STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

Carson City

Irrigation development and dairy industry on the Virgin River flood plain.

WATER RESOURCES – RECONNAISSANCE SERIES

REPORT 51

WATER–RESOURCES APPRAISAL OF THE LOWER VIRGIN RIVER VALLEY AREA, NEVADA, ARIZONA, AND UTAH

By

Patrick A. Glancy

and

A. S. Van Denburgh

Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

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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 51st report prepared by the staff of the Nevada District of the U.S. Geological Survey. These 51 reports describe the hydrology of 158 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
State Engineer

Division of Water Resources

September 1969.

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WATER-RESOURCES APPRAISAL OF THE LOWER VIRGIN RIVER VALLEY AREA, NEVADA ARIZONA, AND UTAH

By Patrick A. Glancy and A. S. Van Denburgh

SUMMARY

The study area includes the lower Virgin River Valley, Tule Desert, and Escalante Desert basin in Nevada. The lower Virgin River Valley comprises the river flood plain and its tributary drainages from The Narrows, about 5 miles east of Littlefield, Ariz., downstream to the river's confluence with Lake Mead. This valley, plus Tule Desert and the small part of Escalante Desert in Nevada, encompass about 1,840 square miles. Although the report boundary encloses territory within three States, the report emphasizes hydrology of the 1,205-square-mile area in Nevada. Principal hydrologic estimates pertaining to the Nevada part are summarized in table 1.

The lower Virgin River is the dominant hydrologic feature of the area. Water contributed to the river's flood-plain area includes direct precipitation, river inflow, and ground-water underflow from east of the report area, plus surface-and ground-water inflow from tributary drainages within the report area. Outflow from the basin includes streamflow and ground-water underflow to Lake Mead, consumptive use of surface and ground water within the basin, and natural evapotranspiration.

For Escalante Desert in Nevada, input is provided solely by precipitation. Some ephemeral surface outflow occurs, but the greatest loss of possibly salvable water is ground-water underflow to Utah.

Most consumptive use of water in the lower Virgin River Valley is for irrigation of crops by diversion of surface flow. Only a small amount of ground water is pumped for irrigation, but ground-water reservoirs furnish most of the municipal, domestic, and livestock supply.

Most natural discharge of water by evaporation of surface water and phreatophytic transpiration of ground water occur along the Virgin River flood plain. Phreatophyte growth along the river flood plain is apparently increasing with time.

The principal known aquifer system occurs within the valley-fill deposits. However, untapped aquifers may also exist within the consolidated rocks, most likely in the carbonate rocks. Ground-water movement through the valley-fill deposits of the lower

Table 1.--Hydrologic summary

[All water quantities are estimated, rounded, and shown as acre-feet per year, except where noted. Water budgets shown in table 16.]

	Lower Virgin River Valley	Tule Desert	Escalante Desert, Nevada
Approximate valley area (sq mi)	910	190	105
Assumed degree of hydrologic integrity	(a b)	(a)	(c)
Virgin River flow at Littlefield adjusted to Nevada State line	159,000	--	--
Surface-water runoff at mountain front	6,300	d 1,400	3,200
Ground-water recharge	3,600	d 2,100	2,300
Ground-water inflow	3,100	Minor	Minor
Evapotranspiration in phreatophyte areas	30,000	Minor	Minor
Evaporation from water surfaces	1,200	Minor	Minor
Consumptive use by crops irrigated with surface water	13,000	None	None
Consumptive use by crops irrigated with ground water	250	None	None
Municipal consumptive use of ground water	230	None	None
Domestic and livestock consumptive use of ground water not associated with municipal consumption	40	Minor	Minor
Surface-water outflow }	123,000 (combined)	1,200	400
Ground-water underflow to adjacent areas }		2,100	2,300
Perennial yield	e 100,000	1,000	1,000

Table 1.--Continued

	Lower Virgin River Valley	Tule Desert	Escalante Desert, Nevada
Estimated ground water in storage in upper 100 feet of saturated valley-fill reservoir (total acre-feet)	2,900,000	530,000	190,000

a. Ground-water underflow and ephemeral surface-water runoff to main Virgin River hydrologic system.

b. Surface-water flow and ground-water underflow from main Virgin River hydrologic system to Lake Mead.

c. Ground-water outflow and ephemeral surface-water flow to Escalante Desert, Utah.

d. Cavernous carbonate rocks presumably restrict runoff and enhance recharge.

e. System yield.

Virgin River Valley is generally toward the river, which is the focus of natural discharge in the hydrologic system. Once there, it is either dissipated by evapotranspiration, or moves toward Lake Mead as surface or subsurface flow.

Water in the Virgin River usually contains 1,000-3,000 mg/l (milligrams per liter) of dissolved solids--largely calcium, sodium, sulfate, and chloride. The water typically is most dilute during periods of high flow, and it is most concentrated during low flow, when the discharge is sustained by springs upstream from Littlefield. Throughout the year, the dissolved-solids concentration increases markedly in the 20-mile reach between Littlefield and Riverside (in water year 1967, the increase averaged almost 30 percent). The river transports large quantities of sediment, particularly during high flow. The suspended-sediment load averaged almost 3 million tons per year during 1958-67. Despite the problems caused by excessive sediment, the streamflow in 1968 was generally acceptable for irrigation.

Ground water along the river characteristically is very hard, and contains 500 to as much as 5,000 mg/l of dissolved solids, dominated by sulfate and sodium or calcium. Throughout much of the basin tributary to Beaver Dam Wash, and in many other upgradient parts of the report area, streamflow and ground water are known or inferred to be of much better quality than waters along the Virgin River flood plain. However, wells half a mile to 1 mile south of, and upgradient from, the flood plain yield generally acceptable municipal supplies.

The available water supply of the lower Virgin River Valley is considered in the context of a system yield for conditions as of 1967-68, which includes both surface and ground water. For Tule Desert and Escalante Desert, Nevada, about half the estimated subsurface outflow is considered the perennial supply. Estimates of ground water stored in the upper 100 feet of saturated valley fill represent preliminary determinations of the availability of ground water for future development.

Although present water development in the lower Virgin River Valley is geared to surface flow of the river, future development may depend in part on the quantity and quality of underground water available to meet the needs of the area.

INTRODUCTION

Purpose and Scope of the Investigation

Nevada is currently experiencing a rapid growth in population and associated development that began more than a decade ago. Increased water requirements for domestic, industrial, agricultural, and conservation uses have accompanied this growth. Anticipating these increasing water needs, the Nevada State Legislature enacted legislation (Chapter 181, Statutes of 1960) authorizing an expansion of the established program of hydrologic investigations being conducted by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources, Division of Water Resources. The legislation provided financing, in the form of matching funds with the Federal Government, to conduct a reconnaissance appraisal of the ground-water resources of the State. The appraisal is being made as a series of reconnaissance investigations of individual areas or groups of areas. This investigation is the 51st in the series.

As studies progressed, the necessity for supplementary information on surface-water resources was recognized. Accordingly, the reconnaissance program was broadened in scope to include appraisals of the surface-water resources.

The objectives of the reconnaissance investigation, including this study, are to (1) describe the general geology as it relates to the water resources, (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) evaluate the surface-water resources in the valleys, and (5) provide preliminary estimates of the yield and ground-water storage. Although the area encompasses parts of three States, most quantitative estimates of the water resources are limited to Nevada.

This investigation was made under the general supervision of G. F. Worts, Jr., district chief in charge of hydrologic studies by the Geological Survey in Nevada. Field work was done during November 1967.

Location and General Geographic Features

The lower Virgin River Valley area of this report includes territory roughly enclosed by lat 36°30' and 37°54' N., and long 113°48' and 114°28' W., and is in the southeastern part of Nevada (fig. 1). It mainly comprises that area tributary to the Virgin River in Nevada as modified by the filling of Lake Mead. It includes Beaver Dam Wash drainage, which originates partly in

Nevada and joins the Virgin River near Littlefield, Arizona. It also includes a small area in Arizona that drains directly into the Virgin River from the northwestern slopes of the Virgin Mountains (pl. 1). It excludes the Muddy River basin, which was tributary to the Virgin River prior to the filling of Lake Mead in the late 1930's. The Muddy River area was discussed by Rush (1968b).

The Virgin River drainage of this report, including the Tule Desert (190 square miles), thus encompasses about 1,735 square miles, of which about 1,100 square miles is in Nevada (Rush, 1968a) and the remainder (about 635 square miles) is in Arizona and Utah. This report also includes the Nevada part of the Escalante Desert drainage which comprises about 105 square miles in Nevada (Rush, 1968a) and is north of the lower Virgin River Valley.

Overall population of the area probably is less than 1,200 people, most of whom live on or along the Virgin River flood plain; about 10 people reside in the upper Beaver Dam Wash. About 1,100 people are concentrated in the Mesquite-Bunkerville area and more than 50 reside in Littlefield and lower Beaver Dam Wash. No known residents are in Tule Desert or in Escalante Desert, Nevada.

Agriculture is the major industry and many people are engaged in the operation of dairies and small farms along the river bottom. Some cattle ranches operate along the river, and the upper Beaver Dam Wash residents are all engaged in ranching. Livestock is grazed throughout the area, although native vegetation acceptable for grazing is generally sparse, particularly in the drier parts of the area in Nevada.

The town of Mesquite is on U.S. Highway 91 connecting Las Vegas and Salt Lake City, and therefore interstate travel and tourism contribute to the local economy. Construction on interstate highway 15 has been completed over much of this route in Nevada. The old route of U.S. 91 through Riverside and Bunkerville to Mesquite is still maintained in its paved condition. The remainder of the lower Virgin River Valley is served by a few well-maintained gravel roads. Numerous dirt roads and trails also provide limited access to and within the area. The Escalante Desert, Nevada is served by paved Nevada Highway 25 and a gravelled route, Nevada Highway 75, as well as several dirt roads and jeep trails. The Los Angeles-Salt Lake section of the Union Pacific Railroad traverses the area.

History of Water Development

Indians were the first residents of the area, and evidence of their habitation exists along the lower Virgin River Valley.

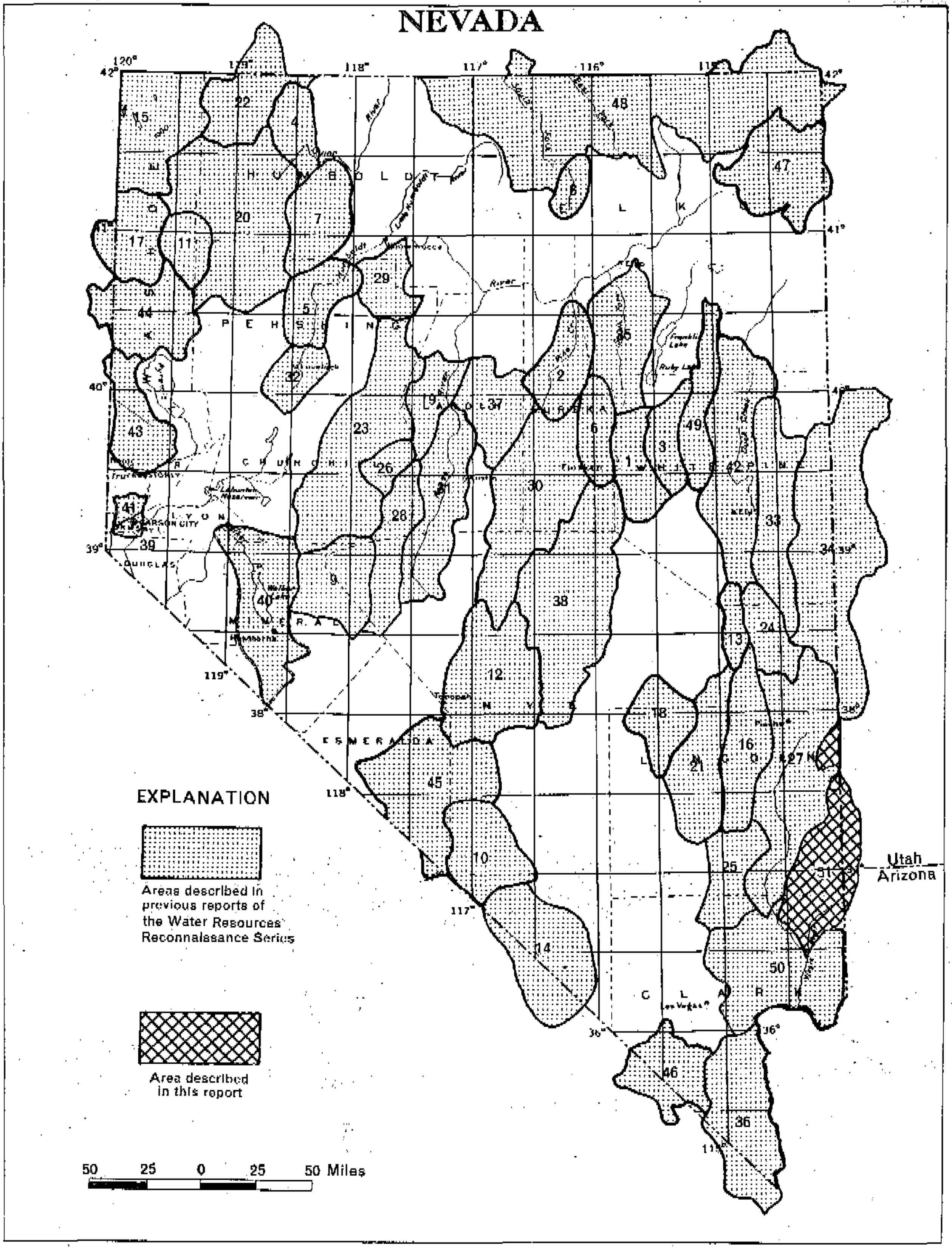

Figure 1.—Areas in Nevada described in previous reports of this series and the area described in this report

According to R. Gwinn Vivian (written commun., 1968), Arizona State Museum, an archaeological survey in the Littlefield area revealed an extensive development by the Anasazi culture Indians near the confluence of Beaver Dam Wash and the Virgin River. The site was excavated by the Museum of Northern Arizona. Other sites inhabited by the Indians also occur in the lower Virgin River Valley. Vivian stated that these sites probably belong to the Virgin Branch of Southwestern Anasazi culture. The culture in this area may date back to A.D. 500 and was well established by A.D. 900; however, these people largely abandoned the Virgin River area by A.D. 1150. The Anasazi-Virgin Branch inhabitants practiced agriculture and probably utilized streamflow for irrigation. Therefore, some primitive development and utilization of streamflow in the area probably was undertaken several hundred years before exploration and settlement in the 1800's.

The establishment of an Indian village at the confluence of the Virgin River and Beaver Dam Wash may have been partly influenced by the perennial availability of good-quality domestic and irrigation water from Beaver Dam Wash. As discussed later in this report, the flow of Beaver Dam Wash is superior in general chemical quality to the low flow of the Virgin River.

A party of American explorers led by Jedediah Smith, enroute to California, made the first recorded entry into the report area during their downstream journey along the Virgin River in September 1826 (Morgan, 1953, p. 197-198). Smith reportedly named the Virgin River the "Adams River" in honor of President John Quincy Adams (Morgan, 1953, p. 197, and Cline, 1963, p. 199). However, the origin of the river's present name is somewhat controversial. Leigh (1964, p. 106-107) stated that the original name was "Rio de la Virgen" as given by the Spanish in honor of the Virgin Mary. He claimed it was later shortened by the Spanish to "Rio Virgen", which form adhered for about a century until it finally became Americanized to Virgin River. Leigh speculated that the name may have been bestowed by the Spanish explorer Armigo. Averett (1962, p. 97) stated the name is variously credited to either Father Escalante or Jedediah Smith. Nevada State Writers Project (1941, p. 18) credited the naming to Jedediah Smith, who reportedly named it after Thomas Virgin, one of the explorers in his party.

Jedediah Smith, on a second trip to California in the summer of 1827, again passed through the lower Virgin River Valley. On this trip, instead of descending the river through its canyon and emerging at The Narrows, he crossed the Beaver Dam Mountains north of the canyon, apparently somewhat along the present route of U.S. Highway 91. At the base of the west slope of the mountains he intercepted the dry Beaver Dam Wash, which he called "Poutch Creek", and followed it downstream to its confluence with the Virgin River

(Morgan, 1953, p. 237-238). Smith's recorded observations of the area include the muddy and brackish nature of the river water and the agricultural practices of the few Indians he observed (Cline, 1963, p. 331-334). The Indians were farming corn and pumpkins, which implies some use of water for irrigation.

The old Spanish trail, the first charted course across the Great Basin, connected New Mexico with southern California and included part of the lower Virgin River Valley. It became an established route in about 1830 (Cline, 1963, p. 165-167, and Hulse, 1966, p. 43-44). Fremont used the trail on the return leg of his extensive western exploration and camped at the confluence of Beaver Dam Wash and the Virgin River in early May 1844 (Cline, 1963, p. 213-214).

Mormon missionaries visited the Indians of the Virgin River Valley as early as 1854 (Morgan, 1953, p. 414). Mormons later started the first settlement of the area when the community of Bunkerville was founded by a group led by Edward Bunker, Sr., in January 1877 (Hulse, 1966, p. 149-150). Another group arrived in 1879 and founded the neighboring community of Mesquite. The economies of both communities were based on agriculture, and the farmers diverted Virgin River water for irrigation along the flood plain. Unfortunately, disastrous flooding in 1882 caused extensive damage to the irrigation works of both communities. More floods and problems plagued the Mesquite settlers; discouraged, they abandoned the Mesquite colony in 1891. Mesquite was eventually resettled in 1895 (Hulse, 1966, p. 149-150). The Bunkerville-Mesquite area remained the major center of habitation in the report area, and although the economy is now somewhat more diversified, it is still based mainly on agriculture, which in turn is dependent largely on the quantity and quality of Virgin River water.

Previous Work

Geologic investigations in the area, and in adjacent areas, began in the 1870's. Longwell (1928, p. 4) mentioned a significant geologic study in the Virgin Mountains by A. R. Marvine, a geologist with the Wheeler Survey party in 1871. Longwell (1928, p. 5) also credited geologic work done in the Virgin Mountains and summarized by Spurr in 1903. Longwell's works in an adjacent area (1921, 1922, 1928, and 1949) cover many aspects of the regional geology. Specific geology of the report area is also covered by Utah Geological Society (1952), Wilson and others (1959), Tschanz and Pampeyan (1961), Hintze (1963), and Longwell and others (1965). Raphael (1954) discussed crustal disturbances in the Lake Mead area.

Hydrology was first discussed specifically by Carpenter (1915,

p. 58-64). The University of Nevada (1944, p. 13), Hardman (1946, p. 95-98), and Miller and others (1953, p. 18-21 and 56) published data and discussions relating to the chemical quality of water in the area. Shamberger (1954) discussed surface-water hydrology in detail in his report on the Colorado River and its tributaries in Nevada. A watershed work plan for the Mesquite area of the lower Virgin River Valley was cooperatively prepared and activated by the Mesquite Irrigation Company, Inc., and others (1962). Various aspects of the hydrology of adjacent areas are covered in reports by Smith (1960), U.S. Bureau of Reclamation (1961), and Rush (1964 and 1968b).

Acknowledgments

The writers are grateful to the many residents of the area who provided valuable information about water use and land development, and allowed access to their land and wells. Especially helpful in this regard were Bruno Biassi, Archie Hughes, Dee Hughes, Mrs. Jean Hughes, Vince Leavitt, Andy Lytle, and William Walter, III. Kenneth Romriell of the U.S. Soil Conservation Service provided extensive assistance during the field investigation, and Malcolm Charlton of the U.S. Bureau of Land Management furnished valuable information on well locations. A. B. West, Regional Director, U.S. Bureau of Reclamation, Boulder City, provided information on a Virgin River project in Utah. Considerable data were supplied by the Arizona and Utah Water Resources Division districts of the U.S. Geological Survey. Information on wells was supplied by Patrick H. Thompson, well driller, Las Vegas; Charles T. Parker Construction Company, Las Vegas; and C. C. Larkin, Union Pacific Railroad Co., Salt Lake City, Utah. R. Gwinn Vivian, Arizona State Museum, University of Arizona, provided information on prehistoric habitation of the area.

GENERAL HYDROLOGIC ENVIRONMENT

Physiographic Features

The Virgin River is a major tributary of the Colorado River; its confluence with the Colorado River occurs at Lake Mead, the reservoir behind Hoover Dam. The Virgin River has cut a precipitous canyon through the Virgin Mountains and emerges at "The Narrows", about 4 miles east of Littlefield. The lower Virgin River Valley is northeast-trending and is oblong (pl. 1). Most of the valley is bounded by mountains, and near the river the land is comparatively flat. The major tributaries are Tule Desert, surficially drained by Toquop Wash; Beaver Dam Wash; Sand Hollow Wash; and numerous ephemeral drainages heading in the Virgin Mountains southeast of the river and in the Mormon Mountains northwest of the river.

Altitudes in the lower Virgin River Valley range from a maximum of about 8,350 feet above sea level in the Virgin Mountains to about 1,150 feet at the river's confluence with Lake Mead. In Escalante Desert, Nevada, altitudes range from about 7,700 to about 5,700 feet. Major mountain ranges are the Virgin, Beaver Dam, Mormon, and East Mormon Mountains. The mountains are generally rugged and sparsely vegetated. Transitional sloping alluvial surfaces join the steeper mountainous masses with the comparatively flat-lying dissected mesa topography of the valley interior.

Lithologic Units

The generalized geology of the area is shown on plate 1, and a summary of lithologic units and their character is included in table 2. Differentiation of the four lithologic units on the plate and in the table was based mainly on their hydrologic properties. For this reconnaissance, the several alluvial deposits were grouped into either older or younger alluvium. Criteria for separation of the units are as follows: (1) alluvial areas where erosion and deformation appears to have been recently dominant over deposition are classified as older alluvium, (2) alluvial areas that are either thinly mantled by younger alluvium or mantled by younger alluvium that has no particular significance with respect to ground-water conditions are classed as older alluvium, (3) alluvial areas where recent deposition has been the dominant process and where thickness and location of the deposits renders them significant with respect to ground-water hydrology are classed as younger alluvium, and (4) younger alluvium is assumed to have been deposited during comparatively recent geologic time, and is generally less than 100 feet thick.

For this report, the consolidated rocks are grouped into

Table 2.--Generalized lithologic units and their water-bearing properties[1]

Geologic age: Period	Geologic age: Epoch		Lithologic unit	Thickness (feet)	General characteristics and extent (see pl. 1)	Water-bearing properties
QUATERNARY	Holocene and Pleistocene	VALLEY FILL	Younger alluvium	0-100±	Unconsolidated lenses of gravel, sand, silt, and clay comprising fluvial deposits; detritus derived mainly from bordering upland consolidated rocks and reworking of older alluvium, and sediment load transported into the area by Virgin River; although younger alluvium may mantle much of the area, its hydrologic significance is mainly restricted to flood plains of Virgin River and Beaver Dam Wash, and the Tule Desert.	Younger and older alluvium together form valley-fill reservoir, the principal source of water from wells in the area; where saturated, they yield water to municipal, domestic, irrigation, and stock wells; well yields are variable both in quantity (from a few gpm to possibly several thousand gpm) and quality, depending on character of deposits encountered and source of recharge (precipitation in the area in the area versus infiltrated Virgin River flow).
TERTIARY AND QUATERNARY	Pleistocene to Miocene(?)	VALLEY FILL	Older alluvium (includes Muddy Creek Formation)	0-several thousand(?)	Unconsolidated to consolidated deposits of boulders, gravel, sand, silt, and clay exposed in most valley lowlands and buried at generally shallow depth beneath younger alluvium; composed mainly of debris from bordering mountains, debris washed in from adjacent areas by ancestral streams, and probably some lacustrine deposits, including evaporites; locally cemented; probably thickest in valley troughs; mantles consolidated rock near mountains.	

Continued

Table 2.--Generalized lithologic units and their water-bearing properties--continued

Geologic age: Period	Geologic age: Epoch		Lithologic unit	Thickness (feet)	General characteristics and extent (see pl. 1)	Water-bearing properties
CAMBRIAN TO TRIASSIC	Triassic to Middle Cambrian	CONSOLIDATED ROCKS	Carbonate rocks[2]	--	Mainly limestone and dolomite; include some interbedded noncarbonate sedimentary rocks; structurally deformed; probably occurs extensively beneath valley-fill deposits.	Transmit water through fracture and solution cavities; some interbasin subsurface flow may occur through these conduits; yield water to springs.
PRECAMBRIAN TO TERTIARY		CONSOLIDATED ROCKS	Noncarbonate rocks[2]	--	Igneous, metamorphic, and sedimentary rocks; igneous rocks are mainly volcanic and are most prevalent in northern part of area; metamorphic rocks are mainly gneiss found in Virgin Mountains; sedimentary rocks include shale, siltstone, sandstone, conglomerate and evaporites, and are most prevalent in southern and eastern parts of area; unit may occur extensively beneath valley-fill deposits.	Generally untested by wells; yield minor amounts of water to springs; might yield small amounts of water to wells locally from fracture zones; considered poorest water-yielding unit in area.

1. Lithologic units synthesized from various reports, as credited on plate 1.
2. Carbonate and noncarbonate rocks are interbedded, and are not discreet geologic time units.

noncarbonate and carbonate rocks (pl. 1). The carbonate rocks commonly contain solution cavities or enlarged joints and fractures which, where interconnected, readily conveyed ground water. In contrast, local data suggest that the noncarbonate rocks are generally of low permeability and do not readily convey ground water. Structural deformation may have increased or decreased the transmissibility of the consolidated rocks, depending on a variety of factors and conditions; therefore, the present hydrologic charactaristics of the rocks may differ to varying degrees from those common to the rocks at the time of their emplacement. Structural deformation is generally more complex and common in consolidated rocks than in the valley-fill deposits; however, deformation of some of the older alluvium has occurred, and locally may have significantly altered the transmissive character of this unit.

VALLEY-FILL RESERVOIRS

Extent and Boundaries

The valley-fill reservoirs are formed by the younger and older alluvium. Lateral extent of these deposits is shown on plates 1 and 2. Three distinct valley-fill reservoirs are identified in the report area: The large lower Virgin River Valley, Tule Desert, and Escalante Desert. The reservoir in the lower Virgin River Valley is divided arbitrarily into the part lying in Arizona and Utah and two parts in Nevada. The two Nevada parts are separated by the Virgin River.

The reservoir boundaries of the lower Virgin River Valley are formed by the consolidated rocks of the peripheral mountain ranges and by a ground-water divide on the southwest, which is presumed to coincide with the surface boundary between this area and Lower Moapa Valley. The ground-water divide is a transient boundary subject to lateral displacement, depending on the stresses imposed on either side by discharge and recharge.

The boundaries of Tule Desert are formed by the peripheral mountain ranges. The reservoir boundaries of Escalante Desert in Nevada are formed by unnamed mountains around the south, west, and north sides. The east side is arbitrarily set at the State line, and the valley-fill reservoir is continuous eastward with the very large valley in Utah.

Wherever the reservoir boundaries are carbonate rocks, they are likely to be leaky. The most significant leaky boundaries of this type are probably those between Tule Desert and lower Virgin River Valley, and the consolidated-rock mountain segment east of the report area in the general vicinity of The Narrows. The arbitrary Stateline boundaries, of course, are political rather than hydrologic.

The maximum thickness of the valley-fill reservoirs may be as much as several thousand feet. Well 10/69-7bb is the deepest in Tule Desert and penetrates 566 feet of valley fill without encountering bedrock (table 22; see well-numbering system). Well 14/69-33a1, along the Virgin River downstream from Riverside, bottomed in valley fill at 880 feet. Wells 13/70-35cdd1 and 2 along the Virgin River in Nevada, upstream near the Nevada-Arizona State line, bottomed at 300 feet in valley fill (table 22). Well A41/15-29dcd, near the confluence of Beaver Dam Wash and the Virgin River, is reported to have been drilled 2,600 feet deep as an oil test well, but no log is available. Railroad well U34/19-36c at Modena, Utah, just east of the Nevada part of Escalante Desert bottomed in valley fill at 635 feet.

Occurrence and Movement of Ground Water

The known depth below land surface to the zone of saturation in the valley-fill reservoirs ranges from zero in spring areas to about 390 feet in well 10/69-7bb in the Tule Desert. Available data on depth to water are areally biased, with the greatest data concentrations generally near areas of greatest habitation.

Information on ground-water movement in areas removed from the developed part of the Virgin River flood plain is restricted because of a shortage of well data; therefore, springs provide most of the information in those areas. Spring areas occur most commonly near the heads of ephemeral drainages where the valley-fill reservoir is generally thinnest. However, the largest spring discharges occur along the Virgin River from about the Nevada-Arizona State line upstream to The Narrows, and in Beaver Dam Wash near its confluence with the Virgin River. The spring discharge in these channels probably is the result of stratigraphic or structural barriers to downgradient flow in the carbonate rocks, which may underlie the valley fill at moderate depth. The combined flow of these springs exceeds that possible from local recharge within the report area, as described in a later section of this report.

Shallow depths to water (less than 50 feet) are common along the flood plains of Virgin River and in the downstream part of Beaver Dam Wash. At increasing distances from these flood plains, slope of the land surface generally steepens toward the uplands at a greater rate than the ground-water surface. As a result, depths to water generally are greater near the mountain fronts than along the flood plains.

In the Virgin River Valley, the movement of ground water through the valley fill is generally from the bordering mountain masses toward the Virgin River and down the valley toward Lake Mead. The hydraulic gradients resulting from changes in river stage govern the movement of the ground water in the areas adjacent to the stream. In Nevada, ground-water movement in the Virgin Mountains is northward to the river, and in the Mormon Mountains and Tule Desert ground water moves southward to the river. In Escalante Desert ground water generally moves eastward toward the main part of the valley in Utah.

CARBONATE-ROCK RESERVOIR

Carbonate rocks locally may form a storage and transmission medium for ground water where solution cavities were formed along fracture systems and in other zones of weakness caused by percolating waters. Carbonate rocks, as shown on plate 1, make up a considerable part of the exposed, and probably also the buried, consolidated rocks of the area. Structural deformation of these rocks is intense and widespread. Field examination disclosed that some of the carbonate rocks are riddled by solution cavities. Fresh exposures in roadcuts in The Narrows (pl. 1) disclose numerous cavities in the carbonate rocks, many of which are as much as several feet in diameter. The cavities appear to be stratigraphically controlled because they occur in zones parallel to bedding planes. Undoubtedly, many others are structurally controlled because the mountainous consolidated rock masses are structurally deformed. Assuming that solution cavities are also common in the subsurface, the carbonate rocks of the area probably are capable of containing and transmitting appreciable quantities of water.

Only one well (U43/18-7d) has been drilled deeply (630 feet) into carbonate rocks in the area. It resulted in a dry hole, but it bottomed more than 400 feet above the water-surface altitude in the nearest adjacent well (U43/19-20b) about 6 miles to the southwest. Therefore, that test was inconclusive and the water-yielding capabilities of the carbonate rocks remain untested.

The carbonate rocks probably provide the route by which ground water in Tule Desert moves generally south or southeastward to the lower Virgin River Valley (fig. 2). Also, as previously mentioned, carbonate rocks are believed to convey water from the east to the springs downstream from The Narrows.

INFLOW TO THE VALLEYS

Precipitation

Precipitation within the area is the main source of ground water entering the valley-fill reservoirs in Tule and Escalante Deserts, but in the lower Virgin River Valley, infiltration of streamflow provides the principal source of ground water.

The climate of southern Nevada ranges from semiarid to arid, the valley floors being arid and the bordering mountains semiarid. Most precipitation occurs during the winter, and typically the amounts increase with altitude. Winter storms usually are regional, whereas summer storms typically are localized thundershowers. The climate is further characterized by an abundance of sunshine, dry winds, and associated high evaporation rates.

Much of the precipitation occurs as rain, but snow can accumulate in significant amounts in the higher mountain areas during the winter. A summary of average annual precipitation at selected stations in and near the report area is shown in table 3. Many of the station locations are shown in figure 2. The table shows annual averages for the stated period of record, and estimated averages for the period 1931-66. The estimates for 1931-66 are synthesized on the basis of long-term records for Boulder City, Nevada, and Gunlock Powerhouse, Utah. Table 3 shows that the estimated long-term precipitation in the region, at the altitudes sampled, ranges from about 4 to more than 20 inches per year. The data suggest that precipitation for given altitude zones may be slightly greater in the eastern and northern parts of the area.

Surface Water

By D. O. Moore

Surface water of the report area consists of Virgin River streamflow entering the lower Virgin River Valley from the east, tributary streamflow originating within the report area, and springflow entering the Virgin River near Littlefield. Streamflow quantities were determined from available records of flow within the report area, records of flow in adjacent areas, and by indirect methods based on channel-geometry measurements.

Records Available

The only active streamflow gaging station in the study area is

Table 3.--Summary of average annual precipitation at selected stations

[Computed from published records of the U.S. Weather Bureau]

Station	Approximate Location Long.	Lat.	Altitude (feet)	Period of full-year record since 1931 (years)	Average annual precipitation for period of record (inches)	Estimated average annual precipitation for period 1931-66 (inches)
NEVADA						
Acoma	114°09'	37°34'	5,521	1951, 1954-58	10.8	10
Boulder City1/	114°51'	35°59'	2,525	1932-66	5.2	5
Bunker Peak	114°07'	37°27'	5,575	1952-63	15.4	16
Caliente	114°31'	37°37'	4,402	1939-66	8.6	9
Carp	114°29'	37°07'	2,600	1950, 1952-54, 1956, 1962	4.0	5
Crestline	114°08'	37°40'	5,982	1958-65	12.8	13
Desert National Wildlife Range1/	115°22'	36°26'	2,920	1941-66	4.0	4
Elgin	114°32'	37°21'	3,385	1953-66	8.7	9
Hidden Forest Camp1/	115°12'	36°38'	7,550	1946-58, 1960-64	13.3	14
Las Vegas1/	115°02'	36°14'	1,879	1937-48	4.3	4
Las Vegas (McCarran Field)1/	115°10'	36°05'	2,162	1949-66	3.6	4
Mesquite	114°04'	36°48'	1,600	1943-46, 1959-60, 1963	6.1	6
Overton	114°25'	36°31'	1,220	1953-66	3.7	4
Pine Canyon	114°14'	37°24'	6,500	1952-64	12.7	14
Pioche	114°27'	37°56'	6,110	1939-66	12.6	13
Ursine	114°13'	37°59'	5,760	1965-66	13.2	11

Table 3.--Continued

Station	Approximate Location Long.	Lat.	Altitude (feet)	Period of full-year record since 1931 (years)	Average annual precipitation for period of record (inches)	Estimated average annual precipitation for period 1931-66 (inches)
UTAH						
Cedar City Steam Plant	113°02'	37°40'	5,980	1962-66	12.3	14
Enterprise	113°43'	37°34'	5,330	1955-66	11.9	13
Enterprise-Beryl Jct.	113°39'	37°43'	5,200	1961-66	9.1	11
Gunlock Powerhouse	113°43'	37°17'	4,060	1931-66	11.3	11
LaVerkin	113°16'	37°12'	3,450	1953-66	9.8	11
Little Grassy Creek	113°51'	37°29'	6,100	1959-64	17.1	22
Long Flat	113°23'	37°30'	8,000	1959-64	19.1	25
Lund	113°26'	38°00'	5,091	1953-66	7.2	8
Modena	113°55'	37°48'	5,460	1931-66	9.3	9
St. George Powerhouse	113°34'	37°06'	2,700	1959-65	6.9	8
Veyo	113°39'	37°21'	4,500	1958-66	12.3	13
ARIZONA						
Littlefield	113°56'	36°53'	1,800	1952-58	6.2	6
Pierce Ferry 17 SSW1/	114°05'	35°53'	3,860	1964-66	11.1	12

1. Station location not shown on figure 2.

on the Virgin River at Littlefield, Ariz., just below the confluence with Beaver Dam Wash; the station has been operated since 1929. A crest-stage partial-record station has been operated since 1963 on Big Bend Wash at U.S. Highway 91, 2.7 miles southwest of Littlefield. Miscellaneous streamflow measurements were made on Virgin River, Beaver Dam Wash, and several of their tributaries during the course of this study. Miscellaneous measurements were made on several springs, canals, and Beaver Dam Wash during previous years. Selected channel features were measured on a number of ephemeral and perennial streams during this study and were used in estimating average annual runoff, using techniques devised by Moore (1968). Gaging-station and measurement sites are shown on plate 1, and results of most of the miscellaneous measurements are listed in table 4.

Streamflow

Most streamflow in the area occurs in the Virgin River. The major part of the flow originates in the upper Virgin River basin, which is upstream from, and generally northeast of, the report area. Intermittent runoff occurs within the report area, some of which contributes to the flow of the Virgin River.

Virgin River.--Virgin River flow is variable, both annually and seasonally. Summaries of streamflow at the gage at Littlefield, Ariz., for 38 water years (year ending Sept. 30) of record (1930-67), are shown in tables 5 and 6, and figures 3 and 4. Figure 3 shows the average monthly discharge of the Virgin River at Littlefield as a percentage of its mean annual discharge. The dashed line in figure 3 indicates the median discharge for each month; that is, 50 percent of the monthly flows were less and 50 percent were greater than the value shown. The upper line is the upper quartile indicating the value for which only 25 percent of the monthly flows were greater and 75 percent were less than the value indicated. Similarly, the lower line is the lower quartile, indicating the value for which 75 percent of the monthly flows were greater and only 25 percent were less than the value indicated.

Although some additional inflow occurs below the Littlefield gage, field observations indicate that a substantial net decrease in flow occurs between Littlefield and Lake Mead. An attempt was made to determine the mean annual flow of the river near its mouth (15/69-30c) using channel-geometry techniques (Moore, 1968). Preliminary results suggest that the average annual flow is about 80,000 acre-feet; however, the degree of reliability of this method is unknown where upstream diversions, such as those into irrigation canals near the Arizona-Nevada border, are extensive.

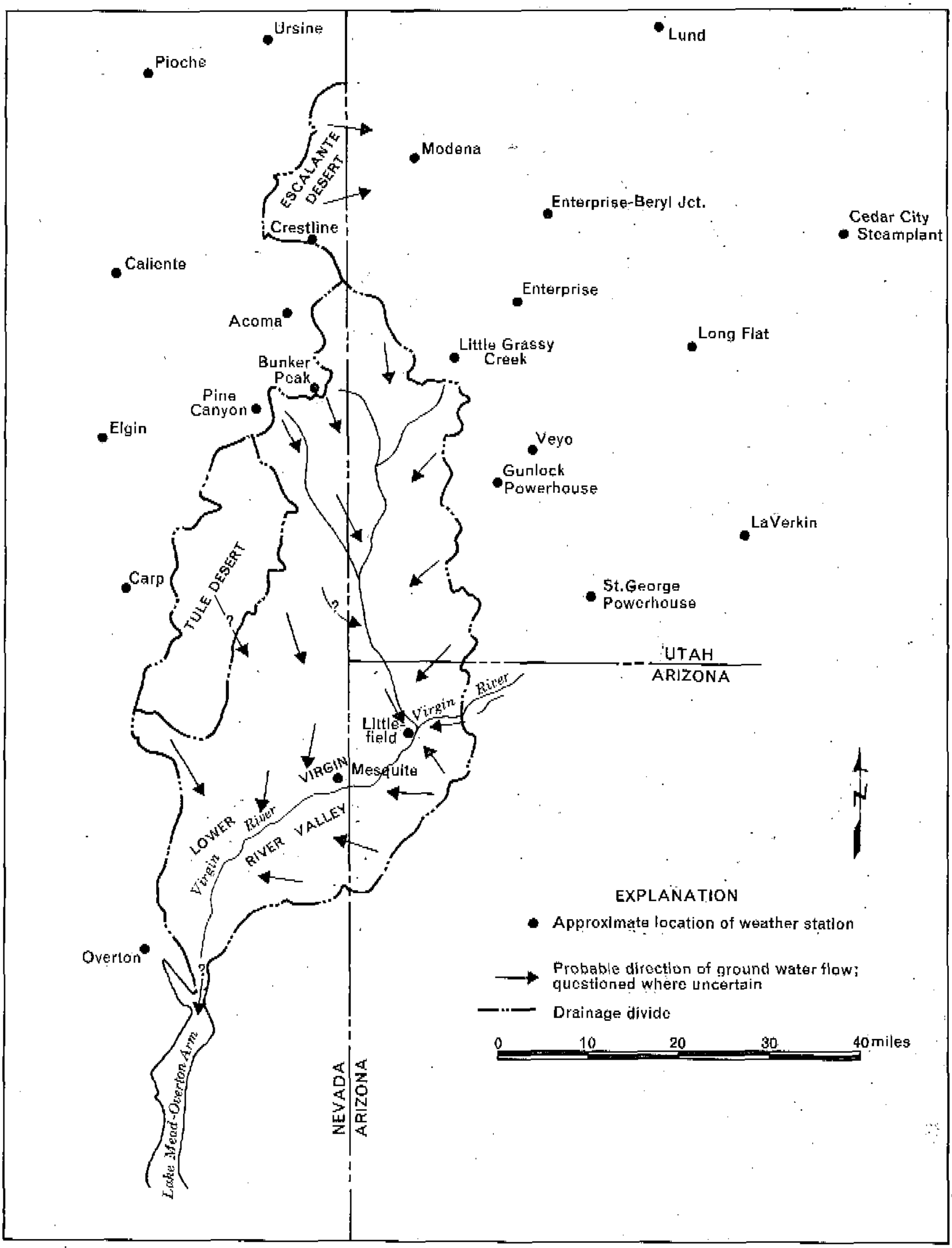

Figure 2.—Locations of weather stations and general directions of ground-water movement

Table 4.--Miscellaneous streamflow and springflow measurements in the lower Virgin River Valley

Site number (pl. 1)	Site	Location	Date	Discharge (cfs)
1	Virgin River	A41/14-32a	11- 7-51	69.8
			12-13-51	143
2	Do.	A41/14-30c	12-13-51	158
3	Do.	A41/15-25d	12-13-51	170
4	Do.	A40/15-4bd	6-18-54	52.4
			6-16-55	55.1
			7- 2-57	48.6
			6-30-58	49.2
5	Slaughterhouse Creek	U39/19-8	10- 3-57	2.24
6	Beaver Dam Wash	U39/19-32	2-22-67	7.11
7	Unnamed tributary	U40/19-5	2-22-67	.48
8	Beaver Dam Wash	U40/19-8	2-22-67	5.55
9	East Fork Beaver Dam Wash	U39/19-26	2-22-67	.00
10	Beaver Dam Wash	U41/19-4	2-22-67	.00
11	Do.	A40/15-5 (at highway bridge)	7- 2-57	.37
			6-30-58	.00
			2-22-67	.00
12	Do.	A40/15-4 (at mouth)	7- 3-46	4.02
			7- 2-47	3.69
			6-30-49	4.15
			6- 1-50	3.03
			7- 1-50	2.26
			7- 1-51	3.25
			7- 1-52	4.81
			6-17-53	3.48
			6-18-54	5.55
			6-16-55	3.93
			7- 2-57	2.82
			6-30-58	.74
			2-22-67	2.80
			2- 8-68	2.72
13	Slim Creek Springs	A40/15-4	7- 1-51	1.29
14	Camp Wash Falls Springs	A40/15-4	6- 1-50	1.68
			7- 1-50	1.78
			7- 1-51	.32
15	Petrified Springs	A40/15-4 (at orifice)	6- 1-50	1.38
			7- 1-50	2.03

Table 4.--Continued

Site number (pl.1)	Site	Location	Date	Discharge (cfs)
16	Petrified Springs	A40/15-4 (spring mouth)	6- 1-50	2.32
			7- 1-50	2.65
			7- 1-51	3.27
			7- 1-52	2.43
			7-18-52	1.86
			6-17-53	2.14
			6-18-54	1.90
			6-16-55	1.94
17	Littlefield Springs	A40/15-4c	7- 2-51	.60
18	Virgin River	A40/16-35ac	7-17-68	59.3
19	Do.	13/71-19	7- 3-46	11.2
			7- 2-47	5.29
			6-30-49	8.80
			6- 1-50	16.3
			7- 2-51	30.6
20	Do.	14/70-7bc	7-17-68	.1 est.
21	Do.	15/69-30c	7-17-68	.00
22	Littlefield Canal	A40/15-4c	7- 3-46	1.39
			7- 2-47	1.31
			6-30-49	.98
			6- 1-50	1.03
			7- 1-50	1.14
			7- 1-51	1.18
			7- 1-52	.88
			6-17-53	.77
			6-18-54	.70
			6-16-55	1.08
			6-18-56	.40
			7- 2-57	.45
			6-30-58	.47
23	Petrified Springs Canal	A40/15-4	6-18-54	3.41
			6-16-55	3.23
			6-18-56	2.82
			7- 2-57	2.14
			7-15-58	2.38
24	Bunkerville Canal	13/71-19	7- 3-46	16.3
			7- 2-47	15.4
			6-30-49	11.9
			6- 1-50	12.1
			7- 2-51	23.4

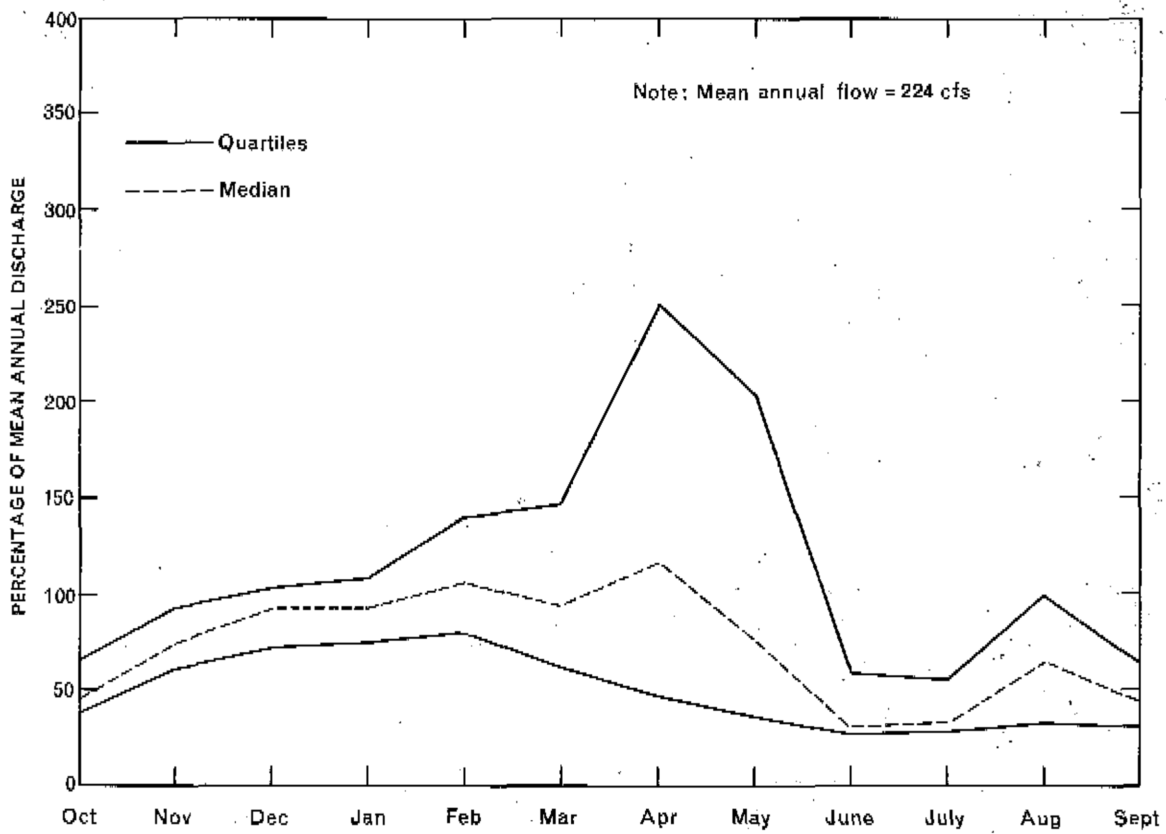

Figure 3.—Average monthly discharge as a percentage of mean annual discharge for Virgin River at Littlefield, Arizona, 1930-67

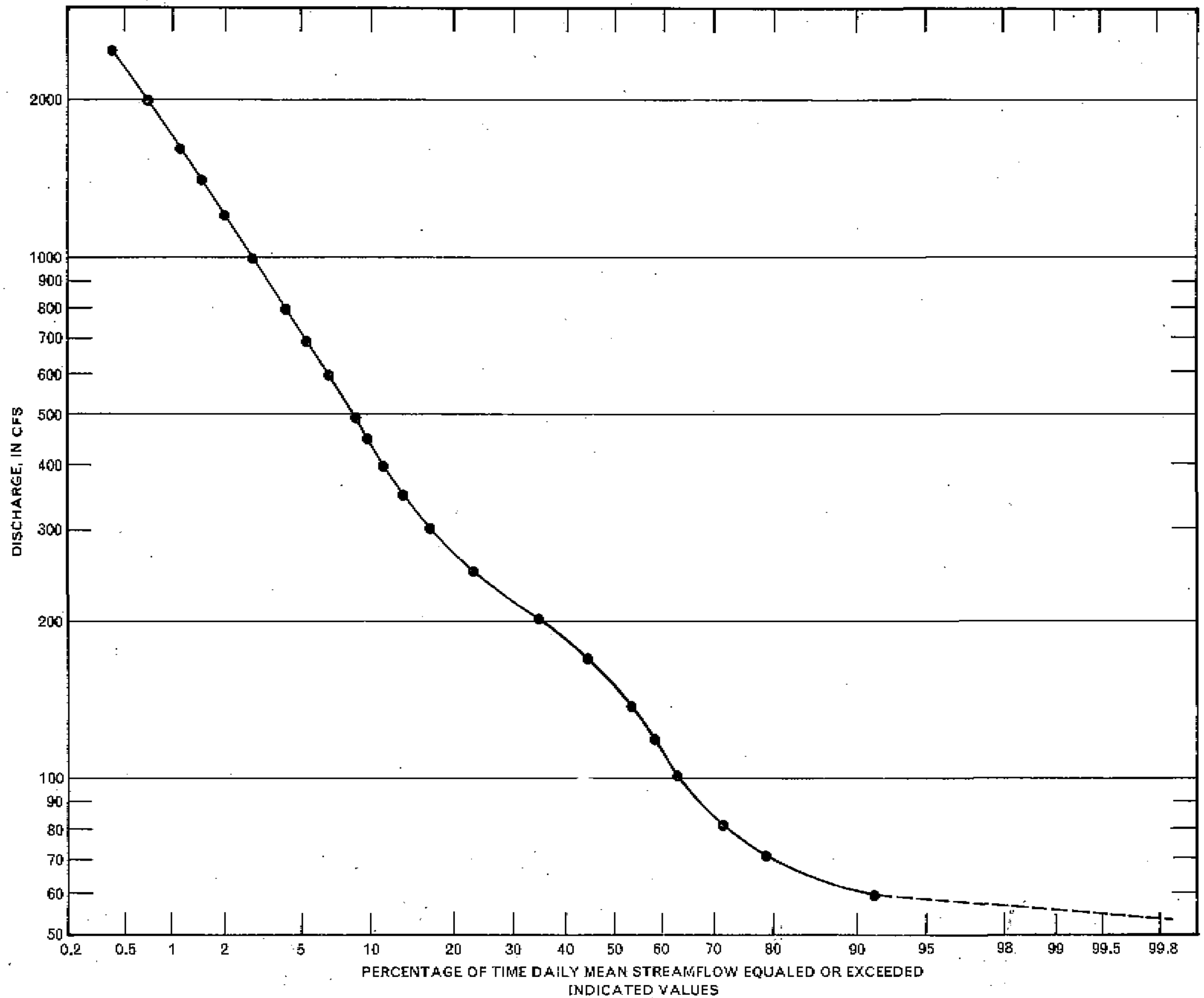

Figure 4.—**Flow** duration curve for Virgin River at Littlefield, Arizona, 1931-59

Table 5.--Summary of annual streamflow of Virgin River at Littlefield, Ariz., 1930-67

(All values in acre-feet)

Water Year	Flow	Water Year	Flow	Water Year	Flow
1930	188,100	1943	178,100	1956	92,820
1931	119,400	1944	182,700	1957	100,200
1932	381,900	1945	166,300	1958	294,600
1933	127,400	1946	121,300	1959	92,860
1934	78,000	1947	192,200	1960	83,440
1935	164,800	1948	116,400	1961	108,500
1936	131,000	1949	115,900	1962	142,400
1937	240,300	1950	127,100	1963	83,230
1938	278,600	1951	99,930	1964	89,510
1939	154,900	1952	273,700	1965	120,400
1940	173,700	1953	99,470	1966	132,700
1941	400,000	1954	136,500	1967	187,600
1942	215,000	1955	135,500	1968	a 128,700

Maximum annual flow: 400,000 acre-feet in 1941.

Minimum annual flow: 78,000 acre-feet in 1934.

Mean annual flow: 162,200 acre-feet.

Median annual flow: 134,000 acre-feet.

a. Value became available since completion of report; not included in computations.

Table 6.--Summary of monthly streamflow in Virgin River at Littlefield, Ariz., 1930-67

(All values in cubic feet per second)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water year
Average	141	190	233	211	289	306	381	363	105	107	202	155	224
Maximum	602	552	1,247	344	1,330	1,380	1,340	2,120	344	381	976	737	a 552
Minimum	53.4	102	111	141	130	98.8	61.6	62.2	46.8	51.6	50.0	53.3	b 108

a. Maximum recorded water year, 1941.

b. Minimum recorded water year, 1934.

Local runoff.--The amount of runoff in the mountains within the report area cannot be computed directly because of the absence of stream-gaging stations. Therefore, estimates were made using methods devised by Moore (1968). Runoff was estimated using runoff-altitude relations and channel geometry.

Mean annual runoff generated at the mountain fronts in the three study areas is summarized in table 7. Only about 35 percent of the report area generally contributes a significant amount of dependable runoff. Occasionally runoff may occur locally on the valley floors but generally is so erratic in frequency and duration that it has little value to economic development.

Channel-geometry measurements were made near the mouths of several of the larger ephemeral washes that enter the Virgin River to determine their average annual discharge. Table 8 lists estimated runoff of three major washes discharging to the Virgin River. These estimates, in turn, were used to estimate the total runoff to the Virgin River. Results are as follows: runoff to the river within Nevada is about 5,000 acre-feet per year, and runoff to the river in Arizona downstream from the Littlefield gaging station is about 2,000 acre-feet per year.

Estimated flow from springs that discharge into the Virgin River.--A large part of the runoff at the Littlefield gaging station is supplied by springs entering the Virgin River upstream from the station. For example, the following table shows the flows at Littlefield during several months when the flow near St. George, about 18 miles upstream, was zero:

Date	Flow at Littlefield (cfs)
June 1951	62.6
June 1953	68.6
June 1955	66.6
September 1957	59.9

However, the gage at Littlefield does not measure the total springflow, because two canals bypass the gage: the Littlefield Canal, which diverts water from Beaver Dam Wash, and the Petrified Springs Canal, which diverts some of the springflow that would otherwise enter the river above the gage. The total springflow is estimated to be nearly 70 cfs--65 cfs at the Littlefield gage plus 4 cfs combined flow of Littlefield and Petrified Springs Canals--or about 50,000 acre-feet per year.

Two perennial springs systems were identified: (1) The dominant system along the Virgin River, which supplies about 65 cfs and which

Table 7.--Estimated average annual local runoff at the mountain fronts

Area	Area contributing runoff (acres)	Estimated average annual runoff (acre-feet)
Lower Virgin River Valley		
Area in Nevada north of river	105,000	5,600
Area in Nevada south of river	13,000	700
Area in Arizona and Utah	173,000	8,000
Total (rounded)	290,000	14,000
Tule Desert	75,000	1,400
Escalante Desert (Nevada)	34,000	a 3,200

a. Of this total, the estimated average annual flow across the State line to Utah is about 400 acre-feet, on the basis of channel geometry measurements (Moore, 1968).

Table 8.--Estimated average annual runoff of three ephemeral streams discharging to the Virgin River

Stream	Location of runoff estimate	Estimated average annual runoff (acre-feet)
Sand Hollow Wash	A40/16-35	1,300
Toquop Wash	13/70-32	3,000
Nickel Creek	14/70-18	150

is moderately saline (table 17); and (2) the springs and ground-water inflow in Beaver Dam Wash, which contribute about 5 cfs of good quality water to the Virgin River. About 1 cfs in Beaver Dam Wash is diverted into Littlefield Canal for irrigation. Most of the 65 cfs of saline water enters the Virgin River channel between The Narrows (or within The Narrows) and Littlefield gage. Moreover, this water is believed to originate upstream and largely outside the report area. It probably reaches this area by flow through carbonate rocks.

Beaver Dam Wash and the more saline major spring system (mainly the latter) provide most of the river flow entering Nevada during low-flow periods; they therefore constitute a significant part of the local irrigation supply in Nevada during the hot summer part of the growing season.

In addition to the spring systems discussed above, ground-water flow from recharge areas northwest and southeast of the river probabl enters the river system along the channel between the Littlefield gage and Lake Mead. However, the magnitude of flow and areas where it enters the Virgin River are unknown. Discharge of the Virgin River was measured on July 17, 1968, about 8 river miles below the Littlefield gage (site A40/16-35ac, table 4 and pl. 1). The discharge was about 6 cfs (10 percent) greater than that recorded at the gage, and the river stage was steady at the time. The pickup in flow may have been the result of return flow from the Littlefield and Petrified Springs Canals, additional ground-water discharge to the stream channel, or a combination of both. Also, local residents report that springs were occasionally observed along the channel near Mesquite, Bunkerville, and Riverside, and that the quality of water was better than that of the Virgin River during low flow. However, areas where ground-water discharge entered the Virgin River reportedly were plugged and the flow dispersed by sediment depositio and channel changes during flood periods. Therefore, the springs do not have well-defined points of discharge to the river but vary along the river channel. The total cumulative flow represents that part of the local recharge not consumed by evapotranspiration or discharged as subsurface flow to Lake Mead.

Ground-Water Recharge

Ground-water recharge throughout most of the report area originates mainly as precipitation within the area. A method described by Eakin and others (1951, p. 79-81) was used to estimate recharge in this report. Hardman (1965) demonstrated that in gross aspect the average annual precipitation in Nevada is related closely to altitude and that it can be estimated with a reasonable degree of accuracy by assigning precipitation rates to various altitude zones. Estimates of precipitation and recharge are shown in table 9. As shown in table 3, data for Utah suggest that precipitation in given altitude zones may increase slightly in the eastern part of the Virgin Mountains and in the Beaver Dam Mountains. However, for the purposes of this reconnaissance, precipitation-altitude relations in the western part of the report area are utilized to compute recharge for all areas.

The estimated average annual precipitation on the lower Virgin River Valley is about 580,000 acre-feet, and the estimated average annual recharge totals about 9,500 acre-feet. Thus, only about 1.6 percent of the precipitation apparently reaches the ground-water reservoir.

Much of the recharge probably occurs by seepage as streams cross alluvial fans. Mean annual runoff in the lower Virgin River Valley reaching the alluvial areas, excluding Virgin River flow, is estimated at about 14,000 acre-feet (table 7). Therefore, these estimates suggest that runoff is about 1.5 times greater than estimated recharge.

Some of the recharge occurs in the mountains by infiltration of precipitation and runoff into the carbonate rocks that are widespread surficially (pl. 1). The highly transmissive and structurally deformed character of the carbonate rocks can strongly affect the magnitude and direction of ground-water flow. Therefore, the assumed recharge boundaries, arbitrarily chosen to coincide with surficial drainage boundaries for the compilation of table 9, may not be correctly located. However, the reconnaissance nature of the study and the lack of conclusive data do not permit more accurate location of recharge boundaries.

Although the Virgin River gains some flow locally, perhaps from springs (p. 36), throughout much of its course in the lower valley, it is a losing stream recharging aquifers underlying its flood plain. Recharge from that source probably is greatest during high river stages and exceeds that from precipitation in the lower Virgin River Valley.

Subsurface Inflow

The lower Virgin River Valley receives ground-water inflow from the east and from Tule Desert. The subsurface inflow from the east was estimated in the section "Estimated flow from springs that discharge into the Virgin River" to be about 70 cfs, or about 50,000 acre-feet per year. Inflow from Tule Desert, where no evapotranspiration losses from ground water occur (minimum depths to water in excess of 65 feet) is considered to be equal to the estimated recharge, or about 2,100 acre-feet per year.

Table 9.--Estimated average annual precipitation and ground-water recharge

Altitude zone (feet)	Area (acres)1/	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average Feet	Estimated annual precipitation: Average Acre-feet	Estimated recharge: Assumed percentage of precipitation	Estimated recharge: Acre-feet per year
LOWER VIRGIN RIVER VALLEY						
In Nevada North of River						
Above 7,000	400	>15	1.3	520	15	78
6,000-7,000	10,760	12-15	1.1	12,000	7	840
4,000-6,000	93,990	8-12	.8	75,000	3	2,200
Below 4,000	366,940	<8	.5	180,000	--	--
Subtotal (rounded)	472,000			270,000		a 3,100
In Nevada South of River						
Above 7,000	620	>15	1.3	810	15	120
6,000-7,000	2,510	12-15	1.1	2,800	7	200
4,000-6,000	9,450	8-12	.8	7,600	3	230
Below 4,000	84,900	<8	.5	42,000	--	--
Subtotal (rounded)	97,500			53,000		500
In Arizona and Utah						
Above 7,000	2,540	>15	1.3	3,300	15	500
6,000-7,000	27,000	12-15	1.1	30,000	7	2,100
4,000-6,000	143,000	8-12	.8	110,000	3	3,300
Below 4,000	234,000	<8	.5	120,000	--	--
Subtotal (rounded)	407,000			260,000		5,900
Total (rounded)	976,000			580,000		9,500
TULE DESERT						
Above 7,000	160	>15	1.3	210	15	32
6,000-7,000	4,820	12-15	1.1	5,300	7	370
4,000-6,000	70,270	8-12	.8	56,000	3	1,700
Below 4,000	87,410	<8	.5	44,000	--	--
Total (rounded)	163,000			106,000		2,100

Table 9.--Continued

Altitude zone (feet)	Area (acres)[1]	Estimated annual precipitation: Range (inches)	Estimated annual precipitation: Average: Feet	Estimated annual precipitation: Average: Acre-feet	Estimated recharge: Assumed percentage of precipitation	Estimated recharge: Acre-feet per year
		ESCALANTE DESERT (Nevada)				
Above 7,000	4,340	>15	1.3	5,600	15	840
6,000-7,000	57,000	12-15	1.1	63,000	--	--
	(b20,000)	do.	do.	(b 22,000)	7	1,500
Below 6,000	9,760	8-12	.8	7,800	--	--
	(b 0)	do.	do.	(b 0)	--	--
Total (rounded)	71,000			76,000		2,300

1. Areas are based on planimeter data using U.S. Geological Survey 1:250,000-scale topographic maps. They do not agree exactly with those listed elsewhere in the report, which were obtained from a less accurate 1:500,000-scale map and reported by Rush (1968a).

a. Of this subtotal, an estimated 2,800 acre-feet reaches Beaver Dam Wash drainage and 300 acre-feet reaches the Virgin River drainage in Nevada.

b. Because little recharge is believed to occur in alluvial areas where precipitation averages less than 12 inches per year, the effective area for recharge is assumed to be 20,000 acres between 6,000 and 7,000 feet, and 0 acres below 6,000 feet.

Subsurface inflow beneath the Virgin River to Nevada occurs through the valley fill and probably the underlying consolidated rocks. No estimate of flow through the consolidated rocks is attempted. However, a crude estimate of underflow through the valley fill can be computed by a form of Darcy's law, using estimated values, as follows: transmissibility, 25,000 gallons per day per foot, times effective width, about 2 miles, times hydraulic gradient, about 25 feet per mile, the same as the riverbed slope, which suggests an underflow of at least 1,000 acre-feet per year.

OUTFLOW FROM THE VALLEYS

Surface-Water Discharge

The Virgin River empties into Lake Mead, about 30 miles downstream from the Nevada-Arizona border. The mean annual discharge of the river near its mouth is not measured, but is estimated to be about 80,000 acre-feet, as determined from characteristics of the channel geometry.

Mean annual runoff leaving Escalante Desert in Nevada, calculated from channel-geometry characteristics, is about 400 acre-feet. Similarly, average surface-water outflow from Tule Desert to the lower Virgin River Valley is estimated to be about 1,200 acre-feet annually.

Surface-Water Diversions for Irrigation

Several surface-water diversions for irrigation occur in the lower Virgin River Valley. The canals and most of the irrigated lands are shown on plate 2. Mesquite and Bunkerville Canals are the largest. According to Shamberger (1954, p. 68), the combined water rights for these canals by a decree of 1927 are 17,512 acre-feet per year; total perfected water rights on Virgin River, as of 1922, were 18,574 acre-feet. Two streamflow measuring stations were operated on these canals during the period April 1951 to September 1955. The gage on Mesquite Canal was 1½ miles east of Mesquite and 2¼ miles downstream from the point of diversion (pl. 1). The gage on Bunkerville Canal was 100 feet downstream from the bridge on old U.S. Highway 91, about 2¼ miles northeast of Bunkerville Table 10 lists the monthly and yearly diversions at these two stations.

Comparison of the average monthly diversions (table 10) with monthly streamflow (table 6) shows that the periods of maximum diversion are somewhat out of phase with the periods of maximum streamflow in the Virgin River. The peak diversions for the period 1951-55 generally occurred during April-July, whereas peak streamflow at the Littlefield gaging station during the period 1930-67 occurred during February-May.

As previously mentioned, Littlefield and Petrified Springs Canals bypass the Littlefield gage; they supply water to farmlands along the north and south banks of the Virgin River, respectively, near the town of Littlefield, Arizona. As shown in table 4, miscellaneous measurements of the flow in these canals in June and July during the period 1946-58 ranged as follows: Littlefield Canal, 0.40-1.39 cfs; Petrified Springs Canal, 2.14-3.41 cfs.

Table 10.--Monthly and yearly discharge, in acre-feet, for Mesquite and Bunkerville Canals, April 1951-September 1955

(Records from U.S. Geol. Survey, 1964, p. 457)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year
MESQUITE CANAL, 2½ miles downstream from diversion													
1951	--	--	--	--	--	--	1,810	1,750	1,970	1,760	1,410	1,270	--
1952	928	727	696	0	595	1,330	1,680	1,210	1,740	2,170	1,750	1,680	14,510
1953	1,530	1,160	1,070	1,090	1,170	1,340	2,110	2,110	2,090	1,240	1,500	1,390	17,800
1954	1,420	1,250	970	845	1,190	1,360	1,850	2,140	2,050	1,970	1,530	1,520	18,100
1955	1,320	1,440	1,370	1,590	1,170	1,650	1,510	2,100	1,960	1,560	771	1,490	17,920
1952-55 Average (rounded)	1,300	1,140	1,030	880	1,030	1,420	1,790	1,890	1,960	1,740	1,390	1,520	17,000
BUNKERVILLE CANAL, 2½ miles northeast of Bunkerville													
1951	--	--	--	--	--	--	1,180	1,250	1,090	1,030	832	764	--
1952	970	935	835	341	42	920	1,170	835	1,170	1,070	817	886	9,990
1953	1,010	688	821	928	223	1,180	1,210	1,160	1,130	720	770	921	10,760
1954	1,170	804	987	782	656	326	1,190	980	909	933	922	873	10,530
1955	966	1,090	822	822	689	881	1,080	1,060	990	668	0	705	9,770
1952-55 Average (rounded)	1,030	880	870	720	400	830	1,160	1,010	1,050	850	630	850	10,000

Diversions from the Virgin River also occur just downstream from the town of Riverside, and are used to irrigate lands along the south side of the flood plain for several miles farther downstream. According to Kenneth Romrielle (U.S. Soil Conserv. Service, oral commun., 1967), an irrigated area of about 200 acres is being developed along the Virgin River just upstream from Lake Mead.

Several comparatively small surface-water diversions occur in the upper part of Beaver Dam Wash in Utah. In Escalante Desert in Nevada, some runoff from a few ephemeral streams is retained by earthen dams for stockwatering; however, only minor water quantities are involved.

Table 11 shows the estimated irrigated land and consumptive use of diverted surface water in the lower Virgin River Valley. The principal crops include alfalfa, grasses, small grains, and some vegetables.

Air temperatures provide a rough guide in estimating the growing season, and the length of growing season largely determines the crop type and the irrigation requirements. Temperature is recorded at several weather stations in and near the report area, and a summary of those data is shown in table 12. Temperature data at the Mesquite and Littlefield stations together with longer records at Las Vegas, Overton, and St. George, suggest that crops able to grow at temperatures above 28°F have an average growing season of about 250-275 days along the Virgin River flood plain. A considerably shorter growing season prevails in the upper Beaver Dam Wash area, where the altitude is several thousand feet higher. The lower parts of Escalante Desert in Nevada, although not presently farmed, probably have a growing season slightly shorter than that at Enterprise-Beryl Junction, where temperatures above 28°F probably prevail for at least 125 days a year.

Evapotranspiration

A substantial quantity of water is discharged from the Virgin River system within the report area by evapotranspiration in areas of phreatophytic vegetation. Phreatophytes obtain most of their water from the ground-water reservoir or overlying capillary fringe. In the report area, most ground-water bodies shallow enough to support phreatophyte growth are close to perennial stream courses, namely the Virgin River and the perennially flowing reaches of Beaver Dam Wash. Along the Virgin River and lower Beaver Dam Wash the dominant phreatophyte is saltcedar. Saltbush, mesquite, willows, tules, cottonwoods, and a few other types are less prevalent. Some of the phreatophyte areas are shown on plate 2. Areas of evapotranspiration along the Virgin River generally coincide with the area of younger alluvium shown on plate 1 along the Virgin River flood plain.

Table 11.--Estimated irrigated acreage and consumptive use of crops supplied by diversion of surface water from Virgin River and its tributaries

Diversion system or location of irrigated area	Crop type[1]	Estimated irrigated area (acres)	Consumptive use: Rate (feet per year)[2]	Consumptive use: Acre-feet per year
NEVADA -- Virgin River				
Mesquite area (Mesquite Canal)	Alfalfa and pasture	900	5	4,500
	Small grains and vegetables	500	3	1,500
Bunkerville area (Bunkerville Canal)	Alfalfa and pasture	700	5	3,500
	Small grains and vegetables	300	3	900
Area just downstream from Riverside	Alfalfa and pasture	200	5	1,000
Area just upstream from Lake Mead	Probably alfalfa and pasture	350	5	1,800
Total (rounded)		3,000		13,000
ARIZONA - Virgin River and lower Beaver Dam Wash				
Mesquite area (Mesquite Canal)	Alfalfa and pasture	160	5	800
	Small grains and vegetables	80	3	240
Littlefield area (Littlefield Canal)	Probably mostly alfalfa	70	5	350
Littlefield area (Petrified Springs Canal)	Probably mostly alfalfa	60	5	300
Total (rounded)		370		1,700
UTAH - upper Beaver Dam Wash				
Several ranches	Alfalfa and pasture	50	3	150

1. Kenneth Romrielle (U.S. Soil Conserv. Service, oral commun., 1967) reports distribution of irrigation from Mesquite and Bunkerville Canals is about two-thirds for alfalfa and pasture and about one-third for small grains and vegetables.

2. Use rates along lower Beaver Dam Wash and Virgin River are based on findings of Houston and Blaney (1954), U.S. Bureau of Reclamation (1962), and Houston (1950). The rates for alfalfa and pasture are thought to be less in upper Beaver Dam Wash because of increased altitude, cooler temperatures, and shorter growing season.

Table 12.--Length of growing season between killing frosts that occur at 32°, 28°, and 24°F

Station1/	Period of record (years)	Growing season (days)					
		32°		28°		24°	
		Average	Range	Average	Range	Average	Range
Cedar City Steam Plant	1962-66	156	129-187	165	133-188	196	133-232
Desert National Wildlife Refuge2/	1948-66	217	184-249	244	205-291	278	236-347
Enterprise-Beryl Jct.	1960-66	102	70-150	127	98-167	158	130-190
Las Vegas (McCarren Field)2/	1949-66	250	214-285	276	232-313	305	277-343
LaVerkin	1953-66	177	158-202	209	181-248	242	205-284
Littlefield	1953-54, 1956	222	209-233	249	213-280	295	279-324
Lund	1953-66	108	88-145	137	127-168	154	134-190
Mesquite	1959-60, 1965	247	242-256	264	262-267	(a)	(a)
Overton	1948-66	224	168-256	252	173-298	291	227-319
Pioche	1948-66	150	128-173	175	132-210	204	173-232
St. George	1953-66	209	189-234	246	224-284	272	236-302
Veyo	1958-66	153	106-188	173	134-200	219	186-248

1. See table 3 and figure 2 for location and altitude.

2. Not shown in figure 2.

a. Unavailable.

They also occur intermittently throughout Beaver Dam Wash. No significant evapotranspiration losses by phreatophytes occur in Tule Desert or Escalante Valley in Nevada. Minor evapotranspiration losses occur in the mountains of all areas around the mountain springs, where small concentrations of willow, meadowgrass, wild rose, and cottonwoods are common.

Estimated discharge in the principal areas of phreatophytes is shown in table 13. Rates in the table are based on work done in other areas by Lee (1912), White (1932), Young and Blaney (1942), and Robinson (1958 and 1965).

A part of the Virgin River flood plain was aerially photographed for the U.S. Department of Agriculture's Soil Conservation Service in 1939 and 1940. Comparison of those photographs with others taken in 1953 and 1966 suggests that phreatophyte encroachment, principally saltcedar, has increased markedly along the flood plain during the 27-year period. The phreatophyte increase probably results in a greater discharge of water by evapotranspiration, and therefore, average annual water quantities reaching Lake Mead probably are somewhat less now than they were prior to the heavy encroachment.

Evaporation from Water Surfaces

Surface-water evaporation rates in the lower altitudes of the area are large. Kohler and others (1959) estimate that the average annual lake-surface evaporation ranges from about 58 to 74 inches, or averages about $5\frac{1}{2}$ feet, per year. Estimated evaporation from canals and live streams is shown in table 14. However, no estimates were made for Lake Mead because it is the terminal sink of the system and water reaching Lake Mead is no longer available for use in the study area.

Ground-Water Pumpage

Ground water is used mainly for domestic, municipal, and stock-watering purposes in the report area. Although using ground water for irrigation is practical in some areas, most irrigation utilizes water diverted from the Virgin River. Along the Virgin River flood plain, irrigation with surface water is occasionally supplemented by pumpage in a few places. Actual quantities used are unknown, but they are small compared to surface water. The pumped wells generally are shallow, and the water they pump probably is contiguous with and chemically similar to Virgin River water.

Table 15 shows the estimated pumpage in 1968 in the lower Virgin River Valley area. Pumpage in Tule Desert and Escalante Desert, Nevada, is minor.

Table 13.--Estimated evapotranspiration of ground water by phreatophytes

Location	Phreatophyte	Depth to water (feet)	Area (acres)	Areal plant density (percent)	Probable average annual rate of water use (feet)	Approximate discharge (acre-feet per year)
			NEVADA			
Virgin River flood plain	Mostly saltcedar; some saltgrass, saltbush, cottonwood, mesquite, willow, and tules	0-20 (mostly 1-5)	7,400	25-100	4	30,000
			ARIZONA			
Virgin River flood plain	Mostly saltcedar; some saltgrass, saltbush, cottonwood, mesquite, willow, and tules	0-20	1,250	25-100	4	a 5,000
Beaver Dam Wash, at confluence with Virgin River to 1½ miles upstream	Mostly willow and trees, mesquite, cottonwood, and associated deciduous trees	0-30 (mostly 1-5)	160	25-100	4	600
Beaver Dam Wash, from 1½ miles to about 4 miles above confluence with Virgin River	Mostly willow and saltbush	10-30	about 500	5-10	0.1	50
Total (rounded)			1,700			5,600
			UTAH			
Beaver Dam Wash headwaters	Mostly meadowgrass, cottonwood, and wildrose	0-30	est. 100	--	1	100

a. About 95 percent (4,800 acre-feet) of this discharge is estimated to occur downstream from the Littlefield gaging station.

Table 14.--Estimated evaporation from water surfaces

Water body	Estimated average area (acres)	Average evaporation (acre-feet per year)[1]
	NEVADA	
Virgin River	a 200	1,100
Mesquite, Bunkerville, and small canals	15	80
Total (rounded)	215	1,200
	ARIZONA	
Virgin River	a 150	825
Mesquite and small canals	4	22
Total (rounded)	150	850
	UTAH	
Beaver Dam Wash and tributaries	<10	100

1. Based on evaporation rate of about 5½ feet per year from free water surface (Kohler and others, 1959).

a. Average area throughout year of average annual runoff.

Table 15.--Estimated ground-water pumpage in 1968

Wells or development	Use	Estimated average use rate (acre-feet per acre per year)	Acres	Crop	Estimated average pumpage[1] (acre-feet per year)
		NEVADA			
Mesquite municipal well field[2]	Municipal and dairy industry	--	--	--	a 130
Bunkerville municipal well field[3]	Municipal and dairy industry	--	--	--	b 100
Irrigation wells[4]	Mainly supplementary to surface-water diversion	about 5	50±	Alfalfa, grain, vegetables, and grass	250
Domestic wells	About 100 people	(c)	--	--	10
Stock supplies (wells and springs)[5]	Livestock watering	(d)	--	--	30
Total (rounded)					500
		ARIZONA			
Archie Hughes	Irrigation	5	About 160	Alfalfa and grain	800
Dee Hughes	Irrigation	5	About 160	Alfalfa and grain	800
Lower Beaver Dam Wash Area	Irrigation	5	About 250	Mostly alfalfa, some grain and vegetables	1,200
Domestic wells and springs	Domestic supply	(e)	--	--	10
Total (rounded)					2,800

Table 15.--Estimated ground-water pumpage in 1968--Continued

Wells or development	Use	Estimated average use rate (acre-feet per acre per year)	Acres	Crop	Estimated average pumpage[1] (acre-feet per year)
			UTAH		
Wes Atkins Ranch	Irrigation	3	About 120	Alfalfa and pasture	360
D. I. Ranch	Irrigation	3	About 12	Alfalfa and pasture	35
Stock wells and springs	Livestock watering	(f)	--	--	6
Domestic wells and springs	Domestic supply	(g)	--	--	1
Total (rounded)					400

1. Estimate shown for each user is the net pumpage, or the amount consumed. Pumpage at the well would be roughly 25 to 50 percent greater.
2. Supplies a population of about 700 and 3 or 4 dairies.
3. Supplies a population of about 300 and 6 or 7 dairies.
4. Includes Mesquite and Bunkerville cemeteries.
5. Mainly beef cattle; some horses and hogs.
a. According to Mesquite City Secretary, about 42 million gallons of water have been marketed annually during recent years.
b. Quantities of pumpage and delivery unavailable. Estimate made by comparisons with Mesquite based on population and dairy distribution.
c. Estimated about 0.1 acre-foot per person per year.
d. Estimate about 3,000 head, each using an average of 10 gallons per day.
e. Includes about 75 people, each using an estimated 100 gallons per day, and *100 head of livestock*, each using about 10 gallons per day.
f. Estimate about 500 head, each using an average of about 10 gallons per day.
g. Estimate about 10 people, each using an average of about 100 gallons per day.

Ground-water development is increasing rapidly in the Arizona part of the area. Much of the recent drilling has taken place along lower Beaver Dam Wash near its confluence with the Virgin River and additional development is reportedly planned for this area (Kenneth Romriell, U.S. Soil Conserv. Service, oral commun., 1967). Two new (1967) wells were drilled north of the Virgin River, on a bench above the flood plain, just east of the Nevada-Arizona border (pl. 2). Well A40/16-34cab (table 21, pl. 2) reportedly yields about 1,500 gpm, and is the best-producing well known in the area.

Springs

The larger springs in the lower Virgin River Valley area have been described in the surface-water section of the report. Small springs occur in places upstream along Beaver Dam Wash. There, the flow is either utilized for small scale irrigation (table 11), or is dissipated by evapotranspiration or by infiltration into the generally dry streambed.

Numerous small springs occur in the upland valley-fill and consolidated-rock areas. The flow of these springs was not measured during this study. Many of these springs furnish limited quantities of water for livestock. Several of the springs in the Virgin Mountains south of Mesquite and Bunkerville furnished the municipal water supplies for these towns via long pipelines prior to development of the municipal well fields. The total flow of these springs is about 50 gpm.

Chemical-quality data for some springs are in table 17 and the spring locations are shown on plates 1 and 2.

Subsurface Outflow

Subsurface outflow occurs from the lower Virgin River Valley to Lake Mead, in Escalante Desert across the State line to Utah, and from Tule Desert to the lower Virgin River Valley. Outflow from Tule Desert has already been discussed in the section on subsurface inflow (to the lower Virgin River Valley) and was estimated to be about 2,100 acre-feet per year.

Subsurface outflow to Lake Mead beneath the Virgin River Valley occurs through the valley fill and probably through the underlying consolidated rocks. Although no direct estimates have been made, the water budget suggests that the subsurface outflow may be substantial, possibly as much as 40,000 acre-feet per year (table 16). This amount may seem unreasonably large and may well be considerably in error, but as already described, the Virgin River upstream from Littlefield gage gains about 50,000 acre-feet per year by upward ground-water flow within a few miles. Thus, a seepage loss of this magnitude in the 30-mile reach downstream from the State line may be possible. If so, the bulk of the flow probably occurs through the underlying rocks.

In Escalante Desert, Nevada, the estimated annual recharge is 2,300 acre-feet (table 9). No significant natural evapotranspiration from the ground-water reservoir occurs in the valley, so the bulk of the recharge is assumed to move eastward as underflow to Escalante Desert in Utah.

WATER BUDGETS

Over the long term and for natural conditions, inflow to and outflow from an area are equal, provided that the long-term climatic regimen remains nearly constant. An equilibrium condition is assumed to prevail for the study area--an assumption that may not be actually correct for the lower Virgin River Valley. If it is not correct, the amount of ground water in storage may be changing.

For all three areas of this study, the estimated recharge and discharge totals in table 16 are shown to be in balance because the subsurface outflow for each was computed by difference; that is, outflow equals recharge minus all other estimated elements of discharge. Obviously, this determination is an over-simplification, because the difference also contains all errors in the other elements of the budget.

The budget for the lower Virgin River Valley is limited to the Nevada part of the valley. By far the largest element in the budget is the Virgin River flow. The large outflow to Lake Mead of 123,000 acre-feet, although provisionally estimated to be two-thirds surface water and one-third ground water, is best considered as a total quantity until more reliable data are available.

Table 16.--Water budgets for the valley-fill reservoirs in Nevada for 1968 conditions

(All estimates in acre-feet per year)

Budget elements	Lower Virgin River Valley	Tule Desert	Escalante Desert
	System budget	Ground-water budgets	
INFLOW:			
Streamflow at Littlefield gaging station (table 5), adjusted to Nevada State line	a 159,000	--	--
Local runoff directly to Virgin River (p. 33)	5,000	--	--
Ground-water recharge (table 9)	800	2,100	2,300
Subsurface inflow (p. 37)		--	--
From Tule Desert	2,100		
Across State line	1,000		
Total (rounded): (1)	168,000	2,100	2,300
OUTFLOW:			
Consumptive use by crops irrigated with surface water (table 11)	13,000	0	0
Evapotranspiration in phreatophyte areas (table 13)	30,000	--	--
Ground-water pumpage (table 15)	500	Minor	Minor
Evaporation from water surfaces (table 14)	1,200	--	--
Subtotal (rounded): (2)	45,000	Minor	Minor
By difference: (1) - (2) = (3)			
Surface-water outflow } Subsurface outflow }	b 123,000	--	--
Subsurface outflow		b 2,100	b 2,300
Total: (2) + (3)	168,000	2,100	2,300

a. Adjustments include: (1) Additional inflow, principally from canal diversions bypassing the gage, local runoff, and local recharge, about 6,000 acre-feet per year; and (2) additional outflow, principally surface-water diversions (except Mesquite Canal which is included with streamflow), pumpage, and evapotranspiration, about 9,000 acre-feet per year.

b. Computed as difference between total inflow (1) and subtotal outflow (2); in lower Virgin River Valley, surface-water outflow may be two-thirds of this total (p. 22), leaving one-third for subsurface outflow (p. 51).

CHEMICAL QUALITY OF THE WATER

Chemical analyses of water from wells, springs, Virgin River, and Beaver Dam Wash are listed in table 17. Additional analyses of samples collected prior to 1950, largely from canals, springs, and the Virgin River, were given by Hardman and Miller, 1934, p. 45, and by Miller and others, 1953, p. 56-57. Most of the data in table 17 are for ground water from wells adjacent to the river; only a few analyses are available for water elsewhere in the valley. Thus, knowledge of water chemistry throughout much of the study area is scanty.

General Chemical Character

Sampled ground water along the Virgin River shows the influence of geologic units, particularly the Muddy Creek Formation (table 2), which contain soluble minerals such as halite (sodium chloride) and gypsum (calcium sulfate). Most of these waters contain 1,000-5,000 mg/l (milligrams per liter) of dissolved solids. (Milligrams per liter are equivalent to parts per million; see footnote 1, table 17.) Sodium and (or) calcium characteristically are the principal positive ions, and sulfate generally is the predominant negative ion.

Virgin River water usually contains 1,000 to 3,000 mg/l of dissolved solids, largely calcium, sodium, sulfate, and chloride. The river typically is most dilute during periods of abundant runoff, and is most concentrated at low flow, when springs in the Littlefield area and upstream (for example, spring A40/15-4dc, table 17) provide the entire discharge. The dissolved-solids concentration increases markedly between Littlefield and Riverside, about 20 miles downstream where return flow from irrigation has entered the stream. Samples collected concurrently at the two sites (by the U.S. Geol. Survey and Federal Water Pollution Control Adm., respectively) throughout water year 1967 suggest that the downstream increase in dissolved solids was almost 30 percent--from about 2,000 mg/l at Littlefield to about 2,700 mg/l at Riverside. For all available data during the water year, time-weighted average concentrations of several important constituents at the two sites were as follows, in milligrams per liter:

	Sodium	Bicarbonate	Sulfate	Chloride	Hardness	Dissolved solids (residue on evaporation)
Littlefield1/	281	273	903	357	1,060	2,140
Riverside2/	359	244	1,180	502	1,320	2,800

1. Samples collected daily by the U.S. Geol. Survey.
2. Samples collected weekly by the Federal Water Pollution Control Adm.

The Virgin River is muddy, and it transports large quantities of mostly silt- and clay-sized sediment in suspension, and mostly sand-sized sediment as bedload. During the 10 water years 1958-67 (from Oct. 1, 1957, to Sept. 30, 1967), annual quantities of suspended sediment passing the measuring station near Littlefield have ranged from 0.8 million to 6.4 million tons, and have averaged 2.7 million tons (data from annual publications of the U.S. Geol. Survey). The quantity of bedload transported by the river is unknown.

Throughout much of the basin tributary to Beaver Dam Wash, and in many other upgradient parts of the study area, streamflow and ground water are known or thought to be more dilute than along the Virgin River. Even near the river, wells such as the Bunkerville and Mesquite municipal supplies, which are half a mile to a mile south of, and upgradient from, the flood plain, yield much more dilute water than do wells on the flood plain itself (300-500 mg/l versus 1,000-5,000 mg/l). Apparently the municipal wells in large part tap dilute ground water that moves downgradient from the Virgin Mountains.

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 17, are as follows:

Constituent	Recommended maximum concentration (milligrams per liter)
Iron (Fe)	0.3
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	About 0.8a/
Nitrate (NO_3)	45
Dissolved-solids content	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.

Table 17.--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]

Part I

Location	Source (with well depth where appropriate)	Date sampled	Temperature °F	°C	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)3/	Bicarbonate (HCO3)4/	Sulfate (SO4)	Chloride (Cl)	Dissolved-solids content5/	Hardness as CaCO3	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 irrigation2/		
GROUND WATER																	
Nevada																	
8/70-14a2	Well (30 ft)	11-14-67	64	18	178 8.88	49 4.05	19 0.81	303 4.97	390 8.12	23 0.65	c 800	647 12.93	1,200	7.5	High	0.3	Low
8/71-32cd	Well (61 ft)	11-14-67	--	--	57 2.84	22 1.80	--	--	99 2.06	24 .68	e 320	232 4.64	510	--	Medium	--	--
10/69-7bb	Well (566 ft)	11-15-67	--	--	34 1.70	14 1.12	22 .97	157 2.57	41 .85	13 .37	c 240	141 2.82	370	7.8	do.	.8	Low
13/70-13ddd	Well (60 ft)	11-15-67	70	21	244 12.18	126 10.40	522 22.72	209 3.43	1,320 27.48	510 14.39	e 3,100	1,130 22.58	4,000	8.0	Very high	6.8	Medium
-32a	Well (300 ft)	11-13-676/	--	--	144 7.19	65 5.32	103 4.50	168 2.75	649 13.51	22 .62	c 1,000	626 12.51	1,500	8.3	High	1.8	Low
-34c1	Well (118 ft)	11-11-67	--	--	162 8.08	94 7.74	385 16.76	221 3.62	749 15.59	474 13.37	e 2,300	792 15.82	3,100	7.9	Very high	6.0	Medium
-34c2	Well	11-11-67	70	21	310 15.47	169 13.90	631 27.44	341 5.59	1,510 31.44	701 19.78	e 3,900	1,470 29.37	4,900	7.8	do.	7.1	High
-35cdd1	Well (300 ft)	11-10-67	77	25	28 1.40	28 2.32	--	--	72 1.50	22 .62	c 350	186 3.72	560	--	Medium	--	--
-35cdd2	Well (300 ft)	11-10-67	76	24	38 1.90	29 2.36	--	--	128 2.66	42 1.18	e 460	213 4.26	730	--	do.	--	--
13/71-16aa	Well (138 ft)	11-16-67	--	--	458 22.85	167 13.71	489 21.26	425 6.97	1,670 34.77	570 16.08	c 3,600	1,830 36.56	4,600	7.3	Very high	5.0	Medium
-16ca7/ 8/	Well (12 ft)	7-17-46	68	20	487 24.30	162 13.33	528 22.94	400 6.56	1,770 36.83	609 17.18	3,780	1,880 37.63	--	--	do.	5.3	Do.
-19dac7/	Well (98 ft)	4-20-49	68	20	96 4.79	50 4.11	232 10.00	288 3.74	395 8.22	245 6.91	1,150	440 8.90	1,830	--	High	4.7	Do.
-20ccd7/	Well (210 ft)	6-27-49	74	23	37 1.85	19 1.56	55 2.41	141 2.31	109 2.27	38 1.07	369	170 3.41	568	--	Medium	1.8	Low
-20ccd7/	do.	1-14-52	--	--	42 2.10	18 1.48	50 2.18	139 2.28	106 2.21	40 1.13	365	179 3.58	561	--	do.	1.6	Do.
-29bba7/	Well (225 ft)	1-14-52	72	22	36 1.80	15 1.23	--	148 2.43	73 1.52	--	c 300	152 3.03	486	--	do.	--	--
-29bba and possibly -20ccd (collected from storage tank)		11-15-67	--	--	60 2.99	27 2.26	60 2.63	145 2.38	192 4.00	53 1.50	c 490	263 5.25	780	7.7	High	1.6	Low
14/69-13cb	Well (234 ft)	11-11-67	--	--	178 8.88	89 7.28	254 11.06	204 3.34	944 19.65	150 4.23	e 1,700	809 16.16	2,400	8.1	Very high	3.9	Medium
-23aa2	Well (625 ft)	11-11-67	--	--	210 10.48	116 9.50	261 11.34	226 3.70	982 20.45	254 7.17	e 2,000	1,000 19.98	2,800	8.1	do.	3.6	Do.
-23b or c1 7/ 8/	Well (105 ft)	9-26-46	--	--	557 27.79	186 15.30	933 40.54	305 5.00	2,460 51.24	971 27.39	5,280	2,160 43.09	--	--	do.	8.7	High
-23b or c2 7/ 8/	Well (198 ft)	10-28-46	--	--	714 35.63	240 19.74	550 23.89	373 6.11	2,300 47.87	896 25.28	4,920	2,770 55.37	--	--	do.	4.5	Medium
15/70-2d7/ 8/	Spring	7-17-46	--	--	89 4.44	30 2.47	83 3.62	371 6.08	143 2.98	52 1.47	606	345 6.91	--	--	High	1.9	Low
-12b7/ 8/	Dud Spring	7-17-46	--	--	85 4.24	28 2.30	77 3.36	390 6.39	84 1.75	40 1.13	550	327 6.54	--	--	do.	1.9	Do.
-148/	Water from Great Eastern Mine	5-31-35	--	--	84 4.19	19 1.56	83 3.61	366 6.00	116 2.42	33 .93	539	288 5.75	--	--	Very high	2.1	Do.
15/71-4 and -16b7/	Cabin Canyon Springs	10-10-49	--	--	89 4.45	31 2.54	33 1.43	408 6.69	58 1.21	18 .51	461	350 6.99	759	--	High	.8	Do.
Arizona																	
A39/16-4a7/	Well	9-12-50	--	--	85 4.24	62 5.10	216 9.41	138 2.26	583 12.14	152 4.29	1,170	467 9.34	1,750	--	do.	4.4	Do.
A40/15-3abb	Well (105 ft)	11-16-676/	--	--	454 22.65	123 10.12	310 13.50	464 7.60	1,280 26.65	426 12.02	e 2,900	1,640 32.77	3,800	7.6	Very high	3.3	Medium
-4cbd7/ 8/	Littlefield Spring	7- -46	--	--	80 3.99	27 2.22	52 2.26	298 4.88	113 2.35	44 1.24	483	311 6.21	--	--	High	1.3	Low
-4d7/ 8/	Petrified Springs	7- -46	--	--	425 21.21	141 11.60	309 13.42	464 7.60	1,270 26.44	432 12.19	2,820	1,640 32.81	--	--	Very high	3.3	Medium
-4db	Seep in roadcut	2- 5-65	76	24	348 17.37	129 10.63	295 12.81	124 2.03	1,280 26.65	430 12.13	a 2,600	1,400 28.00	3,430	7.9	do.	3.4	Do.
-4dc	Spring	5-21-65	--	--	378 18.86	133 10.91	343 14.90	327 5.36	1,300 27.07	434 12.24	c 2,800	1,490 29.77	3,730	7.5	do.	3.9	Do.
-5bab	Well (100 ft)	11-15-67	68	20	96 4.79	28 2.34	24 1.05	250 4.10	138 2.87	43 1.21	e 500	357 7.13	800	7.4	High	.6	Low
A40/16-33cc	Well (340 ft)	11-15-676/	--	--	96 4.79	48 3.94	--	--	371 7.72	125 3.53	c 910	437 8.73	1,400	--	do.	--	--
-34cab	Well (285 ft)	7-25-68	77	25	189 9.43	73 6.01	221 9.59	210 3.29	685 14.26	265 7.48	c 1,700	773 15.44	2,400	8.2	Very high	3.5	Low
A41/15-29dcc	Well (about 230 ft)	11-15-676/	--	--	27 1.35	14 1.19	--	--	95 1.98	29 .82	e 280	127 2.54	440	--	Medium	--	--
-33cbd2	Well (about 100 ft)	11-14-67	--	--	193 9.63	79 6.47	160 7.00	297 4.87	531 11.06	254 7.17	a 1,400	806 16.10	2,100	7.9	High	2.4	Low
Utah																	
U35/20-35a	Well	11-17-67	--	--	48 2.40	7 .54	19 .83	145 2.38	17 .35	37 1.04	e 250	147 2.94	390	7.4	Medium	.7	Do.
U42/18-33bab	Summit Spring	11-13-67	--	--	60 2.99	49 4.06	86 3.74	251 4.11	199 4.14	90 2.54	c 700	353 7.05	1,100	7.5	High	2.0	Do.

Table 17.--Partial and detailed chemical analyses of water from wells, springs, seeps, and streams--Continued

Part I--Continued

Location	Source	Date sampled	Temperature °F °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]		
STREAMS[9]																
040/19-17ab	West Fork Beaver Dam Wash	11-16-67	59 15	46 2.30	30 2.50	--	--	34 .71	18 .51	e 260	240 4.80	410	--	Medium	--	--
042/19-6b	Beaver Dam Wash	11-14-67	-- --	60 2.99	23 1.93	--	--	49 1.02	20 .56	e 350	246 4.92	560	--	do.	--	--
A40/15-4bc[7,8]	do.	5-29-32	-- --	74 3.69	22 1.85	47 2.06	288 4.72	102 2.12	27 .76	454	277 5.54	--	--	do.	1.2	Low
-4bc[7]	do.	4-22-50	-- --	72 3.59	24 1.97	24 1.04	258 4.23	85 1.77	20 .56	394	278 5.56	621	--	do.	.6	Do.
-4bc[7]	do.	9-30-55	73 23	80 3.99	20 1.64	(7)	274 4.49	93 1.94	26 .73	e 420	282 5.63	667	8.1	do.	1.0	Do.
-4bc	do.	11-15-67	65 18	--	--	--	--	109 2.27	38 1.07	e 440	311 6.21	700	--	do.	--	--
-4cc[7]	Virgin River	4-13-66	64 18	196 9.78	61 5.02	(7)	290 4.75	452 9.41	282 7.96	1,340	740 14.80	1,980	7.8	High	2.8	Low
-4cc[7]	do.	9-20-66	80 27	409 20.41	117 9.62	(7)	374 6.13	1,270 26.44	403 11.37	2,730	1,500 30.03	3,560	7.8	Very high	3.3	Medium
14/70-7bcb[7,10]	do.	12- 7-66	-- --	365 18.21	63 5.18	(7)	186 3.05	1,070 22.28	132 3.72	2,020	1,170 23.39	2,330	7.1	do.	1.5	Low
-7bcb[7,10]	do.	7- 5-67	-- --	493 24.60	229 18.34	(7)	207 3.39	2,060 42.89	967 27.28	4,800	2,170 42.94	5,870	7.4	do.	6.3	High

Additional determinations from detailed analyses

Part II

Location	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrate (NO_3)	Boron (B)
	Milligrams per liter (upper number) and milliequivalents per liter (lower number)[1]					
GROUND WATER						
13/71-16ca	26	--	--	--	--	--
-19dac	25	--	--	0.4 0.02	0.8 0.01	0.1
-20ccd (1949)	32	--	--	.3 .02	9.4 .15	.0
-20ccd (1952)	32	--	--	--	8.8 .14	--
-29bba	35	--	--	--	9.3 .15	--
14/69-23b or c1	22	--	--	--	--	--
-23b or c2	35	--	--	--	--	--
15/70-2d	26	--	--	--	--	--
-12b	25	--	--	--	--	--
15/71-4 and -16b	31	--	--	--	.4 .01	--
A39/16-4a	4.3	--	--	0.7 .04	1.0 .02	0.1
A40/15-4cbd	20	--	--	--	--	--
-4d	15	--	--	--	--	--
STREAMS						
A40/15-4bc (1932)	40	--	--	--	--	--
-4bc (1950)	40	--	--	--	2.2 .04	--
-4bc (1955)	56	37 1.61	--	--	3.4 .05	--
-4cc (4-13-66)	14	175 7.61	16 0.41	1.0 0.05	2.0 .03	.48
-4cc (9-20-66)	16	293 12.75	31 .79	1.2 .06	1.6 .03	.95
14/70-7bcb (12-7-66)	--	118 5.13	15 .38	--	--	--
-7bcb (7-5-67)	--	673 29.28	42 1.07	--	--	--

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 10,000 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 15/70-12b, which has a value of 0.48 (safe). 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: 13/70-32a, 4 mg/l (0.13 me/l); 15/70-12b, 19 mg/l (0.63 me/l).

5. Computed sum, with bicarbonate expressed as carbonate. Letter "e" denotes estimated sum. For Virgin River at 14/70-7bcb, values represent residue on evaporation, rather than computed sum.

6. Sample bailed from unused well; may not represent chemical character of water yielded by well after appreciable pumping.

7. Detailed laboratory analysis; additional determinations are listed in Part II of this table.

8. Analysis by State of Nevada.

9. Stream-water analyses are listed in downstream order. Analyses of Virgin River at sites 40/15-4cc and 14/70-7bcb show representative chemical character for low and high dissolved-solids contents.

10. Analysis by Federal Water Pollution Control Adm.

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, large concentrations of chloride and dissolved solids impart an unpleasant taste, and sulfate can have a laxative effect on persons who are drinking the 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 as it may increase the possibility of "blue-baby" disease.

Other substances, such as arsenic, cyanide, and selenium, can have serious physiological affects if present in more than trace amounts in drinking water. The U.S. Public Health Service (1962, p. 8) has established concentration limits for the several substances (for example, 0.05 mg/l for arsenic). Although no trace-element analyses are available for water in the Virgin River Valley area, the fact that local water has been used for many years, seemingly without adverse effects, suggests that no trace elements are present in harmful quantities. 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.

Most waters sampled along the Virgin River flood plain, including the river itself, contain more than the recommended concentrations of sulfate and dissolved solids, and they characteristically are very hard. Elsewhere in the study area, the quality is more favorable for domestic use, though very hard water occurs almost everywhere. The chemical quality of well water used as municipal supplies for Bunkerville and Mesquite is generally acceptable at present (1968). However, the quality of these waters apparently can deteriorate with time if the wells are pumped heavily. The following data for the Mesquite wells suggest a moderate increase in dissolved-solids concentration between 1952 and 1967:

Well	Date	Specific conductance (micromhos)
13/71-20ccd	1952	561
13/71-29bba	1952	486
13/71-29bba, and possibly 20ccd	1967	780

Further deterioration may occur if heavy pumping continues. The alternative probably is a greater number of widely-spaced wells, with only small to moderate pumping of each well.

On the basis of very limited information, neither fluoride nor nitrate seem to be a problem in the study area. If any doubt exists regarding the acceptability of a drinking-water supply, the user should contact the Nevada Health Division, Bureau of Environmental Health, Las Vegas or Carson City.

Suitability for Agricultural Use

In evaluating the suitability of a water for irrigation, critical factors to be analyzed include dissolved-solids concentration, the proportion of sodium to calcium plus magnesium, and the occurrence of constituents, such as boron, that can be toxic to plants. Four factors used by the U.S. Salinity Laboratory Staff (1954, p. 69-82) to evaluate the suitability of irrigation water are listed in table 17, and are discussed briefly in footnote 2 of that table. Minor amounts of boron are essential to plant nutrition, but large quantities can be highly toxic. The recommended limits for boron in water used for irrigating sensitive, semitolerant, and tolerant crops are about 1, 2, and 3 mg/l, respectively, according to Scofield (1936).

Virgin River, which presently supplies most irrigation water in the study area, has proved generally acceptable chemically although it has a high to very high salinity hazard. The river water is acceptable because (1) soil drainage is adequate in most irrigated areas, (2) the river's sodium hazard is low or only moderate, (3) large volumes of fresher, though sediment-laden, river water are available to flush out, or leach, accumulated salts during the spring snowmelt period, and (4) the crops grown (largely alfalfa) are adequately tolerant from a water-quality standpoint.

Sediment that accompanies water diverted from the river into irrigation canals, as well as sediment dumped into the canals by local thundershower runoff, is a major problem in the Mesquite-Bunkerville area. Reportedly, the quantity of sediment is so great, particularly during large runoff, that the canals must be flushed at least once a week during the irrigation season (oral commun. from several local irrigators, 1967).

The river may not remain as acceptable for irrigation in the future as it is now (1968). Proposed upstream diversions, as part of the U.S. Bureau of Reclamation's proposed Dixie Project (1961), may reduce the present-day average streamflow at Littlefield by as much as 40 percent (U.S. Dept. of Interior, 1967, table 18). As a result, the average dissolved-solids concentration may almost double, from about 1,700 to as much as 3,000 mg/l (U.S. Dept. of Interior, 1967, table 18). Moreover, the overall salinity hazard of water used for leaching and irrigation would increase. On the other hand, favorable aspects of the upstream development would include a better control of the time, quantity, and hopefully, the sediment content of the leaching and irrigation water. In addition, if streamflow were augmented during the summer period of low flow, the quality of irrigation water during that period might be improved somewhat.

Much of the ground water beneath the Virgin River flood plain is less desirable for irrigation than the river water, because of characteristically higher salinity and sodium hazards. Elsewhere in the study area, most water is much more suitable for irrigation. This is particularly true along Beaver Dam Wash. Boron apparently is not a problem in the study area.

As a precaution, water from a newly drilled irrigation well should be analyzed to determine its chemical acceptability. The sample should be collected after the well is test pumped for a period of time sufficient to provide water truly representative of that in the water-bearing strata. Analyses may be obtained free of charge by Nevada residents. For information, contact the University of Nevada, Cooperative Extension Service agent, Las Vegas.

Most animals are more tolerant of poor-quality water than man. Although available data are somewhat conflicting, dissolved-solids concentrations below 4,000-7,000 mg/l apparently are safe and acceptable for most animals (McKee and Wolf, 1963, p. 112-113), provided that specific undesirable constituents are not present in excessive concentrations. All water sampled within the study area is sufficiently dilute for livestock use; however, dairy cattle watered with river water are reported to have been less productive than when watered with clear, more dilute ground water (George Hardman, written commun., 1969).

THE AVAILABLE WATER SUPPLY

Sources of Supply

In the lower Virgin River Valley, the available water supply consists of two interrelated quantities: (1) the system yield, and (2) part of the ground water in storage. In Tule Desert and Escalante Desert, Nevada, the available water supply is limited to the perennial yield of the ground-water system plus part of the ground water in storage. Surface runoff is considered too undependable and too erratic for much successful development.

System Yield

System yield has been defined by Worts and Malmberg (1966) as the maximum amount of surface and ground water of usable quality that can be obtained economically each year from sources within a system for an indefinite period of time. System yield cannot exceed 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 estimated system yield of the lower Virgin River Valley is based on the quantities listed in table 16 and the following limitations and assumptions: (1) Use by irrigation and municipalities is considered salvage; (2) most evapotranspiration discharge can be salvaged; (3) up to half the surface-water and ground-water outflow can be salvaged; (4) evaporation from water surfaces cannot be salvaged; (5) water quality, though marginal for some uses, is acceptable for the intended use; and (6) the estimated system yield is within the limits allowed by legal appropriations and decrees.

For this reconnaissance, then, the estimated system yield shown in table 18 is the sum of consumptive use by crops, evapotranspiration in phreatophyte areas, ground-water pumpage, and roughly half the surface-water and ground-water outflow. (See table 16.)

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. Preliminary estimates of perennial yield are given in table 18.

Table 18.--Yield and water consumption, lower Virgin River Valley area

(All estimates rounded)

Hydrographic area	Estimated system yield (acre-feet per year)	Estimated perennial yield (acre-feet)	Estimated water consumption in 1968 (acre-feet)
Lower Virgin River Valley, Nevada	a 100,000	--	14,000
Tule Desert	--	b 1,000	Minor
Escalante Desert, Nevada	--	b 1,000	Minor

a. Not of suitable chemical quality for some uses.

b. From ground-water reservoir only.

Natural discharge from the Tule Desert area occurs by subsurface outflow. For lack of contrary evidence, the underflow is assumed to be southward toward the Virgin River. The possibility of salvaging all or part of the outflow within the valley depends on the manner in which the outflow takes place. If water is moving over a "spillway" or "lip," a large part could be salvaged by drawing down the ground-water level below the outlet altitude. On the other hand, if the outflow is dispersed vertically through a permeable fault system or joint pattern, or if it occurs at considerable depth, only a small amount could be salvaged by pumping within the valley. Because the salvable discharge probably lies somewhere between these two limits, the preliminary estimate of water that could be salvaged within the Tule Desert is assumed for reconnaissance purposes to be about one-half the estimated annual recharge or about 1,000 acre-feet.

Natural ground-water discharge from Escalante Desert, Nevada, is by subsurface outflow to Utah. Problems of salvage would be similar to those of Tule Desert. Thus, for the purposes of this reconnaissance, it is assumed that about one-half of the subsurface outflow could be salvaged by pumping.

Ground Water in Storage in the Valley-Fill Reservoir

The amount of ground water stored in the valley-fill reservoir equals the volume of saturated deposits multiplied by the specific yield of the material. Specific yield of a rock or soil, with respect to water, is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume (Meinzer, 1923, p. 28). Specific yield is commonly expressed as a percentage.

In the lower Virgin River Valley 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 80 percent of the alluvial area shown on plate 1. This is based on topography, subsurface distribution of the alluvium, depth to water, and 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 19.

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 water in storage may be highly mineralized and therefore unsuitable for irrigation or domestic uses. The amount of usable ground water in storage that is economically available depends largely on the distribution of water-storing deposits and the distribution and range in chemical quality of the ground water.

Table 19.--Estimated stored water in the upper 100 feet of saturated valley fill in Nevada

Hydrographic area	Estimated area underlain by 100 feet or more of saturated valley fill (acres)	Estimated stored water (acre-feet)
Lower Virgin River Valley:		
In Nevada north of river	240,000	2,400,000
In Nevada south of river	46,000	460,000
Total (rounded)	290,000	2,900,000
Tule Desert	53,000	530,000
Escalante Desert	19,000	190,000

WATER USE, 1968

Estimated total water use in the lower Virgin River Valley area, Nevada, during 1968 is summarized in table 20. The evaporation loss from canals cannot be prevented, and therefore is assumed to be a necessary loss associated with irrigation.

Total consumptive use of water for all purposes in Tule Desert and Escalante Desert, Nevada, probably averages less than 10 acre-feet annually.

Table 20.--Summary of water use in 1968 in the lower Virgin River Valley, Nevada

	Estimated use (acre-feet)
Irrigation consumption of surface water (table 11)	13,000
Evaporation from main irrigation canals (table 14)	80
Irrigation consumption of ground water (table 15)	250
Municipal consumption of ground water (table 15)	230
Private domestic consumption of ground water (table 17)	10
Livestock consumption of ground water (table 15)	30
Total (rounded)	14,000

FUTURE WATER SUPPLY

Present water development in the lower Virgin River Valley centers mainly around the flow of the river. The proposed Dixie Project of the U.S. Bureau of Reclamation provides for upstream dams and reservoirs in Utah for power generation and additional irrigated acreage (U.S. Bur. Reclam., 1961). The report states on page 7:

> "Releases from the Virgin City Reservoir would be made to meet the irrigation demands in the Hurricane Division and the municipal requirements, and within the limits of the remaining water supply, to so regulate the combined power output of the three project power plants that the power supplied would conform as nearly as possible to the pattern of the power market, <u>due consideration being given to downstream irrigation requirements along the Virgin River in Arizona and Nevada."</u> (Emphasis added.)

More specifically, the impact of the proposed Dixie Project on stream regimen is given in tables 18 and 21 of the Bureau's report, which show a depletion in average streamflow, under the 1930-55 conditions, from 178,400 acre-feet per year to 116,800 acre-feet per year. The flow reaching Nevada would be diminished by more than 30 percent under the proposed plan of development. Because downstream users depend on the better quality of water provided by flood and snowmelt runoff to leach lands, and in part to irrigate crops, detention of these flows may cause problems, as is indicated on page 36 of the report:

> "The Virgin River is an interstate stream with parts of its watershed located in the States of Arizona, Nevada, and Utah. A number of meetings between the Governors and/or representatives of these States have resulted in a substantial measure of agreement regarding the Dixie Project. <u>The quality of water under the Dixie Project development that would reach downstream users in Arizona and especially Nevada appears to be one of the unresolved items at this time."</u> (Emphasis added.)

Ground-water reservoirs in the area are as yet largely untapped. However, these reservoirs are in part hydraulically controlled by the Virgin River. Thus, any intensive ground-water development adjacent to the Virgin River flood plain, generally upstream from Riverside, could be expected to affect the river itself. Conversely, any substantial depletion in river flow would affect adjacent ground-water reservoirs. Large ground-water withdrawals adjacent to the river flood plain might be accompanied by deterioration of the chemical quality of the ground water caused by intrusion of poor quality water from beneath the flood plain into the ground-water reservoirs.

Future ground-water development in the Nevada part of the Virgin River Valley will depend to varying degrees on: (1) water requirements, (2) technological and economic problems controlling the extraction of the water, (3) quality of the ground water as related to intended uses, and (4) effects of upstream development on the river system.

For Tule Desert and Escalante Desert, Nevada, the only dependable source of water is the ground-water reservoir. Salvage of ground-water outflow (table 18) is possible by pumping. Any appreciable reduction of outflow would be accompanied by a substantial depletion of ground water in storage. This in turn means that to salvage as much as 1,000 acre-feet per year of outflow, pumping lifts could be expected to increase markedly.

NUMBERING SYSTEM FOR HYDROLOGIC SITES

In this report, numbers assigned to hydrologic sites in Nevada are based on the rectangular subdivisions of the public lands referenced to the Mount Diablo base line and meridian. Each 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; and the third unit, separated from the second by a dash, designates the section number, which in turn is followed by a letter that indicates the quarter section. The quarter sections are designated counterclockwise sequence. Following the letter, a number indicates the order in which the site was recorded within the particular tract. For example, well 13/70-25dbb1 is the first well recorded in NW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 25, T. 13 S., R. 70 E., Mount Diablo base line and meridian. If only one site was recorded in a particular tract, no number follows the tract letter.

The numbering systems normally used in Arizona and Utah are the same as for Nevada with respect to section number and quarter section; however, township designations are slightly different. In this report, the Nevada numbering system is also used for Arizona and Utah wells and springs to provide continuity for the reader; however, sites in Arizona are preceded by the letter A, as in A40/15-3a1, and those in Utah are preceded by the letter U, as in U40/19-3d1. The township and range numbers for all sites in the Arizona part of the report area are north of the Gila base line and west of the Salt River meridian, respectively. Those for Utah are south and west of the Salt Lake base line and meridian.

Table 21.--Well records

Owner or name: BLM, U.S. Bureau of Land Management
Use: C, construction; D, domestic; Da, dairy; I, irrigation; M, municipal; S, stock; U, unused. Symbol preceding a slant designates original well use; symbol following the slant designates current use
Yield and drawdown: Reported, or from records of the Nevada State Engineer
Remarks: C, chemical analysis in table 17; L, driller's log in table 22. Number is the log number in the files of the Nevada State Engineer

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude of land surface (feet above mean sea level)	Water-level measurement: Date	Water-level measurement: Depth to water table (feet below land surface)	Remarks
VIRGIN RIVER VALLEY - Nevada										
5/71-17a	Nevada State Park Commission	1963	33+	6	D	--	5,050	10- -63	13.7	7454 L
-21c	Do.	1963	40	6	D	--	5,000	10- -63	19.5	7453
8/69-2a	BLM, Sams Camp Well	1952	30	--	S	--	4,650	9- -52	8	--
8/70-14a1	BLM	1964	40	6	S/U	--	3,750	11-14-67	15.80	8142 L
-14a2	BLM, Bull Valley Well	1951	30	6	S	est. 10/--	3,750	9- -51	16	1756 C
8/71-32cd	BLM, Lime Mountain Well	1949	61	6	S	10/--	3,400	11-14-67	35.21	968 C,L
10/69-7bb	Andy Lytle	1953	566	14	S	--	3,150	11-12-67	392.09	2243 C,L
12/70-23d	BLM	1965	497	8	U	Dry hole	2,030	--	--	6591 L
13/70-4cd	BLM	1949	245	6	S	10/3	1,765	9- -49	220	1156 L
-13ddd	Hafen Dairy	--	60	6	Da,S	--	1,580	11-15-67	15-20	C
-25dbb1	Bunkerville Water Users Assoc.	1965	110	8	I/U	--	1,550	--	--	8818 L
-25dbb2	Do.	1967	300	8	I	300/190	1,550	11-10-67	24.6	L
-32a	C. T. Parker Construction Co.	1966	300	12	C/U	500/--	1,565	11-13-67	43.2	C,L

Table 21.--Well records--Continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude of land surface (feet above mean sea level)	Water-level measurement: Date	Water-level measurement: Depth to water table (feet below land surface)	Remarks
13/70-34c1	Bruno Biasi	1958	118	8	Da/S	--	1,520	11-11-67	34.4	4363 C,L
-34c2	Do.	--	--	8	S	--	1,500	11-11-67	9.3	C,L
-35cdc	Bunkerville Water Users Assoc.	1952	265	8	M/U	35/0	1,680	1- -52	179	1865 L
35cdd1	Do.	1960	300	20	M	225/--	1,680	11-11-67	240.9	5983 C,L
35cdd2	Do.	1965	300	16	M	80/--	1,680	11-15-67	232.5	C,L
13/71-16aa	Mesquite Farmstead Water Assoc.	1966	138	12	I	--	1,620	11-15-67	32.4	9090 C,L
-16ca	Mesquite Dairy	--	12	48 (dug)	D	--	1,590	7- -46	9.0	C
-16bda	Mesquite School District No. 1	1934	440	8	D	--	1,605	7- -46	25.9	--
-19dac	Marrinar Cox	1949	98	6	D	--	1,560	11-11-67	16.64	C,L
-20ccd	Mesquite Farmstead Water Assoc.	1949	210	8	M	32/50	1,680	--	102	C,L
-21ca	Do.	1954	200	8	M	--	1,700	5- -54	120	2582 L
-29bba	Do.	1951	225	8	M	35/0	1,690	12- -51	110	1866 C,L
-29bbb	Do.	1962	251	16	M	150/--	1,660	11-10-67	121.8	7775 L
14/69-23c1	Riverside Auto Court	--	25	60 (dug)	D/U	--	1,435	7-17-46	23.22	--
-13cb	Cliven Bundy	1958	234	8	D	--	1,440	11-11-67	65.5	4364 C,L
-23a1	Dr. Robert Taylor's Arriba Verde Ranch	--	--	12	I	--	1,400	--	--	L
-23a2	Do.	1965	625	6	D	--	1,420	11-11-67	57.4	3798 C,L
-23c1	John A. Lundell	1946	105	6	U	--	1,370	2-24-49	19.1	C,L
-23c2	Do.	1946	198	16	I/U	812/30	1,370	10-28-46	11	C,L
-33a	D. & H. Adams	1961	380	14	I/U	1200/--	1,350	7- -61	36	6120 L
15/68-25c	Forest Purdy	--	--	--	I/U	--	1,260	--	--	--
15/69-7c	R. M. Jensen	1954	85	12	U	--	1,310	--	--	2513 L

Table 21.--Well records--Continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude of land surface (feet above mean sea level)	Water-level measurement: Date	Water-level measurement: Depth to water table (feet below land surface)	Remarks
						VIRGIN RIVER VALLEY - Arizona				
A39/16-4a	Government Test Well	1936	--	10	U	--	--	7-16-46	4.4	C
A40/15-3abb	Burdett Reber	1967	105	14	I/U	--	1,930	11-16-67	21.8	C,L
-5ab	El Rancho Arivada	1938	20-70	60 (dug)	D,I	--	1,920	10- 1-46	17.2	--
-5ba	K. N. Romriell	--	100	16	D,I	500/14	1,910	11-15-67	25.0	C,L
A40/16-4a	Santa Clara Cattle Assoc.	--	532	--	U	Dry hole	2,150	--	Dry	--
-33cc	Archie Hughes	1965	340	14	I,U	--	1,700	11-15-67	80.77	C
-33cd	Do.	1967	200	14	I	600/--	1,700	11-15-67	79.6	L
-34cab	Dee Hughes	1968	285	14	I	1620/40	1,770	3- -68	142	C,L
-34ccb	Do.	1968	274	14	I	750/86	1,770	2- -68	141	L
A41/15-29dbc	Bruno Biasi	1966	230	14	I	--	1,965	2- -66	100	--
-29dcc	Do.	--	230±	14	I/U	--	1,965	11-15-67	88.90	C
-29dcd	Do.	1927(?)	2,600	16	I	--	1,965	7-17-50	86.8	--
-29ddc	Do.	1967	300	14	I	--	1,960	6- -67	98	--
-29ddd	Do.	--	66	14	U	Dry hole	1,960	11-15-67	Dry	--
-30d	Santa Clara Cattle Assoc.	1965	106	10	S	--	--	7- -65	35	L
-32ad	Virgin Village Development Co.	--	--	12	D	--	1,880	11-13-67	80.4	--
-32b	Burdett Reber	1946	100	16	I	600-700/--	--	11-15-67	26.66	--
-32c	W. H. Broussard	--	--	16	I/U	--	--	11-15-67	26.0	--
-33bcc	William Walter, III	1959	102	10	I	375/--	1,880	11-13-67	81	L
-33bcb	Do.	1963	220	10	I/U	--	1,900	11-13-67	85.37	--
-33cbd1	Do.	1950	100	6	D	--	1,870	--	--	--
-33cbd2	Do.	1965	100-105	8	D	--	1,880	--	--	C

Table 21.--Well records--Continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Altitude of land surface (feet above mean sea level)	Water-level measurement: Date	Water-level measurement: Depth to water table (feet below land surface)	Remarks
						VIRGIN RIVER VALLEY - Utah				
U39/19-29b	Wes Atkins	--	--	6	D,S	--	3,850	--	--	--
-34d	D. I. Ranch (upper well)	1956	65	12	--	225/40	--	9- -56	15	L
U40/19-3d1	Do. (barn well)	1956	68	12	D,S	--	3,850	9- -56	9	L
-3d2	Do. (middle well)	1956	70	12	I	225/41	--	8- -56	14	L
-10b	Do. (lodge well)	1956	35	10	D	--	3,800	11-16-67	6	
-5d	Wes Atkins	--	--	--	I	--	--	--	--	--
-17a	Do.	--	--	14-16	I	--	3,450	--	--	--
U42/20-24a	Levi Snow	1966	80	16	I	--	2,650	11-14-67	16.28	L
U43/18-7d1	Utah Emergency Relief	1935	630	--	U	Dry hole	3,400+	--	Dry	L
U43/19-20b	BLM, Beaver Dam Well	1958	137	6	S	--	2,400±	2- -58	84	L
						ESCALANTE DESERT - Nevada				
3/70-26a	Union Pacific Railroad Co.	1914	193+	6	U	Dry hole	6,150	--	--	L
3/71-7db	Sumption Well	--	--	10	S	--	5,790	11-17-67	130.6	--
						ESCALANTE DESERT - Utah				
U34/19-36c	Union Pacific Railroad Co.	1943(?)	635	12	M	--	5,470	--	--	L
U35/20-26dd	John Wadsworth	--	--	6-8	S	--	5,730	--	--	--
-35a	Union Pacific Railroad Co.	--	--	6-8	D	--	5,730	11-17-67	69.8	C

Table 22.--Well logs

Material	Thickness (feet)	Depth (feet)
3/70-26a		
Clay, red and brown, and boulders	12	12
Rock, decomposed	14	26
Sand, red	8	34
Rock, decomposed	26	60
Sand and boulders	5	65
Clay, yellow, and boulders	33	98
Granite	5	103
Granite, red, disintegrated	23	126
Conglomerate, cemented	41	167
Clay, red, and conglomerate	6	173
Sandstone, red	15	188
Conglomerate	5	193
Shale, white, tufa, and conglomerate	--	193+
5/71-17a		
Soil, sandy	14	14
Sand and gravel	19½	33½
8/70-14a		
Gravel	33	33
Bedrock, lime	7	40
8/71-32cd		
Sand and boulders	5	5
Gravel, cemented	30	35
Gravel, water-bearing	20	55
Boulders	6	61
10/69-7bb		
Sand and gravel	30	30
Clay, sandy, and gravel	275	305
Sand and gravel	60	365
Sand and gravel	45	410
Gravel, sand, and clay	40	450
Gravel	63	513
Clay, red	53	566
12/70-23d		
Sand, loose, and gravel	90	90
Sandstone in alternating layers of damp and dry	220	310
Sandstone, porous, dry	187	497
13/70-4cd		
Gravel, cemented	20	20
Clay, red	20	40
Clay, sandy, red	180	220
Sand, fine flowing, water-bearing	8	228
Limestone, hard	4	232
Clay, red, sandy, water-bearing	13	245
13/70-25dbb1		
Boulders	3	3
Clay, brown, and sand	33	36
Sand, brown, water-bearing	14	50
Water	10	60
Gravel, water-bearing	30	90
Clay, brown	10	100
Clay, brown, and gravel	10	110
13/70-25dbb2		
Gravel, cemented, and cobbles	35	35
Gravel, cobbles, and loose sand	52	87
Sand, coarse, and gravel	18	105
Slightly cemented	50	155
Sand, red with streaks of red clay	145	300
13/70-32a		
Sand, loose, and gravel	65	65
Conglomerate, slightly cemented	10	75
Gravel, cemented	15	90
Sand, red, and sandstone stratas	200	290
Clay, blue	10	300
13/70-34c1		
Boulders	10	10
Sand and clay	15	25
Sand, water-bearing	20	45
Clay	15	60
Sand and clay	12	72
Clay	14	86
Hardpan	2	88
Clay	17	105
Sand, hard	5	110
Clay	8	118

Table 22.--Continued

Material	Thickness (feet)	Depth (feet)
13/70-35cdc		
Clay	2	2
Sand and gravel	5	7
Gravel	8	15
Gravel, yellow	20	35
Sand, coarse, and gravel	6	41
Clay, sandy	11	52
Clay, sandy, and gravel	8	60
Clay, sandy	20	80
Sand, red	5	85
Clay, sandy	51	136
Sand, red	6	142
Clay, sandy	41	183
Quicksand, water-bearing	17	200
Clay, sandy	40	240
Quicksand, water-bearing	10	250
Clay, red	13	263
Clay, blue	2	265
13/70-35cdd1		
Gravel and boulders	42	42
Gravel, cemented	26	68
Sand, red, and clay	140	208
Clay, red	15	223
Sandstone, gray	1	224
Sand, red, with thin layers of clay	76	300
13/70-35cdd2		
Boulders, gravel, and clay	13	13
Gravel, sand, and clay	22	35
Clay, brown, and gravel	15	50
Clay, brown, sandy	120	170
Sand, brown, and gravel	5	175
Sand, brown, and clay	15	190
Sand, brown, water-bearing	40	230
Sand, brown, a little clay and gravel, water-bearing	28	258
Sand, water-bearing	12	270
Sandstone, brown, water-bearing	1	271
Sand, brown and layer of sandstone	14	285
Sand, brown, and brown clay	15	300
13/71-15aa		
Soil, sandy.	38	38
Sand with gravel	2	40
Sand, fine	10	50
Gravel with sand	18	68
Clay with gravel	17	85
Gravel	20	105
Sand	33	138
13/71-19dac		
Soil, sand, and gravel, water-bearing	25	25
Clay(?)	40	65
Sand, gravel, and quicksand	33	98
13/71-20ccd		
Sand, red, and gravel	23	23
Gravel, blue	12	35
Gravel, brown	37	72
Sand and gravel	33	105
Sand, water-bearing	20	125
Clay, sandy	30	155
Sand, water-bearing	17	172
Gravel, water-bearing	3	175
Clay, sandy	15	190
Gravel	4	194
Clay, sandy	16	210
13/71-21ca		
Gravel, coarse	42	42
Sand, red	98	140
Gravel, water-bearing	3	143
Sand, red, mixed with clay	52	195
Sand and coarse gravel	5	200

Table 22.--continued

Material	Thickness (feet)	Depth (feet)
13/71-29bba		
Sand and gravel	18	18
Gravel	7	25
Sand, coarse	6	31
Sand and gravel	9	40
Clay, sandy	15	55
Sand and gravel	3	58
Gravel, cemented	9	67
Sand and gravel	38	105
Sand, red, and a little water at 115 feet	43	148
Clay, sandy, with gravel	13	161
Sandstone, red	4	165
Sand, hard	20	185
Gravel, water-bearing	5	190
Clay, sandy	10	200
Gravel	4	204
Clay	20	224
Sand, water-bearing	1	225
13/71-29bbb		
Sand, brown	4	4
Sand, brown, with lenses of gravel	47	51
Boulders	2	53
Sand, brown	7	60
Gravel, cemented	2	62
Gravel, cemented, and sand	33	95
Sand, brown	3	98
Sand, brown, with small streaks of fine gravel	144	242
Clay, brown	8	250
14/69-13cb		
Gravel	12	12
Clay	58	70
Sand, water-bearing	10	80
Clay	30	110
Sand and clay	14	124
Hardpan	10	134
Clay, sandy	24	158
Clay	10	168
Sandstone layers	8	176
Clay, sandy	10	186
Clay, hard	9	195
Clay, sandy	11	206
Sand and hard clay	6	212
Clay, sticky	4	216
Clay, sandy	18	234
14/69-23a2		
Sand, gravel, and boulders	36	36
Sand, clay, and gravel	32	68
Sand and gravel	37	105
Clay, sandy, mixed with gravel	185	290
Clay, sand, and gravel mixed with some coarse rock strata	135	425
Pea gravel with streaks of cemented gravel	60	485
Gravel, cemented with streaks of coarse sand and pea gravel	140	625

Table 22.--continued

Material	Thickness (feet)	Depth (feet)
14/69-23c1		
Unknown	24	24
Gravel, large-pebble and granules, and some fine- to coarse-grained sand	4	28
Unknown	3	31
Sand, fine- to coarse-grained, and a few pebbles and granules	24	55
Sand, pink, fine- to medium-grained, silty	2	57
Gravel, large pebble to granule, and some sand	3	60
Sand, fine- to coarse-grained	6	66
Gravel, large pebble to granule, and some sand	16	82
Gravel	14	96
Clay, heavy, and little gravel	7	103
Sand	2	105
Clay, heavy	--	105+
14/69-23c2		
Sand	10	10
Sand and clay	8	18
Sand	4	22
Gravel, fine, water-bearing	5	27
Sand	4	31
Clay, sandy	4	35
Sand and gravel	3	38
Sand	2	40
Gravel	2	42
Gravel and clay	6	48
Clay	14	62
Gravel, fine	2	64
Gravel, coarse	4	68
Sand	1	69
Gravel	21	90
Clay	15	105
Clay, rock, water-bearing	10	115
Clay	7	122
Clay, sandy	32	154
Gravel	4	158
Clay	4	162
Gravel	3	165
14/69-23c2--continued		
Sand	9	174
Sand, hard	8	182
Clay and gravel	1	183
Sand	4	187
Gravel	4	191
Clay, blue	1	192
Sand	3	195
Clay, blue	3	198
14/69-33a		
Sand and gravel	35	35
Quicksand	125	160
Clay, red	80	240
Gravel	20	260
Clay, red	110	370
Gravel and water-bearing sand	70	440
Clay, red	100	540
Gravel and water-bearing sand	30	570
Clay, red	20	590
Clay, red, hard, and shale	30	620
Clay, blue	190	810
Clay, red, hard, and shale	70	880
15/69-7c		
Gravel, dry	37	37
Gravel, water-bearing	6	43
Clay, sticky	39	82
Gravel, tight	3	85
Hardpan	46	131
Gravel	1	132
A40/15-3abb		
Soil	12	12
Clay and gravel	12	24
Sandstone and gravel	2	26
Limestone, white	6	32
Limestone and clay	36	68
Clay, red	34	102
Gravel	3	105

Table 22.—continued

Material	Thick-ness (feet)	Depth (feet)
A40/15-5ba		
Gravel, sandy, pebbles to 1-inch diameter, and some clay, 1-foot water-bearing zone at 18 feet.	23	23
Silt, sandy	7	30
Gravel, sandy, pebbles to ½-inch diameter	11	41
Conglomerate, pebbles to 5-inch diameter	15	56
Gravel, sandy, pebbles to ½-inch diameter	7	63
Grit, sandy, and some clay with some granule-size pebbles	38	101
A40/16-33cd		
Clay, sandy	5	5
Gravel and sand	55	60
Gravel and sand	30	90
Sand, water-bearing	4	94
Clay	12	106
Gravel, coarse	14	120
Gravel	15	135
Clay	3	138
Gravel	2	140
Clay	15	155
Sand	10	165
Clay	5	170
Sand and clay	30	200
A40/16-34cab		
Soil, sandy	4	4
Sand	66	70
Clay	20	90
Clay, sandy	20	110
Sand	35	145
Sand and gravel	16	161
Gravel	14	175
Clay	3	178
Sand	3	181
Gravel	6	187
Clay	1	188
Gravel	3	191
Clay	22	213
Gravel, sand, and clay	7	220
Gravel, coarse	3	223
Clay	17	240
Sand, gravel, and clay	7	247
Gravel	8	255
Clay	5	260
Gravel and sand	15	275
Sand and clay	10	285
A40/16-34ccb		
Sand	90	90
Gravel, dry	60	150
Clay	40	190
Sand	15	205
Clay	15	220
Sand and gravel, water-bearing	30	250
Clay	2	252
Sand	22	274
A41/15-29dbc		
Sand and clay	4	4
Gravel, dry	98	102
Gravel, water-bearing	10	112
Sand and clay	22	134
Gravel, water-bearing	12	146
Clay	47	193
Gravel, water-bearing	7	200
Sand, clay, and gravel	12	212
Gravel	2	214
Hardpan, clay, and gravel	16	230

Table 22.--continued

Material	Thickness (feet)	Depth (feet)
A41/15-29dac		
Clay	6	[illegible]
Gravel, dry	84	[illegible]
Gravel, dry	25	115
Clay, sandy	3	118
Sand and gravel	12	130
Clay, sandy	10	140
Sand and gravel	6	146
Clay, sandy	13	159
Gravel	6	165
Gravel and clay	7	172
Clay	58	230
Gravel	14	244
Clay	6	250
Gravel	4	254
Clay	10	264
Gravel	11	275
Clay	25	300
A41/15-30d		
Sand, a little gravel	35	35
Gravel	34	69
Clay	27	96
Sand and gravel	4	100
Clay	6	106
A41/15-33bcc		
Gravel and clay	60	60
Clay, sandy	20	80
Gravel, tight	22	102
A41/15-33bcb		
Clay, gravelly	80	80
Clay, sandy	5	85
Gravel, water-bearing	15	100
Clay	26	126
Clay, sandy	45	171
Clay, gravelly	7	178
Gravel, tight	13	191
Sandy	15	206
U34/19-33c		
Hardpan and gravel	14	14
Clay, sand, and gravel	8	22
Gravel, cemented	84	106
Clay, sand, and gravel	4	110
Gravel, cemented	18	128
Clay and sand	7	135
Gravel, cemented	75	210
Clay, sand, and gravel	20	230
Gravel, cemented	15	245
Cement and sand, water-bearing	15	260
Sandstone, rotten, water-bearing	25	285
Clay, sand, and gravel	105	390
Sand and gravel, cemented	35	425
Sand and clay, sticky	25	450
Clay, sand, and gravel	33	483
Clay, reddish-brown	32	515
Clay, brown	120	635
U35/19-34d		
Gravel and boulders	27	27
Gravel, cemented	30	57
Granite, pink	8	65
U42/19-3d1		
Soil	4	4
Gravel	31	35
Gravel, cemented	33	68
U42/19-3d2		
Sand and gravel	30	30
Gravel, cemented	27	57
Granite, pink	13	70
U42/20-24a		
Clay and sand	20	20
Gravel	35	55
Clay and gravel	25	80

Table 22.--continued

Material	Thickness (feet)	Depth (feet)
U43/18-7a		
Gravel, cemented	25	25
Gravel and clay	75	100
Gravel, cemented	200	300
Lime, black	18	318
Gravel, cemented	22	340
Gravel, lime, black	20	360
Gravel	40	400
Lime, black	35	435
Quartzite, hard	35	470
Gravel, cemented, pink	30	500
Limestone	60	560
Gravel, cemented	70	630
U43/19-20b		
Sand and gravel, firm	30	30
Clay, sandy, firm	15	45
Sand and gravel with thin layers of clay, firm	70	115
Sand and gravel, loose	11	126
Gravel and rocks, firm	11	137

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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
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	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
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	Newcomb Lake
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	Dry
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	Spanish Springs
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	Sun
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44	Smoke Creek Desert
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	Pilgrim Flat
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	Sano

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46	Mesquite Valley Ivanpah Valley Jean Lake Valley Hidden Valley
47	Thousand Springs Valley
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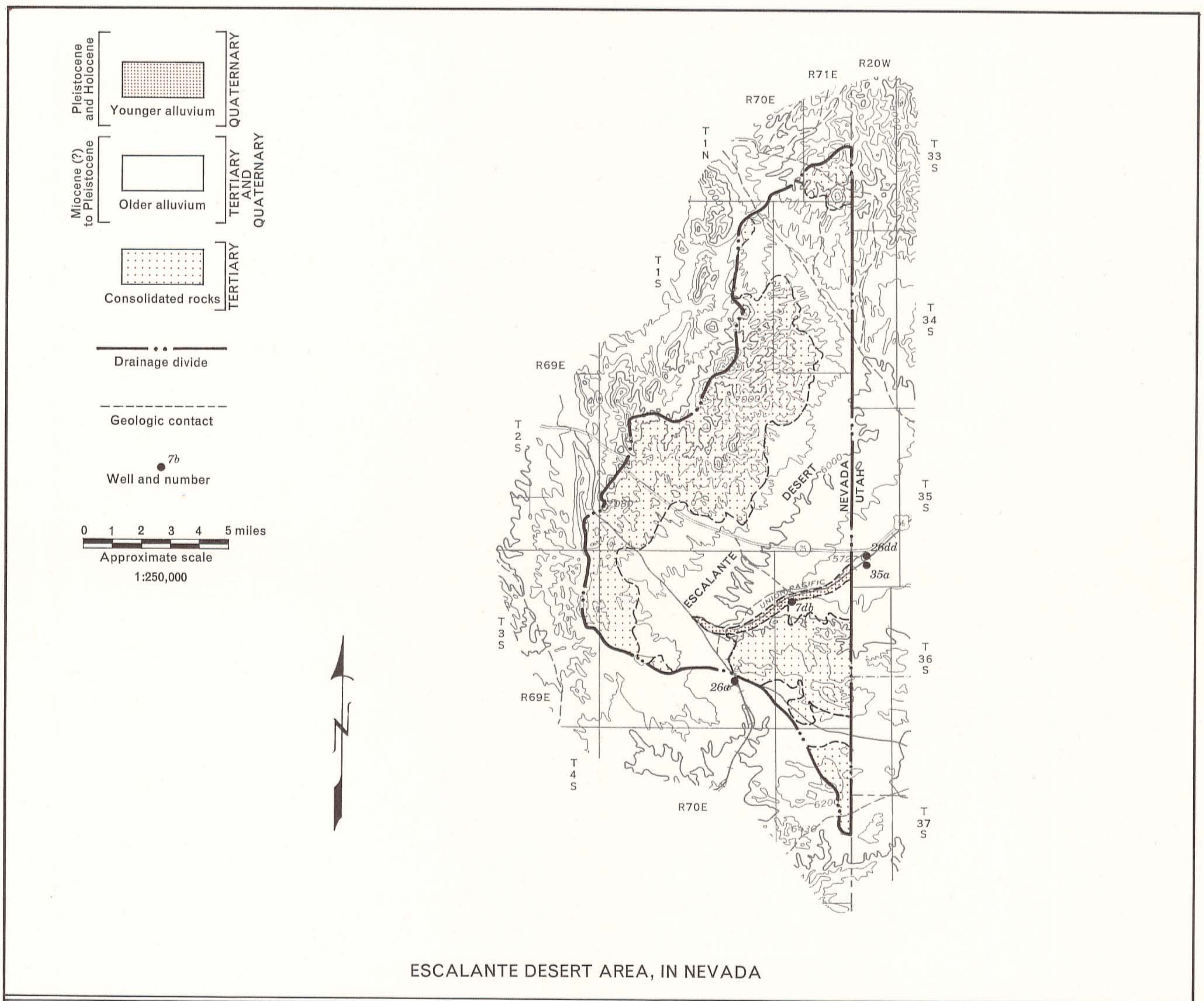
49	Butte Valley
50	Lower Moapa Valley Hidden Valley Garnet Valley California Wash Black Mountains Area Gold Butte Area Greasewood Basin

Base from U.S. Geological Survey 1:250,000 Scale maps: Caliente, Nevada (1954); Cedar City, Utah (1953); Grand Canyon, Arizona (1953); and Las Vegas, Nevada, Arizona, and California (1954)

Hydrogeology by P.A. Glancy and A.S. Van Denburgh, 1967-68. Geology modified from Hintze, 1963; Longwell and others, 1965; Tschanz and Pampeyan, 1961; and Wilson and others, 1959.

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF THE LOWER VIRGIN RIVER VALLEY, NEVADA, ARIZONA, AND UTAH, AND TULE DESERT, NEVADA



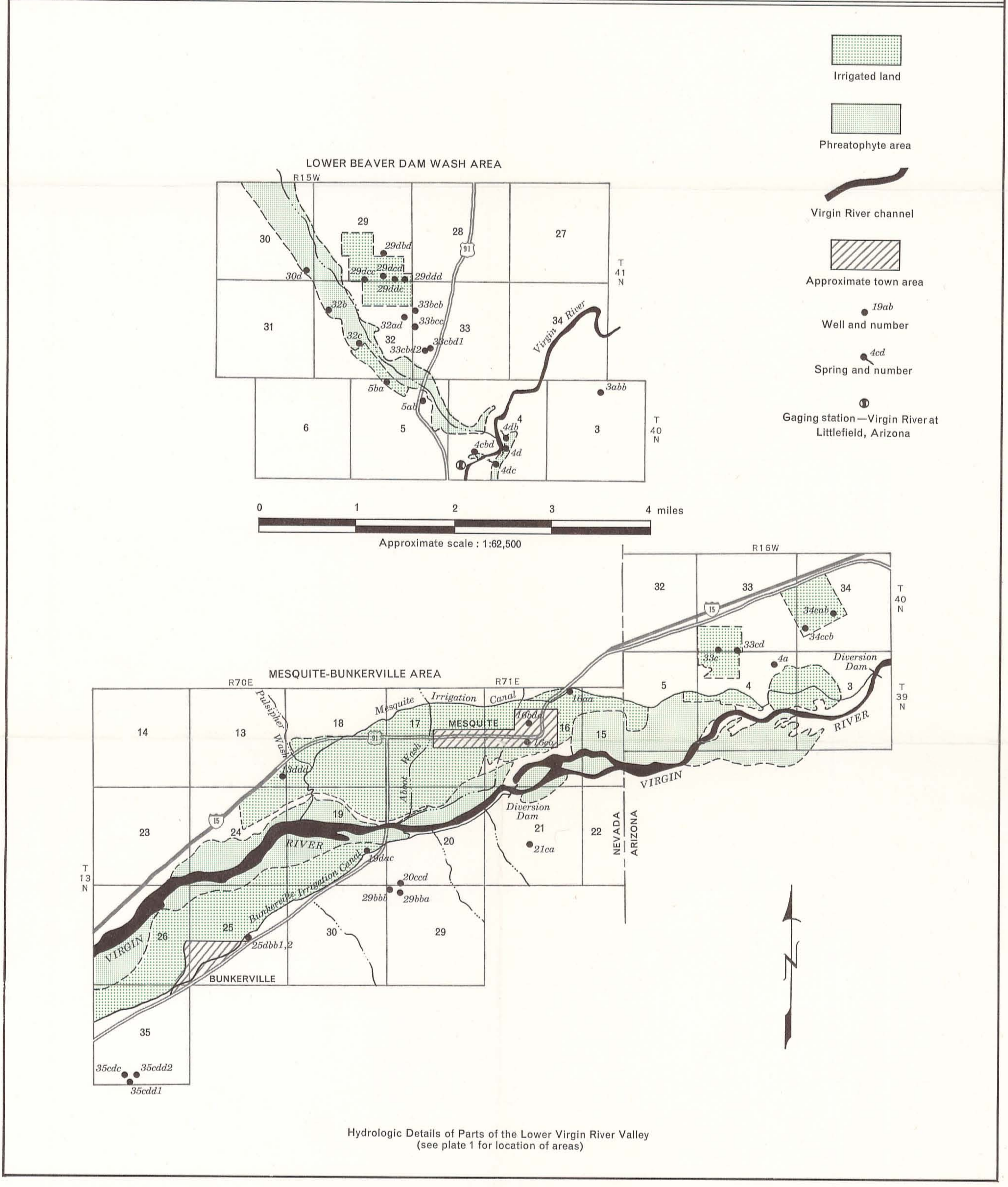


PLATE 2.—GENERALIZED HYDROGEOLOGIC MAP OF THE ESCALANTE DESERT, NEVADA, AND HYDROLOGIC DETAILS OF PARTS OF THE LOWER VIRGIN RIVER VALLEY