GROUND WATER IN THE NORTHEAST PART OF TWENTYNINE PALMS MARINE CORPS BASE, BAGDAD AREA, CALIFORNIA

By J. H. Koehler

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 83-4053

Prepared in cooperation with the

U.S. MARINE CORPS

July 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, SECRETARY

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Federal Building, Room W-2235
2800 Cottage Way
Sacramento, Calif. 95825

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers readers who prefer the International System of Units (SI), the conversion factors for the terms used are listed below:

Multiply	By	To obtain
acre	0.4047	hm^2 (square hectometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
gal/min (gallons per minute)	0.06309	L/s (liters per second)
μmho/cm at 25°C (micromhos per centimeter at 25° Celsius)	1.000	μS/cm at 25°C (microsiemens per centimeter at 25° Celsius)

Degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by using the formula:

$$\text{Temp } ^\circ\text{C} = (\text{temp } ^\circ\text{F} - 32)/1.8.$$

Additional abbreviations used:
- mg/L, milligrams per liter
- μg/L, micrograms per liter

ALTITUDE DATUM

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 mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The hydrologic characteristics of the Bagdad area, in the northeast part of Twentynine Palms Marine Corps Base, were investigated to determine the feasibility of obtaining a supply of ground water. The area consists of mountains ranging to 4,000 feet in altitude, generally of volcanic origin, and broad alluvium-filled valleys as much as 10-miles wide. The alluvium is composed of well sorted to poorly sorted layers of boulders, gravel, sand, and clay which store and transmit ground water. The Ludlow fault trends northwesterly through the study area. Five test holes were drilled; three of these were completed with 6-inch casings and two were abandoned.

Mean annual precipitation is 3.3 inches. The precipitation generally occurs in late summer as infrequent storms of high intensity and short duration. These storms may cause sheet flow and flash flooding.

The general direction of ground-water movement in the alluvium is from the northwest toward Bristol Lake playa in the southeast. Ground-water in the intermountain valleys in the west side of the study area moves eastward.

The ground water in the eastern part of the study area contains large concentrations of dissolved solids; water from well 5N/11E-36H1 contains 252,000 milligrams per liter of dissolved solids, and well 4N/12E-7R1 contains 21,800 milligrams per liter of dissolved solids. The dissolved-solids concentration in water from the three cased test wells on the west side of Ludlow fault ranges from 669 to 961 milligrams per liter. The recommended limits for chloride and fluoride were exceeded in water from test well 4N/10E-21K1, arsenic and fluoride in water from well 5N/9E-3B1, and chloride in water from test well 6N/9E-34F1.

An estimated 640,000 acre-feet of ground water is stored in the alluvium west of Ludlow fault. This estimate was made on the basis of estimates of areal extent, saturated thickness, and specific yield.

INTRODUCTION

Purpose and Scope

The U.S. Marine Corps conducts training maneuvers in the study area. Lack of a local source of water has severely limited the utilization of the area. In the past, limited quantities of water have been transported to the area by truck or helicopter.

The purpose of this study was to determine the feasibility of obtaining a supply of ground water in the area for use when field maneuvers are being conducted.

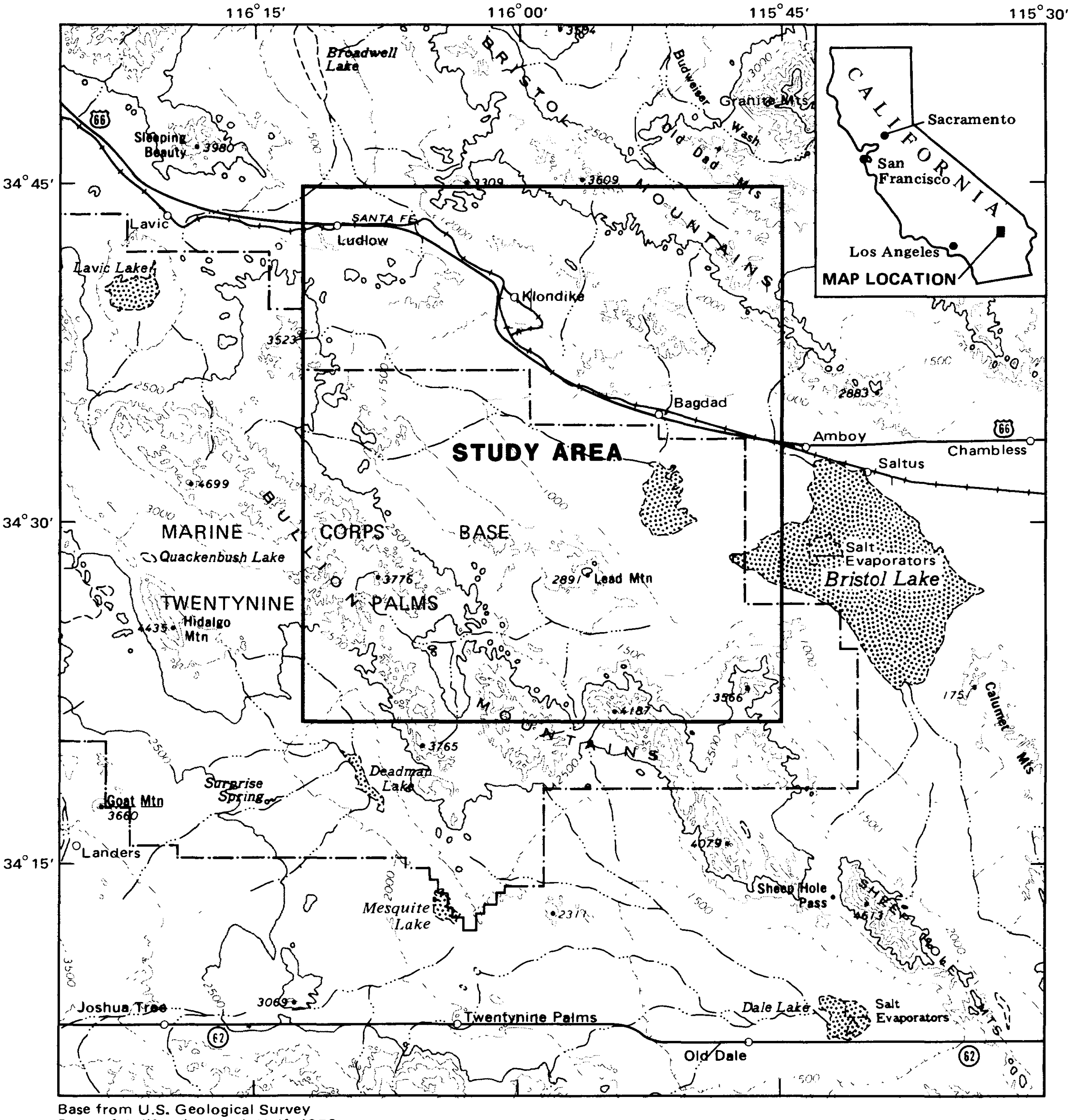
The major effort for this study was concentrated on the part within the Marine Corps base boundary. The study involved the assessment of ground-water quality, ground water in storage, and aquifer characteristics.

Location and Description of Study Area

The study area is generally referred to as the Bagdad area, an area of about 300 mi^2 near the abandoned town of Bagdad in San Bernardino County, Calif. (fig. 1). Approximately half of the Bagdad area is within the boundary of Twentynine Palms Marine Corps Base.

The study area is bounded by mountains on the north, west, and south that range to 4,000 feet in altitude, and by Bristol Lake on the east. The altitude of the valley floor ranges from about 600 feet on the east side of the study area to about 2,000 feet near the northwest corner of the study area.

Mean annual precipitation is 3.3 inches. The precipitation generally occurs in late summer as infrequent storms of high intensity and short duration. These storms cause sheet flow and flash flooding. Mean daily minimum and maximum temperatures are 35°F and 63°F in January and 72°F and 105°F in July (National Oceanic and Atmospheric Administration, 1974).



Base from U.S. Geological Survey
State of California, South Half, 1970

0 10 20 MILES

0 10 20 30 KILOMETERS

CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

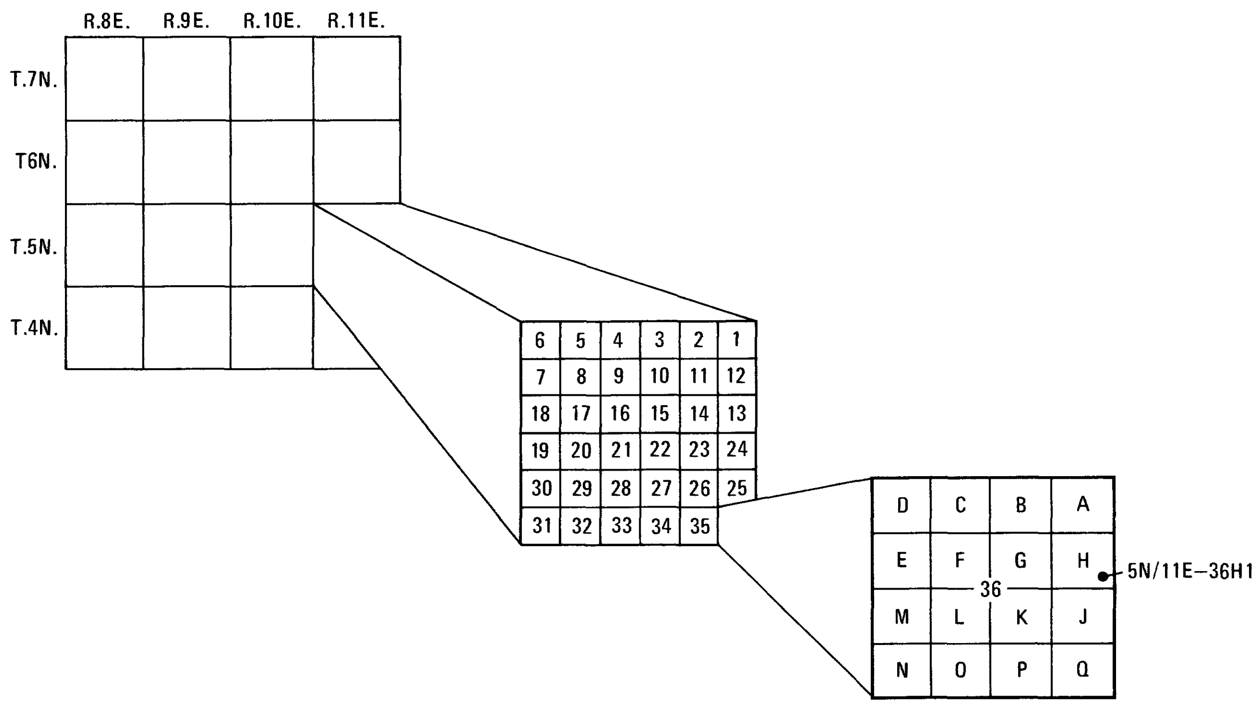
EXPLANATION

Playa

FIGURE 1. – Location of study area.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. As shown by the diagram, that part of the number preceding the slash, as in 5N/11E-36H1, indicates the township (T. 5 N.); the number following the slash indicates the range (R. 11 E.); the number following the hyphen indicates the section (sec. 36); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision. All wells mentioned in this report are in the northeast quadrant of the San Bernardino base line and meridian.



Acknowledgments

This study was a cooperative effort between the U.S. Geological Survey and the U.S. Marine Corps. Special thanks are given to the Seventh Engineering Group who graded access roads and provided valuable support during the drilling operation, and to personnel of the Public Works Office who coordinated the program. A sincere expression of gratitude is given to personnel of the U.S. Navy Construction Battalion and all who participated in the drilling of the test holes.

HYDROLOGY OF AREA

Geohydrology

The mountains in the study area are composed of flows and welded pyroclastic deposits of volcanic origin. Most of the volcanic deposits are of Tertiary age; however, some basalt flows are of Quaternary age. These deposits are locally fractured and may contain small quantities of water but are generally considered to be nonwaterbearing.

The broad valleys contain unconsolidated alluvial deposits of Quaternary age. The alluvium is composed of well sorted to poorly sorted layers of boulders, gravel, sand, and clay which store and transmit ground water. Generally, the sediments are coarser near the mountains and grade to finer sediments in the eastern part of the study area. The unconsolidated deposits, where saturated, yield water to wells. Two dry lakes (commonly called playas) in the study area represent areas where surface water has ponded and fine silt and clay have been deposited. The playas are normally dry, but occasionally in late summer contain water resulting from flash flooding caused by infrequent storms of high intensity and short duration. Playa deposits may occur at depth throughout the area.

The Ludlow fault trends northwesterly through the study area (fig. 2). It is a vertical dip-slip fault with the west side upthrown relative to the east side.

Occurrence and Movement of Ground Water

Water-level data indicate that the general flow of ground water is from the northwestern part of the area toward Bristol Lake in the southeast (fig. 2). Recharge to the ground-water system is derived from subsurface inflow from the northwest and from infiltration of precipitation and infrequent streamflow within the area. Some of the streamflow percolates into the ground, and some of it flows to Bristol Lake or the playa in T. 5 N., R. 11 E., where it is lost by evaporation. Precipitation that enters the ground in the intermountain valleys and fans moves through the alluvium toward Bristol Lake.

Faults in unconsolidated alluvium generally act as barriers which, to varying degrees, restrict the movement of ground water. The eastward movement of ground water is probably hindered, to some degree, by the Ludlow fault.

Ground water is being withdrawn by a few domestic wells in Ludlow and from well 4N/12E-7R1 near Bristol Lake, which supplies water for a mining operation. Ground water is being pumped from wells in Bristol Lake into ponds where it is evaporated for the commercial production of salt. No pumpage data are available; however, the amount of water pumped from these wells is presumed to be small and probably has very little effect on the ground-water system within the base boundaries.

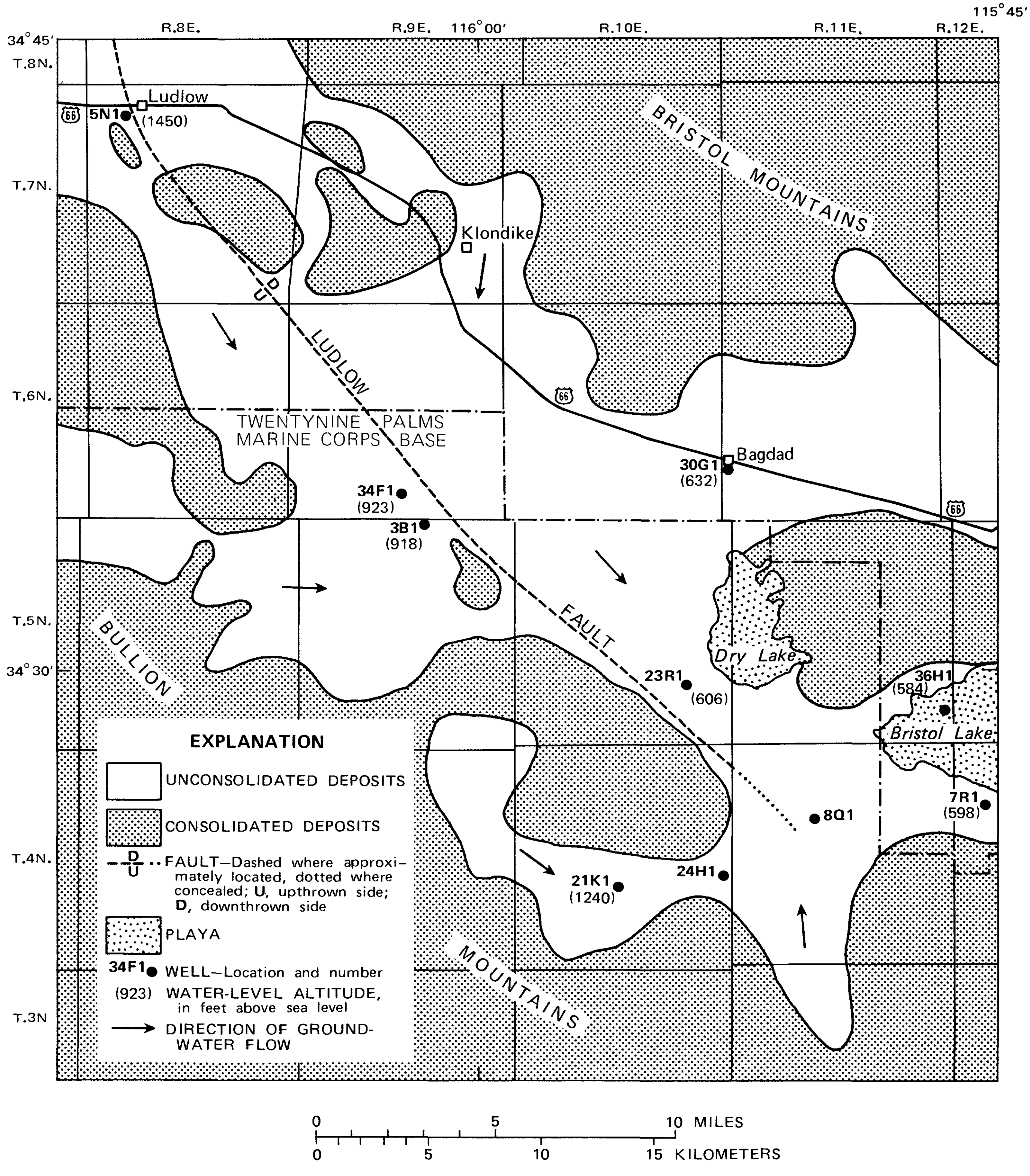


FIGURE 2. — Location of wells and geohydrologic features.

Chemical Quality of Ground Water

The quality of water in the northeastern part of the study area is probably represented by the water from well 6N/11E-30G1 (table 1), which has a dissolved-solids concentration of 4,750 mg/L. Ground water to the south contains more dissolved solids as indicated by the dissolved-solids concentration of 6,640 mg/L at well 5N/10E-23R1.

Water from well 7N/8E-5N1, at Ludlow, has a dissolved-solids concentration of 1,420 mg/L, and probably represents the quality of water entering the study area as subsurface inflow from the northwest. Ground water to the southeast is derived from local recharge in the intermountain valleys and fans. The water from test wells 5N/9E-3B1 and 6N/9E-34F1 contains dissolved solids of 669 and 907 mg/L respectively. The Ludlow fault may act as a ground-water barrier and help retain better quality water on the southwest side of the fault.

Water from test well 4N/10E-21K1 has a dissolved-solids concentration of 961 mg/L. This well is in a valley upgradient from the main basin and the water is derived from local recharge and is contained in relatively salt-free sediments.

The water from well 5N/11E-36H1, in Bristol Lake, contains 252,000 mg/L of dissolved solids (Moyle, 1967). Water from well 4N/12E-7R1, just south of Bristol Lake, contains 21,800 mg/L dissolved solids.

Potability of Water from Test Wells

The concentration of individual chemical constituents in water from the test wells is shown in table 1. Of those constituents listed, the U.S. Environmental Protection Agency has established primary drinking water regulations (1976) for fluoride, nitrate, and arsenic; and secondary regulations (1977) for sulfate, chloride, dissolved solids, and iron. The primary regulations relate to health and safety aspects, and the secondary regulations relate to the esthetic quality of water. None of the water samples from the test wells were above the recommended limits for sulfate, nitrate, and iron; all the samples were above the recommended limit of 500 mg/L for dissolved solids. Each of the water samples from wells 4N/10E-21K1 and 6N/9E-34F1 had a chloride concentration of 270 mg/L, slightly above the recommended limit of 250 mg/L. The limit for fluoride is based on the average annual maximum daily air temperature which presumably affects individual water consumption and the amount of fluoride ingested. The approval limit for fluoride is 1.4 mg/L based on temperature records for Twentynine Palms. Water from test well 6N/9E-34F1 had a fluoride concentration of 1.1 mg/L, which is below the limit, but each of the samples from test wells 4N/10E-21K1 and 5N/9E-3B1 were above the approval limit. The limit for arsenic is 50 μg/L; the water sample from test well 5N/9E-3B1 contained 98 μg/L.

TABLE 1. - *Chemical*

Characteristic or constituent	Recommended limit	Test wells		
		4N/10E-21K1	5N/9E-3B1	6N/9E-34F1
Date of collection----------		10-14-81	10-27-81	10-24-81
Depth of well, below land surface----------------ft--		230	265	500
Perforated interval, below land surface-----------ft--		130-230	220-265	200-380
Water level, below land surface----------------ft--		125	202	193
Specific conductance µmho/cm at 25°C------------	--	1,630	1,170	1,520
pH--------------------units--	--	8.1	6.4	7.8
Hardness as $CaCO_3$------mg/L--	--	120	30	150
Noncarbonate hardness as $CaCO_3$-------------mg/L--		8	0	61
Calcium----------------mg/L--	--	38	7.8	36
Magnesium--------------mg/L--	--	5.4	2.4	14
Sodium-----------------mg/L--	--	280	230	240
Percent sodium--------------	--	82	94	77
Potassium--------------mg/L--	--	9.6	2.4	6.3
Sulfate----------------mg/L--	[1]250	240	90	220
Chloride---------------mg/L--	[1]250	270	140	270
Fluoride---------------mg/L--	[2]1.4	3.4	4.6	1.1
Silica-----------------mg/L--	--	41	55	49
Dissolved solids-------mg/L--	[1]500	961	669	907
Nitrate as N-----------mg/L--	[2]10	3.3	4.6	3.4
Arsenic----------------µg/L--	[2]50	31	98	11
Boron------------------µg/L--	--	1,600	2,100	2,300
Iron-------------------µg/L--	[1]300	13	29	10
Strontium--------------µg/L--	--	980	130	600

[1]U.S. Environmental Protection Agency (1977).
[2]U.S. Environmental Protection Agency (1976).

analyses of ground water

Other wells				
4N/12E-7R1	5N/10E-23R1	5N/11E-36H1	6N/11E-30G1	7N/8E-5N1
10-1-79	10-1-79	--	5-8-53	10-3-79
320	28	50	154	600
160-310	--	--	--	--
89	25	14	128	300
28,500	11,200	--	7,920	2,170
5.8	7.8	--	7.0	7.1
5,900	970	--	1.300	220
5,900	700	--	1,300	0
2,300	330	--	480	68
33	36	--	32	16
7,800	2,000	--	1,200	440
74	83	--	66	86
150	34	--	24	6.2
490	690	--	280	190
11,000	3,300	--	2,700	160
2.1	0.2	--	2.6	2.0
7.5	75	--	--	45
21,800	6,640	252,000	4,750	1,420
0.5	0.1	--	3.5	4.2
--	--	--	--	--
3,800	8,700	--	--	2,600
420	100	--	--	140
--	--	--	--	2,700

The quality of water from the test wells may change after the wells are pumped for a considerable period of time. During development, water was pumped into each well to remove the drilling mud. After the mud was removed, each well was pumped at an estimated 30 gal/min by air lift method for several hours until the water was clear and relatively free of sediment. The water samples for chemical analysis were collected at the end of the development process. Periodic sampling would help improve the knowledge of the actual quality of water in the aquifer.

Ground Water in Storage

An exact determination of ground water in storage cannot be made because of lack of data. However, a rough estimate can be made from estimates of basin size, saturated thickness, and specific yield.

Water in storage on the east side of the Ludlow fault is assumed to be too mineralized for direct use as a drinking water supply; therefore, only the water in storage in the alluvium on the west side of the fault is considered. The total area of the basin west of Ludlow fault is about 100 mi^2.

The total saturated thickness is not known because none of the test wells reached bedrock. However, well 6N/9E-34F1, near the center of the basin, was drilled to a depth of 500 feet. A static water level of about 200 feet below land surface indicates a saturated thickness of at least 300 feet. Well 4N/10E-21K1 was drilled to a depth of 230 feet and had a static water level of about 125 feet below land surface, indicating a saturated thickness of at least 105 feet. The saturated thickness near the periphery of the basin is presumably less. Therefore, for purposes of estimation, the average saturated thickness for the area considered is taken to be 100 feet.

Specific yield is defined as the percentage, by volume, of water that can be drained by gravity from pore space in the sediment. The estimate of specific yield, using the method described by Davis, Green, Olmsted, and Brown (1959), is about 10 percent.

Using these estimated values, about 640,000 acre-feet of ground water is in storage in the upper 100 feet of aquifer west of Ludlow fault. If all three of the test wells were pumped at 75 gal/min 8 hours per day for 30 days a year, the total withdrawal would be about 10 acre-feet per year or only 0.0016 percent of the total storage. Therefore, the water in storage, plus a small amount of annual recharge, should be sufficient to provide water to these wells for many years.

DESCRIPTION OF TEST WELLS

Test well sites were selected on the basis of hydrologic characteristics of the area and logistics of building access roads to the sites. The terrain is very rugged and building access roads was time consuming; therefore, some compromises had to be made in selecting the sites. Six drilling sites were selected after the initial investigation phase of the study was completed. Test holes were drilled at five of these sites.

The test holes were drilled during a 3-week period in October 1981 by the U.S. Navy Construction Battalion. All the test holes were drilled by the hydraulic rotary method with a drilling rig rated at 1,000 feet depth capacity. Drill cutting samples were collected at 5-foot intervals. Lithologic logs of the test holes are shown in table 2. Sand, gravel, and boulders were the predominate lithology at each of the test-well sites. Geophysical logs (fig. 3) consisting of spontaneous potential, single-point resistivity, and 6-foot lateral (measures resistivity between two electrodes spaced 6 feet apart) were made at four of the sites.

Six-inch casing was installed in three of the holes; the perforated sections have 1/8-inch-wide vertical slots with a total open area of 4 square inches per linear foot. The wells were gravel packed; the upper 25 feet of the well annulus was filled with concrete as a sanitary seal. The wells were developed by injecting clear water into the casing; when most of the drilling mud had been washed out, the well was pumped at an estimated 30 gal/min by the air-lift method until the discharge water was relatively clear and free of sediment (about 4 to 6 hours). Water samples were collected for chemical analysis just before pumping was stopped. Pumping tests were not done, but estimates from drill cuttings indicate wells will yield 100 gal/min.

The following is a brief description of the procedure used at each test well:

The site for test well 4N/10E24H1 was selected to intercept ground water moving eastward from the drainage system to the west. At a depth of 172 feet the penetration rate became slow because of boulders, and drilling was stopped. A geophysical log was not run and the test well was not cased because it was thought that it was not deep enough to have reached the water table.

The site selected for test well 4N/10E-21K1 was expected to encounter fewer boulders than at the site of test well 24H1. Drilling was relatively easy to a depth of 230 feet where a boulder was encountered and penetration stopped. The geophysical log indicated water at a depth of about 130 feet; the well was cased to 230 feet, with perforations from 130 to 230 feet. After the well was completed and developed, the static water level was 125 feet below land surface.

TABLE 2. - *Lithologic logs of test wells*

Lithology	Depth in feet: From	To
Test well 4N/10E-21K1. Six-inch casing to 230 ft. Perforated 130-230 ft.		
Sand and gravel	0	80
Sand and gravel, scattered cobbles	80	90
Sand, gravel, and cobbles	90	115
Sand and gravel	115	165
Sand, gravel, and cobbles	165	175
Sand, gravel, and boulders	175	230
Test well 4N/10E-24H1. No casing, well was abandoned.		
Sand and gravel	0	5
Gravel, scattered cobbles	5	15
Sand, gravel, and cobbles	15	65
Gravel and boulders	65	85
Sand and gravel, scattered cobbles	85	115
Gravel and cobbles	115	135
Gravel and boulders	135	172
Test well 4N/11E-8Q1. No casing, well was abandoned.		
Sand and gravel	0	70
Sand	70	90
Sand and gravel	90	115
Sand and gravel, scattered cobbles	115	160
Boulders	160	170
Sand and gravel, scattered cobbles	170	200
Boulders, sand, and gravel	200	300
Test well 5N/9E-3B1. Six-inch casing to 265 ft. Perforated 200-265 ft.		
Sand and gravel	0	60
Sand and gravel, scattered cobbles	60	160
Sand	160	170
Sand and gravel	170	265
Test well 6N/9E-34F1. Six-inch casing to 380 ft. Perforated 200-380 ft.		
Sand and gravel	0	75
Sand and gravel, some cobbles	75	125
Sand	125	135
Sand and gravel	135	205
Sand and gravel, scattered cobbles	205	305
Sand and gravel, scattered boulders	305	400
Sand and gravel	400	435
Sand and gravel, scattered boulders	435	500

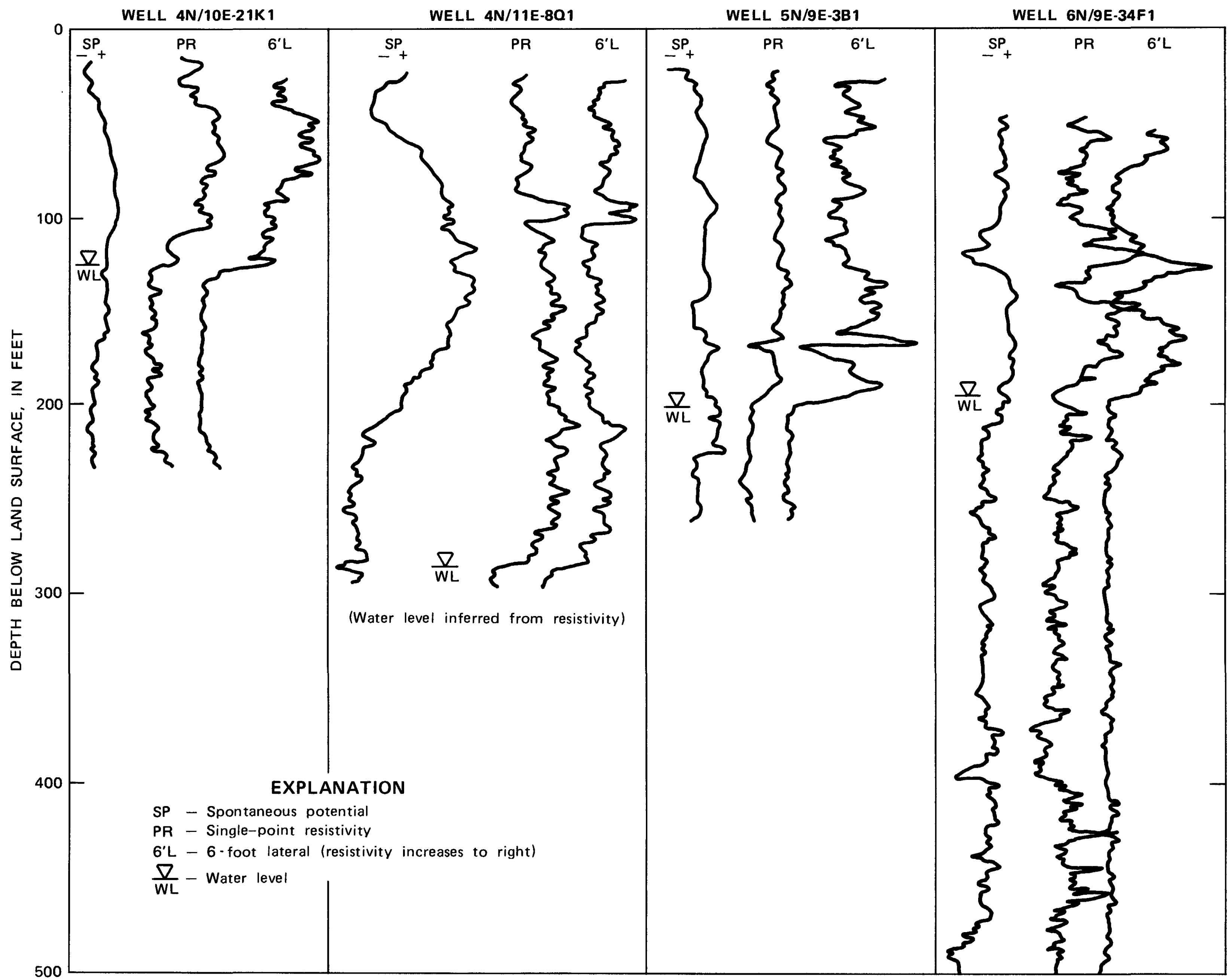


FIGURE 3. – Geophysical logs of test wells.

The existence and location of the Ludlow fault is not known in the southeast part of the study area. The site for well 4N/11E-8Q1 was selected to help determine the existence and effectiveness of the fault as a ground-water barrier. Drilling was easy to a depth of about 200 feet where penetration rate slowed because of boulders. At a depth of 295 feet drilling was stopped and a geophysical log run in the hole. The geophysical log indicated that the water table was at a depth of about 285 feet. An attempt was made to drill at least another 50 feet so there would be enough saturated material to warrant installing casing in the hole. However, penetration rate was so slow that at a depth of 300 feet the hole was abandoned.

A hole was drilled to a depth of 500 feet for well 6N/9E-34F1 and a geophysical log was run. The geophysical log indicated that the water table was at a depth of about 200 feet. The hole was cased to 380 feet, with perforations from 200 feet to 380 feet. After the well was completed and developed, the static water level was 193 feet below land surface.

The location for test well 5N/9E-3B1 was selected to intercept the water that is being recharged locally to the west. The hole was drilled to a depth of 265 feet. The geophysical log indicated water at a depth of about 200 feet below land surface. The well was cased to 265 feet, with perforations from 200 to 265 feet. After the well was completed and developed, the static water level was 202 feet below land surface.

SUMMARY AND CONCLUSIONS

The general direction of ground-water movement is from the northwest part of the study area toward the southeast. Recharge that occurs in the intermountain valleys on the west side of the study area moves eastward.

The ground water in the vicinity of Bristol Lake has a dissolved-solids concentration of as much as 252,000 mg/L. The dissolved-solids concentration in water from the test wells on the west side of the basin ranges from 669 to 961 mg/L. The Ludlow fault may serve to separate the two types of water.

Five test holes were drilled as part of this study; three were cased and completed, two were abandoned. Several of the chemical constituents in the water from the completed test wells were above the recommended limits for drinking water, but water of similar quality is used for drinking water supplies in other places in the Nation.

Pumping tests were not made on the test wells, but, the water level recovered to near the levels indicated on the geophysical logs shortly after development pumping ceased. Well yields are estimated at about 100 gal/min. An estimated 640,000 acre-feet of ground water is in storage west of the Ludlow fault. The water in storage, plus a small amount of annual recharge, should be sufficient to provide water to the three wells for many years.

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