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HYDROLOGIC RECONNAISSANCE OF THE PINE VALLEY DRAINAGE BASIN, MILLARD, BEAVER, AND IRON COUNTIES, UTAH

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METRIC (SI) UNITS

Most numbers are given in this report in English units followed by metric units in parentheses. The conversion factors used are:

English Units (Multiply)	English Abbreviation	(by)	Metric Units (to obtain)	Metric Abbreviation
Acres		0.4047	Square hectometres	hm^2
Acre-feet	acre-ft	.001233	Cubic hectometres	hm^3
Cubic feet	ft^3	.02832	Cubic metres	m^3
Feet	ft	.3048	Metres	m
Gallons per minute	gal/min	.06309	Litres per second	l/s
Inches	in	25.40	Millimetres	mm
Miles	mi	1.609	Kilometres	km
Square miles	mi^2	2.590	Square kilometres	km^2

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per litre (mg/l). For concentrations less than 7,000 mg/l, the numerical value is about the same as for concentrations in the English unit, parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per litre (meq/l). Meq/l is numerically equal to the English unit, equivalents per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8(°C) + 32.$$

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ABSTRACT

The Pine Valley drainage basin is an area of about 730 square miles (1,890 square kilometres) in Millard, Beaver, and Iron Counties in southwestern Utah. Total annual precipitation in the basin averages about 410,000 acre-ft (acre-feet) or 506 hm^3 (cubic hectometres). Less than 500 acre-ft (0.6 hm^3) of runoff reaches the playa on the lowest part of the valley floor. There is no surface outflow from the basin. All streams are ephemeral except in short headwater reaches of a few streams where perennial or intermittent ground-water discharge sustains flow. Surface-water development and use in the basin are insignificant.

Ground-water recharge from precipitation in the drainage basin averages about 21,000 acre-ft (26 hm^3) annually. However, about 3,000 acre-ft (3.7 hm^3) of the recharge moves eastward under the topographic divide into the adjacent Wah Wah Valley drainage basin.

Many of the 80 known springs in the basin issue from perched zones in extrusive igneous rocks in the Needle Range. Carbonate rocks and quartzite yield water to a few springs, and the valley fill yields water to a few wells in the northern part of the valley.

Estimated average annual ground-water discharge is about 21,000 acre-ft (26 hm^3)—650 acre-ft (0.8 hm^3) by springs; 940 acre-ft (1.2 hm^3) by seepage to streams; 5,500 acre-ft (6.8 hm^3) by evapotranspiration; less than 5 acre-ft (0.006 hm^3) by pumping from wells; and 14,000 acre-ft (17.3 hm^3) (including about 3,000 acre-ft or 3.7 hm^3 that goes to the Wah Wah Valley drainage basin) that is assumed to be discharged by subsurface outflow to maintain the natural balance between recharge and discharge.

All water sampled in the basin was chemically suitable for most existing uses. The least mineralized water was ground water from quartzitic rocks, and the most mineralized was ground water from carbonate and extrusive igneous rocks.

Additional supplies could be developed from both surface- and ground-water sources. Much of the water consumed by evapotranspiration could be captured and diverted to other locations in the basin. Before extensive development of the water resources is undertaken, exploratory

drilling and detailed water-quality investigations are needed to refine the reconnaissance estimates and further define regional ground-water conditions.

INTRODUCTION

This report is the fifteenth in a series by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights, which describes the water resources of the western basins of Utah (fig. 1). The purposes of the report are to present hydrologic data for the Pine Valley drainage basin, to provide an evaluation of present and potential water-resources development in the area, and to identify needed studies that would improve understanding of the area's water supply.

The investigation on which the report is based consisted largely of a study of available data for geology, streams, wells, springs, climate, water quality, and water use. These data were supplemented with data on landforms, vegetation, geology, and water sources collected during brief field reconnaissances in October 1972 and June and November 1973.

Several published reports listed in the selected references contain information on the geology and water resources of the Pine Valley area. Principal sources of basic hydrologic data are the files of the U.S. Geological Survey and of the Utah State Engineer. The map of the geology of Utah by Stokes (1964) is the main source for the geologic information contained in the report.

Location and general features

The area described in this report includes Pine Valley and its tributary drainage area, a total of about 730 mi^2 (1,890 km^2) in Beaver, Iron, and Millard Counties in southwestern Utah (fig. 1). The Pine Valley drainage basin is an elongate, closed basin extending about 40 mi (64 km) north from the Beaver-Iron County boundary and averaging about 20 mi (32 km) in width between topographic divides. Plate 1 shows the topography and geology of the area. The photographs in figure 2 are representative views of the area.

The land in the Pine Valley drainage basin is used mainly for livestock grazing. Based on land-status maps prepared by the U.S. Bureau of Land Management (1969, 1970), about 407,000 acres (164,700 hm^2) or 87 percent of the land, including about 51,000 acres (20,640 hm^2) of the U.S. Forest Service Desert Experimental Range that is within the basin, is Federally owned. About 51,000 acres (20,640 hm^2) or 11 percent, including the Indian Peak Wildlife Management area of about 10,000 acres (4,050 hm^2), is owned by the State of Utah. The remaining 8,000 acres (3,240 hm^2) are privately owned.

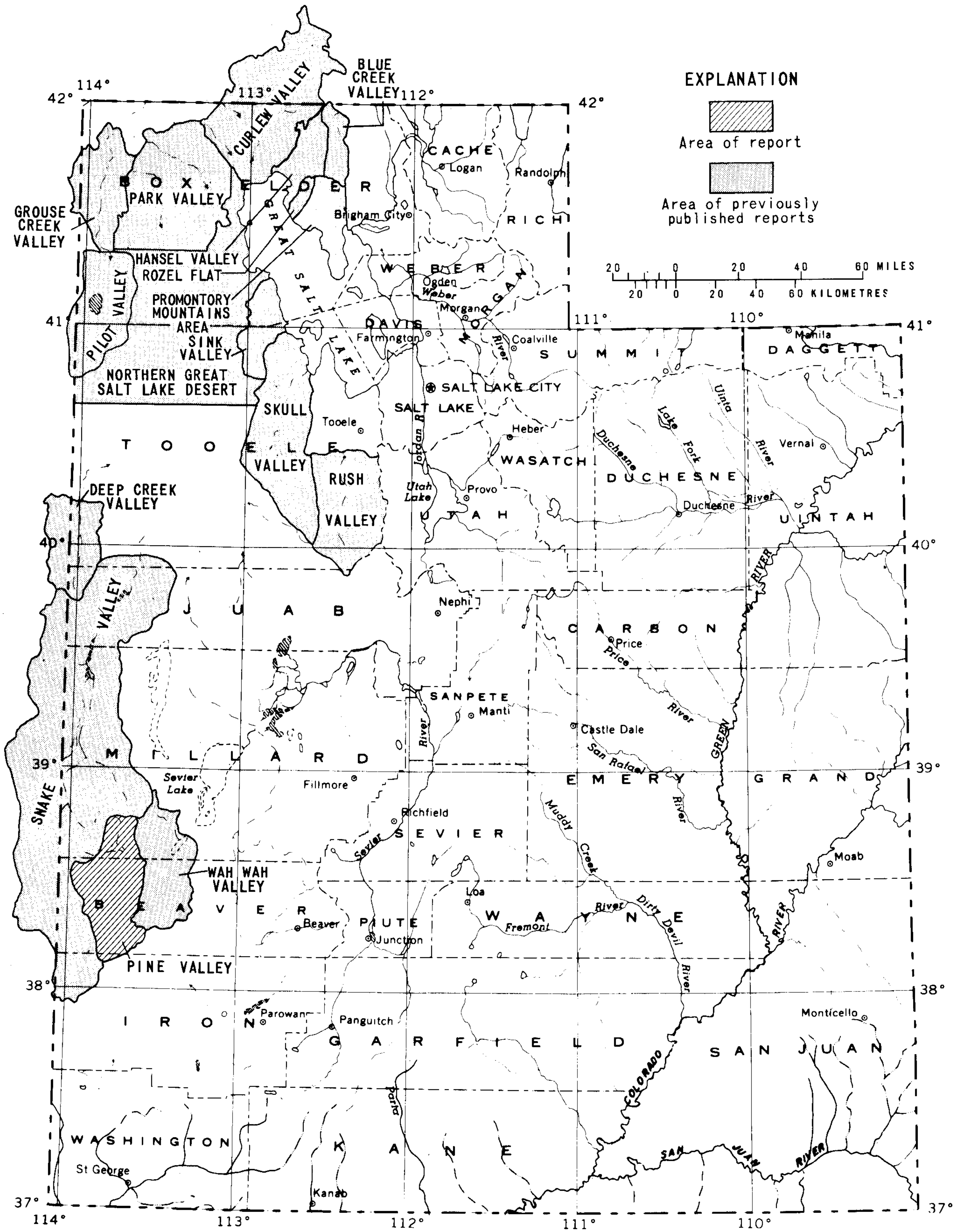

Figure 1.—Location of the Pine Valley drainage basin and areas described in previously published reports in this series.

Northern end of Pine Valley, looking east. Wah Wah Mountains in background

Pine Grove Creek Canyon just east of Pine Grove Spring, looking west. Pine Valley and Needle Range in background

Southern end of Pine Valley, looking northwest. Needle Range in left background

Figure 2.— Photographs of Pine Valley.

Physiography and drainage

The Pine Valley drainage basin is a closed basin bounded in part by drainage divides in the Wah Wah Mountains on the east and the Needle Range on the west (pl. 1). The northern and northwestern boundary of the basin is a broad, low divide connecting the northern end of the Wah Wah Mountains with isolated Middle Mountain, the Tunnel Spring Mountains and the Needle Range. The southern boundary is likewise a broad, low divide, which connects the Wah Wah Mountains and the Needle Range.

The crests of the Needle Range and the Wah Wah Mountains generally are at altitudes of 8,000-9,000 ft (2,440-2,740 m). Minimum altitudes on the northern and southern drainage divides are about 5,800 ft (1,792 m) and 6,290 ft (1,917 m), respectively. The highest point in the basin is Indian Peak in the southern Needle Range--altitude 9,790 ft (2,984 m)--and the lowest is on the playa near the north end of the valley--altitude about 5,075 ft (1,547 m). Total relief in the basin thus is about 4,715 ft (1,437 m).

The Pine Valley drainage basin adjoins the Snake Valley drainage basin on the north and west, the Escalante Desert drainage basin on the south and southeast, and the Wah Wah Valley drainage basin on the east. Lake Bonneville, the large freshwater lake that covered much of western Utah and parts of Idaho and Nevada (Gilbert, 1890, pl. 1) during Pleistocene time, inundated the lower parts of each of these adjacent drainage basins. The maximum altitudes of Lake Bonneville deposits range from about 5,090 ft (1,551 m) in T. 32 S., R. 14 W., about 15 mi (24 km) southeast of Pine Valley to about 5,120 ft (1,561 m) in T. 20 S., R. 18 W., about 20 mi (32 km) north (Crittenden, 1963, p. E5-E6). The maximum stage of the lake, therefore, was at least 760 ft (232 m) lower than the lowest point on the Pine Valley drainage divide. Thus, Pine Valley was not inundated by Lake Bonneville, though it may have been the site of a contemporaneous, closed-basin lake.

No streams flow out of Pine Valley. Although a well-developed network of ephemeral stream channels leads onto the playa, runoff seldom reaches the playa from other than intense local storms. Most runoff from the southern two-thirds of the drainage basin is dissipated by infiltration and evaporation before it reaches the playa.

Climate

The climate of the Pine Valley drainage basin is arid--estimated average annual precipitation over the entire basin is about 10.6 in (269 mm). Plate 1 shows the general distribution of precipitation over the area. As indicated in table 1, about one-half of the annual precipitation at the Desert Experimental Range occurs during May-September.

Vegetation

Because of the general aridity, native vegetation in Pine Valley consists primarily of "salt-desert" shrubs that are typical of millions

Table 1.--Selected climatologic data for Desert Experimental Range

(Based on U.S. National Oceanographic and Atmospheric Administration, U.S. Environmental Science Services Administration, and U.S. Weather Bureau publications listed in selected references)

Altitude: 5,352 ft (1,631 m)
Period of record: January 1950-December 1973

Average monthly:	Temperature (°F)	Precipitation (in)
January	26.5	0.25
February	32.7	.27
March	38.5	.44
April	46.5	.63
May	56.1	.49
June	65.5	.48
July	73.8	.81
August	71.7	.77
September	62.2	.46
October	50.6	.44
November	37.0	.34
December	28.3	.34
Average annual	49.1	5.72
Maximum/minimum:		
Period of record	104/-29	-
Annual	-	9.72/2.40
Monthly	-	2.41/0.00

of acres in the Great Basin. Vegetation is absent on the playa in T. 25 S., Rs. 16 and 17 W. (pl. 1). On the gravelly soils surrounding the playa and covering most of the remaining valley floor, a mixed association of shadscale (*Atriplex* sp.) and bunchgrasses predominates. This vegetative cover is sparse, generally covering less than 10 percent of the ground.

On the alluvial slopes adjacent to the valley floor, sagebrush (*Artemesia* sp.) is the dominant vegetation below an altitude of about 6,000 ft (1,830 m). Above that altitude juniper (*Juniperus* sp.) and pinyon (*Pinus* sp.) woodlands predominate on both alluvial and residual soils. Several types of deciduous shrubs grow in the uplands, especially on northward-facing slopes.

Rabbitbrush (*Chrysothamnus* sp.) and greasewood (*Sarcobatus vermiculatus*) grow locally in and along stream channels in the alluvium and in places on the valley floor. These shrubs are limited primarily to areas of sandy soils that absorb precipitation and runoff readily and temporarily store it as soil moisture for subsequent plant use. Where moisture is perennially available in the vicinity of certain springs and in areas where the water table is shallow, meadowgrasses, saltgrass (*Distichlis stricta*), greasewood, rabbitbrush, willow (*Salix* sp.), and other phreatophytes are common. Cottonwood (*Populus* sp.) and saltcedar (*Tamarix* sp.) grow as phreatophytes at a few locations. Cattail (*Typha latifolia*), watercress (*Rorippa nasturtium-aquaticum*), and other hydrophytes grow locally in areas of spring discharge.

Geology

Rocks ranging in age from Cambrian to Quaternary crop out in the Pine Valley drainage basin. On the basis of lithologic and hydrologic similarities, these rocks are grouped into generalized hydrogeologic units, each of which has a significant effect on the hydrologic system of the basin. Table 2 gives a generalized description of the lithology

Table 2.--Generalized lithologic and water-bearing characteristics of hydrogeologic units

Era System Series	Hydrogeologic unit and symbol on plate 1		Lithology, thickness, and extent	Water-bearing characteristics
CENOZOIC: Quaternary	Stream-channel alluvium (Qay)	↑	Mainly sand and gravel, but includes some clay and silt. Present as channel fill along larger streams. Thickness probably less than 20 ft (6.1 m) in most places.	Generally moderately permeable. Deposits may be saturated to or within a few inches of land surface during and for short periods following runoff. Locally contains perched ground water where underlain by less permeable rocks, but generally unsaturated where underlain by older alluvium.
CENOZOIC: Quaternary	Alluvium: (Qas)		Mainly sandy, gravelly clay. Occurs as thin veneer overlying and adjacent to lakebed clays near center of valley; thickens laterally and grades into coarser alluvium on gently sloping land along valley margin. Maximum thickness unknown.	Permeability generally low. Deposits generally above zone of saturation.
CENOZOIC: Quaternary	(Qag)		Mainly sand, gravel, and boulders, but includes some intermixed and interbedded clay and silt. Forms steeply sloping alluvial apron at base of mountains; grades laterally into finer grained alluvium toward valley axis. Includes colluvial material adjacent to bedrock outcrops. Maximum thickness unknown.	Slightly to highly permeable. Direct precipitation and runoff from higher altitudes infiltrate these deposits and move downward and laterally into underlying aquifers. Deposits are generally above the zone of saturation, except in upstream areas on the lower slopes of the mountains.
CENOZOIC: Quaternary	Lacustrine deposits (Qlc)	Valley fill	Lakebed clay and silt, including surficial playa deposits near north end of valley. Probably underlie most of gently sloping alluvial deposits (Qas). Maximum thickness unknown; probably thin laterally from axis of valley and toward south end of valley.	Permeability generally low. Most precipitation and runoff reaching the playa remains ponded until it evaporates. At such times, the thin playa deposits may be saturated for short periods. Locally may confine water in underlying aquifer.
CENOZOIC: Tertiary and Quaternary	Older alluvium (QTa)	Valley fill	Materials ranging in size from clay through boulders, intermixed and interbedded, unconsolidated to well cemented. Probably includes some lacustrine deposits and colluvium, but consists primarily of alluvium. Well-cemented gravel beds crop out locally along valley margins, but exposures are too small to show scale of map (pl. 1). Underlies younger deposits throughout most of area. Reportedly interbedded with extrusive igneous rocks at well (C-26-17)17d (table 6). Maximum thickness unknown.	Slightly to highly permeable, depending on size and degree of sorting of materials and degree of cementation in individual strata. Well (C-25-17)33dab-1 is reported to yield water from sand beds in this unit from 600 to 628 ft (183-191 m) below land surface (table 6). This unit forms the bulk of the valley fill, which is the major ground-water reservoir in Pine Valley.
CENOZOIC: Tertiary	Extrusive igneous rocks (Te)	?↓	Primarily ignimbrites and lava flows ranging in composition from mafic to felsic. May include some tuffs, breccias, and other volcanic rocks. Crop out extensively on the eastern side of the Needle Range and near the southeastern corner of the area in the Wah Wah Mountains. Reportedly occur in the subsurface, interbedded with older alluvium, at well (C-26-17)17d (table 6). Maximum thickness unknown.	Primary permeability generally low except locally in some breccias and interflow zones. Where fractured and broken by faulting, secondary permeability may be high. Numerous springs, seeps, and a few abandoned mine workings discharge water from perched ground-water zones in these rocks in the southern part of the area. Surficial weathered zones, especially on the ignimbrite sheets in the Needle Range, readily absorb precipitation and runoff.
CENOZOIC: Tertiary	Intrusive igneous rocks (Ti)		Mainly porphyritic quartz monzonite; small outcrops of diabase and granite in the southern Wah Wah Mountains. Thickness and subsurface extent unknown.	Primary permeability low. Surficial weathered zones and fractured zones may be moderately to highly permeable. Not known to yield water in Pine Valley drainage basin.
PALEOZOIC: Middle Cambrian to Permian	Sedimentary and metasedimentary carbonate rocks (Pzc)		Mainly limestone and dolomite, with some beds of shale, siltstone, and sandstone. Altered by contact metamorphism adjacent to intrusive rocks. Overlain by extrusive igneous rocks in most of Needle Range. Probably underlie most of area at depth. Thickness and subsurface extent unknown.	Primary permeability generally low; secondary permeability moderate to high where solution openings are present, especially along bedding planes, fractures, and faults. Yield water to a few springs.
PALEOZOIC: Lower Cambrian to Middle Ordovician	Sedimentary and metasedimentary quartzitic rocks (Pzq)		Mainly quartzite, but include some phyllite and phyllitic shale. Generally resistant, cliff-forming strata exposed on the western flank of the Wah Wah Mountains. Thickness and subsurface extent unknown, but may underlie most of the area at depth.	Primary permeability low. Because of the dense, relatively impermeable nature of these rocks, most precipitation runs off. A few small ephemeral springs discharge from talus below quartzite outcrops; several perennial springs discharge directly from fractured quartzite.

and water-bearing characteristics of these units, and plate 1 shows their distribution.

Pine Valley is part of an eastward-tilted fault block that is bounded by faults along the western sides of the Needle Range (Stokes, 1964) and the Wah Wah Mountains (pl. 1). Additional complex folding and faulting and extensive fracturing are present, especially in the rocks of Paleozoic age.

Numbering system for hydrologic-data sites

Hydrologic-data sites referred to in the report are assigned a number that serves both to identify and to specifically locate the site. The system of numbering hydrologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres (4 hm^2);[1] the letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre (4-hm^2) tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used and the serial number is omitted. Thus, (C-25-17)33dab-1 designates the first well constructed or visited in the NW¼NE¼SE¼ sec. 33, T. 25 S., R. 17 W. Other sites where hydrologic data were collected are numbered in the same manner, but no serial number is used. The numbering system is illustrated in figure 3.

WATER-RESOURCES APPRAISAL

Precipitation on the Pine Valley drainage basin is the source of nearly all the water available there. Total precipitation on the basin is estimated to average about 410,000 acre-ft (506 hm^3) annually (table 4).

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[1]Although the basic land unit, the section, is theoretically 1 mi^2 (2.6 km^2), many sections are irregular. Such sections are subdivided into 10-acre (4-hm^2) tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west side of the section.

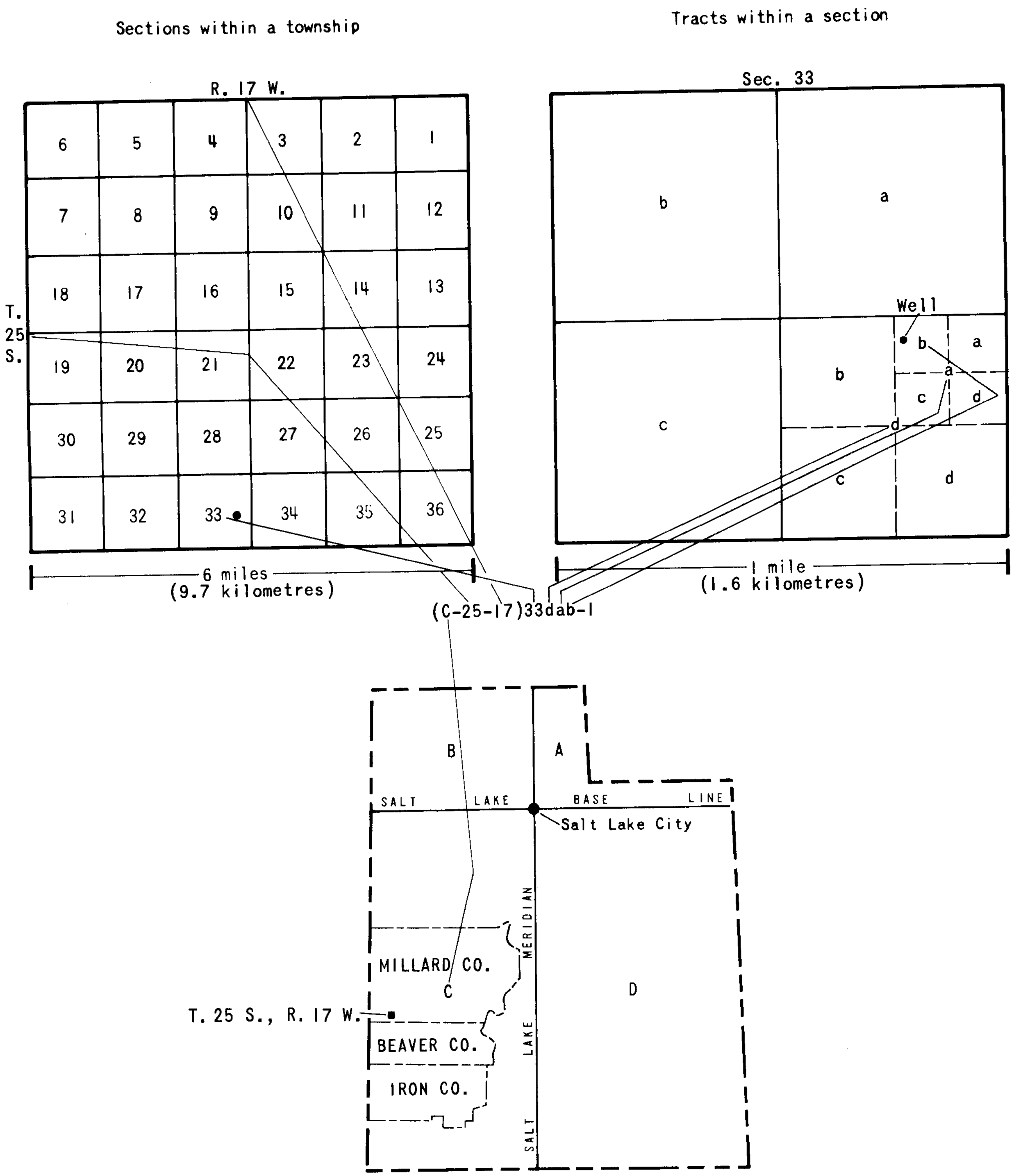

Figure 3.—Numbering system for hydrologic-data sites.

Surface water

Most streams in the Pine Valley drainage basin are ephemeral. Sheep and Indian Creeks, on the east flank of the southern Needle Range, and Pine Grove Creek, on the west flank of the central Wah Wah Mountains, are perennial in their upper reaches. On the alluvial slopes at the base of the mountains, however, even these streams are ephemeral.

Pine Valley Wash, the principal drainageway for the southern three-fourths of the basin, is ephemeral through its entire course from the southern drainage divide to the Pine Valley playa. Estimates of runoff at three sites on this wash are given in table 3, together with estimated precipitation in the drainage areas above the sites. The estimates of average annual volume of runoff were made by F. K. Fields (written commun., 1973) using a technique based on measurements of channel geometry (Moore, 1968). The locations of these sites and boundaries of the drainage areas are shown on plate 1.

As indicated in table 3, the estimated average annual runoff in Pine Valley Wash at site 4 is about 1,200 acre-ft (1.5 hm^3) or 0.12 in (3.0 mm) from the 192 mi^2 (497 km^2) drainage area. This equals about 1 percent of the average annual precipitation on the drainage area. No specific site estimates of runoff were made at lower altitudes in the basin. Field examination of numerous dry washes, however, indicates that their channels become progressively smaller and the mean volume of runoff progressively less with decreasing altitude. It is estimated on the basis of these observations that runoff reaching the Pine Valley playa averages less than 500 acre-ft (0.6 hm^3) annually, or about 0.1 percent of the total precipitation on the drainage basin.

Several small stock ponds and reservoirs have been constructed to intercept local runoff or springflow. At times during the fall, winter,

Table 3.--Estimated average annual precipitation and runoff in selected areas in southern Pine Valley

(Drainage area and average rate of precipitation calculated from pl. 1. Runoff volume estimated from channel-geometry measurements.)

Site No.	Location (see pl. 1)	Altitude (ft)	Drainage area (mi^2)	Precipitation		Runoff		Ratio of runoff to precipitation
				Volume (acre-ft)	Average rate (in)	Volume (acre-ft)	Average rate (in)	
				PINE GROVE CREEK				
1	(C-28-16)27cd	6,820	6.35	6,100	18.0	380	1.12	0.06
				PINE VALLEY WASH				
2	(C-30-16)7dab	6,150	43.9	27,600	11.8	350	.15	.01
3	(C-29-17)24bd	5,950	117	74,900	12.0	690	.11	.01
4	(C-28-17)13ca	5,575	192	122,000	11.9	1,200	.12	.01

and spring these reservoirs store small quantities of water for livestock, but during summer most of them are dry. Total storage capacity of such impoundments is probably less than 100 acre-ft (0.12 hm^3).

At least two stream impoundments serve, in part, to store water for diversion to off-stream uses. Water from Pine Grove Creek is diverted intermittently from a reservoir at (C-28-16)28dbc by an open unlined ditch to the East Pine Reservoir, a stock pond at (C-27-16)31cac. Water has also been pumped from an impoundment on Sheep Creek at (C-30-17)19cda for use in adjacent mineral-recovery operations. Total volume of water diverted from these impoundments is unknown but probably is small.

There is no surface outflow from the Pine Valley drainage basin; thus the long-term average consumptive use of surface water by evapotranspiration, livestock, and wildlife equals the difference between total precipitation and ground-water recharge within the basin (table 4). The estimated consumptive use of surface water (excluding springflow), therefore, averages nearly 95 percent of the total precipitation.

Ground water

Most of the known ground-water sources in the Pine Valley drainage basin are in extrusive igneous rocks (Te, table 2) in the Needle Range. The major ground-water reservoir in the basin, however, is in the older alluvium (QTa, table 2), which forms the bulk of the valley fill. The physical characteristics of these hydrogeologic units and the other units described in table 2 control the recharge, occurrence, movement, storage, and discharge of ground water in the basin.

Recharge

Total recharge from precipitation in the Pine Valley drainage basin is estimated to average about 21,000 acre-ft (26 hm^3) annually or about 5 percent of total precipitation (table 4). The estimate was made using a method developed by Eakin and others (1951, p. 79-81) for use in Nevada and modified by Hood (Hood and Waddell, 1968, p. 22-23) for use in western Utah. More than 80 percent of the recharge is from precipitation at altitudes greater than about 6,000 ft (1,829 m), where normal annual precipitation exceeds 12 in (305 mm) (pl. 1). A significant part of the area where recharge actually occurs, however, is at altitudes below 6,000 ft (1,829 m), where runoff from the higher parts of the drainage basin infiltrates the relatively permeable sand and gravel deposits in and along the stream channels.

Although no direct determinations of channel losses are available for streams in Pine Valley, measurements made on similar streams in Wah Wah Valley, a few miles to the east, indicate channel losses by infiltration of 0.3-1.3 $ft^3/s/mi$ (0.005-0.023 $m^3/s/km$) (Stephens, 1974, p. 13). It is probable that infiltration losses of similar magnitude occur in stream-channel alluvium in Pine Valley.

Table 4.--Estimated average annual volumes of precipitation and ground-water recharge

(Areas of precipitation zones measured from pl. 1)

Precipitation zone (in)	Area (acres)	Precipitation		Recharge	
		Ft	Acre-ft	Percent of precipitation	Acre-ft
Area within Pine Valley ground-water basin					
Quaternary and Tertiary rocks					
Less than 8	101,400	0.58	58,810	0	0
8-10	104,300	.75	78,220	0	0
10-12	100,400	.92	92,370	3	2,770
12-16	52,200	1.17	61,080	6	3,660
More than 16	8,400	1.42	11,930	20	2,390
Subtotal	366,700		302,410		8,820
Paleozoic rocks					
Less than 8	2,100	0.58	1,220	0	0
8-10	14,100	.75	10,570	0	0
10-12	20,400	.92	18,770	4	750
12-16	22,400	1.17	26,210	8	2,100
More than 16	11,900	1.42	16,900	25	4,220
Subtotal	70,900		73,670		7,070
Total (rounded)	438,000		376,000		16,000
Area within Wah Wah Valley ground-water basin					
Quaternary and Tertiary rocks					
10-12	1,800	0.92	1,660	3	50
12-16	2,600	1.17	3,040	6	180
Subtotal	4,400		4,700		230
Paleozoic rocks					
10-12	2,100	0.92	1,930	4	80
12-16	12,500	1.17	14,620	8	1,170
16-20	8,400	1.50	12,600	25	3,150
More than 20	600	1.75	1,050	25	260
Subtotal	23,600		30,200		4,660
Total (rounded)	28,000		35,000		5,000[1]
Total Pine Valley drainage basin (rounded)	466,000		410,000		21,000

[1]3,000 acre-ft per year is assumed to move eastward under the drainage divide into Wah Wah Valley drainage basin; 2,000 acre-ft per year is recharge in Pine Valley from surface runoff that infiltrates the alluvial slopes on the western flank of the Wah Wah Mountains.

In addition to infiltration of runoff at altitudes below 6,000 ft (1,829 m), some recharge takes place directly on the outcrops of consolidated rocks in the mountains. Although these rocks generally have low primary permeability (table 2), locally they may absorb large quantities of recharge through fractures and other secondary openings. The extrusive igneous rocks exposed over much of the Needle Range are extensively weathered. The weathering products accumulated on the surface absorb recharge rapidly. Some of the recharge is transmitted downward to the underlying rocks through intergranular spaces or through fractures and other secondary openings, and some of it accumulates locally as perched ground water.

The Pine Valley drainage basin includes part of the Wah Wah Valley ground-water basin (Stephens, 1974, p. 12). The area and volumes of precipitation and recharge in this segment of the drainage basin are itemized separately in table 4. Total recharge from precipitation in the area within the Pine Valley part of the Wah Wah Valley ground-water basin is estimated to average about 5,000 acre-ft (6.2 hm^3) annually. About 2,000 acre-ft (2.5 hm^3) of this recharge is assumed to result from infiltration of surface runoff on the alluvial slopes on the western flank of the Wah Wah Mountains. This recharge moves westward through the alluvial strata, and thus remains in the Pine Valley ground-water basin. The remaining 3,000 acre-ft (3.7 hm^3) of recharge is assumed to move eastward under the topographic divide along joints, fractures, and other secondary openings in the eastward-dipping Paleozoic rocks. The location of the inferred ground-water divide is shown on plate 1.

Occurrence and movement

Ground water in the Pine Valley drainage basin occurs under both water-table (unconfined) and artesian (confined) conditions as a result of local variations of lithology and structure in the different hydrogeologic units. The available subsurface data are not adequate to define the altitude and configuration of the water table or potentiometric surface in most of the basin.

Examination of spring locations, topography, and geology on maps and in the field indicates that many of the springs that discharge from the extrusive igneous rocks on the eastern flank of the Needle Range probably are perched. They issue either from a surficial weathered zone or from permeable interbeds within the volcanic rocks. Buckhorn Spring, (C-28-18)27dda-S1, and a nearby unnamed spring, (C-28-18)32dad-S1 (table 7), are typical perched springs. Both issue on hillsides well above adjacent stream channels, apparently from saturated zones in permeable strata overlying relatively impermeable strata in the same volcanic rock unit.

Ground water also occurs under artesian conditions in the extrusive igneous rocks. Vance Spring, (C-28-18)16cdb-S1 (table 7), issues in the bottom of a roughly circular pool about 5 ft (1.5 m) in diameter and about 1.5 ft (0.5 m) deep. A "sand boil" several inches high, created by the upward movement of the discharging water, is visible above the small orifice in the bottom of the pool. Volcanic rocks exposed in the vicinity of the pool are dense and relatively impermeable; ground water apparently moves upward to the point of issue along fractures or other secondary openings in these rocks.

Locally, as at well (C-26-17)17d, relatively impermeable volcanic rocks interbedded with the sedimentary materials may give rise to artesian conditions in the valley fill. According to the driller's log (table 6), the first water-bearing bed penetrated by this well was at a depth of 732-752 ft (223.1-229.2 m) below land surface, immediately under a layer of igneous rocks. The reported static water level after completion of the well was 717 ft (218.5 m) below land surface, or 15 ft (4.6 m) above the reported top of the first water-bearing stratum. Whether the rise of water level was a result of artesian pressure in this first stratum or in deeper strata (see log, table 6) is unknown. Details concerning well construction and depth of completion are not available. It is possible that the entire sequence of beds below 732 ft (223.1 m) is saturated, and that the overlying volcanic rocks act as a confining layer.

Shallow water-table conditions exist in stream-channel alluvium (Qay, table 2) along parts of Turkey Wash and Indian and Sheep Creeks, and possibly some of the other major streams draining the Needle Range. Similar conditions exist in unconsolidated colluvial deposits and talus along Pine Grove Creek in the Wah Wah Mountains. These shallow water-table areas probably do not represent a regional water table. Instead, they appear to be perched zones resulting from the accumulation of ground water in permeable unconsolidated deposits underlain by less permeable, unsaturated consolidated rocks. On the lower slopes and in the bottom of Pine Valley, where the stream-channel alluvium overlies older alluvium, the stream-channel alluvium is unsaturated because of downward seepage into older alluvium.

In general, ground water in the Pine Valley drainage basin moves downgradient from recharge areas in the mountains and on the alluvial slopes toward the axis of the valley. Reported water levels for three wells in the northern third of the valley, (C-25-16)18bdd-1, (C-25-17)33dab-1, and (C-26-16)19bbd-1 (table 5 and pl. 1), indicate that under this part of the valley floor, ground water is moving generally northward or northwestward.

A reported water level at well (C-26-17)17d (table 5) indicates ground-water movement in a direction nearly opposite to that determined from the other three water levels (that is, toward the south or southwest instead of toward the north or northwest). It is probable that well (C-26-17)17d was completed in a different aquifer or in a part of the aquifer that is not in complete hydraulic continuity with the aquifer in the area of the other three wells. Well (C-26-17)17d was abandoned and later destroyed, apparently because of a ruptured or offset casing (R. Holmgren, oral commun., 1973), so that the reported water level cannot be confirmed.

Occurrences of regional, interbasin ground-water flow through carbonate rocks in areas of Nevada where stratigraphy, structure, and topography are similar to the Pine Valley drainage basin (Harrill, 1971, pl. 1; Rush, 1970, p. 8) suggest that similar flow patterns may exist there. The few reported and measured water levels in Pine Valley can be reasonably explained if regional flow toward the northeast is assumed.

Storage

Under natural conditions, a ground-water system is in dynamic equilibrium; long-term average annual recharge and discharge are equal, and the amount of ground water in transient storage remains nearly constant. Changes in the volume of ground water in storage result in corresponding changes in discharge from springs and water levels in wells. Available data are inadequate to define such changes in the Pine Valley drainage basin. Ground-water development by man is negligible and has not significantly affected the natural conditions. It is probable that in Pine Valley, therefore, seasonal and annual changes tend to balance out in the long-term average; and the natural dynamic equilibrium is maintained.

The total volume of ground water in storage in the Pine Valley basin is unknown. To make a reasonable estimate of ground-water storage, much more information is needed concerning the thickness and lithology of the valley fill, the altitude and configuration of the potentiometric surface and of the surface of the consolidated rocks below the valley fill, and the ground-water conditions in the consolidated rocks and the valley fill.

The volume of water that could be recovered from storage by pumping from wells undoubtedly is large. However, initial pumping lifts would be 300 to 700 ft (91 to 213 m), as indicated by water levels in table 5; and the lifts would increase as storage was depleted.

Discharge

Ground-water discharge in the Pine Valley drainage basin is almost entirely by flow from springs, seepage to streams, evapotranspiration, and subsurface outflow. Discharge by wells, estimated to average less than 5 acre-ft (0.006 hm^3) annually, is an insignificant part of total discharge.

Springs discharge an estimated 650 acre-ft (0.8 hm^3) annually. Locations of about 80 springs are given on preliminary and published U.S. Geological Survey topographic maps; these springs are shown on plate 1. Records of 20 springs that were visited during the reconnaissance, or for which data were otherwise available, are given in table 7. All known springs in the basin discharge at altitudes above 6,200 ft (1,890 m) in and along the base of the Needle Range and in the southern part of the Wah Wah Mountains. Many are known to have variable discharge rates (table 7); some, such as (C-29-16)14cbb-S1, apparently flow only in response to precipitation and snowmelt and are dry during parts of the year. Total discharge by springs was estimated by assuming an average continuous flow of 5 gal/min (0.3 l/s) from each spring.

Natural discharge of ground water by seepage directly to streams is estimated to average about 1,100 acre-ft (1.4 hm^3) annually, including that amount that returns to the ground-water reservoir by streambed infiltration. Most discharge directly to streams probably occurs in reaches of Turkey Wash and Indian and Sheep Creeks where shallow, perched ground-water conditions were observed. Similar conditions may exist along other streams draining the southern Needle Range where perched ground water commonly is present in the extrusive igneous rocks. Some ground water also discharges directly to Pine Grove Creek from the colluvium and talus in the bottom of the canyon and from faults and fractures in the adjacent consolidated rocks. Total discharge to streams was estimated from streamflow observed in the above-named streams during November 1973, as follows (data from table 8):

	Cubic feet per second
Pine Grove Creek at (C-28-16)27ccc	1.0
Turkey Wash at (C-28-18)33bbd	.1
Indian Creek at (C-29-18)24bac	.3
Sheep Creek at (C-30-17)19ddd	.2
Subtotal	1.6
Less estimated snowmelt contribution	.1
Total estimated flow from ground-water seepage	1.5

Ten percent of the observed flow in the streams was estimated to return to the ground-water reservoir by streambed infiltration. Thus, the estimated net ground-water discharge was about 1.3 ft^3/s (0.04 m^3/s), or about 940 acre-ft (1.2 hm^3) per year. This amount was assumed to approximate the average annual net discharge of ground water by seepage to streams in the entire drainage basin.

Discharge of ground water by evapotranspiration in the Pine Valley basin takes place mainly in the areas where ground water is discharged directly to streams. Elsewhere in the basin the water table generally is too far below land surface to be reached by plant roots. The most significant areas of phreatophyte growth are shown in plate 1.

The principal phreatophytes are willow, rabbitbrush, greasewood, and native grasses. In some spring-discharge areas, scattered cottonwood and saltcedar use ground water, but these plants are not common in the basin. About 5,000 acres (2,020 hm^2) along Turkey Wash and Indian, Sheep, and Pine Grove Creeks support moderate to dense growths of phreatophytes.

In the headwater areas of Turkey Wash, dense, luxuriant growths of rabbitbrush cover the alluvial flats along the tributaries, and some reaches of the channels are lined with dense growths of willows. The few open areas are covered by native grasses. Hydrophytes, such as watercress, thrive in the streams and in spring-discharge areas along the valley sides.

The reaches of the valleys of Indian and Sheep Creeks where significant quantities of ground water are discharged by evapotranspiration (pl. 1) support vegetation similar to that in the headwaters area of Turkey Wash. Extensive grassy meadows and marshy areas, with dense willow thickets along the stream channels, characterize these areas. Rabbitbrush is quite common, occurring principally as a fringe along the periphery of open meadows and in dense stands on the alluvial floors of tributary valleys, where it may be interspersed with greasewood.

An area of shallow water table along Pine Grove Creek upstream from Pine Grove Spring [(C-28-16)27ca-S] supports a dense growth of meadow and marsh grasses with scattered willow thickets in places along the stream.

In addition to areas of shallow water table along streams, an estimated 500 acres (202 hm^2) in spring-discharge areas support moderate to dense stands of phreatophytes. Plant growth in these areas is sustained by a combination of springflow and ground water withdrawn directly from the saturated zone by plant roots.

The total area of ground-water use by phreatophytes in Pine Valley is estimated at 5,500 acres (2,225 hm^2). Water use by different phreatophyte species varies, depending on depth to water, climatic conditions, and other factors. For purposes of this reconnaissance, an average consumption rate of 1 ft (30.5 cm) of ground water per year was assumed, exclusive of springflow and surface water. Thus, discharge of ground water by evapotranspiration is estimated to average 5,500 acre-ft (6.8 hm^3) annually.

The foregoing estimates of annual ground-water discharge by natural means in the Pine Valley drainage basin total more than 7,000 acre-ft (8.6 hm^3)--650 acre-ft (0.8 hm^3) from springs; 940 acre-ft (1.2 hm^3) by seepage to streams; and 5,500 acre-ft (6.8 hm^3) by evapotranspiration. Additional ground-water use by man averages less than 5 acre-ft (0.006 hm^3) annually. Estimated annual recharge to the ground-water system averages about 21,000 acre-ft (25.9 hm^3) (table 4). Thus, to maintain the natural condition of dynamic equilibrium between recharge and discharge that apparently prevails, about 14,000 acre-ft (17.3 hm^3) of ground water must be discharged annually by means other than those described. About 3,000 acre-ft (3.7 hm^3) of ground water is assumed to flow under the topographic divide into the Wah Wah Valley drainage basin (Stephens, 1974, p. 12). Because no other sources of discharge are known, it is assumed that subsurface outflow discharges an average of about 11,000 acre-ft (13.6 hm^3) from the basin annually.

Chemical quality of the water

All natural water contains dissolved mineral matter. Water that falls as precipitation contains minute amounts and, because water is a solvent, it dissolves additional mineral matter from the rocks and soil as it moves over or through the ground. Ground water usually is in contact with the rocks and soil longer than surface water; it also usually contains more dissolved minerals. However, the amount and chemical character of the minerals dissolved in the water depend principally upon the nature of materials it contacts, and to only a minor extent upon the duration of contact. The total concentration of dissolved minerals and the concentrations of individual ions determine the usefulness of the natural water for various purposes.

Chemical analyses of 14 water samples from 2 streams, 8 springs, 2 wells, and 1 mine are given in table 9. Table 8 gives field measurements of specific conductance of water from five additional stream sites and one surface reservoir, and table 7 gives similar measurements for four additional springs. The chemical-quality map (pl. 1) summarizes the available information on chemical quality of water in the Pine Valley drainage basin.

Quality relative to source

The least mineralized water (water with the lowest concentration of dissolved solids) sampled in the Pine Valley drainage basin was ground water discharging from spring (C-29-16)16dbd-S1 (table 9). This water, which contained 94 mg/l of dissolved solids, and water draining from the Wah Wah Mine at (C-28-16)26ccc (table 9), which contained 130 mg/l of dissolved solids, issue from quartzitic rocks (Pzq, table 2 and pl. 1). Circulation of water in these rocks is primarily in fractures and joints. The predominant mineral in the rocks is quartz, which is relatively insoluble. The absence of significant quantities of readily soluble minerals results in low concentrations of dissolved solids in the ground water.

The highest concentrations of dissolved solids in water from the basin were found in ground water from three springs--(C-26-18)22cbb-S1, (C-26-19)3acc-S1, and (C-27-18)35ccb-S1 (table 9)--all of which contained more than 500 mg/l of dissolved solids. Two of these springs issue from weathered extrusive igneous rocks (Te, table 2 and pl. 1), where circulation is largely through intergranular openings and where soluble minerals are relatively abundant. The other spring issues from carbonate rocks, which are readily soluble.

Dissolved-solids concentrations in samples from most surface- and ground-water sources in the Pine Valley basin are fairly uniform. Excluding the five sources described in the preceding paragraphs, measured and estimated concentrations of dissolved solids ranged from 180 to 440 mg/l (pl. 1).

A sample obtained from Central Pine Reservoir on October 11, 1972, had a specific conductance of 300 micromhos/cm at 25°C (table 8), from which a dissolved-solids concentration of about 180 mg/l was estimated. The water in the reservoir was from rainfall during the previous week--longer storage, with concomitant evaporation, would result in increasing concentrations of dissolved solids.

Most of the streamflow samples (pl. 1 and tables 8 and 9) were obtained in reaches where flow was sustained by ground-water discharge. Thus, the concentrations of dissolved solids as well as the overall chemical character of the water were generally similar to nearby ground-water sources.

Two wells completed in the valley fill in the northern part of Pine Valley--(C-25-16)18bdd-1 and (C-25-17)33dab-1 (table 9)--yield water containing slightly more than 200 mg/l of dissolved solids. The Stiff diagrams on plate 1 show that the water from these two wells has generally similar chemical characteristics, which differ significantly from the chemical characteristics of water from other sources in the basin.

The great depth to water in the two wells (table 5), together with the relatively low concentration of dissolved solids in the water, indicate that ground water is being discharged from this part of the basin, either laterally or downward. In the absence of such discharge, the valley fill should be saturated and the concentration of dissolved solids in the ground water should be much greater as a result of evapotranspiration at the surface.

Quality relative to use

All water sources sampled in the Pine Valley drainage basin yielded freshwater (dissolved solids less than 1,000 mg/l). Water hardness ranged from 58 to 570 mg/l.

The U.S. Public Health Service (1962) has recommended maximum limits for certain chemical constituents in public drinking water supplies as follows:

	Milligrams per litre
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.2[1]
Nitrate (NO_3)	45[2]
Dissolved solids	500

[1] Based on an average daily maximum temperature of 65.6°F at Desert Experimental Range, 1968-72. See page 8 of reference cited above for method of determination of limits. The optimum concentration recommended is 0.9 mg/l; water containing fluoride in average concentrations greater than two times the optimum value (or 1.8 mg/l in Pine Valley) cannot be used for public drinking water supply.

[2] Equivalent to 10 mg/l nitrate (NO_3) as nitrogen (N).

As shown in table 9, the recommended limit for manganese was exceeded in one surface-water sample from the Pine Valley drainage basin, and the recommended dissolved-solids limit was exceeded in samples from three springs. None of the water sources in the basin supplies water for public use, and only one well, (C-25-17)33dab-1, regularly supplies water for domestic use.

Water-quality characteristics widely used for evaluating water for irrigation are: (1) the concentration of dissolved solids, as indicated by the specific conductance, which determines the salinity hazard; (2) the relative proportion of sodium (Na) to other cations in the water, as indicated by SAR (sodium-adsorption ratio), which determines the sodium hazard; and (3) the concentration of boron (B) and other toxic elements. Hem (1970, p. 324-333) and U.S. Salinity Laboratory Staff (1954) provide more detailed discussions of the relationship of quality of water to agricultural use.

Specific conductances measured for water samples ranged from 155 to 1,120 micromhos/cm at 25°C. Sodium-adsorption ratios ranged from 0.3 to 2.0. On the basis of these values and the classification system developed by the U.S. Salinity Laboratory Staff (1954, p. 79-81), the samples all had low sodium hazard; two samples had low salinity hazard (specific conductance less than 250 micromhos/cm at 25°C); nine samples had medium salinity hazard (specific conductance 250-750 micromhos/cm at 25°C); and three samples had high salinity hazard (specific conductance 750-2,250 micromhos/cm at 25°C). The maximum concentration of dissolved boron found in a water sample from Pine Valley was 0.13 mg/l, well below the permissible limit of 0.33 mg/l established for crops most sensitive to boron in irrigation water (U.S. Salinity Laboratory Staff, 1954, p. 67).

At present, there is no irrigation development in Pine Valley. A large amount of potentially irrigable land exists in the valley, however, and available water-quality data indicate that the water is generally suitable for irrigation.

SUMMARY OF WATER-RESOURCES AVAILABILITY AND POTENTIAL FOR ADDITIONAL DEVELOPMENT

An estimated 410,000 acre-ft (506 hm^3) of precipitation falls annually in the Pine Valley drainage basin. Annual runoff reaching the playa in the lowest part of the valley averages less than 500 acre-ft (0.6 hm^3). There is no surface outflow from the basin. All streams are ephemeral, except in short headwater reaches of a few streams where intermittent or perennial ground-water discharge sustains flow. Off-channel storage capacity of stock ponds and small reservoirs totals less than 100 acre-ft (0.12 hm^3). Stream diversions and on-channel storage are insignificant.

Annual ground-water recharge from precipitation in the drainage basin is estimated to average about 21,000 acre-ft (26 hm^3). Perched ground water occurs locally in the mountains; most of the 80 known springs issue from perched zones in extrusive igneous rocks in the Needle Range. Carbonate rocks and quartzite yield water to a few springs in the mountains, and the valley fill yields water to a few wells in the northern part of the valley.

Ground-water development by man is insignificant in Pine Valley. Thus, the ground-water system is essentially under natural conditions in which a dynamic equilibrium between recharge and discharge prevails.

Annual discharge of ground water by springs is estimated to average 650 acre-ft (0.8 hm^3); discharge by seepage to streams in areas of shallow water tables averages about 940 acre-ft (1.2 hm^3); discharge by evapotranspiration averages about 5,500 acre-ft (6.8 hm^3); and discharge by pumping from wells probably averages less than 5 acre-ft (0.006 hm^3). About 3,000 acre-ft (3.7 hm^3) of recharge in Pine Valley occurs east of the divide between the Pine Valley and Wah Wah Valley ground-water basins; this water moves under the topographic divide in the Wah Wah Mountains into Wah Wah Valley. Total discharge by springflow, seepage to streams, evapotranspiration, pumping from wells, and outflow to Wah Wah Valley thus averages about 10,000 acre-ft (12.3 hm^3) annually. To maintain the equilibrium between recharge and discharge, subsurface outflow, probably toward the northeast, must discharge about 11,000 acre-ft (13.6 hm^3) of ground water from the Pine Valley drainage basin.

All water sources in the basin yield freshwater. The least mineralized water is ground water from quartzitic rocks, and the most highly mineralized water is ground water from extrusive igneous rocks and carbonate rocks. All water sampled appears chemically suitable for most existing uses in the basin.

Additional supplies could be developed from both surface- and ground-water sources in the Pine Valley drainage basin. Discharge of many of the undeveloped springs could be increased by installation of underground collector systems in the discharge areas, thus capturing water now being consumed by evapotranspiration of natural vegetation. Wells or infiltration galleries in the weathered extrusive rocks should yield significant quantities of water at some locations. Additional wells could be constructed to obtain water from the valley fill. Additional water could be supplied to locations on the valley floor by constructing pipelines to divert water from springs or reaches of streams where perennial flow is sustained by ground-water discharge.

The principal effect of increased consumptive use of water on the hydrologic system in the Pine Valley drainage basin would be a reduction in the quantity of subsurface outflow. Diversions from springs and reaches of perennial streams in the mountains would have little net effect on the system--only the place of consumption would be changed.

RECOMMENDATIONS FOR ADDITIONAL STUDIES

Before extensive development of the water resources of the basin is undertaken, additional hydrologic data are needed to refine the estimates made in this reconnaissance and to provide a basis for planning.

The most significant data deficiencies would be met by a program that included:

1. Exploratory drilling in the valley fill, especially in the southern two-thirds of the valley. Lithologic, water-level, and water-quality information in this part of the valley is essential to understanding the ground-water system.

2. Exploratory drilling at selected locations in the southern part of the Needle Range. The presence, location, and extent of the perched ground-water zones in the extrusive rocks should be determined, and the regional water table should be defined if extensive perched zones are indeed present.

3. Detailed investigations of water-quality variations, laterally and with depth, in conjunction with exploratory drilling.

SELECTED REFERENCES

Crittenden, M. D., Jr., 1963, New data on the isostatic deformation of Lake Bonneville: U.S. Geol. Survey Prof. Paper 454-E.

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

Gilbert, G. K., 1890, Lake Bonneville: U.S. Geol. Survey Mon. 1.

Harrill, J. R., 1971, Water-resources appraisal of the Pilot Creek Valley area, Elko and White Pine Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources Water Resources Reconn. Ser. Rept. 56.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2nd ed.): U.S. Geol. Survey Water-Supply Paper 1473.

Hood, J. W., and Rush, F. E., 1965, Water-resources appraisal of the Snake Valley area, Utah and Nevada: Utah State Engineer Tech. Pub. 14.

Hood, J. W., and Waddell, K. M., 1968, Hydrologic reconnaissance of Skull Valley, Tooele County, Utah: Utah Dept. Nat. Resources Tech. Pub. 18.

Moore, D. O., 1968, Estimating mean runoff in ungaged semiarid areas: Nevada Dept. Cons. and Nat. Resources Water Resources Bull. 36.

Rush, F. E., 1970, Regional ground-water systems in the Nevada Test Site area, Nye, Lincoln, and Clark Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources Water Resources Reconn. Ser. Rept. 54.

Sandberg, G. W., 1966, Ground-water resources of selected basins in southwestern Utah: Utah State Engineer Tech. Pub. 13.

Snyder, C. T., 1963, Hydrology of stock-water development on the public domain of western Utah: U.S. Geol. Survey Water-Supply Paper 1475-N.

Stephens, J. C., 1974, Hydrologic reconnaissance of the Wah Wah Valley drainage basin, Millard and Beaver Counties, Utah: Utah Dept. Nat. Resources Tech. Pub. 47.

Stiff, H. A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Jour. Petroleum Technology, v. 3, no. 10, p. 15-17.

Stokes, W. L., (ed.), 1964, Geologic map of Utah: Utah Univ.

U.S. Bureau of Land Management, 1969, Southwest Utah - recreation and wildlife on BLM lands: U.S. Dept. of Interior, Bur. of Land Management, Cedar City [Utah] District.

_____1970, West central Utah - recreation and wildlife on BLM lands: U.S. Dept. of Interior, Bur. of Land Management, Fillmore [Utah] District.

U.S. Environmental Science Services Administration, 1966-70, Climatologic data, Utah 1965-69: v. 67-71, no. 13.

U.S. National Oceanic and Atmospheric Administration, 1971-74, Climatologic data, Utah 1970-73: v. 72-75, no. 13.

U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service Pub. 956.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkalai soils: U.S. Dept. Agriculture Handb. 60.

U.S. Weather Bureau, 1957, Climatic summary of the United States - Supplement for 1931 through 1952, Utah: Climatography of the United States No. 11-37.

_____1962-65, Climatologic data, Utah, 1961-64: v. 63-66, no. 13.

_____1965, Climatic summary of the United States - Supplement for 1951 through 1960, Utah: Climatography of the United States No. 86-37.

_____(no date), Normal annual and May-September precipitation (1931-60) for the State of Utah: Map of Utah, scale 1:500,000.

Table 5.--Records of selected wells and mine drains

Location: See page 8 for explanation of numbering system.
Owner or user and local name: Local name in parentheses.
Year constructed: a, about.
Depth of well: a, about.
Geologic source of water: See table 2 for explanation of symbols and description of lithologic units.
Altitude of land-surface datum: Feet above mean sea level, as interpolated from U.S. Geological Survey topographic maps.
Reported water level: Date - a, about.
Method of lift: F, flowing; N, none; P, piston pump; T, turbine pump.
Yield: Rate - R, reported; E, estimated. Date - a, about.
Use of water: H, domestic, including lawn watering; M, mining or mineral-recovery operations; S, livestock; U, unused.
Remarks and other data available: C, chemical analysis in table 9; L, driller's log in table 6; Z, plugged and abandoned or otherwise destroyed.

Location	Owner or user and local name	Year constructed	Depth of well (ft)	Diameter of well (in)	Geologic source of water	Altitude of land-surface datum	Reported water level: Feet below land-surface datum	Reported water level: Date	Method of lift	Yield: Rate (gal/min)	Yield: Date	Use of water	Water temperature (°C)	Remarks and other data available
(C-25-16)18bdd-1	J. Dearden (Guyman Well)	a1924	a340	8	QTa	5,085	300	a1955	T	100R 30R	a1924 a1955	S	16.0	Not used in 1972-73. C.
(C-25-17)33dab-1	Desert Experimental Range	1934	628	8	QTa	5,263	466.5	3-16-34	T	12R	3-16-34	H,S	12.0	Well cased to 600 ft; screened 600-628 ft; backfilled with gravel 628-649 ft; specific capacity reported 0.8 gal/min/ft after 57 hours; C;L.
(C-26-16)19bbd-1	W. Woods (Cow Camp Well)	1928	394	4	QTa	5,205	329	1960	P	-	-	S	-	Bottom 8 ft of well reported filled with sand when pump pulled in 1960; well used only as standby source since pipeline diversion completed in 1972.
(C-26-17)17d	A. Anderson	-	801	-	QTa	5,355(?)	717	a1955	N	7R	a1955	-	-	Well reportedly failed due to ruptured or offset casing; unable to locate in 1973; L, Z.
(C-28-16)26ccb	(Wah Wah Mine)	a1909	-	-	Pzq	7,080	-	-	F	5E	6-22-73	U	-	Adit on north side of canyon; yield estimated.
26ccc	do	a1909	-	-	Pzq	7,100	-	-	F	-	8- -63	U	10.0	Adit on south side of canyon; C.
(C-30-17)27aaa-1	U.S. Bureau of Land Management	1936	648	-	-	6,550	Dry	1936	N	-	-	-	-	Utah Emergency Relief Admin. Well No. 90; L; Z.
30bab-1	-	-	-	12	Te(?)	7,093	-	-	T	-	-	M	-	
(C-30-18)10dab	(Cougar Spar Mine)	a1944	-	-	Te(?)	7,480	-	-	F	-	-	U	-	Site not visited in field.
25aad-1	-	-	-	-	Te(?)	7,098	-	-	-	-	-	M	-	Well shown on 7½' topographic maps; not visited in field.

Table 6.--Drillers' logs of selected wells

Altitudes are for land surface at well, in feet above mean sea level.
Thickness, in feet.
Depth to bottom of unit, in feet below land surface.

Material	Thickness	Depth
(C-25-17)33dab-1. Log by H. T. Kaminska. Alt. 5,263.		
Gravel	28	28
"Solid rock porphyry"(?)	11	39
Gravel, cemented	3	42
Conglomerate	9	51
Rock, solid	24	75
Clay and gravel	2	77
Rock, solid	7	84
Clay and gravel	4	88
Rock, solid	11	99
Gravel, cemented	51	150
Gravel, loose; moist	12	162
Gravel, cemented, and "side rock"(?)	7	169
Gravel, fine, cemented	27	196
Rock, solid	4	200
Gravel, loose	8	208
Rock, solid	12	220
Gravel, cemented	7	227
Rock, solid	6	233
Gravel	3	236
Rock, solid	36	272
Clay and gravel	82	354
Lime and sand	6	360
Gravel	20	380
Sand and gravel	10	390
Clay	10	400
Gravel	26	426
Clay	23	449
Clay and sand, dense, solid	31	480
Clay and sand; struck water at 482 ft	23	503
Clay and sand, very hard	6	509
Clay and sand	14	523
Rock	3	526
Sand, fine	6	532
Clay	5	537
Clay and sand	56	593
Sand, coarse, hard	35	628
"Sand rock"	21	649

Table 6.--Drillers' logs of selected wells - Continued

Material	Thickness	Depth
(C-26-17)17d. Log from U.S. Bureau of Land Management (written commun., 1962). Alt. about 5,355.		
Soil	62	62
"Lava wash," red	41	103
Clay, red	65	168
Clay, white	24	192
Clay, alternating red and white streaks	70	262
Rock, hard, red	25	287
Clay, red	103	390
Clay, yellow	37	427
Clay, red	19	446
Clay, orange	26	472
Clay, red	89	561
Clay, purple	23	584
Clay, red	32	616
Clay, purple	25	641
Lava rock, red	91	732
Lava, porous; water	20	752
Clay, yellow	5	757
Clay, brown	5	762
Clay, blue	5	767
Clay, gray	5	772
Sand and gravel; water	6	778
Clay, gray	13	791
Clay, red	10	801
(C-30-17)27aaa-1. Log from U.S. Geological Survey files; driller unknown. Alt. 6,550.		
Soil	3	3
Quicksand and boulders	39	42
Granite, brown and purple	458	500
Granite, soft, "crystallized"	148	648

Table 7.--Records of selected springs

Location: See page 8 for explanation of numbering system.
Owner or user and local name: Local names in parentheses; BLM, U.S. Bureau of Land Management.
Geologic source of water: See table 2 for explanation of symbols and description of lithologic units.
Altitude of land surface: Feet above mean sea level, interpolated from U.S. Geological Survey topographic maps.
Yield: Estimated, except m, measured.
Use of water: S, livestock.
Remarks and other data available: BLM, U.S. Bureau of Land Management; C, chemical analysis in table 9; K, specific conductance in micromhos/cm at 25°C.

Location	Owner or user and local name	Geologic source of water	Altitude of land surface (ft)	Yield (gal/min)	Date of measurement	Use of water	Water temperature (°C)	Remarks and other data available
(C-26-18)16add-S1	State of Utah (Beers Tunnel Spring)	Te	6,405	Seep	11-19-73	S	-	Flow from 4 ft x 5 ft horizontal infiltration gallery extending at least 30 ft into hillside; piped to nearby stock tank; no measurable flow when visited; pool of water on tunnel floor had K = 725.
22cbb-S1	(Pine Spring)	Te	6,570	2 .15m	1955 11-19-73	S	-	Flow from bottom of 5 ft x 5 ft vertical pit excavated several feet into rocks adjacent to streambed; piped to nearby storage tank and troughs; C.
(C-26-19)3abc-S1	BLM (Mountain Home Spring)	Pzc(?)	7,150	8 .5	3-21-59 11-21-73	S	11.0	Collector pipe and headbox in discharge area in streambed; piped to storage tanks and troughs near spring and at (C-25-18)8d (in Snake Valley drainage basin) and (C-25-19)25d; BLM project; C.
(C-27-18)27dba-S1	(Potch-im-po Spring)	Pzc	6,340	5 20	1955 11-20-73	S	13.0	Collector pipe and headbox in discharge area at base of hill; piped to stock tanks or troughs near spring and at (C-26-16)19bbd, (C-26-17)17b, 17d, 27d, and 28b, (C-27-17)8a and 10a, and (C-27-18)13a; additional seepage collects in stock pond near spring; BLM project; C.
35ccb-S1	(Willow Spring)	Te	6,260	5 2.5m	1955 11-20-73	S	11.5	Collector pipe installed in streambed; piped to storage tanks and troughs near spring and at (C-27-18)36a; C.
(C-28-16)27ccc-S1	(Pine Grove Spring)	Pzq	6,700	15	11-21-73	S	11.0	Collector pipe and headbox installed in streambed; piped to storage tanks and troughs at (C-27-16)10a and (C-28-16)3d; BLM project; C.
27ddd-S1	-	Pzq	7,080	5	1955	S	-	
(C-28-18)16cdb-S1	State of Utah (Vance Spring)	Te	6,675	10 60	1955 11-20-73	S	14.0	Spring undeveloped; formerly used for irrigation and household; C.
27dda-S1	BLM (Buckhorn Spring)	Te	6,670	10	1955	S	11.0	Collector pipe and headbox in discharge area on hillside; piped to storage tanks and troughs at (C-28-17)20b and 23b and (C-28-18)26b; BLM project; C.
32ada-S1	BLM	Qay	6,920	(1/)	11-20-73	S	-	Flow originates over distance of several hundred yards from volcanic-rock gravels in and along stream channel; K = 550 (discharge included some snowmelt).
32ada-S2	do	Qay	6,920	(1/)	11-20-73	S	-	Origin same as (C-28-18)32ada-S1.
32cca-S1	-	Qay	7,150	7	11-20-73	S	-	Flow originates over distance of about 750 feet along sides and bottom of stream channel; K = 400 (discharge included some snowmelt).
32dad-S1	BLM	Te	7,000	1/7	11-20-73	S	13.5	Issues from small excavation in large seep area on hillside; formerly piped to nearby homestead; K = 340 (discharge may have included some snowmelt).
33bbd-S1	do	Qay	6,845	(1/)	11-20-73	S	-	Origin similar to (C-28-18)32ada-S1.
33bbd-S2	do	Te	6,835	(1/)	11-20-73	S	-	Discharges from large seep area on slope above stream channel.
(C-29-16)14cbb-S1	-	Pzq	7,730	Dry	10-11-72	-	-	Vegetation indicates shallow ground water; spring apparently flows only in spring and early summer.
16dbd-S1	State of Utah (Water Hollow Spring)	Pzq	7,320	20 18m	1963 10-11-72	S	11.5	Headbox installed in discharge area; piped to storage tanks and troughs at (C-29-16)20b and 31b, (C-29-17)12a, and (C-30-16)8b; additional 1-inch pipeline diverts water into Escalante Desert drainage basin; some diffuse discharge in spring area not estimated; BLM project; C.
(C-29-18)14ddd-S1	State of Utah	Te	6,780	(2/)	11-20-73	S	-	In channel of Indian Creek upstream from breached dam; see analysis (table 9) of Indian Creek sample collected at this location.
16ccc-S1	do	Te	7,860	(2/)	11-20-73	S	-	
(C-30-17)19ddc-S1	BLM	Te(?)	6,900	8	1964	S	-	Collector pipe and headbox installed in streambed; piped to stock troughs at (C-30-17)20c, 21d, 22c, 23c, 27b, and 28b; BLM project; see analysis (table 9) of Sheep Creek sample collected near this location.

1/ Total flow in creek (estimated 25 gal/min) on 11-20-73 near (C-28-18)33bbd-S1 originated chiefly as discharge from these springs.
2/ Total flow through breach in dam at (C-29-18)14ddd (estimated 0.25 ft^3/s) on 11-20-73 originated chiefly as flow from these springs and others upstream.

Table 8.--Field measurements of water temperature and specific conductance and estimated discharge of selected surface-water sources

Location: See page 8 for explanation of numbering system.
Estimated discharge: Average annual from channel-geometry measurements by F. K. Fields (written commun., 1973).

Location	Source	Date	Temperature (°C)	Specific conductance (micromhos/cm at 25°C)	Estimated discharge: Instantaneous (ft^3/s)	Estimated discharge: Average annual (acre-ft)	Sampling site and remarks
(C-27-17)13ada	Central Pine Reservoir	10-11-72	8.5	300	0	-	Water stored was runoff from rainfall during previous week. Dry on 6-22-73 and 11-20-73.
(C-28-16)27ccc	Pine Grove Creek	11-21-73	2.0	430	1	-	At Pine Grove Spring. Air temperature -2.0°C.
27cd	do.	6-22-73	-	-	2	380	About one-half mile east of Pine Grove Spring (site 1, table 3).
35bac	do.	6-22-73	9.0	700	1.5	-	At breach in earthen dam in area of ground-water inflow.
36acb	do.	6-22-73	13.0	520	.01	-	About three-quarters of a mile west of Wah Wah Mountains drainage divide; below spring-discharge area.
(C-28-17)13ca	Pine Valley Wash	5-10-73	-	-	1	1,150	At road crossing. No flow 10-11-72, 6-22-73, 11-20-73 (site 4, table 3).
30cac	Unnamed tributary to Antelope Wash	11-20-73	3.5	710	.01	-	At road crossing. Discharge probably from upstream springs and some snow meltwater. Vegetation in and along channel indicates perennial flow. Air temperature 3.0°C.
(C-28-18)33bbd	Turkey Wash	11-20-73	-	-	.06	-	See table 7, footnote 1.
(C-29-17)24bd	Pine Valley Wash	6-22-73	-	-	0	690	At road crossing. No flow 10-11-72, 11-20-73 (site 3, table 3).
(C-29-18)14ddd	Indian Creek	11-20-73	6.0	1/607	.2	-	At breach in earthen dam in area of ground-water inflow.
24bac	do.	11-20-73	6.0	600	.3	-	At road crossing.
(C-30-16)7dab	Pine Valley Wash	6-22-73	-	-	0	350	At road crossing. No flow 10-11-72, 11-20-73 (site 2, table 3).
(C-30-17)19ddd	Sheep Creek	11-20-73	4.0	1/690	.2	-	At concrete check-dam upstream from road crossing in area of ground-water inflow.

1/ Laboratory measurement; see table 9 for chemical analysis.

Table 9.--Chemical analyses of

(Analyses by U.S. Geological

Location: See page 8 for explanation of numbering system.
Dissolved solids: r, residue on evaporation at 180°C; all others are sum of determined constituents

Location	Name or owner	Date of collection	Temperature (°C)	Dissolved silica (SiO_2)	Dissolved iron (Fe)	Dissolved manganese (Mn)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)
				Milligrams							
											Streams
(C-29-18)14ddd	Indian Creek	11-20-73	6.0	40	0.00	0.18	75	15	34	1.2	291
(C-30-17)19ddd	Sheep Creek	11-20-73	4.0	22	.01	.01	92	16	32	2.1	327
											Springs
(C-26-18)22cbb-S1	Pine Spring	11-19-73	-	64	0.01	0.00	110	28	41	2.3	334
(C-26-19)3acc-S1	Mountain Home Spring	11-21-73	11.0	12	.03	.00	170	36	35	.7	414
(C-27-18)27dba-S1	Potch-im-po Spring	1/1-31-71	-	12	.00	.00	52	7.0	16	2.0	161
		11-20-73	13.0	13	.01	.00	39	15	16	1.3	159
35ccb-S1	Willow Spring	11-20-73	11.5	48	.00	.00	100	41	61	1.0	257
(C-28-16)27ccc-S1	Pine Grove Spring	11-21-73	11.0	15	.01	.00	93	12	12	1.3	329
(C-28-18)16cdb-S1	Vance Spring	11-20-73	14.0	42	.01	.01	67	14	19	2.5	210
27dda-S1	Buckhorn Spring	11-20-73	11.0	36	.01	.00	51	4.7	55	2.3	232
(C-29-16)16dbd-S1	Water Hollow Spring3/	9-17-63	(4/)	12	-	.00	17	3.6	8.2	1.8	63
											Wells
(C-25-16)18bdd-1	J. Dearden (Guyman Well)	9-13-62	16.0	31	-	-	24	12	27	3.3	124
(C-25-17)33dab-1	Desert Experimental Range	2-12-74	12.0	54	0.18	0.00	16	6.7	30	6.1	138
											Mine adit
(C-28-16)26ccc5/	Wah Wah Mine	8- -63	10.0	11	-	0.00	31	4.4	8.4	1.0	108

1/ Analysis by Utah Division of Health; also included (in mg/l): arsenic, 0.00; barium, 0.00; cadmium, 0.00; copper, 0.02; lead, 0.00; selenium, 0.00; silver, 0.00; and zinc, 0.01.
2/ Nitrate only, reported as NO_3.
3/ Average of three analyses of samples collected at stock troughs on pipelines diverting water from spring. Analyses also included (average, in mg/l): bromide, 0.0; copper, 0.15; iodide, 0.01; lead, 0.02; lithium, 0.3; strontium, 0.0; and zinc, 0.8.
4/ Temperature at head of pipeline in discharge area was 11.5°C on 10-11-72.
5/ Exact location of sampling site unknown; most probable location given. Analysis also included (in mg/l): bromide, 0.0; copper, 0.01; iodide, 0.00; lead, 0.02; lithium, 0.2; strontium, 0.0: and zinc, 0.65.

water from selected sources

Survey unless otherwise noted)

per litre														
Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3) + nitrite (NO_2) as nitrogen (N)	Dissolved phosphate (PO_4)	Dissolved boron (B)	Dissolved solids	Hardness as $CaCO_3$ (Ca,Mg)	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH
10	21	36	0.3	0.03	0.40	0.10	377	250	0	23	0.9	606	8.4
0	35	46	.5	.01	.18	.11	407	300	27	19	.8	690	8.3
0	37	110	0.2	0.37	0.49	0.12	559	390	120	19	0.9	897	8.3
0	220	53	.2	.18	.09	.12	732	570	230	12	.6	1,120	8.0
1	6.0	38	.1	2/8.6	.10	.11	216	160	-	-	-	365	8.1
4	12	27	.2	2.0	.15	.05	215	160	22	18	.6	379	8.4
0	81	180	.3	.29	.34	.13	641	420	210	24	1.3	1,100	8.2
0	11	18	.2	.18	.12	.05	326	280	12	8	.3	569	7.6
0	20	54	.2	1.7	.28	.07	330	230	53	15	.6	545	8.2
8	15	34	.3	.80	.31	.07	325	150	0	44	2.0	504	8.4
0	5.5	16	.3	2/.60	1.4	.02	94r	58	7	23	.5	155	7.4
0	19	30	0.7	2/4.6	-	0.08	204r	109	7	34	1.1	344	7.6
0	13	5.9	1.2	1.5	.15	.12	208	68	0	46	1.6	278	8.1
0	9.1	14	0.1	2/1.8	1.0	0.03	130r	95	6	16	0.4	221	7.5

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TECHNICAL PUBLICATIONS

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WATER CIRCULARS

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BASIC-DATA REPORTS

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No. 17. Hydrologic and climatologic data, 1968, Salt Lake County, Utah, by A. G. Hely, R. W. Mower, and C. A. Horr, U.S. Geological Survey, 1969.

No. 18. Quality of surface water in the Bear River basin, Utah, Wyoming, and Idaho, by K. M. Waddell, U.S. Geological Survey, 1970.

No. 19. Daily water-temperature records for Utah streams, 1944-68, by G. L. Whitaker, U. S. Geological Survey, 1970.

No. 20. Water-quality data for the Flaming Gorge area, Utah and Wyoming, by R. J. Madison, U.S. Geological Survey, 1970.

No. 21. Selected hydrologic data, Cache Valley, Utah and Idaho, by L. J. McGreevy and L. J. Bjorklund, U.S. Geological Survey, 1970.

No. 22. Periodic water- and air-temperature records for Utah streams, 1966-70, by G. L. Whitaker, U.S. Geological Survey, 1971.

No. 23. Selected hydrologic data, lower Bear River drainage basin, Box Elder County, Utah, by L. J. Bjorklund and L. J. McGreevy, U.S. Geological Survey, 1973.

No. 24. Water-quality data for the Flaming Gorge Reservoir area, Utah and Wyoming, 1969-72, by E. L. Bolke and K. M. Waddell, U.S. Geological Survey, 1972.

INFORMATION BULLETINS

*No. 1. Plan of work for the Sevier River Basin (Sec. 6, P. L. 566), U.S. Department of Agriculture, 1960.

*No. 2. Water production from oil wells in Utah, by Jerry Tuttle, Utah State Engineer's Office, 1960.

*No. 3. Ground-water areas and well logs, central Sevier Valley, Utah, by R. A. Young, U.S. Geological Survey, 1960.

*No. 4. Ground-water investigations in Utah in 1960 and reports published by the U.S. Geological Survey or the Utah State Engineer prior to 1960, by H. D. Goode, U.S. Geological Survey, 1960.

*No. 5. Developing ground water in the central Sevier Valley, Utah, by R. A. Young and C. H. Carpenter, U.S. Geological Survey, 1961.

*No. 6. Work outline and report outline for Sevier River basin survey, (Sec. 6, P.L. 566), U.S. Department of Agriculture, 1961.

*No. 7. Relation of the deep and shallow artesian aquifers near Lynndyl, Utah, by R. W. Mower, U.S. Geological Survey, 1961.

*No. 8. Projected 1975 municipal water-use requirements, Davis County, Utah, by Utah State Engineer's Office, 1962.

No. 9. Projected 1975 municipal water-use requirements, Weber County, Utah, by Utah State Engineer's Office, 1962.

*No. 10. Effects on the shallow artesian aquifer of withdrawing water from the deep artesian aquifer near Sugarville, Millard County, Utah, by R. W. Mower, U.S. Geological Survey, 1963.

*No. 11. Amendments to plan of work and work outline for the Sevier River basin (Sec. 6, P.L. 566), U.S. Department of Agriculture, 1964.

*No. 12. Test drilling in the upper Sevier River drainage basin, Garfield and Piute Counties, Utah, by R. D. Feltis and G. B. Robinson, Jr., U.S. Geological Survey, 1963.

*No. 13. Water requirements of lower Jordan River, Utah, by Karl Harris, Irrigation Engineer, Agricultural Research Service, Phoenix, Arizona, prepared under informal cooperation approved by Mr. William W. Donnan, Chief, Southwest Branch (Riverside, California) Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A., and by Wayne D. Criddle, State Engineer, State of Utah, Salt Lake City, Utah, 1964.

*No. 14. Consumptive use of water by native vegetation and irrigated crops in the Virgin River area of Utah, by Wayne D. Criddle, Jay M. Bagley, R. Keith Higginson, and David W. Hendricks, through cooperation of Utah Agricultural Experiment Station, Agricultural Research Service, Soil and Water Conservation Branch, Western Soil and Water Management Section, Utah Water and Power Board, and Utah State Engineer, Salt Lake City, Utah, 1964.

*No. 15. Ground-water conditions and related water-administration problems in Cedar City Valley, Iron County, Utah, February, 1966, by Jack A. Barnett and Francis T. Mayo, Utah State Engineer's Office.

*No. 16. Summary of water well drilling activities in Utah, 1960 through 1965, compiled by Utah State Engineer's Office, 1966.

*No. 17. Bibliography of U.S. Geological Survey water-resources reports for Utah, compiled by Olive A. Keller, U.S. Geological Survey, 1966.

*No. 18. The effect of pumping large-discharge wells on the ground-water reservoir in southern Utah Valley, Utah County, Utah, by R. M. Cordova and R. W. Mower, U.S. Geological Survey, 1967.

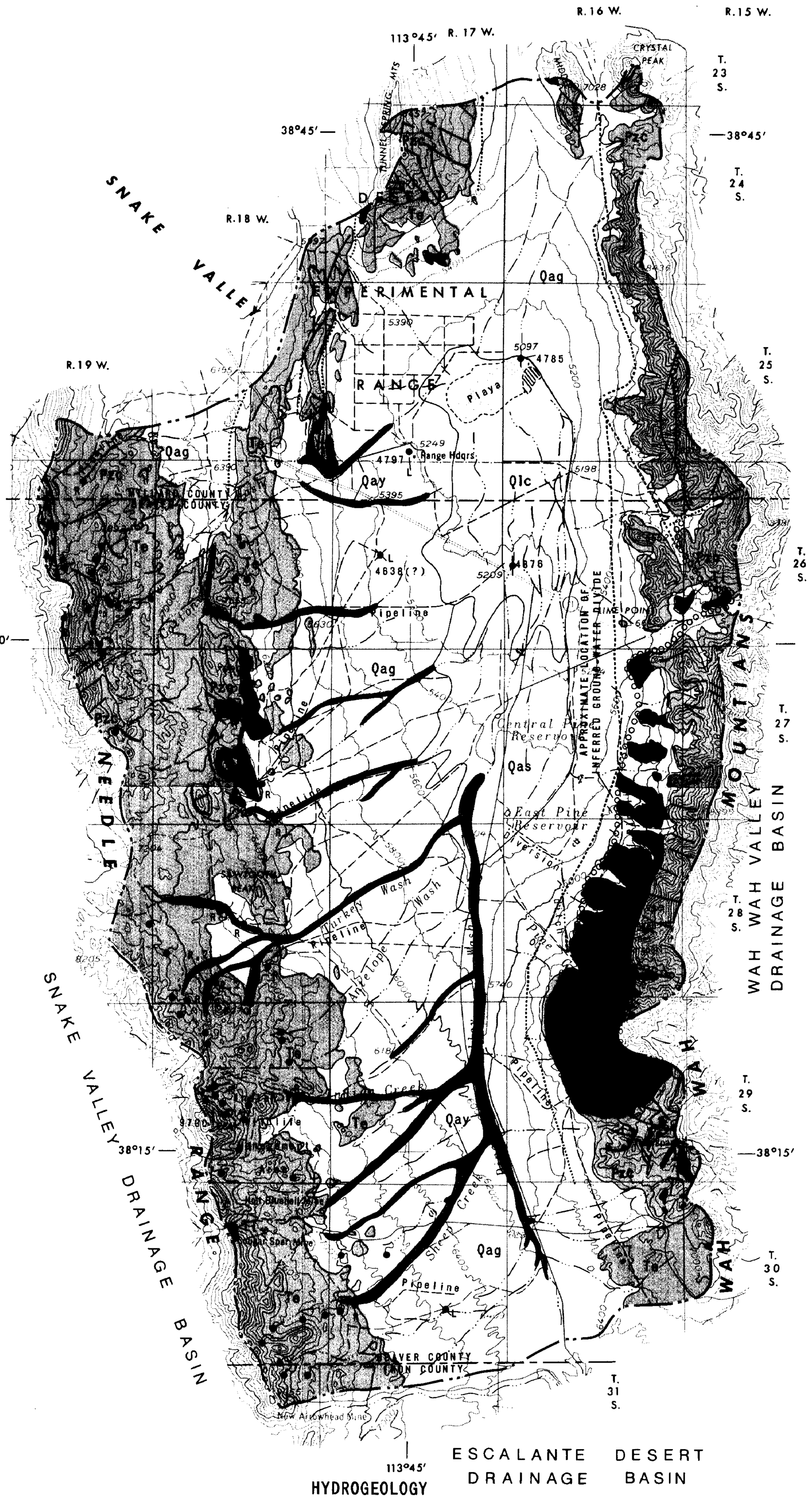
No. 19. Ground-water hydrology of southern Cache Valley, Utah, by L. P. Beer, 1967.

*No. 20. Fluvial sediment in Utah, 1905-65, A data compilation by J. C. Mundorff, U.S. Geological Survey, 1968.

*No. 21. Hydrogeology of the eastern portion of the south slopes of the Uinta Mountains, Utah, by L. G. Moore and D. A. Barker, U.S. Bureau of Reclamation, and James D. Maxwell and Bob L. Bridges, Soil Conservation Service, 1971.

*No. 22. Bibliography of U.S. Geological Survey water-resources reports for Utah, compiled by Barbara A. LaPray, U.S. Geological Survey, 1972.

No. 23. Bibliography of U.S. Geological Survey water-resources reports for Utah, compiled by Barbara A. LaPray, U.S. Geological Survey, 1975.



HYDROGEOLOGY

EXPLANATION

GEOLOGY (see table 2)

Era	Period	Symbol	Unit	Description
CENOZOIC	Quaternary	(solid black)	Stream-channel alluvium	Sand and gravel; moderately permeable; locally contains perched ground water
		Qas	Alluvium	Sandy, gravelly clay; permeability generally low; generally unsaturated
		Qag	Alluvium	Sand, gravel, and boulders; slightly to highly permeable; generally unsaturated
		Qlc	Lacustrine deposits	Clay and silt; permeability low; generally unsaturated except immediately after runoff
	Tertiary	Te	Extrusive igneous rocks	Ignimbrites and lava flows; permeability low except where fractured or weathered; locally contain perched ground water
		(solid black)	Intrusive igneous rocks	Porphyritic quartz monzonite; permeability low; not known to yield water
PALEOZOIC	Middle Cambrian to Permian	Pzc	Sedimentary and metasedimentary carbonate rocks	Limestone and dolomite, with some shale, siltstone, and sandstone; permeability low except where fractured or containing solution openings; yield water to a few springs
	Lower Cambrian to Middle Ordovician	(solid black)	Sedimentary and metasedimentary quartzitic rocks	Quartzite, with some phyllite and phyllitic shale; permeability low except where fractured; yield water to a few springs

Approximate contact

Fault, dashed where concealed, dotted where inferred

Thrust fault, barbs on side of thrust sheet

HYDROLOGY

4785 Reported altitude of water level in well

R,2 Spring
Number by symbol refers to number of springs at same location; R, record of spring in table 7 (locations of other springs from U.S. Geological Survey topographic maps)

Well (see table 5)
L, *log of well in table 6*

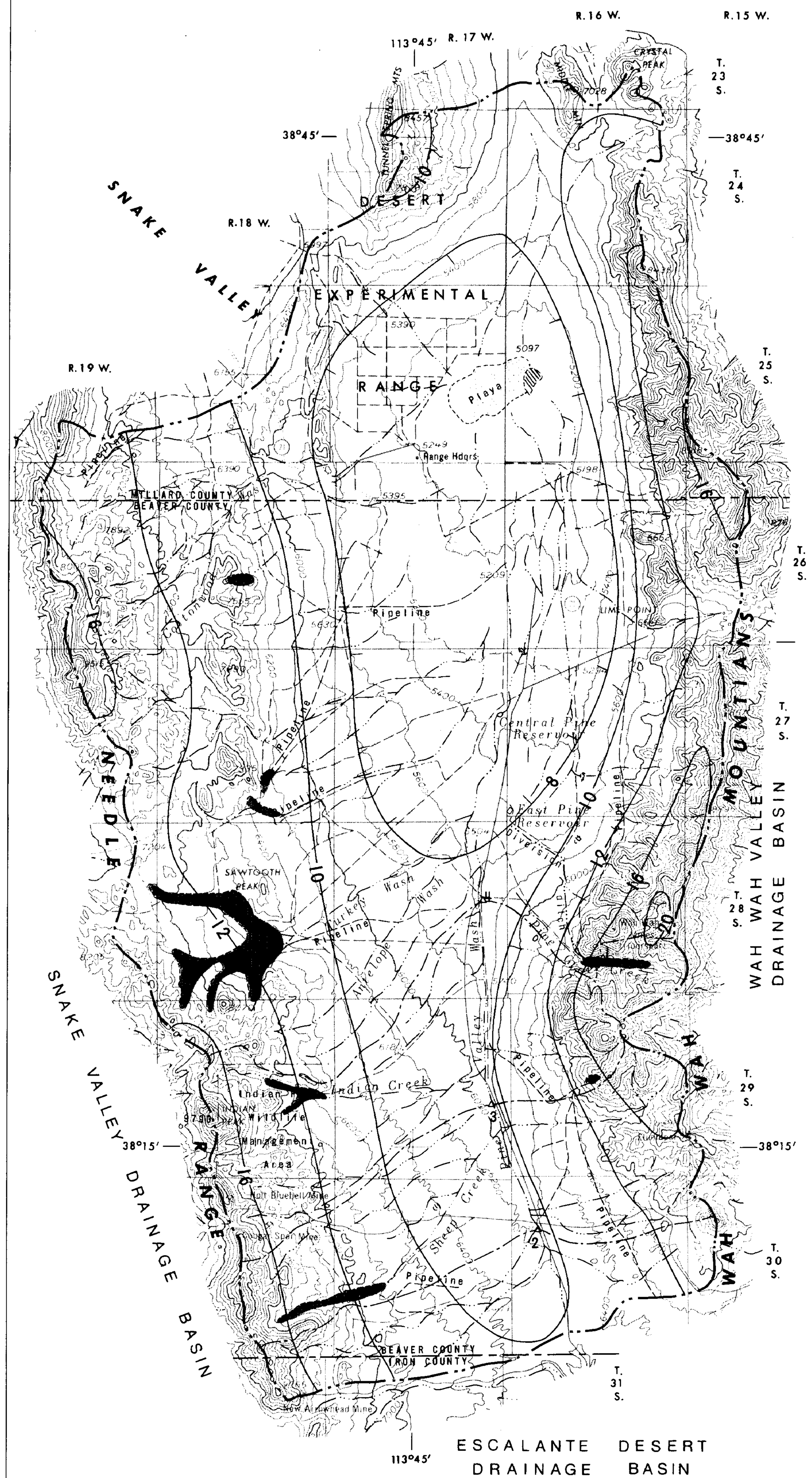
Unused well (see table 5)

Abandoned well (see table 5)

Mine drain (see table 5)

Drainage divide

Base from U.S. Geological Survey 1:250,000 series: Richfield, Utah, 1953



PRECIPITATION

EXPLANATION

8 — Line of approximately equal normal annual precipitation, 1931-60; interval 2 and 4 inches (51 and 102 mm) (from U.S. Weather Bureau, no date)

Drainage divide (basin boundary)

Drainage divide (subbasin boundary)

2 Channel-geometry measurement site (number refers to site number in table 3)

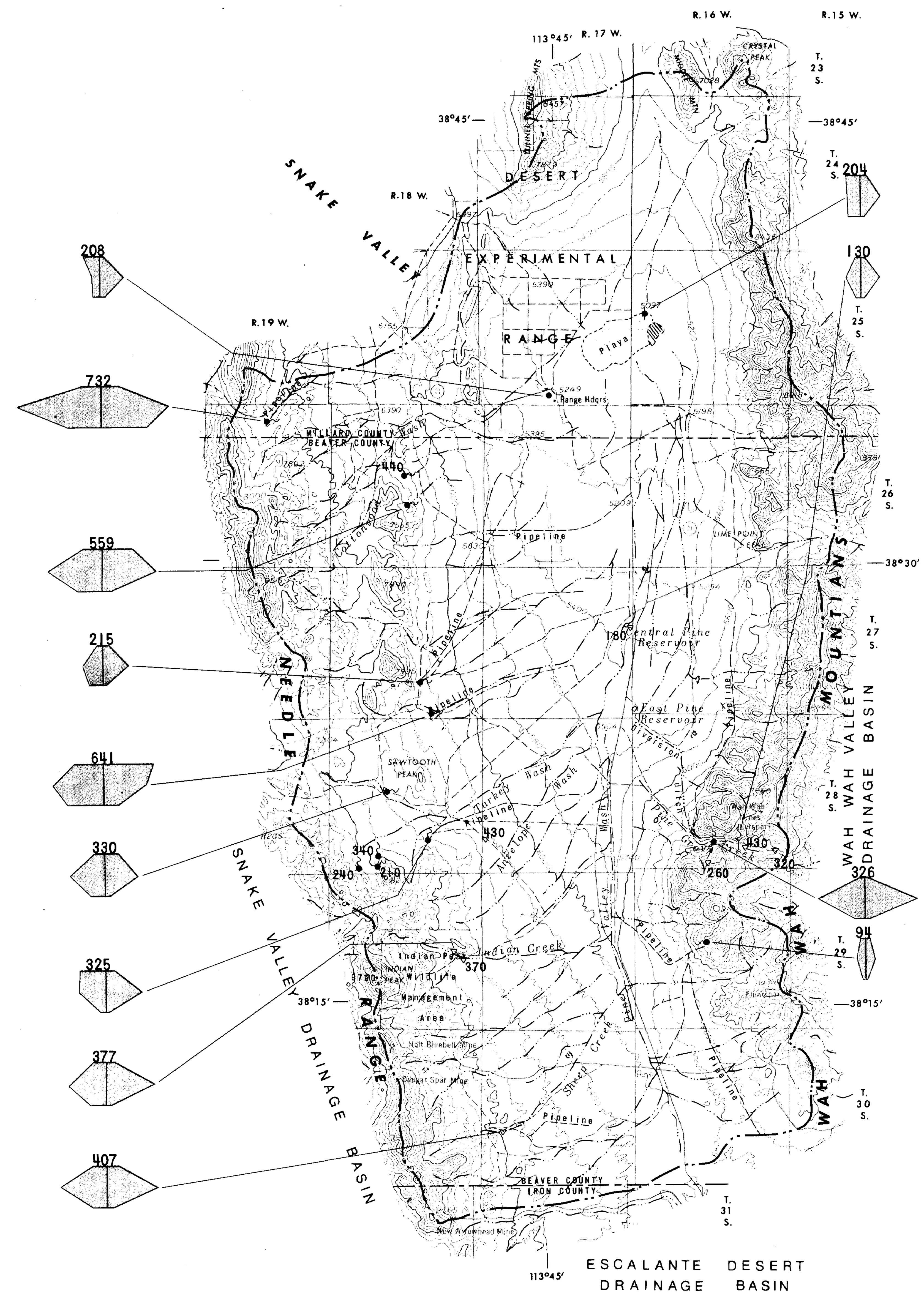
Area of significant evapotranspiration by phreatophytes.

CONVERSION UNITS

Inches	Millimetres
8	203
10	254
12	305
16	406
20	508

5 0 5 MILES
5 0 5 KILOMETRES

CONTOUR INTERVAL 200 FEET (60 METRES)
WITH SUPPLEMENTARY CONTOURS AT 100-FOOT (30-METRE) INTERVALS
DATUM IS MEAN SEA LEVEL



CHEMICAL QUALITY OF WATER

EXPLANATION

CHEMICAL-QUALITY SAMPLING SITES

440 Spring

Well

Unused well

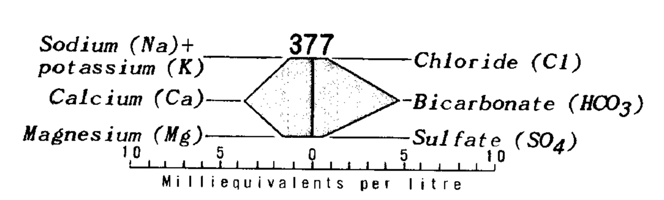
Mine drain

Stream or reservoir

Number by symbol is dissolved-solids concentration, in milligrams per litre, estimated from specific conductance (table 5, 7, or 8)

STIFF DIAGRAMS (Stiff, 1951)

Show concentrations of cations and anions, in milliequivalents per litre, for selected water analyses



Number at top is dissolved-solids concentration, in milligrams per litre. Chemical analyses for individual sources given in table 9

Drainage divide

Hydrogeology by Jerry C. Stephens, 1974; geology after Stokes (1964) with modifications by Jerry C. Stephens, 1974

MAPS SHOWING HYDROGEOLOGY, CHEMICAL QUALITY OF WATER, PRECIPITATION, AND SUBBASINS FOR WHICH RUNOFF WAS ESTIMATED IN THE PINE VALLEY DRAINAGE BASINS, MILLARD, BEAVER, AND IRON COUNTIES, UTAH