 18	194.74	Jan. 26	196.25
Oct. 1	194.91			Feb. 18	196.28
Dec. 15	194.94	**1949**			
		Nov. 18	195.3		
Well 1N/9-4N1 (USN Old SW 1). Depth 500 ft. Altitude 1,786.8 ft					
1946		**1952—Continued**		**1953—Continued**	
Nov. 13	11.62	Oct. 3	12.75	Mar. 27	[b]13.24
		Nov. 25	[a]13.10	Apr. 30	12.68
1952				May 29	[b]14.10
Feb. 13	11.84	**1953**			
Apr. 7	[d]11.83	Jan. 23	[b]13.73		
28	11.84	Feb. 18	12.78		

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-4N2. Depth 59.2 ft. Altitude 1786.9 ft					
1940		1949—Continued		1952—Continued	
Apr. 1	19.80	Apr. 28	21.43	July 19	22.38
		Nov. 18	22.85	24	22.40
1946				31	22.40
Apr. 11	20.83	1950		Aug. 7	22.39
Nov. 13	21.67	Apr. 13	21.76	Oct. 3	22.56
		Nov. 9	22.45	Nov. 25	[a]22.35
1947					
Apr. 10	21.34	1951		1953	
Nov. 20	21.95	Mar. 15	21.70	Jan. 23	21.94
		Nov. 15	22.37	Feb. 18	21.80
1948				Mar. 27	21.71
Apr. 6	21.90	1952		Apr. 30	21.66
Nov. 17	22.27	Apr. 16	21.77	May 29	21.73
		July 10	22.25		
1949		11	22.39		
Jan. 3	21.91				

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-5G1 (USN Old SW 2). Depth 500 ft. Altitude 1,779.2 ft					
1952		1953		1953—Continued	
Feb. 13	5.48	Jan. 23	[c]12.82	Apr. 30	[c]8.49
Apr. 28	4.98	Feb. 15	5.18	May 29	[c]21.95
Dec.5	[c]20.31	16	[c]12.55		

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-5M1. Depth 60 ft. Altitude 1,798 ft					
1952		1952—Continued		1953	
Apr. 28	26.03	July 30	[b]29.12	Jan. 28	26.69
May 28	28.04	Aug. 1	26.77	Feb. 18	24.90
July 9	26.40	Oct. 3	26.88	Apr. 30	26.57
				May 29	26.76

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-5Q2. Depth 148 ft. Altitude 1,801 ft					
1952		1952—Continued		1953—Continued	
Apr. 29	27.52	Oct. 3	28.10	Feb. 18	27.89
May 28	27.60			Mar. 27	27.88
July 9	27.84	1953		Apr. 30	27.85
Aug. 6	27.90	Jan. 23	27.92	May 29	27.95

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
		Well 1N/9-5R1. Depth 93.8 ft. Altitude 1,788.8 ft			
1940		**1942—Continued**		**1951—Continued**	
Feb. 2	17.55	Apr. 20	15.10	Nov. 15	18.56
17	17.42	Aug. 1	17.65		
Apr. 1	17.36	Oct. 15	17.63	**1952**	
June 3	17.55			Apr. 16	18.43
27	17.68	**1946**		May 28	18.26
Aug. 1	17.87	Apr. 11	18.53	July 9	18.42
Sept. 6	17.92			Aug. 6	18.56
Oct. 11	17.95	**1947**		7	18.43
Nov. 4	17.95	Nov. 20	18.52	14	18.43
Dec. 6	17.82			21	18.43
		1948		28	18.43
1941		Apr. 6	18.12	Sept. 10	18.63
Jan. 7	17.72	Nov. 17	18.60	Oct. 23	18.80
Feb. 9	17.63			Nov. 7	18.81
Mar. 4	17.58	**1949**		Dec. 15	18.77
Apr. 8	17.57	Apr. 28	18.18		
June 1	17.61	Nov. 18	18.68	**1953**	
Aug. 1	17.99			Jan. 11	18.80
Oct. 1	18.03	**1950**		23	18.01
Dec. 15	17.80	Apr. 14	18.20	28	18.14
		Nov. 9	18.64	Feb. 18	18.35
1942				Mar. 27	18.51
Feb. 16	[c]18.94	**1951**		Apr. 30	18.50
		Mar. 15	17.95	May 29	18.53

Date	Water level	Date	Water level	Date	Water level
		Well 1N/9-7H1. Depth 110 ft. Altitude 1,843.3 ft			
1940		**1949**		**1952—Continued**	
Apr. ?	66.90	Apr. 29	68.15	May 28	68.58
		Nov. 18	68.04	July 9	[c]68.72
1946				Aug. 6	68.80
Apr. 12	67.80	**1950**		Oct. 4	68.94
Nov. 14	67.93	Nov. 9	70.07		
				1953	
1947		**1951**		Jan. 26	[b]68.96
Apr. 11	67.85	Nov. 15	68.35	Feb. 18	69.00
Nov. 21	67.94			Mar. 27	[b]69.02
		1952		Apr. 30	69.00
1948		Apr. 16	69.45	May 29	69.04
Apr. 9	67.96				
Nov. 18	68.03				

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-9M1. Depth 64.3 ft. Altitude 1,810 ft					
1946		**1949—Continued**		**1952—Continued**	
Nov. 14	40.60	Nov. 18	37.41	July 9	37.42
				11	37.37
1947		**1950**		19	37.46
Apr. 11	40.40	Apr. 14	37.22	31	37.49
Nov. 21	39.59	Nov. 9	37.21	Aug. 7	37.52
				Oct. 3	37.64
1948		**1951**			
Apr. 9	39.08	Mar. 15	37.07	**1953**	
Nov. 18	38.18	Nov. 15	37.25	Jan. 23	[b]41.55
				Feb. 18	40.15
1949		**1952**		Mar. 27	39.86
Apr. 29	38.53	Apr. 16	37.10	(Measurements discontinued)	
		May 28	37.29		
Well 1N/9-9M2. Depth 61.5 ft. Altitude 1,810.0 ft					
1940		**1953**		**1953—Continued**	
Apr. 24	37.18	Jan. 23	37.60	Apr. 30	37.46
		Feb. 18	37.50	May 29	37.72
1952		Mar. 27	37.36		
Aug. 6	37.32				
Well 1N/9-16D1. Depth 96 ft. Altitude 1,812.9 ft					
1952		**1952—Continued**		**1953—Continued**	
May 1	39.40	Oct. 3	40.75	Feb. 18	40.53
28	40.49			Mar. 27	39.51
July 9	40.77	**1953**		Apr. 30	39.85
Aug.7	[c]40.85	Jan. 26	39.88	May 29	38.46
Well 1N/9-16H3. Depth 153.9 ft. Altitude 1,771 ft					
1952		**1952—Continued**		**1953—Continued**	
May 7	8.76	Aug. 8	10.67	Feb. 18	10.20
28	9.95	14	10.59	Mar. 28	10.08
July 9	10.14			Apr. 30	10.22
Aug. 6	10.77	**1953**		May 29	10.37
7	10.65	Jan. 29	10.34		

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 1N/9-17E1. Depth 133 ft. Altitude 1,882.7 ft					
1946		**1952—Continued**		**1953**	
Apr. 12	108.25	May 28	107.06	Jan. 26	107.44
Nov. 14	107.78	July 9	[e]107.48	Mar. 27	107.48
		Aug. 7	[e]110.08	Apr. 30	107.49
1952		Oct. 4	109.66		
Apr. 29	[e]114.14				
Well 1N/9-21E2. Depth 90 ft. Altitude 1,816 ft					
1952		**1953**		**1953—Continued**	
Oct. 3	44.48	Jan. 26	44.60	Mar. 27	44.64
		Feb. 18	44.56	Apr. 30	44.69
Well 1N/9-26N1. Depth 162 ft. Altitude 1,932.4 ft					
1939		**1941—Continued**		**1948**	
Dec. 6	146.71	Apr. 8	146.90	Apr. 7	147.62
		June 1	148.89	Nov. 15	147.66
1940		Aug. 1	146.90		
Jan. 16	146.74	Oct. 1	146.95	**1949**	
Feb. 2	146.76	Dec. 15	146.98	Jan. 3	147.69
17	146.76			Apr. 27	147.70
Apr. 1	146.74	**1942**		Aug. 12	147.81
May 3	146.75	Feb. 16	147.00	Nov. 16	147.80
June 3	146.76	Apr. 20	146.98		
27	146.78	Aug. 1	147.04	**1950**	
Aug. 1	146.78	Oct. 15	147.09	Apr. 11	147.89
Sept. 6	146.81			Nov. 7	148.08
Oct. 11	146.81	**1946**			
Nov. 4	146.81	Jan. 29	147.48	**1951**	
Dec. 6	146.84	Apr. 10	147.49	Mar. 14	147.96
		Nov. 7	147.50	Nov. 14	148.06
1941					
Jan. 7	146.84	**1947**		**1952**	
Feb. 9	146.85	Apr. 8	147.55	Apr. 15	148.45
Mar. 4	146.87	Nov. 17	146.60	Nov. 20	148.10
				1953	
				May 25	148.30

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
		Well 2/7-2C1 (USN TW 5). Depth 400.0 ft. Altitude 2,272.1+ ft			
1952		**1953**		**1953—Continued**	
Apr. 21	[d]25.44	Jan. 29	25.29	May 2	25.46
July 8	25.50	Feb. 3	[f]26.50	30	25.42
Sept. 10	25.61	20	25.80	June 25	25.41
Oct. 2	25.55	Mar. 27	25.55		
		Well 2/7-3A1 (USN SW 3A). Depth 560.0 ft. Altitude 2,300.9 ft			
1953		**1953—Continued**		**1953—Continued**	
Feb. 1	[g]84.26	Feb. 20	54.87	May 30	54.39
5	55.49	Mar. 27	54.55	June 25	54.41
13	55.02	May 2	54.44		
		Well 2/7-3B1 (USN SW 2A). Depth 700.0 ft. Altitude 2,355.3 ft			
1953		**1953—Continued**		**1953—Continued**	
Jan. 10	104.68	Feb. 20	104.77	May 30	104.69
14	[h]155.75	Mar. 27	104.67	June 25	104.70
[?Feb] 12	104.87	May 2	104.68		
		Well 2/7-4H1 (USN TW 12). Depth 500.0 ft. Altitude 2,442.2 ft			
1952		**1953**		**1953—Continued**	
Oct. 2	188.72	Jan. 11	188.67	May 2	188.73
27	188.74	14	188.65	30	188.64
		Feb. 4	188.69	June 25	188.66
		Well 2/8-11B1. Depth 64.6 ft. Altitude 1,833 ft			
1952		**1952—Continued**		**1953—Continued**	
Apr. 26	[e]35.52	Oct. 4	35.62	Feb. 20	35.53
May 28	35.53			Mar. 27	35.53
July 7	35.58	**1953**		Apr. 30	35.52
Aug. 6	3 5.64	Jan. 23	35.56	May 29	35.57
		Well 2/8-24H1 (USN TW 1). Depth 320.0 ft. Altitude 1,856.2 ft			
1952		**1952—Continued**		**1953**	
Mar. 6	[d]80.16	Oct. 3	80.28	Jan. 23	80.38
May 28	80.19	4	80.24	Feb. 18	80.38
July 7	80.22	23	80.25	Mar. 27	80.45
Aug. 6	80.23	31	80.24	Apr. 30	80.46
Oct. 2	80.33			May 29	80.47

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 2/8-26J1. Depth 185 ft. Altitude 1,938 ft					
1946		**1949**		**1952**	
Apr. 12	154.97	Apr. 28	155.20	Apr. 16	155.37
Nov. 14	155.06	Nov. 18	155.29	May 28	155.41
				July 7	155.39
1947		**1950**		Aug. 6	155.39
Apr. 10	155.00	Apr. 14	155.31	Oct. 4	155.39
Nov. 21	155.16	Nov. 9	155.39		
				1953	
1948		**1951**		Jan. 26	156.10
Apr. 8	155.18	Mar. 15	155.29	Feb. 18	155.45
Nov. 18	155.17	Nov. 15	155.32	Apr. 30	155.48
				May 29	155.45

Well 2/9-30P2. Depth 55.8 ft. Altitude 1,790 ft					
1952		**1952—Continued**		**1953—Continued**	
Apr. 27	[e]27.38	Oct. 4	28.17	Mar 27	27.40
May 28	27.52			Apr. 30	27.36
July 7	27.82	**1953**		May 29	27.49
Aug. 6	27.99	Jan. 26	27.61		
		Feb. 18	27.52		

Well 3/7-13N1 (USN TW 10). Depth 501.0 ft. Altitude 2,020.2 ft					
1952		**1952—Continued**		**1952—Continued**	
Oct. 28	189.5	Nov. 8	189.40	Dec. 6	189.36
30	189.39	13	189.36		
Nov. 3	189.42	Dec. 2	189.40	**1953**	
				May 30	189.37

Well 3/7-35L1. Depth 36.0 ft. Altitude 2,259.6 ft					
1952		**1953—Continued**		**1953—Continued**	
July 8	13.51	Feb. 20	12.90	May 30	12.57
		Mar. 27	12.73	June 25	12.64
1953		Apr. 30	12.60		
Jan. 23	12.70				

Well 3/7-35P1. Altitude 2,244.5 ft					
1953		**1953—Continued**		**1953—Continued**	
Mar. 27	[i]+1.73	Apr. 29	+2.42	June 25	[i]+1.73
Do.	+2.28	May 30	+2.45		

See footnotes at end of table.

Table 3A. Records of water levels in observation wells, Twentynine Palms Basin, California—Continued

Date	Water level	Date	Water level	Date	Water level
Well 3/8-17L1 (USN TW 3). Depth 512.0 ft. Altitude 1,850.4 ft					
1952		**1952—Continued**		**1953**	
July 9	46.87	Dec. 2	46.88	Jan. 17	46.87
Oct. 30	46.85	8	46.93	May 29	46.86
31	46.84	9	46.96		
Nov. 7	46.86	12	46.97		
13	46.85				
Well 3/8-29C1 (USN TW 8). Depth 800.0 ft. Altitude 1,890.9 ft					
1952		**1952—Continued**		**1953**	
June 2	[b,d]87.65	Dec. 9	87.50	Jan. 23	87.57
July 9	87.49	12	[j]88.18	Feb. 20	87.54
Sept. 10	87.52	13	[k]88.10	Mar. 27	87.51
Oct. 2	87.50	15	87.60	Apr. 30	87.50
Dec. 4	87.39	18	87.60	May 30	87.52
8	87.53				
Well 3/8-29L1 (USN SW 1A). Depth 600.0 ft. Altitude 1,905.7 ft					
1952		**1953**		**1953—Continued**	
Dec. 13	[m]129.39	Feb. 20	102.07	May 30	102.02
14	102.27	Mar. 27	102.04	June 25	102.04
15	102.20	Apr. 30	102.03		
Well 3/8-33B1 (USN TW 2). Depth 526.0 ft. Altitude 1,845.7 ft					
1952		**1952—Continued**		**1953**	
Feb. 21	[d]42.95	Nov. 7	42.95	Jan. 23	42.99
May 28	42.94	22	43.18	Mar. 27	42.96
July 8	42.95	Dec. 2	43.17	Apr. 30	42.96
Aug. 6	42.95	9	43.20	May 29	42.95
Oct. 2	43.06	12	43.21		
24	42.97	14	43.18		
31	42.96				

[a]Record by San Bernardino Flood Control District.
[b]Pumped recently.
[c]Pumping.
[d]Measured by W.O. Wagner.
[e]Measurement by U.S. Geological Survey.
[f]SW3A pumping 1,800 gallons per minute.
[g]Pumping 1,070 gallons per minute.
[h]Pumping 960 gallons per minute.
[i]Flowing 6.1 gallons per minute.
[j]SW1A pumping 2,000 gallons per minute.
[k]SW1A pumping 1,500 gallons per minute.
[m]Pumping 1,075 gallons per minute.

Table 4A. Logs of U.S. Navy test wells

[Materials classified by the U.S. Geological Survey. ft, foot; in, inch; °F, degree Fahrenheit]

Material	Thickness (ft)	Depth (ft)
Test well 1, 2/8-24H1, in Mesquite Basin. Altitude: 1,856.2 ft. Casing diameter 10 in; drilled Jan. 24–Feb. 15, 1952.		
Soil, sandy, soft, yellowish-brown	2	2
Sand, fine to coarse, calcareous, hard, white to brown	8	10
Sand, calcareous, soft, poorly sorted	2	12
Sand, fine to coarse, calcareous, very hard	4	16
Sand, fine to coarse, soft	2	18
Sand, fine to coarse, calcareous, very hard	1	19
Sand, coarse, and gravel, fine; soft	2	21
Clay, silt, and sand, generally fine; light brown, fairly hard; sand in layers	11	32
Gravel, soft; water rose to 4 ft	1	33
Sand, very coarse, with considerable silt and clay; hard, calcareous, light gray-green	23	56
Sand, fine to coarse; gravel, fine to medium; and some silt and clay; soft, buff	5	61
Sand, medium to very coarse, soft, light gray	9	70
Clay, silt, and sand, coarse, calcareous; plastic, micaceous, in part in layers	6	76
Clay, sandy to silty, laminated, micaceous, hard, green to red	8	84
Sand, fine to medium, silty, soft, dark brown-gray	5	89
Clay, laminated, variegated, micaceous, hard	2	91
Sand, fine to medium, silty, very hard, dark brown-gray	21	112
Clay, silty, and gravel, sandy; in layers, water-bearing	6	118
Clay and sand, silty, in layers, soft, iron-stained	3	121
Sand, medium, silty, very soft to hard, iron-stained	5	126

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 1, 2/8-24H1, in Mesquite Basin.—Continued		
Sand, medium to coarse, calcareous, with layers of clay, hard	2	128
Sand, medium, silty, variegated, laminated	5	133
Clay, sandy, calcareous, light brown-gray, with calcareous inclusions, hard	8	141
Sand, fine to very coarse, silty, laminated, hard to soft, gray-brown	4	145
Clay, calcareous, very hard, with calcareous inclusions, buff	2	147
Sand, coarse, silty, calcareous, laminated, hard, light gray to brown; a few pebbles	5	152
Sand, medium, silty, laminated, gray-brown, soft	9	161
Clay, micaceous, buff, hard	2	163
Sand, medium to coarse, silty, soft, iron-stained, laminated, medium to coarse sand near bottom	16	179
Sand, medium to coarse, micaceous, soft, iron-stained	16	195
Clay, sandy to silty, micaceous, calcareous, light green to brown, hard	8	203
Gravel, fine; sand, medium to very coarse; and sand, fine, silty; in alternating layers, fairly hard, light brown-gray, water-bearing	9	212
Sand, medium to very coarse, calcareous cement, light buff, hard to soft	9	221
Silt, sandy, micaceous, some calcareous sand inclusions, very soft, steel gray	27	248
Gravel, medium; sand, very fine to coarse; sand, silty; and clay; in layers, micaceous, light gray, soft, water-bearing	3	251
Sand, fine to coarse, clayey, micaceous, light gray, soft	4	255
Silt, sandy, light green-gray, hard, with some concretions	4	259
Sand, very fine to coarse; and clay, silty; micaceous, light gray, soft	9	268
Silt, sandy, micaceous, steel gray, very soft, with some concretions; and few pebbles in very thin layers	19	287
Clay and silt, laminated, with some pebbles	1	288

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 1, 2/8-24H1, in Mesquite Basin.—Continued		
Silt, sandy, micaceous, steel gray, soft	6	294
Silt, sandy, clay, silty; laminated, green-gray, hard	4	298
Gravel, coarse to fine, with clay and silt streaks; hard to soft, water-bearing	3	301
Sand, fine to very coarse, clayey, light gray, soft	4	305
Silt, sandy, micaceous, steel gray, soft	4	309
Sand and gravel, silty to clayey, light gray, hard	3	312
Gravel, medium to very coarse; and sand, fine to very coarse, silty; in layers, light gray, soft, water-bearing (heaves up in well)	26	338
Clay, calcareous, buff, hard	1	339
Gravel, medium to coarse; and sand, fine to coarse, silty; in layers, light gray, packed, water-bearing	25	364
Sand, fine to coarse, silt, clay, and some gravel, buff, cemented	5	369
Sand, fine to coarse, silty to clayey, light gray to buff, soft; water-bearing below 373 ft	7	376
Clay, slightly sandy, buff, sticky, hard	2	378
Sand, very fine to very coarse, silty to clayey, green to orange, hard, dry; some very hard thin clay streaks	22	400

Water samples bailed during drilling at depths of 210, 316, and 400 ft.
Water temperatures during drilling: 77° to 84°F, increasing with depth.
Water level during drilling: 76 to 125 ft below land surface.
Water level before and after perforating: 84 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 8 cuts per round, one round per ft; 203–212, 248–251, 298–301, 314–352, and 372–376 ft.
Cement plug set at 320 ft.

Table 4A Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 2, 3/8-33B1, in Deadman Basin. Altitude: 1,845.7 ft. Casing diameter 10 in; drilled Jan. 10–Feb. 4, 1952.		
Soil, sandy	8	8
Sand, coarse to very coarse, and few pebbles, gray, soft; some calcareous sand concretions below 30 ft	39	47
Clay, plastic, brown, hard; some black organic fragments	2	49
Sand, coarse to very coarse, and some pebbles, light gray, soft; buff below 52 ft	9	58
Sand, very coarse, clayey, gray, fairly soft	10	68
Sand, very coarse, pebbly, buff, soft; lower 2 ft sand and gravel concretions, very hard calcareous cement	48	116
Clay; sand, fine to coarse; and some pebbles; pale buff, soft	12	128
Sand, coarse to very coarse; and gravel, up to 2 in; buff, soft; soft clay streaks and less gravel 136 to 146 ft; water-bearing	28	156
Clay; sand, fine to coarse; and few pebbles; gray, fairly hard; cemented sand concretions 166 to 169 ft	13	169
Sand, mostly fine to little coarse, and some silty clay; dark gray, hard; some sand concretions below 180 ft	15	184
Sand, coarse to very coarse, and gravel, coarse; buff, soft	8	192
Clay, sandy to pebbly, reddish-brown, hard	2	194
Sand, coarse to very coarse, gravel, and boulders up to 8 in; buff, soft; water-bearing	29	223
Sand, coarse to very coarse, and some gravel; buff, soft, water-bearing; partially cemented 270 to 275 ft	52	275
Sand, fine to coarse, and few small pebbles; medium gray, soft	8	283
Sand, coarse to very coarse, and fine gravel; buff, soft	2	285
Sand, fine to coarse, medium gray, fairly hard	4	289
Sand, coarse to very coarse, and gravel, up to 1 in; few streaks of silty sand; gray to buff, fairly soft	12	301

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 2, 3/8-33B1, in Deadman Basin.—Continued		
Sand, coarse to very coarse, and gravel; gray to buff, very loose; cemented 330 to 336 ft; water-bearing	43	344
Clay and gravel alternating with streaks of fine sand and streaks of coarse sand and gravel; brown to gray, hard; more sand, red-brown, 360 to 368 ft	24	368
Sand, coarse, and gravel; gray to buff, hard	3	371
Sand, fine to coarse, clayey, cemented (?), gray, hard	9	380
Sand, coarse, gravel, and some boulders, buff to brown, soft, water-bearing	18	398
Sand, coarse, cemented ($CaCO_3$), gray, very hard	2	400
Sand, coarse, and gravel, cemented, buff to gray, rather hard	6	406
Clay; sand, coarse; and gravel, up to 0.5 in; gray-green, hard; and some clay streaks	15	421
Sand, coarse, and gravel, up to 2-in; cemented, buff to brown, fairly hard	7	428
Clay, sandy, pebbly, medium brown, very hard	4	432
Sand, fine to very coarse, and gravel, up to 2 in; loosely cemented ($CaCO_3$), vivid orange-red, fairly soft; lower 2 ft a cobble conglomerate; water-bearing	12	444
Clay, fine sandy to silty, and some pebbles; dark brown, hard, some organic spots, and iron stains	18	462
Sand, very coarse, and gravel; cemented, light gray, hard	2	464
Sand, fine to very coarse, cemented, dark gray, hard; cemented gravel streak 492 to 493 ft	42	506
Sand, very coarse, and gravel, coarse, orange-brown, loose (heaves up in well); water-bearing	6	512
Clay, sandy, dark brown, hard	2	514
Sand, fine to coarse, and gravel; cemented, dark gray, hard	5	519
Sand, fine to coarse, cemented, dark gray, hard	7	526

Water samples bailed during drilling at depths of 135, 290, 385, and 510 ft.
Water temperatures during drilling: 67° to 70°F, increasing with depth.
Water level during drilling: 42 ft below land surface.
Water level before and after perforating: 42 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per ft; 136–152, 194–224, 305–330, 336–344, 380–398, 432–444, and 506–512 ft.
Cement plug set at 526 ft.

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 3, 3/8-17L1, in Deadman Basin. Altitude: 1,850.4 ft. Casing diameter 10 in; drilled Jan. 11–Mar. 3, 1952.		
Soil, sandy to silty, light brown, hard	8	8
Sand, fine to coarse, light buff, soft	4	12
Clay, calcareous, plastic, sticky, light gray	12	24
Gravel, medium to fine, and some sand	1	25
Clay, red- to yellow-brown, plastic	3	28
Sand, very fine to coarse, light buff, soft; few pebbles	5	33
Sand and clay, with layers of fine sand and silty clay, gray	21	54
Sand, fine, silty, few coarse grains, micaceous, yellow-gray	19	73
Clay, sandy, silty, yellow-gray, hard	6	79
Sand, fine, silty, yellow-brown	14	93
Sand, largely fine, silty, yellow, brown, gray, and lavender streaks; medium and coarse fraction increasing with depth	29	122
Sand, silty, soft to hard; proportion of sand greatly increased over that from 93 to 122 ft	19	142
Gravel, fine to very coarse, and sand, fine to coarse	3	145
Sand, very fine, silty, hard, a few concretions, gray	43	188
Clay, very fine sandy, dark brown, plastic, hard; some white $CaCO_3$ layers	1	189
Sand, fine to coarse, silty, some pebbles 0.5 in, olive green, hard; iron stains abundant; yellow-green from 189–190 ft	3	192
Sand, coarse to very coarse, and gravel to 0.5 in; streaks of fine sandy clay; light brown, fairly soft	4	196
Sand, very fine to medium, silty; some coarse sand streaks, and some clay; light brown, hard; some layers of cemented ($CaCO_3$) sand	36	232
Sand, coarse to very coarse, and gravel to 1 in, red-brown, soft	4	236

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 3, 3/8-17L1, in Deadman Basin.—Continued		
Clay, fine to very coarse sandy, and some pebbles to 0.25 in; dark brown, extremely hard; white $CaCO_3$ fragments	12	248
Sand, coarse to very coarse; and gravel to 3 in; few streaks of silty sand; light brown, soft, some $CaCO_3$ cementing; water-bearing	10	258
Sand, very fine to very coarse, silty; some gravel to 1 in; medium brown, hard. Gray, green, violet, and red colors 258 to 259 ft	14	272
Sand, coarse to very coarse, some fine to medium, and gravel to 6 in, buff, soft; heaves up in hole; water-bearing	28	300
Sand, coarse to very coarse, some fine to medium; some gravel to 1 in; buff, soft; heaves up in hole; gray-brown from 320 to 332 ft	32	332
Sand, fine to medium, dark brown-gray, firm; some 1-in gravel from 332 to 340 ft; some fine sandy clay streaks 346 to 360 ft	28	360
Sand, very fine silty to some very coarse, and clay; dark gray-brown, fairly hard; hard iron-stained light brown clay 360 to 362 ft; hard light brown clay and 0.5-in gravel 373 to 374 ft	14	374
Sand, medium to very coarse, and gravel to 3 in, light brown to buff, soft; heaves up in hole; water-bearing	6	380
Sand, medium to very coarse, some gravel to 2 in, and streaks of clay; brown-buff, soft; cemented ($CaCO_3$) 390 to 396 ft	16	396
Sand, medium to very coarse, and gravel to 3 in, gray to buff, soft; some $CaCO_3$ cemented sand and gravel; clayey fine to coarse sand with red-brown, very hard, white $CaCO_3$ stringers from 408 to 410 ft; water-bearing	20	416
Sand, medium to very coarse, occasional gravel to 2 in, brown-buff, soft; gravel to 4 in 444 to 456 ft; water-bearing; many cemented ($CaCO_3$) fine to coarse sand concretions, gray-brown, very hard from 499 to 510 ft	94	510
Sand, fine to very coarse, cemented, gray-brown, hard	2	512

Water samples bailed during drilling at depths of 236, 294, 404, and 470 ft.
Water temperatures during drilling: 76° to 82°F, increasing with depth.
Water level during drilling: 44.6 to 55.0 ft below land surface.
Water level before and after perforating: 46.5 and 48.8 ft below land surface, respectively.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per foot; 248–258, 272–300, 374–380, 396–408, 410–416, and 444–456 ft.
Cement plug set at 512 ft.

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 5, 2/7-2C1, in Surprise Spring Basin. Altitude: 2,272.1 ft. Casing diameter 10 in; drilled Feb. 25–Mar. 14, 1952.		
Sand, fine to very coarse, light orange, soft, windblown	13	13
Gravel, fine to coarse, light buff to light orange, arkosic, soft	6	19
Clay, slightly sandy, calcareous, flocculent, light green-gray, hard	4	23
Gravel, fine, and sand, fine to very coarse; arkosic, calcareous, soft, with small basalt pebbles, water-bearing	1	24
Clay, slightly sandy to silty, calcareous, micaceous, light green-gray, hard	4	28
Gravel, fine, sandy, arkosic, soft; heaves up in well	5	33
Clay, slightly sandy, silty, micaceous, calcareous, sticky, light green-gray hard	3	36
Sand, fine to very coarse, slightly silty and clayey, micaceous, light buff, packed, very hard, except from 42 to 46 ft, which is soft and water-bearing	12	48
Clay, sandy, silty, calcareous, light brown, hard to soft	11	59
Silt, sandy, clayey, calcareous, micaceous, light green-gray; compact and fairly hard	8	67
Sand, coarse to very coarse, some silt, occasional pebbles; arkosic, light buff, compact and medium hard	4	71
Sand, very fine to medium, silty, clayey, buff, hard	7	78
Sand, fine to very coarse, silty, clayey, micaceous, arkosic, slightly iron-stained, soft, water-bearing	10	88
Gravel, fine; and sand, medium to very coarse, arkosic, micaceous, soft; water-bearing	5	93
Gravel, fine to medium; sand, coarse to very coarse; clayey, brown-gray, angular, soft; water-bearing	3	96
Sand, coarse to very coarse; and gravel, fine; arkosic, light buff, soft, water-bearing	20	116
Clay, sandy, calcareous, micaceous, light yellow to brown, hard	7	123
Sand, coarse to very coarse, gravelly; sand, fine, silty; and clay; in layers, buff to green to brown, moderately soft, with some sandstone concretions, water-bearing	4	127
Sand, very fine to coarse, clayey, light yellow to buff, hard	6	133

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 5, 2/7-2C1, in Surprise Spring Basin.—Continued		
Sand, coarse to very coarse, some gravel, silty, clayey, light orange, soft	14	147
Sand, medium to very coarse, clayey, silty, light brown, hard	2	149
Gravel, fine to coarse; and sand, coarse to very coarse; slightly silty, light buff, soft, water-bearing	3	152
Sand, coarse to very coarse; and little gravel, in very thin laminae, silty, arkosic, light buff, soft, water-bearing	37	189
Sand, medium to very coarse, slightly silty and clayey, white to buff; contains thin cemented sand layers, very thin gravel layer at top, and a few calcareous sandstone concretions, in part water-bearing. Sand, clayey to slightly silty, strong sulfurous smell, temperature over 110°F, 225 to 227 ft; possibly minor fault zone	50	239
Sand, coarse to very coarse, slightly silty and clayey, with very small amount of gravel and a few pebbles; arkosic, micaceous, light to dark buff, soft, water-bearing	10	249
Gravel, medium to coarse; and sand, coarse to very coarse; silty, clayey; micaceous, arkosic, white to buff, soft, water-bearing	7	256
Gravel, coarse to fine, sandy, cobbley, angular to well rounded, gray-buff, soft, water-bearing	3	259
Sand, fine to very coarse, cemented, hard	2	261
Gravel, fine to coarse, sandy, cobbley, arkosic, soft, water-bearing	7	268
Silt, sandy to clayey, light brown to green-gray, micaceous, hard	2	270
Gravel, cemented, nonwater-bearing	1	271
Gravel, fine to coarse; sand, coarse to very coarse, layered; slightly iron-stained in upper few feet, but grading into a gray-buff to buff below, in part slightly silty, with a few calcareous sandstone concretions, soft, water-bearing throughout	31	302
Gravel, medium to coarse, only slightly sandy, arkosic, light gray to buff, soft, clearn, quite well sorted, soft, water-bearing	1	303
Sand, coarse to very coarse, silty, slightly clayey, gravelly, poorly sorted, medium hard; some clay in colloidal suspension, poorly water-bearing	22	325
Gravel, fine to coarse; and sand, very coarse; clayey, arkosic, light buff, medium soft, poorly water-bearing	3	328
Sand, fine to very coarse, slightly silty, clayey, gravelly, light buff, medium soft, in part water-bearing	10	338

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 5, 2/7-2C1, in Surprise Spring Basin.—Continued		
Gravel, fine to coarse; and sand, fine to coarse; silty to clayey, brown-gray to buff, soft; some colloidal clay, water-bearing	3	341
Sand, fine to very coarse, silty to clayey, slightly gravelly, gray-buff, medium hard, poorly water-bearing but soft and water-bearing below 356 ft	22	363
Gravel, fine to coarse; and sand, fine to coarse; somewhat silty, arkosic, light gray-buff to white, soft, water-bearing	4	367
Sand, fine to very coarse, gravelly, and clayey to silty, buff, relatively compact, partly water-bearing	33	400

Water samples bailed during drilling at depths of 140, 255, 336, and 396 ft.
Water temperatures during drilling: 81° to 96°F, increasing with depth, except for the zone 225–227 ft in which temperature was greater than 110°F.
Water level during drilling: 20 to 34 ft below land surface.
Water level before and after perforating: 25.0 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 8 cuts per round, one round per ft; 149–152, 189–192, 239–259, 261–268, 271–305, 325–330, and 356–377 ft.
Cement plug set at 400 ft.

Material	Thickness (ft)	Depth (ft)
Test well 6, 3/7-18D1, in Surprise Spring Basin. Altitude: 2,403.7 ft. Casing diameter 10 in; drilled Mar. 12–Apr. 8, 1952.		
Soil, very fine to very coarse sandy, soft, light gray-brown	3	3
Clay, fine to very coarse sandy, hard, red-brown	2	5
Sand, very fine to very coarse, soft, light gray	7	12
Sand, medium to coarse, soft, gray-brown; some gravel to 1 in from 12 to 17 ft; brown silty clay streaks from 31 to 46 ft; fairly hard, packed, with some caliche from 48 to 56 ft	44	56
Sand, medium to very coarse, and some gravel to 3 in, fairly soft, gray-brown; becomes very fine to very coarse from 60 to 190 ft; water-bearing below 147 ft	134	190
Sand, very fine to very coarse, and silty sand streaks, occasional gravel to 2 in; overall fairly soft, gray-brown; hard cemented sand concretions from 190 to 198 ft, and from 210 to 212 ft; water-bearing	50	240
Sand, very fine to very coarse, and some gravel to 2 in, soft, gray-brown; occasional cobbles to 6 in; water-bearing	52	292
Sand, very fine to fine, silty, fairly soft, dark gray	8	300
Sand, fine to very coarse, and gravel to 3 in, soft, brown-gray, water-bearing	4	304

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 6, 3/7-18D1, in Surprise Spring Basin.—Continued		
Sand, very fine to fine, silty, fairly hard, dark gray	5	309
Sand, fine to very coarse, and some gravel to 3 in, soft, brown-gray; more gravel in zones from 314 to 332 ft and from 336 to 352 ft; water-bearing	45	354
Sand, fine to very coarse, hard, brown-gray, cemented	6	360
Sand, very fine to very coarse, with occasional gravel to 1 in, soft brown-gray, more gravel in zone from 370 to 372 ft; water-bearing	12	372
Sand, fine to very coarse, and some gravel to 1 in, hard, gray-brown, cemented	6	378
Sand, fine to very coarse, and gravel to 1 in, soft, gray-brown, water-bearing; heaved up in casing 6 ft.	4	382
Sand, fine to very coarse, with some gravel to 1 in, hard, gray-brown, cemented.	2	384
Sand, fine to very coarse, and gravel to 2 in, soft, gray-brown; steaks of fine silty sand and less gravel from 390 to 408 ft; cemented zone from 402 to 404 ft; largely water-bearing.	24	408
Sand, very fine to fine and some medium to very coarse, silty; with gravel to 0.5 in; fairly soft, gray-brown; coarse sand from 412 to 413 ft; water-bearing	5	413
Sand, very fine to fine, and some very coarse, very hard, gray	3	416
Sand, fine to very coarse, and some gravel to 1 in, hard, gray-brown; cemented	6	422
Sand, very fine to medium, fairly soft, gray-brown, alternating with very coarse sand streaks about 1 ft thick from 426 to 432 ft; water-bearing.	10	432
Sand, very fine to very coarse, silty, fairly hard packed, gray-brown; occasional cobbles to 7 in from 438 to 442 ft	10	442
Sand, very fine to very coarse, silty, and gravel to 3 in, fairly hard, gray-brown, partially cemented, largely water-bearing	8	450

Water samples bailed during drilling at depths of 286, 354, 403, and 450 ft.
Water temperatures during drilling: 70° to 72°F, increasing with depth.
Water level during drilling: 147.6 ft below land surface.
Water level before and after perforating: 147.6 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per ft; 240–246, 300–304, 312–332, 336–356, 370–372, and 378–390 ft.
Cement plug set at 449 ft.

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 8, 3/8-29C1, in Deadman Basin. Altitude: 1,890.9 ft. Casing diameter 10 in; drilled Mar. 26–May 16, 1952.		
Soil, sandy to silty, buff-brown, hard near bottom	12	12
Sand, very fine to coarse; some silt; and a few cobbles; calcareous, light brown, soft	12	24
Sand, fine to very coarse, slightly silty; and some fine gravel; some iron stain, buff-brown, soft, dry. Less gravel and cleaner with depth	14	38
Sand, very fine to coarse, and silt; clayey, micaceous, light brown, fairly hard; in hard and soft layers below 54 ft	45	83
Silt, clayey, and some fine sand, calcareous, micaceous, gray-brown, fairly hard	16	99
Sand, very fine to very coarse, poorly sorted; and some gravel and cobbles up to 5 in; micaceous, gray-brown, very hard, dry	12	111
Sand, fine to medium, some coarse, micaceous, gray-brown, soft, dry	5	116
Sand, coarse and some fine; and fine gravel; brown, hard	1	117
Sand, very fine to very coarse, poorly sorted; and some gravel and cobbles to 5 in; gray-brown, soft, water-bearing. Water rose to 88 ft overnight	21	138
Sand, very fine to very coarse, poorly sorted; some very large cobbles up to 6 in; gray-brown to buff, very hard, water-bearing	6	144
Sand, fine to coarse, poorly sorted, micaceous; and silt; gray-brown, moderately hard, slightly water-bearing	6	150
Sand, very fine to very coarse, poorly sorted; some silt and fine gravel; micaceous, gray-brown, soft, slightly water-bearing	8	158
Sand, very fine to very coarse, poorly sorted; occasionally silty; and some gravel and cobbles up to 4 in; gray to gray-brown, soft to occasionally hard, largely water-bearing	46	204
Clay, silty, laminated, considerably iron stained, olive-gray to gray, some thin dark chocolate-brown layers, hard	2	206
Sand, very fine to medium and some coarse, micaceous; and silt; olive-gray to brown-gray, soft, occasional layers of clay 0.25-in thick, moderately water-bearing	9	215
Sand, very fine to very coarse, poorly sorted, micaceous; some silt; gravel; and cobbles up to 6 in; gray-brown, hard, moderately water-bearing	5	220

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 8, 3/8-29C1, in Deadman Basin.—Continued		
Sand, mostly very coarse, some fine and medium; occasionally silty; and considerable gravel and cobbles; gray, soft. The percentage of coarse sand, gravel, and cobbles decreases gradually with depth, largely water-bearing	13	233
Sand, fine to medium, micaceous; and silt; calcareous, cemented, gray-brown to gray, very hard. Considerable gravel and cobbles 236 to 237 and 245 to 247 ft; slightly water-bearing	14	247
Sand, very fine to very coarse, micaceous; some gravel; and cobbles up to 5 in; gray-brown, moderately soft, largely water-bearing	13	260
Sand, mostly coarse, some fine to medium; gravel, mostly coarse, some fine; and cobbles up to 7 in; gray to gray-brown, soft, highly water-bearing	30	290
Sand, fine to coarse, poorly sorted, some concretions, strongly cemented, calcareous and siliceous (?) cement, light gray to gray, very hard	2	292
Sand, very fine to very coarse, mostly fine to medium, poorly sorted, micaceous; some silt; and some gravel and cobbles; gray to gray-brown, soft, water-bearing	48	340
Sand, fine to medium; silt; and some gravel; gray-brown, cemented, very hard, slightly water-bearing	17	357
Sand, very fine to very coarse, mostly medium and coarse, micaceous; and some gravel; gray-brown to buff, soft, water-bearing	38	395
Sand, fine to very coarse, mostly coarse; and gravel, fine to medium, some coarse; and few cobbles; partially cemented, gray to brownish-gray, hard to soft, moderately water-bering. Sandy soil below 403 ft	12	407
Sand, fine to medium, some coarse, clayey, micaceous; silt; gravel, fine to medium with some coarse; and some cobbles up to 5 in; gray to brownish-gray, partially cemented, hard, slightly water-bearing. Less silt and more coarse sand with depth	12	419
Clay, silty, sandy, considerably iron stained, light to medium brown, hard	1	420
Sand, fine to very coarse, mostly medium and coarse, concretionary; and gravel, fine to very coarse; and some cobbles up to 10 in; calcareous, partially cemented, gray to brownish-gray, hard to moderately hard, moderately water-bearing. Cemented 420 to 427 ft	39	459
Sand, fine to coarse; and gravel, mostly fine to medium; gray-brown, some cementation, moderately hard, water-bearing	4	463
Sand, fine to very coarse, mostly medium and coarse; gravel, mostly fine and medium, some coarse; and a few cobbles up to 5 in; gray-brown, fairly soft, largely water- bearing. Occasional hard lenses of cemented sand and gravel. Somewhat finer-grained 487 to 500 ft	60	523
Clay, silty to sandy; and few gravel; light to dark gray, banded, hard	2	525

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 8, 3/8-29C1, in Deadman Basin.—Continued		
Sand, mostly fine to medium, some coarse; silt; considerable gravel; and some clay; light to dark gray, calcareous, moderate cementation, hard, moderately water-bearing	13	538
Sand, very fine to very coarse; gravel, mostly fine; and some cobbles up to 4 in; brownish-gray, fairly soft, water-bearing. Hard to moderately hard sand and gravel beds below 542 ft, in part water-bearing	41	579
Sand, fine to coarse, mostly fine to medium; and some fine gravel 579 to 589 and 599 to 601 ft; calcareous, partially cemented, light to medium gray, moderately hard, moderately water-bearing	22	601
Sand, very fine to coarse; and some silt; calcareous, cemented, light to medium gray, extremely hard	10	611
Clay, silty to sandy, dark brown, considerably iron-stained, hard	5	616
Sand, fine to coarse; silt; and occasional thin lenses of clay; calcareous, partially cemented, buff to tan, moderately hard, slightly water-bearing	13	629
Clay, micaceous, silty to sandy, dark brownish gray, moderately hard	3	632
Sand, fine to medium silt; and some gravel 642 to 643 ft; clayey, cemented calcareous, brown to buff, hard, slightly water-bearing	11	643
Sand, fine to coarse; some silt; and fine to some coarse gravel; calcareous, partially cemented, buff to light gray, moderately hard, moderately water-bearing	30	673
Sand, fine to very coarse; and gravel, mostly fine to medium; some coarse; occasionally silty, brown to gray-brown, soft, water-bearing. Partially cemented below 682 ft	13	686
Clay, silty to sandy, considerable biotite mica and iron-stained, calcareous, generally dark grayish brown, hard, occasionally sticky (plastic). Occasional lenses of gray, cemented, fine sand; and occasional thin layers of laminated, dark chocolate-brown, noncalcareous clay'	62	748
Silt, clay, and considerable fine sand, micaceous, dark grayish brown, soft. Considerably less dense and compact than clay above. Occasional thin lenses of cemented sand	10	758
Clay, silty, occasionally sandy, considerable biotite mica, color varies from buff to gray, but generally grayish brown, occasionally calcareous, hard. Some thin layers of laminated noncalcareous clay, various shades of gray and brown. Occasional thin layers of clayey silt with fine sand; also thin lenses of gray, cemented, clayey, fine sand	31	789
Sand, fine to medium, some coarse, micaceous, medium brown, soft, moderately water-bearing	3	792
Clay, silty, occasionally sandy, micaceous, slightly calcareous, medium to dark brown, hard	6	798

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 8, 3/8-29C1, in Deadman Basin.—Continued		
Sand, fine to medium, highly micaceous, moderately cemented, calcareous, light to medium gray, moderately hard	2	800

Water samples bailed during drilling at depths of 163, 252, 472, 474, 564, 653, 794, and 800 ft.
Water temperatures during drilling: 73° to 90.5°F, increasing with depth.
Water level during drilling: 88 to 92 ft below land surface.
Water level before and after perforating: 88.3 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per ft; 500–523, 540–565, 584–605, 640–646, and 660–684 ft. If greater yield is desired at cost of a probable increase in fluoride, the following intervals could be perforated: 260–290, 396–403, 427–459, and 466–487 ft.

Test well 9, 37-31E1, in Surprise Spring Basin. Altitude: 2,514.3 ft. Casing diameter 10 in; drilled Apr. 15–May 26, 1952.

Material	Thickness (ft)	Depth (ft)
Soil, fine to very coarse sandy and gravelly, brown, fairly hard	3	3
Caliche (calcium carbonate), white, very hard	2	5
Sand, fine to very coarse, and some gravel to 3 in, gray-brown, hard; boulders to 20 in and thin caliche (calcium carbonate) layers from 5 ft to 7 ft; no gravel from 40 ft to 44 ft	39	44
Clay, very fine to very coarse sandy, brown, very hard	36	80
Sand, very fine to very coarse, silty, brown, fairly hard, calcium carbonate cement	3	83
Clay, very fine to very coarse sandy, brown, hard	5	88
Sand, very fine to very coarse, and gravel to 4 in, brown, fairly soft	4	92
Clay, silty, and very fine to very coarse sandy, brown, hard	32	124
Clay, silty and fine sandy, brown, fairly soft; contains black organic material and some iron stains	2	126
Clay, silty and fine sandy; some coarse sand; brown, fairly hard; contains some caliche (white calcium carbonate), more coarse to very coarse brittle sand from 186 to 210 ft	84	210
Sand, very fine to very coarse; some silty clay; gray-brown, hard, cemented; fine to coarse brown sandy clay from 214 to 215 ft	14	224
Sand, fine to coarse; occasional gravel; and cobbles up to 5 in; gray, fairly hard, partially cemented	20	244

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 9, 37-31E1, in Surprise Spring Basin.—Continued		
Sand, very fine to very coarse; occasional gravel; and cobbles up to 5 in; gray, soft; pebbles smaller, to 0.5 in, and more silty from 328 ft to 338 ft; very hard, round, fine to coarse sand concretions from 340 to 358 ft; partially cemented and fairly hard from 358 ft to 392 ft; in part water-bearing	148	392
Sand, fine to coarse, and some gravel with boulders larger than 10 in; gray, very hard drilling; at least partially cemented with an extremely hard calcareous cement; Calcite (?) crystal approximately 1 in long observed on cobble recovered from 410 ft; gray, fine to coarse sand heaves in hole from 415 to 415 ft–6 in; in part water-bearing	38	430
Water samples bailed during drilling at depths of 366 and 421 ft. Water temperatures during drilling: 75° to 76°F, increasing with depth. Water level during drilling: 244 to 252 ft below land surface. Water level before and after perforating: 250 ft below land surface. Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per foot; 300–328, and 340–401 ft. Bottom of casing at 418 ft.		
Test well 10, 37-13N1, in Deadman Basin. Altitude: 2,020.2 ft. Casing diameter 10 in; drilled May 26–July 18, 1952.		
Sand, fine to coarse; occasionally silty, some thin lenses of caliche; some thin lenses of fine to medium gravel; buff to tan, soft. No real soil or soil profile; grains are fresh	18	18
Sand, fine to very coarse, mostly coarse; and gravel, mostly fine to medium, some coarse, some cobbles up to 6 in; medium to light grayish brown, soft to hard due to compaction, no cemented grains found. Interbedded calcareous, whitish clay from 76 to 78 ft. Some cementation and large cobbles up to 8 in from 85 to 86 ft. Generally less coarse from 93 to 96 ft.	94	112
Sand, fine to coarse, mostly fine; and considerable clay and silt; gray-brown to brown, calcareous, hard.	4	116
Sand, fine to very coarse, mostly very coarse; and gravel, mostly fine; grayish brown, moderately hard, partially water-bearing. Some medium to coarse gravel 143 to 144 ft; some caliche at 160 ft; considerable biotite and magnetite giving a dark grayish color to the cuttings 173 to 179 ft; cemented sand and gravel at 191 ft; coarse gravel 194 to 195 ft	84	200
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; some small cobbles, gray-brown, soft, water-bearing	20	220
Sand, fine to coarse, mostly coarse; and considerable fine gravel, some medium; gray-brown, moderately soft, water-bearing	57	277
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; occasionally calcareous, gray-brown, soft, water-bearing. Mostly fine but little tan coarse gravel 293 to 303 ft; some cobbles up to 4 in 303 to 318 ft	41	318
Sand, fine to coarse, mostly fine to medium, gray-brown, soft, water-bearing	8	326

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 10, 37-13N1, in Deadman Basin.—Continued		
Sand, fine to coarse, mostly fine to medium, considerable biotite, dark brownish gray, soft, water-bearing	10	336
Sand, fine to coarse, mostly coarse; and gravel, mostly fine to medium, with some coarse; gray-brown to gray, soft, water-bearing. Cemented sand and gravel 381 to 382 ft.	53	389
Sand, fine to coarse, mostly fine, with considerable silt and clay, dark grayish-brown, soft, partially water-bearing	8	397
Sand, fine to coarse, mostly coarse; and gravel, mostly fine, with some medium to coarse; gray-brown, soft, water-bearing. Considerable amounts of medium and coarse gravel 401 to 407, 411 to 414, and 416 to 426 ft	29	426
Sand, fine to coarse; and some gravel, mostly fine; gray-brown, soft, water-bearing	22	448
Sand, fine to coarse, mostly coarse; gravel, fine to coarse; and some cobbles up to 6 in; light grayish brown, soft, water-bearing. Considerable basalt gravel and cobbles from 456 to 458 ft.	11	459
Sand, fine to coarse; and some fine gravel; cemented, calcareous, gray-brown, hard, partially water-bearing	19	478
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; gray-brown, soft, water-bearing. Somewhat cemented 479 to 481 ft.	9	487
Sand, fine to coarse, silty, cemented, considerable biotite, dark brownish gray, hard, partially water-bearing	9	496
Sand, fine to coarse, mostly coarse; and gravel, mostly fine to medium, some coarse; partially cemented, gray-brown, moderately soft, water-bearing. Bail test indicates bottom hole material very good water-bearing formation	5	501

Note: Sands, largely quartz and feldspar with varying amounts of magnetite, biotite (phlogopite), grains subrounded to angular and poorly sorted; color is largely gray-brown, but is commonly gray when there is considerable biotite and magnetite. Gravels and cobbles are largely altered and unaltered granitics with gneiss and granite (?) with some basalt and quartzite, usually subrounded to rounded.

Water samples bailed during drilling at depths of 270, 314, 386, 450, and 501 ft.
Water temperatures during drilling: 82° to 88.5°F, increasing with depth.
Water level during drilling: 189 to 200 ft below land surface.
Water level before and after perforating: 189.3 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per ft; 280–293, 305–317, 345–389, 416–426, 450–460, and 480–487 ft.

Owing to coarseness of perforations and relatively fine loose material, well has tendency to sand in. After perforating, well sanded to 470 ft; after "fanning," it sanded to nearly 400 ft below land surface. Well is to be sand pumped.

This well started 15 ft S. 50° E. of present location; drilled to a depth of 120 ft; abandoned when driller tried to straighten hole and casing parted leaving starter in hole. Log the same as for upper 120 ft of test well 10.

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 11, 2/7-14K1, south of Surprise Spring Basin. Altitude: 2,532.1 ft. Casing diameter 10 in; drilled June 6–July 25, 1952.		
Soil, sandy, loose, gray-brown	2	2
Clay, fine to coarse sandy, very hard, red-brown; veinlets of calcium carbonate	32	34
Sand, fine to very coarse, clayey; some small (0.5 in) pebbles; fairly hard, red-brown; color change to gray-brown and no clay present at 47 ft	54	88
Sand, fine to medium, some very coarse; occasional cobbles to 3 in; fairly soft, gray-brown	20	108
Sand, very fine to very coarse, hard, gray-brown; silty clay streaks from 108 to 112 ft, and generally more fine material from 122 to 160 ft	80	188
Sand, fine to very coarse, and gravel to 2 in; soft, gray-brown	4	192
Sand, very fine to very coarse, clayey; streaks of very coarse sand and gravel to 0.5 in; hard, gray-brown; some veinlets of white calcium carbonate	12	204
Sand, medium to coarse, and some very coarse, very hard, medium gray, fairly well sorted	12	216
Sand, very fine to very coarse; some pebbles to 0.5 in; hard, gray-brown; streaks of very hard silty fine sand from 216 to 220 ft; some gravel to 1 in; softer from 230 to 240 ft	24	240
Sand, fine to very coarse, and gravel and boulders larger than 5 in; hard, gray-brown; calcium carbonate crystals (calcite) well developed in vesicles of basalt cobble	10	250
Sand, very fine to medium and some very coarse, silty, hard, gray-brown	4	254
Clay (interstitial); sand, mostly medium to very coarse; some fine to medium; and gravel, mostly fine, occasional cobbles; fairly soft; light gray-brown	8	262
Clay, very sandy, mostly fine to medium, a little coarse, fairly soft, medium grayish-brown	4	266
Sand, coarse to very coarse, with some clay; fairly soft, light gray-brown	4	270
Sand, mostly coarse to very coarse, some medium; gravel, very fine to fine; and clay, interstitial; fairly soft, light gray-brown	4	274
Sand, mostly coarse to very coarse; considerable gravel, very fine to medium; and some cobbles; fairly soft, light gray-brown	15	289
Sand, mostly medium, some fine and coarse; with a little very fine gravel; and much interstitial clay; rather hard; plastic and cohesive when wet; light gray-brown. Sand finer and gravel absent 298 to 308, 326 to 329, and 331 to 335 ft. Slight increase in clay, and gravel coarser (fine to medium) 308 to 326 and 329 to 331 ft	46	335

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 11, 2/7-14K1, south of Surprise Spring Basin.—Continued		
Sand, mostly medium to very coarse; and gravel, mostly very fine to medium, some cobbles to 2 in; fairly soft, gray-brown	4	339
Sand, fine to coarse; some clay and silt; and a little gravel 339 to 346 ft; fairly soft, gray-brown	11	350
Sand, mostly medium to very coarse; and gravel, mostly very fine to medium, some to 2 in; occasional thin clayey streaks; fairly soft, light gray-brown. Less and finer gravel 368 to 388 ft	38	388
Sand, mostly medium to very coarse, some fine to medium; gravel, mostly fine, a few small cobbles; clay, interstitial, apparently fills much of pore space, comes up in large chunks, plastic when wet, hard when dry, increasingly micaceous below 420 ft; rather soft, medium gray-brown. Drilling water has milky appearance and feels soapy; probably contains kaolinite. Encountered first water at 424 ft; rose rapidly to 340 ft. No discernible change in formation; beds below 424 ft may be clean sands and gravels	61	449
Sand, mostly coarse to very coarse, some medium to coarse; and considerable gravel, mostly fine, some medium; contains some maroon basalt pebbles largely altered to clay; rather soft, yellowish gray-brown, good water-bearing material. Drilling water continues milky. From 510 to 558 ft quantity and size of gravel varies slightly in beds 3 to 10 ft thick and drilling water somewhat more milky; occasional clay streaks 543 to 558 ft	109	558
Clay, containing much sand, very fine to very coarse, and a little fine gravel from 558 to 598 ft; pale lavender-brown from 558 to 575 ft, becoming increasingly darker yellow-brown below; moderately to strongly calcareous, and occasionally cemented, quite hard. Drilling water is very milky. Streak of loose, coarse sand and medium gravel encountered at 638 to 639 ft.	86	644

Note: Sand grains are predominantly quartz and feldspar, with minor amounts of biotite, magnetite, and granitic minerals; subangular to subrounded. Gravel and cobbles largely gneiss and granitics, with few basalt and some metamorphic rocks; subrounded to rounded.

Water temperatures during drilling: 90° to 100°F, increasing with depth.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per ft; 450–525, 538–548, and 550–558 ft.

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 12, 2/7-4H1, in Surprise Spring Basin. Altitude: 2,442.2 ft. Casing diameter 10 in; drilled July 29–Sept. 3, 1952.		
Soil, poorly developed, sandy	3	3
Sand, fine to coarse, poorly sorted, iron-stained, red to buff, soft	32	35
Sand, fine to coarse, mostly coarse; some fine gravel; buff to tan, soft. Coarse gravel from 42 to 48 ft	13	48
Sand, fine to coarse, mostly coarse; some fine gravel; buff to tan, partially cemented or hard packed, intermittently hard and soft	20	68
Gravel, fine to coarse; and sand, fine to coarse, mostly coarse; buff to tan, soft	26	94
Sand, fine to coarse, mostly coarse, some fine to medium gravel, somewhat more mica (biotite) than above, gray-brown, soft	20	114
Gravel, fine to coarse; some small cobbles; and sand, fine to coarse, mostly coarse; gray-brown, moderately hard	6	120
Sand, fine to coarse, mostly coarse; and some gravel, mostly very fine; gray-brown, hard. Occasional beds cemented with calcium carbonate	35	155
Sand, fine to coarse, mostly coarse; occasionally some fine gravel, with little to no medium or coarse gravel; gray-brown, hard to soft, intermittently cemented, partially water-bearing. Sand is intermixed with a whitish, possibly calcareous or bentonitic colloidal clay, which remains suspended in water	145	300
Sand, fine to coarse, mostly very coarse; and gravel, fine to very fine; gray-brown, moderately soft, some cementation, largely water-bearing	20	320
Sand, fine to coarse, mostly coarse; some very fine gravel; gray-brown, hard, intermittent cementation, partly water-bearing	18	338
Sand, fine to coarse, mostly coarse; some very fine gravel; gray-brown, hard, intermittent cementation, partly water-bearing	18	338
Sand, fine to very coarse, mostly very coarse; and gravel, very fine to fine, with occasional pebbles; gray-brown, moderately soft, largely water-bearing	8	346
Gravel, fine to coarse; some pebbles; and sand, fine to very coarse, mostly very coarse; gray-brown, soft, largely water-bearing. Cemented from 347 to 350 ft	13	359
Sand, fine to very coarse, mostly very coarse; and gravel, very fine to fine; gray-brown, moderately soft, largely water-bearing	10	369
Sand, very fine to coarse, mostly medium and coarse; little to no fine gravel; gray-brown, hard, intermittent cementation, partly water-bearing	31	400

Table 4A. Logs of U.S. Navy test wells—Continued

Material	Thickness (ft)	Depth (ft)
Test well 12, 2/7-4H1, in Surprise Spring Basin.—Continued		
Sand, fine to very coarse, mostly very coarse; gravel, very fine to fine; and occasionally pebbles; gray-brown, moderately soft, largely water-bearing	20	420
Sand, very fine to coarse, mostly medium and coarse; and little to no fine gravel; gray-brown, poorly water-bearing, hard, intermittent cementation	27	447
Sand, very fine to coarse, clayey, and some silt, light gray to gray-brown, hard, some cementation, essentially not water-bearing	10	457
Sand, fine to very coarse, mostly very coarse; some fine gravel, gray-brown, very soft, heaving sand, largely water-bearing	12	469
Gravel, fine to coarse; few small cobbles; and sand, fine to coarse, mostly coarse; gray-brown, hard, calcareous cementation, poorly water-bearing	3	472
Sand, very fine to coarse, mostly coarse; and some gravel, fine to very fine; gray-brown, hard intermittent cementation, poorly water-bearing	28	500

Note: The sands are predominantly quartz and feldspars with some mica minerals (biotite); are poorly sorted, angular to subrounded, highly calcareous. The gravels are predominantly gneisses and basalts with considerable amounts of quartzite and granitics, poorly sorted, rounded to subrounded, generally, exceedingly few coarse gravels encountered.

Water samples bailed during drilling at depths of 296, 300, 358, 410, 450, 469, and 500 ft.
Water temperatures during drilling: 82° to 84.7°F, increasing with depth.
Water level during drilling: 189.2 to 191.0 ft below land surface.
Water level before and after perforating: 189.4 ft below land surface.
Perforations: 0.25-in x 3-in Mills knife, 6 cuts per round, one round per foot; 300–320, 338–370, and 400–420 ft.

Table 5A. Drillers' logs of U.S. Navy supply wells

[ft, foot; in, inch. Material: The term "shells" refers to thin cemented beds]

Material	Thickness (ft)	Depth (ft)
Supply well 1, 1N/9-4N1, in Mesquite Basin. Altitude 1,786.8 ft. Drilled by Mogle Brothers, 1941. 14-in casing. Casing perforated 390–495 ft.		
Top soil	9	9
Sandy clay	36	45
Coarse water sand	3	48
Sandy clay	47	95
Sticky clay	15	110
Packed silt and sand	15	125
Fine sand	5	130
Yellow clay	32	162
Fine sand	5	167
Sticky clay	38	205
Fine sand	12	217
Packed silt	13	230
Quicksand	34	264
Coarse water sand	21	285
Packed silt	19	304
Coarse water sand	4	308
Silty clay	17	325
Coarse sand	7	332
Silty clay	58	390
Coarse water sand	105	495
Dark packed sand	5	500
Supply well 2, 1N/9-5G1, in Mesquite Basin. Altitude 1,779.2 ft. Drilled by Mogle Brothers, 1941. 14-in casing. Casing perforated 266–284, 324–330, 358–365, 390–396, 415–428 ft.		
Top soil	10	10
Dry gravel	3	13
Silty clay	35	48
Fine gravel and sand	3	51
Dark packed sand	35	86
Sandy clay	4	90
Sticky clay	19	109
Hard cemented white sand	3	112
Packed silt and sand	10	122
Green packed sand	6	128
Fine silty water sand	6	134
Silty clay	2	136
Fine sand	13	149
Yellow clay	3	152
White clay	8	160

Table 5A. Drillers' logs of U.S. Navy supply wells—Continued

Material	Thickness (ft)	Depth (ft)
Supply well 2, 1N/9-5G1, in Mesquite Basin—Continued		
Sand and silt	4	164
Silt and clay	30	194
Sticky white clay	16	210
Fine sand	5	215
Tight silt	5	220
Quicksand	40	260
Packed sand	6	266
Coarse sand and gravel	18	284
Packed silt	16	300
Coarse sand and silt	12	312
Tight silt and clay	12	324
Clean coarse sand	6	330
Silt	28	358
Clean coarse sand	7	365
Silt	25	390
Clean coarse sand	6	396
Silt	19	415
Medium coarse sand	13	428
Alternate sand and silt	72	500
Supply well 3, 3/8-34D1, in Deadman Basin. Altitude 1,823.9 ft. Drilled by Mogle Brothers, March 1943. 12-in casing. Casing perforated 186–210, 270–290, 360–370, 384–396 ft.		
Drift sand	6	6
Sandy clay	44	50
Coarse water sand and rock	20	70
Yellow clay	10	80
Quicksand	55	135
Coarse sand and small gravel	10	145
Packed silt and fine sand	41	186
Coarse water sand	24	210
Fine silt and sand	28	238
Coarse sand and fine gravel	10	248
Clay and sand	8	256
Cemented sand	14	270
Coarse sand and rock	20	290
Packed silt and cement	70	360
Coarse water sand	10	370
Packed silt	14	384
Coarse water sand	12	396
Packed silt	4	400

Table 5A. Drillers' logs of U.S. Navy supply wells—Continued

Material	Thickness (ft)	Depth (ft)
Supply well 1A, 3/8-29L1, in Deadman Basin. Altitude 1,905.7 ft. Drilled by F.W. Walker, December 1952. 16-in casing 0–250 ft; 12-in casing 250–600 ft, with bullnose at 600 ft; uncased pilot hole, 600–800 ft. Casing perforated 270–590 ft. Gravel packed 0–600 ft.		
Surface soil and sand	10	10
Coarse sand and cobbles up to 2 in in diameter, some basalt cobbles	10	20
Coarse sand	10	30
Sand and gravel	10	40
Coarse sand	25	65
Fine sand, hard; cobbles at 110 ft	45	110
Coarse sand	20	130
Hard packed sand	20	150
Coarse sand and hard "shells"	40	190
Coarse sand	55	245
Hard packed sand	5	250
Coarse sand	35	285
Coarse sand and hard "shells"	41	326
Hard packed sand	20	346
Coarse sand	23	369
Hard packed sand	11	380
Cobbles and hard sandy "shells"	10	390
Coarse sand	45	435
Hard sand and "shells"	15	450
Coarse sand	20	470
Fine sand	10	480
Sandy yellow clay	20	500
Coarse sand	15	515
Hard-packed fine sand	8	523
Sandy yellow clay	7	530
Sand	20	550
Yellow sandy clay	20	570
Cobbles	2	527
Coarse sand	38	610
Sandy yellow clay	10	620
Coarse sand	15	635
Yellow sand clay	55	690
Coarse sand	20	710
Sandy clay	20	730
Sandy yellow clay and streaks of coarse sand	30	760
Coarse sand and streaks of yellow sandy clay	40	800

Table 5A. Drillers' logs of U.S. Navy supply wells—Continued

Material	Thickness (ft)	Depth (ft)
Supply well 2A, 2/7-3B1, in Surprise Spring Basin. Altitude 2,355.3 ft. Drilled by F.W. Walker, December 1952. 16-in casing 0–250 ft; 12-in casing 250–700 ft, with bullnose at 700 ft; uncased pilot hole 700–800 ft. Casing perforated 260–690 ft. Gravel packed 0–600 ft.		
Coarse, hard packed sand	50	50
Coarse sand and thin streaks of yellow clay	30	80
Coarse sand, hard sand, and "shells"	20	100
Cobbles, sand, and hard "shells"	10	110
Sand and hard "shells"	30	140
Coarse sand and yellow clay	20	160
Sand and hard "shells"	20	180
Coarse sand	30	210
Sand, cobbles, and hard "shells"	25	235
Coarse sand and hard "shells"	65	300
Coarse sand	20	320
Coarse sand and streaks of yellow clay	30	350
Coarse sand, streaks of yellow clay, and hard "shells"	30	380
Sand and hard "shells"	20	400
Sand and streaks of yellow sandy clay	30	430
Yellow sandy clay and streaks of sand	40	470
Sand and hard "shells"	20	490
Sand and streaks of yellow sandy clay	35	525
Sand	95	620
Yellow sandy clay and streaks of coarse sand	35	655
Hard packed sand	5	660
Sand	25	685
Hard "shells"	10	695
Sand and thin streaks of clay	65	760
Coarse sand	20	780
Yellow clay	20	800

Table 5A. Drillers' logs of U.S. Navy supply wells—Continued

Material	Thickness (ft)	Depth (ft)
Supply well 3A, 2/7-3A1, in Surprise Spring Basin. Altitude 2,300.9 ft. Drilled by F.W. Walker, January 1953. 16-in casing 0–200 ft; 12-in casing 200–560 ft, with bullnose at 560 ft; uncased pilot hole 560–800 ft. Casing perforated 210–550 ft. Gravel packed 0–560 ft.		
Sand, hard "shells" and thin streaks of clay	20	20
Coarse sand and gravel, and thin "shells"	60	80
Cobbles and coarse sand	10	90
Sand and streaks of sandy clay	15	105
Sand and "shells"	25	130
Hard "shells" and coarse sand	18	148
Coarse sand	92	240
Sandy yellow clay, streaks of sand	20	260
Sand, "shells," and cobbles	35	295
Very hard "shells"	5	300
Sandy yellow clay, coarse sand, and "shells"	20	320
Sand and streaks of yellow sandy clay	42	362
Hard "shells"	3	365
Sand, cobbles, and thin "shells"	25	390
Coarse sand and cobbles	30	420
Coarse sand, cobbles, and "shells"	96	516
Hard "shells"	4	520
Sand, thin "shells," and cobbles	40	560
Sand, and streaks of yellow sandy clay	30	590
and, and thin streaks of yellow sandy clay	95	685
Sand, cobbles, and yellow sandy clay	15	700
Coarse sand	60	760
Hard packed sandy clay	10	770
Coarse sand	30	800

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California

[ft, foot; in, inch]

Material	Thickness (ft)	Depth (ft)
1N/6-9Q1. Owner: Mogle Brothers, north of Bartlett Mountains. Altitude 3,214 ft. Drilled by Mogle Brothers in 1947. 16-in casing 0–540 ft; uncased hole 540–570 ft. Casing perforated 335–540 ft.		
Sand	4	4
Clay	18	22
Sand	63	85
Clay	7	92
Sand	113	205
Clay	17	222
Clay and gravel (dry)	70	292
Rock	2	294
Clay	146	440
Hill formation ?	42	482
Clay	29	511
Clay and rocks	59	570
1N/6-29H1. Owner: Johnson, in Yucca Valley.		
[No data]	235	235
"Blue shale" (probably decomposed bedrock), dry	23	258
1N/7-14N1. In Copper Mountain Valley. Drilled by Mogle Brothers in March 1943. 12-in casing. Casing perforated 386–425 ft.		
Top soil	16	16
Sticky clay	66	82
Black clay	10	92
Sticky clay	294	386
Water sand	39	425
Sandy clay	25	450

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/7-35D1. Owner: R.E. Sturdevant, in Copper Mountain Valley. Drilled by Harry Wheeler in February 1951. 12-in casing.		
Clay, silt, and sand	27	27
Sand, small, and clay (40%)	63	90
Sand, small, and clay (50%)	40	130
Hardpan sand, small, and clay (40%)	10	140
Sand, small, and clay (40%)	26	166
Sand, fine, and clay and silt, little water	14	180
Sand, and pea gravel, water	25	205
Sand, small, and clay (20%)	10	215
Sand, small, and clay (50%)	30	245
Sand, small, and clay (30%)	11.5	256.5
1N/8-25R1. Owner: Pacific Coast Land Co., near Twentynine Palms. Drilled by Taylor Brothers. Casing perforated 160–218, 224–291 ft.		
Surface (material)	18	18
Dry gravel	52	70
Cemented gravel	90	160
Water gravel	58	218
Clay	6	224
Water gravel	67	291
Clay	1	292
1N/8-26G1. Owner: W. Schutze, near Twentynine Palms. Altitude 2,414.2 ft. Drilled by Taylor Brothers in 1940. 12-in casing. Casing perforated 502–507, 547–549, 554–559 ft.		
Surface (material)	15	15
Dry gravel	105	120
Clay and gravel	20	140
Dry gravel	255	395
Clay and cement	37	432
Dry gravel	5	437
Clay	10	447
Dry gravel	33	480
Water gravel	15	495
Clay	7	502
Gravel	5	507
Hard clay	24	531
Gravelly clay	4	535
Hard clay	12	547
Gravel	2	549
Hard clay	5	554

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/8-26G1. Owner: W. Schutze, near Twentynine Palms—Continued		
Coarse gravel	5	559
Soft clay	4	563
Small gravel	7	570
Coarse gravel	12	592
Hard clay	11	603
1N/9-5R1. Owner: M. Elliott, in Mesquite Basin. Altitude 1,788.9 ft. Drilled in April 1941. 8-in casing. Casing perforated 96–102 ft.		
Surface (material)	21.6	21.6
Water (sand?)	7.4	29
Clay	7	36
Stream gravel	1.5	37.5
Clay	1	38.5
Quicksand	47.5	86
Vegetable matter, black, smelly	1	87
Clay	1	88
Iron cemented hardpan (probably old soil horizon)	1	89
Clay	3	92
Good gravel	10	102
Clay	1	103
Gravel	—	—
1N/9-9M1. Owner: O. Taylor, in Mesquite Basin. Altitude 1,810 ft. Drilled by Hufford in 1946. 12-in casing 0–75 ft. Casing perforated 45–75 ft.		
Sand and silt (vein of hardpan at 35 ft)	30	30
Gravel, sand, and silt	9	39
Clay	1	40
Good clean sand	3	43
Gravel and clay	22	65
Sand	5	70
Gravel and clay	8	78

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/9-27C1. Owner: Wrubel, in Mesquite Basin. Drilled by Taylor Brothers in June 1934. Casing perforated 238–245, 251–275, 306–311 ft.		
Surface (material)	12	12
Dry gravel	23	35
Clay	31	66
Streaks of clay and gravel (first water)	2	68
Packed sand	12	80
Hard green clay	34	114
Yellow clay	29	143
Soft clay with gravel	4	147
Hard yellow clay	11	158
"Slummy" yellow clay	24	182
Hard red clay	26	208
Small dirty gravel	1	209
"Slummy" yellow clay	7	216
Fair gravel	3	219
Clay and rock	5	224
"Slummy" gravel	10	234
Packed gravel	4	238
Good gravel	7	245
Packed gravel	6	251
Good gravel	24	275
Hard clay	25	300
Packed gravel and clay	6	306
Fair gravel	5	311
Hard clay	39	350
1N/9-30K1. Owner: W.A. Nicolson, in Twentynine Palms. Altitude 2,120.5 ft. Drilled by C.E. Emerson in April 1936. 8-in casing.		
Surface (material)	37	37
Clay	17	54
Clay, no rock	36	90
[No data]	40	130
Clay, seepage water at 140 ft	10	140
Clay	24	164
Water gravel	4	168
Coarse water gravel	3	171

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/9-31C1. Owner: Abell Water Co., in Twentynine Palms. Altitude 2,103.0 ft. Drilled by Taylor Brothers. 14-in casing. Casing perforated 242–306 ft.		
Dry gravel	120	120
Cemented gravel	10	130
Clay	10	140
Good water gravel	96	236
Clay and cement	6	242
Good gravel	64	306
1N/9-31H1. Owner: Abell Water Co., in Twentynine Palms. Drilled by Mann Brothers in May 1953. 12-in casing. Casing perforated 200–340 ft.		
Surface (material)	25	25
Sand, coarse, with rock	65	90
Sand, coarse, with gravel	33	123
Gravel	11	134
Sand, medium	10	144
Sand, coarse	4	148
Sand, coarse, with rock	9	157
Gravel and sand, coarse	16	173
Sand, coarse, with cemented streaks	23	196
Sand, coarse	5	201
Sand, coarse, and gravel	24	225
Gravel, with shale and streaks of cemented sand	15	240
Gravel	17	257
Rocks	2	259
Gravel	11	270
Sand, coarse	5	275
Sand, coarse	11	286
Sand, medium and coarse	64	350

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/9-33F3. Owner: Twentynine Palms, Corp., at Twentynine Palms Oasis. Drilled by Taylor Brothers in 1939. 12-in casing. Casing perforated 132–156, 180–188, 206–285 ft.		
Surface (material)	16	16
Clay	37	53
Small dirty gravel	7	60
Quicksand	4	64
Clay	14	78
Packed sand and gravel	4	82
Coarse sand, some gravel	3	85
Gravelly clay	9	94
Small gravel, dirty	4	98
Clay	4	102
Gravel and clay, mixed, dirty	4	106
Small gravel, fair	9	115
Clay	5	120
Gravel and clay, mixed, packed	10	130
Clay	2	132
Small gravel, fair	24	156
Clay	12	168
Coarse sand, "Slummy"	12	180
Small gravel, fair	8	188
Small gravel, dirty	9	197
Dirty sand	9	206
Small gravel, fair	20	226
Coarse gravel, good	10	236
Small gravel, fair	49	285
1N/9-35F1. Owner: H.L. Watson, near Twentynine Palms. Altitude 1,971.6 ft. Drilled by Taylor Brothers. 12-in casing. Casing perforated 154–176, 186–196 ft.		
Surface (material)	12	12
Hard clay with gravel	64	76
Sandstone	78	154
Cemented gravel	22	176
Clay	10	186
Cemented gravel	10	196
Sandstone	12	208
Cemented boulders	4	212
Sandstone	41	253

Table 6A. Drillers' logs of wells in the Twentynine Palms Basin, California—Continued

Material	Thickness (ft)	Depth (ft)
1N/9-35N1. Owner: Southwest Subdividers, near Twentynine Palms. Altitude 2,079 ft. Drilled by Taylor Brothers in April 1935. 12-in casing. Casing perforated 147–247 ft.		
Gravel and rock	16	16
Dry gravel	8	24
Gravel and boulders	4	28
Dry gravel	42	70
Cemented gravel and rock	3	73
Dry gravel	28	101
Good gravel	42	143
Cemented gravel and rock	4	147
Good gravel	15	162
Rock and boulders	2	164
Good gravel	83	247
Cemented gravel and rock	13	260
2/9-19N1. Owner: H.A. Porter, in Mesquite Basin. Drilled by H.A. Porter in 1950. 8-in casing.		
Soil	8	8
Clay	4	12
Sand and gravel	25	37
Blue clay	8	45
[No data]	29	74
Clay, very hard	—	—
Coarse sand	—	136

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California

[Constituents shown in parentheses are calculated. Analysis by: SPH, State of California, Department of Public Health; USN, Sanitation Division Laboratory, Public Works Office, Eleventh Naval District; SBC, San Bernardino County Flood Control District; Pom, Pomeroy and Associates, Pasadena, Calif.; Bab, E.S. Babcock and Sons, Riverside, Calif.; and USGS, U.S. Geological Survey, Quality of Water Branch. Constituents, except specific conductance and pH, in parts per million. TDS, dissolved solids; Sp C, specific conductance, in microhmos per centimeter at 25 degrees Celsius; Hardness, hardness as Calcium Carbonate ($CaCO_3$); pH in standard units; Temp (°F), temperature in degrees Fahrenheit]

Constituent	Well number			
	1S/9-3D1	1S/9-5A1	1N/5-2N1	1N/5-22N1
Silica (SiO_2)				
Iron (Fe)	0.1	0.6		
Calcium (Ca)	16	26	32	38
Magnesium (Mg)	5	3	15	6.2
Sodium (Na)	[a]36	[a]17	33	32
Potassium (K)			1.2	1.3
Carbonate (CO_3)		0	0	0
Bicarbonate (HCO_3)	127	98	108	174
Sulfate (SO_4)	12	13	(101)	(24)
Chloride (Cl)	15	14	14	16
Nitrate (NO_3)				
Boron (B)				
Fluoride (F)	3.0	1.1	.6	.6
TDS	(150)	(123)	(250)	(204)
Sp C			404	362
Hardness	61	78	142	120
pH	7.5	7.3	8.4	8.2
Temp (°F)				64
Date analyzed	5/37	7/37	4/20/53	3/27/53
Analysis by	SPH	SPH	USGS	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number						
	1N/6-4Q1	1N/6-6E1	1N/6-10F1	1N/7-35D1	1N/8-1D1	1N/8-9L1	1N/8-12G1
Silica (SiO_2)				5			
Iron (Fe)							
Calcium (Ca)	2.5	4.3	22	24	32	46	16
Magnesium (Mg)	.9	.3	5.3	9	5.5	8.3	1.0
Sodium (Na)	73	67	52	[a]23	198	[a]92	209
Potassium (K)	2.3	1.6	3.5		4.0		2.5
Carbonate (CO_3)	0	18	0	0	0		0
Bicarbonate (HCO_3)	164	97	164	125	84	113	3
Sulfate (SO_4)	(12)	(17)	(17)	17	(334)	170	(281)
Chloride (Cl)	14	20	28	14	60	50	120
Nitrate (NO_3)		4.5				8	
Boron (B)							
Fluoride (F)	1.9	.3	1.0	.6	14	5.3	14
TDS	(188)	(181)	(210)	(155)	(689)	(436)	(645)
Sp C.	359	325	377	312	1,150		1,160
Hardness	10	12	77		102		44
pH	8.1	8.3	8.2		7.9	7.8	4.8
Temp (°F)	82	70			78		82
Date analyzed	10/20/53	6/18/53	10/20/53	2/23/51	10/20/53	4/41	10/20/53
Analysis by	USGS	USGS	USGS	Bab	USGS	SBC	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number						
	1N/8-25R1	1N/8-26G1	1N/8-36A1	1N/9-4N1	1N/9-5G1	1N/9-5Q1	1N/9-5Q2
Silica (SiO_2)				18	18		
Iron (Fe)	0.1	0.3		0	0	0.2	0.1
Calcium (Ca)	22	9.7	17	30	32	44	46
Magnesium (Mg)	3	2.1	2.1	4	3	17	17
Sodium (Na)	[a]24	[a]56	[a]37	[a](167)	[a](173)	[a]86	[a]112
Potassium (K)							
Carbonate (CO_3)	0			0	0		
Bicarbonate (HCO_3)	117	115	124	76	71	83	88
Sulfate (SO_4)	13	17.5	11	280	290	212	230
Chloride (Cl)	7	11.5	11	58	56	56	84
Nitrate (NO_3)		8	5				
Boron (B)				.38	.4		
Fluoride (F)	2.0	3.5	1.6	7.5	11	9.0	8.5
TDS	(119)	(161)	(146)	(602)	(618)	(465)	(621)
Sp C							
Hardness	68			92	94	181	187
pH	8.0		8.3	8.1	8.1	7.2	7.0
Temp (°F)			74	77	73		
Date analyzed	5/37		4/41	4/21/52	4/21/52	6/37	6/37
Analysis by	SPH	[b]SPH; SBC	SBC	USN	USN	SPH	SPH

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	1N/9-6N1	1N/9-7E1	1N/9-9C1	1N/9-9M2	1N/9-9Q1	1N/9-10D1
Silica (SiO_2)						
Iron (Fe)	0.1	0.2		0.2		
Calcium (Ca)	39	37.5	206	29	122	2
Magnesium (Mg)	6	3	110	6	46	.4
Sodium (Na)	[a]247	[a]203	[a]1,110	[a]147	[a]881	[a]346
Potassium (K)						
Carbonate (CO_3)	0	0		5	5	34
Bicarbonate (HCO_3)	98	73	368	73	244	173
Sulfate (SO_4)	460	380	1,925	212	1,702	400
Chloride (Cl)	73	66	746	90	306	112
Nitrate (NO_3)			2			
Boron (B)						
Fluoride (F)	14.0	13.0	10.6	10.0	8.0	9.2
TDS	(887)	(739)	(4,291)	(535)	(3,190)	(955)
Sp C.						
Hardness	124	107		98	496	
pH	8.0	7.8	7.5	8.2	8.2	9.4
Temp (°F)			72			78
Date analyzed	6/37	6/37	4/41	7/37	7/37	4/41
Analysis by	SPH	SPH	SBC	SPH	SPH	SBC

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	1N/9-16H3	1N/9-17E1	1N/9-17J2	1N/9-20R1	1N/9-21J2	1N/9-22B1
Silica (SiO_2)		4.0				
Iron (Fe)		0.1	0	0		
Calcium (Ca)	12	38	31	20	39	4
Magnesium (Mg)	8.4	5	14	8	10	4.9
Sodium (Na)	137	[a]265	[a]98	[a]58	[a]82	[a]225
Potassium (K)	6.6					
Carbonate (CO_3)	0	0	0	0		
Bicarbonate (HCO_3)	148	73	205	161	185	304
Sulfate (SO_4)	(143)	465	77	38	62	150
Chloride (Cl)	58	106	71	26	70	78
Nitrate (NO_3)						
Boron (B)			0			
Fluoride (F)	7.0	11.5	7.5	4.0	9.0	14
TDS	(445)	(931)	(400)	(233)	(363)	(626)
Sp C	764					
Hardness	64	115	135	83	139	
pH	7.9	7.6	8.0			7.8
Temp (°F)	74					78
Date analyzed	10/20/53	6/37	6/37	6/37	5/37	4/41
Analysis by	USGS	SPH	SPH	SPH	SPH	SBC

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	1N/9-22D1	1N/9-22E1	1N/9-27K1	1N/9-29F1	1N/9-29R1	1N/9-30Q1
Silica (SiO_2)						
Iron (Fe)	0.2		0	0.1		1.5
Calcium (Ca)	17	18	18	11	23	26
Magnesium (Mg)	8	2.6	12	1.3	3.6	7
Sodium (Na)	[a]66	[a]63	[a]32	[a]134	[a]72	[a]91
Potassium (K)						
Carbonate (CO_3)	5		0	16		0
Bicarbonate (HCO_3)	166	172	156	43	218	190
Sulfate (SO_4)	38	30	15	152	26	54
Chloride (Cl)	24	14	15	68	17	57
Nitrate (NO_3)		2			4	
Boron (B)						
Fluoride (F)	9.0	8.2	6.0	16	5.3	4.0
TDS	(249)	(223)	(175)	(420)	(258)	(335)
Sp C						
Hardness	76		95			94
pH	8.2	8.0	8.0		7.8	7.5
Temp (°F)		72.5			76	
Date analyzed	7/37	4/41	7/37		4/41	5/37
Analysis by	SPH	SBC	SPH	[b]SPH; SBC	SBC	SPH

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	1N/9-31A1	1N/9-31C1	1N/9-31H1	1N/9-32H1	1N/9-32H2	1N/9-32R1
Silica (SiO_2)						
Iron (Fe)				0.2	0	0.2
Calcium (Ca)	12	18	13	13	13	26
Magnesium (Mg)	2	2.2	2.1	4	6	3
Sodium (Na)	[a]61	[a]29	37	[a]38	[a]52	[a]23
Potassium (K)			1.6			
Carbonate (CO_3)	0		0	5		0
Bicarbonate (HCO_3)	112	110	112	102	117	107
Sulfate (SO_4)	58	12	(13)	8	31	15
Chloride (Cl)	13	10	10	22	33	17
Nitrate (NO_3)		6				
Boron (B)						
Fluoride (F)	4.0	1.6	1.6	1.8	3.0	1.1
TDS	(205)	(133)	(133)	(142)	(196)	(138)
Sp C			248			
Hardness	38		41	49	58	78
pHz	7.1	7.9	8.0	7.5	7.9	7.5
Temp (°F)		74	85			
Date analyzed	6/37	4/41	10/20/53	5/37	6/37	5/37
Analysis by	SPH	SBC	USGS	SPH	SPH	SPH

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	1N/9-33F3	2/5-1H1	2/6-6D1	2/6-7Q1	2/7-2C1	2/7-3A1
Silica (SiO_2)			18		18	18
Iron (Fe)	0.1		0		0	.05
Calcium (Ca)	22	42	20	34	3	11
Magnesium (Mg)	3	7.8	7	7.5	0	.5
Sodium (Na)	[a]29	55	[a](66)	43	[a](50)	44
Potassium (K)		2.7		2.5		2.1
Carbonate (CO_3)	0	0	10	0	17	0
Bicarbonate (HCO_3)	112	138	78	172	51	82
Sulfate (SO_4)	10	(88)	75	(39)	24	30
Chloride (Cl)	18	38	40	21	12	20
Nitrate (NO_3)						1.5
Boron (B)		0.32		0.3	0.12	
Fluoride (F)	1.5	0.8	2.5	0.6	1.1	1.0
TDS	(139)	(303)	(277)	(233)	(150)	168
Sp C		520		400		270
Hardness	68	137	80	116	7	30
pH	8.0	8.1	8.9	8.2	9.0	8.6
Temp (°F)					93	84.5
Date analyzed	6/37	3/27/53	12/5/51	3/27/53	4/21/52	2/17/53
Analysis by	SPH	USGS	USN	USGS	USN	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	2/7-3A1	2/7-3B1	2/7-3B1	2/7-4H1	2/7-14K1	2/8-11B1
Silica (SiO_2)	24	21	23	25	20	
Iron (Fe)	0.1	0.00	0.	0		
Calcium (Ca)	9	14	11	12	2	4.3
Magnesium (Mg)	1	0.7		1	1	4.7
Sodium (Na)	[a](44)	49	[a](52)	[a](43)	[a](57)	1,720
Potassium (K)		2.4				8.6
Carbonate (CO_3)	5	0	7	1	24	187
Bicarbonate (HCO_3)	68	77	61	76	73	1,338
Sulfate (SO_4)	29	37	40	39	15	(1,170)
Chloride (Cl)	18	29	28	15	10	725
Nitrate (NO_3)		2.0				
Boron (B)	.06	.10	.06	.1		
Fluoride (F)	.9	.8	.5	.7	1.1	50
TDS	(164)	194	(193)	(174)	(166)	(4,529)
Sp C		311				7,010
Hardness	26	38	32	35	8	30
pH	8.8	8.4	8.8	8.5	8.9	9.0
Temp (°F)	84.5	82.2	82.2	80	96	71
Date analyzed	2/24/53	2/17/53	2/24/53	9/30/52	9/29/52	6/10/53
Analysis by	USN	USGS	USN	USN	USN	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	2/8-24H1	2/8-26J1	2/9-30B1	2/9-31N1	3/6-4L1	3/6-4P1
Silica (SiO_2)	10				18	
Iron (Fe)	.1	0.2	0	1.2	0	
Calcium (Ca)	8	42	22	46.5	38	20
Magnesium (Mg)	1	15	8	6	9	3.5
Sodium (Na)	[a](181)	[a]100	[a]150	[a]205	[a](39)	49
Potassium (K)						2.5
Carbonate (CO_3)	10		10	0	0	0
Bicarbonate (HCO_3)	22	78	68	93	168	148
Sulfate (SO_4)	258	212	192	390	42	(19)
Chloride (Cl)	66	70	100	75	30	22
Nitrate (NO_3)						
Boron (B)	.52				.08	
Fluoride (F)	8	4.0	7.5	9.0	5	.7
TDS	(554)	(481)	(523)	(779)	(264)	(195)
Sp C.						356
Hardness	26	163	88	140	132	64
pH	8.9	7.6	8.3	7.5	7.9	8.2
Temp (°F)	85					
Date analyzed	3/11/52	5/37	5/37	6/37	12/5/51	3/27/53
Analysis by	USN	SPH	SPH	SPH	USN	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	3/7-13N1	3/7-18D1	3/7-31E1	3/7-35P1	3/7-35P1	3/7-35Q
Silica (SiO_2)	24	16	16		18	
Iron (Fe)	0	0	0		0	
Calcium (Ca)	52	56	10	6.8	6	14
Magnesium (Mg)	5	11	2	.2	1	4.3
Sodium (Na)	[a](173)	[a](81)	[a](42)	50	[a](56)	106
Potassium (K)				4.2		12
Carbonate (CO_3)	0	0	4	0	2	16
Bicarbonate (HCO_3)	93	76	81	96	83	210
Sulfate (SO_4)	245	120	25	(21)	36	(59)
Chloride (Cl)	136	122	17	20	18	24
Nitrate (NO_3)						
Boron (B)	.14	.24	.01		0.12	
Fluoride (F)	1.6	.3	.5	1.0	2.5	1.8
TDS	(683)	(444)	(157)	(150)	(181)	(340)
Sp C				271		494
Hardness	150	184	34	18	20	52
pH	8.2	7.7	8.4	7.0	8.2	8.3
Temp (°F)	83	74	78			
Date analyzed	8/8/52	5/1/52	8/8/52	6/10/53	12/5/51	6/10/53
Analysis by	USN	USN	USN	USGS	USN	USGS

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number					
	3/8-17L1	3/8-28C1	3/8-29L1	3/8-29L1	3/8-33B1	3/8-34D1
Silica (SiO_2)	16	18	18	18	18	18
Iron (Fe)	.1	0	0		.1	0
Calcium (Ca)	20	33	46	46	50	23
Magnesium (Mg)	3	5	5	4.6	8	3
Sodium (Na)	[a](318)	[a](258)	[a](305)	305	[a](268)	[a](280)
Potassium (K)						
Carbonate (CO_3)	4	0	4		0	4
Bicarbonate (HCO_3)	76	90	63	78	85	103
Sulfate (SO_4)	268	298	427	407	381	276
Chloride (Cl)	280	196	202	215	188	204
Nitrate (NO_3)				1.0		
Boron (B)	.7	.7	1.0	.67	1.1	1.2
Fluoride (F)	4	1.5	4.5	3.6	4	4.5
TDS	(951)	(854)	(1,044)	1,040	(960)	(865)
Sp C.				1,690		
Hardness	62	102	136	134	160	72
pH	8.3	8.0	8.3	7.9	8.0	8.25
Temp (°F)	83	85	80	79	72	74
Date analyzed	3/18/52	6/12/52	12/22/52	1/14/53		4/2/52
Analysis by	USN	USN	USN	USGS	USN	USN

See footnotes at end of table.

Table 7A. Chemical analyses of water from wells in the Twentynine Palms Basin, California—Continued

Constituent	Well number			
	4/6-27C1	4/6-27D1	4/6-27F1	4/6-27M1
Silica (SiO_2)				
Iron (Fe)				
Calcium (Ca)	27			128
Magnesium (Mg)	12			21
Sodium (Na)	790	206	790	160
Potassium (K)	5.8	2.0	4.9	4.7
Carbonate (CO_3)	43	12	421	0
Bicarbonate (HCO_3)	640	252	568	112
Sulfate (SO_4)	(563)	(9)	(173)	(257)
Chloride (Cl)	465	164	88	282
Nitrate (NO_3)				
Boron (B)				
Fluoride (F)	1.9	6.4	100	.9
TDS	(1,723)	(523)	(1,857)	(909)
Sp C	2,710	997	3,170	1,560
Hardness	117	34	10	406
pH	8.8	8.6	9.7	7.8
Temp (°F)				
Date analyzed	3/27/53	3/27/53	3/27/53	6/10/53
Analysis by	USGS	USGS	USGS	USGS

[a] Sodium and potassium expressed as sodium.
[b] Average of two analyses.

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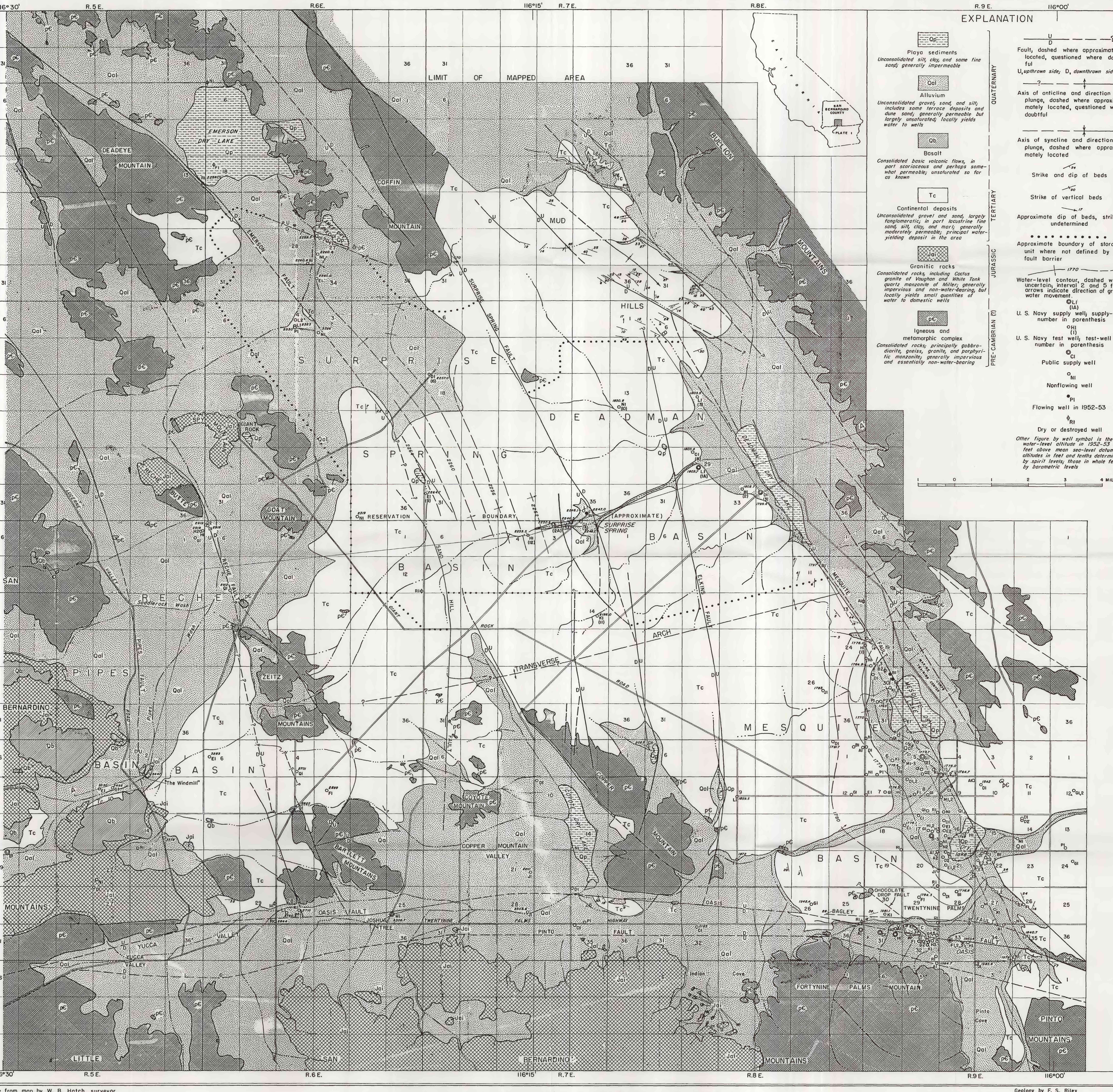
OPEN-FILE REPORT 98-167
PLATE 1



Base chiefly from map by W. B. Hatch, surveyor, and from AMS photomaps.

Geology by F. S. Riley

MAP OF THE TWENTYNINE PALMS BASIN, CALIFORNIA

SHOWING GEOLOGY, LOCATIONS OF WELLS, AND ALTITUDES OF WATER LEVELS IN 1952-53

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
DEPARTMENT OF THE NAVY

OPEN-FILE REPORT 98-167
PLATE 2

GEOLOGIC SECTION A-A' ACROSS THE TWENTYNINE PALMS BASIN
SHOWING DEPOSITS AND WATER-LEVEL PROFILE, 1952-53

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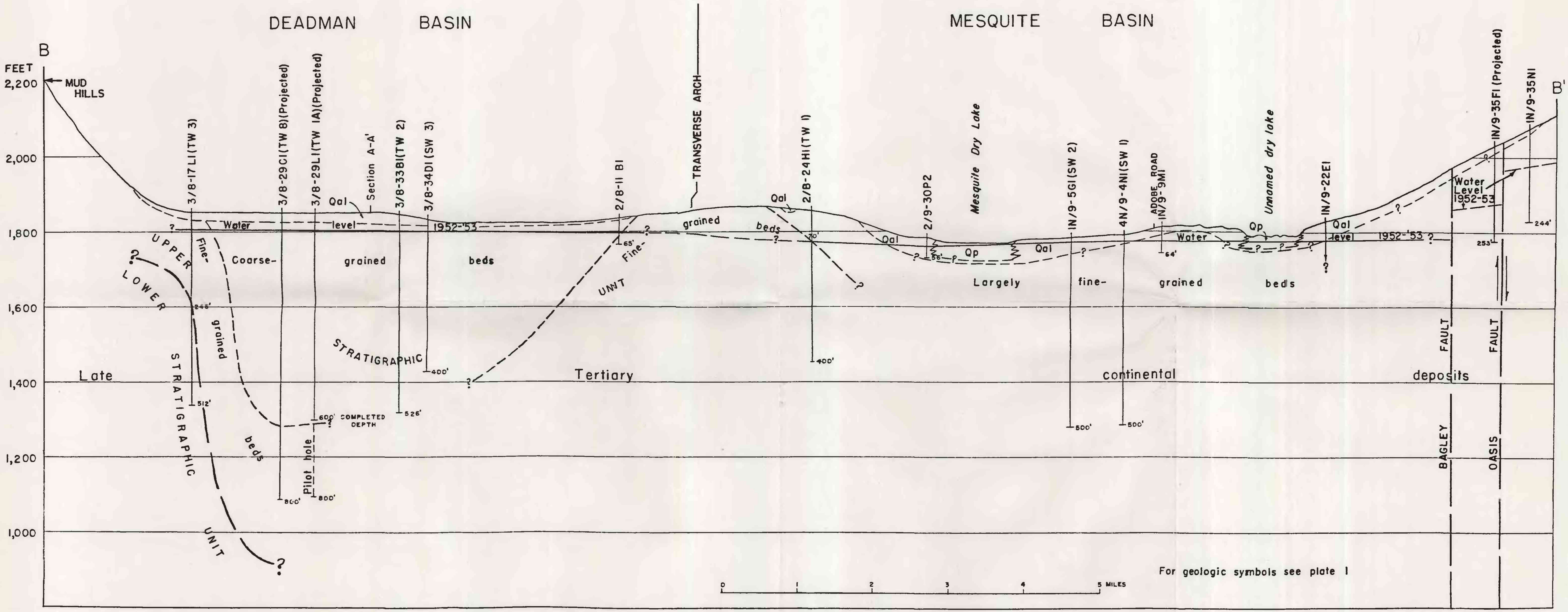

DIAGRAMMATIC SECTION B-B' SHOWING LATE TERTIARY CONTINENTAL DEPOSITS AND WATER LEVEL PROFILE, 1952-53

U.S. DEPARTMENT OF THE INTERIOR
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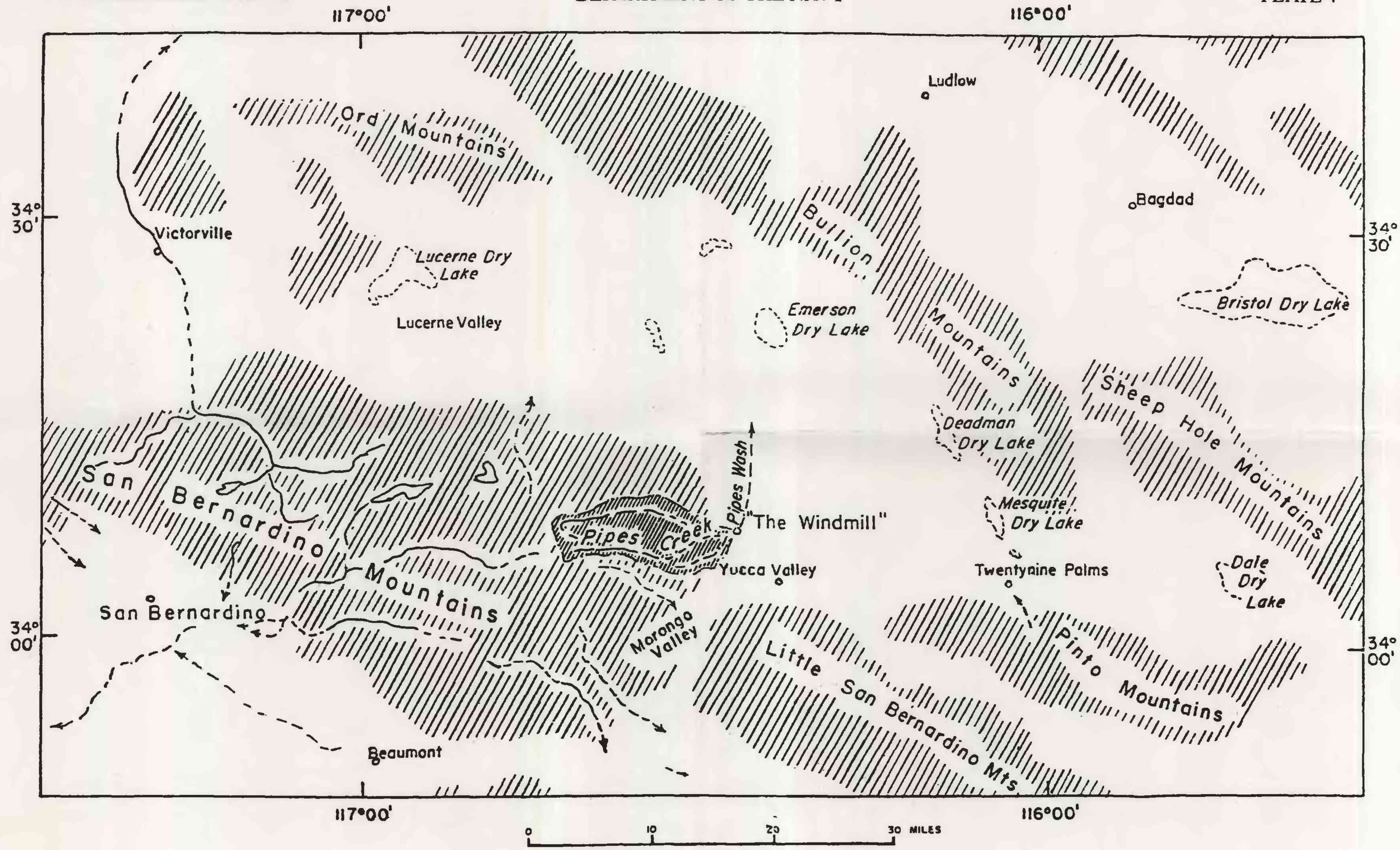
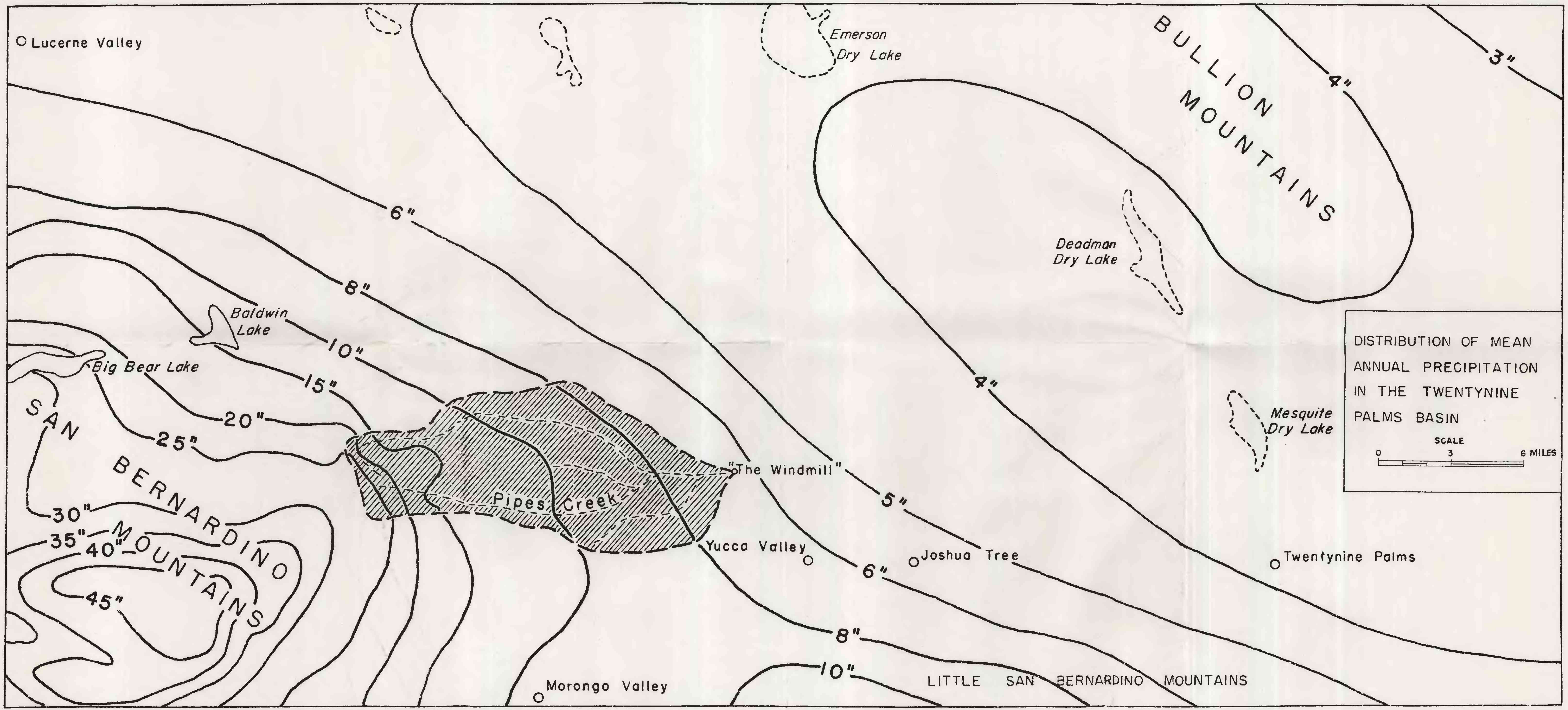
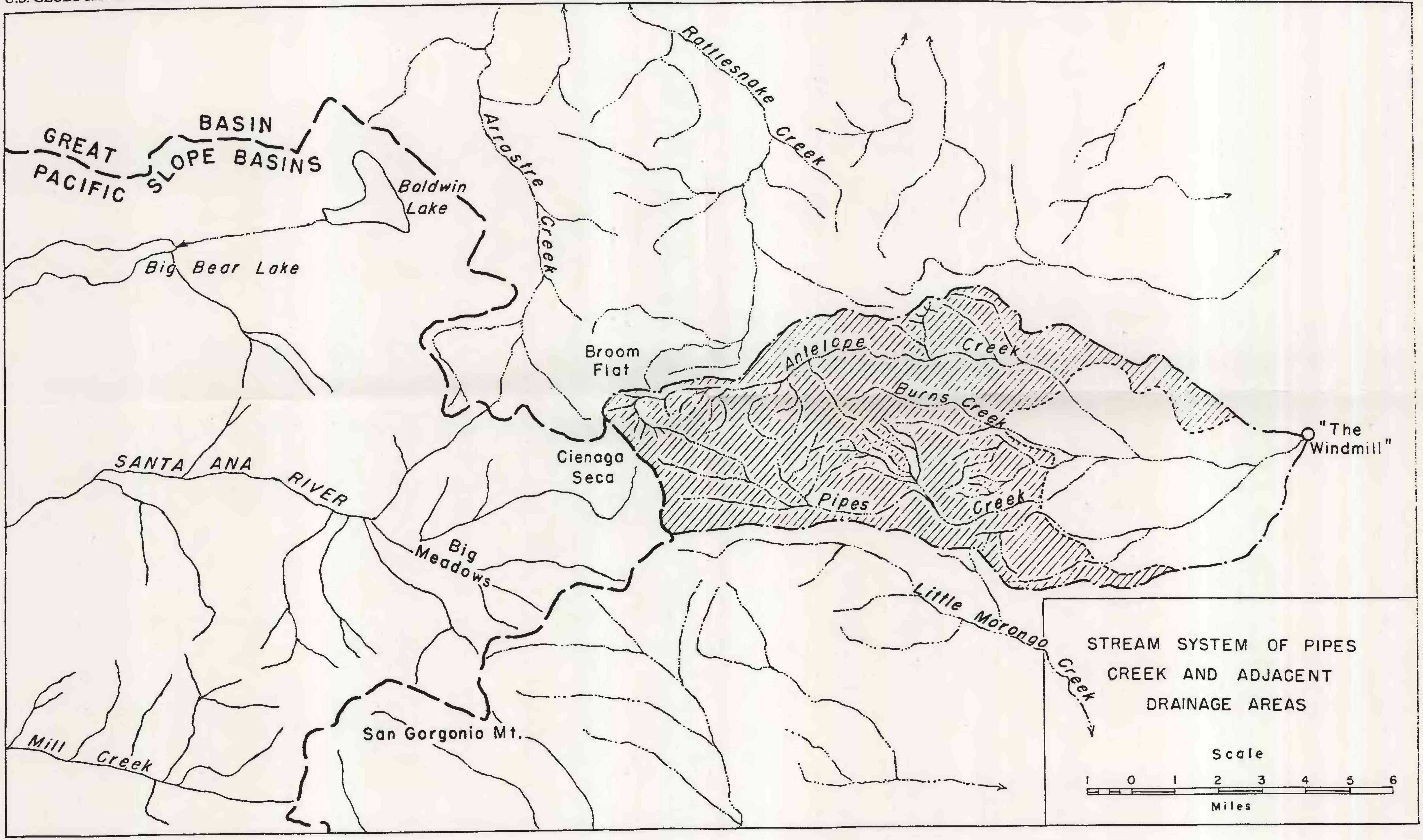
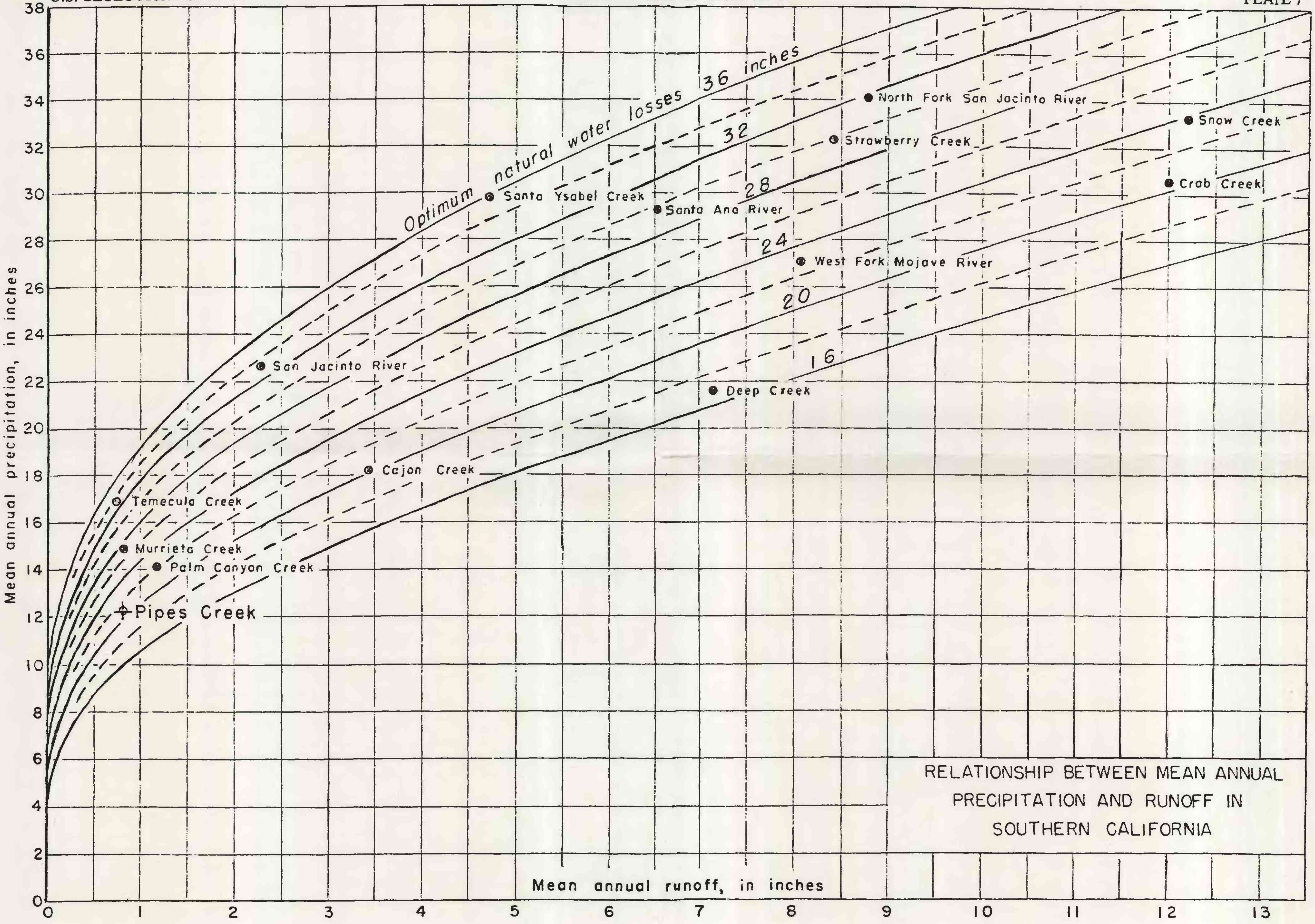
PLATE 4



PIPES CREEK DRAINAGE BASIN AND SURROUNDING LAND FORMS


Lucerne Valley
Emerson
Dry Lake
BULLION
MOUNTAINS
3"
4"
6"
8"
Baldwin
Lake
10"
Big Bear Lake
15"
Deadman
Dry Lake
4"
Mesquite
Dry Lake
SAN
BERNARDINO
MOUNTAINS
20"
25"
30"
35"
40"
45"
Pipes Creek
"The Windmill"
5"
Yucca Valley
Joshua Tree
Twentynine Palms
6"
8"
10"
Morongo Valley
LITTLE SAN BERNARDINO MOUNTAINS
DISTRIBUTION OF MEAN
ANNUAL PRECIPITATION
IN THE TWENTYNINE
PALMS BASIN
SCALE
0
3
6 MILES


GREAT BASIN
PACIFIC SLOPE BASINS
Baldwin Lake
Big Bear Lake
Arrastre Creek
Rattlesnake Creek
Broom Flat
Antelope Creek
Burns Creek
Cienaga Seca
SANTA ANA RIVER
Pipes Creek
"The Windmill"
Big Meadows
Little Morongo Creek
San Gorgonio Mt.
Mill Creek
STREAM SYSTEM OF PIPES CREEK AND ADJACENT DRAINAGE AREAS
Scale
1 0 1 2 3 4 5 6
Miles



RELATIONSHIP BETWEEN MEAN ANNUAL PRECIPITATION AND RUNOFF IN SOUTHERN CALIFORNIA

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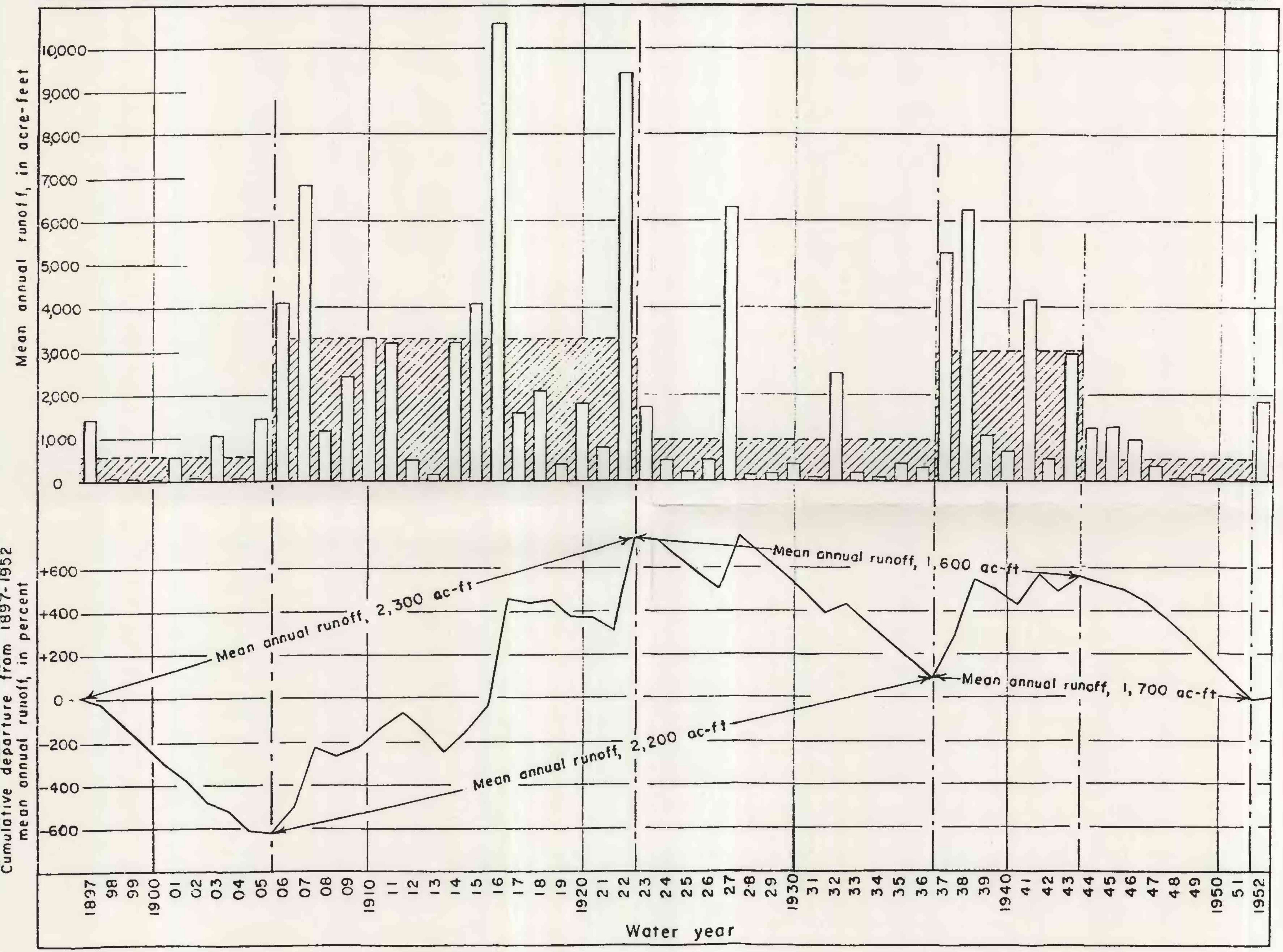
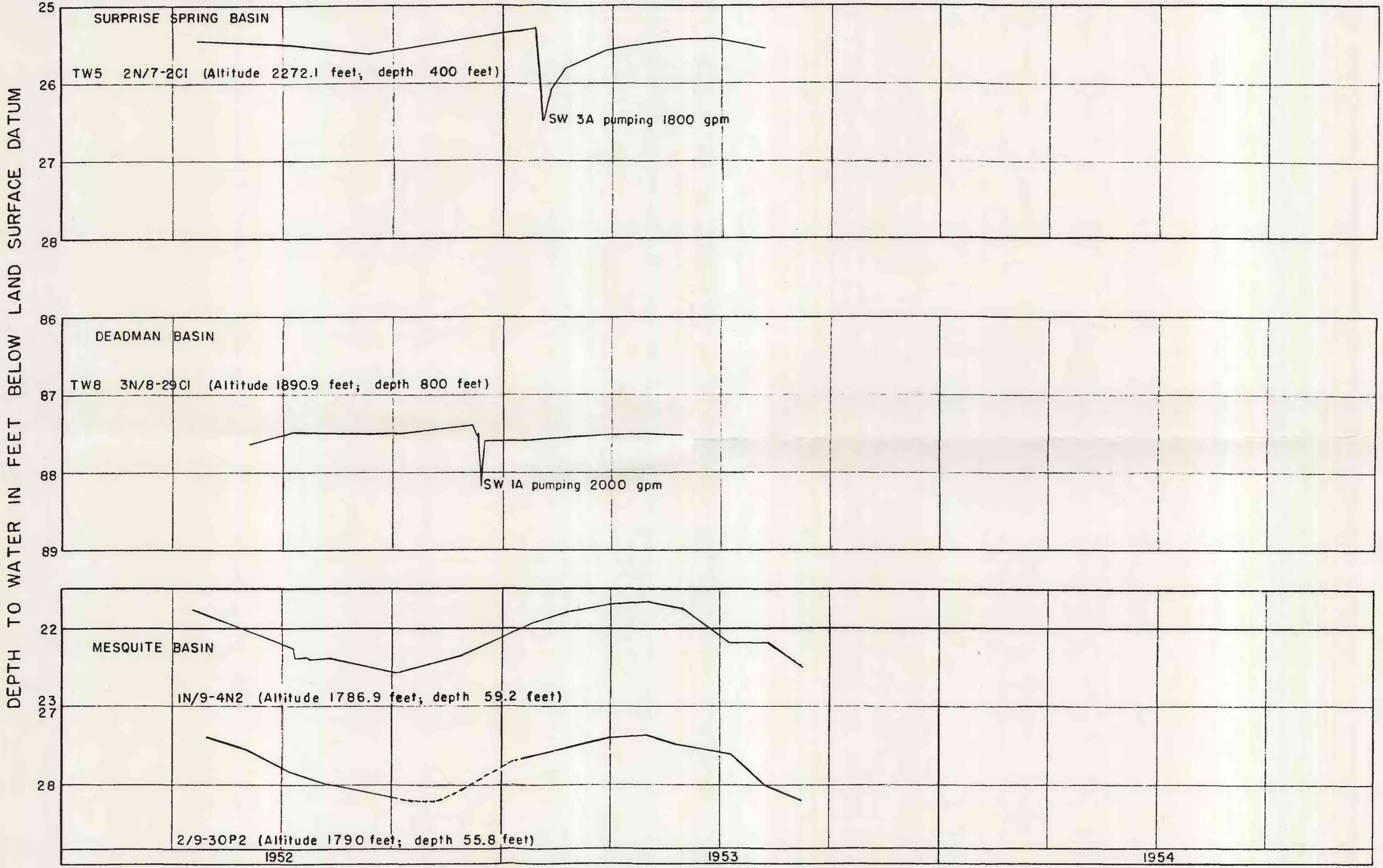


ESTIMATED MEAN ANNUAL RUNOFF OF PIPES CREEK FROM 1897 TO 1952
AND CUMULATIVE DEPARTURE FROM AVERAGE



HYDROGRAPHS FOR FOUR WELLS IN TWENTYNINE PALMS BASIN. 1952-1953

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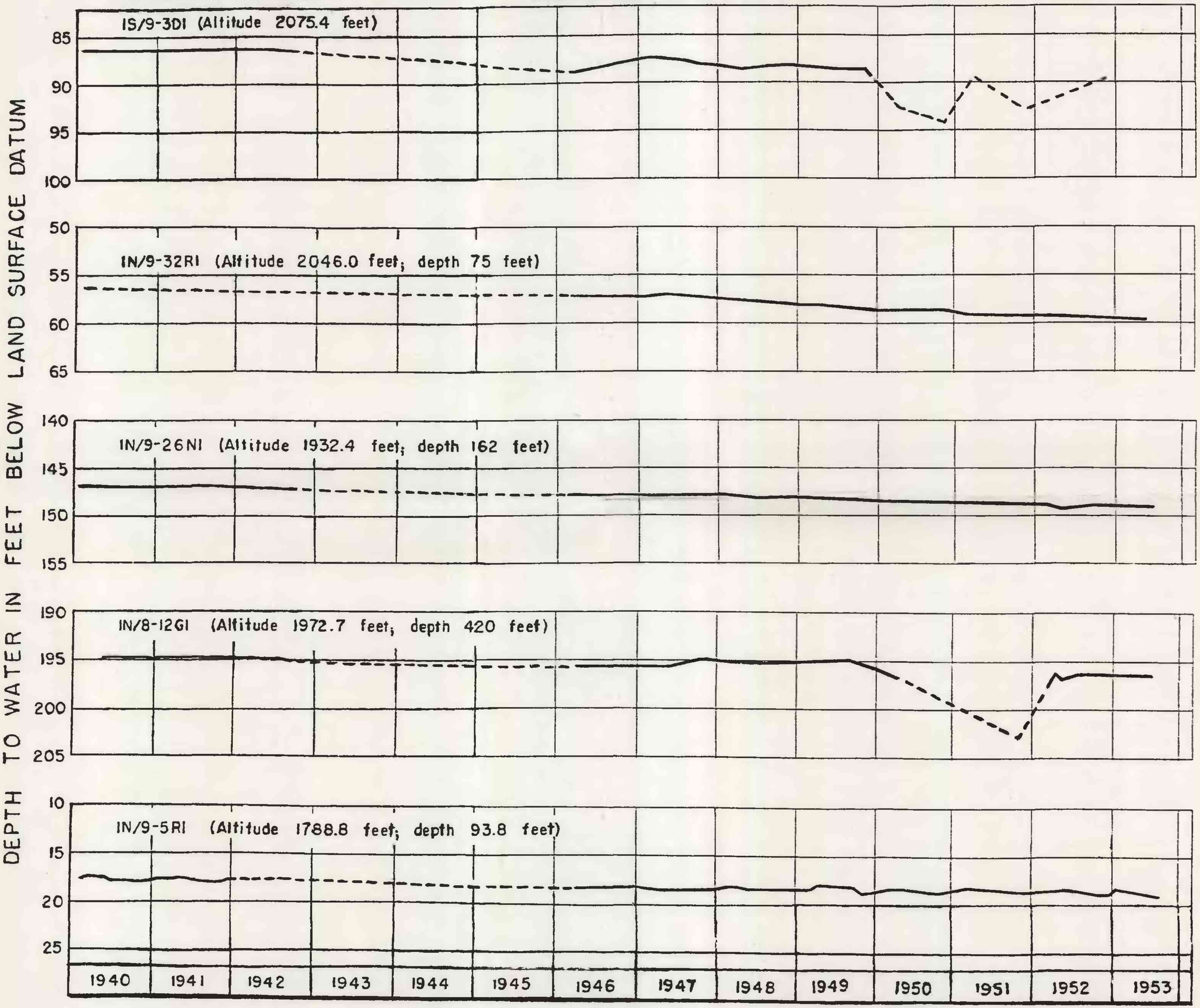

HYDROGRAPHS FOR FIVE WELLS IN MESQUITE AND ADJACENT BASINS, 1940-1953

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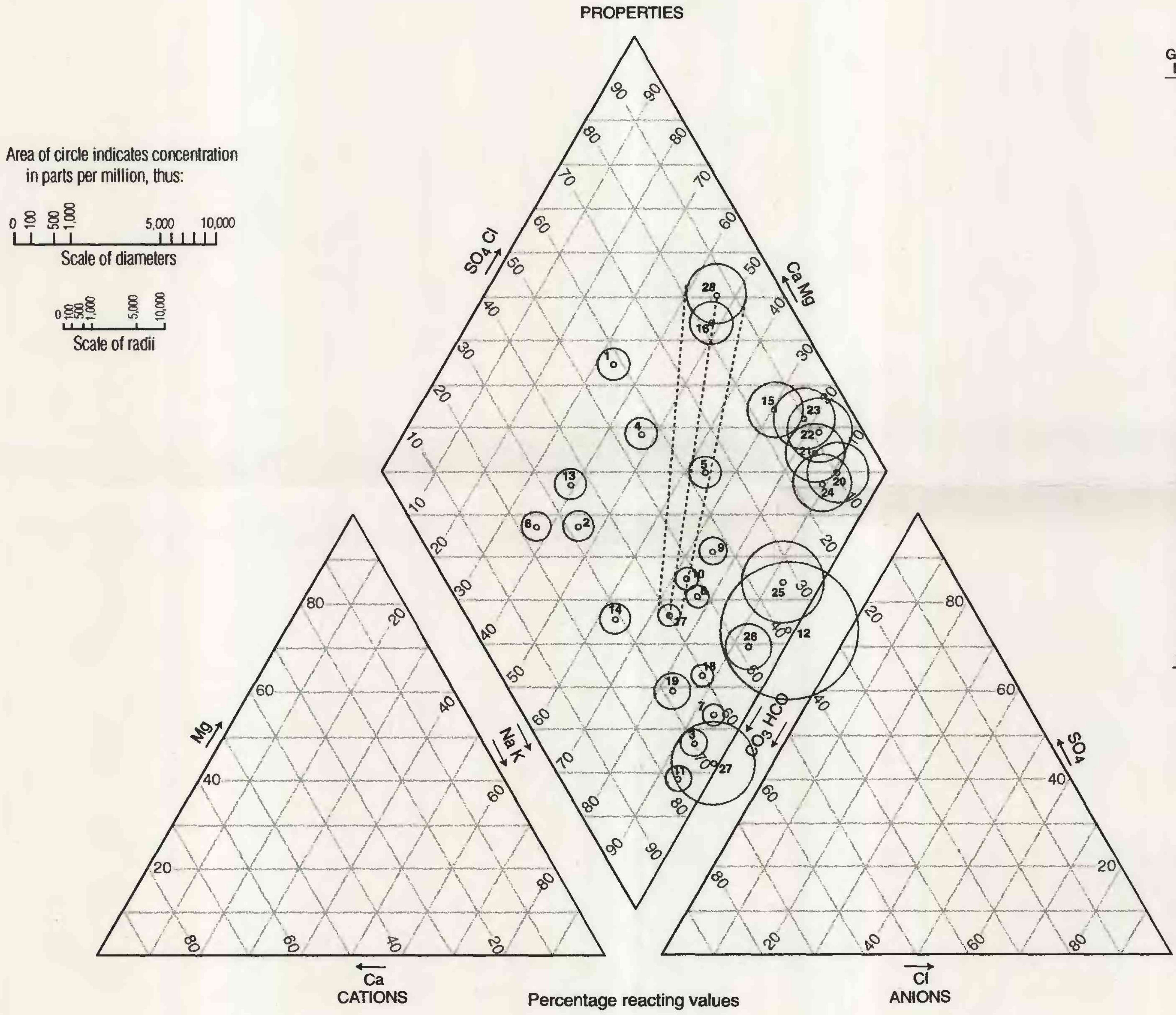

Graph No.	Geological Survey No.	Navy No.	Basin[1]
1	1N/5-3P1		P
2	22N1		do.
3	1N/6-6E1		R
4	2/5-1H1		do.
5	2/-6D1		do.
6	2/6-7Q1		do.
7	2/7-2C1	b TW 5	SP
8	3A1	a SW 3A	do.
9	3B1	a SW 2A	do.
10	4H1	b TW 12	do.
11	2/7-14K1	b TW 11	U
12	2/8-11B1		D
13	3/6-4L1		SP
14	4P1		do.
15	3/7-18D1	b TW 10	D
16	3/7-18D1	b TW 6	SP
17	31E1	b TW 9	do.
18	35P1		do.
19	c 35Q		do.
20	3/8-17L1	b TW 3	D
21	3/8-29C1	b TW 8	do.
22	29L1	a SW 1a	do.
23	33B1	b TW 2	do.
24	34D1	a SW 3	do.
25	4/6-27C1	b TW 10	U
26	4/6-27D1		do.
27	27F1		do.
28	27M1		SP

a. SW denotes Navy supply well.
b. TW denotes Navy test well
c. Seep below Surprise Spring

[1] P denotes Pipes; R, Reche; SP, Surprise Spring; D, Deadman; U, Unnamed

DIAGRAM SHOWING CHARACTER OF GROUND WATERS IN PIPES, RECHE, SURPRISE SPRING, AND DEADMAN BASINS

Prepared in cooperation with the
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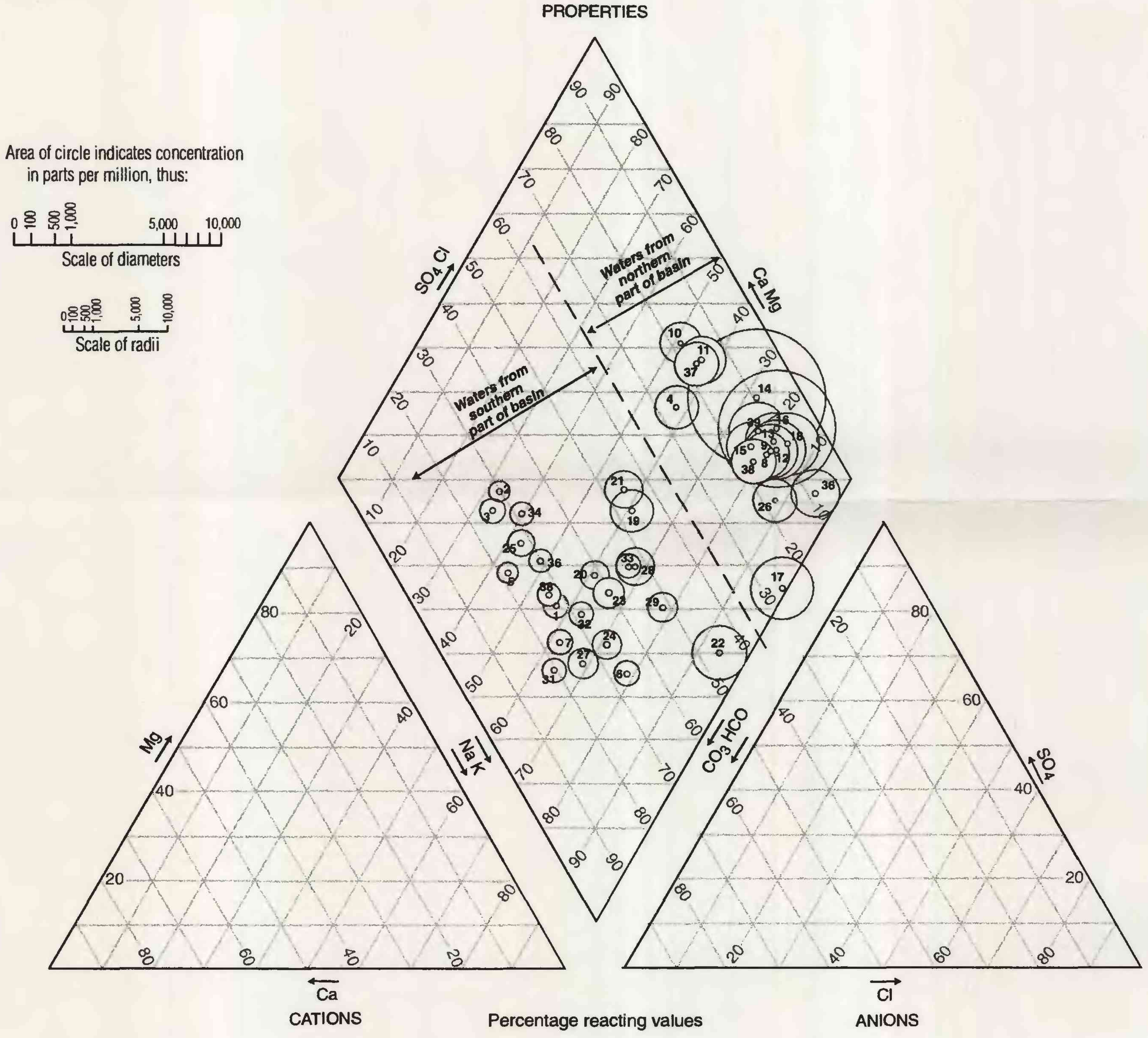

Graph No.	Geological Survey No.	Navy No.
Waters from northern part of basin:		
4	1N/8/9L1	
8	1N/9-4N1	a SW 1
9	-5G1	a SW 2
10	-5Q1	
11	-5Q2	
12	1N/9-6N1	
13	7E1	
14	9C1	
15	9M1	
16	9Q1	
17	1N/9-10D1	
18	17E1	
26	29F1	
36	2/8-24H1	b TW 1
37	26J1	
38	2/9-30B1	
39	31N1	
Waters from southern part of basin and nearby areas:		
1	1S/9-3D1	
2	5A1	
3	1N/7-35D1	
5	1N/8-25R1	
6	26G1	
7	1N/8-36A1	
19	1N/9-17J2	
20	20R1	
21	21J2	
22	22B1	
23	1N/9-22D1	
24	22E1	
25	27K1	
27	29R1	
28	30Q1	
29	1N/9-31A1	
30	31C1	
31	32F1	
32	32H1	
33	32H2	
34	32R1	
35	33F3	

a. SW denotes Navy supply well.
b. TW denotes Navy test well.

DIAGRAM SHOWING CHARACTER OF GROUND WATERS IN AND NEAR MESQUITE BASIN