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STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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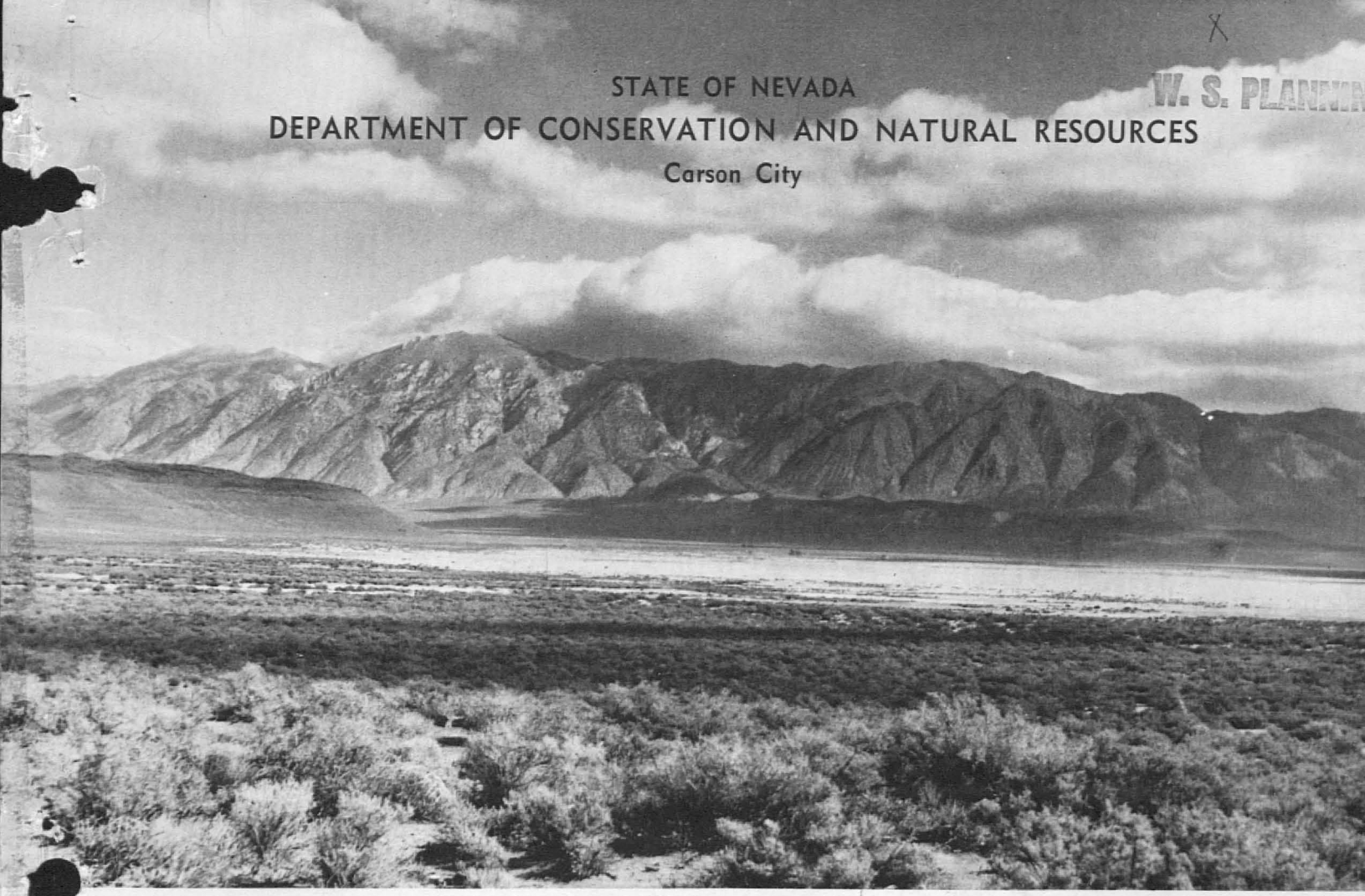

Granite Range and Northern part of Smoke Creek Desert.

WATER RESOURCES–RECONNAISSANCE SERIES

REPORT 44

WATER–RESOURCES APPRAISAL OF SMOKE CREEK–SAN EMIDIO DESERT AREA, NEVADA AND CALIFORNIA

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By

Patrick A. Glancy

and

F. Eugene Rush

Prepared cooperatively by the

Geological Survey, U.S. Department of the Interior

APRIL 1968

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The harsh playa environment reclaims the deserted railroad town of Smoke Creek.

WATER RESOURCES - RECONNAISSANCE SERIES

Report 44

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F. Eugene Rush

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February 1968

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 in cooperation with the U.S. Geological Survey.

This report is the 44th report prepared by the staff of the Nevada District of the U.S. Geological Survey. These 44 reports describe the hydrology of 107 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 met the immediate needs for information on the water resources of the areas covered by the reports.

Elmo J. DeRicco
Director

Department of Conservation
and Natural Resources

February 1968

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WATER-RESOURCES APPRAISAL OF SMOKE CREEK-

SAN EMIDIO DESERT AREA,

NEVADA AND CALIFORNIA

By

Patrick A. Glancy
and
F. Eugene Rush

SUMMARY

The report area includes two major valleys and five smaller valleys in northwestern Nevada and northeastern California and covers a total area of about 1,590 square miles. Major valleys are Smoke Creek and San Emidio Deserts; smaller valleys are Painters Flat, Pilgrim Flat, Dry Valley, Sano Valley, and central Skedaddle Creek valley.

Precipitation within the area is assumed to be the source of practically all water occurring in the area. Most precipitation occurs during the winter, and summers are usually hot and dry, except for thundershowers.

Geologic terrane controlling the natural hydrologic system consists principally of consolidated-rock mountain masses bordering and separating the valleys, and alluvial-mantled valley floors. Mountain ranges and intervening basins are the result of structural deformation of the earth's crust that set the gross hydrologic framework of the area.

The principal known and developed aquifers occur in alluvial deposits, generally at relatively shallow depths. Knowledge is presently unavailable about the presence, size, or quality of water reservoirs at great depths in the alluvium or in the consolidated rocks.

Field-office chemical analyses of 25 water samples show water quality ranges from good to very poor. The quality of water in shallow ground-water reservoirs upgradient from playa areas is generally suitable for most purposes; poorer quality water was encountered in shallow aquifers in natural discharge areas on and near the playas.

Principal hydrologic facts and estimates resulting from this reconnaissance are summarized in table 1.

Table 1.--Hydrologic summary

(All estimates in acre-feet per year, except where noted)

	Hydrologic units (valleys)						
	Smoke Creek Desert	San Emidio Desert	Painters Flat	Pilgrim Flat	Dry Valley	Sano Valley	Central Skedaddle Creek Valley
Approximate valley area (square miles)	1,120	308	56	10	42	12	42
Assumed hydrologic integrity	(a,b)	(a,b)	(a)	(a,b)	(a,b)	(a)	(b,c)
Surface-water runoff from mountains	20,000	2,900	1,900	700	330	80	860
Ground-water recharge	13,000	2,100	1,300	500	200	<10	600
Natural ground-water discharge by evapotranspiration	19,000	3,000	1,200	<10	20	30	<10
Preliminary estimate of perennial yield	16,000	2,500	1,200	200	100	25	200
Preliminary estimate of transitional storage reserve 1/	400,000	300,000	12,000	--	6,000	5,000	--
Present surface- and ground-water development	2,100	60	<10	<10	<10	<10	<10

a. Internal surface drainage.

b. Significant subsurface flow to or from adjacent valleys.

c. External surface drainage.

1. Total acre-feet.

Water-resources development of the area has been for agricultural, industrial, municipal, domestic, and mining use and has been mainly restricted to Smoke Creek and San Emidio Desert areas. Development throughout the area as a whole is currently less than 10 percent of the preliminary estimated perennial yield. Future development may depend principally upon whether the quantity and quality of available water are adequate for the intended use.

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, conservation, agricultural, and industrial uses have accompanied this growth. Anticipating these increasing water needs, the Nevada State Legislature enacted legislation (Chapter 181, Statutes 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. The legislation provided for 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 or groups of areas. This investigation is the 44th in the series.

During progression of the investigative series, the necessity for supplementary information on surface-water resources was recognized. Accordingly, the reconnaissance program was broadened in scope to include an accompanying appraisal of the surface-water resources of the areas being investigated.

The objectives of the reconnaissance investigations, including this study, are to (1) present the general geologic setting, (2) appraise the source, occurrence, movement, storage, 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 a preliminary estimate of the perennial yield.

The 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 and analysis of hydrologic data were done during the period September-December 1966.

Location and General Geographic Features

The Smoke Creek Desert-San Emidio Desert area, as used in this report, designates an area enclosed by lat 40°10' and 41°00'N., and long 119°15' and 120°15' W. (fig. 1). It is mainly in the central part of Washoe County, Nevada, but part extends eastward into Pershing County and westward several miles into Lassen County, California. The area, about 1,590 square miles, is approximately 55 miles long and 52 miles wide at its greatest extent.

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Major drainage basins are Smoke Creek Desert and San Emidio Desert, minor areas include Painters Flat, the central part (Nevada segment only) of Skedaddle Creek valley, which is a tributary of Honey Lake valley to the southwest, and three small adjacent valleys to the northwest, southwest, and southern parts of the area. For the purposes of this report, these minor valleys, heretofore unnamed, are referred to as Pilgrim Flat, Dry Valley, and Sano Valley, respectively (pl. 1).

Empire and Gerlach, small towns in the eastern part of the area; are the main centers of population. A few farms and ranches are scattered throughout the area, railroad workers intermittently live at Sand Pass, and a mining family resides in Wild Horse Canyon in the mountains east of the Smoke Creek Desert. Main access to the area is by Nevada State Highway 34, which runs north from Interstate 80 (U.S. Highway 40) to Gerlach, and Nevada State Highway 81, which enters from the north and terminates at Gerlach (fig. 2). An improved gravelled road follows the western edge of the Smoke Creek Desert and extends southward into Honey Lake Valley; it also connects with a gravelled road that trends northward part way up Smoke Creek Desert and ultimately connects with U.S. Highway 395 in northeastern California (fig. 2). Several other unimproved roads and trails traverse the area, but travel over many of these can be slow and uncertain. The Western Pacific Railroad crosses the area from northeast to southwest and passes through Gerlach, a junction point for a spurline to Empire (pl. 1).

Principal industries of the area are ranching, farming, railroad facilities at Gerlach, the United States Gypsum Co. mining and products plant at Empire, and a minor amount of other mining.

Previous Work

The first utilization of and report on water resources of the area by white men was by the Fremont expedition, which camped at the Great Boiling Springs (32/23-15b1), while passing through the area during the winter of 1844 (Fremont, 1845). A more detailed exploration and study of the natural environment was made by Lieutenant E. G. Beckwith during the summer of 1854 (Beckwith, 1854) as part of an exploration of possible railroad routes to the west coast. The geology of part of the area was studied and described by members of the Fortieth Parallel Survey (King, 1878).

The earliest detailed hydrologic information on the area was published by Russell (1885) in his famous Geologic History of Lake Lahontan. A report on a reconnaissance ground-water study of Winnemucca Lake Valley, southeast of and adjacent to the study area, was published by the U.S. Geological Survey (Zones, 1961). Recently published reports of the hydrology of adjacent areas northeast and north of the area are part of this

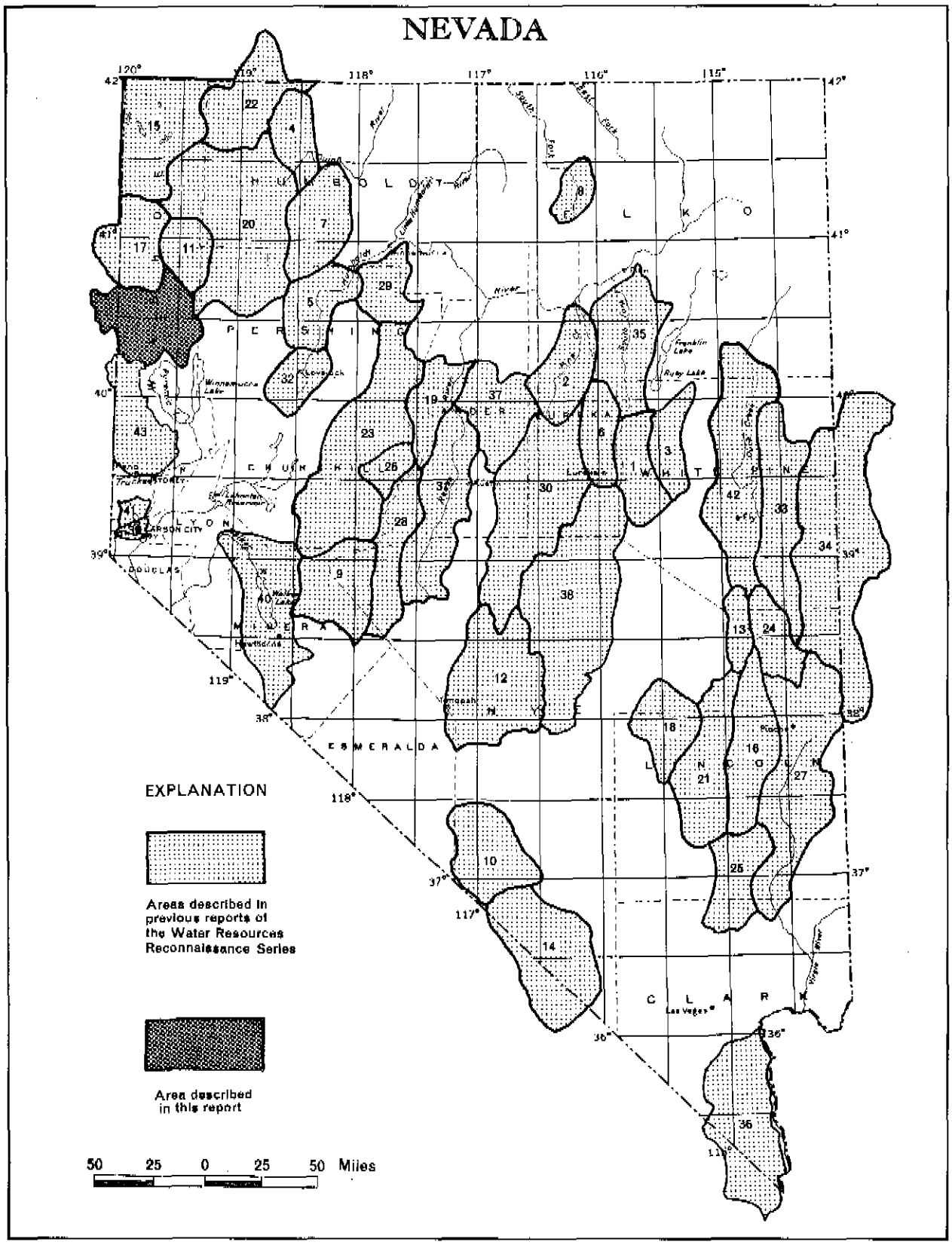
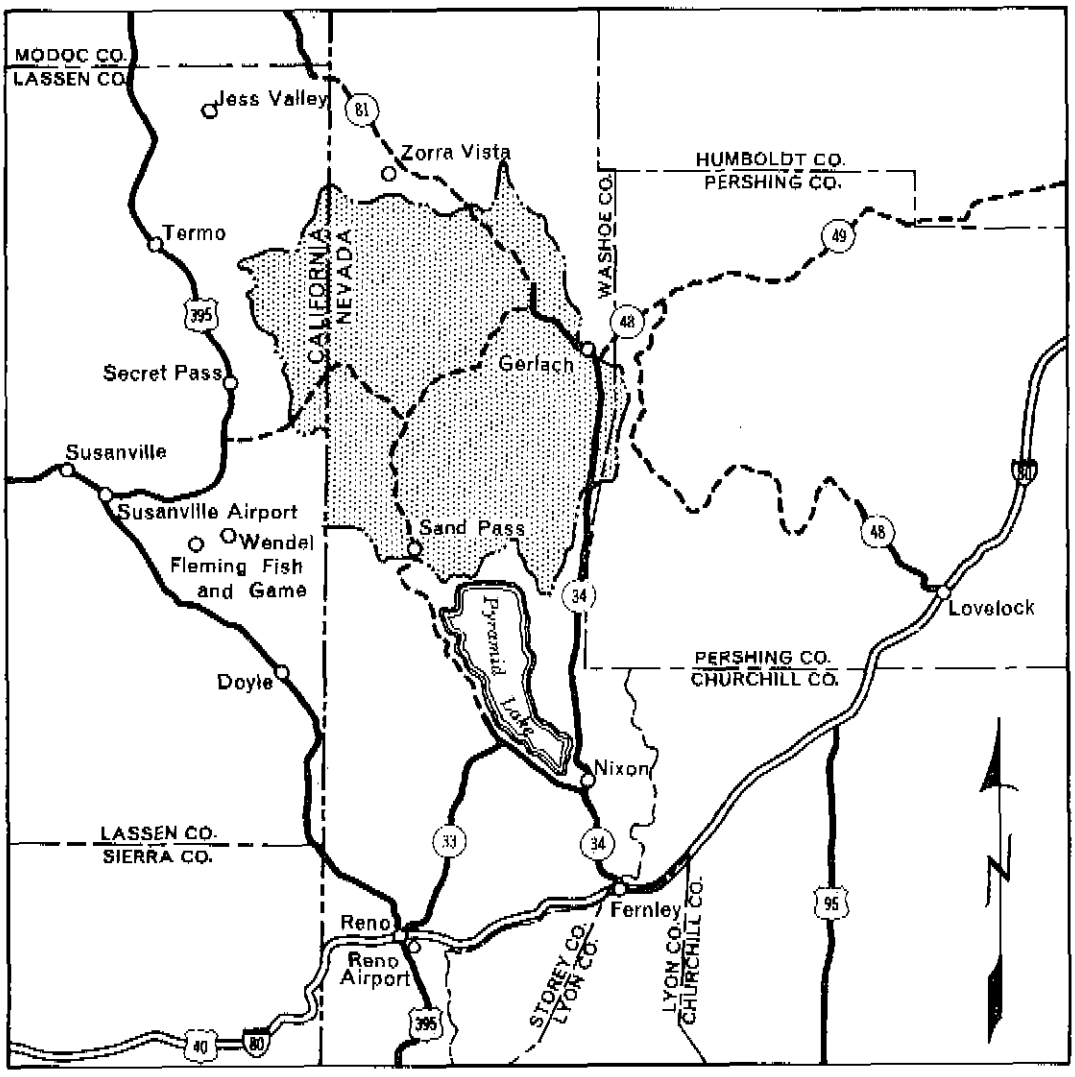


Figure 1.—Areas in Nevada described in previous reports of the Water Resources Reconnaissance Series and the area described in this report



EXPLANATION

- U.S. Interstate Highway
- U.S. Highway
- Nevada State Highway
- Unpaved gravelled road
- Report area
- Gerlach — Weather station
- Drainage divide

Scale

0 10 20 30 40 50 Miles

Figure 2.—Locations of roads and weather stations

current Water Resources - Reconnaissance Series (Sinclair, 1962 and 1963a and b). A study of the area to the southwest, a part of this same series, is currently in progress (Rush and Glancy, 1968).

Acknowledgments

The writers are grateful to the residents of the area who provided valuable information on water use and development of the area. Land owners kindly permitted access to their property. Farmers and ranchers provided useful data on their wells, springs, and irrigation practices. Mr. A. M. Meeks, plant engineering superintendent of United States Gypsum Co., provided pumpage data and information about wells at Empire. Mr. M. K. Anderson, division engineer of the Western Pacific Railroad Co., furnished information about springs supplying Gerlach. Many owners permitted sampling of their water supplies for analytical purposes and furnished data on water use.

GENERAL HYDROGEOLOGIC ENVIRONMENT

Physiography

The Smoke Creek Desert is a northeast-trending valley that merges at its northeast end with the northwest corner of the north-trending San Emidio Desert (pl. 1). The juncture of these two desert valleys is in an area where their playas also merge with the southwest end of Black Rock Desert.

The valleys are bounded mainly by consolidated rocks which form the mountain masses. However, a small part of the topographic boundary between Smoke Creek Desert and its southwesterly neighboring depression, Honey Lake Valley, consists of an alluvial divide in the neighborhood of Sand Pass. Likewise, a part of the eastern boundary of San Emidio Desert is a gently sloping alluvial divide that separates it from Winnemucca Lake Valley.

Both Smoke Creek and San Emidio Deserts are characterized by extensive playas. The playa surface of Smoke Creek Desert makes up about 20 percent of its valley area, and that of San Emidio Desert about 13 percent of its valley area. Altitude of the playa surface of Smoke Creek Desert ranges from about 3,855 feet at the south end to about 3,820 feet near the northeast end.

San Emidio Desert contains two playa areas (pl. 1). The northern one is called Granite Creek Desert on some maps or a part of Black Rock Desert on other maps. However, for discussion purposes in this report, both playas are considered part of the San Emidio Desert. Altitude of the southern playa ranges from about 4,010 to 4,040 feet and that of the northern playa ranges from about 3,900 to 3,920 feet. Surface flooding of the southern playa could reach only relatively shallow water depth before spilling to the northern playa through an interconnecting ephemeral channel. Likewise, surface flooding on the northern playa could reach only very shallow depth before spilling northwestward through an ephemeral drainage into Smoke Creek Desert.

The mountainous boundary of Smoke Creek Desert includes Granite Range at the northeast, Buffalo Hills at the north, a group of mountains belonging to an unnamed group of highlands at the west, Terraced Hills at the south, and Fox Range at the east. Highest mountain peaks in Smoke Creek Desert are Granite Peak (altitude, 9,056 feet) of Granite Range; Observation Peak, Spanish Springs Peak, and Shinn Peak (altitudes, 7,964, 7,626, and 7,562 feet, respectively) in the western highlands; and Pah Rum Peak (altitude, 7,606 feet) of Fox Range.

The mountainous boundary of San Emidio Desert includes Fox Range at the west, Lake Range at the south, and Selenite Range at the east. Highest mountain peaks of San Emidio Desert are Pah Rum Peak of Fox Range, Tohakum Peak (altitude, 8,075 feet)

of Lake Range, and an unnamed peak (altitude 7,424) and Selenite Peak (altitude 7,115) of Selenite Range.

Dry and Sano Valleys, relatively small topographic depressions southwest and southeast of Smoke Creek Desert, respectively, are generally bordered by consolidated-rock mountains. However, small segments of their boundaries consist of alluvium of unknown thickness. These segments occur at the northeast and south ends of Dry Valley along the borders of Smoke Creek Desert and Honey Lake Valley, respectively, and in Sano Valley along the northern and southwestern edges where it borders Smoke Creek Desert and at its southeast edge where it borders Pyramid Lake Valley. Although these segments are laterally restricted and their alluvial surfaces maintain topographic closure of the valleys, the alluvium, if sufficiently thick, may permit subsurface leakage of water from the valleys. Playas in these valleys are somewhat higher than that of Smoke Creek Desert; Dry Valley playa has an altitude of 4,200 feet and the two small playas of Sano Valley have altitudes of about 4,000 feet.

Painters and Pilgrim Flats are topographically closed depressions in the northwestern part of the study area. Their basin boundaries are composed of consolidated rocks, except for a very narrow band of alluvium at the northwest edge of Painters Flat, which is probably quite thin and would not be capable of transmitting appreciable quantities of ground water out of the area. The playas of Painters and Pilgrim Flats have altitudes of about 5,630 and 6,200 feet, respectively.

Skedaddle Creek valley is both topographically and hydrologically open to Honey Lake Valley. Within Nevada the creekbed decreases in altitude from about 5,030 to 4,570 feet. The highest topographic features in the highlands bounding Dry Valley, Sano Valley, Painters Flat, Pilgrim Flat, and Skedaddle Creek valley are less than 7,000 feet in altitude.

Geologic Units

A simplified geologic map of the area is shown on plate 1. The geology was prepared by interpretation of aerial photographs, from the Geologic Map of California (Lydon and others, 1960), and by field observations and mapping during the study period. For the purposes of this reconnaissance only three units were identified: consolidated rocks, younger, and older alluvium.

Consolidated Rocks

The mountains and uplands surrounding the valleys are chiefly composed of consolidated rocks. These rocks also underlie the younger and older alluvium of the valleys. The consolidated rocks are mainly igneous, with a lesser areal distribution of sedimentary and metamorphic rocks.

The Selenite Range contains representatives of all three major groups, and the igneous rocks occur as both fine-grained volcanic rocks and coarser grained intrusive granitic rocks. Uplands around the southeastern part of San Emidio Desert are mainly volcanic rocks consisting of lava flows, breccia, and tuff. These same general volcanic types are well represented in the Lake Range and in the Fox Range, and form the divide between Smoke Creek and San Emidio Deserts. Gneiss, schist, and slate are the principal metamorphic rocks in the Lake and Fox Ranges.

The Granite Range northwest of Gerlach consists mainly of granitic intrusive rock and some fine-grained extrusive volcanic rock. The rocks in the mountains and uplands around the western and southern parts of Smoke Creek Desert and surrounding the remainder of the smaller valleys are composed mainly of tuff, breccia, and lava flows generally of basaltic composition.

Faults generally separate the consolidated-rock masses of the mountains and those underlying the alluvium of the valleys. Some of these faults are shown on plate 1. The upland rock masses are also faulted and structurally deformed, particularly in the Selenite, Lake, and Fox Ranges where rocks of various ages, probably Paleozoic to Pleistocene, are represented. Some formations in these ranges were probably subjected to several generations of structural deformation. The volcanic rocks of the western part of the study area are also faulted and deformed, but the younger emplacement age, Tertiary to Pleistocene, reduces the number of episodes of regional structural deformation to which the rocks have been subjected in comparison to the older rocks.

The consolidated rocks have been eroded to form pediment surfaces along the edges of most of the mountain fronts in the study area. The pediments generally are mantled with a relatively thin layer of alluvial material near the mountain front. Where pediments are covered by an alluvial blanket too thin to form an important aquifer, they are included with consolidated rocks on the geologic map (pl. 1).

Little direct information is available concerning the water-bearing properties of the consolidated rocks in this area. However, small springs and seeps issue from the consolidated rocks, mainly the volcanic rocks, which indicates that some water is stored and transmitted by them. Only one known well in the area (32/20-32b1) is believed to have intercepted or penetrated the consolidated rocks, and then only to a depth of 4 feet, which is not deep enough to test their water-yielding capability.

The metamorphic and intrusive igneous rocks may yield small to moderate amounts of water from fracture zones, but water requirements of the area have not yet been demanding enough to warrant investigation of this source of supply. The extensive areas of volcanic rocks in the western and northwestern part of

the area might contain moderate to large quantities of ground water stored in fracture zones and in porous zones between lava flows. The water-yielding character of the reservoir is untested, and therefore the presence or absence of economical water supplies within its confines is not known.

Alluvium

Alluvium in the report area consists of rock debris derived from the consolidated rock-mountain masses. It was transported downgradient by the action of water, gravity, and wind, and deposited either subaerially or beneath the water surfaces of ancient lakes. Individual rock fragments or mineral grain constituents composing the deposits have individual erosional, transportational, and depositional histories; most of the particles have undergone several cycles of transport and deposition. The lithologic composition of the fragmental constituents generally reflects the composition of the bedrock (consolidated rocks) from which they were originally derived with due regard to any later changes that may have occurred as a result of chemical weathering.

The alluvium is the chief known ground-water reservoir in the area. Its water storage and transmissive characteristics are related to the erosion, transport, and deposition of its individual constituents and to the post-depositional history of the deposits. Its water-bearing character may be further altered by post-depositional structural deformation. Therefore, water-bearing characteristics may vary considerably within individual deposits as well as between different deposits.

Thickness of the alluvium ranges from a mantle commonly less than a foot thick over much of the consolidated rock uplands to more than a thousand feet in the valley troughs. Only one well in the study area (32/20-32b1), near the mouth of Buffalo Creek, apparently completely penetrates the alluvium. However, the thickness of alluvium at this particular site is 182 feet (table 18), and the relative position of the site near the valley edge suggests a much greater alluvial thickness near the valley axis. Wells at the United States Gypsum Co. plant in Empire, along the northeastern part of San Emidio Desert, penetrate deepest in the alluvium of any wells in the area: well 31/23-11d1 bottomed at 854 feet without penetrating consolidated rocks and well 31/23-14a1 extends through alluvium to a depth of 449 feet before penetrating a 44-foot interval of hard lava. Beneath the lava unit 57 feet of gravel, sand, and clay were penetrated; these lower deposits represent a continuation of the alluvial fill of unknown thickness deposited before extrusion of the lava. The Trego well, drilled in the Black Rock Desert playa (34/25-8) about 17 miles northeast of Gerlach, penetrated 1,500 feet of alluvium without encountering bedrock (Sinclair, 1963b, p. 6). Although alluvial thickness near the valley-trough axis of Smoke Creek Desert is unknown, geologic and physiographic characteristics

suggest thicknesses generally comparable in magnitude to those of Black Rock Desert.

Alluvium in the report area was separated into two general types--older and younger alluvium--as shown on plate 1. Separation was based on inferred history of deposition and on hydrologic characteristics.

Older alluvium.--Older alluvium ranges from late Tertiary to Quaternary in age. Where exposed, the deposits consist primarily of semiconsolidated to unconsolidated alluvium at an altitude above the maximum level attained by ancient Lake Lahontan (about 4,380 feet); however, it includes lake deposits of late Tertiary age in the general area of the confluence of Rush Creek and Smoke Creek drainages (Lydon and others, 1960).

Although the older alluvium surficially covers a much smaller area than the younger alluvium, it underlies the younger alluvium in most of the area, and its total volume is, therefore, large. Much of the older alluvium is covered by rather thin deposits of younger alluvium. Around the southern and eastern periphery of San Emidio Desert the older alluvium is partly covered by very fine-grained eolian deposits of high porosity and low permeability.

No wells have been drilled in areas where the older alluvium is exposed. However, because the younger alluvium probably is less than 100 feet thick in most places, most wells drilled in areas of younger alluvium and more than 100 to 200 feet deep probably derive the bulk of their water from the older alluvium.

Younger alluvium.--Younger alluvium probably ranges in age from late Pleistocene to Recent. It consists mainly of upland stream-channel deposits, fan deposits adjacent to the mountain fronts, and lacustrine deposits of the valley floors; it also includes surficial eolian deposits, largely dune deposits, which are thin and laterally discontinuous. As shown on plate 1, the younger alluvium is areally most extensive on the floors of larger valleys below the maximum stage attained by Lake Lahontan (altitude about 4,380 feet).

The younger alluvium is unconsolidated, and its water-bearing character is highly variable, depending on its depositional history. Its thickness is also variable, ranging from a few feet to possibly more than a hundred feet locally; the subsurface contact between older alluvium and younger alluvium, whether sharply defined or more probably transitional, has not been determined.

Exposures of younger alluvium in the upland stream valleys are generally elongate and alined with the general basinward trend of the stream channels. Because of the small map scale and narrowness of most of the upland channel deposits, they are not

shown on plate 1. They are generally thin compared to those of larger areal extent that occupy the valley troughs. Patricle size of the rock and mineral constituents composing these deposits ranges from boulder to clay. Permeability of the stream-channel deposits probably is moderate. Where they are sufficient in volume and contain adequate amounts of stored water, they would probably yield water readily to properly constructed wells.

The fans and aprons are underlain by detritus deposited in both subaerial and subaqueous environments, depending on the existence and extent of Lake Lahontan at time of deposition. These deposits are texturally similar to the upland stream-channel deposits but are differently shaped and generally are much thicker. Fan and apron surfaces are characterized by basinward slopes that are gentle where compared to the generally steeper slopes on most of the upland consolidated rock masses. Water-level data show the water-table surface to have a similarly oriented basinward slope even more subdued than the land surface, with the result that the water-level surface within the deposits is deepest near the boundary of the mountain fronts and is progressively shallower toward the valley axis.

Permeability of the alluvial-fan deposits is generally good except where the deposits contain interstratified beds of fine-grained; poorly permeable silt and clay deposited during the subaqueous depositional phases.

Lacustrine deposits consist of fine-grained material that settled in the generally quiet waters of the lake, and fine- to coarse - grained near-shore deposits. The near-shore deposits are of mixed grain size and range widely in particle size and degree of sorting, depending mainly on the interaction of fluvial depositional currents, general lake circulatory currents, and wave action. The near-shore deposits exhibit a wide range in waterbearing characteristics. Some deposits consist of well-sorted sand and gravel and are moderately permeable; others contain substantial quantities of silt and clay having low permeability. The latter are extensive because they were laid down in large areas covered by lakes. This fine-grained younger alluvium, commonly called playa deposits, accumulated to thicknesses of 25 to more than 100 feet in the axial parts of the larger valleys. The fine-grained deposits are nearly flat-lying, generally areally extensive, and underlie the playas shown on plate 1. Their low topographic position in the drainage basins makes them recipients of runoff not absorbed by the alluvial-fan deposits. Their flat surfaces cause the runoff to pond thinly over extensive areas. Because the playa deposits are poorly permeable, most of the water is lost by evaporation.

The playas and their peripheral areas are mantled locally by relatively thin eolian deposits. This material is moderately permeable where the individual grains are mostly sand-sized.

Climate

The Sierra Nevada of California exerts a major influence on the climate of the report area. Warm, moist air masses moving eastward lose much of their moisture over the Sierra Nevada; therefore, the air masses moving eastward across northwestern Nevada are generally deficient in moisture. Many of the winter storms move into the area from the northwest. Precipitation that does occur in the area falls mainly at the higher altitudes because of orographic influence. Therefore, valley floors, particularly the playas of Smoke Creek and San Emidio Deserts, are arid. The sun shines during most days of the year.

Precipitation has been recorded at Gerlach and Sand Pass in the report area. These stations and several other selected stations in adjacent areas are shown in figure 2. Annual precipitation at these stations ranges from about 5½ to 18½ inches for the periods of record. Further discussion of precipitation is included in the hydrology section of this report.

Temperature data also have been recorded at Gerlach and Sand Pass. Maximum temperatures recorded in the area since 1931 were 107°F on July 27, 1934 and August 9, 1942 at Gerlach, and on July 19, 1931, August 13, 1933, and July 28, 1934 at Sand Pass. Minimum temperatures recorded during the same period were -29°F on January 21, 1937 at Gerlach, and -22°F on the same date at Sand Pass. Diurnal temperature fluctuations of as much as 50°F are common in the area. Fleming Fish and Game, Fernley, and Reno Airport are several selected stations in adjacent areas for which temperature data are also available.

Since 1948 the Weather Bureau has been publishing freeze data; the information for the five stations mentioned above is given in table 2. Because killing frosts vary with the type of crop, temperatures of 32°F, 28°F, and 24°F are used to determine the number of days between the last spring minimum (prior to July 1) and the first fall minimum (after July 1). Both temperature recording stations in the study area, Gerlach and Sand Pass, are on or near the valley floor where most agricultural development is either located or might possibly take place. Therefore, the freeze data should furnish a reasonable guide for determining the expected growing season in the future development of agriculture.

No known evaporation data have been collected in the study area. However, according to the U.S. Weather Bureau (Kohler, Nordenson, and Baker, 1959) potential average annual lake evaporation from free-water surfaces in the lowlands of the area was about 4 feet for the period 1946-55. The potential average annual rate of evaporation from free-water surfaces, therefore, may be seven to nine times the average annual precipitation.

Table 2.-- Length of growing season between killing frosts that occur at 32°, 28°, and 24°F

(Summarized from published records of the U.S. Weather Bureau)

Station[1/]	Period of record (years)	Minimum recorded (days)			Maximum recorded (days)			Average (days)		
		32°F	28°F	24°F	32°F	28°F	24°F	32°F	28°F	24°F
Fernley	1950-52, 1955-65	112	125	144	181	191	222	141	161	187
Fleming Fish and Game	1961-65	99	117	158	119	183	201	109	136	181
Gerlach	1948-56, 1963-65	115	146	187	181	225	228	146	179	204
Reno Airport	1948-65	57	107	121	150	167	204	106	140	166
Sand Pass	1920-25, 1927-31, 1934-41, 1948-62	98	124	124	176	225	274	137	169	198

1. See table 3 for station location.

In summary, the area can be characterized as having an arid climate with low relative humidity and an abundance of sunshine. Summers are typified by a relatively short growing season for this part of Nevada and large diurnal temperature fluctuations (hot days and cool nights). Precipitation occurs as summer thundershowers and winter rains and snowfall. Periods of low temperature are common during winter months.

HYDROLOGY

Precipitation

Summaries of average annual precipitation for Gerlach and Sand Pass in the report area and 14 other selected stations in adjacent areas are shown in table 3. Although most of the selected stations are a considerable distance from the study area, their average annual precipitation gives a general idea of precipitation trends in the region.

Hardman (1965) showed that the precipitation distribution pattern in Nevada is related principally to the topography. That relationship generally applies to the report area as shown by the data in table 3 where the eight stations at higher altitudes generally receive more precipitation than the eight stations at lower altitudes. However, the data in table 3 more prominantly indicate a decrease in average precipitation from west to east. This decrease in precipitation eastward apparently is in response to the orographic effect of the Sierra Nevada, which exerts a dominant influence on the climate of the region.

Precipitation amounts in the report area are believed to generally agree with Hardman's (1965) values and range from more than 20 inches annually in the Granite Range northwest of Gerlach to less than 5 inches on the valley floors of the Smoke Creek and San Emidio Deserts. For the purpose of estimating the total average annual precipitation in the report area, the range of average annual precipitation is distributed with respect to altitude as follows: less than 5 inches below 4,000 feet, 5 to 8 inches between 4,000 and 5,000 feet, 8 to 12 inches between 5,000 and 6,000 feet, 12 to 15 inches between 6,000 and 7,000 feet, and 15 to 20 inches between 7,000 and 8,000 feet.

The average monthly and seasonal precipitation during the year varies greatly. Maximum and minimum monthly averages range from 0.13 inch to 0.76 inch at Gerlach and 0.11 inch to 0.97 inch at Sand Pass. Data for the two stations in the area and from four stations in adjacent areas are shown in table 4. The data verify well-known regional precipitation trends; that is, the summers are dry, the winters are relatively wet, and the spring and fall are transitional periods. Precipitation during the 6-month period December through May at Gerlach and Sand Pass averages 65 percent and 67 percent of the mean annual precipitation, respectively.

Table 3.--Summary of measured annual precipitation

(Summarized from published records of the U.S. Weather Bureau)

Station	Location (See fig. 2)	Altitude (feet)	Period of record (years)	Average annual precipitation (inches)	Remarks
Doyle	24 mi. SW of Sand Pass	4,300	1948-55	10.10	
Fernley	41 mi. SSE of Tohakum Peak	4,150	1950-52, 1955-65	4.96	
Fleming Fish and Game	23 mi. SSE of Shinn Mountain	4,000	1961-65	8.55	
Gerlach	Sec. 15, T. 32 N., R. 23 E.	3,980	1912-57, 1962-65	5.62	In study area
Jess Valley	32 mi. NNW of Painters Flat	5,290	1931-65	17.44	
Lovelock	45 mi. ESE of Selenite Range	3,977	1891-1906, 1908-14, 1916-35, 1937-65	4.84	
Nixon	25 mi. S of Tohakum Peak	3,900	1928-52, 1962-65	7.16	
Reno	50 mi. S of Sand Pass	4,432	1870-1942	7.19	
Reno Airport	53 mi. S of Sand Pass	4,404	1937-65	7.23	
Sand Pass	Sec. 30, T. 28 N., R. 20 E.	3,900	1920-25, 1927-31, 1934-41, 1948-62	6.43	In study area
Secret Valley	4 mi. SW of Shinn Mountain	4,662	1960-65	9.17	
Susanville	29 mi. SW of Shinn Mountain	4,271	1889-1918, 1927-43, 1953-63	18.52	
Susanville Airport	do.	4,152	1944-65	13.28	
Termo	20 mi. WNW of Painters Flat	5,380	1948-52, 1962-65	11.82	
Wendel	15 mi. W of Sand Pass	4,035	1959, 1962-65	6.83	
Zorra Vista	T. 36 N., R. 19 E. About 6 mi. N. of study area	4,725	1915-34	5.75	

Table 4.--Average monthly and annual precipitation, in inches, at selected stations

(From published records of the U.S. Weather Bureau)

Station[1/]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Gerlach	0.73	0.64	0.46	0.43	0.64	0.46	0.13	0.16	0.23	0.47	0.51	0.76	5.62
Jess Valley	1.87	1.86	1.81	1.72	2.10	1.70	.38	.32	.63	1.40	1.65	2.00	17.44
Reno	1.46	1.13	.73	.47	.51	.31	.21	.22	.23	.36	.58	.98	7.19
Reno Airport	1.17	.95	.73	.47	.67	.38	.30	.19	.26	.47	.64	1.00	7.23
Sand Pass	.94	.86	.58	.43	.53	.46	.19	.11	.32	.50	.54	.97	6.43
Termo	1.43	.60	.98	.89	1.23	1.40	.19	.35	.51	1.47	1.21	1.56	11.82

1. See table 3 for station locations and period of record.

Surface Water

General Conditions

Surface water in the Smoke Creek-San Emidio Desert area is generated principally by the combined effect of high-intensity precipitation falling on the mountain blocks during melting periods when snowpacks are in the mountains and locally where the ground-water table is intercepted by stream channels. Most of the surface water infiltrates or is removed from the system by evapotranspiration as it moves downstream. During periods of high-intensity rainfall or during snowmelt periods, part of the runoff reaches the playa where most is lost by evaporation. The small quantities of runoff and the large losses that occur preclude the existence of more than a few perennial stream reaches in the report area. Irregularity in the quantity and duration of precipitation also limits the number of perennial streams.

Major streams that are alternately intermittent and perennial throughout significant reaches of their channels are upper Squaw Creek and Smoke Creek on the north and west side of Smoke Creek Desert, respectively, and the upper reaches of Wildhorse Canyon Creek along the east side of Smoke Creek Desert. Smoke Creek is the only major stream in the area that continually discharges water near its juncture with the playa, and it is often dry in its middle reaches while flowing in the headwater and lower reaches. Squaw Creek is probably a perennial stream above its reservoir, and the regulated flow below the dam is supplemented by the perennial flow in Clear Creek. However, Squaw Creek flows only intermittently near its juncture with the playa. Wildhorse Canyon Creek is springfed and generally perennial throughout most of its mountainous reach, but is ephemeral downvalley from the consolidated rock-alluvium contact. All other streams probably are ephemeral.

Occasional flow occurs locally on the alluvial fans and lowlands in response to heavy precipitation from thunderstorms. This type of streamflow is so erratic in frequency and duration that it has little value for development purposes other than impoundment in small stock and irrigation reservoirs for limited agricultural use. However, its value as a recharge mechanism for the ground-water system may be quite significant.

Runoff

By D. O. Moore

Available records.--Streamflow has not been recorded by gaging stations in the Smoke Creek-San Emidio Desert area. For the purpose of this study miscellaneous streamflow measurements were made on the perennial streams and the mean annual discharge estimated for several ephemeral channels. Results of the miscellaneous measurements and estimates of streamflow from ground-water sources, October 13-15, 1966, are shown in table 5.

Runoff characteristics.--Surface-water runoff in the report area is variable with respect to the time of the year and the particular year during a given time period. As there is no record of gaged streamflow in the area, available records of nearby areas are used to show the variability of streamflow. Peavine Creek, an ephemeral stream near Reno, Nevada, southwest of the Smoke Creek-San Emidio Desert area, is assumed to have about the same flow characteristics as the ephemeral streams in the report area. Streamflow in the perennial streams of the report area is assumed to have about the same flow characteristics as the perennially flowing Leonard Creek near Denio, Nevada. Table 6 shows the monthly mean discharge and number of days of flow for Peavine Creek near Reno during the period January 1963-December 1965. It also shows the amount of flow and the length of time the flow varies from year to year. During the 3 years of record, flow occurred exclusively during the winter; however, flow can also result from summer thunderstorms.

The graph in figure 3 shows the annual streamflow pattern for Leonard Creek, based on streamflow records for water years 1961-65. The monthly plot points are shown as a percentage of the average annual streamflow. The middle line of the graph represents the median distribution of the monthly mean discharge for each month; that is, for each month, 50 percent of the monthly flows of record were less than and 50 percent were more than the proportional amount shown by the median line. The upper line of the graph, the upper quartile, is a plot of the proportional monthly flow for which only 25 percent of the monthly flows of record were higher than and 75 percent were less than the proportions indicated. The lower line of the graph, the lower quartile, is a plot of the monthly proportion of annual flow for which 75 percent of the monthly flows of record were greater than and 25 percent were less than the proportion indicated. Figure 3 shows that the annual hydrograph of flow for Leonard Creek reflects a dominant influence by snowmelt runoff. This influence probably is dominant for streams of the Smoke Creek - San Emidio Desert area.

Table 5.-- Measurements and estimates of streamflow from ground-water sources, October 13-15, 1966

Map no.1/		Location			Discharge
		Section	Township	Range	(cfs)
1.	Rodeo Creek	35	30 N.	22 E.	0
2.	Rattlesnake Canyon	11	29 N.	22 E.	0
3.	San Emidio Creek	36	29 N.	22 E.	0
4.	Crutchers Canyon Creek	1	34 N.	21 E.	0
5.	Crutchers Canyon Creek	18	34 N.	22 E.	0.66
6.	Jones Canyon Creek	18	34 N.	22 E.	0.41
7.	Clear Creek	33	34 N.	22 E.	0.29
8.	Squaw Creek	21	33 N.	22 E.	0
9.	Little Sawmill Canyon Creek	3	32 N.	21 E.	0
10.	West Fork Buffalo Creek	10	33 N.	19 E.	0.20
11.	East Fork Buffalo Creek	10	33 N.	19 E.	0
12.	Parsnip Wash	15	33 N.	19 E.	0
13.	Trail Canyon Creek	22	33 N.	19 E.	0
14.	Crooked Canyon Creek	36	33 N.	19 E.	0
15.	Buffalo Creek	33	32 N.	20 E.	0
16.	Unnamed Spring	2	32 N.	16 E.	a 0.7
17.	Sage Hen Spring	36	33 N.	16 E.	a 0.2
18.	Unnamed Spring	25	33 N.	16 E.	a 1.4
19.	Smoke Creek	25	33 N.	16 E.	a 1.2
20.	Smoke Creek	13	32 N.	17 E.	2.81
21.	Rush Creek	16	31 N.	18 E.	0.46
22.	Smoke Creek	10	30 N.	19 E.	0.50
23.	Wild Horse Canyon Creek	34	30 N.	21 E.	a 0.1
24.	Painters Creek	24	34 N.	17 E.	a <1
25.	Skedaddle Creek	1	29 N.	17 E.	0
26.	Skedaddle Creek	23	28 N.	17 E.	0

1. Site and number shown in plate 1.
a. Estimated.

Table 6.--Monthly mean discharge and number of days of flow for Peavine Creek near Reno, Nevada for period January 1963 to December 1965

Date	1963 Discharge (acre-ft)	1963 No. days of flow	1964 Discharge (acre-ft)	1964 No. days of flow	1965 Discharge (acre-ft)	1965 No. days of flow
January	14	1	0	0	55	31
February	59	11	0	0	10	22
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	46	10	0	0
Total	73	12	46	10	65	53

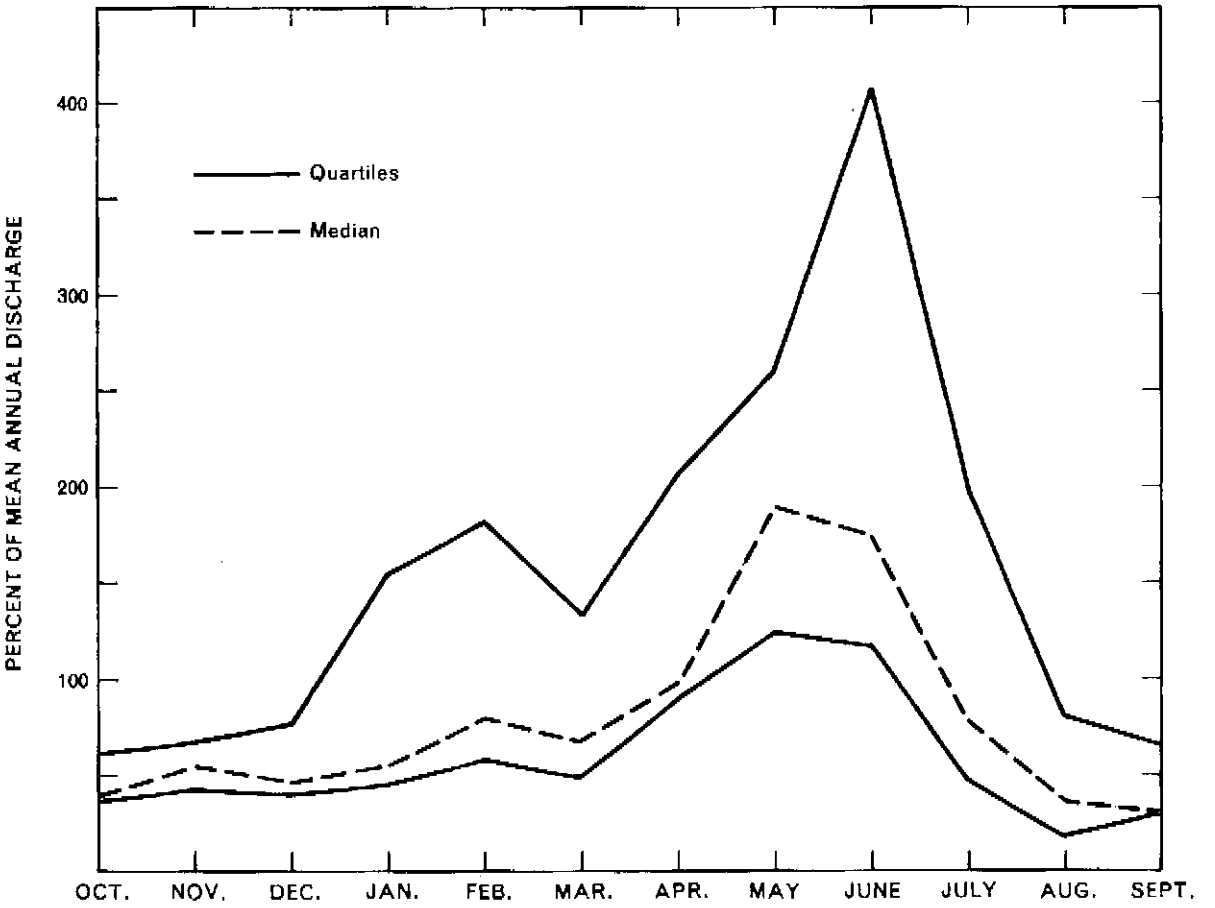


Figure 3.—Monthly discharge in percent of mean annual discharge of Leonard Creek near Denio, Nevada for water years 1961-65.

During periods of high-intensity runoff, such as those occurring as a result of localized summer thundershowers or heavy snowmelt, surface flow causes partial flooding of the playas. The magnitude and frequency of playa flooding is unknown, because flood-frequency data are meager for the area. However, reports of local residents suggest that runoff reaches the playas rather frequently; about every 2 or 3 years, on the average, standing water can be observed on some parts of the playas.

Estimated average annual runoff.--The amount of runoff that reaches the alluvial fans from the mountain blocks cannot be computed directly because of scarcity of available streamflow data. A method has been devised by Riggs and Moore (1965) for estimating runoff in areas where few or no streamflow data are available. Moore refined this method for use in estimating runoff in Nevada (report in preparation) and has determined six general relations of runoff to elevation that can be used to estimate runoff throughout the State of Nevada. The six relations derived are applicable to large areas in the State. As different influential physical characteristics, such as vegetation, precipitation quantity, geology, land slope, and types of soil mantle vary within the large general areas, the runoff-elevation relations generally require adjustment when applied to local areas. Adjustments were made to the relation used in the report area employing miscellaneous discharge measurements and channel-geometry characteristics (method being developed by Walter Langbein, U.S. Geological Survey).

The estimated average runoff in the Smoke Creek-San Emidio Desert area, summarized in table 7, is about 26,000 acre-feet per year. The runoff is not evenly distributed throughout the area. About 80 percent of the runoff occurs in the northern half of the area and about 20 percent in the southern half.

Development

Surface-water development in the area has centered almost exclusively around agriculture in Smoke Creek Desert. Table 8 shows the type of use and estimated amount of surface water used, which totals only 1,600 acre-feet per year. Smoke Creek and Squaw Creek Reservoirs impound runoff that is utilized for downstream irrigation of native-grass pastures during the growing season. Several smaller stockwater reservoirs and small earthen dams are scattered around the area. Impounded runoff from some of the smaller reservoirs also is used for irrigation of native pasture but most furnish water for livestock. These small reservoirs generally dry up during the summer months. Several are able to impound water only after occasional periods of heavy runoff, and they are often dry for periods of months or years before being refilled.

Table 7.--Estimated average annual runoff

Upland runoff segment	Approximate runoff area (acres)	Estimated runoff (acre-feet per year)
SMOKE CREEK DESERT		
Fox Range and Terraced Hills above 5,000 feet	24,600	1,600
Area south of Smoke Creek above 5,000 feet	62,800	3,200
Buffalo Hills northeast of Smoke Creek and southwest of Buffalo Creek above 5,000 feet	109,400	6,000
Buffalo Hills northeast of Buffalo Creek and southwest of Squaw Creek above 5,000 feet	105,900	5,800
West flank Granite Range above 5,000 feet	21,700	3,000
Total (rounded)	324,000	20,000
SAN EMIDIO DESERT		
West flank Selenite and Lake Ranges above 5,000 feet	27,400	1,500
East flank Fox Range above 5,000 feet	26,700	1,400
Total (rounded)	54,000	2,900
PAINTERS FLAT		
Entire valley	20,000	1,900
PILGRIM FLAT		
Entire valley	6,400	700
DRY VALLEY		
Entire valley above 5,000 feet	7,300	330
SANO VALLEY		
Entire valley above 5,000 feet	160	80
CENTRAL SKEDADDLE CREEK VALLEY		
Entire valley above 5,000 feet	22,000	860

Table 8.--Surface-water development and estimated average annual consumption in Smoke Creek Desert

Name	Approximate location	Type development	Use	Estimated average use rate (feet per year)	Approximate area (acres)	Crop or type of water loss	Estimated average annual consumption (acre-feet per year)
Dewey Parker Home Ranch	T. 31 N., R. 20 E.	Diversion from Buffalo Creek	Irrigation	1.0	150	Native grass	150
Dewey Parker Reservoir	T. 31 N., R. 20 E.	Small earthfill dam and reservoir on Buffalo Creek	do.	ab 4.0	10	(b)	10
Smoke Creek Reservoir	T. 32 N., R. 17 E.	Earthfill dam and reservoir on Smoke Creek	do.	b 4.0	60	(b)	240
John Casey-Smoke Creek Ranch	T. 32 N., R. 18 E.	Diversion from Smoke Creek Reservoir	do.	1.0	880	Native grass	880
John Casey-Clear Creek Ranch	T. 34 N., R. 22 E.	Diversion from Clear Creek and Squaw Creek	do.	c 3.0	40 30	Alfalfa Native grass	120 30
Squaw Creek Reservoir	T. 34 N., R. 22 E.	Earthfill dam on Squaw Creek	do.	b 4.0	20	(b)	80
Clyde Fiske Ranch	T. 34 N., R. 22 E.	Diversion from Squaw Creek Reservoir	do.	1.0	60	Native grass	60
Total (rounded)							1,600

a. Reportedly contains water for only about 3 months each year.

b. Evaporation loss from reservoir.

c. Alfalfa use estimated at 1 acre-foot per acre per cutting per year; irrigated alfalfa reportedly yields two to three cuttings per year.

Ground Water

Occurrence and Movement

The principal ground-water reservoirs in the Smoke Creek-San Emidio Desert area occur in the younger and older alluvium. However, as mentioned earlier in this report, no known wells have penetrated the consolidated rocks deeply enough to test their water-yielding capability. Some springs issuing from consolidated rocks discharge significant quantities of water and make them locally useful in the development of ground water. As an example, springs 33/22-13a1 and 34/22-35d1 along the west side of the Granite Range provide the water supply for Gerlach.

Ground water occurs in the alluvial valley-fill reservoirs under both confined (artesian) and unconfined (water-table) conditions. Artesian conditions occur extensively in the valley areas, and springs are common; also, flowing wells occur in Smoke Creek Desert. No flowing wells are known in San Emidio Desert or the other minor valleys in the area.

Water levels in the alluvium range from a few feet above to 215 feet below land surface in the Smoke Creek and San Emidio Deserts. Wells having the greatest depths to water are generally nearer the upslope margins of the alluvial fans. Decreasing depths to water generally occur in the downslope direction toward the valley axes.

In the alluvium, ground-water flow occurs through the intergranular pore spaces. In consolidated rocks, ground-water flow occurs through fractures, joints, and solution channels. In lava, movement may also occur in porous zones between flows, through lava tubes, or through interconnected primary pore spaces formed by gas bubbles trapped in the lava at the time of extrusion; permeability of the lava is further improved by secondary fracturing.

Scarcity of wells limits detailed knowledge of ground-water movement in the report area. Available water-level data indicate that gross movement is generally in the direction of surface-water flow; that is, from mountainous areas, where the greatest precipitation occurs and recharge is initiated, toward the valley axes. There most of the water discharges naturally, or is pumped, and returns to the atmosphere by evapotranspiration. A small amount of ground water may move to an adjacent valley, or it may be discharged to streams by springs and seepage along the banks where it is lost by evapotranspiration.

Underflow Between Valleys

This reconnaissance suggests that ground-water underflow, or subsurface flow, occurs from San Emidio Desert to Smoke Creek Desert, from San Emidio Desert to Black Rock Desert, and from Dry Valley probably to Smoke Creek Desert. Lack of data and control complicates determination of the direction of underflow from Pilgrim Flat; however, for purposes of this reconnaissance it is assumed to be westward into California. Significant subsurface flow probably does not occur from Sano Valley and Painters Flat. Underflow is computed by the following equation:

$$Q = 0.00112\ TIW$$

in which Q is the quantity of flow, in acre-feet per year; T is the coefficient of transmissibility, in gallons per day per foot; I is the hydraulic gradient, in feet per mile; W is the width of the underflow section, in miles; and 0.00112 is a factor for converting gallons per day to acre-feet per year. Table 9 shows the estimated underflow for the above-named valleys.

Recharge

Ground-water recharge in the Smoke Creek-San Emidio Desert area is mainly derived from precipitation within the area. A method for making a preliminary estimate of recharge was described by Eakin (1951); it is based on the assumption that a percentage of the average annual precipitation ultimately reaches the ground-water reservoir. The method is used for estimating recharge in this report. A precipitation map of Nevada prepared by Hardman (1965) shows that average annual precipitation is closely related to altitude. Therefore, recharge for the area was determined using several altitude zones, their estimated average annual precipitation, based on Hardman's map, and Eakin's estimate of the percentage of average annual precipitation in each altitude zone that ultimately recharges the ground-water reservoir. Estimates of recharge are shown in table 10.

The estimated average annual precipitation on the areas is about 620,000 acre-feet, and the estimated average recharge is about 18,000 acre-feet. Thus, only about 3 percent of the total precipitation recharges the ground-water reservoir. The most obvious recharge mechanism is surface-water runoff percolating into the unconsolidated alluvium in stream valleys and alluvial fans.

Climatic events favoring runoff, such as rapidly melting snowpack and intense rainfall, are necessary to provide a substantial supply of virgin runoff to recharge the system. Although these climatic events are erratic in nature, statistically they are probably reasonably well related to average annual precipitation over the area; or stated slightly differently, the long-term average hopefully represents the large assemblage of extremes.

Table 9.--Estimated underflow between valleys

Underflow section	Assumed transmissibility (gpd/ft)	Hydraulic gradient (ft/mi)	Effective width (mi.)	Estimated underflow (ac-ft/year)
San Emidio Desert to Smoke Creek Desert (near Gerlach)	25,000	a 8	1	200
San Emidio Desert to Black Rock Desert (near Gerlach)	25,000	a<1	3	<100
Dry Valley to Smoke Creek Desert (probable)	(b)	(b)	(b)	c 180
Pilgrim Flat to California (assumed)	(b)	(b)	(b)	d 500

a. Assumed to be the same as the land-surface gradient.

b. Not estimated.

c. Assumed to be the recharge (200 acre-feet, table 10) less evapotranspiration (20 acre-feet, table 11).

d. Assumed to be the same as the recharge (table 10).

Table 10.--Estimated average annual precipitation and ground-water recharge

Altitude zone (feet)	Area (acres)	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)
			SMOKE CREEK DESERT			
Above 8,000	1,550	20+	1.8	2,800	25	700
7,000-8,000	4,180	15-20	1.5	6,300	15	900
6,000-7,000	68,810	12-15	1.1	76,000	7	5,300
5,000-6,000	242,400	8-12	.8	190,000	3	5,700
Below 5,000	399,600	<8	.4	160,000	--	--
Total (rounded)	716,500			440,000		13,000
			SAN EMIDIO DESERT			
Above 7,000	620	15+	1.5	900	15	140
6,000-7,000	13,480	12-15	1.1	15,000	7	1,000
5,000-6,000	39,990	8-12	.8	32,000	3	960
Below 5,000	142,700	<8	.4	57,000	--	--
Total (rounded)	197,000			100,000		2,100
			PAINTERS FLAT			
Above 6,000	8,370	12+	1.1	9,200	7	640
5,000-6,000	27,280	8-12	.8	22,000	3	660
Below 5,000	0	<8	.4	0	--	--
Total (rounded)	35,650			31,000		1,300
			SKEDADDLE CREEK VALLEY (Nevada segment)			
Above 6,000	620	12+	1.1	680	7	50
5,000-6,000	21,240	8-12	.8	17,000	3	510
Below 5,000	4,960	<8	.4	2,000	--	--
Total (rounded)	26,820			20,000		600

Table 10.--continued

Altitude zone (feet)	Area (acres)	Estimated annual precipitation: Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge: Assumed percentage of precipitation	(acre-feet per year)
			PILGRIM FLAT			
Above 6,000	6,360	12+	1.1	7,000	7	490
Below 6,000	0	<8	.4	0	3	--
Total (rounded)	6,360			7,000		500
			DRY VALLEY			
Above 6,000	310	12+	1.1	340	7	25
5,000-6,000	6,980	8-12	.8	5,600	3	170
Below 5,000	19,840	<8	.4	7,900	--	--
Total (rounded)	27,120			14,000		200
			SANO VALLEY			
Above 5,000	160	8+	.8	130	3	<10
Below 5,000	7,440	<8	.4	3,000	--	--
Total (rounded)	7,600			3,100		<10

Direct infiltration of rainfall on the valley floor probably is negligible as a source of recharge, as shown by table 10. Much of the exposed land surface in the area consists of consolidated rocks having a low concentration of primary openings to absorb the precipitation, and the surface of much of the alluvium consists of fine-grained lake deposits having low permeability. Therefore, recharge through these geologic units is relatively small. However, the consolidated-rock uplands contain secondary openings, such as fissures, joints, and solution cavities, which are difficult to categorize with respect to infiltration potential. The density of these secondary openings is quite variable locally, but generally they provide an opportunity for infiltration of water that becomes concentrated in small rivulets at the land surface or at a shallow soil-bedrock contact. Water that infiltrates this system of secondary openings finds its way downgradient to be discharged by springs or in the subsurface as underflow to alluvial aquifers.

Discharge

Discharge from the ground-water reservoirs in the Smoke Creek-San Emidio Desert area occurs by evapotranspiration, subsurface flow from one valley to another (table 9), through springs, and by pumping and flowing wells.

Evapotranspiration.--Much of the ground water in the report area is discharged by evapotranspiration from the phreatophyte areas and playas shown on plate 1. Phreatophytes obtain most of their water from the ground-water reservoir or the overlying capillary fringe. They grow around the edges of playas and along the major stream channels. In the report area they consists mainly of greasewood, saltgrass, and rabbitbrush; also some cottonwood and willows grow along stream channels and in spring and seep areas.

Table 11 lists phreatophyte acreages and summarizes estimates of evapotranspiration. The estimates are based on rates of ground-water consumption in other areas, as described by Lee (1912), White (1932), Young and Blaney (1942), Houston (1950), and Robinson (1958).

Ground water is also discharged by evaporation from the bare playas of Smoke Creek and San Emidio Deserts. Extensive playas in both deserts have static water levels ranging from 5 to 7 feet below the ground surface; the capillary fringe in these areas extends upward to within a few inches of the surface where the soil surface becomes fluffy and larger pore spaces disrupt capillary action. Vehicles and foot travelers often sink into the fluffy surface several inches before their load is stabilized by the wetter, compacted underlying sediments. The dry, loosely-compacted, porous, granular surface contrasts markedly with the underlying wetter, fine-grained, compacted, relatively uniform-grained playa deposits. The fluffiness is believed to indicate

Table 11.--Estimated average annual evapotranspiration of ground water

Phreatophyte	Area (acres)	Depth to water (feet)	Average annual evapotranspiration (acre-feet per acre)	(acre-feet, rounded)
		SMOKE CREEK DESERT		
Native grass	200	5-10	1.0	200
Saltgrass and greasewood	400	5-10	.4	160
Greasewood and rabbitbrush	30,000	20-50	.2	6,000
Greasewood	14,000	30-60	.1	1,400
Bare soil (playa)	114,000	5-7	.1	11,000
Total (rounded)	160,000			19,000
		SAN EMIDIO DESERT		
Mostly greasewood and some saltgrass	3,000	5-20	0.3	900
Greasewood	15,000	20-60	.1	1,500
Bare soil (playa)	6,000	5-7	.1	600
Total (rounded)	24,000			3,000
		PAINTERS FLAT[1/]		
Native meadowgrass and marsh plants	60	0-10	2.0	120
Native meadowgrass	140	5-10	1.0	140
Rabbitbrush, greasewood, and saltgrass	430	5-15	.5	220
Rabbitbrush and greasewood	3,400	10-50	.2	680
Total (rounded)	4,000			1,200
		SANO VALLEY[1/]		
Greasewood	300	--	0.1	30
		DRY VALLEY[1/]		
Greasewood	160	--	.1	20
		SKEDADDLE CREEK VALLEY		
Rabbitbrush	<10	--	--	<10
		PILGRIM FLAT[1/]		
Rabbitbrush and greasewood	<10	--	--	<10

1. Depth to water beneath playa probably more than 10 feet; therefore, evaporation considered minor.

that water is moving upward through the playa deposits and precipitating its dissolved salt load during evaporation in the upper sediment horizons. Near the surface, water is in motion, and phase changes between the liquid, solid, and gaseous state are continually occurring. This condition causes physical instability of the surface material, which is demonstrated by its fluffy nature.

The nature of the playas with respect to hydrologic equilibrium is not understood; continued desiccation of areas formerly occupied by lakes may still be occurring, in which case the natural mean annual discharge of the system might be expected to exceed the mean annual recharge. However, in spite of uncertainty of equilibrium conditions, the system is assumed to be in equilibrium for purposes of discussion and analysis of the annual water budget.

Evaporation rates from bare playas are not well understood. However, the evaporation rate from the playas of the report area, typified by the above discussed characteristics, is assumed to average about 0.1 foot per year where the water level is 5-7 feet below land surface.

The relative distribution of phreatophytes and bare-soil evaporation surfaces in the Smoke Creek and San Emidio Deserts results in average annual phreatophyte consumption of 8,000 acre-feet and 2,400 acre-feet, respectively, and similar bare-soil evaporation of about 11,000 acre-feet and 600 acre-feet, respectively. Therefore, the major part of natural ground-water discharge in the Smoke Creek Desert is by bare-soil evaporation, whereas the major discharge in the San Emidio Desert is by phreatophyte consumption.

Springs.--The report area contains many springs which have discharges ranging from small seeps to flows of about 600 gpm. Table 12 lists most of the springs of the area, their use, and estimates of flow, which were made during this study. Because springflow can generally be accounted for as phreatophyte discharge in the report area, no attempt was made to measure the discharge of the many springs.

The largest spring, 33/16-25c1, flowing about 620 gpm, is unused near its source but supplies much of the base flow of Smoke Creek which is ultimately used for irrigation downstream. The next largest spring flowing about 300 gpm, 32/16-2b1, is also in the upper Smoke Creek drainage and is used for irrigation of native pasture before it discharges into Smoke Creek. Granite Springs and Garden Springs, discharging in the Granite Range, flow about 70 gpm and 65 gpm, respectively, and are used by the town of Gerlach as a municipal water supply.

Table 12.--Records of selected springs

Use: B, bathing; D, domestic; I, irrigation; M, municipal; S, stock; U, unused

Spring number1/	Name or owner	Estimated discharge (gpm)	Use	Temperature (°F)
28/20-28a1	Unknown	10	S	58
32/16-2b1	Unknown	300	S,I	59
32/23-15b1	Great Boiling Springs	200	B	Boiling
32/23-16d1	Unknown	50	S	153
33/16-25c1	Unknown	620	U	58
33/16-26d1	Sage Hen Spring	90	U	--
33/19-15b1	Dewey Parker	50	D,I	62
33/22-13a1	Western Pacific Railroad, Granite Springs	70	M2/	56
33/22-20c1	Unknown	a<1	S	58
33/22-27d1	John Casey	b20	I,S	56
34/22-7c1	John Casey	5	S	68
34/22-19a1	Clyde Fiske	--	S,D,I	62
34/22-35d1	Western Pacific Railroad, Garden Springs	65	M2/	--
35/21-13b1	Crutcher Canyon Springs	20	S	63

1. Chemical analyses for all springs except 34/22-35d1 and 33/16-26d1.

2. Gerlach municipal supply.

a. Seep.

b. Sample from one of several springs with composite discharge of about 100 gpm.

Locally the flow of springs helps sustain vegetation between periods of direct runoff along the principal stream channels; these principal streams include tributaries in the upper basin areas of Smoke Creek, Squaw Creek, and Wild Horse Canyon. Water from many of the springs re-enters the ground-water reservoir a short distance from the point of emergence by percolating into the alluvial fill of stream valleys. Springs flowing from openings in consolidated rocks probably furnish water to aquifers in the alluvium by this process. Losses by evaporation and transpiration always accompany these transfers of water from bedrock to alluvium when the transfer occurs at the land surface or near enough to the surface to be affected by atmospheric and vegetative processes. The estimated evapotranspiration losses are included in the preceding section of the report.

Pumpage and flow from wells.--Ground-water development has been under way in the Smoke Creek Desert area since shortly after the turn of the century. Springs supplied the needs of the first settlers and ranchers, and beginning about 1909, developed springs supplied the needs of the Western Pacific Railroad Co. and the town of Gerlach. The railroad also piped water from springs in Wild Horse Canyon to the town of Smoke Creek. However, both the town and transmission system are now abandoned. Many of the flowing wells were drilled in the period 1915-35, and Dewey Parker's irrigation well was drilled in 1955. Some industrial wells were in production at Empire in the 1930's and several have been drilled since. The Mike Matheson irrigation wells drilled in the San Emidio Desert in 1966 are the most recent and probably the largest ground-water develpment in the area. However, the wells were not in production at the time of this writing (October 1966).

The few wells in the area pump or flow relatively small amounts of ground water compared to the natural discharge. Most wells in the area are described in table 13. Many of the pumping wells are used for stock and domestic uses, and combined consumption for these uses probably is not more than 25 acre-feet per year.

Table 14 lists the principal ground-water developments and shows that the estimated water consumption was about 800 acre-feet in 1966. The major development in terms of total water consumption and number of development facilities has been for agricultural purposes. Three wells supply municipal and industrial water at Empire, and in 1966 the consumption was about 50 acre-feet. The flowing wells in Smoke Creek Desert are around the west, north, and southwest sides of the playa. The estimated flow from the wells ranges from 20 to 400 gpm and totals between 700 and 800 gpm (table 13), or about 1,200 acre-feet per year.

Table 13.--Records of selected wells

Use D. domestic I. irrigation M. municipal
O. observation S. stock U. unused
State log number: Log number in the files of the State Engineer

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement 1/ Date	Water-level measurement 1/ Depth (feet)	State log number
28/19-12a1-6	Jack Bonham	1918	--	6	I	--	3,920	9-13-66	Flowing 400 gpm	--
29/19-3c1	Bonham well	--	154	6	S,U	--	4,010	9-13-66	88.60	--
29/22-36b1	White Sage Flat well	--	--	6	S	--	4,095	9-14-66	95.43	--
29/23-29a1	Threemile Canyon well	--	--	4ftx8ft	S,U	--	4,042	9-14-66	11.93	--
30/19-11a1	Jack Bonham	--	--	4	I	--	3,900	9-13-66	Flowing 25 gpm	--
-11b1	Jack Bonham	--	--	4	I	--	3,900	9-13-66	Flowing 25 gpm	--
-16c1	Smoke Creek Well	--	194	6	S	--	4,020	--	109	--
30/22-1d1	Matheson #4	1966	226	16	I	2,200/57	3,980	7- -66	63	9053
-13d1	Matheson #3	1966	240	16	I	2,700/59	4,010	5- -66	60	9008
-24d1	Matheson #2	1966	253	16	I	--	4,060	4- -66	85	8974
-25d1	Mike Matheson	1966	248	16	I	2,500/37	4,090	10-12-66	75.60	8972
30/23-6a1	Unknown	--	±25	--	S,U	--	3,962	10-12-66	12.30	--
-29b1	Unknown	--	--	6	S,U	--	4,013	11- 9-66	46.71	--
31/19-26b1	Salt Works well	--	123	6	S,U	--	4,000	9-15-66	37.91	--
31/20-18b1	Buffalo Salt Works	--	--	5ftx10ft	U	--	3,890	3-12-63	3	--
31/23-11d1	United States Gypsum Co.	1956	854	20	I	255/20	4,050	10- -56	159	3582
-11d2	United States Gypsum Co.	1949	244	12	I	175/41	4,050	1949	146	1127

Table 13.--continued

Well number	Owner or name	Year drilled	Depth (feet)	Diameter (in)	Use	Yield (gpm) and drawdown (feet)	Altitude (feet)	Water-level measurement[1] Date	Water-level measurement[1] Depth (feet)	State log number
31/23-14a1	United States Gypsum Co.	1961	550	20	I,M	508/100	4,180	1961	215	6013
32/20-18d1	W. D. Parker	--	--	6	S,U	--	4,080	9-15-66	74.20	--
-32b1	W. D. Parker	1955	186	14	I	1,600/101	3,890	1955	9	3001
-32c1	W. D. Parker	--	--	6	D	--	3,885	--	--	--
32/21-3c1.2	John Casey	1918	±240	4	I	--	3,910	9-13-66	Flowing 250 gpm	--
32/23-18d1	Unknown	--	--	8	U	--	3,980	9-16-66	Flowing 20 gpm	--
-27b1	Unknown	1966	8	3	O	--	3,905	11- 9-66	5.30	--
33/22-26d1-3	L. F. Phillips	±1930	--	6	D,I	--	3,900	10-15-66	Flowing 20 gpm	--

1. Water-level depth to hundredths of feet when measured by U.S.G.S., and in feet only when reported; discharge of flowing wells, estimated.

Table 14.--Ground-water development and estimated average annual consumption

Name	Approximate location	Type development	Use	Average use rate (acre-feet per acre per year)	Approximate area (acres)	Crop	Average annual consumption (acre-feet per year)
			SMOKE CREEK DESERT				
Jack Bonham-Bonham Ranch	T. 28 N., R. 19 E.	6 flowing wells (est. combined flow of 400 gpm)	Irrigation	a 3.0 1.0	12 60	Alfalfa Native grass and saltgrass	36 60
Jack Bonham-Bonham Ranch	T. 28 N., R. 19 E.	2 flowing wells (est. combined flow of less than 20 gpm)	Stock and domestic	--	--	--	2
Jack Bonham-near mouth of Smoke Creek	T. 30 N., R. 19 E.	2 flowing wells (est. combined flow of 50 gpm)	Irrigation	1.0	15	Native grass	15
Dewey Parker home ranch	T. 32 N., R. 20 E.	Pumping well	Domestic	--	--	--	0.5
Dewey Parker home ranch	T. 32 N., R. 20 E.	Pumping well (6 mos. at 1,400 gpm)	Irrigation	a 3.0 1.0	80 20	Alfalfa Native grass	240 20
John Casey Parker Ranch	T. 32 N., R. 21 E.	2 flowing wells (est. combined flow of 250 gpm)	Irrigation Storage in surface pond	0.8 4.0	30 2	Native grass and saltgrass --	25 8
Unknown	Sec. 18, T. 32 N., R. 23 E.	1 well flowing (est. 20 gpm)	Natural irrigation of saltgrass	--	--	Saltgrass	est. 10
Dewey Parker-Buffalo Meadows Ranch	T. 33 N., R. 19 E.	Developed springs	Irrigation, minor domestic	a 3.0 1.0	12 50	Alfalfa Native grass	36 50
L. F. Phillips Ranch	T. 33 N., R. 22 E.	3 flowing wells (est. combined flow of 20 gpm)	Irrigation	1.0	40	Native grass	40
Total (rounded)							540

Table 14.--continued

Name	Approximate location	Type development	Use	Average use rate (acre-feet per acre per year)	Approximate area (acres)	Crop	Average annual consumption (acre-feet per year)
			SAN EMIDIO DESERT				
White Sage Flat well	Sec. 36, T. 29 N., R. 22 E.	Pumping well	Watering stock	--	--	--	est. 2
Mike Matheson	T. 30 N., R. 22 E.	4 pumping wells (not yet in production)	Proposed irrigation after 1966	--	1,280	Wheat and safflower	(b)
United States Gypsum Co. and town of Empire	T. 31 N., R. 23 E.	2 pumping wells and 1 standby well	Manufacturing and municipal	Estimates based on pumpage figures	--	--	50
Town of Gerlach	T. 32 N., R. 23 E.	Springs along west side Granite Range - water piped to town	Municipal	Est. 0.1 acre-foot per person per year	--	--	10
Total (rounded)							60

a. Alfalfa use estimated at 1 acre-foot per acre per cutting per year; irrigated alfalfa reportedly yields two to three cuttings per year.

b. Mr. Matheson reportedly holds State permits to develop 5,120 acre-feet per year.

Budget for Natural Conditions

Over the long term and for natural conditions inflow to and outflow from an area are equal, provided that the long-term climatic regime remains constant. The equilibrium condition is assumed to prevail for the study area--an assumption that may not actually be correct. Comparisons of annual estimates of recharge and discharge for all but Skedaddle Creek valley are shown in table 15. Skedaddle Creek valley in Nevada is only a small piece of the drainage basin, and virtually all ground-water and surface-water discharge is to Honey Lake Valley, California.

The imbalances between recharge and discharge where each was computed separately range from only 8 percent for Painters Flat to nearly 50 percent for San Emidio Desert. The imbalances largely result from inadequacies of the assumptions used in making the estimates of recharge and discharge. For lack of conclusive data that would provide confidence to favor either the recharge or discharge estimates, average annual ground-water budgets are balanced by averaging the two estimates, which are shown in table 15 as the "selected value of recharge and discharge."

Table 15.--Ground-water budget, in acre-feet per year, for natural conditions

Budget item	Smoke Creek Desert	San Emidio Desert	Painters Flat	Pilgrim Flat	Dry Valley	Sano Valley
ESTIMATED RECHARGE:						
Precipitation (table 10)	13,000	2,100	1,300	500	200	<10
Subsurface inflow (table 9)	380	--	--	--	--	--
Total (rounded): (1)	13,400	2,100	1,300	500	200	<10
ESTIMATED DISCHARGE:						
Evapotranspiration (table 11) a/	19,000	3,000	1,200	Minor	20	30
Subsurface outflow (table 9)	--	300	--	500	180	--
Total (rounded): (2)	19,000	3,300	1,200	500	200	30
IMBALANCE: (1) - (2)	5,600	1,200	100	(b)	(b)	15
SELECTED VALUE OF RECHARGE AND DISCHARGE:	16,000	2,500	1,200	500	200	25

a. Spring discharge included with evapotranspiration losses.

b. Discharge considered to be equal to recharge. (See footnotes c and d, table 9.)

CHEMICAL QUALITY OF WATER

Twenty-five water samples from wells, springs, and streams were analyzed during the investigation to provide the basis for a general appraisal of the chemical composition of water in the study area, disclose its suitability for various uses, and help define potential water-quality problems. Results of the analyses are shown in table 16. Sampling was restricted to the San Emidio and Smoke Creek Deserts, because sampling sources were generally unavailable in the smaller valleys.

Surface waters sampled generally consisted of ground-water effluent rather than direct runoff and were generally a mixed bicarbonate type. On the basis of the specific conductance the dissolved chemical constituents were generally present in low to moderate quantities. Also, the ground waters sampled ranged widely in quantity of dissolved chemical constituents.

Relation to the Hydrologic System

Naturally occurring water, including rainwater, displays a surprisingly wide range in chemical composition, depending on its environmental history. Its composition is influenced by the nature of the material with which it has come in contact, the chemical and physical conditions that prevailed during contact, and the length of contact time. Therefore, direct runoff generally has a much lower concentration of dissolved chemicals than surface flow derived from effluent seepage, and ground water generally has a higher content of dissolved chemicals than surface flow.

Evapotranspiration of water concentrates soluble chemicals in zones where these natural discharges occur. Therefore, chemical concentration of water in the area, particularly ground water, generally increases toward the playas, as shown in table 16; possible exceptions occur in thermal-spring water, which generally has a more complex environmental history than nonthermal ground water.

Specific conductance provides a general indication of the water's chemical concentration. The specific conductance of ground water in the area ranges from 145 micromhos per centimeter at 25°C (hereafter abbreviated "micromhos") in spring 33/16-25c1, of upper Smoke Creek drainage, to 43,500 micromhos in the shallow augered well 32/23-27b1 of San Emidio Desert playa.

Suitability for Agricultural Use

According to the Salinity Laboratory Staff, U.S. Department of Agriculture (1954, p. 69-82), some significant factors with regard to the chemical suitability of water for irrigation are the dissolved-solids content, the relative proportion of sodium to calcium and magnesium, the amount of bicarbonate relative to calcium and magnesium, and the concentration of specific ions that are toxic

Table 16.--Field chemical analyses of water from selected sources 1/

[Analyses by the U.S. Geological Survey]

Location	Date sampled	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K) 2/	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Irrigation quality: Salinity hazard	Irrigation quality: Alkalinity hazard	RSC	Water type	Rock source
			Parts per million (upper number), equivalents per million (lower number)															
WELLS																		
28/19-12a1	9-13-66	74	37 1.85	2.3 0.19	815 35.44	155 2.54	0 0.00	528 10.99	849 23.95	102	0	3,490	8.0	Very high	Very high	Safe	Sodium chloride	Alluvium
29/23-29d1	9-14-66	57	207 10.33	23 1.90	3,800 165.33	216 3.54	0 0.00	1,800 37.48	4,840 136.54	612	435	13,300	7.5	Very high	Very high	Safe	Sodium chloride	Alluvium
30/19-11a1	9-13-66	61	12 0.60	4.9 0.40	600 26.07	350 5.74	0 0.00	118 2.46	669 18.87	50	0	2,590	8.0	Very high	Very high	Not suitable	Sodium chloride	Alluvium
30/22-25d1	11- 9-66	63	20 1.00	2.9 0.24	154 6.68	199 3.26	0 0.00	83 1.73	104 2.93	62	0	750	7.7	Medium-high	Low	Marginal	Mixed sodium	Alluvium
30/23-6a1	10-17-66	49	24 1.20	17 1.00	833 36.20	414 6.79	0 0.00	246 5.12	939 26.49	110	0	3,750	7.6	Very high	Very high	Not suitable	Sodium chloride	Alluvium
-29b1	11- 9-66	57	-- --	-- --	-- 0.13	8 --	0 0.00	450 9.37	150 9.37	--	--	15,500	5.4	Very high	--	--	--	Alluvium
32/20-32d1	9-15-66	62	16 0.80	6.1 0.50	146 6.33	254 4.16	0 0.00	58 1.21	80 2.26	65	0	685	7.7	Medium	Low	Not suitable	Mixed sodium	Alluvium
32/21-3c1	9-13-66	83	9.6 0.48	3.4 0.28	51 2.21	101 1.66	0 0.00	22 0.46	30 0.85	38	0	266	8.1	Medium	Low	Safe	Mixed sodium	Alluvium
32/23-18d1	9-16-66	66	2.0 0.10	1.2 0.10	968 42.10	500 8.20	187 6.23	416 8.66	681 19.21	10	0	3,790	8.9	Very high	Very high	Not suitable	Sodium chloride	Alluvium
-27b1	11- 9-66	--	-- --	-- --	-- --	358 5.87	0 0.00	4,500 93.69	833 23.50	--	--	43,500	7.4	Very high	--	--	--	Alluvium
33/22-26d1-3	10-15-66	62	8.8 0.44	2.4 0.20	134 6.68	275 4.51	0 0.00	44 0.92	67 1.89	32	0	659	8.2	Medium	Medium	Not suitable	Sodium bicarbonate	Alluvium
34/22-7c1	10-15-66	68	15 0.75	3.3 0.27	40 1.76	98 1.61	0 0.00	22 0.46	25 0.71	51	0	262	7.8	Medium	Low	Safe	Sodium bicarbonate	Alluvium
SPRINGS																		
28/20-28c1	9-13-66	58	4.0 0.20	2.4 0.20	931 40.49	443 7.29	30 1.00	524 10.91	769 21.69	20	0	3,730	8.4	Very high	Very high	Not suitable	Sodium chloride	Alluvium
32/16-2b1	10-14-66	59	10 0.50	6.1 0.50	19 0.82	88 1.44	0 0.00	12 0.25	4.6 0.13	50	0	143	7.8	Low	Low	Safe	Mixed bicarbonate	Volcanic
32/23-16d1	10-14-66	153	66 3.29	8.1 0.67	1,510 65.68	126 2.07	0 0.00	400 8.33	2,100 59.24	198	95	6,800	7.9	Very high	Very high	Safe	Sodium chloride	Granitic
33/16-36b1	10-14-66	58	11 0.55	5.7 0.47	22 0.97	96 1.57	0 0.00	14 0.29	4.6 0.13	51	0	145	8.1	Low	Low	Safe	Mixed bicarbonate	Volcanic
33/19-15b1	9-15-66	62	17 0.85	7.4 0.61	49 2.12	156 2.56	0 0.00	26 0.54	17 0.48	73	0	317	7.3	Medium	Low	Safe	Sodium bicarbonate	Volcanic
33/22-13a1	11-10-66	56	50 2.50	5.6 0.46	32 1.40	104 1.70	0 0.00	34 0.71	69 1.95	148	63	427	8.1	Medium	Low	Safe	Mixed	Granitic
-20c1	9-13-66	58	5.6 0.28	2.9 0.24	128 5.55	260 4.26	0 0.00	26 0.54	45 1.27	26	0	531	8.1	Medium	Medium	Not suitable	Sodium bicarbonate	Alluvium
-27d1	11-10-66	56	38 1.90	9.0 0.74	101 4.37	236 3.87	0 0.00	48 1.00	76 2.14	132	0	640	8.0	Medium	Low	Safe	Mixed sodium	Alluvium
34/22-19a1	10-15-66	62	23 1.15	5.2 0.43	47 2.04	123 2.02	0 0.00	36 0.75	30 0.85	79	0	325	7.9	Medium	Low	Safe	Mixed bicarbonate	Volcanic
35/21-13b1	10-15-66	63	16 0.80	6.3 0.52	27 1.19	107 1.75	0 0.00	18 0.37	14 0.39	66	0	209	7.8	Low	Low	Safe	Mixed bicarbonate	Volcanic
STREAMS																		
Wild Horse Canyon 30/21-34	9-13-66	54	61 3.04	20 1.68	44 1.93	195 3.20	0 0.00	98 2.04	50 1.41	236	76	574	7.5	Medium	Low	Safe	Mixed	Volcanic
Smoke Creek 33/16-23	10-14-66	44	9.6 0.48	6.3 0.52	20 0.86	90 1.48	0 0.00	12 0.25	4.6 0.13	50	0	132	7.7	Low	Low	Safe	Mixed bicarbonate	--
Clear Creek 34/22-33	10-15-66	44	28 1.40	2.9 0.24	34 1.50	112 1.84	0 0.00	19 0.40	32 0.90	82	0	279	7.8	Medium	Low	Safe	Mixed bicarbonate	--

1. No water samples were collected in Painters Flat, Pilgrim Flat, Dry Valley, Sano Valley, or Skedaddle Creek valley.

2. Computed by arithmetic difference.

to plants. Dissolved-solids content commonly is expressed as "salinity hazard," and the relative proportion of sodium to calcium and magnesium as "alkalinity hazard." The amount of bicarbonate in excess of calcium and magnesium is referred to as residual sodium carbonate, or "RSC," hazard. Boron, which is necessary in small quantities for healthy plant growth, is toxic to plants when present in water in quantities only slightly exceeding the desirable amounts. However, no boron determinations were made on the samples analyzed.

Table 16 shows that all sampled surface water is safe for agricultural use on well-drained soils, based on evaluations of the hazards described above. Ground water analyzed ranged widely in acceptability for agricultural use. Some waters considered unsuitable because of salinity, alkalinity, or RSC hazard are currently being used for agricultural purposes. Large application of unsuitable or marginal waters with inherent leaching and flushing yields somewhat favorable results when better quality water is economically unavailable. Success in this approach naturally depends on the degree of "unsuitability" of the water being used, the drainability of the soil, and other factors.

Suitability of ground water for agricultural uses in the study area is generally related to location of the source of supply with respect to the playa deposits. Acceptable water for forage crops is generally available in the alluvium bordering the playas, but water in the upper zones of the playa deposits commonly is highly saline and alkaline. The nearly flat lands around the playa margins, although suited to farming by the low degree of surface slope, often tend to be fine-grained and of poor chemical and physical characteristics. Moreover, the water level in these areas commonly is shallow, and leaching is difficult. These factors limit the suitability of the lands to irrigation with water of poor or marginal chemical quality. Agricultural development in the study area may be ultimately more influenced by the chemical quality of the available water than by the quantity of water available. In any event, evaluation of prospective agricultural development warrants careful consideration of the chemical quality of the water and the chemical and physical character of the lowland soils. This would help ensure compatibility of soil and irrigation water with the type of crops planned for the development.

Future recycling of ground water for intensive irrigation may tend to degrade chemical quality of the water, particularly if commercial fertilizers are used in substantial quantities, and if the soils contain leachable salts. Extensive agricultural ground-water development will require study to determine potential hazards arising from reuse of water, some of which is only chemically marginal for agricultural use in its natural state.

Suitability for Domestic and Industrial Use

The limits recommended by the U.S. Public Health Service (1962), for water used on interstate carriers for drinking purposes, commonly are cited as standards for domestic use. Chloride and sulfate concentrations, as determined by the analyses, were used in determining the acceptability of the waters, based on Public Health Service recommendations. A concentration of 250 ppm (parts per million) for each ion is recommended as an upper limit of acceptability when more suitable supplies are or can be made available. Water considered unacceptable by these standards occurs commonly in the study area, but for the analyses made its occurrence was restricted to supplies occurring in the upper playa deposits or very close to the margins of these deposits.

Water analyzed in the study area and considered acceptable for domestic consumption, based on the chloride and sulfate content, might be considered unacceptable or unsafe based on the concentration of a number of ions not determined in analyses made during this study. Questionable water should be submitted to a reliable laboratory for a complete analysis, when domestic or municipal development is planned for a particular water supply, to assure that the water is safe and acceptable for human consumption.

Excessive hardness of water, which is caused principally by calcium and magnesium, adversely affects its suitability for domestic use, especially for cooking and washing. The U.S. Geological Survey uses the following classification of water hardness:

Hardness range (ppm)	Classification
0-60	Soft
61-120	Moderately hard
121-180	Hard
Greater than 180	Very hard

As shown in table 18, water analyzed from the study area ranges from soft to very hard. Some of the waters considered very hard are acceptable from the standpoint of chloride and sulfate content (particularly spring 33/22-13a1 and surface stream 30/21-34). Also, some of the water not recommended because of high chloride and sulfate content would be acceptable based on hardness criteria (wells 30/19-11a1 and 32/23-18d1, and spring 28/20-28c1).

The suitability of water for industrial use depends on the quality requirements of the industry. Water considered unacceptable for internal consumption by humans and animals might be desirable for industrial use. Therefore, water of questionable quality should be analyzed by a competent laboratory to determine suitability for a particular requirement early during the planning phase of any industrial development.

Results of this reconnaissance suggest in general that water having lower concentrations of most individual constituents will be found with increasing distance from the playas. However, locally the water may be of poor chemical quality, such as was found at the United States Gypsum Co. plant at Empire. The Company reportedly found better quality water east of State Highway 34.

THE AVAILABLE WATER SUPPLY

The available ground-water supply of the larger valleys in the Smoke Creek-San Emidio Desert area consists of two interrelated entities: (1) perennial yield and (2) transitional storage reserve.

Perennial Yield

Perennial yield of a ground-water reservoir may be defined as the maximum amount of water of usable chemical quality that can be withdrawn and consumed economically each year for an indefinite period of time. If the perennial yield is continually exceeded, water levels will decline until the ground-water reservoir is depleted of water of usable quality or until the pumping lifts become uneconomical to maintain. Perennial yield cannot exceed the natural recharge to an area and ultimately is limited to the maximum amount of natural discharge that can be salvaged for beneficial use. Salvage of natural discharge implies diversion of ground water presently destined for consumption by native evapotranspirative processes and part of the subsurface outflow to areas of pumping. A method of accomplishing the diversion is lowering water levels in and near areas of natural discharge by scheduled depletion of storage according to the concept of transitional storage reserve (defined below).

Table 15 shows the selected values of recharge and discharge for all valleys in the area except Skedaddle Creek. Smoke Creek Desert, San Emidio Desert, Painters Flat, and Sano Valley discharge virtually all ground water by evapotranspiration in and adjacent to their playas. For these valleys, all the natural discharge is considered salvable by pumping. On the other hand, Pilgrim Flat and Dry Valley have external discharge, losing ground water by subsurface outflow to adjacent areas. For these two valleys, if the outflow is occurring over a subsurface barrier, possibly all the discharge could be salvaged by drawing water levels down below the barrier "lip"; but if the outflow is dispersed vertically through a permeable joint or fracture system or occurs at considerable depth, only a small amount might be salvaged by pumping within the valley. The preliminary value selected assumes roughly half the outflow is salvable.

The above assumptions and considerations lead to the following estimates of perennial yield for the six valleys: Smoke Creek Desert, 16,000 acre-feet; San Emidio Desert, 2,500 acre-feet; Painters Flat, 1,200 acre-feet; and Sano Valley, 25 acre-feet; and for the valleys having subsurface outflow, Pilgrim Flat, 200 acre-feet; and Dry Valley, 100 acre-feet.

Only the central part of Skedaddle Creek valley is in Nevada (pl. 1). The estimated potential recharge to the segment is about 600 acre-feet per year (table 10); the salvable natural discharge is considered to be possibly less than half the recharge.

Thus, the perennial yield may be only about 200 acre-feet, provided that adequate well yields can be obtained from the volcanic rocks.

Transitional Storage Reserve

Transitional storage reserve has been defined by Worts (1967) as the quantity of water in storage in a particular ground-water reservoir that can be extracted and beneficially used during the transition period between equilibrium conditions in a state of nature and new equilibrium conditions under the perennial yield concept of ground-water development. In the arid environment of the Great Basin the transitional storage reserve of such a reservoir is the amount of stored water available for withdrawal by pumping during the nonequilibrium period of development or period of lowering water levels. Therefore, transitional storage reserve is a specific part of the total ground-water resource that can be taken from storage; it is a quantity additional to that of perennial yield, but can be withdrawn on a once-only basis.

Ground-water development inherently involves storage depletion; the magnitude of depletion is commensurate with the hydraulic characteristics of the aquifer and location of the wells with respect to recharge and discharge boundaries. Desert valleys often have well-defined discharge boundaries, such as areas of evapotranspiration, but recharge boundaries, such as live streams or lakes, are uncommon.

Computation of transitional storage reserve for valleys of the report area was based on the following assumptions: (1) Development wells would be strategically located in, near, and around the areas of natural discharge so that any subsurface outflow losses could be reduced and any evapotranspiration losses stopped with a minimum of water-level drawdown in the pumped wells; (2) in general, water levels would be lowered to and stabilized at a minimum depth of 50 feet below the land surface in areas of phreatophyte growth, which would curtail virtually all evapotranspiration losses from the ground-water reservoir; (3) long-term pumping would cause a moderately uniform depletion of storage throughout the alluvium, except in the very fine-grained playa deposits of Smoke Creek and San Emidio Deserts, where transmissibility and storage coefficients are small and therefore storage depletion also would be small or occur over a very long period of time; (4) the specific yield of the valley fill is 10 percent; (5) water levels are within the range of economic pumping lift for the intended use; (6) the pumping development causes little or no effect on adjacent valleys; and (7) the water is of suitable chemical quality for the desired use.

The areas of alluvium used in the computations conform to the valley shape and geology to help ensure that areas used are underlain by a saturated alluvial thickness of at least 50 feet--the proposed amount of water-level lowering. In the smaller valleys, such as Painters Flat, some storage depletion would also occur in the underlying and adjacent volcanic rocks. Table 17 shows the estimated transitional storage reserve for the Smoke Creek-San Emidio Desert area. However, for Skedaddle Creek Valley and Pilgrim Flat, where virtually no alluvium occurs, no estimates were made.

The manner in which transitional storage reserve augments the perennial yield has been described by Worts (1967) and in its simplified form is shown by the following equation:

$$Q = \frac{\text{Transitional Storage Reserve}}{t} + \frac{\text{Perennial Yield}}{2}$$

in which Q is the pumping rate, in acre-feet per year, and t is the time, in years, to exhaust the transitional storage reserve. This basic equation, of course, could be modified to allow for changing rates of storage depletion and salvage of natural discharge. The equation, however, is not valid for pumping rates less than the perennial yield.

Using the above equation and the estimates for San Emidio Desert as an example (Transitional storage reserve 300,000 acre-feet, table 17; perennial yield 2,500 acre-feet, p.50) and using a pumping rate (Q) equal to perennial yield in accordance with the general intent of Nevada water law, the time (t) to deplete the transitional storage reserve is computed to be 240 years. At the end of that time, the transitional storage reserve would be exhausted, subject to the assumptions previously described.

What is not shown by the example is that in the first year virtually all the pumpage would be derived from storage, and very little, if any, would be derived by salvage of natural discharge. On the other hand, during the last year of the period nearly all pumpage would be derived from the salvage of natural discharge and virtually none from the storage reserve.

During the period of depletion the ground-water flow net would be substantially modified. The estimated recharge of 2,500 acre-feet per year (table 15) that originally flowed from around the sides of the valley to areas of natural discharge would ultimately flow directly to the pumping wells.

To meet the needs of an emergency or other special purpose requiring ground-water pumpage in excess of the perennial yield for specified periods of time, the transitional storage reserve would be depleted at a more rapid rate than in the example

Table 17.--Estimated transitional storage reserve

Valley	Selected area of depletion (acres) (1)	Selected depletion thickness (feet) (2)	Transitional storage reserve (acre-feet) (1)x(2)x 0.1
Smoke Creek Desert	80,000	50	a 400,000
San Emidio Desert	60,000	50	a 300,000
Dry Valley	6,000	10	6,000
Sano Valley	2,000	25	5,000
Painters Flat	4,000	30	12,000
Pilgrim Flat	--	--	Not computed
Skedaddle Creek Valley	--	--	Not computed

a. Excludes most of playa deposits, where shallow water is of poor chemical quality.

given. The above equation can be used to compute the time required to exhaust the storage reserve for any selected pumping rate in excess of the perennial yield. However, once the transitional storage reserve was exhausted, the pumping rate should be reduced to the perennial yield. Pumpage in excess of the perennial yield would result in an overdraft, and pumping lifts would continue to increase and stored water would continue to be depleted until some undesired result occurred.

Future Development

The small amount of development of water resources in the Smoke Creek-San Emidio Desert area has evolved mainly around agriculture and industry in the past, and the same uses probably will continue in the foreseeable future. (See table 14.) Agricultural development will be controlled by the quantity and quality of available water, climatic factors, and the availability of suitable land. Total land area is extensive, but land suitable for irrigation and intensive farming by presently developed techniques appears to the writers to be quite limited. Although appreciable areas have land surface slopes favorable to agricultural development, the major part of these areas consists of playas which are agriculturally unacceptable because of poor quality soil and water. Overpumping of nearby peripheral areas may induce salt-water flow from the playa deposits to the areas of pumping. Therefore, determination of the pumping rate to salvage the maximum amount of water before contaminated water reaches the wells would be critical in determining maximum development potential. Land acceptable for farming must also be associated with economically available water supplies and a favorable growing season.

Increased industrial development of the water resources is possible, particularly with requirements of space-age developments that might seek to utilize the nearly flat surfaces of the extensive playa areas. Availability of adequate water for this type of development would depend on total water available, water-quality requirements of the industry, and economic feasibility of treatment facilities to improve the quality of substandard water. Mineral industries might find economic supplies of minerals in the waters beneath the playa areas.

Increases in domestic and municipal requirements for water would probably be related to agricultural and industrial development and therefore are quite unpredictable. No large-scale population increase would be expected in the area without substantial agricultural or industrial expansion.

NUMBERING SYSTEM FOR WELLS AND SPRINGS

Numbers assigned to wells and springs in this report 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 north of the base line. The second unit, separated from the first by a slant, is the range east of the meridian. The third unit, separated from the second by a dash, designates the section number, which in turn is followed by a letter that indicates the quarter section. The quarter sections are designated counter-clockwise in sequence beginning with "a" for the northeast quarter section. Following the letter, a number indicates the order in which the well or spring was recorded within the 160-acre tract. For example, well 31/19-26b1 is the first well recorded in the NW¼ sec. 26, T. 31 N., R. 19 E., Mount Diablo base line and meridian.

Because of limitation of space, wells and springs are identified on plate 1 only by the section number, quarter-section letter, and the number indicating the order in which the well or spring was located. Township and range numbers are shown along the margins of the plate.

Table 18.--Available drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
29/19-3c1		
Sand and gravel	8	8
Clay	92	100
Shale, hard	16	116
Clay, water-bearing	38	154
30/19-16c1		
Sand and gravel	8	8
Sand rock	47	55
Clay	120	175
Sand and gravel	4	179
Sand, clay, and gravel	15	194
30/22-1d1		
Clay, sandy, brown	30	30
Sand, coarse, and gray clay	50	80
Sand, fine, and gray clay	5	85
Sand and gravel, water-bearing	20	105
Clay and gravel, brown	35	140
Sand, coarse, water-bearing	16	156
Sand, fine, water-bearing	18	174
Gravel, medium, water-bearing	23	197
Sand, fine	23	220
Clay, sticky, brown	6	226
30/22-13d1		
Clay and sand, brown	4	4
Clay and gravel, brown	6	10
Clay, brown	21	31
Sand and clay, brown	4	35
Gravel and clay, brown	5	40
Gravel and sand, brown	10	50
Sand and clay, brown	15	65
Sand, brown	3	68
Clay and gravel, brown	12	80
Sand and clay, brown	5	85
Sand, water-bearing	6	91
Sand and clay, brown	18	109
Gravel and clay, brown	11	120
Clay, sticky, brown	18	138
Clay and sand, brown	8	146
Clay and gravel, sticky	20	166
Gravel and sand, water-bearing	74	240
30/22-24d1		
Soil	3	3
Clay, sandy, brown	7	10
Clay, yellow	20	30
Clay and small gravel, brown	8	38
Clay, yellow	7	45
Clay and medium gravel	23	68
Sand, medium, water-bearing	2	70
Clay, sandy, brown	34	130
Clay, brown	5	135
Clay and small gravel	32	167
Gravel, water-bearing	8	175
Gravel, small, water-bearing	23	198
Sand, fine	7	205
Clay, sticky, white	3	208
Sand, coarse, water-bearing	7	215
Clay, brown, and gravel	5	220
Gravel, small	1	221
Clay, sticky, yellow	27	248
31/19-26b1		
Sand, gravel, and boulders	20	20
Clay and sand	102	122

Table 18.--continued

Material	Thickness (feet)	Depth (feet)
31/23-11d1		
Rock (lava) and soil	10	10
Rock (lava) and sandy clay	23	33
Clay, gray	2	35
Rock (lava) and gravel	28	63
Clay (hardpan)	3	66
Rock (lava) and gravel	14	80
Clay	4	84
Rock	3	87
Rock (lava) and gravel in sandy clay	23	110
Rock (lava) and gravel, trace of red sandy clay	40	150
Clay, sandy, red, water-bearing	30	180
Clay, sandy, red, and strata of rock, water-bearing	20	200
Clay	8	208
Sand	2	210
Sand and clay	16	226
Sand and clay with rock, water-bearing	20	246
Clay, blue, with gravel and rock, water-bearing	8	254
Gravel with a little clay, water-bearing	10	264
Clay, brown, and boulders, water-bearing	24	288
Rock and clay, tough, water-bearing	6	294
Gravel and soft gray clay with boulders	30	324
Clay, red and gray	6	330
Clay and gravel with boulders	9	339
Clay, soft, and boulders	3	342
Clay, sandy, red	4	346
Clay, soft, gray, and gravel	6	352
Sand, coarse	2	354
Boulders, small	1	355
Clay, soft, sandy, gray and gravel, water-bearing	25	380
Clay, sandy, red and gray, water-bearing	40	420
Clay, sandy, gray, water-bearing	26	446
Rock and sand in light-colored sticky clay	6	452
Clay, sticky, gray, and gravel	16	468
Sand	2	470
Clay, sandy, gray, yellow, and red, water-bearing	20	490
Gravel and sandy clay, water-bearing	10	500
Clay, sandy, gray-blue	130	630
Clay, sandy, red and blue-gray	46	676
Clay, blue-gray, and gravel	84	760
Clay, soft, gray and gravel	18	778
Gravel	2	780
Clay, soft, gray and gravel	16	796
Gravel	2	798
Clay	3	801
Gravel	2	803
Gravel and clay	18	821
Gravel	9	830
Sand, clay, and gravel	24	854

Table 13.--continued

Material	Thickness (feet)	Depth (feet)
31/23-11d2		
Soil	5	5
Clay, sandy	14	19
Rock, small	1	20
Clay, sandy	20	40
Rock, coarse	20	60
Clay, yellow	5	65
Rock, black	7	72
Clay, blue	2	74
Streak, very hard	1	75
Rock, coarse	7	82
Clay, sandy, gray	8	90
Clay and gravel	15	105
Clay, sandy	19	124
Rock, coarse	4	128
Clay and gravel	2	130
Rock, coarse	12	142
Clay and gravel	10	152
Clay, yellow	13	165
Gravel, loose	3	168
Clay and gravel	3	171
Sand rock	4	175
Gravel, water-bearing	1	176
Clay, yellow	24	200
Clay and gravel	12	212
Gravel	7	219
Clay, yellow	11	230
Gravel, coarse	2	232
Clay, yellow	4	236
Gravel	5	241
Sand, red	2	243
Rock	1	244
31/23-14a1		
Soil and boulders	12	12
Rock (lava) with pumice	78	90
Sand rock	22	112
Sand and clay	45	157
Sand and clay with some gravel	5	162
Sand, coarse, with some clay	20	182
Gravel and clay, water-bearing	34	216
Boulders	7	223
Clay, brown, with trace of black sand	33	256
Sand, coarse, and fine gravel	3	259
Sand, gravel, and clay	40	299
Clay, dark blue	42	341
Sand, coarse, and clay	4	345
Clay, brown, and gravel	2	347
Clay, gray, and gravel	5	352
Clay, brown, blue, changing colors	83	435
Boulders and clay, water-bearing	14	449
Rock (lava), hard, water-bearing	44	493
Sand, coarse, clean, and clean gravel, water-bearing	42	535
Clay, gray	15	550
32/20-32b1		
Soil	3	3
Clay, brown	11	14
Sand, coarse	2	16
Clay, soft, brown	15	31
Clay, hard, yellow	3	34
Clay, soft, green	13	47
Sand, black, water-bearing	3	50
Clay, soft, green	8	58
Sand and gravel	4	62
Clay, soft, gray	3	65
Clay, hard, brown	10	75
Clay, gray	6	81
Clay, hard, gray, with layers of sand	13	94
Sand, black, water-bearing	3	97
Gravel and boulders, water-bearing	6	103
Clay, sticky, yellow	2	105
Sand and gravel, cemented, water-bearing	5	110
Sand, black, and gravel, water-bearing	2	112
Clay, hard, gray	7	119
Clay, hard, yellow	7	126
Clay, yellow, and boulders	9	135
Gravel, coarse, water-bearing	1	136
Clay, medium-soft, yellow	9	145
Clay, hard, brown	8	153
Gravel, water-bearing	5	158
Clay, soft, yellow	6	164
Clay, hard, yellow, with boulders	4	168
Gravel and boulder, water-bearing	14	182
Rock (lava), hard	4	186

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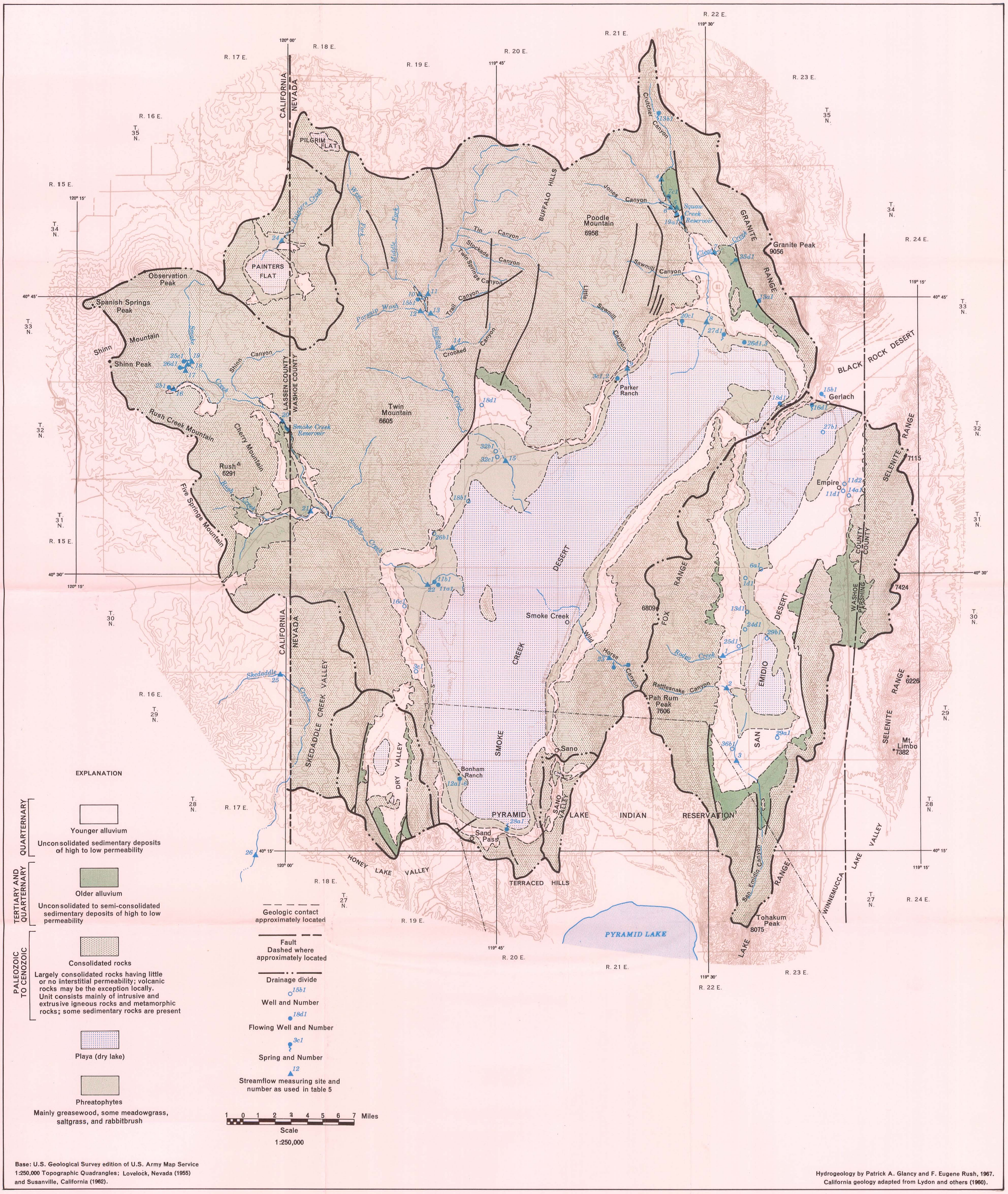
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES



Base: U.S. Geological Survey edition of U.S. Army Map Service 1:250,000 Topographic Quadrangles; Lovelock, Nevada (1955) and Susanville, California (1962).

Hydrogeology by Patrick A. Glancy and F. Eugene Rush, 1967.
California geology adapted from Lydon and others (1960).

PLATE 1.—GENERALIZED HYDROGEOLOGIC MAP OF SMOKE CREEK—SAN EMIDIO DESERT AREA, WASHOE AND PERSHING COUNTIES, NEVADA AND LASSEN COUNTY, CALIFORNIA