Ground-Water Hydrology of the San Pitch River Drainage Basin, Sanpete County, Utah

By G. B. ROBINSON, JR.

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By G. B. Robinson, Jr.

ABSTRACT

The San Pitch River drainage basin in central Utah comprises an area of about 850 square miles; however, the investigation was concerned primarily with the Sanpete and Arapien Valleys, which comprise about 250 square miles and contain the principal ground-water reservoirs in the basin. Sanpete Valley is about 40 miles long and has a maximum width of 13 miles, and Arapien Valley is about 8 miles long and 1 mile wide. The valleys are bordered by mountains and plateaus that range in altitude from 5,200 to 11,000 feet above mean sea level.

The average annual precipitation on the valleys is about 12 inches, but precipitation on the surrounding mountains reaches a maximum of about 40 inches per year. Most of the precipitation on the mountains falls as snow, and runoff from snowmelt during the spring and summer is conveyed to the valleys by numerous tributaries of the San Pitch River. Seepage from the tributary channels and underflow beneath the channels are the major sources of recharge to the ground-water reservoir in the valleys.

Unconsolidated valley fill constitutes the main ground-water reservoir in Sanpete and Arapien Valleys. The fill, which consists mostly of coalescing alluvial fans and flood deposits of the San Pitch River, ranges in particle size from clay to boulders. Where they are well sorted, these deposits yield large quantities of water to wells.

Numerous springs discharge from consolidated rocks in the mountains adjacent to the valleys and along the west margin of Sanpete Valley, which is marked by the Sevier fault. The Green River Formation of Tertiary age and several other consolidated formations yield small to large quantities of water to wells in many parts of Sanpete Valley. Most water in the bedrock underlying the valley is under artesian pressure, and some of this water discharges upward into the overlying valley fill.

The water in the valley fill in Sanpete Valley moves toward the center of the valley and thence downstream. The depth to water along parts of the sides of the valley is more than 100 feet, but in much of the central part of the valley, the water level is at or above the land surface. The valley fill pinches out in the southern part of the valley, and most of the ground water moves

to the surface, where it discharges into the San Pitch River or is consumed by evapotranspiration.

Ground water is discharged principally by wells, springs, and evapotranspiration. The discharge from wells varies considerably from year to year because most of the water is used for irrigation, and the wells are used only as necessary to supplement the available surface-water supply. Thus, in 1965, a year of above-normal precipitation, the discharge from wells was 12,000 acre-feet, whereas in 1966, a year of below-normal precipitation, the wells discharged 21,000 acre-feet. The discharge from springs during 1966 was estimated to be 36,000 acre-feet, and an additional 113,000 acre-feet of water was discharged by phreatophytes.

Water levels in the valleys, for the most part, fluctuate in direct response to variations in precipitation, and the discharge from wells has had little long-term effect on water levels. Approximately 3 million acre-feet of water available to wells is stored in the upper 200 feet of saturated valley fill.

The ground water in most parts of the valleys is fresh and suitable for public supply and irrigation. The Green River and Crazy Hollow Formations may, in some places, yield slightly or moderately saline water.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

A study of the ground-water hydrology of the Sevier River basin was started in 1956 by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. This report, which is the result of an investigation of the San Pitch River drainage basin, completes the study of the individual areas of the Sevier River basin. (See fig. 1.) Other areas within the Sevier River basin that have been investigated are the central Sevier River valley (Young and Carpenter, 1965), the upper Sevier River valleys (Carpenter and others, 1967), the Sevier Desert (Mower and Feltis, 1968), and the segment of the Sevier River basin between Yuba Dam and Leamington Canyon (Bjorklund and Robinson, 1968).

The purpose of the present investigation was to determine the source, recharge, occurrence, movement, storage, discharge, use, and chemical quality of the ground water within the San Pitch River drainage basin. Major emphasis was placed on Sanpete and Arapien Valleys because the unconsolidated deposits in these valleys contain the principal ground-water reservoirs in the drainage basin. In addition, attempts were made to complete a water budget for Sanpete Valley and to determine the relation between ground and surface water, to determine the effects of potential ground-water development on the existing hydrologic conditions, and to determine the effect of geology on the chemical quality and availability of the ground water within the drainage basin.

LOCATION AND EXTENT OF THE AREA

The investigation was concerned primarily with the Sanpete and Arapien Valleys, which comprise about 250 square miles, and secondarily with the rest of the San Pitch River drainage basin, which comprises about an additional 600 square miles. The term "valley" as used in this report refers to the valley floor and the slopes immediately adjacent. The term "drainage basin," or "basin," refers to the overall area. The San Pitch River drainage basin is in the approximate geographical center of Utah, about 90 miles southeast of Salt Lake City (fig. 1). The drainage basin is in Sanpete County, with the exception of two small areas that are in Juab County. The area of investigation includes all drainage of the San Pitch River above a point about 2 miles west of Nine Mile Reservoir. It also includes the drainage of Twelvemile Creek, which drains Arapien Valley, a small narrow valley extending 8 miles south of a low divide south of Nine Mile Reservoir (pl. 1). The drainage of Twelvemile Creek is tributary to the San Pitch River about 2 miles southwest of Nine Mile Reservoir, just outside the area of investigation.

PREVIOUS INVESTIGATIONS

The first investigation of the ground-water resources of the San Pitch River drainage basin, conducted and published by the U.S. Geological Survey, described the ground-water conditions in Sanpete and central Sevier Valleys (Richardson, 1907). Woolley (1947) completed a study of the surface-water resources of the entire Sevier Lake basin, which provided streamflow records and information concerning geology, irrigation, drainage, storage, and hydroelectric development through 1937. Marsell (1958) briefly described potential development of the ground-water resources in Sanpete Valley. A compilation of chemical analyses for ground and surface waters in Utah by Connor, Mitchell, and others (1958) included analyses for water from 24 wells and springs in the San Pitch River drainage basin, from four sites along the San Pitch River, and from seven additional streams in the basin. Hahl and Cabell (1965) listed chemical analyses of water samples from four sites along the San Pitch River and analyses for two other streams in the area.

The U.S. Geological Survey has collected and published streamflow records in the San Pitch River drainage basin since 1949 and has measured and published ground-water levels since 1935. These data have been published annually or at 5-year intervals in various U.S. Geological Survey Water-Supply Papers. Records of diversions for irrigation from ditches, canals, and streams are maintained by water commissioners and irrigation company officials. Information on water rights in the San Pitch River drainage basin was compiled and pre-

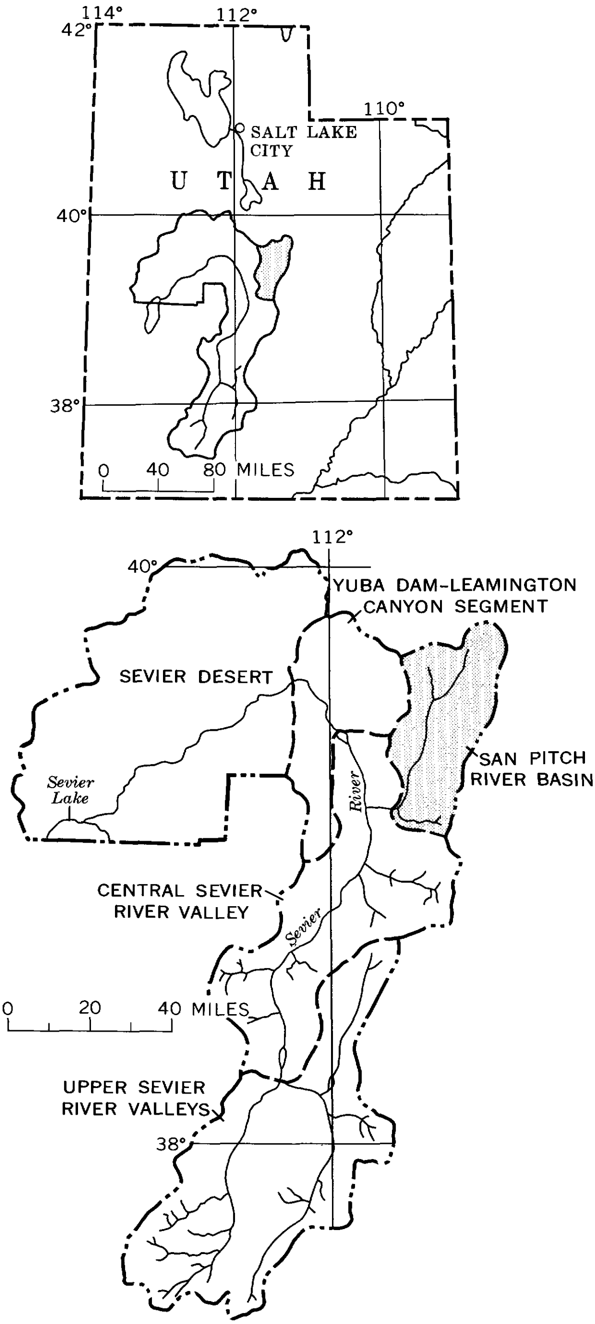

FIGURE 1.—Index map showing area described in this report (shaded) and other areas studied in the Sevier River basin.

sented in a court decree adjudicating the Sevier River system by the Honorable L. H. Cox (1936), Judge of the Fifth Judicial District of the State of Utah.

The geology of parts of the basin and adjacent areas has been investigated by Dutton (1880), Richardson (1906,) Eardley (1933, 1934), Spieker and Billings (1940), Duncan (1944), Spieker (1946, 1949), Schoff (1951), Hardy and Zeller (1953), Hintze (1962), and Stokes (1964). In addition, the geology of parts of the area is described in unpublished theses and maps on file at Ohio State University by C. M. Bonar, 1948; N. R. Faulk, 1948; R. E. Hunt, 1948 and 1950; G. R. Washburn, 1948; Julius Babisak, 1949; M. D. Wilson, 1949; H. D. Zeller, 1949; A. C. Fograsher, 1956; E. F. Pashley, 1956; and M. S. Johnson, 1959.

METHODS OF INVESTIGATION

Fieldwork was started in April 1964 and was continued in conjunction with some compilation and interpretation of data until about mid-January 1967. Many of the basic data, including well and spring records, water-level measurements, well logs, and chemical analyses, were published as a separate report (Robinson, 1968).

About 500 wells were visited during the investigation, and water levels and discharges were measured where possible. These selected wells included almost all wells in the area that are 4 inches or larger in diameter, and they are believed to be representative of the more than 1,500 wells in the area of investigation. The altitudes of land surface at wells and springs in the area were estimated from topographic maps or determined by hand leveling.

Water levels were measured monthly in 72 observations wells, one of which was equipped with an automatic water-level recording gage. Water samples from 29 wells were collected for chemical analysis, and the results were tabulated with analyses from 20 other wells sampled prior to the investigation. The specific conductance of water was obtained for samples from 272 additional wells.

Fifty-three springs were visited during the investigation; the discharge was measured, and the water source was determined where possible. Water samples from eight springs were collected for chemical analysis, and the results were tabulated with analyses from 11 other springs previously sampled. Samples were collected also at 34 additional springs for measurement of the specific conductance. Fifteen of the springs were visited about every 3 months to determine variations in discharge, temperature, and specific conductance.

Periodic discharge measurements were made at selected wells and springs. These measurements were used to estimate the total ground-water discharge in the valley. Aquifer tests were made at 10 wells to determine the water-bearing properties of the materials penetrated by the wells. These data were used in estimating the amount of ground water in storage in the valley.

An areal geologic map of the San Pitch River drainage basin was compiled almost entirely from Stokes (1964) with only a few adaptations. Geologic sections of the subsurface were constructed using surface geologic maps, drillers' logs, and electrical and gamma-ray logs.

The consumptive use of ground water by evapotranspiration was estimated on the basis of area and applied rates of evapotranspiration. Areas and types of vegetation were adapted from mapping on aerial photographs by the U.S. Soil Conservation Service. Evaporation rates from open-water surfaces were obtained from the U.S. Weather Bureau.

Records of streamflow at about 20 locations within the basin were compiled, and periodic measurements were made at five additional locations. These data and the records of some irrigation diversions were correlated with ground-water levels to determine relations between ground water and streamflow in the basin. In addition, measurements were made at selected intervals along the San Pitch River during March–April 1966 to determine the amount of interchange, if any, between the river and the ground-water reservoir.

WELL- AND SPRING-NUMBERING SYSTEM

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The well or spring number, in addition to designating the well or spring, locates its position to the nearest 10-acre tract in the land net. By this 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; thus, A, for the northeast quadrant; B, for the northwest; C, for the southwest; and D, for the southeast quadrant. Numbers designating the township and range, respectively, follow the quadrant letter, and the three are enclosed in parentheses. The number after the parentheses designates the section, and the lowercase letters give the location of the well or spring within the section. The first letter indicates the quarter section, which is generally a tract of 160 acres, the second letter indicates the 40-acre tract, and the third letter indicates the 10-acre tract. The numbers that follow the letters indicate the serial number of the well or spring within the 10-acre tract. Thus, well (D-16-3)33acd-1, in the San Pitch River drainage basin, is in the SE¼SW¼NE¼ sec. 33, T. 16 S., R. 3 E., and was the first well constructed or visited in that tract. (See fig. 2.)

All springs are designated by the letter S preceding the serial number. If a spring is located to the 40- or 160-acre tract, the S is used without a serial number. Thus, spring (D–14–2)2bab–S1, also in the basin, is in the NW¼NE¼NW¼ sec. 2, T. 14 S., R. 2 E., and was the first spring visited in that tract. Surface-water sites along the San Pitch River and miscellaneous streams at which water samples were collected or discharge measurements were made are also located according to this well-numbering system. The surface-water sites, however, are located only to the nearest 160- or 40-acre tract.

USE OF METRIC UNITS

The U.S. Geological Survey is gradually changing its system of measurements from the previously used English system to the metric

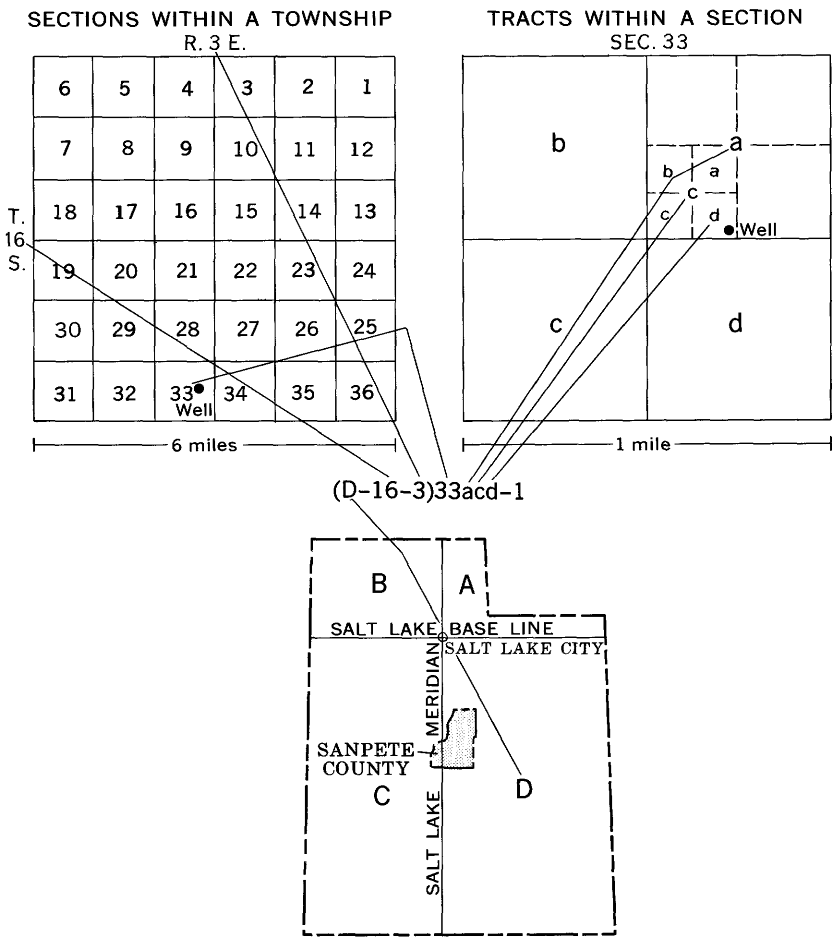

FIGURE 2.—Well- and spring-numbering system.

system in general use by the scientific community. Accordingly, in this report, the chemical analyses are given in milligrams per liter (mg/l), rather than in parts per million, and the temperatures are given in degrees Celsius (°C), rather than in degrees Fahrenheit (°F). For water having a concentration of dissolved solids of less than about 7,000 mg/l (which includes all water discussed in this report), milligrams per liter can be considered to be equivalent to parts per million. Readers who are not familiar with the Celsius scale of temperature can use the following temperature-conversion chart to convert the temperature to the more familiar Fahrenheit scale.

[For conversion of temperature in degrees Celsius (°C) to degrees Fahrenheit (°F). Conversions are based on the equation, $°F = 1.8(°C) + 32$; temperatures in °F are rounded to nearest degree. Italic equivalent temperatures are exact equivalents. For temperature conversions beyond the limits of the table, use the equation given, and for converting from °F to °C, use $°C = 0.5556 (°F - 32)$. The equations say, in effect, that from the freezing point (0°C, 32°F) the temperature rises (or falls) 5°C for every rise (or fall) of 9°F]

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
−20	*−4*	*−10*	*14*	*0*	*32*	*10*	*50*	*20*	*68*	*30*	*86*	*40*	*104*
−19	−2	−9	16	+1	34	11	52	21	70	31	88	41	106
−18	0	−8	18	2	36	12	54	22	72	32	88	42	108
−17	+1	−7	19	3	37	13	55	23	73	33	91	43	109
−16	3	−6	21	4	39	14	57	24	75	34	93	44	111
−15	*5*	*−5*	*23*	*5*	*41*	*15*	*59*	*25*	*77*	*35*	*95*	*45*	*113*
−14	7	−4	25	6	43	16	61	26	79	36	97	46	115
−13	9	−3	27	7	45	17	63	27	81	37	99	47	117
−12	10	−2	28	8	46	18	64	28	82	38	100	48	118
−11	12	−1	30	9	48	19	66	29	84	39	102	49	120

ACKNOWLEDGMENTS

The cooperation of area residents, well and spring owners, and city, county, and irrigation company officials in providing information and allowing measurements at their wells and springs is gratefully acknowledged. Officers of the Utah Power & Light Co. and of the local power companies made available their company records of power usage at irrigation wells. Much information was contributed by R. A. Olsen, who drilled many of the wells in the valley. The Soil Conservation Service of the U.S. Department of Agriculture provided data on native vegetation and cropland.

GEOGRAPHY

PHYSIOGRAPHY

The San Pitch River drainage basin is at the north end of the High Plateaus of Utah section of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 294–296). Sanpete Valley is a Y-shaped north-south trending intermontane valley that is about 40 miles long and has a maximum width of about 13 miles. In this report the western segment of the Y is called the Silver Creek arm of the valley, and the eastern segment is called the Fairview arm. The Arapien

Valley, extending southward from the lower end of Sanpete Valley, is about 8 miles long and 1 mile wide. These two valleys are bordered on the east by the lofty Wasatch Plateau (pl. 2), which ranges in altitude within the drainage basin from about 9,000 feet at its north end to about 11,000 feet along its crest, near its south end. Sanpete Valley is bounded on the west by the San Pitch Mountains (Gunnison Plateau), which are about 9,700 feet in altitude at the north end but which gradually slope downward to about 5,200 feet in altitude at their south end, where they merge with the valley floor. The north boundary of Sanpete Valley is formed mostly by the Cedar Hills, which occupy the center of the Y, and by a low drainage divide northwest of the Silver Creek arm. The Cedar Hills attain a maximum altitude of about 8,000 feet within the drainage basin.

The southern part of Sanpete Valley is separated from Arapien Valley by a divide about 1 mile south of Nine Mile Reservoir. The altitude of Sanpete Valley itself ranges from about 7,000 feet at the upper end of the Fairview arm, and about 6,300 feet in the Silver Creek arm, to about 5,200 feet where the San Pitch River leaves the valley, west of Nine Mile Reservoir. The land-surface gradient of Sanpete Valley is about 10 feet per mile between the lower end, near Sterling, and the confluence of the San Pitch River and Silver Creek, west of Chester. The gradient of the Silver Creek arm of the valley increases from about 10 feet per mile to about 130 feet per mile in its upper part. The Fairview arm of the valley steepens more abruptly, with a gradient of about 185 feet per mile in its upper part.

Arapien Valley is bounded on the west by low hills and at the south is separated from the central Sevier River basin by a low drainage divide. (See pl. 2.)

DRAINAGE AND RESERVOIRS

Sanpete Valley is drained by the San Pitch River, which originates in the Wasatch Plateau northeast of Milburn (pl. 2) and is tributary to the Sevier River near Gunnison, about 5 miles west of the area of investigation. The Silver Creek arm of the valley is drained by Silver Creek, which originates north of Fountain Green and joins the San Pitch River west of Chester. The Fairview arm of the valley is drained by the San Pitch River. During certain periods of the year, the channels of the San Pitch River and Silver Creek may be dry in some places because of diversion for irrigation or storage in reservoirs. Arapien Valley is drained by Twelvemile Creek, which originates in the Wasatch Plateau east of Mayfield and is tributary to the San Pitch River a short distance west of the area of investigation.

The San Pitch River is fed along its course in Sanpete Valley by numerous tributaries which drain into it from the surrounding mountains (pl. 2). Table 1 lists the major tributary streams and their drainage areas.

Five reservoirs have been constructed in Sanpete Valley (pl. 2). Table 2 summarizes the source of supply and storage capacity of these reservoirs.

TABLE 1.—*Major tributary streams in the San Pitch River drainage basin*

Tributary (downstream order)	Type of stream	Approximate acres	Drainage area (sq mi)
	Wasatch Plateau		
South San Pitch River Canyon	Intermittent	3,600	5.6
Oak Creek near Fairview	Perennial	8,200	12.8
Cottonwood Creek	do	5,100	8.0
Birch Creek near Fairview	do	6,500	10.1
Pleasant Creek	do	11,900	18.5
Twin Creek	do	4,400	6.9
Cedar Creek	do	4,300	6.7
Oak Creek near Spring City	do	6,100	9.5
Canal Canyon Creek	do	10,100	15.8
Ephraim Canyon Creek	do	14,300	22.3
Willow Creek	do	8,400	13.1
Manti Canyon Creek	do	20,000	31.3
Sixmile Creek	do	22,200	34.7
Twelvemile Creek	do	47,900	74.8
Total		173,000	[1] 270
	San Pitch Mountains		
Log Hollow Creek	Intermittent	800	1.2
Birch Creek near Fountain Green	Perennial	1,500	2.3
Maple Canyon Creek near Freedom	Intermittent	2,400	3.8
Wales Canyon Creek	Perennial	2,900	4.5
Peach Canyon Creek	do	3,400	5.3
Axhandle Canyon Creek	do	9,300	14.5
Dry Canyon Creek	Intermittent	3,000	4.7
Maple Canyon Creek near Manti	do	10,500	16.4
Total		33,800	[1] 53
	Cedar Hills		
Big Hollow Creek	Intermittent	13,300	20.8

[1] Rounded to nearest whole number.

TABLE 2.—*Major reservoirs in the San Pitch River drainage basin*

Reservoir (downstream order)	Major source of supply	Capacity (acre-ft)
Wales Reservoir	Silver Creek	[1] 1,480
Chester Ponds	Oak Creek near Spring City	[1] 545
Funks (Palisade) Lake	Sixmile Creek and Morrison Coal Mine Tunnel Spring, (D-18-2)35d-S.	[1] 607
Gunnison Reservoir	San Pitch River, Saleratus Creek, and Sixmile Creek.	[2] 18,210

TABLE 2.—*Major reservoirs in the San Pitch River drainage basin*—Continued

Reservoir (downstream order)	Major source of supply	Capacity (acre-ft)
Nine Mile Reservoir	Nine Mile Cold Spring, (D–19–2)9cbb–S1, Peacock Spring, (D–19–2)4dca–S1, and Sixmile Creek.	[1] 3,537
Total (rounded)		24,000

[1] Data from Utah State University and Utah Water and Power Board (1963, p. 48).
[2] Data from U.S. Soil Conservation Service (oral commun. 1966).

CLIMATE

Climate in the drainage basin ranges from semiarid in the valleys to subhumid in the adjacent mountains. The average annual precipitation generally ranges from 10 to 12 inches in Sanpete Valley and from 12 to 14 inches in Arapien Valley. The Wasatch Plateau receives an average of about 14–40 inches per year; the San Pitch Mountains, about 14–25 inches; and the Cedar Hills, about 12–16 inches (U.S. Weather Bureau, no date). The valleys are characterized by sunny days, large daily temperature ranges, and low humidity. Midday summer temperatures above 32°C occur only about 24 days per year and only rarely exceed 38°C according to records of the U.S. Weather Bureau; nighttime temperatures are cool, generally 17°–22° below the daytime maximums. Winters are cold, and temperatures near or below −18°C are common. The average annual temperature at the Manti weather station during the period 1948–66 was 8.7°C. The number of consecutive frost-free days per year for the same period ranged from 93 to 175 and averaged 128 days.

The largest amount of the yearly precipitation is snow in the mountains from about November through April. The driest period each year is generally from about June through August; however, heavy, but localized and brief, thunderstorms sometimes make these the months of greatest precipitation. The effect of such a climate upon agriculture in the two valleys is rather evident; the agriculture depends chiefly upon water from the snowmelt in the late spring and early summer to irrigate crops. When the supply is insufficient for sustained runoff during the late summer, supplemental water is obtained by pumping wells tapping the ground-water reservoir.

Annual precipitation at the Manti weather station since 1908 has ranged from a minimum of 7.08 inches in 1934 to a maximum of 18.94 inches in 1957. Normal annual precipitation at Manti for the period 1931–60 was 11.93 inches. A graph showing cumulative departure of annual precipitation from the 1931–60 normal at Manti is shown on plate 3. On this graph, rises indicate above-normal precipitation, and declines indicate below normal; the wettest years are shown by the steepest rises on the graph, and the driest years are

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shown by the steepest declines. Precipitation was below normal during the periods 1931–35 and 1948–51 and was above normal during the periods 1935–48 and 1960–65. During 1966 precipitation was deficient.

Evaporation in the San Pitch River drainage basin exceeds annual precipitation by about 3½ times. The Sanpete and Arapien Valleys have an annual evaporation rate from open-water surfaces of about 42 inches (Kohler and others, 1959).

POPULATION AND ECONOMY

An estimated 8,750 people resided in Sanpete and Arapien Valleys in 1960. This number is about 81 percent of the population in 1950 and about 70 percent of that in 1940.

The following table lists the populations of towns and rural areas:

Town	*Population (1960 census)*	*Town*	*Population (1960 census)*
Ephraim	1,801	Sterling	137
Manti	1,739	Wales	130
Mount Pleasant	1,572	Chester	182
Moroni	879	Milburn	200
Fairview	655	Freedom	68
Fountain Green	544	Rural areas	[1] 50
Spring City	463		
Mayfield	329	Total	8,749

[1] Estimated by the author.

The economy of the two valleys is mostly agricultural; crops grown are alfalfa, grain, corn, and sugar beets, and livestock raised are sheep, cattle, and turkeys. Uncultivated rangeland makes up a large part of the west side of Sanpete Valley and much of the higher part of the east side of the valley. Irrigated land is chiefly on the lower east side of the valley, and dryland farms are chiefly north of Wales in the Silver Creek arm. Chief industries include a turkey-processing plant, a large feed mill, a logging, lumber, and forest-products operation, a mobile-trailer manufacturing plant, and a garment-manufacturing plant.

GEOLOGY

The geologic formations exposed in the San Pitch River drainage basin are those common to the northern section of the High Plateaus of Utah and range in age from Late Jurassic to Holocene. Areal exposure of these formations within the basin is shown on the geologic map (pl. 1), which was adapted from Stokes (1964). Slight modifications were necessary for this study; several formations were combined, and the Sevier fault was extended along the west side of the Silver Creek arm to correspond to a map by Hintze (1962). Plate 1 also shows typical geologic sections of the valley fill in Sanpete Valley, which were based on data from drillers' logs and electric and gamma-ray logs.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

A summary of the geologic formations exposed in the drainage basin and their water-bearing properties is shown in table 3. The lithologic descriptions of the formations were adapted freely from Spieker (1946), Hardy (1962), and Schoff (1951). The lithology and water-bearing properties of the valley fill, which contains the principal aquifers in the drainage basin, are described in greater detail in the following pages.

The valley fill of Pleistocene and Holocene age in both Sanpete and Arapien Valleys is the principal aquifer in the San Pitch River drainage basin and yields most of the water that flows or is pumped from wells in the basin.

The valley fill consists mostly of coalescing alluvial-fan deposits along the valley sides and flood-plain deposits of the San Pitch River and Silver Creek in the central and western parts of Sanpete Valley. Fine-grained fairly continuous deposits, which may be lacustrine, are at depth beneath the valley floor in the central part of Sanpete Valley.

The alluvial-fan deposits consist of interbedded and interfingered boulders, cobbles, gravel, sand, and silt. These deposits are coarsest near the highlands and become progressively finer textured toward the valley center. The flood-plain deposits of the San Pitch River consist of graded sand, gravel, and cobbles, mostly reworked from the alluvial-fan deposits. The valley fill along a zone in the central part of Sanpete Valley consists mostly of flood-plain, and possibly lacustrine, deposits of fine sand, silt, and clay. This zone of fine-grained material is prominent particularly in the central and lower parts of the valley, from Manti to north of Ephraim. Although much of the fill in the valley appears to be heterogeneous, lenticular, and discontinuous, geophysical logs obtained in wells during the investigation showed that much of the material, especially that in thick beds, is correlatable across the valley. In some places the coarser grained deposits grade laterally across the valley into finer grained deposits, and in others they continue almost without change. (See geologic sections on pl. 1.) In some places, however, the deposits are lenticular and cannot be traced even for short distances.

The valley fill in the basin is thickest near the Sevier fault in the central part and along the west side of Sanpete Valley between Manti and Ephraim and along the west side of the valley from

TABLE 3.—*Generalized geologic section and water-bearing properties of the principal formations exposed in the San Pitch River drainage basin*

System	Series	Stratigraphic unit	Maximum thickness (feet)	Area of exposure	Description of rocks	Water-bearing properties
Quaternary	Pleistocene and Holocene	Valley fill	500+ (See table 4.)	Forms the valley floors in Sanpete and Arapien Valleys and is exposed along several of the major streams entering the valleys from the Wasatch Plateau.	Consists mostly of coalescing alluvial fans, flood-plain deposits of the San Pitch River, and possible lacustrine deposits at depth beneath the valley floors; mostly boulders, cobbles, gravel, sand, silt, and clay.	Principal aquifer in the San Pitch River drainage basin; low to high permeability; yields small to very large quantities of water to wells and springs.
		Tertiary and Quaternary alluvial formations		Exposed generally in small outcrops along the mountain bases in Sanpete Valley and in some of the larger canyons.	Includes miscellaneous alluvial deposits and surfaces which generally are older than the more recent alluvium filling the valleys; includes landslide deposits, terrace deposits above active streams, glaciated ground and moraines, small patches of the Axtell Formation of Spieker (1949), and other colluvial and alluvial deposits.	Not significant as a source of ground water.
Tertiary		Tertiary andesitic rocks (Moroni Formation of Schoff (1938))	2,100	Exposed as one of the principal formations in the Cedar Hills; also exposed in the valley as part of the hills northeast of Mount Pleasant, and as	Sandstone, tuff, and volcanic conglomerate.	Permeability believed to be generally low; generally avoided in drilling water wells for irrigation supplies; locally yields small quantities of water to

Table 3.—*Generalized geologic section and water-bearing properties of the principal formations exposed in the San Pitch River drainage basin*—Continued

System	Series	Stratigraphic unit	Maximum thickness (feet)	Area of exposure	Description of rocks	Water-bearing properties
Tertiary—Continued				a hill northwest of Fountain Green; known from well logs to underlie the area around Fountain Green.		springs in the Cedar Hills.
	Upper (?) Eocene	Unconformity Crazy Hollow Formation of Spieker (1949)	200+ (base not exposed)	Exposed on eastern flank of Cedar Hills, on hills southeast of Moroni, on hills between Ephraim and the junction of U.S. Highway 89 and Utah Highway 11, and in hills north of Sterling.	Variegated shale and red to white sandstone, with local conglomerate and limestone.	Permeability generally low to moderate in sandstone beds, but locally high, possibly where fractured. Yields small to large quantities of water to wells northwest of Mount Pleasant and large quantities to several irrigation wells north of Ephraim; is source of water for Saleratus Spring, north of Sterling.
	Eocene	Unconformity Green River Formation	1,000+	Caps the central San Pitch Mountains and is also exposed at south end; exposed in Cedar Hills and in hogbacks and hills from Fairview to north of Milburn; forms faulted hills along east side of Arapien Valley at base of Wasatch Plateau; forms hills in Sanpete Valley near Sterling and Manti and is ex-	Gray to green lacustrine shale, with interbeds of gray to buff sandstone and fresh-water limestone that is algal and oolitic in places.	Low primary permeability in shale, but moderate permeability in sandstone; acts as ground-water barrier in most places. Very high permeability where fractured in shale and limestone zones and where solution has occurred along fractures in oolitic limestone zones, as near

TABLE 3.—*Generalized geologic section and water-bearing properties of the principal formations exposed in the San Pitch River drainage basin*—Continued

System	Series	Stratigraphic unit	Maximum thickness (feet)	Area of exposure	Description of rocks	Water-bearing properties
Tertiary—Continued	Eocene—Continued			posed in large hills between Ephraim and Spring City. Known from well logs to underlie large sections of Sanpete Valley, particularly near Manti, Fairview, and between Chester and Spring City.		Manti; yields very large quantities to a well near Manti; also is aquifer that feeds Nine Mile Cold Spring and Little Nine Mile Spring at lower end of Sanpete Valley and Spannard Spring in Arapien Valley.
		Colton Formation	1,500	Exposed mainly in the central and southern San Pitch Mountains; also exposed in Wasatch Plateau east of Mayfield and as narrow band of low hills along east boundary of Sanpete Valley; also exposed in Cedar Hills.	Fluvial "red bed" shale, green, red, gray, and buff to brown sandstone and siltstone; discontinuous because of flood-plain and channel origin.	Water-bearing properties unknown; probably has low permeability. Not significant as a source of ground water.
	Upper Paleocene and lower Eocene(?)	Flagstaff Limestone	1,500	Exposed on Wasatch Plateau in northern part of area and as principal formation in southern part of area; also exposed on the central and southern San Pitch Mountains and as patches on Cedar Hills.	Tan and gray to blue fresh-water limestone predominating, with interbedded gray shale and sandstone; contains algal limestone; lacustrine origin.	Probably low primary permeability but locally very high permeability in solution channels along fractures and joints; yields small to large quantities of water to numerous springs on the Wasatch Plateau, the largest of which are used for municipal supplies.

TABLE 3.—*Generalized geologic section and water-bearing properties of the principal formations exposed in the San Pitch River drainage basin*—Continued

System	Series	Stratigraphic unit	Maximum thickness (feet)	Area of exposure	Description of rocks	Water-bearing properties
Tertiary—Con.		Local unconformity				
Tertiary—Con. / Cretaceous	Paleocene and Upper Cretaceous	North Horn Formation	2,400	Exposed on Wasatch Plateau from Ephraim to north of Milburn; exposed in major canyons between Ephraim and Mayfield; also exposed in central part and along western base of San Pitch Mountains.	Buff to gray sandstone, variegated shale, limestone, and conglomerate; origin probably both fluviatile and lacustrine.	Permeability probably low to moderate in sandstone beds, but probably high secondary permeability in the calcareous sandstone and limestone sections along fractures and joints; yields small to large quantities of water to numerous springs on the Wasatch Plateau and San Pitch Mountains, the largest of which are used for public supply.
Cretaceous	Upper Cretaceous	Price River Formation (includes Castlegate Sandstone Member)	2,000	Exposed in the Wasatch Plateau in several canyons between Spring City and Fairview and in Twelvemile Canyon; also exposed in Maple Canyon near Freedom and along the east base of the San Pitch Mountains.	Gray to red sandstone and massive conglomerate, with some shale; largely continental origin.	Moderate permeability in sandstone and conglomerate, particularly along bedding planes, high permeability where fractured; yields large quantity of water to Coal Fork Spring.
		Blackhawk Formation	1,800	Exposed only in the Wasatch Plateau in several canyons between Spring City and Fairview and in Twelvemile Canyon.	Sandstone, shale, and coal; chief coal-producing formation in the Wasatch Plateau; marine origin.	Water-bearing properties unknown; not significant as a source of ground water.

Table 3.—*Generalized geologic section and water-bearing properties of the principal formations exposed in the San Pitch River drainage basin*—Continued

System	Series	Stratigraphic unit	Maximum thickness (feet)	Area of exposure	Description of rocks	Water-bearing properties
Cretaceous—Con.	Upper Cretaceous—Con.	Indianola Group	15,000(?)	Forms major part of northern San Pitch Mountains and occurs in a narrow band as fault blocks along the east base of the San Pitch Mountains; also exposed in and near mouth of Sixmile Canyon.	Massive chiefly red conglomerate, sandstone, and siltstone, although also gray, brown, or white; fluviatile and marine origin.	Moderate to high permeability in sandstone units, along bedding planes, and where fractured and jointed; yields large quantities of water to several springs in the basin; also is source of a large amount of water believed to be entering the Silver Creek arm of Sanpete Valley in the subsurface.
Jurassic	Upper Jurassic	Morrison(?) Formation	1,300	Partially forms hill along west side of Sanpete Valley between Sterling and Nine Mile Reservoir.	Gray sandstone and red beds of conglomerate and shale.	Water-bearing properties unknown; not significant as a source of ground water.
	Middle or Upper Jurassic	Arapien Shale (includes Twist Gulch Member)	10,000+	Forms hills along west side of Arapien Valley and in vicinity of Sterling at lower end of Sanpete Valley; also is exposed as narrow discontinuous band along east base of San Pitch Mountains in Sanpete Valley; underlies narrow "bottleneck" of Sanpete Valley in vicinity of Gunnison Reservoir.	Upper part (Twist Gulch Member) consists of red thin-bedded siltstone and shale that contains many thin layers of greenish-white siltstone. Lower part (Arapien Shale) consists of gray thin-bedded limestone and gypsiferous and salt-bearing shale that has red blotches to continuous red zones; also contains some sandstone.	Extremely low permeability; not known to yield water to wells or springs; acts as barrier to ground-water movement. Gypsum and salt beds are a source of sulfate and chloride ions in the western and southern parts of the valley.

Ephraim to north of Moroni. (See table 4 and pl. 1.) Wells in these areas have been drilled to depths of over 500 feet without penetrating the full thickness of the alluvium. The fill is thinner along the east side of the valley, as can be seen in geologic sections *A–A′*, *C–C′*, and *D–D′* (pl. 1).

TABLE 4.—*Thickness of the valley fill in various parts of the San Pitch River drainage basin*

[Estimated from drillers' logs of wells]

Area	Estimated thickness of valley fill
Fairview arm of Sanpete Valley	
Milburn and north	50–100 ft near San Pitch River; 150 ft in fans to east.
Milburn to Fairview	Do.
Fairview to Mount Pleasant	20–50 ft near San Pitch River; 250–300 ft higher in fans to east.
Mount Pleasant	250–350 ft, possibly more; higher in fans to east; much less near river.
Mount Pleasant to Spring City	150–300 ft, becoming thinner near Spring City.
Spring City to Chester	20–150 ft, thinning toward Chester.
Silver Creek arm of Sanpete Valley	
Fountain Green and north	175–300+ ft.
Fountain Green to Moroni	100 ft on east side; 400+ ft on west side.
Moroni	50–250 ft.
Sanpete Valley (main body)	
Moroni to Chester	50–150 ft on east side; 200–400+ ft in central part and on west side.
Chester to Ephraim	100–150 ft on east side; 300–500+ ft on west side.
Ephraim	400+ ft.
Ephraim to Manti	150–400+ ft on east side, thinning toward Manti; 350–400+ ft in central part and on west side.
Manti	200–350× ft.

The permeability of the valley fill is dependent on the relative size of the particles present in a particular area and on the degree of sorting. The valley fill yields small to very large quantities of water to wells and springs. The larger yields are obtained from well-sorted deposits of sand and gravel.

STRUCTURE

The geologic structure of the San Pitch River drainage basin is discussed only generally in this report. For additional information, the reader is referred to the section "Selected References" for a list of geologic reports that describe the structure in greater detail.

The two elements of geologic structure that are primarily responsible for the presence of the drainage basin are the monocline bounding the west edge of the Wasatch Plateau and the Sevier fault. The monocline is a large flexure of the earth's crust in which the virtually flat-lying beds of the Wasatch Plateau bend down abruptly westward to pass beneath the floors of Sanpete and Arapien Valleys. The vertical displacement of the strata on this monoclinal flexure is 4,000–5,000 feet; the dips of the strata on the monocline are mostly to the west and northwest and generally range from 15° to 30°. Some evidence supports the belief that the strata beneath the valley floor are complexly folded and faulted and that most of Sanpete Valley is underlain by a large anticline (Gilliland, 1963). It is also possible that the strata flatten out beneath the valley floor. However, regardless of which theory is true, the beds beneath the valley floor are terminated abruptly at the west margin of Sanpete Valley by the Sevier fault.

The Sevier fault is a long normal fault that has been traced from northern Arizona to the upper end of Sanpete Valley (Fenneman, 1931, p. 295). This fault has the downthrown side to the east (Sanpete Valley) and the upthrown side to the west (the San Pitch Mountains). The fault thus has not only terminated, in the subsurface, the monocline that bounds the west edge of the Wasatch Plateau, but has also formed the west margin of the valley.

The San Pitch Mountains are believed to be a broad southward-plunging syncline which has been highly faulted, folded, and overturned on its eastern flank (Julius Babisak, written commun., 1949). In the southern half of the San Pitch Mountains, the beds in the interior are flat or dip gently west, but the dip increases toward the east face of the mountains. In the northern half of the mountains, however, most of the rocks in the interior and on the eastern flank strike about northeast and have an average dip of about 40° SE. (H. D. Zeller, written commun., 1949).

Most rocks in the Cedar Hills dip 25° SE. or less, but the dip ranges from 75° to 90° SE. in the west-central part of the hills (Schoff, 1951, p. 637–638). Rocks in the western, central, and northern parts of the Cedar Hills have been folded, and those in the southern part have been broken by normal faulting (Schoff, 1951, p. 638).

GROUND WATER

SOURCE

Three possible sources exist for all water in the San Pitch River drainage basin—precipitation within the drainage basin, surface-water inflow from another drainage basin by means of transmountain diversions, and ground-water inflow from other drainage basins through the bedrock that bounds the drainage basin. Precipitation within the drainage basin is by far the largest source. In a year of normal annual precipitation, about 800,000 acre-feet of water falls as rain and snow in the drainage basin (U.S. Weather Bureau, no date).

Transmountain diversions bring surface water into the basin from the Colorado River drainage to the east. Thirteen ditches and tunnels along the crest of the Wasatch Plateau annually deliver about 10,000 acre-feet of water to the San Pitch River drainage basin through the creeks in Cottonwood, Pleasant Creek, Twin Creek, Oak Creek near Spring City, Canal, and Ephraim Canyons. Only two of these diversions flow throughout the year; the other 11 flow only during the summer. The U.S. Geological Survey has maintained discharge measurements from 1949 to the present for three of the diversions, and from 1949 and 1950 to 1958 for the other 10 diversions (U.S. Geological Survey, 1960, 1961–65, 1963a).

Ground-water inflow from other drainage basins through bedrock is also an important source of water to the San Pitch River drainage basin. The rocks that dip to the southeast in the northern San Pitch Mountains are believed to transport a sizeable quantity of water into the basin from the drainage of Juab Valley, to the west. This water originally falls as rain or snow on the crest and the west side of the San Pitch Mountains; it seeps into the Indianola Group, and migrates along the southeastward-dipping rocks into Sanpete Valley. Bjorklund and Robinson (1968, p. 40) indicated this same possibility.

The rocks that dip westward and northwestward on the monocline of the Wasatch Plateau also bring a sizeable quantity of water into the basin from the Colorado River drainage on the Wasatch Plateau, to the east. An example of this transport through bedrock is the leakage from the Jet Fox Reservoir, which is in the Colorado River drainage east of Manti. This reservoir discharges water by subsurface leakage into the drainage of Manti Creek; part of this water subsequently discharges from Hougaard Springs, (D–18–4)20bb–S, in Sanpete Valley. Quantitative estimates of the interbasin movement of ground water from either the Colorado River Basin or the Juab Valley Basin to the San Pitch River drainage basin were not made in this investigation.

RECHARGE

The two major sources of recharge to the ground-water reservoir in the valley fill of the San Pitch River drainage basin are seepage of water from stream channels and underflow of streams at the mouth of their canyons. Other sources of recharge include return seepage of irrigation water from canals, ditches, and irrigated fields, subsurface inflow of ground water through the interface of bedrock and valley fill along basin boundaries, and infiltration of precipitation which falls directly on the valley floors.

Seepage of water from stream channels as they emerge from canyons onto permeable alluvial fans is probably the largest single source of recharge. Quantitative estimates of seepage losses from typical streams were made during the summer of 1905 (Richardson, 1907, p. 19). These tests, which analyzed the streams only within a short distance of the canyon mouths, determined that Ephraim Creek lost approximately 10 percent of its flow in 0.6 mile, Oak Creek near Spring City lost about 9 percent in 2.4 miles, Twin Creek lost about 38 percent in 2.75 miles, and the Moroni upper canal lost about 28 percent in 7 miles. These figures probably are representative of losses from the upstream reaches of most streams in the valleys and indicate the importance of seepage from streams as a source of recharge. Farther out from the canyon mouths, recharge would be less because the sediments are finer grained and less permeable and because artesian conditions prevail near the center of the valley. Inasmuch as most of the precipitation in the basin occurs as snow during the winter, the main period of recharge from stream losses is during spring snowmelt, mainly during April, May, and June. On plate 3, most of the hydrographs of water levels in wells show the period of recharge from snowmelt by the abrupt rise of water levels. Although considerable precipitation occurs in the basin during the summer, most occurs as rain in torrential downpours. The effectiveness of such storms as a source of recharge is reduced by the rapid runoff and by the abundance of clay and silt carried in the resulting flashflood or mudflow.

A second major source of recharge to the ground-water reservoir that is related closely to the first is underflow of streams at the mouths of their canyons. The amount of recharge from this source depends on the volume and permeability of the alluvium underlying the stream and on the hydraulic gradient.

Recharge from seepage of irrigation water occurs mostly where crops are grown on well-drained permeable alluvial fans on either side of the valley. The amount of recharge from this source depends on the permeability of the soil and the amount of water applied in excess of that required for plant growth and for maintenance of soil moisture.

Subsurface inflow of ground water through the bedrock and valley-fill interface constitutes a major source of recharge to the ground-water reservoir of Sanpete Valley, but it cannot be measured directly. Indirect evidence of such recharge is apparent in the Silver Creek arm of Sanpete Valley. The annual discharge of ground water from irrigation wells tapping the valley fill in the vicinity of Fountain Green normally exceeds 2,000 acre-feet and was almost 3,000 acre-feet in 1966. This amount of discharge would require constant recharge to the valley fill of about 4 cfs (cubic feet per second) to maintain relatively constant water levels. Most of the surface streams of the area are intermittent, and their total annual average flow is less than 4 cfs. Hydrographs of wells in this area (pl. 3) do not exhibit an abrupt rise in water levels during the spring runoff each year, as do those of most wells elsewhere in the valley; thus, the effect of spring runoff of surface waters on the ground-water reservoir in this area is probably negligible. Inasmuch as water levels in the area recover completely each autumn and winter from the effects of pumping in the previous spring and summer, water is assumed to enter the valley from the abutting bedrock in the subsurface, probably from the San Pitch Mountains.

The annual precipitation directly on the valley floors is generally barely enough to maintain soil moisture. Furthermore, in a large part of Sanpete Valley, the piezometric surface is above the land surface, and water could not infiltrate directly. Therefore, recharge to the ground-water reservoir from direct precipitation on the valley floors is assumed to be negligible.

Direct infiltration of precipitation, however, is the principal source of recharge to the consolidated rocks in the drainage basin. The soil cover is thin or absent in much of the higher parts of the basin, and water from rainfall or snowmelt readily enters the permeable formations where they are exposed.

OCCURRENCE

Ground water in the San Pitch River drainage basin occurs in both unconsolidated valley fill and consolidated rock, under both water-table (unconfined) and artesian (confined) conditions.

VALLEY FILL

In the Fairview arm of Sanpete Valley, the valley fill contains ground water which is mostly under water-table conditions. The depth to water in the Fairview arm ranges from less than 10 feet along the San Pitch River to more than 100 feet on the alluvial fans to the east. (See pl. 2.) The only known area of flowing wells that derive water from the valley fill in the Fairview arm is about 4 miles southwest of Mount Pleasant.

In the Silver Creek arm and the main part of Sanpete Valley, the valley fill contains ground water under both water-table and artesian conditions. The precise location of the line separating the two conditions is not easily defined and varies with changes in water levels. (See pl. 2.) In general, water-table conditions prevail near the margins of the valley, where the valley fill is coarse grained and permeable. The valley fill along the east side of the valley contains the widest zone under water-table conditions, with depths to water ranging from 10 to 30 feet in the lowlands and exceeding 100 feet on the higher fans to the east. The zone of water-table conditions along the base of the San Pitch Mountains and the west side of the Cedar Hills is much narrower than that on the east side of the valley; depth to water exceeds 60 feet in a few areas but is generally less than 60 feet (pl. 2).

Ground water is under artesian pressure in the lower and middle parts of the Silver Creek arm and in the main part of Sanpete Valley, where fine-grained materials of low permeability overlie and interfinger with the more permeable beds of gravel and sand. (See sections on pl. 1.) Such conditions exist in approximately 60 percent of the valley fill in the Silver Creek arm and the main part of Sanpete Valley. In general, that part of the valley north of the area midway between Ephraim and Chester seems to be underlain by a single rather uniform artesian aquifer. Wells ranging in depth from 100 to 200 feet apparently tap the same aquifer and have about the same artesian pressure.

In that part of the valley south of the area midway between Ephraim and Chester, however, the water-bearing material is apparently interbedded with layers of clay to form several discrete aquifers; and water in the deeper aquifers is under higher artesian pressure. In this area, wells about 100 feet deep produce water under artesian heads of 3–10 feet above land surface, whereas wells only a few feet away, but 200–300 feet deep, tap water under artesian heads of as much as 30 feet above land surface.

The ground water in the Arapien Valley appears to be under water-table conditions. Depths to water in this area are 30–40 feet below land surface. (See pl. 2.)

CONSOLIDATED ROCKS

Ground water occurs in the consolidated rocks in the mountains and plateaus bounding Sanpete and Arapien Valleys and also in the rocks underlying the valley fill. In fact, water in the formations underlying the valley fill probably recharges the overlying fill and helps maintain the pressures in the large artesian areas in Sanpete

Valley. Most water in the bedrock of the basin is under artesian conditions because the formations are recharged high on the surrounding mountains, and the water in them is confined by impermeable beds.

The most important consolidated-rock aquifers in the basin are sandstone and oolitic limestone in the Green River Formation. Several irrigation wells obtain large supplies of water from an artesian zone in the formation near, and north of, Manti. Wells obtain smaller yields from artesian zones in the Green River Formation, east of Fairview, near Spring City, and between Spring City and Chester.

The Crazy Hollow Formation of Spieker (1949) is a source of water for several irrigation wells near the mouth of Pigeon Hollow, north of Ephraim, where the water is believed to be mostly under water-table conditions. Several small stock wells a few miles northwest of Mount Pleasant also obtain water from the Crazy Hollow Formation.

Several test wells for oil and gas drilled into the westward-dipping formations on the Wasatch Plateau have tapped water under great artesian pressure. Well (D–14–5)16bdd–1, drilled to a depth of over 9,000 feet from an altitude of 7,364 feet, derives water from the Emery Sandstone Member of the Mancos Shale. The well flowed about 400 gpm (gallons per minute) at an artesian head of 142 feet above land surface in December 1956.

A coal tunnel dug in Sixmile Canyon, east of Sterling, intersected ground water moving toward the valley (Richardson, 1907, p. 26). The source of the water is believed to be the North Horn Formation or the Price River Formation.

MOVEMENT

The ground water in the San Pitch River drainage basin is not stationary; rather, it constantly moves downgradient from points of recharge to points of discharge. The water-table and piezometric surfaces in the basin are not level or uniform surfaces but are irregular and sloping. Irregularities in the surfaces are caused by differences in permeability and saturated thickness of the aquifer or by the addition or withdrawal of water from the ground-water reservoir. The general configuration of a ground-water surface can be shown on a map by contour lines connecting points of equal altitudes on the ground-water surface. Such a map is called a water-level contour map. On such a map the more widely spaced contours indicate a more gentle slope of the water surface, probably due to greater permeability of the material through which the water is moving, or greater thickness of the water-bearing materials, or both. Conversely, the more closely spaced contours indicate less permeability, a thinner section of the saturated materials, or approach to a point of discharge, or any combination of the three.

VALLEY FILL

Plate 2 shows the general configuration of the ground-water surface in the valley fill in the Sanpete and Arapien Valleys during November and December 1966. The direction of ground-water movement is indicated by arrows, but it can also be inferred from the contour lines, as ground water moves downgradient, generally at right angles to the contour lines. The overall movement of ground water in Sanpete Valley is in a southerly direction, generally along the courses of the San Pitch River and Silver Creek. Ground water also moves from points of recharge at tributary streams at the sides of the valley toward the center of the valley. The slope of the ground-water surface is relatively steep (shown on pl. 2) in the upper part of the Silver Creek and Fairview arms and becomes increasingly flatter toward the lower end of Sanpete Valley.

SANPETE VALLEY

The movement of ground water in the valley fill of the Fairview arm is mostly southward and southwestward, generally along the course of the San Pitch River (pl. 2). The configuration of the contours on plate 2 indicates that most of the ground-water recharge to the Fairview arm comes from the alluvial fans along the east side of the arm. The general direction of ground-water movement from these fans to the river is westward and southwestward in the area above Mount Pleasant, but it is generally northwestward in the area south of Mount Pleasant.

The ground water moves from the Fairview arm into the main part of the Sanpete Valley through the valley fill in the gateway cut by the San Pitch River, just south of the Cedar Hills; through the valley fill in the gateway cut by Oak Creek, west of Spring City; and through the valley fill in four other smaller gateways southwest of Spring City.

Ground water in the Silver Creek arm moves southeastward from the chief recharge area along the San Pitch Mountains at the west edge of the arm. The ground water then moves generally southward, downvalley along the course of Silver Creek. (See pl. 2.) At the upper end of the Silver Creek arm, a ground-water divide separates ground-water movement into Sanpete Valley from movement into the Salt Creek drainage of Juab Valley. No wells have been constructed in this area; hence, the position of the ground-water divide is not known. This divide is assumed, however, to be very near the surface-drainage divide at the north boundary of the Silver Creek arm. If the ground-water divide is at this position, then virtually no ground water originating in Sanpete Valley is lost to Juab Valley.

The ground water moving south from the Silver Creek arm joins that moving through the gateways of the San Pitch River and Oak Creek from the Fairview arm between Moroni and the Chester area. The movement then continues in a downvalley, southerly direction.

From the junction of the Silver Creek and Fairview arms, ground water moves southward to southwestward along the course of the San Pitch River.

Southwest of Manti, a north-south line of low hills divides Sanpete Valley into two narrow arms. The valley fill pinches out in both arms, and movement of water from the valley in the subsurface is effectively blocked. Thus, ground water can escape from the valley only after it moves to the surface and enters the San Pitch River, which leaves the valley through the western arm downstream from Gunnison Reservoir. A bedrock high across the eastern arm of the valley forms a ground-water divide about 1 mile north of Sterling (pl. 2). From this divide, ground water moves northward into Saleratus Creek and southward into Sixmile Creek, both of which flow westward through narrow gaps in the hills to join the San Pitch River. This "bottle-necking" and consequent impounding of ground water at the lower end of Sanpete Valley has resulted in a large marshy area that extends as far north as the latitude of Manti and that reportedly extended as far north as the latitude of Ephraim prior to settlement in the valley.

ARAPIEN VALLEY

The general movement of ground water in the valley fill in the Arapien Valley is toward Twelvemile Creek. At Mayfield the ground water joins the underflow from Twelvemile Creek and continues northwestward beneath the creek to the point at which it leaves the area of investigation (pl. 2).

CONSOLIDATED ROCKS

Ground water moves toward the valley fill of the San Pitch River drainage basin through consolidated rocks bordering the valley, mainly in the northern San Pitch Mountains and in the Wasatch Plateau.

In the Silver Creek arm of Sanpete Valley several large springs, notably Big Springs, (D–14–2)2bab–S1, that discharge at the base of the San Pitch Mountains, are believed to be major points of discharge for ground water moving downdip in the Indianola Group. Much of the ground water also discharges directly into the valley fill at the contact with the bedrock formations in the subsurface.

Ground water also moves through the consolidated rocks that form the monocline which bounds the west edge of the Wasatch Plateau. Much of this water is discharged through springs in the mountains or through springs contributing to the base flow of the numerous streams. Much of the water also discharges directly into the valley fill at the valley margins, or it moves beneath the valleys, where it is confined by the Sevier fault on the west and by clay overlying it. This water is then forced slowly upward, under artesian pressure, into the alluvium of the valley fill and helps maintain the artesian pressure in the valley. Evidence for this movement includes the following:

1. The presence of numerous sinkholes and solution channels along the crest and western flank of the Wasatch Plateau.
2. The presence of abundant water under high artesian pressure in such wells as (D–14–5)16bdd–1 and (D–16–4)23add–1 and in a tunnel, (D–18–2)35d–S, on the western flank of the Wasatch Plateau.
3. The presence of water under artesian pressure in the bedrock underlying the valley fill in several parts of Sanpete Valley, such as near Manti (for example, well (D–17–2)36dcb–1) and near Spring City (for example, well (D–15–4)32bab–1).

WATER-LEVEL FLUCTUATIONS

Water levels in wells fluctuate for many reasons, such as a net addition or reduction of water to the ground-water reservoir, changing barometric pressures, earthquakes, and other factors. The various influences may act singly or in combination, and the resulting fluctuations may be brief, or may be seasonal, annual, or long term. The discussion in this report is devoted to the seasonal, annual, and long-term fluctuations.

SEASONAL FLUCTUATIONS

In the part of the Fairview arm north of Mount Pleasant, water levels change abruptly and considerably on a seasonal basis. (See hydrographs of wells (D–13–4)12acc–1 and (D–14–4)2dbc–1 on pl. 3.)

A period of recharge, beginning about March of each year and continuing to about May or June, raises the water levels in the valley fill as much as 45 feet, bringing the water table to only a few feet below the surface. This recharge period coincides with the spring runoff of snowmelt from the surrounding mountains. Annually, the period from about July to the following March is one of water-level decline due to downvalley drainage and, to a lesser extent, to discharge from wells and losses from evapotranspiration.

In the Mount Pleasant–Spring City area, the hydrographs for wells (D–15–4)4dda–1 and (D–15–4)29bac–1 show that recharge occurs from about April or May to July of each year, raising the water levels about 10–20 feet. A period of decline then ensues from July to about the following April, owing mostly to downvalley drainage but also to some discharge from wells and evapotranspiration.

In the Silver Creek arm in the area of Fountain Green and to the south, hydrographs for wells, such as (D–14–3)20cbb–1 and (D–14–3)33bcc–1, show (pl. 3) that the water levels decline from about March to September or October of each year and that they rise from October to March of the following year. The decline is due mostly to pumping at irrigation wells but is also due, in part, to downvalley drainage and losses from evapotranspiration. The rise is due mostly to recovery from the effects of pumping but also to recharge that probably comes from springs beneath the valley fill along the base of the San Pitch Mountains. The decline of water levels during the period April to June or July shows the lack of recharge from seasonal runoff to the ground-water reservoir in this area.

In the main part of Sanpete Valley, water levels rise generally from about April or May through July or August, and decline generally from about September to the beginning of rise in the following year. The rise of water levels is caused by recharge from snowmelt and subsequent runoff during the spring and early summer months. The declines probably are due mostly to withdrawal of ground water through pumped wells in the period preceding September, to movement of ground water to lower points of discharge, and to evapotranspiration. These changes, which are most pronounced along the east side of the valley and particularly higher on the alluvial fans or nearer to a source of recharge, are illustrated on plate 3 in hydrographs for irrigation well (D–15–3)27ada–1, north of Chester; irrigation well (D–17–3)9cbd–1 and flowing well (D–17–3)30dbd–1, both on the east side of the valley between Ephraim and Manti; well (D–17–2)26dba–1, between Ephraim and Manti on the west side of the valley; irrigation wells (D–18–2)1daa–1 and (D–18–2)12cdb–1, at Manti; well (D–18–2)27ccc–1, north of Sterling; and wells (D–19–2)16bcb–1 and (D–19–2)17aad–1, south of Sterling.

A number of wells in the main part of Sanpete Valley show water-level fluctuations which are strongly affected by wells discharging water for irrigation. Representative hydrographs are shown on plate 3 for flowing well (D–15–3)28aba–1, south of Moroni; well (D–16–2)36cbd–1, an irrigation well between Chester and Ephraim; flowing well (D–16–3)4aaa–1, southwest of Chester; flowing well (D–16–3)32ddc–2, north of Ephraim; and (since 1958) flowing well (D–17–2)lbca–2, west of Ephraim.

In Arapien Valley, the hydrograph of irrigation well (D–19–2)32aac–1, at Mayfield on the flood plain of Twelvemile Creek, shows large seasonal fluctuations. The water level rises abruptly from about April to June or July and then declines until the following year. The period of rise reflects recharge to the ground-water reservoir during the high runoff of Twelvemile Creek; and the decline reflects subsurface drainage and pumpage since 1964, sometime after installation of a pump at the well.

ANNUAL FLUCTUATIONS

Figures 3 and 4 show the changes in water levels throughout Sanpete Valley from March 1965 to March 1966 and from March 1966 to March 1967. Water levels were higher in March 1966 than in March 1965 throughout most of the valley (fig. 3) mainly because of above-average precipitation during 1965. (See precipitation cumulative departure graph on pl. 3.) Water levels rose 1–3 feet in most of the valley areas, but rises of about 6–9 feet were recorded around Ephraim and Mount Pleasant and north of Milburn. Most of the areas where water levels rose more than 3 feet are at the sides of the valley near the mouths of perennial creeks that supply large quantities of water for recharge to the ground-water reservoir. Small water-level declines were centered around Moroni, around Fairview, and southwest of Spring City. Wells in these areas are distant from major recharge areas and are heavily pumped.

Water levels were lower in March 1967 than in March 1966 throughout most of Sanpete Valley and in Arapien Valley (fig. 4). Water levels rose slightly in only three small areas in the valley. The decline of water levels was less than 1 foot in a large area centered around Moroni but was more than 9 feet in areas along the east side of the valley. Near Ephraim, the water-level decline was nearly 13 feet, and north of Milburn it was more than 15 feet. The general lowering of water levels was caused by less than normal recharge to the ground-water reservoir and by increased withdrawal of water from wells for irrigation, both of which resulted from below-normal precipitation during 1966 (precipitation cumulative departure graph on pl. 3) and from a longer growing season.

LONG-TERM FLUCTUATIONS

Water levels in nearly all wells in the San Pitch River drainage basin fluctuate in direct response to variations in precipitation. By

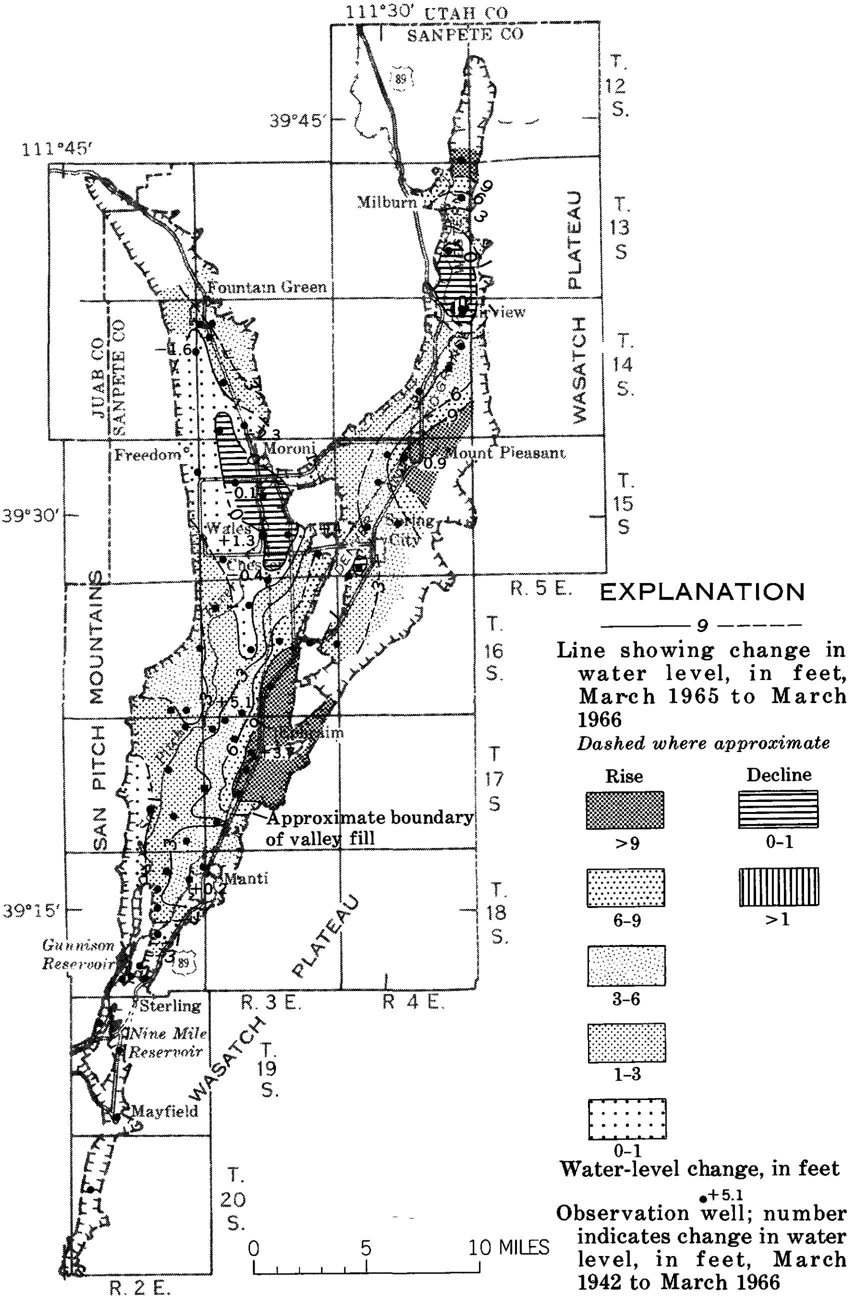


Figure 3.—Change of ground-water levels in Sanpete Valley, March 1965 to March 1966.

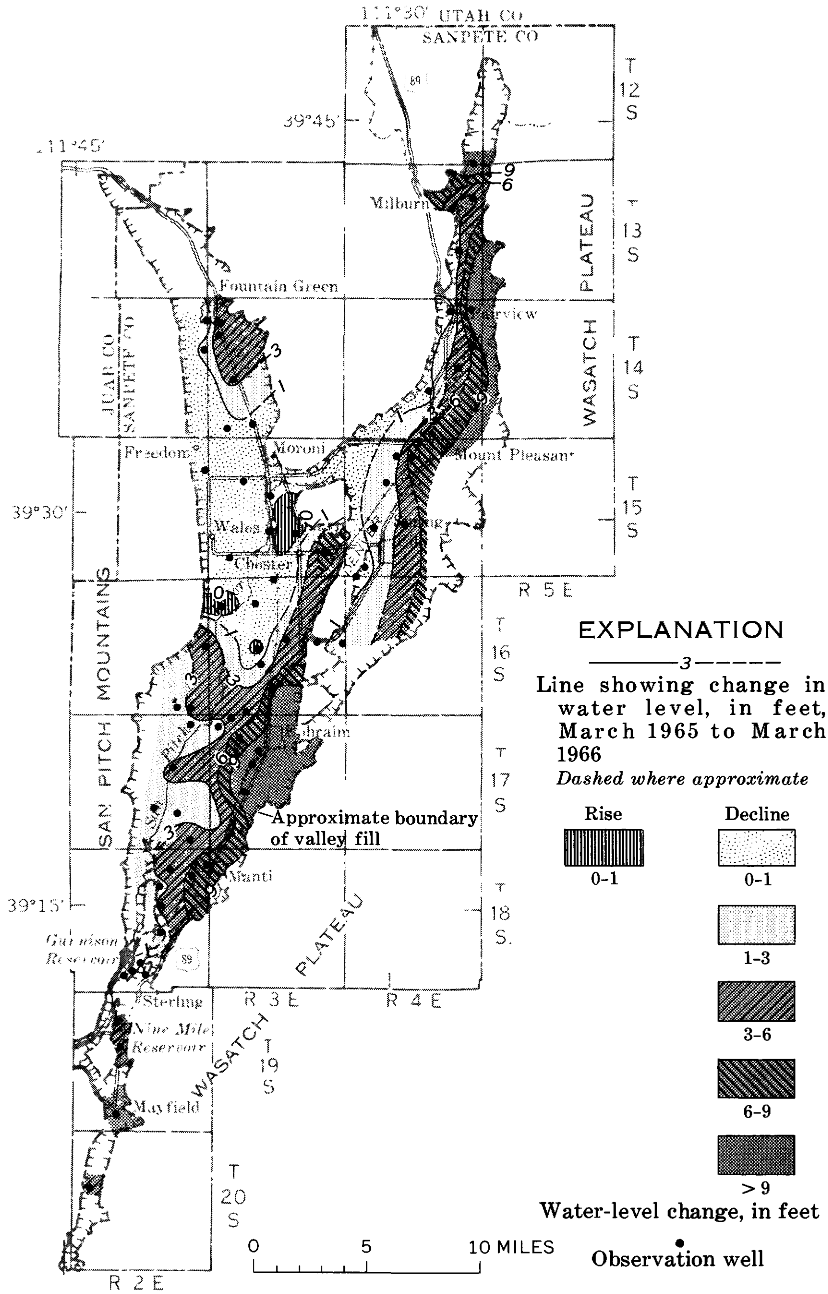


Figure 4.—Change of ground-water levels in Sanpete and Arapien Valleys, March 1966 to March 1967.

comparing the water-level hydrographs on plate 3 for selected wells in the valleys with the curve showing cumulative departure of precipitation at Manti from the 1931–60 normal, it can be seen that the water levels in most wells rise following a series of wet years (above-normal precipitation) and decline following a series of dry years (below-normal precipitation). The hydrographs of wells (D–14–2)13aaa–1, (D–15–4)4dda–1, (D–16–3)32ddc–2, (D–17–3)9cbd–1, (D–17–3)17adb–1, and, collectively, (D–19–2)16bcb–1 and (D–19–2)17aad–1 show this relation, even though in some wells the water-level changes can lag the precipitation changes by as much as 1 year. These hydrographs also show large rises of water levels without apparent cause in 1952. The curve showing cumulative departure from normal precipitation at Manti shows that precipitation was slightly below average in 1952 and only slightly above average in 1951. In 1951, however, most of the precipitation accumulated as snow in the mountains surrounding the valley; therefore, runoff in the streams in the spring of 1952 was much above average, and ground-water levels rose accordingly.

The hydrographs on plate 3 show no long-term fluctuations of water levels other than those caused by variations in precipitation. Thus, it may be inferred that at the present time (1967) the discharge of ground water from wells has not caused a net decline of water levels in any part of the San Pitch River drainage basin.

HYDRAULIC CHARACTERISTICS OF THE AQUIFERS

The capacity of water-bearing materials to contain and transmit ground water depends on the thickness and areal extent of the aquifer and on the characteristics of transmissibility and storage of the material. The thickness and areal extent of the aquifer can be determined from drillers' logs of wells and electric or gamma-ray logs of wells. The characteristics of transmissibility and storage were discussed by Ferris, Knowles, Brown, and Stallman (1962, p. 72–78) and can be determined by several types of aquifer tests related to the pumping of a well and the observing of water levels in the well or in nearby observation wells.

During the investigation, 10 aquifer tests were made to determine the coefficients of transmissibility and storage of the valley fill in Sanpete Valley. (See table 5.) Three of the tests involved a large-discharge pumped well and two to five observation wells about 1,480 to 5,220 feet from the pumped well. The coefficients of transmissibility and storage were obtained for the aquifers according to the Theis nonequilibrium formula, as modified by Jacob (Ferris and others, 1962, p. 98–100). Seven of the tests involved only a large-discharge well. The coefficients of transmissibility and storage were determined for the aquifers according to the Theis recovery formula (Ferris and others, 1962, p. 100–102).

TABLE 5.—*Results of aquifer tests on irrigation wells in Sanpete Valley*

Pumped well	Observation well	Date of test	Type of test	Aquifer material	Field coefficient of transmissibility (gpd per ft)	Coefficient of storage
(D-14-3)20bba-1		8-30-66	Recovery	Valley fill	56,000	
(D-14-4)12cdd-1		9-16-66	do	do	96,000	
(D-15-3)16adb-1		9- 9-66	do	do	20,000	
(D-15-4)4cab-1		9- 2-66	do	do	321,000	
(D-16-2)36cbd-1	(D-16-2)36cda-1	6- 5-65 to 6- 8-65	Pumping	do	126,000	0.0029
	(D-17-2)1baa-1				89,000	.00064
	(D-17-2)1bca-2				100,000	.00075
	(D-17-2)1cba-1				300,000	.00092
	(D-17-2)1cba-2				267,000	.0012
(D-16-3)15dcb-1		9-21-66	Recovery	Valley fill, sandstone, and shale.	40,000	
(D-17-3)5add-1	(D-16-3)32ddc-2	6- 9-66 to 6-11-66	Pumping	Valley fill	137,000	.00068
	(D-17-3)5abd-1				93,000	.0026
	(D-17-3)5adb-2				72,000	.0021
	(D-17-3)5dba-2				57,000	.00071
(D-17-3)20cdb-1		9- 8-66	Recovery	do	381,000	
(D-18-2)1daa-2		9-19-66	do	do	383,000	
(D-18-2)14aac-1	(D-18-2)14bbb-1	6- 8-66 to 6-11-66	Pumping	do	68,000	.00007
	(D-18-2)14bdb-1				137,000	.0016

The coefficient of transmissibility also can be estimated from the specific capacity of a well (which designates the number of gallons per minute of water the well can produce per foot of drawdown) by the method described by Theis, Brown, and Meyer (1963, p. 331–334). However, the coefficient of transmissibility values obtained by this method may reflect the physical conditions of the well in addition to those of the aquifer. Nonetheless, these values are, in general, fairly reliable. Table 6 lists the coefficients of transmissibility estimated for the specific capacities at a number of large-diameter pumped wells. In comparing these estimates of coefficients of transmissibility from the various areas of the basin with those values obtained from aquifer tests, it was concluded that the estimates based on the specific capacities are too low and that the values given in table 6 should be 25–35 percent higher.

The coefficients of transmissibility determined for the valley fill from the aquifer tests and the specific capacities of wells ranged from 4,100 to 380,000 gpd per ft (gallons per day per foot). The coefficients

TABLE 6.—*Coefficients of transmissibility in the vicinities of selected wells, as estimated from the specific capacities of the wells*

Rate of discharge: m, measured; r, reported. Drawdown: e, estimated; m, measured; r, reported.

Pumped well	Date of measurement	Aquifer material	Rate of discharge (gpm)	Drawdown (ft)	Specific capacity (gpm per ft of drawdown)	Coefficient of transmissibility (gpd per ft)
(D-14-2) 12aad-1	7-27-66	Valley fill	221m	48m	5	11,000
(D-14-3) 6bcd-1	7-27-66	do	237m	40e	6	13,000
6cad-1	7-27-66	do	140m	30e	5	11,000
7abb-1	7-27-66	do	339m	30m	11	24,000
7acc-1	7-27-66	do	501m	21m	24	53,000
7bbb-1	7-27-66	do	455m	45m	10	22,000
17cca-1	7-27-66	do	332m	10m	33	71,000
18adb-1	7-27-66	do	286m	25m	11	24,000
(D-14-4) 1abc-1	6-28-52	Sandstone	700r	200+r	<3	7,000
1acb-1	10-11-66	do	250r	157r	2	4,400
(D-15-3) 5ada-2	7- 8-60	Valley fill	300r	58r	5	11,000
9acb-1	1955	Sandstone and volcanic rock.	20r	160+r	<8	17,000
15cac-1	8-26-34	Valley fill	525r	58r	9	19,000
16abc-1	7-12-51	do	500r	45r	11	24,000
16dca-1	10-23-61	Sandstone(?) and volcanic rock(?).	1,680r	92r	18	39,000
21ada-1	7- 1-52	Valley fill	540r	78r	7	15,000
22bcb-3	3-23-61	do	150r	30r	5	11,000
27acb-1	9-29-48	Valley fill and shale(?).	72r	3r	24	56,000
27ada-1	7-22-66	do	723m	18m	40	86,000
28daa-1	9- 8-34	Valley fill	450r	60r	8	17,000
(D-15-4) 2adb-1	6- 1-52	do	800r	80r	10	14,000
3bdb-2	7-23-52	do	1,200r	30r	40	55,000
4bad-2	6-21-53	Valley fill and sandstone.	1,300r	87r	15	32,000
4dda-1	7-29-66	Valley fill	980m	26m	38	52,000
8dcd-1	7-28-66	do	450m	70r	6	8,200
9bab-1	7-29-66	do	753m	18m	42	57,000
17ccb-1	8-10-48	do	786r	32r	20	27,000
21cda-1	12- 5-55	do	350r	108r	3	4,100
(D-16-2) 13dda-1	4-25-35	do	900r	107r	8	18,000
24dbb-1	9-18-52	do	300r	97r	3	6,600
35acd-2	7-21-66	do	710m	28m	25	34,000
(D-16-3) 5abd-1	10-13-34	do	800r	150r	5	11,000
27cba-1	11-14-66	Valley fill, sandstone, and limestone.	1,335m	91m	15	32,000
28aad-1	7-15-64	Valley fill and shale.	839m	31m	27	58,000
28cda-1	7-21-66	Valley fill	671m	30e	25	54,000
(D-17-2) 36dcb-1	7- 4-56	Valley fill, sandstone, and limestone.	2,790r	6r	465	1,000,000
(D-17-3) 3cbb-1	7-10-64	do	196m	100m	2	3,000
8cda-2	9- 4-64	Valley fill	1,135m	21m	54	117,000
8cdd-1	7-20-66	do	1,290m	50m	26	56,000
9cdb-1	4-28-60	do	685r	78r	9	13,000
17adb-1	7-20-66	do	623m	30m	21	29,000
17caa-1	7-20-66	Valley fill and sandstone(?).	946m	49m	19	41,000
20acc-1	7-14-66	do	766m	64m	12	16,000
20bdd-1	7-20-66	Valley fill	692m	48m	14	20,000
30aaa-1	7-13-66	do	664m	70m	10	22,000

TABLE 6.—*Coefficients of transmissibility in the vicinities of selected wells, as estimated from the specific capacities of the wells*—Continued

Pumped well	Date of measurement	Aquifer material	Rate of discharge (gpm)	Drawdown (ft)	Specific capacity (gpm per ft of drawdown)	Coefficient of transmissibility (gpd per ft)
(D-18-2) 1bdd-1	3-17-51	do	1,200r	14r	86	120,000
1cdb-1	5-26-66	do	860m	10m	86	120,000
12bab-1	7-18-66	do	648m	14m	46	63,000
12cdb-1	3- 3-48	do	400r	27r	15	20,000
(D-19-2) 32aac-1	7-18-66	do	605m	96m	6	8,200

of storage determined from aquifer tests ranged from 0.00007 to 0.0029. In general, the wells with the lowest coefficients of transmissibility are those that tap artesian aquifers containing only thin sand and gravel zones or that tap aquifers containing considerable amounts of admixed clay and silt. The coefficients of transmissibility in the valley fill are generally higher on the upper parts of the alluvial fans, where the coarser and better sorted deposits occur.

The coeffiicients of transmissibility of the consolidated-rock aquifers, as determined from specific capacities of wells, ranged from 4,400 to 7,000 gpd per ft for sandstone and shale of the Green River Formation, from 17,000 to 39,000 gpd per ft for sandstone and volcanic rock of the Moroni(?) Formation of Schoff (1938), from 32,000 to 58,000 gpd per ft for sandstone, limestone, and shale of the Crazy Hollow Formation of Spieker, and from 3,000 to 1,000,000 gpd per ft for sandstone and oolitic limestone of the Green River Formation. The coefficient of transmissibility of 1,000,000 gpd per ft was obtained at a well that probabily tapped solution channels in the limestone.

STORAGE

Most of the ground water in the basin is in storage in the unconsolidated valley fill of Sanpete and Arapien Valleys. The amount of ground water physically available for withdrawal by wells is much less than the total amount in storage. The coarse-grained sediments, such as sand and gravel, are capable of yielding about 15–25 percent of their volume; whereas fine-grained deposits, such as clay and silt, although containing large quantities of water, are only capable of yielding about 3 percent of their volume, and this only after long periods of time. A large amount of ground water is also stored in the consolidated-rock formations underlying the valleys, but no estimate of the amount was made.

The approximate amount of ground water available to wells from storage in the upper 200 feet of saturated valley fill in the part of

Sanpete Valley above the Gunnison Reservoir dam was calculated, using the methods of Davis, Green, Olmsted, and Brown (1959, p. 199–214). Sanpete Valley was subdivided into township subunits, and the storage in each township was obtained as the product of the areal extent of the valley fill, the saturated thickness of the fill, and the average storage coefficient of the fill in the township. The average storage coeffiicent was obtained by (1) examining drillers' logs of wells in the township and classifying the materials into five major groups; (2) assigning storage coefficients of 25 percent to gravel, sand, or sand and gravel, 10 percent to fine sand or tight sand or gravel, 5 percent to mixtures of clay and sand, or clay and gravel, and 3 percent to silt and clay; and (3) calculating the average storage coefficient for the upper 200 feet of saturated valley fill in the township.

The calculations indicate that approximately 3 million acre-feet of water available to wells is stored in the upper 200 feet of saturated valley fill in the part of Sanpete Valley above the Gunnison Reservior dam. Of this amount, approximately 600,000 acre-feet is in the top 30 feet of saturated material; approximately 400,000 acre-feet is in the 30- to 50-foot zone; approximately 800,000 acre-feet is in the 50- to 100-foot zone; and approximately 1,200,000 acre-feet is in the 100- to 200-foot zone.

The total of 3 million acre-feet of available ground water would not be immediately available if the water surface were uniformly lowered through the entire 200 feet because (1) water in a large part of the area is under artesian conditions, and the lowering of water levels would represent a decrease in water pressure (artesian head) rather than a dewatering of the sediments; and (2) part of the available ground water is stored in clay and silt, which yield water very slowly.

DISCHARGE AND UTILIZATION

Ground water is discharged in the San Pitch River drainage basin by springs and seeps, wells, and drains, and evapotranspiration. Ground water also is discharged from the basin as subsurface outflow at two locations.

SPRINGS AND SEEPS

Numerous springs and seeps discharge in the drainage basin in both the valleys and the surrounding mountains. Many of the springs cease flowing during periods of below-normal precipitation but begin to discharge again as precipitation increases. Fifty-three of the larger springs and seeps that have perennial flow during most years were visited during 1966. The locations of these springs and seeps are shown on plate 1. Most of the springs visited are in the valleys or on adjacent mountain slopes. The only springs visited in the higher mountains were those that are used for public supply or that have unusually large discharges. Numerous other springs in the mountains, particularly along the streambeds, are considered to be the sources of the base flows to the streams that discharge into the valleys and are measured at various gaging stations. Information pertaining to ownership, altitude, geologic source, yield, use of water, temperature, specific conductance of the water, and improvements at all 53 springs and seeps, the periodic measurements during 1965–66 of discharge, temperature, and specific conductance of the water from 15 springs, and the chemical analyses of water samples from 32 springs are listed in a basic-data release by Robinson (1968).

The 53 springs discharged about 50 cfs, or a total of about 36,000 acre-feet, of water during 1966, approximately distributed as follows: 10 springs in the Fairview arm of Sanpete Valley discharged about 10 cfs (about 7,300 acre-ft per yr); 12 springs in the Silver Creek arm discharged about 16 cfs (about 11,700 acre-ft per yr); 28 springs in the main part of Sanpete Valley discharged about 21 cfs (about 15,300 acre-ft per yr); and three springs in Arapien Valley discharged about 2 cfs (about 1,500 acre-ft per yr).

The area of greatest spring discharge is along the base of the San Pitch Mountains north of Wales, where seven springs discharge a total of about 12–18 cfs. The largest spring in this group and in the drainage basin is Big Springs, (D–14–2)2bab–S1, northwest of Fountain Green. The discharge of this spring has a large seasonal variation, and it has ranged from a high of about 17.5 cfs to a low of about 4 cfs during the period 1953–66. (See fig. 5.) The discharge of the spring increases markedly from April through July of most years, the time of snowmelt in the higher altitudes above the spring, and reflects the long-term trends in precipitation in the area. (Compare the spring hydrograph (fig. 5) with the graph showing cumulative departure from normal annual precipitation at Manti, 1931–60, on pl. 3.)

The source of the water discharged at Big Springs has long been controversial. One suggestion is that the water actually enters the bedrock on the Wasatch Plateau to the east and moves westward beneath the floor of Sanpete Valley and beneath the Cedar Hills to the Sevier fault, where the impermeable zone formed by the fault forces the water to the surface at the base of the San Pitch Mountains. However this author believes that the water discharged by Big Springs (and by the other springs nearby) is derived from the San Pitch Mountains, for the following reasons:

1. The springs discharge from rocks of the Indianola Group that crop out extensively in the northern San Pitch Mountains and

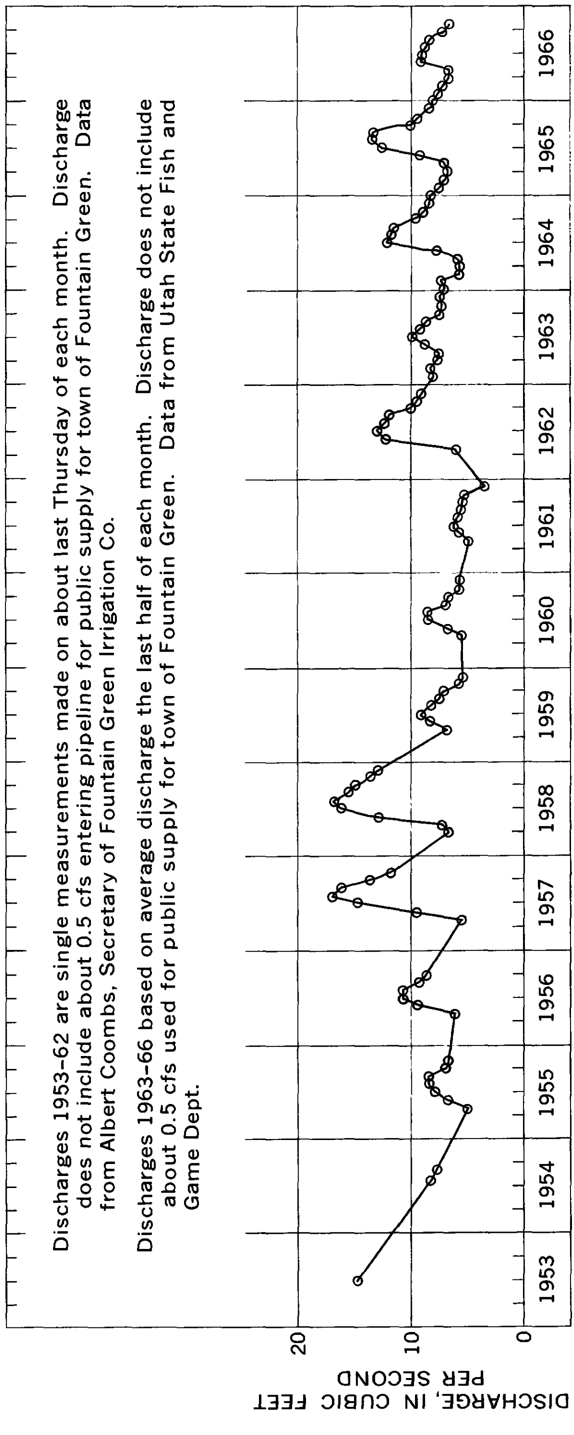


FIGURE 5.—Discharge of Big Springs, (D-14-2)2bab-S1, northwest of Fountain Green.

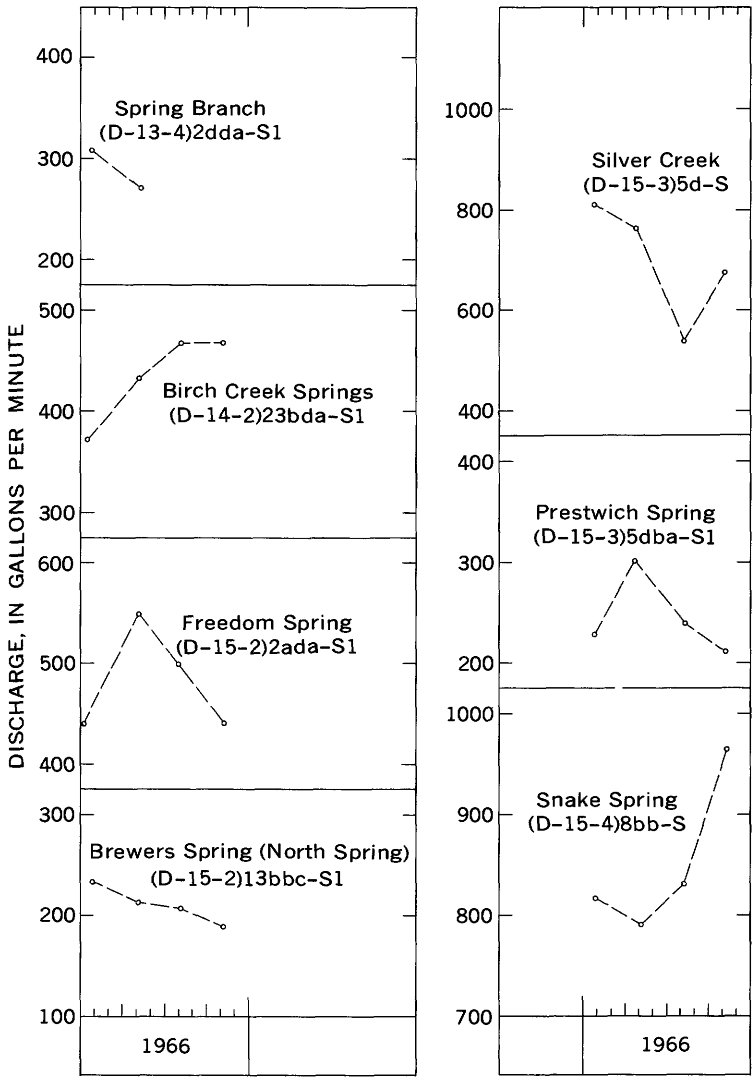
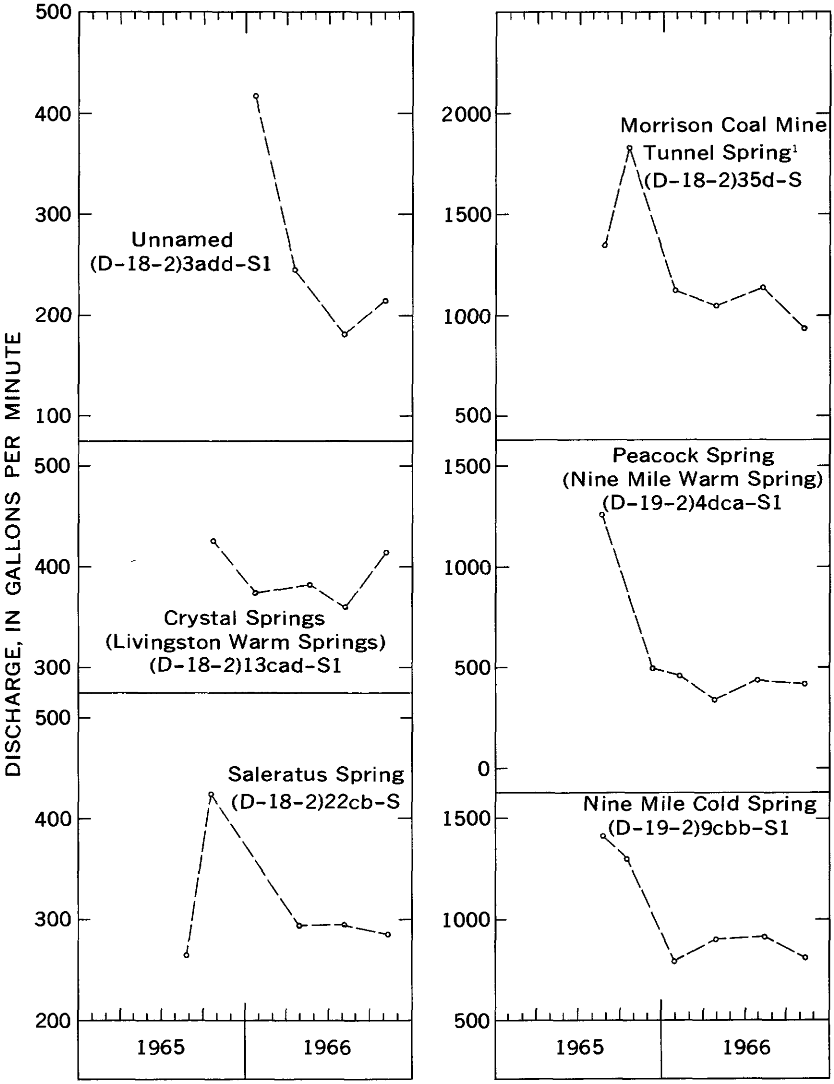


FIGURE 6.—Discharge of selected springs in

dip toward Sanpete Valley. Water that enters these rocks on both sides of the drainage divide formed by the mountains would move downdip toward Sanpete Valley.

2. The springs are on the west side of the main Sevier fault. If water moving from the east were forced to the surface along the fault zone, the resulting springs would be on the east side of the fault.



[1] Discharge reportedly exceeded 2,500 gpm in August 1905 (Richardson, 1907, p. 26)

the San Pitch River drainage basin, 1965–66.

3. The water is not highly mineralized, as would be expected if the water moved long distances through the rocks.
4. The temperature of the water discharged by the springs (about 12°C) suggests that the water is not rising from great depths, as would be necessary if it moved beneath the Cedar Hills from the Wasatch Plateau.

Figure 6 shows hydrographs of the discharges of 13 springs in the

San Pitch River drainage basin. The hydrographs of most of the springs in figure 6 do not correlate well with each other and show that the springs fluctuate in response to conditions in their individual recharge areas. The hydrographs for Crystal Springs, (D–18–2)-13cad–S1; Saleratus Spring, (D–18–2)22cb–S; Morrison Coal Mine Tunnel Spring, (D–18–2)35d–S; Peacock Spring, (D–19–2)4dca–S1; and Nine Mile Cold Spring, (D–19–2)9cbb–S1, all located along the base of the Wasatch Plateau at the south end of Sanpete Valley, however, do show similar fluctuations. The hydrographs show large discharges in August–October 1965 and a large decline by January 1966. All these springs discharge from bedrock and are recharged from the Wasatch Plateau. The large discharges during August–October 1965 were due to the above-normal precipitation as snow on the Wasatch Plateau during the preceding winter and as rain during the spring and summer.

The 36,000 acre-feet of water discharged from the 53 springs was used approximately as follows: Irrigation and stock, 28,000 acre-feet from 31 springs; stock, 200 acre-feet from five springs; and domestic and public supply, 8,000 acre-feet from 17 springs. The total discharge of each spring was assigned to the predominant use of the water to obtain these figures, although many of the springs are used for multiple purposes.

WELLS

More than 1,500 wells have been constructed in the San Pitch River drainage basin according to records of the Division of Water Rights, Utah Department of Natural Resources. Several hundred additional wells have been constructed but are not on record. Figure 7, compiled from records of the Division of Water Rights, shows the general distribution of wells in the valleys. During the investigation, about 500 of the wells in the basin were visited (pl. 1), and data were obtained on ownership, depth, diameter, water levels, discharge, and materials penetrated. These and other well data are reported in a basic-data release by Robinson (1968).

About two-thirds of the more than 1,500 wells in the basin are small diameter (4 in. or less), are 150–250 feet deep, flow at land surface, and are used mainly for stock. About 70 large-diameter wells have been constructed in the basin, and 66 of them are equipped with large-discharge turbine pumps. The wells, which are mostly 10–16 inches in diameter and 150–300 feet deep, discharge 200–1,200 gpm, and average about 650 gpm. Only 60 of the wells were used during the period of investigation, but these 60 wells annually yield more water than do all other wells in the basin combined.

Table 7 shows the discharge of ground water from wells in the basin, broken down into the various uses during the period 1963–66. It was assumed in the compilation of table 7 that the discharge from

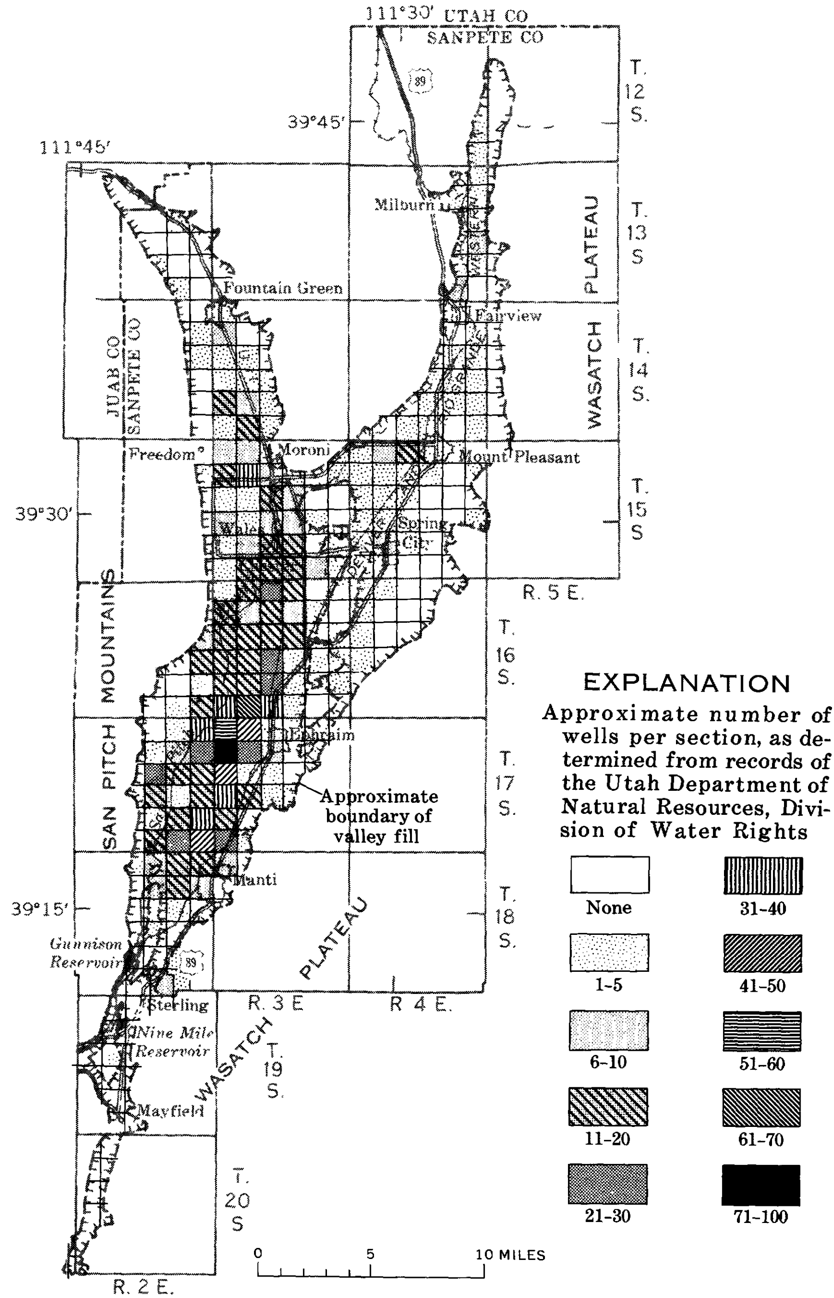


FIGURE 7.—General distribution of wells in Sanpete and Arapien Valleys.

the flowing wells both for irrigation and for domestic and stock use would remain approximately the same from year to year because the needs for these uses remain approximately the same, and the flows are mostly unregulated. Fluctuations in artesian heads in the flowing wells do change the discharge somewhat, but such changes are felt to be negligible in comparison with the total quantity of discharge. Pumpage from small-diameter nonflowing wells is assumed to have remained about the same each year. The total discharge from each large-diameter pumped well was carefully monitored by relating the measured discharge of the well at regular intervals to the power or fuel consumption (electricity, diesel fuel, or gasoline).

TABLE 7.—*Annual discharge of ground water from wells, in acre-feet, in the San Pitch River drainage basin, 1963–66*

Well use	Year			
	1963	1964	1965	1966
Irrigation:				
Pumped wells (60 large-diameter wells equipped with turbine pumps)	8,300	8,000	4,100	13,200
Flowing wells (and wells equipped with small pumps)	3,600	3,600	3,600	3,600
Public supply (three large-diameter wells equipped with turbine pumps)	500	500	400	400
Industry (three large-diameter wells equipped with turbine pumps)	400	400	400	400
Domestic, stock, and some irrigation (flowing wells and wells equipped with small pumps)	3,500	3,500	3,500	3,500
Totals [1]	16,000	16,000	12,000	21,000

[1] Rounded to the nearest thousand acre-feet.

The total annual discharge from large-diameter pumped irrigation wells varies greatly because most of the irrigation wells in the basin are used to supplement the surface-water supply. Hence, during years of abundant precipitation and streamflow, the wells are pumped less than during years of deficient precipitation and streamflow. For example, in 1965, a year of above-normal precipitation and stream discharge in the basin, only 44 of the 60 large-diameter pumped irrigation wells were used, and five of the 44 wells discharged less than 5 acre-feet of water each. Total pumpage for irrigation in 1965 was only about 4,000 acre-feet. By contrast, 1966 was a year of below-normal precipitation, above-average temperatures, and longer growing season for crops; and the draft on the ground-water reservoir by pumping from wells was more than three times that required in 1965. Thus, all 60 large-diameter wells were pumped during 1966, and the total amount of water discharged was more than 13,000 acre-feet.

The water used in 15 towns is obtained from wells and springs in the San Pitch River drainage basin. Nine towns use springs as the sole source of supply, three towns use springs supplemented by pumped wells; one town uses a pumped well supplemented by a spring; and two towns rely on individually owned domestic wells. Table 8 summarizes data for the public-supply systems in the basin.

DRAINS

Numerous drains have been constructed in Sanpete Valley to control water levels and to provide water for irrigation. Most of these drains consist of networks of tile pipe installed in wet and waterlogged areas, but other drains are merely open channels that intercept the ground water. No effort was made in this investigation to determine the areal extent of the drains nor to determine their annual yield, which probably amounts to several thousand acre-feet of water per year. Several networks of drains were observed south of Fairview in secs. 11 and 12, T. 14 S., R. 4 E.; west and north of Mount Pleasant in secs. 27, 28, 32, 33, and 34, T. 14 S., R. 4 E., and secs. 5, 6, and 8, T. 15 S., R. 4 E.; north of Chester in secs. 22 and 27, T. 15 S., R. 3 E.; and northwest of Manti in secs. 25 and 26, T. 17 S., R. 2 E.

EVAPOTRANSPIRATION

Ground water is discharged by evapotranspiration where it is near or at the land surface. Ground water in these areas may rise to the surface by capillary action in the soil and be evaporated or it may be taken in by roots of plants and discharged into the atmosphere by transpiration. Plants that extend their roots into the saturated zone and derive water are called phreatophytes. Phreatophytes transpire large quantities of water where the growth is dense, the area covered is large, and the depth to water is less than 10 feet. The most common phreatophytes in the San Pitch River drainage basin are saltgrass (*Distichlis stricta*), wiregrass (*Juncus balticus*), greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnus* sp.), willow (*Salix* sp.), and cottonwood (*Populus* sp.). Only the areas of saltgrass, wiregrass, greasewood, and rabbitbrush in Sanpete Valley are considered extensive enough to be included in estimates of evapotranspiration for the drainage basin. The saltgrass and wiregrass grow mostly in the wet meadows in the lower parts of the basin; the greasewood and rabbitbrush grow mostly in fringe areas along the wet meadows.

In this investigation, the amount of ground water discharged by evapotranspiration was estimated for the part of Sanpete Valley above the Gunnison Reservoir dam. All water discharged by evapotranspiration was assumed to have been obtained from the ground-water reservoir, although some surface water probably was obtained from irrigation canals and ditches and runoff from irrigated lands.

TABLE 8.—*Public water-supply systems in the San Pitch River drainage basin*

Town	Population (1960 census)	Spring	Well	Improvements, accommodations, and remarks
Milburn	200	Several unnamed	Several	Individual domestic wells and springs.
Fairview	655	Fairview Springs (D–13–5)33ada–S1	(D–14–4)1abc–1	Four springs (upper springs in 33ada; lower spring in 33caa) in Cottonwood Canyon along canyon bottom which yield total of 210 gpm; seep areas collected by 4-in. tile collecting lines; 6-in. pipeline to headhouse at powerplant near mouth of canyon; pumped well, which has a measured yield of 435 gpm and is located at powerplant, is a standby well, used when demand exceeds discharge of the springs; water delivered by gravity from headhouse to the town.
Fountain Green	544	Big Springs (D–14–2)2bab–S1		Springs at base of San Pitch Mountains northwest of Fountain Green; town uses about 200–300 gpm, a small part of the discharge of Big Springs; 12-in. collecting pipes and boxes at springs, 4-in. pipeline to headhouse at west edge of town; water delivered by gravity from headhouse to the town.
Freedom	68	Freedom Spring (D–15–2)2ada–S1		Spring in small canyon in San Pitch Mountains west of Freedom; town uses only part of total discharge of 440 gpm; water transported by pipeline to small headhouse above town; delivered by gravity to the town.
Wales	130	Lime Kiln Spring (D–15–2)26acb–S1		Spring in Wales Canyon in San Pitch Mountains west of Wales; discharge is about 125 gpm; water collected by short tunnel into hillside and by concrete-lined collecting chamber and piped to reservoir headhouse above town; delivered by gravity to the town.
Moroni	879	Moroni Spring (D–15–3)9acb–S1	(D–15–3)9ddc–1	Pumped well, which has a reported discharge of 350 gpm, is main supply for city; water pumped from well to reservoir headhouse on hill above town; water from Moroni Spring is used as standby to well; spring has large collecting chamber and two large pumps; water delivered by gravity from headhouse to the town.
Mount Pleasant	1,572	Coal Fork Spring (D–15–5)22bbb–S1	(D–15–4)2adb–1	Spring in Coal Fork of Pleasant Creek Canyon east of Mount Pleasant; reported discharge of 500–600 gpm; spring equipped with 6-in. feeder pipelines and collecting boxes; water delivered by 6-in. pipeline to two reservoir headhouses east of city; pumped well, which has a reported discharge of 500 gpm and is at the headhouse, is used as a supplement to the springs; water delivered by gravity to the town.
Spring City	463	Old Ox Spring (D–16–4)13adb–S1	(D–15–4)32bab–1	One of 10 springs and seeps in Oak Creek Canyon, east of Spring City; measured discharge of 52 gpm; system includes feeder pipelines, collect-

TABLE 8.—*Public water-supply systems in the San Pitch River drainage basin*—Continued

Town	Population (1960 census)	Spring	Well	Improvements, accommodations, and remarks
				ing boxes, and 4-in. pipeline to reservoir headhouse above town; water delivered by gravity to town; pumped well, used as a supplement to springs, pumps directly into pressure lines; reported pumped yield is 300 gpm.
Chester	182		Several	No centralized public-supply system except well (D–15–3)26ccd–1, which was drilled for use by several families but was abandoned except for certain uses when water was found to be impotable; drinking water derived from individual shallow wells.
Ephraim	1,801	Big Spring (D–17–4)16dcd–S1		Largest of five springs near top of Ephraim Canyon, east of Ephraim; total discharge is about 1,100 gpm (measured); water used to drive wheels at two powerplants near mouth of canyon prior to entering headhouse; system consists of feeder pipelines, collecting boxes, one pressure line to powerplants and one overflow line; both lines join at reservoir headhouse; water delivered by gravity to the town.
Manti	1,739	Hougaard Springs (D–18–4)20bb–S		Springs near top of Manti Canyon, east of Manti, have a reported total discharge of about 900–1,100 gpm; springs are recharged through consolidated-rock formations from Jet Fox Reservoir located on top of Wasatch Plateau and in Colorado River drainage; recharge is controlled by amount of water exposed to the permeable bedrock; system from springs consists of feeder pipes, collecting boxes, pipelines, and two headhouses above town; water used to drive wheels in upper powerplant prior to entering headhouses; water delivered by gravity to the town.
Sterling	137	Cove Spring (D–19–2)1dbc–S1		Spring located in small side canyon of Sixmile Canyon east of Sterling; spring discharges about 75 gpm (estimated); system consists of collecting boxes, 4-in. to 3-in. to 2-in. pipeline to headhouse above town; water delivered by gravity to the town.
Mayfield	329	Mayfield Spring (D–19–2)33acd–S1		Spring located on flood plain of Twelvemile Creek about 1 mile east of Mayfield; discharge of spring reported to be about 60 gpm; system consists of concrete collecting box, pipeline, and headhouse above town; water delivered by gravity to the town; a second spring in (D–20–2)3aaa–1 supplies water to eight families living above the headhouse.

TABLE 8.—*Public water-supply systems in the San Pitch River drainage basin*—Continued

Town	Population (1960 census)	Spring	Well	Improvements, accommodations, and remarks
Gunnison [1]	1,059	Peacock Spring (D–19–2)4dca–S1	----------------	Spring located along base of Wasatch Plateau south of Sterling; spring has large seasonal variation in discharge but averages about 400 gpm; system consists of concrete collecting chamber and building containing aerator at spring, 8-in. pipeline to Gunnison (7 mi southwest of Sterling), and second aerator and headhouse above Gunnison; water delivered by gravity to the town.
Centerfield [1]	475	Spannard Spring (D–19–2)20ddd–S1	----------------	Spring located along base of Wasatch Pleateau in north end of Arapien Valley; town uses only part of the total spring discharge of about 900 gpm; system consists of concrete collecting box built into hillside at spring and pipeline to headhouse above Centerfield (about 8 mi southwest of Sterling); water delivered by gravity to the town.

[1] Outside the boundary of the study area.

The total evapotranspiration in Sanpete Valley was estimated by planimetering the areas of phreatophytes shown on plate 2, and by applying an evapotranspiration rate of 30 inches per year. The rate was estimated from data by T. W. Robinson (1958, p. 49–75). The estimated total annual discharge of ground water by evapotranspiration is approximately 113,000 acre-feet. Approximately 95,000 acre-feet of water is discharged from about 38,000 acres of saltgrass and wiregrass, which form large meadow areas along the lower parts of the valley, and approximately 18,000 acre-feet of water is discharged from 7,200 acres of greasewood and rabbitbrush (mapped together with big sagebrush), which are associated with wet lands.

SUBSURFACE OUTFLOW

Ground water discharges from the basin in the subsurface at two locations: (1) beneath the San Pitch River channel into the central Sevier Valley in sec. 18, T. 19 S., R. 2 E. (virtually all this water is derived from underflow beneath Sixmile Creek), and (2) beneath the channel of Twelvemile Creek into the central Sevier Valley in secs. 18 and 19, T. 19 S., R. 2 E. No calculations were made of the amount of water moving out of the basin because the permeability and thickness of the valley fill beneath the two streams are not known. However, the total subsurface outflow is estimated to be small, not more than 3 cfs (about 2,200 acre-ft per yr).

SEEPAGE RUNS ON THE SAN PITCH RIVER

Two seepage runs were conducted on the San Pitch River during the periods March 23–25 and April 4–5, 1966, to determine the gains or losses in streamflow from both ground water and surface water. Those periods were selected for the seepage runs because at those times the ground was not frozen, outflow from diversions was at a minimum, and tributary inflow from surface water was near a minimum. Conditions at the time the seepage runs were conducted were unusual, however, in that water levels in the valley were extremely high because of above-average precipitation during the preceding year. Thus, an unusually large flow was maintained in the San Pitch River during the winter preceding the seepage runs. However, the seepage runs do indicate the close relation between ground water and surface water along the river system.

During the seepage runs, the river was measured at numerous sites, tributary inflow and diversions were measured or estimated, and water samples were collected for measurement of specific conductance. The first run was conducted March 23–25 from the headwaters of the river north of Milburn to the bridge west of Ephraim. The meadows and lowlands below the bridge west of Ephraim were flooded with water which had been diverted from the river above; thus, the seepage run was discontinued at the bridge west of Ephraim. The second run was conducted on April 4–5 from a point above the bridge west of Ephraim to the bridge west of Manti. Details of the two seepage runs are tabulated in tables 9 and 10. Figures 8 and 9 show graphic representations of the overall gain and losses of the river in the two reaches; figures 10 and 11 show graphic representations of the cumulative gains due entirely to ground-water accretion in the two reaches.

The overall gain in flow of the San Pitch River, from both ground and surface waters, in the reach from its headwaters north of Milburn to the bridge west of Ephraim was about 103 cfs on March 23–25. The overall ground-water accretion to the river at this time was about 95 cfs (table 9). The greatest gains of the river from ground-water accretion were in the area a few miles north of Fairview, in the area from west of Mount Pleasant to Moroni, and in the area a few miles above the bridge west of Ephraim. In the first two areas numerous springs, seeps, and tile drains discharge along the lower part of the valley near the river. The third area is swampy and waterlogged, and ground-water accretion to the river is appreciable.

In the reach of the river from a point a few miles north of the bridge west of Ephraim to the bridge west of Manti, the overall gain in flow in the San Pitch River was about 40 cfs on April 4–5. The cumulative gain of the river due to ground-water accretion in this area was about 27 cfs (table 10). In the part of this reach from the bridge west of Ephraim to a few miles north of the bridge west of Manti, the waters have been diverted into a manmade channel along the west side of the valley that is higher than the original river channel. The present channel is above the sometimes swampy and waterlogged area and, therefore, does not derive much additional flow from ground-water accretion. The original channel, however, does derive a flow from ground-water accretion and delivers this water to the San Pitch River at a point a few miles north of the bridge west of Manti (table 10). Additional ground water is added between the confluence of the two channels and the bridge west of Manti. The accretion is attributed to the damming effect of the bedrock formations in this area and the lower end of the valley, which disrupt the downvalley movement of ground water and force it to the surface.

CHEMICAL QUALITY

Prior to and during the investigation, water samples were collected for chemical analyses from 49 wells, from 19 springs, from five sites along the San Pitch River, and from six creeks in the San Pitch River drainage basin. These analyses are presented in a basic-data

TABLE 9.—*Approximate gain in flow of the San Pitch River and specific conductance of water at miscellaneous sites from north of Milburn to the bridge west of Ephraim, March 23–25, 1966*

[Diversions : e, estimated. Surface-water inflow : e, estimated]

Location and description of measuring station	Cubic feet per second							Specific conductance of water sample (micromhos per cm at 25°C)
	Flow at measuring station	Diversions	Surface-water inflow	Ground-water gain from preceding station on river	Cumulative gain from ground water	Cumulative gain from surface water	Total cumulative flow (ground and surface water)	
NW¼NW¼ sec. 36, T. 12 S., R. 4 E., San Pitch River north of Milburn	2.34	----	----	2.34	2.34	----	2.34	550
NE¼SE¼ sec. 11, T. 13 S., R. 4 E., diversion into ditch at Milburn	----	0.58	----	----	----	----	----	----
NE¼SE¼ sec. 14, T. 13 S., R. 4 E., San Pitch River south of Milburn	5.19	----	----	3.43	5.77	----	5.77	680
NW¼SE¼ sec. 23, T. 13 S., R. 4 E., diversion into canal	----	.93	----	----	----	----	----	----
Sec. 23, T. 13 S., R. 4 E., diffused inflow from Oak Creek	----	----	0.5e	----	----	----	----	----
NE¼NW¼ sec. 2, T. 14 S., R. 4 E., San Pitch River at Fairview bridge	9.50	----	----	4.74	10.5	0.5	11.0	650
SE¼ sec. 2, T. 14 S., R. 4 E., Cottonwood Creek at Fairview	----	----	.42	----	----	----	----	----
SE¼ sec. 15, T. 14 S., R. 4 E., diversion into Mount Pleasant Canal	----	4.32	----	----	----	----	----	----
Sec. 22, T. 14 S., R. 4 E., diffused inflow from Birch Creek	----	----	.5e	----	----	----	----	----
NE¼ sec. 22, T. 14 S., R. 4 E., San Pitch River south of Fairview	17.8	----	----	11.7	22.2	1.42	23.6	620
NW¼ sec. 27 and NE¼ sec. 28, T. 14 S., R. 4 E., diffused inflow from Birch Creek	----	----	.5e	----	----	----	----	----
NE¼ sec. 28, T. 14 S., R. 4 E., diversion into Frandsen Canal	----	.2e	----	----	----	----	----	----
NE¼NE¼ sec. 32, T. 14 S., R. 4 E., San Pitch River west of Mount Pleasant	24.8	----	----	6.7	28.9	1.92	30.8	680

TABLE 9.—*Approximate gain in flow of the San Pitch River and specific conductance of water at miscellaneous sites from north of Milburn to the bridge west of Ephraim, March 23–25, 1966*—Continued

Location and description of measuring station	Cubic feet per second: Flow at measuring station	Diversions	Surface-water inflow	Ground-water gain from preceding station on river	Cumulative gain from ground water	Cumulative gain from surface water	Total cumulative flow (ground and surface water)	Specific conductance of water sample (micromhos per cm at 25°C)
SE¼ sec. 33, T. 14 S., R. 4 E., Pleasant Creek 1 mile west of Mount Pleasant	----	----	6.18	----	----	----	----	----
SW¼ sec. 12, T. 15 S., R. 3 E., diversion into Spring Ditch	----	4.63	----	----	----	----	----	----
NW¼NW¼ sec. 14, T. 15 S., R. 3 E., diversion into the canal	----	1.0e	----	----	----	----	----	----
SE¼SW¼ sec. 10, T. 15 S., R. 3 E., San Pitch River at Moroni bridge	54.1	----	----	28.8	57.7	8.10	65.8	710
SW¼SW¼ sec. 28, T. 15 S., R. 3 E., San Pitch River at Chester Wales bridge	62.7	----	----	8.6	66.3	8.10	74.4	850
NW¼ sec. 33, T. 15 S., R. 3 E., diversion into Bagnall ditch	----	15.5	----	----	----	----	----	----
SE¼ sec. 32, T. 15 S., R. 3 E., diversion into West Point Canal	----	5.11	----	----	----	----	----	----
NE¼ sec. 18, T. 16 S., R. 3 E., San Pitch River northwest of Ephraim	44.1	----	----	2.0	68.3	8.10	76.4	1,100
NW¼SE¼ sec. 1, T. 17 S., R. 2 E., San Pitch River at Ephraim bridge	70.3	----	----	[1] 26.2	94.5	8.10	103	1,800

[1] Part of gain is probably due to return surface flow of water diverted at Bagnall Dam and from Oak and Canal Creeks; exact amount cannot be determined but probably is about 50 percent of gain listed.

TABLE 10.—*Approximate gain in flow of the San Pitch River and specific conductance of water at miscellaneous sites from northwest of Ephraim to the bridge west of Manti, April 4–5, 1966*

[Diversions: e, estimated. Surface-water inflow: e, estimated]

Location and description of measuring station	Cubic feet per second							Specific conductance of water sample (micromhos per cm at 25°C)
	Flow at measuring station	Diversions	Surface-water inflow	Ground-water gain (+) or loss (−) from preceding station on river	Cumulative gain from ground water	Cumulative gain from surface water	Total cumulative flow (ground and surface water)	
NE¼ sec. 18, T. 16 S., R. 3 E., San Pitch River northwest of Ephraim	25.0	----	----	----	----	25.0	25.0	1,100
T. 16 S., R. 2 E., and T. 16 S., R. 3 E., diffused inflow from Oak Creek near Spring City and Canal Creek	----	----	2.0e	----	----	----	----	----
NW¼SE¼ sec. 1, T. 17 S., R. 2 E., San Pitch River at Ephraim bridge	35.4	----	----	+8.4	8.4	27.0	35.4	1,770
SW¼ sec. 1, T. 17 S., R. 2 E., diversion into ditch	----	3.13	----	----	----	----	----	----
NE¼ sec. 11, T. 17 S., R. 2 E., diversion into ditch	----	.66	----	----	----	----	----	----
SE¼ sec. 11, T. 17 S., R. 2 E., diversion into ditch	----	.64	----	----	----	----	----	----
SE¼ sec. 11, T. 17 S., R. 2 E., diversion into ditch	----	7.64	----	----	----	----	----	----
SW¼SE¼ sec. 11, T. 17 S., R. 2 E., San Pitch River at bridge	20.8	----	----	−2.5	5.9	27.0	32.9	1,830
NE¼ sec. 14, T. 17 S., R. 2 E., leakage into canal	----	.5e	----	----	----	----	----	----
SW¼ sec. 23, T. 17 S., R. 2 E., San Pitch River at bridge	21.4	----	----	+1.1	7.0	27.0	34.0	1,860
NE¼ sec. 34, T. 17 S., R. 2 E., San Pitch River just above large drain west of Manti	22.1	----	----	+.7	7.7	27.0	34.7	1,860
NE¼ sec. 34, T. 17 S., R. 2 E., large drain entering river[1]	----	----	[2]11	----	----	----	----	2,520

TABLE 10.—*Approximate gain in flow of the San Pitch River and specific conductance of water at miscellaneous sites from northwest of Ephram to the bridge west of Manti, April 4–5, 1966*—Continued

Location and description of measuring station	Cubic feet per second							
	Flow at measuring station	Diversions	Surface-water inflow	Ground-water gain (+) or loss (−) from preceding station on river	Cumulative gain from ground water	Cumulative gain from surface water	Total cumulative flow (ground and surface water)	Specific conductance of water sample (micromhos per cm at 25°C)
SW¼ sec. 34, T. 17 S., R. 2 E., San Pitch River just below inflow of large drain west of Manti	44.6	----	----	[3]+11.5	19.2	38.0	57.2	2,220
SE¼ sec. 3, T. 18 S., R. 2 E., San Pitch River at Manti bridge	52.4	----	----	+17.8	27.0	38.0	65.0	2,190

[1] Original channel of the San Pitch River which has been abandoned.
[2] Estimated surface-water part of drain discharge which was derived from river diversions above measuring station.
[3] Estimated ground-water part of drain discharge.

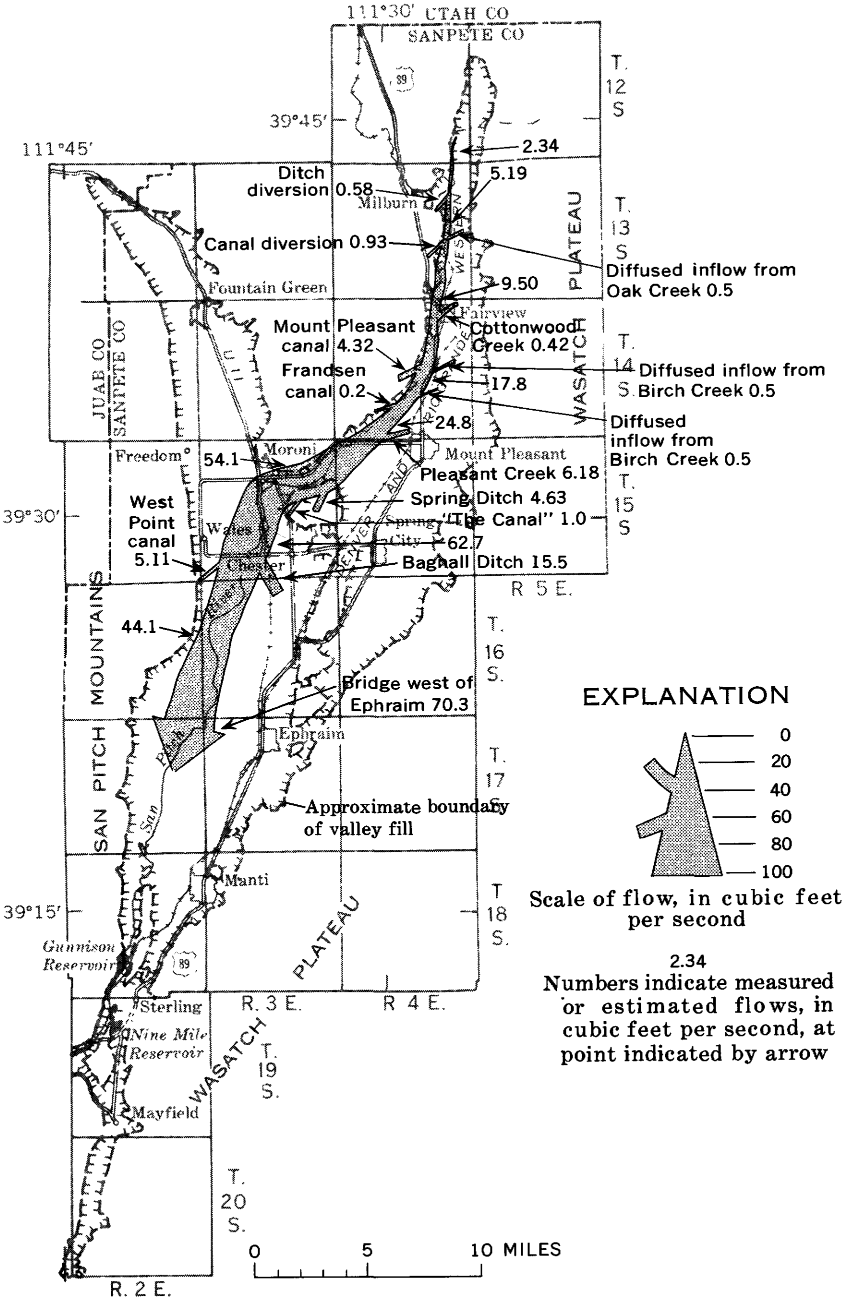


FIGURE 8.—Measured flows of the San Pitch River at selected sites and of tributary inflow and diversions from north of Milburn to the bridge west of Ephraim, March 23–25, 1966.

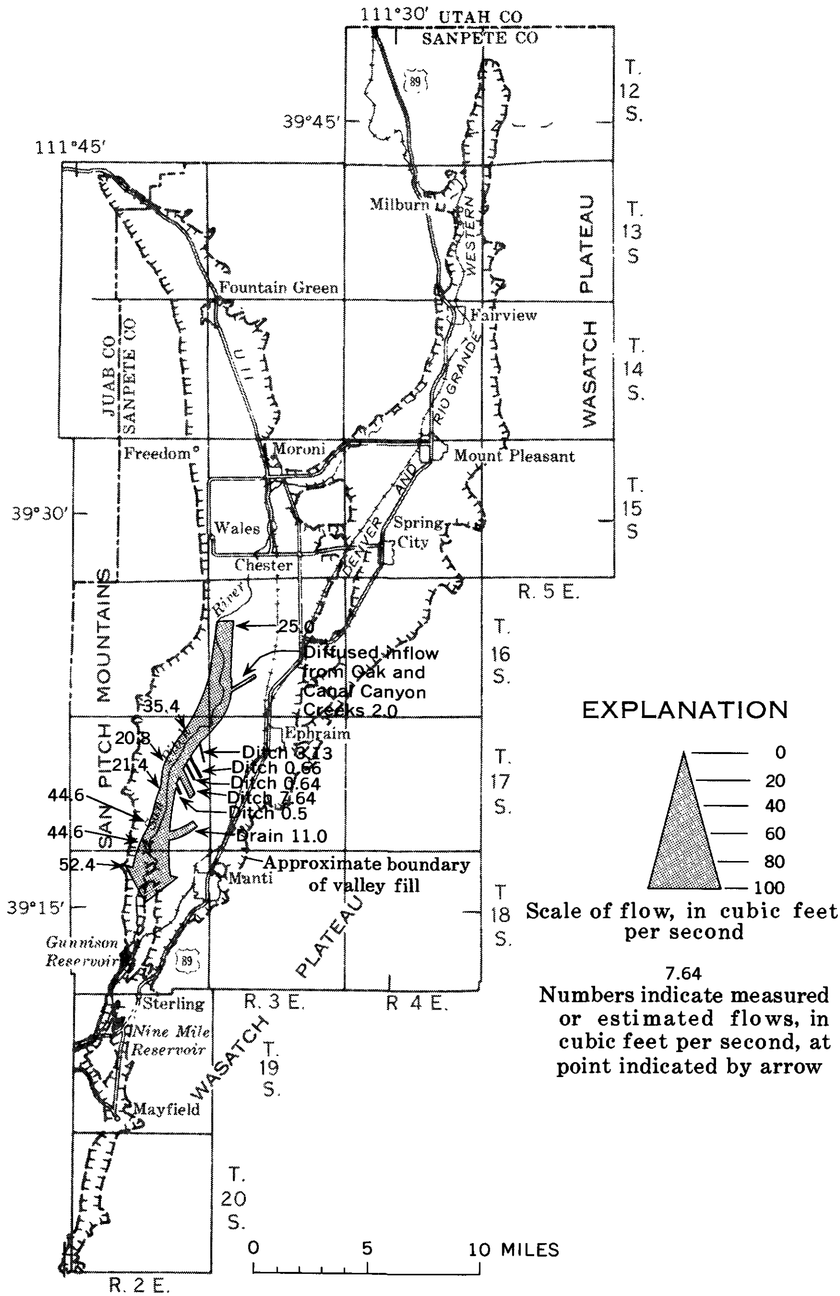


FIGURE 9.—Measured flows of the San Pitch River at selected sites and of tributary inflow and diversions from northwest of Ephraim to the bridge west of Manti, April 4–5, 1966.

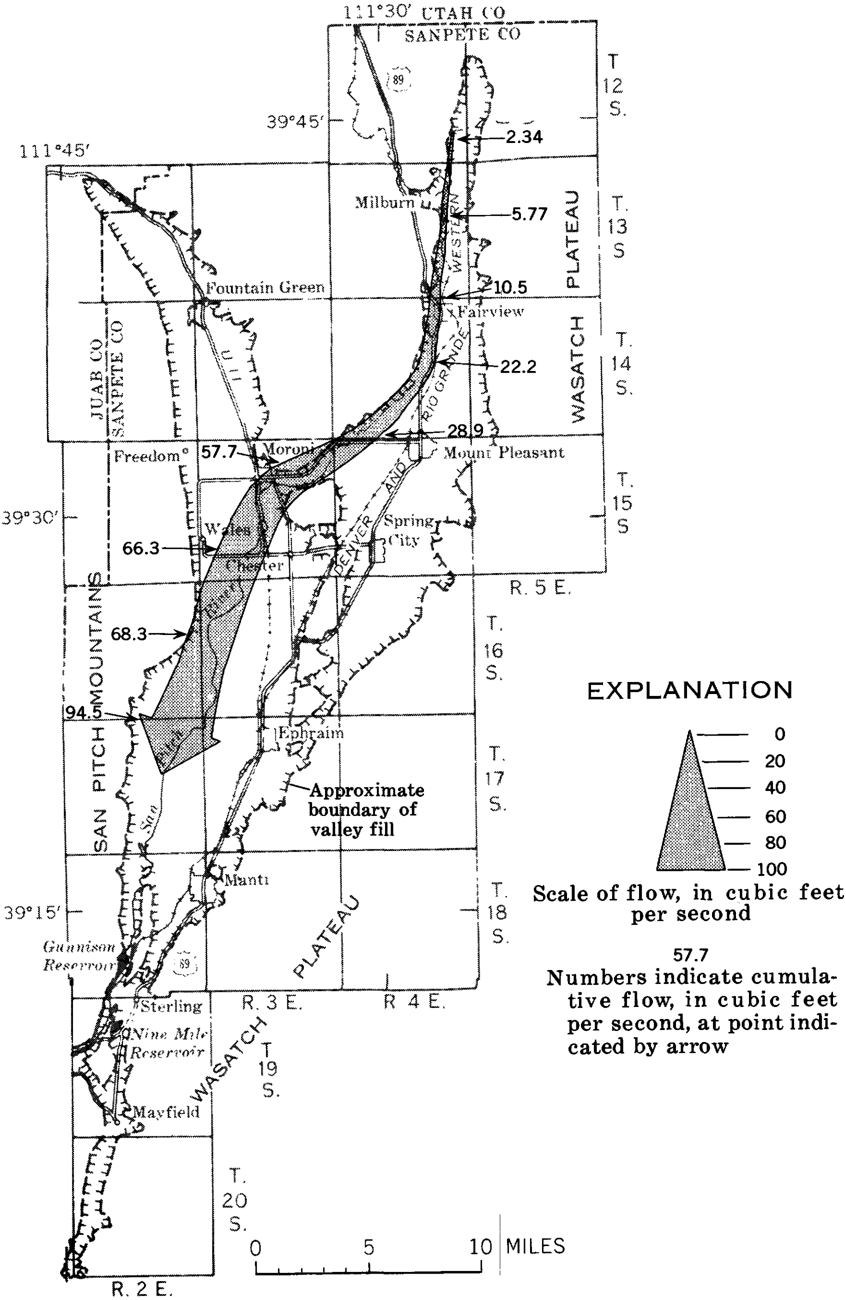


FIGURE 10.—Cumulative gain in flow in the San Pitch River from ground-water discharge from north of Milburn to the bridge west of Ephraim, March 23–25, 1966.

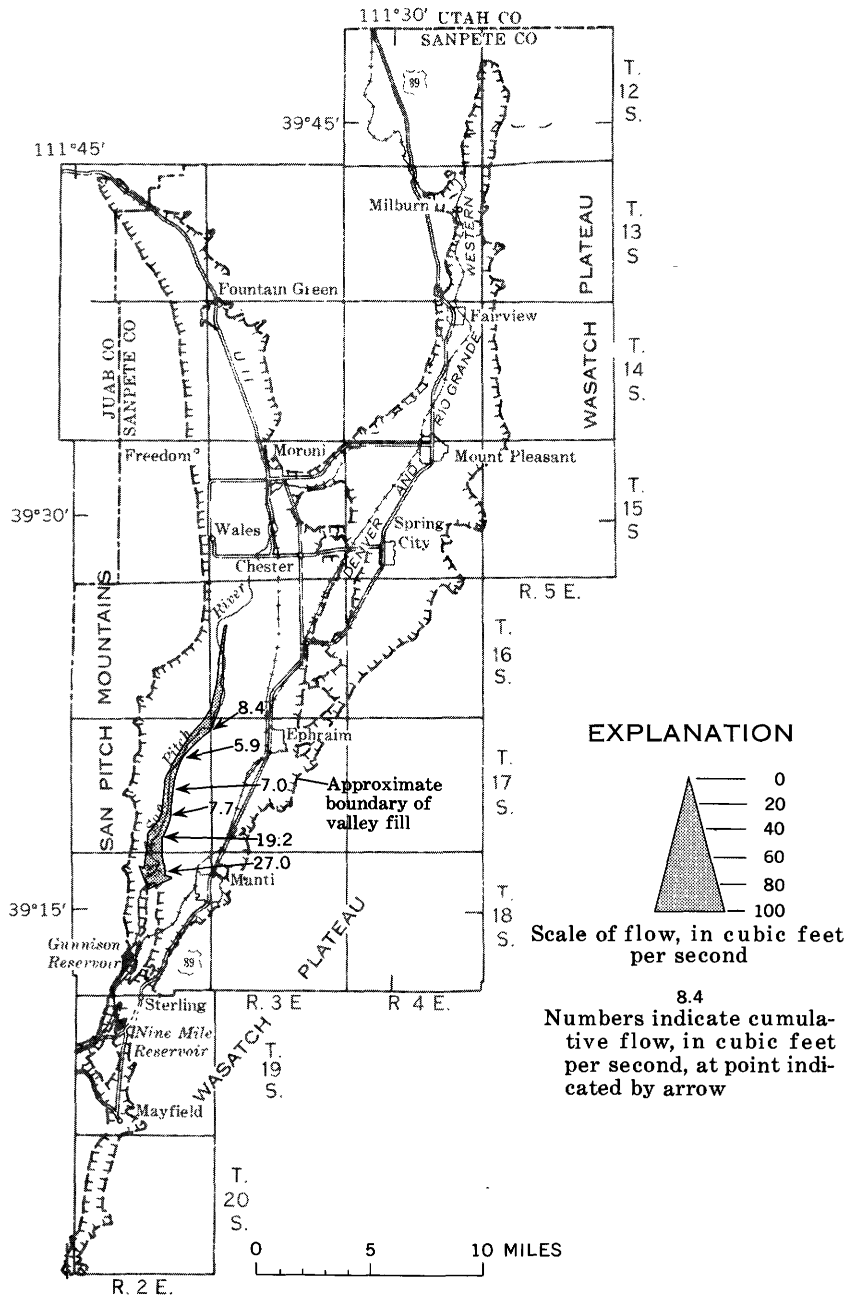


Figure 11.—Cumulative gain in flow in the San Pitch River from ground-water discharge from northwest of Ephraim to the bridge west of Manti, April 4–5, 1966.

release (Robinson, 1968). Additional water samples also were collected for measurement of specific conductance from 272 wells, 32 springs, nine creeks, and one site on the San Pitch River; these data also were listed by Robinson (1968). Specific conductances were obtained during two seepage runs for water samples from 17 sites along the San Pitch River, and the results are given in tables 9 and 10.

The concentration of minerals in water may be expressed in units of dissolved solids or in units of specific conductance. The relation between dissolved solids and specific conductance in the San Pitch River drainage basin is shown in figure 12. The average relation is that the concentration of dissolved solids, in milligrams per liter, is approximately two-thirds of the specific conductance, in micromhos per centimeter at 25°C. The classification of water used in this report is that of Robinove, Langford, and Brookhart (1958) and is as follows:

Class	Concentration of dissolved solids (mg/l)	Specific conductance (micromhos per cm at 25°C)
Fresh	<1,000	<1,400
Slightly saline	1,000– 3,000	1,400– 4,000
Moderately saline	3,000–10,000	4,000–14,000
Very saline	10,000–35,000	14,000–50,000
Briny	>35,000	>50,000

GROUND WATER

Of the 366 ground-water samples collected in the San Pitch River drainage basin, 349 were fresh water, 16 were slightly saline, and one was moderately saline. Plate 4 shows the general chemical quality of the ground water in the basin as indicated by the specific conductances of the 366 ground-water samples. Plate 4 indicates that the largest amount of ground water in the basin has a specific conductance of less than 800 micromhos per centimeter at 25°C, or a concentration of dissolved solids of less than 500 mg/l (milligrams per liter).

RELATION TO GEOLOGY

The freshest ground water is nearest the areas of recharge, particularly along the Wasatch Plateau on the east side of the basin. The ground water contains more dissolved solids (but is still considered fresh) along the west side of Sanpete Valley (pl. 4), probably because of the presence of the Arapien Shale, which includes beds of halite and gypsum that are readily dissolved, and possibly because of slightly or moderately saline water rising along the Sevier fault.

The specific conducatance of ground water ranged from 800 to 1,700 micromhos per cm at 25°C in several local areas of Sanpete Valley where the Crazy Hollow and Green River Formations are exposed at

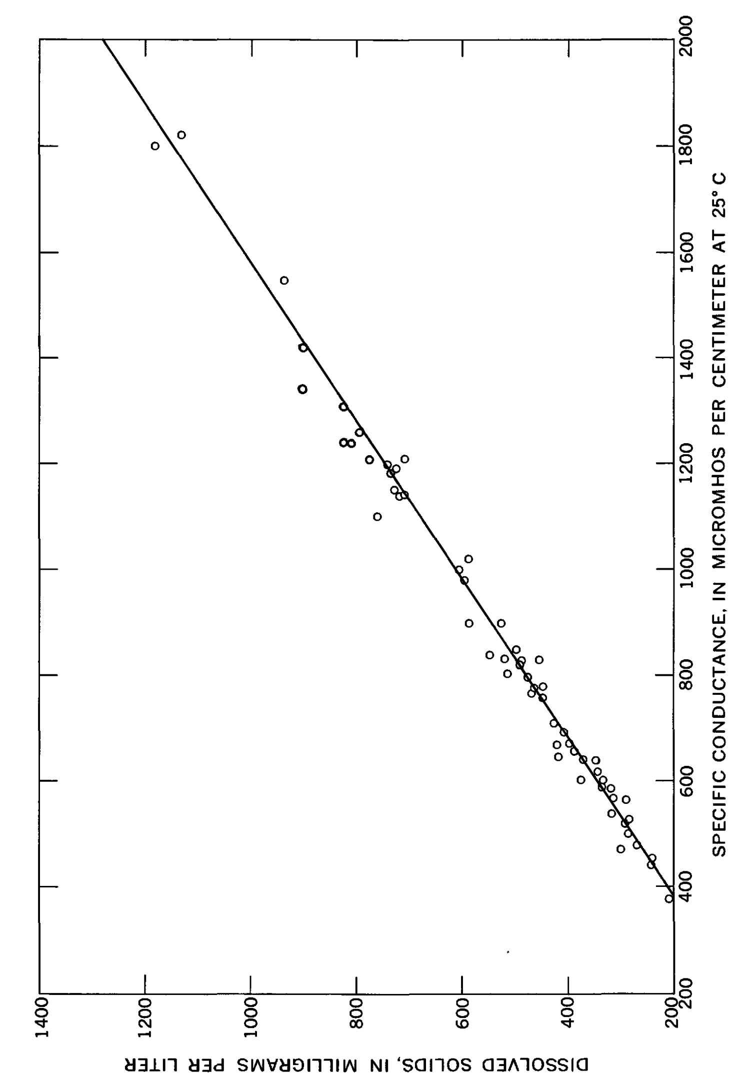


FIGURE 12.—Relation of specific conductance to concentration of dissolved solids in ground-water samples collected in the San Pitch River drainage basin.

the surface or underlie the surface at shallow depth. (See pls. 1, 4.) The area in and around Chester is underlain by either or both of these formations, and wells penetrating them obtain slightly saline water. Residents in this area have abandoned the deeper wells that tap these formations for domestic supplies because the water is impotable; as a substitute they have augered holes 10–20 feet deep in the valley fill. The Crazy Hollow and Green River also yield poor-quality water to wells in an area of several square miles north of Ephraim. Local residents speak of a "buried ridge," which seems to separate potable from impotable water; the ridge is formed by the contact of the Crazy Hollow and Green River with other formations that yield potable water.

South of Manti, flowing well (D–18–2)22add–1 discharges water that has a specific conductance of 1,820 micromhos per cm at 25°C. This well is in the "Saleratus" area, where ground water is impounded by a subsurface barrier formed by bedrock. The relatively high salinity of the ground water in the area is believed to be due to concentration by evaporation as the water seeps up toward the surface.

The only ground water in the basin that is classified as moderately saline was obtained from well (D–14–4)27daa–1, north of Mount Pleasant; the specific conductance of this water was 4,800 micromhos per cm at 25°C. Well (D–14–4)27daa–1 is 1,500 feet deep and was drilled originally as an oil test. The well flows, and for several years the water was bottled and sold as mineral water for therapeutic use. No driller's log is available for the well; thus, the source of the water is unknown, but it is believed to be the Crazy Hollow Formation or the Green River Formation.

RELATION TO USE

IRRIGATION

Two of the principal factors in determining the suitability of water for irrigation are the concentration of dissolved solids and the relative proportion of sodium to other cations (U.S. Salinity Laboratory Staff, 1954, p. 69).

The concentration of dissolved solids, or the salinity, affects plant growth by limiting the ability of the plant to take in water by osmosis. The rate at which water can enter the roots of a plant depends on the difference between the salinity of the water within the plant and the salinity of the water in the soil. If the salinity of the water in the soil is considerably less than the salinity of the water in the plant, the plant can assimilate the water rapidly. If the difference is small, the assimilation is slow, and the plant must be exposed to the soil water for a longer period of time to satisfy its needs. If the salinity of the water in the soil is equal to or greater than the salinity of the water in the plant, then the plant cannot assimilate the water and may even lose water in the process. In this event, the plant will die for lack of water. The degree of salinity in irrigation water is called the salinity hazard.

The relative proportion of sodium to other cations in water affects the extent to which a soil will adsorb sodium from the water. The adsorption of sodium causes the deflocculation of the soil and thus

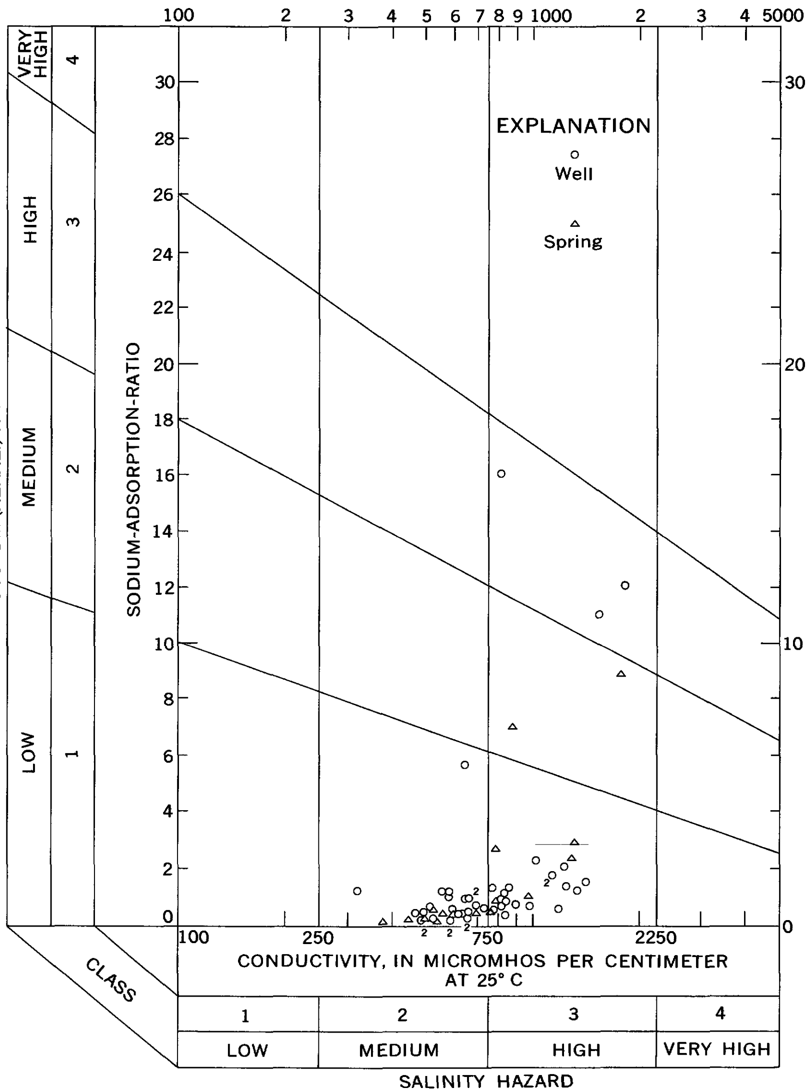


FIGURE 13.—Sodium hazard and the salinity hazard in ground water from selected wells and springs in the San Pitch River drainage basin. (Number near symbol is the number of analyses represented.)

makes the soil gummy, less permeable, less fertile, and difficult to reclaim. An index to the sodium hazard in irrigation water is called the sodium-adsorption-ratio (SAR) and is expressed as:

$$SAR = \frac{Na^{+1}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}},$$

where the concentrations of sodium, calcium, and magnesium are expressed as milliequivalents per liter.

The salinity and sodium hazards in water from 61 wells and springs are shown in figure 13. The method of classification is that of the U.S. Salinity Laboratory Staff (1954, p. 80). All but five of the 61 samples classified in figure 13 are in the low-sodium-hazard class, and all samples are in either the medium- or high-salinity-hazard class. Little danger of sodium damage to irrigated lands in the basin exists so long as fields are drained of excess water. The salinity hazard does not constitute a problem because the crops grown—alfalfa and grains—are moderately tolerant to salinity (Hem, 1959, p. 249).

Water classified in the high-sodium-hazard class was obtained from three wells—(D–16–3)24aba–1, in Pigeon Hollow; (D–18–2)14aac–1, at the southwest edge of Manti; and (D–18–2)22add–1, in Saleratus. The first two wells are in well-drained areas; hence, the sodium hazard poses no problem. The water from the well in Saleratus is used only for stock; no irrigated crops are grown in this area. Water in the medium-sodium-hazard class was obtained from two springs in the basin—(D–18–2)23aac–S1 and (D–18–2)13cad–S1. Both springs discharge warm water and are believed to issue along a concealed fault system.

DOMESTIC AND PUBLIC SUPPLIES

Drinking-water standards for public supply are suggested by the U.S. Public Health Service (1962). The suggested maximum concentrations of some of the more common chemical constituents are as follows:

Constituent	*Concentration (mg/l)*
Chloride	250
Fluoride	[1]
Iron	.3
Manganese	.05
Nitrate	45
Sulfate	250
Dissolved solids	500

[1] The suggested maximum fluoride concentration depends on the annual average maximum daily air temperatures (U.S. Public Health Service, 1962, p. 8). According to this criterion, the maximum concentration at Manti should be 1.3 mg/l.

In the chemical analyses of ground water from 68 wells and springs in the San Pitch River drainage basin, the suggested maximum concentrations for domestic and public supply were exceeded in one analysis for chloride, three analyses for iron, one analysis for sulfate, and 22 analyses for dissolved solids (Robinson, 1968, table 6). The concentration of dissolved solids exceeded 1,000 mg/l in only two of the analyses. All but two of the 15 public supplies listed in table 8 had concentrations below the standards listed for all described constituents. Well (D-15-4)2adb-1, used by Mount Pleasant, exceeded the suggested maximum for iron; Spannard Spring, (D-19-2)20ddd-S1, used by Centerfield, outside the San Pitch River drainage basin, exceeded the suggested maximum of 500 mg/l of dissolved solids. Of the 272 wells which were sampled for specific conductance only, 92 wells yielded water that exceeded 500 mg/l of dissolved solids (about 750 micromhos per cm at 25°C), and only nine wells yielded water that exceeded 1,000 mg/l of dissolved solids (about 1,500 micromhos per cm at 25°C). Of 32 springs sampled for specific conductance only, 14 springs discharged water that exceeded 500 mg/l of dissolved solids, and none discharged water that exceeded 1,000 mg/l of dissolved solids.

The hardness of water is a consideration in any domestic or public supply because it affects the cleansing properties of water and the amount of soap consumed, and it is related to incrustation from water (Hem, 1959, p. 145-148). The principal constituents that cause hardness in water are calcium and magnesium. The U.S. Geological Survey classifies water with respect to hardness as follows:

Water classification	*Hardness (mg/l)*
Soft	<60
Moderately hard	61-120
Hard	121-180
Very hard	>180

As indicated by the chemical analyses of water sampled at 68 wells and springs in the basin, ground water in the San Pitch River drainage basin is generally very hard. One well yielded soft water, one well and one spring yielded moderately hard water, two wells and one spring yielded hard water, and 62 wells and springs yielded very hard water. The hardness ranged from 27 to 618 mg/l and averaged about 320 mg/l.

LIVESTOCK

Virtually all water tested within the basin is suitable for use by all types of livestock. The Officers of the Department of Agriculture and Government Chemical Laboratories of Western Australia (1950) list the following upper limits for concentrations of dissolved solids in water for livestock:

Livestock and poultry	*Dissolved solids (mg/l)*
Poultry	2,860
Pigs	4,290
Horses	6,435
Cattle, dairy	7,150
beef	10,000
Sheep, adult	12,900

Water from well (D–14–4)27daa–1 was the only sample from the drainage basin that exceeded any of the upper limits for the concentration of dissolved solids in water for livestock. The water from this well contained about 3,200 mg/l of dissolved solids.

SURFACE WATER

Plate 4 shows the general quality of the surface water in the San Pitch River drainage basin, as indicated by the specific conductance of water in streams entering the valleys from the adjacent mountains. The chemical quality of the water in these streams affects the chemical quality of the ground water because the streams provide recharge to the ground-water reservoir. Water in all sampled streams entering Sanpete Valley is fresh and had a specific conductance of generally less than 500 micromhos per cm at 25°C along the east side, and a specific conductance of less than 800 micromhos per cm at 25°C (less than 500 mg/l) along the west side.

Specific conductance values for water samples obtained at four sites along the San Pitch River are also shown on plate 4. The specific conductances in the San Pitch River in the Fairview arm of the valley to Moroni were less than 700 micromhos per cm at 25°C; thus the water is classified as fresh. Water at the bridge west of Manti, however, had a specific conductance of about 2,200 micromhos per cm at 25°C and is classified as slightly saline. The water of the San Pitch River, therefore, deteriorates somewhat as it moves downstream. This deterioration is probably due to the concentration of minerals by evapotranspiration along the river system and to the return flow of water from irrigation. Tables 9 and 10, which list specific conductances of samples collected at numerous sites along the San Pitch River during seepage runs in March and April 1966, indicate this same deterioration of the river water as it flows downstream.

All but one of the 11 surface-water samples classified in figure 14 are in the low-sodium-hazard class and are either in the medium- or high-salinity-hazard class. Water in the medium-sodium-hazard class and the very high salinity hazard class was obtained from the San Pitch River near Sterling.

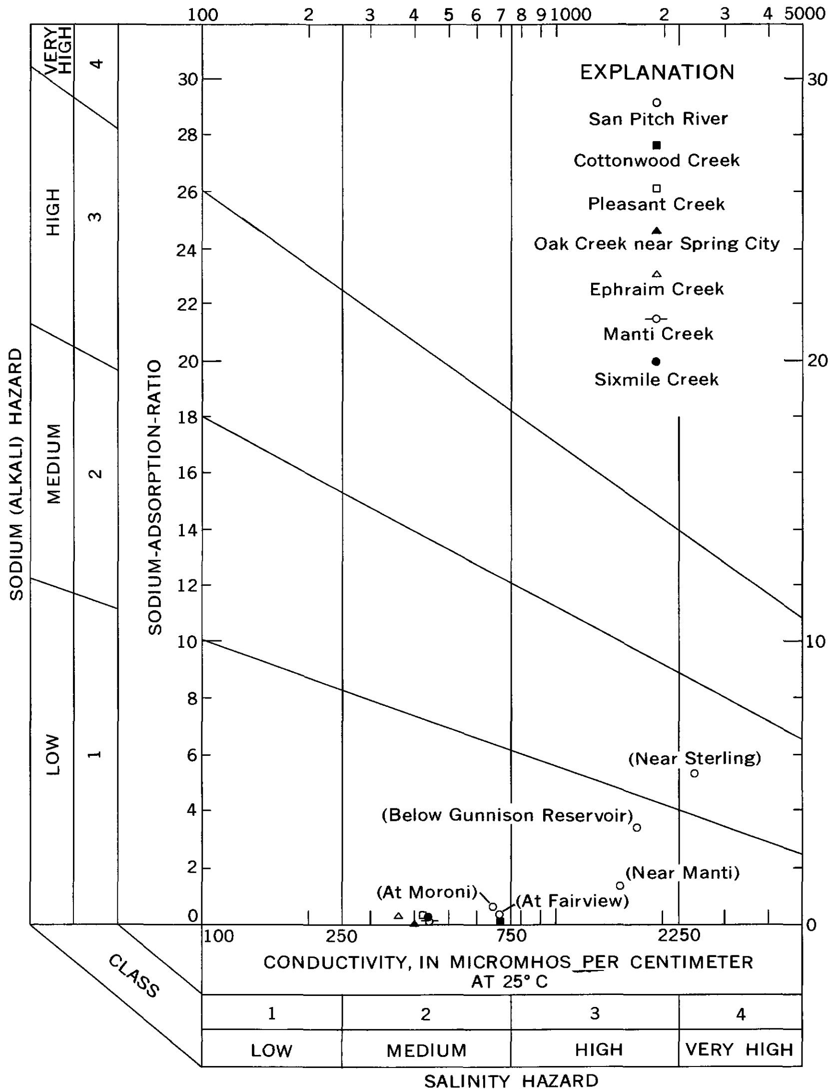


Figure 14.—Sodium hazard and salinity hazard in surface water from selected sites on the San Pitch River and tributaries in the San Pitch River drainage basin.

TEMPERATURE

The temperature of water is important in evaluating its suitability for use for cooling. The temperature of water in streams directly reflects local atmospheric conditions and may range from 0° to about 32°C during the course of a year. The temperature of ground water, however, generally remains within a few degrees of the mean annual air temperature, regardless of the season. The temperature of the water from about 350 wells in the San Pitch River drainage basin ranged from 8° to 55°C and averaged 11°C (Robinson, 1968, table 1). The temperatures of the water from 51 springs ranged from 3° to 22°C and averaged 11°C.

WATER-BUDGET ANALYSIS OF SANPETE VALLEY

In any basin or valley, the total quantity of water entering in a given time is equal to the total quantity leaving, plus or minus the quantity gained or lost from surface- and ground-water storage. An analysis of all elements of inflow and outflow in a valley is determined by means of a water budget. Such a budget was completed for the 1966 water year [1] for the part of the Sanpete Valley above Gunnison Reservoir dam, including the discharge of Sixmile Creek. In preparing the analysis it was necessary to make some assumptions and estimates; therefore, the figures in the budget should not be considered as absolute. The methods used in measuring or estimating the different elements of inflow and outflow are described in the following paragraphs.

Surface-water inflow from streams entering Sanpete Valley along the east side was estimated by relating the drainage area and normal annual precipitation on the drainage area of the individual ungaged streams to the measured discharge, drainage area, and precipitation on the drainage area of streams that are gaged at their mouths. The discharge entering the creeks from the 13 transmountain diversions was considered in these estimates. The annual discharge of streams from the west side of Sanpete Valley and from the Cedar Hills was estimated from periodic measurements or observations. The total discharge into the valley from springs during the 1966 water year was obtained from the average discharge measured or estimated during field observations. Table 11 summarizes the measured, estimated, or calculated discharges of the major streams and springs that discharge into Sanpete Valley. Of the total inflow of about 116,000 acre-feet of water entering Sanpete Valley from streams and springs, about 88 percent is derived from the Wasatch Plateau, along the east side of the valley; about 11 percent is derived from the San Pitch Mountains along the west side; and only about 1 percent is derived from the Cedar Hills.

Inflow from precipitation on the floor of Sanpete Valley was estimated from records of the U.S. Weather Bureau by applying the amount that fell at Manti during the 1966 water year (8.48 in.) to the entire area of Sanpete Valley. The total inflow from this source for the 1966 water year was estimated to be 115,000 acre-feet of water.

[1] The 1966 water year is the period October 1, 1965, to September 30, 1966.

TABLE 11.—*Discharges of major streams and springs into Sanpete Valley above the Gunnison Reservoir dam during the 1966 water year*—Continued

[Discharge: c, calculated; e, estimated: m, measured]

	Discharge (acre-ft)
East side of Sanpete Valley	
Stream[1]	
Unnamed canyon north of South San Pitch River Canyon (Oak Creek near Fairview)	1,700c
South San Pitch River (Oak Creek near Fairview)	2,800c
Dry Creek (Oak Creek near Fairview)	2,200c
Oak Creek near Fairview	5,570m
Cottonwood Creek (Oak Creek near Fairview)	[2] 4,800c
Spring Creek (Oak Creek near Fairview)	1,800c
Birch Creek (Pleasant Creek)	4,600c
Cove Creek (Pleasant Creek)	4,000c
Pleasant Creek	[3] 10,460m
Twin Creek	[4] 5,510m
Cedar Creek (Twin Creek)	[5] 5,400c
Oak Creek near Spring City	[6] 4,920m
Canal Creek (Oak Creek near Spring City)	[6] 7,000c
Ephraim Creek (Manti Creek)	[7] 12,300c
Willow Creek (Manti Creek)	4,000c
Manti Creek	10,980m
Sixmile Creek	8,450m
Reeder Ditch [8]	450e
Total (rounded)	96,900
Spring	
Fairview Springs, (D-13-5)33ada-S1	330e
Coal Fork Spring, (D-15-5)22bbb-S1	800e
Old Ox Spring, (D-16-4)13adb-S1	110e
Big Spring near Ephraim, (D-17-4)16dcd-S1	1,100e
Hougaard Springs, (D-18-4)20bb-S	1,600e
Crystal Springs, (D-18-2)13cad-S1	620e
Stinking Springs, (D-18-2)23aac-S1	365e
Saleratus Spring, (D-18-2)22cb-S	550e
Cove Spring, (D-19-2)1dbc-S1	125e
Total (rounded)	5,600
Total inflow from east side	102,500
West side of Sanpete Valley	
Stream	
Birch Creek near Fountain Green	400e
Wales Canyon Creek	700e
Peach Canyon Creek	500e
Axehandle Canyon Creek	500e
Maple Canyon Creek near Manti	200e
Other creeks	1,000e
Total (rounded)	3,000
Spring	
Big Springs, (D-14-2)2bab-S1	6,200e
Birch Creek Springs, (D-14-2)23bda-S1	710e
Freedom Spring, (D-15-2)2ada-S1	730e
Lime Kiln Spring, (D-15-2)26acb-S1	200e
Brewers Spring, (D-15-2)13bbc-S1	330e
Other springs	1,400e
Total (rounded)	9,600
Total inflow from west side	12,600

TABLE 11.—*Discharges of major streams and springs into Sanpete Valley above the Gunnison Reservoir dam during the 1966 water year*—Continued

	Discharge (acre-ft)
Cedar Hills	
Stream	
Big Hollow stream	15m
Other streams	85e
Total (rounded)	100
Spring	
Spring Branch, (D-13-4)2dda-S1	500e
Moroni Spring, (D-15-3)4c-S	365e
Total (rounded)	900
Total inflow from Cedar Hills	1,000
Total inflow to Sanpete Valley (rounded)	116,000

[1] Stream names in parentheses indicate streams whose gaged flow was used as the basis for the calculation.

[2] Includes measured discharge of Fairview tunnel (transmountain diversion).
[3] Includes estimated discharge of Candland ditch and Coal Fork ditch (transmountain diversion).
[4] Includes estimated discharge of Twin Creek tunnel (transmountain diversion).
[5] Includes estimated discharge of Cedar Creek tunnel (transmountain diversion).
[6] Includes measured discharge of Spring City tunnel (transmountain diversion) and estimated discharge of Black Canyon ditch.
[7] Includes discharge of five transmountain diversions—Ephraim tunnel, John August ditch, Madsen ditch, Larsen tunnel, and Horseshoe tunnel.
[8] Transmountain diversion.

Ground-water inflow from the adjacent mountains through the interface of valley fill and bedrock in the subsurface was obtained by indirect means. The difference required to balance the total inflow to the valley with the total outflow, after change in storage was subtracted from the outflow, was considered to be ground-water inflow. Thus, the amount, 19,000 acre-feet of water, is calculated and should not be taken as absolute.

Surface-water outflow from Sanpete Valley was determined at three locations. The outflow of the San Pitch River through the Gunnison Reservoir dam, about 46,000 acre-feet of water, was measured at the U.S. Geological Survey gaging station below the dam. Surface-water outflow of Sixmile Creek, about 8,000 acre-feet of water, was obtained by periodic measurements below the diversion to Gunnison Reservoir, by periodic measurements at the upper diversion in lower Sixmile Canyon, and by consideration of priority rights stated in the Cox Decree (Cox, 1936).

A small amount of ground water probably leaves Sanpete Valley as underflow beneath Sixmile Creek below Gunnison Reservoir dam and as underflow beneath Twelvemile Creek. The amount is estimated to be a maximum of 2,000 acre-feet of water.

The outflow of water by evapotranspiration from cultivated, irrigated, and cropped land in the valley was estimated to be 122,000 acre-feet on the basis of data from the Soil Conservation Service, U.S.

Department of Agriculture (written commun., 1963). Evapotranspiration of water from noncultivated wet areas containing phreatophytes was estimated to be 113,000 acre-feet. The method of estimating is described in the section "Evapotranspiration." Evapotranspiration of water from noncultivated brushland areas was estimated at 47,000 acre-feet, based on the assumption that the evapotranspiration equaled the total precipitation received in these areas during the 1966 water year. Little, if any, precipitation recharges the ground-water reservoir in these noncultivated areas.

Outflow by evaporation of water from open-water surfaces was determined to be about 6,000 acre-feet by multiplying the estimated surface areas of Gunnison and Wales Reservoirs by the assumed annual evaporation rate of about 42 inches for Sanpete Valley.

The change in storage in Gunnison Reservoir during the 1966 water year was almost 14,000 acre-feet of water. On October 1, 1965, the reservoir content was 13,640 acre-feet; on September 30, 1966, the reservoir was empty. Changes in storage during the same period in the other reservoirs in Sanpete Valley are not known, but they are believed to have been negligible.

The change in ground-water storage during the 1966 water year amounted to 80,000 acre-feet of water. This amount was determined

TABLE 12.—*Water-budget analysis of Sanpete Valley above the Gunnison Reservoir dam, including the drainage of Sixmile Creek, for the 1966 water year*

Classification of inflow and outflow	Volume of water (acre-ft)
Inflow	
Surface-water inflow from streams and springs [1]	116,000
Precipitation on valley floor	115,000
Ground-water inflow from adjacent mountains	19,000
Total inflow	250,000
Outflow	
Surface-water outflow in San Pitch River through Gunnison Reservoir	46,000
Surface-water outflow from Sixmile Creek below diversion to Gunnison Reservoir and at upper canal diversion	8,000
Ground-water outflow	2,000
Evapotranspiration from cultivated areas (approx. 50,000 acres)	122,000
Evapotranspiration from noncultivated wet areas containing phreatophytes (approx. 45,000 acres)	113,000
Evapotranspiration from noncultivated and brushland areas (approx. 66,000 acres)	47,000
Evaporation from open-water surface (approx. 2,000 acres)	6,000
Total outflow	344,000
Change in surface-water storage in Gunnison Reservoir	−14,000
Change in ground-water storage	−80,000
Total outflow (minus the amounts removed from storage)	250,000

[1] See table 11, p. 68, for individual contributions.

as the product of three factors: (1) the total area where ground water is under water-table conditions, (2) the average annual change in the level of the water table, and (3) the average storage coefficient (specific yield) of the water-table aquifer. Changes in storage in artesian aquifers were not included in the analysis, as they were considered to be negligible because of the extremely small storage coefficients of artesian aquifers and the rather small changes in head. Changes in soil moisture were not considered in the analysis because little net change was assumed to have occurred annually.

A summary of the water-budget analysis of Sanpete Valley for the 1966 water year is given in table 12.

CONCLUSIONS

Virtually no ground water leaves the San Pitch River drainage basin in the subsurface above the Gunnison Reservoir dam. The area is a closed basin with respect to ground water, in that hills of impermeable clay and shale north of Sterling effectively block the southward movement of ground water. Thus, virtually the only escape for the ground water is by rising to the surface, where it flows into the Gunnison Reservoir through the San Pitch River or Saleratus Creek.

An estimated 95,000 acre-feet of ground water is discharged each year by evapotranspiration in wet meadows and fringing areas. An estimated 25–30 percent of this water could be salvaged by the lowering of water levels in these areas. This lowering could be accomplished by constructing and pumping additional large-discharge wells, which would tap the aquifers underlying the wet areas, or by constructing large drains. A surficial layer of clay, generally 10–30 feet thick, underlies the wet meadows, and the ground water beneath the clay layer is under artesian pressure. In those areas where the drains could not be constructed deep enough to penetrate the clay layer, numerous shallow wells could be jetted along the bottom of the drain into the underlying sand and gravel aquifers. These wells would flow, thereby partly dewatering the surrounding sediments as the pressures on the underlying aquifers are reduced.

The lowering of water levels in the wet areas of the valley, however, would result in the following side effects: (1) Cessation of flow from numerous wells used for stock and local irrigation of pastures; (2) drying up of large areas which presently are subirrigated by artesian leakage and are used as pastures for grazing or for growing hay and grasses; and (3) reduction in the quantity of ground-water seepage into the San Pitch River. In some areas the river would derive less seepage from the ground-water reservoir, and in other areas the river might even lose water to the reservoir. These three side effects could, in turn, be mitigated by the following three factors:

(1) Careful selection of sites for construction of pumped wells so that the pumping would have the least effect on existing wells; (2) use of water obtained from the new wells and drains (directly or by exchange rights) to irrigate more efficiently those areas that are now subirrigated; and (3) use of water from the new wells and drains to replace any deficiencies that might appear in the San Pitch River.

Water levels in the Sanpete Valley show little long-term effect due to the pumping of wells. Thus, overall, the discharge from the ground-water reservoir has not exceeded recharge. Approximately 3 million acre-feet of water available to wells is stored in the upper 200 feet of saturated valley fill. This water could be withdrawn from storage through pumped wells if the ground water were mined by permanently dewatering 200 feet of the saturated fill. In addition to lowered water levels, however, such mining would also cause the three side effects discussed in the preceding paragraph.

Several large-discharge wells in Sanpete Valley derive large quantities of ground water from consolidated rocks underlying the valley fill. The extent and the hydraulic characteristics of these potential aquifers are not known; therefore, future test drilling and subsequent test pumping of wells tapping the aquifers are desirable. Such areas of testing would include: north and west of Manti (oolitic limestone of the Green River Formation), north of Ephraim (Crazy Hollow Formation of Spieker (1949) and Green River Formation), and northwest of Mount Pleasant (Crazy Hollow Formation).

More information is needed concerning the thickness of the valley fill in Sanpete Valley. Test drilling to bedrock would be desirable in the thickest sections of the valley fill, along the west-central part of the valley near the Sevier fault.

SELECTED REFERENCES

Bjorklund, L. J., and Robinson, G. B., Jr., 1968, Ground-water resources of the Sevier River between Yuba Dam and Leamington Canyon, Utah: U.S. Geol. Survey Water-Supply Paper 1848, 79 p.

Carpenter, C. H., Robinson, G. B., Jr., and Bjorklund, L. J., 1967, Ground-water conditions and geologic reconnaissance of the upper Sevier River basin, Utah: U.S. Geol. Survey Water-Supply Paper 1836, 91 p.

Connor, J. G., Mitchell, C. G., and others, 1958, A compilation of chemical quality data for ground and surface waters in Utah: Utah State Engineer Tech. Pub. 10, 276 p.

Cox, L. H., 1936, Decree adjudicating the Sevier River system: Fillmore, Utah, The Progress Printing Co., 232 p.

Criddle, W. D., Harris, Karl, and Willardson, L. S., 1962, Consumptive use and water requirements for Utah: Utah State Engineer Tech. Pub. 8 (revised), 47 p.

Davis, G. H., Green, J. H., Olmsted, F. H., and Brown, D. W., 1959, Ground-water conditions and storage capacity in the San Joaquin Valley, California: U.S. Geol. Survey Water-Supply Paper 1469, 287 p.

Duncan, D. C., 1944, The Mount Pleasant coal field, Sanpete County, Utah: U.S. Geol. Survey Coal Inv. Map, scale 1:36,000.

Dutton, C. E., 1880, Report on the geology of the High Plateaus of Utah with atlas: U.S. Geog. and Geol. Survey of the Rocky Mountain Region (J. W. Powell in charge), p. 31–34, 143–168; atlas sheets 2, 3, 1879.

Eardley, A. J., 1933, Stratigraphy of the southern Wasatch Mountains, Utah: Michigan Acad. Sci. Papers, v. 18, p. 307–344.

——— 1934, Structure and physiography of the southern Wasatch Mountains, Utah: Michigan Acad. Sci. Papers, v. 19, p. 377–400.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw-Hill Book Co., 534 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifier tests: U.S. Geol. Survey Water-Supply Paper 1536–E, p. 69–174.

Gilliland, W. N., 1963, Sanpete–Sevier Valley anticline of central Utah: Geol. Soc. America Bull., v. 74, no. 2, p. 115–124.

Hahl, D. C., and Cabell, R. E., 1965, Quality of surface water in the Sevier Lake basin, Utah, 1964: U.S. Geol. Survey open-file report, 24 p. (Duplicated as Utah Basic-Data Release 10.)

Hardy, C. T., 1962, Mesozoic and Cenozoic stratigraphy of north-central Utah, *in* Geology of the southern Wasatch Mountains and vicinity, Utah: Brigham Young Univ., Geology Studies, v. 9, pt. 1, p. 50–64.

Hardy, C. T., and Zeller, H. D., 1953, Geology of the west-central part of the Gunnison Plateau, Utah: Geol. Soc. America Bull., v. 64, no. 11, p. 1261–1278.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Hintze, L. F., ed., 1962, Geology of the southern Wasatch Mountains and vicinity, Utah: Brigham Young Univ., Geology Studies, v. 9, pt. 1, 104 p.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps of the United States: U.S. Weather Bur. Tech. Paper 37, 13 p.

Marsell, R. E., 1958, Potential ground-water resources of Sanpete Valley, Utah: App. A of State of Utah 6th Bienn. Rept. of the Utah Water and Power Board to the Governor of Utah for the period July 1, 1956, to June 30, 1958, p. 28–36.

Meinzer, O. E., 1923a, Outline of ground-water hydrology, *with* definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

——— 1923b, The occurrence of ground water in the United States, *with* A discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

Mower, R. W., and Feltis, R. D., 1968, Ground-water hydrology of the Sevier Desert, Utah: U.S. Geol. Survey Water-Supply Paper 1854, 75 p.

Officers of the Department of Agriculture and Government Chemical Laboratories, 1950, Water for agricultural purposes in Western Australia: Western Australia Jour. Agriculture, v. 27, ser. 2, 156 p.

Richardson, G. B., 1906, Coal in Sanpete County, Utah. U.S. Geol. Survey Bull. 285, p. 280–284.

——— 1907, Underground water in Sanpete and central Sevier Valleys, Utah: U.S. Geol. Survey Water-Supply Paper 199, 63 p.

Robinove, C. J., Langford, R. H., and Brookhart, J. W., 1958, Saline-water resources of North Dakota: U.S. Geol. Survey Water-Supply Paper 1428, 72 p.

Robinson, G. B., Jr., 1968, Selected hydrologic data, San Pitch River drainage basin, Utah: U.S. Geol. Survey open-file report, 44 p. (Duplicated as Utah Basic-Data Release 14.)

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

Schoff, S. L., 1938, Geology of Cedar Hills, Utah: Ohio State Univ. Abs. Doctors' Dissert. 25, p. 381–382.

——— 1951, Geology of the Cedar Hills, Utah: Geol. Soc. America Bull., v. 62, no. 6, p. 619–645.

Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U.S. Geol. Survey Prof. Paper 205–D, p. 117–161.

——— 1949. The transition between the Colorado Plateau and The Great Basin in central Utah: Utah Geol. Soc. Guidebook to the Geology of Utah, no. 4, 106 p.

Spieker, E. M., and Billings, M. P., 1940, Glaciation in the Wasatch Plateau, Utah: Geol. Soc. America Bull., v. 51, no. 8, p. 1173–1198.

Stokes, W. L., 1964, Geologic map of Utah: Salt Lake City, Utah Univ.

Theis, C. V., Brown, R. H., and Meyer, R. R., 1963, Estimating the transmissibility of aquifers from the specific capacity of wells, *in* Methods of determining permeability, transmissibility, and drawdown: U.S. Geol. Survey Water-Supply Paper 1536–I, p. 331–340.

U.S. Geological Survey, 1936–57, Water levels and artesian pressure in observation wells in the United States, Part 5, Northwestern States: U.S. Geol. Survey Water-Supply Papers 777 [1935], 817 [1936], 840 [1937], 845 [1938], 886 [1939], 910 [1940], 940 [1941], 948 [1942], 990 [1943], 1020 [1944], 1027 [1945], 1075 [1946], 1100 [1947], 1130 [1948], 1160 [1949], 1169 [1950], 1195 [1951], 1225 [1952], 1269 [1953], 1325 [1954], 1408 [1955].

——— 1960, Compilation of records of surface waters of the United States through September 1950, Part 10, The Great Basin: U.S. Geol. Survey Water-Supply Paper 1314, p. 232–235.

——— 1961–65, Surface-water records of Utah, 1961, 1962, 1963, 1964, 1965: Water Resources Div., 272 p., 270 p., 272 p., 283 p., 315 p.

——— 1963a, Compilation of records of surface waters of the United States, October 1950 to September 1960, Part 10, The Great Basin: U.S. Geol. Survey Water-Supply Paper 1734, p. 155–162.

——— 1963b, Ground-water levels in the United States, 1956–60, Part 5, Northwestern States: U.S. Geol. Survey Water-Supply Paper 1760, p. 156–158.

U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service Pub. 956, 61 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 160 p.

U.S. Weather Bureau [no date], Normal annual precipitation, Sevier River basin, Utah, based on 1931–60 values, map, sheet 3 of 3: Water Supply Forecast Unit and Office of State Climatologist, Salt Lake City, Utah.

Utah State University and Utah Water and Power Board, 1963, Developing a State water plan, Utah's water resources—problems and needs, a challenge: Utah Water and Power Board—Utah State Univ., 122 p.

Woolley, R. R., 1947, Utilization of surface-water resources of Sevier Lake basin, Utah: U.S. Geol. Survey Water-Supply Paper 920, 393 p.

Young, R. A., and Carpenter, C. H., 1965, Ground-water conditions and storage in the central Sevier Valley, Utah: U.S. Geol. Survey Water-Supply Paper 1787, 95 p.

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