WATER RESOURCES OF MILLARD COUNTY, UTAH

by

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Utah Geological Survey, retired

OPEN-FILE REPORT 447 **May 2005**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

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2005

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Introduction

This summary of the water resources of Millard County is designed to accompany Utah Geological Survey (UGS) Bulletin 133, Geology of Millard County, Utah (Hintze and Davis, 2003). It provides a general overview of the surface- and ground-water conditions based on data compiled from a variety of sources. Technical details on the water resources are present in the reference sources cited in this report and in additional publications at the end of the reference list, in particular the Utah Department of Natural Resources Technical Publications and Basic Data Reports. The geology in this water-resources report will be more understandable if the reader refers to UGS Bulletin 133.

Historical Climatic Precipitation and Temperature Records

When weather data, especially precipitation and temperature, are compiled and averaged over a long period of time they become climate data. Weather stations have recorded data in Millard County for more than 100 years. All the weather stations are, and have been, in the valleys and deserts of the county, except for Oak City and Cove Fort. Oak City is on the bordering alluvial slope of the Canyon Mountains and Cove Fort is on the alluvial flank of the Pahvant Range (figure 1). In Pine Valley weather data were recorded at the headquarters of the Desert Experimental Range for many years. However, that facility has been shut down since 1982. Also, for a considerable time there was a weather station at McCornick on the old railroad line between Fillmore and Delta. Kelsey (1992) reported that this railroad line operated from 1923 to 1984.

Historical precipitation and temperature records are presented in two tables (tables 1 and 2) that span the time interval 1892 to 1992. There is overlap in some of the records due to different periods of compilation by authors. It should be noted that the basic maximum temperature is the highest temperature measured each 24-hour period at the station. The average monthly maximum temperature is an average of the daily maximum temperatures. The altitudes of the weather stations are given in table 2. Meinzer (1911) did not report any temperature data (table 1).

Table 1. Annual precipitation for Millard County locations, in inches, 1892 to 1901 (Meinzer, 1911).

	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901
Deseret	9.47	7.66	8.01	--	--	--	--	--	5.38	9.01
Fillmore	--	15.59	13.37	16.36	11.16	17.04	14.59	14.48	9.32	12.88
Scipio	--	--	--	--	13.62	19.24	--	15.52	6.92	12.69

Table 2. Climate data for Millard County locations (average monthly and annual precipitation in inches, and average monthly maximum temperature with annual average in degrees Fahrenheit [°F]); [w]=1898 to 1932 (Woolley, 1947); [s]=1951-1980 (Stevens and others, 1983); [a]=various (Ashcroft and others, 1992).

Location	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Black Rock[w]	0.52	0.78	1.01	1.01	0.89	0.36	0.56	0.78	0.65	0.92	0.64	0.51	8.63 inches
Black Rock[a]	0.50	0.48	1.12	0.98	0.78	0.54	0.86	0.83	0.86	0.78	0.77	0.57	9.07 inches
Cove Fort[s]	0.97	1.35	1.54	1.54	1.20	0.65	1.00	1.12	0.95	0.98	1.03	1.07	13.40 inches
Delta[a]	0.49	0.56	0.85	0.78	0.90	0.47	0.54	0.57	0.81	0.81	0.70	0.62	8.11 inches
Deseret[w]	0.61	0.75	0.89	0.92	1.02	0.37	0.40	0.60	0.69	0.73	0.61	0.57	8.16 inches
Deseret[s]	0.59	0.52	0.75	0.80	0.82	0.43	0.45	0.63	0.49	0.67	0.63	0.55	7.33 inches
Eskdale[s]	0.26	0.33	0.53	0.51	0.57	0.54	0.35	0.39	0.45	0.68	0.50	0.40	5.51 inches
Eskdale[a]	0.23	0.32	0.67	0.55	0.70	0.61	0.54	0.54	0.75	0.63	0.40	0.31	6.25 inches
Fillmore[w]	1.13	1.46	1.86	1.67	1.46	0.50	0.87	0.78	0.97	1.30	1.14	1.16	14.30 inches
Fillmore[a]	1.29	1.27	2.10	1.80	1.47	0.90	0.77	0.85	1.22	1.41	1.42	1.50	16.00 inches
Garrison[w]	0.46	0.70	0.85	0.73	0.75	0.29	0.54	0.55	0.70	0.75	0.76	0.28	7.36 inches
Garrison[a]	0.36	0.51	0.85	0.88	0.75	0.56	0.60	0.89	0.84	0.81	0.54	0.44	8.03 inches
Kanosh[w]	1.12	1.55	1.97	1.62	1.56	0.49	0.84	1.11	0.92	1.26	1.23	1.11	14.78 inches
Kanosh[a]	1.12	1.17	1.94	1.78	1.37	0.78	0.89	1.04	1.15	1.29	1.36	1.36	15.26 inches
McCornick[w]	0.86	1.12	1.41	1.22	1.22	0.35	0.42	0.52	0.80	0.96	0.78	0.92	10.58 inches
Oak City[w]	1.06	1.16	1.61	1.44	1.50	0.50	0.80	0.90	0.86	1.31	1.10	1.06	13.30 inches
Oak City[a]	1.03	1.03	1.50	1.41	1.39	0.78	0.52	0.86	1.08	1.33	1.25	1.23	13.41 inches
Pine Valley[s]	0.30	0.31	0.55	0.60	0.62	0.42	0.78	0.84	0.56	0.50	0.35	0.29	6.12 inches
Scipio[w]	1.29	1.56	1.67	1.27	1.32	0.52	0.78	1.14	1.06	1.13	1.04	1.05	13.83 inches
Scipio[a]	1.03	1.17	1.29	1.18	1.21	0.84	0.88	1.16	1.19	1.50	1.17	1.25	13.86 inches
Black Rock[a]	40.3	47.9	56.3	65.6	75.3	85.7	92.7	90.0	80.5	68.4	53.4	41.7	66.5 °F
Cove Fort[s]	41.8	44.9	50.2	59.5	70.1	82.0	90.5	87.7	79.6	67.0	52.1	43.4	64.1 °F
Delta[a]	36.8	45.3	54.4	63.6	73.7	85.1	93.1	90.6	80.1	67.7	51.3	38.5	65.0 °F
Deseret[w]	38.1	44.9	55.0	64.2	72.7	83.7	91.2	89.3	79.9	67.4	53.4	38.5	64.8 °F

Deseret[s]	38.6	46.6	85.2	64.0	74.5	85.1	93.6	90.1	80.8	67.9	51.2	40.2	65.6 °F
Eskdale[s]	42.9	48.7	56.2	64.1	75.0	85.6	94.7	93.0	82.4	69.8	53.9	43.9	67.6 °F
Eskdale[a]	41.5	48.6	56.4	64.8	75.0	85.4	93.0	90.7	80.7	67.9	53.4	41.8	66.6 °F
Fillmore[w]	42.0	47.1	55.1	65.2	74.9	86.9	93.9	92.1	82.9	69.5	55.8	41.6	67.2 °F
Fillmore[a]	39.5	45.9	54.1	63.0	72.7	83.9	91.6	89.1	80.0	67.2	51.9	40.3	64.9 °F
Garrison[a]	41.9	48.4	55.1	64.1	73.9	85.0	92.6	89.5	80.0	67.5	53.1	43.0	66.2 °F
Kanosh[a]	39.5	46.2	54.3	62.5	72.6	83.9	92.3	89.7	80.7	67.6	52.4	40.7	65.2 °F
Oak City[a]	39.0	46.1	54.2	63.0	74.1	85.7	94.3	92.1	82.2	69.1	52.4	40.5	66.1 °F
Pine Valley[s]	41.0	47.1	53.7	62.5	73.0	84.4	92.5	89.4	80.8	68.1	52.3	43.1	65.7 °F
Scipio[w]	40.7	45.0	52.9	62.8	71.0	82.4	88.7	86.4	78.3	66.3	53.5	40.9	64.1 °F
Scipio[a]	38.2	45.2	52.8	62.7	72.4	82.2	89.7	87.4	78.9	66.6	51.4	39.9	63.9 °F

Elevations in feet and period of record for [a] and [s]:

[a] Black Rock 4,896, 1951-1992; [s] Cove Fort 5,980, 1951-1980; [a] Delta 4,623, 1938-1992; [s] Desert 4,585, 1951-1980; [a] Eskdale 4,976, 1966-1992; [s] Eskdale 4980, 1951-1980; [a] Fillmore 5,125, 1928-1992; [a] Garrison 5,277, 1951-1990; [a] Kanosh 5,020, 1928-1992; [a] Oak City 5,069, 1928-1992; [s] Pine Valley/Desert Experimental Range Headquarters 5,249, 1951-1980; [a] Scipio 5,306, 1928-1992.

Based on recorded precipitation, Millard County has an arid to semiarid climate. Only the highest parts of the Canyon Mountains and Pahvant Range receive 20 inches (51 cm) or more of precipitation in a year. The deserts and valleys of the central and western parts of the county are classified as arid whereas Pahvant Valley, Scipio Valley, Round Valley, and the Cove Fort area are semiarid. Typical characteristics of a dry climate include: (1) potential evaporation is greater than the average annual precipitation, and (2) precipitation is erratic and undependable. An "average" annual precipitation rarely occurs. A station may receive 12 inches (30 cm) in a year and in the next year receive only 6 inches (15 cm).

Water Resources of the Valleys and Deserts

Water is precious and vital for culinary, agricultural, industrial, and utility needs in Millard County. Water is obtained by diversions from rivers, streams, springs, and by withdrawal of ground water from wells. The allocation of all surface water was determined by adjudication many years ago and now the dependence and demand on ground water is becoming increasingly important.

Precipitation in the valleys and deserts of the county contributes very little to surface water or ground water because of the high evapotranspiration rate in those areas. All streams originate in mountainous areas where precipitation is highest and evapotranspiration is lowest. Likewise, recharge to valley ground water is from the bordering mountains and alluvial slopes. Irrigation water also recharges ground water.

Water takes up chemical constituents in solution as it flows over or through rocks and unconsolidated deposits. The major ions in solution include calcium, sodium, potassium, magnesium, silica, nitrate, sulfate, and chloride. Manganese, fluoride, boron, and iron are generally present in small amounts (Bjorklund and Robinson, 1968). An indication of water quality is the total dissolved solids (tDS) content, measured in parts per million (ppm) or milligrams per liter (mg/L). The concentration of soluble salts (tDS) is termed "salinity" which can be used to classify water quality (table 3).

Table 3. Water quality classification (Robinove and others, 1958)

Class	Dissolved solids (ppm or mg/L)
Fresh	0-1,000
Slightly saline	1,000-3,000
Moderately saline	3,000-10,000
Very saline	10,000-35,000
Briny	More than 35,000

High magnesium and calcium content make the water hard while high iron and sulfate content produce odors and discoloration. Culinary water (water for human consumption) should have less than 500 ppm tDS, but humans can usually tolerate up to 1,000 ppm. Horses and cattle can usually tolerate up to 3,000 ppm, and sheep probably a little more. Water for irrigation should have a 700 ppm tDS content or less (Mark Jensen, Utah Division of Drinking Water, March 5, 1998). Soluble salts tend to accumulate in the soils if the tDS content is greater than that.

The first comprehensive report on water resources in the county was by Oscar E. Meinzer

(1911). Since then many state and federal reports have been published on water resources in the county, especially on ground-water conditions in the Sevier Desert and Pahvant Valley. Detailed information about yields of pumped and flowing wells, stream flows, and quality of water from wells, springs, and streams in the county is beyond the purposes of this report. The interested reader will find additional information in the cited reports in the following summaries of water resources data for the valleys and deserts of Millard County and in the references listed at the end of this open-file report.

Scipio and Round Valleys

These two small valleys, in easternmost Millard County (figure 1), are connected by a narrow water gap. Scipio Valley occupies about 36 square miles (93 km^2) and Round Valley, to the south, contains about 27 square miles (70 km^2). Together, the two valleys form a closed basin with no surficial drainage outlet. Farming and ranching are the main economic activities. The average annual precipitation is 13.86 inches (35.2 cm) in the town of Scipio.

Surface water: Irrigation water is obtained from a series of large springs and spring-fed streams in the southwestern part of Round Valley. Water from Maple Grove Springs, Pharo Creek, Rock Creek, and Willow Creek flows to the Scipio Lake reservoir in the lower (northern) part of Round Valley (Meinzer, 1911). Water from the reservoir flows northward in Round Valley Creek to Scipio Valley where it is used. The water from Maple Grove Springs had a tDS content of 236 mg/L on September 25, 1978 (Utah Division of Drinking Water, written communication March 5, 1998). Presumably, water from other springs in the area has a similar quality.

The main culinary water supply for the town of Scipio is obtained from springs 5 miles (8 km) south of town (NW1/4 section 16, T. 19 S., R. 2 W.). The large spring and seep area discharges about 115 gallons per minute (435 L/min) and the water had a tDS content of 348 mg/L on March 16, 1995 (Utah Division of Drinking Water, written communication, March 5, 1998).

Ground water: Shallow water-table conditions in Scipio Valley change across an east-west line about 2 miles (3.2 km) north of the town of Scipio. South of this line at least 6 wells obtained water at depths of 8 to 55 feet (2-17 m) from the shallow ground-water table in 1963 (Bjorklund and Robinson, 1968). North of this line there is no shallow ground-water table. The many northeast-trending sinkholes in this area apparently drain all shallow water to deeper levels (Bjorklund and Robinson, 1968; also see the geologic map of the Delta 30- x 60-minute quadrangle, Hintze and Davis, 2002). The sinkholes are oblong, range from 3 feet (1 m) to about 25 feet (7.6 m) in depth, from less than 1 foot (0.3 m) to more than 30 feet (9.1 m) in width, and from 3 feet (1 m) to more than 200 feet (61 m) in length. The disturbed and jumbled sediments beneath the sinkholes provide an easy descent for water. Bjorklund and Robinson (1968) believed that the sinkholes were produced by the collapse of caverns in limestones in the North Horn or Flagstaff Formations underlying the valley and the subsequent collapse of the overlying valley-fill deposits. The limestone caverns were caused by ground-water solution along fractures, joints, and fault planes.

Artesian aquifers underlie Scipio Valley at depths from 265 to 450 feet (81-137 m) or deeper. At any given location a drill hole may encounter 1 to 3 or 4 aquifers within this depth interval. The artesian pressures are low to moderate, but not sufficient to raise the water to the ground surface. The aquifers are in permeable beds of the valley fill as well as limestone and sandstone bedrock. A water well in the SW1/4 NE1/4 NW1/4 section 28, T. 17 S., R. 2 W. is

373 feet (114 m) deep and penetrated bedrock at a depth of 180 feet (55 m). Another well, in the NW1/4 SE1/4 NE1/4 section 31, T. 17 S., R. 2 W. is 346 feet (105 m) deep and penetrated bedrock at a depth of 196 feet (60 m). The major aquifer is in the permeable bedrock for these two wells (Bjorklund and Robinson, 1968).

A water well to augment the culinary water supply for the town of Scipio was drilled in 1973 in the NW1/4 NE1/4 section 20, T. 18 S., R. 2 W. The well was drilled to a depth of 450 feet (137 m) and did not encounter bedrock. Water, under pressure, entered the well from 2 or 3 gravel beds between depths of 300 and 402 feet (91-123 m). About 300 gallons per minute (1,136 L/min) can be pumped from the well (Terry Monroe of Scipio, verbal communication, March 18, 1998). A February 2, 1978, water sample from the well had a tDS content of 487 mg/L (Utah Division of Drinking Water, written communication, March 5, 1998).

The major ground-water aquifer underlying central Round Valley is artesian. The water is in coarse-grained beds of the valley fill as well as underlying sandstone of the North Horn Formation. Artesian pressure brings water to the ground surface. Data for four of the water wells that penetrate the aquifer are given in table 4.

Table 4. Artesian water wells in Round Valley (Bjorklund and Robinson, 1968).

Well	Well location	Total depth, feet	Depth to bedrock, feet	Depth(s) to tops of water-bearing zones, in feet
(a)	SW1/4 SW1/4 SE1/4 section 27, T. 20 S., R. 2 W.	587	557 sandstone	220, 331, 557
(b)	SW1/4 NW1/4 NE1/4 section 34, T. 20 S., R. 2 W.	770	?	Water in sandstone
(c)	NE1/4 NE1/4 NW1/4 section 34, T. 20 S., R. 2 W.	700	450 sandstone	450, 612
(d)	NW1/4 NW1/4 NE1/4 section 15, T. 20 S., R. 2 W.	855	833 sandstone	255, 396, 833

It appears likely that within the valley fill there are 2 to 3 aquifers at different depths and probably overlapping, that are interconnected by leakage. Driller's logs show that the sandstone bedrock is capped by relatively impermeable silt and clay or shale. This confining material produces the artesian pressure in the sandstone. Water wells (a), (b), and (c) (table 4) are spaced fairly close together, tap permeable zones in the sandstone, and collectively discharge 1,300 to 1,800 gallons per minute (4,900 to 6,800 L/min) (Bjorklund and Robinson, 1968). Water well (d) discharges about 35 gallons per minute (130 L/min). Water from these 4 wells is used for irrigation.

Pahvant Valley

This valley is in the eastern part of the county (figure 1) and occupies about 280 square miles (725 km^2). The majority of the county's population lives in the valley which contains the towns of Holden, Fillmore (the county seat), Meadow, and Kanosh. The economy is chiefly agricultural, but tourist services (U.S. Interstate Highway 15) are important. Agricultural activities include irrigation farming, dry farming, and stock raising. The major irrigated crops are alfalfa, sugar beets, potatoes, and grains. About 35,300 acres (14,300 hm^2) of land were irrigated in 1960 (Mower, 1965).

Meinzer (1911), Livingston and Maxey (1944), Dennis and others (1946), Woolley (1947), Mower (1965), Handy and others (1969), Thiros (1988), and Holmes and Thiros (1990) have reported on the water resources of Pahvant Valley.

Surface water: Many streams flow into Pahvant Valley from the Canyon Mountains and the Pahvant Range (table 5). Chalk Creek and Corn Creek have the largest and most continuous flows while Pine and Meadow Creeks have small, but steady flows. All the other streams have intermittent or small flows especially during the summers. The flow of Chalk Creek was measured irregularly from 1938 to 1943 and has been measured continuously since 1944. The flows of Pine, Meadow, and Corn Creeks have been measured at numerous, but irregular intervals since 1938. Flow measurements of the other streams have been estimated on the basis of physical, hydrologic, and climatologic data, plus runoff efficiency and characteristics of the individual watershed areas (Mower, 1965).

Table 5. Measured and estimated average annual streamflows into Pahvant Valley, 1944-1959 (Mower, 1965).

Stream	Average altitude (feet)	Size of watershed (acres)	Average annual flow (acre-feet)
Whisky Creek	6,060	17,200	4,800
Eightmile Creek	6,290	20,800	5,800
Scipio Pass	5,940	29,400	3,000
Wild Goose Creek	6,620	12,200	6,300
Wide Canyon	6,870	12,900	6,000
Maple Hollow	6,470	11,900	5,000
Pioneer Creek	6,720	20,500	10,000
Chalk Creek	7,980	36,000	25,100
Pine Creek	7,650	3,800	2,000
Meadow Creek	8,130	8,700	5,800
Sunset Creek	6,740	9,800	3,800
Corn Creek	7,590	50,000	11,800
All other streams	--	80,800	14,600
Totals	--	314,000	104,000

The average annual streamflows given in table 5 should be, more or less, similar to averages in other 16-year time intervals. Nearly all the surface runoff of 104,000 acre-feet (128 hm^3) of water is diverted for irrigation. The quality of the stream waters, from all indications, is very good. In September 1985, water samples were obtained from Chalk Creek, Meadow Creek, and Corn Creek at the points where they emerge from the Pahvant Range. The samples had tDS contents of 220, 250, and 360 mg/L, respectively (Thiros, 1988).

Ground water: Sand and gravel beds within the basin-fill are the main aquifers. These beds are thicker and coarser near the mountains and as they slope gently downwards to the west they become thinner and finer grained under the central and western parts of the valley. Beneath the lower parts of the valley the aquifers are overlain by confining silt and clay beds which produce artesian conditions. However, the silt and clay beds are not completely confining and there is vertical movement of water between aquifers. At any given location, a drill hole to a depth of 750 feet (229 m) may encounter 3 to as many as 12 water-saturated beds of sand and gravel that hydraulically act as one aquifer. Almost everywhere the subsurface thickness of water saturated sediments is 200 feet (61 m), or more, and the artesian pressure increases with depth (Mower, 1965). The ground-water movement is westwards and a considerable amount enters the basalt flows bordering the west side of the valley. In places the subsurface basalt is highly jointed and fractured and it yields copious amounts of water to wells. The ground-water flow continues westward and a large amount issues from the basalt as springs in the vicinity of Clear Lake.

A number of wells have penetrated, at various depths, the highly eroded, high relief, poorly cemented boulders, cobbles, sand, and silt of the Oak City Formation. Mower (1965) called this rock unit the Sevier River (?) Formation and considered the top of the unit to be the base of the ground-water reservoir beneath the valley. The Oak City Formation is not permeable.

By the end of 1962 there were 540 water wells in the valley (Mower, 1965). Most of the wells are 200 to 500 feet (61-152 m) deep, but many are less than 200 feet deep, and a few are deeper than 800 feet (244 m) (Thiros, 1988). All the non-flowing wells are pumped and many of the flowing wells are pumped to increase yields. Pumped yields range up to 2,000 gallons per minute (7,570 L/min), or more. The general area of artesian flowing wells is about 2 to 4 miles (3.2-6.2 km) wide and extends from Greenwood (4 miles west of Holden) southerly to about 1 mile (1.6 km) west of Meadow (Thiros, 1988). Well water is used for irrigation, livestock watering, and municipal purposes. Municipal water for the towns of Holden, Fillmore, Meadow, and Kanosh is obtained from springs in canyons near to these towns.

During 1987 to 1996 the average annual ground water withdrawal from wells in the valley was about 80,000 acre-feet (98.6 hm^3) (Susong and others, 1998). Mower (1965) estimated that less than 1 million acre-feet (1,200 hm^3) of ground water beneath the valley is recoverable and that depletion is exceeding recharge. Handy and others (1969) reported on the large increase of tDS in the ground water west of Kanosh and west of Interstate 15. The tDS content in that area ranges from 1,000 to 9,000 mg/L while the ground water in the remainder of Pahvant Valley has a tDS content that ranges from 300 to 1,000 mg/L (Holmes and Thiros, 1990).

Sevier and Black Rock Deserts

These two deserts occupy a little more than one-third the area of Millard County (figure 1). The Sevier Desert extends northward into Juab County and southwest to include the Sevier Lake playa. The Millard County part of the Sevier Desert is bounded on the east by the Canyon Mountains and on the west by the Drum Mountains, Little Drum Mountains, and the House Range. East of the Cricket Mountains the Sevier and Black Rock Deserts are arbitrarily divided by latitude 39 degrees north. The Black Rock Desert is bounded on the east by the volcanoes and lava flows that border Pahvant Valley. The desert extends southwesterly to the Mineral Mountains.

In the Sevier Desert the towns of Delta, Deseret, and Hinckley comprise the second most populous area in the county. Agriculture, electricity generation, and tourist services are the chief economic enterprises. Agricultural activities include irrigation farming, dairy farming, dry farming, and stock feeding. The main irrigated crops are small grain, alfalfa, and alfalfa seed;

wheat is the principal dry-farming crop (Mower and Feltis, 1968). About 65,000 acres (26,300 hm^2) of cropland are irrigated (Holmes, 1984).

The Black Rock Desert is virtually uninhabited. There is little or no farming. Cattle grazing and limestone mining in the Cricket Mountains are about the only economic endeavors.

Meinzer (1911), Nelson and Thomas (1953), Mower (1967), Mower and Feltis (1968), Handy, Mower, and Sandberg (1969), Enright and Holmes (1982), and Holmes (1984) reported on the water resources of the Sevier Desert. Wilberg (1991) made a hydrologic reconnaissance of the Sevier Lake area. Meinzer (1911), Thiros (1988), and Holmes and Thiros (1990) furnished data on the water resources of the Black Rock Desert.

Surface Water: The Sevier River is the chief source of irrigation water for the Sevier Desert and all its water is derived from outside the county. The river issues into the Sevier Desert at the mouth of Leamington Canyon, winds its way through its dissected Lake Bonneville delta (figure 2), passes north of the town of Delta, then flows southwesterly toward the Sevier Lake playa. Susong and others (1998) reported that the Sevier River had an average annual flow of 181,700 acre-feet (224 hm^3) into the Sevier Desert during the period 1935 to 1997. All of the river water is diverted for irrigation and, except during intervals of unusually heavy upstream precipitation, none of the water reaches the Sevier Lake playa. In 1964 a river water sample obtained near Lynndyl had a tDS content of about 1,000 ppm and a sample downstream at Deseret had a tDS content of about 3,000 ppm (Hahl and Mundorff, 1968). Prior to irrigation Oak Creek and the Beaver River were tributaries to the Sevier River. Mower and Feltis (1968) estimated that the annual perennial flow of Oak Creek is 10,000 to 15,000 acre-feet (12.23-18.35 hm^3). Ephemeral annual runoff from drainages such as Swasey and Soap Washes on the west and southwest sides of the desert was estimated by Holmes (1984) to be 8,000 acre-feet (9.9 hm^3).

There are no permanent streams in the Black Rock Desert. The Beaver River channel has been dry since 1914 (Holmes and Thiros, 1990) except for occasional wet years such as 1983. All drainages, including Cove Creek, are ephemeral. The estimated annual runoff from the Cricket Mountains is 3,600 acre-feet (4.4 hm^3).

Ground Water: The unconsolidated upper part of the basin fill in the Sevier Desert is at least 1,300 feet (396 m) thick and perhaps as much as 2,140 feet (652 m) thick (Holmes, 1984). The aquifers in the unconsolidated sediments are fluvial beds except those in the Clear Lake area where basalt yields large amounts of water to springs and wells. Alluvial-fan and fluvial deposits interfinger with basinal lacustrine sediments around the margin of the basin. Many fluvial beds extend a considerable distance into the basin where they generally become finer grained. The uppermost lacustrine sediments are the Lake Bonneville delta deposits of the Sevier River in the northeast part of the area and the lake-bottom silts of Lake Bonneville in the remainder of the basin. The Lake Bonneville sediments overlie a great thickness of interbedded fluvial and lacustrine strata including a considerable thickness of the Pliocene-early Pleistocene "lacustrine deposits of Sevier Desert." Lacustrine beds generally consist of silt, clayey silt, or fine sand whereas fluvial beds generally consist of sand and gravel.

Numerous aquifers are present within the basin fill. Mower and Feltis (1968) grouped the aquifers into a shallow water-table aquifer, an upper artesian aquifer, and a lower artesian aquifer. Less permeable strata (aquitards) separate the aquifers. Ground water beneath the eastern and western margins of the desert in Millard County is found only under non-artesian water-table conditions. The basalt aquifer east and southeast of Clear Lake is included in the shallow water-table aquifer (Holmes, 1984). Boundaries of aquifer zones and aquitards are most clearly identified in the vicinity of Lynndyl. In descending order, these aquifers and aquitards are: (1) a water-table aquifer near the land surface to a depth of 50 to 60 feet (15-18 m); (2) an aquitard that varies from 25 feet (7.6 m) to about 90 feet (27 m) thick; (3) the upper artesian aquifer, the top of which is 90 to 130 feet (27-40 m) below the land surface, is a group of aquifers that is about 60 to 120 feet (18-37 m) thick; (4) an aquitard that ranges from 300 to 500 feet (91-152 m) thick; and (5) the lower artesian aquifer that varies from about 500 to 700 feet (152-213 m) below the land surface. The thickness of this zone of aquifers is 400 feet (122 m), or more (Holmes, 1984, figure 4). Elsewhere in the basin the depth to the artesian aquifers vary, the thicknesses of the aquitards vary, but the general relationships are the same.

About 1,500 water wells were in the Sevier Desert in 1964 (Mower and Feltis, 1968). The upper artesian aquifer is tapped by most of the domestic and stock wells and some irrigation wells near Lynndyl and Leamington; the lower artesian aquifer is tapped by most of the public supply, industrial, and irrigation wells. The average withdrawal from wells during 1987 to 1996 was 25,000 acre-feet (30.6 hm^3) per year (Susong and others, 1998). In 1935 almost all the water wells were artesian flowing wells. However, by 1964 the artesian flowing wells were found only in the Deseret area, areas north and east of Sugarville, and a large area southeast of Delta. This indicates ground-water mining. The well water in the Delta, Sugarville, Hinckley, and Deseret areas contains tDS of 500 ppm, or less (Mower and Feltis, 1968). Ground water is near the land surface in the Sevier Lake playa and all the sediments beneath the playa are saturated with saline to briny water.

Clear Lake (figure 3), in the southeastern part of the Sevier Desert, is fed by springs that issue from the shallow west margin of the basalt of Pavant Butte. The spring water flows from numerous small openings in the basalt along the eastern shore and from the bottom of Spring Lake. The water flows through a flume from Spring Lake to Clear Lake. The spring waters that sustain the lake had a tDS content of 1,000 mg/L on April 24, 1986 (Thiros, 1988). The average annual discharge of the springs was 14,900 acre-feet (18.4 hm^3) during 1960 to 1964 (Mower, 1967). Water enters the extensive basalt flow chiefly as direct recharge from precipitation and the westward movement of unconsumed surface and ground water in Pahvant Valley (Mower, 1967).

Thiros (1988) supplied the records of a small number of water wells in the Black Rock Desert. Data for five of these wells are given in table 6.

Table 6. Water wells in the Black Rock Desert (Thiros, 1988).

No.	Location	Altitude (feet)	Depth, (feet)	Depth to water (feet), and date	Comments
1	NE1/4 NE1/4 NE1/4 section 5, T. 22 S., R. 8 W.	4,690	134	49.1 8/3/86	stock water
2	NW1/4 NE1/4 SE1/4 section 34, T. 21 S., R. 7 W.	4,690	117	40.5 3/2/86	stock water
3	NE1/4 NE1/4 NE1/4 section 12, T. 23 S., R. 9 W.	4,780	?	24.3 3/2/86	4 gal/min pumped, 1,800 mg/L tDS
4	NE1/4 SE1/4 NE1/4 section 16, T. 23 S., R. 7 W.	4,890	390	208.5 3/2/86	stock water
5	NW/4 NE1/4 NW1/4 section 21, T.24 S., R. 7 W.	5,520	500	373.4 10/25/85	stock water

There is no shallow water table in most of the Black Rock Desert. All wells are pumped and the water, low in quality, is for livestock. Drillers' logs are available for well number 1 and well number 4 (table 6) (Thiros, 1988). These logs, plus the log of a 1,998 feet (609 m) deep railroad well at Neels (Meinzer, 1911), show the clays of the Pliocene-early Pleistocene "lacustrine deposits of Sevier Desert," that have been mapped extensively in the Black Rock Desert (Oviatt, 1991), are thick. Wells number 1 and 4 (table 6) are entirely within this unit and it extends from near the land surface to a depth of at least 1,339 feet (408 m) in the Neels well. Probably much of the unit is water saturated, but the thin, interbedded sand and sandy gravel beds that are aquifers yield relatively small amounts of water to wells. The major water production in the Neels well was pumped from thick beds of sand and gravel and sandstone between depths of 1,345 and 1,450 feet (410-442 m). Meinzer (1911) reported that three analyses of water showed tDS contents of 2,888 to 3,345 ppm. The well was eventually abandoned because of the saline water. A drill hole, 897 feet (273 m) deep, near the railroad siding at Black Rock (Thompson and others, 1995), penetrated a large thickness of the "lacustrine deposits of Sevier Desert" and was still within the unit at the bottom of the hole. No significant aquifers were encountered in the hole.

Whirlwind Valley

This valley is in north-central Millard County and south-central Juab County (figure 1). The Millard County part of the valley occupies about 113 square miles (293 km^2). The valley is uninhabited and stock grazing is the only activity.

Surface water: No perennial streams are present. Swasey Wash, in the center of the valley, is the main drainage and many channels of ephemeral streams are tributary to it. Soap Wash, another main drainage, branches off from Swasey Wash near the southern end of the valley. All the stream channels transport water only during a rapid spring snowmelt or during summer thunderstorms.

Ground water: Insofar as known there are no water wells in the valley. However, in 1980, two exploratory holes were drilled in the valley as part of a water-resources study for the MX-missile siting project. Unfortunately the drill holes were only a short distance apart, both at altitude 5,260 feet (1,603 m) in the SE1/4 SE1/4 NE1/4 section 19, T. 15 S., R. 12 W. The holes were on the eastern alluvial slope of the House Range and above the Bonneville shoreline of Lake Bonneville. Lithologic logs are available for both holes. Hole number 1 was 1,220 feet (372 m) deep and the log was reported by Mason and others (1985). Hole number 2 was 1,033 feet (315 m) deep and the log was reported by Enright and Holmes (1982). Both logs show thick interbeds of sand and gravel, sand, and sandy clay. Hole number 1 was in sand and gravel at a depth of 1,050 feet (320 m); no data was obtained for the lower 170 feet (52 m) of the hole. Hole number 2 drilled into andesite bedrock from depths of 1,020 feet (311 m) to 1,033 feet (315 m). The depth to the water level in hole number 1 was 795.8 feet (243 m) on February 5, 1982. The depth to the water level in hole number 2 was 793.1 feet (242 m) on December 14, 1981. Both holes were plugged and abandoned.

Swasey Spring, at an altitude of 6,635 feet (2,022 m) in the House Range (SE1/4 NE1/4 section 23, T. 16 S., R. 13 W.), had a flow of about 50 gallons per minute (180 L/min) and the water had a tDS content of 382 mg/L (Snyder, 1963; Enright and Holmes, 1982). The spring water is piped to a stock tank near the center of Whirlwind Valley.

Snyder (1963) believed that the drilling prospects were good for finding stock water at the following locations and estimated depths:

(1) section 25, T. 15 S., R. 12 W.; altitude 5,210 feet (1,588 m); estimated depth to water is 800 feet (244 m).

(2) SE1/4 section 17, T. 16 S., R. 11 W.; altitude 5,100 feet (1,554 m); estimated depth to water is 700 feet (213 m).

(3) S1/2 section 3, T. 17 S., R. 11 W.; altitude 4,790 feet (1,460 m); estimated depth to water is 250 to 350 feet (76-107 m).

Wah Wah Valley

This valley is in the south-central part of Millard County and the north-central part of Beaver County. The Millard County portion of the valley is uninhabited and contains about 180 square miles (466 km^2) (figure 1). The valley has a desert climate, less than 8 inches (20.3 cm) of precipitation per year. Vegetation consists of sagebrush, shadscale, greasewood, rabbit brush, and bunch grass. The land is used only for livestock grazing. No vegetation grows on the playa. All of the water-resources information is from Stephens (1974).

<u>Surface water:</u> No perennial streams exist in the valley. Channels of ephemeral streams are present on the bordering alluvial slopes, but water flow in them is restricted to intervals of rapid snowmelt in the mountains and thunderstorms. The water mostly percolates into the alluvium before it reaches the valley floor. Only occasionally does water reach the playa.

<u>Ground water</u>: The basin fill undoubtedly contains several ground-water aquifers. The shallower basin fill is probably a maximum of 2,400 feet (730 m) thick and chiefly consists of unconsolidated and interbedded lacustrine and alluvial sediments of Quaternary and latest Tertiary age and older Tertiary volcanic rocks.

The ground-water aquifers are virtually untapped in the Millard County part of the valley. Only one water well (NW1/4 SW1/4 SW1/4 section 34, T. 24 S., R. 13 W.) has been drilled into it, to a total depth of 294 feet (90 m). A gravel aquifer was penetrated at a depth of 270 feet (82 m). The depth to water was 212 feet (65 m) in October, 1972, which indicated some artesian pressure. In 1972, and prior years, an estimated one to two acre-feet (1,230-2,470 m^3) were pumped annually from the well for livestock watering. The quality of the water ranged from 1,370 to 2,640 milligrams per liter of dissolved solids for samples obtained in 1935, 1962, and 1963.

The Von Glahn No. 1 Federal oil-test hole that was drilled in 1951 in the NE1/4 NE1/4 SE1/4 section 33, T. 24 S., R. 13 W. to a total depth of 1,971 feet penetrated water-bearing strata at depths of 233 feet (71 m), 490 feet (149 m), and 1,125 feet (343 m) (Stephens, 1974). The data from this hole and the water well, however, are not sufficient to evaluate the aquifers, the potentiometric surface of the aquifers, or to enable a reliable estimate of the quantity of stored water. A few more water wells are needed.

Tule Valley

This valley is a long, north-south oriented, closed basin in western Millard and Juab Counties. The valley is about 56 miles (90 km) long and it is narrow in the southern part and fairly broad in the northern part (figure 1). The Millard County part of the valley occupies about 438 square miles (1,134 sq. km). Precipitation is quite variable, but the annual average is likely about 7 inches (18 cm), or slightly less, within the valley. Precipitation is greater in the surrounding mountains. Tule Valley is uninhabited and the only activity is stock grazing; chiefly the winter grazing of sheep.

Meinzer (1911), Stephens (1977), Gates and Kruer (1981), and Wilberg and Stolp (1985) have written about water resources in the valley.

Surface water: There are no permanent streams in the valley nor in the canyons that drain to the valley. Many ephemeral stream channels exist, but they only transport water during, or just after, a thunderstorm or during a rapid spring snowmelt. Mountain stream runoffs usually infiltrate the alluvial fans around the valley. Water reaches the playas only during extraordinary runoffs. Thirteen small rock or earthen dam livestock reservoirs have been constructed in the valley. They only contain runoff briefly and are not a dependable source of water (Stephens, 1977).

Ground Water: The maximum thickness of basin fill (late Tertiary and Quaternary) is estimated to be 6,600 feet (2,000 m) (Allmendinger and others, 1985, figure 6). This maximum thickness is likely attained beneath the valley between U.S. Highway 6-50 and Chalk Knolls. Elsewhere, in the middle of both northern and southern Tule Valley, bedrock ridges and bedrock outliers indicate that the basin fill is much shallower in those areas. Probably much of the fill is unconsolidated or only weakly cemented fluvial and lacustrine deposits.

At least 26 water wells have been drilled in the Millard County part of Tule Valley (Stephens, 1977; Mason and others, 1985). The wells range from 42 to 624 feet (13-190 m) in depth. Nineteen wells were drilled in 1979 and 1980; however, by the end of 1983, 11 of these wells which were all 200 feet (61 m), or less, in depth, were plugged and abandoned (Mason and others, 1985). None of the wells drilled in the valley have been, or are, artesian flowing wells and all have to be pumped when water is needed. Stephens (1977) provided drillers' logs of a few wells which all show interbedded clay, sand, and sand and gravel. Data for 7 water wells are given in table 7. The Ibex well (number 7 in table 7) was drilled in 1935 and is the only well in southern Tule Valley. Artesian pressures are only slight and aquifers do not yield copious amounts of water to wells. The depth of the shallow water table is from the land surface to about 40 feet (12 m) in most of the northern valley floor (Stephens, 1977). This is also the main discharge area of springs. Data for 6 springs in the valley are given in table 8.

Table 7. Water wells in Tule Valley (Stephens, 1977; Mason and others, 1985).

No.	Location	Altitude (feet)	Depth, (feet)	Depth to water (feet), and date	Comments
1	SE1/4 SE1/4 SE1/4 section 22, T. 15 S., R. 14 W.	4,545	300	148 8/3/86 130 1/15/76	stock water, 18 gal/min pumped
2	SE1/4 NW1/4 NE1/4 section 11, T. 15 S., R. 16 W.	4,6850	521	440 1/22/35	20 gal/min pumped, 716 mg/L tDS
3	SW1/4 SW1/4 NE1/4 section 17, T. 17 S., R. 15 W.	4,479	430	46.6 12/15/81	BLM observation well
4	SE1/4 SW1/4 NW1/4 section 34, T. 16 S., R. 16 W.	4,790	260	148 12/20/73 146 4/9/76	55 gal/min pumped
5	NW/4 NW1/4 SW1/4 section 25, T. 17 S., R. 15 W.	4,433	42	4 11/20/52 4.9 4/9/76	200 gal/min pumped
6	NE/4 SE1/4 SE1/4 section 6, T. 20 S., R. 14 W.	4,520	624	86 12/15/81 86 2/5/82	BLM observation well
7	NE1/4 NW1/4 SW1/4 section 1, T. 22 S., R. 14 W.	4,780	515	414 1935 >320 4/9/76	14 gal/min pumped 821 mg/L tDS

Stephens (1977) reported that the annual withdrawal of ground water by pumping from wells averaged less than 35 acre-feet (43,000 m^3). This was an almost negligible amount in the overall picture for the valley. Gates and Kruer (1981) estimated that evapotranspiration of water from springs, marshy areas, vegetation, and the shallow water table in northern Tule Valley amounted to about 32,000 acre-feet (39.5 hm^3) annually. Recharge from precipitation over the entire Tule Valley drainage basin was estimated to be 7,600 acre-feet (9.4 hm^3) annually. Thus, about 24,000 acre-feet (29.6 hm^3) of water annually was required to balance the natural discharge and recharge. Gates and Kruer (1981) surmised that this amount entered the consolidated rocks beneath the valley by interbasin ground-water flow. Stephens (1977) suggested that the down-to-the-west normal fault along the west base of the House Range could be a major conduit for ground water moving northward through the consolidated rocks and overlying basin fill. This great fault crosses Sand Pass and extends northward near a down-to-the-east normal fault along the east base of the Fish Springs Range (Morris, 1987). Gates and Kruer (1981) estimated that 680,000 acre-feet (838 hm^3) of ground water was in storage beneath Tule Valley, but much of it may be in sediments of low permeability and specific yield. A considerable amount could be involved in a slow, deep, northward movement as water moves into, and out of, the basin.

Table 8. Springs in Tule Valley (Stephens, 1977; Wilberg and Stolp, 1985).

Name	Location	Altitude (feet)	Discharge (gal/min), and date	tDS (mg/L) and date
Coyote Spring	NW1/4 NE1/4 NW1/4 section 13, T. 16 S., R. 15 W.	4,421	10 4/19/74 100 1/15/76 320 12/14/83	1,430 9/19/74 1,450 8/25/81 1,460 12/14/83
Willow Spring (3 springs)	NE1/4 NW1/4 NE1/4 section 3, T. 15 S., R. 16 W. SW1/4 NW1/4 NE1/4 section 3, T. 15 S., R. 16 W. NE1/4 NW1/4 SE1/4 section 3, T. 15 S., R. 16 W.	4,415 4,418 4,420	21 7/31/84 1.5 30	no analyses
Tule Spring (2 springs)	NW1/4 NE1/4 NE1/4 section 10, T. 17 S., R. 15 W. NE1/4 NW1/4 NE1/4 section 10, T. 17 S., R. 15 W.	4,420 4,420	198 12/14/83 1312/14/83	910 12/14/83 no analysis
South Tule Spring	SW1/4 NW1/4 NE1/4 section 15, T. 17 S., R. 15 W.	4,427	100 11/17/84	no analysis
Skunk Spring	SE1/4 NW1/4 SE1/4 section 28, T. 17 S., R. 16 W.	5,470	3 6/20/73	1,580 6/20/73
Painter Spring	SW1/4 SE1/4 NE1/4 section 5, T. 19 S., R. 14 W.	5,510	12 1929 10 1955 4.4 9/19/74	585 9/19/74 516 1/2/75

Pine Valley and Antelope Valley

Pine Valley is a topographically closed basin in southwestern Millard County, western Beaver County, and northwestern Iron County. The Millard County part of the valley (figure 1) contains about 110 square miles (285 km^2). Antelope Valley (figure 1) is not a closed basin and is open to the north; it extends southwards into Beaver County about 3 miles (5 km), and it occupies about 74 square miles (192 km^2). Neither Pine Valley nor Antelope Valley are inhabited and the only economic activity is stock grazing. Both valleys have a desert climate.

Snyder (1963), Stephens (1976), Gates and Kruer (1981), and Gates (1987) have reported on the water resources of Pine Valley. Hood and Rush (1965) reported on Antelope Valley and Snyder (1963) described three wells in the valley.

<u>Surface water:</u> Streams in Antelope Valley and the Millard County part of Pine Valley are ephemeral. The stream channels only transport water during, or just after, a rainfall or during a rapid spring snowmelt. In Pine Valley all streams drain towards the playa; however, water seldom reaches it. In Antelope Valley the master ephemeral stream is Antelope Valley Wash which drains to the northwest, passes through a narrow water gap (Mormon Gap) in the west rim of the valley, then empties into southern Snake Valley.

<u>Ground water:</u> The permeable basin fill is likely not very thick in Pine Valley. Well 75-1, on the west side of Pine Valley and just south of the Millard-Beaver County line, drilled through Oligocene tuffs, slide blocks, and rhyolitic flows and penetrated Cambrian bedrock at a depth of 2,810 feet (856 m) (Hintze and Davis, 2003, appendix A). Stephens (1976) provided the drillers' log of the water well (well number 1 in table 9) at the headquarters of the Desert Experimental

Range. The log shows gravel, clay and gravel, clay, and clay and sand interbedded with "solid rock" to a depth of 649 feet (198 m) where "sand rock" was encountered. The 9 interbedded "solid rock" intervals ranged from 3 to 36 feet (1-11 m) thick and could be volcanic tuffs or flows or merely large slide-block boulders of Paleozoic rocks like those exposed nearby.

Table 9. Water wells in northern Pine Valley (Stephens, 1976).

No.	Location	Altitude (feet)	Depth, (feet)	Depth to water (feet), and date	Comments
1	NW1/4 NE1/4 SE1/4 section 33, T. 25 S., R. 17 W.	5,263	649	467 3/16/34	12 gal/min pumped 208 mg/L tDS
2	SE1/4 SE1/4 NW1/4 section 18, T. 25 S., R. 16 W.	5,085	340	300 1955	30 gal/min pumped 204 mg/L tDS
3	SE1/4 NW1/4 NW1/4 section 19, T. 26 S., R. 16 W.	5,205	394	329 1960	--
4	SE1/4 section 17, T. 26 S., R. 17 W.	5,355(?)	801	717 1955	7 gal/min pumped

Four water wells have been drilled in northern Pine Valley. Data for these wells are given in table 9. Well number 2 is called the Guyman well and well number 3 is called the Cow Camp well. Wells 3 and 4 are each about 2 miles (3 km) south of the Millard-Beaver County line. Well 1 was used for domestic and stock water; the others were used for stock water. Well 4 was destroyed sometime prior to 1973. Undoubtedly, water-saturated strata are present at depth, but evidently they have a low permeability and only a small artesian pressure. Data are insufficient to calculate the volume of ground water stored in the Pine Valley fill. Stephens (1976) estimated the following: (1) annual recharge from precipitation to the ground-water reservoir is about 21,000 acre-feet (25.9 hm^3); and (2) annual discharge of ground water by springs, seepage to streams, and evapotranspiration totals about 7,000 acre-feet (8.6 hm^3). The discharge to water wells is insignificant. To maintain the long-term natural equilibrium between discharge and recharge about 14,000 acre-feet (17.3 hm^3) of ground water must be discharged annually by means other than those described. Stephens (1976) assumed that about 3,000 acre-feet (3.7 hm^3) of water flowed through the Wah Wah Mountains into the Wah Wah Valley drainage basin annually and that subsurface outflow to other areas averaged about 11,000 acre-feet (13.6 hm^3) annually.

Springs are not significant around northern Pine Valley, but there are some good, perennial-flowing springs in the foothills around the Beaver County part of Pine Valley.

The basin fill of Antelope Valley is evidently not very thick. Snyder (1963) described three wells that had been drilled in the valley: (1) A water well in the SW1/4 SW1/4 NW1/4 section 20, T. 24 S., R. 18 W. was drilled to a depth of 360 feet (110 m) and was dry; (2) a water well in the NE1/4 section 27, T. 24 S., R. 18 W. drilled to a depth of 500 feet (152 m) was dry and it penetrated bedrock less than 200 feet (61 m) below the land surface; and (3) the Von Glahn #1 1951 Desert Range oil-test well in the NW1/4 section 29, T. 24 S., R. 18 W. was drilled to a depth of 936 feet (285 m) and was dry. Hood and Rush (1965) furnished the drillers' log of the well in section 20: clay 0-8 feet (0-2 m), conglomerate 8-20 feet (2-6 m), sandy clay

20-75 feet (6-23 m), sticky clay 75-193 feet (23-59 m), limestone 193-360 feet (59-110 m). The logical conclusion is that the ground water drains into the Paleozoic carbonate bedrock beneath the basin fill.

Tunnel Spring, on the east side of Antelope Valley, should be noted. This spring, on the west flank of the Tunnel Spring Mountains (SW1/4 SE1/4 section 8, T. 24 S., R. 17 W.), is likely associated with a fault. The water discharge and chemical quality are unknown.

Snake Valley

This is a long, north-south valley that straddles the Utah-Nevada border. Hamlin Valley, Utah and Nevada, forms the southern part of the Snake Valley drainage system. Thus, the Snake Valley drainage basin covers the western parts of Juab, Millard, and Beaver Counties, Utah, parts of the western areas of Tooele and Iron Counties, as well as northeastern Lincoln and eastern White Pine Counties, Nevada. The Millard County part of Snake Valley (figure 1), including the Ferguson Desert, occupies about 677 square miles (1,753 km^2). Based on the precipitation records at Garrison and Eskdale the valley has an arid climate. Farming and stock raising are the main economic endeavors. Baker, in Nevada, and Garrison and Eskdale, in Utah, are the major settlements. Gandy and Burbank are small farming and ranching communities.

Meinzer (1911), Snyder (1963), Hood and Rush (1965), Gates and Kruer (1981), Wilberg and Stolp (1985), and Gates (1987) have reported on the water resources of Snake Valley.
<u>Surface water:</u> Six perennial streams (Big Wash, Snake, Baker, Lehman, Silver, and Hendrys Creeks) drain the eastern flank of the Snake Range (Nevada) and flow into the Millard County part of Snake Valley. Many other canyons have intermittent stream flows. The waters of Big Wash and Snake Creeks are used for irrigation in the Garrison area. The waters of Baker and Lehman Creeks are consumed in the vicinity of the town of Baker. Silver Creek, Hendrys Creek, and water from intermittent streams are utilized at farms near the road from U.S. Highway 6-50 north to Gandy. On the east side of Snake Valley all drainages from the Confusion Range, the Conger Range, and the Burbank Hills are ephemeral.

Water from Warm Springs (table 10) sustains Warm Creek for about three miles (5 km) near Gandy where it is used for irrigation. Water at Big Spring issues from gravel on the west side of Hamlin Valley in White Pine County, Nevada. The spring water produces the perennial Lake Creek (Big Spring Creek on some maps) that flows northeast to Snake Valley. Some of the creek water is used in the Burbank area and the remainder flows north for storage in Pruess Lake reservoir (figure 4). The reservoir water is used for irrigation in the Garrison area. Hood and Rush (1965) estimated that the annual stream runoff into Snake Valley was 58,000 acre-feet (71.5 hm^3) and that much of it recharges the ground-water reservoir.
<u>Ground water</u>: The thickness of the unconsolidated basin fill varies with the relief on the underlying bedrock. Hood and Rush (1965) reported the following depths to bedrock in wells: (1) 4,200 feet (1,280 m) to bedrock in the SW1/4 SE1/4 section 19, T. 20 S., R. 19 W. (well 56-1 in appendix A of Hintze and Davis (2003); (2) 200 feet (61 m) to bedrock at the south side of Garrison in the SE1/4 NW1/4 section 7, T. 22 S., R. 19 W.; (3) 247 feet (75 m) to limestone at the west side of the Burbank Hills in the NW1/4 NE1/4 NE1/4 section 13, T. 22 S., R. 19 W.; and (4) 519 feet to limestone in the Ferguson Desert in the SW1/4 SW1/4 SW1/4 section 7, T. 22 S., R. 16 W. Farther north basin fill is about 1,000 to 5,600 feet (300-1,700 m) thick (wells 79-1, 95-1, and 96-2 in appendix A of Hintze and Davis, 2003)

Drillers' logs of water wells show an abundance of sand and gravel beds in the basin fill.

The sand and gravel are commonly interbedded with beds of sand and sandy clay. The sand and gravel beds, at depth, are the aquifers.

Ground water is present in a shallow, unconfined water-table aquifer and in confined, artesian aquifers, at depth, in the valley. The shallow water table exists around the margins of the valley where recharge occurs, as well as in the lower parts of the valley where it receives water from springs and upward leakage from artesian aquifers. Hood and Rush (1965) listed data on many wells in the Millard County part of Snake Valley. Three wells, 100 to 680 feet (30-207 m) deep in the eastern Ferguson Desert, were dry. A well, 316 feet (96 m) deep, in the western Ferguson Desert had a water level at a depth of 224 feet (68 m). Twenty-eight water wells, all in the main part of Snake Valley, had depths ranging from 33 to 640 feet (10-195 m) and an average water level of 29 feet (9 m) below the land surface. Seven of these 28 wells were artesian flowing wells of which 6 were located on farms near the road from U.S. Highway 6-50 north to Gandy. It's likely that all 28 water wells penetrated one to three aquifers with artesian pressure. About 18,000 acre-feet (22.2 hm^3) of ground water was withdrawn by wells from the basin fill in 1977 (Gates and Kruer, 1981). The tDS content of well waters ranged from 186 to 614 ppm and the water is used for irrigation, stock, and culinary purposes.

Table 10. Selected springs in Snake and Hamlin Valleys (Hood and Rush 1965; Wilberg and Stolp, 1985).

Name	Location	Altitude (feet)	Discharge (gal/min), and date	tDS (mg/L) and date
Warm Springs	SW1/4 NW1/4 section 31, T. 15 S., R. 19 W.	5,300	3,600 11/3/64	298 11/1/64
Twin Springs	NW1/4 NE1/4 SW1/4 section 22, T. 16 S., R. 18 W.	4,812	1,220 3/25/81	429 12/15/83
North Knoll Spring	NE1/4 SW1/4 SW1/4 section 3, T. 18 S., R. 18 W.	4,871	15 12/15/83	383 12/15/83
Knoll Springs	NW1/4 NW1/4 NE1/4 section 16, T. 18 S., R. 18 W.	4,878	20 12/15/83	386 12/15/83
Kell Springs	SW1/4 SE1/4 section 20, T. 17 S., R. 19 W.	4,930	120 1964?	no analysis
Big Spring	Hamlin Valley, Nevada 10/70, 33b {section, T., and R. location not available}	5,580	3,600 11/3/64	216 11/3/65

The estimated annual recharge to the ground-water reservoir, chiefly from precipitation (and runoff), is 105,000 acre-feet (129.5 hm^3) (Hood and Rush, 1965). An estimated 4,000 acre-feet (4.9 hm^3) of this amount is thought to move through the carbonate rocks from the southeastern part of Spring Valley, Nevada, to the northern part of Hamlin Valley. Hood and Rush (1965) also estimated that at least 12 million acre-feet (14,800 hm^3) of recoverable water was stored as ground water in the basin fill of Snake Valley. The ground-water movement appears to be generally northeast and a goodly amount likely drains to the underlying Paleozoic carbonate rocks.

Springs are an important source of water in Snake Valley. Many springs, such as Twin

Springs (figure 5), are impounded and, or diverted to ditches for distribution as irrigation and stock water. Twin Spring water has a temperature of 68ºF and is believed to originate in the carbonate rocks beneath the valley. The water at Warm Springs (table 10) has a temperature of 81ºF and likely has a deeper circulation. Data for 6 springs are given in table 10.

Interbasin Carbonate Rock Aquifers

A great thickness of Paleozoic carbonate rocks is present in the mountains and underlies the valleys of the Great Basin in western Utah and eastern Nevada. Dettinger and Shaefer (1996) postulated that in areas of crustal extension, where carbonate rocks are thick, like the eastern Great Basin, continuous aquifers allow for broadly integrated flow to large regional springs. Within the Great Basin, ground-water discharge is typically from mountain-front springs with additional ground-water loss from broad areas of evapotranspiration on basin floors. Theoretically the carbonate rocks in the eastern Great Basin can store and transmit considerable amounts of ground water, especially where they have a large permeabilities due to solution-enlarged joints and fractures (Gates, 1987). In Millard County, the carbonate-rock aquifers are deeper than 6,000 feet (1,800 m) in many valleys and they are in the mountains as well. The aquifers are recharged by precipitation in mountainous areas and by gravity drainage of ground water in valleys. Water in the aquifers is driven by hydraulic gradients that are reportedly continuous over long distances (Gates, 1987). However, geologic maps of Millard County (Hintze and Davis, 2002a-c; Hintze and others, 2003) show numerous faults, range-bounding faults in particular, that likely "cut" bedrock aquifers into small discontinuous compartments that contain local and therefore discontinuous gradients. Thus, deep interbasin water flow is only postulated and has not been documented.

Gates (1987) surmised that much of the water moving in the carbonate-rock aquifers near the Utah-Nevada border discharged at two groups of large springs - Blue Lake Springs in western Tooele County and Fish Springs in northwestern Juab County; the combined annual discharge is about 45,000 acre-feet (55.5 hm^3). Also, it is likely that the carbonate rocks discharge some water to the basin fill in the Great Salt Lake Desert. These three areas are the topographically low spots for west-central Utah and east-central Nevada.

With regards to western Millard County, Gates (1987) described the deep interbasin water movements as follows: (1) an annual flow of about 9,000 acre-feet (11.1 hm^3) from the Sevier Desert towards Tule Valley and Fish Springs; (2) a substantial amount of flow from Wah Wah, Pine, and Snake Valleys for transient storage or discharge in Tule Valley; and (3) flows from and through Tule Valley which discharge at Fish Springs.

Acknowledgments

Joseph S. Gates, retired U.S. Geological Survey, reviewed this report, made valuable suggestions, and provided information. Jon K. King reviewed this report during his work on the Geology of Millard County (Hintze and Davis, 2003) and added the introduction and the additional references on water in Millard County that follow the cited references.

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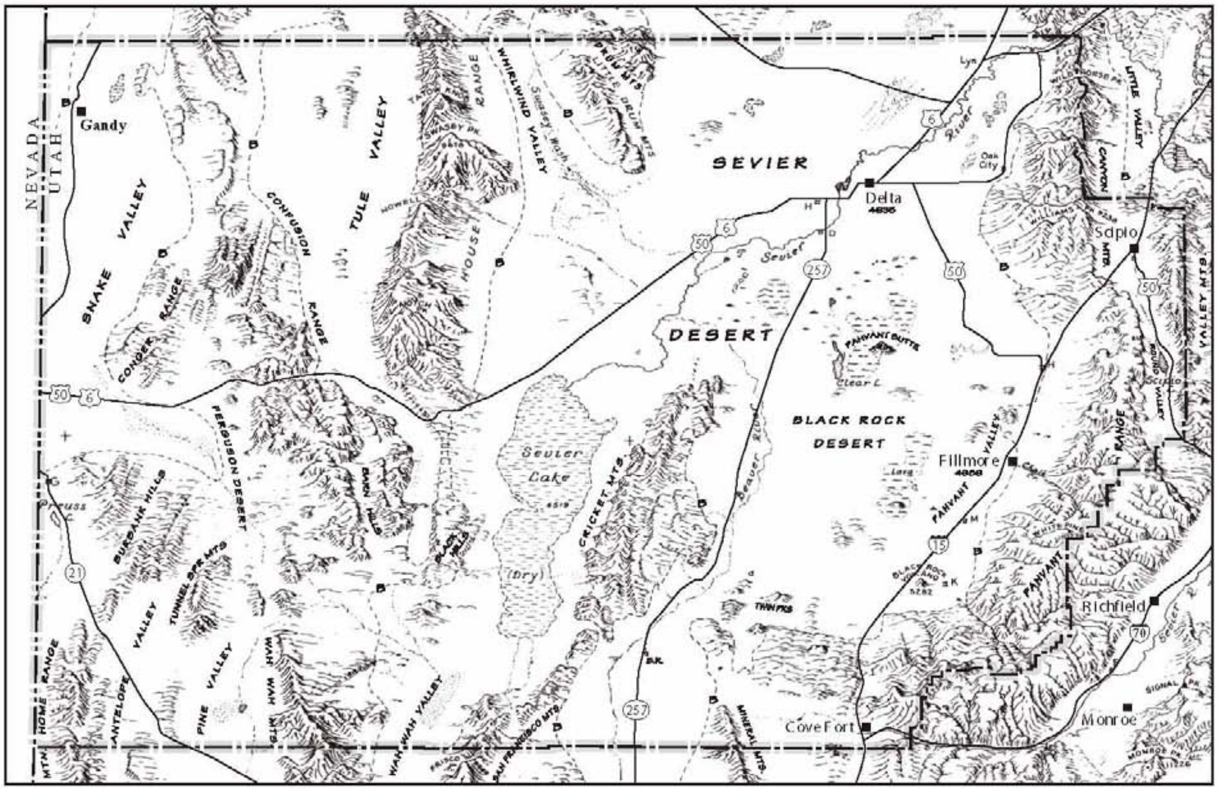

Figure 1. Principal geographic features of Millard County. Fillmore and Delta are the largest towns; Fillmore is the county seat. Millard County covers 4,346,310 acres or 6,791 square miles (17,589 km^2). Agriculture is the county's chief industry, with production concentrated on alluvial slopes at the west base of the Pahvant Range between Kanosh (K) and Holden (H), and on the Lake Bonneville bottom flats west of Delta. The western two-thirds of the county is virtually unpopulated because of limited water resources. The U.S. Bureau of Land Management (BLM) administers 69 percent of the land within Millard County; U.S. Forest Service oversees 7 percent; State of Utah (School and Institutional Trust Lands Administration) owns 9 percent of the land as school sections scattered across the county; 15 percent is privately owned, primarily in the agricultural eastern part of the county. The dashed line marked -B- on the map shows the highest shoreline that Lake Bonneville attained between 16,000 and 14,500 years ago. Several peaks in the Pahvant Range are more than 10,000 feet (3,048 m) above sea level and supported small glaciers during the Ice Age. The highest peak in Millard County is Mine Camp Peak east of Meadow (M); its elevation is 10,222 feet (3,116 m). Landform map is modified from Ridd (1963).

Figure 2. A view east of the Sevier River 5 miles (9 km) northeast of the town of Delta. The river has eroded a wide flood plain through its paleo-delta in Lake Bonneville (deposited about 14,000 years ago). The delta bluffs are in the background.

Figure 3. Clear Lake, in the southeastern part of the Sevier Desert, is an important wildlife management area.

Figure 4. A view northwest of Pruess Lake reservoir 2.5 miles (4 km) south of Garrison in southern Snake Valley. The reservoir stores water for irrigation in the Garrison area. The Snake Range is in the background.

Figure 5. A view of Twin Springs pond 7 miles (11 km) southeast of Gandy.