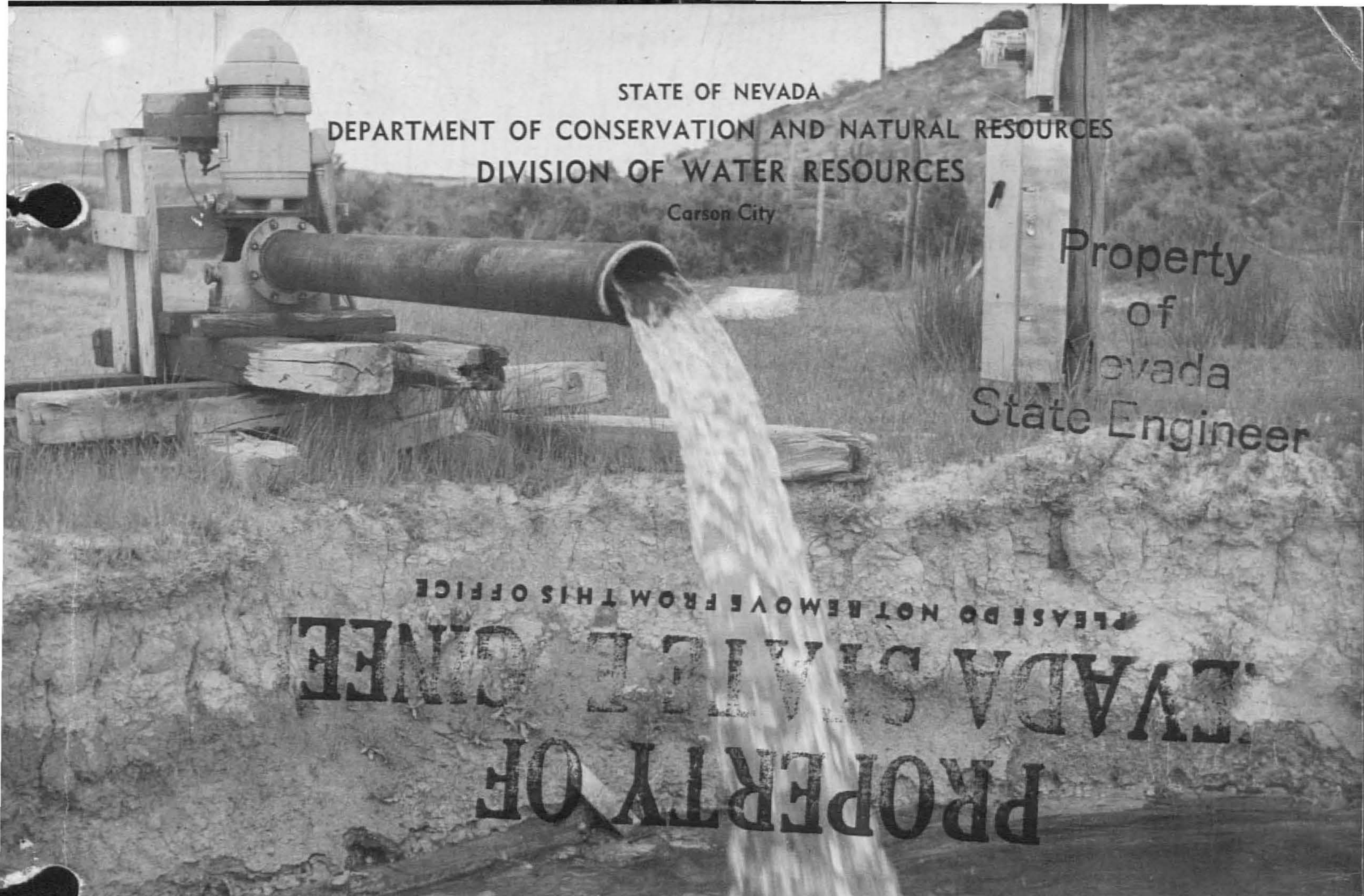
STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
Carson City



View of irrigation well on Gamble Ranch.

WATER RESOURCES–RECONNAISSANCE SERIES

REPORT 47

WATER–RESOURCES APPRAISAL OF THOUSAND SPRINGS VALLEY, ELKO COUNTY, NEVADA

By

F. Eugene Rush

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

JUNE 1968

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ROLAND D. WESTERGARD
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In reply refer to
No.

Address All Communications to
the State Engineer, Division
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FOREWORD

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

This report is the 47th in the series to be prepared by the staff of the Nevada District Office of the U.S. Geological Survey. These 47 reports describe the hydrology of 120 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 studies are timely and adequately meet the immediate needs for information on the water resources of the areas covered by the reports.

Roland D. Westergard
State Engineer

June 1968

Division of Water
Resources

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WATER-RESOURCES APPRAISAL OF THOUSAND SPRINGS VALLEY, ELKO COUNTY, NEVADA

By F. Eugene Rush

SUMMARY

Sparsely populated Thousand Springs Valley is in northeastern Nevada and has an area of about 1,440 square miles. The valley is divided into four hydrologic segments, through which Thousand Springs Creek flows. Carbonate rocks, which are abundant throughout the report area, and alluvium may transmit between segments substantial parts of the valley's water resources.

Agriculture, other than grazing, is limited to the mile-wide flood plain of Thousand Springs Creek, where hay and pasture land are irrigated. Sampled well and surface waters were generally chemically suitable for irrigation in the three western segments, but samples collected in Montello Valley were more highly mineralized.

Table 1 summarizes most of the estimated hydrologic quantities for the area. Not included in table 1 are the estimates of intersegment flow of ground and surface water and the recharge from precipitation in the Nevada part of Grouse Creek Valley (700 acre-feet per year)--the mountainous area between Thousand Springs Valley and the Utah border.

Table 1.--Preliminary estimates of hydrologic elements

[All water quantities are average annual volumes, in acre-feet, except where noted]

	Herrell Siding-Brush Creek area	Toano-Rock Spring area	Rocky Butte area	Montello-Crittenden Creek area	Total for Thousand Springs Valley
Area (square miles)	160	620	190	470	1,440
Minimum altitude of flood plain (feet)	5,500	5,250	5,000	4,800	4,800
Approximate growing season (days)	70-100	90-140	90-140	80-140	70-140
Precipitation	72,000	250,000	75,000	190,000	600,000
Runoff	8,000	13,000	4,000	10,000	35,000
Water consumed by crops:					
Surface water	1,500	2,000	2000	1,000	4,700
Pumpage	300	0	0	1,000	1,300
Subirrigation	800	1,000	800	9,400	12,000
Evapotranspiration of ground water	700	600	400	4,000	5,700
Reconnaissance value of inflow and outflow	8,000	19,000	5,000	17,000	30,000
System yield	5,800	6,400	2,000	16,000	24,000
Transitional storage reserve[1]	200,000	1,000,000	80,000	500,000	2,000,000

1. Estimated total quantity available for use on a one-time basis.

INTRODUCTION

Purpose and Scope of the Study

Ground-water development in Nevada has increased substantially in recent years. Part of this increase is due to the cultivation of new land, and to an increase in population. The increasing interest in ground-water development has created a substantial demand for information on water resources throughout the State. Recognizing this need, the State Legislature enacted special legislation (Chapter 181, Statutes of 1960) authorizing a series of reconnaissance studies of the ground-water resources of Nevada. Subsequently, the studies were broadened to include pertinent streamflow and water-quality data. These studies are being made by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. This is the 47th report prepared as part of the reconnaissance series (fig. 1).

Objectives of this reconnaissance are to (1) describe the hydrologic environment, (2) appraise the source, occurrence, movement, and chemical quality of water in the area, (3) estimate average annual recharge to and discharge from the ground-water reservoir, (4) provide a preliminary estimate of system yield and transitional storage reserve, and (5) estimate present and evaluate potential water development in the area.

Field work was done in June 1967. Otis Purkiss of the U.S. Geological Survey staff assisted the author in collecting and analyzing data.

Location and General Features

Thousand Springs Valley is in northeastern Nevada (fig. 1), northeast of the town of Wells, in Elko County, and is approximately enclosed by lat 41°00' and 42°00' N., long 114°00' and 115°00' W. The valley is roughly equidimensional, measuring about 40 miles across; it comprises 1,440 square miles and includes seven subareas (fig. 2 and pl. 1). These subareas are called, for the purposes of this report, from west to east: (1) Herrell Siding area, (2) Brush Creek Valley, (3) Toano Draw, (4) Rock Spring Valley, (5) Rocky Butte area, (6) Montello Valley, and (7) Crittenden Creek Valley. In addition, the narrow area between Thousand Springs Valley and the Utah border (pl. 1), which is a mountainous part of Grouse Creek Valley, is briefly described in the section, "Recharge from precipitation." The subareas, in turn, are grouped into four major hydrologic segments or areas: (1) Herrell Siding-Brush Creek area, (2) Toano-Rock Spring area, (3) Rocky Butte area, and (4) Montello-Crittenden

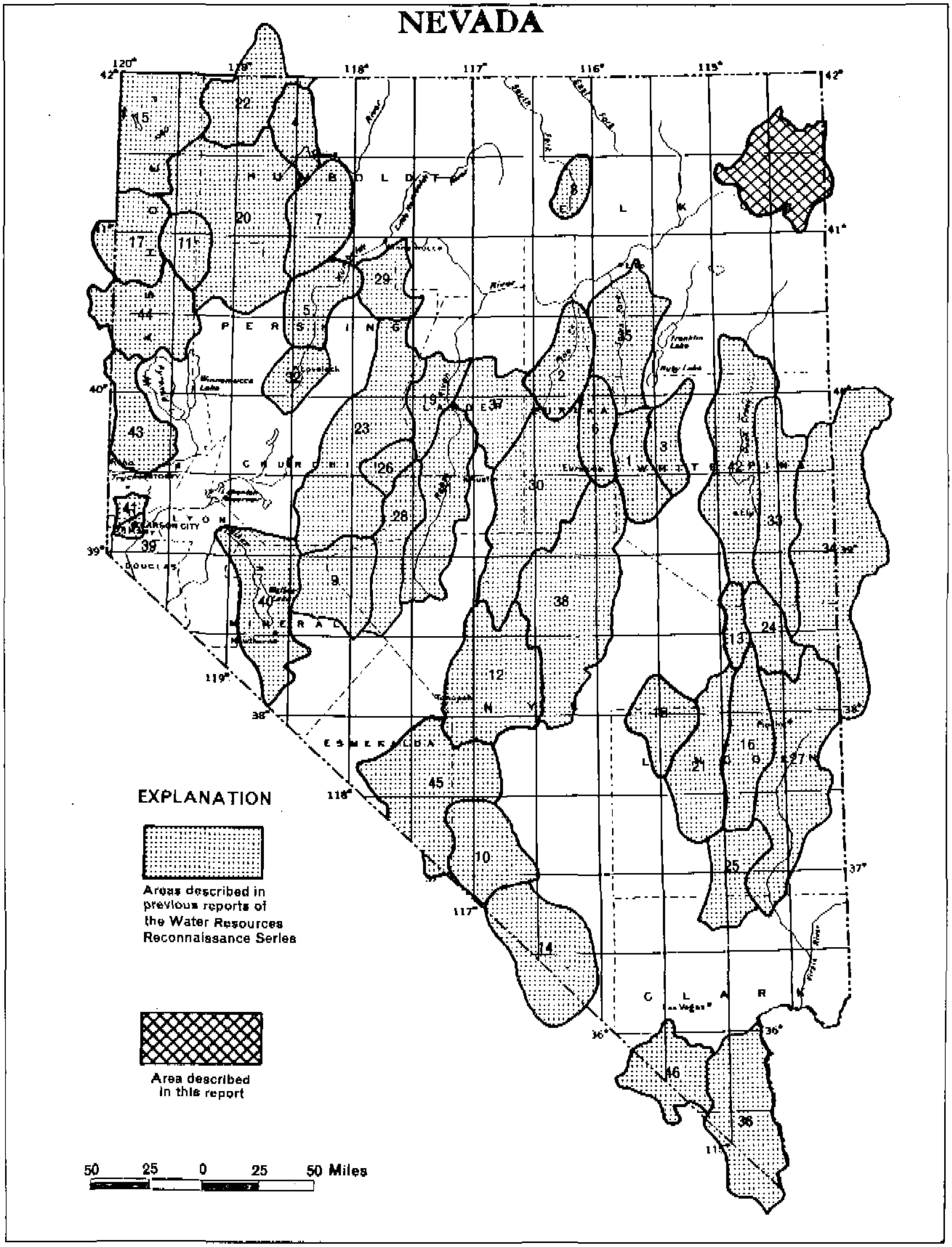

Figure 1.—Index map showing areas in Nevada described in previous reports of the Water Resources Reconnaissance Series and the area described in this report

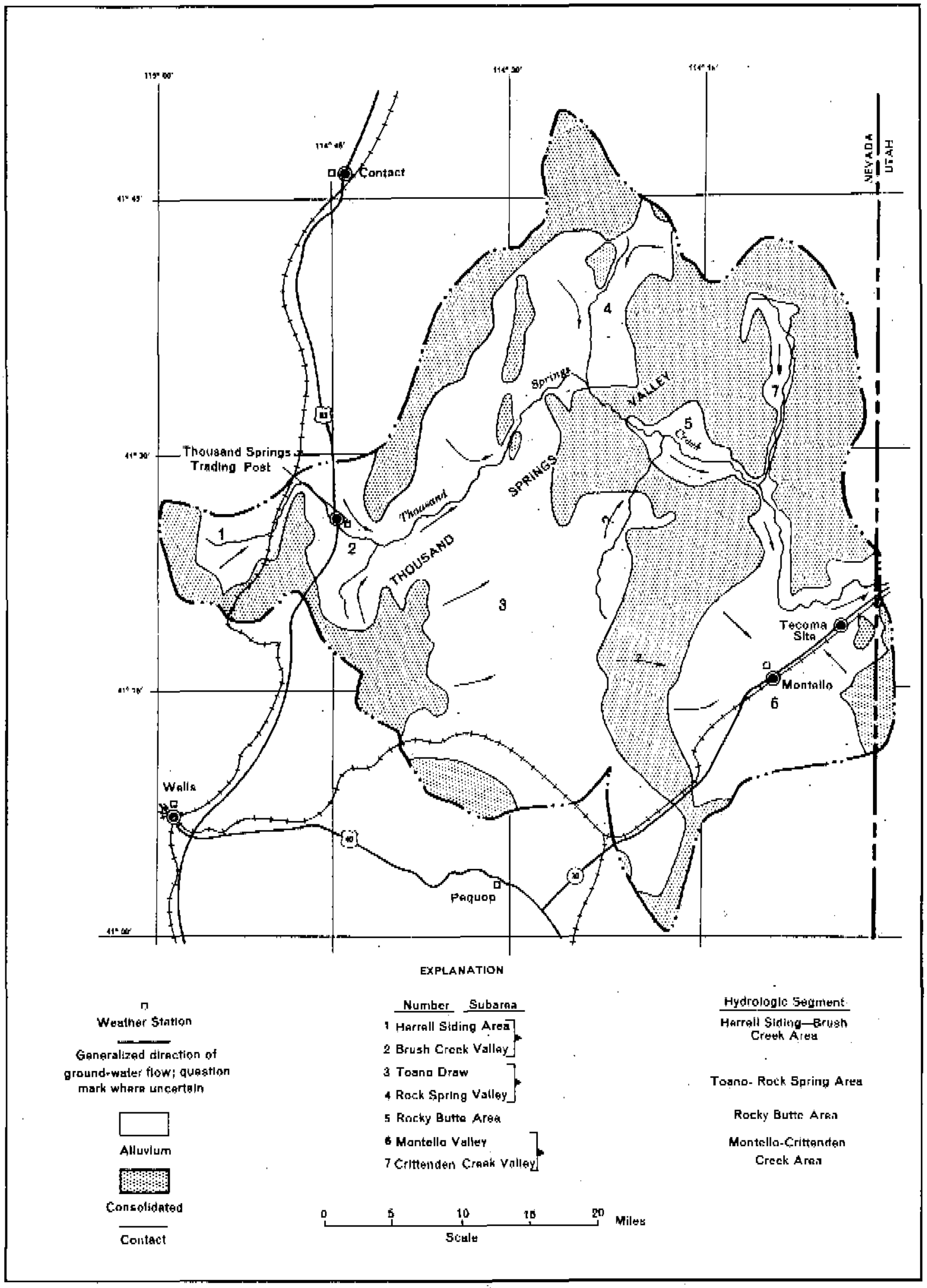

Figure 2.—Location of hydrologic segments, generalized ground-water flow, and nearby weather stations

Creek area. The hydrologic significance of each segment of the drainage system is considered separately.

The estimated population of Thousand Springs Valley is about 200. Montello, with about 150 people, is the only town. Economic activity in the area is mainly ranching.

HYDROLOGIC ENVIRONMENT

Physiography and Drainage

Thousand Springs Valley lies within the Great Basin near its northern margin. Four north-trending mountain ridges, as shown on plate 1, divide the report area into seven small subareas. Thousand Springs Creek, which drains to the Great Salt Lake Desert, traverses the report area from west to east and cuts through the ridges. Topographic features of the area are summarized in table 2.

Geologic Units and Structural Features

The geologic units shown on plate 1 are an extremely generalized representation of the principal rock types in the area. The distribution and identification of the units are based principally on the geologic map of Elko County, compiled by Granger and others (1957), on aerial photograph interpretation, and on field checking at widely scattered points.

Four gross lithologic units are described: carbonate rocks, noncarbonate rocks, and older and younger alluvium. This division is based largely on hydrologic properties.

Carbonate rocks are of Paleozoic age, ranging from Cambrian to Permian. This unit is chiefly limestone, but contains some dolomite. This unit also includes minor interbeds of noncarbonate rocks, such as shale and quartzite. Most of the mountain areas are underlain by these rocks; also most of the valley fill probably is underlain by them. Carbonate rocks, being susceptible to solution by ground water, commonly contain channelways through which ground water circulates. In many areas of eastern and southern Nevada, the carbonate rocks convey intervalley ground-water flow and supply water to large springs.

Much of the northern part of the HD Range and parts of the Goose Creek Hills are underlain by noncarbonate rocks. Other small outcrops of these rocks are shown on plate 1. The northern part of the HD Range is mostly Jurassic and Cretaceous granitic intrusive rocks (monzonite, granodiorite, and granite). The noncarbonate rocks in the Goose Creek Hills are mostly Tertiary volcanic rocks--rhyolite, andesite, basalt, and tuff. The noncarbonate rocks, as a group, generally have low permeability, and therefore generally transmit only small amounts of water.

Twenty-two logs of wells that penetrate consolidated or semiconsolidated rock have been inspected. Of this number, 11 describe the penetration of carbonate rocks, mostly limestone.

Table 2.--General topographic features

Segments (in downstream order)	Area (square miles)			Adjoining mountain altitude (feet)	Flood-plain altitude (feet)	Approximate relief (feet)	Altitude of alluvium-consolidated rock contact (feet)
	Consolidated rock	Alluvium	Total				
Herrell Siding-Brush Creek area	70	90	160	7,000-8,600	5,500-6,000	2,600	5,800-6,800
Toano-Rock Spring area	220	400	620	7,000-8,800	5,250-5,800	3,500	5,300-6,800
Rocky Butte area	120	70	190	7,000-7,800	5,000-5,200	2,800	5,200-6,400
Montello-Crittenden Creek area	280	190	470	7,000-8,300	4,800-5,400	3,400	4,900-6,000

Six refer to sandstone; the remainder describe various types of "rock." Only one of the wells (39/68-1c; pl. 1) is more than a mile or two from outcrops of consolidated rock similar to those encountered in drilling. The driller's log of this well (table 20), refers to hard, blue limestone at a depth of 295 feet. All consolidated rocks, because of their topographic position as mountains and because of their unknown depth and distribution beneath the valley fill, presently are not considered an economic source of water, except where ground water discharges from them as springs.

Older alluvium is debris derived from adjacent mountains during Cenozoic time. It is of two types:

(1) Tertiary lake deposits of clay, silt, sand, and gravel. They include poorly sorted, moderately to poorly consolidated beds of limestone and shale fragments, forming conglomerate and fanglomerate of moderate to low permeability. The unit includes the Humboldt Formation (Sharp, 1939) and associated strata of Miocene and Pliocene age.

(2) Unconsolidated and poorly consolidated silt, sand, and gravel underlying alluvial fans and valley lowlands. These deposits are generally younger than the Tertiary lake deposits described above and contain some reworked rock fragments derived by erosion mainly from older lake deposits. They are moderately permeable.

The younger alluvium, which is a thin flood-plain deposit along the principal drainageways, is mainly moderately well-sorted, unconsolidated sand and gravel of Quaternary age, and has moderate to high permeability. This material is a good source of ground water where it has accumulated to a thickness of several tens of feet and is saturated. The younger alluvium is derived principally from the erosion and reworking of older alluvium.

The older and younger alluvium together constitute the valley-fill reservoir, the principal source of well water.

Many faults cut the consolidated rocks and alluvium in Thousand Springs Valley. Most of the faults shown on plate 1 are marginal to the mountains, and they generally have a north-trending orientation parallel to the major structural trends of the area. Two prominent fault groups are shown: One on the eastern flank of HD Range and the other on the eastern flank of the Gamble Range.

Climate

Winters are long with moderate to light snow on both the valley floors and the mountains. The summers are short, with warm daytime temperatures and cool nights. Little precipitation occurs in the summer, except for occasional thunderstorms.

Precipitation data have been recorded at seven stations in or near the project area and are summarized in table 3. Two of the stations, Montello and Wilkins (at Thousand Springs Trading Post), are in the project area (fig. 2). Most of the stations have not been in operation for as much as 20 years; therefore, no general long-term variations can be identified. However, data for stations at Montello and Wells, which have long-term records, indicate that above-normal precipitation occurred during the periods 1903-7, 1943-49, and 1960-65, and droughts occurred in the periods 1877-83 and 1910-35.

Seasonal variations in precipitation have been great at Grouse Creek but less at Wells and Montello, as shown in figure 3. The average precipitation at Wells and Montello during July through September was similar in total amount. Both stations are on valley floors.

For the report area, the average growing season, based on a killing frost at a temperature of 28°F, is summarized in table 4. Houston (1950) states that the average growing season for Montello is 117 days; the reported average growing season at Tecoma is 97 days. Variations of as much as 30 to 50 days can be anticipated from year to year, as suggested by data in table 3.

Table 3.--Summary of precipitation

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

Station	Location[1]	Period of record (years)	Altitude (feet)	Average annual precipitation (inches)
Contact	25 mi. N. of Thousand Springs Trading Post	1948-66	5,365	a 9.15
Gibbs Ranch	23 mi. W. of Herrell Siding	1953-66	6,000	b 8.86
Grouse Creek	15 mi. N. of Carney Siding	1960-66	5,050	c 11.07
Montello[2]	At Montello	1877-1966	4,877	5.82
Pequop	8 mi. SW of Cobre	1948-66	6,400	a 10.21
Wells	25 mi. SW of Thousand Springs Trading Post	1870-1915, 1936-62	5,631	9.62
Wilkins	At Thousand Springs Trading Post	1948-66	5,640	a 10.20

1. Location numbers: Contact, 45/64-17; Gibbs Ranch, 42/60-5d; Grouse Creek, (Utah) 10/18-30d; Pequop, 37/66-29; and Wells, 37/62-4. Figure 2 shows locations of most of these stations.

2. Station was 7 miles northeast at Tecoma (altitude, 4,812 feet) from 1877 to 1921.

a-c. Based on long-term records for Montello and Wells, recorded precipitation for these stations is larger than would be expected for the long term. Long-term average probably would be less by:
(a) about 15 percent, (b) about 20 percent, (c) about 35 percent.

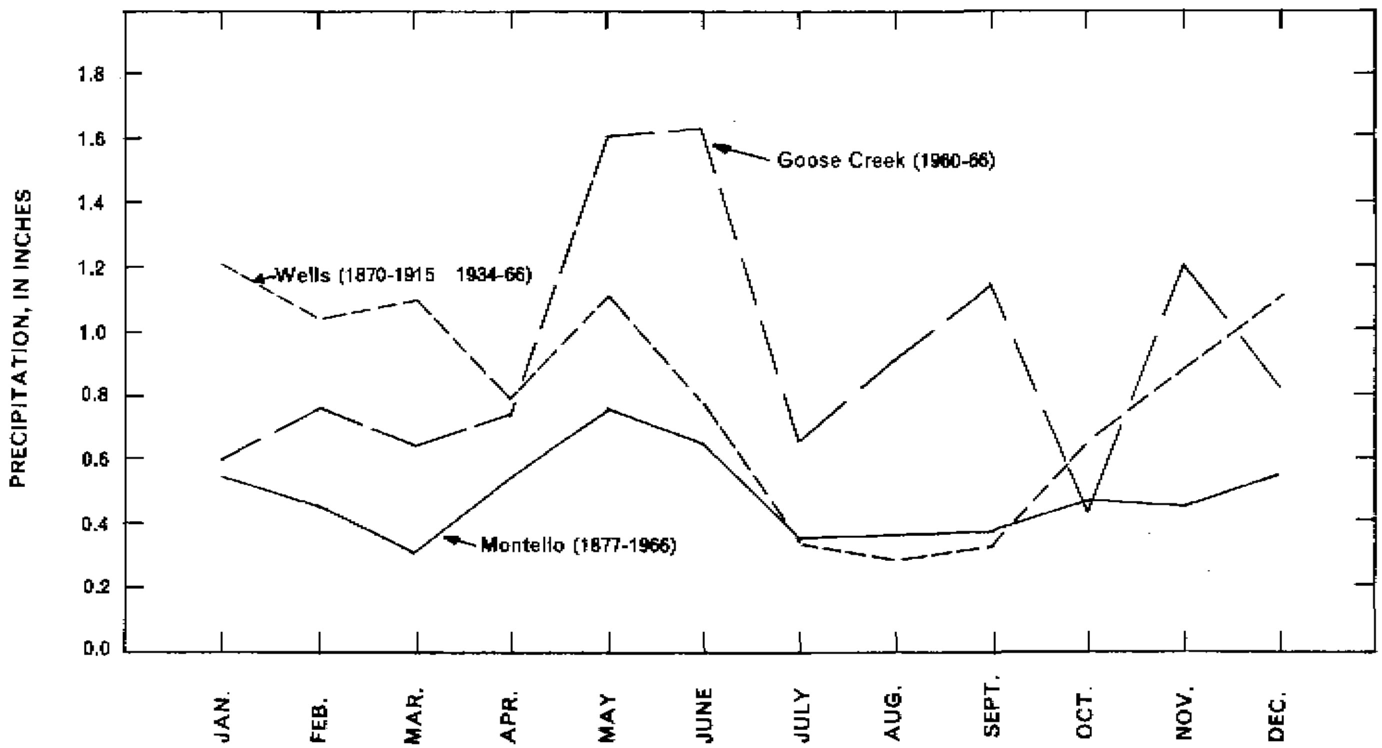

Figure 3.—Average monthly distribution of precipitation

Table 4.--Length of growing season between killing frosts

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

Station[1]	Period of record	Minimum (days) 32°F	Minimum (days) 28°F	Minimum (days) 24°F	Maximum (days) 32°F	Maximum (days) 28°F	Maximum (days) 24°F	Average (days) 32°F	Average (days) 28°F	Average (days) 24°F
Contact	1949-66	63	91	108	137	182	211	91	121	146
Gibbs Ranch	1954-66	40	57	63	96	109	139	60	79	117
Grouse Creek	1960-63	78	114	116	152	190	191	106	141	159

1. See table 3 for station locations.

VALLEY-FILL RESERVOIRS

General Features

The older and younger alluvium of the four hydrologic segments form valley-fill reservoirs, that contain the principal ground-water supply. The greatest thickness of alluvium encountered in well drilling was 600 feet in well 40/67-3d. No consolidated rocks were encountered in this well; therefore, the maximum thickness of alluvium at this site is not known. Fourteen other drillers' logs indicate an alluvial thickness of 400 feet or more; these wells are scattered and in no segment do they penetrate the entire thickness of alluvium.

External hydraulic boundaries of the reservoirs are formed by the consolidated rocks (pl. 1); all of which are permeable to varying degrees. The carbonate rocks may contribute recharge to the valley-fill reservoirs; locally these rocks may convey ground water from valley-fill reservoirs by subsurface flow to adjacent areas of natural discharge. Recharge boundaries are formed by creeks, where they flow across alluvial areas.

The principal internal hydraulic boundaries are the faults cutting the valley-fill reservoirs and subsurface lithologic changes, such as from unconsolidated to semiconsolidated valley fill. Some faults are shown on plate 1. Many more probably are present but have not been identified. The effectiveness of the boundaries cannot be evaluated until much additional information is available or until substantial ground-water development has occurred.

The transmissibilities of the valley-fill reservoirs in Thousand Springs Valley have not been determined directly. However, a few widely scattered large-diameter wells reportedly have specific capacities ranging from 3 to about 200 gpm (gallons per minute) per foot of drawdown, as determined from drillers' records (table 20). These values suggest coefficients of transmissibility ranging from less than 10,000 to more than 200,000 gpd (gallons per day) per foot, based on a form of Thiem's (1906) formula. The large specific-capacity values for wells in Montello Valley indicate large coefficients of transmissibility; for example, data for wells 40/69-16c and 40/69-23d indicate values of about 200,000 gpd per foot.

Most of the drillers' well records indicate that the main aquifers beneath the flood plain of Thousand Springs Creek are generally within 150 feet of the surface, even though most of the wells are more than 200 feet deep and many are in the 300- to 600-foot range.

The valley fill is composed of lenticular beds comprising gravel, sand, silt, and clay. Under long-term pumping stress, all these deposits would drain. The specific yield, as estimated from well logs (table 20), may average about 10 percent.

Ground-Water Flow

Ground water flows from areas of recharge to areas of discharge. In each segment of Thousand Springs Valley, the ground water in general flows from the mountains and upland alluvial areas (fig. 2), which are the principal recharge areas, toward the flood plain of Thousand Springs Creek, where much of it is discharged by phreatophytes. Beneath the flood plain, ground water flows in the direction of surface drainage, and some of the water flows from one segment to the next. The quantity of ground water that flows through alluvium in consolidated-rock narrows connecting the segments depends on width, transmissibility of the alluvial material, and the hydraulic gradient. At the narrows near Wine Cup and Eccles Ranches and between Eighteen and Twelve Mile Ranches (pl. 1), where the cross-sectional area of alluvium is restricted, ground water commonly rises to the surface and flows in the channel of Thousand Springs Creek. Downstream from the narrows, where the cross-sectional area is greater, the water commonly returns to the subsurface.

Locally, carbonate rocks probably transmit moderately large quantities of ground water from upstream to downstream parts of the area. This underflow seems to move principally in the direction of surface-water flow. The water enters the carbonate-rock system either in the mountains or from the overlying lowland alluvium, and it discharges at springs on the flanks of the mountains or rises along the flood plain of Thousand Springs Creek, principally in Montello Valley. Flow through carbonate rocks will be discussed further in the section, "Water Budget."

INFLOW TO THE VALLEY-FILL RESERVOIRS

Inflow to the valley-fill reservoirs is estimated by reconnaissance techniques developed by the Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources. The components of inflow to the valley-fill reservoirs, surface-water runoff and streamflow and ground-water underflow through alluvium and carbonate rocks, are summarized in table 15, which shows that the estimated average total inflow is 35,000 acre-feet per year.

Surface Water

By D. O. Moore

Runoff

During April, May, and June, rapid snowmelt and spring rains produce maximum seasonal streamflow. During such periods, flow occurs in most of the larger stream channels. During drier periods, flow in Thousand Springs Creek commonly is limited to: (1) the area west of Five Mile Draw, (2) in the narrows south-east of Eccles Ranch, (3) between Twenty-One Mile and Eighteen Mile Ranches, and (4) southeast of Warm Springs in T. 40 N., Rs. 69 and 70 E. Perennial flow occurs from springs in the southern part of T. 40 N., R. 64 E., to Brush Creek, from Rock Spring to Rock Spring Creek, and from Crittenden Spring to Crittenden Creek (tables 5 and 6). The least amount of streamflow generally is during August, September, and October.

Streamflow of Thousand Springs Creek at site 43/67-31d (pl. 1) was gaged during 1911-13 (U.S. Geological Survey, 1960, p. 260). These data are summarized in table 7. The associated current-meter measurements at this station for the same period are listed in table 5, together with more recent streamflow data obtained from the State Engineer's Office. Table 6 lists the streamflow data collected in 1966-67 specifically for this report to identify the distribution of flow at the time of the field work; the measuring sites are shown on plate 1.

The volume of runoff that reaches the lowlands cannot be computed by the usual methods because of the minimum streamflow data for the area. However, estimates can be made based on the development of runoff-altitude relations by a method described by Riggs and Moore (1965). Adjustments of these general relations can be made for the effects of geology, vegetation, and land slope by use of miscellaneous streamflow measurements and by measurement of channel geometry (D. O. Moore, paper in press, 1968). Table 8 shows the estimated average annual runoff that

Table 5.--Streamflow measurements prior to 1966[1/]

Stream	Location	Date	Discharge (cfs)	Stream	Location	Date	Discharge (cfs)
Thousand	At U.S. 93,	2-24-51	9.74	Thousand	Near Lower	11- 1-10	0.52
Springs	41/64-20d	3-21-51	35.2	Springs	HD (Eccles)		
Creek		3-27-51	20.0	Creek	Ranch,	3- 3-11	72.8
		4- 2-51	25.6		43/67-31d	3-26-11	65.3
		4- 9-51	56.5				49.6
		4-16-51	52.5			3-27-11	31.7
		4-23-51	44.5				41.8
		5- 3-51	30.1			5- 2-11	24.1
		5-10-51	35.1				21.9
		5-16-51	23.5				
		5-24-51	23.6			3-26-12	5.49
		5-31-51	16.8			3-27-12	5.25
		6- 8-51	9.20			3-28-12	8.08
							7.41
		4-23-53	4.85				
		4- 9-54	4.60			7-18-13	.79
						9-26-13	2.24
Brush	6 miles	4- 9-51	2.01				
Creek	SE of	4-16-51	2.57			4-23-14	66.1
	Wine Cup	4-23-51	2.37				
	Ranch,	5- 3-51	2.09			3-21-51	22.1
	40/64-21d	5-10-51	1.57			3-27-51	21.3
		5-16-51	.88			4- 2-51	26.4
						4- 9-51	32.2
Unnamed	About 6	4- 2-51	1.58			4-16-51	28.2
tributary	miles SE	4- 9-51	3.08			4-23-51	30.3
to Brush	of Wine Cup	4-16-51	1.55			5- 3-51	29.4
Creek	Ranch,	4-23-51	.74			5-10-51	21.2
	40/69-22b	5- 3-51	1.29			5-16-51	22.4
		5-10-51	.80			5-24-51	13.8
		5-16-51	.96			5-31-51	6.18
		5-24-51	.90			6- 8-51	1.33
Brush	About 1	4-11-51	1.89	Rock	Near	3-21-51	3.36
Creek	mile west	4-16-51	2.52	Creek	Eccles	4- 9-51	2.16
	of Wine	4-23-51	1.11		Ranch at	4-16-51	3.44
	Cup Ranch,	5- 3-51	2.25		bridge,	4-23-51	1.72
	41/64-35b	5-10-51	2.01		43/67-30c	5- 3-51	2.75
		5-16-51	1.02			5-10-51	2.89
						5-16-51	2.90
						5-24-51	2.87
						5-31-51	2.32

Table 5.--Continued

Stream	Location	Date	Discharge (cfs)	Stream	Location	Date	Discharge (cfs)
Thousand Springs Creek	Between 18-Mile and 12-Mile Ranches, 42/68-35a	During 1951, channel apparently carried no flow. Observations made weekly.		Crittenden Creek	About 1 mile north of 12-Mile Ranch, 42/69-31d	3- 2-51	5.63
						3-28-51	3.23
						4- 3-51	3.21
						4-10-51	3.11
						4-17-51	3.05
						4-24-51	3.06
Crittenden Creek	About 2.5 miles north of 12-Mile Ranch 42/69-30a	3-28-51	3.56			5- 4-51	3.29
		4- 3-51	3.62				
		4-10-51	3.94	Thousand Springs Creek	About 500 feet north of Gamble Ranch, above diversion, 40/69-8a	3-22-51	.78
		4-17-51	3.55			3-28-51	1.03
		4-24-51	3.77			4- 3-51	.91
		5- 4-51	4.11			4-10-51	.85
		5-11-51	3.74			4-17-51	.82
		5-17-51	3.71			4-24-51	.99
		5-25-51	3.83			5- 4-51	.80
		6- 8-51	3.56			5-25-51	.75
				Warm Spring	About 2.5 miles SE of Gamble Ranch, 40/69-14b	3-22-51	.10

1. Most of the data are from the files of the State Engineer's Office, Elko; measurements in cfs (cubic feet per second).

Table 6.--Estimates of streamflow, 1966-67

Map no.[1]	Site	Location Township	Location Range	Date	Discharge[2] (cfs)
1	Tributary to Thousand Springs Creek	41 N.	62 E.	10-21-66	(2.0)
2	Do.	41 N.	63 E.	10-21-66	(2.4)
3	Thousand Springs Creek near Herrell Siding	41 N.	63 E.	10-21-66	(.2)
4	Thousand Springs Creek near Wilkins	41 N.	63 E.	10-21-66 6-19-67	(2.8) .5
5	Thousand Springs Creek at U.S. 93	41 N.	64 E.	6-20-67	7.5
6	Brush Creek	41 N.	64 E.	10-22-66	0
7	Thousand Springs Creek at Wine Cup Ranch	41 N.	65 E.	6-16-67	(1.8)
8	Thousand Springs Creek near Wine Cup Ranch	41 N.	65 E.	6-20-67	2
9	Toano Draw	40 N.	65 E.	10-22-66	0
10	Tributary to Thousand Springs Creek	42 N.	66 E.	6-20-67	0
11	Thousand Springs Creek near Eccles Ranch	42 N.	66 E.	6-20-67	.3
12	Tributary to Thousand Springs Creek	42 N.	66 E.	10-22-66	0
13	Burnt Creek	42 N.	66 E.	10-22-66 6-20-67	0 0
14	Corral Canyon	43 N.	66 E.	10-22-66	0
15	Rock Spring Creek	44 N.	67 E.	10-22-66	(.4)
16	Do.	44 N.	66 E.	10-22-66	(.5)
17	Texas Spring Canyon	44 N.	66 E.	10-22-66	0
18	Do.	44 N.	67 E.	6-21-67	0
19	Bell Canyon	43 N.	67 E.	6-21-67	0
20	Rock Spring Creek	43 N.	67 E.	10-22-66	0

Table 6.--Continued

Map no.[1/]	Site	Township		Date	Discharge[2/] (cfs)
		Township	Range		
21	Rock Spring Creek near Eccles Ranch	43 N.	67 E.	6-20-67	0.3
22	Tributary to Thousand Springs Creek	43 N.	67 E.	10-22-66	0
23	Thousand Springs Creek at Dam	42 N.	67 E.	6-21-67	0
24	Tributary to Thousand Springs Creek	42 N.	67 E.	10-22-66	0
25	Thousand Springs Creek below 21-Mile Ranch	42 N.	68 E.	6-15-67 6-21-67	(2.4) 3.0
26	Tributary to Thousand Springs Creek	42 N.	68 E.	10-22-66	0
27	Thousand Springs Creek at 12-Mile Ranch	41 N.	68 E.	6-15-67	.05
28	Granite Creek above reservoir	44 N.	69 E.	10-23-66 6-21-67	0 0
29	Granite Creek above Mill Creek Reservoir	43 N.	69 E.	6-21-67	0
30	Crittenden Creek below Mill Creek Reservoir	43 N.	69 E.	6-21-67	.1
31	Crittenden Creek above Crittenden Ranch	42 N.	69 E.	6-21-67	0
32	Mill Canyon	42 N.	69 E.	10-23-66	0
33	Crittenden Creek below spring	42 N.	69 E.	10-23-66	(2.6)
34	Crittenden Creek below reservoir	42 N.	69 E.	6-21-67	0
35	Crittenden Creek near 12-Mile Ranch	41 N.	69 E.	6-21-67	0
36	Thousand Springs Creek below 12-Mile Ranch	41 N.	69 E.	10-23-66 6-21-67	0 0
37	Thousand Springs Creek at Gamble Ranch	40 N.	69 E.	6-21-67	1.5
38	Thousand Springs Creek below Gamble Ranch	40 N.	69 E.	10-23-66 6-15-67	(.20) (.58)

Table 6.--Continued

Map no.[1/]	Site	Location Township	Location Range	Date	Discharge[2/] (cfs)
39	Tributary to Thousand Springs Creek	40 N.	70 E.	6-15-67	(0.20)
40	Thousand Springs Creek below Dake Reservoir	40 N.	70 E.	6-22-67	.3

1. Map number corresponds to the measuring site number shown on plate 1.

2. Numbers in parenthesis were measured with a flow meter; others are estimated.

Table 7.--Monthly mean discharge at gaging station on Thousand Springs Creek near Tecoma (location; 43/67-31d)

Year	Monthly discharge, in acre-feet											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1911	3,320	2,620	6,820	1,710	1,130	96	138	0	0	0	0	0
1912	--	--	646	1,390	2,990	1,270	152	152	58	446	515	--
1913	--	--	--	1,680	904	934	200	186	228	531	702	492

reaches the lowlands in each hydrologic segment of Thousand Springs Valley. The most productive area of runoff, considering its size, is the Herrell Siding-Brush Creek area.

Stream Inflow

Thousand Springs Creek traverses the area from west to east, cutting through the mountains that divide the area into four hydrologic segments. The estimated average annual flow between segments was computed using the channel-geometry method. Streamflow between segments is summarized in table 9.

George Hardman (oral commun.) reports that during the period 1900-20 tremendous floods passed through the channels near Montello. It is probable that such large flows of water was in part intersegment flow and much of this water probably flowed from the report area into the Great Salt Lake Desert.

Ground Water

Recharge from Precipitation

The precipitation pattern in Nevada is related principally to the topography; stations at the highest altitudes generally receive more precipitation than those at lower altitudes. However, this relation may be considerably modified by local conditions. The alluvial areas of Thousand Springs Valley probably receive an average of 5 to 8 inches of precipitation per year. The highest mountain areas may have an average annual precipitation of 15 inches or more. The estimated average annual precipitation for the hydrologic segments is computed in table 10. The data in table 3 suggest that the estimates in table 10 may be somewhat low.

On the valley floors, where the amount of precipitation is small, little of the precipitation directly infiltrates into the ground-water reservoirs. The greater amounts of precipitation in the mountains provide most of the recharge; this water reaches the ground-water reservoirs by seepage loss from streams, ditches, and fields on the alluvial areas and by underflow from the consolidated rocks. Some of the precipitation is evaporated before infiltration, but most of it adds to soil moisture at shallow depths.

A method described by Eakin and others (1951, p. 79-81) is used to estimate recharge in this report. The method assumes that a percentage of the average annual precipitation recharges the ground-water reservoirs. Hardman (1965) showed that in gross aspect the average annual precipitation in Nevada

Table 8.--Estimated average annual runoff

Hydrologic segment	Runoff area (acres)	Percentage of total runoff area	Estimated average annual runoff (acre-feet)	Percentage of total runoff
Herrell Siding-Brush Creek area	100,000	12	8,000	23
Toano-Rock Spring area	390,000	45	13,000	37
Rocky Butte area	120,000	14	4,000	11
Montello-Crittenden Creek area	250,000	29	10,000	29
Total (rounded)	870,000	100	35,000	100

Table 9.--Estimated average annual streamflow between hydrologic segments

Outflow from	Inflow to	Location	Estimated average annual streamflow[1] (acre-feet)
Herrell Siding-Brush Creek area	Toano-Rock Spring area	At Wine Cup Ranch	5,000
Toano-Rock Spring area	Rocky Butte area	At narrows east of Eccles Ranch	3,500
Rocky Butte area	Montello-Crittenden Creek area	At narrows west of Twelve Mile Ranch	1,200
Montello-Crittenden Creek area	Great Salt Lake Desert	At State line	a 800

1. Includes estimates of flow produced by rising ground water, as listed in table 12.

a. Surface-water outflow from Thousand Springs Valley.

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

Precipitation zone (feet)	Area (acres)	Estimated precipitation: Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge[1/]: Percentage of precipitation	Acre-feet
HERRELL SIDING-BRUSH CREEK AREA						
>8,000	700	>15	1.5	1,200	15	180
7,000-8,000	6,800	12-15	1.1	7,500	7	520
6,000-7,000	56,200	8-12	.8	45,000	3	1,400
<6,000	37,300	<8	.5	19,000	--	minor
Subtotal (rounded)	101,000			72,000		2,000
TOANO-ROCK SPRING AREA						
>8,000	660	>15	1.5	990	15	150
7,000-8,000	17,600	12-15	1.1	19,000	7	1,300
6,000-7,000	155,000	8-12	.8	120,000	3	3,600
<6,000	221,000	<8	.5	110,000	--	minor
Subtotal (rounded)	394,000			250,000		5,000
ROCKY BUTTE AREA						
>7,000	4,400	>12	1.1	4,800	7	340
6,000-7,000	38,400	8-12	.8	31,000	3	930
<6,000	77,600	<8	.5	39,000	--	minor
Subtotal (rounded)	120,000			75,000		1,300
MONTELLO-CRITTENDEN CREEK AREA						
>8,000	120	>15	1.5	180	15	30
7,000-8,000	16,500	12-15	1.1	18,000	7	1,300
6,000-7,000	95,900	8-12	.8	77,000	3	2,300
<6,000	186,000	<8	.5	93,000	--	minor
Subtotal (rounded)	299,000			190,000		4,000
TOTAL (rounded)	914,000			600,000		12,000

Table 10.--continued

Precipitation zone (feet)	Area (acres)	Estimated precipitation Range (inches)	Average (feet)	Average (acre-feet)	Estimated recharge[1/] Percentage of precipitation	Acre-feet
		NEVADA PART OF GROUSE CREEK VALLEY				
>7,000	1,900	>12	1.1	2,100	7	150
6,000-7,000	21,800	8-12	.8	17,000	3	510
<6,000	9,600	<8	.	4,800	--	minor
TOTAL (rounded)	33,300			24,000		a 700

1. As indicated in text, estimates probably are somewhat conservative.

a. All flows to Utah where it is discharged.

is related closely to altitude and that it can be estimated with a reasonable degree of accuracy by assigning precipitation rates to various altitude zones.

Table 10 shows the values used to estimate the volumes of precipitation and ground-water recharge. The estimated recharge for the hydrologic segments is only 2 to 3 percent of the estimated total precipitation. For many areas of Nevada, the estimated recharge averages about 5 percent of the total precipitation. This fact plus the higher precipitation values shown in table 3 and the water budget in table 15 suggest that the recharge estimates are somewhat low. For these reasons the recharge estimates are not used in the water budget (table 15).

Also included in table 10 is an estimate of recharge for the Nevada part of Grouse Creek Valley between Thousand Springs Valley and the Utah border. This 52-square-mile area is briefly evaluated principally to complete the areal coverage of Nevada. Because the area is mountainous, only stock and domestic wells might be drilled there.

Subsurface Inflow

Subsurface flow between hydrologic segments of Thousand Springs Valley is of two types: flow through consolidated rocks and through alluvium. The available data do not indicate inflow to the report area from beyond its boundaries. Table 11 summarizes the subsurface flow through younger and older alluvium and between segments. The inflow to one segment is also the outflow from the adjacent upstream segment.

Montello Valley and Pilot Creek Valley (pl. 1) to the south are separated by a low alluvial divide through which ground water might flow. Water-level altitudes were determined by altimeter in three wells, 39/69-17b, 39/69-32c, and 38/69-26c, adjacent to the divide. The levels in wells 39/69-32c and 38/69-26c, on the north side, were computed to be about 8 feet lower than that in well 39/69-17b, south of the divide. As this difference is within the limit of error of the altimeter, it is assumed that little or no gradient exists across the alluvial divide and hence that probably no appreciable quantity of water flows into or out of Montello Valley through the alluvium.

Table 11.--Estimated average annual subsurface flow through alluvium between hydrologic segments

Outflow from	Inflow to	Location	Estimated flow width (miles) (W)	Estimated hydraulic gradient[1] (feet per mile) (I)	Estimated coefficient of transmissibility (gpd per foot) (T)	Estimated inflow[2] (acre-feet per year) (Q)
Herrell Siding-Brush Creek area	Toano-Rock Spring area	At Wine Cup Ranch	1	30	20,000	700
Toano-Rock Springs area	Rocky Butte area	At narrows east of Eccles Ranch	.05	20	10,000	10
Rocky Butte area	Montello-Crittenden Creek area	At narrows west of Twelve Mile Ranch	.1	30	10,000	50
Montello-Crittenden Creek area	Great Salt Lake Desert	At State line	2	40	20,000	a 1,800

1. Gradients are assumed to be about equal to the land-surface gradient.

2. Inflow is computed by a form of Darcy's law, $Q = 0.00112\ TIW$, in which the factor 0.00112 converts gallons per day to acre-feet per year.

a. Outflow from Thousand Springs Valley is also the outflow from the Montello-Crittenden Creek area.

Rising Ground Water between Segments

As described in the "Ground-water flow" section, ground water rises to the surface and flows in Thousand Springs Creek in the flood-plain constrictions between the hydrologic segments. This flow plus snowmelt and storm runoff constitute the total streamflow between segments, as listed in table 9. During the late summer and fall, most of the time the flow through the constrictions consists solely of rising ground water. Data in tables 5 - 7 were used to estimate these quantities, which are listed in table 12.

Imported Water

Flow from Cove Spring, 37/70-3b, is transmitted by pipeline to Montello, where the water is used by the community and by the Southern Pacific Railroad. Cove Spring is about 5 miles south of the report-area boundary in Pilot Creek Valley (pl. 1). Neither the springflow nor the flow in the pipeline have been measured. The net annual importation of water is estimated to be about half the estimated use at Montello, or about 50 acre-feet. Of this amount, some is assumed to recharge the ground-water reservoir by percolation from septic tanks. The rest is either consumed or discharged as soil moisture.

Table 12.--Estimated average annual rising ground water between hydrologic segments

Outflow from	Inflow to	Estimated flow (acre-feet per year)
Herrell Siding-Brush Creek area	Toano-Rock Spring area	500
Toano-Rock Spring area	Rocky Butte area	1,000
Rocky Butte area	Montello-Crittenden Creek area	minor
Montello-Crittenden Creek area	Great Salt Lake Desert	a 100

a. Outflow from Thousand Springs Valley.

OUTFLOW FROM THE VALLEY-FILL RESERVOIRS

The components of outflow are streamflow, irrigation use, evapotranspiration, subsurface outflow through alluvium and possibly through carbonate rocks, rising ground water, and pumpage from wells. The subsurface flow and rising ground water between segments have already been estimated (tables 9 and 12). The components of outflow from the segments of the report area are summarized in table 15, which shows that the estimated average natural outflow is 26,000 acre-feet per year.

Surface Water

Irrigation

Water is diverted from Thousand Springs and Crittenden Creeks for irrigation on their flood plains. Most of the diverted flow of Thousand Springs Creek west of Eccles Ranch is from snowmelt. East of the ranch, springs and seeps supply most of the diverted flow. Most of the diverted flow of Crittenden Creek is from Crittenden Spring, 42/69-8b.

A large dam was built in 1919 on Thousand Springs Creek at 42/67-15a. When the reservoir is full it reportedly stores 9,000 acre-feet of water--a 2-year supply for irrigation between the dam and the State line. The reservoir was full in 1960, had 12 feet of water in it in 1964, only a little in 1966, and was dry during the other years since 1960.

Consumptive-use rates for meadow, pasture, and alfalfa are based on findings of Houston (1950, p. 11), and probably average about 1.5 feet per season for two cuttings of hay. Because of ditches losses and the need for leaching, more water has to be diverted than is consumed by the crops. Water percolates to the water table from ditches and fields, and some runs off to adjacent areas where it supports phreatophytes or evaporates. These losses associated with irrigation are not included in the estimates of water consumption by crops, but are included in estimates of evapotranspiration and stream and subsurface outflow. Table 13 summarizes the quantity of surface water consumed by crops; it also includes the supplemental use of ground water.

Stream Outflow

The outflow from Thousand Springs Valley is equal to the outflow from the Montello-Crittenden Creek area, or an estimated 800 acre-feet per year. Intersegment flow is summarized in table 9.

Table 13.--Estimated consumption of water by irrigated and subirrigated crops

[Water quantities in acre-feet per year except where otherwise identified]

Location	Area (acres)	Crop	Estimated average annual water consumption: Rate (acre-feet per acre)	Source: Surface water	Source: Ground water: Wells	Source: Ground water: Shallow water table[1]	Total
			HERRELL SIDING-BRUSH CREEK AREA				
Wine Cup Ranch	1,700	Meadow grass and alfalfa	1.5	1,500	300	800	2,600
			TOANO-ROCK SPRING AREA				
Wine Cup and Eccles Ranches	2,000	Mostly meadow grass	1.5	2,000	0	1,000	3,000
			ROCKY BUTTE AREA				
Eighteen Mile Ranch	400	Alfalfa	1.5	200	0	400	600
	400	Meadow grass	1	0	0	400	400
Subtotal	800			200	0	800	1,000
			MONTELLO-CRITTENDEN CREEK AREA				
Crittenden, Twelve Mile and Gamble Ranches	2,300	Meadow grass and alfalfa	1.5	1,000	1,000	1,400	3,400
	8,000	Meadow grass	1	0	0	8,000	8,000
Subtotal (rounded)	10,000			1,000	1,000	9,400	11,000
TOTAL (rounded)	15,000			4,700	1,300	12,000	18,000

1. Ground water supplied naturally by subirrigation.

Ground Water

Evapotranspiration

Ground water is discharged by evaporation from soil and transpiration by plants that root in shallow water-table areas. Plants that tap the ground-water reservoir are called phreatophytes. Plate 1 shows the areal distribution of most of the phreatophytes; they are limited to the flood plains of the larger streams and to the floor of Montello Valley. The principal types of phreatophytes are meadowgrass, alfalfa, saltgrass, greasewood, rabbitbrush, willow, and tules. In the mountains, other types, such as cottonwood and wildrose, grow but their acreage and discharge is relatively small. Tables 13 and 14 summarize the estimated evapotranspiration of ground water for beneficial phreatophytes, such as subirrigated alfalfa and grass, and for nonbeneficial phreatophytes, such as greasewood and rabbitbrush. Rates assigned are based on work done in other areas by Lee (1912), White (1932), Young and Blaney (1942), and Robinson (1965).

Irrigation by Wells

Eleven wells are pumped to irrigate crops. Two cuttings of grass and alfalfa hay usually are obtained from the cropland each year. Table 13 summarizes the net pumpage (quantity of water) consumed from irrigation wells. As explained under Surface Water, Irrigation, it is necessary to pump and apply more water to the fields than what is consumed by the crops. The pumping has not, as yet, salvaged any natural discharge; therefore all pumpage is from ground-water storage.

Springs

A few large springs are used for irrigation. At Twenty-One Mile Ranch, on the flood plain of Thousand Springs Creek, rising ground water contributes a large volume of flow to the creek. (See table 6, map no. 25 on pl. 1.) A lesser flow of rising ground water occurs at Gamble Ranch.

Gamble Ranch spring, 40/69-8b, reportedly has a flow of about 1 cfs (cubic foot per second). A pipeline carries part of the flow to buildings at the ranch; the remainder is used for irrigation during the growing season. Rock Spring, 44/67-16c, has a flow of about 0.4 cfs, and Crittenden Spring, 42/69-8b, yields about 2.6 c.f.s. Some of the flow from each spring seeps into the ground and supports phreatophytes or is diverted for irrigation. The net discharge of both is included in the phreatophyte discharge (table 14) and the irrigation estimates (table 13).

Table 14.--Estimated evapotranspiration of ground water by nonbeneficial phreatophytes

Hydrologic segment	Phreatophyte	Depth to water (feet)	Area (acres)	Ground cover (percent)	Probable average annual rate of ground-water use (feet)	Aproximate discharge (acre-feet per year)
Herrell Siding-Brush Creek area	Mostly rabbit-brush, grease-wood, and saltgrass	a 5-50	1,700	10-25	0.4	700
Toano-Rock Spring area	Mostly rabbit-brush, grease-wood, and saltgrass	5-50	3,200	10-20	.2	600
Rocky Butte area	Mostly rabbit-brush and greasewood	5-50	2,000	10-20	.2	400
Montello-Crittenden Creek area	Mostly grease-wood and rabbitbrush	5-50	20,000	10-20	.2	4,000
TOTAL (rounded)	--	--	27,000	--	--	5,700

a. In most of area, depth to water 5-15 feet.

The town of Montello obtains its water supply from two mountain springs, Cove Spring, 37/70-3b, and Montello Spring, 39/68-7a, as shown on plate 1. In Montello Valley, the use of spring water by the people of Montello, the Southern Pacific Railroad, and by ranchers probably is less than a hundred acre-feet per year. Because much of this quantity recharges the ground-water reservoir by percolation from septic tanks, the net consumption probably is about half this quantity, or less than 50 acre-feet per year. The remainder of the spring flow not entering these supply systems seeps to the water table, adds to soil moisture, and supports phreatophytes near the spring sites. These elements of discharge, except for Cove Spring which is outside the report area, are included in other discharge estimates.

Stock and Domestic Pumpage

Ground water is pumped from wells for domestic and stockwatering use in all four hydrologic segments. The net pumpage in each segment probably is less than 50 acre-feet per year. At Wine Cup Ranch, a well drilled near a fault produces hot water, 138°F, which is piped to the buildings. In addition, the usual cold-water supply is maintained.

WATER BUDGET

For long-term conditions, inflow to and outflow from a system are about equal, if there has been no net change in stored water in the system resulting from long-term climatic changes or diversions from storage due to development. Thus, the purpose of preparing a water budget is to compare the estimates of inflow and outflow for each segment, to determine the magnitude of the difference between estimates, and to select a value that may reasonably represent both the inflow and outflow. Table 15 shows the budget for Thousand Springs Valley; the imbalance in the budget is 9,000 acre-feet, or between one-third and one-fourth of the natural inflow or outflow.

In selecting a value to represent both inflow and outflow for each hydrologic segment and for Thousand Springs Valley, the average of the two estimates was used for the Herrell Siding-Brush Creek area, the Rocky Butte area, and the total for Thousand Springs Valley. Because large volumes of ground water may flow through carbonate rocks between the Toano-Rock Spring area and the Montello-Crittenden Creek area (partly beneath Rocky Butte area), the larger values of natural inflow and outflow in each area, respectively, were selected to be the reconnaissance approximation of both.

Using the selected values that represent both natural inflow and outflow for the Toano-Rock Spring area and the Montello-Crittenden Creek area, estimates for the flow through carbonate rocks between these segments can be computed. If most of the computed budget imbalance is due to this type of intersegment flow, computations indicate that the intersegment flow may be either about 12,000 or 6,000 acre-feet per year, depending on which imbalance value in table 15 is used. Because neither estimate is assumed to be more accurate than the other, the average of the two, or about 9,000 acre-feet, may be the amount of intersegment flow through carbonate rocks.

In table 15, the water-quality estimates listed for the entire area of Thousand Springs Valley (the right column) commonly are not the sum of the quantities of the hydrologic segments (the four left columns). For example, surface-water inflow to downstream segments from upstream segments of Thousand Springs Valley are not components of inflow to Thousand Springs Valley. The same is true for most other components of inflow.

Similar conditions prevail for components of outflow. Surface-water outflow from upstream hydrologic segments to downstream segments of Thousand Springs Valley are not components of outflow from Thousand Springs Valley. Only surface-water outflow

Table 15.--Preliminary water budget

[All estimates in acre-feet per year]

Budget elements	Herrell Siding-Brush Creek area	Toano-Rock Spring area	Rocky Butte area	Montello-Crittenden Creek area	Total for Thousand Springs Valley (rounded)
INFLOW					
Surface water:					
Runoff (table 8)	8,000	13,000	4,000	10,000	35,000
Inflow from upstream segment (table 9)	--	5,000	3,500	1,200	a 0
Subtotal (rounded)	8,000	18,000	7,500	11,000	35,000
Ground water:					
Underflow through alluvium (table 11)	0	700	10	<50	(a)
Underflow through carbonate rocks (p. 15 and 28)	--	--	--	Probably large	(d)
	--	700	10	Probably large	(a)
Imported water (p. 30)	--	--	--	50	50
TOTAL INFLOW (rounded): (1)	8,000	19,000	7,500	11,000	a 35,000
OUTFLOW					
Surface water:					
Outflow to downstream segment (table 9)	5,000	3,500	1,200	800	a 800
Irrigation (table 13)	1,500	2,000	200	1,000	4,700
Subtotal: (2)	6,500	5,500	1,400	1,800	a 5,500
Ground water:					
Evapotranspiration (table 14)	700	600	400	4,000	5,700
Underflow through alluvium (table 11)	700	10	<50	1,000	a 1,000
Underflow through carbonate rocks (p. 15 and 28)	--	Probably large	--	--	--
Subirrigation by a shallow water table (table 13)	800	1,000	800	9,400	12,000
Subtotal: (3)	2,200	>1,600	1,200	15,000	a 20,000
Pumpage[1]: (4)					
Irrigation (table 13)	300	0	0	1,000	1,300
Stock and domestic	<50	<50	<50	<50	<200

Table 15.--continued

Budget elements	Herrell Siding-Brush Creek area	Toano-Rock Spring area	Rocky Butte area	Montello-Crittenden Creek area	Total for Thousand Springs Valley (rounded)
OUTFLOW continued:					
NEAR-NATURAL OUTFLOW (rounded): (2) + (3) = (5)	8,700	7,100	2,600	17,000	a 26,000
TOTAL OUTFLOW (rounded) (4) + (5)	9,000	7,100	2,600	18,000	a 27,000
IMBALANCE[2/]: (1) - (5)	- 700	12,000	4,000	- 6,000	a 9,000
RECONNAISSANCE VALUE SELECTED FOR NATURAL INFLOW AND OUTFLOW	8,000	19,000	5,000	17,000	30,000

1. Most pumpage probably is from storage and is not included in total natural outflow. Quantity is not pumpage. See text.

2. For near-natural conditions. Much of the imbalance is due to soil-moisture losses and possible flow through carbonate rocks, which were not estimated, and errors in assumptions and estimates of the larger budget elements.

a. Not sum of hydrologic elements at left.

from the Montello-Crittenden Creek area is surface-water outflow from Thousand Springs Valley. The same is true for most other components of outflow.

CHEMICAL QUALITY OF WATER

Nineteen samples of well, spring, and creek water were collected and analyzed to make a generalized appraisal of the suitability of ground and surface water for agricultural and domestic use, and to help define the relation of quality to the hydrologic system. These analyses are listed in table 16.

Suitability for Agricultural Use

The streamflow resulting from snowmelt during the spring of the year is low in dissolved material, and is excellent for irrigation in all segments of Thousand Springs Valley. Sampled well and surface waters were generally suitable for irrigation in the three western segments. In Montello Valley, several samples had high salinity hazards (table 16). The hot-water wells at Wine Cup Ranch, 41/64-25dl, also yield water with a high salinity hazard. Because of the small number of samples and the limitations of the chemical analyses, no specific conclusions have been drawn as to the overall suitability of water in any segment. Both better-quality and poorer-quality water may occur in each segment.

The only springflow sampled was from Crittenden Spring (42/69-8b). It was found suitable for irrigation in regard to the three quality factors listed in table 16.

Suitability for Domestic and Public-Supply Use

The U.S. Public Health Service (1962) formulated drinking-water standards which have been endorsed by the American Water Works Association as minimum standards for all public water supplies. These standards are used as a basis in evaluating the water samples in this report. However, water not meeting these standards may be suitable to many users. Chemical characteristics are evaluated only in relation to the data listed in table 16. Fluoride, iron, manganese, arsenic, and nitrate, which are among the important ions effecting the suitability of water for domestic use, were not determined. Bacteriological, physical, and radiological quality also affect the potability of water, but are not considered. If doubt exists as to the potability of the supply from a water system, contact the Nevada Department of Health and Welfare, Bureau of Environmental Health, Reno.

Table 16 lists water hardness, which is important to many domestic water users. The U.S. Geological Survey has adopted the following hardness rating:

Hardness range (ppm)	Rating	Remarks
0-60	Soft	Suitable for most uses without softening
61-120	Moderate	Usable except in some industrial applications. Softening profitable for laundries
121-180	Hard	Softening required by laundries and some other industries
> 180	Very hard	Softening desirable for most purposes

By this rating, 13 of the samples are very hard, 5 are hard, and 1 is moderately hard.

Of the constituents listed in table 16, the U.S. Public Health Service (1961, p. 7) recommends the following upper limits: chloride, 250 ppm (parts per million); sulfate, 250 ppm; and dissolved solids, 500 ppm. Specific conductance is a measure of dissolved-solids content. Generally, the dissolved-solids content, in parts per million, is about two-thirds the specific conductance, in micromhos per centimeter at 25°C (abbreviated "micromhos"). Therefore, samples having specific conductance of more than 750 micromhos exceed the recommended limit.

No sulfate values in table 16 exceed the 250-ppm limit, and only one chloride value (Thousand Springs Creek at 40/70-8d) is excessive. However, eight of the 19 samples exceeded a specific conductance of 750 micromhos. Of the eight, six (five well waters and one stream sample) were collected in the Montello-Crittenden Creek area.

Relation to the Hydrologic System

The water of best chemical quality generally has had a minimum contact with the rocks and soil. In the hydrogeologic environment of the report area, the surface water flowing in mountain streams and on the alluvial apron is generally low in dissolved-solids content. In contrast, surface water that ponds in marsh areas of Montello Valley tends to deteriorate in quality

Table 16.—Chemical analyses of water from selected sources

[Field-office analyses by the U.S. Geological Survey]

Location	Date of collection	Source type	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus Potassium (K)	Bicarbonate (HCO_3)	Chloride (Cl)	Sulfate (SO_4)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Salinity hazard	Alkalinity hazard	RSC	Water type	Rock source
				Parts per million (upper number) equivalents per million (lower number)										Some factors affecting irrigation quality[1]				
HERRELL SIDING-BRUSH CREEK AREA																		
41/64-20d	6-20-67	Thousand Springs Creek	--	38 1.90	14 1.18	17 0.75	190 3.11	5.0 0.14	28 0.58	154	0	317	8.2	Medium	Low	Safe	Calcium magnesium bicarbonate	--
-23d1[2]	6-21-67	Well	138	49 2.45	17 1.37	139 6.05	426 6.98	30 0.85	69 1.44	191	0	850	8.4	High	Low	Not suitable	Sodium bicarbonate	Carbonate rock
-34d	6-19-67	Well	49	54 2.69	20 1.63	17 0.73	258 4.23	9.8 0.28	26 0.54	216	5	425	8.2	Medium	Low	Safe	Calcium magnesium bicarbonate	Alluvium
TOANO-ROCK SPRING AREA																		
38/66-24d	6-22-67	Well	51	47 2.35	9.4 0.77	18 0.80	175 2.87	29 0.82	11 0.23	156	13	408	7.8	Medium	Low	Safe	Calcium bicarbonate	Alluvium
41/65-15a[2]	6-20-67	Thousand Springs Creek	--	58 2.89	26 2.14	73 3.19	340 5.57	24 0.68	66 1.37	252	0	654	8.5	Medium	Low	Safe	Mixed bicarbonate	—
42/66-8d[3]	6-20-67	do.	79	15 0.75	25 2.05	157 6.83	328 5.38	47 1.33	128 2.66	140	0	833	8.3	High	Medium	Not suitable	Sodium bicarbonate	—
43/67-31b	6-20-67	Rock Springs Creek	84	44 2.20	7.8 0.64	49 2.11	227 3.72	15 0.42	39 0.81	142	0	421	8.1	Medium	Low	Safe	Mixed bicarbonate	—
ROCKY BUTTE AREA																		
41/67-15d	6-23-67	Well	71	32 1.60	8.3 0.68	41 1.77	160 2.62	20 0.56	42 0.87	114	0	373	8.0	Medium	Low	Safe	do.	Alluvium
42/68-19b	6-21-67	Thousand Springs Creek	69	27 1.35	22 1.77	78 3.38	222 3.64	38 1.07	89 1.79	156	0	590	8.0	Medium	Low	Safe	do.	--
-35a	6-21-67	Twelve Mile Ranch Well	55	38 1.90	23 1.86	60 2.60	244 4.00	27 0.76	77 1.60	188	0	574	8.0	Medium	Low	Safe	do.	Alluvium
MONTELLO-CRITTENDEN CREEK AREA																		
40/69-16a[4]	6-21-67	Gamble Ranch Well no. 1	55	91 4.54	42 3.47	166 7.20	382 6.26	116 3.27	250 5.21	401	64	1,290	8.3	High	Low	Safe	Mixed	Alluvium
-16b1	6-21-67	Gamble Ranch Well no. 2	57	46 2.30	35 2.91	91 3.96	198 3.25	51 1.44	215 4.48	261	98	833	8.1	High	Low	Safe	do.	Alluvium
-16b2	6-21-67	Gamble Ranch Well no. 3	54	70 3.49	30 2.46	92 3.98	302 2.95	71 2.00	143 2.98	298	50	850	8.2	High	Low	Safe	do.	Alluvium
-16c	6-21-67	Gamble Ranch Well no. 4	76	74 3.69	27 2.26	93 4.05	278 4.56	117 3.30	103 2.14	298	70	885	8.2	High	Low	Safe	do.	Alluvium
-22b	6-21-67	Gamble Ranch Well no. 5	64	41 2.05	34 2.83	62 2.70	262 4.29	45 1.27	97 2.02	244	30	544	8.1	Medium	Low	Safe	Mixed bicarbonate	Alluvium
-22c	6-21-67	Gamble Ranch Well no. 6	63	54 2.69	34 2.82	110 4.78	192 3.15	121 3.41	179 3.73	276	118	923	8.0	High	Low	Safe	Mixed	Alluvium
-23d	6-21-67	Gamble Ranch Well no. 7	62	57 2.84	24 1.96	56 2.45	275 4.51	41 1.16	76 1.58	240	15	607	8.2	Medium	Low	Safe	Mixed bicarbonate	Alluvium
40/70-8d[4]	6-22-67	Thousand Springs Creek	82	47 2.35	62 5.08	286 12.4	414 6.79	313 8.83	181 3.77	372	9	1,770	8.3	High	Medium	Safe	Mixed	--
42/69-8b	6-21-67	Crittenden Spring	64	48 2.40	15 1.24	22 0.96	205 3.36	18 0.51	35 0.73	182	14	401	8.01	Medium	Low	Safe	Calcium magnesium bicarbonate	Alluvium

1. Descriptive terms are for water applied to good soils requiring little or no leaching and having favorable drainage characteristics. Factors described by U.S. Salinity Laboratory Staff (1954).
2. Carbonate (CO_3): 18 ppm, 0.60 epm.
3. Carbonate (CO_3): 7.9 ppm, 0.26 epm.
4. Carbonate (CO_3): 14 ppm, 0.47 epm.

because of concentration by evaporation and by solution of salts from the soil.

As ground water flows from the source areas to the discharge areas, it generally increases in dissolved solids. In discharge areas where water is evaporated or transpired by plants, much of the dissolved material is deposited in the soil or remains in the shallow ground water, increasing the mineral concentration of the water. Likewise, the small amount of outflow at the Utah State line is highly mineralized (table 16, Thousand Springs Creek at 40/70-8d). However, water of better quality may occur at greater depth beneath some discharge areas.

Shallow ground water in the alluvium generally has a temperature near the average annual air temperature of the area, which is approximately 50°F. Water temperatures appreciably higher than this may indicate high geothermal gradients, relatively deep water circulation, or faulting. Ground water occurring under such conditions may reach boiling. The highest temperature measured in the report area was 138°F, from Wine Cup Ranch well 41/64-25d1 (table 19). The well is near a fault.

THE AVAILABLE GROUND-WATER SUPPLY

Sources of Supply

The available ground-water supply of Thousand Springs Valley consists of two interrelated quantities: (1) the system yield, and (2) the transitional storage reserve, which are defined and estimated below.

System Yield

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

The estimates of system yield listed in table 17 are based on data listed in table 15 and the following limitations and assumptions: (1) virtually all the evapotranspiration of ground water can be salvaged by properly placed wells; (2) half the surface-water outflow and ground-water outflow through alluvium can be salvaged; (3) because the mechanics and location of ground-water outflow through carbonate rocks are not known, only a small part of this outflow is considered salvable in the Toano-Rock Spring area; and (4) diversions of streams and subirrigation by a shallow water table in 1967 represent salvage of water from the systems for beneficial use, and therefore are included. Because net pumpage in recent years may be derived largely from storage, it is not included as a part of the system yield; it probably represents a depletion of the transitional storage reserve.

In table 17 the system yield of Thousand Springs Valley is less than the sum of the yields of the hydrologic segments because of intersegment flow of water. Because water flows between the segments it could be utilized in several different segments. To determine the maximum amount of water usable in each segment this flowing water is included in each estimate, but obviously if all or part is utilized in one segment, that amount is no longer available in other segments.

Table 17.--Estimated system yield

[All quantities in acre-feet per year]

Hydrologic segment	Estimated system yield	Development and beneficial use, 1967 (table 15)
Herrell Siding-Brush Creek area	5,800	2,600
Toano-Rock Spring area	a 6,400	3,000
Rocky Butte area	2,000	1,000
Montello-Crittenden Creek area	16,000	11,000
Total for Thousand Springs Valley	b 24,000	b 18,000

a. Includes the salvage of about 1,000 acre-feet per year of underflow through carbonate rocks.

b. Sum of above quantities.

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 natural equilibrium conditions and new equilibrium conditions under the perennial-yield (also system-yield) concept of 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 non-equilibrium 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 water that is available in addition to the system yield, but on a once-only basis.

Most pertinent is the fact that no ground-water source can be developed without causing storage depletion. The magnitude of depletion varies directly with distance of development from any recharge and discharge boundaries in the ground-water system. Thousand Springs Valley has well-defined recharge boundaries where Thousand Springs Creek has perennial flow and where springs and seeps recharge the valley-fill reservoir. An area of evapotranspiration is an example of a well-defined discharge boundary.

To compute the transitional storage reserve of the hydrologic segments, several assumptions are made: (1) wells would be strategically situated in, near, and around areas of natural discharge so that these natural losses (subsurface and surface outflow and evapotranspiration losses) could be reduced or stopped with a minimum of water-level drawdown in pumped wells; (2) a perennial water level 50 feet below land surface would curtail virtually all evapotranspiration losses from ground water and substantially reduce surface-water and ground-water outflow; (3) over the long term, pumping would cause a moderately uniform depletion of storage throughout most of the valley fill (excluding semi-isolated tributary areas); (4) specific yield of the valley fill is 10 percent; (5) water levels are within the range of economic pmmping lift for the intended use; (6) development would have little or no effect on water stored in adjacent valleys or hydrologic segments; and (7) water is of suitable chemical quality for the intended use.

Table 18 presents the preliminary estimates of transitional storage reserve of Thousand Springs Valley, based on the above assumptions. For each segment, the estimated storage depletion is the product of the area beneath which depletion can be expected

Table 10.--Preliminary estimates of transitional storage reserve

[All quantities rounded]

Segment	Area of depletion (acres) (1)	Dewatered thickness (feet) (2)	Transitional storage reserve (acre-feet) (1) x (2) x 0.1
Herrell Siding-Brush Creek area	a 45,000	50	200,000
Toano-Rock Spring area	b 190,000	50	1,000,000
Rocky Butte area	c 15,000	50	80,000
Montello-Crittenden Creek area	110,000	50	600,000
Total (rounded)	360,000	--	2,000,000

a. Area does not include Tps. 40 and 41 N., R. 62 E. because saturated alluvial thickness probably is small.

b. Area does not include several small, isolated parts of the hydrologic segment.

c. Includes only the alluvial area traversed by Thousand Springs Creek. See figure 2.

to occur, the average thickness of saturated valley fill to be dewatered, and the specific yield.

The manner in which transitional storage reserve augments perennial yield has been described by Worts (1967). The same general concepts apply to system yield, provided that most of it is developed by pumping, and the relation is shown in its simplest form by the following equation:

$$Q = \frac{\text{Transitional storage reserve}}{t} + \frac{\text{System yield}}{2}$$

in which Q is the selected or desired rate of diversion (largely ground-water pumping), in acre-feet per year, and t is the time, in years, to exhaust the 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 system yield.

Using the above equation and the estimates for the Montello-Crittenden Creek area, as an example (transitional storage reserve 600,000 acre-feet, table 18; system yield 16,000 acre-feet, table 17) and using a diversion rate (Q) equal to system yield in accordance with the general intent of Nevada water law, the time (t) to deplete the transitional storage reserve is computed to be about 75 years. This assumes that the diversions would be almost wholly by pumping.

At the end of that time, the transitional storage reserve would be exhausted, subject to the assumptions given in the preceding section. 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 the pumpage would be derived from 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 recharge that originally flowed to areas of natural discharge would ultimately flow directly to pumping wells.

To meet the needs of an emergency or other special purpose requiring ground-water pumpage in excess of the system yield for specific periods of time, the transitional storage reserve would be depleted at a more rapid rate than the example 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 system yield. However, once the transitional storage reserve was exhausted, the pumping rate should be reduced to system yield as soon thereafter as possible. Pumpage in excess of system yield after exhaustion of the transitional storage reserve, 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 SUPPLY

Future water development will probably occur on the flood plains of the principal creeks. Because most surface water is presently utilized, additional large-scale development will require construction of wells. In order to salvage evapotranspiration in phreatophyte areas and some surface-water and subsurface outflow, wells would have to be drilled in or near the areas where discharge occurs. Ground-water levels would have to be lowered substantially (50 feet as shown in table 18) to eliminate water loss by phreatophytes or to reduce the outflow. Dewatering of alluvium beneath channels of perennial streams would cause greater infiltration from the streams to the water table. This in turn would have the effect of reducing streamflow in areas near and downstream from well fields. As a result, ground-water development on the flood plains of the principal creeks should be in conjunction with local surface-water development. During years of large runoff, surface water might be the principal source of water. During drier years, wells could be pumped to meet the same needs. If wells were pumped most years and at high, continuous rates, downstream segments would be deprived of some streamflow that now reaches those areas.

Few large-capacity wells have been drilled in the report area. Accordingly, the possibliity of obtaining high-yield wells throughout the area is speculative. Variation in the success of developing large ground-water supplies probably will be found within each segment and between segments. Because of this uncertainty, test drilling probably should precede any attempt to obtain a large supply. Most wells sampled in Montello Valley yielded poor-quality water for irrigation, and any test-drilling program there should include chemical tests to evaluate water quality. Considering the nature of the outflow from each segment, most of this water probably would be salvaged by pumping in Montello Valley.

NUMBERING SYSTEM FOR HYDROLOGIC SITES

The numbering system for hydrologic sites in this report is based on the rectangular subdivision of the public lands, referenced to the Mount Diablo base line and meridian. It 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. The section number is followed by a letter that indicates the quarter section, the letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quarters, respectively. For example, well 38/65-24c is in the SW$\frac{1}{4}$ sec. 24, T. 38 N., R. 65 E., Mount Diablo base line and meridian.

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

HYDROLOGIC DATA

The following two tables contain well data. Table 19 is a selection of well data for 45 wells which are generally representative of the nearly 100 wells that have been drilled in the valley. Table 20 lists drillers' logs for a few of these wells.

Table 19.--Selected well records

Use: S, stock; I, irrigation; D, domestic; H, heating
State log number: Log number in the files of the State Engineer

Location number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Land-surface altitude (feet)	Water-level measurement Depth (feet)	Water-level measurement Date	State log number	Remarks
37/67-11a	--	--	--	8	S	--/--	5,825	244.04	6-22-67	--	Windmill
38/65-24c	Johnson Ranch	1948	245	6	S	12/--	6,800	190	9- 5-48	639	
39/65-30c	Mircuy Ranch	1965	90	6	S	4/3	6,150	29	6-22-65	8576	
39/67-15d	Lawrence & Stegall Ranches, Inc.	1964	203	6	S	--/--	6,450	88	4-17-64	7945	
39/68-1c	do.	1964	300	6	S	--/--	5,100	155	6-20-64	7944	
-10b	do.	1964	501	6	S	--/--	5,400	390	4- 8-64	7943	
-21d	do.	1964	555	6	S	--/--	5,300	456	4-13-64	7942	
40/64-4b	Brush Creek well	--	--	--	S	--/--	5,700	83.55	6-20-67	--	Windmill
-24c	Wine Cup Ranch	--	450	8	S	--/--	6,000	24.24	6-19-67	--	Windmill
40/65-24b	Toano well 1	--	--	6	S	--/--	5,590	97.67	6-20-67	--	Windmill
40/67-3d	Gamble Ranch	1963	600	8	S	10/--	5,900	432	11-26-63	7591	
								435.36	6-21-67		
40/68-25a	do.	1962	450	16	I	--/--	5,100	338.75	11-15-62	7094	Insufficient yield
40/69-16a	do. well 1	--	--	24	I	700/--	4,850	--	--	--	
-16b1	do. 2	--	--	--	I	300/--	4,850	--	--	--	
-16b2	do. 3	1956	58	20	I	900/--	4,850	9	6-28-56	3461	
-16c	do. 4	1956	210	16	I	3,200/--	4,850	6	4-23-56	3414	
-22b	do. 5	--	--	--	I	600/--	4,830	--		--	
-22c	do. 6	1956	350	16	I	1,000/--	4,830	.5	11-15-56	3563	
-23d	do. 7	1955	274	16	I	1,100/--	4,820	9	11-29-55	3358	
41/63-10c	Union Pacific R.R.	--	92	6	D	20/--	--	3.96	6-28-50	--	
41/64-20a	Wine Cup Ranch	1947	179	8	D	45/--	5,650	23	11-15-47	295	
-25d1	do.	1947	68	8	H	50/--	--	30	10-17-47	292	Hot water
-25d2	do.	1947	59	8	H	100/--	--	10	10-21-47	293	Hot water
-25d3	do.	1947	187	6	D	45/--	--	--	11- 8-47	294	
-28b	do. well 6	1947	203	12	I	800/--	5,600	8	12-11-47	324	
-34d	do. 7	1965	201	10	I	400/72	5,550	14	2- 2-65	8374	

Table 19.--Continued

Location number	Owner or name	Year drilled	Depth (feet)	Diameter (inches)	Use	Yield (gpm) and drawdown (feet)	Land-surface altitude (feet)	Water-level measurement Depth (feet)	Water-level measurement Date	State log number	Remarks
41/64-35b	Wine Cup Ranch well 5	1965	190	16	I	800/166	--	9	11-24-65	8760	
41/66-12c	Gamble Ranch	1955	155	8	S	--/--	6,420	100.57	6-20-67	2878	Windmill
-24c	Wine Cup Ranch	1955	192	6	S	5/--	6,000	32	2-18-55	2879	Windmill
								23.23	6-20-67		
41/69-6c	Gamble Ranches, Inc.	1956	56	6	D	--/--	--	30	9-13-56	3531	
-20a	do.	1956	116	6	D	--/--	--	2	9-16-56	3543	
-25c	Gamble Ranch	1964	401	6	S	10/--	5,000	310	1- 9-64	7694	
42/65-20a	Wine Cup Ranch	1958	450	6	S	--/--	5,700	310	7-18-58	4257	Windmill
								295.76	6-19-67		
42/66-9a	do.	1955	255	6	S	--/--	--	205	8-19-55	3153	Windmill
42/68-5a	Gamble Ranches, Inc.	1955	233	6	S	--/--	5,900	187	11- 6-55	3332	
-29b	Eighteen Mile Ranch	1955	96	6	S,D	--/--	5,100	40	11- 7-55	3331	Windmill
								42.39	6-21-67		
-35a	Twelve Mile Ranch	1957	320	20	I	700/--	--	23	4-25-57	3774	
43/66-3c	Wine Cup Ranch	1965	640	--	S	4/30	5,583	235	8-13-65	8650	
-18d	do.	1958	425	6	S	--/--	--	212	8-21-58	4259	First water at 260 ft.
-25d	Eccles Ranch front porch well	--	28	60	D	--/--	--	10.29	7-20-50		
								12.73	6-20-67		
43/67-4b	Gamble Ranch	1955	264	6	S	--/--	5,557	190	10- 6-55	3333	First water at 190 ft.
-17a	do.	1955	220	6	S	--/--	5,491	152	10-12-55	3329	First water at 171 ft.
44/68-7c	Delano Gulch well	1939	301	6	S	5/--	5,900	277	10-21-39	268	First water at 290 ft. Windmill
								285.11	7-12-65		
-23c	Gamble Ranch	1964	950	6	S	--/--	6,200	810	2-22-64	7693	
45/67-36b	Bureau of Land Management	--	350	--	S	15/--	5,800	226	--	--	

Table 20.--Selected drillers' logs of wells

[Chief aquifer indicated by a star]

Material	Thickness (feet)	Depth (feet)
38/65-24c		
Gravel, boulders, and yellow clay	72	72
Shale, gray, sandy	28	100
Shale, brown, sandy	95	195
Shale, gray, sandy	10	205
*Lime, coarse, sandy	19	224
Sand, brown	21	245
39/68-10b		
Clay and gravel	45	45
Gravel	7	52
Clay and gravel	94	146
Rock	1	147
Clay and gravel	18	165
Rock and gravel in layers	170	335
*Clay and gravel	166	501
40/67-3d		
Soil	2	2
Gravel	32	34
Clay, red, and sand	38	72
Sandstone	35	107
Clay, red	38	145
Sandstone	48	193
Clay, red, and sand	72	265
*Sandstone	250	515
Clay and gravel	55	570
Clay, red	30	600
41/64-20a		
Clay, yellow	23	23
*Gravel and clay mixed	7	30
Clay	17	47
Gravel	5	52
Gravel and clay mixed	82	134
Gravel	10	144
Gravel and clay	35	179
41/67-15d		
Soil	3	3
Sandstone	3	6
Gravel	4	10
*Sandstone	475	485
Sand and gravel	9	494
Limestone	1	495
41/69-6c		
Clay, brown	12	12
Clay, tan, and rock	23	35
*Gravel, fine	6	41
Gravel and clay	13	54
Limestone, gray	2	56
41/69-25c		
Sand and gravel	60	60
Sandstone, green and brown	219	279
Clay, white	22	301
Sandstone, gray	25	326
*Sandstone, brown	42	368
Clay, white	33	401
42/68-29b		
Gravel	22	22
Sandstone	27	49
*Gravel	47	96
42/68-35a		
Clay, brown	35	35
*Sand, gray, and fine gravel	2	37
*Gravel, medium	33	70
*Sand and fine gravel	22	92
*Gravel, coarse	7	99
Limestone chips and gravel	18	117
Rock, broken, with clay seams	46	163
Rock, black	107	270
Rock, black, with clay seams	50	320
43/66-3c		
Shale	60	60
Clay, yellow	175	235
Clay, gray	37	272
*Clay, black	73	345
Shale, black	295	640

Table 20.--Continued

Material	Thick-ness (feet)	Depth (feet)
44/68-23c		
Clay, sand, and gravel	162	162
Clay	40	202
Clay and gravel	220	422
Clay	92	514
Sandstone	29	543
Clay	61	604
Sandstone	17	621
Clay	74	695
Sandstone	110	805
Clay	10	815
Sandstone	5	820
*Clay and sandstone	130	950

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

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46	Mesquite Ivanpah	Jean Lake Hidden

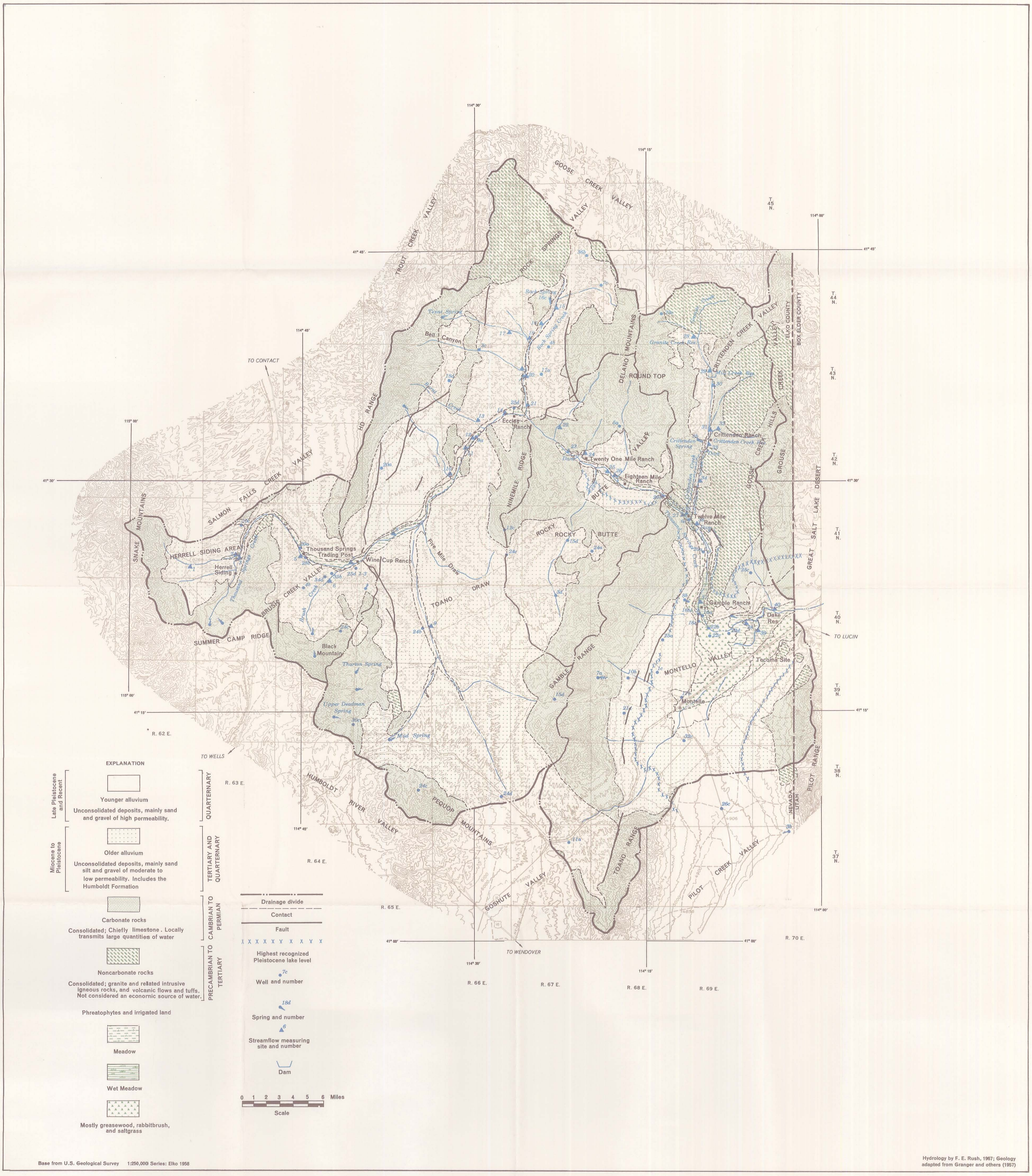

PLATE 1.—GENERALIZED HYDROGEOLOGY OF THOUSAND SPRINGS VALLEY, ELKO COUNTY, NEVADA