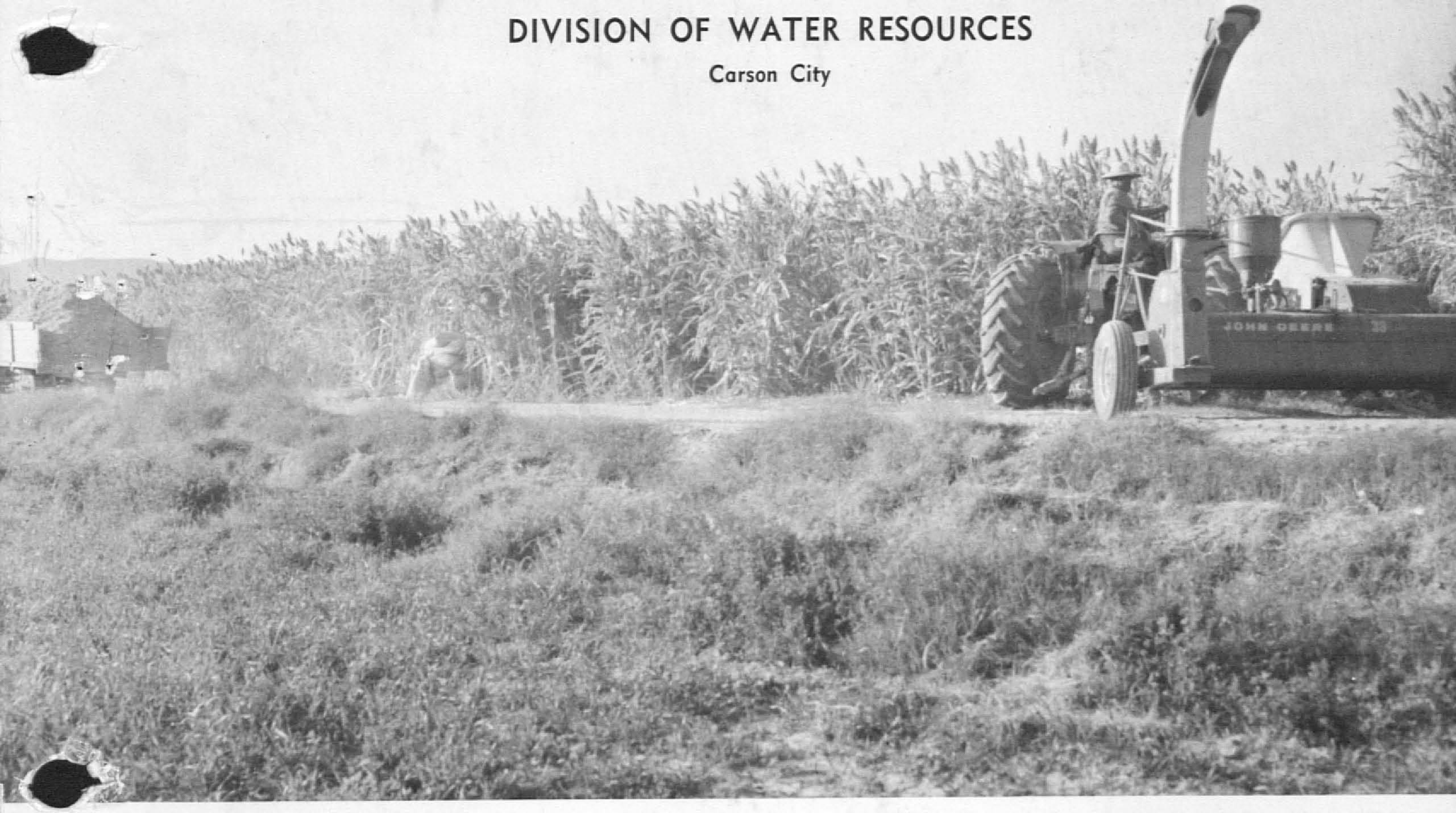
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
Carson City



WATER RESOURCES – RECONNAISSANCE SERIES
REPORT 50

WATER–RESOURCES APPRAISAL OF THE LOWER MOAPA–LAKE MEAD AREA, CLARK COUNTY, NEVADA

By
F. Eugene Rush

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

DECEMBER 1968

WATER RESOURCES - RECONNAISSANCE SERIES

REPORT 50

WATER-RESOURCES APPRAISAL OF THE LOWER MOAPA-LAKE MEAD AREA, CLARK COUNTY, NEVADA

By

F. Eugene Rush

Hydrologist

Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

December

1968

ELMO J. DeRICCO
Director

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
201 South Fall Street, Carson City, Nevada 89701

ROLAND D. WESTERGARD
State Engineer

In reply refer to
No.

Address All Communications to the State Engineer, Division of Water Resources

FOREWORD

The program of reconnaissance water-resources studies was authorized by the 1960 Legislature to be carried on by the Department of Conservation and Natural Resources, Division of Water Resources, in cooperation with the U.S. Geological Survey.

This report is the 50th report prepared by the staff of the Nevada District of the U.S. Geological Survey. These 50 reports describe the hydrology of 155 valleys.

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

Roland D. Westergard
Roland D. Westergard
State Engineer

Division of Water Resources

December 1968

CONTENTS

TABLES

Tables continued

ILLUSTRATIONS

WATER-RESOURCES APPRAISAL OF THE

LOWER MOAPA-LAKE MEAD AREA, CLARK COUNTY, NEVADA

By F. Eugene Rush

SUMMARY

The lower Moapa-Lake Mead area is in arid southeastern Nevada, extending from Las Vegas Valley eastward to the Arizona State line. That part of Lake Mead in Nevada is included in the report area. Seven hydrographic areas are described: Hidden, Garnet, and Lower Moapa Valleys, Black Mountains and Gold Butte Areas, California Wash, and Greasewood Basin; and for each a water budget was compiled. Surface-water and ground-water flow into the report area from the Muddy River Springs Area, Lower Meadow Valley, and Las Vegas Valley. All the areas drain either in the subsurface or on the surface to the Muddy River or to Lake Mead.

Excluding consideration of water stored in Lake Mead, most of the areas have very limited water resources. The largest are dominated by streamflow and include California Wash Area, where the estimated average annual inflow and outflow are about 43,000 acre-feet; for Lower Moapa Valley, about 35,000 acre-feet; and for the Black Mountains Area, 12,000 acre-feet. In the other areas where runoff is minor, estimated average annual recharge and discharge are about 1,000 acre-feet or less.

The largest element of inflow to three hydrographic areas, California Wash, Lower Moapa Valley, and the Black Mountains Area, is streamflow entering the area. Muddy River has as its source springs in the Muddy River Springs Area north of California Wash hydrographic area. The average annual Muddy River flow into California Wash area is about 33,000 acre-feet. The average annual flow in the river from the California Wash area to Lower Moapa Valley is about 34,000 acre-feet. From Las Vegas Valley, the estimated average annual flow in Las Vegas Wash to the Black Mountains area is 12,000 acre-feet. Most of this flow discharges into Lake Mead.

In the California Wash area, the dominant element of outflow, excluding flood flows, is the 34,000 acre-feet of average annual flow in the Muddy River to Lower Moapa Valley. About 7,000 acre-feet of water is consumed in California Wash. In Lower Moapa Valley, the three largest elements of outflow are nearly equal;

irrigation, 13,000 acre-feet, outflow of the Muddy River, 10,000 acre-feet, and evapotranspiration of ground water by nonbeneficial phreatophytes, 11,000 acre-feet.

Ground-water quality reflects the abundance of soluble minerals in the area; most ground-water samples had high concentrations of dissolved solids. The flow in Las Vegas Wash, mostly water used in Las Vegas Valley, was high in dissolved solids. Muddy River water, though having a high salinity hazard, has been proved chemically acceptable for irrigation under good management and soil conditions.

System yield of the combined California Wash-Lower Moapa Valley area is estimated to be 40,000 acre-feet, of which 22,000 acre-feet was consumed in 1967. For the Black Mountains Area, the estimated system yield is 7,000 acre-feet. Estimated perennial yields of the remaining areas are: Hidden Valley, 200 acre-feet, Garnet Valley, 400 acre-feet, Gold Butte Area, 500 acre-feet, and Greasewood Basin, 300 acre-feet.

Water use in 1967 in all areas was less than the estimated yields. However, development of water in Las Vegas Wash may be limited because of its poor quality. In areas adjoining Lake Mead, supplies can be developed from the lake, subject to legal limitations.

INTRODUCTION

The Lower Moapa-Lake Mead area is in southeastern Nevada, as shown in figure 1, extending from Las Vegas Valley eastward to the Arizona State line. Seven hydrographic areas are evaluated in this report: Hidden, Garnet, and Lower Moapa Valleys, California Wash area, Black Mountains and Gold Butte Areas, and Greasewood Basin, as defined by Rush and others (1968). The report area covers about 2,070 square miles. That part of Lake Mead in Nevada is part of the report area and is included on plate 1. However, because of its unique nature in relation to the hydrologic character of the southern Nevada area, the lake is not included in the hydrologic budget or any of its elements.

Lower Moapa Valley has the largest population of the hydrographic areas included in this report, and is estimated to be about 1,000. California Wash area has an estimated population of about 200, most of whom live along the Muddy River. Less than 50 people live in Garnet Valley; Hidden Valley, the Gold Butte Area, and Greasewood Basin are nearly uninhabited. Because the Black Mountains Area is mostly in the Lake Mead National Recreation area, its population is largely transient and varies with tourist and recreational activity.

Purpose and Scope of the Study

Ground-water development in Nevada has shown a substantial increase in recent years. A part of this increase is due to the effort to bring new land into cultivation, a renewed interest in mining, and a rapidly growing population. The increasing interest in ground-water development has created a substantial demand for information on ground-water resources throughout the State.

Recognizing this need, the State Legislature enacted special legislation (Chapter 181, Statutes of 1960) for beginning a series of reconnaissance studies of the ground-water resources of Nevada. As provided in the legislation, these studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the 50th report prepared as part of the reconnaissance studies (fig. 1).

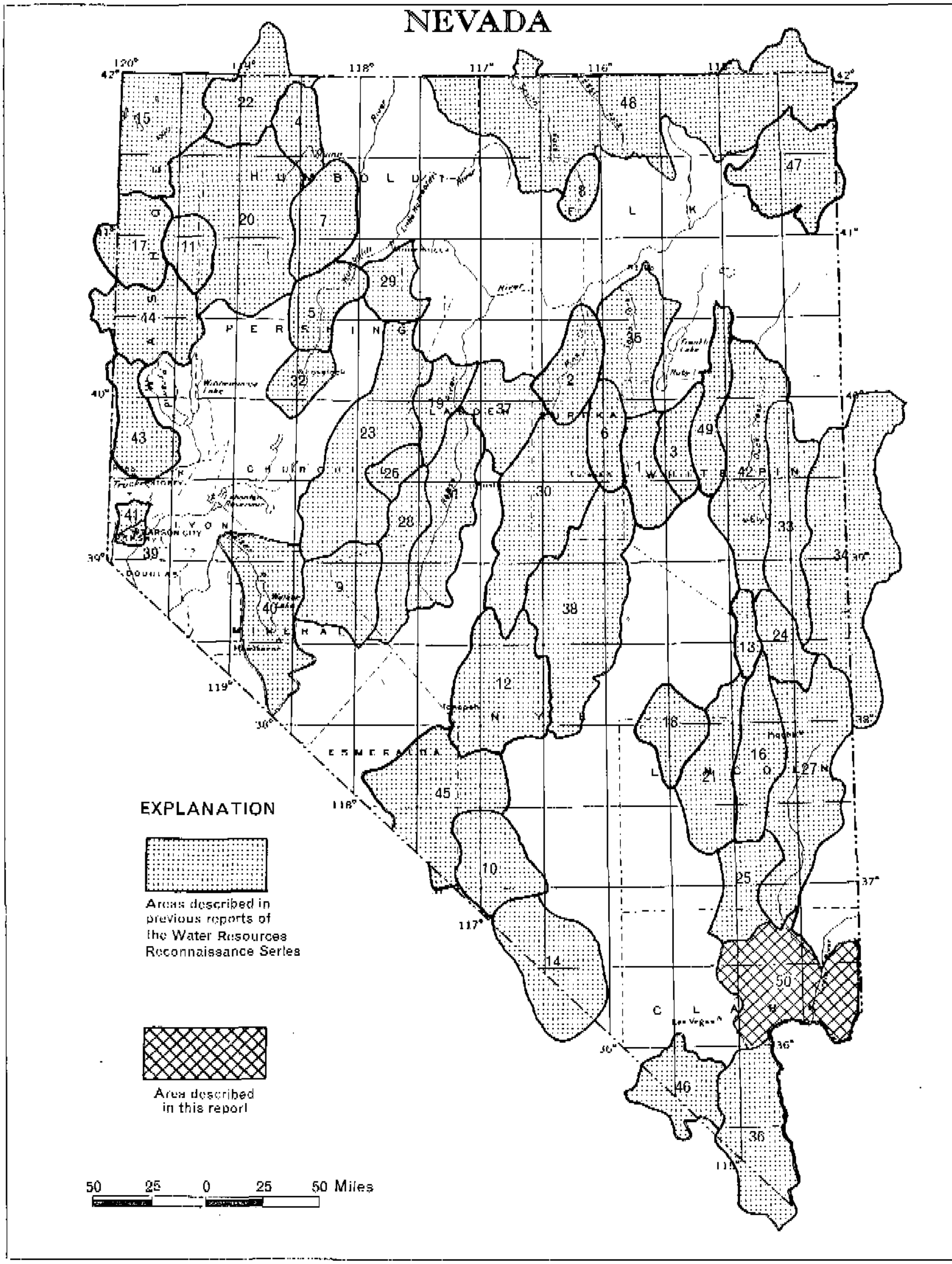


Figure 1.—Index map showing areas in Nevada described in previous reports of the Water Resources Reconnaissance Series and the area described in this report

The objectives of the reconnaissance studies and this report are to (1) describe the hydrologic environment, (2) appraise the source, occurrence, movement, and chemical quality of water in the area, (3) estimate average annual recharge to and discharge from the ground-water reservoir, (4) provide preliminary estimates of yield and ground-water storage, and (5) estimate present and evaluate potential water development in the area. The field work was done mostly during November 1967.

Previous Work

Carpenter (1915) presented a brief description of ground-water conditions of Lower Moapa Valley. The University of Nevada (1944) and Miller and others (1953) published descriptions of the water quality of Muddy River. The flow characteristics of Muddy River Springs, which are the principal source of streamflow of the Muddy River, were described by Eakin and Moore (1964). Moore (1948) reported on flood control on the lower reach of the Muddy River. Shamberger (1954) described the past and potential water use on the flood plain of the Muddy River. A plan for development of the Moapa Valley Pumping Project was presented by the U.S. Bureau of Reclamation (1962). A feasibility report on water use by a proposed power plant near Glendale was written by Bourns (1963). Eakin (1964) described the hydrology of the Muddy River Springs Area, the headwater area of the Muddy River.

Las Vegas Valley, which is tributary to Lake Mead through Las Vegas Wash and the report area, was the subject of several hydrologic studies. The most recent of these are a general analysis of the hydrology of the valley by Malmberg (1965) and a discussion of flood control on Las Vegas Wash by the U.S. Army Corps of Engineers (1967).

Lake Mead hydrology is described in several reports: Physical limnology of the lake (Anderson and Pritchard, 1951), crustal subsidence associated with the impounding of water behind Hoover Dam (Raphael, 1954), water loss (Harbeck and others, 1958), and sedimentation of the lake (Smith and others, 1960).

The geology of the Muddy Mountains was described by Longwell (1928). A guidebook of the geology from Cedar City, Utah, to Las Vegas, which includes part of the project area, was published by the Utah Geological Society (1952). Recently, a geologic map of Clark County was published (Longwell and others, 1965). Geologic cross sections of Garnet Valley were included in a report by Anderson (1966).

Soils of the flood plain of the Muddy River were mapped by Young and Carpenter (1928) and more recently by the Bureau of Reclamation (1962).

Most of the project area has been mapped as part of the 15-minute topographic quadrangle series (scale about 1 inch to the mile) of the Topographic Division, U.S. Geological Survey. The maps include Arrow Canyon, Dry Lake, Gass Peak, Gold Butte, Hayfork Peak, Henderson, Hoover Dam, Iceberg Canyon, Las Vegas, Moapa, Muddy Peak, Overton, Overton Beach, Virgin Basin, and Virgin Peak.

Acknowledgments

Information was provided by many residents, companies, and agencies and was greatly appreciated: Jim Long, Bureau of Indian Affairs; Howard Pulsipher, Hidden Valley Ranch; Bill Loftis, National Park Service; Jay Whipple, Moapa Valley Water Company; Carl Marshall, Muddy Valley Irrigation Company; C. E. McClaren, Bureau of Reclamation; Jim Zornes, Nevada Power Company; Durrell Evans, Soil Conservation Service; C. C. Larkin, Union Pacific Railroad Company; Simplot Silica Products, Incorporated; Pabco Gypsum; and many land owners and water users of the area.

HYDROLOGIC ENVIRONMENT

Physiography and Drainage

The report area is in the southern part of the Great Basin. The bordering mountains trend generally northward and are separated by valleys or alluvial areas that are commonly 5 to 15 miles wide.

Of the seven hydrographic areas described in this report, Hidden and Garnet Valleys, as shown on plate 1, are topographically closed. Greasewood Basin drains to Grand Wash Bay, a small arm of Lake Mead in Arizona. Only the Nevada part of Greasewood Basin is included in this report. The other areas drain to that part of Lake Mead that is in Nevada. Streams flow into the report area from Las Vegas Valley, the Muddy River Springs Area, and Lower Meadow Valley, as shown on plate 1.

California Wash area (pl. 1 and fig. 3), is named after the drainage system that drains most of the area. It enters the Muddy River near Glendale. The Muddy River traverses the eastern part of the hydrographic area and is the source of most of the water inflow listed in the water budget (table 14). California Wash flows only in response to infrequent rainfall resulting largely from sudden, intense storms.

The subareas are bounded by low- to medium-altitude mountain ranges, as shown on plate 1. The highest peaks are in the Virgin Mountains (altitude about 8,000 feet) and the Las Vegas Range (altitude about 7,000 feet). Present topographic relief is largely the result of movement along many faults, some of which are shown on plate 1, erosion forming canyons, and volcanic activity. Table 1 summarizes the general topography features of the area.

Three major geomorphic units are recognized in the area: Complexly folded and faulted mountain ranges, valley floors, and aprons or intermediate slopes between the mountains and the valley floors. The aprons include both alluvial fans and pediments. Pediments are erosional surfaces cut on bedrock but commonly are mantled with a veneer of alluvium ranging in thickness from a few to several tens of feet. By contrast, the alluvial fans are underlain by thick deposits of alluvium deposited by runoff from the mountains.

Pediments have formed in many parts of the report area. For example, pediments occur in much of the area shown as alluvium on plate 1 in Greasewood Basin (T. 17 N., Rs. 70 and 71 E.), in T. 17 N., R. 66 E., and in T. 19 N., R. 64 E.

Table 1.--General topographic features

Hydrographic area	Area (square miles)				Adjoining mountains (altitude in feet)	Valley floor (altitude in feet)	Average relief (feet)	Consolidated rock-alluvium contact (altitude in feet)
	Consolidated rock	Alluvium	Lake Mead[1]	Total				
Hidden Valley	38	35	0	73	3,000-7,000	2,650-2,720	4,000	2,700-4,000
Garnet Valley	52	115	0	167	3,000-7,000	1,970-2,000	5,000	2,100-4,200
California Wash area	85	240	0	325	3,000-5,000	1,500-2,200	3,000	1,600-3,800
Lower Moapa Valley	53	183	0	236	3,000-6,000	1,250-1,400	4,000	1,600-4,000
Black Mountains Area	230	307	90	627	3,000-5,000	a 1,221	3,000	1,200-3,400
Gold Butte Area	233	240	55	528	2,000-8,000	a 1,221	6,000	1,200-4,000
Greasewood Basin	70	43	1	114	3,000-8,000	a 1,221	6,000	2,200-4,100

a. No valley floor present; number is altitude of lowest alluvial area at maximum Lake Mead level.

1. Area of lake at maximum stage within Nevada and adjacent to valley or area shown.

Snyder and others (1964) have prepared a map that shows Pleistocene lakes in Hidden and Garnet Valleys. The lakes essentially were confined to the vicinity of present playas.

The climate of the area is characterized by arid conditions, long, hot summers, and mild winters. Precipitation and growing season are discussed below.

Geologic Units and Structural Features

Rocks of the report area are divided into four lithologic units: Noncarbonate rocks, carbonate rocks, older alluvium, and younger alluvium. This division is based largely on their hydrologic properties; however, the hydrologic properties of all four types may vary widely with differences in their physical and chemical properties. The areal extent of the units is shown on plate 1. The geology is based principally on the Clark County geologic map of Longwell and others (1965) and on aerial-photo and drillers'-log interpretations.

Noncarbonate and carbonate rocks form the mountain masses and underlie the younger and older alluvium at depth. The carbonate rocks, Cambrian to Triassic in age, are mostly limestone, although Longwell and others (1965) mapped some dolomite. As shown on plate 1, carbonate rocks dominate in most of the mountain ranges, except the River, Hiller, Black Mountains, and Hells Kitchen.

In Nevada, carbonate rocks commonly contain fractures and solution channels, and therefore the carbonate rocks of this area probably are capable locally of transmitting water through mountain blocks from one basin to another.

Noncarbonate rocks, Precambrian to Tertiary in age, are mostly volcanic flows and tuff, gneiss, schist, granite, and sandstone. The River and Black Mountains are mostly volcanic flows and tuff, whereas Hells Kitchen and the Hiller Mountains are mostly gneiss, schist, and granite. The noncarbonate rocks are less susceptible to solution than carbonate rocks and are generally much less permeable.

Older alluvium, Cretaceous (?) to Pleistocene in age, is composed mostly of clay, silt, sand, and gravel formed from debris washed from the adjacent mountains. This unit includes the Muddy Creek Formation, which contains abundant gypsum, and alluvium of Pleistocene (?) age that is moderately dissected. Older alluvium underlies much of the aprons and valley floors. These deposits are characteristically semiconsolidated, dissected, poorly sorted, and locally deformed.

Younger alluvium, in contrast to older alluvium, generally is unconsolidated, undissected, moderately well sorted, and undeformed. It is Quaternary in age and is composed of sand, silt, and clay deposited by the principal streams on the valley floors as shown on plate 1. Younger alluvium also underlies playa; the deposits are of late Pleistocene and Holocene (Recent) age. The coarse-grained material of the younger alluvium probably is more porous and more permeable than older alluvium.

Faults have been mapped by Longwell and others (1965) and by the writer from aerial photos. Only those that cut older alluvium are shown on plate 1.

VALLEY-FILL RESERVOIRS

General Characteristics

Younger and older alluvium of the valleys (pl. 1) form the valley-fill reservoirs and, except for the large springs flowing from carbonate rocks, is the principal source of ground water in the area. Few deep wells have been drilled; therefore, little is known about the thicknesses of the valley-fill reservoirs. The reservoirs beneath most valley floors probably are at least 600 feet thick (Longwell, 1928, p. 90). Although bedrock reportedly has been encountered in wells at shallower depths, these wells, such as well 17/64-21c (table 20) were near the bedrock-alluvium contact where the valley-fill reservoirs are generally thin. A well (17/64-19bd, table 20) was drilled to a depth of 1,500 feet near the center of the playa in Garnet Valley and encountered clay, gypsum, and sand. However, a nearby well (17/63-14dd, table 20) penetrated limestone at a depth of 958 feet.

External hydraulic boundaries are formed by the consolidated rocks (pl. 1), which underlie and form the sides of the valley-fill reservoirs, live streams and lakes, such as the Muddy River and Lake Mead. The consolidated rocks, particularly the carbonate rocks, are leaky in that they may transmit moderate amounts of recharge from the mountains to the valley-fill reservoirs by subsurface flow.

The principal internal hydraulic boundaries are the faults cutting the valley fill, as shown on plate 1, and lithologic changes. The extent to which these potential barriers impede ground-water flow probably will not be determined until substantial ground-water development occurs.

Transmissibility of the valley-fill reservoirs has not been measured at any sites, but has been estimated at sites of inter-basin flow. However, it is assumed that the lake and playa deposits in Hidden and Garnet Valleys have very low coefficients of transmissibility, but beneath these beds, more permeable beds may be present. Older alluvium probably has a wide range in transmissiblity. The finer grained, poorly sorted, or partially cemented materials of the older alluvium have low coefficients. The saturated coarser grained and better sorted materials, where not cemented, probably form productive aquifers. However, much of the older alluvium is Muddy Creek Formation, which generally is a poor aquifer. Younger alluvium (pl. 1), where it has accumulated to a sufficient thickness and is saturated, probably contains the best aquifers of the area.

Water levels in Lower Moapa Valley, along the Muddy River in California Wash area, along the shores of Lake Mead, and along the banks of Las Vegas Wash probably are higher than they were under native conditions, because of the new ground-water base level created by Lake Mead. Carpenter (1915) lists two wells in an area of Lower Moapa Valley now flooded by Lake Mead. A dug well, 16/68-33, had a depth to water of 20.4 feet, and a drilled well 805 feet deep at St. Thomas (probably in 17/68-10d) first struck water at 30 feet but was cased out with a final depth to water of 284 feet (neither well is shown on pl. 1). These measurements were made in 1912. Today, on the flood plain of the Muddy River in the report area, no depths to water probably are as great as 20 feet.

At St. Thomas, the apparent loss of head with depth would imply that water was moving downward in that area and then laterally, probably to the Colorado River. The deep-well site was probably at an altitude of about 1,150 feet; the water level would have been about at an altitude of 870 feet. This is much lower than the Virgin River, about 3 miles southeast, that was flowing on a flood plain at altitude 1,100 feet. In fact, the Virgin River did not reach an altitude of 870 feet until 8 miles north of its mouth or about 18 miles downstream from St. Thomas. The circulation system that causes the loss of head at St. Thomas may also have reduced the flow of the Virgin River in the same area, the water reappearing again at the surface along the channel of the Colorado River, the regions former discharge level. A spring at the Syphus Ranch (about 19/68-16), as shown by Carpenter, may have been a discharge point for the system, but this writer's estimated altitude of the spring (about 920 feet) is too high to discharge the system related to the St. Thomas area. The water quality of this spring and of the deep well at St. Thomas were similar, as listed by Carpenter (1915, p. 30). Elsewhere in the report area, near native conditions prevail. Pumping of wells has had a negligible effect throughout the area.

The rocks in the area contain mostly calcium and magnesium carbonates and silicate minerals. In addition, Longwell and others (1965, Appendix A and B) list many metallic and nonmetallic mineral deposits in the area, including: Metallic sulfides in the Gold Butte Area, borate deposits in the Black Mountains Area, gypsum beds, the most extensive of which are in the Black Mountains Area, and salt (halite) deposits, now inundated, along the Overton Arm of Lake Mead. These minerals, therefore, provide a ready source for most of the dissolved constituents in the ground water of the area.

Ground-Water Flow

Within the valley-fill reservoirs, ground water flows from areas of recharge to areas of discharge. The reservoirs are recharged in five ways: (1) seepage loss from local and interbasin streams into alluvium, (2) local underflow from consolidated rocks of the mountains to valley-fill reservoirs, (3) leakage beneath topographic divides from one basin to another, (4) precipitation on alluvial areas, and (5) inflow from Lake Mead. Locally, water may enter consolidated rocks from alluvium or streams. Local streamflow and underflow have as a source, precipitation within the drainage areas, as defined by the topographic divides shown on plate 1. Most of these recharge quantities are attributed to precipitation on the mountains. Interbasin streamflow and the third type of recharge originate as precipitation beyond a drainage divide and enter an area as underflow either through consolidated rocks or alluvium and (or) as streamflow. Type 4 is considered to be very small and in this part of Nevada, probably not an important source. Inflow from Lake Mead (type 5) to adjacent ground-water reservoirs occurs only when the lake stage is rising.

All the areas included in this report apparently drain in the subsurface to either the Muddy River or directly to Lake Mead, as shown in figure 2. Hidden Valley probably drains to Garnet Valley, which in turn probably drains eastward to California Wash, as shown in figure 2. Subsurface drainage may be both northeastward from California Wash Area toward the Muddy River and southeastward toward Lake Mead, as shown on figure 2. Ground water may enter the report area at several places: (1) along Meadow Valley Wash, flowing through alluvium, (2) along the Muddy River, flowing through alluvium, and (3) from Las Vegas Valley, near Lake Mead Base (Loeltz, 1963, fig. 2), flowing through carbonate rocks, and (4) from Las Vegas Valley, along Las Vegas Wash flowing through alluvium. All these flow quantities probably are small.

Because of the abundance of carbonate rocks in the area and the possibility that they may take water from or yield water to the perennial streams, the Muddy River was gaged with flow meters at several locations near White Narrows and Jackman Narrows, as shown on plate 1. On February 5, 1968, just above White Narrows at 14/65-26ca, the gaged flow was 46.6 cfs (cubic feet per second). Just below the narrows at 14/65-26dc, a second measurement was made within a few minutes; the flow was gaged at 48.3 cfs, or nearly 2 cfs larger. This apparent increase in flow may be caused by either or both of two conditions: (1) small cross sectional area of transmissive younger alluvium at the narrows, reducing the amount of water that can flow in the subsurface

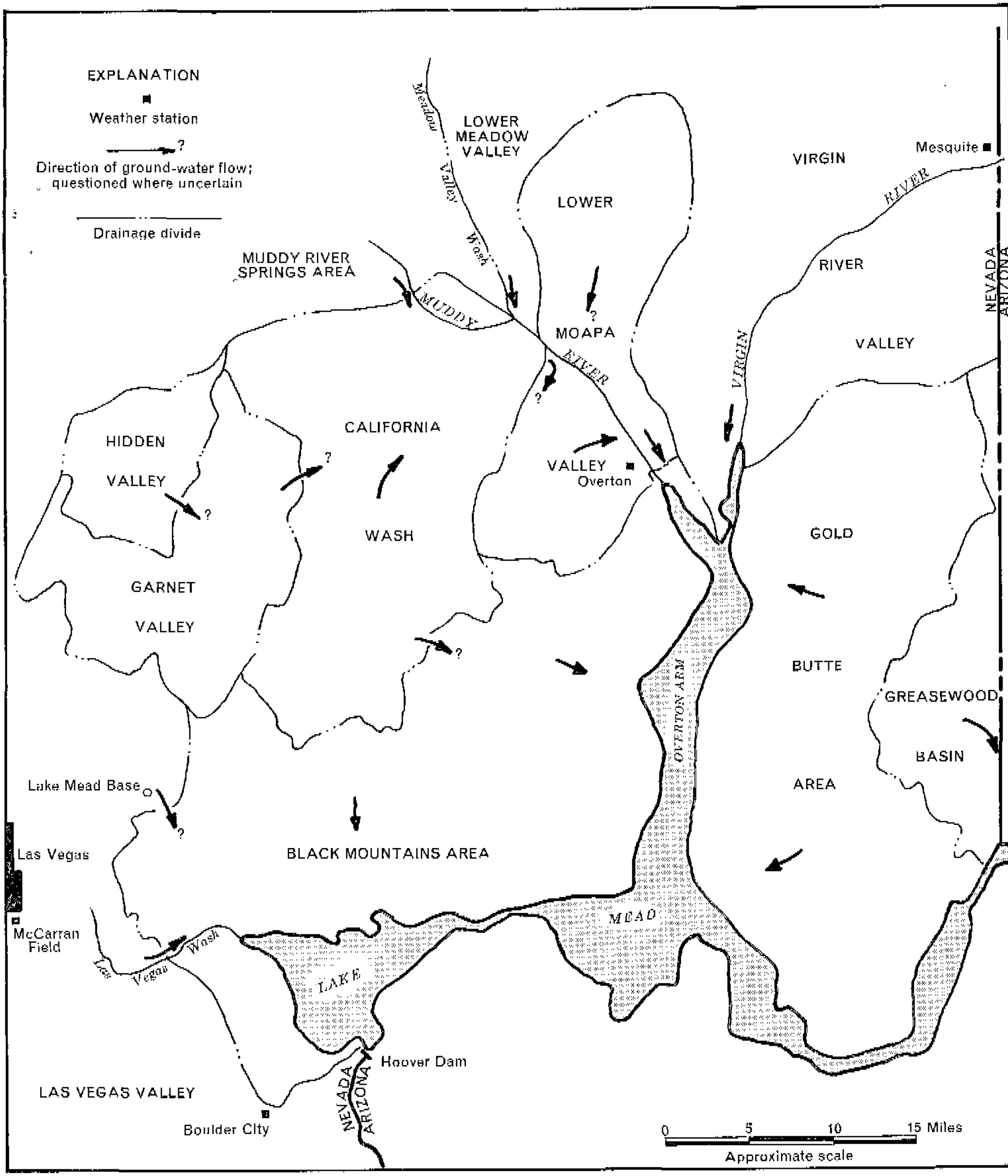


Figure 2.—Location of nearby weather stations and direction of ground-water flow

and causing this water to move into the stream channel between the gage sites; (2) migration of water from underlying carbonate rocks through alluvium to the Muddy River. The second explanation is favored by the writer.

Farther downstream near Jackman Narrows, measurements were made at three sites on February 6, 1968. At the most upstream site near Glendale, at 15/66-2aa, the gaged flow was 48 cfs. At the narrows, 15/67-7ca, the flow was 54 cfs, and downstream about one mile, at 15/67-17bd, the flow was 47.8 cfs. The apparent increase in flow above the narrows probably is caused by contribution to streamflow from ground-water sources. Whether this water is transmitted to this reach of the river by consolidated rocks or alluvium is not known, but because the increase is possibly 6 cfs (about 4,300 acre-feet on a yearly basis), it must be water draining from a large area. Below the narrows the flow apparently decreases by about 6 cfs. Because the alluvium along this reach of the river is limited to a canyon that is less than a quarter of a mile wide and therefore probably not able to transmit large quantities of ground water, it is likely that water enters carbonate rocks. If more detailed gaging were done elsewhere on the Muddy River, similar conditions might be discovered. However, extensive seepage runs on the Muddy River were beyond the scope of this study.

INFLOW TO THE VALLEY-FILL RESERVOIRS

Inflow to the valley-fill reservoirs is estimated by reconnaissance techniques developed by the Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. The components of inflow to the valley-fill reservoirs include precipitation, surface-water runoff, subsurface inflow through alluvium and carbonate rocks, and importation of water (table 14). Lake Mead is not included in the hydraulic budget of the area.

Precipitation

The precipitation pattern in Nevada is related principally to the topography; the weather stations at higher altitudes generally receive more precipitation than those at lower altitudes (Hardman, 1965). However, this relation may be considerably modified by local conditions. The valley floors of the report area probably receive an average of only about 3 to 5 inches of precipitation per year, whereas the highest mountain areas may have an average annual precipitation of 12 inches or more. Figure 3 demonstrates the increase in precipitation with altitude.

Nearby weather stations at Mesquite, Boulder City, Overton, and McCarran Field at Las Vegas are shown in figure 2. Five more remote stations have the following locations:

Littlefield, Arizona, 10 miles northeast of Mesquite
Carp, 30 miles north of Glendale
Desert National Wildlife Range, 22 miles northwest of Las Vegas
Mount Trumbull, 50 miles southeast of Mesquite
Hidden Forest Camp, 32 miles north of Las Vegas

Using the data recorded at these nine stations, an altitude-precipitation relation, as shown by the dashed line in figure 3, was identified. This relation is used as a basis to compute estimated average annual precipitation and ground-water recharge in table 6.

On valley floors and aprons, where the average annual precipitation is small, little precipitation directly infiltrates into ground-water reservoirs. Most precipitation is evaporated before infiltration and some adds to soil moisture. However, intense precipitation during thunderstorms may supply infrequent recharge. Greater precipitation in the mountains provides most of the recharge and runoff.

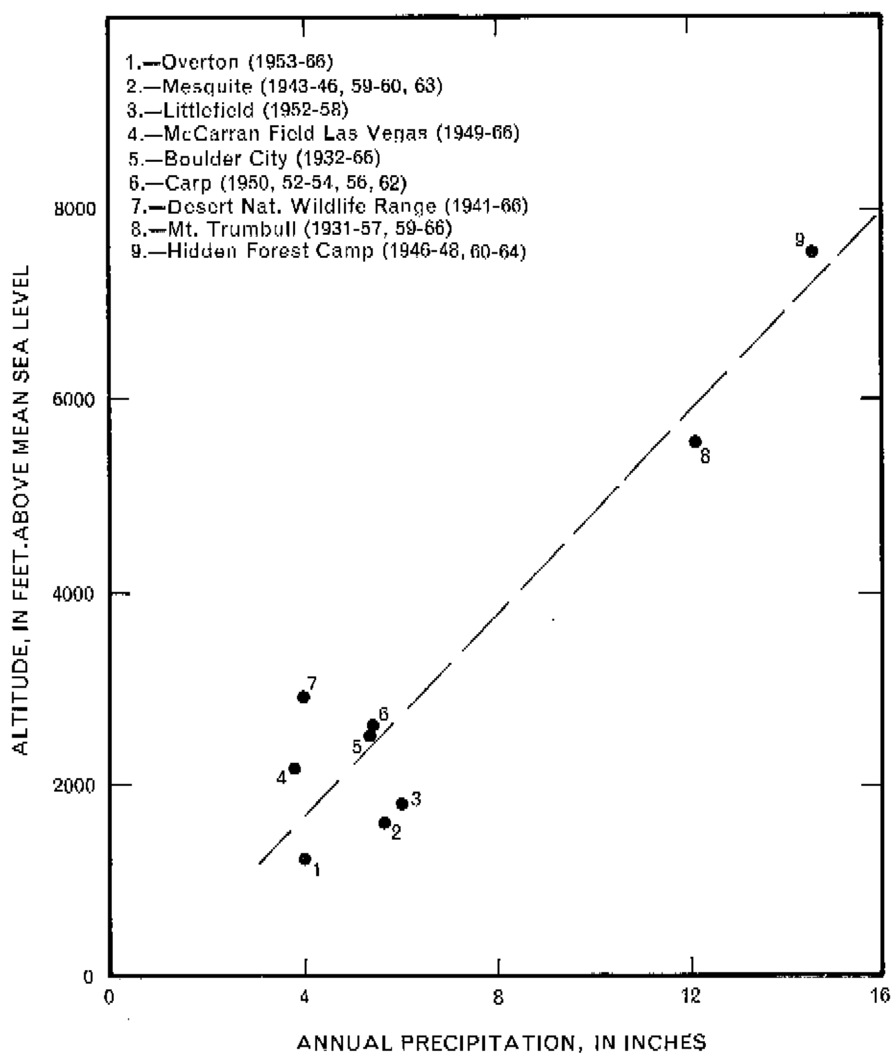


Figure 3.—Relation between precipitation and altitude in and adjacent to the study area. Data for the various periods of full-year record have been adjusted to long-term averages for the period 1931-66.

Surface Water

By D. O. Moore

The dominant hydrologic feature of the area is Lake Mead. The lake was formed behind Hoover Dam, when the bypass gates were closed in 1935. With water level at the spillway, altitude 1,221 feet, the maximum depth of the reservoir would be 571 feet at the dam; the water-surface area would be 164,000 acres, and the reservoir capacity would be 29,680,000 acre-feet (Ames and others, 1960, p. 87-91). The weight of Lake Mead, about 40 billion tons at spillway level, has caused settlement of the general area, which by 1950 had reached a maximum of 7 inches (Raphael, 1954). This settlement is still continuing, but at decreasing rate; the total may eventually reach 10 inches.

Water from Lake Mead infiltrates into the adjoining rocks and sediments, causing a local rise in ground-water levels. Langbein (1960, p. 100-102) estimates that bank storage amounts to an average of about 12 percent more than Lake Mead capacity at any given stage.

The flood plain of the Muddy River is well watered because of irrigation by water from the Muddy River, a perennial stream. Las Vegas Wash, in the report area, is also perennial. The remaining parts of the report area have a few short perennial streams where they are springfed.

The Muddy River has been gaged at five different sites within the report area. Only one of these gages, Muddy River near Glendale, is still in operation. This gage is at Jackman Narrows (15/67-7ca, pl. 1) and has been operated from April through October 1910, July 1913 to February 1914, and from February 1950 to the present time. The location and period of record for the four discontinued gages on the Muddy River are as follows:

(1) Muddy River at railroad pumping plant (15/66-6d). Operated from 1904 to 1906 and 1914 to 1917.

(2) Muddy River above Moapa Indian Reservation (14/65-26c). This gage was operated from 1914 to 1918.

(3) Muddy River at Weiser Ranch (15/66-2bd). Operated from 1915 to 1917.

(4) Muddy River near Overton (15/67-21ab). Operated intermittently from 1913 to 1954.

Las Vegas Wash (near Henderson) is gaged about 3 miles upstream from the boundary for this report at 21/63-30cd. Records have been obtained at this site starting in 1957 and continuing at this writing.

Runoff

Surface-water runoff in ephemeral channels of the report area is variable with season and year. Because no records of gaged streamflow on ephemeral channels of the area are available, records of a nearby stream are used to show the general intermittent flow character. Table 2 shows the flow volume and flow duration for Las Vegas Wash at North Las Vegas, about 5 miles west of the area boundary, during the period June 1962-September 1966.

The amount of runoff from the mountains that reaches the valley-fill reservoirs cannot be computed directly because of the absence of sufficient streamflow data in the area. Therefore, methods that were devised by Moore (1968) are used for estimating the runoff-altitude relations and the relation between channel geometry and mean annual runoff in areas where little or no streamflow data are available. Runoff can be estimated using these relations.

The estimated mean annual runoff to valley-fill reservoirs is summarized in table 3. Only about 2 percent of the report area is assumed to contribute appreciably to runoff. Occasional runoff may be locally developed on valley floors and aprons, but this type of runoff generally is so erratic in frequency and duration that it has little value for economic development.

Inflow of Streams

Muddy River, Meadow Valley Wash, and Las Vegas Wash carry surface water into the report area. The Muddy River also flows through two of the hydrographic areas, California Wash and Lower Moapa Valley, to Lake Mead. At the gage on Las Vegas Wash (21/63-30cd), the flow rate is generally between 10 and 30 cfs for the period of record but had been as high as 1,400 cfs. Most of the low flow is water previously used in Las Vegas Valley. For the gage site on the Muddy River at Jackman Narrows (15/67-7ca) during the period of record 1950-67, the flow rate generally was between 30 and 50 cfs, but reached a recorded peak flow of 7,380 cfs on November 6, 1960. The low flow is mostly from springs in the Muddy River Springs Area, north of California Wash Area (pl. 1). The mean annual discharges of the Muddy River and Las Vegas Wash are listed in table 4.

Table 2.--Flow volume and duration for Las Vegas Wash at North Las Vegas, June 1962-September 1966

Period[1]	Flow (acre-feet)	Duration (days)
1962		
August	8.7	11
1963		
April	1.2	2
May	1.4	2
June	14.0	2
September	181.	2
1965		
April	41.3	3
November	34.	1

1. No flow was recorded during unlisted months.

Table 3.--Estimated average annual runoff from mountains

Area	Runoff area (acres)	Runoff (acre-feet)
Hidden Valley	7,410	500
Garnet Valley	4,170	300
California Wash area[1]	150	<50
Lower Moapa Valley	610	<50
Black Mountains Area	310	<50
Gold Butte Area	11,900	900
Greasewood Basin	5,720	500

1. California Wash area has been the source area of many floods; these floods generally originate on alluvial areas rather than in the mountains.

Table 4.--Mean annual discharge of the Muddy River and Las Vegas Wash

Year	Gaged discharge in acre-feet per year	
	Muddy River at 15/67-7ca	Las Vegas Wash at 21/63-30cd
1951	32,450	--
1952	39,600	--
1953	32,420	--
1954	32,140	--
1955	39,130	--
1956	31,500	--
1957	36,900	--
1958	33,450	15,200
1959	32,760	15,390
1960	42,070	14,490
1961	34,310	14,370
1962	31,150	12,230
1963	28,910	15,493
1964	29,270	16,028
1965	31,980	18,220
1966	30,810	19,170
1967	32,030	19,160
Average (rounded)	33,600	16,000

The estimated average annual surface-water flows between the valleys of the report area are listed in table 5; they are based on streamflow records from gages and measurements made of flow at several sites during the fall of 1967 and winter of 1968. Obviously, inflow to one area is outflow from another.

Ground Water

Recharge from Precipitation

Water enters valley-fill reservoirs from local precipitation, by seepage loss from streams, and by local underflow through consolidated rocks. The amount of underflow generated within each area and flowing to valley-fill reservoirs from consolidated rocks is not known, but probably is a small part of the total recharge.

A method described by Eakin and others (1951, p. 79-81) is used to estimate recharge. The method assumes that a percentage of the average annual precipitation may recharge the ground-water reservoirs, principally by seepage loss from streams.

Table 6 shows the values used to estimate precipitation and ground-water recharge in the area. The estimates of recharge for the areas generally are less than 1 percent of the estimates of total precipitation. These percentages generally are smaller than the amounts usually found by this method for desert valleys of Nevada, where estimated recharge commonly range between 2 and 5 percent of estimated total precipitation. The lower amounts computed for the report area are due to the general lack of large areas of substantial precipitation which occur largely above an altitude of 4,000 feet.

Subsurface Inflow

Ground water probably is transmitted between areas through consolidated rocks and alluvium, as suggested in figure 2. Table 7 summarizes the estimated average annual subsurface inflow and outflow of the report area.

Importation of Water

Water is imported to the California Wash Area from the Muddy River Springs Area. In 1967, Nevada Power Company reported that it had rights to and consumed water at the Reid-Gardner generating plant from two sources: (1) about 1,800 acre-feet transported in a pipeline from five wells in the Muddy River Springs Area, (2) about 300 acre-feet from the Muddy River, diverted near the plant site (not imported). In late 1968, the Nevada Power Company plans

Table 5.--Estimated average annual surface-water flow between hydrographic areas

Outflow[1] from	Inflow[2] to	Stream	Location	Estimated average annual quantity (acre-feet)
Muddy River Springs Area	California Wash Area	Muddy River	White Narrows	a 33,000
Lower Meadow Valley	California Wash Area	Meadow Valley Wash	Glendale	b 400
Total (rounded)				33,000
California Wash Area	Lower Moapa Valley	Muddy River	Jackman Narrows	34,000
Las Vegas Valley	Black Mountains Area	Las Vegas Wash	At area boundary	12,000
Lower Moapa Valley	Lake Mead	Muddy River	At river mouth	c 10,000±
Black Mountains Area	Lake Mead[3]	Las Vegas Wash and numerous washes	At shoreline	10,000
Gold Butte Area	Lake Mead[3]	Numerous washes	do.	Small
Greasewood Basin	Arizona	do.	At State line	Small

1. No streamflow out of Hidden and Garnet Valleys.
2. No streamflow into Hidden and Garnet Valleys, Gold Butte Area, and Greasewood Basin.
3. For the purposes of this report, the shoreline of Lake Mead is taken as of an altitude of 1,200 feet. On February 1, 1968 the actual altitude of the lake surface was 1,123 feet (U.S. Bureau of Reclamation, oral commun.).

a. From Eakin (1964).
b. From Rush (1964).
c. Rough approximation based on few data gathered in 1967.

Table 6.--Estimated average annual precipitation and ground-water recharge

Precipitation zone (feet)	Area (acres)	Estimated precipitation			Estimated recharge	
		Range (inches)	Average (feet)	Average (acre-feet)	Percentage of precipitation	acre-feet
				HIDDEN VALLEY		
>6,000	1,390	>12	1.1	1,500	7	100
4,000-6,000	12,350	8-12	.8	9,900	3	300
<4,000	33,200	<8	.5	17,000	Minor	--
Total (rounded)	46,900			28,000		400
				GARNET VALLEY		
>6,000	1,080	>12	1.1	1,200	7	80
4,000-6,000	11,740	8-12	.8	9,400	3	280
<4,000	94,500	<8	.5	47,000	Minor	--
Total (rounded)	107,000			58,000		400
				CALIFORNIA WASH AREA		
>4,000	2,470	>8	.8	2,000	3	60
<4,000	206,000	<8	.5	100,000	Minor	--
Total (rounded)	208,000			100,000		<100
				LOWER MOAPA VALLEY		
>6,000	150	>12	1.1	160	7	10
4,000-6,000	1,230	8-12	.8	1,000	3	30
<4,000	150,000	<8	.5	75,000	Minor	--
Total (rounded)	151,000			76,000		<50
				BLACK MOUNTAINS AREA[1]		
>4,000	2,780	>8	.8	2,200	3	70
<4,000	398,000	<8	.5	200,000	Minor	--
Total (rounded)	401,000			200,000		<100
				GOLD BUTTE AREA[1]		
>6,000	4,170	>12	1.1	4,600	7	320
4,000-6,000	28,700	8-12	.8	23,000	3	690
<4,000	306,000	<8	.5	150,000	Minor	--
Total (rounded)	339,000			180,000		1,000
				GREASEWOOD BASIN[1]		
>6,000	2,630	>12	1.1	2,900	7	200
4,000-6,000	14,400	8-12	.8	12,000	3	360
<4,000	55,700	<8	.5	28,000	Minor	--
Total (rounded)	72,700			43,000		600

1. The part of the area which is Lake Mead covers 93,300 acres and receives an average annual precipitation of about 46,000 acre-feet.

Table 7.--Estimated average annual subsurface flow between areas

Outflow from	Inflow to[1]	Location	Probable transmitting lithology	Estimated flow width (miles) (W)	Estimated hydraulic gradient (feet per mile) (I)	Estimated coefficient of transmissibility (gpd per foot) (T)	Estimated inflow[2] (acre-feet per year) (Q)
Garnet Valley	California Wash area	16/64, 17/64	Carbonate rock and alluvium	--	--	--	a 800
Muddy River Springs Area	California Wash area	White Narrows	Alluvium	--	--	--	Small[3]
Lower Meadow Valley	California Wash area	Glendale	Alluvium	--	--	--	b 7,000
	Total (rounded)						8,000
Las Vegas Valley	Black Mountains Area	20/63-7	Carbonate rock	c 1	c 15	c 1,000	d 20
Las Vegas Valley	Black Mountains Area	21/63-22	Alluvium	.5	e 80	10,000	<400
	Total (rounded)						400
Black Mountains Area	Lake Mead	At shore-line	Noncarbonate rock and alluvium	--	--	--	f <100
Gold Butte Area	Lake Mead	do.	do.	--	--	--	f 1,000
	Total (rounded)						1,000
Hidden Valley	Garnet Valley	16/63	Carbonate rock	--	--	--	f 400
California Wash area	Lower Moapa Valley	Jackman Narrows	Alluvium	--	--	--	Small
Lower Moapa Valley	Lake Mead	16/68	Alluvium	1	e 20	50,000	1,100
Greasewood Basin	Arizona	At State line	Alluvium	--	--	--	f 600

Footnotes for table 7.

1. No ground-water underflows to Hidden Valley, Gold Butte Area, and Greasewood Basin.

2. Q = 0.00112 TIW; 0.00112 converts gallons per day to acre-feet per year.

3. Estimated by Eakin (1964, p. 24).

a. Not computed; assumed to be equal to ground-water recharge (table 9) plus subsurface flow from Hidden Valley to Garnet Valley.

b. Rush (1964, p. 24) estimates that for the Meadow Valley area subsurface outflow plus evaporation from wet areas during the nongrowing season is 7,000 acre-feet per year. Nearly all this quantity probably is subsurface inflow to California Wash.

c. Based on data compiled by Loeltz (1963, p. Q9 and Q10).

d. This outflow from Las Vegas Valley may not occur. Loeltz (1963, p. Q5) states that if this subsurface outflow occurs, the quantity of water is very small.

e. Gradient is assumed to be about equal to the slope of the land surface.

f. Not computed; assumed to be equal to ground-water recharge, table 9.

to start utilizing water from a third source, diversion of 2,000 acre-feet from the Muddy River at a site in the Muddy River Springs Area and imported to the generating station by pipeline. The power company reports that this diversion will be made only in the winter. At the generating station, the water is consumed principally by evaporation from cooling towers.

Moapa Valley Water Company reportedly imported about 520 acre-feet of water in 1967 from springs in the Muddy River Springs Area. The water was used for domestic, public supply, and stockwatering purposes along the flood plain of the Muddy River in the California Wash area and Lower Moapa Valley. Part of the used water percolates from septic disposal systems and artificially recharges the ground-water reservoirs. Table 8 summarizes the utilization of this imported water.

Water is imported into California Wash area, Lower Moapa Valley, and Garnet Valley, and the Black Mountains Area. A small amount of drinking water is hauled to Valley of Fire State Park in the Black Mountains Area from Lower Moapa Valley and to a mining facility at Arrolime in Garnet Valley from Las Vegas Valley. At Boulder Beach, Las Vegas Beach, Callville Bay, and Echo Bay, water from Lake Mead is pumped to recreational facilities along the shore for public supply. The net pumpage (consumption) of lake water at these sites in 1967 probably was on the order of 100 acre-feet. In addition, in 1967 about 275 acre-feet of lake water was piped to the Pabco Gypsum plant at 20/64-18b and consumed in manufacturing gypsum products.

Table 8.--Utilization of water imported by Moapa Valley Water Company, 1967

	Lower Moapa Valley (acre-feet)	California Wash area (acre-feet)	Total (acre-feet)
Import for public supply	370	150	520
Consumed[1]	270	100	370
Percolates to water table[1,2]	100	50	150

1. Estimates by author; based on estimates by local residents of population and number of head of livestock.

2. Becomes artificial recharge.

OUTFLOW FROM THE VALLEY-FILL RESERVOIRS

The components of outflow are surface irrigation and sub-irrigation, industrial use, evaporation from surface-water bodies, streamflow, evapotranspiration of ground water, pumpage, subsurface outflow, export, and public supply use. Outflow of streams, subsurface outflow, export, and public supply has been estimated in earlier sections (tables 5, 7, 8, and p. 28).

Irrigation

Growing Season

Air temperature is a major factor in determining the length of the growing season and is of interest to farmers and ranchers. Other factors, such as wind movement, amount of daytime hours, exposure and location of field, and type of crop are important, but their consideration is beyond the scope of this report. Temperature data can be used as a rough guide in estimating the growing-season length.

Temperature data for Overton and Las Vegas Airport were used to illustrate the period between the fall and spring temperature of 28°F, a temperature at which killing frosts may occur, and are summarized in table 9. Although the periods ranged from 173 to 298 days at Overton, most years they were between 240 and 270 days. The data for Overton probably are representative of the Muddy River flood plain, the principal area of irrigation.

Water Consumption

In California Wash area and Lower Moapa Valley, the Muddy River is diverted for irrigation on its flood plain. Additional supplemental water is provided by a shallow water table that is reached by plant roots and by an irrigation well (15/66-1dd) on the Lewis Ranch. In California Wash Area, the flood plain ranges from about a quarter to three-quarters of a mile wide and has a length of about 9 miles. About a third of the flood plain is irrigated; the remainder is uncultivated and commonly covered by phreatophytes. (See "Evapotranspiration" section.) Irrigation is localized in three areas: (1) Moapa Indian Reservation, (2) Hidden Valley Ranch, and (3) Lewis Ranch.

In Lower Moapa Valley, the flood plain of the Muddy River ranges from about three-quarters to one and a quarter miles wide and is about 9 miles long. Most of the irrigated cropland is north of Overton where about three-fourths of the flood plain is irrigated. At Overton and southeast to Lake Mead, only a few

Table 9.--Length of period between air temperature of 28°F

Weather station	Location	Period (years)	Minimum recorded (days)	Maximum recorded (days)	Average (days)
Las Vegas Airport	20/61-34	1948-66	232	313	275
Overton	16/68-19	1948-66	173	298	255

small areas of cropland are irrigated. The irrigated areas are not shown on plate 1, but are limited to areas shown as younger alluvium along the Muddy River (pl. 1). Water is diverted into a complex system of ditches. Some water is temporarily stored in Bowman Reservoir, which in the fall of 1967 was being enlarged from a reported capacity of about 1,000 acre-feet to about 4,000 acre-feet. At the downstream end of the Muddy River flood plain, the State Fish and Wildlife Commission maintains the Overton Wildlife Management Area, part of which is irrigated with water from the Muddy River, from a shallow water table, and from irrigation wells. Grass is the main vegetation in irrigated areas.

In table 10, the average consumptive-use rates for irrigated crops are based on findings of Houston and Blaney (1954), U.S. Bureau of Reclamation (1962), and Houston (1950). Factors considered in assigning use rates by these workers were length of growing season, crop, geographic location, air temperature, and length of daytime hours. Because irrigation is less than optimum in the wildlife management area, the consumptive-use rate is estimated to be about 3 feet. Table 10 summarizes the water consumption by irrigation.

Water Used for Leaching Fields

Along the Muddy River, leaching of soils to keep salts moving downward below the effective root zone of the crop is a necessary irrigation practice. Leaching requires that more water be applied to fields than is necessary to grow the crop at the salt level intended. To estimate the amount of water needed for leaching, the following equation may be used (Fuller, 1965):

$$LP = \frac{ECiw}{2\ EC_e} \times 100 \qquad (1)$$

where LP is the leaching percentage; ECiw, the specific conductance of the irrigation water; and EC_e, the specific conductance of saturated-soil-paste extract associated with 50 percent decrement of crop yield. Bernstein (1964, p. 12) lists values of salt tolerance (expressed as EC_e) for several crops. A few of these crops (and their EC_e values) are listed below:

Crop	EC_e (micromhos per cm at 25°C)
Alfalfa	8,000
Beets	11,500
Bermuda grass	18,000
Cotton	16,000
Sorghum	12,000

Table 10.--Estimated consumption of water by irrigated crops[1/]

Crop	CALIFORNIA WASH AREA: Alfalfa and grass (pasture): Moapa Indian Reservation and Hidden Valley Ranch	CALIFORNIA WASH AREA: Alfalfa and grass (pasture): Lewis Ranch	LOWER MOAPA VALLEY: Alfalfa and grass (pasture)	LOWER MOAPA VALLEY: Cane, sorghum, cotton beets, and misc. crops	LOWER MOAPA VALLEY: (Wildlife Management Area) Mainly grass
Approximate area (acres) (1)	750	250	1,500	1,500	400
Estimated water use rate on above land (feet per year):					
Surface water	4	2	4	2.5	3 (combined)
Shallow ground water[2/]	1	1	1	.5	
Pumpage from wells	0	a 2	0	0	
Total (2)	5	5	5	3	3
Estimated water use (acre-feet per year) (1) x (2)	3,750	1,250	7,500	4,500	1,200
Total (acre-feet per year)	5,000		13,000		

1. No irrigation in Hidden and Garnet Valleys, Black Mountains and Gold Butte Areas, and Greasewood Basin.

2. Most of the water is from seepage from nearby fields and ditches to a shallow water table.

a. Estimated net pumpage (crop consumption) is 500 acre-feet. Gross pumpage is computed to be about 800 acre-feet and is based on information provided by the well owner. Most of the difference percolates back to the water table.

For California Wash area, the specific conductance of irrigation water from the Muddy River may average about 1,300 micromhos. Using the EC_e value for alfalfa, the most abundant crop of the area (table 11), the computation of leaching percentage is:

$$LP = \frac{1,300 \times 100}{2 \times 8,000} = 8 \text{ percent}$$

With 60 inches of water needed to grow the crops (table 11) 65 inches have to be applied annually to the fields so that 5 inches or nearly 500 acre-feet is available for leaching.

For Lower Moapa Valley, the specific conductance of irrigation water from the river may average about 1,700 micromhos. For crops of alfalfa and grass (table 11), and using the EC_e value for alfalfa, the computation of leaching percentage is:

$$LP = \frac{1,700 \times 100}{2 \times 8,000} = 11 \text{ percent}$$

About 0.6 foot of leaching water is needed annually, or about 900 acre-feet. For the 1,500 acres of cane, sorghum, cotton, beets, and miscellaneous crops (table 11), the quantity of leaching water required annually, using EC_e of 12,000 micromhos, is about 0.25 foot, or 400 acre-feet; for the Wildlife Management Area (table 11), using EC_e of 18,000 micromhos, about 0.15 foot, or 60 acre-feet.

In summary, the annual leaching-water requirements for the irrigated land of California Wash is 500 acre-feet; for Lower Moapa Valley, nearly 1,400 acre-feet.

The leaching water is not consumed, but percolates through the soil to the water table where it migrates laterally to ditches, the Muddy River, or phreatophyte areas. Therefore, this quantity does not appear in the water budget (table 14); however, it must be available for successful farming operations.

Industrial Use

In Lower Moapa Valley, water from the Muddy River is used by Simplot Silica Products, Inc. at their two silica plants near Overton. The plant manager reports that about 160 acre-feet of water was transported by ditches to the plants in 1967 and consumed. The water was recycled through the plants many times, with a gross circulation of about 1,000 acre-feet. As described in the "Importation" section, water was imported for a gypsum plant, a power generating station, and a mining operation. Industrial use in the area totaled about 2,500 acre-feet in 1967.

Table 11.--Estimated evapotranspiration of ground water by nonbeneficial phreatophytes

Area[1]	Phreatophyte	Depth to water (feet)	Area (acres)	Ground cover (percent)	Probable average annual rate of ground-water use (feet)	Approximate discharge (acre-feet per year)
California Wash area	Mostly saltbush; some saltgrass, saltcedar, mesquite, and cottonwood	a 2-50	1,700	15-25	1	1,700
Lower Moapa Valley	Mostly saltbush and saltgrass; some saltcedar, mesquite, cottonwood, and tules	a 2-50	5,600	15-25	2	11,000
Black Mountains Area	Mostly tules and mesquite along the banks of Las Vegas Wash and near Rogers Spring	0-5	200	25-100	6	1,200
Gold Butte Area and Greasewood Basin	Cottonwood, willow, grass, and tules near small springs	0-10	Small	--	--	Small

1. In Hidden and Garnet Valleys no ground water is discharged by evapotranspiration.

a. Average depth to water is less than 10 feet.

Evapotranspiration of Ground Water by Nonbeneficial Phreatophytes

Ground water is discharged by evaporation from soil and transpiration by plants that root in shallow water-table areas. These plants that tap the ground-water reservoir are called phreatophytes. The phreatophytes essentially are limited to the flood plain of the Muddy River and in Las Vegas Wash. The principal types of phreatophytes are saltbush (shadscale), alfalfa, saltgrass, meadow grasses, saltcedar, mesquite, cottonwood, and tules. For the purpose of this report, they are divided into two groups: (1) beneficial phreatophytes, such as alfalfa and meadowgrass, have been described and are shown in table 10, and (2) nonbeneficial phreatophytes, such as saltbush and mesquite. Discharge by nonbeneficial phreatophytes is summarized in table 11. Rates used in table 11 are based on work done in other areas by Lee (1912), White (1932), Young and Blaney (1942), and Robinson (1958, 1965), and on rates used by Malmberg (1965) in Las Vegas Valley. Phreatophyte areas are not shown on plate 1, but along with irrigated fields, they generally are within the areas shown as younger alluvium along the Muddy River or elsewhere as indicated in table 11.

Evaporation from Surface-Water Bodies

Kohler and others (1959) estimate that the average annual lake evaporation for the area is about 80 inches, or nearly 7 feet per year. The evaporation from surface-water bodies is listed in table 12.

Lake Mead, at spillway level, has an area of 157,000 acres and at this level would lose by evaporation an average of about 1,000,000 acre-feet per year, or equal to nearly 10 percent of the average annual flow past Hoover Dam. Evaporation from Lake Mead is not included in table 12 or the water budget for the area.

Pumpage from Wells

Only a few wells are utilized as a source of water in the report area. Most are used to meet stock, public-supply, and domestic needs; in 1967 one irrigation well (15/66-1dd, table 19) on the Lewis Ranch was pumped. Its pumpage is listed in table 10. Lower Moapa Valley and Black Mountains Area probably have less than 10 active wells each, with a total estimated net pumpage of less than 100 acre-feet per year in each area. The Moapa Valley Water Company has two high-yield, public-supply wells (15/67-22bb1, 2, table 19), but because the water quality of these wells is marginal, they are used only to supplement the piped-in spring supply in emergencies. Not including the Lewis Ranch irrigation well, all the other valleys have fewer than five active wells

Table 12.--Evaporation from surface-water bodies

Water body[1]	Estimated average area (acres)	Average evaporation[2] (acre-feet per year)
LOWER MOAPA VALLEY		
Bowman Reservoir	a 50	350
Muddy River	10	70
Ponds, Wildlife Management Area	b 110	770
Total (rounded)	170	1,200
CALIFORNIA WASH AREA		
Muddy River	10	70
BLACK MOUNTAINS AREA		
Las Vegas Wash	10	70

1. No perennial surface-water bodies are in Hidden and Garnet Valleys, Gold Butte Area, and Greasewood Basin.

2. Estimated average annual evaporation rate is about 7 feet per year.

a. When full, reservoir has an area of about 80 acres. Average water-surface area is less.

b. Estimated by U.S. Bureau of Reclamation (1962).

with estimated net pumpages probably less than 10 acre-feet per year. Hidden Valley has only one stock well. In the Black Mountains Area, most of the pumpage is from a well at Overton Beach; no pumpage data were available from the National Park Service, the owners of the well. The well is used for public supply at the park and recreational facilities there.

Springs

Only a few large springs are in the report area. Data for these springs are summarized in table 13. Their flow, in general, supports small areas of phreatophytes but mostly seeps back to the water table. Their net discharge is included in nonbeneficial phreatophyte discharge estimates in table 11.

Springs at the consolidated rock-alluvium contact, such as Rogers and Blue Point Springs, probably flow to the surface because the alluvium at the contact is unable to receive and transmit the water as rapidly as the consolidated rocks can supply it. As a result, water flows to the surface at the contact and flows on the land surface to where it can be absorbed by the alluvium, usually not far downstream from where it first appears.

Table 13.--Selected springs[1/]

Name	Location number	Estimated flow (gpm)	Rock source	Remarks
			CALIFORNIA WASH AREA	
Hogan Spring	15/65-11cd	--	--	No information available.
			LOWER MOAPA VALLEY	
Unnamed spring	Uncertain	Small	Older alluvium	Along Magnesite Wash (Longwell, 1928, p. 17).
Perkins Spring	16/68-7cb	5	Older alluvium	
Unnamed spring	17/67-2ac	Small	Older alluvium	Reported as excellent water by Longwell (1928, p. 17).
			BLACK MOUNTAIN AREA	
Rogers Spring	18/67-12dd	a 780	Carbonate rock	Warm water. Used for swimming. High mineral content.
Blue Point Spring	18/68-7ab	150	Carbonate rock	Warm water. High mineral content.
Bitter Spring	19/67-16bb	10	Carbonate rock?	High mineral content.
Sandstone Spring	20/66-13d(?)	Small	Noncarbonate rock	Reported to be potable by Longwell (1928, p. 17).
Cottonwood Spring	20/66-20ba	Small	Carbonate rock	Reported to be good water by Longwell (1928, p. 17).
			GOLD BUTTE AREA	
Red Bluff Spring	17/69-14bb	180	Carbonate rock	Brackish water.
Numerous springs	(b)	Small	Consolidated rock	Many yield potable water.
			GREASEWOOD BASIN	
Horse Spring	18/70-24cd	--	--	Good water according to Longwell (1928, p. 17).
Whitney Ranch spring complex	16/71-22	50 to 100	Carbonate rock	Seven springs; potable water.

1. No large springs were recorded for Hidden or Garnet Valleys.
a. Flow measured, by U.S. Geological Survey, 2-5-68. On 10-25-63, measured flow was 875 gpm.
b. Southern part of area.

WATER BUDGETS

For natural conditions and over the long-term, inflow to and outflow from an area are about equal, assuming that long-term climatic conditions remain reasonably unchanged. Thus, a water budget can be used (1) to compare the estimates of inflow to and outflow from each area, (2) to determine the magnitude of imbalances in the inflow and outflow estimates, and (3) to select values that, within the limits of accuracy of this reconnaissance, hopefully represent both inflow and outflow for each area. These values in turn are utilized in a following section of the report to estimate the perennial yield or system yield of each area. Two types of budgets are presented in this report. For areas where the runoff (tables 3 and 5) is sufficient to be developed, the water budget includes both surface-water and ground-water elements (table 14). In those areas where the runoff and streamflow are minimal, only ground-water budgets are presented (table 15).

Table 14.--Preliminary water budget for the valley-fill reservoirs of California Wash area, Lower Moapa Valley, and Black Mountains Area - 1967

[All estimates in acre-feet per year]

Budget elements	California Wash area	Lower Moapa Valley	Black Mountains Area
INFLOW:			
Estimated average annual runoff (table 3)	<50	<50	<50
Inflow of streams (table 5)	a 33,000	a 34,000	b 12,000
From consolidated rocks (p. 23)	(c)	(c)	(c)
Interbasin ground-water inflow (table 7)	8,000	small	400
Imported water, total (p. 23 and table 8)	1,950	370	375
Total (rounded) (1)	43,000	34,000	13,000
OUTFLOW:			
Irrigation (table 10)	5,000	13,000	0
Industrial consumption (p. 34)	2,100	160	275
Evapotranspiration by nonbeneficial phreatophytes (table 11)	1,700	11,000	1,200
Evaporation from surface-water bodies (table 12)	70	1,200	70
Nonirrigation pumpage from wells (p. 36)	<10	<100	<100
Outflow of streams (table 5)	a 34,000	ad 10,000±	bd 10,000
Interbasin ground-water outflow (table 7)	small	d 1,100	d <100
Exported water (p. 30)	0	small	0
Public-supply consumption (table 8 and p. 28)	100	270	100
Total (rounded) (2)	43,000	37,000	12,000
IMBALANCE: (1) - (2)	0	-3,000	1,000
VALUE SELECTED TO REPRESENT BOTH INFLOW AND OUTFLOW	43,000	35,000	12,000

a. Muddy River.
b. Las Vegas Wash.
c. Small in relation to the ground-water recharge from precipitation.
d. Discharge to Lake Mead.

Table 15.--Preliminary ground-water budget for the valley-fill reservoir of Hidden and Garnet Valleys, Gold Butte Area, and Greasewood Basin - 1967

[All estimates in acre-feet per year]

Budget elements	Hidden Valley	Garnet Valley	Gold Butte Area	Greasewood Basin
RECHARGE:				
Recharge from precipitation (table 6)	400	400	1,000	600
Subsurface inflow (p. 23 and table 7)	0	a 400	0	0
Total (rounded)	400	800	1,000	600
DISCHARGE:				
Subsurface outflow[1] (table 7)	400	800	b 1,000	c 600
Evapotranspiration by nonbeneficial phreatophytes (table 11)	0	0	small	small
Pumpage from wells (p. 36)	small	small	small	small
Total (rounded)	400	800	1,000	600
VALUE SELECTED TO REPRESENT BOTH RECHARGE AND DISCHARGE	400	800	1,000	600

1. Assumed equal to ground-water recharge (tables 6 and 7).
a. From Hidden Valley.
b. Discharge to Lake Mead.
c. Flows across State line to Arizona.

CHEMICAL QUALITY OF THE WATER

By A. S. Van Denburgh

Chemical analyses of water from wells, springs, Muddy River, and Lake Mead are listed in table 16. Additional analyses of samples collected prior to 1950, largely from the Muddy River, are given by Hardman and Miller (1934, p. 41-42) and by Miller and others (1953, p. 58-59). Most of the data in table 16 are for ground water adjacent to the Muddy River, in Lower Moapa Valley and along the northeastern margin of California Wash area. In contrast, only two analyses at the most are available for the following areas: Hidden and Garnet Valleys, Gold Butte Area, Greasewood Basin, all but the northeastern limits of California Wash area, and large parts of the Black Mountains and Lower Moapa Valley drainage areas. Thus, the chemistry of water throughout most of the study area is largely unknown.

General Chemical Character

Most of the sampled ground waters show the influence of geologic units containing soluble and moderately soluble minerals, such as halite (sodium chloride) and gypsum (calcium sulfate). Almost all of the sampled waters contained more than 700 mg/l (milligrams per liter, which are equivalent to parts per million; see footnote 1, table 16) of dissolved solids, and many, especially in the Black Mountains Area, contained from 2,000 to as much as 4,000 mg/l. Sodium and (or) calcium are characteristically the principal positive ions, and sulfate is almost always the predominant negative ion.

The dissolved-solids concentration and relative abundance of sulfate in Muddy River increase downstream, due to increments of more concentrated ground water and, during the growing season, irrigation return flow.

The chemical character of water in Las Vegas Wash is very poor (table 16), largely because the stream carries sewage-plant effluents and industrial wastes from Las Vegas Valley. The greatest dissolved-solids contents generally occur during periods of lowest flow.

Table 16.--Partial and detailed chemical analyses of water from wells, springs, seeps, and streams

[Field-office and detailed laboratory analyses by the U.S. Geological Survey, except as indicated]

Location	Source	Date sampled	Temperature °F	Temperature °C	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)[3]	Bicarbonate (HCO_3)[4]	Sulfate (SO_4)	Chloride (Cl)	Dissolved-solids content[5]	Hardness as $CaCO_3$	Specific conductance (micromhos per cm at 25°C)	pH (lab. determination)	Salinity hazard	Sodium-adsorption ratio (SAR)	Sodium hazard
					Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]										Factors affecting suitability for irrigation[2]		
							GROUND WATER										
							Black Mountains Area										
17/68-23ab[6]	Well	1-31-66	--	--	405 20.21	216 17.79	(6)	296 4.85	2,060 42.89	516 14.56	4,020	1,900 35.00	5,070	7.1	Very high	5.5	Medium
18/67-12da[6]	Rogers Spring	1-31-66	--	--	443 22.11	140 11.49	(6)	166 2.72	1,680 34.95	334 9.42	3,020	1,680 33.60	3,750	7.3	do.	3.1	Low
18/68-7ab[7]	Blue Point Spring	11-27-65	--	--	472 24.05	167 13.93	317 13.78	122 2.00	1,910 36.67	355 10.01	e 3,300	1,900 37.98	--	--	do.	3.2	Medium
19/67-16dd	Bitter Spring	11-13-67	65	18	601 29.99	189 15.56	251 10.92	141 2.31	2,360 49.13	178 5.02	e 3,670	2,280 45.55	4,100	7.6	do.	2.3	Low
21/65-9ab[8]	Well	10-12-67	84	29	296 14.87	113 9.33	828 36.04	98 1.61	1,200 24.98	1,190 33.57	3,720	1,210 24.20	5,700	7.0	do.	10	High
							California Wash										
14/66-31c[4]	Well	Late 1946	--	--	55 2.74	18 1.48	261 11.37	371 6.08	285 5.93	125 3.53	940	211 4.22	--	--	High	7.8	Medium
15/66-1dc[7]	Well	1-22-60	--	--	474 23.65	164 13.47	153 6.65	183 3.00	1,750 36.37	156 4.40	2,500	1,860 37.12	4,100	--	Very high	1.6	Low
-2b[6]	Seep	10-13-49	--	--	74 3.69	38 3.13	138 6.01	311 5.10	254 5.29	85 2.40	700	340 6.82	1,210	--	High	3.2	Do.
-4c[6]	Seep	10-13-49	66	19	85 4.24	55 4.52	174 7.57	354 5.80	355 7.39	110 3.10	995	438 8.76	1,550	--	do.	3.6	Do.
-4d[6]	Seep	10-13-49	--	--	66 3.29	38 3.13	141 6.13	302 4.95	251 5.23	82 2.31	768	320 6.42	1,190	--	do.	3.5	Do.
-5a[6]	Seep	10-13-49	--	--	109 5.44	80 6.58	256 11.11	332 5.44	529 11.01	180 5.08	1,410	601 12.02	2,110	--	do.	4.5	Medium
							Garnet Valley										
17/64-21cb1	Well	9-24-12	--	--	116 5.79	50 4.11	100 4.36	178 2.92	335 6.97	155 4.37	870	495 9.90	870	--	do.	2.0	Low
-21cb2	Well	11- 9-67	--	--	118 5.89	57 4.70	145 6.30	215 3.52	405 8.43	175 4.94	e 1,050	530 10.59	1,600	7.6	do.	2.7	Do.
							Greasewood Basin										
16/71-22cc	Spring	11-11-67	63	17	54 2.69	31 2.54	4 .17	303 4.97	10 .20	8 .23	e 290	262 5.23	490	7.6	Medium	.1	Do.
							Lower Moapa Valley										
15/67-22bb[7,8]	Well	7- -67	68	20	184 9.18	80 6.58	(6)	355 5.82	771 16.05	174 4.91	1,690	789 15.76	--	7.6	Very high	3.8	Do.
-27bc[6]	Seep	10-12-49	--	--	272 13.57	180 14.81	325 14.13	408 6.69	1,300 27.07	235 6.63	2,640	1,420 28.38	3,460	--	do.	3.8	Medium
-30ab[6]	Well	10-12-49	76	24	106 5.29	54 4.44	177 7.73	371 6.08	421 8.77	92 2.60	1,070	486 9.73	1,610	--	High	3.5	Low
16/67-1bc[6]	Seep	10-12-49	67	19	196 9.78	139 11.42	409 17.79	446 7.31	1,230 25.61	215 6.06	2,470	1,060 21.21	3,320	--	Very high	5.5	Medium
-1bc	Well	11-10-67	--	--	85 4.24	73 6.01	188 8.18	309 5.06	462 9.62	133 3.75	e 1,050	513 10.25	1,700	7.7	High	3.6	Low
-1cc	Well	10-11-49	67	19	161 8.03	88 7.24	231 10.06	554 9.08	550 11.45	168 4.74	e 1,530	764 15.27	2,200	--	do.	3.6	Do.
-1dc[6]	Seep	10-12-49	70	21	153 7.63	104 8.56	256 11.14	338 5.54	805 16.76	175 4.94	1,720	809 16.19	2,470	--	Very high	3.9	Medium
-11dc[6]	Well	10-12-49	--	--	148 7.39	103 8.47	408 17.73	260 4.26	998 20.78	205 5.78	2,130	793 15.86	2,900	--	do.	6.3	Do.
15/56-7cb	Well	11-10-67	68	20	187 9.33	132 10.85	478 20.80	496 8.13	1,150 23.94	316 8.91	e 2,560	1,010 20.18	3,600	7.7	do.	6.5	Do.
-7cb[6]	Seep	10-11-49	62	17	164 8.18	132 10.86	326 14.20	398 6.52	984 20.49	220 6.21	2,050	952 19.05	2,910	--	do.	4.6	Do.
-20bd[6]	Angel Spring	1-31-66	--	--	146 7.29	102 8.41	(6)	251 4.11	834 17.36	186 5.25	1,740	785 15.70	2,430	7.4	do.	4.1	Do.
-30bd	Well	11-10-67	68	20	422 21.06	133 10.91	336 14.63	281 4.61	1,670 34.77	256 7.22	e 3,000	1,600 31.97	3,700	7.6	do.	3.7	Do.
							Muddy River Springs Area										
14/65-21aa[6]	Muddy River Springs	9-12-63	89	32	70 3.49	26 2.11	(6)	274 4.49	179 3.73	64 1.81	620	280 5.60	964	7.5	High	2.6	Low
							SURFACE WATER										
14/65-15d[6]	Muddy River[9]	8- 9-63	71	22	71 3.54	33 2.72	(6)	303 4.97	216 4.50	75 2.12	719	313 6.26	1,090	--	do.	3.1	Do.
15/67-21ab	Do.	11-10-67	66	19	119 5.94	43 3.51	146 6.35	313 5.13	373 7.77	102 2.88	e 970	473 9.45	1,500	--	do.	2.0	Do.
16/67-12db	Do.	11-10-67	68	20	151 7.53	65 5.34	221 9.59	362 5.93	590 12.28	152 4.29	e 1,390	646 12.91	2,000	--	do.	3.8	Do.
21/63-14a[6,10]	Las Vegas Wash	Lowest[11]	--	--	408 20.36	192 15.79	(6)	265 4.34	1,520 31.65	876 24.71	3,980	1,820 36.36	5,090	7.3	Very high	5.3	Medium
		Highest[11]	--	--	672 33.53	306 27.17	(6)	335 5.49	2,180 45.39	1,620 45.70	6,290	2,950 58.70	7,640	8.2	do.	6.6	High
17/68-21[6]	Lake Mead	1-31-66	--	--	88 4.39	26 2.17	(6)	153 2.51	282 5.87	88 2.48	676	328 6.56	1,060	8.0	High	2.3	Low
22/64-14[6]	Do.	2-21-66	--	--	94 4.69	31 2.57	(6)	151 2.47	326 6.79	104 2.93	760	360 7.20	1,180	8.2	do.	2.6	Do.

1. Milligrams per liter and milliequivalents per liter are metric units of measure that are virtually identical to parts per million and equivalents per million, respectively, for all waters having a specific conductance less than about 20,000 micromhos. The metric system of measurement is receiving increased use throughout the United States because of its value as an international form of scientific communication. Therefore, the U.S. Geological Survey recently has adopted the system for reporting all water-quality data. Where only one number is shown, it is milligrams per liter.

2. Salinity hazard is based on specific conductance (in micromhos) as follows: low, 0-250; medium, 251-750; high, 751-2,250; very high >2,250. Sodium adsorption ratio (SAR) provides an indication of what effect an irrigation water will have on soil-drainage characteristics. SAR is calculated as follows, using milliequivalents per liter: $SAR = Na/\sqrt{(Ca + Mg)/2}$. Sodium hazard is based on an empirical relation between salinity hazard and sodium-adsorption ratio. Residual sodium carbonate (expressed in milliequivalents per liter) is tentatively related to suitability for irrigation as follows: safe, 0-1.25; marginal, 1.26-2.50; unsuitable, >2.50. RSC is 0.00 (safe) for all analyses listed above except well water 14/66-31c, which has a value of 1.80 (marginal).

The several factors should be used as general indicators only, because the suitability of a water for irrigation also depends on climate, type of soil, drainage characteristics, plant type, and amount of water applied. These and other aspects of water quality for irrigation are discussed by the U.S. Salinity Laboratory Staff (1954).

3. Computed as the milliequivalent-per-liter difference between the determined negative and positive ions; expressed as sodium (the concentration of sodium generally is at least 10 times that of potassium). Computation assumes that concentrations of undetermined negative ions--especially nitrate--are small.
4. All carbonate (CO_3) values 0 mg/l except: 15/66-5d, 47 mg/l (1.57 me/l); 15/67-27bc, 61 mg/l (2.03 me/l); 16/67-11dd, 83 mg/l (2.77 me/l).
5. Computed sum, with bicarbonate expressed as carbonate. Letter "e" denotes estimated sum. For Las Vegas Wash only, values represent residue on evaporation, rather than computed sum.
6. Detailed laboratory analysis; additional determinations are listed on next page.
7. Analysis by State of Nevada.
8. Analysis by Desert Research Institute.
9. Muddy River analyses are listed in downstream order.
10. Analyzed by Federal Water Pollution Control Administration.
11. Lowest and highest values from analyses of 54 samples collected between September 26, 1966 and October 10, 1967.

Table 16.--Partial and detailed chemical analyses of water from wells, springs, seeps, and streams--Continued

Additional determinations from detailed analyses

Location	Silica (SiO_2)	Iron (Fe)[13]	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrate (NO_3)	Boron (B)
	Milligrams per liter (upper number) and milliequivalents per liter (lower number)[12]						
GROUND WATER							
14/65-21aa	29	0.03	101 4.39	11 .28	2.3 .12	2.2 .04	0.3
15/66-2b	35	--	--	--	--	2.6 .04	--
-4c	39	--	--	--	--	2.3 .04	--
-4d	38	--	--	--	--	3.6 .06	--
-5d	62	--	--	--	--	1.9 .03	--
15/67-22bb	46	T .07	244 10.61	13 .33	1.8 .09	--	1.4
-27ba	61	--	--	--	--	5.5 .09	--
-34ab	36	--	--	--	--	.6 .01	--
16/67-1bc	57	--	--	--	--	2.1 .03	--
-1dc	54	--	--	--	--	5.4 .09	--
-11dd	56	--	--	--	--	.0 .00	--
16/68-7cb	62	--	--	--	--	1.4 .02	--
-20bd	43	T 0.04	261 11.35	21 .54	3.3 .17	20 .32	1.0
17/68-23ab	43	T .29	551 23.97	35 .89	2.2 .12	44 .71	2.3
18/67-12dd	17	T .02	296 12.88	22 .56	1.5 .08	.8 .01	1.2
21/65-9db	38	.00	--	--	1.5 .08	--	--
SURFACE WATER							
14/65-15d	32	--	125 5.44	14 .36	2.4 .13	1.5 .02	.4
17/68-23	11	--	98 4.26	4.9 .13	.4 .02	2.3 .04	.28
21/63-14da Lowest[11]	--	--	516 22.45	52 1.33	--	--	--
Highest[11]	--	--	818 35.59	88 2.55	--	--	--
22/64-14	8.5	--	114 4.96	5.5 .14	.4 .02	2.8 .05	.21

12. See footnote 1 on preceding page.

13. Values represent iron in solution at time of sample collection, unless preceded by "T". The letter "T" indicates a total-iron value, which represents iron in solution at time of collection, plus any iron that may have been present as a component of sediment or turbid material unavoidably collected as part of the sample.

Suitability for Domestic Use

The U.S. Public Health Service (1962, p. 7-8) has formulated drinking-water standards that are generally accepted as a guideline for public supplies. The standards, as they apply to data listed in table 16, are as follows:

Constituent	Recommended maximum concentration (milligrams per liter)
Iron (Fe)	0.3
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	a About 0.8
Nitrate (NO_3)	45
Total dissolved solids	500

a. The optimum concentration is about 0.7 mg/l. Water containing more than about 1.4 mg/l should not be consumed regularly, especially by children.

Most of these are only recommended limits, and water therefore may be acceptable to many users despite concentrations exceeding the given values.

Among the listed constituents, excessive iron causes staining of porcelain fixtures and clothes, whereas large amounts of chloride and dissolved solids impart an unpleasant taste, and sulfate can have a laxative effect on persons who are drinking a water for the first time. Excessive fluoride tends to stain teeth, especially of children, and large amounts of nitrate are dangerous for infants and pregnant women because of the possibility of "blue-baby" disease.

The hardness of a water is important to many domestic users. Therefore, the U.S. Geological Survey has adapted the following rating:

Hardness range (milligrams per liter)	Rating and remarks
0-60	Soft (suitable for most uses without artificial softening)
61-120	Moderately hard (usable except in some industrial applications; softening profitable for laundries)
121-180	Hard (softening required by laundries and some other industries)
More than 180	Very hard (softening desirable for most purposes)

The bacteriological quality of drinking water also is important, but is outside the scope of this report. If any doubt exists regarding the acceptability of a drinking-water supply, contact the Nevada Bureau of Environmental Health, Las Vegas.

Almost all sampled waters in the project area contain more than the recommended amounts of sulfate and total dissolved solids, and they characteristically are very hard. Nitrate does not seem to be a problem, with one exception: Water from well 17/68-23ab at Overton Landing contained 44 mg/l when sampled in January 1966. This water is undesirable in other respects as well, but is the only available drinking supply except for nearby Lake Mead. More important, however, this well water may be generally characteristic of conditions that would be encountered by wells in other parts of the Black Mountains Area (for example, well 21/65-9db near Callville Bay yields water not much better chemically than that of the Overton Landing well).

Fluoride may be a problem in much of the study area, on the basis of limited information. The Moapa Springs (see 14/65-21aa, table 16), which provide the domestic supply for people living on the Muddy River flood plain, contain 2.0-2.5 mg/l of fluoride (the optimum concentration for drinking water in this area is only about 0.7 mg/l). Likewise, sampled spring and well waters in and adjacent to the Black Mountains Area contain from 1.5 to as much as 3.3 mg/l of fluoride.

Suitability for Agricultural Use

In evaluating the desirability of a water for irrigation, the most critical factors include dissolved-solids concentration, the relative proportion of sodium to calcium plus magnesium, and the abundance of constituents such as boron that can be toxic to plants. Four factors used by the U.S. Salinity Laboratory (1954, p. 69-82) to evaluate the suitability of irrigation water are listed in table 16, and are discussed briefly in footnote 2 of that table. Boron, though essential to plant nutrition in minor amounts, is highly toxic to some plants when it exceeds certain limits. The recommended limits for boron in water irrigating sensitive, semitolerant, and tolerant crops are about 1, 2, and 3 mg/l, respectively, according to Scofield (1936).

Muddy River, which presently supplies almost all irrigation water in the study area, has proved acceptable chemically where used along its flood plain. Because of its high salinity hazard, the water must be applied carefully, and only in areas of adequate soil drainage, to prevent salt buildup. These potential problems of high salinity are eased somewhat, however, by the river's low sodium hazard throughout most of the year. Boron apparently is not a problem.

Most ground water beneath the Muddy River flood plain is less desirable for irrigation than river water, because of characteristically higher salinity and sodium hazard. In other areas the suitability of ground water for irrigation is uncertain. Analyses of two well waters in 17/64-21cb suggest that water throughout large parts of areas such as California Wash area, Garnet Valley, and Hidden Valley may be generally suitable, but deep.

The water of Lake Mead, though high in salinity hazard, is otherwise suitable for irrigation.

Most animals are more tolerant of poor water than man. Although available data are somewhat conflicting, dissolved-solids contents below 4,000-7,000 mg/l apparently are safe and acceptable (McKee and Wolf, 1963, p. 112-113). Thus, all sampled water within the study area is sufficiently dilute for livestock.

THE AVAILABLE GROUND-WATER SUPPLY

Sources of Supply

The available water supply of California Wash area, Lower Moapa Valley, and the Black Mountains Area consists of two interrelated quantities: (1) the system yield or perennial yield and (2) ground water in storage. In the other areas, where insufficient surface water is available for development, the supply is limited to (1) the perennial yield of the ground-water system and (2) ground water in storage.

System Yield

System yield has been defined by Worts and Malmberg (1966) as the maximum amount of surface and ground water of usable chemical quality that can be obtained economically each year from sources within a system for an indefinite period of time. System yield cannot be more than the natural inflow to or outflow from a system. Under practical conditions of development, the yield is limited to the maximum amount of surface-water, ground-water, and water-vapor outflow that can be salvaged or diverted economically and legally each year for beneficial use.

The estimates of system yields listed in table 17 are based on data listed in table 14 and the following limitations and assumptions: (1) irrigation, industrial, and public-supply consumption is salvage; (2) nonbeneficial phreatophyte discharge can be salvaged; (3) half of the surface-water and ground-water outflow can be salvaged; (4) evaporation from surface-water bodies cannot be salvaged; and (5) nonirrigation well pumpage in 1967 generally was from ground water in storage and was not salvage of discharge.

Separate estimates of system yield for California Wash area and Lower Moapa Valley were not attempted because of the unifying and dominating effect the Muddy River has on the two systems. Table 17 lists a combined system yield for the two areas of 40,000 acre-feet. The system yield of the Black Mountains Area is mostly water flowing in Las Vegas Wash.

Perennial Yield

The perennial yield of a ground-water reservoir may be defined as the maximum amount of natural discharge that can be salvaged each year over the long term by pumping without bringing about some undesired result. Nearly all the discharge from Hidden Valley, Garnet Valley, Gold Butte Area, and Greasewood Basin is subsurface outflow (table 15). The possibility of

Table 17.--Yield and water consumption from the hydrologic system

[All quantities rounded]

Hydrographic area	Estimated system yield (acre-feet per year)	Estimated perennial yield (acre-feet)	Estimated water consumption from system in 1967 (acre-feet)
Hidden Valley	--	200	a <10
Garnet Valley	--	400	a 10
California Wash area } Lower Moapa Valley }	40,000	--	22,000
Black Mountains Area	b 7,000	--	500
Gold Butte Area	--	500	a <10
Greasewood Basin	--	300	a <10

a. From ground-water system only.

b. Not of suitable chemical quality for some uses.

salvaging all or part of the outflow by pumping is dependent upon the nature and extent of the transmitting lithology, which is generally unknown. For the purposes of this reconnaissance, it is assumed that the subsurface geohydrologic controls might permit salvage of half the outflow by pumping. Thus, preliminary estimates of perennial yield for these four hydrographic areas, based on this assumption, are listed on table 17.

Ground Water in Storage

The amount of ground water in storage in the Lower Moapa-Lake Mead Area is equal to the volume of saturated valley fill multiplied by the specific yield of the material. Specific yield is the ratio of (1) the volume of water that will drain by gravity from the zone of saturation to (2) the volume of the saturated valley fill drained, commonly expressed as a percentage.

In the Lower Moapa-Lake Mead area, the specific yield of the uppermost 100 feet of saturated valley fill is assumed to average about 10 percent. The area mapped as alluvium having 100 feet or more of saturated thickness is estimated to be about 70 percent of the alluvial area shown in table 1. This is based on topography, the subsurface distribution of the alluvium, depth to water, and the shape of the areas. The areas mapped as alluvium on plate 1, the areas used to compute storage, and the estimated amount of stored water are summarized in table 18.

Although the estimates of ground water in storage are large, the amount where the depth to water is less than 100 feet and where suitable land is available for cultivation is appreciably less. Much of this water is highly mineralized and is unsuitable for irrigation or domestic uses. The amount of usable ground water in storage that is economically available depends in part on the distribution of water-storing deposits, the distribution and range in chemical quality of the ground water, and the number and distribution of pumped wells.

Table 18.--Estimated stored water in the upper 100 feet of saturated valley fill

Hydrographic area	Estimated area having 100 feet or more of saturated thickness[1] (acres)	Estimated stored water[2] (acre-feet)
Hidden Valley	15,000	150,000
Garnet Valley	50,000	500,000
California Wash area	100,000	1,000,000
Lower Moapa Valley	80,000	800,000
Black Mountains Area	150,000	1,500,000
Gold Butte Area	100,000	1,000,000
Greasewood Basin	20,000	200,000

1. Rounded.
2. Based on an assumed specific yield of 10 percent. May include a large percent of poor-quality water.

WATER USE—1967

Table 17 lists the total estimated water consumption in 1967, for the hydrographic areas. These quantities are based on the estimates in table 14 and include: (1) irrigation consumption, (2) industrial consumption, (3) evaporation from surface-water bodies. This loss is not preventable and therefore is assumed to be a necessary loss associated with water storage and use. Also included is (4) nonirrigation pumpage of wells, (5) exported water, and (6) public-supply consumption.

In addition, other quantities of water are used but are not consumed. They remain in the hydrologic system and are available for consumption only downgradient from the use areas in the system. They include the following, in acre-feet:

	California Wash area	Lower Moapa Valley	Total
Public supply (table 8)	50	100	150
Leaching (p. 34)	500	1,400	1,900
Total (rounded)	600	1,500	2,100

In the California Wash and Lower Moapa Valley hydrographic areas, nearly all the water is used or consumed on the flood plain of the Muddy River.

FUTURE SUPPLY

The largest future supply of water is in the combined California Wash-Lower Moapa Valley area. The unused part of the system yield, most of which is evapotranspiration losses by nonbeneficial phreatophytes and Muddy River flows to Lake Mead. Ultimately, most of this water is from the Muddy River. Because of the enlargement of Bowman Reservoir, most of the salvable surface-water outflow to Lake Mead (an estimated 5,000 acre-feet per year) could now be salvaged during the winter, the period of principal loss. The salvage of principal losses by pumping irrigation wells, that is, surface-water and ground-water outflow and nonbeneficial phyreatophyte discharge, is impractical under the present water-quality requirements. Ground water in the discharge areas generally is not suitable for irrigation. However, phreatophyte losses (about 13,000 acre-feet per year) could be partly salvaged by denying them a plentiful supply of water by lining more ditches, reservoirs, and the Muddy River channel with an impermeable material and by using more efficient irrigation practices, such as applying water to fields with sprinklers rather than with ditches. These more efficient water-use practices, however, may not be feasible under present economic conditions.

For Hidden and Garnet Valleys, Gold Butte Area, and Greasewood Basin, the only dependable source of water is the ground-water reservoir or springs. Salvage of ground-water outflow is possible if wells are near the discharge areas, but in salvaging ground-water outflow, ground water in storage probably would continue to be pumped for a prolonged period of time as part of the well discharge. The best areas to salvage ground-water outflow are in Hidden and Garnet Valleys, along the southeastern and eastern sides of the valley-fill reservoir; in the Gold Butte Area and Greasewood Basin, along the alluvial slopes between recharge and discharge areas.

The flow from springs issuing from consolidated rocks in the Black Mountains and Gold Butte Areas and Greasewood Basin can be diverted and consumed. This would deprive the valley-fill reservoir of some recharge and have much the same effect as salvaging water from the reservoir. Most of the larger springs in these areas are not potable, but some small, potable springs (table 13) probably could be developed to supply the needs of campers and tourists in recreation areas. A comprehensive inventory of springs and their hydrologic settings was not made, but it could be accomplished by a hydrologist in a few weeks of field work, including collection of water samples for chemical and bacterial analyses.

In the Black Mountains Area, the availability of water is similar to that in the Gold Butte Area, except that Las Vegas Wash in 1967 was a source of a large quantity of poor-quality water.

In those areas adjoining Lake Mead, the lake is the ultimate source of any large water supply, subject of course to any limitations imposed by the Colorado River Compact and the Supreme Court decisions.

NUMBERING SYSTEM FOR HYDROLOGIC SITES

The numbering system for hydrologic sites in this report is based on the rectangular subdivision of the public lands, referenced to the Mount Diablo base line and meridian. This location number consists of three units: the first is the township south of the base line; the second unit, separated from the first by a slant, is the range east of the meridian; the third unit, separated from the second by a dash, designates the section number. The section number is followed by letters that indicate the quarter section and quarter-quarter section, the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. For example, well 15/65-1dd (table 19) is the well recorded in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 1, T. 15 S., R. 65 E., Mount Diablo base line and meridian. For sites that cannot be located accurately to the quarter-quarter section, only that part of the location number is given that represents the ability to determine the location of the site.

Because of limitation of space, wells and springs are identified on plate 1 only by section number and quarter-quarter section letters. Township and range numbers are shown along the margins of the area on plate 1 and apply only to Nevada.

SELECTED WELL LOGS AND DATA

Selected well data are listed in table 19, and selected drillers' logs of wells in table 20. Most of the well data and logs are from the files of the Nevada State Engineer.

Data in table 19 were selected to include most of the data available on wells in the area. Table 20 contains logs for only a few wells.

Table 19.--Data of selected wells

Owner or name: BLM, Bureau of Land Management;
NPS, National Park Service
Use: C, construction; D, domestic; E, exploration;
I, irrigation; Ind, industrial; O, oil test;
PS, public supply; RR, railroad; S, stock;
U, unused
Water-level measurement: M, measured; R, reported
Log number: Log number in the files of the State Engineer

Location number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Land surface altitude (feet)	Water-level measurement: Depth (feet)	M or R	Date	Chief aquifer (depth in feet)	Log number	Remarks
						GARNET VALLEY							
17/63-14dd	U.S.G.S. Dry Lake No. 2	1966	970	--	E	--	2,070	--	-	--	-	--	From Jenkins (1966).
17/64-19bd	U.S.G.S. Dry Lake No. 1	1966	1,500	--	E	--	1,967	--	-	--	--	--	Do.
17/64-21c1	Wells-Stewart Construction Co.	1958	575	8	C,U	--	2,060	260	R	1958	532-75	--	West of RR. First water at 532 ft.
17/64-21c2	do.	1958	550	8	C,U	--	2,060	272	R	1958	297-550	4105	East of RR. First water at 297 ft.
17/64-21cb1	Union Pacific Railroad Co, well 1	Pre-1912	461	--	U	--	2,100	284	R	1912	--	--	
17/64-21cb2	do, well 2	--	576	16	RR	30/13	2,080	264	R	1967	--	--	100 ft. west of tracks.
17/64-26	Jack Pelham	1951	582	10	S,D	150/--	2,230	160	R	1951	530-583	1769	Water smells bad. First water at 140 ft.
18/64-7bb1	Martin and son oil well	1955	793	16	O	--	2,045	226.40	M	11-29-56	235-264	--	500 ft. east of old highway and 500 feet north of road to Carnet
18/64-7bb2	Vinnell Corporation	1963	600	12	C,U	100/--	2,060	235.75	M	11- 9-67	389-505	--	
						CALIFORNIA WASH							
14/66-35d	--	1947	118	16	I	1,400/60	1,490	20	M		62-88	243	
15/66-1dc	R. A. West	--	325	7	S	10/--	1,500	--	-	--	257-325	--	
15/66-1dd	Paul Lewis	1960	170	14,12	I	830/69	1,640	12	R	1960	75-89	5290	Cold water
15/66-2bb	Jay Robb	1947	114	16	I	100/--	1,550	12	R	1947	60-66	286	Cold water
15/66-4aa	Hidden Valley Ranch	1950	178	20	I,U	200/--	1,580	0	R	1950	0-33	1720	75°F. Drilled in spring.
15/66-6	Hidden Valley Ranch, No. 2	1950	100	12	I,U	600/--	--	1	R	1950	--	1461	¼ mile NW of dairy barn, 250 ft. W of flowing well.
16/65-10cd	BLM	--	--	6	S	--	--	--	-	--	--	--	
16/65-33aa	BLM, Marshall well 16	1949	400	6	S,U	12/--	1,970	325.90	M	11-12-67	372-380	826	First water at 350 ft. Salt water.
17/65-31db	BLM	1949	258	8	S	--	2,275	238	R	1949	238-245	790	Slightly salty water.
18/64-25aa1	BLM, Muddy Mountain well	1948	--	8	S,U	--	--	--	-	--	--	--	
18/64-25aa2	Apex Oil well	1949	1,025	16	O	--	2,590	945	R	1949	945-950	1012	Salt water
18/65-18cc	BLM	1949	860	--	S	--	2,590	825	R	1949	845-851	939	Windmill
						LOWER MOAPA VALLEY							
13/67-22aa	F. H. Langford	1958	112	8	S	--	1,430	5.5	R	1958	19-30	4224	
15/67-22b	Louis Adams	1957	120	6	D,U	--	1,400	21	R	1957	102-107	3943	
15/67-22bb1	Moapa Valley Water Co. No. 1	1967	154	16	TS	3,750/31	1,410	22	R	1967	152-154	9714	68°F. First water at 60 ft. Chief aquifer is limestone.
15/67-22bb2	Moapa Valley Water Co. No. 2	1967	163	16	PS	2,500/104	1,410	22	R	1967	60-154	9716	68°F
15/67-26cb	Logandale Cemetary	1957	100	6	I	--	1,370	22	R	1957	30-50	3944	
15/67-34ab	W. Whipple	--	87	8	U	--	1,360	8.49	M	5-10-50	77-87	--	
16/67-1b	Paul Lewis	--	97	6	S	--	--	7.82	M	5-11-50	--	--	
16/67-1bc	--	--	--	6	D	--	--	8.50	M	11-10-67	--	--	
16/67-24bd	M. B. Metcalf	1966	140	16,8	I	1,100/--	1,250	6	R	1966	95-140	9392	Cool water
16/68-7cb	J. C. Perkins	--	80	6	D	--	--	20 13.92	R M	-- 11-10-67	80	--	Drilled to 300 ft. deep.
16/68-30ad	Simplot Silica Products, Ind.	1948	75	12	Ind	--	1,230	23	R	1948	57-73	379	Cool water
16/68-30ba	do.	--	98	--	Ind	--	1,230	--	-	--	--	--	
						BLACK MOUNTAINS AREA							
17/67-26b	Valley of Fire State Park	1965	100	6	PS,U	20/--	1,880	33.25	R	1965	--	8325	First water at 55 ft.
17/68-23ab	NPS, Overton Beach well	1964	175	5	PS	80/--	--	97.5	R	1964	132-143	--	Cool water. Used at landing.
19/68-6	NPS, Echo Bay No. 1	1956	300	14,10	PS,H	--	1,300	83	R	1956	93-116	3509	Salt water
19/68-6	NPS, Echo Bay No. 2	1956	175	10	PS,U	--	1,300	125	R	1956	125-136	3510	Salt water
20/63-1db	Fibreboard Paper Products Corp. well No. 9	1958	240	10	Ind	8/--	1,960	40	R	1958	46-50	4401	First water at 46 ft.
20/64-18cb	Fibreboard Paper Products Corp. well No. 5	1958	130	12	Ind	1/--	1,770	20	R	1958	35-45	4402	First water at 35 ft.
20/65-7bd	Rosen Oil, No. 1 Muddy Dome	1965	5,666	10	O	--	2,305	--	-	--	--	--	
21/64-21cc	Wells-Stewart Construction Co.	1958	550	10,8	C,U	--	1,550	272	R	1958	297-550	5607	
21/65-9db	NPS, Callville Bay campground	1967	200	--	PS,U	30/--	1,300	105	M	10-12-67	--	--	Salt water
22/64-14cc	NPS, Boulder Beach well	1955	200	8	PS,U	--	1,300	135	R	1955	143-200	3018	Salt water
						GOLD BUTTE AREA							
17/70-25cd	Dan Mason	1953	802	6	S	--	2,380	--	-	--	--	2435	Salt water
19/70-17ad	--	--	--	12	D,U	--	3,800	35.15	M	11-11-67	--	--	
20/70-2dd	Blue Bird Mine Co.	1956	152	10,6	Ind	--	3,620	109	R	1956	109-115	4819	

Table 20.--Drillers' logs of selected wells

[Chief aquifer marked by a star]

Material	Thickness (feet)	Depth (feet)
15/65-1dd		
Clay, brown	18	18
Sand	1	19
Clay, brown	11	30
Clay, blue, sandy, and gravel	45	75
*Sand and gravel, water-bearing	14	89
Clay, gray, sandy	41	130
Gravel	5	135
Clay, gray, sandy	13	148
Gravel and sand	7	155
Clay, brown, sandy, and gravel	15	170
15/66-6		
Sod and gray clay	3	3
Gravel, water-bearing	17	20
Clay, yellow	4	24
*Sand and gravel, water-bearing	68	92
Clay, sandy	8	100
15/67-22bb1		
Sand and gravel	34	34
Sand, silty	13	47
Limestone, white	6	53
Limestone, hard, red	4	57
Limestone, white	78	135
Limestone, white, sandy	4	139
Limestone, white, hard	13	152
Subsurface opening, water-filled	2	154
16/65-33aa		
Lime and gypsum	95	95
Shale, gray and brown	45	140
Clay, red	35	175
Shale, gray and blue	45	220
Sand, dry	20	240
Shale, blue	73	313
Clay, red	59	372
*Sand, water-bearing	8	380
Clay, red	20	400
17/63-14dd		
Pebbles, mostly limestone	35	35
Clay, calcareous silty	90	125
Siltstone, calcareous clayey	60	185
Clay, calcareous silty	245	430
Limestone and clay, interbedded	115	545
Gypsum and clay, interbedded	10	555
Clay, silty	20	575
Clay, calcareous	130	705
Clay, calcareous silty	253	958
Limestone, gray	12	970
For more detailed log see Jenkins (1966, p. 45)		
17/64-19bd		
Clay and some interbedded gypsum	310	310
Clay, calcareous silty	95	405
Clay and siltstone, interbedded	45	450
Clay, silty	310	760
Sand, fine to medium quartz	40	800
Clay, calcareous silty	65	865
Clay, silty	330	1,195
Clay and gypsum interbedded	285	1,480
Clay, silty	20	1,500
17/64-21cb		
Gravel	6	6
Clay, red and blue	224	230
Clay, white	10	240
Clay, brown and gray	257	497
Sandstone	28	525
Clay, red	7	532
*Limestone, gray, broken	44	576

Table 20.--Continued

Material	Thickness (feet)	Depth (feet)
17/68-23ab		
Sand and gravel	105	105
Clay, sand, and gravel, water-bearing	5	110
Sand and gravel, water-bearing	33	143
Sandstone	13	156
Sand and gravel	14	170
Clay and sand	12	182
17/70-25cd		
Sand and gravel	6	6
Shale, red	465	471
Shale, blue and brown	123	594
Lime, hard and soft	208	802
18/64-7bb		
Clay and gravel	55	55
Clay	90	145
Clay and gravel	118	263
Clay, streaks of limestone	67	330
Clay and gravel	15	345
Gravel, cemented	18	363
Clay, sandy	12	375
Limestone	2	377
Clay, sandy	12	389
*Gravel, cemented	116	505
Clay, red	20	525
Clay, gray	5	530
Clay, blue	70	600
18/65-18cc		
Gravel, cemented	90	90
Clay, blue	10	100
Gravel and sandstone	155	255
Clay, blue and yellow	250	505
Gravel, cemented	55	560
Clay, red	110	670
Gravel, cemented	65	735
Clay, sand, and rock	70	805
Lime, gray	15	820
Sand, water-bearing	15	835
Limestone, black	10	845
Sand, water-bearing	6	851
Lime	9	860
19/68-6		
*Sand and gravel	131	131
Clay, gray	8	139
Sand and gravel	3	142
Clay, white and red	113	255
Salt	10	265
Clay, red, sandy, and salt	35	300
21/64-21cc		
Gravel, cemented	8	8
Clay, yellow, blue, and red	264	272
Limestone	25	297
*Sandstone	28	325
*Limestone, broken	225	550

REFERENCES CITED

Ames, F. C., and others, 1960, Area and capacity computations for 1948-49 survey - Tables in Smith, W. O., and others, Comprehensive survey of sedimentation in Lake Mead, 1948-49: U.S. Geol. Survey Prof. Paper 295, p.

Anderson, E. R., and Pritchard, D. W., 1951, Physical limnology of Lake Mead, Lake Mead sedimentation survey: U.S. Navy Electronics Lab., San Diego, 153 p. 87-93.

Anderson, R. E., 1966, Geology of the Dry Lake and Hidden Valley areas, Nevada: U.S. Geol. Survey Rept. NTS-176, p. 15-30.

Bernstein, Leon, 1964, Salt tolerance of plants: U.S. Dept. Agriculture Inf. Bull. 283, 23 p.

Bourns, C. T., 1963, Feasibility of exchange of waters from the Muddy River and wells of the Nevada Power Company at Glendale, Nevada: Nevada Univ. Agr. Ext. Service, Reno, 10 p.

Carpenter, Everett, 1915, Ground water in southeastern Nevada: U.S. Geol. Survey Water-Supply Paper 365, 86 p.

Eakin, T. E., 1964, Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs area, Lincoln and Clark Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources - Reconn. Ser. Rept. 25, 40 p.

Eakin, T. E., and Moore, D. O., 1964, Uniformity of discharge of Muddy River Springs, southeastern Nevada, and relation to interbasin movement of ground water: U.S. Geol. Survey Prof. Paper 500-D, p. D171-D176.

Eakin, T. E., and others, 1951, Contributions to the hydrology of eastern Nevada: Nevada State Engineer, Water Resources Bull. 12, 171 p.

Fuller, W. H., 1965, Water, soil, and crop management principles for the control of salts: Arizona Univ. Agr. Expt. Sta. and Coop. Ext. Service Bull. A-43, 22 p.

Harbeck, G. E., and others, 1958, Water-loss investigations: Lake Mead Studies: U.S. Geol. Survey Prof. Paper 298, 100 p.

Hardman, George, and Miller, M. R., 1934, The quality of the waters of southeastern Nevada: Nevada Univ. Agr. Expt. Sta. Bull. 136, 62 p.

Hardman, George, 1965, Nevada precipitation map, adapted from map prepared by George Hardman and others, 1936: Nevada Univ. Agr. Expt. Sta. Bull. 183, 57 p.

Houston, C. E., 1950, Consumptive use of irrigation water by crops in Nevada: Nevada Univ. Agr. Expt. Sta. Bull. 185, 27 p.

Houston, C. E., and Blaney, H. F., 1954, Consumptive use of water rates by the irrigated lands in the Colorado River Basin of Nevada, in Shamberger, H. A., 1954, Present and potential use of the waters of the Colorado River and tributaries within Nevada: Carson City, Nevada State Engineer's Office, 140 p.

Jenkins, E. C., 1966, Lithologic logs of drill holes in Dry Lake and Hidden Valleys, Nevada: U.S. Geol. Survey Rept. NTS-176, p. 31-53.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps for the United States: U.S. Weather Bur. Tech. Pub. 37, 13 p.

Langbein, W. B., 1960, Water budget, in Smith, W. O., and others, Comprehensive survey of sedimentation in Lake Mead, 1948-49: U.S. Geol. Survey Prof. Paper 295, p. 95-102.

Lee, C. H., 1912, An intensive study of the water resources of a part of Owens Valley, California: U.S. Geol. Survey Water-Supply Paper 294, 135 p.

Loeltz, O. J., 1963, Ground-water conditions in the vicinity of Lake Mead Base, Las Vegas, Nevada: U.S. Geol. Survey Water-Supply Paper 1669-Q, 17 p.

Longwell, C. R., 1928, Geology of the Muddy Mountains, Nevada: U.S. Geol. Survey Bull. 798, 152 p.

Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bur. Mines Bull. 62, 218 p.

Malmberg, G. T., 1965, Available water supply of the Las Vegas ground-water basin, Nevada: U.S. Geol. Survey Water-Supply Paper 1780, 116 p.

McKee, J. E., and Wolf, H. W., 1963, Water quality criteria, 2nd ed.: California Water Quality Control Board Pub. 3-A, 548 p.

Miller, M. R., Hardman, George, and Mason, H. G., 1953, Irrigation waters in Nevada: Nevada Univ. Agr. Expt. Sta. Bull. 187, 63 p.

Moore, A. T. W., 1948, Interim report on survey, flood control, Meadow Valley Wash and lower Muddy River, Nevada: U.S. Army Corps Eng., Los Angeles Dist., 44 p.

Moore, D. O., 1968, Estimating mean runoff in ungaged semiarid areas: Internat. Assoc. Sci. Hydrology, v. 13, no. 1, p. 29-39.

Raphael, J. M., 1954, Crustal disturbances of the Lake Mead area: U.S. Bur. Reclamation Eng. Mon. 21, 14 p.

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

_____ 1965, Water use studies utilizing evapotranspiration tanks in Water resources of the Humboldt River Valley near Winnemucca, Nevada: U.S. Geol. Survey Water-Supply Paper 1795, p. 83-104.

Rush, F. E., 1964, Ground-water appraisal of the Meadow Valley area, Lincoln and Clark Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources - Reconn. Ser. Rept. 27, 43 p.

Rush, F. E., and others, 1968, Hydrographic areas of Nevada: Carson City, Nevada State Engineer's Office map.

Scofield, C. S., 1936, The salinity of irrigation water: Smithsonian Inst. Ann. Rept., 1935, p. 275-287.

Shamberger, H. A., 1954, Present and potential use of the waters of the Colorado River and tributaries within Nevada: Nevada State Eng., 140 p.

Smith, W. O., and others, 1960, Comprehensive survey of sedimentation in Lake Mead, 1948-49: U.S. Geol. Survey Prof. Paper 295, 254 p.

Snyder, C. T., Hardman, George, and Zdenek, F. F., 1964, Pleistocene lakes in the Great Basin: U.S. Geol. Survey Misc. Geol. Inv. Map I-416.

University of Nevada, 1944, Chemical analyses of municipal water supplies, bottled mineral waters, and hot springs of Nevada: Reno, Nevada Univ., 16 p.

U.S. Army Corps of Engineers, 1967, Water-resources development by the U.S. Army Corps of Engineers in Nevada: Los Angeles dist., U.S. Army Corps Eng., 35 p.

U.S. Bureau of Reclamation, 1962, Moapa Valley pumping project: Boulder City, Nevada, Bur. Reclamation Reconn. Rept., 84 p.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. no. 956, 61 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. no. 60, 160 p.

Utah Geological Society, 1952, Guidebook to the geology of Utah, no. 7, Cedar City, Utah to Las Vegas, Nevada: Salt Lake City, Utah Geol. and Mineralog. Survey, 165 p.

White, W. N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U.S. Geol. Survey Water-Supply Paper 659-A, p. 1-105.

Worts, G. F., Jr., and Malmberg, G. T., 1966, Water-resources appraisal of Eagle Valley, Ormsby and Douglas Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Water Resources - Reconn. Ser. Rept. 39, 55 p.

Young, A. A., and Blaney, H. F., 1942, Use of water by native vegetation: California Dept. Pub. Works, Div. Water Resources Bull. 50, 154 p.

Young, F. O., and Carpenter, E. J., 1928, Soil survey of the Moapa Valley area, Nevada: U.S. Dept. Agriculture, Bur. Chem. and Soils, p. 749-774.

LIST OF PREVIOUSLY PUBLISHED REPORTS IN THIS SERIES

Report No.	Valley	
1	Newark (out of print)	
2	Pine (out of print)	
3	Long (out of print)	
4	Pine Forest (out of print)	
5	Imlay area (out of print)	
6	Diamond (out of print)	
7	Desert	
8	Independence	
9	Gabbs	
10	Sarcobatus and Oasis	
11	Hualapai Flat	
12	Ralston and Stonecabin	
13	Cave	
14	Amargosa	
15	Long	Surprise
	Massacre Lake	Coleman
	Mosquito	Guano
	Boulder	
16	Dry Lake and Delamar	
17	Duck Lake	
18	Garden and Coal	
19	Middle Reese and Antelope	
20	Black Rock Desert	
	Granite Basin	
	High Rock Lake	
	Summit Lake	
21	Pahranagat and Pahroc	
22	Pueblo	Continental Lake
	Virgin	Gridley Lake
23	Dixie	Stingaree
	Fairview	Pleasant
	Eastgate	Jersey
	Cowkick	
24	Lake	
25	Coyote Spring	
	Kane Spring	
	Muddy River Springs	
26	Edwards Creek	
27	Lower Meadow	Patterson
	Spring (near Panaca)	
	Panaca	Eagle
	Clover	Dry
28	Smith Creek and Ione	
29	Grass (near Winnemucca)	
30	Monitor, Antelope, Kobeh	
31	Upper Reese	
32	Lovelock	
33	Spring (near Ely) (out of print)	
34	Snake	
	Hamlin	
	Antelope	
	Pleasant	
	Ferguson Desert (out of print)	
35	Huntington	
	Dixie Flat	
	Whitesage Flat (out of print)	
36	Eldorado - Piute Valley (Nevada and California)	
37	Grass and Carico Lake (Lander and Eureka Counties)	
38	Hot Creek	
	Little Smoky	
	Little Fish Lake	
39	Eagle (Ormsby County)	
40	Walker Lake	
	Rawhide Flats	
	Whiskey Flat	
41	Washoe Valley	
42	Steptoe Valley	
43	Honey Lake	Warm Springs
	Newcomb Lake	Cold Spring
	Dry	Lemmon
	Red Rock	Spanish Springs
	Bedell Flat	Sun
	Antelope	
44	Smoke Creek Desert	
	San Emidio Desert	
	Pilgrim Flat	
	Painters Flat	
	Skedaddle Creek	
	Dry (near Sand Pass)	
	Sano	

LIST OF PREVIOUSLY PUBLISHED REPORTS IN THIS SERIES -- continued.

Report No.	Valley
45	Clayton Valley
	Alkali Spring Valley
	Lida Valley
	Stonewall Flat
	Oriental Wash
	Grapevine Canyon
46	Mesquite Valley
	Ivanpah Valley
	Jean Lake Valley
	Hidden Valley
47	Thousand Springs Valley
48	Snake River Basin
49	Butte Valley

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
STATE OF NEVADA

Base: U.S. Geological Survey 1:250,000 topographic series; Las Vegas (1954)

Hydrogeology by F. E. Rush, 1968. Geology adapted from Longwell and others 1965)

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF LOWER MOAPA—LAKE MEAD AREA, CLARK COUNTY, NEVADA