GEOHYDROLOGIC RECONNAISSANCE OF LAKE MEAD NATIONAL RECREATION AREA— VIRGIN RIVER, NEVADA, TO GRAND WASH CLIFFS, ARIZONA

By J.T. BALES and R.L. LANEY

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[Plate is in pocket]

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Multiply	*By*	*To obtain*
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second
degree Fahrenheit (°F)	°C=(°F-32)/1.8	degree Celsius

In this report, water temperatures are given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F=1.8(°C)+32.$$

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

GEOHYDROLOGIC RECONNAISSANCE OF LAKE MEAD NATIONAL RECREATION AREA—VIRGIN RIVER, NEVADA, TO GRAND WASH CLIFFS, ARIZONA

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ABSTRACT

This study is one of a series of geohydrologic reconnaissance studies being made in the Lake Mead National Recreation Area. The study area includes about 250 square miles north of Lake Mead from the Virgin River (Overton Arm), Nevada, east to Grand Wash Cliffs, Arizona. Except for the Colorado and Virgin Rivers, streamflow in the area is meager and extremely variable. Ground water can be obtained from two sources: (1) rocks and deposits into which water from Lake Mead has infiltrated and (2) deposits in basins that drain to the lake. The quantity of water from Lake Mead that has saturated adjacent rocks and deposits probably is greater than the quantity of ground water in the rocks and deposits in the basins that drain to the lake. Rocks saturated by water from the lake probably extend less than 0.5 mile inland from the lake shore.

The most favorable areas for obtaining ground water are those underlain by the coarse-grained unit of the older alluvium, the younger alluvium, and the Chemehuevi Formation. The least favorable areas are those underlain by the mudstone facies of the Muddy Creek Formation and a fine-grained unit of the older alluvium. Five areas identified as having potential for ground-water development are Grand Wash and Tassi Ranch area, Arizona; Devils Cove in the Hells Kitchen area, Nevada; Scanlon Hill and Gregg Wash area, Nevada; Snap Canyon and Pierce Canyon area, Arizona; and Twin Springs Wash and Quail Spring Wash area, Nevada.

INTRODUCTION

The Lake Mead National Recreation Area (LMNRA) includes Lake Mead and Lake Mohave. Lake Mead extends from Hoover Dam to about 105 miles up the old course of the Colorado River, and Lake Mohave extends 67 miles from Davis Dam to the base of Hoover Dam (fig. 1). The two lakes have about 700 mi of shoreline, which consists of wide gravel beaches, shadowed coves, and steep canyon walls. These physical settings provide opportunities for boating, fishing, swimming, scuba diving, water skiing, and beach camping. In addition, the surrounding desert canyons and mountains provide opportunities for hiking, climbing, and photography. Use of the area has increased steadily over the years, and in 1990 more than 8.8 million people visited the recreation area. As the number of visitors increases, so does the demand for potable water.

A series of geohydrologic reconnaissance studies of the Lake Mead National Recreation Area is being made by the U.S. Geological Survey

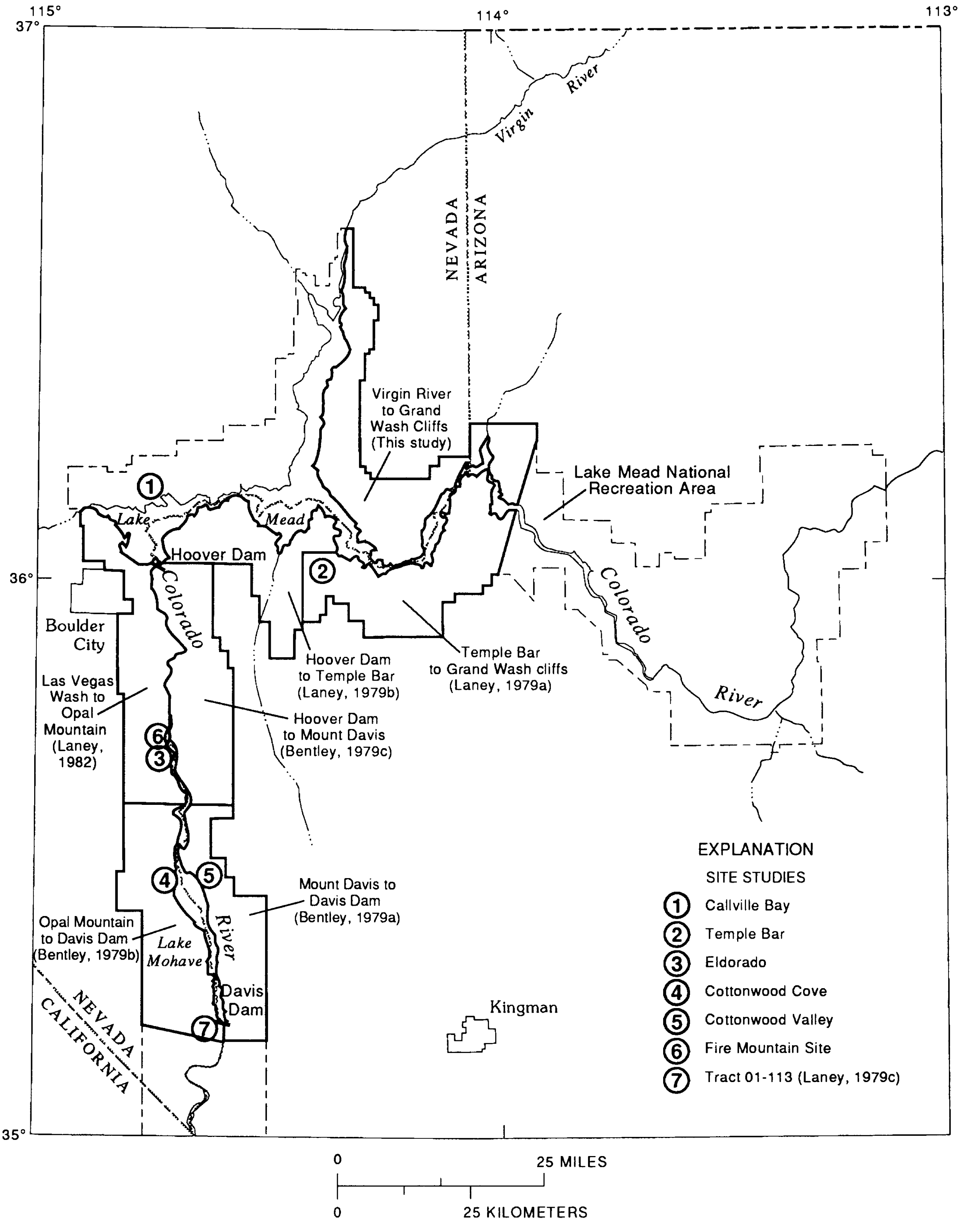


Figure 1.—Area of study and areas of previous geohydrologic reconnaissance studies and site studies in the Lake Mead National Recreation Area, Arizona and Nevada.

in cooperation with the National Park Service. The studies were undertaken to evaluate the water resources in the recreation area and identify areas having potential for development of water supplies that would be adequate for marinas and campgrounds. The investigation included (1) reconnaissance geologic mapping at a scale of 1:62,500, (2) an inventory of wells and springs, (3) determination of the chemical quality of ground water, and (4) determination of the geologic controls on the occurrence and movement of ground water. This report describes the seventh of eight study areas (fig. 1).

The area of this report includes about 250 mi^2 north of Lake Mead from Virgin River (Overton Arm), Nevada, to Grand Wash Cliffs, Arizona (pl. 1). Altitudes range from about 1,200 ft above sea level at the lake level to more than 5,000 ft at Bonelli Peak and along the crest of Grand Wash Cliffs. In the eastern part of the study area, most of the terrain slopes steeply toward Lake Mead. In the western part, near Overton Arm, most of the land surface is underlain by alluvial material that forms long gently sloping surfaces. The climate is arid; summer temperatures range from about 80° to 115°F, and winter temperatures range from about 35° to 55°F (Arizona State University, 1975). The average annual precipitation ranges from 4 in. along the east shore of Overton Arm to 8 in. along the western front of Grand Wash Cliffs (University of Arizona, 1965a, b). Vegetation in the study area includes creosote bush, white bursage, bladdersage, blackbrush, goldenhead, Mohave yucca, catclaw, and mesquite (Lowe and Brown, 1973).

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

The study area is underlain by metamorphic, plutonic, volcanic, and sedimentary rocks. A summary of the rock units and their hydrogeologic characteristics is shown in table 1. The metamorphic rocks include quartz-mica schist and banded gneiss, and the plutonic rocks are porphyritic granite. Most exposures of metamorphic and plutonic rocks are in the highlands between Overton Arm and Gregg Basin (pl. 1). The volcanic rocks consist of the Fortification Basalt Member of the Muddy Creek Formation and a younger unnamed basalt. The Fortification Basalt Member is present near Temple Mesa and locally along the southern part of Overton Arm. The younger basalt is in the Grand Wash Bay area.

Sedimentary rocks are at the surface throughout the study area and include, from oldest to youngest, undifferentiated sedimentary rocks of Paleozoic and Mesozoic age, Horse Spring Formation, Muddy Creek Formation, older alluvium, Chemehuevi Formation, and younger alluvium. Many of the undifferentiated sedimentary rocks are at higher altitudes outside the LMNRA but are mapped in this report because, as a group, they influence the quality of ground water reaching the study area. The sedimentary rocks consist of sandstone, shale, limestone, dolomite, and quartzite. The Horse Spring Formation of Tertiary age consists of brownish-red sandstone. The Muddy Creek Formation of Tertiary age consists of a conglomerate facies, mudstone facies, limestone facies, and the Fortification Basalt Member and is a major unit that unconformably

Table 1.--Summary of rock units and their hydrogeologic characteristics

Rock unit	Rock type	Estimated potential yield to wells where saturated	Remarks
Younger alluvium	Sand, gravel, silt, clay, and boulders	A few tens to a few hundred gallons per minute	Present along bottoms of present-day washes. Saturated only near Lake Mead.
Chemehuevi Formation	Fine sand with clay lenses	A few tens to a few hundred gallons per minute	Present as remnants on truncated ridges along tributary channels close to Lake Mead. Saturated only near Lake Mead.
Older alluvium			
Coarse-grained unit	Silty, sandy gravel	Several hundred gallons per minute near Lake Mead; few tens of gallons per minute elsewhere	Present extensively along the east side of Overton Arm and in the Grand Wash area. Is the major water-producing unit in the area.
Fine-grained unit	Silty clay	Less than 10 gallons per minute	Present extensively along the east side of Overton Arm. Contains gypsum in places; may cause ground water to be unacceptable for drinking.
Younger basalt	Basalt flows	A few tens of gallons per minute where fractured	Present for about 6 miles on both sides of Grand Wash. Locally interbedded with the coarse-grained unit of the older alluvium.
Muddy Creek Formation			
Conglomerate facies	Silty, sandy gravel	As much as 10 gallons per minute near Lake Mead	Present from Overton Arm to Virgin Canyon and from Grand Wash to the Grand Wash Cliffs. Moderately to strongly cemented with calcium carbonate.
Mudstone facies	Clayey silt and siltstone	Less than 1 gallon per minute	Present in the Grand Wash area. Is a confining unit. Locally contains gypsum.
Limestone facies	Marly limestone	Drained of water	Caps hills or mesas near west end of Virgin Canyon.
Fortification Basalt Member	Basalt flows	Near Lake Mead a few tens of gallons per minute depending on degree of fracturing	Present locally on east side of Overton Arm near and on Gull Island and at Temple Mesa near Virgin Canyon.
Horse Spring Formation	Sandstone	Less than 1 gallon per minute	Present in a small area on the east side of Overton Arm opposite Calico Bay.
Paleozoic and Mesozoic rocks, undifferentiated	Limestone, shale, sandstone, and siltstone	Locally as much as 5 gallons per minute	Present north of Iceberg Canyon and the north end of Overton Arm, east of the Lake Mead National Recreation Area boundary.
Metamorphic and plutonic rocks	Schist, gneiss, and granite	Less than 5 gallons per minute	Present in the southern Virgin Mountains between Overton Arm and Gregg Basin.

overlies all older units in the study area. The conglomerate facies is exposed from the mouth of Virgin Canyon northwestward to Twin Springs Wash and between Grand Wash Bay and Grand Wash Cliffs northeastward to Pigeon Wash (pl. 1). The mudstone facies is in the Grand Wash Bay area and in small, widely scattered exposures near Lake Mead on Overton Arm. The conglomerate facies and mudstone facies of the Muddy Creek Formation and the older alluvium are overlain by a veneer of caliche-cemented sand and gravel as much as 10 ft thick. The limestone facies is exposed near Temple Mesa and the Grand Wash Cliffs. The older alluvium, which consists of a coarse-grained facies and a fine-grained facies, unconformably overlies the Muddy Creek Formation and older units. The coarse-grained facies of the older alluvium is the most widespread unit in the mapped area and is present along Overton Arm, Nevada, and in the Grand Wash area, Arizona. The fine-grained facies is present along the northern part of Overton Arm and in small exposures near Delmar Butte. The Chemehuevi Formation, which is exposed at scattered locations near Lake Mead in the eastern part of the area, generally consists of fine-grained, crossbedded sand that contains some disseminated silt and thin clay lenses and unconformably overlies older rock units. The younger alluvium, which consists of sand and gravel and some boulders and is present along the bottom of most present-day washes and along the Virgin River, is the youngest deposit found in the area.

Metamorphic and Plutonic Rocks

Metamorphic and plutonic rocks of Precambrian age underlie the southern part of the Virgin Mountains east of the Virgin River in the northern part of the area and between Overton Arm and Gregg Basin in the southern part (pl. 1). Metamorphic rocks consist of quartz-mica schist and strongly contorted, banded gneiss (Longwell and others, 1965). A large body of mega-banded gneiss is present in the metamorphic highlands north of Scanlon Hill along the west side of Gregg Basin, and metamorphic rocks are exposed east of Mormon Mesa (pl. 1). A mylonitized zone more than 400 ft wide is present within the western limit of the metamorphic rocks that crop out north of Virgin Canyon about 1 mi east of Burro Bay.

Plutonic rocks crop out in three areas—along Gregg Wash northwest of Scanlon Hill, in the Cottonwood Canyon area about 3 mi northwest of Devils Cove, and at Virgin Reef at the east end of Virgin Canyon (pl. 1). Scanlon Hill is composed of granitic rocks, which have a porphyritic texture and range from pink to pinkish gray in color. These rocks resemble the Precambrian Gold Butte Granite (Longwell, 1936). The plutonic rocks northwest of Devils Cove also are similar to the Gold Butte Granite. Lucchitta (1966, p. 13) reported ages for the granite as 1.05 to 1.09 billion years and for a pegmatite intruded into a gneiss as 1.63 to 1.70 billion years. Where fractured, the metamorphic and plutonic rocks would yield less than 5 gal/min of water to wells.

The steep cliffs and the structure and foliation of the metamorphic rocks make the area north of Virgin Canyon susceptible to rock slides. Two large slides have occurred in the area in the recent geologic past, and prediction of future rock slides is uncertain.

Paleozoic and Mesozoic Sedimentary Rocks, Undifferentiated

Undifferentiated sedimentary rocks that range in age from Paleozoic to Mesozoic are exposed north of Iceberg Canyon, east of Grand Wash Bay, and east of Overton Arm near the LMNRA boundary (pl. 1). These rocks include the Tapeats and Aztec Sandstones; Bright Angel Shale; Muav, Muddy Peak, Rogers Spring, and Callville Limestones; and Kaibab, Toroweap, Coconino, Chinle, and Moenkopi Formations (Longwell and others, 1965). The exposures in Lime Ridge east of Overton Arm are broken by the complex Lake Mead Fault System (Bohannon, 1983). Almost all the beds are steeply dipping and deformed. The Paleozoic and Mesozoic rocks underlie several higher drainage basins that contribute ephemeral surface flow and ground-water underflow to LMNRA. Some rocks contain soluble minerals, such as gypsum, that can make water unacceptable for drinking. Locally, springs yield less than 5 gal/min of water.

Horse Spring Formation

The Horse Spring Formation of Tertiary age is exposed on the east side of Overton Arm opposite Calico Bay (pl. 1). Most of these exposures were mapped as the Thumb Member of the Horse Spring Formation by Bohannon (1984, fig. 8, p. 24) and consist of large, broken blocks of sandstone as much as 100 ft on the sides and of unknown thickness. The blocks generally dip eastward at about 55°. Layers of detritus are 1 to 4 in. thick and range in clast size from granule to silt. The rocks are brownish red, well stratified, and strongly indurated with a hematite(?) cement. Gypsum (selenite crystals) is present in places and can make water unacceptable for drinking. The unit is at or near lake level on the east side of Overton Arm. Because the exposure is small and the unit is strongly indurated, probably only minor quantities of water could be obtained from wells drilled into this formation.

Muddy Creek Formation

Rocks of the Muddy Creek Formation in the Grand Wash area were termed "rocks of the Grand Wash trough" by Bohannon (1984). Bohannon recommended that the name Muddy Creek Formation be restricted to those rocks generally contiguous with rocks that are north of Glendale, Nevada. Also, the limestone of the Muddy Creek Formation was reclassified by Bohannon (1984) as the Hualapai Limestone. Acknowledgment is made of these changes, but to retain continuity between this report and previously published reports in this series, the older terminology for the Muddy Creek Formation has been used. In this report, the Muddy Creek Formation is divided into the conglomerate facies, the mudstone facies, the limestone facies, and the Fortification Basalt Member.

Conglomerate Facies

The conglomerate facies of the Muddy Creek Formation consists of gray to grayish-brown or reddish-brown silty, sandy sedimentary deposits, which contain clasts that range in size from gravel to boulders. The unit is thinly to thickly bedded and moderately to strongly cemented by calcium carbonate. Clasts are angular to subangular metamorphic, igneous, and sedimentary detritus derived from nearby highland areas. The clast-to-matrix ratio generally is greater than 1 in the area from Overton Arm southeastward to Virgin Canyon (pl. 1); however, the ratio generally is less than 1 from Grand Wash to the Grand Wash Cliffs. The conglomerate is only moderately deformed, and the beds generally dip less than 20°. No wells are known to have been drilled in this facies within the study area; however, the unit could yield as much as 10 gal/min to wells where saturated near Lake Mead.

Mudstone Facies

The mudstone facies of the Muddy Creek Formation consists of weakly to moderately cemented clayey silt (or siltstone) and minor amounts of generally subangular, fine sand. Calcium carbonate cement is not visible but is disseminated throughout the facies. The mudstone varies in color from reddish tan or reddish brown to pinkish brown, and in places, tan. The unit ranges from massive to stratified with faint thin laminations. Slumping of steeply weathered slopes, however, may mask stratification. Locally, the facies contains gypsum, either as loose, small crystals of selenite or as large laths of selenite as much as 8 ft long, that fills slip planes and fractures. Gypsum also may be disseminated throughout the unit. In the northeastern part of Overton Arm, zones of high clay content within the unit have a gray mottling. Throughout the study area, the mudstone facies is a confining unit.

Along the west side of Grand Wash Bay, the mudstone facies may overlie the conglomerate facies (pl. 1). Throughout the Grand Wash Bay-Grand Wash area, the mudstone underlies the older alluvium and the younger basalt flows. Near Delmar Butte, the mudstone overlies the conglomerate facies and is overlain by the limestone facies (pl. 1). Along Overton Arm opposite Bighorn Island, the Fortification Basalt overlies the mudstone facies, but other exposures of the facies around Overton Arm are capped by the coarse-grained unit of older alluvium. Exposures were not found where the mudstone was overlain by the conglomerate facies. In the Grand Wash area, springs discharge above or near the contact of the facies and the more permeable overlying older alluvium. The mudstone facies would yield only small quantities of water to wells where saturated. The presence of gypsum could make water unacceptable for drinking.

Locally, east of Grand Wash from near the LMNRA boundary south to Pigeon Wash (pl. 1), sinkholes have developed in the mudstone near the contact with the overlying older alluvium. The mudstone weathers to steep slopes where exposed below cliffs that are composed of indurated older alluvium. Sinkholes as much as 10 ft deep in the steep mudstone slopes have developed inwardly below the cliffs. A series of sinkholes near the mouth of Quail Spring Wash on the east side of Overton Arm is as much as

20 ft across and 4 ft deep. Evaporite deposits, including halite, are at the surface and at depth in several locations along the west side of Overton Arm and southward across Lake Mead in Detrital Valley (Mannion, 1963; Laney, 1979b, p. 13). Collapse of overlying material into solution cavities in possibly underlying evaporite deposits could be the cause of these sinkholes. Sinkholes in these two areas are potential hazards for the unaware person.

Limestone Facies

The limestone facies of the Muddy Creek Formation consists of gray to grayish-white, thinly bedded marly to thickly bedded limestone containing some disseminated mud. The limestone facies generally is drained of water and caps higher hills or mesas in the area surrounding Temple Mesa near the west end of Virgin Canyon. At Aqua Chiquita Spring, (D-19-69)29cdc, however, ground water may flow through the limestone facies; the underlying, less permeable mudstone facies acts as a barrier to the downward movement of water (pl. 1, table 2). See figure 2 for spring-numbering system.

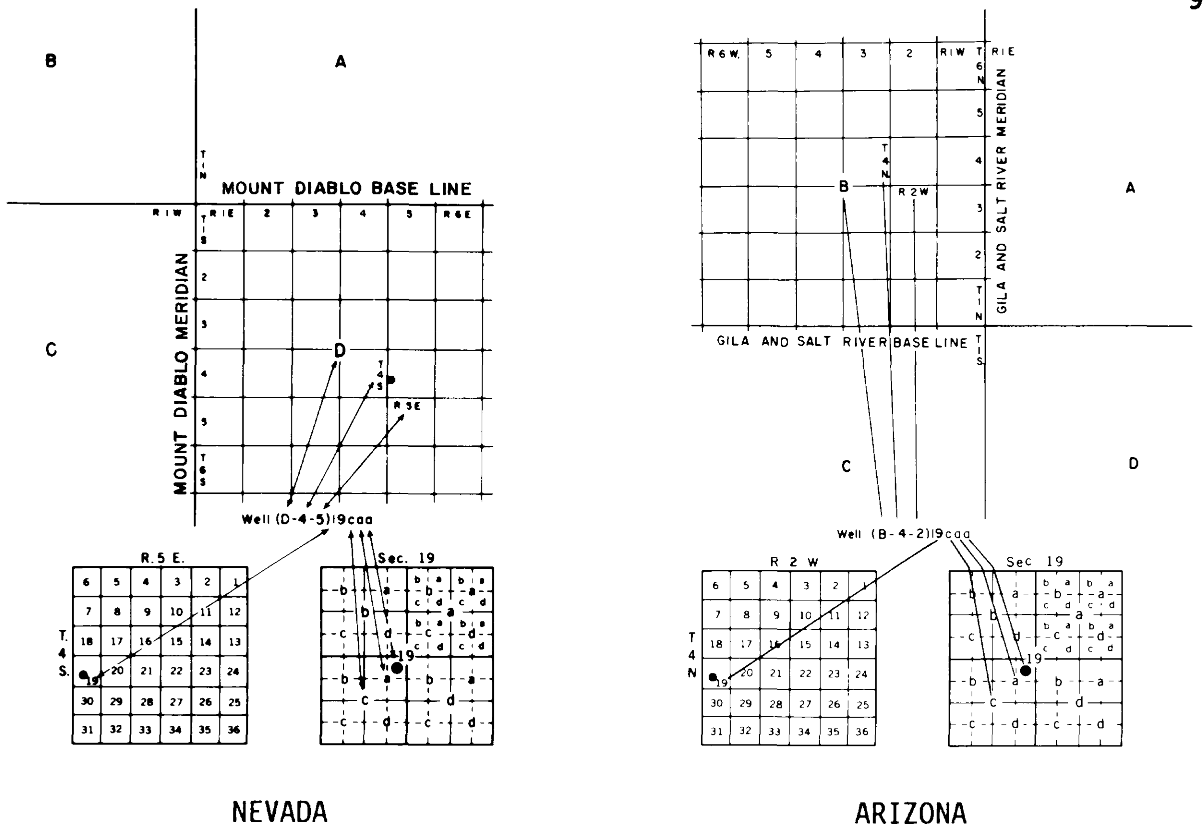
Fortification Basalt Member

The Fortification Basalt Member of the Muddy Creek Formation is exposed along the east side of Overton Arm opposite Bighorn Island and on nearby Gull and Heron Islands and is interbedded with the conglomerate facies at Temple Mesa (pl. 1). The unit is a series of dark-gray, olivine basalt flows (Laney, 1979a) dated by whole-rock analysis as 5.88 m.y. ±.18 m.y. (Damon and others, 1978).

The basalt underlying Gull Island is at lake level, and where the basalt is fractured, wells penetrating the unit might be in direct hydraulic connection with the lake water. The yield to wells would depend on the degree of fracturing but could be a few tens of gallons per minute of water. Water quality probably is similar to the quality of the lake water (tables 3 and 4). Northeast of Gull Island, the basalt overlies the mudstone facies and is drained of water. Where interbedded with the conglomerate facies at Temple Mesa, the basalt is above maximum lake level and is drained of water.

Younger Basalt

The younger basalt consists of gray to dark-gray, moderately fractured olivine basalt flows of Tertiary age. The unit is vuggy in places; however, the vugs do not contain secondary minerals. A sample of basalt collected from Cormorant Cliffs west of the entrance to Grand Wash Bay (pl. 1) was dated by whole-rock analysis as 3.80 m.y. ±.11 m.y. (Damon and others, 1978). The rock sample correlates with the basalt at Sandy Point, Arizona (Laney, 1979a), which also was dated by whole-rock analysis as 3.79 m.y. ±.46 m.y. (Damon and others, 1978).



The spring numbers used in this report are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Nevada is based on the Mount Diablo meridian and base line. The land survey in Arizona is based on the Gila and Salt River meridian and base line. These two sets of meridians and base lines divide the two states into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of intersection of the meridian and base line is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a spring number indicates the township, the second the range, and the third the section in which the spring is situated. The lowercase letters a, b, c, and d after the section number indicate the spring location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the spring number. In the example shown for Nevada, spring number (D-4-5)19caa designates the spring as being in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 5 E. A similar example is shown for Arizona. In this report, all spring locations beginning with the letter D are located in Nevada, and those beginning with the letter B are located in Arizona.

Figure 2.--Spring-numbering systems for Nevada and Arizona.

Table 2.--Records of selected springs, Virgin River to Grand Wash Cliffs

[Use: N, not used; S, stock; M, mining; D, domestic. Remarks: C, chemical analysis of water shown in tables 3 and 4]

Spring number	Spring name	Water-bearing unit	Altitude of the land surface	Estimated discharge: Amount, in gallons per minute	Estimated discharge: Date estimated	Use	Remarks
			Nevada				
(D-17-69)14bba	Red Bluff (North)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	1,590	1	3-11-80	N	C; in Mud Wash 3 miles east of Lake Mead
(D-17-69)14bbd	Red Bluff (South)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	1,585	3	3-11-80	N	C; in Mud Wash 3 miles east of Lake Mead and 600 feet south of Red Bluff Spring (North)
(D-19-69)20dcb	Maynard	Older alluvium in wash; Muddy Creek Formation may be present at shallow depth	2,570	2	3-11-80	S	C; 3.75 miles east of Lake Mead. In wash, 1 mile south of Quail Spring Wash
(D-19-69)29cdc	Agua Chiquita	Limestone facies of the Muddy Creek Formation and (or) older alluvium	2,337	0.1	3-16-78	S	C; in Catclaw Wash, 3.5 miles east of Lake Mead
(D-20-69)6aad	Cataract	Younger alluvium and conglomerate facies of the Muddy Creek Formation	2,060	([1])	3-16-78	S	In Cataract Wash, 3 miles east of Lake Mead
(D-20-69)21bdc	Walker	Metamorphic and plutonic rocks (gneiss and schist)	2,680	4	3-12-80	S	C; in Walker Wash, 4.5 miles east of Lake Mead
(D-20-70)13dbc (unsurveyed)	Cottonwood	Metamorphic and plutonic rocks (granite)	2,240	50	3-12-80	N	C; in Cottonwood Canyon, 3 miles northeast of Lake Mead; flow may be ephemeral; observed discharge was preceded by 2 months of above-average precipitation
			Arizona				
(B-32-16)10dab	Unnamed	Younger alluvium in area of Paleozoic sedimentary (limestone) and mudstone facies of the Muddy Creek Formation	1,240	0	3-12-80	S	15 yards north of Lake Mead in Gods Pocket Wash. Area covered by dense vegetation, but no flow issued from vegetated area at time of visit

See footnote at end of table.

Table 2.--Records of selected springs, Virgin River to Grand Wash Cliffs--Continued

Spring number	Spring name	Water-bearing unit	Altitude of the land surface	Estimated discharge: Amount, in gallons per minute	Estimated discharge: Date estimated	Use	Remarks
			Arizona--Continued				
(B-33-15)9bca	West Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	1,960	<0.1	3-12-80	S	C; One of 2 small seeps near south end of Gyp Hills between Pigeon and Gyp Washes, about 5 miles northeast of Lake Mead
(B-33-15)9bda	East Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	1,980	.1	3-12-80	N	C; Another of two small seeps near the south end of Gyp Hills between Pigeon and Gyp Washes, about 5 miles northeast of Lake Mead
(B-33-15)18adb	Unnamed	Younger alluvium in wash overlying mudstone facies of the Muddy Creek Formation	1,700	2	3-12-80	S	C; About 3 miles northeast of Lake Mead
(B-33-16)4ddd	Burro	Conglomerate facies of the Muddy Creek Formation	1,420	.5	3-12-80	N	C; Near mouth of unnamed wash entering Grand Wash, about 1.5 miles north of Lake Mead
(B-33-16)13dbd	Tassi	Older alluvium overlying mudstone facies of the Muddy Creek Formation	1,570	25	2-06-80	S,D	C; On northwest side of Pigeon Wash, about 3 miles northeast of Lake Mead. Consists of five springs that issue near the base of the older alluvium
(B-33-16)34aca	Unnamed	Older alluvium overlying mudstone facies of the Muddy Creek Formation	1,260	12	3-12-80	S	C; Near mouth of unnamed wash entering Grand Wash, about 4 miles north of Lake Mead
(B-33-16)34add	Chill Heal	Older alluvium overlying mudstone facies of the Muddy Creek Formation	1,280	25	3-12-80	S	C; In unnamed wash entering Grand Wash Bay, 1.5 miles southeast of Pigeon Wash
(B-34-16)26cdb	Whiskey	Older alluvium between two basalt flows	1,610	40	2-06-80	N	C; Near mouth of unnamed wash entering Grand Wash, about 4 miles north of Lake Mead
(B-34-16)35bdc	Unnamed	Older alluvium between two basalt flows	1,570	20	2-06-80	S	C; Near mouth of unnamed wash entering Grand Wash Bay, 1 mile southeast of Pigeon Wash

[1]Intermittent; 0.1 gallon per minute, 1978.

Table 3.--Chemical analyses of water from selected springs in Nevada, and water-quality criteria, Virgin River to Grand Wash Cliffs

[Analyses by U.S. Geological Survey; results in milligrams per liter, except as indicated; all analyses from unfiltered samples; values of electrical conductance in parentheses measured in the field]

Spring number	Spring name	Water-bearing unit	Date of collection	Temperature (°C)	Silica (as SiO_2)	Iron (as Fe)	Manganese (as Mn)	Calcium (as Ca)	Magnesium (as Mg)
(D-17-69)14bba	Red Bluff (North)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	17.5	20	0.06	0.01	440	110
(D-17-69)14bbd	Red Bluff (South)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	16.0	31	.08	.87	600	330
(D-19-69)20dcb	Maynard	Older alluvium; Muddy Creek Formation may be present at shallow depth	3-11-80	17.5	57	.04	.02	470	210
(D-19-69)29cdc	Agua Chiquita	Muddy Creek Formation (?) and (or) older alluvium	3-16-78	14.0	32	.04	0	71	26
(D-20-69)21bdc	Walker	Metamorphic and plutonic rocks (gneiss and schist)	3-12-80	16.0	32	.02	.002	76	18
(D-20-70)13dbc (unsurveyed)	Cottonwood	Metamorphic and plutonic rocks (granite)	3-12-80	11.5	30	.02	.002	53	13
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b 1989)		---------------	-------	----	--	.3 (SMCL)	.05 (SMCL)	---	---

Table 3.--Chemical analyses of water from selected springs in Nevada, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

[Analyses by U.S. Geological Survey; results in milligrams per liter, except as indicated; all analyses from unfiltered samples; values of electrical conductance in parentheses measured in the field]

Spring number	Spring name	Water-bearing unit	Date of collection	Sodium (as Na)	Potassium (as K)	Alkalinity (as $CaCO_3$)	Sulfate (as SO_4)	Chloride (as Cl)
(D-17-69)14bba	Red Bluff (North)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	450	14	92	2,000	450
(D-17-69)14bbd	Red Bluff (South)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	1,500	30	280	3,400	1,700
(D-19-69)20dcb	Maynard	Older alluvium; Muddy Creek Formation may be present at shallow depth	3-11-80	570	13	210	770	1,800
(D-19-69)29cdc	Agua Chiquita	Muddy Creek Formation (?) and (or) older alluvium	3-16-78	43	5.6	150	92	77
(D-20-69)21bdc	Walker	Metamorphic and plutonic rocks (gneiss and schist)	3-12-80	40	5.2	190	65	47
(D-20-70)13dbc (unsurveyed)	Cottonwood	Metamorphic and plutonic rocks (granite)	3-12-80	38	5.3	150	89	16
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b 1989)		---------------	-------	-----	----	---	250 (SMCL)	250 (SMCL)

Table 3.--Chemical analyses of water from selected springs in Nevada, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

[Analyses by U.S. Geological Survey; results in milligrams per liter, except as indicated; all analyses from unfiltered samples; values of electrical conductance in parentheses measured in the field]

Spring number	Spring name	Water-bearing unit	Date of collection	Fluo-ride (as F)	Boron (as B)[1]	Nitro-gen, NO_2+NO_3 (as N)	Phos-phate ortho, (as PO_4)	Phos-phate (as P)
(D-17-69)14bba	Red Bluff (North)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	1.1	1.1	--	--	--
(D-17-69)14bbd	Red Bluff (South)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	2.4	3.6	--	--	--
(D-19-69)20dcb	Maynard	Older alluvium; Muddy Creek Formation may be present at shallow depth	3-11-80	3.3	1.8	--	--	--
(D-19-69)29cdc	Agua Chiquita	Muddy Creek Formation (?) and (or) older alluvium	3-16-78	1.9	.2	--	--	--
(D-20-69)21bdc	Walker	Metamorphic and plutonic rocks (gneiss and schist)	3-12-80	0.5	.2	--	--	--
(D-20-70)13dbc (unsurveyed)	Cottonwood	Metamorphic and plutonic rocks (granite)	3-12-80	4.6	.21	--	--	--
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b 1989)		---------------	-------	4.0 (MCL)	----	10 (MCL)	--	--

See footnote at end of table.

Table 3.--Chemical analyses of water from selected springs in Nevada, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

[Analyses by U.S. Geological Survey; results in milligrams per liter, except as indicated; all analyses from unfiltered samples; values of electrical conductance in parentheses measured in the field]

Spring number	Spring name	Water-bearing unit	Date of collection	Dis-solved solids (calcu-lated)	Hardness: Noncar-bonate (as $CaCO_3$)	Hardness: Total	Electrical conduct-ance (micro-mhos at 25°C)	pH (lab-ora-tory)
(D-17-69)14bba	Red Bluff (North)	Younger alluvium overlying Paleozoic and Mesozoic sedimentary rocks	3-11-80	3,540	1,500	1,600	4,585 (4,600)	8.2
(D-17-69)14bbd	Red Bluff (South)	Younger alluvium overlying Paleozoic and Mesozoic sadimentary rocks	3-11-80	7,770	2,600	2,900	10,149 (9,610)	7.9
(D-19-69)20dcb	Maynard	Older alluvium; Muddy Creek Formation may be present at shallow depth	3-11-80	4,020	1,800	2,000	6,938 (6,800)	7.8
(D-19-69)29cdc	Agua Chiquita	Muddy Creek Formation (?) and (or) older alluvium	3-16-78	437	140	280	610	6.7
(D-20-69)21bdc	Walker	Metamorphic and plutonic rocks (gneiss and schist)	3-12-80	398	74	260	713 (719)	8.1
(D-20-70)13dbc (unsurveyed)	Cottonwood	Metamorphic and plutonic rocks (granite)	3-12-80	339	36	190	458 (440)	8.1
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b 1989)		----------------	-------	500 (SMCL)	-----	-----	-------	6.6-8.5 (SMCL)

[1]U.S. Environmental Protection Agency has no Maximum Contaminant Level or Secondary Maximum Contaminant Level for boron for drinking water. 0.75 mg/L is criterion for water that is used for long-term use on sensitive crops (U.S. Environmental Protection Agency, 1986a).

Table 4.--Chemical analyses of water from selected springs in Arizona, from Lake Mead, and water-quality criteria, Virgin River to Grand Wash Cliffs

[Analyses by U.S. Geological Survey; results in milligrams per liter, except as indicated; all analyses from unfiltered samples; values of electrical conductance in parentheses measured in the field]

Spring number	Spring name	Water-bearing unit	Date of collection	Temperature (°C)	Silica (as SiO_2)	Iron (as Fe)	Manganese (as Mn)	Calcium (as Ca)	Magnesium (as Mg)
(B-33-15)9bca	West Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	13.5	11	0.06	0.01	480	130
(B-33-15)9bda	East Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	----	24	.06	.02	440	790
(B-33-15)18adb	Unnamed	Younger alluvium in wash overlying mudstone facies of the Muddy Creek Formation	3-12-80	13.0	51	.05	.03	470	570
(B-33-16)4ddd	Burro	Conglomerate facies, Muddy Creek Formation	3-12-80	16.0	25	.05	.01	350	110
(B-33-16)13dbd	Tassi[1]	Older alluvium overlying mudstone facies of the Muddy Creek Formation	2-5-80	25.0	22	<.01	<.001	48	23
(B-33-16)34aca	Unnamed	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	14.5	29	.01	<.001	170	71
(B-33-16)34add	Chill Heal	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	17.5	23	.01	<.001	65	41
(B-34-16)26cdb	Whiskey	Older alluvium between two basalt flows	2-6-80	22.0	24	<.01	<.001	47	25
(B-34-16)35bdc	Unnamed	Older alluvium between two basalt flows	2-6-80	17.0	25	<.01	<.001	73	28
Lake Mead at South Cove boat landing[2]		-------------------	1-23-75	13.0	9.1	.01	.03	70	28
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b, 1989)		-------------------	-------	----	----	.3 (SMCL)	.05 (SMCL)	---	---

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected springs in Arizona, from Lake Mead, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

Spring number	Spring name	Water-bearing unit	Date of collection	Sodium (as Na)	Potassium (as K)	Alkalinity (as $CaCO_3$)	Sulfate (as SO_4)	Chloride (as Cl)
(B-33-15)9bca	West Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	570	92	94	2,400	300
(B-33-15)9bda	East Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	1,600	150	160	6,600	600
(B-33-15)18adb	Unnamed	Younger alluvium in wash overlying mudstone facies of the Muddy Creek Formation	3-12-80	1,100	53	300	4,300	850
(B-33-16)4ddd	Burro	Conglomerate facies, Muddy Creek Formation	3-12-80	1,600	13	68	2,100	2,000
(B-33-16)13dbd	Tassi[1]	Older alluvium overlying mudstone facies of the Muddy Creek Formation	2-5-80	26	3.4	140	110	10
(B-33-16)34aca	Unnamed	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	140	12	260	680	64
(B-33-16)34add	Chill Heal	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	79	10	170	320	22
(B-34-16)26cdb	Whiskey	Older alluvium between two basalt flows	2-6-80	19	2.7	140	100	8.3
(B-34-16)35bdc	Unnamed	Older alluvium between two basalt flows	2-6-80	26	2.8	200	150	14
Lake Mead at South Cove boat landing[2]		-------------------	1-23-75	86	4.4	164	260	110
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b, 1989)		-------------------	-------	-----	-----	---	250 (SMCL)	250 (SMCL)

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected springs in Arizona, from Lake Mead, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

Spring number	Spring name	Water-bearing unit	Date of collection	Fluoride (as F)	Boron (as B)[3]	Nitrogen, NO_2+NO_3 (as N)	Phosphate ortho, (as PO_4)	Phosphate (as P)
(B-33-15)9bca	West Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	0.1	7.7	----	----	----
(B-33-15)9bda	East Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	.3	24	----	----	----
(B-33-15)18adb	Unnamed	Younger alluvium in wash overlying mudstone facies of the Muddy Creek Formation	3-12-80	.6	5.5	----	----	----
(B-33-16)4ddd	Burro	Conglomerate facies, Muddy Creek Formation	3-12-80	1.1	.85	----	----	----
(B-33-16)13dbd	Tassi[1]	Older alluvium overlying mudstone facies of the Muddy Creek Formation	2-5-80	.3	.1	2.4	0.03	0.01
(B-33-16)34aca	Unnamed	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	1.4	.39	----	----	----
(B-33-16)34add	Chill Heal	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	1.2	.32	----	----	----
(B-34-16)26cdb	Whiskey	Older alluvium between two basalt flows	2-6-80	.2	.06	.13	0	0
(B-34-16)35bdc	Unnamed	Older alluvium between two basalt flows	2-6-80	.3	.08	1.2	.25	.08
Lake Mead at South Cove boat landing[2]		------------------	1-23-75	.4	-----	4.1	.74	----
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b, 1989		------------------	-------	4.0 (MCL)	-----	10 (MCL)	----	----

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected springs in Arizona, from Lake Mead, and water-quality criteria, Virgin River to Grand Wash Cliffs--Continued

Spring number	Spring name	Water-bearing unit	Date of collection	Dissolved solids (calculated)	Hardness: Noncarbonate (as $CaCO_3$)	Hardness: Total	Electrical conductance (micromhos at 25°C)	pH (laboratory)
(B-33-15)9bca	West Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	4,050	1,600	1,700	5,321 (5,290)	8.2
(B-33-15)9bda	East Gyp	Mudstone facies (gypsiferous) of the Muddy Creek Formation	3-12-80	10,300	4,200	4,400	11,383 (17,800)	8.2
(B-33-15)18adb	Unnamed	Younger alluvium in wash overlying mudstone facies of the Muddy Creek Formation	3-12-80	7,580	3,200	3,500	9,144 (9,000)	8.0
(B-33-16)4ddd	Burro	Conglomerate facies, Muddy Creek Formation	3-12-80	6,240	1,300	1,300	9,293 (9,450)	8.2
(B-33-16)13dbd	Tassi[1]	Older alluvium overlying mudstone facies of the Muddy Creek Formation	2-5-80	338	75	210	534	8.3
(B-33-16)34aca	Unnamed	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	1,320	460	720	1,794 (1,820)	8.2
(B-33-16)34add	Chill Heal	Older alluvium overlying mudstone facies of the Muddy Creek Formation	3-12-80	664	160	330	1,000 (990)	8.2
(B-34-16)26cdb	Whiskey	Older alluvium between two basalt flows	2-6-80	311	80	220	487	8.0
(B-34-16)35bdc	Unnamed	Older alluvium betweem two basalt flows	2-6-80	445	98	300	675	8.2
Lake Mead at South Cove boat landing[2]		-------------------	1-23-75	654	160	290	995	7.8
U.S. Environmental Protection Agency drinking water Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) as noted (U.S. Environmental Protection Agency, 1986b, 1989)		-------------------	-------	500 (SMCL)	-----	-----	------	6.6-8.5 (SMCL)

[1]Aggregate flow of five springs.
[2]From Laney (1979). Sample taken near Sandy Point, Arizona.
[3]U.S. Environmental Protection Agency has no Maximum Contaminant Level or Secondary Maximum Contaminant Level for boron for drinking water. 0.75 mg/L is criterion for water that is used for long-term use on sensitive crops (U.S. Environmental Protection Agency, 1986a).

The basalt is exposed in the Grand Wash area (pl. 1). The unit west of Grand Wash overlies the conglomerate and mudstone facies of the Muddy Creek Formation and underlies scattered small deposits of older alluvium. The unit east of Grand Wash is interbedded with the coarse-grained unit of the older alluvium and may form a continuous aquifer. The younger basalt has limited areal extent, and exposures near the mouth of Grand Wash generally are above lake level and are drained of water.

Older Alluvium

The older alluvium of late Tertiary and early Quaternary age is the most widespread deposit in the study area. Older alluvium is present extensively along the east shoreline of Overton Arm and the Virgin River and in the Grand Wash area. The unit is divided into a coarse-grained unit and a fine-grained unit. Neither unit has undergone significant deformation.

The coarse-grained unit of the older alluvium consists of gray to brownish-gray silty, sandy gravel with clasts ranging in size from sand to boulders. The unit is weakly to moderately cemented and consists largely of poorly sorted angular to subrounded clasts of locally derived material. In many places, the unit also contains some well-rounded, sand- and gravel-sized clasts of quartz, quartzite, red jasper, and black chert that are exotic to the area. These exotic clasts were brought into the area by the ancestral Virgin and Colorado Rivers. Laney (1979a, p. 32; 1979b, p. 21) described similar deposits containing exotic clasts south of Lake Mead. A white 5-foot-thick tuff bed is interbedded with the coarse-grained unit above lake level on the east side of Overton Arm, 1 mi north of Lime Cove in sec. 23, T. 18 S., R. 68 E., in Nevada. The tuff bed overlies a layer of well-rounded exotic gravel. Isotope determinations on the tuff could provide additional stratigraphic information on the age of the older alluvium and the ancestral river systems in the Lake Mead area. In the northern Overton Arm area, many cliffs that are composed of the coarse-grained unit exhibit large-scale trough crossbedding. The ratio of clasts to matrix is greater than one. Ratios generally are highest in channel-fill deposits. The matrix generally consists of angular fine sand and some silt.

The fine-grained unit of the older alluvium consists of massive to stratified, subangular to rounded, poorly sorted sand containing some silt and clay. The unit generally is tan to light brown but in places is olive, light green, or reddish brown. In deposits at the north end of Overton Arm, the fine-grained unit may contain gypsum as small crystals of selenite. Some exposures of the fine-grained unit along Overton Arm contain large scoured channels that are about 50 ft wide and 15 ft deep and are filled with coarser material. A high terrace capped by the fine-grained unit occurs southwest of the entrance of Grand Wash Bay. The terrace is composed of well-sorted, massive-bedded, rounded to well-rounded, fine, tan sand.

The coarse-grained unit is the major potential water-producing unit in the study area. As much as several hundred gallons per minute of water might be obtained from wells in the coarse-grained unit near Lake Mead. The quality of the pumped water probably would be similar to that of water in the lake (tables 3 and 4). Springs in this unit generally yield water of excellent quality for drinking.

No springs are known to discharge from the fine-grained unit; wells in the unit probably would produce less than 10 gal/min of water. The fine-grained unit contains gypsum in places that could make the water unacceptable for drinking.

Chemehuevi Formation

The Chemehuevi Formation consists of white, pink, or tan thinly bedded fine sand. The unit is crossbedded and well sorted to very well sorted and contains thin clay lenses. Remnants of the Chemehuevi Formation are on truncated ridges along the borders of tributary channels at altitudes close to altitudes of the lake. The formation is present on the west side of Gregg basin south of Devils Cove, near the mouths of Snap and Pierce Canyons in the eastern part of the study area, and near The Narrows in secs. 6 and 7, T. 17 S., R. 69 E., at the northeast end of Overton Arm (pl. 1). The 2-mile-long channel-fill deposit southeast of The Narrows tentatively is mapped as the Chemehuevi Formation. The deposit is in a channel cut into the coarse facies of the older alluvium and consists of clayey silt and fine sand that varies in color from light tan to light green to light olive. The dissected deposit is 75 to 100 ft thick and exhibits either no stratification or only faint stratification. More distinct bedding may be masked by the slight slumping of the material down the steeply sloping surfaces of the deposit.

The well-sorted sands found in most deposits of the Chemehuevi Formation might yield a few tens to a few hundreds of gallons per minute of water to wells where the deposit is saturated by water from the lake. The fine sand in the unit can cause problems in wells unless the correctly sized sand packs and well screens are used.

Younger Alluvium

The younger alluvium consists of tan to brown, unconsolidated, angular to subangular sand and gravel and some silt, clay, and boulders. The materials are all of local origin. The unit is present along the bottoms of present-day washes and probably is less than 50 ft thick. The younger alluvium generally is drained of water except where a wash enters the lake or where saturated by ground water from an underlying unit. The younger alluvium may yield from a few tens to a few hundred gallons per minute of water to shallow, large-diameter wells that penetrate saturated material near the lake. The yields, however, would be affected by fluctuations in the lake level that determine the saturated thickness of the unit. Minor ground-water underflow in this unit may issue as small ephemeral springs at places where bedrock intersects the wash and forces underflow to the surface. Flow from the springs, however, generally reenters the alluvium within a short distance downgradient from the bedrock barrier.

HYDROLOGY

The average annual precipitation in the study area is about 7 in., and the average annual evaporation is about 15 times greater than the precipitation. Most precipitation evaporates soon after it reaches the ground or is transpired by vegetation. The Colorado and Virgin Rivers are the only perennial streams in the study area. Surface-water flow in the larger washes of LMNRA occurs on the average of about once a year and is sparse (Bentley, 1979a). Occasional floodflows may result from local intense thunderstorms. Recharge to the ground-water reservoir from precipitation or local surface runoff is small. The only reliable sources of surface water are Lake Mead and the Virgin River.

The ground water in the study area has two major sources: water that infiltrates the permeable rocks adjacent to the lake and underflow from basins that drain into the study area. An additional source is the Virgin River above lake level in the extreme northern part of the area. The quantity of ground water that can be derived from sediments saturated by Lake Mead is much greater than underflow to the lake from the surrounding basins. Sediments saturated by lake water probably extend less than 0.5 mi from the lake, and the level of Lake Mead exerts the major control on ground-water movement near the lake. The water table in the saturated sediments near the lake varies in response to lake-level changes. When the lake level rises, water from the lake is recharged into the adjacent permeable deposits; when the lake level declines, water stored in the permeable sediments is discharged into the lake.

A well-defined, extensive aquifer not connected to the lake that is potentially productive is present in only one area. The older alluvium and interbedded younger basalt flows form a wedge-shaped aquifer of about 20 mi^2. About 10 mi^2 is within LMNRA between Grand Wash and Gyp Wash (pl. 1). The mudstone facies of the Muddy Creek Formation underlies the aquifer and is a confining unit that prevents downward movement of water from the aquifer. Three of the largest springs in the study area discharge from the aquifer. The springs, which are in Arizona, are an unnamed spring, (B-34-16)35bdc; Tassi Springs, (B-33-16)13dbd; and Whiskey Spring (B-34-16)26cdb (table 2).

No wells are known to exist in the study area. Seventeen springs were inventoried in or near the study area; however, only six yield 5 gal/min or more (table 2). Three of the six springs are within the boundaries of LMNRA. Springs that have the highest discharge rates are associated with the older alluvium.

QUALITY OF WATER

Samples were collected from 15 springs for chemical analysis (tables 3 and 4). Seven of the water samples were of acceptable quality for drinking on the basis of the constituents analyzed (U.S. Environmental Protection Agency, 1986a, b). The samples having acceptable quality for drinking were from springs in the older alluvium and the metamorphic and plutonic rocks. Water from Cottonwood Spring, (D-20-70)13dbc unsurveyed, in the metamorphic and plutonic rocks contained fluoride slightly in excess of the Maximum Contaminant Level for drinking water; otherwise, the water is of acceptable quality for drinking on the basis of the constituents analyzed (U.S. Environmental Protection Agency, 1986b). Water of unacceptable quality for drinking because of large concentrations of sulfate and chloride was obtained from springs in the Paleozoic and Mesozoic sedimentary rocks and the Muddy Creek Formation, especially the mudstone facies. Water from springs in the older alluvium—Whiskey Spring, (B-34-16)26cdb; an unnamed spring, (B-34-16)35bdc; and Tassi Spring, (B-33-16)13dbd—contained less than 500 milligrams per liter (mg/L) of dissolved solids and had a calcium magnesium bicarbonate sulfate composition (table 4).

Cottonwood Spring, (D-20-70)13dbc unsurveyed, is the only spring in the metamorphic and plutonic rocks in the study area within the LMNRA (table 3). The spring is northeast of Bonnelli Peak in the Hells Kitchen area and consists of multiple springs that issue from weathered granitic rocks. Water from Cottonwood Spring contained 339 mg/L of dissolved solids and would be of excellent quality for drinking (table 3). The water, however, contained 4.6 mg/L of fluoride, which exceeded the Maximum Contaminant Level of 4.0 mg/L for fluoride in drinking water (U.S. Environmental Protection Agency, 1986b).

Several springs are in the metamorphic and plutonic rocks northeast of Bonelli Peak but are outside the LMNRA boundary (pl. 1). Walker Spring, (D-20-69)21bdc, which is the nearest of these springs to the boundary, was sampled because water from the spring might be used within LMNRA. Water from Walker Spring contained 398 mg/L of dissolved solids and is of excellent quality for drinking on the basis of constituents analyzed.

Water from Red Bluff Springs (North), (D-17-69)14bba, and Red Bluff (South), (D-17-69)14bbd, discharged from alluvium overlying Paleozoic and Mesozoic sedimentary rocks (table 3). The water samples contained 3,540 and 7,770 mg/L of dissolved solids, respectively, had a mixed-cation sulfate chloride composition, and were not suitable for drinking.

The mudstone facies of the Muddy Creek Formation contributes water of poor quality for drinking to two springs—West Gyp, (B-33-15)9bca, and East Gyp, (B-33-15)9bda. The springs discharged 0.1 gal/min or less of water, and samples from West Gyp Spring and East Gyp Spring contained dissolved-solids concentrations of 4,050 and 10,300 mg/L, respectively (table 4).

The mudstone facies may degrade the quality of water from three springs in the older alluvium—an unnamed spring, (B-33-16)34aca; Chill Heal Spring, (B-33-16)34add; and Maynard Spring, (D-19-69)20dcb. The unnamed spring and Chill Heal Spring discharged 12 and 25 gal/min, and water samples contained dissolved-solids concentrations of 1,320 and 664 mg/L, respectively. The mudstone facies of the Muddy Creek Formation underlies the older alluvium at these two springs. The mudstone facies may degrade the water at Maynard Spring, although no mudstone was exposed at the spring. However, the mudstone facies is exposed beneath the older alluvium at Agua Chiquita Spring about 1 mi to the south. Maynard Spring discharged 2 gal/min of water from the older alluvium (table 2), and the water contained 4,020 mg/L of dissolved solids, which included 1,800 mg/L of chloride and 770 mg/L of sulfate (table 3). These concentrations exceeded the Secondary Maximum Contaminant Level for drinking water (U.S. Environmental Protection Agency, 1989). The water was a mixed-cation chloride sulfate type. The quality of the water could be affected by water in the older alluvium that has contacted the mudstone facies, or the lower part of the older alluvium may contain reworked material from the mudstone facies from which dissolved constituents were derived. Water from or affected by the mudstone facies of the Muddy Creek Formation generally is a mixed-cation sulfate type.

FAVORABLE AREAS FOR GROUND-WATER DEVELOPMENT

The principal source of ground water is permeable rocks adjacent to Lake Mead. Smaller quantities of water can be developed in permeable rocks farther from the lake and in less permeable rocks near the lake. Wells drilled in fault and fracture zones near the lake probably will yield small to moderate quantities of water to wells. In the eastern part of the area, metamorphic and plutonic rocks and undifferentiated Paleozoic and Mesozoic sedimentary rocks that border the lake generally are fractured sufficiently to allow movement of small quantities of water to wells. Quality of water, however, may be unsuitable for drinking. In several places, the conglomerate facies of the Muddy Creek Formation probably will yield small quantities of water to wells near the lake.

The most favorable areas for developing large ground-water supplies are those underlain by the coarse-grained unit of the older alluvium, the younger alluvium, and in places, the Chemehuevi Formation near the lake. The least favorable areas are those underlain by the mudstone facies of the Muddy Creek Formation and the fine-grained unit of the older alluvium. Even near Lake Mead, these units probably will yield only small quantities of water to wells, and the water could contain large concentrations of dissolved solids.

On the basis of the field investigations in the LMNRA between the Virgin River, Nevada, and Grand Wash Cliffs, Arizona, described in this report, five areas can be identified as having the potential for ground-water development. These areas, listed in order of decreasing favorability, are Grand Wash and Tassi Ranch area, Arizona; Devils Cove in the Hells Kitchen area, Nevada; Scanlon Hill and Gregg Wash area, Nevada; Snap and Pierce Canyons area, Arizona; and Twin Springs Wash and Quail Spring Wash area, Nevada (pl. 1). Because this study is a reconnaissance evaluation, a detailed examination of any of these areas would need to precede test-well drilling.

Area 1—Grand Wash and Tassi Ranch Area, Arizona

The coarse-grained unit of the older alluvium yields water to multiple springs at three locations in the Grand Wash and Tassi Ranch area: an unnamed spring, (B-34-16)35bdc; Tassi Springs, (B-33-16)13dbd; and Whiskey Spring, (B-34-16)26cdb (pl. 1). The three springs discharged water at rates of 20, 25, and 40 gal/min, respectively, in February 1980 (table 2). The water is of excellent chemical quality for drinking and contains 445, 338, and 311 mg/L, respectively, of dissolved solids (table 4). Whiskey Spring and the unnamed spring are 1.25 and 0.5 mi, respectively, north of the LMNRA boundary. About 10 mi^2 of the wedge-shaped aquifer that extends from Grand Wash eastward to Gyp Wash is within the LMNRA. The aquifer consists of the coarse-grained unit of older alluvium and interbedded, fractured basalt flows of the younger basalt. The combined maximum thickness of the older alluvium and the interbedded basalt flows is 200 to 300 ft. The mudstone facies of the Muddy Creek Formation underlies the older alluvium and the fractured basalt flows and is a confining unit that limits downward movement of ground water. The springs are at or near the contact of the mudstone and the overlying older alluvium or basalt. The three springs probably are the principal discharge points of the aquifer; however, unknown quantities of water are lost to evapotranspiration along the 7-mile exposed south and west edges of the aquifer between the unnamed spring and Tassi Springs. Phreatophytic vegetation was growing in some of the dry washes that cut the exposed edges of the aquifer.

Tassi Springs consist of as many as five springs issuing from the base of the older alluvium. A pipe and concrete trough are at one spring, and laterals for crop irrigation at the other springs. The unnamed spring and Whiskey Spring were undeveloped when the springs were inventoried in 1980.

Proposals for development of water at the springs could include adding or improving existing water-handling facilities such as cribs, pipes, and storage tanks. Improving collection and storage facilities at the springs probably would be less expensive than drilling wells. On the basis of estimated discharge values, the three springs might provide more than 4 million gal/yr of water. Because seasonal fluctuations are unknown, however, it would be prudent to determine the seasonal variations in discharge of the springs.

Water probably could be obtained by drilling wells almost anywhere in the wedge-shaped aquifer within the LMNRA. The most favorable area would be near the exposed south edge of the aquifer from Tassi Springs in either direction to the LMNRA boundary. The area with the highest potential for a successful well would be north of and near Tassi Springs. Ground-water pumping from this aquifer, however, could reduce spring flow. Because the aquifer probably drains at unknown underground points in addition to the springs, an evaluation of the quantity of water that could be pumped and the resultant spring-flow reduction cannot be made on the basis of the information in this study. Monitoring of the spring flow for several years prior to any well production and continued monitoring of both spring flow and well production would be necessary to determine effects of development on the springs. A detailed site evaluation would be needed to specify drilling locations. Drilling equipment access to the area would be a consideration.

Area 2—Devils Cove in the Hells Kitchen area, Nevada

In Devils Cove in the Hells Kitchen area, the most favorable location for development of a dependable ground-water supply is near Lake

Mead where the Chemehuevi Formation is exposed 1 to 2 mi southwest of Devils Cove (pl. 1). The Chemehuevi Formation consists of crossbedded sands with scattered, thin lenses of clay. These exposures are partly saturated by the lake and probably will yield moderate quantities of water to wells that penetrate the saturated material. A saturated thickness of about 20 ft might yield a few hundred gallons per minute of water to a well in this deposit. The coarse-grained unit of the older alluvium, which is only weakly cemented in this area, underlies the Chemehuevi Formation and probably will yield comparable quantities of water to wells. The water quality probably would be similar to the water quality of the lake (table 4). The saturated thickness of the units near the lake and therefore depth to water in wells will vary as lake levels rise and fall.

Granitic rocks in Cottonwood Canyon in the eastern part of T. 20 S., R. 70 E. (Nevada), yield water to Cottonwood Spring, approximately 3 mi northwest of Devils Cove in the Hells Kitchen area. Total discharge of the springs was estimated to be 50 gal/min on March 12, 1980. The water contained 339 mg/L of dissolved solids (table 3) and was acceptable for drinking water for all determined constituents except fluoride (U.S. Environmental Protection Agency, 1986a, b). The source of the springs appears to be a field of large boulders 20 to 30 ft in diameter and associated small, weathered granitic fragments (grus) covering an area of about 1 mi^2 upgradient from Cottonwood Spring. Specific information on fluctuations of spring discharge is not known, but the springs are thought to be ephemeral. Discharge from these springs was large enough to reach the lake in March 1980; however, a flow of this magnitude was not observed at other times during the field work for this study. Climatic records indicate that precipitation in the Lake Mead area was significantly above average for the winter months before observation of the spring discharge in March 1980 (National Environmental Satellite Data and Information Service, 1980).

The drainage basin of the Hells Kitchen area generally is underlain by rocks that might yield small to moderate quantities of water to properly located wells. An exposure of metamorphic rocks about 2 mi wide underlies Cottonwood Wash downgradient from Cottonwood Spring (pl. 1). South of Devils Cove, the coarse-grained unit of the older alluvium is exposed between the metamorphic rocks and the lake. Small quantities of water of probable acceptable quality for drinking might be obtained from wells in the older alluvium near major washes in this area. The water probably would be of better quality than lake water. Larger quantities of water could be produced from the unit near the lake, however, water quality would be similar to that of lake water (table 4). The supply near the lake would be more dependable than the ground water draining to the lake, although availability could be affected by rising and falling lake levels.

Area 3—Scanlon Hill and Gregg Wash area, Nevada

In the Scanlon Hill and Gregg Wash area, the most favorable location for development of ground-water resources is in the coarse-grained unit of the older alluvium near Scanlon Hill in secs. 14 and 23, T. 21 S., R. 70 E. (pl. 1). If saturated, this unit generally has sufficient permeability to yield a few gallons to as much as a few hundred gallons per minute of water to wells. Larger yields to wells probably would be from the deposits that are saturated by the lake; therefore, the quality of the water would be similar to that of water in the lake (table 3). Much smaller yields would be expected in the deposits farther from the lake. The area northwestward from the lake along Gregg Wash is underlain mostly by granitic rocks and some exposures of metamorphic rocks. Where fractured, the granitic rocks might yield small quantities of water to properly constructed wells.

A gently sloping area as much as 0.5 mi wide extends from Scanlon Hill westward through Jumbo Pass (pl. 1) and is underlain by the older alluvium, most of which is the coarse-grained unit. Some outcrops of the fine-grained unit were present but were too small to map. This area may be recharged by intense rainstorms but would be a limited source of ground water. Because no wells or springs are known to exist in the area, no water quantity or quality data are available.

Area 4—Snap and Pierce Canyons area, Arizona

In the Snap and Pierce Canyons area, Arizona, the sands of the Chemehuevi Formation may yield as much as a few hundred gallons per minute of water to wells near the mouths of the canyons (pl. 1). The Chemehuevi Formation occurs on truncated ridge ends between the two canyons in T. 32 N., R. 16 W. (unsurveyed). The unit covers an area of 0.25 to 0.50 mi^2 and its thickness is unknown. The material underlying the Chemehuevi probably is the conglomerate facies of the Muddy Creek Formation. The conglomerate, which is tightly cemented in exposures nearby, may yield less than 10 gal/min of water. The quality of water from wells in the area probably would be similar to that of water in the lake (table 4). Water levels in wells and yields to wells would rise and fall in response to major changes in lake level, which would affect the dependability of the supply.

Area 5—Twin Springs Wash and Quail Spring Wash area, Nevada

In the Twin Springs Wash and Quail Spring Wash area, the coarse-grained unit of the older alluvium may yield as much as hundreds of gallons per minute of water to wells near the lake between the washes. Wells drilled to the top of the mudstone facies of the Muddy Creek Formation would provide the maximum yield and the best water quality. The mudstone facies would need to be cemented off to prevent water of poor quality from entering the well. The mudstone facies is present locally along the bottom of the scarps of older alluvium in several washes in the area. The presence of the facies indicates that only a few feet to a few tens of feet of the older alluvium is present near the lake. Water levels and saturated thickness of the unit in any well in this area would change in response to changes in lake level, which could make the supply undependable.

The coarse-grained unit of the older alluvium yields water to three small ephemeral springs 3 to 4 mi east of the lake—Maynard

Spring, D-19-69)20dcb; Agua Chiquita Spring, (D-19-69)29cdc; and Cataract Spring, (D-20-69)6aad (table 2). Maynard Spring had an estimated discharge of 2 gal/min when inventoried and sampled in March 1980. The water contained 4,020 mg/L dissolved solids and would not be acceptable for drinking. The Muddy Creek Formation may be present at shallow depth and might be the cause of the poor water quality. In March 1980, Cataract Spring consisted of a seep, and a water sample could not be obtained. In May 1980, Maynard and Cataract Springs were dry. Agua Chiquita Spring had an estimated discharge of about 0.1 gal/min when inventoried and sampled in March 1978 (table 2). The water contained 437 mg/L dissolved solids and met drinking-water standards for all analyzed constituents (table 3).

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