UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RECONNAISSANCE EVALUATION OF WATER RESOURCES FOR HYDRAULIC COAL MINING, GRAND HOGBACK COAL FIELD, GARFIELD AND RIO BLANCO COUNTIES, COLORADO

By William M. Alley, Linda J. Britton, and Elaine L. Boyd

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METRIC CONVERSIONS

Inch-pound units used in this report may be converted to metric units by the following conversion factors:

Multiply inch-pound unit	*By*	*To obtain metric unit*
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per acre (acre-ft/acre)	3,048	cubic meter per hectare
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.)	25.4	millimeter
square mile (mi^2)	2.590	square kilometer
ton (short, 2,000 lbs)	0.9072	metric ton
ton per day (ton/d)	0.9072	metric ton per day
ton per year	0.9072	metric ton per year

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ABSTRACT

Surface-water and ground-water data were compiled for the parts of the Colorado River and the White River basins in and adjacent to the Grand Hogback coal field. The data were evaluated to assess the quantity and quality of water resources available in the area for use in hydraulic coal mining.

Based on discharge records, surface-water supplies of most streams should be adequate to meet the demands for hydraulic mining of 1 million tons of coal per year with a recycled water system. However, on some of the smaller streams in the area, some storage of water may be required for use during low-flow periods to meet minimum-flow requirements for downstream reaches. Other potential sources of water include Rifle Gap Reservoir, Harvey Gap Reservoir, and ground water from valley-fill deposits along major streams and rivers.

The surface and ground water in the study area should be of adequate quality for use in hydraulic mining, with the possible exceptions of suspended-sediment concentrations that periodically may be as much as 18,800 milligrams per liter in streams in the Rifle Creek drainage, and dissolved-solids concentrations that are greater than 20,000 milligrams per liter in some aquifers. Data are insufficient to assess the potential impact of hydraulic coal mining on downstream water quality.

INTRODUCTION

Colorado has approximately 10 percent of the total estimated remaining coal resources in the United States (Hornbaker and Holt, 1973). The coal deposits in the State occur in diverse physiographic and structural environments, which may require varying mining techniques. A particular technique that recently has come into worldwide use is hydraulic mining, which may be used on the surface or underground (Cooley, 1975). Hydraulic coal mining entails the use of water jets to break the coal-bearing rock and to transport the coal out of the mine (Cooley, 1975). The development of this process in the United States has been primarily directed to its use in underground coal mining, because surface mining is restricted in many areas.

PURPOSE AND SCOPE

An area in Colorado designated by the U.S. Bureau of Mines as a potential site for hydraulic coal mining is the Grand Hogback coal field, which extends northwestward along the trend of coal-bearing rocks from near Glenwood Springs, to near Rio Blanco, and then northward to Meeker (fig. 1). Proper consideration for development of coal resources using hydraulic-mining techniques requires a knowledge of the hydrologic conditions of the designated area. Recognizing this need for hydrologic information, the U.S. Geological Survey, in August 1977, began a reconnaissance evaluation of the water resources in the vicinity of the Grand Hogback coal field.

The purpose of this report is to provide:

(1) A compilation and analysis of available data on the quantity and quality of surface and ground water; and

(2) An evaluation of the water resources for potential use in hydraulic coal mining.

PHYSICAL SETTING

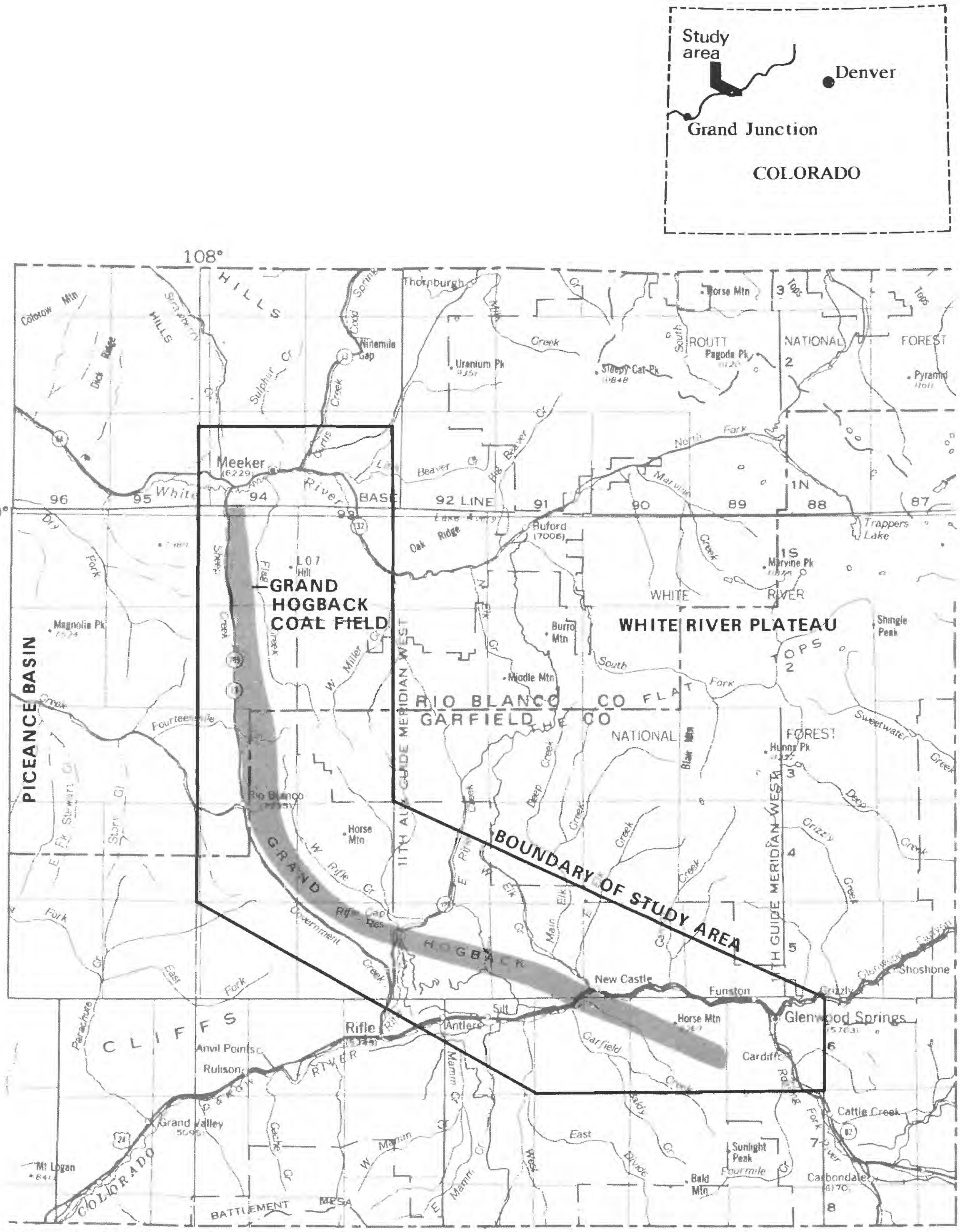
Physiography

The Grand Hogback study area includes parts of two major drainage basins. The southern part of the study area is drained by the Colorado River and its tributaries. The northern part is drained by the White River and its tributaries. Land-surface altitudes range from about 5,000 ft in the Colorado River valley to more than 9,000 ft on the Grand Hogback. Major physiographic features surrounding the Grand Hogback include the White River Plateau to the east and the Piceance basin to the west (fig. 1).

Geology

Geologic maps which include the study area have been compiled by Tweto (1975), and by Tweto, Moench, and Reed (1976). The Grand Hogback is a monoclinal fold formed by steeply dipping beds of the Mesaverde Formation of Late Cretaceous age (Hornbaker and Holt, 1973). Younger geologic units include the valley-fill and terrace deposits of Quaternary age in river and stream valleys, and the variegated claystones, siltstones, sandstones, and conglomerates of the Wasatch Formation of Tertiary age. The Wasatch Formation is exposed to the west and south of the Grand Hogback.

Rocks exposed east and north of the Grand Hogback toward the White River Plateau are generally older than the Mesaverde Formation. These include, from youngest to oldest, the Mancos Shale and the Dakota Sandstone of Cretaceous age; the Morrison Formation of Late Jurassic age, which is composed of variegated siltstone and mudstone with beds of sandstone and limestone; the Entrada Sandstone of middle Jurassic age; the Glen Canyon and Wingate Sandstones of Jurassic and Triassic age; the Maroon Formation of Permian and Pennsylvanian age, which is composed of maroon and grayish-red sandstone, conglomerate, and mudstone; and the Weber Sandstone of



Base from U.S. Geological Survey
State base map, 1969

0 5 10 15 MILES
0 5 10 15 KILOMETERS

Figure 1.--Location of study area.

Permian and Pennsylvanian age. These formations are, in turn, underlain by geologic units of Early Pennsylvanian age; the Leadville Limestone of Mississippian age; the Chaffee Group of Early Mississippian(?) and Late Devonian age, which is composed of sandstone and dolomite; and Precambrian schist and gneiss.

The coals in the area occur in the Mesaverde Formation. The Mesaverde Formation in this area has been divided into the Iles Member overlain by the Williams Fork Member. The coals at the top of the Iles Member, the Black Diamond group, are generally thin and discontinuous. Within the Grand Hogback field, most of the coal is mined from seams in the lower 2,500 ft of the Williams Fork Member (Hornbaker and Holt, 1973).

The coal in the southern part of the Grand Hogback field is mostly high-volatile B bituminous in rank and is generally noncoking. The coal in the northern part of the field is mostly high-volatile C bituminous, but may in places be subbituminous in rank (Landis, 1959). In 43 mi^2 of the field surveyed, identified resources total 885 million tons of coal (Landis, 1959). A potential exists for mining these resources using sublevel hydraulic mining (Cooley, 1975).

WATER QUANTITY

Initiation of hydraulic mining operations will require about 20 acre-ft of water for a production rate of 1 million tons of coal per year (Cooley, 1975). The continuing water supply required for replenishment due to losses in the moist coal product, refuse disposal, and evaporation will be approximately 50 acre-ft for a production rate of 1 million tons of coal per year (Cooley, 1975).

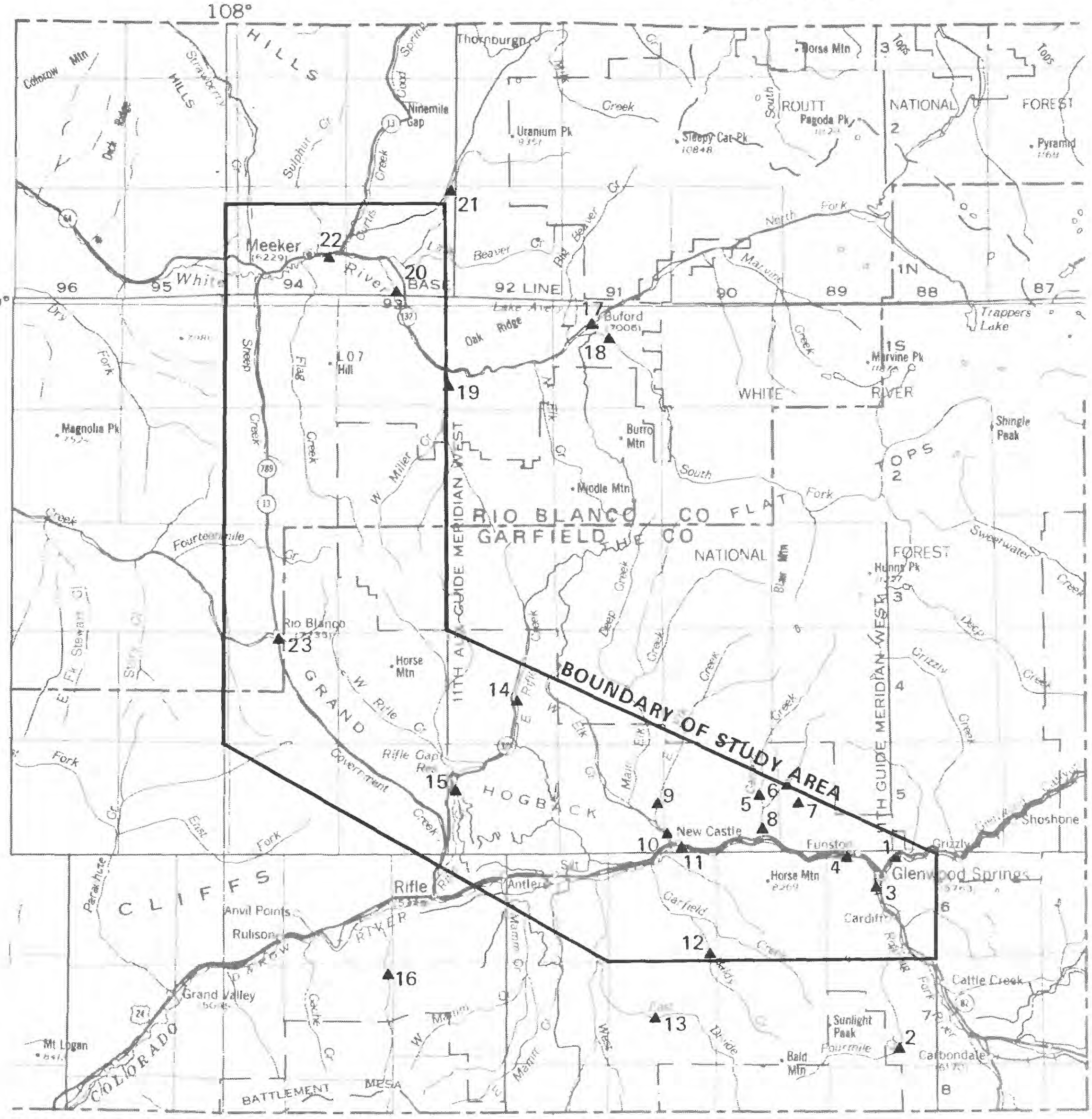
Surface Water

Factors affecting the time distribution and quantity of streamflow in the study area are discussed first. This is followed by hydrologic analyses of streamflow records and an evaluation of the surface-water resources for potential use in hydraulic coal mining.

The hydrologic analyses used in this investigation are based on streamflow records collected by the U.S. Geological Survey. The locations of U.S. Geological Survey streamflow-gaging stations in the vicinity of the Grand Hogback are shown on figure 2, and the stations are described in table 1. All streamflow records collected at the stations have been published by the U.S. Geological Survey (1954, 1964, 1961-76).

EXPLANATION

▲9 STREAMFLOW-GAGING STATION—Number for stations listed in tables 1, 2, and 3



Base from U.S. Geological Survey State base map, 1969

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0 5 10 15 KILOMETERS

Figure 2.--Location of streamflow-gaging stations.

Table 1.--*Summary of streamflow-gaging stations*

Index number on fig. 2	U.S. Geological Survey downstream order number	Station name	Period of record	Drainage area (mi^2)	Remarks
1	09072500	Colorado River at Glenwood Springs.	May 1899-September 1966------	4,560	Greatly affected by numerous diversions.
2	09084600	Fourmile Creek near Glenwood Springs.	October 1957-September 1965--	16.7	
3	09085000	Roaring Fork River at Glenwood Springs.	October 1905-September 1909, September 1910-Present.	1,451	Do.
4	09085100	Colorado River below Glenwood Springs.	October 1966-Present---------	6,013	Do.
5	09085200	Canyon Creek above New Castle.	March 1969-Present-----------	23.8	
6	09085300	East Canyon Creek near New Castle.	March 1969-Present-----------	15.1	
7	09085400	Possum Creek near New Castle.	March 1969-Present-----------	6.41	
8	09085500	Canyon Creek near New Castle.	October 1954-September 1960--	55.0	
9	09087000	East Fork Elk Creek near New Castle.	October 1910-September 1915--	40.0	Entire record estimated.
10	09087500	Elk Creek at New Castle.	March 1922-September 1924, October 1954-September 1960.	180	
11	09087600	Colorado River at New Castle.	July 1966-September 1972-----	6,308	Greatly affected by numerous diversions.
12	09088000	Baldy Creek near New Castle.	October 1955-September 1961--	15.3	No flow at times each year.
13	09090700	East Divide Creek near Silt.	October 1959-September 1965--	40.8	No flow at times each year, except 1965 water year.

Table 1.--*Summary of streamflow-gaging stations*--Continued

Index number on fig. 2	U.S. Geological Survey downstream order number	Station name	Period of record	Drainage area (mi^2)	Remarks
14	09091500	East Rifle Creek near Rifle.	October 1936-September 1943, October 1956-September 1964.	34.3	Regulation by powerplant prior to October 1958.
15	09092000	Rifle Creek near Rifle.	October 1939-September 1946, October 1952-September 1964.	137	Diversion upstream of station of about 14,000 acre-ft annually by Grass Valley Canal for use outside basin.
16	09092500	Beaver Creek near Rifle.	October 1952-Present---------	7.90	
17	09303000	North Fork White River at Buford.	May 1910-December 1915, July 1919-December 1920, October 1951-Present.	254	
18	09304000	South Fork White River at Buford.	July 1919-December 1920, October 1951-Present.	170	
19	09304150	Miller Creek near Meeker.	October 1970-Present---------	57.6	
20	09304200	White River above Coal Creek, near Meeker.	October 1961-Present---------	660	
21	09304300	Coal Creek near Meeker.	October 1957-September 1968--	[1]25	Slight regulation by two small storage reservoirs upstream from station.
22	09304500	White River near Meeker.	June 1901-December 1906, October 1909-Present.	762	
23	09305500	Piceance Creek at Rio Blanco.	October 1952-September 1957--	[1]9	

[1]Approximate.

Factors Affecting Streamflow

Annual and seasonal variations of precipitation and temperature have the greatest natural influence on streamflow. Mean annual precipitation in the study area ranges from about 12 in. along the Colorado River near Silt to about 25 in. at higher altitudes (fig. 3). Precipitation is fairly evenly distributed throughout the year, as illustrated in figure 4. However, owing to cold temperatures from October through April, a snowpack accumulates to great depths at higher elevations. This snowpack is the principal source of streamflow as it melts in the spring and summer. Summer precipitation occurs primarily as thundershowers, sometimes having high local intensities. Summer precipitation seldom contributes significantly to the base streamflow, but may cause annual peak flows in the smaller basins. The distribution of monthly streamflows of Beaver Creek near Rifle (fig. 5) is typical of that for streams in the vicinity of the Grand Hogback. Mean monthly streamflow reaches a peak during the snowmelt period of April through July. The streamflow then subsides as the supply of snow is exhausted.

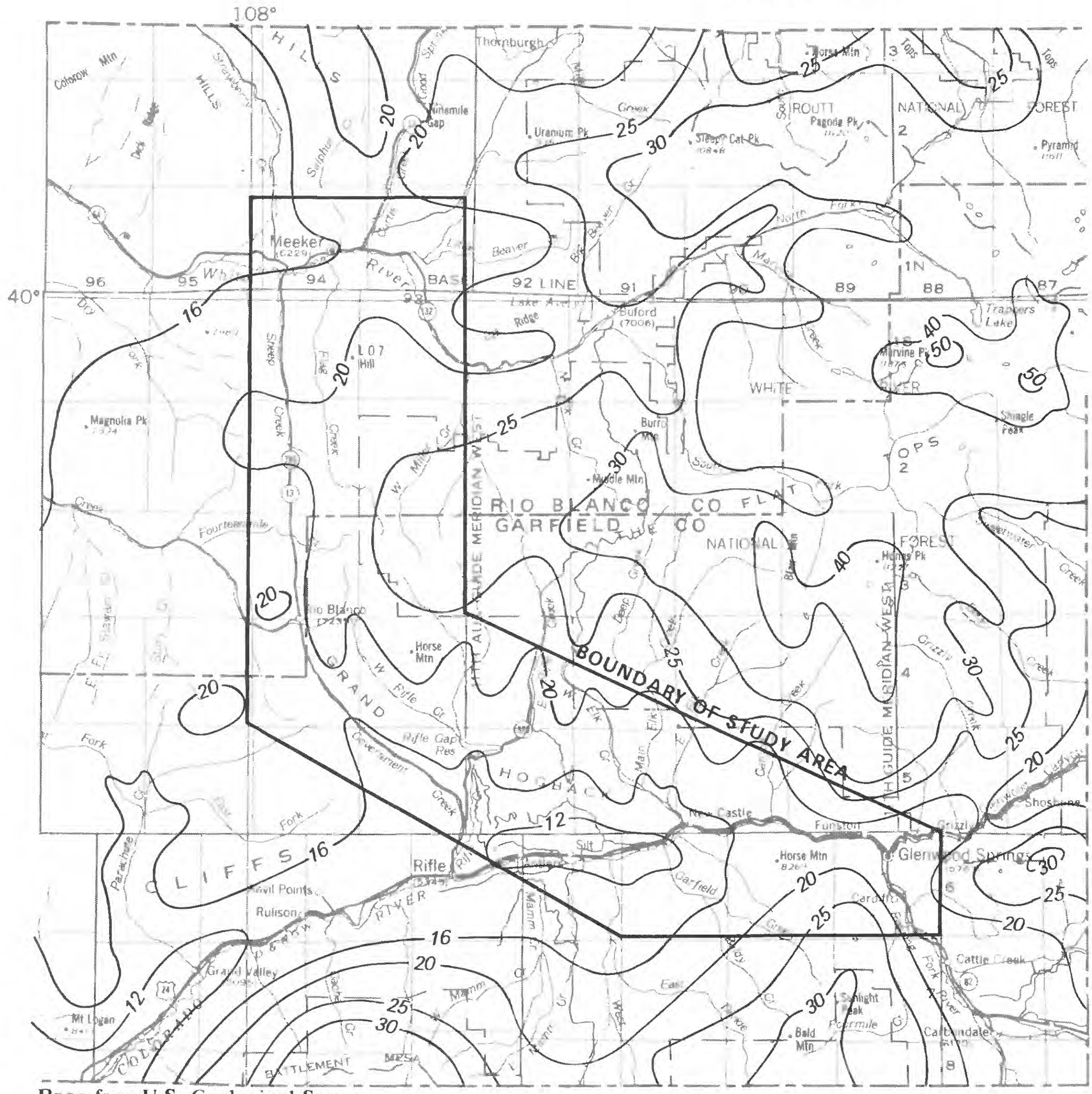
Other important factors affecting the amount and distribution of streamflow include diversions for irrigation, transmountain diversions, manmade storage and regulation, soils, geology, and vegetation. Man's activities have affected the amount and distribution of streamflow through large transmountain diversions and smaller diversions for irrigation within the Upper Colorado River Basin. The development of dynamic regulation and diversion hampers statistical interpretation of streamflow records for the Colorado River. The White River has remained free from major reservoir projects; however, several significant reservoir projects are being planned for this river.

During the irrigation season of March to November, diversions of streamflow for irrigation of crops and evapotranspiration losses associated with irrigation practices may have a marked influence on the streamflow regimen. The amount of water diverted and the number of acres irrigated at any one time are functions of water availability, water-right priorities, crop type, and weather conditions. In the Grand Hogback area, irrigated lands are mostly on terraces and valley bottoms at altitudes of about 5,000 to 6,000 ft. In general, the principal crops are alfalfa, grass, and hay. Much of the water is obtained from tributaries of the Colorado and the White Rivers. Irrigation water is generally applied at rates of 3 to 5 acre-ft/acre annually. About one-half to two-thirds of the applied water returns to the streams (Iorns and others, 1965).

Geology also can affect the distribution of runoff. For example, the base flow of East Rifle Creek is sustained by ground water from permeable rocks of Pennsylvanian and Mississippian age in the White River Plateau (Iorns and others, 1965).

EXPLANATION

——30—— LINE OF EQUAL AVERAGE ANNUAL PRECIPITATION – Interval, in inches, is variable



Base from U.S. Geological Survey
State base map, 1969

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Figure 3.--Average annual precipitation (from U.S. Weather Bureau, 1967).

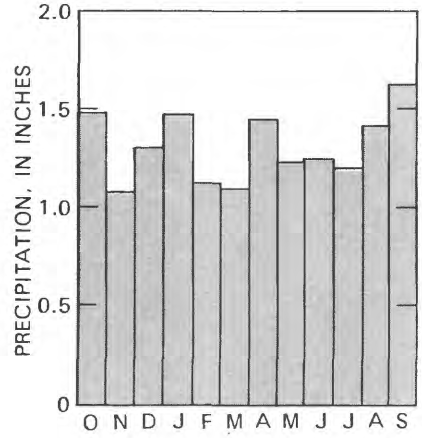


Figure 4.--Mean monthly precipitation at Glenwood Springs, October 1952 through September 1976.

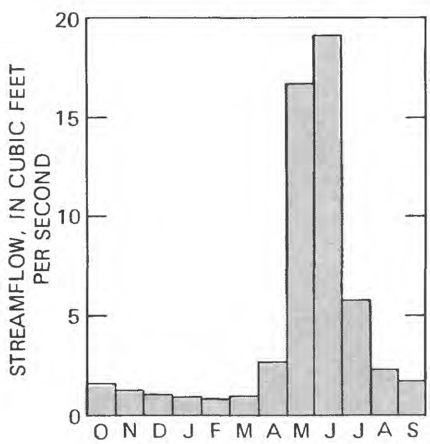


Figure 5.--Mean monthly streamflow for Beaver Creek near Rifle, October 1952 through September 1976.

Hydrologic Analyses

Two types of hydrologic analyses were used to provide information about surface-water supplies for hydraulic coal mining. The first analysis determined the maximum-mean, mean, and minimum-mean monthly and annual flows at selected stream-gaging stations in and near the study area (table 2). These data illustrate the timing and magnitude of high and low streamflows. The second analysis used annual low-flow data to determine magnitudes and frequencies of extreme low flows for several periods of consecutive days.

Low-flow-frequency data were determined from daily streamflow data for the six stations in the study area that have sufficient length of record representative of current conditions (10 years or more of record, as recommended by Riggs, 1972). These low-flow data are listed in table 3. In addition, frequency data for mean 7-day low flows are included for two stations, each having (1) at least 5 years of daily streamflow records, (2) streamflows under relatively natural conditions, and (3) correlation coefficients of greater than 0.8 in a log-log regression of the base flows of the station with concurrent base flows of a station having greater than 10 years of record. The correlation of base flows of these two stations with base flows of the long-term stations are shown in figure 6.

Evaluation for Potential Use in Hydraulic Coal Mining

A water supply from a stream may be either a continuous or an intermittent withdrawal of water at either a constant or variable rate. If the required withdrawal rates are large compared with the low flows of the stream, storage of water may be required for low-flow periods. The designer of a water-supply project often can determine whether storage is required from an examination of low-flow-frequency data, such as is given in table 3.

To meet the demands of approximately 50 acre-ft of water per year for a coal-production rate of 1 million tons per year (Cooley, 1975), with a constant continuous withdrawal of water, would require a withdrawal rate of approximately 0.07 ft^3/s. At each of the stations listed in table 3, the streams would apparently be capable of maintaining such a withdrawal rate. However, at other stations listed in table 1, this withdrawal rate could not be maintained. For example, zero daily discharges were reported for Baldy Creek near New Castle and East Divide Creek near Silt, and minimum daily discharges for Piceance Creek at Rio Blanco are reported to be approximately 0.10 ft^3/s (U.S. Geological Survey, 1964). For sites such as these, either an alternative withdrawal scheme would be required or the necessary water could be stored. In addition, statutes or laws may require some storage to meet minimum-flow requirements for downstream reaches. Additional water requirements for other mining needs, such as coal gasification and liquefaction, powerplant cooling, or coal-slurry pipelines, also may result in a requirement for storage. The data in tables 2 and 3 are useful for a general assessment of water availability. However, the need for storage should be evaluated on a site-specific basis once a mining site is selected. Finally, two existing reservoirs in the study area are also potential sources of surface water. These are Harvey Gap and Rifle Gap Reservoirs.

Table 2.--*Summary of monthly and*

Index number on fig. 2	U.S. Geological Survey downstream order number	Station name	Period of record		October	November	December
2	09084600	Fourmile Creek near Glenwood Springs.	October 1960-September 1965	Max.	1.89	1.27	1.04
				Mean	.81	.75	.60
				Min.	.33	.51	.39
4	09085100	Colorado River below Glenwood Springs.	October 1966-September 1976	Max.	2,620	2,270	1,840
				Mean	2,110	1,930	1,620
				Min.	1,670	1,390	1,160
5	09085200	Canyon Creek above New Castle.	March 1969-September 1976	Max.	36.5	23.3	18.4
				Mean	21.6	17.6	14.9
				Min.	13.5	12.8	11.1
6	09085300	East Canyon Creek near New Castle.	March 1969-September 1976	Max.	12.6	10.2	7.66
				Mean	7.35	6.72	5.60
				Min.	4.41	3.81	3.31
7	09085400	Possum Creek near New Castle.	March 1969-September 1976	Max.	3.75	2.79	3.09
				Mean	3.04	2.47	2.28
				Min.	2.25	1.98	1.39
8	09085500	Canyon Creek near New Castle.	October 1954-September 1960	Max.	31.2	27.1	27.2
				Mean	15.6	20.9	20.4
				Min.	4.99	15.4	15.4
10	09087500	Elk Creek at New Castle.	October 1954-September 1960	Max.	24.9	28.4	30.2
				Mean	14.3	17.8	21.1
				Min.	3.26	10.8	15.6
11	09087600	Colorado River at New Castle.	July 1966-September 1972	Max.	2,700	2,270	2,000
				Mean	2,140	1,920	1,660
				Min.	1,680	1,430	1,210
14	09091500	East Rifle Creek near Rifle.	October 1958-September 1964	Max.	41.8	40.1	38.4
				Mean	35.7	34.8	34.2
				Min.	32.1	31.1	30.0
15	09092000	Rifle Creek near Rifle.	October 1952-September 1964	Max.	29.3	13.9	16.4
				Mean	20.5	9.33	8.39
				Min.	12.8	5.06	4.29
16	09092500	Beaver Creek near Rifle.	October 1952-September 1976	Max.	3.40	2.20	1.76
				Mean	1.63	1.23	1.03
				Min.	.93	.60	.68
17	09303000	North Fork White River at Buford.	May 1910-September 1915, October 1919-September 1920, October 1951-September 1976	Max.	267	242	229
				Mean	199	183	166
				Min.	151	139	122
18	09304000	South Fork White River at Buford.	July 1919-December 1920, October 1951-September 1976	Max.	185	174	170
				Mean	128	115	107
				Min.	92.6	91.1	79.0
19	09304150	Miller Creek near Meeker.	October 1970-September 1976	Max.	22.1	19.0	20.4
				Mean	20.0	18.3	17.1
				Min.	18.3	17.0	15.4
21	09304300	Coal Creek near Meeker.	October 1957-September 1968	Max.	3.29	3.17	3.20
				Mean	1.88	1.95	1.81
				Min.	1.19	1.17	1.20
22	09304500	White River near Meeker.	October 1901-September 1906, October 1909-September 1976	Max.	569	648	460
				Mean	390	365	332
				Min.	264	269	240
23	09305500	Piceance Creek at Rio Blanco.	October 1952-September 1957	Max.	0.63	0.98	0.98
				Mean	.41	.63	.63
				Min.	.17	.37	.46

Maximum-mean (max.), mean, and minimum-mean (min.) monthly and annual flows for period of record, in cubic feet per second

January	February	March	April	May	June	July	August	September	Annual
0.95	1.16	1.42	52.6	96.5	40.8	4.75	1.74	1.69	15.8
.58	.59	.92	17.2	59.6	19.2	2.29	.86	.92	8.75
.39	.36	.56	3.62	11.6	2.74	.36	.14	.35	2.48
1,810	1,880	2,340	4,320	11,540	13,420	8,530	3,390	2,990	4,200
1,520	1,530	1,790	2,640	7,140	10,290	5,410	2,680	2,240	3,410
1,180	1,150	1,330	1,980	4,480	6,840	3,380	2,170	1,930	2,660
16.1	15.8	20.4	50.4	292	408	174	26.5	20.4	65.0
13.5	13.1	13.8	24.5	183	240	61.0	19.1	16.9	53.1
10.3	11.0	11.1	15.0	67.2	131	27.8	12.3	12.4	44.5
6.55	7.06	7.41	23.1	122	217	120	12.7	9.47	34.9
5.19	5.08	5.52	11.7	82.4	104	34.0	9.43	7.07	23.5
3.35	3.54	4.33	5.92	27.9	49.9	11.5	7.15	5.17	14.0
3.12	2.51	2.66	5.73	24.0	38.8	15.4	6.32	4.86	7.32
2.00	1.89	1.75	3.27	17.7	19.4	7.79	4.66	3.39	5.86
1.20	1.08	1.17	1.79	9.82	9.03	3.92	3.02	2.35	4.03
24.4	21.7	21.6	54.3	304	558	310	28.1	26.1	93.9
19.1	17.5	17.8	34.4	203	313	68.1	6.84	7.72	62.0
15.9	15.0	15.2	24.4	95.1	210	10.2	1.27	.79	49.7
22.4	26.2	25.3	71.8	647	1,200	369	20.6	16.8	161
19.2	17.9	18.2	41.6	406	491	68.7	7.82	5.56	94.2
15.5	13.2	9.59	20.5	221	207	3.69	1.76	1.64	65.9
1,870	1,830	2,310	4,440	12,880	14,710	7,110	3,540	2,940	4,410
1,550	1,550	1,800	2,930	7,780	11,620	4,720	2,560	2,260	3,590
1,220	1,220	1,390	2,070	4,800	8,090	2,590	1,950	1,690	2,820
35.9	35.9	36.0	38.8	90.8	63.5	51.7	43.1	42.0	43.0
32.7	31.8	31.5	33.8	46.9	40.0	36.7	34.3	33.9	35.5
29.4	29.0	29.0	29.8	30.7	29.5	29.9	30.2	26.7	30.2
33.3	34.3	34.0	44.5	99.8	83.9	46.4	46.3	37.4	35.9
9.37	12.2	16.9	18.1	46.0	42.1	36.0	34.3	31.4	23.8
5.00	5.30	5.84	6.76	31.4	28.8	28.0	26.5	26.9	18.3
1.49	1.31	1.28	7.23	30.1	37.7	17.9	4.32	3.02	7.03
.94	.86	.93	2.63	16.6	19.1	5.74	2.23	1.66	4.55
.62	.57	.65	1.35	6.85	5.11	1.57	1.17	.78	2.56
233	199	210	527	1,320	1,590	1,130	431	306	467
159	154	157	262	763	848	383	242	206	311
118	119	125	168	477	292	164	151	136	221
129	144	149	287	1,070	1,800	1,120	267	184	357
104	104	106	151	645	1,010	297	159	131	285
76.6	80.9	86.6	104	328	309	118	105	90.0	180
17.9	16.8	17.8	16.7	60.2	57.7	23.7	17.1	21.4	22.0
16.1	14.9	15.4	15.4	40.2	26.0	16.5	15.0	19.3	19.5
14.6	13.6	14.5	13.9	29.0	11.9	11.9	13.1	16.7	16.3
2.80	3.20	4.12	29.6	61.5	21.5	4.64	2.68	2.20	9.51
1.70	1.94	2.74	8.81	24.4	11.9	2.31	1.69	1.48	5.23
1.20	1.00	1.20	3.25	9.79	2.83	.96	1.04	.86	2.78
410	420	478	1,090	2,510	4,090	2,520	747	716	985
313	310	338	539	1,560	1,900	665	388	368	622
235	232	261	313	711	264	150	190	188	339
1.04	1.20	1.90	4.61	12.0	6.04	1.74	1.93	1.72	2.55
.71	.73	1.04	3.59	5.41	1.92	.61	.59	.54	1.40
.50	.50	.65	2.12	1.38	.44	.14	.12	.10	.77

Table 3.--*Low-flow frequency data for selected stations*

Index number on fig. 2	U.S. Geological Survey downstream order number	Station name	Period of record	Period (consecutive days)	Mean streamflow, in cubic feet per second, for indicated recurrence interval, in years			
					2	5	10	20
2	09084600	Fourmile Creek near Glenwood Springs.[1]	---------------------	7	0.23	0.17	0.15	------
7	09085400	Possum Creek near New Castle.[2]	---------------------	7	1.55	1.36	1.26	1.19
15	09092000	Rifle Creek near Rifle---	April 1953-March 1964	7	5.55	4.39	3.91	3.55
				30	6.59	5.35	4.81	4.40
				90	6.97	5.67	5.30	5.09
16	09092500	Beaver Creek near Rifle--	April 1953-March 1976	7	.59	.50	.45	.42
				30	.68	.60	.56	.54
				90	.82	.72	.67	.64
17	09303000	North Fork White River at Buford.	April 1911-March 1915, April 1952-March 1976	7	132	118	112	108
				30	142	128	122	118
				90	151	137	130	125
18	09304000	South Fork White River at Buford.	April 1952-March 1976	7	89.3	80.8	76.0	72.0
				30	96.2	86.9	82.0	78.0
				90	102	91.8	86.5	82.1
21	09304300	Coal Creek near Meeker---	April 1958-March 1968	7	.80	.62	.55	.51
				30	1.10	.91	.84	.78
				90	1.34	1.12	1.04	.98
22	09304500	White River near Meeker--	April 1902-March 1906, April 1910-March 1976	7	267	218	191	169
				30	291	248	223	201
				90	313	275	253	233

[1]Frequency data for mean 7-day low flows estimated from correlations of base-flow measurements on concurrent days at station and at Coal Creek near Meeker.

[2]Frequency data for mean 7-day low flows estimated from correlations of base-flow measurements on concurrent days at station and at Beaver Creek near Rifle.

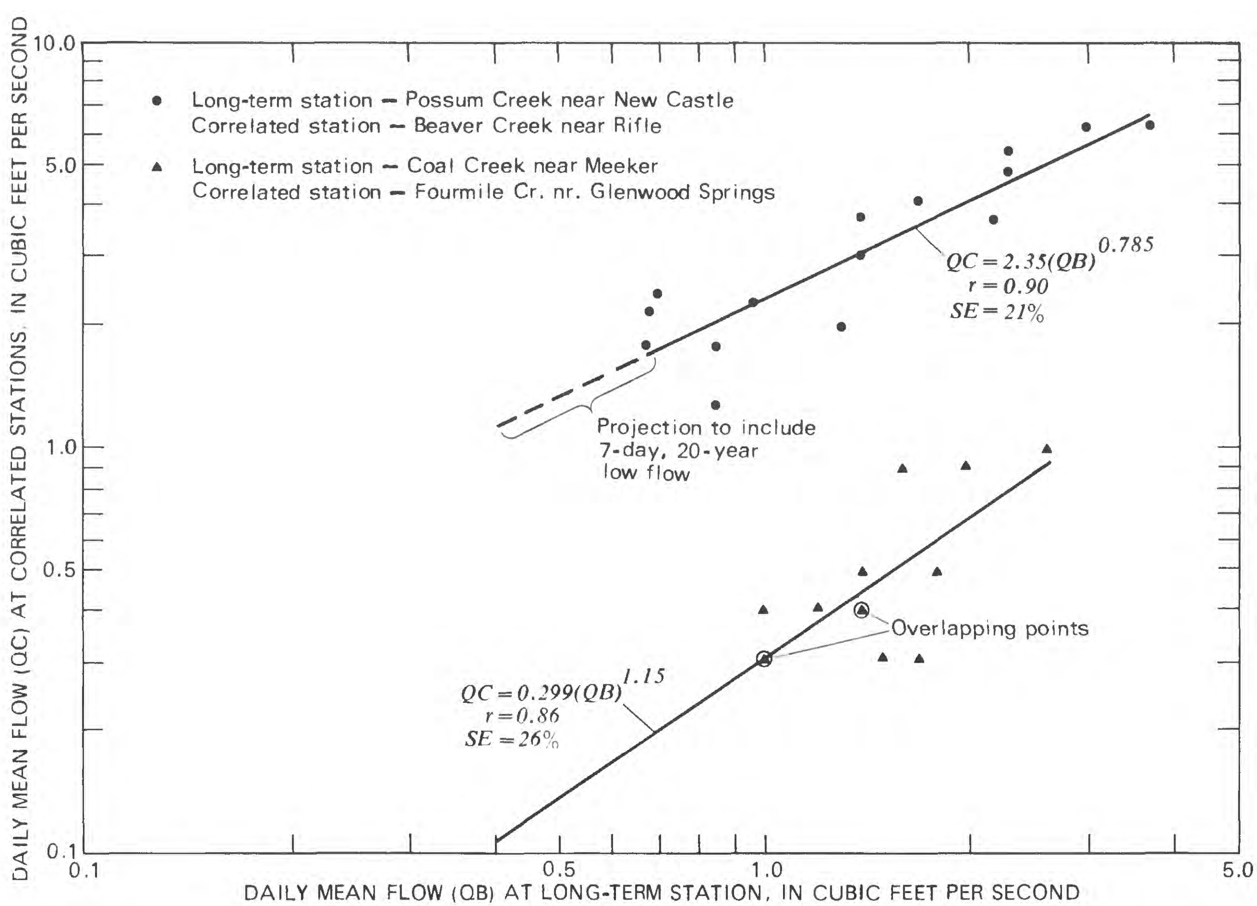


Figure 6.--Base-flow correlations.

Ground Water

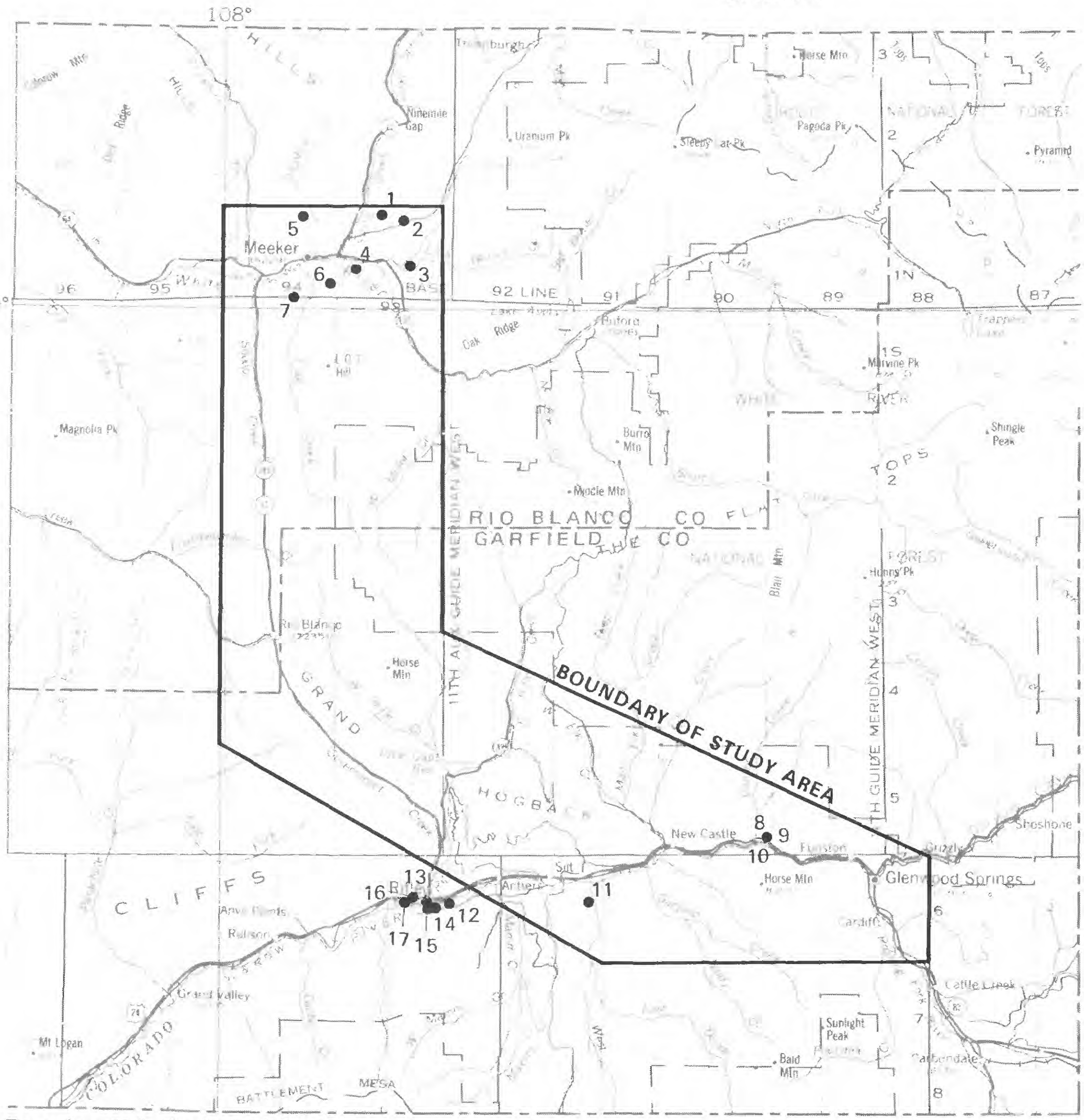
The ground-water supplies in the vicinity of the Grand Hogback are largely unknown and undeveloped. The locations of wells in the area are shown on figure 7 and records of the wells are listed in table 4 according to the well-location and well-numbering system described on pages 36 and 37. As indicated in table 4, principal development has been in the valley-fill deposits. Valley-fill aquifers occur principally along the White River and along the Colorado River, particularly downstream of New Castle. The valley fill is comprised of fluvial and glaciofluvial deposits consisting of clay, sand, and gravel. Generally, the well yields from valley-fill deposits will range from 5 to 100 gal/min, but yields may exceed 1,000 gal/min (Boettcher, 1972). Water levels in the aquifers are generally within a few feet of the water-surface levels of the nearby stream. However, because the valley-fill aquifers are of limited areal extent, discharge rates of more than 100 gal/min can be maintained only for short periods of time. In addition, pumping from alluvial aquifers may be subject to regulation by the State because of effects on the flow of nearby streams.

The steeply dipping beds of the Mesaverde Formation and the Dakota, Entrada, Glen Canyon, and Wingate Sandstones in the vicinity of the Grand Hogback are in areas of natural ground-water recharge. These formations are potential but undetermined sources of ground water. The Mancos Shale yields water to stock and domestic wells where it contains fractures or weathered zones, but its water is commonly highly mineralized and the formation is generally considered to be an unimportant source of water (Boettcher, 1972). The Leadville Limestone in the vicinity of Glenwood Springs and Rifle Creek may yield water from fractures and solution openings but the quantity of water that could be pumped is unknown. Finally, Precambrian crystalline rocks in the Canyon Creek drainage basin may offer a potential source of ground water from fractures and weathered zones. However, yields from this source probably will be less than 10 gal/min (Boettcher, 1972).

In conclusion, to meet the annual demands of approximately 50 acre-ft of water for a coal-production rate of 1 million tons per year (Cooley, 1975) would require a continual pumping of approximately 30 gal/min. Along parts of the Colorado and the White Rivers, valley-fill aquifers may be a potential source of water for hydraulic mining.

EXPLANATION

●1 WELL--Number refers to site listed in table 4



Base from U.S. Geological Survey State base map, 1969

0 5 10 15 MILES
0 5 10 15 KILOMETERS

Figure 7.--Location of wells.

Table 4.--*Records of wells*

Site number on fig. 7	Well location	Aquifer	Depth of well (ft)	Depth to water below land surface (ft)	Date of water-level measurement	Altitude of land surface (ft)	Estimated yield (gal/min)
1	SB1-93-09BDB	Mancos Shale-------	53	7	6/18/75	-----	---
2	SB1-93-10CDA	Mancos Shale-------	60	33	6/18/75	6,750	---
3	SB1-93-27BAB	Mancos Shale-------	100	25	6/18/75	-----	10
4	SB1-93-30AAB	Valley fill--------	---	2	7/31/75	6,300	---
5	SB1-94-10DBB	Terrace deposits---	20	8	7/29/75	6,150	---
6	SB1-94-25CDD	Terrace deposits---	35	17	7/31/75	6,405	---
7	SB1-94-34CDA	Terrace deposits---	40	6	7/31/75	6,420	---
8	SC5-90-36ACA	Valley fill--------	63	47	10/30/73	5,660	30
9	SC5-90-36ACB	Valley fill--------	59	36	4/10/65	-----	10
10	SC5-90-36ADB	Valley fill--------	60	40	6/18/59	-----	7
11	SC6-92-14ADB	Terrace deposits---	87	67	10/30/73	5,590	250
12	SC6-93-15CAD	Valley fill--------	8	3	11/28/73	5,278	---
13	SC6-93-16CDB	Valley fill--------	40	19	10/30/73	5,310	---
14	SC6-93-16DCC	Valley fill--------	44	18	3/27/69	5,315	20
15	SC6-93-16CDD	Valley fill--------	24	8	3/27/69	5,305	20
16	SC6-93-17BBD	Valley fill--------	38	18	3/26/69	5,290	5
17	SC6-93-18ADB	Valley fill--------	42	31	3/26/69	5,290	10

WATER QUALITY

One of the concerns with hydraulic coal mining is that water needed for the process may have restricted use because of inadequate quality. According to Cooley (1975), water for hydraulic coal mining should contain less than 20,000 mg/L (milligrams per liter) suspended solids, because greater concentrations cause excessive wear of equipment. In addition, water used for mining having relatively large concentrations of trace elements, such as iron or zinc, could cause corrosion of equipment.

A final concern is the potential effect of mine drainage on downstream water quality. Adverse changes in water quality have been documented from a hydraulic coal-mining site (F. A. Packard and W. L. Haushild, written commun., 1977) and these changes could be harmful to aquatic life (U.S. Environmental Protection Agency, 1976).

Surface Water

The surface-water quality of the part of the study area in the Colorado River basin is discussed separately from that of the part in the White River basin. Locations of surface-water sites for water-quality analyses are shown on figure 8, and the data are presented in tables 5 and 6. The site index numbers (for example, CR-1 or WR-1) pertain to the particular drainage basin (Colorado River basin or White River basin) where the sampling site is located.

Colorado River Basin

Streams in the Colorado River basin that drain the study area and adjacent areas have dissolved-solids concentrations that have ranged from about 100 to 2,030 mg/L (tables 5 and 6). Mamm Creek at site CR-5 and the Colorado River at Glenwood Springs (site CR-13 in table 6) had the largest concentrations of dissolved solids. The pH values shown in table 5 for streams in the Colorado River basin ranged from neutral to slightly alkaline (7.0 to 8.1). The pH values shown in table 6 for the Colorado River near Glenwood Springs ranged from 6.7 to 9.5. The data show that dissolved manganese was as much as 1,600 µg/L (micrograms per liter) in Rifle Gap Reservoir (site CR-9).

Additional unpublished water-quality data from 1958 to 1977 are available from the Colorado Department of Health for the Colorado River at New Castle and the Roaring Fork River at its mouth. Dissolved solids in the Colorado River at New Castle have ranged from 128 to 830 mg/L and the maximum total-iron concentration was 5,500 µg/L. Dissolved solids in the Roaring Fork River have ranged from 99 to 520 mg/L, and the maximum total-iron concentration was 14,000 µg/L.

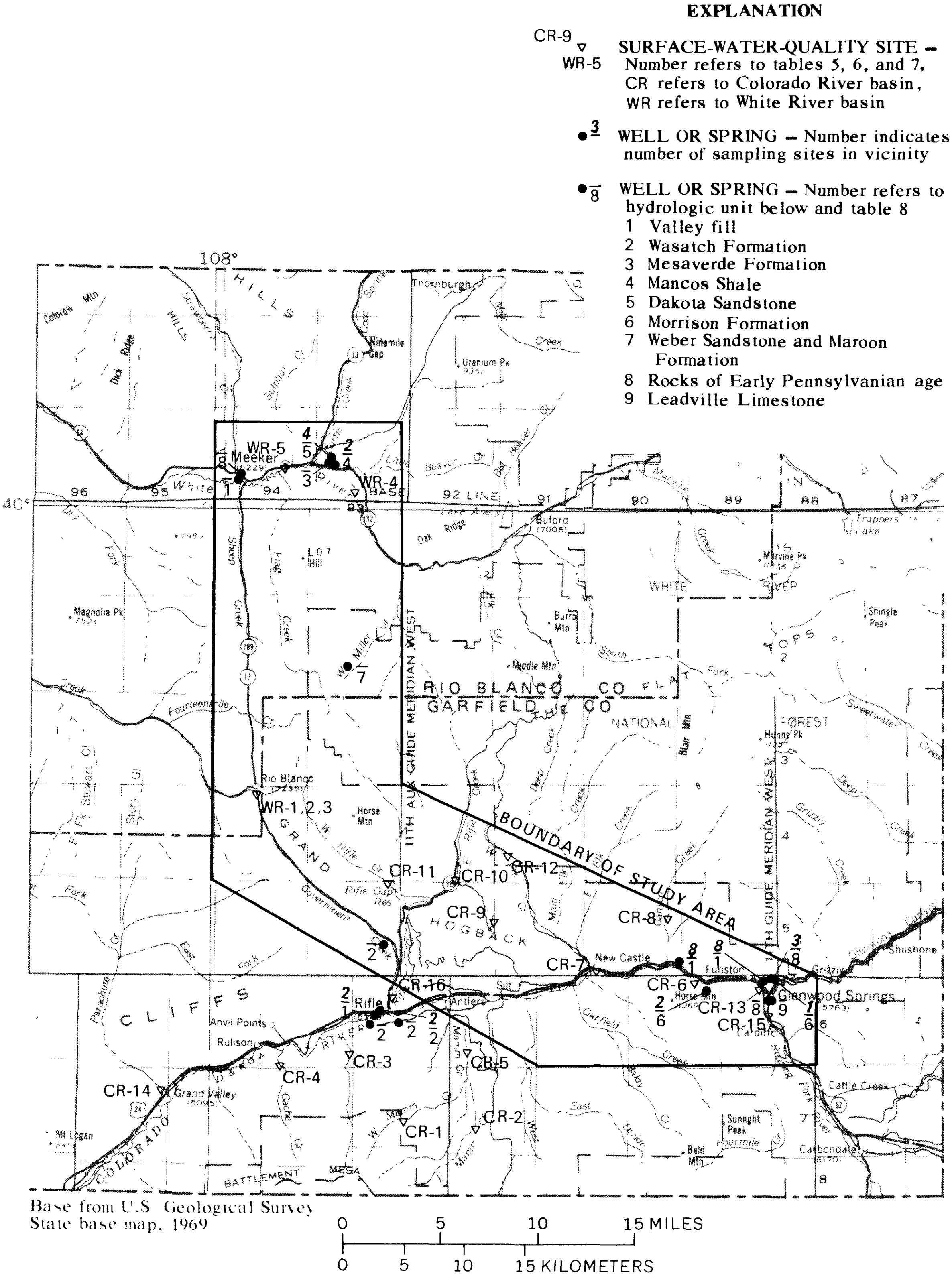


Figure 8.--Location of water-quality sampling sites.

Table 5.--*Chemical quality of surface water*

[CR=station in Colorado River basin; WR=station in White River basin]

SITE NUMBER ON FIG. 8	DATE	TIME	TEMPERATURE (DEG C) (00010)	SPECIFIC CONDUCTANCE (MICROMHOS) (00095)	PH (UNITS) (00400)	SILICA, DISSOLVED (MG/L AS SIO2) (00955)	CALCIUM DISSOLVED (MG/L AS CA) (00915)	MAGNESIUM, DISSOLVED (MG/L AS MG) (00925)	SODIUM, DISSOLVED (MG/L AS NA) (00930)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	ALKALINITY, TOTAL (MG/L AS CACO3) (00410)
CR-1	392544107461200 - WEST MAMM CREEK (LAT 39 25 44 LONG 107 46 12)										
	AUG , 1969										
	27...	1145	13.5	648	7.6	--	62	31	--	--	295
CR-2	392604107402900 - EAST MAMM CREEK (LAT 39 26 04 LONG 107 40 29)										
	SEP , 1969										
	02...	1500	27.0	1460	8.1	--	51	60	--	--	550
CR-3	392818107495400 - BEAVER CREEK 4.8 MILES SW OF RIFLE (LAT 39 28 18 LONG 107 49 54)										
	MAR , 1969										
	24...	--	1.0	350	7.8	19	45	11	15	1.1	172
	SEP										
	20...	1209	10.0	282	8.1	--	36	8.0	--	--	142
CR-4	392832107543000 - CACHE CREEK (LAT 39 28 32 LONG 107 54 30)										
	AUG , 1969										
	27...	1025	13.5	171	7.0	--	21	4.5	--	--	83
CR-5	392947107412200 - MAMM CREEK (LAT 39 29 47 LONG 107 41 22)										
	AUG , 1969										
	27...	1300	27.5	1820	7.7	--	51	93	--	--	482
CR-6	393337107242900 - SOUTH CANYON C AT MO NR GLENWOOD SPGS, CO (LAT 39 33 37 LONG 107 24 29)										
	JUL , 1972										
	17...	1410	29.0	2220	--	--	--	--	--	--	--
	17...	1410	29.0	2300	9.0	--	--	--	--	--	--
CR-7	393407107322600 - COLO RIVER AT NEW CASTLE (LAT 39 34 07 LONG 107 32 26)										
	AUG , 1969										
	26...	1225	19.0	898	7.3	--	71	14	--	--	132
CR-8	393622107243000 - UNNAMED TRIB 1 TO CANYON CREEK (LAT 39 36 22 LONG 107 24 30)										
	SEP , 1974										
	11...	0915	10.0	265	7.9	6.3	24	7.8	17	1.9	53
	12...	0920	11.5	--	7.8	--	--	--	--	--	--
CR-9	393734107452700 - RIFLE GAP RESERVOIR (LAT 39 37 34 LONG 107 45 27)										
	SEP , 1975										
	26...	1600	16.0	760	8.4	--	--	--	--	--	--
	26...	1601	16.0	760	8.3	7.2	95	39	22	2.7	169
CR-10	393821107425900 - E RIFLE C AB DRY RIFLE C NR RIFLE, CO (LAT 39 38 21 LONG 107 42 59)										
	OCT , 1971										
	20...	0910	8.0	--	--	--	--	--	--	--	--
	20...	0910	8.0	600	8.1	--	--	--	--	--	--
CR-11	393846107464700 - W RIFLE C AB MIDDLE RIFLE C NR RIFLE, CO (LAT 39 38 46 LONG 107 46 47)										
	JUL , 1972										
	03...	1130	17.0	2050	--	--	--	--	--	--	--
	03...	1130	17.0	2800	8.0	--	--	--	--	--	--

Table 5.--*Chemical quality of surface water*--Continued

SITE NUMBER ON FIG. 8	DATE	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS, DISSOLVED (MG/L AS CACO3) (00900)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	ARSENIC DISSOLVED (UG/L AS AS) (01000)	BORON, DISSOLVED (UG/L AS B) (01020)
CR-1	392544107461200 - WEST MAMM CREEK (LAT 39 25 44 LONG 107 46 [illegible])									
	AUG , 1969									
	27...	--	--	369	--	282	--	--	--	--
CR-2	392604107402900 - EAST MAMM CREEK (LAT 39 26 04 LONG 107 40 29)									
	SEP , 1969									
	02...	--	--	1050	--	374	--	--	--	--
CR-3	392818107495400 - BEAVER CREEK 4.8 MILES SW OF RIFLE (LAT 39 28 18 LONG 107 49 54)									
	MAR , 1969									
	24...	.5	17	218	212	158	--	--	--	20
	SEP									
	20...	--	--	149	--	124	--	--	--	--
CR-4	392832107543000 - CACHE CREEK (LAT 39 28 32 LONG 107 54 30)									
	AUG , 1969									
	27...	--	--	81	--	71	--	--	--	--
CR-5	392947107412200 - MAMM CREEK (LAT 39 29 47 LONG 107 41 22)									
	AUG , 1969									
	27...	--	--	1390	--	510	--	--	--	--
CR-6	393337107242900 - SOUTH CANYON C AT MO NR GLENWOOD SPGS, CO (LAT 39 33 37 LONG 107 24 29)									
	JUL , 1972									
	17...	--	110	--	--	--	--	--	1	--
	17...	--	--	--	--	--	--	--	--	--
CR-7	393407107322600 - COLO RIVER AT NEW CASTLE (LAT 39 34 07 LONG 107 32 26)									
	AUG , 1969									
	26...	--	--	534	--	235	--	--	--	--
CR-8	393622107243000 - UNNAMED TRIB 1 TO CANYON CREEK (LAT 39 36 22 LONG 107 24 30)									
	SEP , 1974									
	11...	19	43	--	153	92	.21	--	--	--
	12...	--	--	--	--	--	--	--	33	--
CR-9	393734107452700 - RIFLE GAP RESERVOIR (LAT 39 37 34 LONG 107 45 27)									
	SEP , 1975									
	26...	--	--	--	--	--	--	--	--	--
	26...	5.9	250	--	524	400	.04	5.0	--	--
CR-10	393821107425900 - E RIFLE C AB ORY RIFLE C NR RIFLE, CO (LAT 39 38 21 LONG 107 42 59)									
	OCT , 1971									
	20...	--	110	--	--	--	--	--	0	--
	20...	--	--	--	--	--	--	--	--	--
CR-11	393846107464700 - W RIFLE C AB MIDDLE RIFLE C NR RIFLE, CO (LAT 39 38 46 LONG 107 46 47)									
	JUL , 1972									
	03...	--	1100	--	--	--	--	--	6	--
	03...	--	--	--	--	--	--	--	--	--

Table 5.--*Chemical quality of surface water*--Continued

SITE NUMBER ON FIG. 8	DATE	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
CR-1	392544107461200 - WEST MAMM CREEK (LAT 39 25 44 LONG 107 46 12)									
	AUG, 1959									
	27...	--	--	--	--	--	--	--	--	--
CR-2	392604107402900 - EAST MAMM CREEK (LAT 39 26 04 LONG 107 40 29)									
	SEP, 1969									
	02...	--	--	--	--	--	--	--	--	--
CR-3	392818107495400 - BEAVER CREEK 4.8 MILES SW OF RIFLE (LAT 39 28 18 LONG 107 49 54)									
	MAR, 1969									
	24...	--	10	20	--	--	--	<10	--	20
	SEP									
	20...	--	--	--	--	--	--	--	--	--
CR-4	392832107543000 - CACHE CREEK (LAT 39 28 32 LONG 107 54 30)									
	AUG, 1969									
	27...	--	--	--	--	--	--	--	--	--
CR-5	392947107412200 - MAMM CREEK (LAT 39 29 47 LONG 107 41 22)									
	AUG, 1969									
	27...	--	--	--	--	--	--	--	--	--
CR-6	393337107242900 - SOUTH CANYON C AT MO NR GLENWOOD SPGS, CO (LAT 39 33 37 LONG 107 24 29)									
	JUL, 1972									
	17...	0	2	30	--	1	--	0	--	0
	17...	--	--	--	--	--	--	--	--	--
CR-7	393407107322600 - COLO RIVER AT NEW CASTLE (LAT 39 34 07 LONG 107 32 26)									
	AUG, 1969									
	26...	--	--	--	--	--	--	--	--	--
CR-8	393622107243000 - UNNAMED TRIB I TO CANYON CREEK (LAT 39 36 22 LONG 107 24 30)									
	SEP, 1974									
	11...	--	--	30	--	--	--	0	--	--
	12...	7	220	660	--	10	--	60	--	280
CR-9	393734107452700 - RIFLE GAP RESERVOIR (LAT 39 37 34 LONG 107 45 27)									
	SEP, 1975									
	26...	--	--	--	--	--	--	--	--	--
	26...	--	--	20	--	--	--	20	--	--
CR-10	393821107425900 - E RIFLE C AB DRY RIFLE C NR RIFLE, CO (LAT 39 38 21 LONG 107 42 59)									
	OCT, 1971									
	20...	0	1	10	--	0	--	30	--	0
	20...	--	--	--	--	--	--	--	--	--
CR-11	393846107464700 - W RIFLE C AB MIDDLE RIFLE C NR RIFLE, CO (LAT 39 38 46 LONG 107 46 47)									
	JUL, 1972									
	03...	0	2	10	--	1	--	200	--	20
	03...	--	--	--	--	--	--	--	--	--

Table 5.--*Chemical quality of surface water*--Continued

SITE NUMBER ON FIG. 8	DATE	TIME	TEMPER-ATURE (DEG C) (00010)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS) (00095)	PH (UNITS) (00400)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	ALKA-LINITY, TOTAL (MG/L AS CACO3) (00410)
CR-12	394058107391900 - W ELK C AB W ELK RE NR NEW CASTLE, CO (LAT 39 40 58 LONG 107 39 19)										
	OCT , 1971										
	20...	1005	3.5	--	--	--	--	--	--	--	--
	20...	1005	3.5	1000	8.1	--	--	--	--	--	--
WR-1	394346107561800 - PICEANCE CREEK AT RIO BLANCO C4-94-03BCDC (LAT 39 43 46 LONG 107 56 18)										
	JUL , 1973										
	27...	1430	20.0	681	7.9	15	67	27	45	2.9	273
WR-2	394358107563800 - PICEANCE CREEK AT HWY 13 BRIDGE (LAT 39 43 58 LONG 107 56 38)										
	MAR , 1975										
	01...	0830	.0	810	6.7	14	82	27	55	2.1	309
WR-3	394529107534700 - PICEANCE C NR SOURCE NR RIO BLANCO, CO (LAT 39 45 29 LONG 107 53 47)										
	JUN , 1972										
	22...	1230	18.0	920	--	--	--	--	--	--	--
	22...	1230	18.0	900	8.0	--	--	--	--	--	--
WR-4	09304200 - WHITE RIVER ABOVE COAL CREEK, NEAR MEEKER, CO. (LAT 40 00 18 LONG 107 49 29)										
	AUG , 1973										
	30...	0750	10.5	424	8.1	18	62	12	5.0	1.2	128
	NOV										
	14...	1530	4.5	378	8.8	16	58	11	4.1	1.2	113
	FEB , 1974										
	14...	0905	.0	418	7.9	18	65	12	3.9	1.0	115
	MAY										
	30...	1045	7.0	191	7.9	9.8	28	6.4	3.1	.9	76
	SEP										
	23...	1030	8.0	412	8.3	16	60	13	5.0	1.3	121
	NOV										
	11...	1500	5.0	390	8.4	16	55	11	4.2	1.1	111
	DEC										
	19...	0910	.0	--	8.8	17	60	11	4.2	1.8	111
	MAR , 1975										
	17...	1100	2.0	400	--	16	62	11	6.1	1.1	114
	APR										
	14...	1000	4.0	380	--	--	--	--	--	--	--
	MAY										
	08...	1030	5.0	380	--	--	--	--	--	--	--
	20...	1500	10.0	220	--	--	--	--	--	--	--
	JUN										
	09...	0945	6.0	200	8.3	10	33	6.3	2.7	1.1	85
WR-5	09304500 - WHITE RIVER NEAR MEEKER, CO. (LAT 40 02 01 LONG 107 51 42)										
	DEC , 1970										
	15...	1040	.0	135	7.8	14	16	3.3	7.2	1.7	66
	AUG , 1973										
	30...	0830	11.0	174	8.2	18	71	15	21	1.5	145
	NOV										
	14...	1610	4.5	486	8.8	16	63	12	18	1.4	122
	FEB , 1974										
	14...	0940	.0	569	7.9	4.4	70	15	25	1.5	127
	MAY										
	30...	1130	8.0	207	7.9	10	29	6.3	3.8	1.1	80
	SEP										
	23...	1100	10.0	577	8.3	12	73	17	23	2.0	148

Table 5.--*Chemical quality of surface water*--Continued

SITE NUMBER ON FIG. 8	DATE	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	HARD-NESS, DIS-SOLVED (MG/L AS CACO3) (00900)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	BORON, DIS-SOLVED (UG/L AS B) (01020)
CR-12	394058107391900 - W ELK C AB W ELK RE NR NEW CASTLE, CO (LAT 39 40 58 LONG 107 39 19)									
	OCT , 1971									
	20...	--	370	--	--	--	--	--	10	--
	20...	--	--	--	--	--	--	--	--	--
WR-1	394346107561800 - PICEANCE CREEK AT RIO BLANCO C4-94-03BCDC (LAT 39 43 46 LONG 107 56 18)									
	JUL , 1973									
	27...	5.1	100	--	439	280	2.6	--	8	70
WR-2	394358107563800 - PICEANCE CREEK AT HWY 13 BRIDGE (LAT 39 43 58 LONG 107 56 38)									
	MAR , 1975									
	01...	6.1	100	--	473	320	.20	--	--	--
WR-3	394529107534700 - PICEANCE C NR SOURCE NR RIO BLANCO, CO (LAT 39 45 29 LONG 107 53 47)									
	JUN , 1972									
	22...	--	250	--	--	--	--	--	0	--
	22...	--	--	--	--	--	--	--	--	--
WR-4	09304200 - WHITE RIVER ABOVE COAL CREEK, NEAR MEEKER, CO. (LAT 40 00 18 LONG 107 49 29)									
	AUG , 1973									
	30...	2.2	100	--	278	200	.08	--	--	--
	NOV									
	14...	1.6	83	--	244	190	.02	--	--	--
	FEB , 1974									
	14...	2.6	96	--	269	210	.17	--	--	--
	MAY									
	30...	1.7	19	--	116	96	.12	--	--	--
	SEP									
	23...	2.2	80	--	251	200	.01	--	--	--
	NOV									
	11...	2.0	79	--	236	180	.01	--	--	--
	DEC									
	19...	3.2	85	--	250	200	.18	--	--	--
	MAR , 1975									
	17...	2.4	91	--	259	200	.04	--	--	--
	APR									
	14...	--	--	--	--	--	--	--	--	--
	MAY									
	08...	--	--	--	--	--	--	--	--	--
	20...	--	--	--	--	--	--	--	--	--
	JUN									
	09...	1.7	23	--	130	110	.18	--	--	--
WR-5	09304500 - WHITE RIVER NEAR MEEKER, CO. (LAT 40 02 01 LONG 107 51 42)									
	DEC , 1970									
	15...	1.4	7.5	--	92	54	--	--	--	0
	AUG , 1973									
	30...	25	110	--	349	240	.05	--	--	--
	NOV									
	14...	22	99	--	305	210	.01	--	--	--
	FEB , 1974									
	14...	33	120	--	340	240	.09	--	--	--
	MAY									
	30...	3.2	22	--	124	98	.14	--	--	--
	SEP									
	23...	26	110	--	353	250	.17	--	--	--

Table 5.--*Chemical quality of surface water*--Continued

SITE NUMBER ON FIG. 8	DATE	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
CR-12	394058107391900 - W ELK C AB W ELK RE NR NEW CASTLE, CO (LAT 39 40 58 LONG 107 39 19)									
	OCT , 1971									
	20...	0	0	50	--	0	--	10	--	30
	20...	--	--	--	--	--	--	--	--	--
WR-1	394346107561800 - PICEANCE CREEK AT RIO BLANCO C4-94-038CDC (LAT 39 43 46 LONG 107 56 18)									
	JUL , 1973									
	27...	--	--	50	610	--	<50	30	60	--
WR-2	394358107563800 - PICEANCE CREEK AT HWY 13 BRIDGE (LAT 39 43 58 LONG 107 56 38)									
	MAR , 1975									
	01...	--	--	10	--	--	--	100	--	--
WR-3	394529107534700 - PICEANCE C NR SOURCE NR RIO BLANCO, CO (LAT 39 45 29 LONG 107 53 47)									
	JUN , 1972									
	22...	0	1	20	--	2	--	70	--	10
	22...	--	--	--	--	--	--	--	--	--
WR-4	09304200 - WHITE RIVER ABOVE COAL CREEK, NEAR MEEKER, CO. (LAT 40 00 18 LONG 107 49 29)									
	AUG , 1973									
	30...	--	--	20	--	--	--	20	--	--
	NOV									
	14...	--	--	10	--	--	--	0	--	--
	FEB , 1974									
	14...	--	--	50	--	--	--	0	--	--
	MAY									
	30...	--	--	40	--	--	--	30	--	--
	SEP									
	23...	--	--	70	--	--	--	0	--	--
	NOV									
	11...	--	--	380	--	--	--	0	--	--
	DEC									
	19...	--	--	10	--	--	--	10	--	--
	MAR , 1975									
	17...	--	--	20	--	--	--	10	--	--
	APR									
	14...	--	--	--	--	--	--	--	--	--
	MAY									
	08...	--	--	--	--	--	--	--	--	--
	20...	--	--	--	--	--	--	--	--	--
	JUN									
	09...	--	--	100	--	--	--	0	--	--
WR-5	09304500 - WHITE RIVER NEAR MEEKER, CO. (LAT 40 02 01 LONG 107 51 42)									
	DEC , 1970									
	15...	--	--	--	--	--	--	--	--	--
	AUG , 1973									
	30...	--	--	10	--	--	--	20	--	--
	NOV									
	14...	--	--	20	--	--	--	0	--	--
	FEB , 1974									
	14...	--	--	20	--	--	--	0	--	--
	MAY									
	30...	--	--	50	--	--	--	30	--	--
	SEP									
	23...	--	--	210	--	--	--	10	--	--

Table 6.--*Summary of water-quality data, Colorado River near Glenwood Springs (CR-13), October 1941 to February 1978*

[μmho/cm=micromho per centimeter; mg/L=milligram per liter; μg/L=microgram per liter]

Parameter	Minimum	Maximum	Mean	Standard deviation	Number of samples
Temperature (°C)------------------	0.0	19.5	7.8	6.12	133
Specific conductance (μmho/cm)----	180	2,260	620	2.24×10^2	944
Dissolved oxygen (mg/L)-----------	7.0	12.5	9.7	1.45	81
pH--------------------------------	6.7	9.5	------	---------	723
Silica (mg/L)---------------------	.1	17	11	2.05	663
Calcium (mg/L)--------------------	20	560	56	2.53×10	747
Magnesium (mg/L)------------------	4.1	73	12	4.40	746
Sodium (mg/L)---------------------	.5	150	56	2.70×10	749
Potassium (mg/L)------------------	.2	34	2.7	2.28	435
Bicarbonate (mg/L)----------------	66	240	130	2.24×10	827
Alkalinity (mg/L)-----------------	54	200	100	1.86×10	761
Chloride (mg/L)-------------------	1.0	200	75	3.98×10	807
Sulfate (mg/L)--------------------	9.5	1,300	93	6.09×10	807
Dissolved solids (residue, mg/L)--	110	2,030	377	1.45×10^2	796
Dissolved solids (sum, mg/L)------	120	791	359	1.29×10^2	154
Hardness (mg/L)-------------------	34	1,480	188	7.10×10	881
Nitrate (dissolved as N, mg/L)----	.00	.59	.17	.10	55
Orthophosphorus (dissolved as P, mg/L)--------------------------	.00	.11	.01	.02	80
Total iron (μg/L)-----------------	.00	540	40	7.65×10	85
Dissolved manganese (μg/L)--------	.00	120	30	2.53×10	70

Suspended-sediment data for selected sites are shown in table 7. No recent sediment records are available for the Colorado River and its tributaries in the study area. However, recent sediment records are available (table 7) from two sites downstream from the study area: Colorado River near DeBeque and Parachute Creek at Grand Valley. Data from these two sites indicate that, despite the large amount of sediment contributed by Parachute Creek to the Colorado River, the maximum concentration of suspended sediment in the Colorado River at DeBeque was much less than the maximum concentration (20,000 mg/L) that water supplies used for hydraulic coal mining should contain (Cooley, 1975). The maximum suspended-sediment concentration at sites within the study area was 18,800 mg/L at West Rifle Creek near Rifle (site CR-11).

Overall, the data indicate that, with the possible exception of some suspended-sediment and iron concentrations, the surface water is of suitable quality for use in hydraulic coal mining.

White River Basin

Streams in the White River basin that drain the study area and adjacent areas generally contain less than 500 mg/L dissolved solids (table 5). The maximum dissolved-iron concentration was 380 μg/L (site WR-4), and the maximum dissolved-manganese concentration was 100 μg/L (site WR-2). The pH ranged from near neutral to slightly alkaline (6.7 to 8.8). Few suspended-sediment data are available (table 7). Maximum suspended-sediment concentrations ranged from 45 to 1,880 mg/L.

The available water-quality and sediment data indicate that surface water in the northern part of the study area is of suitable quality for hydraulic mining. However, because of the paucity of available information, additional data are needed to verify this preliminary evaluation.

Effects of Coal Mining on Downstream Water Quality

According to a report by F. A. Packard and W. L. Haushild (written commun., 1977), water used in hydraulic coal-mining processes may adversely affect downstream water quality. Based on a borehole hydraulic-mining test, they noted increases in pH, dissolved solids, suspended sediment, dissolved cadmium, total iron, and water temperature in mine-drainage effluent after hydraulic mining.

Several active and inactive coal mines are near the mouth of West Rifle Creek in the study area. From chemical analyses of samples upstream and downstream from these mines (Iorns and others, 1964), there appears to be no degradation in stream-water quality downstream from these mines. However, these data were collected between 1940 and 1958, and contain no record of the mine activity or the quality of the mine effluent. Because of the paucity of data on drainage from underground coal mines in the Grand Hogback area, and because the coals in other parts of Colorado are of a low-sulfur type similar to those in the Grand Hogback area, coal-drainage sites elsewhere in Colorado are used here to indicate possible changes in stream quality resulting from mining in the study area.

Table 7.--*Suspended-sediment data*

Station name and number	Period of record	Number of samples	Suspended sediment			
			Concentration, in milligrams per liter		Discharge, in tons per day	
			Minimum	Maximum	Minimum	Maximum
	COLORADO RIVER BASIN					
Colorado River near Glenwood Springs (CR-13) (09071100).	May 1951-July 1952, October 1959-September 1965.	75	11	1,400	21	41,200
Colorado River near DeBeque (not shown on fig. 8) (09093700).	October 1974-September 1976--	730	2	2,090	8.4	41,300
Parachute Creek at Grand Valley (CR-14) (09093500).	October 1974-September 1976--	730	8	22,000	.04	82,000
Roaring Fork River at Glenwood Springs (CR-15) (09085000).	May 1951-July 1952, October 1959-September 1965.	76	1.4	8,900	7	60,800
Rifle Creek near Rifle (CR-16).	(Scattered) December 1940-September 1958.	53	152	11,100	20	3,330
West Rifle Creek near Rifle (CR-11).	December 1940-November 1941, April 1957.	11	193	18,800	.1	56
East Rifle Creek near Rifle (CR-10) (09091500).	(Scattered) December 1940-November 1941, July 1958-September 1958.	13	2	1,210	.2	183
	WHITE RIVER BASIN					
White River above Coal Creek, near Meeker (WR-4) (09304200).	April 6, 1977----------------	4	22	1,880	26	19,700
White River near Meeker (WR-5) (09304500).	April 1953-May 1953, May 6, 1975.	5	45	910	69	9,710
Piceance Creek near Rio Blanco (WR-3).	July 1958--------------------	2	10	45	0	.1

In a resource evaluation of the Axial Basin coal field, between Meeker and Craig, Colo., the U.S. Bureau of Land Management (1975) concluded that underground mining in the area has resulted in few instances of degradation of stream quality from coal-mine drainage.

Surface and subsurface coal-mine drainage discharges from the Edna Mine near Oak Creek, Colo., into Trout Creek (McWhorter and others, 1974). Chemical analyses of samples collected upstream and downstream from the point of mine discharge into Trout Creek indicated increases in specific conductance downstream from the mine. According to McWhorter, Skogerboe, and Skogerboe (1974), some evidence indicates that similar degradation occurs or may occur in other coal-mining areas. Chemical changes in stream quality, especially increases in calcium, magnesium, and sulfate concentrations, have been widely reported from spoils produced from overburden materials of Late Cretaceous and early Tertiary age (McWhorter and others, 1974).

Other areas affected by coal-mine drainage are the Thompson Creek and Coal Creek drainages in Pitkin County, Colo. (U.S. Geological Survey, 1978). Increases in magnesium, sodium, sulfate, and suspended and dissolved solids in streams downstream from the mine discharges may be as much as 10 times the concentrations upstream from the mines. In some instances, part of the water-quality change also may be due to natural runoff conditions.

In conclusion, data are inadequate to assess the potential effects of hydraulic coal mining on downstream water quality. The above data indicate that changes in pH, water temperature, suspended-sediment, dissolved-solids, and trace-element concentrations may occur as a result of mine drainage.

Ground Water

Because ground-water supplies in the vicinity of the Grand Hogback are poorly known and undeveloped, ground-water-quality data are few (fig. 8). Available water-quality data are summarized in table 8 for each aquifer for samples collected from 1965 through 1976. Because the geologic source was not indicated for all data, aquifers were determined using geologic maps, well permits from the Colorado State Engineer's Office, and water levels for wells in the vicinity of the sampling sites.

The ground-water quality varies greatly throughout the study area. Dissolved solids ranged from 391 mg/L in the Weber Sandstone and Maroon Formation to 19,900 mg/L in the Chaffee Group. Specific conductance of water in the valley-fill aquifer in the vicinity of Rifle ranged from 500 to 5,480 μmho/cm (micromhos per centimeter) at 25°C (Celsius), with most values ranging from 500 to 702 μmho/cm.

Water in the Wasatch, Mesaverde, Morrison, Weber, and Maroon aquifers all had dissolved-solids concentrations of less than 1,000 mg/L. Water samples from the Lower Pennsylvanian, Leadville, and Chaffee aquifers were collected from springs in the Glenwood Springs area. Dissolved-solids concentrations in these samples ranged from 17,600 to 21,500 mg/L.

East of Meeker, dissolved-solids concentrations in samples from the Mancos Shale ranged from 17,400 to 21,800 mg/L. According to Boettcher (1972), water from the Mancos Shale is mineralized and is not generally considered to be potable. Dissolved-solids concentrations in samples from the Dakota Sandstone east of Meeker ranged from 982 to 17,500 mg/L, although water from the Dakota Sandstone generally contained less than 3,000 mg/L dissolved solids (Boettcher, 1972). The larger values shown in table 8 may be the result of numerous saline seeps in the vicinity of the Meeker Dome reported by the U.S. Environmental Protection Agency (1972). Here, naturally occurring saline ground water with a specific conductance of 36,000 μmho/cm is under sufficient head to force it to the surface through natural fractures. This saline water could cause corrosion of equipment used in hydraulic coal mining.

Investigation of the Entrada, Wingate, and Glen Canyon Sandstones in the vicinity of the Grand Hogback may result in the location of aquifers containing water suitable for hydraulic mining. Although no water-quality data were available in the study area from wells completed in the Entrada and Glen Canyon Sandstones, water from wells completed in these sandstones in Moffat County contained dissolved-solids concentrations ranging from 300 to 370 mg/L (Boettcher, 1972). The principal ions were sodium and bicarbonate, resulting in a soft water.

SUMMARY

In general, surface-water supplies from most streams should be adequate to meet the annual demands for hydraulic mining of 1 million tons of coal. However, on some of the smaller streams in the area, some storage of water may be required for use during low-flow periods to meet minimum-flow requirements for downstream reaches. Rifle Gap Reservoir and Harvey Gap Reservoir are potential sources of surface water in the Rifle-Silt area. Ground water from the valley-fill deposits along major streams and rivers is a potential source of water for hydraulic mining.

Available data on surface-water quality in the study area indicate that this water is suitable for use in hydraulic mining, with the exceptions of large suspended-sediment and iron concentrations in some flows in the southern part of the study area. Large dissolved-solids concentrations in ground water from aquifers in the vicinity of the Meeker Dome may make the water unsuitable for use in hydraulic mining of coal. Data are insufficient to assess the potential impact of hydraulic coal mining on downstream water quality.

Table 8.--*Chemical quality of ground water*

[mg/L=milligram per liter; µmho/cm=micromho per centimeter; µg/L=microgram per liter]

Parameter	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Bicarbonate (mg/L)	Alkalinity (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Dissolved solids (mg/L)	Hardness (mg/L)	Specific conductance (µmho/cm)	pH	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Dissolved zinc (µg/L)
						AQUIFER 1: VALLEY FILL								
Minimum---	18	88	1.4	220	182	34	2.0	------	6	500	7.0	30	10	280
Maximum---	45	88	1.4	430	270	180	11	------	280	5,480	7.9	40	10	280
Mean------	29	-----	-----	330	230	66	33	------	66	1,080	----	40	-----	---
Number of samples[1]---	9	1	1	10	2	7	7	------	9	9	8	2	1	1
						AQUIFER 2: WASATCH FORMATION								
Minimum---	58	65	2.9	390	320	340	37	900	590	1,220	7.3	<10	<10	20
Maximum---	58	65	2.9	750	620	340	37	900	590	2,850	7.8	70	<10	20
Mean------	-----	-----	-----	580	470	-------	--------	------	-----	1,910	----	50	-----	---
Number of samples[1]---	1	1	1	5	5	1	1	1	1	5	5	5	1	1
						AQUIFER 3: MESAVERDE FORMATION								
Minimum---	51	180	2.9	640	530	230	6.1	890	370	1,400	7.5	0	40	500
Maximum---	51	180	2.9	640	530	230	6.1	890	370	1,400	7.5	0	40	500
Mean------	-----	-----	-----	---	---	-------	--------	------	-----	------	----	---	-----	---
Number of samples[1]---	1	1	1	1	1	1	1	1	1	1	1	1	1	1
						AQUIFER 4: MANCOS SHALE								
Minimum---	200	4,200	46	210	170	2,100	7,900	17,400	3,000	26,100	7.8	60	8	---
Maximum---	790	5,100	60	330	270	3,100	12,000	21,800	9,500	32,200	8.2	110	550	---
Mean------	500	4,600	53	270	220	2,600	9,950	19,600	6,200	29,200	----	80	280	---
Number of samples[1]---	2	2	2	2	2	2	2	2	2	2	2	2	2	2

						AQUIFER 5: DAKOTA SANDSTONE								
Minimum---	2.0	180	16	0	160	7.0	190	980	480	1,590	7.3	30	20	---
Maximum---	150	5,600	67	730	600	3,000	7,900	17,500	2,300	26,000	10.8	530	2,100	---
Mean------	110	2,400	37	280	360	1,600	3,600	8,430	1,700	11,800	----	160	1,100	---
Number of samples[1]---	4	4	4	4	4	4	4	4	4	4	4	4	4	---
						AQUIFER 6: MORRISON FORMATION								
Minimum---	0.9	260	7.8	290	240	100	190	760	-----	-----	7.3	20	20	0
Maximum---	1.0	280	8.2	300	250	110	190	790	-----	-----	7.6	70	50	20
Mean------	.9	270	8.0	300	240	110	190	780	-----	-----	----	40	40	10
Number of samples[1]---	2	2	2	2	2	2	2	2	-----	-----	2	2	2	2
						AQUIFER 7: WEBER SANDSTONE AND MAROON FORMATION								
Minimum---	20	37	5.8	300	240	80	11	390	250	500	7.1	10	0	10
Maximum---	20	37	5.8	300	240	80	11	390	250	500	7.1	10	0	10
Mean------	-----	-----	-----	---	---	-------	--------	------	-----	------	----	---	-----	---
Number of samples[1]---	1	1	1	1	1	1	1	1	1	1	1	1	1	1
						AQUIFER 8: ROCKS OF EARLY PENNSYLVANIAN AGE								
Minimum---	40	6,300	13	420	610	1,100	9,600	18,000	1,300	26,000	6.3	20	50	20
Maximum---	150	7,200	180	780	640	2,200	11,000	21,500	2,500	36,800	8.5	330	100	30
Mean------	120	6,900	110	670	620	1,500	10,000	20,000	1,800	31,300	----	100	80	30
Number of samples[1]---	5	5	5	5	3	5	5	5	5	5	5	8	4	4
						AQUIFER 9: LEADVILLE LIMESTONE								
Minimum---	88	6,000	160	740	600	980	9,600	17,600	1,400	31,000	6.3	40	70	20
Maximum---	88	6,000	160	740	600	980	9,600	17,600	1,400	31,000	6.3	40	70	20
Mean------	-----	-----	-----	---	---	-------	--------	------	-----	------	----	---	-----	---
Number of samples[1]---	1	1	1	1	1	1	1	1	1	1	1	1	1	1
						AQUIFER 10: CHAFFEE GROUP								
Minimum---	80	6,100	160	710	580	1,000	11,000	17,800	1,500	35,000	6.4	110	60	30
Maximum---	90	6,800	170	750	610	1,000	9,900	19,900	1,500	36,000	6.5	400	90	40
Mean------	90	6,400	170	730	600	1,000	10,000	18,700	1,500	35,000	----	200	80	30
Number of samples[1]---	3	3	3	3	3	3	3	3	3	3	3	3	3	3

[1]Each sample is from a different well or spring location.

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SYSTEM OF NUMBERING WELLS

The well locations in this report are given numbers based on the U.S. Bureau of Land Management system of land subdivision, and show the location of the well by quadrant, township, range, section, and position within the section. A graphic illustration of this method of well location is shown in figure 9. The first letter "S" of the location number indicates that the well is located in the area governed by the sixth principal meridian. The second letter "C" indicates the quadrant in which the well is located. Four quadrants are formed by the intersection of the baseline and the principal meridian: A indicates the northeast quadrant; B, the northwest; C, the southwest; and D, the southeast. The first number indicates the township; the second, the range; and the third, the section in which the well is located. The letters following the section number indicate the location of the well within the section. The first letter denotes the quarter section; the second, the quarter-quarter section; and the third, the quarter-quarter-quarter section. The letters are assigned within the section in a counterclockwise direction, beginning with A in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. For example, SC6-93-16CDB indicates a well in NW$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 16, T. 6 S., R. 93 W.

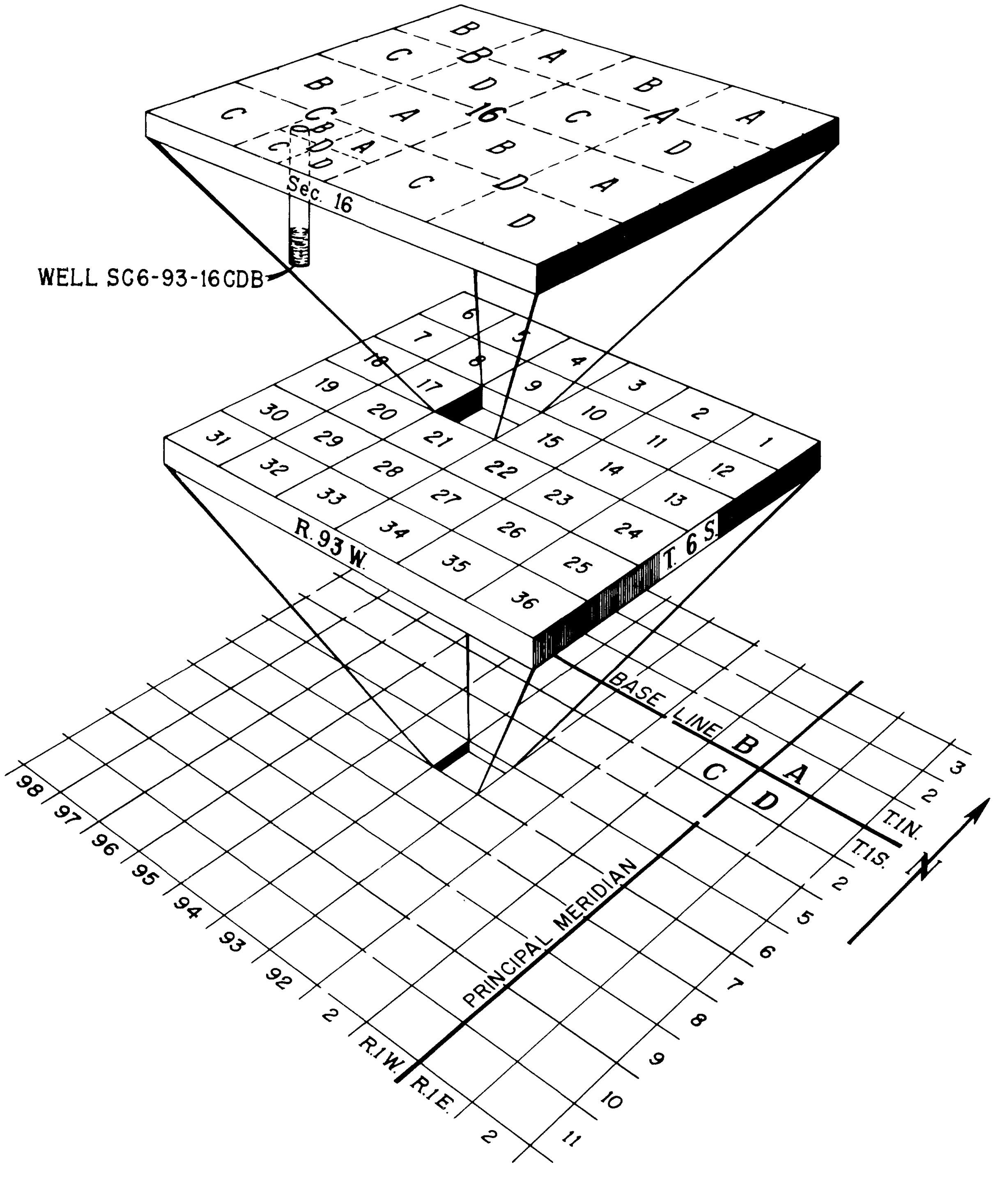

Figure 9.--Well-location and well-numbering system.

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