UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY HYDROLOGIC EVALUATION OF THE NORTH HORN MOUNTAIN COAL-RESOURCE AREA, UTAH

By M. J. Graham, John E. Tooley, and Don Price

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Numbers 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 the report are listed below. Multiply the inch-pound unit by the conversion factor to obtain the equivalent metric unit.

Inch-pound Unit	Abbreviation	Conversion factor	Metric unit
Acre-foot	acre-ft	0.001233 1233	Cubic hectometer Cubic meter
Acre-foot per square mile	acre-ft/mi^2	0.000476	Cubic hectometers per square kilometer
Cubic foot per second	ft^3/s	0.02832	Cubic meter per second
Foot	ft	0.3048	Meter
Gallon per minute	gal/min	0.06309	Liter per second
Inch	in.	25.40 2.540	Millimeter Centimeter
Mile	mi	1.609	Kilometer

PRELIMINARY HYDROLOGIC EVALUATION OF THE NORTH HORN MOUNTAIN COAL-RESOURCES AREA, UTAH (with a section on some potential impacts of coal development on the water resources)

By M. J. Graham, J. E. Tooley, and Don Price

ABSTRACT

North Horn Mountain is part of a deeply dissected plateau in central Utah which is characterized by deep, narrow, steep-walled canyons with local relief of more than 1,000 feet. Geologic units exposed in the North Horn Mountain area range in age from Late Cretaceous to Holocene and contain two mineable seams of Cretaceous coal. The area is in the drainage basin of the San Rafael River, in the Colorado River Basin. Runoff from the mountain is ephemeral. This runoff to the San Rafael River is by way of Cottonwood and Ferron Creeks and represents less than 10 percent of their average annual runoff. Probable peak discharges (100-year flood) for the ephemeral streams draining North Horn Mountain are estimated to range from 200 to 380 cubic feet per second.

The chemical quality of surface water in the area is good. The water is generally of a calcium magnesium bicarbonate type with average dissolved solids less than 500 milligrams per liter. Annual sediment yield in most of the area ranges from 0.1 to 0.2 acre-foot per square mile but locally is as high as 1.0 acre-foot per square mile. Most of the sediment is eroded during cloudbursts.

Most of the ground water above the coal on North Horn Mountain probably is in perched aquifers. These aquifers support the flow of small seeps and springs. In some areas, the regional water table appears to extend upward into the coal. The principal source of recharge is precipitation that probably moves to aquifers along faults, joints, or fractures. This movement is apparently quite rapid. The dissolved-solids concentrations of ground water in the North Horn Mountain area range from less than 500 to about 1,000 milligrams per liter.

Coal mining on North Horn Mountain should have minor effects on the quantity and quality of surface water. The maximum predicted decrease in the annual flow of Ferron and Cottonwood Creeks is less than 4 percent. The sediment loads of affected streams could be significantly increased if construction were to take place during the summer cloudburst season. Subsidence, which usually follows underground coal mining, could create rock fractures through which a perched aquifer might be drained, thus depleting the flow of seeps or springs fed by that aquifer. It is considered unlikely that the mining will adversely affect the chemical quality of the ground water.

INTRODUCTION

Purpose and scope

In June 1978, the U.S. Geological Survey, in cooperation with the U.S. Bureau of Land Management began a 3-year study of the water resources of the central Wasatch Plateau, Utah. The study was undertaken to obtain hydrologic information needed by the Bureau of Land Management to make reasonable stipulations in coal leases to (1) minimize disturbance of the hydrologic system and (2) avoid or reduce adverse impacts on water sources. Under the cooperative agreement, the Geological Survey was to submit a preliminary report of hydrologic conditions in the North Horn Mountain area of the central Wasatch Plateau. This report fulfills that committment.

Evaluations given in this report are based largely on hydrologic data collected prior to June 1978 (mostly in Waddell and others, 1978). The evaluations, especially those relating to ground water, are highly generalized, and doubtless they will be refined as more data become available from future drilling programs and aquifer tests.

Location and physiographic setting

The North Horn Mountain area is in central Utah about 110 air miles south-southeast of Salt Lake City (fig. 1). The principal communities in the area include Ferron, Castle Dale, Orangeville, and Clawson (fig. 2). As of 1978, the combined population of those communities was about 1,800. The local economy is based chiefly on agriculture, with increasing emphasis on energy-resource development.

North Horn Mountain is part of a deeply dissected plateau in the High Plateaus of the Utah section of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 294-299). The area is characterized by deep, narrow, steep-walled canyons with local relief of more than 1,000 ft. The total relief in the area is more than 5,000 ft, with altitudes ranging from about 6,000 ft near Ferron to more than 10,500 ft along the crest of the Wasatch Plateau west of North Horn Mountain. The highest point on North Horn Mountain, The Cap, has an altitude of 9,615 ft (fig. 2).

Geologic setting

Geologic units exposed in the North Horn Mountain area range in age from late Cretaceous to Holocene. They include sedimentary strata consisting chiefly of shale, mudstone, siltstone, lenticular and massive sandstone, and limestone (fig. 3). These strata, which are blanketed locally by talus and stream-valley alluvium of Quaternary age, have undergone relatively little structural deformation. They dip generally only a few degrees to the west-northwest, and those that underlie North Horn Mountain are apparently uncut by major faults. There appear to be two mineable coal seams, both in the lower part of the Blackhawk Formation. These coal seams can be seen cropping out on canyon walls above the massive Star Point Sandstone, a prominent marker bed in the region.

Although the rocks that underlie most of North Horn Mountain appear not to have been cut by major faults, they have been fractured and jointed. It is assumed that the fractures and joints have as much, if not more, influence on the occurrence and movement of ground water in the area as does the regional dip of the strata. The geology of the North Horn Mountain area has been mapped or described in several reports and maps including those of Spieker (1931), Stokes (1964), Doelling (1972), and Johnson (1978). The reader is referred to those reports for more detailed information about the geology.

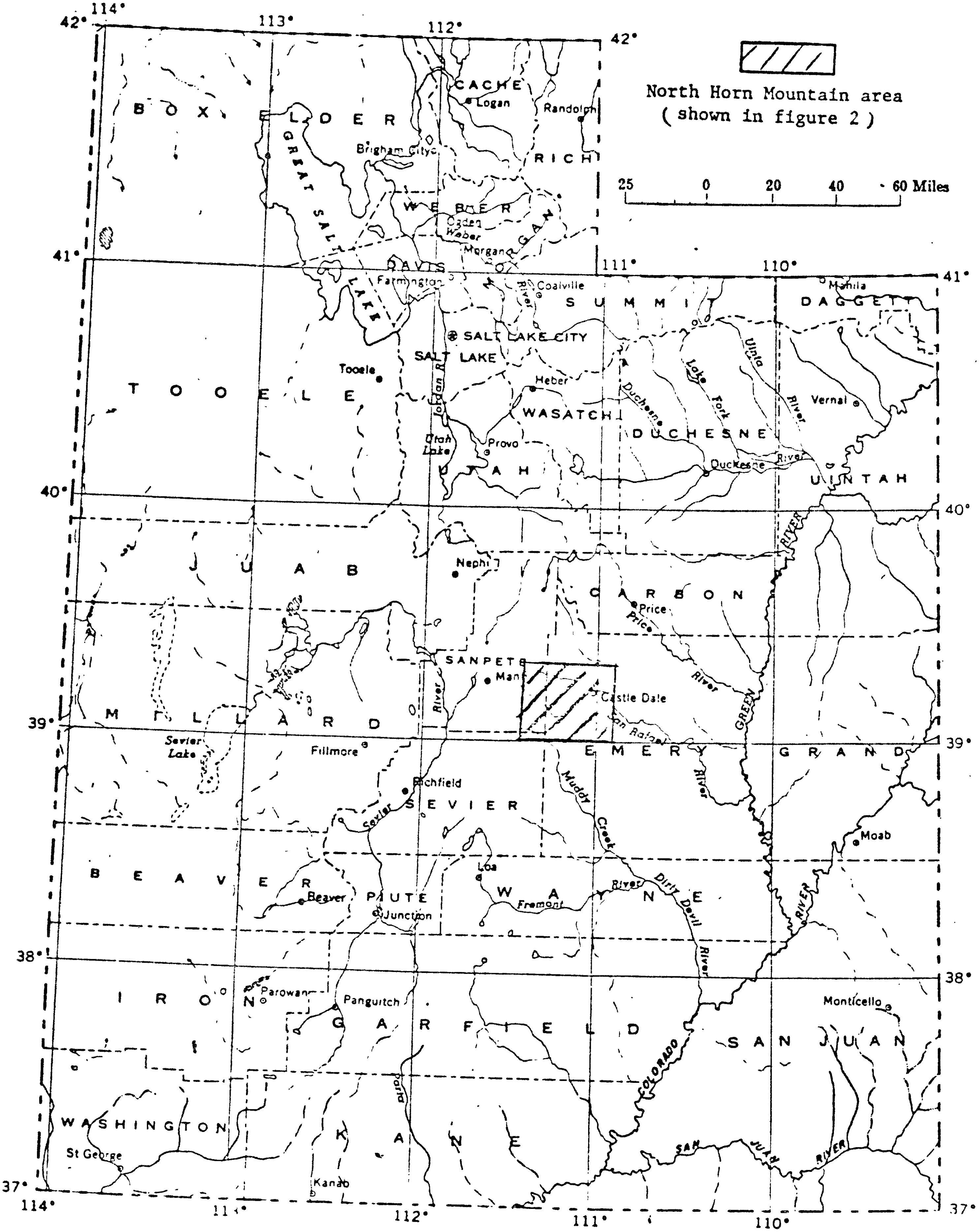


Figure 1.--Location of the North Horn Mountain area.

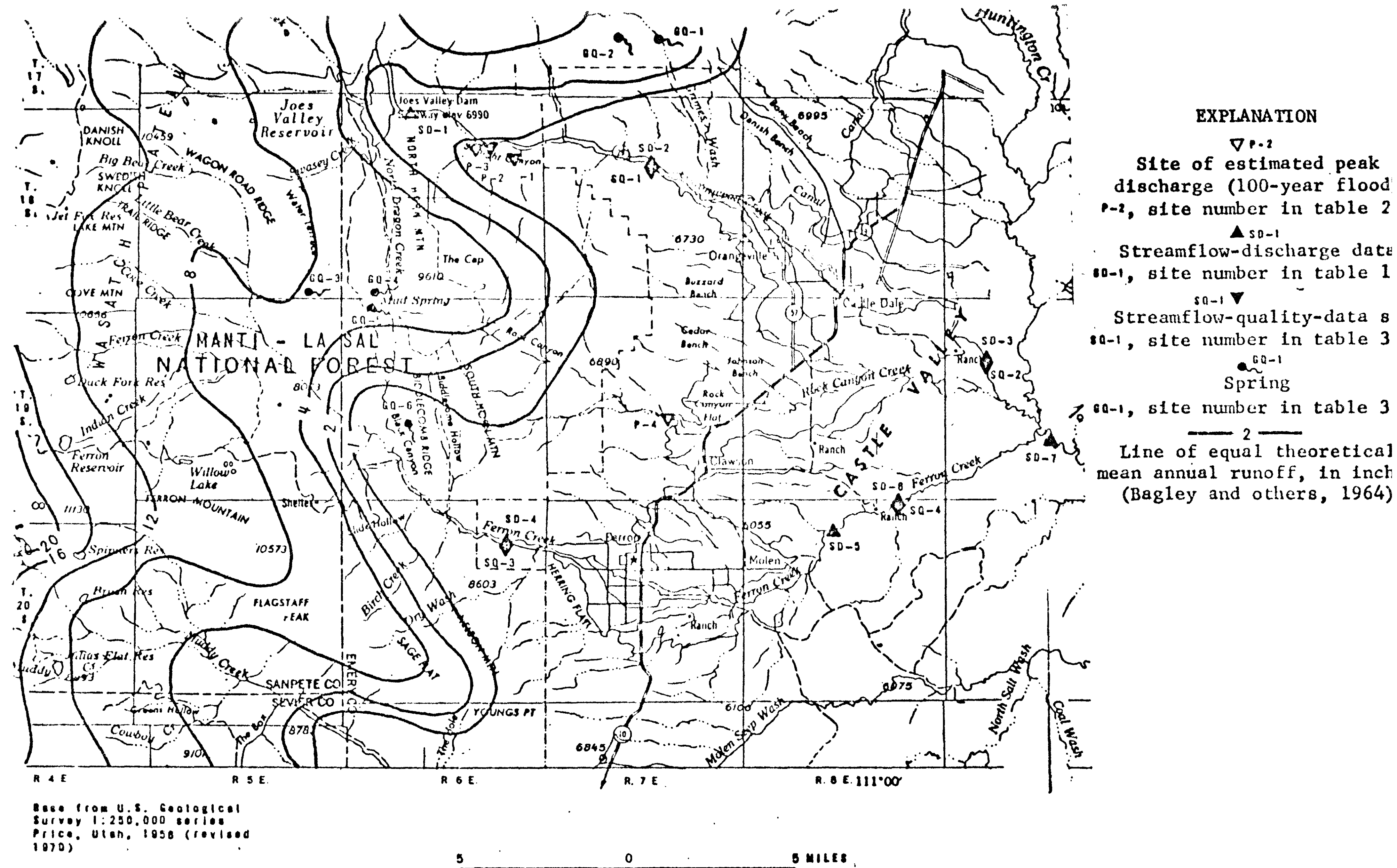


Figure 2.--Geographic features, hydrologic-data sites, and mean runnoff in the North Horn Mountain area.

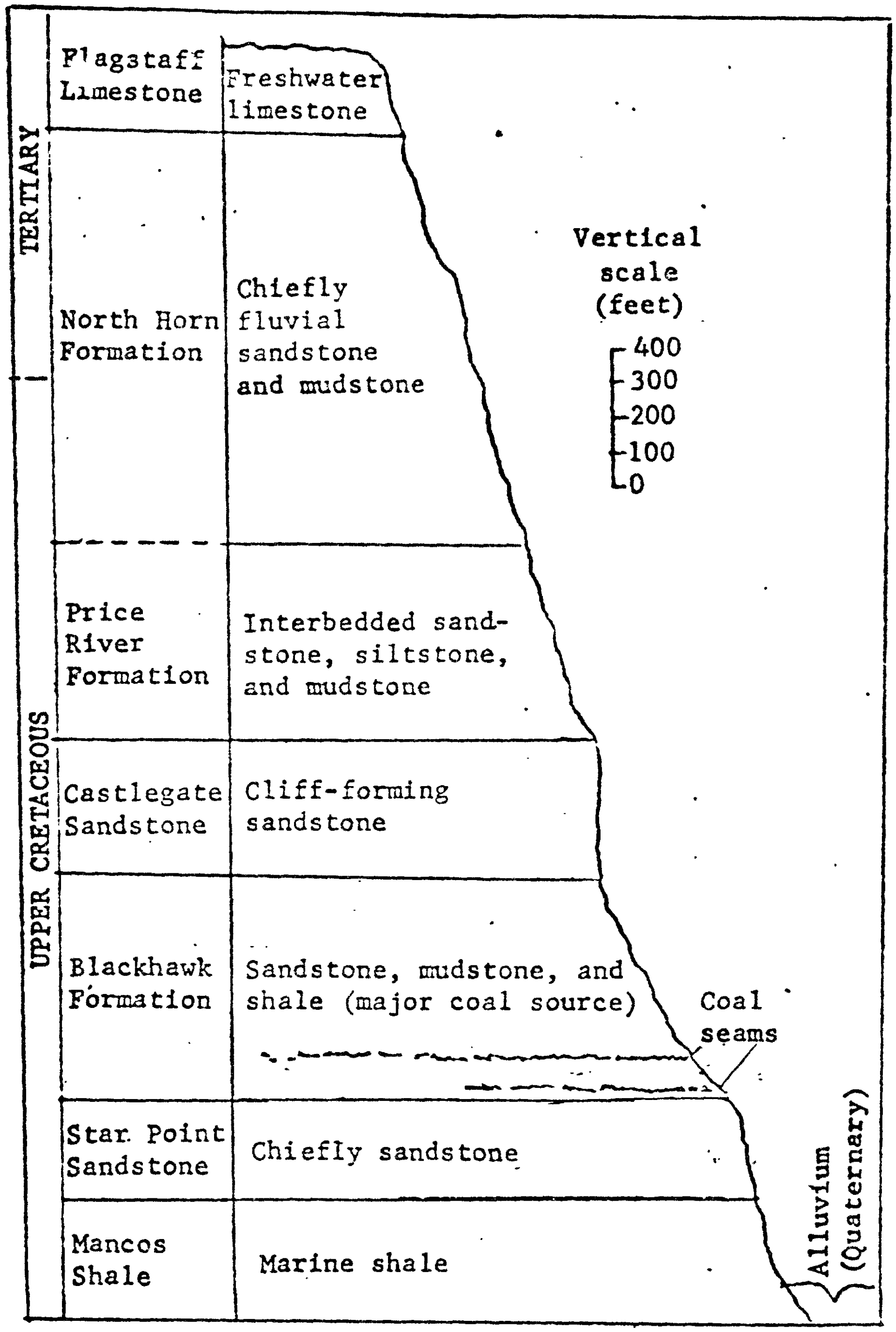


Figure 3.--Diagrammatic geologic section of the North Horn Mountain area (modified from Utah Power & Light Co., written commun., 1979).

Climate

The climate of the North Horn Mountain area is semiarid to subhumid. During the period 1931-60, normal annual precipitation ranged from about 8 in. in Castle Valley to about 40 in. along the crest of the Wasatch Plateau. For the same period and localities, normal May-September precipitation ranged from about 4 to 10 in. and normal October-April precipitation ranged from about 4 to 30 in. On North Horn Mountain during 1931-60, values for normal annual, May-September, and October-April precipitation were about 16, 8, and 8 in., respectively, according to maps of the U.S. Weather Bureau (U.S. Weather Bureau, no date, a and b).

The October-April precipitation generally comes from frontal-type storms that affect large areas and are usually of several hours duration. The precipitation usually occurs as snow, which accumulates until it melts and runs off during the late spring or early summer. By late spring, snow depths of several feet are common on the north-facing slopes of North Horn Mountain.

The May-September precipitation usually comes from localized convection-type storms which are of short duration. The precipitation usually occurs as torrential rain which runs off rapidly, often resulting in highly erosive and destructive floods.

Air temperature ranges widely in the area. Midwinter temperatures often fall below freezing in Castle Valley and below 0°F at the higher altitudes. Midsummer temperatures often exceed 90°F and occasionally exceed 100°F, except in the higher plateau areas. Evaporation rates are high throughout the area, averaging more than 42 in. per year, even in the higher altitudes (Iorns and others, 1965, pl. 6). The high annual evaporation rates, coupled with low summer precipitation, limits perennial runoff to only a few streams that head high in the Wasatch Plateau. This also apparently restricts the principal areas of ground-water recharge to the upper reaches of those streams.

WATER RESOURCES

Surface water

Runoff

The North Horn Mountain area is in the drainage basin of the San Rafael River, a tributary of the Green River that joins the Colorado River about 95 air miles southeast of Castle Dale. Runoff from North Horn Mountain to the San Rafael River is by way of Cottonwood and Ferron Creeks (fig. 2). The two perennial streams receive most of their flow from the higher, wetter areas of the Wasatch Plateau west of North Horn Mountain--the flow in Cottonwood Creek comes mostly from Joes Valley Reservoir by way of Straight Canyon. North Horn Mountain contributes only a small amount of the average annual flows of those streams.

The Geological Survey has operated streamflow-gaging stations on Cottonwood Creek near Orangeville (station 09324500) since 1909 and on Ferron Creek near Ferron (station 09326500) since 1911 (table 1). Most of the flow of Cottonwood Creek, as recorded at station 09324500, is regulated at Joes

Table 1.--Selected data for stream-gaging stations in the North Horn Mountain area

Site No. (see fig. 2)	U.S. Geological Survey station No.	Station	Approximate drainage area (square miles)	Period of record	Average discharge: Cubic feet per second	Average discharge: Acre-feet per year	Average discharge: Years	Recorded extremes (cubic feet per second): Maximum	Date	Minimum	Date
SD-1	09324000	Sealy Creek (Straight Canyon) near Orangeville	150	1953-57	103	-	4	2,110	8-26-57	11	3-14-57
SD-2	09324500	Cottonwood Creek near Orangeville	205	1909-27; 1932-70; 1975-78	95.1	68,900	58	7,220	8- 1-64	1.2	4- 8-66
SD-3	09325000	Cottonwood Creek near Castle Dale	251	1947-58	54.8	39,670	11	1,660	About 6- 3-52	0	(1/)
SD-4	09326500	Ferron Creek (upper station) near Ferron	140	1911-23; 1947-78	65.6	47,530	42	4,180	8-27-52	0	(1/)
SD-5	09327500	Ferron Creek near Castle Dale	210	1911-14; 1947-58	35.6	25,770	13	1,630	8- 3-61	0	(1/)
SD-6	09327550	Ferron Creek below Paradise Ranch, near Clawson	221	1975-78	-	-	3	1,840	7-24-77	0	(1/)
SD-7	09328000	San Rafael River near Castle Dale	930	1947-64; 1972-78	103	74,620	22	4,510	6- 3-52	0	(1/)

1/No flow on several days.

Valley Reservoir which was closed early in water year 1966. There is only a minor regulation of Ferron Creek above station 09326500; this being Ferron and Duck Creek Reservoirs, which store runoff from only about 5 percent of the drainage area upstream from the gaging station. Average annual gaged runoff in Cottonwood Creek at station 09324500 was about 68,900 acre-ft for 58 years of record through water year 1978 and 39,630 acre-ft since the closure of Joes Valley Reservoir. Average annual runoff in Ferron Creek at station 09326500 was 47,530 acre-ft for 42 years of record through water year 1978. As shown in figure 4, the months of highest runoff at both stations for the respective periods of record were May and June. This runoff is chiefly in response to melting of the winter snowpacks. However, regulation of the flow of Cottonwood Creek in Joes Valley Reservoir (chiefly to meet irrigation requirements) has reduced the peak discharges as measured at gaging station 09324500.

Figure 5 shows flow-duration graphs for Cottonwood Creek at station 09324500 before and after closure of Joes Valley Reservoir. Figure 6 shows the flow-duration graph for Ferron Creek at station 09326500 for the entire period of record.

As shown in figure 5, a flow of 10 ft^3/s in Cottonwood Creek at station 09324500 was exceeded more than 99 percent of the time prior to closure of Joes Valley reservoir and only about 66 percent of the time since closure of the reservoir. A flow of 10 ft^3/s in Ferron Creek at station 09326500 was exceeded about 80 percent of the time during the period of record for that station (fig. 6).

Although most of the runoff in Cottonwood and Ferron Creeks comes from snowmelt, the highest instantaneous discharges result from thunderstorms. For example, the highest recorded discharge in Cottonwood Creek at gaging station 09324500 was 7,220 ft^3/s, August 1, 1964 (prior to closure of Joes Valley Reservoir), and that in Ferron Creek at gaging station 09326500 was 4,180 ft^3/s, August 27, 1952, both resulting from cloudbursts.

Figures 7 and 8 are log-Pearson Type III analyses (U.S. Water Resources Council, 1977) of annual peak discharges recorded in Cottonwood and Ferron Creeks at stations 09324500 and 09326500. These graphs indicate likelihood of experiencing flood discharges exceeding specified magnitudes in any future year. For example, figure 7 indicates that there is a 5-percent chance of a discharge of 3,200 ft^3/s being equalled or exceeded. The reciprocal of the exceedence probability is the average period of time between exceedences or "recurrence interval" of the flood. A flood with a 5-percent exceedence probability, therefore, will be exceeded at time intervals averaging 20 years in length; but indicates no regularity of occurrence. Figure 7 is based on annual peak discharges recorded before and after closure of Joes Valley Reservoir, consequently, its applicability for estimating future floods at station 09324500 (which now are influenced by regulation at Joes Valley Reservoir) is uncertain. Because of reservoir effects, a peak flow of about 1,200 ft^3/s may have a less than 50 percent chance of being exceeded in any 1 year. The 50-percent probability of a peak discharge of 1,000 ft^3/s or greater occurring in any 1 year in Ferron Creek at station 09326500 (fig. 8) is more realistic.

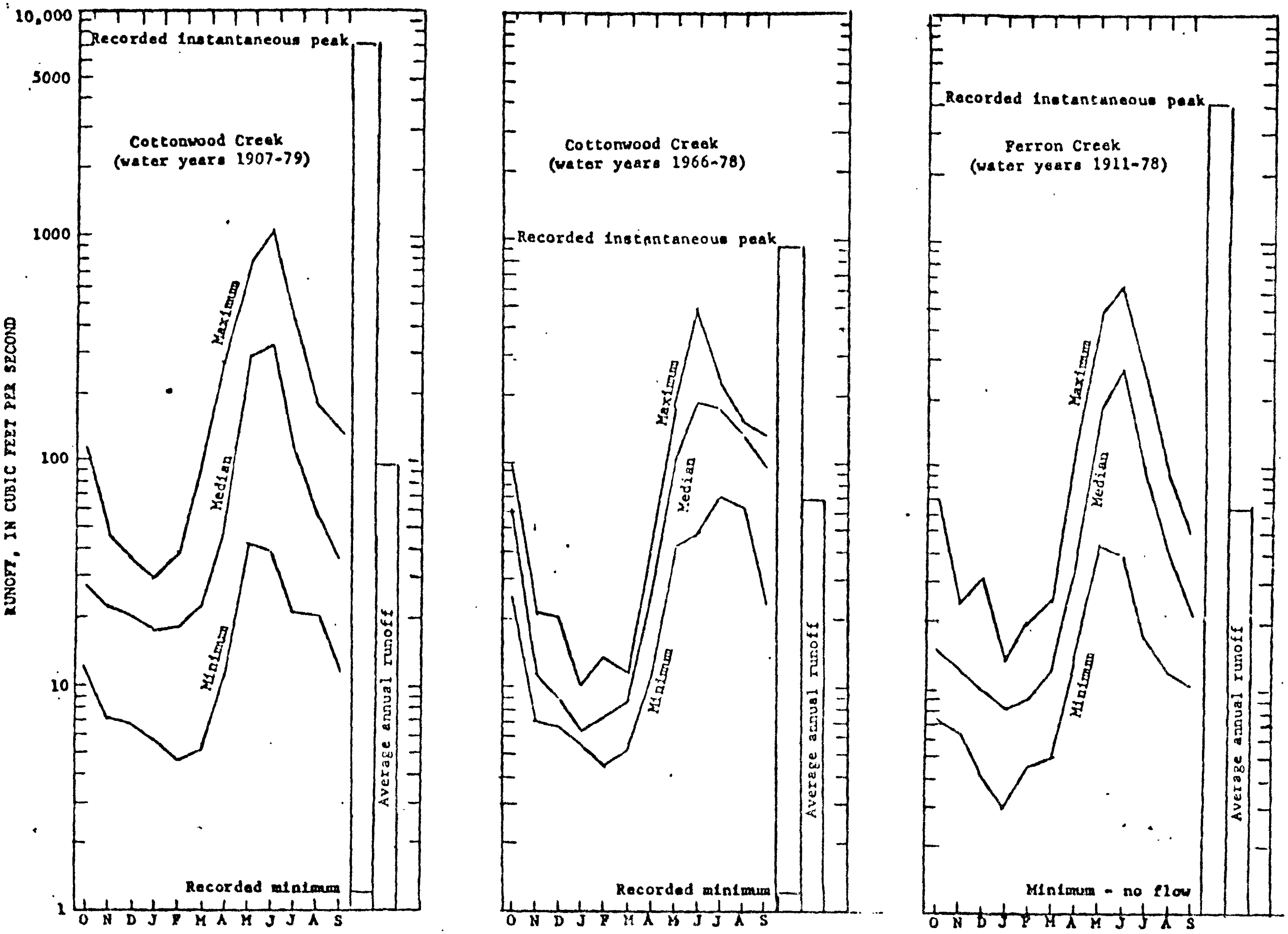


Figure 4.--Maximum, median, and minimum monthly runoff, average annual runoff, and recorded extremes in Cottonwood Creek at gaging station 09324500 and Ferron Creek at gaging station 09326500.

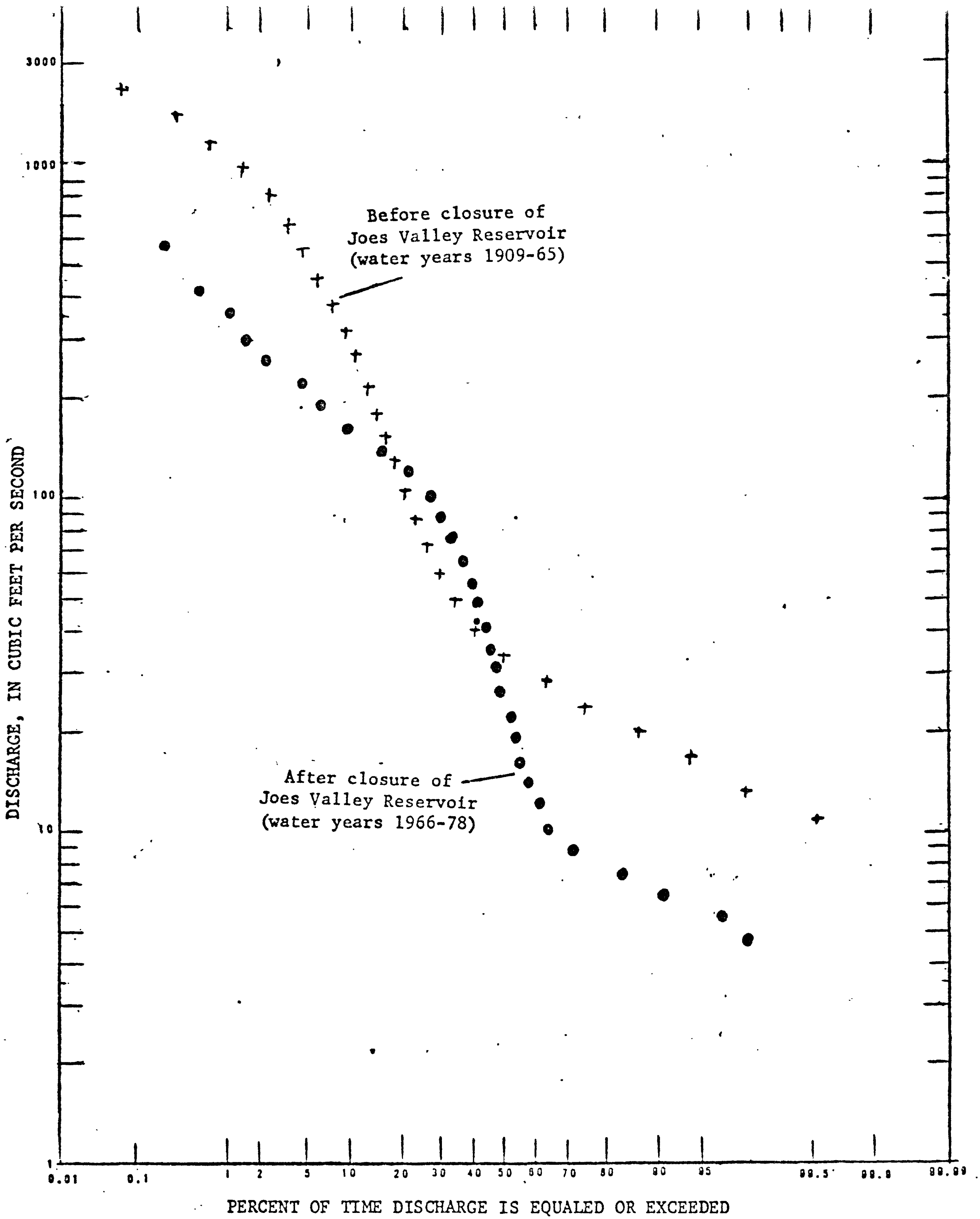


Figure 5.--Flow-duration graphs for Cottonwood Creek at gaging station 09324500 for the periods before and after closure of Joes Valley Reservoir early in water year 1966.

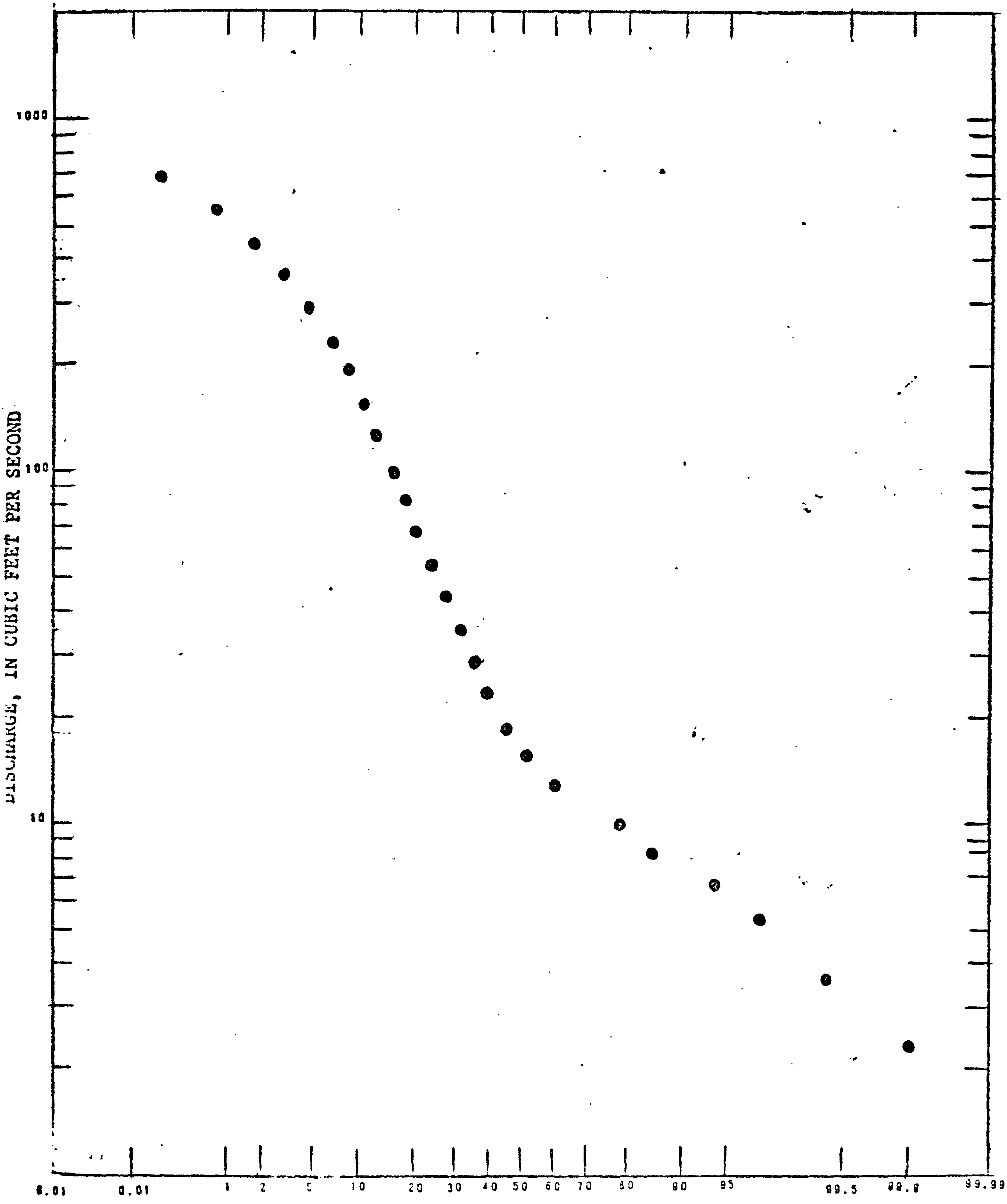


Figure 6.--Flow-duration graph for period 1911-23 to 1947-78 for Ferron Creek at gaging station 09326500.

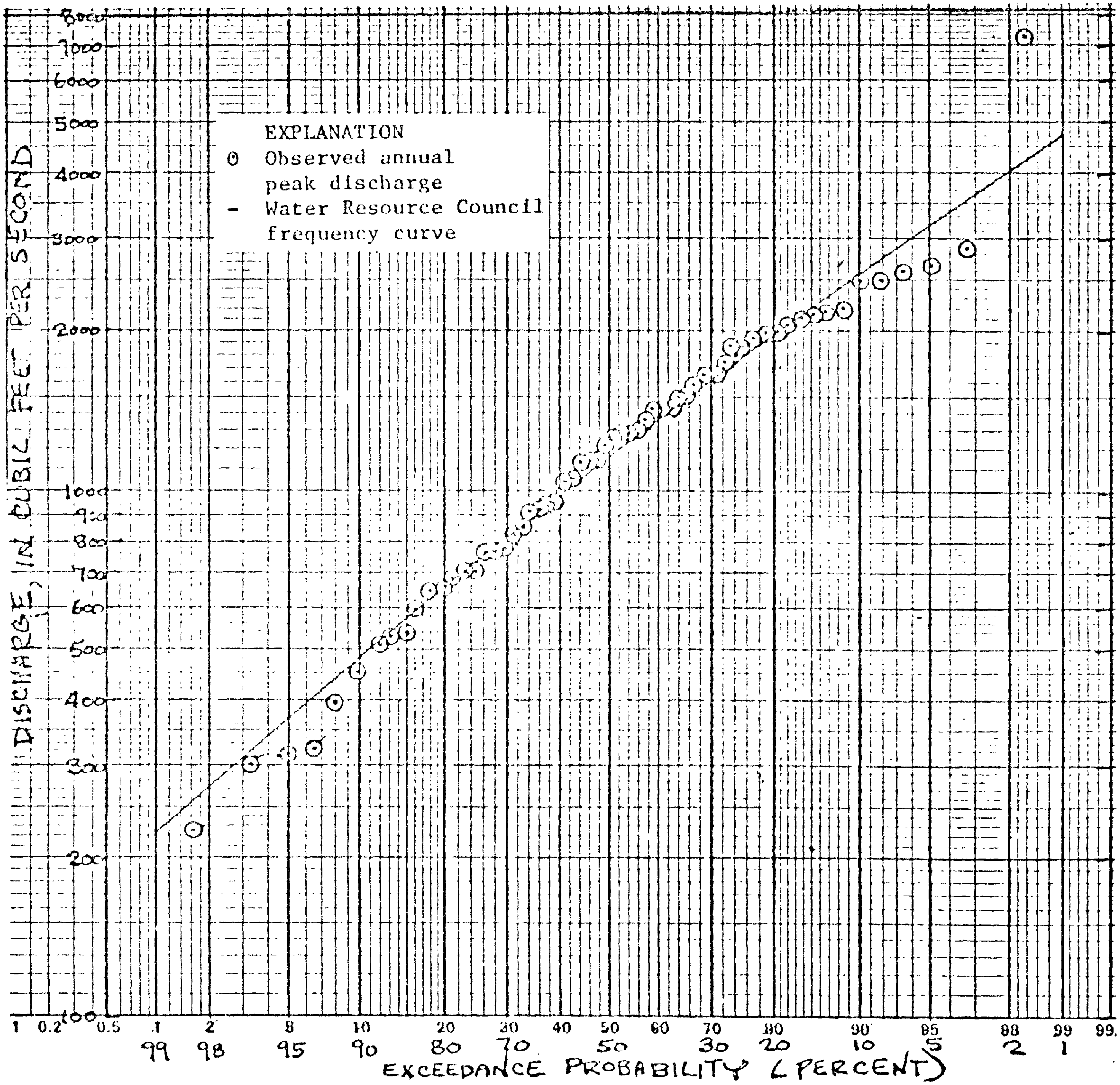


Figure 7.--Log-Pearson Type III analysis of annual peak discharges recorded in Cottonwood Creek at gaging station 09324500.

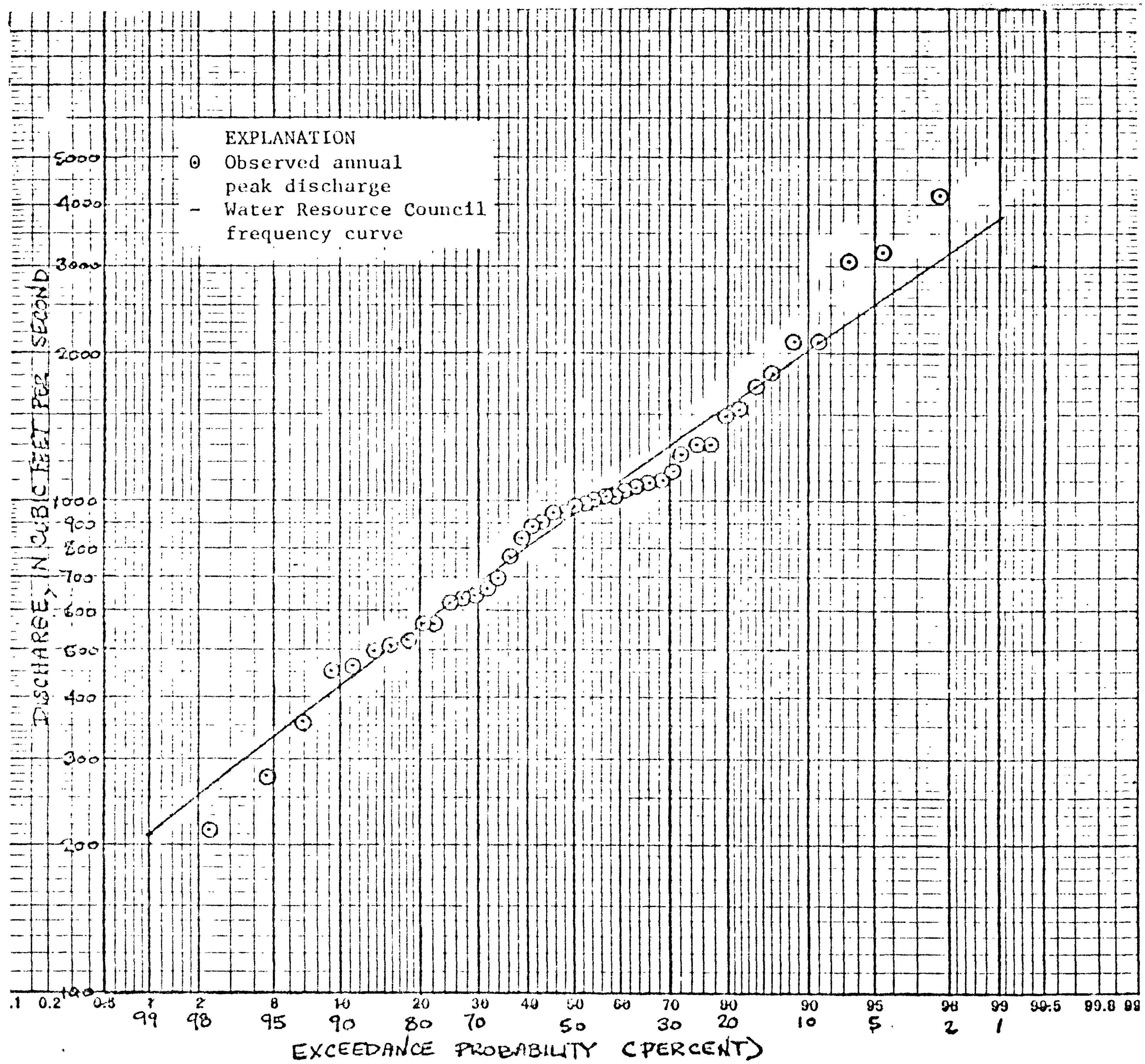


Figure 8.--Log-Pearson Type III analysis of annual peak discharges recorded in Ferron Creek at gaging station 09326500.

Streams on North Horn Mountain are ephemeral and are not gaged. Discharge from springs in the area is lost to evapotranspiration and seepage a short distance from their source. Based a water-yield map of Utah (Bagley and others, 1964, fig. 16), theoretical mean annual runoff from North Horn Mountain alone is estimated to be on the order of 8,000 acre-ft. (A 1:250,000 scale map used be Bagley and others was used to make the estimate.) The map indicates an estimated 5,000 acre-ft (62 percent of the runoff) in Cottonwood Creek, and an estimated 3,000 acre-ft (38 percent) in Ferron Creek. These amounts are only about 7 and 6 percent, respectively, of the average annual runoff recorded at gaging stations 09324500 and 09326500.

Probable peak discharges (100-year flood) have been estimated for several of the ephemeral streams that drain North Horn Mountain (table 2). Those estimates were made by regressing various recurrence-interval peak discharges against basin characteristics for 29 long-term stations--having hydrologic characteristics similar to the North Horn Mountain drainage area. The probable peak discharges, given in table 2, are based on drainage areas and mean annual precipitation on the drainage area. They are subject to refinement on the acquisition and analysis of stream-channel geometry data in 1980.

Table 2.--Probable peak discharges (100-year flood) for selected ephemeral streams on North Horn Mountain

Site No. (See fig. 2)	Name	Discharge (ft^3/s)	Standard error (ft^3/s)
P-1	Clay Banks Swale	380	+231 to -148
P-2	Reid and Nielson Swale	240	+158 to -94
P-3	Cox Swale	240	+158 to -94
P-4	Rock Canyon	200	+132 to -78

The area inundated by a 100-year flood would be small because lower reaches of the stream channels on North Horn Mountain are steep and narrow. The velocities and erosiveness of such a flood doubtless would be destructive to roads, buildings, and other structures in the stream bottoms.

Quality

Available data indicate that the chemical quality of surface water in the North Horn Mountain area is good. Minimum concentrations of dissolved solids in surface water range from 100 to 250 mg/L (milligrams per liter), and maximum concentrations range from 250 to 1,000 mg/L (Waddell and others, 1979, fig. 13). Numerous chemical analyses have been made of water in Cottonwood Creek near gaging station 09324500 and in Ferron Creek near gaging station 09326500 (Waddell and others, 1978, p. 24 and 30). According to those analyses, the discharge-weighted average concentration of dissolved solids at both streams at the respective stations is less than 500 mg/L. However, the concentrations increase to more than 1,000 mg/L downstream from Castle Dale and Ferron. (See Price and Waddell, 1973, sheet 2.) These increases are due chiefly to the return flow of water diverted from the streams to irrigate soils developed on the Mancos Shale in the Castle Dale-Ferron area.

Water upstream from stations 09324500 and 09326500 is generally of a calcium magnesium bicarbonate type. Downstream from Castle Dale and Ferron, where dissolved-solids concentrations of the runoff increase to more than 1,000 mg/L, sodium and sulfate become the dominant ions.

Selected water-quality data for Cottonwood and Ferron Creeks are given in table 3. According to those data, water in the two streams upstream from stations 09324500 and 09326500 was, at the time of sampling, of good biological quality (unpolluted) as well of as good chemical quality. There were no unusually high concentrations of bacteria or toxic trace metals, although concentrations of strontium exceeded 3,000 µg/L (micrograms per liter). Strontium concentrations of more than 1,000 µg/L are common throughout the Wasatch Plateau coal-fields area, but in such concentrations strontium is not harmful to human health.

Little information is available for fluvial sediment in the North Horn Mountain area. A map compiled by the U.S. Soil Conservation Service (see Waddell and others, 1979, fig. 15) indicates that annual sediment yield in most of the area ranges from 0.1 to 0.2 acre-ft/mi^2 but locally is as high as 1.0 acre-ft/mi^2. Most of this sediment is eroded during cloudbursts.

According to J. C. Mundorff and K. R. Thompson (U.S. Geological Survey written commun., 1979), 90 percent or more of the suspended-sediment discharge in the San Rafael River occurs in 10 percent or less of the time. This is attributed to the relatively large volumes of suspended sediment discharged during cloudbursts. In the more arid parts of the study area, suspended-sediment concentrations can exceed 10,000 mg/L for up to several hours during cloudburst floods, depending on the magnitude of those floods. However, during 3 years of data collection in Cottonwood Creek at station 09324500, the largest suspended-sediment concentration recorded was 452 mg/L on March 31, 1978 (table 4).

Use

The principal use of surface water--chiefly from Cottonwood and Ferron Creeks--is for irrigation of several thousand acres of cropland in the Castle Dale-Ferron area. Some streamflow is also diverted for domestic supply in Orangeville, Castle Dale, Ferron, and Clawson; and some water is diverted for industrial use. A minor amount of the area's surface-water supply is also used by wildlife and livestock.

The following estimates for the use of water from Cottonwood and Ferron Creek are taken from the Final Environmental Statement, Emery Power Plant (U.S. Department of the Interior, 1979, p. 2-26):

Water requirement	Water use (acre-ft per year) Cottonwood Creek	Water use (acre-ft per year) Ferron Creek
Agriculture	32,000	16,800
Industry	0	7,000[1]
Domestic	354	129

[1]For use at the Emery Power Plant, Utah Power & Light Co.

Table 3.--Selected water-quality data for Cottonwood and Ferron Creeks

Site No.: See figure 2.
Specific conductance: Determined in field at time of sample collection.
pH: Determined in field at time of sample collection; except L, in laboratory during chemical analysis. All carbonate and bicarbonate determinations in laboratory.
Diversity index: A numerical expression of evenness of distribution of benthic invertebrates.

Chemical analyses of major ions

Site No.; U.S. Geological Survey station No.	Date of sample	Temperature (°C)	Discharge (ft³/s)	Milligrams per liter: Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved nitrite plus nitrate (N)	Dissolved boron (B) (µg/L)	Dissolved solids (sum of constituents) (mg/L)	Specific conductance (micromhos/cm at 25°C)	pH
Cottonwood Creek																			
SQ-1	9-11-75	9.5	-	3.7	47	22	5.8	1.0	229	0	13	3.6	0.1	-	0.22	20	210	350	8.3
09324500	11- 4-75	8.5	15	2.5	48	25	12	1.1	234	4	35	5.0	.1	0.20	.05	-	252	460	8.5
	1-15-76	0.5	6.6	-	-	-	-	-	-	-	-	-	-	.80	.18	-	-	530	8.4
	3-17-76	3.5	9.5	-	-	-	-	-	-	-	-	-	-	.50	.12	-	-	510	8.4
	7- 7-76	12.0	200	2.7	39	23	8.7	.9	223	0	20	-	.1	.60	.14	20	-	380	8.5
	9- 1-76	14.5	164	3.5	46	20	8.5	.9	215	0	20	3.4	.1	-	.20	20	210	390	8.7
	5-12-77	13.0	95	2.9	42	26	15	1.2	250	0	43	6.1	.2	-	.08	30	245	370	8.2
	9-15-77	9.0	61	4.4	40	25	14	1.2	240	0	35	6.2	.1	-	-	-	244	380	8.2
	5-31-78	9.5	98	4.3	42	25	14	1.0	230	0	29	6.7	.1	-	-	50	236	400	7.9
	9-13-78	9.0	114	4.6	45	21	10	.5	230	-	23	5.4	.2	-	.18	60	224	380	8.4L
SQ-2	11- 4-75	9.5	11	1.3	240	150	230	7.4	373	0	1,300	35	.1	.00	.00	270	2,150	2,500	8.3
09325000	1-15-76	0.5	7.4	-	-	-	-	-	-	-	-	-	-	2.6	.62	-	-	2,400	7.9
	3-17-76	8.5	5.8	-	-	-	-	-	-	-	-	-	-	.80	.18	-	-	3,200	8.2
	7- 8-76	20.0	21	8.9	170	120	200	8.1	380	0	940	-	.3	.10	.03	250	-	2,000	8.2
	9- 1-76	14.5	6.9	5.3	210	160	260	9.6	371	0	1,300	32	.3	-	.07	310	2,160	-	8.1
Ferron Creek																			
SQ-3	9-10-75	8.0	30	4.8	50	29	12	1.2	240	0	56	7.7	0.3	-	0.10	30	280	570	8.9
09326500	11- 5-75	6.5	13	2.6	56	33	21	1.1	278	0	70	8.4	.1	0.50	.11	20	331	540	8.2
	1-14-76	0.5	10	-	-	-	-	-	-	-	-	-	-	1.9	.44	-	-	600	8.3
	3-17-76	10.0	9.0	-	-	-	-	-	-	-	-	-	-	1.1	.25	-	-	600	8.3
	7- 8-76	20.0	34	4.5	47	29	10	.9	222	0	52	-	.3	.40	.10	10	-	460	8.6
	9- 1-76	19.5	8.0	5.2	43	33	19	1.2	224	3	76	7.6	.3	-	.06	40	300	500	8.7
SQ-4	9-10-75	22.0	-	7.9	170	120	280	8.8	315	0	1,200	34	.4	-	.70	250	1,980	2,300	8.3
09327550	11- 5-75	9.0	18	1.5	240	150	330	7.2	375	0	1,500	36	.2	1.5	.35	280	2,450	3,080	8.3
	1-14-76	0.0	8.7	11	240	140	250	6.9	456	0	1,300	35	.5	-	1.2	220	2,210	2,500	7.7
	3-17-76	12.0	11	-	-	-	-	-	-	-	-	-	-	4.8	1.1	-	-	3,500	8.3
	7- 8-76	21.5	16	9.5	180	130	280	-	369	0	1,200	-	.6	.60	.14	270	-	2,400	8.3
	9- 1-76	26.0	7.1	8.8	210	160	310	9.0	294	0	1,500	34	.6	-	.04	340	2,380	2,700	8.2
	1-20-77	0.0	6.3	11	220	140	240	5.3	413	0	1,200	38	.5	-	1.1	200	2,060	2,600	8.2
	9-14-77	21.5	.79	11	350	250	850	19	300	0	3,300	80	.6	-	-	570	5,010	5,500	7.8
	1-11-78	0.0	4.7	11	230	170	330	6.5	400	0	1,500	52	.5	-	-	250	2,500	3,050	7.9
	9-13-78	14.0	14	7.3	200	140	280	7.3	360	-	1,300	42	.5	-	.05	270	2,160	2,400	8.1L

Table 3.--Selected water-quality data for Cottonwood and Ferron Creeks--Continued

Organic, biological, and nutrient analyses

Site No.; U.S. Geological Survey station No.	Date of sample	Temperature (°C)	Discharge (ft³/s)	Dissolved solids (sum of constituents) (mg/L)	Specific conductance (micromhos/cm at 25°C)	pH	Milligrams per liter									Phenols (µg/L)	Oil and grease (mg/L)	Fecal coliform (col/100 mL)	Streptococci (col/100 mL)	Total phytoplankton (cells/mL)	Diversity index
							Dissolved oxygen	Dissolved organic nitrogen (N)	Dissolved Kjeldahl nitrogen (N)	Dissolved ammonia nitrogen (N)	Dissolved nitrite (N)	Total Kjeldahl nitrogen (N)	Dissolved nitrite plus nitrate (N)	Dissolved orthophosphorus (P)	Dissolved organic carbon (C)						
									Cottonwood Creek												
SQ-1 09324500	1-15-76	0.5	6.6	-	530	8.4	11.6	0.40	0.44	0.04	0.01	0.19	0.18	0.00	-	0	-	0	2	-	
	3-17-76	3.5	9.5	-	510	8.4	10.6	.28	.30	.02	.00	.30	.12	.00	1.6	0	-	2	7	-	
	7- 7-76	12.0	200	-	380	8.5	8.4	.14	.17	.03	.01	.03	.14	.00	2.3	1	-	2	38	-	
	9- 1-76	14.5	164	210	390	8.7	8.5	.61	.63	.02	.00	.13	.20	.01	-	1	1	7	51	230	1.29
SQ-2 09325000	11- 4-75	9.5	11	2,150	2,500	8.3	9.6	.27	.30	.03	.00	.48	.00	.00	-	-	-	260	264	270	
	1-15-76	0.5	7.4	-	2,400	7.9	9.2	1.1	1.7	.55	.03	1.0	.62	.06	-	10	-	1,960	3,000	-	
	3-17-76	8.5	5.8	-	3,200	8.2	11.6	1.9	2.0	.14	.01	-	.18	.00	21	1	-	80	0	-	
	7- 8-76	20.0	21	-	2,000	8.2	8.2	.50	.50	.00	.00	.51	.03	.00	14	2	5	80	110	-	
	9- 1-76	14.5	6.9	2,160	2,200	8.1	7.6	.61	.61	.00	.01	.42	.07	.01	-	2	0	44	96	380	1.53
									Ferron Creek												
SQ-3 09326500	11- 5-75	6.5	13	331	540	8.2	9.7	0.24	0.25	0.01	0.00	0.05	0.11	0.00	-	-	-	0	4	360	
	1-14-76	0.5	10	-	600	8.3	11.4	.10	.14	.04	.00	.27	.44	.00	-	4	-	6	1	-	
	3-17-76	10.0	9.0	-	600	8.3	9.0	.95	.96	.01	.00	1.0	.25	.00	6.1	0	-	0	1	-	
	7- 8-76	20.0	34	-	460	8.6	7.0	.08	.11	.03	.00	.16	.10	.01	14	0	4	6	10	-	
	9- 1-76	19.5	8.0	300	500	8.7	7.3	.67	.68	.01	.01	.22	.06	.01	-	3	0	4	48	360	1.55
SQ-4 09327550	11- 5-75	9.0	18	2,450	3,080	8.3	9.4	.47	.49	.02	.00	.67	.35	.00	-	-	-	-	56	-	
	1-14-76	0.0	8.7	2,210	2,500	7.7	-	-	-	-	-	-	1.2	.01	-	-	-	-	-	-	
	3-17-76	12.0	11	-	3,500	8.3	9.5	1.3	1.3	.02	.02	1.4	1.1	.00	5.6	0	-	0	24	-	
	7- 8-76	21.5	16	-	2,400	8.3	7.2	1.3	1.3	.05	.00	.52	.14	.01	13	0	6	192	760	-	
	9- 1-76	26.0	7.1	2,380	2,700	8.2	7.1	.56	.57	.01	.00	.48	.04	.00	-	2	0	28	300	2,900	

Table 3.--Selected water-quality data for Cottonwood and Ferron Creeks--Continued

Trace-metal analyses

Site No.; U.S. Geological Survey station No.	Date of sample	Temperature (°C)	Discharge (ft³/s)	Micrograms per liter																
				Dissolved arsenic (As)	Dissolved barium (Ba)	Dissolved beryllium (Be)	Dissolved boron (B)	Dissolved chromium (Cr)	Dissolved cobalt (Co)	Dissolved copper (Cu)	Dissolved lead (Pb)	Dissolved lithium (Li)	Dissolved manganese (Mn)	Dissolved molybdenum (Mo)	Dissolved nickel (Ni)	Dissolved selenium (Se)	Dissolved silver (Ag)	Dissolved strontium (Sr)	Dissolved tin (Sn)	Dissolved vanadium (V)	Dissolved zinc (Zn)
Cottonwood Creek																					
SQ-1	11- 4-75	8.5	15	1	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-
09324500	7- 7-76	12.0	200	1	80	<1	20	0	<3	1	0	10	0	3	<3	0	<0	290	<3	<3.0	0
	9- 1-76	14.5	164	0	100	<2	20	0	<6	2	2	10	20	5	<6	0	<1	310	<8	<6.0	0
SQ-2	11- 4-75	9.5	11	1	40	<8	270	<40	<40	<8	<40	200	70	<20	<40	1	<4	1,600	<40	<40	<10
09325000	7- 8-76	20.0	21	2	40	<10	250	0	<30	<7	2	160	90	20	<30	1	<4	1,800	<30	<30	0
	9- 1-76	14.5	6.9	0	30	<8	310	0	<40	<8	1	210	40	20	<40	0	<4	2,300	<50	<40	0
Ferron Creek																					
SQ-3	11- 5-75	6.5	13	1	20	<3	20	<7	<7	10	<7	20	10	5	<7	0	<1	770	<7	<7.0	<10
09326500	7- 8-76	20.0	34	1	100	<2	10	0	<7	2	2	20	20	5	<7	0	<1	730	<10	<6.0	0
	9- 1-76	19.5	8.0	0	100	<3	40	0	<8	3	2	30	0	<8	<8	0	<2	780	<8	<8.0	0
SQ-4	11- 5-75	9.0	18	0	40	<9	280	<40	<40	<9	<40	240	<40	20	<40	8	<5	2,200	<40	<40	20
09327550	7- 8-76	21.5	16	2	40	<10	270	0	<35	<8	3	190	20	20	<35	2	<5	2,600	<50	<30	0
	9- 1-76	26.0	7.1	1	40	<10	340	0	<40	13	2	260	20	20	<40	3	<4	3,200	<60	<40	0

Table 4.--Measured suspended sediment in Cottonwood Creek at gaging station 09324500

Date	Time	Temperature (°C)	Instantaneous discharge (ft^3/s)	Suspended-sediment concentration (mg/L)	Suspended-sediment discharge (tons/day)
1975					
Oct. 8	1350	10.0	119	44	14
Nov. 5	1045	3.0	15	6	.24
Dec. 10	1145	.0	10	27	.73
1976					
Feb. 11	1215	.0	16	46	2.0
Mar. 11	1045	2.0	7.4	0	.00
Apr. 14	1610	6.0	30	10	.81
May 19	1515	11.5	134	33	12
June 24	1030	9.0	174	3	1.4
July 14	1320	12.5	210	22	12
Aug. 11	1300	14.0	124	22	7.4
Sept. 15	1035	11.5	65	178	31
Oct. 13	1030	7.5	25	2	.13
Nov. 11	1420	3.0	7.2	48	.93
Dec. 7	1400	.0	10	7	.20
1977					
Mar. 2	1115	.0	3.6	8	.08
Apr. 6	1410	14.5	5.9	1	.02
May 12	1430	13.0	95	53	14
June 14	1445	16.0	66	62	11
July 13	1030	11.5	73	66	13
Aug. 10	1030	11.0	70	124	24
Sept. 15	1030	9.0	61	149	25
Oct. 6	1030	9.0	34	19	1.7
Nov. 17	1100	2.0	8.0	2	.04
Dec. 15	1130	.0	11	8	.24
1978					
Jan. 11	1130	.0	5.7	4	.06
Feb. 23	1100	.0	4.5	42	.52
Mar. 31	1130	9.0	9.6	452	12
Apr. 27	1100	7.0	41	142	16
May 31	1200	9.5	98	199	53
June 27	1100	15.5	365	53	52
July 13	1130	13.5	138	34	13
Aug. 23	1130	10.0	128	8	2.8
Sept. 13	1100	9.0	114	9	2.8

Ground Water

General conditions of occurrence

In deeply dissected terrain such as North Horn Mountain, perched aquifers may occur above the levels of the most deeply incised perennial streams--in this case Cottonwood and Ferron Creeks. Such aquifers probably exist at various depths beneath North Horn Mountain, as shown in figure 9. Aquifers of this type are known to exist in the Flagstaff Limestone and the North Horn and Price River Formations and apparently also exist in the Castlegate Sandstone and Blackhawk Formation. Data collected during test drilling in the summer of 1979 by the Utah Geological and Mineral Survey indicate that there may be an extensive water-bearing zone in the Price River Formation. During drilling, water was also occasionally found in the Castlegate Sandstone and commonly found in the Blackhawk Formation above the major coal seams.

The perched aquifers support the flow of small seeps and springs (fig. 10 and table 5) used by livestock and wildlife, but these aquifers probably would not sustain large withdrawals (more than 100 gal/min) for long periods of time.

It appears that the regional water table extends upward into the Blackhawk Formation in some areas. For example, in those drill holes where water was encountered in the Blackhawk, the rocks seemed to be saturated downward into the Star Point Sandstone. The Star Point, where completely saturated, should be capable of yielding sustained quantities of water to wells; however, no yield estimates can be made at this time.

Recharge and movement

The principal source of ground-water recharge in the North Horn Mountain area is assumed to be from precipitation. The perched aquifers beneath North Horn Mountain probably receive recharge only from local precipitation, whereas, the deeper aquifers in the main zone of saturation (fig. 9) probably receive recharge from regional precipitation--chiefly in the higher, wetter areas west of North Horn Mountain. Water probably moves to both perched and deeper aquifers along faults, joints, or fractures, and movement apparently is quite rapid. Evidence for this is the rapid rise in the water level in the Blackhawk Formation in response to large amounts of rainfall. For example, the water level in an observation well in the Blackhawk Formation (fig. 10) rose 12 ft in August 1979 in response to large amounts of rainfall in the first week of the month. The water level had not fallen by the first week of September. Water levels in a nearby well that taps a perched aquifer in the Price River Formation (fig. 10) also responded rapidly to the same rainfall. However, by the first week of September, the water level in the observation well in the Price River Formation had declined to the level previously measured in July.

Some of the water in the main zone of saturation beneath North Horn Mountain may be derived from outside the Cottonwood and Ferron Creek drainage basins by interbasin flow through major fault zones such as the Joes Valley fault west of North Horn Mountain. However, data are insufficient to ascertain this source of recharge.

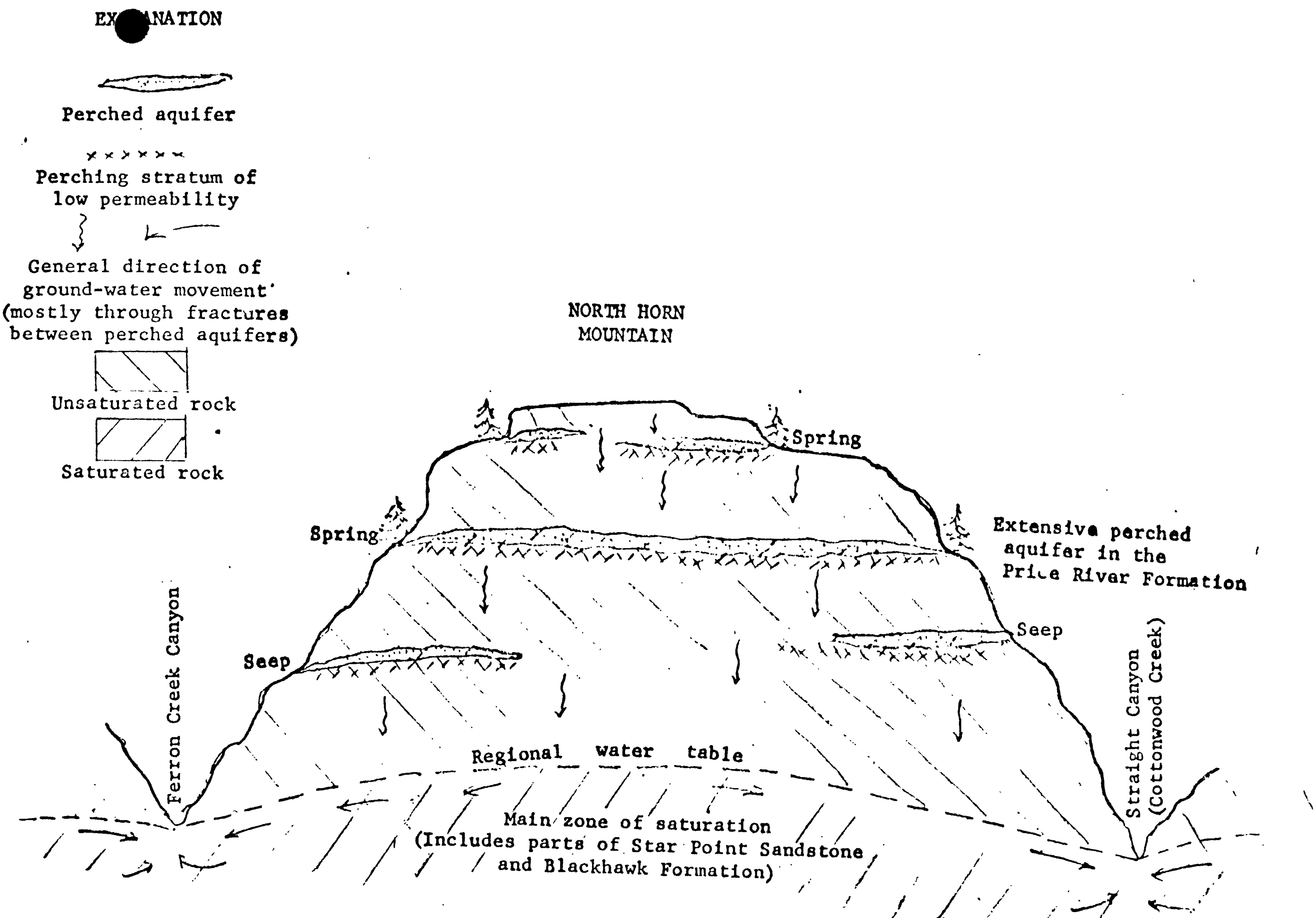
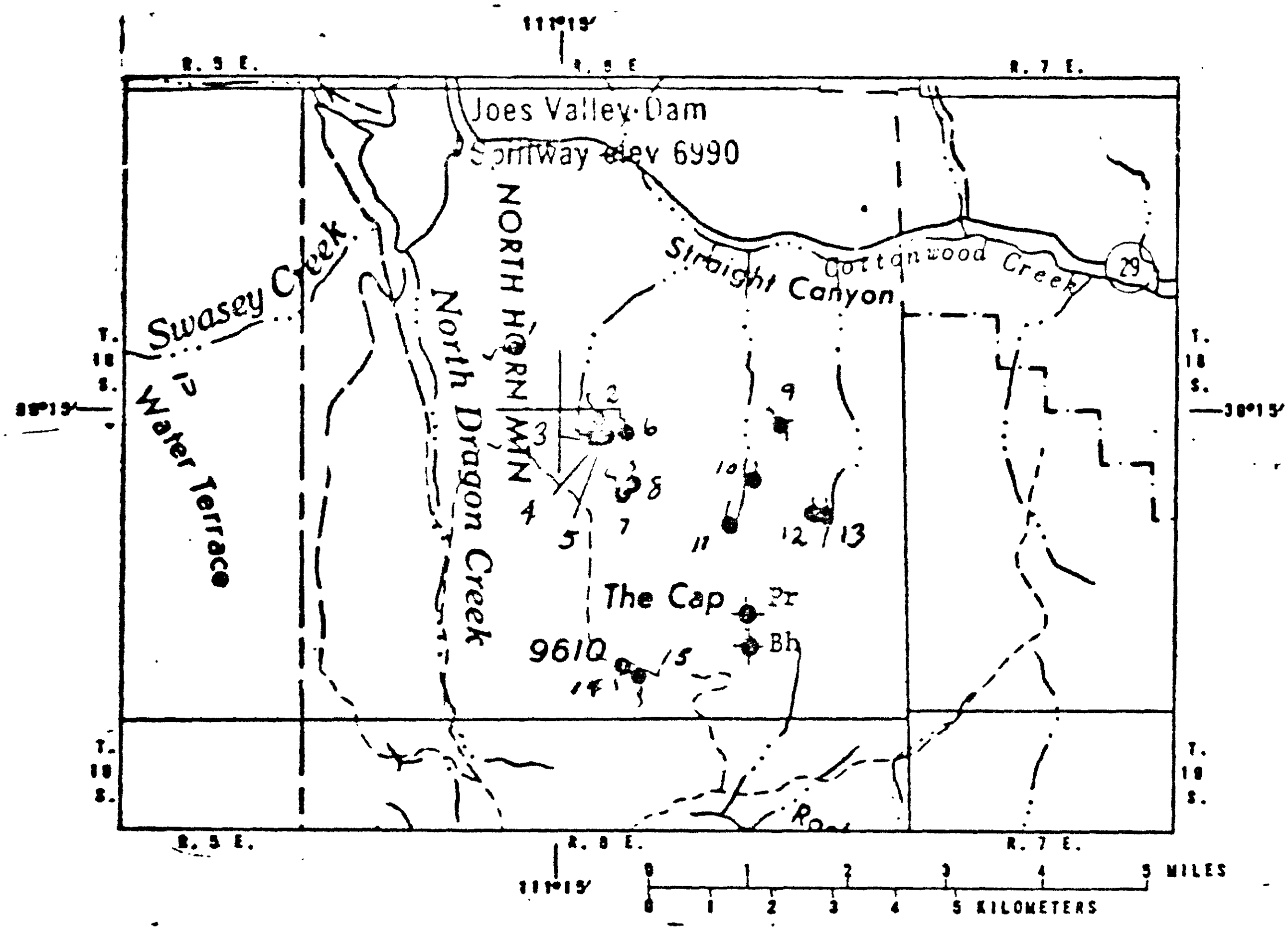


Figure 9.--Diagrammatic section through North Horn Mountain showing inferred general occurrence of ground water.

(Vertical scale greatly exaggerated.)



Base from U.S. Geological Survey 1:250,000 series Price, Utah, 1958 (revised 1972)

EXPLANATION

8 Spring
Number is site number in table 5

Observation well
Pr, taps Price River Formation; Bh, taps Blackhawk Formation

Figure 10.--Location of observation wells and springs investigated on North Horn Mountain.

Table 5.–Selected data for springs on North Horn Mountain

Specific conductance: Micromhos per centimeter at 25°C; determined by field conductivity meter.
pH: Units determined by field pH meter.

Site No. (see fig. 10)	U.S. Geological Survey local No.	Date	Measured discharge (gal/min)	Temperature (°C)	Specific conductance	pH
		1979				
1	(D-18-6) 16bdb-S1	8-23	11.1	8.0	1,500	7.8
2	15ccc-S1	8-30	2.8	8.0	700	7.7
3	21aaa-S1	8-30	.5	7.0	1,150	8.2
4	22bbb-S1	8-24	.7	7.0	1,150	8.0
5	15ccc-S1	8-30	1.5	7.0	700	7.7
6	22bba-S1	8-24	6.7	8.0	1,150	8.3
7	22cdc-S1	8-23	39.2	5.0	510	7.9
8	22cda-S1	8-23	.3	8.0	610	–
9	23abb-S1	9- 5	.52	12.0	1,025	7.7
10	23acc-S1	8-30	.3	6.5	790	8.3
11	26baa-S1	6-28	([1])	19.0	700	7.5
12	25bbd-S1	8-24	.5	19.0	1,500	7.9
13	25bac-S1	8-24	1.0	17.0	1,500	8.8
14	34bdc-S1	6-28	–	26.0	1,600	8.9
15	34cac-S1	6-28	5.0	10.0	1,000	7.8

[1] Seep, discharge too small to measure.

Discharge

Some of the ground water in a perched aquifer discharges in seeps and springs, and some probably seeps down along joints and fractures to lower aquifers (fig. 9). Springs generally issue from the side of stream channels into which rock dips, at the contact of two formations, or above beds of relatively impermeable claystone or shale (such as the Price River-North Horn contact), or above beds of relatively impermeable claystone or shale (such as in the Price River Formation).

The number of springs in a given formation decreases down the stratigraphic column. Most of the springs discharge from the Flagstaff Limestone and the North Horn and Price River Formations. Springs in the Flagstaff Limestone and North Horn Formation fluctuate rapidly in discharge in response to heavy rains, but they also may dry up by late summer. The few visible springs in the Blackhawk Formation and Star Point Sandstone are small, unmeasurable seeps. This is due in part to water in the main zone of saturation moving through these formations directly to the alluvium that blankets their lower portions. Some of the water that enters the alluvium eventually helps to sustain the base flow in Cottonwood and Ferron Creeks; the remainder is probably consumed by evapotranspiration. It is possible that some water in the main zone of saturation moves along faults and fractures to Castle Valley or moves out of the drainage basins of Cottonwood and Ferron Creeks.

Quality

According to Price and Waddell (1973, sheet 2), dissolved-solids concentrations of ground water in the North Horn Mountain area range from less than 500 mg/L in the headwater areas of Cottonwood and Ferron Creeks to about 1,000 mg/L along the west edge of Castle Valley. Water in the Mancos Shale beneath Castle Valley and possibly beneath the lower ends of Cottonwood and Ferron Creek canyons contain more than 1,000 mg/L and locally may be more highly saline.

The dissolved-solids concentrations of water from six springs in the North Horn Mountain area (fig. 2) range from 294 to 750 mg/L (table 6). Samples were collected from 15 other springs on North Horn Mountain (fig. 10), during the summer of 1979, but these samples have not yet (December 1979) been analyzed. Field measurements of the specific conductances of water from these springs ranged from 510 to 1,600 micromhos per centimeter at 25°C (table 5). This indicates that dissolved-solids concentrations of these waters, which issue from the Castlegate Sandstone and overlying formations, range from about 300 to 1,200 mg/L.

The chemical quality of ground water in the Blackhawk Formation and its coal-bearing beds beneath North Horn Mountain has yet to be determined. The water may be chemically similar to that discharged from the Wilberg Mine, which is in the Blackhawk 7.5 miles northeast across Cottonwood Creek from North Horn Mountain. A water sample collected September 20, 1976, from the Wilberg Mine had a dissolved-solids concentration of about 550 mg/L (Waddell and others, 1978, table 7).

Use

The principal use of ground water in the North Horn Mountain area is by wildlife and livestock. This is mostly at undeveloped springs and seeps in the higher, wetter areas on and west of North Horn Mountain. Some springs discharge to watering troughs, but there are no water-supply wells in the immediate vicinity of North Horn Mountain.

SOME POTENTIAL IMPACTS OF COAL MINING ON THE WATER RESOURCES

Surface water

Coal mining on North Horn Mountain should have an insignificant effect on the quantity of runoff in Cottonwood and Ferron Creeks. As noted earlier, most of the flow of those streams is generated in the higher, wetter area west of North Horn Mountain. The estimated mean annual runoff from North Horn Mountain to Cottonwood and Ferron Creeks amounts to only about 7 and 6 percent, respectively, of the average annual runoff recorded in those streams at gaging stations 09324500 and 09326500. Even if clearing of land required to mine the coal were to increase runoff from North Horn Mountain by as much as 50 percent, which is considered highly unlikely, the average annual runoff at stations 09324500 and 09326500 would be increased less than 4 and 3 percent, respectively. On the other hand, if runoff from North Horn Mountain were reduced by 50 percent due to the use of runoff catchments or because of land subsidence,[1] the average annual runoff at stations 09324500 and 09326500

[1] Land subsidence may result in fractures through which water is diverted underground.

Table 6.--Selected chemical analyses of water [illegible]m springs in the North Horn Mountain area

Site No.: See figure 2.
Specific conductance: Determined in field at time of sample collection.
pH: Determined in field at time of sample collection. All carbonate and bicarbonate determinations in laboratory.

Chemical analyses of major ions

Site No.	U.S. Geological Survey local No.	Date of sample	Temperature (°C)	Discharge (gal/min)	Milligrams per liter: Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrite plus nitrate (N)	Dissolved phosphorus (P)	Hardness (Ca,Mg)	Noncarbonate hardness	Dissolved solids (sum of constituents)	Sodium-adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH
GQ-1	(D-17-7) 27aca-S1	9-29-76	10.0	1.2	9.5	120	81	26	4.5	374	0	300	18	0.1	1.3	0.00	630	330	750	0.5	1,000	7.3
GQ-2	28bad-S1	10-22-76	3.5	2.7	5.9	63	32	14	.8	361	0	33	3.7	.2	.28	.00	290	0	332	.4	575	8.5
GQ-3	(D-18-5) 35dda-S1	9-28-76	14.0	1.0	4.3	35	40	20	2.5	327	0	11	17	.2	.41	.00	250	0	294	.5	535	8.0
GQ-4	(D-18-6) 31dca-S1	9-28-76	9.0	1.2	6.8	54	60	110	1.0	526	0	100	61	.3	2.0	.01	380	0	662	2.5	820	7.5
GQ-5	(D-19-6) 6aad-S1	9-28-76	14.0	.20	7.8	51	59	83	2.5	447	0	47	88	.4	.13	.00	370	4	560	1.9	910	8.4
GQ-6	20dba-S1	9-28-76	8.5	2.7	12	19	5.1	280	.6	746	0	38	21	1.2	.07	.02	69	0	745	15	1,120	8.3

Trace-metal analyses

Site No.	U.S. Geological Survey local No.	Date of sample	Micrograms per liter: Dissolved arsenic (As)	Dissolved boron (B)	Dissolved chromium (Cr)	Dissolved iron (Fe)	Dissolved lead (Pb)	Dissolved mercury (Hg)	Dissolved zinc (Zn)	Dissolved strontium (Sr)	Dissolved lithium (Li)	Dissolved selenium (Se)
GQ-1	(D-17-7) 27aca-S1	9-29-76	0	100	0	20	1	0.1	10	780	30	1
GQ-2	28bad-S1	10-22-76	1	20	10	30	3	.3	10	320	10	1
GQ-3	(D-18-5) 35dda-S1	9-28-76	0	60	0	20	0	.3	0	550	30	2
GQ-4	(D-18-6) 31dca-S1	9-28-76	1	90	0	10	0	.0	10	470	20	5
GQ-5	(D-19-6) 6aad-S1	9-28-76	3	100	0	30	0	.1	0	460	40	1
GQ-6	20dba-S1	9-28-76	1	200	0	140	0	.0	10	100	20	1

would be reduced by less than 4 and 3 percent, respectively. The decrease probably could be even less, assuming that some water diverted underground through subsidence fractures would eventually reach the streams--either through seeps or by mine drainage.

Considerable water would be required for dust suppression and other activities associated with mining, processing, and transporting of coal. The most likely source of such water is Cottonwood Creek, which is already fully appropriated (mostly for irrigation). Consequently, existing water rights would have to be purchased, and this would affect the local agricultural economy accordingly.

Coal mining on North Horn Mountain probably would have only a minor effect on the quality of surface water in the area. However, sediment yields locally might increase significantly during periods of construction. The extent of the increase would depend on the time of construction, location, extent of areas disturbed, type of mitigation, and weather conditions during construction periods. As noted earlier, 90 percent or more of the sediment load in the San Rafael River is produced during 10 percent or less of the time due to the effect of cloudburst floods. If construction were to take place during the summer cloudburst season, it could significantly add to the sediment loads of the affected streams. This would add to the cost of treating the water used for public supply. Construction during other times of the year, provided proper mitigating measures were taken, probably would not significantly increase fluvial-sediment loads above natural levels.

Data are insufficient to evaluate potential impacts of coal mining on North Horn Mountain on the chemical and biological quality of surface water in the area. Such mining will increase the potential for unpredictable spills of contaminants, such as fuel oil, into waterways. The increased population associated with mining will also increase the potential for contamination of streamflow in Cottonwood and Ferron Creeks, thus creating health hazards and increasing the cost of water treatment for public supply.

The coal seams beneath North Horn Mountain dip to the west and probably extend into the main zone of saturation. Consequently, if that coal is mined, mine drainage may be required and the mine water may be discharged to a surface drainage. The effect on surface-water quality probably would be insignificant because of the relatively small amount of ground water that would be discharged compared with total runoff. Also, the mine water would have about the same dissolved-solids concentration (generally less than 500 mg/L) as the runoff during low-runoff (baseflow) periods and would be greatly diluted during high-runoff periods. Furthermore, mine water cannot legally be discharged to a stream if it does not meet State of Utah Class C water-quality requirements (Utah Division of Health, written commun., 1971).

Ground water

Potential impacts on ground water that might result from mining of coal on North Horn Mountain are inferred largely from information gained in adjacent coal-mining areas of similar geologic and hydrologic character--particularly East Mountain (about 7 miles to the northeast across Cottonwood Creek from North Horn Mountain). As noted earlier, it appears that much, if not all, the ground water above the coal in North Horn Mountain is in perched aquifers. Some of the perched aquifers, as in the Price River Formation, may be extensive. Subsidence which usually follows underground coal mining, could create rock fractures through which a perched aquifer might be drained, thus depleting the flow of seeps or springs fed by that aquifer. Should this occur, wildlife or livestock might have to find an alternate water source.

Mining of coal on North Horn Mountain may require some mine dewatering which might result in interbasin transfer of water. That is, some ground water naturally tributary to Ferron Creek could be diverted to Cottonwood Creek via the mine-drainage facility (assuming mine portals to be in Cottonwood Creek canyon). The volume of mine-diverted water probably would be small compared to the total water yield of each of the drainage basins involved. However, the interbasin transfer of that water by the mine could lead to legal problems involving water rights.

It is unlikely that mining of the coal on the North Horn Mountain will adversely affect the chemical quality of the ground water. Available data indicate that the water in and above the coal-bearing beds is fresh, generally containing less than 1,000 mg/L of dissolved solids. Therefore, the creation of hydraulic connection between any two aquifers by drill holes, mine workings, or subsidence fractures would not significantly increase the dissolved-solids concentration of the less mineralized water in one aquifer or decrease the dissolved-solids concentration of the more mineralized water in the other. It is considered extremely unlikely that exploration drilling (which is usually to the top of the Star Point Sandstone) or coal-mining operations (all above the Star Point) would create hydrologic connections between the saline water-bearing Mancos Shale and the fresh water-bearing Star Point. Mining of coal on the North Horn Mountain, however, would introduce the potential of contamination of water in the Star Point by accidental spills of fuel oil or other contaminants on mine floors from whence those contaminants could seep to the Star Point.

CONCLUSIONS

1. Coal mining on North Horn Mountain should have an insignificant effect on the quantity of runoff in Cottonwood and Ferron Creeks. The maximum predicted decrease in the annual flow in these streams would be less than 4 percent.

2. The quality of the surface water probably would not be degraded to any major extent by the mining. However, if construction were to take place during the summer cloudburst season, it could significantly add to the sediment loads of affected streams.

3. The coal mining on North Horn Mountain will increase the potential for unpredictable spills of contaminants, such as fuel oil, into waterways.

4. Subsidence, which usually follows underground coal mining, could create rock fractures through which a perched aquifer might be drained, thus depleting the flow of seeps or springs fed by that aquifer.

5. It is considered unlikely that mining of the coal on North Horn Mountain will adversely affect the chemical quality of the ground water. However, the mining would introduce the potential of contamination of water in the Star Point Sandstone by accidental spills of fuel oil or other contaminants on mine floors from whence those contaminants could seep to the Star Point.

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