HYDROLOGY OF COAL-RESOURCE AREAS IN THE SOUTHERN WASATCH PLATEAU, CENTRAL UTAH

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CONVERSION FACTORS

Most values in this report are given in inch-pound units. For those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below. Multiply the inch-pound unit by the conversion factor to obtain the metric equivalent.

Inch-pound Unit	Abbreviation	Conversion factor	Metric unit
Acre		0.4047	Square hectometer
Acre-feet	acre-ft	0.001233	Cubic hectometer
		1,233	Cubic meter
Cubic foot per second	ft^3/s	0.02832	Cubic meter per second
Foot	ft	0.3048	Meter
Foot per mile	ft/mi	0.1894	Meter per kilometer
Gallon per minute	gal/min	0.06309	Liter per second
Inch	in.	25.40	Millimeter
		2.540	Centimeter
Mile	mi	1.609	Kilometer
Square foot	ft^2	0.09290	Square meter
Square mile	mi^2	2.590	Square kilometer

Chemical concentrations and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (g/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter are equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter (meq/L). Milliequivalents per liter are numerically equal to equivalents per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation: $^{\circ}F = 1.8(^{\circ}C) + 32$.

HYDROLOGY OF COAL-RESOURCE AREAS IN THE SOUTHERN WASATCH PLATEAU, CENTRAL UTAH

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ABSTRACT

The study area includes about 700 square miles of the southern Wasatch Plateau in central Utah and is underlain by extensive coal reserves. Data for four streamflow-gaging stations in the area indicate that about 5 to 29 percent of the average annual precipitation on a drainage basin becomes streamflow. Annual peak discharge generally is from snowmelt during spring or early summer; 46 to 68 percent of the average annual discharge occurs during April-June. Discharge measurements indicate that most of the base flow of streams is due to ground-water discharge in the higher altitudes of the watersheds. Chemical quality of 61 surface-water samples was suitable for most uses; dissolved-solids concentrations ranged from 97 to 835 milligrams per liter. None of the analyzed chemical constituents were in concentrations that exceeded the drinking-water standards of the U.S. Environmental Protection Agency. The predominant dissolved ions in most of the surface waters were calcium, magnesium, and bicarbonate.

About 170 springs were inventoried during the study. Of these, about 80 percent issued from the North Horn Formation of Cretaceous and Tertiary age and the Flagstaff Limestone of Tertiary age. These two formations crop out at the higher altitudes of most major drainages and receive large quantities of recharge. Most water moves through the ground-water system through fractures and solution openings. Dewatering of one underground coal mine was the only known manmade discharge from the ground-water system in the study area during 1980. Chemical quality of ground water generally was suitable for most uses; dissolved-solids concentrations in water from 87 springs ranged from 105 to 1,080 milligrams per liter and averaged about 380 milligrams per liter.

INTRODUCTION

Purpose and scope

The hydrology of coal-resource areas in the southern Wasatch Plateau in central Utah (fig. 1) was studied by the U.S. Geological Survey in cooperation with the U.S. Bureau of Land Management. The study area contains large coal reserves, and much of the area was unleased for mining in 1980. In general, study objectives were to define the surface- and ground-water hydrology and to predict, where possible, the effects of coal mining on the hydrologic system. Watersheds and aquifers that were the sole source of supply for public use were to be identified. The objectives were designed to provide the hydrologic information needed by the U.S. Bureau of Land Management to make sound decisions concerning the leasing of Federal lands for coal mining.

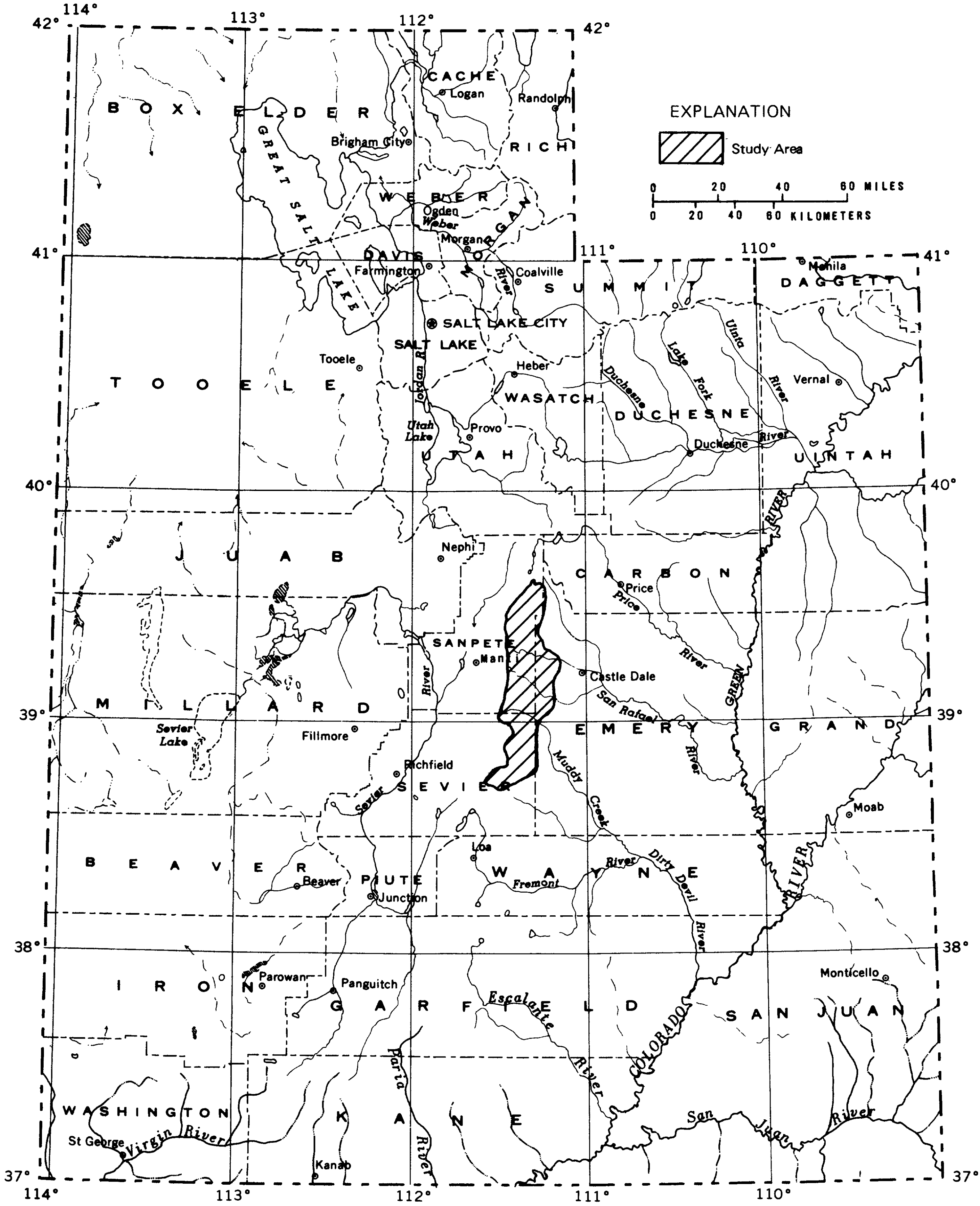

Figure 1.—Location of the study area.

Fieldwork was conducted from July 1977 through September 1980. About 170 springs in the area were inventoried, and 87 were sampled for chemical analysis. Several springs were sampled more than once to define the seasonal variability in chemical quality. A detailed study of springs and seeps was made on North Horn and Ferron Mountains. Discharge measurements were made semimonthly at 28 springs, mainly during the summer of 1980, so that flow characteristics could be defined. Water levels were measured periodically in 17 observation wells. Water samples were collected in one underground coal mine, and mine-discharge data were obtained.

Discharge measurements were made on streams during periods of base flow in an attempt to locate losing and gaining reaches. Samples of surface water from 33 sites throughout the area were collected for chemical analyses to define the areal and seasonal variability in quality. Benthic-invertebrate samples were collected at 11 stream sites, and the mineralogy of the streambed material and suspended-sediment concentrations were determined for most of the same sites. In addition, daily discharge records for four long-term gaging stations (U.S. Geological Survey, 1954, 1964, 1961-75, 1976-80) and some data from the Geological Survey surface-water monitoring network in Utah coal areas (Lines and Plantz, 1981, pl. 1) were used.

Previous studies

Several hydrologic studies have been conducted in the Wasatch Plateau. Waddell, Contratto, Sumsion, and Butler (1981) described the water resources of the Wasatch Plateau and Book Cliffs coal fields based mainly on data (Waddell and others, 1978) collected during a 2-year reconnaissance of the area. Some ground-water data for the Wasatch Plateau also were tabulated by Sumsion (1979). Mundorff and Thompson (1980) studied the quality of surface water, including suspended sediment, in the San Rafael River basin. As a part of this study, Graham, Tooley, and Price (1981) described the hydrology of the North Horn Mountain area.

Other hydrologic studies conducted concurrently with this study include a study of the Huntington-Cottonwood Creek coal-resource area (Danielson and others, 1981) and a study of the hydrology of the Price River basin.

Data-site-numbering systems

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres[1]; the letters a, b, c, and d indicate the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre tract, one or two location letters are used and the serial number is omitted. Thus (D-19-6)1cba-1 designates the first well constructed or visited in the NE¼NW¼SW¼ sec. 1, T. 19 S., R. 6 E., and (D-19-6)1c-S designates a spring known only to be in the southwest quarter of the same section. Other sites where hydrologic data were collected are numbered in the same manner, but three letters are used after the section number and no serial number is used. The numbering system is illustrated in figure 2.

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[1]Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section. and spring-numbering system used in Utah.

All surface-water-data sites in this report are numbered sequentially generally from north to south. In addition, streamflow-gaging stations are identified by the U.S. Geological Survey downstream number. The numbering system is explained in a report by U.S. Geological Survey (1980, p. 14).

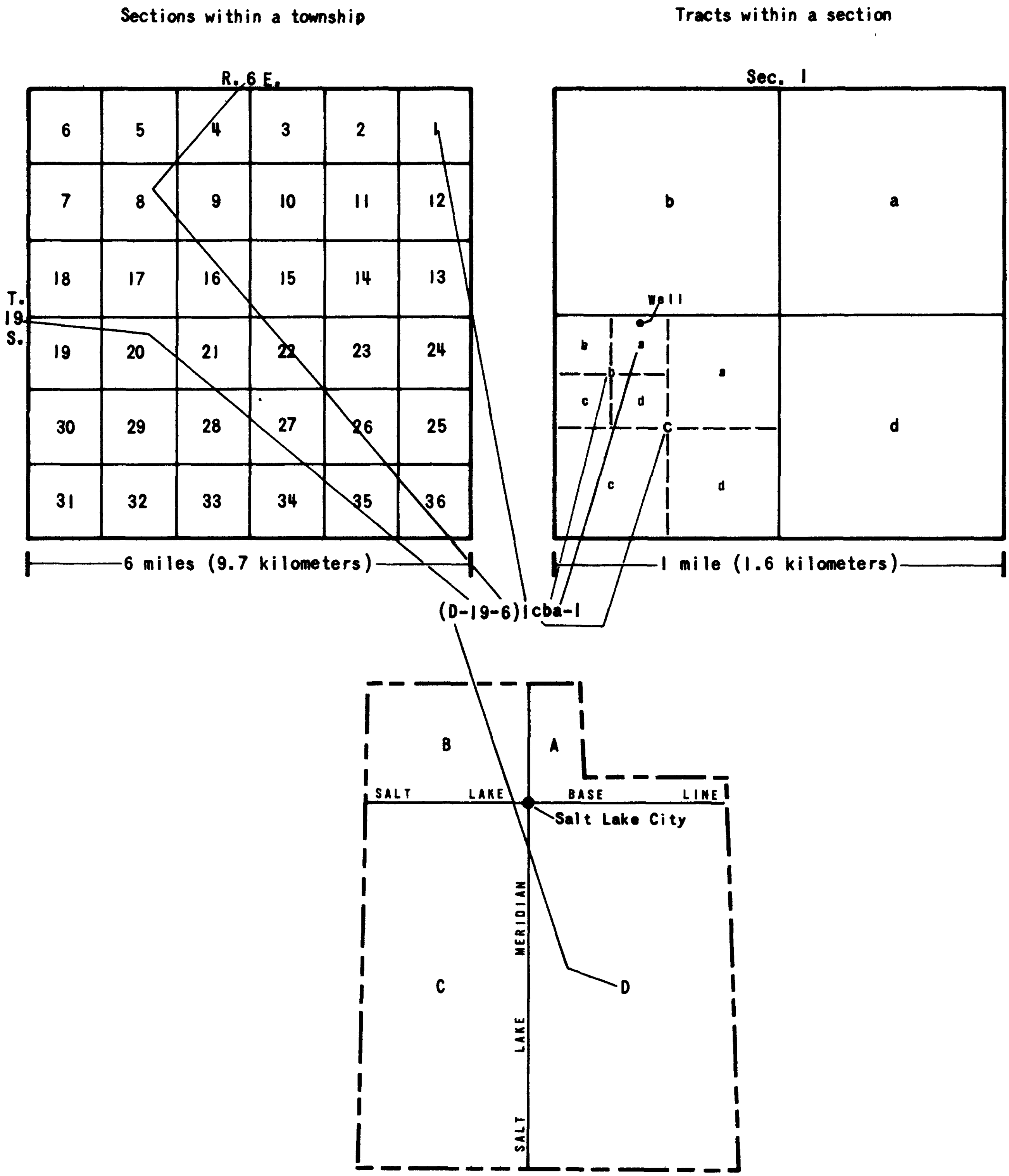

Figure 2.—Well- and spring-numbering system used in Utah.

PHYSICAL SETTING

Topography and surface drainage

The study area (pl. 1) includes about 700 square miles of the Wasatch Plateau in central Utah. The area is characterized by rugged mountainous terrain dissected by deep canyons. Cliffs bound most of the eastern limit of the Plateau where altitude differences of 2,000 feet are common. The area is drained by three major perennial streams--Cottonwood and Ferron Creeks, tributaries to the San Rafael River, and Muddy Creek, a tributary to the Dirty Devil River. Two smaller perennial streams, Quitchupah and Ivie Creeks, drain the southern part of the study area and are tributaries to Muddy Creek.

Altitudes[1] in the study area range from about 6,000 feet at the base of the eastern escarpments southwest of Ferron to more than 11,000 feet at the headwaters of Reeder Canyon northwest of Joes Valley Reservoir. Channel gradients in most of the major drainages are steep; Ferron and Muddy Creeks upstream from gaging stations 09326500 and 09330500 (pl. 1) decrease in altitude at a rate of about 200 feet per mile. Although the relief at the mountain boundaries is large, mountain tops generally are broad and have small relief. The top of South Horn Mountain is an undulated plain (fig. 3). The tops of The Cap, Ferron Mountain, and Wagon Road Ridge are almost flat.

Climate

The climate of the study area is semiarid to subhumid, with precipitation generally increasing with altitude. Normal annual precipitation ranges from less than 10 inches at lower altitudes of the area to locally more than 40 inches along the crest of the Wasatch Plateau (pl. 2). Normal May-September precipitation ranges from about 4 to 10 inches, and normal October-April precipitation ranges from about 6 to 30 inches (U.S. Weather Bureau, 1963). The May-September precipitation usually comes from localized thunderstorms of short duration. Most thunderstorm precipitation runs off rapidly and at times causes flash flooding.

Snow accumulates to depths of several feet during winter at the higher altitudes. April 1 snow depths recorded at the Buck Flat snow course near Ferron Reservoir (pl. 1) averaged more than 4 feet during 1956-79. The average water content of the snow was 16.6 inches (Whaley and Lytton, 1979, p. 203).

Extreme air temperatures range from near 38°C at the lower altitudes of the area during summer to about -34°C at the higher altitudes during winter. Evaporation rates vary with altitude but average about 40 inches per year in the area.

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[1]Altitudes mentioned in this report are in feet above the National Geodetic Vertical Datum of 1929 (NGVD of 1929); this is a datum derived from an adjustment of the first-order level nets of both the United States and Canada, and formerly referred to as mean sea level.

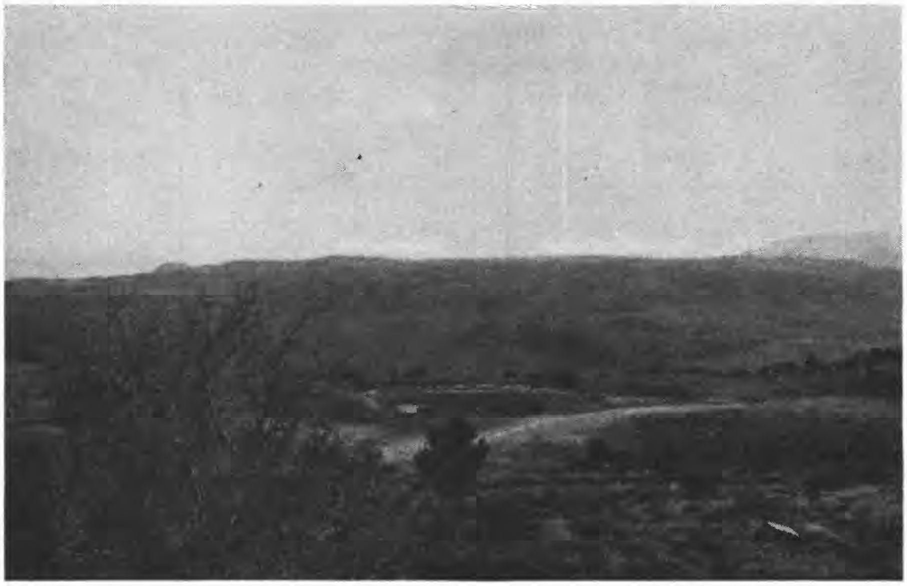

Figure 3.—Undulated plain of South Horn Mountain. View is south from the south side of North Horn Mountain.

Geology

Except in the extreme southwestern part of the study area, where igneous rocks are present, exposed geologic units are sedimentary in origin and range in age from Cretaceous to Quaternary. The stratigraphic relationships, general lithologies, and thicknesses of each unit are summarized in table 1. The outcrop area of each unit and prominent geologic features are shown on plate 3. Except where folded or faulted, the regional dip of rocks in the study area generally is in a northwesterly direction at angles that rarely exceed 4 degrees.

The durability of the exposed rocks controls the topography in most of the area. The resistant Flagstaff Limestone of Tertiary age forms steep sided caps on the highest ridges and summits (fig. 4). The North Horn Formation of Cretaceous and Tertiary age, which underlies the Flagstaff, forms gentle slopes and sometimes hummocky terrain. The North Horn is underlain by erodible sandstones of the Price River Formation of Cretaceous age that typically form steep receding slopes. The Price River is underlain by the resistant Castlegate Sandstone of Cretaceous age which forms cliffs along most of the eastern escarpments of the Wasatch Plateau. As shown in figure 5, the Blackhawk Formation of Cretaceous age is typically exposed on steep slopes. The Blackhawk is underlain by the Star Point Sandstone of Cretaceous age which, like the Castlegate, forms cliffs.

The Blackhawk Formation is the major coal-bearing unit in the study area. The coal usually occurs in a number of seams in the lower 200 feet of the formation. The Hiawatha coal seam of the Blackhawk, in most areas located within 15 feet of the Star Point Sandstone, is the most actively mined bed in the Wasatch Plateau coal field. Other reserves of economic importance also are being mined from the Blind Canyon coal seam located 25 to 75 feet above the Hiawatha seam.

Table 1.—Stratigraphic relationships, thicknesses, lithologies, and water-bearing characteristics of geologic units (modified from Stokes, 1964).

System	Series	Geologic unit	Thickness (feet)	Lithology and water-bearing characteristics
Quaternery	Holocene and Pleistocene	Unconsolidated deposits undifferentiated	0-100	Unconsolidated deposits; clay, silt, sand, gravel, and boulders; yields water to springs that may cease to flow in late summer.
Tertiary	Eocene and Paleocene	Flagstaff Limestone	10-300	Light-gray, dense, cherty, lacustrine limestone with some interbedded thin gray and green-gray shale; light-red or pink calcareous siltstone at base in some places; yields water to many springs. (See table 9.)
	Paleocene	North Horn Formation	800±	Variegated shale and mudstone with interbeds of tan-to-gray sandstone; all of fluvial and lacustrine origin; yields water to springs. (See table 9.)
Cretaceous	Upper Cretaceous	Price River Formation	600-700	Gray-to-brown, fine-to-coarse, and conglomeratic fluvial sandstone with thin beds of gray shale; yields water to springs locally.
		Castlegate Sandstone	150-250	Tan-to-brown fluvial sandstone and conglomerate; forms cliffs in most exposures; yields water to springs locally.
		Blackhawk Formation	600-700	Tan-to-gray discontinuous sandstone and gray carbonaceous shales with coal beds; all of marginal marine and paludal origin; locally scour-and-fill deposits of fluvial sandstone within less permeable sediments; yields water to springs and coal mines, mainly where fractured or jointed.
		Star Point Sandstone	350-450	Light-gray, white, massive, and thin-bedded sandstone, grading downward from a massive cliff-forming unit at the top to thin interbedded sandstone and shale at the base; all of marginal marine and marine origin; yields water to springs and mines where fractured and jointed.
		Masuk Member of the Mancos Shale	600-800	Dark-gray marine shale with thin, discontinuous layers of gray limestone and sandstone; yields water to springs locally.

Figure 4.—The Flagstaff Limestone of Tertiary age atop Ferron Mountain.

Figure 5.—Cretaceous rocks on the eastern slopes of North Horn Mountain. Kc, Castlegate Sandstone; Kbh, Blackhawk Formation; Ksp, Star Point Sandstone.

The Joes Valley Fault system (pl. 3) is the most prominent structural feature in the area. Throughout its length of approximately 80 miles in the Wasatch Plateau, the faults form a graben (fig. 6) in which the rocks have dropped 1,500 to 2,500 feet, and the dropped block is "everywhere much shattered" (Spieker, 1931, p. 57).

Lithologic logs of two coal-test holes that penetrated all formations above the Star Point Sandstone are shown in figure 7. Although the holes are a few miles east of the study area, the lithologies shown are characteristic of rock lithologies in the southern Wasatch Plateau. However, the percentage of sandstone, important for its water-bearing characteristics, in the North Horn, Price River, and Blackhawk Formations varies significantly in short distances. The percentages of sandstone logged in 23 coal-test holes on East Mountain, a few miles east of the study area, were as follows:

Geologic unit	Number of test holes in which formation was penetrated	Percentage of sandstone logged	
		Range	Average
North Horn Formation	5	8-35	25
Price River Formation	11	9-100	53
Blackhawk Formation	23	5-69	24

LAND USE

Most of the land in the southern Wasatch Plateau is used for livestock grazing during the summer months. A small part of the land is used for leisure living and recreation in areas such as Acord Lakes and Joes Valley Reservoir, where clusters of summer homes have been constructed. Ferron Reservoir is used for commercial recreation.

Areas leased for coal mining in the study area are shown on plate 1. Two underground coal mines, the SUFCo Mine (Southern Utah Fuel Co.) and the Knight Mine (Coal Search Corp.) were active in the area during 1980.

Figure 6.—The Joes Valley Fault graben near Joes Valley Reservoir. Rocks underlying foreground have dropped 1,000 to 2,500 feet.

SURFACE-WATER HYDROLOGY

Water use

Several reservoirs in the study area store water for irrigation of farms in Castle Valley east of the Wasatch Plateau. Joes Valley Reservoir, constructed by the U.S. Bureau of Reclamation in 1965, has a usable storage capacity of about 55,000 acre-feet. Water stored in the reservoir also is used for cooling the coal-fired Hunter electrical generating plant near Castle Dale (east of study area), and the water can be used on an exchange basis to cool the Huntington generating plant near Huntington (north of study area). Water is diverted from Cottonwood Creek downstream from Joes Valley Reservoir and is the source of supply for the communities of Castle Dale and Orangeville in Castle Valley.

Millsite Reservoir, constructed in 1971 by the U.S. Soil Conservation Service on Ferron Creek, has a usable storage capacity of about 17,000 acre-feet. The communities of Ferron and Clawson in Castle Valley utilize Millsite Reservoir for public-water supplies. Other reservoirs and lakes include Henningson, Julius Flat, Spinners, Brush, and Emery Reservoirs in the Muddy Creek drainage; Willow Lake, and Ferron and Duck Fork Reservoirs in the Ferron Creek drainage; and Acord Lakes in the Quitchupah Creek drainage.

Eleven transmountain diversions carry water out of the study area. During 1951-58, nine diversions (pl. 1) conveyed an average of about 8,300 acre-feet annually from the Cottonwood Creek drainage into the San Pitch River basin west of the study area. During this same period, two diversions carried an annual average flow of about 270 acre-feet from the Ferron Creek drainage into the San Pitch River basin (U.S. Geological Survey, 1964, p. 342-344, 348).

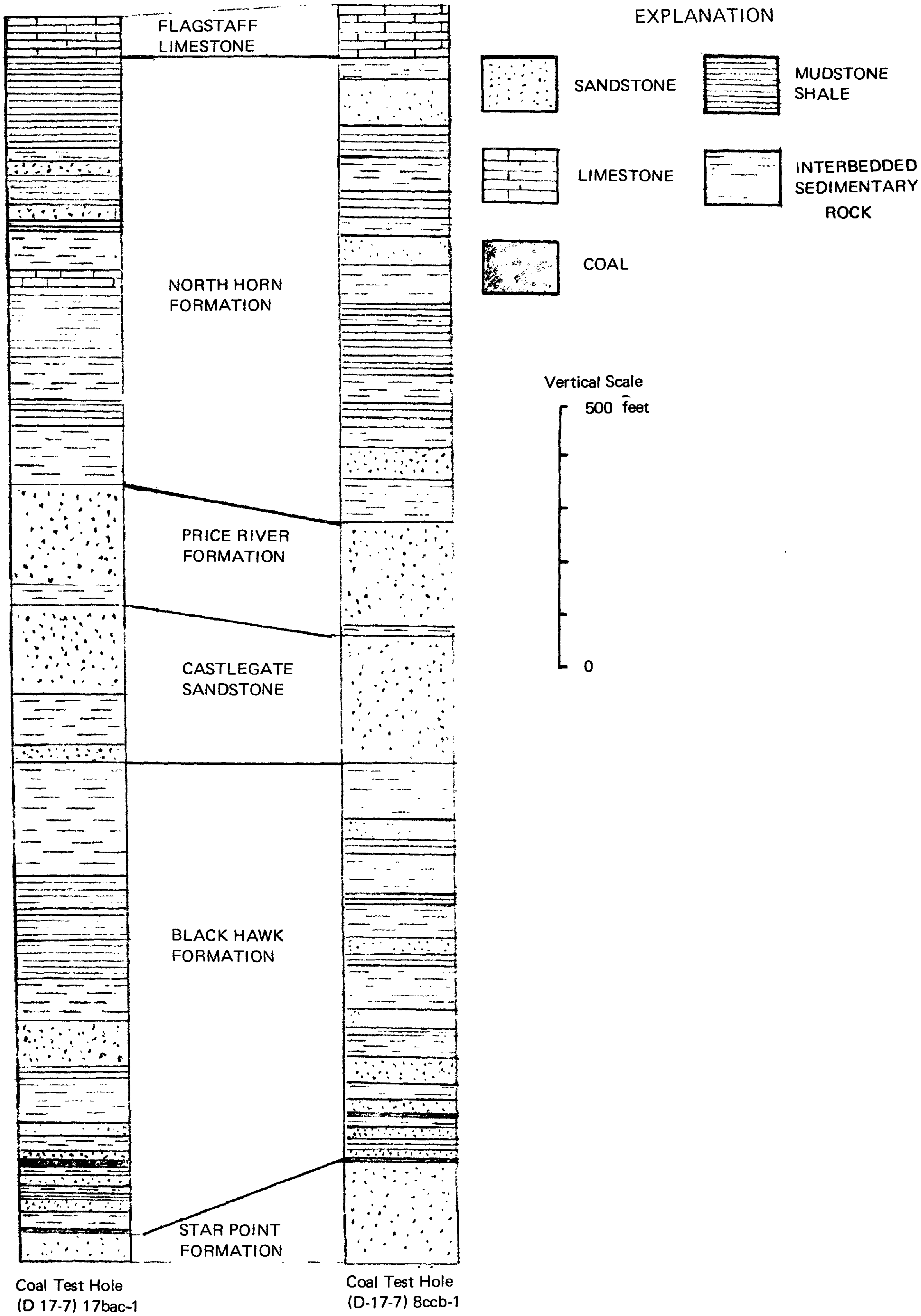

Figure 7.—Lithologic logs of two coal-test holes. The holes are 2,310 and 2,360 feet deep and are about 1 mile apart.

Annual discharge

Three streamflow-gaging stations (pl. 1) were in operation in the study area during 1979--Cottonwood Creek (site 7), Ferron Creek (site 21), and Muddy Creek (site 39). Discharge data for prior years also were available for a gaging station on Ivie Creek (site 81). A summary of average annual discharge at the four stations is shown in table 2. Average annual discharge for Cottonwood Creek (site 7 in table 2) includes water years with complete record prior to completion of Joes Valley Reservoir in 1965.

The average annual precipitation listed in table 2 was computed using the precipitation data shown on plate 2. These data indicate that about 5 to 29 percent of the average annual precipitation on a drainage basin becomes streamflow. Most of the remaining volume probably is lost to evapotranspiration, and a small percentage recharges the ground-water system. Hydrographs of average monthly discharge at the four gaging stations are shown in figure 8. The maximum monthly discharges each year resulted from snowmelt during spring and early summer. About 46 percent of the annual discharge at the Ivie Creek gage (site 81) occurred during April-June; at the other three gaging stations the range was from 58 to 68 percent. Except for years when the snowpack was much above average, there was less variation in monthly discharges for Ivie Creek than for the other three gaged streams. This may indicate that either more snowmelt infiltrates the soils in the Ivie Creek drainage, or that more of the snowpack is lost to evaporation and sublimation due to the more southern exposure.

Table 2.--Summary of precipitation on and discharge from the Cottonwood, Ferron, Muddy, and Ivie Creeks drainage basins

Stream and station No.	Site No. (see pl. 1)	Drainage area (square miles)	Period of record used (complete water years)	Average annual		
				Precipitation (acre-feet)	Discharge (acre-feet)	Discharge per unit area (acre-feet per square mile)
Cottonwood Creek 09324500	7	208	1910-20, 1922-27	327,000	77,200	371
Ferron Creek 09326500	21	138	1912-23, 1948-79	167,000	48,000	348
Muddy Creek 09330500	39	105	1911-13, 1950-79	137,000	26,800	255
Ivie Creek 09331500	81	50.0	1951-61	54,100	2,830	56.6

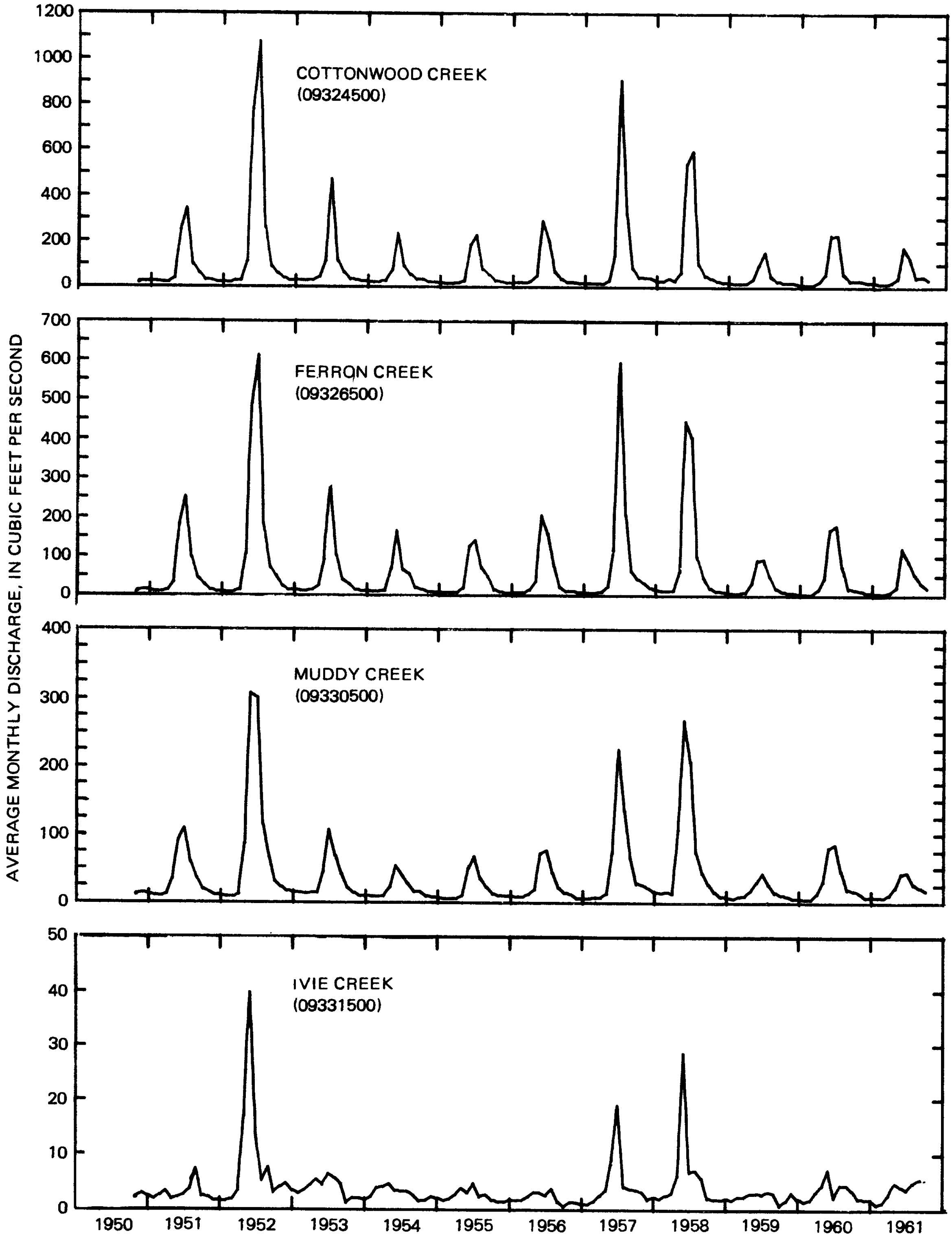

Figure 8.—Average monthly discharge at gaging stations on Cottonwood, Ferron, Muddy, and Ivie Creeks, water years 1951-61.

Base flow

To detect losing and gaining reaches of streams, discharge measurements were made at many sites (pl. 1) in the study area during periods of base flow. Periods of base flow are defined as those with no direct overland runoff from snowmelt or rainfall. Discharge measurements were made upstream and downstream from faulted areas and formation contacts and along numerous other reaches. The base-flow measurements, as well as other measurements of streamflow, are listed in table 4 (at back of report).

The measurements indicate that most of the base flow of major streams originates as ground-water discharge from the Flagstaff Limestone and the North Horn Formation. For example, on October 18, 1978, the discharges at the mouths of the North and South Forks Muddy Creek (sites 27 and 28) near the contact between the North Horn and Price River Formations were 9.3 and 14.3 cubic feet per second (a total of 23.6 cubic feet per second). On the same date at site 34, near the contact between the Blackhawk Formation and the Star Point Sandstone, the discharge of Muddy Creek was 24.2 cubic feet per second.

In many cases the base-flow measurements indicated apparent small gains and losses in stream reaches crossing the Blackhawk Formation and Star Point Sandstone. But the apparent changes in flow were usually within the accuracy of the discharge measurements (5 to 10 percent).

Water quality

Chemical quality

Water collected at 33 surface-water sites throughout the study area during 1977-80 generally was suitable for most uses. Sixty-one samples were analyzed for concentrations of major dissolved constituents (table 5 at back of report). No analyzed chemical constituents were present in concentrations that exceeded the drinking-water standards of the U.S. Environmental Protection Agency (1976). Dissolved-solids concentrations ranged from 97 milligrams per liter at site 59 in East Spring Canyon on May 2, 1979, to 835 milligrams per liter at site 58 in Convulsion Canyon on September 18, 1980. The predominant dissolved chemical constituents in most of the samples were calcium, magnesium, and bicarbonate. Water from Convulsion Canyon (site 58), Water Hollow (site 67), and Quitchupah Creek (site 68) contained relatively large concentrations of sodium and sulfate.

Most water samples were collected during periods of base flow. The chemical quality of water in the streams changed little as the water moved downstream because most of the base flow originated as ground-water discharge from the Flagstaff Limestone and North Horn Formation at the higher altitudes. Little, if any, water was discharged from lower formations. Also, with the exception of the Mancos Shale, the solubility of most of the exposed rocks apparently is so minimal that few additional minerals are added once the water enters the streams. The chemical quality of the water in most streams is changed significantly by soluble minerals in the Mancos Shale. (See Waddell and others, 1981, p. 19.)

One exception to the otherwise consistent chemical quality of surface water upstream from the Mancos Shale was noted in Convulsion Canyon and Quitchupah Creek drainages; the changes in water quality are depicted in figure 9. Inflow from East Spring Canyon in September 1980 decreased the dissolved-solids concentration in Convulsion Canyon from 835 to 555 milligrams per liter. Further decreases in the concentrations of dissolved calcium and magnesium and increases in the concentrations of sodium and sulfate occurred between sites 61 and 62. This change in water chemistry indicates ground-water discharge within the reach between sites 61 and 62.

Sediment

Twenty-nine water samples from 15 stream sites were analyzed for concentration of suspended sediment during 1979-80 (table 6 at back of report). Concentrations ranged from 15 milligrams per liter on August 7, 1979, at site 6 in Straight Canyon to 36,500 milligrams per liter at site 21 on Ferron Creek during a thunderstorm on July 14, 1980. Relatively large concentrations of suspended sediment were present in all samples collected during snowmelt runoff on May 15 and 16, 1980; aside from those samples collected during snowmelt runoff, the suspended-sediment concentration averaged about 60 milligrams per liter.

Other agencies have collected suspended-sediment samples in the Ferron and Cottonwood Creek drainages for use in reservoir design. The U.S. Soil Conservation Service collected 73 samples from Ferron Creek near the present location of Millsite Reservoir between April and August 1963. Concentrations of suspended sediment ranged from 550 milligrams per liter on May 27 to about 400,000 milligrams per liter on August 9 (Robert L. Bridges, U.S. Soil Conservation Service, written commun., August 21, 1963).

Similar data were collected in a study by the U.S. Bureau of Reclamation prior to the design of the Joes Valley Reservoir. Clyde D. Gessel (U.S. Bureau of Reclamation, written commun., May 1960) reported that Seeley Creek and Lowry Water carry a relatively small quantity of fine sediment but that North Dragon and Swasey Creeks present a "* * *picture of accelerated erosion." Samples collected on North Dragon Creek on April 14, 1960, had a suspended-sediment concentration of 17,000 milligrams per liter; the streamflow was about 3 cubic feet per second. During 1958-60 the Bureau of Reclamation collected 19 duplicate sets of samples at the present dam site in Straight Canyon. Average suspended-sediment concentrations in those samples ranged from 57 milligrams per liter on August 13, 1958, to 14,592 milligrams per liter on April 21, 1958. A sediment-discharge curve indicated that suspended sediment entering the reservoir averaged about 10 tons per day when total inflow was 3.5 cubic feet per second and about 1,000 tons per day at 35 cubic feet per second.

In order to determine the mineralogy of streambed material in a potential coal-mining area, 10 samples were collected throughout the study area in September 1980 (table 7 at back of report). Samples were separated into four size fractions less than 4.76 millimeters, and minerals were identified using X-ray diffraction techniques.

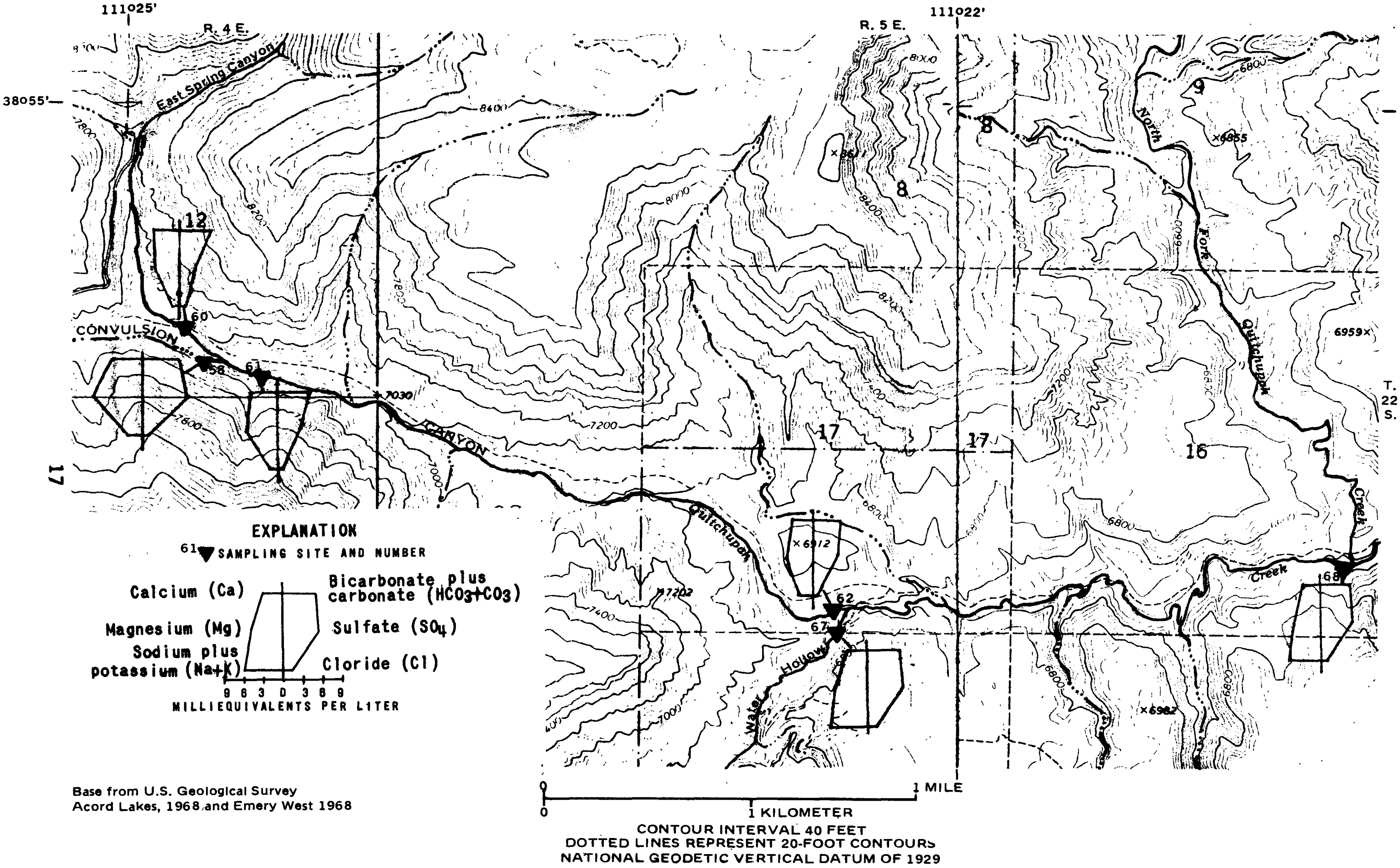

Figure 9.—Changes in water chemistry in the Convulsion Canyon and Quitchupah Creek drainages, September 1980.

Quartz was the most abundant mineral in all size fractions larger than clay (larger than 0.002 millimeter) at all sites except site 29 on Muddy Creek, where calcite and dolomite were predominant in the smaller-than-4.76 millimeter-size fraction. At site 29, 16 percent of the smaller-than-4.76 millimeter-size fraction was quartz; downstream, at site 36, 47 percent of the same size fraction was quartz. The downstream increase in the percentage of quartz reflects the lithologic differences of geologic units that crop out in the Muddy Creek drainage. The upper part of the basin is underlain by the North Horn Formation and Flagstaff Limestone, which are mainly mudstone and limestone. In the lower part of the basin, outcrops of quartzitic sandstones like those in the Castlegate and Star Point Sandstones are abundant.

Benthic invertebrates

Previous studies (Chisholm and Downs, 1978; Fuller and others, 1978, p. 22-27; Cummins, 1973; Herricks and Cairns, 1973; and Patrick, 1949) have shown that benthic invertebrates may be used as an indicator of water quality, and changes in the benthic-invertebrate population may reflect changes in water quality. To help define present (1980) water-quality conditions in the study area, benthic invertebrates were sampled in August of 1979 and August of 1980 at 11 stream sites (pl. 1; tables 3 and 8 at back of report).

The benthic invertebrates were collected using a Surber bottom sampler (Greeson and others, 1977, p. 172-3), which samples 1 square foot of stream bottom. Three samples were collected at each site in riffle areas (from the right side, middle, and left side of the stream). Where streams were too narrow to permit three samples at the same cross section, the samples were taken diagonally from left to right in an upstream direction. The three samples were composited for the organism identification and computation of a diversity index (table 3). Identification generally was carried to the species level (table 8).

The Shannon-Weiner diversity index (Krebs, 1972, p. 506) for each sample is used as an indicator of the "health" of the benthic-invertebrate population. In general terms, a diversity index (computed on the species level) of less than 1, indicates an unhealthy population and a polluted environment. Diversity indexes of about 3 generally indicate a healthy, well-balanced population and an unpolluted environment. The diversity index is most useful in evaluating aquatic environments that have been adversely affected by the addition of organic material, but it may be used to evaluate any effect on that environment.

A comparison of diversity indexes may be used as an indication of differences in water quality, and the variation of the diversity index with time is an indication of the stability of the stream environment. Sampling techniques, streambed material, flow velocities, and identification categories (order, family, genus, or species) need to be similar before comparisons are valid.

The range of diversity indexes computed for the 11 sampling sites was large. (See table 3). The smallest index was 0.96 at site 60 on August 21, 1980; site 60 is in East Spring Canyon downstream from the SUFCo Mine. The largest indexes were 4.11 at site 36 in Muddy Creek on August 7, 1979, and

4.08 and 4.05 at sites 18 and 8 in Ferron Creek on August 7, 1979. The diversity indexes of all other samples ranged from about 2 to 4. The small diversity index computed for site 60 downstream from the SUFCo Mine is not necessarily indicative of polluted water. Mine effluent is pumped into the stream on a sporadic basis. Unstable conditions caused by these abrupt changes of flow creates an unfavorable habitat for a large number of organisms.

Annual variability of both the number of organisms and the number of species are large. Several additional years of data are necessary to define natural changes in the benthic-invertebrate population before the method can be used to detect changes in the stream environment caused by mining.

GROUND-WATER HYDROLOGY

Occurrence

Ground water occurs in all the geologic units exposed in the study area (table 1), but none of the units are saturated everywhere. Rocks commonly are drained within short lateral distances from the walls of deeply incised canyons. Local exceptions occur where ground water is discharged at the surface by springs.

Springs and seep areas (wet areas with no discernible flow) were studied in detail in two areas during the summer of 1980 to determine the areal extent of aquifers. The Ferron Mountain and North Horn-South Horn Mountain areas (pl. 1) were selected for detailed study because the geology in those areas is similar to most of the southern Wasatch Plateau.

Springs and seeps in the Ferron Mountain area are shown in figure 10. Except for one seep that issued from the base of the Castlegate Sandstone on Nelson Mountain, no evidence of ground-water discharge was observed below the contact between the Price River Formation and the Castlegate Sandstone. One spring issued at the Price River-Castlegate contact, and five seeps issued from the Price River Formation. All other ground-water discharge (13 springs and 52 seeps) was from the North Horn Formation. Most springs and seeps in the North Horn Formation are located in "badland" areas. These badland areas, drained by steep-sloping ephemeral streams, are devoid of vegetation and are surfaced with concrete-like soil appearing to consist of dispersed clay.

Springs and seeps, though not numerous, were found throughout the geologic section on North Horn and South Horn Mountains (fig. 11). Only one spring was located that issued from the Price River Formation on South Horn Mountain; seven springs and seeps were located in the lower formations. There are two distinct areas of seepage on North Horn Mountain--one area east-northeast of The Cap and the other directly west of The Cap (fig. 11).

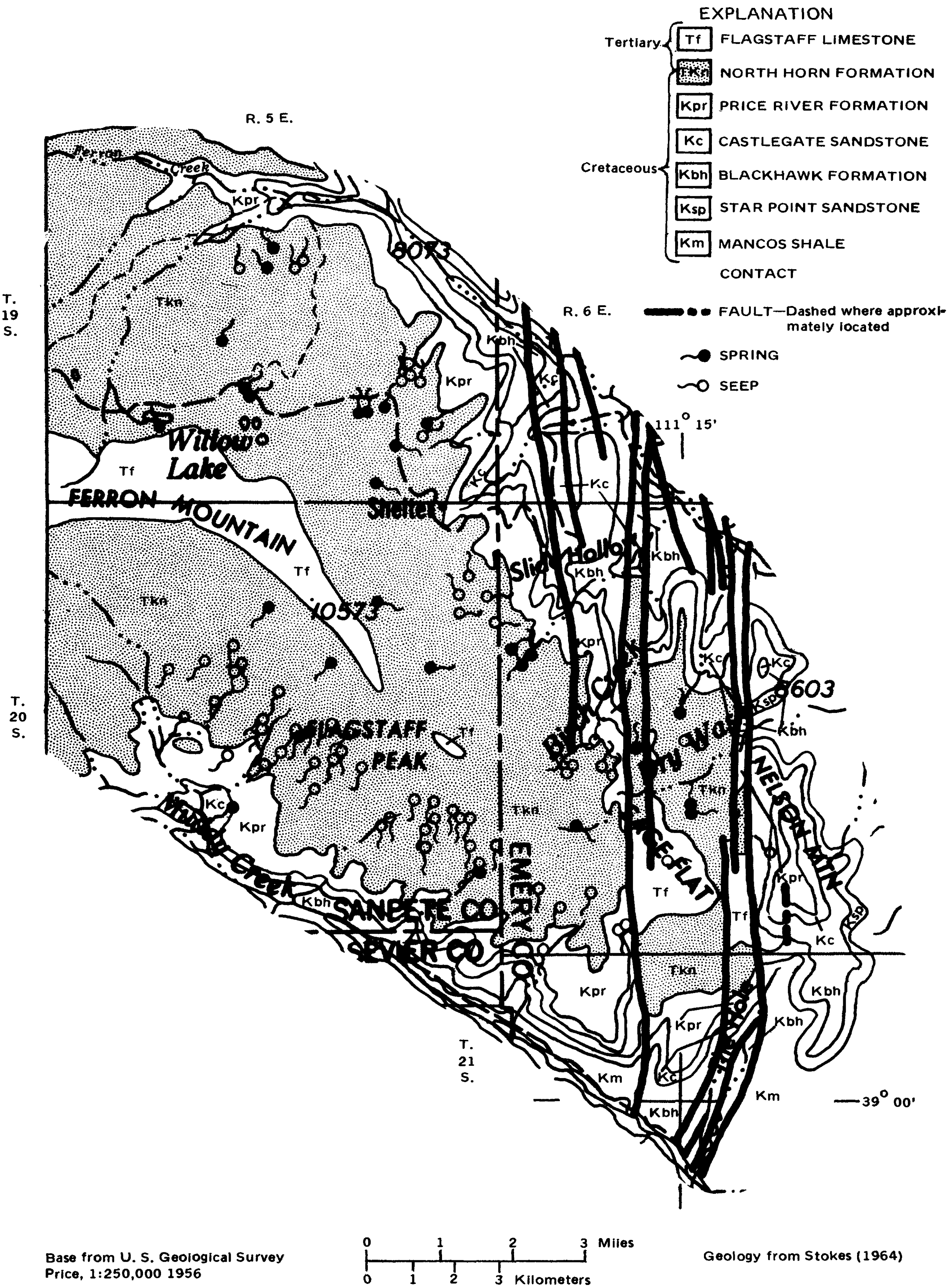

Figure 10.—Geology and location of springs and seeps in the Ferron Mountain area. Springs and seeps inventoried during summer 1980.

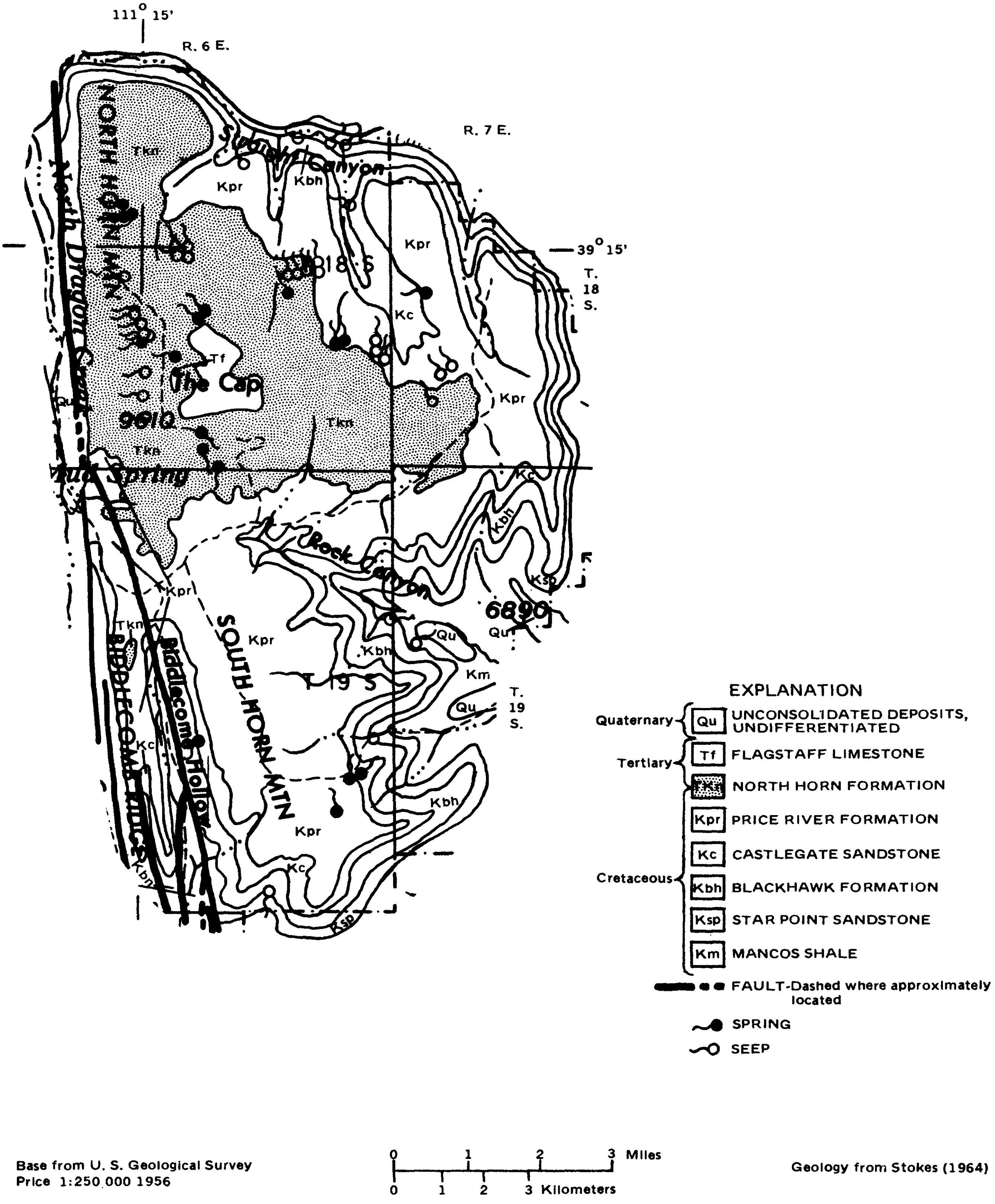

Figure 11.—Geology and location of springs and seeps in the area of North Horn and South Horn Mountains. Springs and seeps inventoried during 1980.

The large number of springs that issue from the Flagstaff Limestone and North Horn Formation indicates that the two units contain water in most areas. About 80 percent of the springs inventoried throughout the study area issued from these two units (fig. 12). Data are not sufficient to determine whether water in the North Horn and Flagstaff is perched[1] or part of a continuous saturated zone. Many test holes have been drilled in the study area to evaluate the coal resource, but those holes have provided little information about the ground-water system. For instance, when an interval of a test hole was reported as being "dry," it is not certain whether the rock was unsaturated or was saturated but not permeable enough to yield detectable quantities of water while drilling. Geologic and hydrologic data from coal-test holes in the area are listed in table 9 (at back of report).

Perched ground water may be either permanent, where recharge is frequent enough to maintain a saturated zone above the perching bed, or temporary, where intermittent recharge is not great or frequent enough to prevent the perched water from disappearing from time to time as a result of drainage over the edge of or through the perching bed."

Water in test holes indicates that the Star Point Sandstone and the Blackhawk Formation are saturated in most areas. Water was reported in the Star Point at test hole (D-22-4)17cdb-1, in the bottom of the Blackhawk at (D-21-4)33bdd-1, and in the top of the Blackhawk at (D-18-7)30bdb-1. Water also was reported in the Castlegate Sandstone at test holes (D-22-4)2cad-1 and (D-22-4)34aca-1. The water in the latter hole may be perched because it could be heard flowing down the hole 3 months after drilling was completed. Water-yielding zones were penetrated in the Price River Formation in test hole (D-21-4)33bdd-1. In addition, Tom Abbay (U.S. Geological Survey, oral commun., November 14, 1980) stated that significant quantities of water were encountered in the North Horn Formation in several U.S. Geological Survey test holes on North Horn Mountain during the summer of 1979.

Of the two underground coal mines in the study area, the Knight Mine is completely dry, and the SUFCo Mine is very wet. Water levels in wells near the SUFCo Mine, (D-22-5)6bb-1, (D-21-4)36dbb-1, and (D-22-5)8bbc-1 (table 9), indicate that most of the Blackhawk Formation is saturated. The saturated zone in the area of the Knight Mine is about 200 feet below the coal seam being mined (Coal Search Corp., written commun., June 1979). In this area, the Hiawatha coal seam of the Blackhawk (locally called the Ivie Creek coal seam) is about 200 feet above the Star Point Sandstone.

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[1]As defined by Lohman and others (1972, p. 7), "* * *perched ground water is unconfined ground water separated from an underlying body of ground water by an unsaturated zone. Its water table is a perched water table. It is held up by a perching bed whose permeability is so low that water percolating downward through it is not able to bring water in the underlying unsaturated zone above atmospheric pressure.

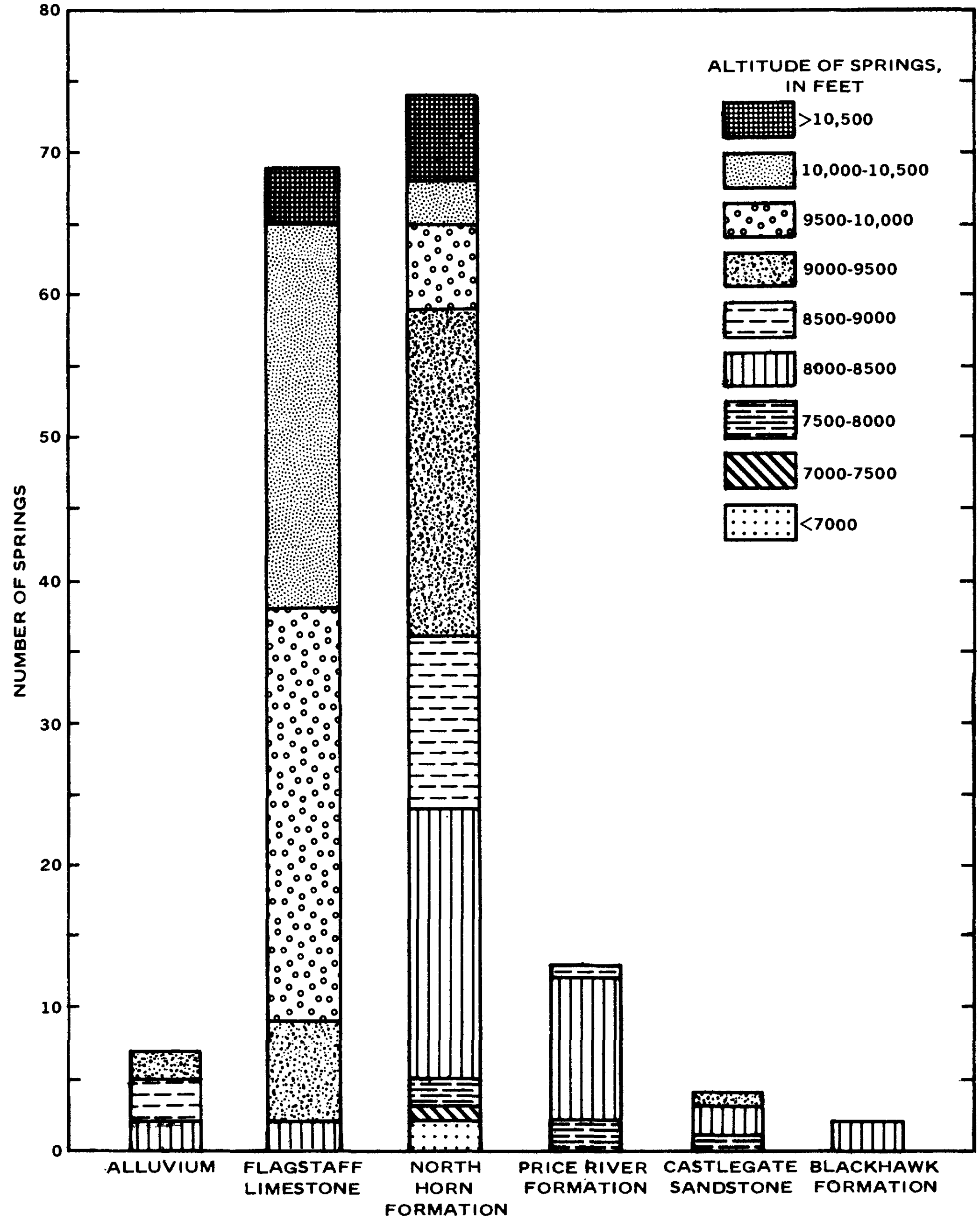

Figure 12.—Number and altitude of springs in each geologic unit in the southern Wasatch Plateau, inventoried during 1978-80.

Thus, it is known that water occurs in and above the Star Point Sandstone. In some areas, the saturated zone extends into the upper part of the Blackhawk Formation. This aquifer, herein called the Star Point-Blackhawk aquifer, exists throughout most of the study area. The North Horn Formation and Flagstaff Limestone also contain water in most areas. Some spring data indicate that water in the North Horn and Flagstaff is perched, but this is not known for certain.

Recharge

Snow in the higher altitudes of the study area commonly accumulates to depths of several feet, and snowmelt is the primary source of recharge to the ground-water system. The quantity of ground-water recharge varies throughout the study area because of differences in the water content of snowpack, exposure, surface relief, and rock permeability. Minimal-surface relief, like that on top of North Horn and Ferron Mountains, slows the runoff from snowmelt and provides the potential for large quantities of water to infiltrate the soils and percolate to deeper levels. Where the Flagstaff Limestone is present, fractures and solution openings provide storage for large volumes of ground water. The many springs that issue from the Flagstaff is evidence of its large recharge capacity.

Recharge to other geologic units varies from place to place, but it appears that nowhere is it as great as to the Flagstaff Limestone. Recharge from snowmelt on the nearly flat surface on the top of South Horn Mountain (fig. 3) should be large. However, the absence of springs in canyons that dissect South Horn Mountain and the fact that no water was detected in any of the coal-test holes drilled on the mountain during the summer of 1980 indicates that little recharge takes place. It is believed that significant exposure to solar radiation and wind contributes to the loss of much of the winter snowpack on South Horn Mountain.

Information from test holes indicates that significant recharge from snowmelt occurs on North Horn Mountain, at least on the northern slopes. Tom Abbay (U.S. Geological Survey, oral commun., November 1980) states that water encountered between 80 and 100 feet in test hole (D-18-6)30bdb-1 in the spring of 1979 caused the hole to be abandoned. When the test hole was redrilled in the fall of 1979, no water was encountered at the 80 to 100-foot depth.

Recharge to the Star Point-Blackhawk aquifer from direct infiltration of snowmelt on outcrop areas probably is small in comparison to recharge to the Flagstaff Limestone. In the northern part of the study area, outcrop areas of the Blackhawk Formation and Star Point Sandstone usually are less than about 1 mile wide and usually are on steep slopes. Most of the recharge to the aquifer in the northern part of the area probably is from downward percolation of water from overlying water-bearing zones, mainly along fractures. In the southern part of the study area, the Blackhawk is exposed over a much greater area, and therefore receives more direct recharge than in the northern part.

Estimates of the percentage of annual precipitation that recharges the ground-water system were made for four drainages in the study area. The estimates were made by assuming: (1) That streamflow during October primarily is ground-water discharge and reflects the average rate of ground-water discharge for the year, and (2) that long-term recharge in a basin equals the long-term ground-water discharge within the basin. At gaging sites 7 (Cottonwood Creek), 21 (Ferron Creek), 39 (Muddy Creek), and 81 (Ivie Creek), average October discharges for the periods of record were 1,680, 900, 890, and 134 acre-feet. The estimated ground-water recharge in the four drainage basins ranged from 3 to 8 percent of the average annual precipitation.

Some ground water may flow between surface drainage basins in the study area. Although there is little evidence to support this concept, the Joes Valley fault system in the eastern part of the study area probably is a conduit for interbasin movement of ground water. Lines and Morrissey (1981, p. 58) state that potentiometric-surface data indicate that the Ferron Sandstone Member of the Mancos Shale of Cretaceous age is recharged in the Emery area mainly by subsurface flow from the Wasatch Plateau along the Joes Valley fault system.

Movement

Ground water generally moves from areas of recharge at higher altitudes in the study area to areas of natural and manmade discharge, such as springs and the SUFCo Mine. Geologic structure, such as faulting and the dip of bedding, in some areas affects the flow path followed between recharge and discharge areas. Most water movement probably occurs through fractures, along bedding planes, and in the case of the Flagstaff Limestone, through solution openings. Some water also moves through the openings between sand grains in sandstones, such as those in the Blackhawk Formation.

Much of the recharge from snowmelt at higher altitudes of the study area is discharged by a large number of springs close to the original recharge areas. The downward movement of water commonly is impeded by less permeable beds of shale and mudstone, especially in the North Horn Formation, and the water is discharged by springs and seeps where the less permeable rocks crop out.

Along faults where rock permeability has been increased by fracturing, water probably passes through beds that normally would impede vertical flow and into underlying rocks such as the Star Point-Blackhawk aquifer. The Star Point-Blackhawk aquifer yields large quantities of water to the SUFCo Mine where the mine workings penetrate fractured rock.

Rapid movement of water through the ground-water system is indicated by the rapid response of natural ground-water discharge to changes in recharge. Generally, most of the stream discharge during the fall of each year is ground-water discharge. As shown in figure 13, the magnitude of base flow during October at gaging station 09330500 on Muddy Creek correlates well with the water content of the previous April 1 snowpack.

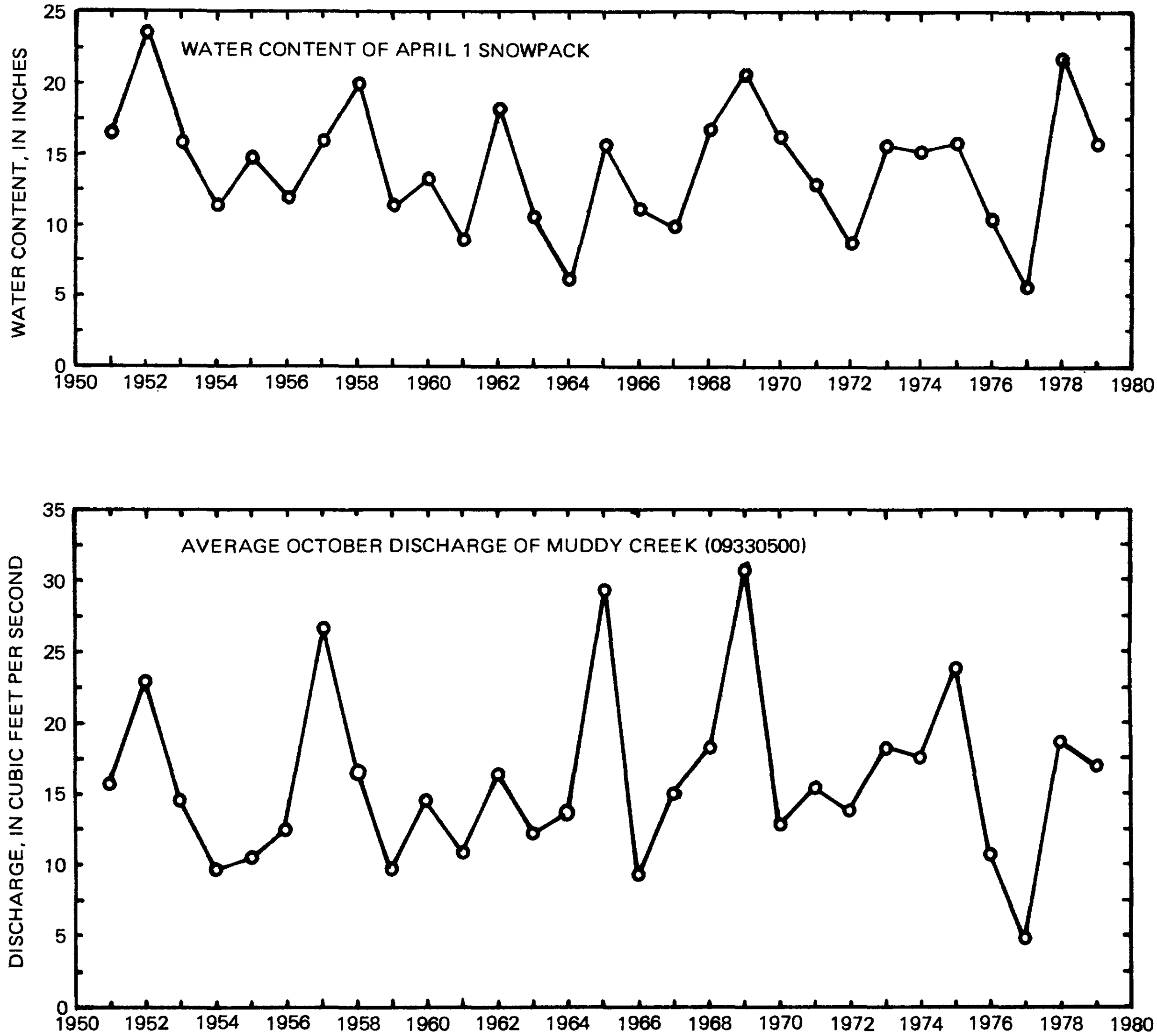

Figure 13.—Water content of April 1 snowpack at the Black's Fork snow course and average October discharge of Muddy Creek at gaging station 09330500, 1951-79.

Discharge

Ground water in the area is discharged naturally by springs and seeps and by evapotranspiration. Some water probably leaves the area by subsurface outflow, mainly along faults. The only known manmade discharge from the ground-water system during 1979-80 was dewatering of the underground SUFCo Mine.

It is not possible with existing data to accurately estimate the quantity of ground water evaporated or transpired by plants or to determine the quantity of subsurface outflow from the area. Data do exist, however, to describe the different types of springs and to describe how spring discharges naturally change with time. The following discussion concentrates on spring and mine discharges, both elements of the ground-water system that are likely to change with increased coal mining.

Springs

Discharge of about 100 springs in the study area ranged from about 0 to 1,080 gallons per minute (table 10 at back of report). Most of the large springs (those that discharge more than 50 gallons per minute) are near the contact between the Flagstaff Limestone and the North Horn Formation. During the spring of each year fracture and solution openings in the Flagstaff fill with water (chiefly from snowmelt). The water generally is discharged by springs at a decreasing rate during the remainder of the year. For example, spring (D-18-6)22cdc-S1, located close to the Flagstaff-North Horn contact on North Horn Mountain, discharged about 155 gallons per minute on July 7, 1980. By September 30, 1980, the discharge had decreased to 34 gallons per minute.

Springs commonly are associated with faulting or folding where rock permeability has been increased by fractures. Spring (D-17-6)7ddd-S1, believed to be the largest spring in the study area, issues from North Horn Formation in the Joes Valley Fault graben where according to Spieker (1931, p. 57) "* * *the rocks are everywhere much shattered." Discharge from the spring was measured at 1,080 gallons per minute on October 30, 1980.

Discharge from 28 springs was measured on a semimonthly basis during the summer of 1980. Graphs of discharge versus time for four of the springs are shown in figure 14. Differences in the rates at which spring discharges recede following periods of ground-water recharge are due to differences in the permeability and storage of the contributing water-bearing zones. Danielson, ReMillard, and Fuller (1981, p. 39) suggest that discharge-recession rates are duplicated after each period of recharge, and that any deviation of this rate of recession may indicate unnatural changes in the ground-water system such as those caused by mining. Discharge-recession rates vary throughout the study area. At the four springs shown in figure 14, discharges at the end of August 1980 ranged from about 1 to 90 percent of the discharges at the first of the month.

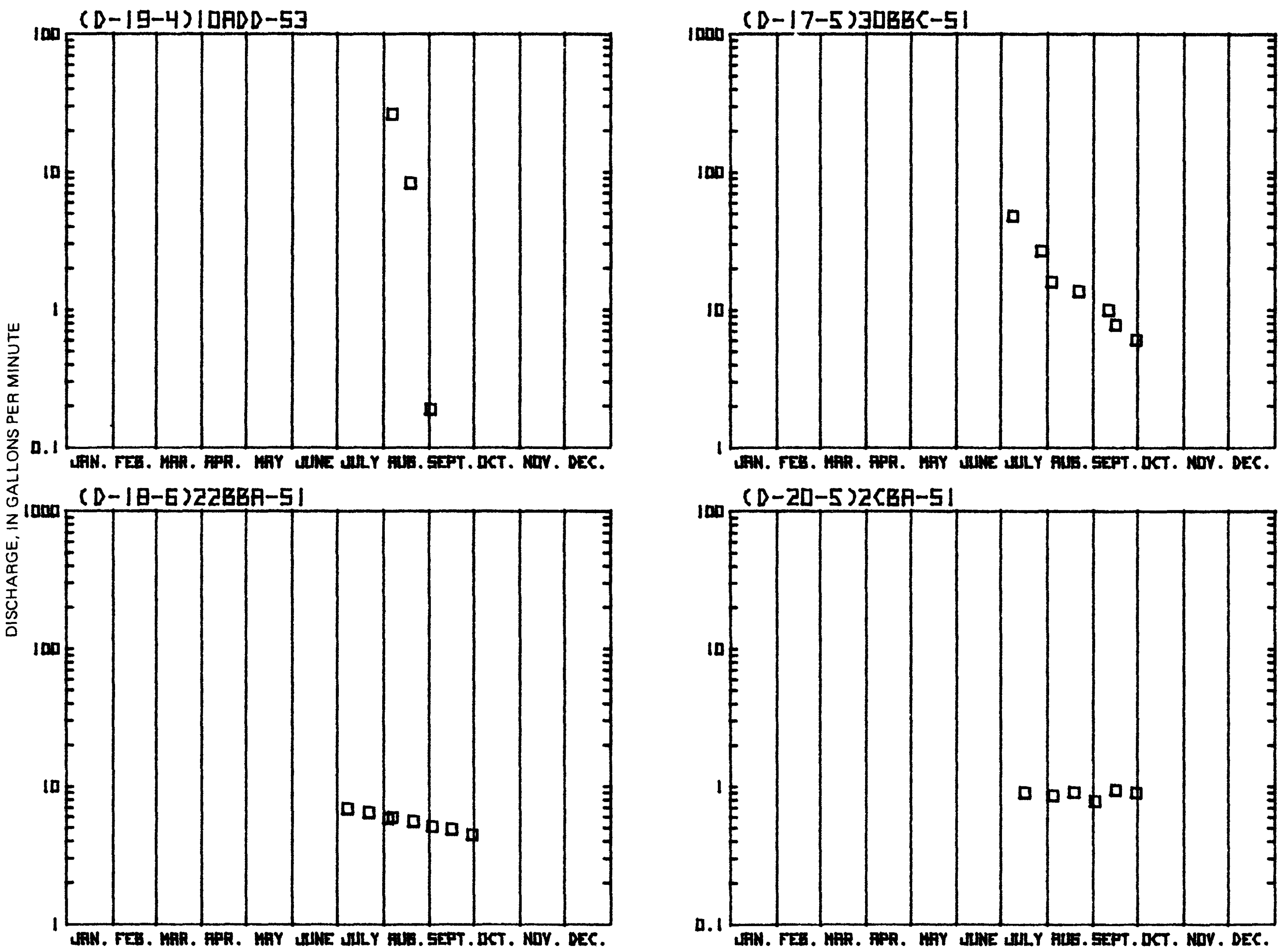

Figure 14.—Discharge recession of four springs in the southern Wasatch Plateau, summer of 1980.

Dewatering of coal mines

Of the two active coal mines in the area, only the SUFCo Mine produced water in sufficient quantities that water had to be discharged from the mine during 1980. Water in the Star Point-Blackhawk aquifer enters the underground mine mainly along fractures and through bolt holes such as those in the Wilberg Mine (fig. 15) about 8 miles east of the study area. The working face is almost always the source of some water; the older workings usually produce progressively less water as mining progresses farther underground.

Quantities of water produced in the SUFCo Mine during 1980 ranged from a trickle at some bolt holes in the roof to tens of gallons per minute at some fracture zones. Water may discharge at some points for only a few days and at others continuously, depending on the quantity of water stored in the rock and the degree of hydraulic connection to areas of recharge. During March 1981, the discharge from the mine averaged about 450 gallons per minute (Kerry Frame, Southern Utah Fuel Corp., oral commun., March 20, 1981).

Chemical quality

Concentrations of major dissolved constituents were highly variable in 87 water samples from springs (table 11 at back of report). Predominant ions in the water samples usually were calcium, magnesium, and bicarbonate. Dissolved-solids concentrations ranged from 105 to 1,080 milligrams per liter and averaged about 380 milligrams per liter. Although no water samples were analyzed for all chemical constituents, no constituent analyzed was in concentrations that exceeded drinking-water standards (U.S. Environmental Protection Agency, 1976).

Figure 15.—Water entering the Wilberg Mine through a bolt hole in the sandstone roof. The Wilberg Mine is about 8 miles east of the study area.

A plot of major constituent concentrations (in milliequivalents), as a percentage of the total concentrations, is shown in figure 16 for water samples from springs that issue from the Flagstaff Limestone and the North Horn and Price River Formations. Predominant ions in spring waters issuing from the Flagstaff Limestone usually were calcium, magnesium, and bicarbonate; sulfate was the predominant anion in a few samples. The predominant cations in water from the Price River Formation were similar to those in water from the Flagstaff, but sulfate was the predominant anion in five of eight samples. The chemistry of the water in the North Horn Formation was more variable than in the formations directly above and below mainly because of relatively large concentrations of sodium in some areas, particularly on North Horn Mountain.

The areal variability in chemical quality of spring waters throughout the study area is shown on plate 3. Although the chemistry of spring waters is variable throughout the study area as a whole, large variations normally do not exist within relatively short distances. Some anomalies, however, do exist. For example, the dissolved-solids concentration in water from spring (D-18-4)22aaa-S1 issuing from the Flagstaff Limestone was 135 milligrams per liter, and the predominant ions were magnesium and bicarbonate. About 0.2 mile away, the dissolved-solids concentration in water from spring (D-18-4)15ddd-S1 (also issuing from the Flagstaff) was 738 milligrams per liter, and the predominant ions were calcium and sulfate. Both springs issued from the Flagstaff Limestone at about the same altitude, and discharges were the same. However, reasons for the differences in water quality are not known.

Multiple samples were collected from 25 springs during the summer of 1979 to determine the seasonal variability in ground-water quality. Maximum and minimum dissolved-solids concentrations at 18 of the 25 springs were within 10 percent of each other. At the remaining seven springs, maximum and minimum dissolved-solids concentrations differed by as much as 26 percent. The differences probably were mostly due to differences in time that the water was in contact with minerals in the aquifers. During early summer when hydraulic heads are largest, water moves more rapidly and therefore has less time to dissolve chemical constituents than during late summer when hydraulic heads are smaller and water moves more slowly.

A few chemical analyses of water from wells and mines in the area are available (table 12 at back of report). Five water samples were collected from the Star Point-Blackhawk aquifer in the SUFCo Mine during 1979-80. Dissolved-solids concentrations ranged from 272 to 394 milligrams per liter, and predominant ions in all samples were calcium, magnesium, and bicarbonate. Water sampled from well (D-22-4)13caa-1, which taps the Price River Formation, had a dissolved-solids concentration of 82 milligrams per liter; predominant ions were calcium and bicarbonate.

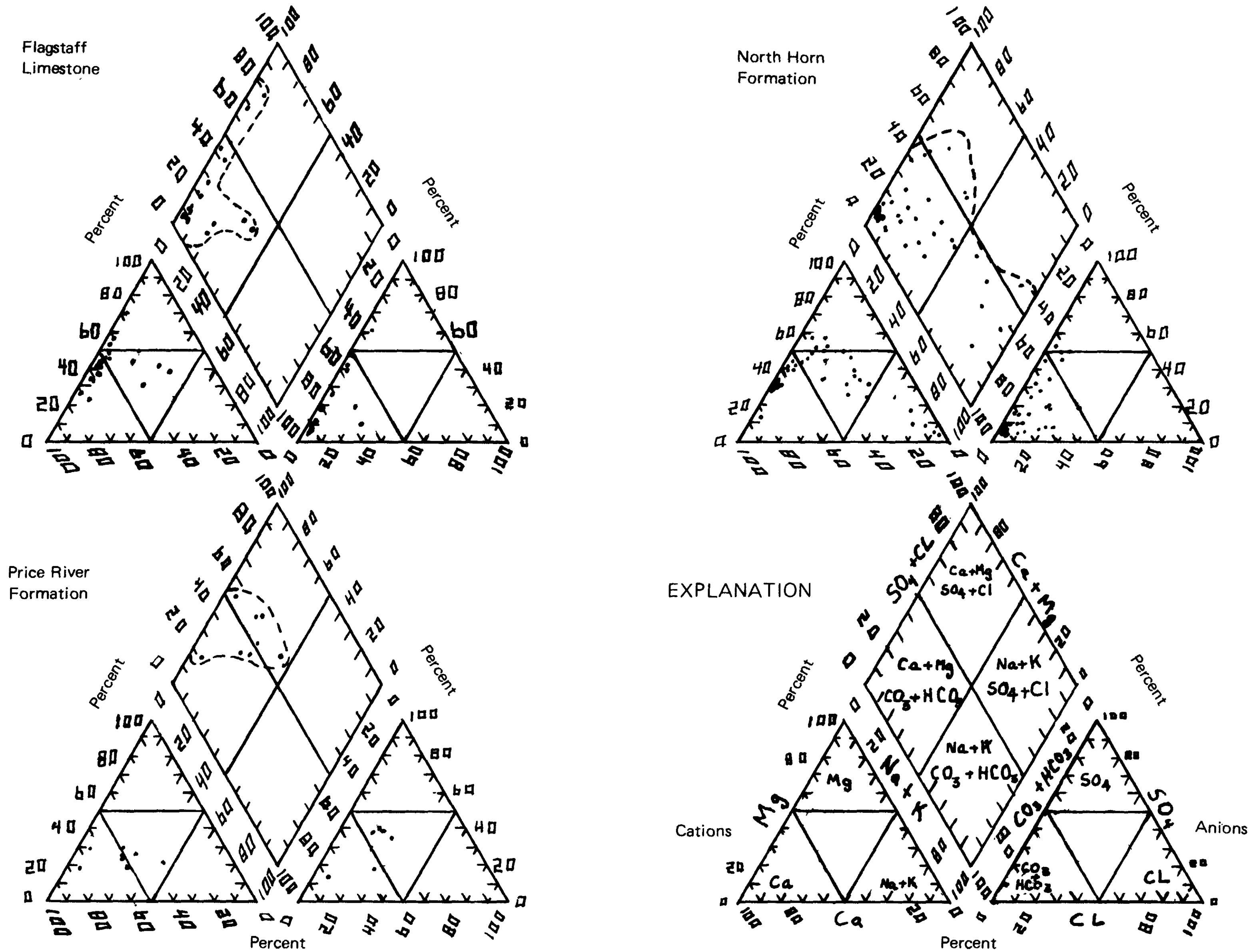

Figure 16.—Percentage composition of major chemical constituents in spring waters from three geologic units in the southern Wasatch Plateau.

HYDROLOGIC EFFECTS OF COAL MINING

The effects of underground coal mining on the water resources of the study area mainly are dependent on the degree of mine dewatering and the magnitude and areal extent of mine-related land subsidence. Increased sediment yield from mine surface facilities (roads, parking lots, and coal-stockpile areas) is a potential impact on surface-water quality, but this is an impact that can be minimized with proper construction, drainage, and maintenance techniques.

Dewatering of mines doubtless will affect the local hydrologic system; however, there are insufficient data from which to quantify the actual effects on aquifers or ground-water recharge, discharge, or storage. Natural discharge and storage probably will be decreased proportionately; recharge could be increased (at the expense of overland runoff) to offset the increased discharge. The quality of ground water that will be encountered during future mining can be predicted with some degree of accuracy based on available chemical analyses of spring waters in the area. This allows for some prediction of the effect on the quality of a stream that may receive excess mine water.

The extent of land subsidence over an underground coal mine is a function of the thickness of the coal being removed, the thickness and competence of rocks over the mine, and the methods used to remove the coal. Overburden above the SUFCo Mine, for example, is approximately 800 feet thick. Removal of coal has resulted in more than 8 feet of surface subsidence over some mine areas. Tension cracks associated with the subsidence (fig. 17) could affect both ground and surface waters.

Figure 17.—Tension crack in soil above the SUFco Mine, in the NE¼ sec. 1, T. 22 S., R. 4 E.

Room-and-pillar mining has been the most common method of coal extraction in the Wasatch Plateau. As this method is replaced by the more productive longwall method, subsidence may have more immediate and evident effects on the hydrologic system. In the longwall method, the roof of the mine is permitted to immediately collapse behind the mining machinery. It allows for recovery of coal that would be left for roof support by the room-and-pillar method.

Effects on ground water

Theis (1957, p. 3) points out that water discharged from a well must be balanced by an increase in recharge to the ground-water system, by a decrease in natural discharge from the system, by a decrease of ground water in storage, or by a combination of all these. Water discharged from underground mines produces the same changes in the ground-water system as do wells. In the following discussion, Theis' explanation is used to analyze the possible changes in the ground-water system that result from removing water from the Star Point-Blackhawk aquifer by dewatering underground mines. The analysis is complicated somewhat by the additional factor of subsidence and associated rock fracturing, which could cause an increase in the hydraulic connection between the Star Point-Blackhawk aquifer and overlying water-bearing zones.

Water in storage in the Star Point-Blackhawk aquifer has decreased around the SUFCo Mine as indicated by the decrease of ground-water flow into the older workings. However, historic water-level data from observation wells are not available to define the extent and degree of the depletion.

Where subsidence is not extensive and where water-bearing zones that overlie the Star Point-Blackhawk aquifer are perched, it is unlikely that mine dewatering would induce greater recharge to the ground-water system. Neither is it likely under these conditions that the flow of springs that issue from the perched zones or the rate of natural downward leakage into the Star Point-Blackhawk aquifer would be affected by mine dewatering. However, natural recharge and discharge relationships can change if hydraulic connection between the perched zones and the Star Point-Blackhawk aquifer is increased by fracturing due to subsidence.

If water-bearing zones above the Star Point-Blackhawk aquifer are not perched, then mine dewatering from the aquifer and the associated lowering of hydraulic head in the aquifer will induce additional downward leakage from overlying zones. The increased downward leakage into the Star Point-Blackhawk aquifer will in turn be balanced by changes in recharge, discharge, and (or) water in storage in the aquifer and in the overlying water-bearing zones. All the changes in the ground-water system become more significant with increased hydraulic connection caused by subsidence.

It is unlikely that mine dewatering will cause significant changes in the chemical quality of ground water, because the chemical character of water in the different water-bearing zones at any one location usually is similar. If any change occurs, it could be a decrease in the concentrations of dissolved solids, because the increased flow rate toward a dewatered mine could decrease the time that water will be in contact with minerals in the rock.

Effects on surface water

Coal mining in the Wasatch Plateau could impact the quantity and quality of surface waters. If not properly controlled, the construction of surface facilities can release oil and grease into the streams and increase erosion and sediment loads. In some instances, the mine dewatering process may change the directions of ground-water movement, and ground-water discharge and resultant streamflow in other drainages could be decreased. If mine water is discharged into streams, the flow downstream from the mine would increase, however, mine dewatering may decrease streamflow upstream by decreasing spring discharges in the upland areas. Although the quality of water entering a mine probably would be about the same quality as water in nearby streams, quality generally deteriorates as the water moves through the mine workings; therefore, mine effluent entering streams could deteriorate the quality of the surface water.

NEEDED STUDIES AND MONITORING

To fully assess hydrologic impacts throughout a mined basin, comprehensive studies are needed to define aquifer characteristics, potentiometric surfaces, directions of ground-water movement, hydraulic connection between water-bearing zones, and recharge-discharge relationships. Monitoring of water levels in properly constructed observation wells, each completed in a single water-bearing zone, is needed near existing mines and in areas proposed for mining. A detailed study of the past and present occurrence and quality of water in underground mines also is needed.

Monitoring of discharge and water quality in streams, both upstream and downstream from mine areas, should be useful in detecting major changes that may occur in the future. Minor changes in surface-water quality probably can be detected and quantified only with increased monitoring of mine discharges.

Discharge-recession curves could be used to detect unnatural changes in the flow of some springs. The magnitude and duration of spring discharge is controlled by the physical characteristics of the water-bearing zone supporting the flow. The magnitude of spring discharge is dependent directly on permeability and hydraulic head in the aquifer; the duration of spring discharge (the discharge recession) is related directly to storage in the aquifer. Because the physical characteristics of an aquifer normally do not change, a unique spring discharge should occur at all levels of hydraulic head. Moreover, as water drains from the aquifer, the discharge-recession curves should be similar (should be parallel) from year to year for similar ranges in discharge if the physical characteristics of the aquifer remain unchanged.

Care needs to be taken in selecting springs for monitoring. The discharge-recession curves of springs that yield water from more than one water-bearing zone may not be similar from year to year because of nonconformity of recharge to the different zones from year to year. Also, algae and plant roots could clog the plumbing used at developed springs, resulting in an unnatural change in flow characteristics. Ideally, the monitoring of spring discharges needs to be in conjunction with water-level monitoring in observation wells, in order to detect recharge that may occur during the normal recession period and that would alter the recession curves.

Periodic sampling of benthic invertebrates downstream from mine areas could be used to detect short-term slugs of pollutants that may enter streams. Samples collected thus far in the study area indicate that there probably is a fairly large natural variation in diversity of organisms at a given site within the same season in different years. Additional samples are needed to adequately document natural variations in the benthic-invertebrate population that occur annually and seasonally. Future changes than can be accurately evaluated.

Changes in water-quality characteristics, such as pH, dissolved solids, and trace metals, due to mining activities have been shown to affect benthic invertebrates. Unnatural changes in the benthic-invertebrate population may be manifest by changes in diversity index, number of species, number of individual organisms, or the presence or absence of a particular species. Increases in the concentrations of organic matter and sediment also affect benthic invertebrates. Members of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddis flies) are especially susceptible to population decreases from increased sediment.

SUMMARY AND CONCLUSIONS

Annual surface-water discharge in the study area is mostly from snowmelt. About 46 to 68 percent of the annual discharge at four gaging stations occurred each year during the April-June snowmelt period. About 5 to 29 percent of the average annual precipitation on a given drainage becomes streamflow. Large variations in the quantities of evaporation and sublimation are believed to be the reasons for large variations in runoff.

Chemical quality of the surface waters in the study area generally was suitable for most uses, and no analyzed chemical constituents were present in concentrations that exceeded drinking-water standards (U.S. Environmental Protection Agency, 1976). Dissolved-solids concentrations in 61 surface-water samples ranged from 97 to 835 milligrams per liter. Predominant ions in most surface waters were calcium, magnesium, and bicarbonate. The average suspended-sediment concentration at 15 sites during fair weather was about 60 milligrams per liter.

Water occurs in all geologic units above and including the Star Point Sandstone. The Star Point and much of the Blackhawk Formation are saturated in most areas, and the Star Point-Blackhawk aquifer is the source of water draining into in the underground SUFCo Mine. Future mining operations also can be expected to drain water from this aquifer.

Most of the larger springs in the study area issue from the Flagstaff Limestone near its contact with the North Horn Formation; the springs generally are near recharge areas. It is not known whether water in the Flagstaff and North Horn is perched.

Dissolved-solids concentrations in water from 87 springs throughout the study area ranged from 105 to 1,080 milligrams per liter. The predominant dissolved chemical constituents usually were calcium, magnesium, and bicarbonate. Some samples from the North Horn Formation contained relatively large concentrations of sodium.

Dewatering of the Star Point-Blackhawk aquifer by the SUFCo Mine was the largest manmade discharge from the aquifer in the study area during 1980. There has been some depletion of storage in the aquifer around the mine, but water-level data are not available to define the extent of depletion. Other possible impacts on the ground-water system that could be caused by mine dewatering include the decrease of spring flows that supply the base flows of streams and perhaps increases in ground-water recharge. Both of these impacts are most likely to occur in areas where there has been land subsidence. While the flow of some streams may decrease as the stream-aquifer systems are altered by mine dewatering and subsidence, others may increase from mine effluents.

Although the quality of water entering a mine may be of similar chemical quality to water in nearby streams, quality generally deteriorates as the water moves through the mine workings. Therefore, mine effluents entering streams could deteriorate the quality of surface water. The degree of degradation of the quality of streamflow resulting from mine effluents cannot be quantified, however, because it is not known how much or where the mine waters would have been discharged naturally by springs.

To fully assess the hydrologic impacts of underground coal mining, comprehensive studies of the ground-water system are needed in conjunction with monitoring of the quantity and quality of both surface water and mine effluents. Benthic invertebrates, good indicators of the "health" of a stream, may be useful to detect possible pollutants that may enter streams. Monitoring the discharge of individual springs to develop discharge-recession curves, in conjunction with water-level monitoring in wells, is needed in mine areas to detect unnatural changes in the ground-water system.

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Table 3.—Summary of benthic invertebrates collected from streambeds, 1979-80

Stream	Site No. (see pl. 1)	August 7, 1979 Diversity index	August 7, 1979 Number of species	August 7, 1979 Number of individuals	August 21, 1980 Diversity index	August 21, 1980 Number of species	August 21, 1980 Number of individuals
Straight Canyon	6	3.58	42	2,079	3.85	35	221
Ferron Creek	8	4.05	36	131	2.89	29	140
Dairy Creek	13	3.30	38	1,127	1.98	18	510
Ferron Creek	18	4.08	38	239	3.11	28	181
Muddy Creek	29	3.99	28	99	3.71	45	402
	36	4.11	29	148	3.61	26	76
North Fork Quitchupah Creek	41	2.70	41	681	3.24	32	133
South Fork Quitchupah Creek	49	3.04	31	637	1.98	35	750
North Fork Quitchupah Creek	52	2.08	29	388	2.49	21	167
East Spring Canyon	60	2.13	16	100	.96	4	22
Ivie Creek	81	2.90	37	1,670	3.45	35	1,294

Table 4.—Discharge, specific conductance, pH, and temperature of water in streams, 1978-80

Discharge: Current-meter or flume measurement except E, estimated.

Specific conductance: In micromhos per centimeter at 25 degrees Celsius. All are field values.

Other data available: B, population of benthic invertebrates in table 8; C, chemical analysis in table 5; S, sediment concentration in table 6.

Drainage basin	Stream	Site No. (see pl. 1)	Date	Discharge (ft^3/s)	Specific conductance	pH (units)	Temperature (°C)	Other data available
Cottonwood Creek	Lowry Water	1	11- 9-78	9.4	480	7.4	3.5	–
	Littles Creek	2	11- 9-78	1.0	420	7.3	0.0	–
	Seeley Creek	3	11- 9-78	6.2	620	7.2	0.5	–
	Swasey Creek	4	11- 9-78	0	–	–	–	–
	North Dragon Creek	5	11- 9-78	0	–	–	–	–
	Straight Canyon	6	11- 9-78	7.7	445	7.4	6.0	–
			8- 7-79	112	–	B.3	9.5	B,C,S
Ferron Creek	Ferron Creek	8	10-19-78	10.6	380	–	3.5	–
	Big Bear Creek	9	10-19-78	4.8	500	–	6.5	–
	Wrigley Creek	11	10-19-78	.42	440	–	6.0	–
	Dairy Creek	14	10-19-78	0	–	–	–	–
	Black Canyon	15	10-19-78	.02	610	–	15.0	–
	Ferron Creek	16	10-19-78	15.0	530	–	7.5	–
	Stevens Creek	17	10-19-78	.20	500	–	9.0	–
	Birch Creek	19	10-19-78	.04	1,550	–	13.0	–
	Ferron Creek	20	10-19-78	16.3	570	–	10.5	–
		B	8- 9-79	20.3	465	8.6	16.5	B,C,S
	Dairy Creek	13	8-10-79	.12	480	B.2	14.5	B,C,S
	Ferron Creek	18	8-15-79	46.3	485	B.7	12.0	C,S
			8-17-79	37.2	520	8.B	14.0	B,C,S
			5-15-80	149	520	8.4	6.0	C,S
	Big Bear Creek	10	9-19-80	6.9	–	–	–	–
	Wrigley Creek	11	9-19-80	1.0E	–	–	–	–
	Ferron Creek	12	9-19-80	24.1	–	–	B.0	C
	Dairy Creek	14	9-19-80	.11	–	–	–	–
	Ferron Creek	16	9-18-80	22.0	–	–	–	–
	Stevens Creek	17	9-18-80	.5	–	–	11.5	C
	Birch Creek	19	9-18-80	.4	500	–	9.0	C
	Ferron Creek	21	9-18-80	24.0	–	–	12.5	C,
Muddy Creek	North Fork Muddy Creek	27	10-18-78	9.3	360	–	6.0	–
	South Fork Muddy Creek	28	10-18-78	14.3	360	–	7.5	–
	Horse Creek	30	10-18-78	1.1	440	–	8.0	–
	Greens Canyon	32	10-18-78	0	–	–	–	–
	Muddy Creek	31	10-18-78	24.2	400	–	7.5	–
		34	10-18-78	24.2	400	–	7.5	–
	Last Water	37	10-18-78	.01	580	–	10.0	–
	The Box	35	10-18-78	0	–	–	–	–
	Muddy Creek	29	B- 3-79	100E	400	8.4	15.0	B,C,S
	North Fork Muddy Creek	22	10- 2-79	.07	350	–	6.0	–
		23	10- 2-79	3.15	310	–	8.0	–
	Unnamed tributary	24	10- 2-79	.27	–	–	–	–
		25	10- 2-79	.71	–	–	–	–
	North Fork Muddy Creek	26	10- 2-79	4.9	–	–	–	–
	Muddy Creek	36	5-16-80	77.2	460	8.8	B.5	C,S
		28	9-18-80	26.6	400	–	9.5	C
	Horse Creek	30	9-18-80	2.B	–	–	14.0	–
	Greens Canyon	32	9-18-80	.32	–	–	8.5	–
	Scab Hollow	33	9-18-80	.14	–	–	12.5	–
	The Box	35	9-18-80	.20	–	–	13.5	–
	Muddy Creek	36	9-19-80	30.3	–	–	12.0	C,
	Last Water	37	9-18-80	.10	–	–	17.0	–
	Muddy Creek	38	9-18-80	30.3	–	–	15.0	–
		39	9-18-80	29.9	410	8.7	15.5	C

Table 4.—Discharge, specific conductance, pH, and temperature of water in streams, 1978-80—Continued

Drainage basin	Stream	Site No. (see pl. 1)	Date	Discharge (ft³/s)	Specific conductance	pH (units)	Temperature (°C)	Other data available
Quitchupah Creek	Convulsion Canyon	55	10-17-78	0	–	–	–	–
	Unnamed tributary	56	10-17-78	0	–	–	–	–
	Broad Hollow	57	10-17-78	0	–	–	–	–
	Convulsion Canyon	58	10-17-78	.02	960	–	10.0	–
	East Spring Canyon	59	10-17-78	.63	650	–	12.5	–
	North Fork Quitchupah Creek	41	11- 7-78	.13	600	–	0.0	–
		42	11- 7-78	.08	590	7.2	0.0	–
	Unnamed tributary	43	11- 7-78	.01	410	–	0.0	–
	South Fork Quitchupah Creek	49	11- 7-78	.02	1,000	–	0.0	–
		50	11- 7-78	.03	590	7.2	0.0	–
	North Fork Quitchupah Creek	51	11- 7-78	.25	670	7.1	4.5	–
		52	11- 7-78	.20	670	7.2	8.0	–
	North Water Hollow	63	11- 8-78	.04	900	7.3	5.5	–
		64	11- 8-78	.01	1,210	7.2	4.5	–
	South Water Hollow	65	11- 8-78	0	–	–	–	–
	Water Hollow	66	11- 8-78	0	–	–	–	–
	South Fork Quitchupah Creek	49	7-31-79	.83	535	8.1	15.0	B,C,S
	East Spring Canyon	60	8- 2-79	.64	790	7.9	16.0	B,C,S
	North Fork Quitchupah Creek	51	8- 8-79	.90	490	8.5	19.0	B,C,S
		41	8- 1-79	.61	540	8.1	19.5	B,C,S
		40	10- 3-79	.14	350	–	11.0	–
		41	10- 3-79	.28	440	–	14.5	–
	South Fork Quitchupah Creek	44	10- 4-79	.47	390	–	–	–
		45	10- 4-79	.30	–	–	–	–
	Unnamed tributary	46	10- 4-79	.01	650	–	9.0	–
	South Fork Quitchupah Creek	47	10- 4-79	18	–	–	–	–
		48	10- 4-79	.16	–	–	–	–
	North Fork Quitchupah Creek	54	5-15-80	22.4	450	8.2	11.0	C,S
	Quitchupah Creek	68	5-15-80	7.3	850	7.8	12.0	C,S
	Convulsion Canyon	58	9-17-80	.04	–	–	6.5	C
	East Spring Canyon	60	9-17-80	.13	–	–	13.5	C
	Convulsion Canyon	61	9-17-80	–	–	–	11.5	C
		62	9-17-80	.31	–	–	8.0	C
	Water Hollow	67	9-17-80	.55	–	–	10.0	C
	Quitchupah Creek	68	9-17-80	.80	–	–	12.5	C
	North Fork Quitchupah Creek	41	9-18-80	.45	–	–	15.0	C
		42	9-18-80	53	–	–	7.0	–
	Unnamed tributary	43	9-18-80	.03	–	–	7.5	–
	South Fork Quitchupah Creek	50	9-18-80	.47	–	–	6.0	–
	North Fork Quitchupah Creek	51	9-18-80	1.14	–	–	8.0	–
		53	9-18-80	.84	–	–	6.5	C
		54	9-17-80	1.05	–	–	15.0	QW
Ivie Creek	Tommy Hollow	75	10-17-78	.006	960	–	11.0	–
		76	10-17-78	0	–	–	–	–
	Draw Creek	77	10-17-78	.003	2,400	8.5	8.5	–
	Tommy Hollow	78	10-17-78	.08	–	–	–	–
	Red Creek	79	10-17-78	1.08	400	–	8.0	–
	Ivie Creek	80	10-17-78	1.24	560	–	7.5	–
		81	8-16-79	6.0	335	8.7	15.0	B,C,S
			5-15-80	16.4	450	8.5	9.5	C,S
		82	9-17-80	.20	1,380	–	–	–
		83	9-17-80	.29	1,400	–	–	–
	Oak Spring Creek	74	9-17-80	.10	–	–	–	–
	Saleratus Creek	69	10-17-78	.02	450	–	9.0	–
		70	10-17-78	.01	1,100	–	8.5	–
	Trough Hollow	72	9-18-80	.23	3,110	–	–	–
	Saleratus Creek	71	9-18-80	.13	1,280	–	12.0	–
		73	9-18-80	.41	4,320	–	13.0	–

Concentration: In milligrams per liter unless otherwise specified.
Discharge. Current-meter or flume measurement except E, estimated.
Specific conductance: In micromhos per centimeter at 25 degrees Celsius.' Field values except L, Laboratory determination.
SAR: Sodium-adsorption ratio (Hem, 1970, p. 228-229).
Other data available: B, population of benthic invertebrates in table 8; S, sediment concentration in table 6.

Drainage basin	Stream	Site No. (see pl. 1)	Date	Discharge (ft^3/s)	Temperature (^oC)	pH	Specific conductance	SAR	Alkalinity (as $CaCO_3$)	Dissolved calcium (Ca)	Dissolved chloride (Cl)	Dissolved fluoride (F)
Cottonwood Creek	Littles Creek	2	8-25-77	0.3	22.5	8.4	350	0.5	180	30	5.3	0.1
			8- 7-78	30	11.5	7.7	300	.1	180	58	2.6	.1
	Seeley Creek	3	8-25-77	5	18.5	8.2	470	.6	170	43	4.1	.2
			6- 7-78	240	10.5	7.6	320	.1	180	47	2.6	.1
	Swasey Creek	4	8-25-77	.01	25.0	8.5	510	3.4	230	27	17	.4
			6- 7-78	5	11.0	7.7	380	.6	200	40	4.6	.3
	North Dragon Creek	5	6- 7-78	.3	22.0	7.9	830	1.7	340	36	28	.5
	Straight Canyon	6	8-25-77	26	12.0	8.3	340	.4	190	41	5.6	.1
			6- 7-78	119	10.0	7.6	370	.4	190	41	6.1	.1
			8- 7-79	112	9.5	8.3	410	.3	150	44	3.7	.1
			5-16-80	100	13.0	8.4	460	.5	200	40	8.4	0
			8-21-80	200E	10.0	8.8	410	.3	190	42	5.4	.1
Ferron Creek	Ferron Creek	8	8- 9-79	20	16.5	8.6	465	.2	160	41	5.4	.1
			8-20-80	30E	6.0	–	480	.2	210	43	3.2	.3
		12	9-17-80	24	8.0	–	505L	.3	210	48	5.1	.3
	Dairy Creek	13	8-10-79	.12	14.5	8.2	480	.3	210	17	4.9	.2
			8-20-80	1.5E	10.0	–	500	.3	210	48	5.9	.2
	Stevens Creek	17	6- 8-78	1.0	21.0	8.4	420	.6	220	44	5.6	.3
			9-20-80	.5	11.5	–	440L	.5	220	36	10	.2
	Ferron Creek	18	8-19-77	5	19.0	8.2	490	.5	190	43	7.7	.3
			6- 8-78	315	11.0	8.1	340	.2	180	48	2.3	.2
			8-15-79	46	12.0	8.7	485	.4	190	46	3.8	.2
			8-17-79	37	14.0	8.8	515	.3	200	50	3.7	.2
			5-15-80	149	6.0	8.4	520	.8	220	44	10	.1
			8-20-80	35E	11.0	8.9	500	.3	190	47	4.6	.3
	Birch Creek	19	9-19-80	.36	9.0	–	500	1.1	250	34	11	.3
	Ferron Creek	21	9-19-80	24	12.5	–	510L	.5	210	49	8.2	.3
Muddy Creek	Muddy Creek	29	8- 3-79	100	15.0	8.4	400	.1	180	41	2.3	.3
			8-20-80	45E	10.5	–	405	.2	180	41	3.0	.3
			9-18-80	26	9.5	–	390L	.2	190	43	4.0	.3
	Horse Creek	30	9-18-80	2.8	14.0	–	480L	.8	230	36	12	.3
	Greens Canyon	32	9-18-80	.32	8.5	–	780L	1.9	310	38	42	.3
	Muddy Creek	36	8-16-79	51	14.5	8.6	395	.2	190	43	2.4	.3
			5-18-80	77	8.5	8.8	480	.7	230	49	8.1	.1
			8-20-80	50E	10.5	8.7	460	.2	190	41	3.8	.3
			9-18-80	30	12.0	–	390L	.3	190	41	3.9	.3
		39	9-18-80	30	15.5	–	425	.3	190	42	4.4	.2
Quitchupah Creek	North Fork Quitchupah Creek	41	8- 1-79	.61	19.5	8.1	540	.7	180	41	8.6	.3
			8-21-80	3E	7.5	–	545	1.0	240	51	16	.3
			9-18-80	.44	14.5	–	570L	1.2	240	49	21	.3
	South Fork Quitchupah Creek	49	7-31-79	.93	15.0	8.1	535	.1	210	58	7.2	.4
			8-21-80	3E	8.0	8.8	565	.6	220	54	10	.4
		50	9-18-80	.47	6.3	8.7	660	.7	230	55	15	.4
	North Fork Quitchupah Creek	51	8- 8-79	.9	19.0	8.5	490	.7	160	38	8.2	.3
			8-21-80	5E	5.0	8.8	620	.8	220	50	14	.4
		53	9-18-80	.84	8.5	8.7	660L	1.0	230	50	21	.3
		54	5-15-80	22	11.0	8.2	450	1.5	160	32	14	.1
			9-17-80	1.0	15.0	–	740L	1.2	230	55	24	.3
	Convulsion Canyon	58	9-18-80	.04	6.5	–	1,270L	.9	350	95	37	.2
	East Spring Canyon	59	6- 2-79	–	2.0	7.5	175	.2	62	19	4.7	.1
		60	8- 2-79	.54	16.0	7.9	690	.5	230	72	15	.3
			8-21-80	1.5E	11.5	8.7	630	.5	200	55	12	.3
			9-17-80	.13	13.5	–	670L	.5	290	82	23	.2
	Convulsion Canyon	81	9-17-80	.17	11.5	–	900L	.6	300	83	26	.2
		62	9-17-80	.31	8.0	–	860L	1.1	260	63	26	.3
	Quitchupah Creek	68	5-15-80	7.3	12.0	7.8	850	1.0	210	59	32	.1
			9-17-80	.81	12.5	–	1,140L	2.6	290	54	42	.2
	Water Hollow	67	9-18-80	.55	10.0	–	1,220L	2.9	320	59	51	.7
	Ivie Creek	81	8-18-79	6	16.0	8.7	335	.3	120	35	13	.2
			5-15-80	16	9.5	8.5	460	.5	140	50	21	.1
			8-20-80	15E	15.0	–	360	.3	110	33	14	.2

Concentration													
Noncarbonate hardness	Total hardness	Dissolved iron (Fe) (ug/L)	Dissolved magnesium (Mg)	Dissolved manganese (Mn) (ug/L)	Dissolved nitrite plus nitrate ($NO_2 + NO_3$)	Dissolved oxygen (O_2)	Dissolved potassium (K)	Dissolved solids	Dissolved silica (SiO_2)	Dissolved sodium (Na)	Dissolved sulfate (SO_4)	Other data available
0	170	–	22	–	–	–	1.0	199	5.4	16	11	–
22	200	–	14	–	–	–	.5	198	3.6	4.4	6	–
50	220	–	28	–	–	–	1.2	268	5.1	20	63	–
11	190	–	18	–	–	–	.5	196	3.1	4.3	12	–
0	130	–	15	–	–	–	5.2	349	6.5	90	5.0	–
0	190	–	21	–	–	–	.5	227	5.8	20	16	–
42	380	–	70	–	–	–	3.5	569	14	75	140	–
6	200	–	23	–	–	–	1.0	224	3.9	12	24	–
17	210	–	25	–	–	–	.9	226	3.0	13	23	–
46	200	20	21	3	0.21	–	.9	196	4.4	8.9	22	B,S
0	200	100	24	6	1.1	–	1.2	254	4.2	17	34	–
0	190	10	20	7	.16	12.2	.9	219	4.2	10	21	B,S
70	230	40	31	2	.66	–	.7	235	5.7	6.1	47	B,S
13	220	20	26	2	.23	12.0	.6	258	5.7	6.3	41	B,S
38	250	20	31	3	.06	–	1.1	290	5.1	12	61	–
0	170	<10	30	<1	.53	–	1.2	209	7.1	10	9.5	B,S
16	230	20	27	3	.70	11.6	1.0	228	6.3	8.6	3.8	B,S
5	230	–	28	–	–	–	1.3	253	3.7	21	17	–
2	220	10	32	1	.53	–	1.4	253	4.9	17	17	–
46	240	–	31	–	–	–	3.2	296	6.0	19	72	–
37	200	–	21	–	–	–	.8	208	5.4	5.3	28	–
44	230	80	29	4	.41	–	1.2	278	5.7	13	63	S
53	250	50	31	4	.13	–	10	285	5.4	11	62	B,S
0	210	30	24	<3	.04	–	1.6	295	5.6	28	49	S
51	240	10	30	4	.13	11.9	.9	271	5.2	12	56	B,S
0	210	30	30	3	.31	–	1.9	296	6.6	38	22	–
48	260	20	33	6	.01	–	1.4	306	5.0	20	63	–
25	210	10	25	0	2.2	–	.6	210	5.6	4.6	12	B,S
9	190	30	21	4	.43	11.3	.6	197	6.2	5.0	9.6	B,S
12	200	20	23	3	.50	–	.7	220	5.8	5.2	22	–
0	220	40	31	3	.12	–	1.6	279	6.4	28	23	–
0	260	50	40	4	.02	–	2.8	442	1.9	71	53	–
16	210	20	24	3	.78	–	.9	218	5.6	6.4	17	B,S
0	220	10	23	3	.08	–	1.5	266	6.3	22	17	S
3	190	20	22	2	.54	11.4	.6	209	5.8	7.4	11	B,S
11	200	20	24	2	.41	–	1.0	217	6.3	10	14	–
16	210	20	25	1	.48	–	1.0	221	6.0	9.6	16	–
13	190	10	22	0	.02	–	1.0	238	6.4	22	28	B,S
0	230	20	24	4	0	11.2	1.1	316	7.1	35	37	B,S
0	240	120	28	10	.04	–	1.9	344	7.9	44	47	–
71	280	20	33	10	.31	–	1.7	333	7.2	4.8	93	B,S
47	270	30	32	10	.11	11.7	1.3	346	7.2	22	86	B
39	270	70	32	8	0	–	1.7	369	8.0	27	92	–
50	210	20	28	<1	.01	–	1.4	277	7.1	22	76	B,S
28	250	20	30	3	0	11.2	1.4	335	7.3	28	72	B
39	270	30	35	7	0	–	1.9	402	7.7	38	110	–
0	130	410	13	10	.11	–	3.1	260	8.9	39	53	S
68	300	40	39	10	0	–	2.2	455	6.2	48	140	S
270	620	30	92	8	.36	–	5.1	635	12	52	330	–
15	77	100	7.2	10	.36	–	4.3	97	6.3	3.9	13	–
140	370	10	45	10	.11	–	2.5	444	9.5	21	140	B,S
61	260	10	35	5	0	10.6	2.5	366	10	21	110	B,S
100	390	10	45	20	.06	–	3.3	472	12	21	110	–
150	450	30	59	20	.20	–	3.9	555	13	29	160	–
99	360	20	49	6	.04	–	3.2	538	11	49	180	–
61	290	100	35	8	.02	–	3.0	423	9.3	38	120	S
47	340	60	49	10	.12	–	3.1	685	12	110	240	–
68	390	40	58	10	.01	–	3.4	779	14	130	270	–
25	150	20	14	20	.12	–	2.4	192	15	9.4	30	B,S
67	210	60	20	10	.20	–	2.4	281	16	15	51	S
30	140	70	14	20	.06	10.7	2.0	182	16	9.3	27	B,S

Table 6.—Concentrations of suspended sediment in surface water, 1979-80

Discharge: Current-meter or flume measurement except E, estimated.

Drainage basin	Stream	Site No. (see pl. 1)	Date	Discharge (ft³/s)	Concentration (mg/L)
Cottonwood Creek	Straight Canyon	6	8- 7-79	112	15
			8-21-80	200E	38
Ferron Creek	Ferron Creek	8	8- 9-79	20	24
			8-20-80	30E	33
	Dairy Creek	13	8-10-79	.12	86
			8-20-80	1.5E	44
	Ferron Creek	18	8-15-79	46	196
			8-17-79	37	68
			5-15-80	149	1,720
			8-20-80	35E	45
	do.	21	7-14-80	—	36,500
Muddy Creek	Muddy Creek	29	8- 3-79	100	67
			8-20-80	45E	24
	do.	36	8-16-79	51	127
			8-20-80	50E	34
			5-16-80	77	312
Quitchupah Creek	North Fork Quitchupah Creek	41	8- 1-79	.61	62
			8-21-80	3E	73
	do.	51	8- 8-79	.9	41
			8-21-79	5E	66
	do.	54	5-15-80	22	10,900
	South Fork Quitchupah Creek	49	8-21-80	3E	65
	Quitchupah Creek	68	5-15-80	7.3	5,260
	East Spring Canyon	60	8- 2-79	.64	62
			8-21-80	1.5E	46
	Convulsion Canyon	61	8-21-80	—	64
Ivie Creek	Ivie Creek	81	8-16-79	6	146
			5-15-80	16	606
			8-20-80	15E	38

Table 7.—Mineralogic analyses of streambed material, 1980

[Analysis by Mary Jo Sweeney, Consulting Mineralogist, Salt Lake City, Utah, using X-ray diffraction techniques. Percentages of minerals in less than 0.002-millimeter size fraction of sample determined using method of Shultz (1964). Percentage of size fraction: By weight except visual estimate, by volume; tr, trace.]

Stream	Site No. (see pl. 1)	Date	Size fraction (millimeters)	Percentage of size fraction																	
																			Visual estimate		
				Quartz	Potassium feldspar	Plagioclase	Calcite	Dolomite	Ankerite	Rhodochrosite	Geothite	Jarosite	Clay	Chlorite	Kaolinite	Illite	Montmorillonite	Mixed-layer clay	Organic	Pyrite	Coal
Ferron Creek	8	9-19-80	<4.78	60	3	.1	14	4	4	2	2	–	–	.3	1	2	3	3	–	–	–
			0.062 to 4.76	59	3	0	14	4	4	2	2	0	9	–	–	–	–	–	0	0	0
			<0.062	60	8	1	6	3	1	1	0	–	16	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	3	12	18.3	36	32	–	–	–
Dairy Creek	13	9-19-80	<4.76	40	2	1	17	5	5	3	0	–	–	0	2	2	5	10	–	–	–
			0.062 to 4.76	38	1	1	21	6	6	4	0	tr	11	–	–	–	–	–	.5	tr	1
			<0.062	45	4	2	7	2	2	1	0	–	37	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	9	9.5	27	54	–	–	–
Ferron Creek	18	9-19-80	<4.76	34	7	0	23	10	4	3	2	–	–	0	1	1	2	4	–	–	–
			0.062 to 4.76	33	7	0	23	10	4	3	2	0	8	–	–	–	–	–	0	0	0
			<0.062	53	4	1	11	8	0	2	0	–	9	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	13	12	30	45	–	–	–
Muddy Creek	29	9-18-80	<4.76	16	3	1	25	20	9	4	0	–	–	0	5	5	7	8	–	–	–
			0.062 to 4.76	15	3	1	25	20	9	4	0	tr	6	–	–	–	–	–	0	0	0
			<0.062	47	4	2	10	5	1	3	2	–	10	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	22	21	27	30	–	–	–
	36	9-18-80	<4.76	47	6	.1	17	9	5	2	0	–	–	0	1	.7	3	4	–	–	–
			0.062 to 4.76	45	6	0	18	10	5	2	0	0	8	–	–	–	–	–	0	0	0
			<0.062	60	5	1	7	3	2	1	0	–	14	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	14	6	36	41	–	–	–
North Fork Quitchupah Creek	41	9-17-80	<4.76	71	4	2	5	2	1	.4	2	–	–	0	1	6	2	3	–	–	–
			0.062 to 4.76	74	3	1	5	2	1	0	2	0	8	–	–	–	–	–	0	0	0
			<0.062	60	6	6	4	3	1	2	2	–	26	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	12	49	14	25	–	–	–
	51	9-17-80	<4.76	67	8	1	11	5	1	2	.1	–	–	.2	1	1	2	4	–	–	–
			0.062 to 4.76	66	8	1	12	5	1	2	0	0	8	–	–	–	–	–	0	0	tr
			<0.062	70	6	1	4	3	1	1	0	–	10	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	2	12	12.9	21	52	–	–	–
South Fork Quitchupah Creek	49	9-17-80	<4.76	63	9	1	10	1	.3	1	1	–	–	0	1	3	2	5	–	–	–
			0.062 to 4.76	66	11	1	11	1	0	1	2	0	8	–	–	–	–	–	.5	0	0
			<0.062	57	5	1	7	2	1	1	0	–	21	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	0	12	24	19	45	–	–	–
East Spring Canyon	60	9-17-80	<4.76	71	1	1	7	8	.1	2	.1	–	–	.2	4	5	.4	2	–	–	–
			0.062 to 4.76	72	1	1	7	7	0	2	0	0	12	–	–	–	–	–	0	0	10
			<0.062	47	2	1	6	18	1	1	1	–	10	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	2	34	42	4	19	–	–	–
Ivie Creek	81	9-19-80	<4.76	75	11	.1	5	1	.2	4	0	–	–	0	.1	.1	0	.1	–	–	–
			0.062 to 4.76	75	0	0	5	1	0	4	0	0	0	–	–	–	–	–	0	0	0
			<0.062	71	8	1	10	2	2	1	0	–	5	–	–	–	–	–	–	–	–
			<0.002	–	–	–	–	–	–	–	–	–	–	3	28	24	10	36	–	–	–

Table 8.—Benthic invertebrates identified in samples collected from streambeds, 1979-80

Organism: Number of organisms collected with a 1-square-foot Surber sampler (see U.S. Geological Survey, 1977, p. 171-180). Organism identification and count by Hydrozoology, Roseville, Calif. Identified by order, . family, . . genus; Uid., unidentified.
Site: See plate 1.

Organism	Site 6 – Straight Canyon		Site 6 – Ferron Creek		Site 13 – Dairy Creek		Site 16 – Ferron Creek		Site 29 – Muddy Creek	
	8- 7-79	8-21-80	8- 9-79	8-20-80	8-10-79	8-20-80	8-17-79	8-20-80	8- 3-79	8-20-80
Enoplida	—	—	—	—	7	—	—			
. Tripylidae										
. . *Tobrilius*	—	—	—	—	7	—	—	—	—	—
Hydroida										
. Hydridae										
. . *Hydra* sp.	26	15	—	—	—	—	—	—	—	—
Tricladida										
. Planariidae										
. . *Polycelis coronata*	—	—	—	—	—	—	—	—	1	2
Haplotaxida										
. Tubificidae										
. . *Limnodrilus hoffmeisteri*	—	—	—	—	—	—	—	—	—	—
. . *Rhyacodrilus* sp.	7	1	—	—	—	—	—	—	—	1
. . Uid. sp.	—	—	—	—	—	—	—	—	—	—
. Naididae										
. . *Nais elinquis*	—	2	—	—	—	—	—	—	—	1
. . *Nais simplex*	4	—	—	—	—	—	—	—	—	—
. . *Ophidonais serpentina*	5	—	—	—	—	—	—	—	—	—
. Enchytraeidae										
. . *Enchytraeus* sp.	4	1	—	—	66	—	3	—	—	—
. Lumbricidae										
. . *Eisenella* sp.	1	1	—	—	—	1	—	—	—	—
Diptera										
. Ceratopogonidae										
. . *Palpomyia* sp.	—	—	—	—	—	—	—	—	—	—
. . *Bezzia* sp.	1	—	1	1	—	—	1	—	—	1
. . *Dasyhalea* sp.	—	—	—	—	—	—	—	—	—	1
. Tipulidae										
. . *Tipula* sp.	—	—	—	—	2	—	—	—	—	—
. . *Hexatoma* sp.	—	—	1	1	—	—	3	1	—	—
. . *Antocha* sp.	—	1	—	—	—	—	—	—	—	1
. . *Dactylolabis* sp.	—	—	—	—	—	—	—	—	—	—
. . *Pedicia* sp.	—	—	—	—	44	—	—	—	—	—
. . *Dicranota* sp.	—	—	—	—	—	1	—	—	—	—
. Psychodidae										
. . *Pericoma* sp.	—	—	—	—	1	1	—	—	—	—
. Simuliidae										
. . *Simulium* sp. B	—	—	6	8	58	327	3	2	6	10
. . *Simulium arcticum*	345	12	—	—	—	—	—	—	—	—
. . *Simulium argus*	—	—	—	—	—	—	—	—	—	1
. . *Simulium canadense*	—	—	—	—	—	—	—	—	—	—
. . *Simulium hunteri*	—	—	—	—	—	17	—	—	—	—
. . *Simulium vittatum*	20	2	—	—	—	—	2	—	—	—
. . *Metacnephia jeana*	—	—	—	—	—	—	—	—	—	—
. Stratiomyiidae										
. . *Euparyphus* sp.	—	—	—	—	—	1	—	—	—	—
. Empididae										
. . *Hemerodromia* sp.	—	—	—	—	—	—	—	—	—	—
. . *Wiedemannia* sp.	—	—	1	—	1	—	—	—	—	—
. . *Wiedemannia* sp. A	—	—	—	—	—	—	—	—	—	5
. . *Wiedemannia* sp. B	—	—	—	—	—	—	—	1	—	—
. . *Chelifera* sp.	1	1	2	—	1	—	—	2	—	1
. Ephydridae										
. . *Hydrellia* sp.	—	—	—	—	—	—	—	—	—	—
. Rhagionidae										
. . *Atherix variegata*	10	1	—	—	—	—	—	—	—	—
. Chironomidae										
. . *Procladius* sp.	1	—	—	—	—	—	—	—	—	—
. . *Psectrotanypus* sp.	—	—	—	—	—	—	—	—	—	—
. . *Ablabesmyia* sp.	—	—	—	—	—	—	—	—	—	—
. . *Thienemannimyia* group	—	—	—	—	—	—	6	1	—	—
. . *Diamesa* sp. A	—	—	—	—	—	—	—	—	2	—
. . *Pseudodiamesa* sp. A	—	1	—	—	—	—	—	—	—	—
. . *Odontomesa* sp.	—	—	—	—	1	—	—	—	—	—
. . *Brillia* sp.	—	—	—	—	11	—	—	—	—	—
. . *Corynoneura* sp.	—	—	1	1	9	1	—	1	—	1
. . *Cricotopus* sp. A	—	—	—	—	—	—	—	—	—	—
. . *Cricotopus* sp. B	—	—	—	—	—	4	—	—	—	—
. . *Cricotopus* sp. C	7	7	—	1	—	—	1	2	1	—
. . *Cricotopus* sp. D	—	—	—	—	—	—	—	—	—	—
. . *Cricotopus* sp. E	—	—	—	—	—	—	—	—	—	—
. . *Heterotrissocladius hirtapex*	2	1	3	—	—	—	6	4	—	—
. . *Heterotrissocladius oliveri*	—	—	1	2	14	—	6	1	3	1
. . *Ortbocladius* sp. A	67	7	1	1	22	—	—	3	1	34
. . *Ortbocladius* sp. B	133	13	1	—	—	—	1	1	5	2
. . *Orthocladius* sp. C	—	—	—	—	—	—	—	—	—	—
. . *Orthocladius* sp. D	—	—	—	—	—	8	—	—	—	—
. . *Orthocladius dorenus*	196	13	2	1	96	—	4	78	—	43
. . *Orthocladius obumbratus*	69	35	1	—	—	—	15	—	—	—
. . *Psectrocladius* sp.	1	—	—	—	1	—	—	—	1	—
. . *Psectrocladius* sp. A	—	1	—	—	—	—	—	—	—	—
. . *Psectrocladius* sp. C	—	—	—	—	—	3	—	—	—	—
. . *Smittia* sp.	12	—	—	—	—	—	—	—	—	—
. . *Trichocladius* sp. A	21	6	1	—	86	51	4	7	—	3
. . *Trichocladius* sp. B	—	—	—	—	35	—	—	—	1	—
. . *Microtendipes* sp.	—	—	—	—	3	—	—	—	—	—
. . *Phaenopsectra* sp.	—	1	—	—	—	—	—	—	—	—
. . *Polypedilum* sp.	3	—	—	—	—	—	—	—	—	—
. . *Constempellina* sp.	—	—	—	—	—	—	—	1	—	—
. . *Micropsectra* sp. A	1	—	—	1	2	—	3	—	2	1
. . *Micropsectra* sp. B	2	—	3	1	7	—	—	1	—	—
. . *Paracladopelma nais*	2	—	—	—	—	—	2	1	—	—
. . *Zavrelimyia* sp. A	1	—	—	—	1	—	—	—	—	—
. . *Borechlus* sp.	—	—	—	—	—	—	—	—	—	—
. . *Eukiefferiella* sp. A	39	6	1	—	—	—	2	—	1	2
. . *Eukiefferiella* sp. B	14	2	2	—	83	43	4	14	12	30
. . *Eukiefferiella* sp. C	—	—	—	—	—	—	—	—	—	2
. . *Eukiefferiella* sp. E	—	—	—	—	—	—	1	—	—	—
. Muscidae										
. . *Limnophora* sp.	—	—	—	—	3	—	—	—	1	—
. . *Lispe* sp.	—	—	—	—	—	—	—	—	—	—
. Dolichopodidae										
. . *Dolichopus* sp.	—	—	—	—	1	—	—	—	—	—
. . *Campsicnemus* sp.	—	—	—	—	—	—	—	—	—	—

Table 8.—Benthic invertebrates identified in samples collected from streambeds, 1979-80—Continued

Organism	Site 6 – Straight Canyon Cont.		Site 6 – Ferron Creek Cont.		Site 13 – Dairy Creek Cont.		Site 18 – Ferron Creek Cont.		Site 29 – Muddy Creek Cont.	
	8- 7-79	8-21-80	8- 9-79	8-20-80	8-10-79	8-20-80	8-17-79	8-20-80	8- 3-79	8-20-80
Diptera—Continued										
. Dixidae										
. . *Dixa* sp.	–	–	–	–	1	1	–	–	–	–
. Canaceidae										
. . *Canacaioides* sp.	–	–	–	–	–	–	–	–	–	–
. Tanyderidae										
. . *Protoplasa* sp.	–	–	–	–	–	–	–	–	–	–
Trichoptera										
. Hydropsychidae										
. . *Hydropsyche* sp.	26	–	2	–	–	–	33	–	–	–
. . *Arctopsyche grandis*	–	–	–	1	–	–	–	–	–	2
. . *Symphitopsyche* sp. A	–	3	–	–	–	–	–	7	–	–
. Rhyacophilidae										
. . *Rhyacophila* sp. D	–	–	–	–	–	–	–	–	–	–
. . *Rhyacophila acropedes*	–	–	–	1	–	–	–	–	–	1
. . *Rhyacophila angelita*	–	–	1	–	–	–	1	–	2	–
. . *Rhyacophila kernada*	4	2	–	1	–	–	–	–	–	–
. Hydroptilidae										
. . *Hydroptila* sp.	–	–	–	–	–	–	–	–	–	–
. . *Ochrotrichia* sp.	–	–	–	–	–	–	–	–	–	–
. Brachycentridae										
. . *Brachycentrus americanus*	11	–	–	–	–	–	1	–	–	–
. Limnephilidae										
. . *Hesperophylax*	–	–	–	–	9	–	–	–	–	–
Plecoptera										
. Pteronercidae										
. . *Pteronarcella badia*	–	1	2	1	–	–	2	1	–	1
. . *Pteronarcys californica*	1	–	–	–	–	–	–	–	–	–
. Nemouridae										
. . *Amphinemura* sp.	–	–	–	–	77	–	–	–	1	–
. . *Malenka* sp.	–	–	–	–	–	13	–	–	–	1
. . *Zapada* sp.	–	–	2	–	–	–	1	–	–	2
. Perlidae										
. . *Hesperoperla pacifica*	–	–	–	–	–	–	–	1	–	–
. Perlodidae										
. . *Isoperla fulva*	–	–	–	–	–	–	–	–	–	–
. . *Isogenoides zionensis*	9	2	1	–	–	–	5	1	3	–
. . *Megarcys* sp.	–	–	–	3	–	–	–	–	–	–
. . Uid. sp.	–	–	–	1	–	4	–	–	–	1
. Chloroperlidae										
. . *Alloperla* sp.	–	–	–	2	–	–	–	1	–	3
. . *Kathroperla perdita*	–	–	1	–	–	–	4	–	–	–
. . Uid. sp.	–	–	3	1	–	–	–	–	1	4
. Taeniopterygidae										
. . *Taenionema* sp.	–	–	1	1	–	–	1	–	–	1
. Capniidae										
. . *Paracapnia* sp.	–	1	–	1	–	1	–	2	–	1
. . Uid. sp.	–	–	6	–	16	–	32	–	3	12
. Leuctridae										
. . Uid. sp.	–	–	–	1	–	–	–	–	–	1
Odonata										
. Coenagrionidae										
. . *Argia emma*	–	–	–	–	–	–	–	–	–	–
Coleoptera										
. Elmidae										
. . *Optiosarvus sariatus*	–	1	–	–	–	–	–	–	–	–
. Hydrophilidae										
. . *Hydrobius* sp.	–	–	–	–	–	–	–	–	1	–
. Dytiscidae										
. . *Hydroporus* or *Hygrotus* sp.	–	–	–	–	–	1	–	–	–	–
. . *Oeronactes* sp.	–	–	–	–	–	–	–	–	–	–
. . *Rhantus* or *Colymbetes* sp.	–	–	–	–	–	–	–	–	–	–
. . *Agabus* sp.	–	–	–	–	4	–	–	–	–	–
. Dryopidae										
. . *Helichus suteralis*	–	–	1	–	–	–	–	1	–	–
Ephemeroptera										
. Ephemerellidae										
. . *Ephemerella coloradensis*	–	–	2	–	–	–	1	–	2	5
. . *Ephemerella doddsi*	–	–	–	–	–	–	1	–	1	14
. . *Ephemerella grandis*	6	1	1	1	–	–	4	1	–	3
. . *Ephemerella inermis*	1	1	–	–	–	–	–	–	1	–
. . *Ephemerella margarita*	–	–	3	–	–	–	6	–	–	–
. . *Ephemerella serratella* sp. A	–	–	–	3	2	–	–	3	–	4
. Baetidae										
. . *Baetis* sp. A	325	58	32	61	449	32	15	17	19	111
. Siphlonuridae										
. . *Ameletus* sp.	–	–	–	–	–	–	1	–	–	–
. Heptageniidae										
. . *Epeorus longimanus*	–	–	2	1	–	–	–	–	1	9
. . *Cinygmula* sp. A	–	–	–	–	4	–	–	–	–	–
. . *Cinygmula* sp. B	–	–	13	4	–	–	1	–	–	6
. . *Rhithrogena morrisoni*	–	–	24	36	–	–	54	25	16	70
. . *Heptagenia criddlei*	–	–	2	1	–	–	–	–	–	–
. . *Heptagenia elegantula*	–	1	–	–	–	–	–	–	–	–
Podocopoda										
. Cypridae										
. *Eucypris* sp.	–	–	–	–	9	–	–	–	–	–
. . *Prionocypris longiforma*	–	–	–	–	1	–	–	–	1	–
. . *Megalocypris* sp.	–	–	–	–	–	–	–	–	–	–
Dorylaimida										
. Dorylaimidae										
. . *Alaimus* sp.	18	1	2	–	4	–	3	–	–	1
. . Uid. genera	–	–	–	–	1	-	–	–	–	–
Cladocera										
. Daphnidae										
. . *Daphnia* sp. A	260	16	–	–	–	–	–	–	–	–
. . *Daphnia* sp. B	–	–	–	–	–	–	–	–	3	–
Copepoda										
. Diaptomidae										
. . *Diaptomus* sp.	35	–	–	–	–	–	–	–	7	–
. Cyclopidae										
. . *Mesocyclops*	395	3	–	–	–	–	–	–	–	1
. . Uid. sp.	–	–	–	–	–	–	–	–	–	–
Acari										
. Hygrobatidae										
. . *Atractides* sp.	1	–	–	–	–	–	2	–	–	–
. Sperchonidae										
. . *Sperchon* sp.	–	–	2	–	1	–	2	–	–	1
. Uid.										
. . Uid. sp.	–	–	–	–	–	–	–	–	–	–
. Lebertiidae										
. . *Lebertia sp.*	2	–	–	–	1	–	–	–	–	1
Heterondonta										
. Sphaeriidae										
. . *Pisidium lilljeborgi*	–	–	–	–	–	–	–	–	–	–

Table 8.—Benthic invertebrates identified in samples collected from streambeds, 1979-80—Continued

Organism	Site 36 – Muddy Creek		Site 41 – North Fork Quitchupah Creek		Site 49 – South Fork Quitchupah Creek		Site 51 – North Fork Quitchupah Creek		Site 60 – East Spring Canyon		Site 81 – Ivie Creek	
	8-16-79	8-20-80	8-1-79	8-20-80	7-31-79	8-20-80	8-8-79	8-20-80	8-2-79	8-21-80	9-16-79	8-20-80
Enoplida												
. Tripylidae												
.. *Tobrilius*	–	–	–	–	–	–	–	1	–	–	–	–
Hydroida												
.. Hydridae												
.. *Hydra* sp.	–	–	–	–	–	–	–	–	–	–	–	–
Tricladida												
. Planariidae												
.. *Polycelis coronata*	–	–	–	–	–	–	–	–	–	–	–	–
Haplotaxida												
. Tubificidae												
.. *Limnodrilus hoffmeisteri*	–	–	4	–	2	–	2	–	–	–	–	–
.. *Rhyacodrilus* sp.	–	–	–	1	–	1	–	–	1	–	–	–
.. Uid. sp.	–	–	–	–	–	16	–	14	64	–	–	–
. Naididae												
.. *Nais alinquis*	–	–	–	–	–	1	–	–	–	–	–	–
.. *Nais simplex*	–	–	–	–	–	–	–	–	4	–	–	–
.. *Ophidonais serpentina*	–	–	–	–	–	–	–	–	–	–	–	–
. Enchytraeidae												
.. *Enchytraeus* sp.	–	–	–	1	–	5	–	1	8	18	1	1
. Lumbricidae												
.. *Eisenella* sp.	–	–	–	–	–	–	–	–	–	–	–	–
Diptera												
. Ceratopogonidae												
.. *Palpomyia* sp.	1	–	–	–	–	–	–	–	–	–	–	–
.. *Bezzia* sp.	–	–	–	–	–	–	1	–	1	–	12	3
.. *Dasyhelea* sp.	–	1	1	–	1	1	–	–	–	–	–	1
. Tipulidae												
.. *Tipula* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Hexatoma* sp.	2	1	–	–	–	–	–	1	–	–	1	4
.. *Antocha* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Dactylolabis* sp.	–	–	1	–	–	–	1	–	–	–	–	–
.. *Pedicia* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Dicranota* sp.	1	–	–	1	–	1	–	–	–	–	–	–
. Psychodidae												
.. *Pericoma* sp.	–	–	–	–	–	–	–	–	–	–	–	–
. Simuliidae												
.. *Simulium* sp. B	–	1	72	–	149	–	–	–	–	–	–	1
.. *Simulium arcticum*	–	–	–	–	1	8	–	1	–	–	180	324
.. *Simulium argus*	–	–	–	–	–	2	–	–	–	–	667	115
.. *Simulium canadense*	–	–	–	–	–	–	–	–	–	–	–	5
.. *Simulium hunteri*	–	–	–	–	–	–	–	–	–	–	–	–
.. *Simulium vittatum*	2	–	–	–	–	–	–	–	–	–	–	–
.. *Metacnephia jeane*	–	–	62	10	–	1	–	–	–	–	–	–
. Stratiomyiidae												
.. *Euparyphus* sp.	–	–	1	–	–	–	–	–	–	–	–	–
. Empididae												
.. *Hemerodromia* sp.	–	–	–	–	–	–	–	–	–	–	1	–
.. *Wiedemannia* sp.	–	–	–	–	–	–	–	–	–	–	3	–
.. *Wiedemannia* sp. A	–	–	–	1	–	–	–	–	–	–	–	–
.. *Wiedemannia* sp. B	–	–	–	–	–	–	–	–	–	–	–	–
.. *Chelifera* sp.	6	1	5	1	6	1	13	1	–	–	10	7
. Ephydridae												
.. *Hydrellia* sp.	–	–	–	–	–	–	–	–	1	–	–	–
. Rhagionidae												
.. *Atherix variegata*	–	–	–	–	–	–	–	–	–	–	–	–
. Chironomidae												
.. *Procladius* sp.	–	–	–	–	–	1	–	–	–	–	–	–
.. *Psectrotanypus* sp.	–	–	–	–	–	1	–	–	–	–	–	–
.. *Ablabesmyia* sp.	–	–	1	–	–	–	–	–	–	–	–	–
.. *Thienemannimyia* group	–	–	3	2	1	1	4	4	–	–	4	4
.. *Diamesa* sp. A	–	–	–	–	–	–	–	–	–	–	–	–
.. *Pseudodiamesa* sp. A	–	–	1	–	12	1	–	–	–	–	–	–
.. *Odontomesa* sp.	1	–	1	–	–	–	–	–	–	–	–	1
.. *Brillia* sp.	–	–	–	–	1	–	–	–	–	–	–	–
.. *Corynoneura* sp.	–	–	2	1	4	1	–	–	–	–	1	–
.. *Cricotopus* sp. A	–	–	–	–	1	–	–	–	–	–	3	4
.. *Cricotopus* sp. B	–	–	–	–	–	–	–	–	–	–	–	–
.. *Cricotopus* sp. C	–	–	1	–	–	–	–	–	–	–	–	–
.. *Cricotopus* sp. D	–	–	–	–	–	–	–	–	–	–	–	–
.. *Cricotopus* sp. E	–	–	–	1	–	–	–	1	–	–	–	38
.. *Heterotrissocladius hirtapex*	3	1	8	2	21	11	4	2	–	–	8	20
.. *Heterotrissocladius oliveri*	13	3	2	1	–	–	–	1	1	–	–	–
.. *Orthocladius* sp. A	1	–	–	–	3	–	–	–	–	–	–	–
.. *Orthocladius* sp. B	–	–	–	–	–	–	–	–	–	–	24	47
.. *Orthocladius* sp. C	–	–	–	1	–	4	–	–	–	–	–	–
.. *Orthocladius* sp. D	–	–	1	–	–	–	–	–	–	–	–	–
.. *Orthocladius dorenus*	5	–	1	1	3	8	–	17	–	–	34	52
.. *Orthocladius obumbratus*	–	1	–	10	–	–	–	–	–	–	–	1
.. *Psectrocladius* sp.	–	–	–	–	–	–	1	–	–	–	1	–
.. *Psectrocladius* sp. A	–	–	–	–	–	–	–	–	–	–	–	–
.. *Psectrocladius* sp. C	–	–	–	1	–	–	–	–	–	–	–	–
.. *Smittia* sp.	–	–	–	–	–	–	–	–	–	–	21	3
.. *Trichocladius* sp. A	3	1	14	2	64	1	1	–	–	–	10	12
.. *Trichocladius* sp. B	–	–	–	–	4	–	1	–	–	–	–	–
.. *Microtendipes* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Phaenopsectra* sp.	–	–	1	1	–	11	1	–	–	–	1	–
.. *Polypedilum* sp.	–	–	2	–	–	–	1	–	–	–	–	–
.. *Constempellina* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Micropsectra* sp. A	1	–	–	3	2	11	–	–	–	–	8	–
.. *Micropsectra* sp. B	–	1	–	1	–	–	–	2	–	–	1	–
.. *Paracladopelma neis*	–	–	1	1	–	1	–	–	–	–	–	–
.. *Zavrelimyia* sp. A	–	–	1	–	–	–	–	–	–	–	–	–
.. *Borechlus* sp.	–	–	–	–	2	–	–	–	–	–	–	–
.. *Eukiefferiella* sp. A	–	–	1	1	–	–	2	–	–	–	126	35
.. *Eukiefferiella* sp. B	21	2	24	1	42	7	8	4	–	–	324	263
.. *Eukiefferiella* sp. C	–	–	–	1	–	–	–	–	–	–	–	–
.. *Eukiefferiella* sp. E	–	–	–	–	–	–	–	–	–	–	17	11
. Muscidae												
.. *Limnophora* sp.	–	–	1	–	2	1	–	–	–	–	2	–
.. *Lispe* sp.	–	–	–	–	–	–	–	–	1	–	–	–
. Dolichopodidae												
.. *Dolichopus* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Campsicnemus* sp.	–	–	1	–	–	–	–	–	–	–	–	–

Table 8.—Benthic invertebrates identified in samples collected from streambeds, 1979-80—Continued

Organism	Site 36 – Muddy Creek Cont.		Site 41 – North Fork Quitchupah Creek—Cont.		Site 49 – South Fork Quitchupah Creek—Cont.		Site 51 – North Fork Quitchupah Creek—Cont.		Site 60 – East Spring Canyon—Cont.		Site 81 – Ivie Creek Cont.	
	8-18-79	8-20-80	8-1-79	8-20-80	7-31-79	8-20-80	8-8-79	8-20-80	8-2-79	8-21-80	8-16-79	8-20-80
Diptera--Continued												
. Dixidae												
.. *Dixa* sp.	–	–	1	–	–	–	–	–	–	–	–	–
. Canaceidae												
.. *Canacaioides* sp.	–	–	–	–	–	–	–	–	1	–	–	–
. Tanyderidae												
.. *Protoplasa* sp.	–	–	–	–	–	–	–	–	1	–	–	–
Trichoptera												
. Hydropsychidae												
.. *Hydropsycha* sp.	3	–	17	–	18	–	73	–	–	–	59	–
.. *Arctopsyche grandis*	–	1	–	–	–	–	–	–	–	–	–	–
.. *Symphitopsyche* sp. A	–	7	–	4	–	15	–	14	–	–	–	56
. Rhyacophilidae												
.. *Rhyacophila* sp. D	–	–	1	–	–	–	–	–	–	–	–	–
.. *Rhyacophila acropedes*	–	–	–	–	–	–	–	–	–	–	–	–
.. *Rhyacophila angelita*	1	1	–	1	–	–	–	1	–	–	–	–
.. *Rhyacophila kernada*	–	1	–	–	–	–	–	–	–	–	–	8
. Hydroptilidae												
.. *Hydroptila* sp.	–	–	–	–	–	–	–	–	–	–	5	–
.. *Ochrotrichia* sp.	–	–	1	–	–	1	–	–	1	–	15	11
. Brachycentridae												
.. *Brachycentrus americanus*	1	1	–	–	–	–	1	–	–	–	4	5
. Limnephilidae												
.. *Hesparophylax*	–	–	1	1	–	–	–	1	1	–	–	–
Plecoptera												
. Pteronarcidae												
.. *Pteronarcella badia*	4	1	–	–	–	–	–	1	–	–	1	1
.. *Pteronarcys californica*	–	–	–	–	–	–	–	–	–	–	–	–
. Nemouridae												
.. *Amphinamura* sp.	–	–	11	–	5	–	8	–	–	–	–	1
.. *Malanka* sp.	–	–	–	3	–	11	–	–	–	–	–	–
.. *Zapada* sp.	3	–	4	–	3	–	–	–	–	–	–	–
. Perlidae												
.. *Hesperoperla pacifica*	–	–	–	–	–	–	–	–	–	–	–	–
. Perlodidae												
.. *Isoperla fulva*	–	–	–	–	–	5	–	–	–	–	–	–
.. *Isogenoides zionansis*	6	1	3	–	–	–	2	1	–	–	3	1
.. *Megarcys* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. Uid. sp.	–	–	–	1	–	–	–	–	–	1	–	–
. Chloroperlidae												
.. *Alloperla* sp.	–	–	–	–	–	–	–	–	–	–	–	–
.. *Kathroperla perdita*	–	–	–	–	–	–	–	–	–	–	–	–
.. Uid. sp.	2	1	–	–	–	–	–	–	–	–	3	–
. Taeniopterygidae												
.. *Taenionama* sp.	–	1	–	–	–	–	–	–	–	–	–	–
. Capniidae												
.. *Paracapnia* sp.	–	4	–	49	–	65	–	9	–	1	–	1
.. Uid. sp.	10	–	38	–	25	–	12	–	–	–	4	–
. Leuctridae												
.. Uid. sp.	–	–	–	–	–	–	–	–	–	–	–	–
Odonata												
. Coenagrionidae												
.. *Argia emma*	–	–	–	–	–	–	–	–	8	–	–	–
Coleoptera												
. Elmidae												
.. *Optiosarvus seriatus*	–	–	–	–	–	–	1	–	–	–	3	20
. Hydrophilidae												
.. *Hydrobius* sp.	–	–	–	–	–	–	–	–	–	–	–	–
. Dytiscidae												
.. *Hydroporns* or *Hygrotus* sp.	–	–	1	–	–	–	–	–	–	–	–	–
.. *Deronectes* sp.	–	–	–	–	4	–	–	–	–	–	–	–
.. *Rhantus* or *Colymbetas sp.*	–	–	4	–	–	–	–	–	–	–	–	–
.. *Agabus* sp.	–	–	–	–	4	1	–	–	–	–	–	–
. Dryopidae												
.. *Helichus suteralis*	2	–	–	–	1	–	1	–	–	–	–	1
Ephemeroptera												
. Ephemerellidae												
.. *Ephemerella coloradensis*	–	1	1	–	1	–	–	–	–	–	–	–
.. *Ephemerella doddsi*	–	2	–	–	–	–	–	–	–	–	–	–
.. *Ephamarella grandis*	9	–	–	–	–	–	1	1	–	–	–	–
.. *Ephemerella inermis*	–	–	–	–	–	1	–	–	–	–	–	–
.. *Ephemerelia margarita*	–	–	–	–	–	–	–	–	–	–	–	–
.. *Ephemerella serratella* sp. A	–	1	–	–	–	–	–	–	–	–	–	–
. Baetidae												
.. *Baetis* sp. A	25	18	370	34	234	536	242	92	1	2	120	166
. Siphlonuridae												
.. *Ameletus* sp.	–	–	–	–	–	–	1	–	–	–	–	–
. Heptagenlidae												
.. *Epeorus longimanus*	1	2	–	–	–	–	–	–	–	–	–	–
.. *Cinygmula* sp. A	–	–	14	–	3	–	1	–	–	–	1	–
.. *Cinygmula* sp. 6	–	–	–	–	–	–	–	–	–	–	–	–
.. *Rhithrogena morrisoni*	14	22	–	1	–	–	–	1	–	–	–	–
.. *Heptagenia criddlei*	–	–	–	2	–	4	–	–	–	–	–	–
.. *Heptagenia elegantula*	–	–	–	–	–	–	–	–	–	–	–	–
Podocopoda												
. Cypridae												
.. *Eucypris sp.*	1	–	–	1	3	1	–		–	–	–	–
.. *Prionocypris longiforma*	–	–	–	–	–	–	–	–	–	–	–	–
.. *Megalocypris* sp.	–	–	–	–	–	–	–	–	5	–	–	–
Dorylaimida												
. Dorylaimidae												
.. *Aleimus* sp.	–	–	1	–	–	–	1	–	–	–	–	17
.. Uid. genera	–	–	–	–	–	–	–	–	–	–	–	–
Cladocera												
. Daphnidae												
.. *Daphnia* sp. A	3	–	–	–	–	–	–	–	–	–	–	–
.. *Daphnia* sp. 6	–	–	–	–	–	–	–	–	–	–	–	–
Copepoda												
. Diaptomidae												
.. *Diaptomus* sp.	3	–	–	–	–	–	1	–	–	–	–	–
. Cyclopidae												
.. *Mesocyclops*	–	–	–	–	–	3	–	–	–	–	–	–
.. Uid. sp.	–	–	–	–	–	–	1	–	–	–	–	–
Acari												
. Hygrobatidae												
.. *Atractides* sp.	–	–	–	–	–	–	1	–	–	–	–	–
. Sperchonidae												
.. *Sperchon* sp.	–	–	–	–	–	–	–	–	–	–	4	–
. Uid.												
.. Uid. sp.	–	–	–	–	–	–	–	–	–	–	1	–
. Lebertiidae												
.. *Lebertia* sp.	–	–	–	–	–	–	–	–	–	–	–	–
Heterondonta												
. Sphaeriidae												
.. *Pisidium lilljeborgi*	–	–	–	–	–	–	–	–	1	–	–	1

Table 9.—Geologic and hydrologic

Location: See data-site numbering system.
Owner or operator: Company or Federal agency responsible for drilling.
Altitude of land surface: National Geodetic Vertical Datum of 1929; interpolated from topographic maps.
Geologic unit: Kbh, Blackhawk Formation; Kc, Castlegate Sandstone; Kpr, Price River Formation; TKnh, North Horn Formation.
Completion of hole: As shown; most coal-exploration drill holes are filled with cement after drilling, coring, and logging, but some were converted to observation wells for recording water levels or logging temperature.
Logs available: From party responsible for drilling — G, gamma; D, density; C, caliper; R, resistivity; SP, spontaneous potential; T, temperature.
Remarks: Recorded on drillers' log or by U.S. Geological Survey representative.

Location	Owner or operator	Date completed	Altitude of land surface (feet)	Geologic unit	Completion of hole
(D-18-6)14cdb-1	U.S. Geological Survey	11-15-79	8,072	Kpr	—
(D-18-7)18bac-1	do.	8-31-79	8,400	Kpr	Cased to 340 feet; perforated at 280-320 feet.
19bad-1	do.	8-25-79	8,440	Kpr	One-inch PVC casing to bottom for temperature measurements.
30bdb-1	do.	10-20-79	8,286	Kc	Cased to 60 feet; perforated near bottom.
31aca-1	do.	9-22-79	9,060	TKnh	Surface casing to 20 feet. Remainder of hole open.
32bdd-1	do.	8- 2-79	8,566	Kpr	Cased to 940 feet; perforated 920-940 feet; cement above 200 feet.
(D-19-6)1cba-1	do.	8-20-76	8,370	Kpr	Cased to 60 feet (pipe open on bottom, cement below).
3ccc-1	do.	9-27-79	8,313	TKnh	—
(D-20-5)30daa-1	do.	7-13-80	6,810	Kpr	—
34cdd-1	do.	7-17-80	7,320	Kpr	—
(D-21-4)24abd-1	do.	8-12-79	8,300	Kpr	Cased to 1,100 feet; top 700 feet cemented.
24cbc-1	do.	7-28-79	8,260	Kpr	Cased to 903 feet; perforated 873-893 feet; cement below 900 feet; cuttings to 150 feet; cement to surface.
25abd-1	do.	8-21-79	8,340	Kpr	—
33bdd-1	do.	7-26-79	8,220	Kpr	Cased to 78 feet; perforated 38-58 feet.
34abd-1	do.	8-14-79	8,440	Kpr	—
35cca-1	do.	8- 8-79	8,310	Kpr	—
36dbb-1	Coastal States Energy	11-17-77	[1]8,379	Kpr	—
(D-21-5)12dda-1	U.S. Geological Survey	([3])	8,560	Kc	One-inch PVC casing installed to 640 feet for temperature measurements.
18ddc-1	do.	8- 3-79	8,260	Kpr	—
21cad-1	do.	7-18-79	8,428	Kpr	—
31abc-1	Coastal States Energy	10-17-77	[1]8,494	Kpr	—
(D-22-4)2cad-1	U.S. Geological Survey	7- 3-79	8,300	Kpr	—
3acd-1	do.	7-19-79	8,190	Kpr	—
4dba-1	Coal Search Corp.	11-25-75	8,069	Kpr	—

data from coal-test holes and wells

Total depth (feet)	Depth to Star Point Sandstone (feet)	Depth to water (feet)	Date of measurement	Logs available	Remarks
1,740	1,505	–	–	C,D,G,R	Picking up water at 760 feet and at 1,200 feet.
1,200	1,045	dry	11- 6-79	C,D,G,R	–
1,140	1,100	–	–	C,D,G,R,T	–
1,175	1,115	35.1	9-25-79	T	Hit water at 300 feet (5-10 gallons per minute). Still producing at 640 feet. Major water between 740-880 feet. Chemical analysis, table 15.
		35.1	11- 6-79		
		32.4	8- 5-80		
		33.1	8-27-80		
1,800	1,765	168	11- 6-79	C,D,G,R,T	Hole apparently caved in, plugged at 100 feet, August 26, 1980.
		dry	9-30-80		
1,160	1,095	609.5	8- 9-79	C,D,G,R,T	–
		590.5	10-20-79		
		586.2	8-31-80		
1,180	1,120	28.4	7-10-79	D,G,R	–
1,640	1,556	–	–	C,D,G,R,T	Lost circulation from start. Dry to 1,200 feet (air drilling). Used mud below 1,200 feet.
1,440	1,331	–	–	C,D,G,R,SP	Water at 800 feet.
1,080	1,034	–	–	C,D,G,R,SP	Water at 980 feet.
1,260	1,209	600	8-12-79	C,D,G,R,T	–
		dry	8-26-79		
		dry	6-30-80		
1,222	1,189	40.4	8-26-79	C,D,G,R,T	Water et 80 and 923 feet.
		>160	11- 4-79		
		dry	6-30-80		
1,210	1,094	–	–	C,D,G,R,T	–
–	–	69.6	9-29-79	–	Water at 80 and 300 feet. Much water at 1,100-1,200 feet; then lost all water out bottom.
		56	11- 4-79		
		55.2	9-29-80		
1,443	1,385	–	–	C,D,G,R	No appreciable water flowing into hole.
1,225	1,175	–	–	C,D,G,R,T	–
[2] 1,095	[2] 992	273.6	10- 5-79	D,G,T	Chemical analysis, table 15.
		269.8	6-20-80		
–	–	–	–	T	–
1,260	1,140	–	–	C,D,G,R,T	–
–	1,005	–	–	T	Drilled with air to 120 feet. Water at 530 feet. Upon completion of drilling, weter could be heard flowing down hole.
[2] 1,220	[2] 1,148	260.3	6- 3-78	–	–
		dry	10- 5-79		
		dry	6-20-80		
1,040	905	–	–	C,D,G	Water in Castlegate Sandstone.
1,080	1,035	–	–	C,D,G,R,T	–
1,373	[4] 1,500	64.6	6-14-78	–	–
		64.7	7-14-78		
		64.5	8-15-78		
		64.4	11- 7-78		

Table 9.—Geologic and hydrologic data from

Location	Owner or operator	Date completed	Altitude of land surface (feet)	Geologic unit	Completion of hole
(D-22-4)13caa-1	U.S. Geological Survey	7-17-79	8,360	Kpr	Cased to 138 feet; perforated 98-118 feet.
15dbb-1	do.	7-16-79	8,270	Kpr	–
17cbd-1	Mountain Fuel Supply Co.	11-13-55	8,180	Kpr	–
34aca-1	U.S. Geological Survey	7-13-78	8,340	Kpr	Cased to 932 feet (bottom of pipe open). Annular space open entire depth.
(D-22-5)5dba-1	Coastal States Energy	7-15-79	[1]8,526	Kpr	Cased to 705 feet; 20 feet of perforations in Blackhawk Formation; cement above and below perforations.
6bb-1	do.	11-10-77	[1]8,422	Kpr	Cased to 160 feet; 110 feet of perforations at Castlegate Sandstone; cement above and below perforations.
8abd-1	do.	7- 3-79	[1]8,551	Kpr	Cased to 880 feet; 20 feet of perforations at upper Hiawatha coal seam; cement above and below perforations.
8bbc-1	do.	7-12-79	[1]8,540	Kpr	Cased to 860 feet; 20 feet of perforations at upper Hiawatha coal seam; cement above and below perforations.
(D-23-4)22bdd-1	U.S. Geological Survey	7- 7-78	8,150	Kbh	Cased to 892 feet (bottom of pipe open). Annular space open entire depth.
34cab-1	Coal Search Corp.	–	–	Kbh	Cased to 400 feet; perforated 345-385 feet; gravel packed below 100 feet; cement above 100 feet.

[1] Bob Braico, Hydrometrics, oral commun., February 2, 1981.
[2] Kerry Frame, Coastal States Energy, oral commun., January 30, 1981.
[3] Hole drilled summer of 1978 but was not completed to coal zone due to caving.
[4] Estimated by Tom Hurst, Coal Search Corp., oral commun., January 1981.

coal-test holes and wells—Continued

Total depth (feet)	Depth to Star Point Sandstone (feet)	Depth to water (feet)	Date of measurement	Logs available	Remarks
1,140	900	64	8-26-79	C,D,G,R	Water zone at 120 feet producing 4-5 gallons per minute. Chemical analysis, table 15.
		65	11- 4-79		
		64.2	7-16-80		
		64.6	8-29-80		
1,100	970	–	–	C,D,G,R,T	–
6,471	1,175	–	–	–	Muddy fresh water in Star Point Sandstone.
932	896	916	10- 3-79	D,G,R	Water in Castlegate Sandstone at 120 feet (3 gallons per minute). Water running down hole October 3, 1979.
		928	8-31-80		
[2]1,010	[2]958	705	10- 5-79	D,G,R,T	–
		dry	6-20-80		
[2]1,140	[2]932	143.1	6- 3-78	D,G	–
		140.4	10- 5-79		
		142.7	6-20-80		
		142.1	10-30-80		
[2]990	[2]914	878.1	10- 5-79	D,G,R,T	–
		dry	6-20-80		
970	924	273.6	10- 5-79	D,G,T	–
		269.8	6-20-80		
892	850	834.5	8-31-80	–	–
595	–	–	–	–	Hit water at 115 feet and 385 feet. Chemical analysis in table 15.

Table 10.—Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80

Location: See data-site numbering system.
Geologic unit: Formation in which spring orifice is located: Kms, Mancos Shale; Ksp, Star Point Sandstone; Kbh, Blackhawk Formation; Kc, Castlegate Sandstone; Kpr, Price River Formation; TKnh, North Horn Formation; Tf, Flagstaff Limestone; Qa, alluvium.
Altitude of land surface: National Geodetic Vertical Datum of 1929. Interpolated from topographic maps.
Discharge: E, estimated.
Specific conductance: In micromhos per centimeter at 25° Celsius. Field values except L, laboratory determination.

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-15-5)24dcb-S1	TKnh	10,870	9-19-79	0.16	—	8.4	8.5
24dcc-S1	TKhn	10,870	9-19-79	12	—	8.3	4.5
35aac-S1	TKnh	10,630	7-28-80	1.8	230	—	3.0
			8- 4-80	1.3	245	—	3.5
			8-22-80	.99	245	—	4.0
			9-11-80	1.2	250	—	5.0
			9-16-80	1.2	265L	—	5.0
			9-30-80	1.0	260L	—	5.0
(D-15-6)31acb-S1	TKnh	10,200	7- 9-80	14	345L	—	4.0
			7-22-80	.00	—	—	—
31acb-S2	TKnh	10,200	7-22-80	11	325	—	4.5
			8- 4-80	6.0	340	—	4.5
			8-21-80	.78	360	—	5.0
32ccd-S1	Qa	9,390	6-29-79	—	430	6.9	4.0
(D-16-5)2dac-S1	TKnh	10,670	9-21-79	.16	—	8.3	6.0
11dac-S1	TKnh	10,610	9-21-79	.25	—	7.8	8.0
22bbb-S1	TKnh	10,480	9-21-79	6.9	—	8.1	4.5
(D-16-6)3caa-S1	TKnh	9,240	7- 9-80	2.5	360L	—	5.5
			7-21-80	—	385	—	5.5
			8- 4-80	—	405	—	6.0
4abd-S1	TKnh	9,150	6-29-79	—	350	7.1	5.0
4acc-S1	Qa	8,990	7- 9-80	9.3	460L	—	5.0
			7-21-80	2.3	425	—	5.0
			7-28-80	.42	420	—	5.5
			8- 4-80	.00	—	—	—
4acc-S2	Qa	8,990	7-28-80	8.5	390	—	5.0
			8- 4-80	7.8	420	—	5.0
			8-22-80	5.9	430	—	6.0
			9- 4-80	5.1	430L	—	6.0
			10- 1-80	3.6	400L	—	5.5
21ddd-S1	Qa	8,485	7- 9-80	30	610L	—	5.5
			7-21-80	22	590	—	5.5
			8- 4-80	14	570	—	6.0
			8-22-80	8.8	600	—	7.0
			9- 4-80	6.8	620L	—	7.5
			10- 1-80	5.1	590L	—	7.0
28daa-S1	TKnh	8,470	9-19-79	6.9	—	7.5	6.0

Table 10.—Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80—Continued

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-16-6)33acc-S1	TKnh	8,380	7- 9-80	65	490	–	6.0
			7-21-80	44	570	–	6.0
			8- 4-80	33	570	–	6.0
			8-22-80	19	600	–	7.0
			9- 4-80	17	600L	–	7.0
			10- 1-80	12	580L	–	7.0
(D-17-4)12bcd-S1	Tf	10,210	8-16-78	7.0	310	–	4.5
13bcc-S1	Tf	9,780	8- 9-78	2.6	420	–	8.0
13cac-S1	Tf	9,660	8- 9-78	34E	385	–	7.0
15ddd-S1	Tf	10,240	8-16-78	37E	280	–	4.0
23abb-S1	Tf	9,920	8- 9-78	–	435	–	9.0
			6-26-79	–	340	–	4.5
23adc-S1	Tf	9,860	6-26-79	32	250	–	4.0
23dbc-S1	Tf	10,080	8- 9-78	–	585	–	4.0
24cab-S1	Tf	9,960	6-26-79	10	250	–	4.0
24cbb-S1	Tf	10,000	6-26-79	3.8	220	–	3.0
25bca-S1	Tf	9,800	8- 9-78	11E	625	–	4.0
26baa-S1	Tf	10,110	8-15-78	15	245	–	5.0
26bac-S1	Tf	10,110	8- 9-78	3.1	320	–	6.0
35ada-S1	Tf	9,980	8- 9-78	2.0	440	–	5.0
35ada-S2	Tf	9,970	8- 9-78	.80	340	–	6.0
35add-S2	Tf	9,950	8- 9-78	4.1	340	–	6.0
36cca-S1	Tf	9,940	8-11-78	36E	380	–	4.0
36cdc-S1	Tf	9,950	8-11-78	2.4	400	–	5.0
(D-17-5)6dba-S1	Tf	10,840	9-11-79	1.2	280	7.9	4.0
15bcc-S1	Tf	9,900	6-12-79	1.9	355	7.6	4.0
15cac-S1	Tf	9,880	6-12-79	33	340	7.6	4.5
16add-S1	Tf	9,820	6-12-79	21	350	7.7	4.0
23acd-S1	TKnh	9,000	6-13-79	56	610	7.3	5.0
23bda-S1	TKnh	9,120	6-13-79	14	590	7.0	9.0
25bac-S1	TKnh	8,300	6-13-79	–	680	7.2	–
25bad-S1	TKnh	8,530	6-13-79	1.3	660	6.7	8.0
25bad-S2	TKnh	8,240	6-13-79	3.0	670	7.3	7.5
25bba-S1	TKnh	8,760	6-13-79	7.5	650	7.1	7.5

Table 10.—Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80—Continued

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-17-5)30bbc-S1	Tf	9,320	8- 9-78	9.0E	300	—	7.0
			7- 9-80	48	295L	—	5.5
			7-28-80	26	295	—	6.0
			8- 4-80	16	305	—	6.0
			8-22-80	13	320	—	6.0
			9-11-80	10	390	—	6.0
			9-16-80	7.8	355L	—	6.0
			9-30-80	6.0	340	—	6.0
31cda-S1	Tf	9,950	8- 9-78	2.5E	240	—	4.0
32bbd-S1	TKnh	8,980	8- 9-78	2.1	460	—	7.0
			6-26-79	—	500	7.8	6.0
34ada-S1	TKnh	8,420	8- 8-78	4.2	530	—	14.0
(D-17-6)7ddd-S1	TKnh	7,300	10-30-80	1,080	500	—	9.0
(D-18-4)1bab-S1	Tf	9,960	8-11-78	—	425	—	4.0
			9- 9-79	85	—	7.9	4.0
1cbb-S1	Tf	10,020	8-10-78	40E	340	—	5.0
1ccb-S1	Tf	10,020	8-10-78	—	480	—	5.0
1ccd-S1	Tf	10,020	8-10-78	35E	305	—	6.0
1dab-S1	Tf	10,270	8-11-78	2.8	380	—	1.0
1dbd-S1	Tf	10,280	8-11-78	.13	490	—	16.0
2baa-S1	Tf	12,080	8-10-78	—	355	—	5.0
12bac-S1	Tf	10,040	8-10-78	20E	290	—	4.0
12ddd-S1	Tf	9,980	8-10-78	6.3	730	—	5.0
(D-18-5)6ccb-S1	Tf	10,220	8-11-78	2.4	335	—	7.0
6cda-S1	Tf	10,200	8-11-78	14	500	—	6.0
9cbc-S1	Tf	10,100	8-11-78	2.6	350	—	8.0
18bcb-S1	Tf	9,820	8-10-78	2.5	600	—	8.0
18bcb-S2	Tf	9,820	8-10-78	11	550	—	7.0
18bcc-S1	Tf	10,080	8-10-78	7.5	540	—	9.0
18bcd-S1	Tf	9,900	8-10-78	24	700	—	6.0
35dda-S1	TKnh	9,000	7-10-78	26	510L	—	7.0
			7-22-80	22	480	—	6.5
			8- 4-80	—	485	—	6.0
			8- 7-80	20	—	—	—
			8-22-80	18	495	—	7.0
			9-11-80	20	510L	—	6.5
			9-16-80	16	510L	—	6.5
			9-30-80	15	495L	—	7.0
(D-18-6)16bdb-S1	TKnh	8,380	8- 5-80	25	1,620	—	7.0
			8- 7-80	24	1,650	—	7.5
			8-21-80	20	1,620L	—	7.5

Table 10.—Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80—Continued

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-18-6)16bdb-S1	TKnh	8,380	9- 3-80	16	1,610L	–	8.0
			9-16-80	15	1,570L	–	8.0
			9-30-80	14	1,550L	–	7.0
16bdc-S1	TKnh	8,315	8- 7-80	5.0	2,020L	–	7.5
			7-22-80	4.3	1,980	–	8.0
			8- 4-80	3.8	1,870	–	8.0
			8- 7-80	4.4	1,960	–	7.5
			8-21-80	4.2	2,010L	–	8.5
			9- 3-80	4.0	1,980L	–	8.5
			9-16-80	3.9	1,930L	–	8.5
			9-30-80	3.7	1,830L	–	8.0
16bdd-S1	TKnh	8,400	7- 8-80	.17	1,430L	–	10.0
			7-22-80	.17	–	–	11.5
			8- 7-80	.17	1,440	–	13.0
			8-21-80	.16	1,440L	–	13.0
			9- 3-80	.14	1,450L	–	12.5
			9-16-80	.18	1,400L	–	12.0
22bba-S1	TKnh	8,520	7- 8-80	6.9	1,150L	–	5.5
			7-22-80	6.4	1,140	–	6.0
			8- 4-80	5.8	1,180	–	5.0
			8- 7-80	5.9	1,210	–	6.0
			8-21-80	5.5	1,240L	–	6.0
			9- 3-80	5.1	1,250	–	6.0
			9-16-80	4.8	1,230L	–	6.0
			9-30-80	4.4	1,170L	–	5.0
22cdc-S1	TKnh	9,125	7- 7-80	155	530	–	4.5
			7-22-80	97	470	–	5.5
			8- 4-80	–	445	–	4.5
			8- 7-80	65	540	–	5.0
			8-21-80	55	530L	–	5.5
			9- 3-80	40	540L	–	5.0
			9-16-80	38	520L	–	5.0
			9-30-80	34	510L	–	4.5
23dbb-S1	TKnh	8,640	7- 8-80	6.0	850L	–	5.5
			7-23-80	5.0	900	–	6.5
			8- 4-80	4.0	870	–	5.5
			8- 7-80	3.7	920	–	6.5
			8-21-80	3.0	930L	–	6.5
			9- 3-80	2.5	930L	–	6.5
			9-16-80	2.4	890L	–	6.0
			9-30-80	1.9	890L	–	5.5
34bdc-S1	TKnh	9,030	6-28-79	–	1,600	8.9	–
(D-19-4)3acc-S2	Tf	9,415	7-11-80	3.2	445L	–	4.5
10add-S2	Tf	9,350	7-11-80	18	495L	–	5.0
			7-22-80	3.2	475	–	5.0
			8- 4-80	.00	455	–	5.0
10add-S3	Tf	9,345	8- 7-80	26	480	–	5.0
			8-19-80	8.3	470	–	5.0
			9- 2-80	.19	480	–	5.0
22cbc-S1	Tf	9,670	8-28-79	–	310	7.9	4.0
(D-19-5)25ccc-S1	TKnh	8,640	6-27-79	–	1,250	8.4	8.0
26cad-S1	TKnh	8,990	6-27-79	–	1,000	–	4.0

Table 10.--Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80--Continued

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-19-5)35cdb-S1	TKnh	9,265	7-18-80	28	435	–	5.0
			8- 4-80	19	445	–	5.0
			8-19-80	14	445	–	5.0
			9- 2-80	11	475	–	5.0
			9-16-80	9.9	470L	–	5.0
			9-30-80	8.4	450L	–	5.0
(D-19-6)25cba-S1	Kpr	8,435	7- 8-80	1.5	340L	–	10.0
			7-21-80	1.5	295	–	12.0
			8- 4-80	1.0	340	–	12.5
			8- 8-80	.98	355	–	12.5
			8-21-80	.89	380L	–	11.5
			9- 3-80	.81	410L	–	12.0
			9-15-80	.81	400L	–	11.0
			9-30-80	.62	410L	–	8.0
32ada-S1	Ksp	6,870	9-18-80	–	–	–	–
(D-20-4)22bcc-S1	TKnh	9,190	7-26-78	7.1	470	–	7.0
22ccc-S1	TKnh	9,210	7-26-78	7.1	470	–	7.0
			8- 9-79	–	440	7.4	6.0
33aaa-S1	TKnh	9,260	8- 9-79	–	380	7.2	6.0
33cbb-S1	Tf	9,640	8- 9-79	–	320	7.3	5.0
35bcb-S1	TKnh	9,190	7-26-78	.75	610	–	15.0
			8- 9-79	–	630	7.3	12.0
36aba-S1	TKnh	9,130	7-26-78	.18	520	–	15.0
			8- 9-79	–	670	7.6	9.0
(D-20-5)2cba-S1	Tf	9,740	7-17-80	.90	365	–	3.0
			8- 5-80	.86	345	–	3.0
			8-19-80	.91	370	–	3.0
			9- 2-80	.78	400	–	3.0
			9-16-80	.94	390L	–	3.0
			9-30-80	.90	375L	–	3.0
10aca-S1	TKnh	9,610	7-17-80	43	455	–	5.0
			8- 5-80	17	445	–	5.0
			8-19-80	12	450	–	5.0
			9- 2-80	9.8	470	–	5.0
			9-16-80	9.0	465L	–	5.5
			9-29-80	7.6	445L	–	5.5
11add-S1	TKnh	9,540	7-17-80	25	400	–	4.5
			8- 5-80	–	400	–	4.5
			8- 7-80	18	–	–	–
			8-19-80	18	415	–	4.5
			9-11-80	17	450	–	4.5
			9-16-80	16	440L	–	5.0
			9-30-80	16	420L	–	5.0
32bbc-S1	Kpr	8,280	8- 9-79	–	420	6.6	7.0
(D-21-4)26bab-S1	TKnh	8,870	7-24-78	.10	535	–	17.0
			6-30-79	–	650	7.5	17.0
26bdd-S1	TKnh	8,760	6-30-79	–	1,150	7.1	7.0

Table 10.—Discharge, specific conductance, pH, and temperature of water from selected springs, 1978-80—Continued

Location	Geologic unit	Altitude of land surface (feet)	Date of sample	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (° Celsius)
(D-21-4)34bcd-S1	Kpr	8,200	6-30-80	4.4	1,200L	—	7.5
			7-23-80	3.4	1,200	—	7.5
			8- 6-80	2.7	1,210	—	8.0
			8-21-80	2.5	1,220	—	8.0
			9- 5-80	2.4	1,290L	—	7.5
			9-16-80	2.9	1,260L	—	8.0
			9-29-80	3.3	1,190L	—	8.0
35cdb-S1	Kpr	8,300	7- 1-79	—	750	7.1	12.0
36ddc-S1	Kc	8,240	7-30-80	2.8	440	—	6.5
			8- 5-80	2.9	425	—	6.0
			8-21-80	2.7	435	—	6.5
			9- 5-80	2.3	455	—	6.5
			9-16-80	2.6	450L	—	6.5
			9-29-80	2.6	425L	—	6.5
(D-21-5)26bba-S1	Kc	8,480	6-30-80	.36	290	—	5.5
			7-23-80	.28	275	—	6.0
			8- 5-80	.23	260	—	6.5
			8-21-80	.20	265	—	6.0
			9-11-80	.20	275	—	6.5
			9-16-80	.15	280	—	6.0
			9-29-80	.25	270L	—	6.0
(D-22-4)16dcd-S1	Kpr	8,080	6-30-80	1.9	1,020L	—	9.0
			7-23-80	1.3	1,220	—	10.5
			8- 5-80	1.1	1,090	—	11.0
			8-21-80	.86	1,140	—	11.5
			9- 5-80	.90	1,200	—	11.0
			9-16-80	1.0	1,170L	—	10.0
			9-29-80	1.1	1,120L	—	9.5
24bac-S1	Kpr	8,320	7-16-80	.53	195	—	8.5
			7-31-80	.44	190	—	9.0
(D-23-4)2ccc-S1	Kpr	8,200	7- 2-79	—	160	6.7	9.0
36ada-S1	Kms	6,520	9-19-80	—	—	—	—
(D-24-4)11ccd-S1	Kbh	8,220	7-17-80	1.0	830	—	7.5
			7-31-80	.86	850	—	8.0
			8- 5-80	.86	810	—	8.0
			8-21-80	.74	820	—	8.0
			9- 5-80	.74	870	—	8.0
			9-16-80	.84	820L	—	7.5
			9-29-80	.82	780L	—	7.5
11cdb-S1	Kbh	8,090	7-16-80	1.7	920	—	7.0
			7-31-80	1.2	960	—	7.0
			8- 5-80	1.0	890	—	7.0
35dac-S1	Kms	7,760	8-25-79	—	1,300	7.3	11.0

Table 11.—Chemical analyses of water

Location: See data-site-numbering system.
Geologic unit: Formation in which spring orifice is located: Kms, Mancos Shale; Ksp, Star Point Sandstone; Kbh, Blackhawk Formation; Kc, Castlegate Sandstone; Kpr, Price River Formation; TKnh, North Horn Formation; Tf, Flagstaff Limestone; Qu, unconsolidated deposits, undifferentiated.
Altitude of land surface: National Geodetic Vertical Datum of 1929. Interpolated from topographic maps.
Specific conductance: In micromhos per centimeter at 25° Celsius. Value is field values except L, laboratory determination.

Location	Geologic unit	Altitude of land surface (feet)	Date	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (°Celsius)	Hardness (as $CaCO_3$)	Noncarbonate hardness (as $CaCO_3$)	Dissolved calcium (Ca)
(D-15-5)25dca-S1	TKnh	9,980	6-29-79	112	360	7.1	4.0	200	17	54
35aac-S1	TKnh	10,630	9-19-79	1.0	265L	8.6	7.0	140	23	39
(D-15-6)31acb-S1	TKnh	10,200	6-29-79	24	390	7.2	5.0	180	21	51
			9-18-79	1.2	360L	7.7	5.0	240	52	74
31acb-S2	TKnh	10,200	6-29-79	—	370	7.1	4.0	210	20	56
(D-16-5)2ddc-S1	TKnh	10,620	9-21-79	57	310L	8.0	4.0	170	21	37
22bac-S1	TKnh	9,890	9-21-79	4.8	410L	7.7	6.0	230	16	61
(D-16-6)3cca-S1	TKnh	9,240	6-22-79	9.5	400	7.8	5.0	230	29	79
			9-20-79	5.1	425L	7.7	8.5	230	19	77
4acc-S1	Qu	8,990	9-19-79	11	420L	8.0	5.5	230	25	61
4acc-S2	Qu	8,990	6-29-79	52	430	7.1	5.0	220	6	60
5acc-S1	Qu	9,205	6-29-79	15	330	7.0	11.0	200	10	62
15cab-S1	Qu	8,370	11-11-77	5.6	520	7.3	5.5	320	51	79
21ddd-S1	Qu	8,485	9-19-79	.59	610L	7.5	10.0	340	9	73
(D-17-4)14cdd-S1	Tf	9,960	6-26-79	41	250	7.9	3.0	130	8	28
23add-S1	Tf	10,040	6-26-79	48	260	7.8	2.0	130	18	28
23dbc-S1	Tf	10,080	9-11-79	2.0	240L	7.6	5.0	120	13	28
24cac-S1	Tf	10,040	6-26-79	28	320	7.7	3.0	170	17	37
26ccc-S1	Tf	10,110	9- 9-79	9.3	310L	8.0	5.0	160	23	34
(D-17-5)15cad-S1	Tf	9,960	6-12-79	1.4	360	7.6	4.0	180	9	52
15dcb-S1	Tf	9,560	9-22-79	9.6	450L	7.9	5.0	250	21	61
17dba-S1	Tf	10,360	9-11-79	.69	250	8.0	10.5	130	5	27
25bda-S1	TKnh	8,160	6-13-79	8.0	650L	7.2	7.0	290	26	57
30bbc-S1	Tf	9,320	6-26-79	60	290	7.8	6.0	140	12	37
			9-11-79	4.5	300	7.7	6.0	210	41	55
31cda-S1	Tf	9,950	9- 9-79	4.5	250L	8.1	7.5	130	0	29
35bda-S1	TKnh	8,280	6-12-79	2.3	770L	8.1	8.5	320	32	30
36aca-S1	TKnh	7,780	9- 1-78	.60	740	7.4	9.5	280	0	48
(D-17-6)4cbb-S1	TKnh	8,190	6-15-79	147	520L	7.6	5.0	280	23	67
7ddd-S1	TKnh	7,300	9-19-80	—	465	—	8.5	250	4	59
(D-18-4)1bab-S1	Tf	9,950	9- 9-79	25	500L	7.7	4.0	270	110	62
1cbb-S1	Tf	10,020	9- 9-79	60	405L	7.8	3.5	210	53	49
15ddd-S1	Tf	10,120	8-31-79	.53	1,030L	7.6	6.0	530	380	160
16dca-S1	Tf	11,010	8-31-79	10	500L	8.0	4.5	260	89	64
22aaa-S1	Tf	10,120	8-31-79	.53	220	7.5	9.0	130	0	29
22bdb-S1	Tf	10,120	8-31-79	12	325L	7.9	6.0	170	6	30
33acc-S1	Tf	10,360	8-28-79	.94	380L	7.7	7.0	200	8	33
33dca-S1	Tf	10,200	8-28-79	3.6	750L	8.1	6.0	430	260	95
(D-18-5)23aab-S1	TKnh	9,160	6-21-79	30	560	8.1	5.0	210	0	29
24dad-S1	TKnh	8,485	6-21-79	1.6	750	8.0	7.0	230	—	41
35dda-S1	TKnh	9,000	6-14-79	19	490L	7.3	7.0	240	11	34
			8-29-79	15	515L	8.2	7.5	260	15	33
			10- 2-79	11	500L	8.3	7.0	240	0	32

Milligrams per liter									Dissolved iron (micro-grams per liter)	Sodium-adsorption ratio
Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Alkalinity (as $CaCO_3$)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved silica (SiO_2)	Dissolved sum of constituents		
15	2.3	0.5	180	8.9	1.3	0.1	4.4	195	20	0.1
11	1.2	.1	120	6.4	1.3	.1	4.1	137	40	.0
13	1.1	.3	160	9.8	1.1	.2	3.6	176	<10	.0
14	1.4	.2	190	11	1.3	.1	4.2	222	1,300	.0
17	1.6	.4	190	9.1	1.7	.1	3.9	206	10	.0
19	1.5	.8	150	8.6	1.7	.1	3.8	164	20	.1
18	3.7	.7	210	8.3	1.6	.1	4.0	225	<10	.1
7.8	2.7	1.5	200	6.0	4.1	.1	4.7	247	20	.1
8.9	2.1	.0	210	6.4	3.5	.1	4.9	237	20	.1
20	2.3	.1	210	5.0	1.9	.1	6.4	226	30	.1
16	2.0	.4	210	5.3	2.0	.1	6.1	221	0	.1
11	2.1	.9	190	6.3	1.6	.1	5.1	203	<10	.1
30	9.4	.9	270	52	4.7	.1	5.4	345	—	.2
38	5.2	.7	330	8.8	5.1	.2	7.8	340	20	.1
14	1.2	.5	120	5.9	1.1	.1	2.8	126	30	.0
14	1.6	.6	110	11	1.2	.1	3.1	126	20	.1
13	1.5	.5	110	12	.8	.1	3.9	126	50	.1
18	1.2	.5	150	7.4	1.1	.1	3.3	160	10	.0
19	2.7	.7	140	13	.9	.2	6.1	162	40	.1
12	1.8	.3	170	7.9	1.8	.1	3.8	185	<10	.1
24	6.0	.4	230	10	2.6	.1	4.6	250	20	.2
14	1.3	.2	120	6.8	1.2	.3	4.4	129	40	.1
35	12	.5	260	23	41	.3	7.6	333	50	.3
12	1.7	.5	130	6.0	1.2	.1	3.6	143	20	.1
18	4.6	.3	170	10	1.2	.1	4.4	197	60	.1
14	1.3	.1	130	5.5	1.2	.2	4.5	135	30	.1
60	41	.5	290	72	40	.3	8.6	432	50	1.0
38	70	1.0	360	37	19	.2	8.1	438	20	1.8
28	3.6	.4	260	10	6.0	.2	7.7	281	50	.1
26	5.9	1.2	250	13	4.3	.1	6.3	268	<10	.2
27	2.2	.5	160	120	1.4	.2	4.6	315	20	.1
22	4.1	.6	160	45	2.2	.2	4.6	225	30	.1
32	17	1.9	150	430	1.2	.1	4.6	738	50	.3
24	1.3	.2	170	99	1.7	.1	4.9	299	10	.0
14	1.1	.4	130	7.6	1.4	.3	2.9	135	20	.0
22	1.3	.9	160	15	1.1	.2	8.0	176	<10	.0
28	1.7	1.1	190	18	1.4	.2	8.0	206	<10	.1
46	4.5	1.1	170	260	1.8	.4	11	524	10	.1
34	39	1.7	240	36	5.7	.3	5.5	302	10	1.2
30	8.6	2.5	—	—	—	—	—	—	20	.2
38	14	1.6	230	13	17	.2	5.9	267	0	.4
42	17	1.6	240	13	17	.2	5.9	278	40	.5
40	19	1.7	260	11	16	.1	6.1	285	10	.5

Table 11.—Chemical analyses of water

Location	Geologic unit	Altitude of land surface (feet)	Date	Discharge (gallons per minute)	Specific conductance	pH	Water temperature (°Celsius)	Hardness (as $CaCO_3$)	Noncarbonate hardness (as $CaCO_3$)	Dissolved calcium (Ca)
(D-18-6)15ccc-S1	TKnh	8,340	8-30-79	2.8	1,360L	7.7	8.0	470	0	79
			9-27-79	.56	1,350L	7.8	9.0	420	0	74
15ccd-S1	TKnh	8,450	8-30-79	1.5	980L	7.7	7.0	390	0	62
16bdb-S1	TKnh	8,380	8-23-79	11	1,500	7.8	8.0	570	110	98
			10- 1-79	6.8	1,450L	7.8	7.5	530	150	95
			10-30-79	7.3	1,480L	7.5	6.5	480	38	81
22bba-S1	TKnh	8,520	8-24-79	6.7	1,150	8.3	8.0	300	0	46
			9-27-79	5.0	1,285	8.1	5.5	290	0	45
22bbb-S1	TKnh	8,440	8-24-79	.70	1,150	8.1	7.0	380	0	63
22cda-S1	TKnh	9,160	8-23-79	.30	610	–	8.0	310	43	51
22cdc-S1	TKnh	9,125	8-23-79	39	510	8.0	5.0	260	10	40
			9-27-79	25	540L	8.1	5.0	240	0	38
			10-30-79	–	495L	7.7	4.0	230	0	36
23aab-S1	TKnh	8,260	9- 5-79	.52	1,230L	7.7	12.0	53	0	10
			10-31-79	.20	1,220L	–	5.5	55	0	11
23dbb-S1	TKnh	8,640	8-30-79	.26	1,390L	8.3	6.5	81	0	16
25bac-S1	TKnh	8,430	8-24-79	1.0	1,500	8.8	17.0	140	0	22
			9-27-79	1.1	1,300L	8.7	12.0	210	0	31
25bbd-S1	TKnh	8,500	8-24-79	.54	1,500	7.9	19.0	830	410	150
31dca-S1	Tf	8,200	6-14-78	1.8	1,290	–	8.0	390	0	57
			8-29-79	2.8	1,120L	8.0	12.0	360	0	52
34cac-S1	TKnh	8,920	6- 1-78	1.8	890	7.2	6.0	320	0	66
			6-28-79	5.0	910L	7.8	10.0	290	0	61
			8-23-79	1.2	1,050	8.0	12.5	370	0	72
(D-19-4)3acc-S1	Tf	9,410	8-28-79	97	620L	7.8	5.0	320	120	63
9cdb-S1	Tf	10,340	8-28-79	2.2	310	7.5	5.5	190	7	37
10add-S1	Tf	9,330	8-28-79	111	510L	8.0	6.0	220	0	34
22dca-S1	Tf	9,510	8-28-79	32	420L	8.3	4.5	200	64	42
26aaa-S1	TKnh	9,360	8-23-79	113	450	7.9	4.5	260	36	40
28cbb-S1	Tf	10,090	8-23-79	.50	435L	7.7	11.0	230	29	52
33bbd-S1	Tf	9,960	8- 8-79	72	320L	6.7	6.0	160	17	38
(D-19-5)21cca-S2	TKnh	9,160	6-27-79	28	515L	7.2	5.0	310	64	73
26cbc-S1	TKnh	9,040	6-27-79	10	1,100	7.4	9.0	480	76	110
26cbd-S1	TKnh	9,080	8-31-79	3.7	1,090L	8.1	9.5	320	0	66
28acc-S1	TKnh	9,400	6-27-79	19.3	445L	7.5	5.5	230	0	51
28dbb-S1	TKnh	9,440	6-27-79	49	500	7.3	6.0	250	0	57
29cdb-S1	TKnh	9,660	8-31-79	71	500	7.8	4.0	290	92	61
(D-19-6)6add-S1	Tf	8,030	6-14-79	.42	1,025	8.5	21.5	340	0	48
			10- 2-79	.30	1,000L	7.9	17.0	380	0	58
20dba-S1	TKnh	6,880	6-14-79	2.1	860	7.0	19.5	37	0	13
			8-29-79	–	830L	9.4	12.0	8	0	1.7
25cba-S1	Kpr	8,435	8-30-79	.27	290L	7.9	15.0	150	29	48
			9-28-79	.11	280L	7.9	13.0	140	0	45
			10-30-79	.20	285L	7.3	1.5	150	19	48
32ada-S1	Ksp	6,870	9-19-80	–	1,500	7.2	10.0	480	6	100
(D-20-5)2cba-S1	Tf	9,740	9- 8-79	3.6	380L	8.1	3.5	180	0	33
4dac-S1	TKnh	9,530	9- 8-79	85	450	7.8	5.5	230	13	39
10aca-S1	TKnh	9,610	9- 8-79	22	400L	8.0	5.0	160	0	21
11add-S1	TKnh	9,540	8-13-79	430	445L	7.0	5.0	220	0	41
31abd-S1	TKnh	8,390	8- 9-79	1.5	750L	7.0	12.0	320	0	72
(D-20-6)7ccc-S1	TKnh	8,880	9- 8-79	.50	1,170L	8.1	6.5	110	0	22
(D-21-4)34bcd-S1	Kpr	8,200	7- 1-79	2.0	1,100	7.5	7.0	320	57	79
			9-27-79	1.0	1,200L	7.7	10.0	350	0	84

from selected springs, 1978-80—Continued

Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Alkalinity (as $CaCO_3$)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved silica (SiO_2)	Dissolved sum of constituents	Dissolved iron (micrograms per liter)	Sodium-adsorption ratio
Milligrams per liter										
66	170	1.7	540	190	35	0.3	7.5	874	10	3.4
58	160	1.9	560	190	35	.3	8.3	865	70	3.4
56	92	1.3	430	120	15	.3	7.4	613	20	2.0
80	170	1.6	460	360	54	.2	7.0	1,050	30	3.1
72	160	1.8	380	360	54	.2	7.1	979	30	3.0
67	150	1.6	440	320	50	.2	6.5	941	<10	3.0
46	210	1.4	440	210	38	.3	7.1	824	20	5.2
44	210	1.5	480	190	30	.3	7.5	821	40	5.3
53	140	1.3	420	170	28	.3	7.1	716	20	3.1
45	23	1.2	270	44	16	.2	7.0	351	30	.6
39	20	.9	250	25	10	.2	6.1	293	30	.5
36	23	1.0	270	23	11	.2	6.5	302	30	.6
35	22	1.0	250	22	9.4	.2	6.1	283	10	.6
6.9	280	1.7	480	110	62	.4	7.7	769	10	17
6.8	260	1.8	450	110	61	.4	7.4	731	20	15
9.9	300	1.5	360	310	28	.2	6.9	889	0	15
21	7.8	2.1	490	210	82	.6	7.5	648	30	.3
31	240	2.3	450	130	81	.5	7.8	795	10	7.3
110	78	2.3	420	410	61	.3	11	1,080	20	1.2
59	110	1.1	420	100	62	.3	6.0	655	50	2.4
55	110	1.2	420	130	59	.3	7.4	675	40	2.5
38	77	1.6	330	75	50	.3	8.4	514	20	1.9
34	74	4.0	350	58	62	.3	11	515	10	1.9
45	120	2.9	410	73	77	.3	10	648	40	2.7
40	5.7	.8	200	150	1.8	.3	8.3	392	<10	.1
23	1.0	.5	180	8.4	2.1	.5	8.7	192	<10	.0
32	22	1.1	230	39	1.9	.4	6.3	277	<10	.7
24	5.4	.7	140	73	3.0	.3	4.4	239	<10	.2
38	5.8	.7	220	34	1.7	.3	7.8	267	10	.2
24	2.1	.6	200	38	1.2	.3	5.9	245	20	.1
15	2.8	.7	140	25	1.6	.2	4.3	174	20	.1
32	2.2	.8	250	12	14	.1	6.4	292	0	.1
49	130	2.1	400	370	14	.4	7.5	924	<10	2.6
37	130	2.6	440	170	12	.3	6.7	691	50	3.2
25	5.0	1.0	230	14	4.0	.2	5.5	248	50	.1
25	5.9	.8	250	15	4.4	.2	5.5	267	10	.2
34	10	1.3	200	130	2.9	.3	5.4	368	30	.3
53	14	1.0	380	53	81	.5	9.4	489	10	.3
57	81	2.3	390	48	83	.4	10	576	30	1.8
1.2	13	.4	400	38	15	.9	8.4	331	120	.9
1.0	210	.4	380	35	14	.9	9.3	501	10	32
7.1	3.2	1.0	120	16	5.2	.1	11	164	0	.1
6.6	3.5	1.1	140	8.0	5.8	.1	12	167	20	.1
7.0	4.0	.9	130	11	6.0	.1	12	167	<10	.1
55	120	4.0	470	150	89	.3	8.0	809	20	2.4
23	17	1.0	190	19	2.1	.4	4.7	216	20	.6
33	11	1.1	220	9.4	3.0	.2	6.5	241	20	.3
25	21	2.2	190	17	2.7	.6	5.3	216	20	.7
29	9.2	1.4	230	9.4	3.6	.2	6.7	245	10	.3
35	39	1.8	350	26	46	.3	9.6	441	20	.9
14	250	1.4	580	54	23	.7	7.8	723	40	10
29	110	3.3	260	190	71	.2	14	654	20	2.7
33	160	4.2	400	180	52	.2	15	771	30	3.7

Table 11.—Chemical analyses of water

Location	Geologic unit	Altitude of land surface (feet)	Date	Discharge (gallons per minute)	Specific conduc- tance	pH	Water temper- ature (°Celsius)	Hardness (as $CaCO_3$)	Non- carbonate hardness (as $CaCO_3$)	Dissolved calcium (Ca)
(D-21-5)26bba-S1	Kc	8,480	8-11-79	.25	310	7.5	20.5	120	26	35
(D-22-4)16aca-S1	Kc	7,990	7- 1-79	1.3	280	7.1	8.0	110	27	31
			8-22-79	.16	255L	—	9.5	110	9	30
16dcd-S1	Kpr	8,080	7- 1-79	1.5	1,100	6.9	9.0	430	81	110
			9-29-79	.30	1,240L	7.7	11.0	500	120	130
24bac-S1	Kpr	8,320	7- 1-79	.88	200	—	10.0	74	20	20
			9-24-79	.20	200L	7.7	10.0	81	5	22
(D-23-4)4ddc-S1	Kpr	8,140	9- 7-79	6.6	470L	7.5	8.5	170	74	48
16bab-S1	Kpr	8,080	7- 2-79	—	420	6.9	8.0	180	76	49
21add-S1	Kpr	8,160	7- 2-79	.25	380	6.4	8.0	120	18	34
			9- 7-79	.25	340L	7.9	11.0	120	24	33
29bad-S1	Kpr	7,830	7- 2-79	.50	1,000	7.3	10.0	—	—	—
			8-22-79	.50	780	7.5	17.0	380	160	96
36bad-S1	Kms	7,040	7- 2-79	—	510L	7.2	11.0	210	6	43
(D-24-4)11ccd-S1	Kms	8,220	8-24-79	.63	805L	8.0	9.0	390	36	82
			9-30-79	.50	790L	8.1	8.0	400	45	84
11cdb-S1	Kbh	8,090	8-24-79	.25	920	7.5	14.0	510	79	110
22dba-S1	Kc	9,000	8-25-79	.60	520	7.5	7.0	300	8	73
			9-30-79	.60	365L	7.8	6.0	310	140	76

from selected springs, 1978-80—Continued

Milligrams per liter									Dissolved iron (micrograms per liter)	Sodium-adsorption ratio
Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Alkalinity (as $CaCO_3$)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved silica (SiO_2)	Dissolved sum of constituents		
8.5	12	1.3	96	20	15	0.2	8.9	159	60	0.5
8.1	12	1.0	8.4	16	11	.2	11	141	10	.5
8.2	11	1.6	100	16	13	.1	12	153	30	.5
38	77	1.8	350	180	77	.2	11	706	40	1.6
43	88	2.4	380	170	90	.2	13	765	60	1.7
5.9	9.2	1.1	54	15	9.2	.2	11	105	20	.5
6.4	9.6	.9	76	14	9.3	.1	12	120	40	.5
13	23	1.7	99	68	38	.2	10	263	30	.8
13	3.4	1.7	100	64	19	.2	12	223	10	.1
7.6	20	.9	98	25	26	.2	10	187	30	.8
7.9	22	1.0	91	26	24	.2	11	185	50	.9
—	—	2.8	300	140	56	.3	—	381	—	—
35	44	3.0	220	160	54	.3	10	535	20	1.0
24	18	3.2	200	65	6.1	.2	12	292	20	.5
44	25	2.5	350	65	31	.4	21	482	20	.6
45	24	2.8	350	60	32	.3	22	483	50	.5
57	11	2.9	430	130	15	.3	13	598	20	.2
28	10	1.3	290	14	21	.3	32	354	30	.3
28	8.2	1.1	170	10	18	.2	31	275	60	8.2

Table 12.—Chemical analyses of water from mines, 1978-80

Source and location: See data-site-numbering system. The number 1 after location number indicates drill hole in mine.
Concentration: In milligrams per liter unless otherwise specified.
pH: Field determination except L, laboratory determination.
Specific conductance: In micromhos per centimeter at 25^{O} Celsius.

Source and location	Date	Temperature (^{O}Celsius)	pH	Specific conductance	Concentration: Alkalinity (as $CaCO_3$)	Dissolved calcium (Ca)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Noncarbonate hardness	Total hardness	Dissolved iron (Fe) (micrograms per liter)	Dissolved magnesium (Mg)	Dissolved manganese (Mn) (micrograms per liter)	Dissolved nitrite plus nitrate (NO_2 + NO_3)	Dissolved potassium (K)	Dissolved solids	Dissolved silica (SiO_2)	Dissolved sodium (Na)	Dissolved sulfate (SO_4)
Knight Mine effluent																			
(D-23-4)34cda-1	9- 1-78	10.5	7.1	2,400	470	170	190	0.3	860	1,300	470	220	90	—	3.9	1,700	8.7	100	730
SUFCo Mine																			
(D-21-4)36ccc	7-23-80	10.0	7.8	675	310	74	11	.3	27	340	<10	37	20	0.00	1.8	356	7.6	8.7	29
36dbb	7-23-80	9.0	7.7	540	240	64	11	.2	31	270	<10	27	10	.00	1.9	288	8.8	7.7	23
(D-21-5)31dbd	7-23-80	11.0	7.3	530	220	60	10	.4	33	250	10	25	10	.00	1.5	272	9.1	6.9	27
(D-22-4)1bcb	5- 2-79	11.0	7.1	680	300	76	14	.2	38	340	70	36	20	.84	2.3	360	7.0	8.3	32
(D-22-5)6dbc	5- 2-79	12.0	7.0	590	190	58	12	.4	120	310	20	39	10	.51	2.8	394	6.9	28	130
Wilberg Mine																			
(D-18-7)30bdb-1	8- 5-80	13.5	7.5L	1,760	320	140	320	.3	230	550	<10	48	170	.00	21	1,030	7.9	150	150
(D-22-4)13caa-1	8- 5-80	12.0	6.8L	130	53	16	5.8	.2	5	58	140	4.4	30	.02	1.5	82	11	4.4	6.3
(D-23-4)34cab-1	9- 1-78	12.5	7.3	1,290	360	96	65	.3	260	620	260	93	60	—	3.8	795	9.8	50	260

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