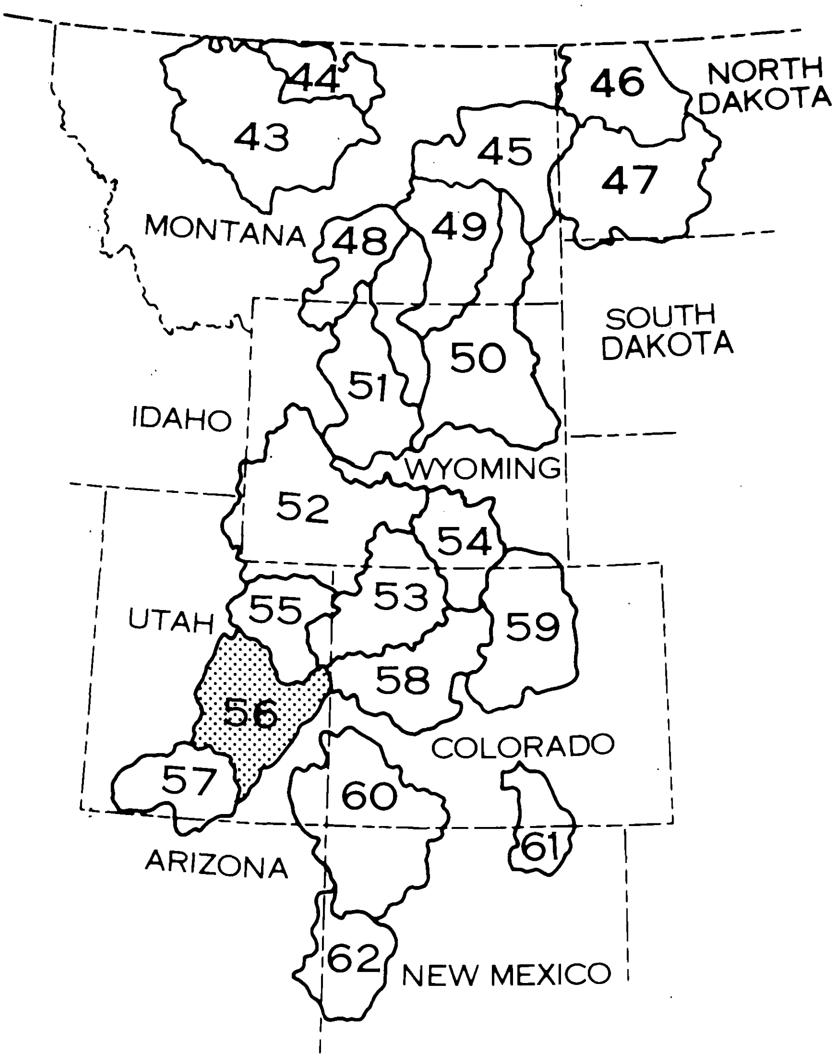
HYDROLOGY OF AREA 56, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, UTAH



- GREEN RIVER
- PRICE RIVER
- COLORADO RIVER
- SAN RAFAEL RIVER
- DIRTY DEVIL RIVER
- SAN PITCH RIVER

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 83-38

HYDROLOGY OF AREA 56, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, UTAH

BY
GREGORY C. LINES AND OTHERS

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SALT LAKE CITY, UTAH
1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, *SECRETARY*

GEOLOGICAL SURVEY

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1016 Administration Building
1745 West 1700 South
Salt Lake City, Utah 84104

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

For the convenience of readers who may want to use the International System of Units (SI), the inch-pound units in this report may be converted by using the following factors:

Multiply inch-pound units	By	To obtain SI units
acre	0.4047	square hectometer
acre-foot	0.001233	cubic hectometer
acre-foot per square mile	0.0004760	cubic hectometer per square kilometer
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
gallon per minute	0.06309	liter per second
inch	25.4	millimeter
mile	1.609	kilometer
square mile	2.590	square kilometer
ton (short, 2,000 pounds)	0.9072	megagram (metric ton)

Temperature is given in this report in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$^{\circ}C = \frac{^{\circ}F - 32}{1.8}$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929) is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

HYDROLOGY OF AREA 56, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, UTAH

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ABSTRACT

Area 56 is one of 20 hydrologic areas defined in the Northern Great Plains and Rocky Mountain Coal Provinces. Area 56 includes the Wasatch Plateau, Book Cliffs, Emery, and Henry Mountains coal fields in central and southeastern Utah and west-central Colorado. All coal mined in the area during 1980 was recovered with underground mining techniques, mainly in the Wasatch Plateau and Book Cliffs fields. Surface mining is possible in the Emery and Henry Mountains fields.

Hydrologic impacts related to coal mining in the area are due mainly to dewatering of mines and land subsidence. Dewatering of coal mines changes the flow pattern through coal-bearing aquifers, and storage in aquifers is reduced. Other impacts are increases in streamflow and degradation of surface-water quality downstream from points of mine discharge. Land subsidence and associated rock fracturing above underground mines could change the flow of springs and locally could alter surface runoff.

The report provides broad hydrologic information for the area, and sources of additional hydrologic information are identified. The report is designed to be useful to mine-permit applicants and to regulatory authorities.

Hydrology of Area 56 Described

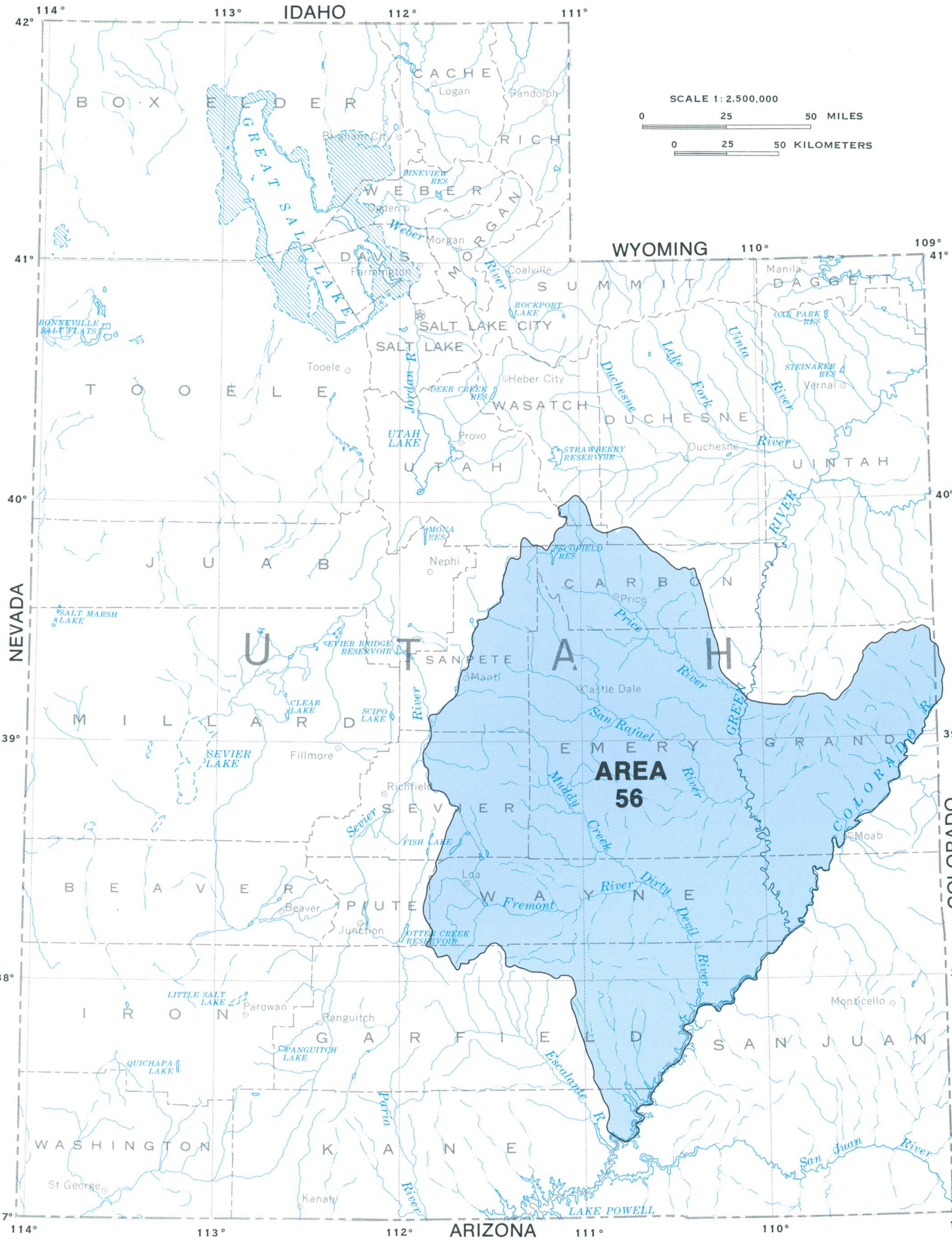
Hydrologic conditions are described, and sources of additional hydrologic information are identified.

Hydrologic information is needed by Federal agencies in order to lease and manage Federally owned coal. The information is needed by mine-permit applicants in order to describe the hydrology of the "general area" of proposed mines. Also, the "Surface Mining Control and Reclamation Act of 1977" requires that an appropriate regulatory authority issue mining permits based on review of mine-permit applications, which in part assess hydrologic impacts of the proposed mining.

This report partly fulfills the need for hydrologic information for Area 56 in Utah and Colorado (figure 1.1-1). Area 56 is one of 20 hydrologic areas in the Northern Great Plains and Rocky Mountain Coal Provinces. The report is one of a series that describes the hydrology of coal provinces nationwide.

The hydrology is described by means of a brief text and accompanying maps, graphs, and tables for each of a series of water-resources related topics. Sources of additional hydrologic information also are identified in the report.

In order to define the hydrologic conditions in the vicinity of a proposed mine and to assess the hydrologic impacts of the proposed mining, information in this report will be supplemented by site-specific data provided by mine-permit applicants. The site-specific data also will be needed by the regulatory authority in order to evaluate the adequacy of the mine-permit applications.



Base from U.S. Geological Survey
State base map, 1959

Figure 1.1-1 Location of Area 56 in Utah and Colorado.

More Than 90 Percent of Area is Federally Owned

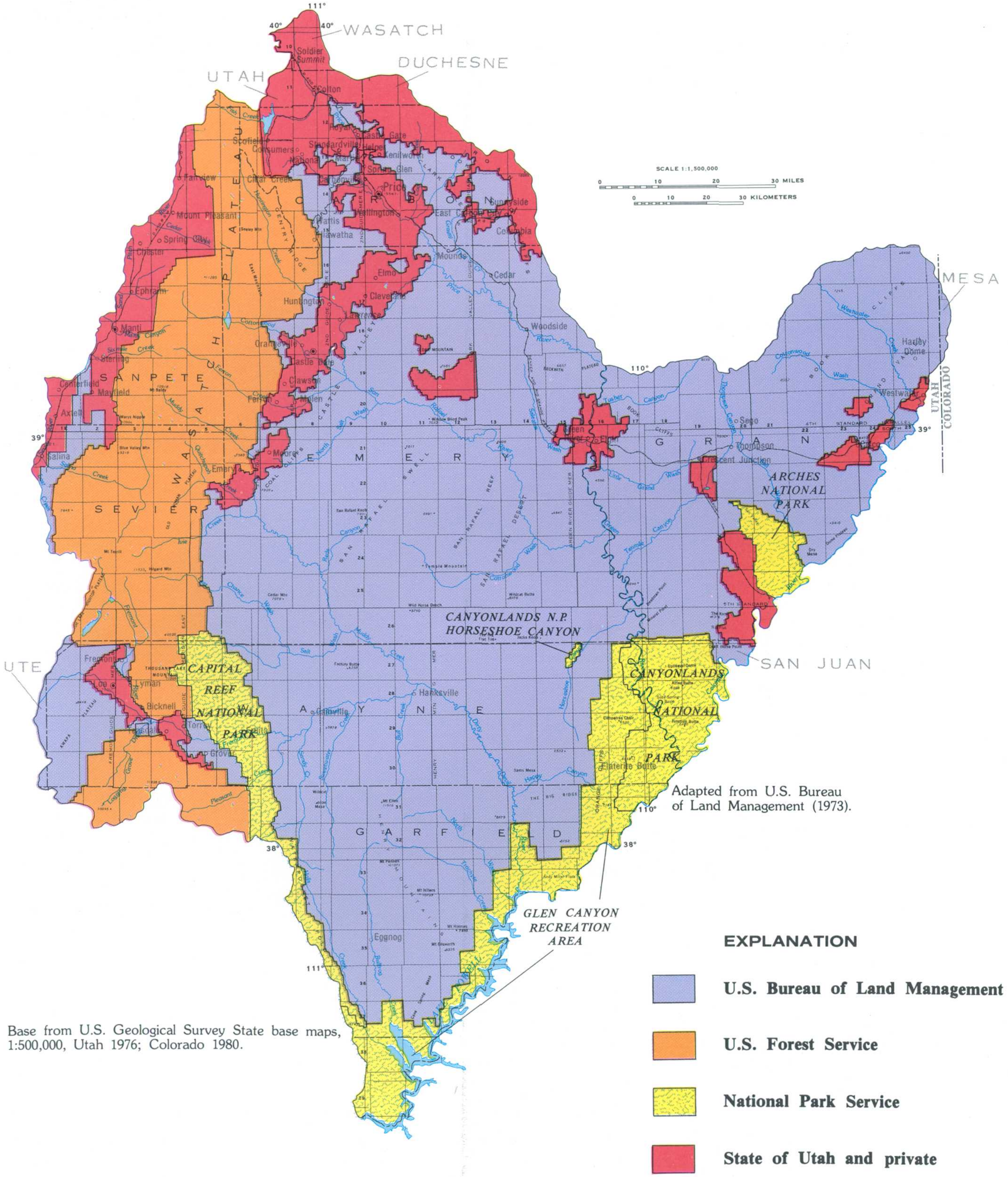
The area includes parts of three National Parks and other recreational land, as well as large coal reserves and other mineral resources.

The U.S. Bureau of Land Management administers the largest part of the area (figures 1.2-1 and 1.2-2) and is responsible for most of the coal-leasing activities. The U.S. Forest Service administered land (Fish Lake and Manti La Sal National Forests) includes most of the important coal reserves in the Wasatch Plateau. It also includes the watersheds of a number of important streams in the Colorado and Sevier River basins.

Areas administrated by the National Park Service include Arches, Canyonlands, and Capital Reef National Parks. These areas are noted for their scenic beauty and natural rock sculpture (figure 1.2-3) and are popular tourist attractions in Utah.

Most of the Federal- and State-owned land is used for grazing and recreation, but locally there is minerals and timber production. Much of the privately-owned land is used for agriculture, however, some of the privately-owned land also contains coal and other mineral resources.

In most instances, mineral ownership is coincident with land ownership--that is, the owner of the land surface also owns the minerals on or beneath the surface. There are, however, some local exceptions. For example, the Federal Government owns some of the minerals beneath privately-owned lands, and the States may own some of the minerals beneath Federally-owned lands.



Adapted from U.S. Bureau of Land Management (1973).

Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Figure 1.2-1 General land ownership and administration.

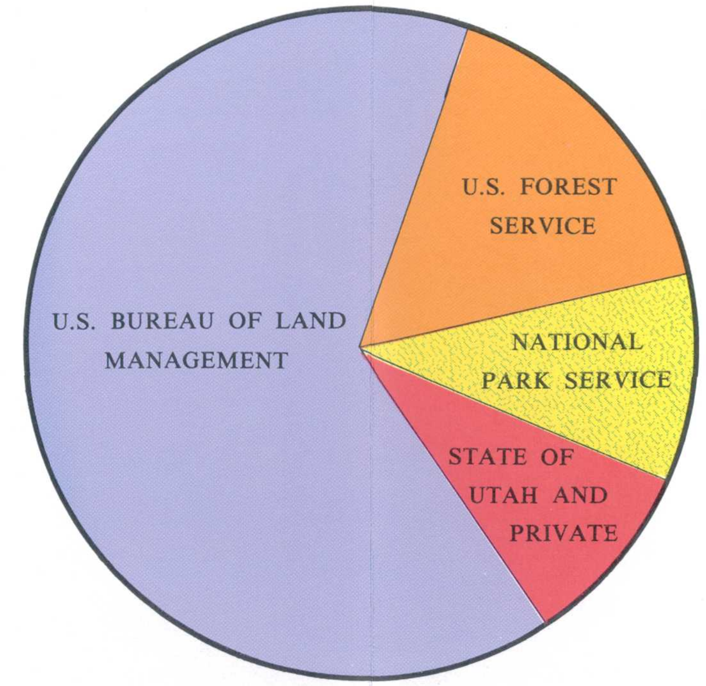


Figure 1.2-2 Comparison of land ownership and administration in Area 56 (determined for fig. 1.2-1)

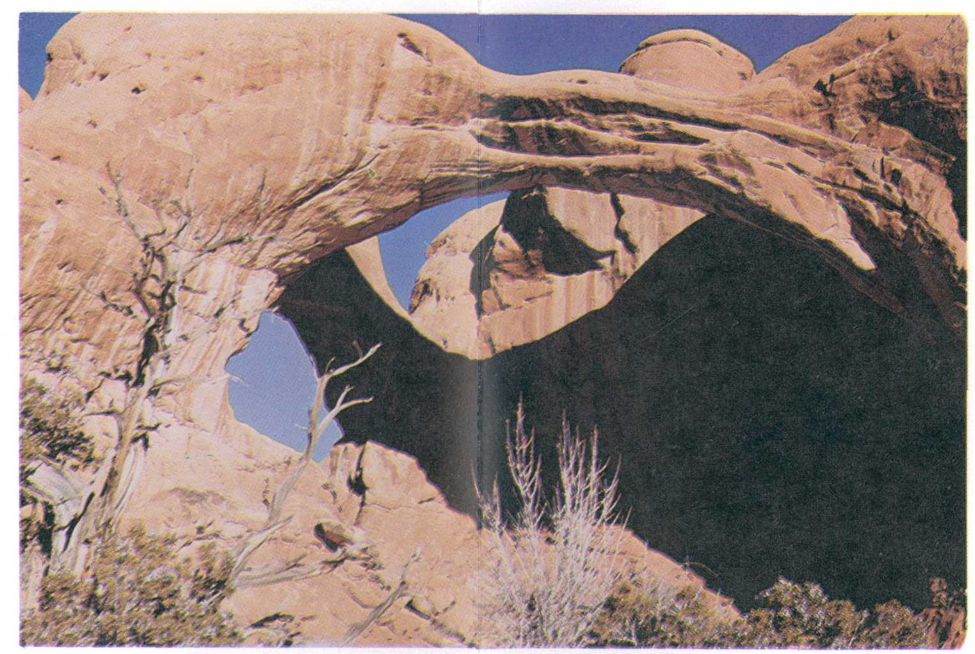


Figure 1.2-3 Rock sculpture in Arches National Park.

A Variety of Topographic Maps Available

The U.S. Geological Survey has compiled topographic maps for virtually the entire area and at several different scales; these maps are available at the Survey's Public Inquiries Offices.

An index of available U.S. Geological Survey 7½- and 15-minute topographic quadrangle maps is shown in figure 1.3-1. The respective scales of these maps are 1:24,000 (about 2.6 inches to the mile) and 1:62,500 (about 1 inch to the mile). The contour intervals for most of the maps range from 5 to 50 feet.

Most of the report area is also included in the U.S. Geological Survey's 1 x 2-degree-topographic map series:

Name	Compilation date	Revision date
Price, Utah	1956	1970
Salina, Utah	1956	1970
Escalante, Utah	1956	1970
Grand Junction, Colorado	1956	1969
Moab, Utah, Colorado	1956	1969

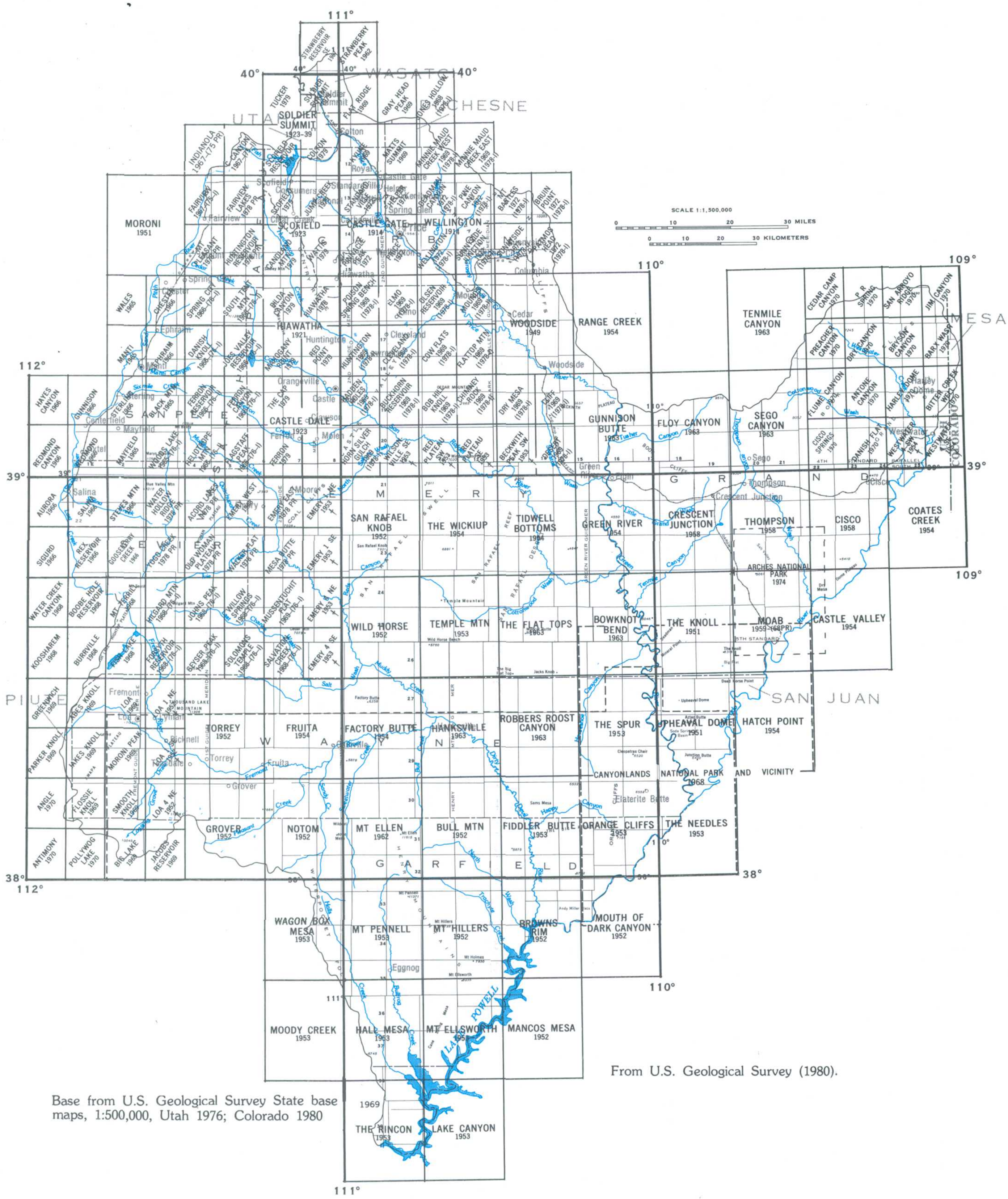
These maps have scales of 1:250,000 (about 0.25 inch to the mile) and contour intervals of 200 feet (with some supplementary contours at 100 feet). The 1 x 2-degree-topographic maps are being recompiled in 30 x 60-minute quadrangles at a scale of 1:100,000 with metric contour intervals.

All the topographic maps may be purchased from U.S. Geological Survey Public Inquiries Offices in both Denver, Colorado and Salt Lake City, Utah. Mailing addresses of those offices are as follows:

U.S. Geological Survey
1012 Federal Building
1961 Stout Street
Denver, Colorado
80294
Phone: (303) 837-4169

U.S. Geological Survey
8105 Federal Building
125 South State Street
Salt Lake City, Utah
84138
Phone: (801) 524-5652

In addition, many of the maps may be examined at public libraries in Utah or purchased from private businesses.



Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980

From U.S. Geological Survey (1980).

Figure 1.3-1 Index of available U.S. Geological Survey 7½- and 15-minute topographic maps.

Most of Area in the Colorado Plateaus Physiographic Province

The area is comprised of a variety of land forms, and the altitude of the land surface ranges from about 4,000 to 11,000 feet above sea level.

Most of the report area is in the Colorado Plateaus physiographic province; a small part of the area is in the Middle Rocky Mountains province. (See figure 2.1-1.) The Colorado Plateau province in the report area contains a variety of land forms, and the province is subdivided into the High Plateaus of Utah, Canyon Lands, and Uinta Basin sections (Fenneman, 1946).

The High Plateaus of Utah section is characterized by long, north-trending mountains dissected by steep canyons. (See figures 2.1 2A and B.) Altitude of the land surface ranges from about 6,000 to more than 11,000 feet above sea level. Locally, relief is as much as 3,000 feet.

The Canyon Lands section is characterized by elevated plateaus separated by deeply incised canyons. Much of the Canyon Lands section, however, has little surface relief. (See figures 2.1-2C and D.) Smaller land forms include natural bridges and alcove arches. Capitol Reef, Canyonlands, and Arches National Parks are three of the many areas within the Canyon Lands section that provide breathtaking natural beauty to visitors. Altitude of the land surface ranges from about 4,000 to 8,000 feet above sea level.

The Uinta Basin section is characterized by steep south-facing cliffs and broad, gently sloping mountain tops. The sedimentary rocks exposed along the south-facing cliffs have the appearance of pages in a book and thus have been named the Book Cliffs. Altitude of the land surface ranges from about 6,000 to 10,000 feet above sea level.

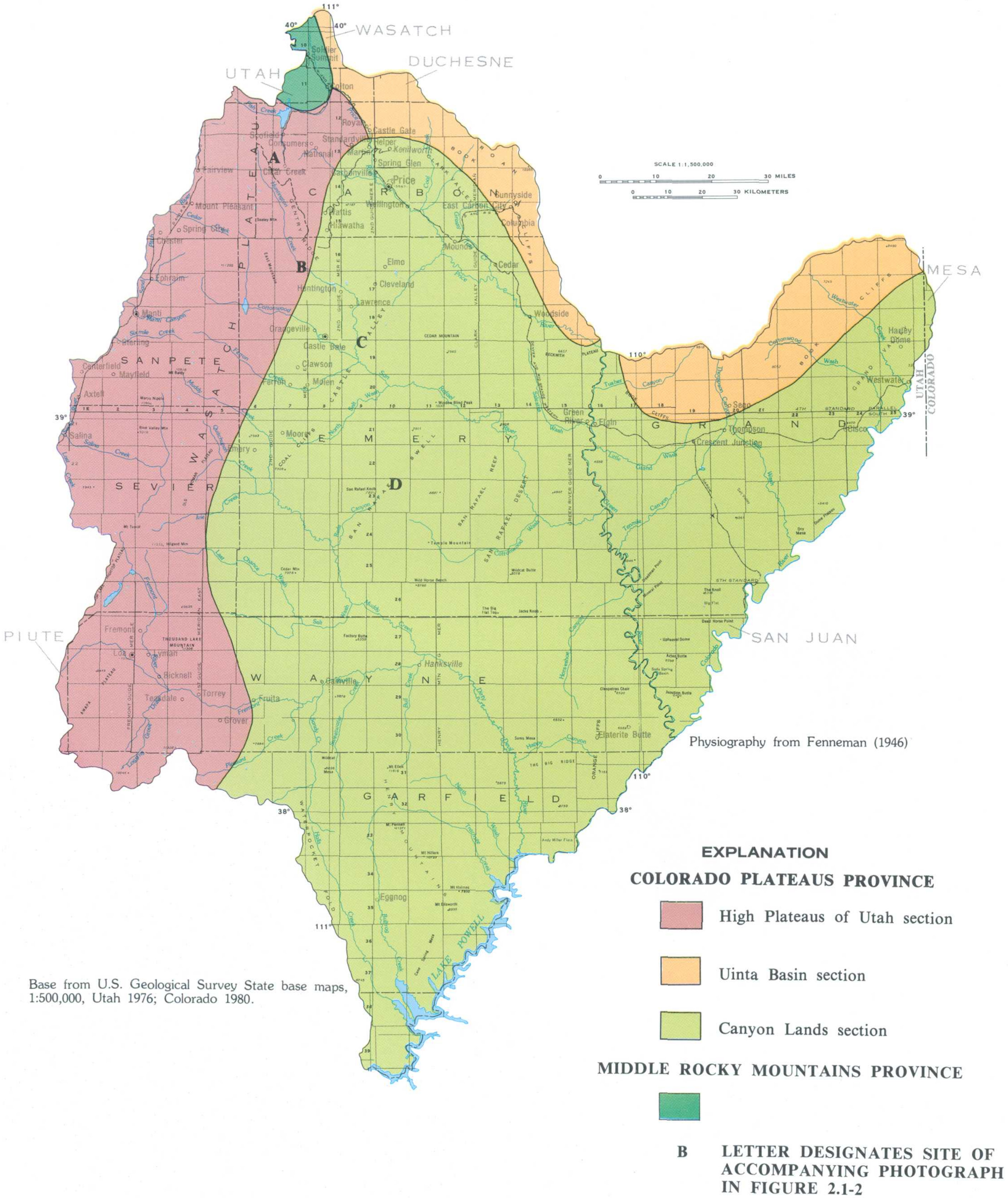


Figure 2.1-1 Physiographic divisions.

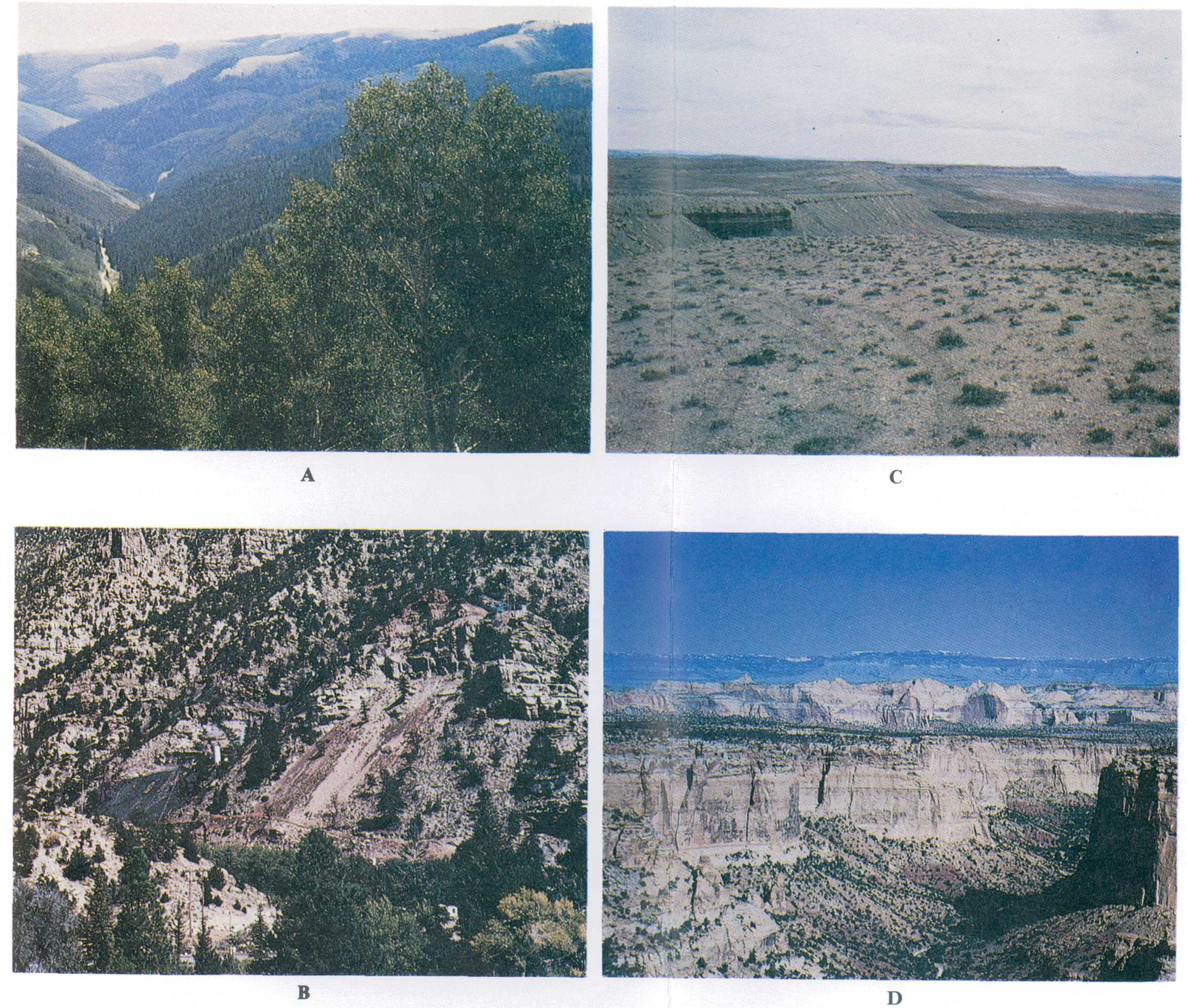


Figure 2.1-2 Views in the area: A, looking east from the headwaters of Eccles Canyon in the Wasatch Plateau (photograph by Kidd M. Waddell); B, looking east across Huntington Creek at surface facilities at the Coop Mine (photograph by Terrence W. Danielson); C, looking northeast in Castle Valley; and D, looking northwest into the San Rafael Swell with the Wasatch Plateau in the background (photographs by James W. Hood). Locations of photographs are shown on figure 2.1-1.

Rocks Range in Age From Pennsylvanian to Quaternary

Coal occurs in four geologic units, the most important being the Blackhawk Formation and Ferron Sandstone Member of the Mancos Shale.

Geologic units exposed in the area range in age from Pennsylvanian to Quaternary and consist of a variety of rock types. Sedimentary rocks exposed in the area have an average total thickness of about 16,000 feet. Outcrop areas and rock types are shown on the geologic map and generalized stratigraphic column (figure 2.2-1).

Coal occurs in several beds in the Dakota Sandstone, in the Ferron Sandstone Member and the Emery Sandstone Member of the Mancos Shale, and in the Blackhawk Formation, all of Cretaceous age. Coal beds in the Blackhawk and Ferron are the thickest, the most continuous, and the most important economically. During 1980, coal was mined from the Blackhawk in the Wasatch Plateau and Book Cliffs and from the Ferron near Emery.

Coal-bearing units are composed primarily of sandstone, but finer grained siltstone, mudstone, and shale also are abundant. Individual sandstone beds in coal-bearing units generally are lenticular and of small areal extent.

The continuity of coal-bearing units commonly is broken by faults in the Wasatch Plateau. Vertical displacement along the faults ranges from a few feet to more than 2,500 feet; only a few of the major faults are shown on the geologic map.

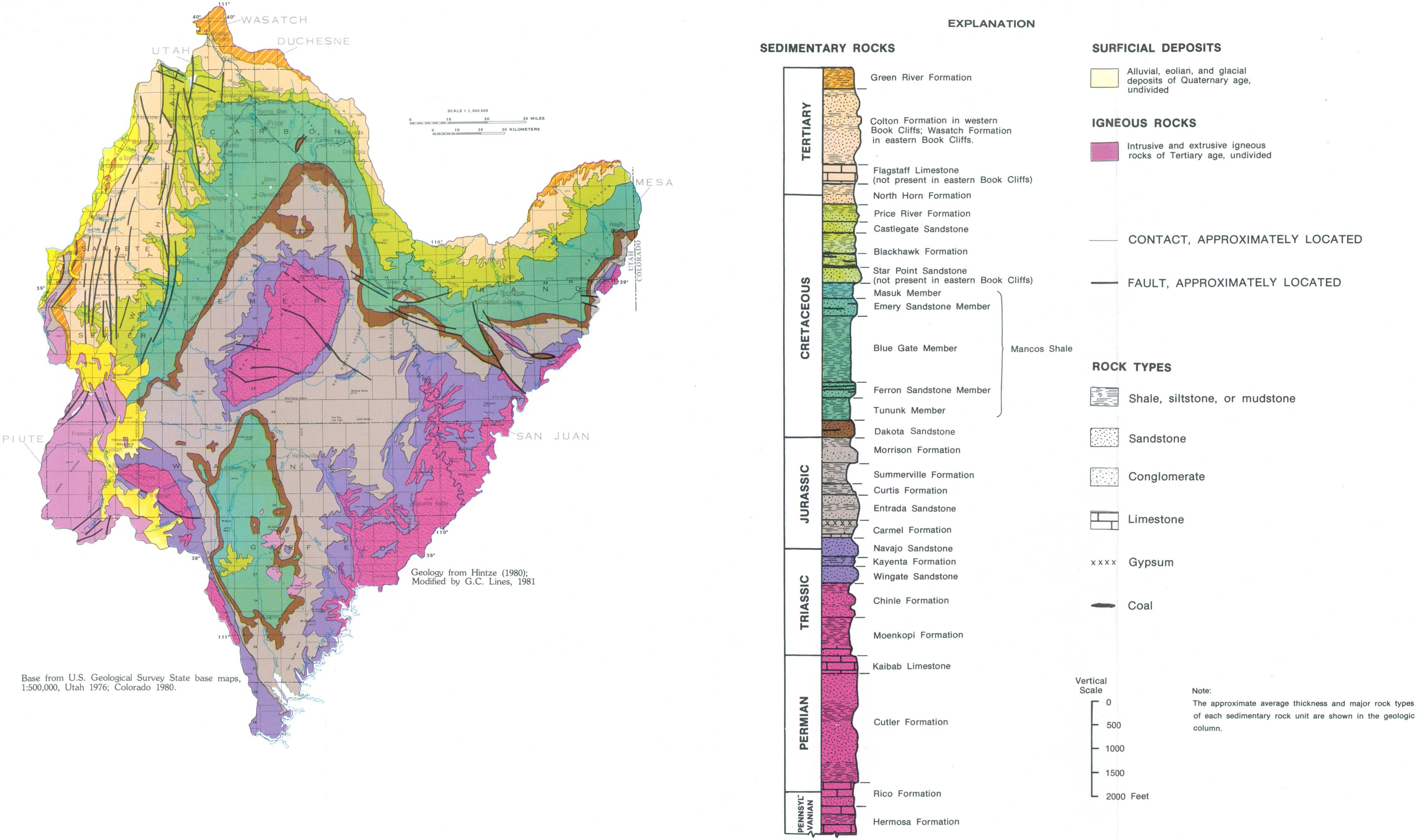


Figure 2.2-1 Geologic map and generalized stratigraphic column.

Area Characterized by Hot, Dry Summers and Cold, Relatively Moist Winters

Normal annual precipitation varies from less than 6 inches in the lower valleys to locally more than 40 inches on the high plateaus; it is estimated to total about 8.5 million acre-feet.

Precipitation on the area varies widely, both areally and with time. Normal annual precipitation ranges from less than 6 inches in the vicinity of the communities of Hanksville and Green River to locally more than 40 inches along the crest of the Wasatch Plateau (figure 2.3-1). Based on figure 2.3-1, the annual is estimated to total about 8.5 million acre-feet.

Most of the annual precipitation falls in the higher altitudes during the winter, as indicated in figure 2.3-2. Winter precipitation chiefly results from generally widespread frontal-type storms that move across the area from west to east, and most of that precipitation is snow. The winter snowpack commonly accumulates to more than 100 inches on the higher plateaus and is the principal source of late spring and early summer runoff in the area. The April 1 water content of the snowpack at Blacks Fork snow course is shown in figure 2.3-3 for 1950-80.

Summer precipitation generally results from convection-type storms that move into the area from the south. Those storms are generally localized and of short duration; however, they produce torrential rains that often result in flash flooding and associated property damage.

Air temperatures vary considerably both diurnally and annually throughout the area. Midsummer daytime temperatures in lower areas commonly exceed 100°F and midwinter night-time temperatures throughout the area commonly are well below 0°F. The summer temperatures are accompanied by large evaporation rates. As shown in figure 2.3-2, evaporation during July at Scofield Dam in the Price River drainage basin averaged almost 17 inches for 1931-75. During that same period, average annual evaporation was about 35 inches at Scofield Dam and about 42 inches at the community of Green River (Waddell and others, 1981, p. 6). Although not recorded, there probably also is significant sublimation of the winter snowpack, particularly in the higher plateaus, which are unprotected from dry winds that are common in this region.

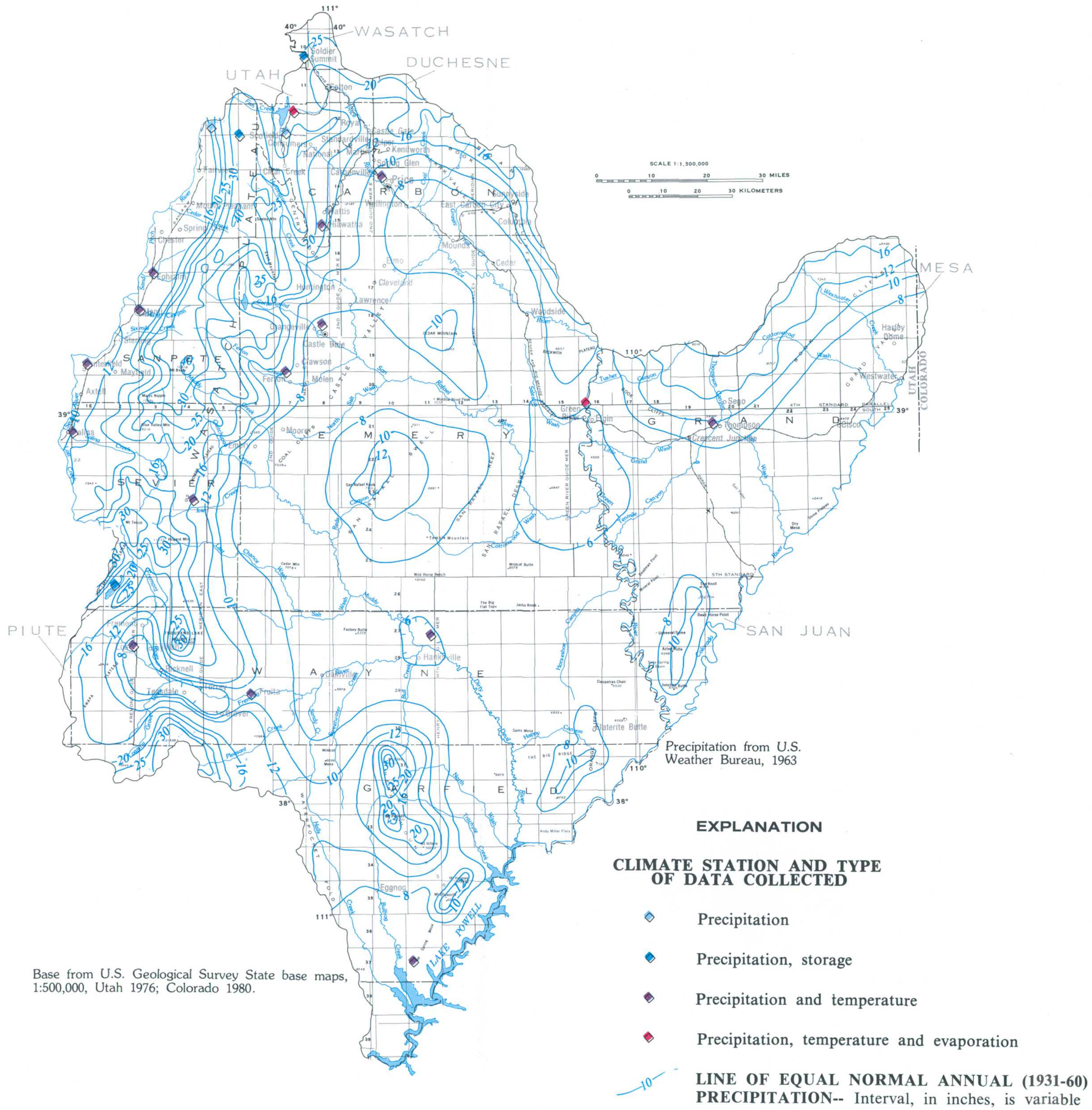


Figure 2.3-1 Normal annual (1931-60) precipitation and location of climate stations.

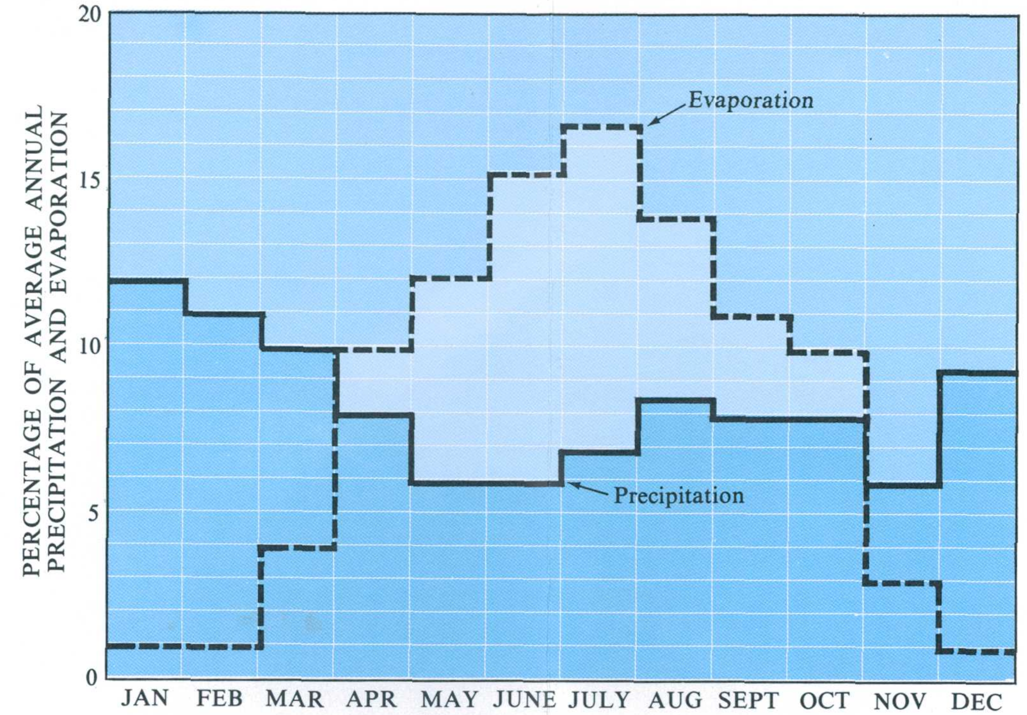


Figure 2.3-2 Monthly distribution of precipitation and evaporation at Scofield Dam, 1931-75 (from Waddell and others, 1981, figure 3; 1931-47 record estimated).

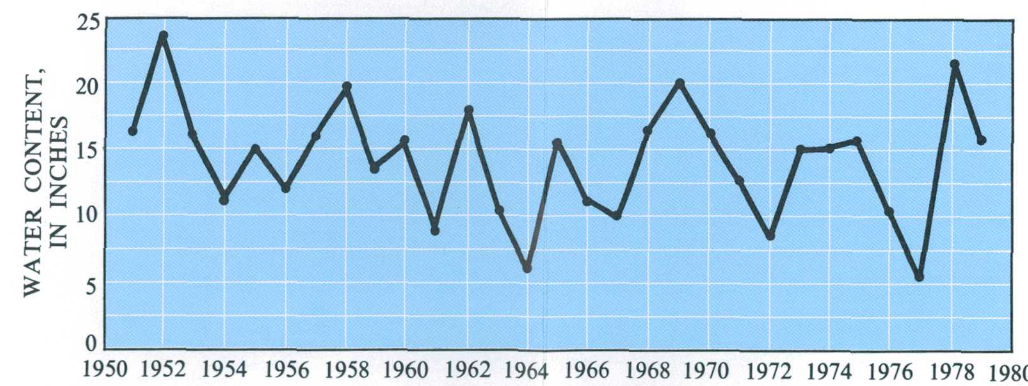


Figure 2.3-3 Water content of April 1 snowpack at Blacks Fork snow course (Danielson and Sylla, 1983).

Four Coal Fields Defined

During 1980 coal was mined in three fields by underground techniques.

The Wasatch Plateau, Book Cliffs, Emery, and Henry Mountains coal fields are in the report area (figure 3.1-1). About 10 percent of the report area is known to be underlain by one or more coal beds that are greater than 4 feet thick.

During 1980, coal was mined in the Wasatch Plateau, Book Cliffs, and Emery coal fields. Most of the mining was concentrated in the northern part of the Wasatch Plateau and Book Cliffs fields. Total coal production in the report area during 1980 was about 13 million tons (Gordon Whitney, U.S. Minerals Management Service, oral commun., 1982).

During 1980, all coal was recovered with underground-mining techniques. Some surface mining has taken place in the northern part of the Henry Mountains, but no coal was mined during 1980. Surface mining has been proposed for the Emery field. Because of large overburden thicknesses short distances from coal-outcrop areas, surface mining is not practical in the Wasatch Plateau and Book Cliffs fields.

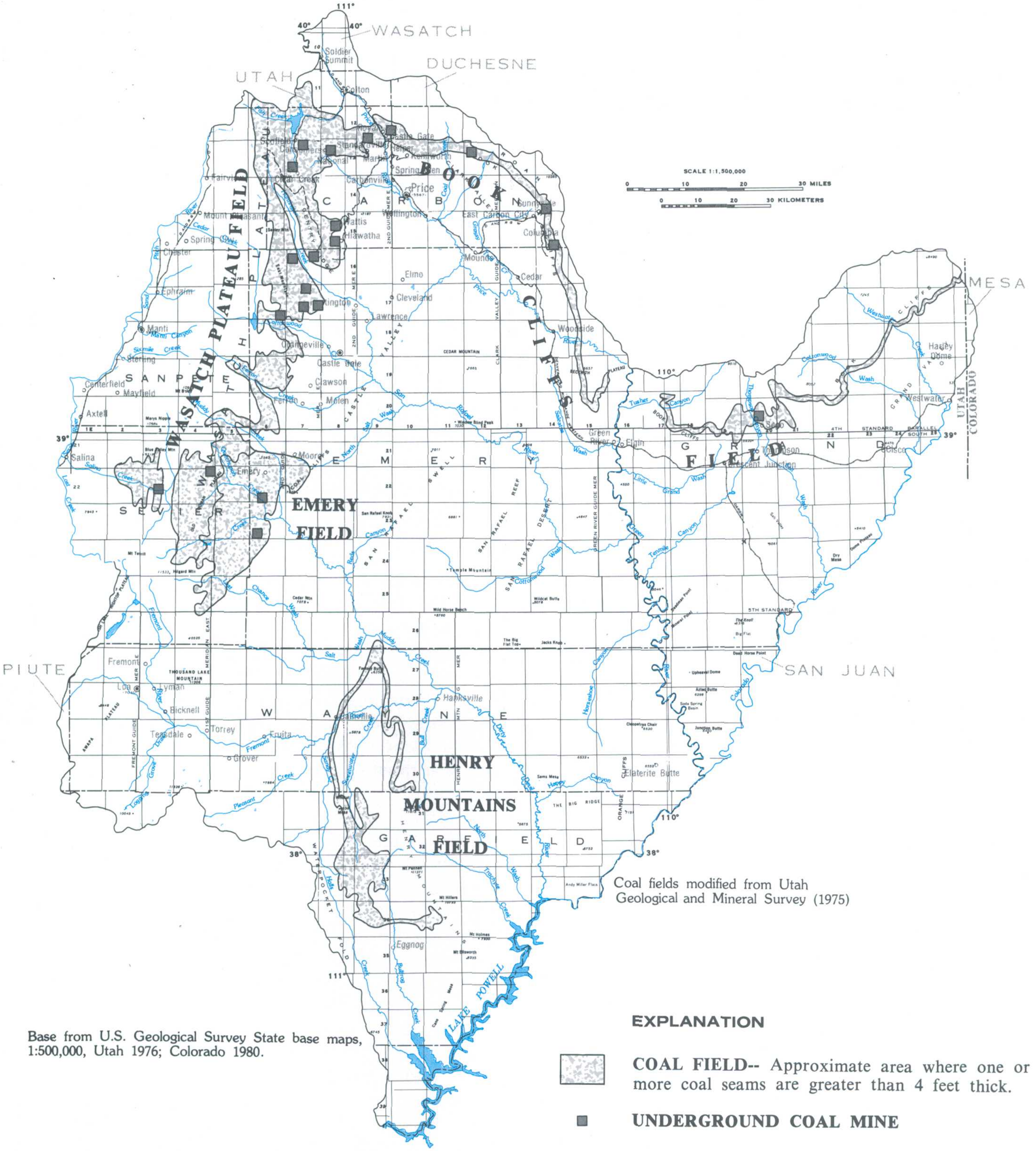


Figure 3.1-1 Location of coal fields and underground mines active during 1980.

Water Produced in Most Mines

Dewatering of underground coal mines has impacted both ground and surface waters.

Large quantities of water flow into underground coal mines in the report area, and mine dewatering was the largest source of manmade discharge from coal-bearing aquifers during 1980. The discharge from most mines is unknown, but several discharge more than 0.2 cubic foot per second. The largest quantities of water usually are encountered where the mines intercept faults or fractured rock. Some water usually is produced at the working faces in mines, and water commonly drains from bolt holes in the mine roofs (see figure 3.2-1). Some mines require continuous dewatering, and others discharge water intermittently. Ground water usually is not present in mines that extend short distances underground from the edges of deeply incised canyons where the coal-bearing rocks are drained naturally.

Dewatering of coal mines changes the flow pattern through coal-bearing aquifers, and storage in the aquifers is reduced. The approximate change in ground-water flow that would occur in a uniformly permeable aquifer near a dewatered underground mine is shown in the cross sections of figure 3.2-2. As depicted in cross section A, prior to mining, flow through the aquifer is uniform and has both vertical and horizontal components. The vertical flow as shown is downward, but this is a hypothetical situation and vertical flow may be upward in some coal-bearing aquifers in the area. During mining, as shown in cross section B, flow through the aquifer is directed toward the dewatered mine, and much of the aquifer above the older mined area is dewatered. The pattern of ground-water flow around each dewatered underground mine will be unique due to the unique configuration of each mine and because coal-bearing aquifers are not uniformly permeable. However, the pattern of flow will be similar to that depicted in cross section B.

Ground-water storage has been reduced around all water-producing mines in the area. The water-level decline in a well near a dewatered underground mine is shown in figure 3.2-3. During 1979-80, water levels in the well declined about 43 feet. Historic water-level data from wells are not available to define the extent and degree of the depletion near most mines.

Where mine water is discharged to a stream, streamflow increases downstream from the point of discharge. The effects of periodic discharge of water from a mine on streamflow is shown in figure 3.2-4. When water was being discharged from the mine, streamflow increased to about 1.79 cubic feet per second. During periods of no mine discharge, streamflow quickly receded to a rate of about 0.05 cubic foot per second.

Other possible impacts related to mine dewatering are the degradation of surface-water quality downstream from points of mine discharge and decreases in flows of springs. Water discharged from mines is more mineralized during most periods of the year than surface water upstream from points of mine discharge. However, the quantity and quality of the water that would have been discharged naturally by springs often is not known.

Figure 3.2-1 Water draining from a bolt hole in the sandstone roof of an underground mine (Danielson, ReMillard, and Fuller, 1981, figure 14).

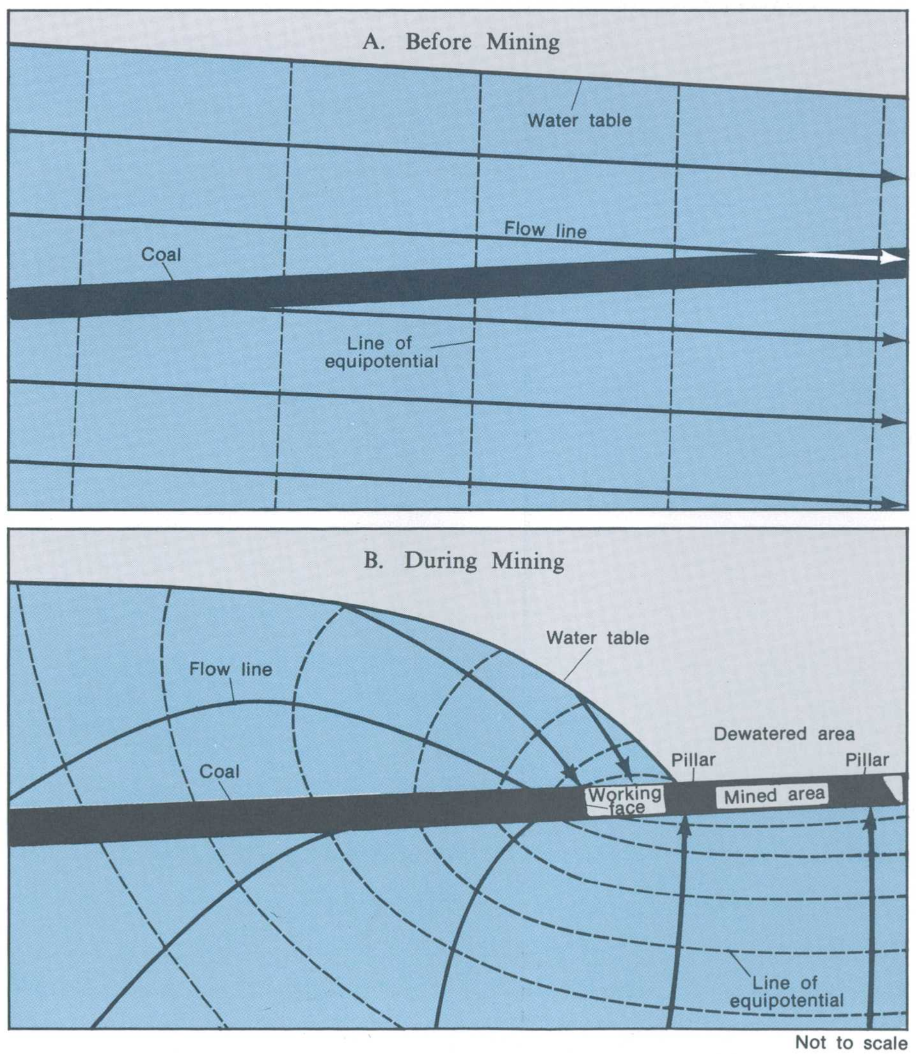


Figure 3.2-2 Cross sections showing changes in flow through a uniformly permeable coal-bearing aquifer near an underground mine.

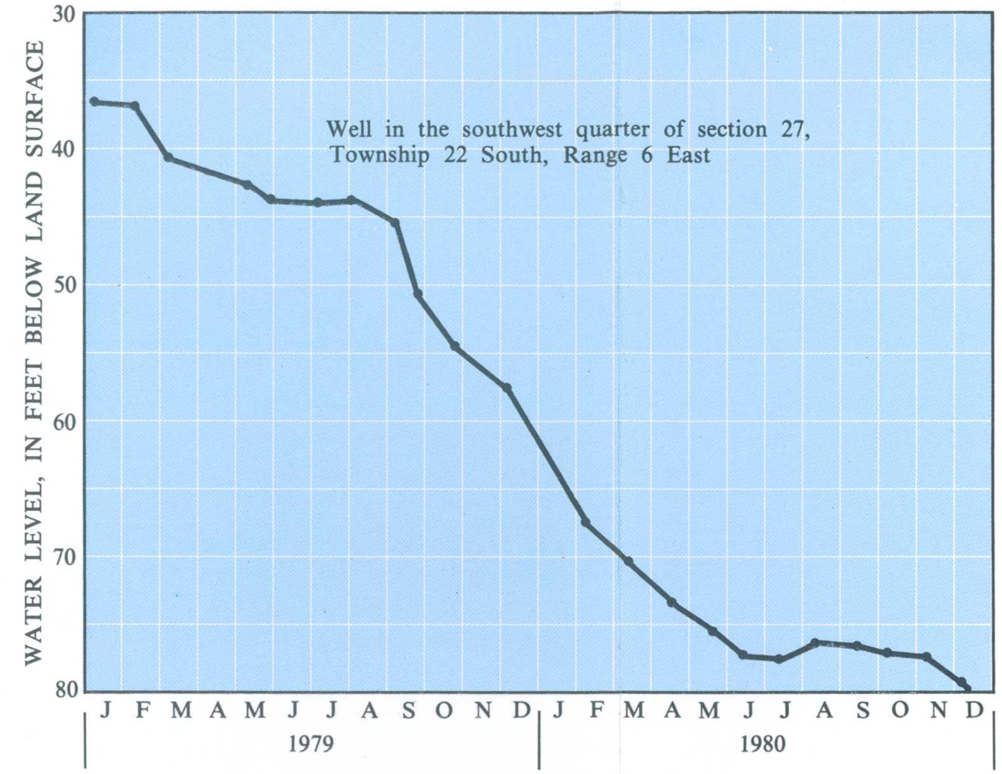


Figure 3.2-3 Water level in a well showing effects of dewatering the Emery Mine. Water levels during 1980 provided by Consolidation Coal Co.

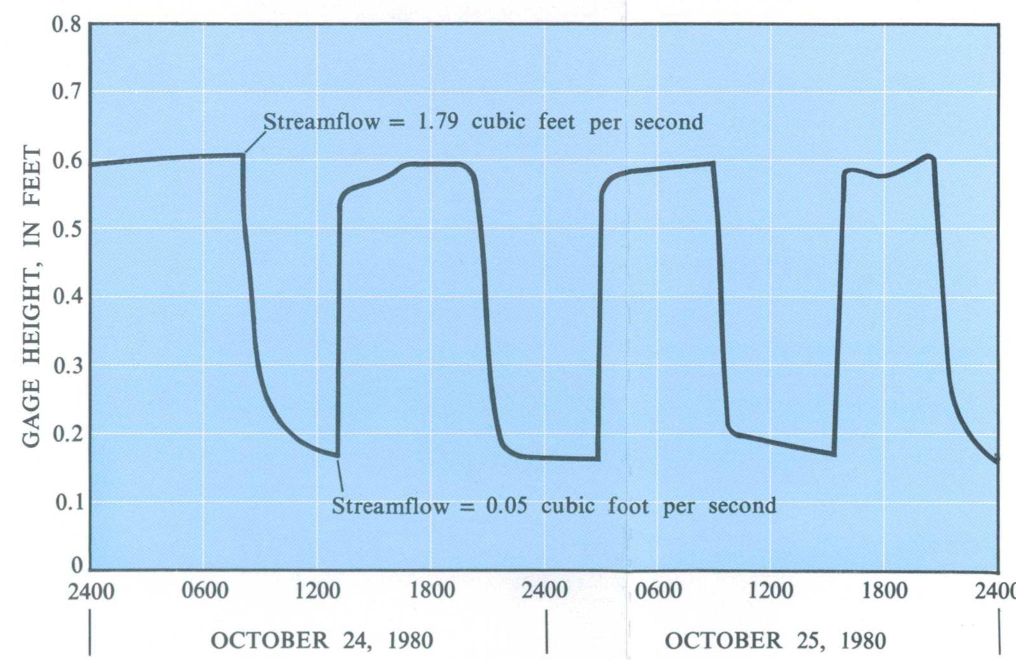


Figure 3.2-4 Effects of periodic discharge of water from the SUFCo Mine on streamflow in Convulsion Canyon at gaging station 09331850 (site 98 in section 10.0).

Water Resources Impacted by Subsidence

The flow of both surface and ground waters can be altered by land subsidence and associated fracturing above underground coal mines.

Land subsidence and associated rock fracturing above underground mines can cause changes in the natural pattern of ground-water flow, can change the flow of springs, and locally can alter surface runoff. The degree of land subsidence above underground mines and the configuration of associated fractures are dependent on the thickness and strength of overburden, the configuration and rate of mining, and the thickness of coal removed. The general pattern of subsidence and rock fracturing that occurs above a mine is shown in the cross section of figure 3.3-1.

Fractures that have developed at the land surface about 900 feet above a mine near Sunnyside in the Book Cliffs coal field are shown in figures 3.3-2 and 3.3-3. According to Dunrud (1976, p. 9), the larger fractures emit air from the mine workings, indicating their continuity with the workings. Dunrud also points out that ". . . these cracks divert all surface- and ground-water flow in this area to lower strata or to the mine workings."

Compression features, such as the small anticline shown in figure 3.3-4, also formed at the land surface above the mine near Sunnyside. The anticline formed when stresses along the compression arch (figure 3.3-1) reached the land surface. Measurements of the compression fractures indicate that the land surface was shortened locally by as much as 3 feet. The vertical displacement of the land surface in this area is unknown, but it probably was several feet.

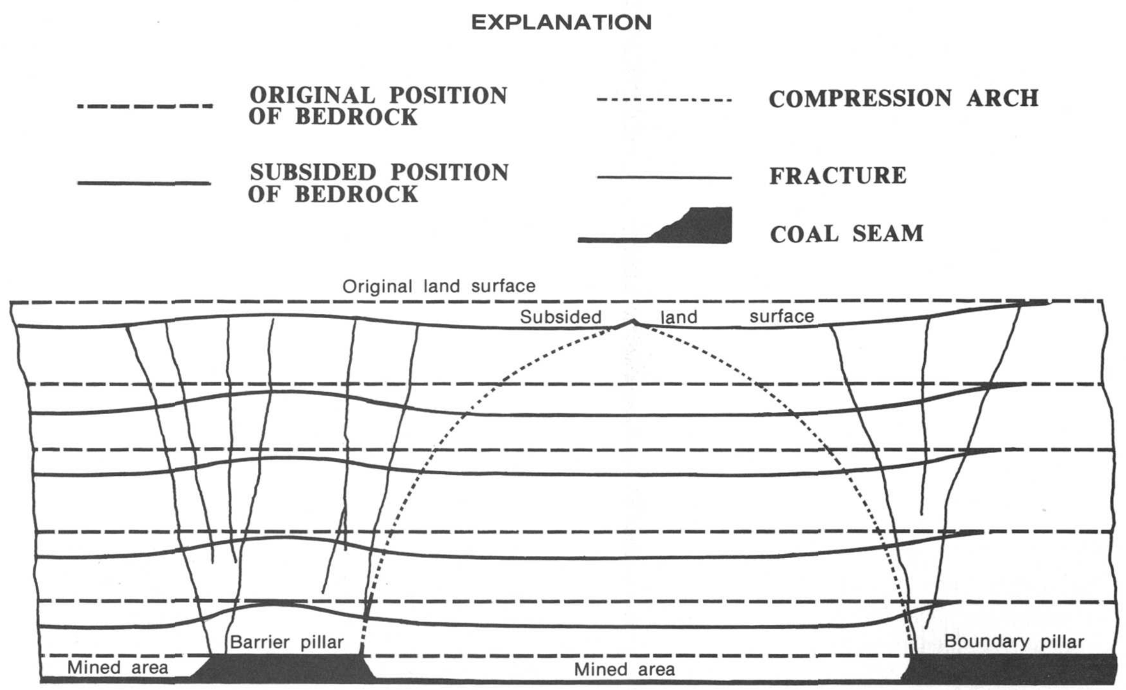


Figure 3.3-1 Generalized cross section showing subsidence and fracturing that occurs above an underground coal mine (modified from Dunrud, 1976, figures 4 and 8).

Figure 3.3-2 Fractures at the land surface above a barrier pillar resulting from subsidence in an underground mine about 900 feet below (Dunrud, 1976, figure 9).

Figure 3.3-3 Fracture as much as 3 feet wide resulting from subsidence over an underground coal mine (Dunrud, 1976, figure 9).

Figure 3.3-4 Compression anticline formed above an underground mine when compression arch reached the land surface (Dunrud, 1976, figure 9).

Irrigation the Largest Use of Water

More than 80 percent of the total estimated use of water was for irrigation; principal sources of the irrigation water are the Green, Sevier, San Pitch, Fremont, and Price Rivers, and Huntington, Cottonwood, Ferron, and Muddy Creeks.

Total estimated use of water in the report area during 1980 was about 391,000 acre-feet. The estimate does not include instream uses such as recreation and fish and wildlife management, or consumption by livestock and wildlife. The largest uses of water were for irrigation and electric-power generation in the areas shown in figure 4.0-1. As shown in the following table and figure 4.0-2, irrigation accounted for more than 80 percent of the total use:

Use	Acre-feet
Irrigation	315,000
Industry	63,000
Public supply	12,600
Domestic	100
Total (rounded)	391,000

There are about 105,000 acres of irrigated cropland in the area (Utah Department of Agriculture, 1981, p. 11); most of that cropland is along the flanks of the Wasatch Plateau (figure 4.0-1). The estimated water use for irrigation of the 105,000 acres assumes an average annual crop requirement of about 3 feet of water.

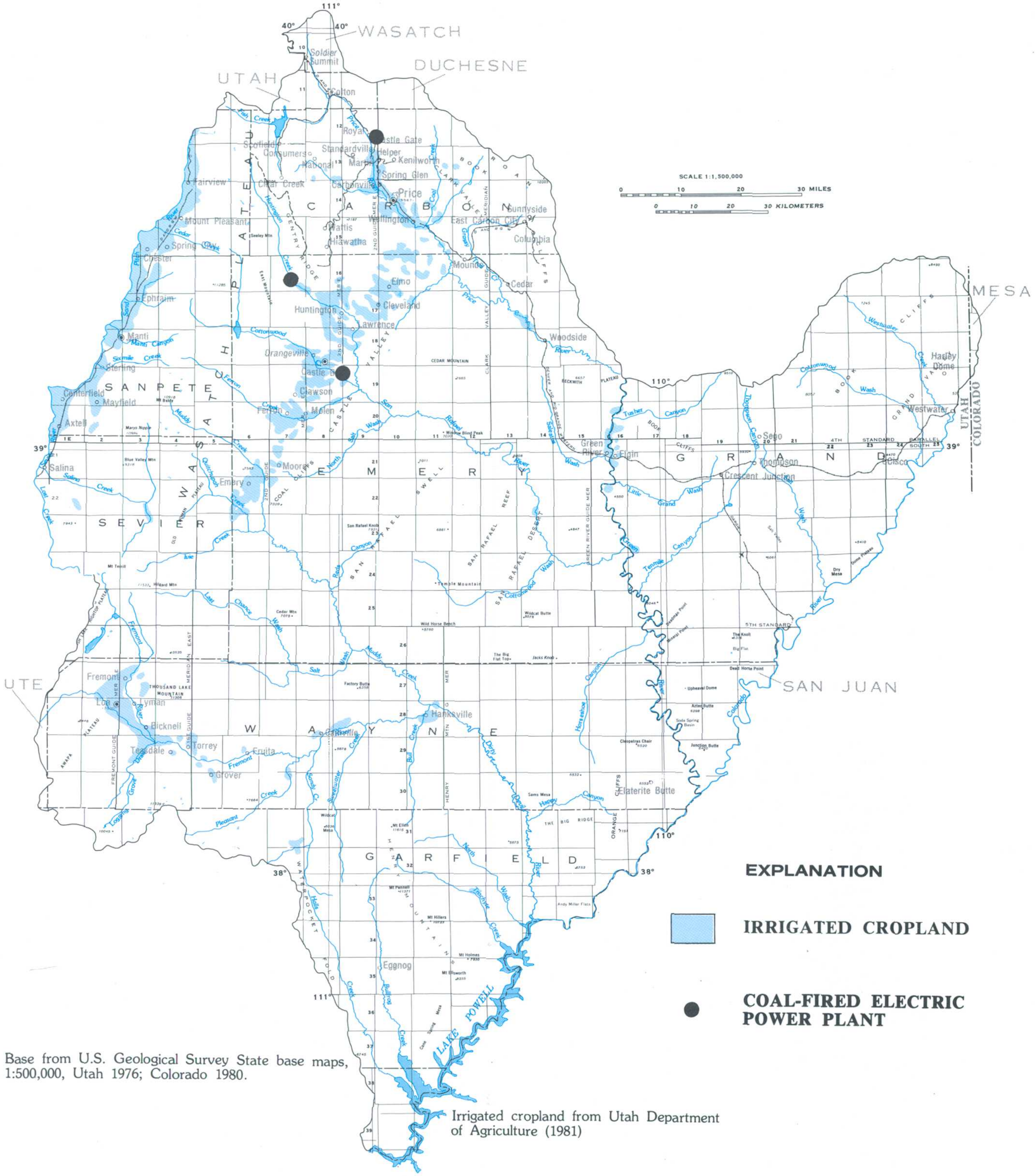
Most of the irrigation water is diverted from the Green, Sevier, Price, Fremont, and San Pitch Rivers, and Huntington, Cottonwood, Ferron, and Muddy Creeks. Probably less than 2 percent of the irrigation water is from wells, most of which are in the Sanpete Valley and upper Fremont River valley.

Water use for industry is chiefly in the generation of electricity at three Utah Power and Light Co. coal-fired, thermo-electric power plants (figure 4.0-1). Based on data from Wayne Campbell (Utah Power and Light Co., oral commun., March 1982), water use in generation of electricity totaled about 62,700 acre-feet during 1980.

Most water used in generation of electricity and other industrial uses is diverted from the Price River and Huntington, Cottonwood, and Ferron Creeks. Some water is discharged from coal mines in the drainage basins of these streams.

Of the estimated 12,600 acre-feet of water withdrawn for public supply, about 63 percent is from ground-water sources and about 37 percent is from surface-water sources (based on data obtained from Dave Hooper, Utah Division of Water Rights, oral commun., March 1982). The ground-water sources are chiefly springs in the Wasatch Plateau, although several communities including Emery and Hanksville obtain water from wells. The surface-water sources include the Green and Price Rivers, and Cottonwood and Ferron Creeks.

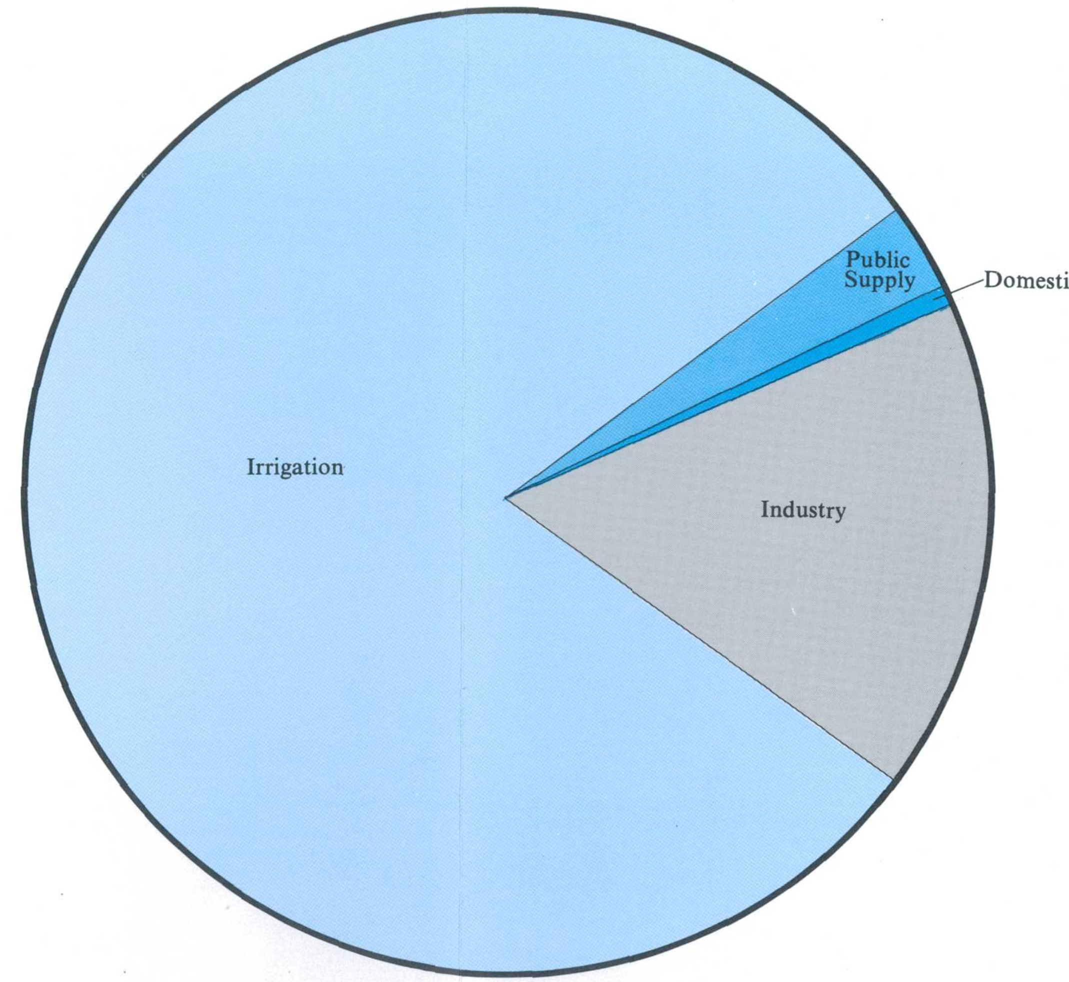
Virtually all the water withdrawn for domestic use is from ground-water sources. The sources include widely scattered, generally small-yielding wells and springs.



Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Irrigated cropland from Utah Department of Agriculture (1981)

Figure 4.0-1 Principal water use areas.



Total use 391,000 acre feet

Figure 4.0-2 Distribution of water use, 1980.

Other Hydrologic Reports Available

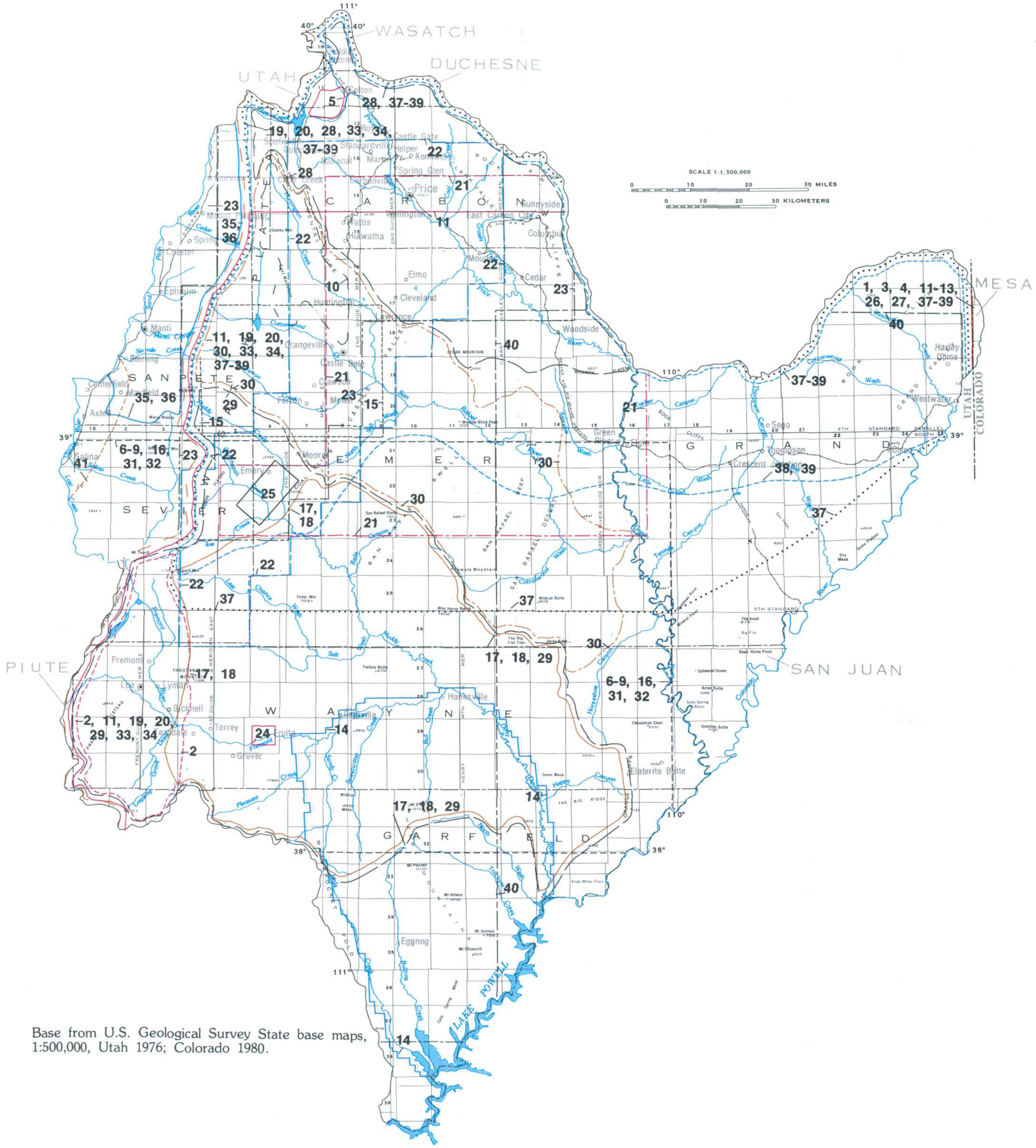
The U.S. Geological Survey has conducted many hydrologic studies in the area that have investigated a variety of subjects.

Many hydrologic studies have been conducted by the U.S. Geological Survey in the area. The reports should be useful references for those people involved with coal-related hydrologic problems.

The 41 reports listed in figure 5.0-1 deal with many components of the hydrologic system, such as the magnitude and frequency of floods, availability of ground water, and hydrologic impacts of coal mining. Most of the reports are interpretive in nature, but some contain only hydrologic data. The hydrologic studies were conducted and reports prepared, for the most part, by personnel of the Geological Survey's Utah District. Most of the studies were conducted in cooperation with other Federal, State, and local agencies.

Publications of the Geological Survey that are still in print may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20420. Reports that are out of print and unavailable for purchase may be examined at the U.S. Geological Survey, Public Inquiries Office, 8102 Federal Building, 125 South State Street, Salt Lake City, Utah. Open-file reports, for the most part, are available only for inspection at the U.S. Geological Survey, Water Resources Division, Room 1016, Administration Building, 1745 West 1700 South, Salt Lake City, Utah.

For complete bibilographic information, the reader is referred to part 9.0, References Cited, in this report. Most of the reports are summarized in an annotated bibliography by Lines (1981).



Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

EXPLANATION

STUDY BOUNDARY AND NUMBER	AUTHOR(S) AND YEAR OF PUBLICATION
1	Berwick (1962)
2	Bjorklund (1969)
3	Butler and Cruff (1971)
4	Connor, Mitchell, and others (1958)
5	Cordova (1963)
6 and 7	Covington (1972a and b)
8 and 9	Covington and Williams (1972a and b)
10	Danielson, ReMillard, and Fuller (1981)
11	Eychaner (1976)
12	Feltis (1966)
13	Fields (1975)
14	Goode and Olson (1977)
15	Graham, Tooley, and Price (1981)
16	Hackman and Williams (1972)
17 and 18	Hood and Danielson (1979a and b)
19	Iorns, Hembree, Phoenix, and Oakland (1964)
20	Iorns, Hembree, and Oakland (1965)
21	King and Mace (1953)
22	Lines and Morrissey (1981)
23	Lines and Plantz (1981)
24	Marine (1962)
25	Morrissey, Lines, and Bartholoma (1980)
26 and 27	Mundorff (1968 and 1971)
28	Mundorff (1972)
29	Mundorff (1979)
30	Mundorff and Thompson (1980)
31 and 32	Price (1972a and b)
33	Price and Arnow (1974)
34	Price and Waddell (1973)
35 and 36	Robinson (1968 and 1971)
37	Sumsion (1979)
38	Waddell, Contratto, Sumsion, and Butler (1981)
39	Waddell, Vickers Upton, and Contratto (1978)
40	Waring (1935)
41	Young and Carpenter (1965)

Note: See Section 9.0, References Cited, for complete bibliographic listing.

Figure 5.0-1 Study areas described in other hydrologic reports.

Streamflows Gaged at 127 Stations

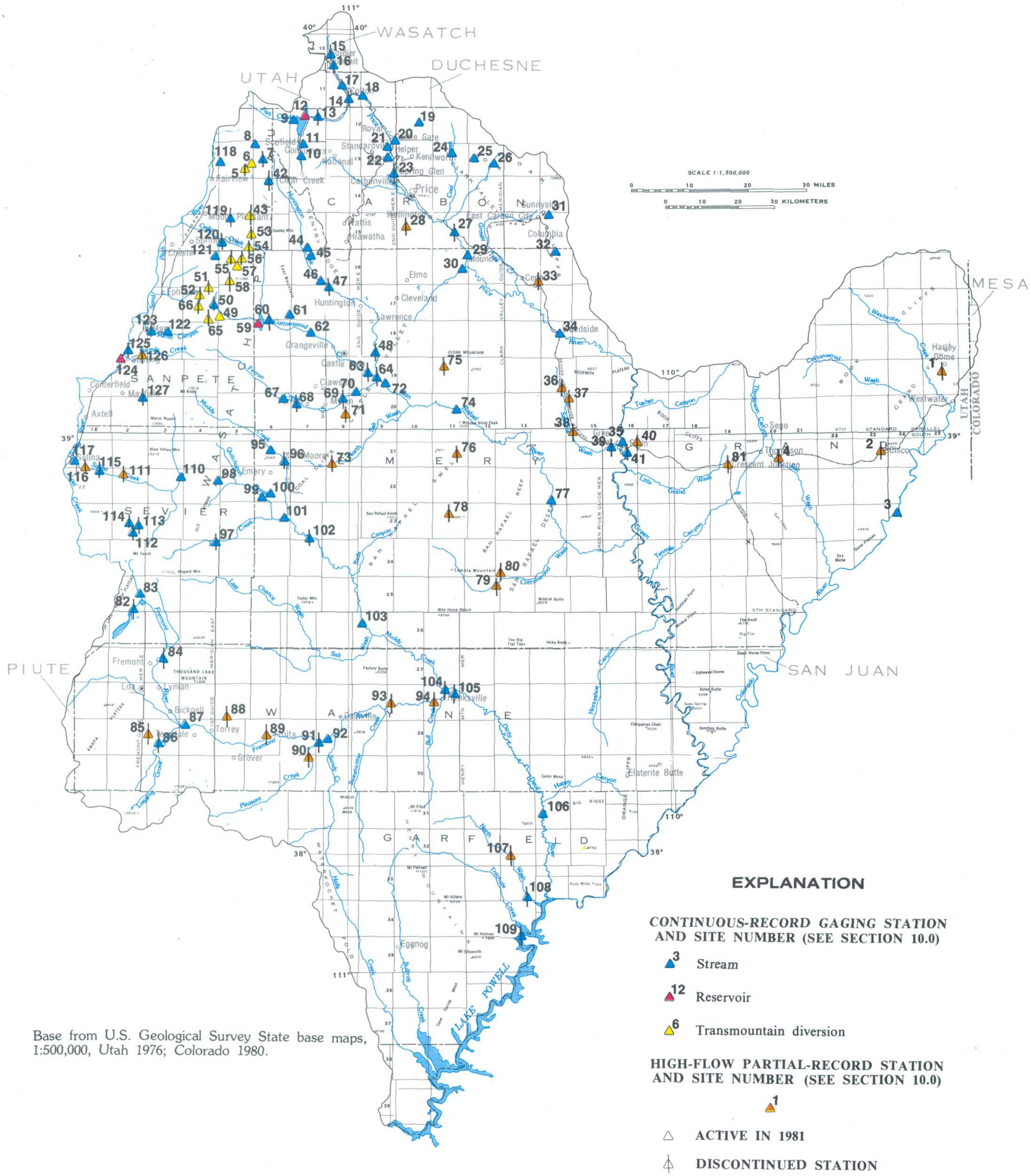
Included in the surface-water network are 50 active and 50 discontinued continuous-record stations and 27 high-flow partial-record stations.

Daily streamflows or reservoir stage and contents are available for 100 continuous-record stations (figure 6.1-1) for the period of record listed in section 10.0. Only annual maximums are available for the partial-record stations (figure 6.1-1), which generally were operated for 10-15 years during 1959-74. About one-third of the discontinued continuous-record stations were operated during 1949-58 to measure transmountain diversions from the upper Price River and Huntington and Cottonwood Creek drainages to the Great Basin.

Chemical-quality, sediment, and biologic data were obtained on a systematic basis at 31 of the 127 stations. (See section 10.0). All types of water-quality data are not necessarily available for each station.

Most of the discharge and water-quality data are stored in the WATSTORE computer files of the Geological Survey and are available through NAWDEX (Edwards, 1977). The data have been reported in Geological Survey annual reports, which have been issued in various series since 1899. The current series is titled "Water Resources Data for Utah" (U.S. Geological Survey, issued annually since 1975).

Other water-quality data are reported in Danielson, ReMillard, and Fuller (1981); Mundorff (1972 and 1979); Mundorff and Thompson (1980); and Waddell and others (1978). Also, many measurements of temperature and specific conductance were obtained with periodic discharge measurements at the 127 stations.



Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Figure 6.1-1 Surface-water network.

Streamflow Varies Markedly

Daily mean flow fluctuates in response to precipitation, and long-term averages vary with drainage area and normal annual precipitation.

Streamflow fluctuates in response to snowmelt and thunderstorms, and average streamflow varies with drainage area and total precipitation. Most high altitude (greater than 7,000 feet) runoff results from snowmelt during March-July. The hydrograph for site 61 (figure 6.2-1) shows the typical distribution of flow for high-altitude sites. Thunderstorms produce much of the annual runoff for sites that drain the lower altitudes. The hydrograph for site 100 (figure 6.2-2) shows the typical distribution of streamflow for sites at lower altitudes.

The average flow of streams that originate in the mountains generally increases downstream. However, when these streams flow through low-altitude areas where average flow per unit area is small, additional inflow may be less than infiltration, evapotranspiration, or diversions. Thus, average flow can decrease downstream. The average flow of the larger streams is shown in figure 6.2-3. The width of the bands generally were constructed using the data listed in table 6.2-1. In some instances, the values for sites on some reaches of the larger streams differ because the periods of record are different; thus, the long-term records (generally more than 20 years) were used to adjust the short-term records.

The relation of average flow to drainage area and normal annual precipitation is shown in figure 6.2-4. Thirty-six of the sites listed in table 6.2-1, which drain areas less than 500 square miles and have 5 or more years of record, were used for the analysis. The equation is:

$$Q = 0.000054\ A^{0.81}\ P^{3.02}$$

where

Q is the average flow, in cubic feet per second;
A is the drainage area, in square miles; and
P is the normal annual precipitation for the drainage area, in inches (computed from U.S. Weather Bureau, 1963).

The standard error of estimate (Riggs, 1973, p. 11) is 49 percent, and the correlation coefficient is 0.92. The equation was developed using data not appreciably affected by regulation. Thus, its use is intended for natural flow.

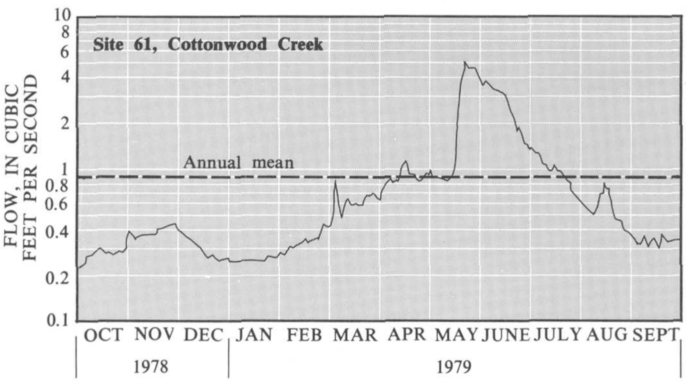


Figure 6.2-1 Typical hydrograph of daily mean flow at a high-altitude site.

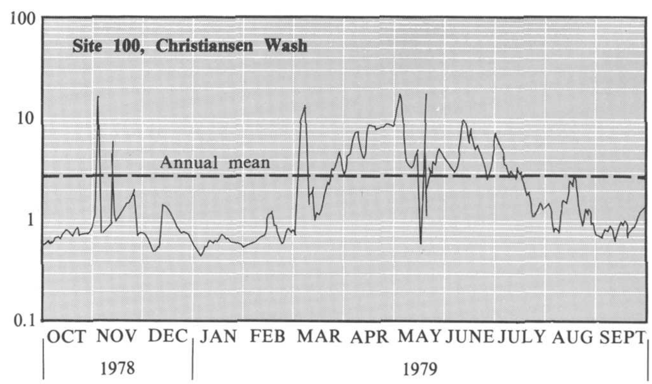
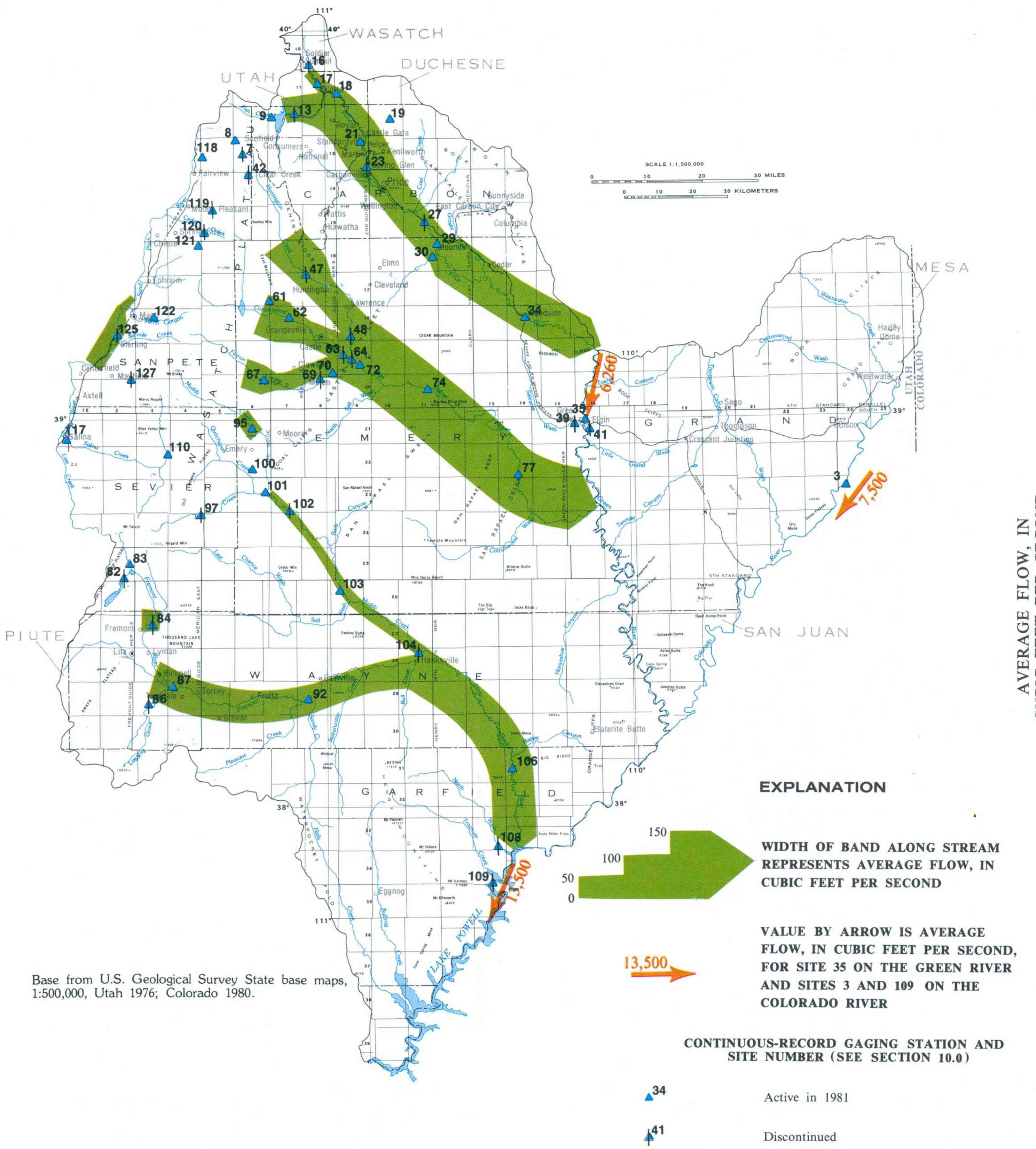


Figure 6.2-2 Typical hydrograph of daily mean flow at a low-altitude site.



Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Figure 6.2-3 Average flow of large streams and location of selected continuous-record gaging stations.

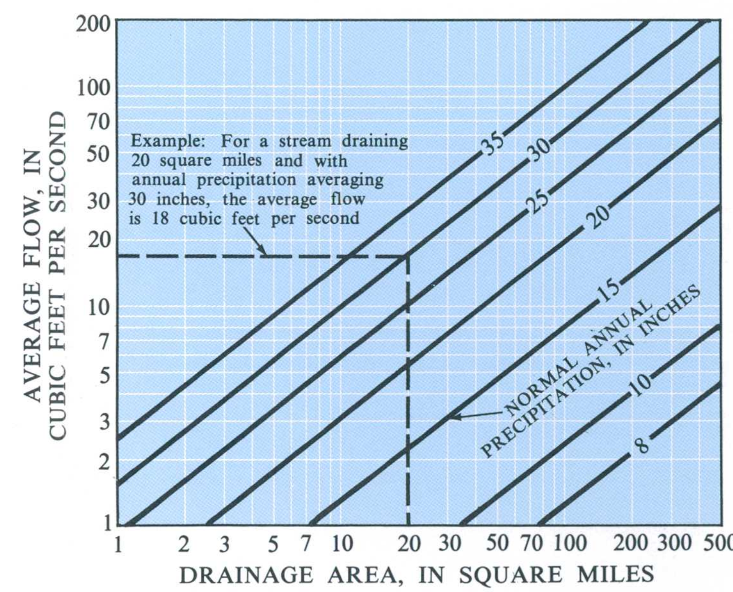


Figure 6.2-4 Relation of average flow to drainage area and normal annual precipitation.

Table 6.2-1 Average flow for continuous-record gaging stations with 5 or more complete years of record.

Site No. (see Section 10.0)	Average flow (cubic feet per second)	Drainage area (square miles)	Normal annual precipitation for drainage area (inches)
3	7,500	24,100	—
7	9.38	7.9	35
8	18.2	16.8	32
9	46.8	60.1	29
13	59.7	155	27
16	19.4	53	26
17	27.3	75.6	25
18	3.88	26.1	21
19	8.15	62.8	17
21	112	415	20
23	143	530	—
27	75.4	850	—
29	84.0	956	—
30	22.6	191	—
34	103	1,540	—
35	6,260	44,850	—
39	2.99	180	8
41	.95	75	8
42	3.86	1.9	35
47	96.3	190	23
48	70.2	325	17
62	95.0	208	25
63	54.8	261	20
64	94.3	680	—
67	66.0	138	26
69	35.6	210	21
70	39.5	221	20
72	104	930	—
74	76.8	1,284	—
77	145	1,628	—
82	7.02	27	18
83	14.1	24	27
84	41.2	205	21
86	3.98	104	18
87	86.8	751	—
92	67.2	1,208	—
95	37.3	105	25
97	3.91	50	20
101	16.4	418	14
102	15.4	440	14
103	21.9	841	—
104	29.0	1,552	—
106	96.3	4,159	—
108	1.20	136	7
109	13,500	76,600	—
110	17.3	51.8	25
117	21.3	292	20
118	10.7	11.8	24
119	17.7	16.4	28
120	8.37	5.9	30
121	10.3	8.35	29
122	29.3	26.4	26
125	44.9	672	—
127	30.9	59.4	26

Low Flows of Streams Vary

Large areal variations in precipitation and geology cause large variations in streamflow during dry periods.

Streamflow is sustained primarily by ground-water discharge during periods of little or no precipitation. Flow of the larger streams, however, generally are affected by diversions and reservoir releases. Precipitation and geology are two of the principal factors affecting natural low flow in streams. Low-flow characteristics for 37 gaging stations (figure 6.3-1) with 10 or more years of record are summarized in table 6.3-1.

An index of low flow commonly used is the 7-day 10-year low flow, which is the annual minimum mean flow for 7 consecutive days with a recurrence interval of 10 years. Another common index is the 7-day 2-year (recurrence interval) low flow. The recurrence interval is the average time, in years, between flows that will average less than the indicated amount. It cannot be predicted when a drought of a given magnitude will occur, but the 7-day low flows during a reasonably long period may be estimated. For example, a 7-day 10-year low flow of 2 cubic feet per second indicates that an average 7-day flow at least as low as 2 cubic feet per second will occur as an annual minimum about 10 times in 100 years. The 7-day 2-year low flow would occur about 50 times in 100 years; there is a 50-percent chance that the average 7-day low flow will not exceed this in any 1 year.

The 7-day 10-year low flows for area 56 range from 0 to 0.57 cubic foot per second per square mile (table 6.3-1). Streams in the higher altitudes have better sustained low flow than those in lower areas. Most of the stations in areas with 16 or more inches of normal annual precipitation have 7-day 10-year low flows exceeding 0.06 cubic foot per second per square mile. The values for streams draining areas with normal annual precipitation less than 16 inches range from 0 to 0.05 cubic foot per second per square mile.

The low-flow frequency curves in figures 6.3-2 and 6.3-3 show variation in low flow for typical streams. Curves with flatter slopes and larger values for flow indicate better sustained flow when compared to those with steep slopes, which show more year-to-year variation. The curves with flatter slopes are either (1) for streams which drain areas that receive more precipitation and generally are hydraulically connected to aquifers with good storage and permeability characteristics or (2) for streams that receive augmented flow from reservoirs. Curves with steeper slopes are for streams that drain areas with less precipitation.

The low-flow freqeuncy curves can be used in determining the potential of streams for water supply. The curves also can be used to determine the effects of mining on streamflow. When flow is augmented by mine drainage or pumpage, the curves become flatter.

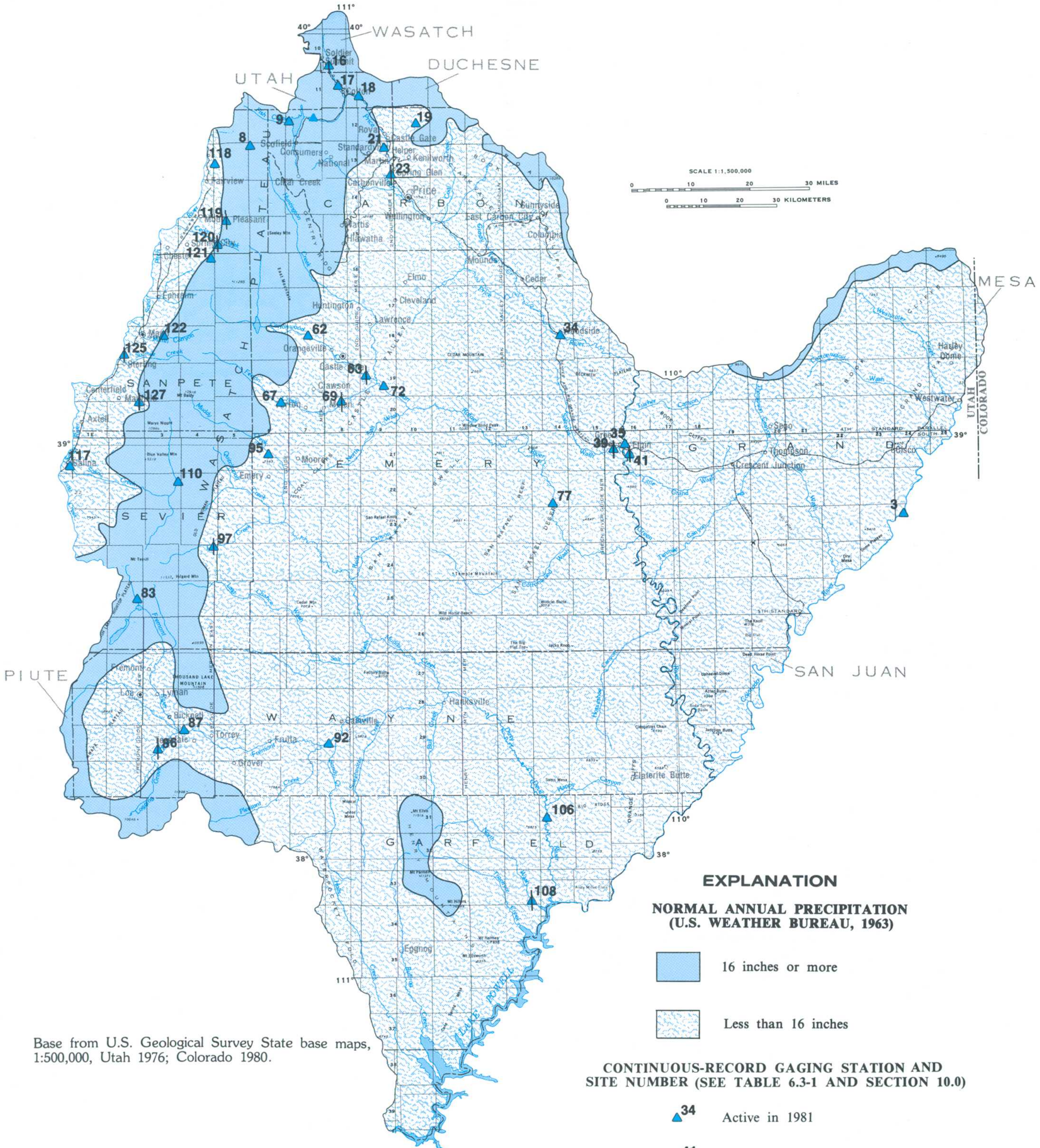


Figure 6.3-1 Gaging stations for which low-flow statistics are summarized and areas receiving more or less than 16 inches of normal annual precipitation.

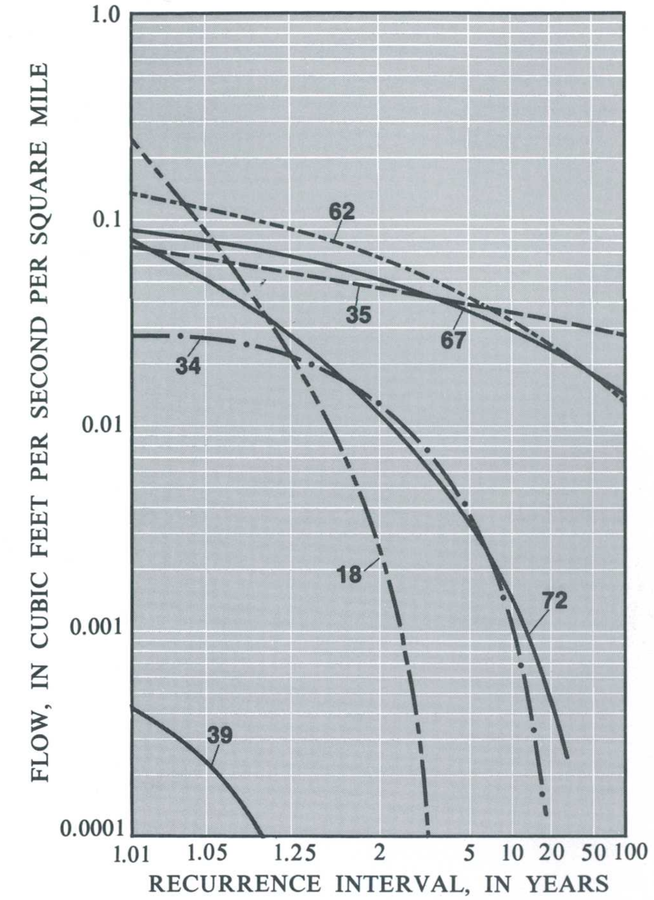


Figure 6.3-2 Frequency curves of 7-day low flow at selected stations on Green River and tributaries.

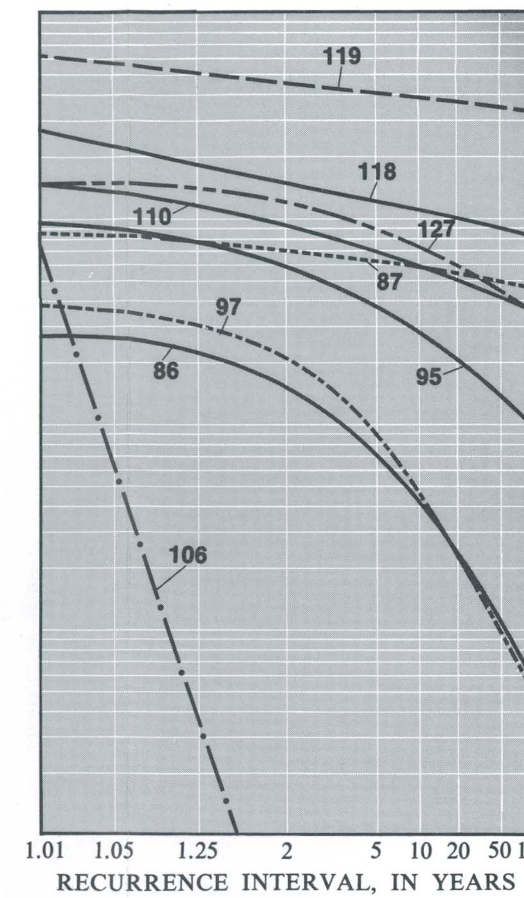


Figure 6.3-3 Frequency curves of 7-day low flow at selected stations on tributaries to Dirty Devil, San Pitch, and Colorado Rivers.

Table 6.3-1 Seven-day low-flow statistics.

Site No. (See Section 10.0)	Recurrence interval, in years: 2		Recurrence interval, in years: 10	
	Cubic feet per second	Cubic feet per second per square mile	Cubic feet per second	Cubic feet per second per square mile
3	1,780	0.074	1,120	0.046
8	2.4	.14	1.0	.060
9	6.51	.11	4.12	.069
13	.50	.003	.07	< .001
16	2.31	.044	1.02	.019
17	2.70	.036	0	0
18	.07	.003	0	0
19	.20	.003	0	0
21	7.26	.017	4.14	.010
23	15.4	.029	5.70	.011
34	22.0	.014	1.65	< .001
35	2,160	.048	1,690	.038
39	0	0	0	0
41	0	0	0	0
62	14.0	.067	6.82	.033
63	1.76	.007	.16	.001
67	7.33	.053	4.18	.030
69	.90	.004	0	–
72	11.0	.012	1.50	.002
77	6.0	.004	0	0
83	5.91	.25	4.30	.18
86	1.68	.016	.45	.004
87	55.0	.073	44.5	.059
92	22.8	.019	17.6	.015
95	6.60	.063	3.09	.029
97	1.08	.022	.24	.005
106	.06	< .001	0	0
108	0	0	0	0
110	5.03	.097	3.24	.063
117	.30	.001	.05	< .001
118	1.83	.16	1.32	.11
119	8.07	.49	6.79	.41
120	3.79	.64	3.37	.57
121	2.71	.32	2.19	.26
122	3.87	.15	2.86	.11
125	0	0	0	0
127	7.38	.12	4.51	.076

Streams That Flow Only in Response to Thunderstorms Have Large Day-To-Day Fluctuations

Flow-duration hydrographs indicate odds of streamflow being high or low during specific seasons.

The percentage of time that daily streamflows are equaled or exceeded is shown in figure 6.4-1 for five streams having different types of flow. Hydrographs in A represent high-altitude streamflow from snowmelt; hydrographs in B represent low-altitude streamflow, which only occurs in direct response to thunderstorms; hydrographs in C represent streamflow produced by a combination of snowmelt and thunderstorms; and hydrographs in D and E represent streamflow affected by reservoir storage and release. Hydrographs in D show a decrease in seasonal flucuations of flow whereas those in E show that no flow is released for many days in some years.

The daily-duration hydrographs for each station were developed by arraying, in ascending order, all daily mean flows for a particular day of the year and calculating the percentage of days the flow on that day was equaled or exceeded. This was repeated for each of the 365 days in a year. For example, the hydrograph for 90 percent gives the daily mean flow that is equaled or exceeded 90 percent of the time for any given day of the year.

Daily flows of the high-altitude streams are more predictable and generally peak during May-June in response to snowmelt. Low-altitude streamflow is not as predictable, and these streams commonly are dry during all times of the year. Large flows in low-altitude streams are possible any time of the year but are more common during the July-September thunderstorm season. Daily flows of streams regulated by reservoirs can be augmented by reservoir releases or completely depleted by reservoir storage.

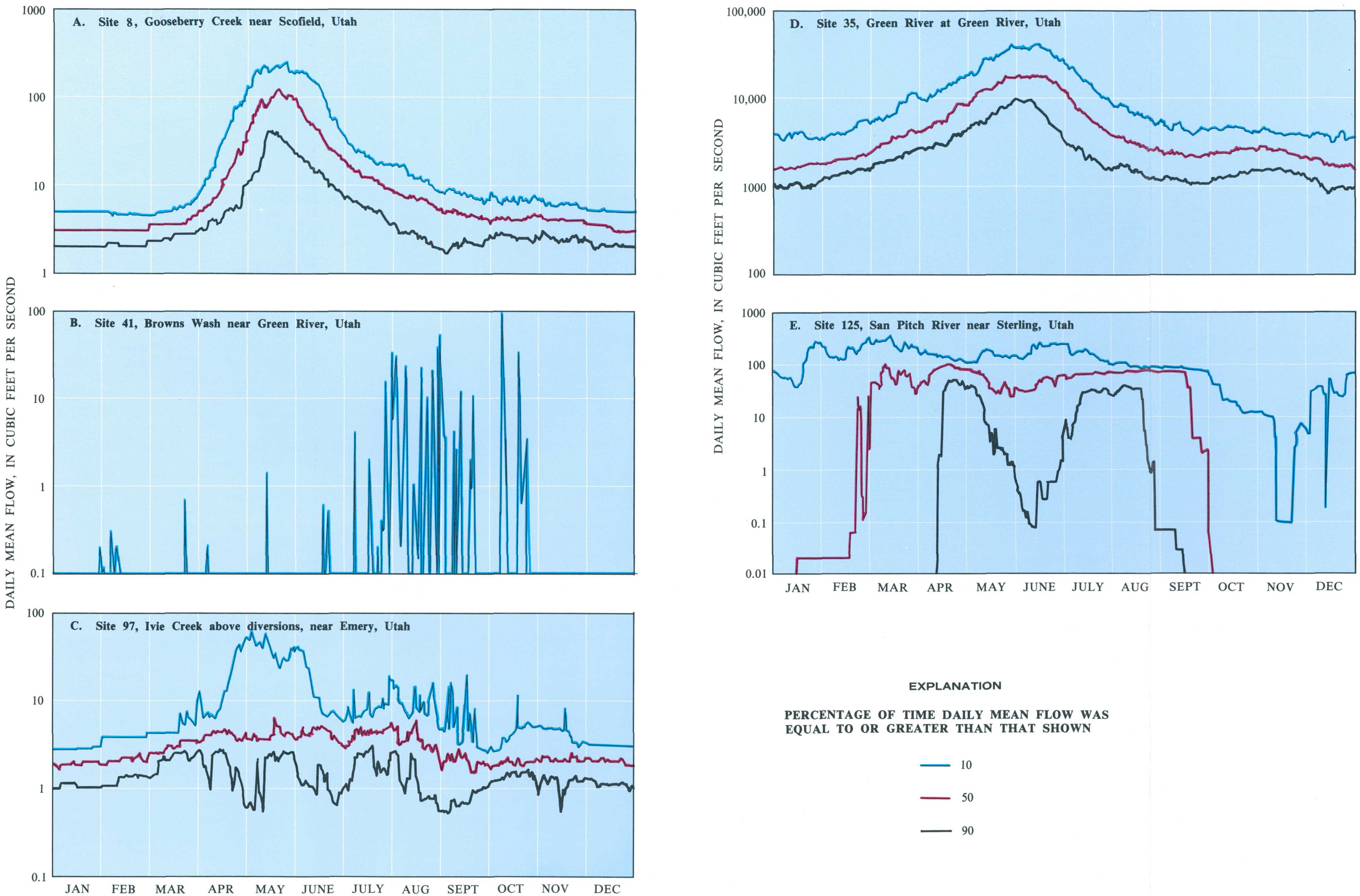


Figure 6.4-1 Daily-duration hydrographs for five sites.

Floods Produced by Snowmelt and Thunderstorms

Magnitudes of peak flow are determined using gaging-station records and are related to basin and climatic characteristics.

Floods in area 56 vary in response to climatic factors in two distinct zones (figure 6.5-1). Peak flows in streams in zone A are primarily from snowmelt. Streams in zone A drain areas with mean basin altitudes that exceed 8,000 feet and that generally receive 15 or more inches of annual precipitation. Peak flows in streams in zone B are primarily from thunderstorms. Streams in zone B drain areas with mean basin altitudes that are less than 8,000 feet and that generally receive less than 15 inches of annual precipitation.

A typical flood-frequency curve is shown in figure 6.5-2. The frequency curve shows the average interval, in years, between floods that equaled or exceeded a given peak flow. This does not mean that floods occur with any regularity; the recurrence intervals are average values only. It is possible to have two floods of the 10-year recurrence-interval magnitude in successive years or even in the same year. A 10-year peak flow would be equaled or exceeded about 10 times in 100 years and has a 10-percent chance of being equaled or exceeded in any 1 year.

Peak-flow values for a specific recurrence interval often are needed for sites where gaging-station records are not available. Thus, it is common to transfer peak-flow values from gaged to ungaged sites by relating to basin and climatic characteristics (Benson and Carter, 1973). Peak flows for larger streams generally are interpolated between stations where frequency curves are defined. The equations for zone A, summarized in table 6.5-1, were developed by multiple-regression techniques using information in table 6.5-2. The equations for zone B were developed by multiple-regression techniques in a study by Blakemore E. Thomas (U.S. Geological Survey, written commun., 1982). Thomas used 81 stations in and near Area 56 with mean basin altitudes less than 8,000 feet. In addition, Thomas outlines procedures for mapping areas inundated by floods of selected recurrence intervals.

The equations in table 6.5-1 need to be used with judgment for small basins underlain by highly permeable rock because estimates from the equations will be larger than the actual values. Geology is important in determining peak-flow differences from one location to another, and a good geologic index would decrease the standard error of estimate for the equations. However, it is difficult to quantify the effects of geology. Also, estimates from the regression equations listed in table 6.5-1 are not intended for use on the larger streams where frequency curves are defined.

Knowledge of peak flows of specific recurrence intervals is necessary for designing structures, such as culverts, dams, holding ponds, and channels. In addition, the information is needed to reduce flood hazards by eliminating where possible, construction in areas inundated by these floods.

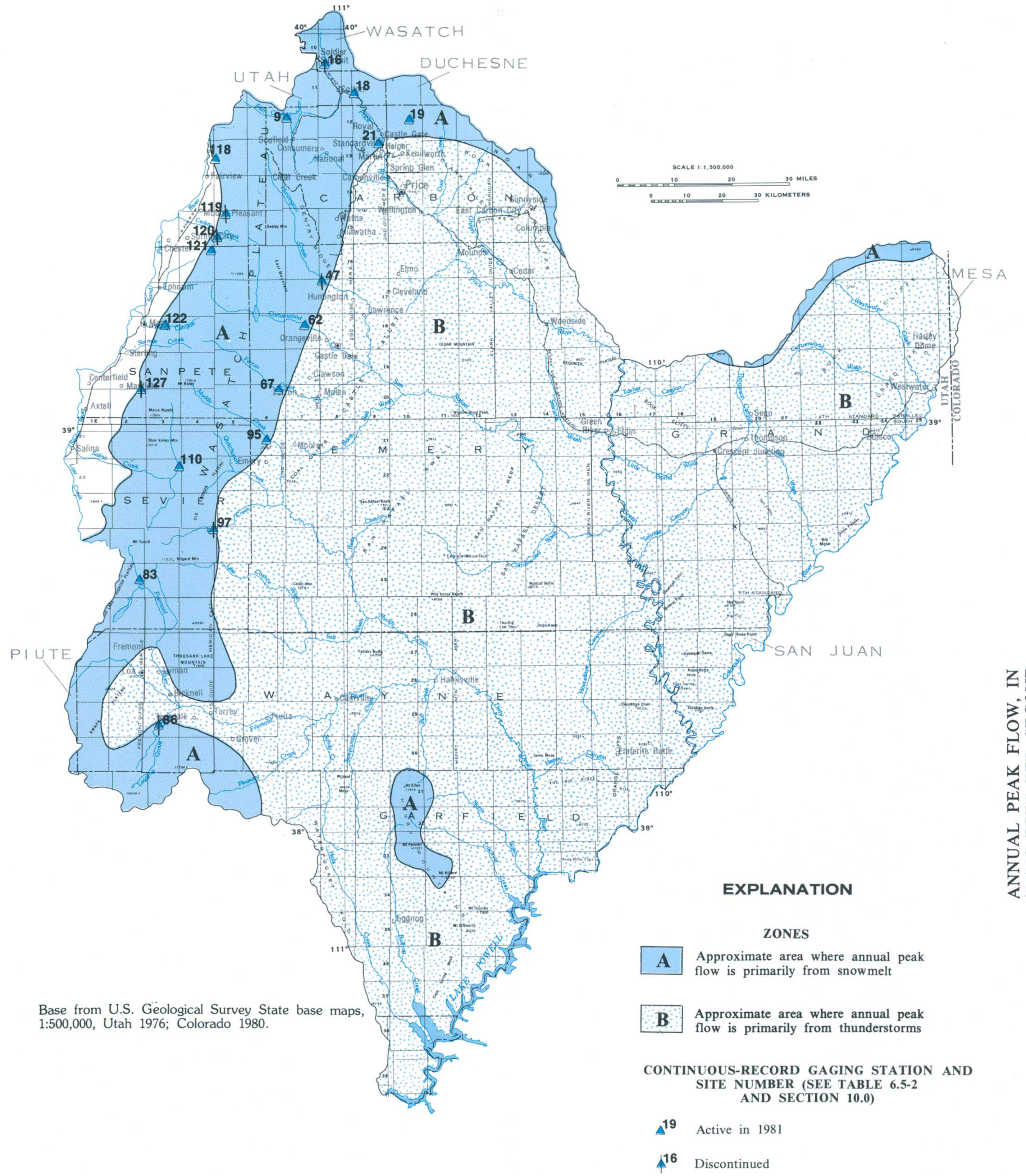


Figure 6.5-1 Location of zones and gaging stations used to develop peak-flow equations for zone A.

Table 6.5-1 Summary of regression equations.

Recurrence interval (years) T	Regression constant a	Exponent x	Exponent y	Exponent z	Average standard error of estimate (percent)
		Zone A: [1] $Q_T = aA^xS^y$			
2	1.25	0.831	0.398	–	68
10	1.16	.927	.507	–	44
100	.659	1.03	.669	–	43
		Zone B: [1] $Q_T = aA^xE^z$			
2	3,980	.535	–	–2.21	87
10	23,700	.433	–	–2.23	67
100	83,100	.356	–	–2.17	66

[1] Q is peak flow, in cubic feet per second;
A is drainage area, in square miles;
S is main channel slope, in feet per mile;
E is mean basin altitude, in feet divided by 1,000.

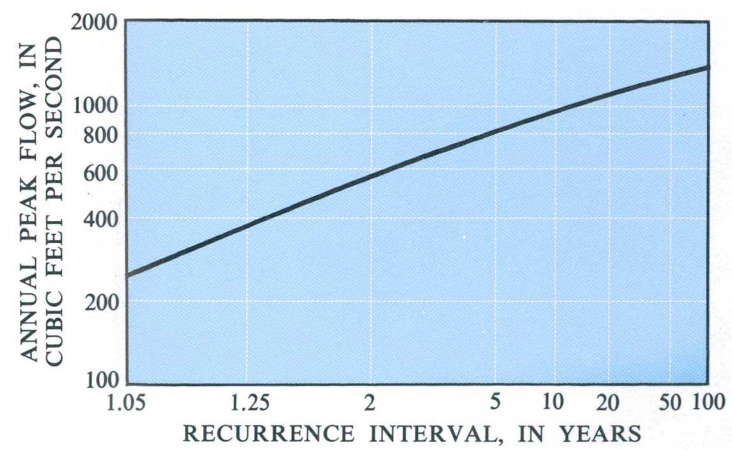


Figure 6.5-2 Flood-frequency curve for site 9, Fish Creek above reservoir, near Scofield.

Table 6.5-2 Basin characteristics and peak-flow frequency for sites in zone A.

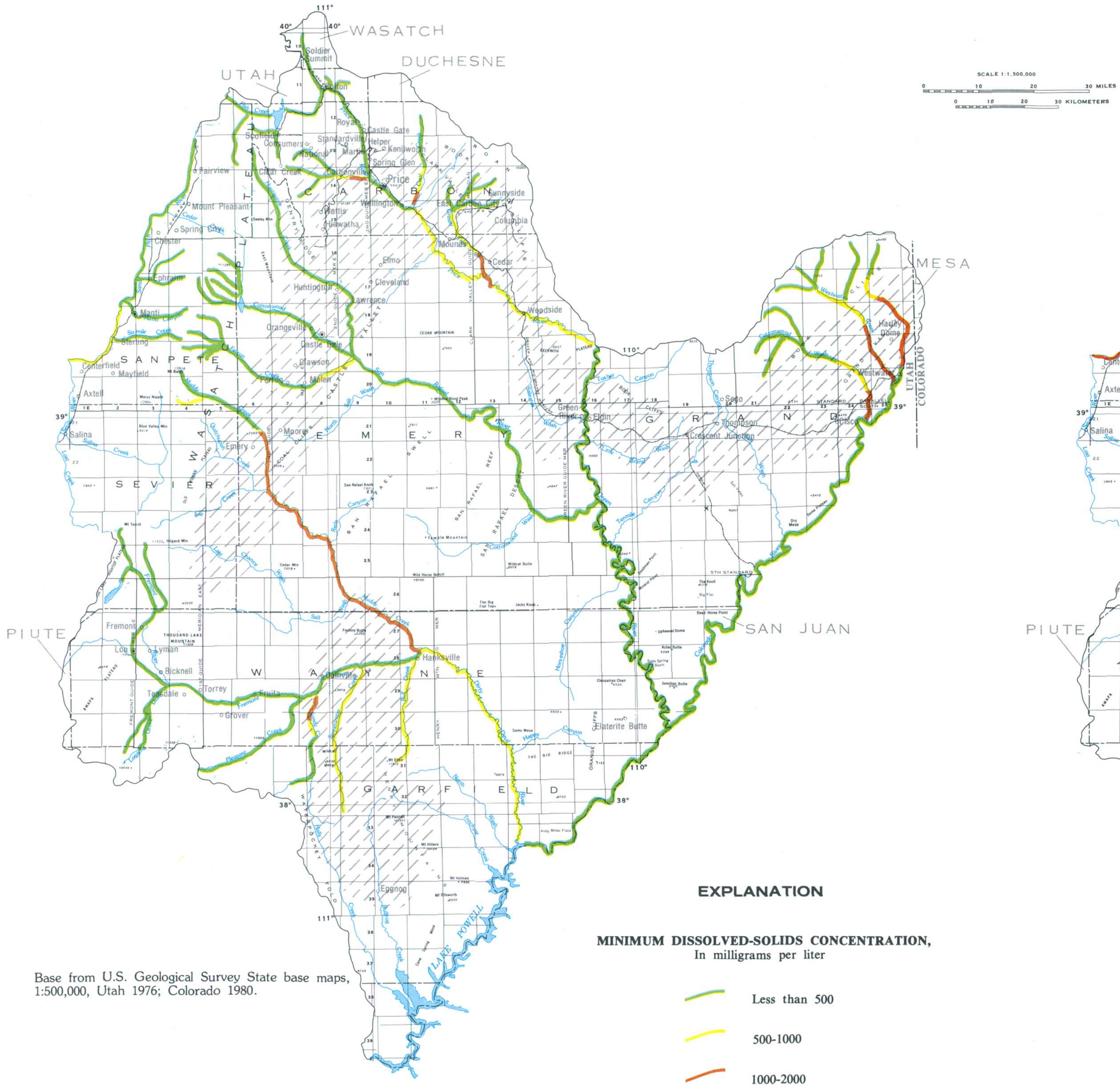
Site No. (See Section 10.0)	Drainage area (square miles)	Main channel slope (feet per mile)	Peak flow (cubic feet per second) for indicated recurrence interval (years) 2	10	100
9	60.1	69.0	561	938	1,320
16	53	94.4	175	409	801
18	26.1	114	49.5	112	203
19	62.8	143	217	551	1,210
21	415	61.0	1,180	3,170	7,780
47	190	84.0	816	1,630	2,660
62	208	136	1,300	2,670	4,760
67	138	199	919	2,010	3,880
83	24.0	90.0	152	259	367
86	104	115	74.5	419	1,680
95	105	180	581	1,690	3,870
97	50	236	188	593	1,440
110	51.8	211	177	485	974
118	11.8	296	138	237	340
119	16.4	577	164	544	1,690
120	5.9	570	68.7	192	487
121	8.35	525	118	247	433
122	26.4	520	349	502	698
127	59.4	390	271	681	1,540

Dissolved Solids in Streams Related to Geology

The concentration of dissolved solids in streams varies from less than 500 to more than 2,000 milligrams per liter.

The smallest dissolved-solids concentrations in surface water are at the higher altitudes where concentrations generally are less than 500 milligrams per liter. Dissolved-solids concentrations increase markedly as the streams emerge from the mountains and cross the Mancos Shale. Shales in the Mancos typically contain large quantities of soluble minerals, including gypsum ($CaSO_4 \cdot 2H_2O$), mirabilite ($Na_2SO_4 \cdot 10H_2O$), and thenardite (Na_2SO_4). In the lowlands, the dissolved-solids concentrations in streams vary from less than 500 to more than 2,000 milligrams per liter.

During most years, the minimum dissolved-solids concentrations (figure 6.6-1) occur during high flows resulting from snowmelt. The maximum concentrations (figure 6.6-2) generally occur during the late summer, fall, and winter when streamflows are maintained primarily by ground-water discharge. The smallest seasonal changes occur at higher altitudes, and the largest changes occur in the lowlands. The dominant dissolved ions in the mountain streams during low and high flow are calcium, magnesium, and bicarbonate. In the lowland streams, the dominant ions during high flow are calcium, magnesium, and bicarbonate but during low flow generally are sodium, calcium, and sulfate.



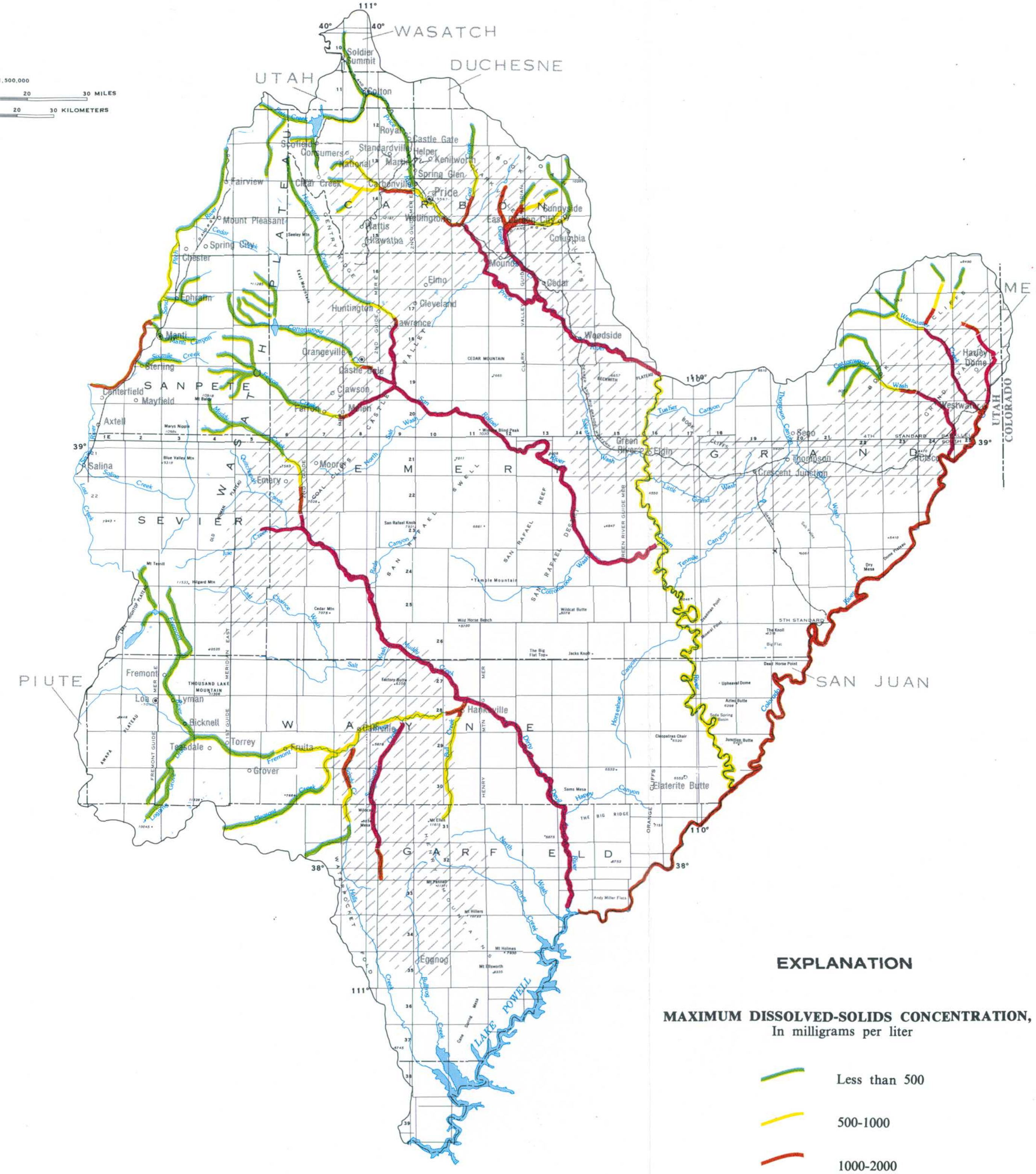
Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

EXPLANATION

MINIMUM DISSOLVED-SOLIDS CONCENTRATION,
In milligrams per liter

- Less than 500
- 500-1000
- 1000-2000
- **OUTCROP AREA OF MANCOS SHALE**

Figure 6.6-1 Minimum dissolved-solids concentrations in streams.



EXPLANATION

MAXIMUM DISSOLVED-SOLIDS CONCENTRATION,
In milligrams per liter

- Less than 500
- 500-1000
- 1000-2000
- More than 2000
- **OUTCROP AREA OF MANCOS SHALE**

Figure 6.6-2 Maximum dissolved-solids concentrations in streams.

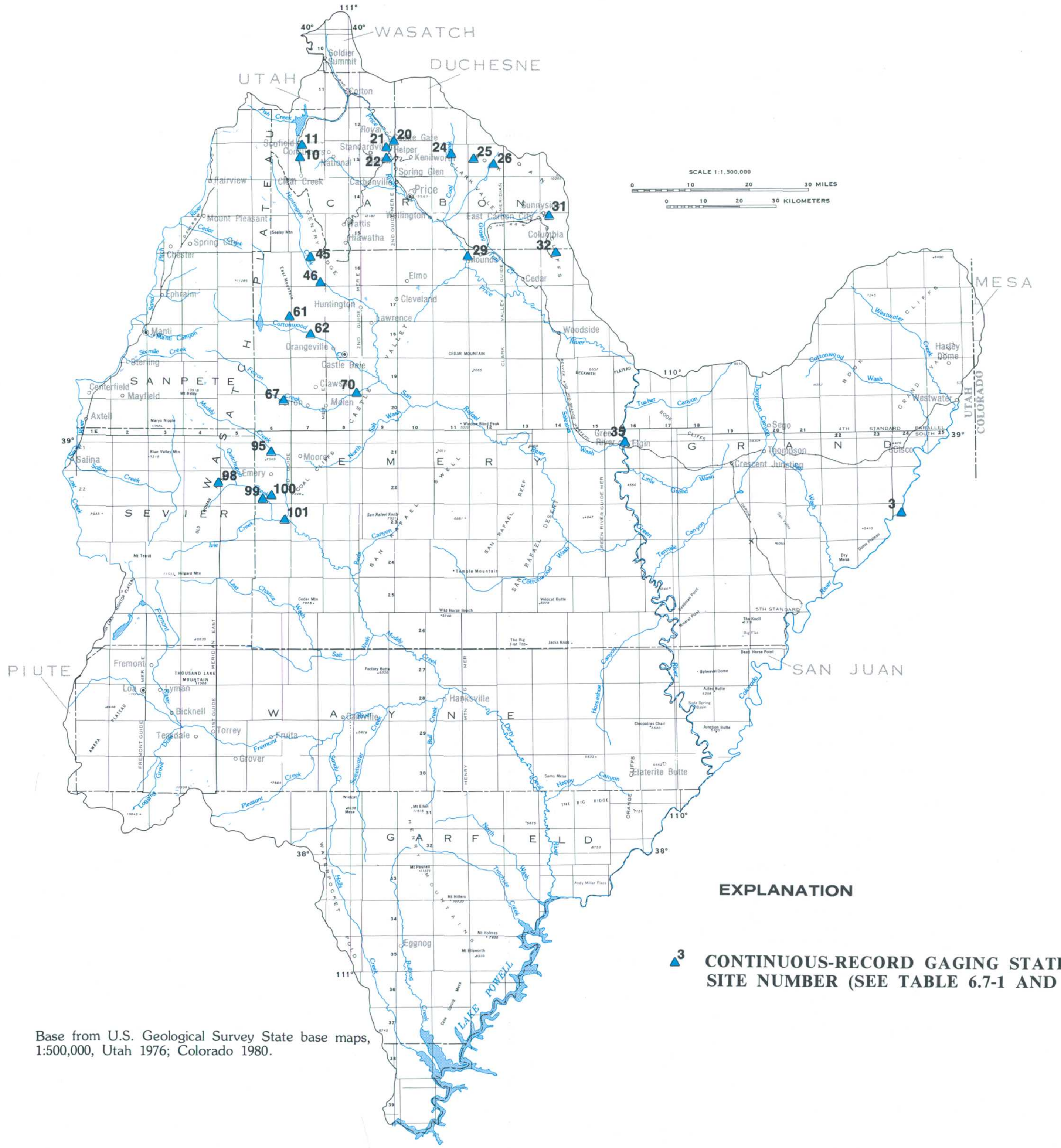
Trace-Element Concentrations are Small in Streams Draining Most Coal Fields

Trace-element concentrations do not exceed standards for public supply in most streams in the coal fields.

The concentration of dissolved trace elements were determined in samples collected at 24 surface-water sites (figure 6.7-1) during 1975-82. The minimum and maximum values for eight selected elements are shown in table 6.7-1, together with the mandatory maximum limits for public supply (U.S. Environmental Protection Agency, 1976, p. 5).

The concentration of one or more of five of the trace elements exceeded the maximum mandatory limit for public supply at eight sites. The concentration of arsenic did not exceed the maximum limit at any site. The concentration of chromium exceeded the maximum limit at one site, the concentration of selenium exceeded the limit at four sites, and the concentration of lead exceeded the limit at seven sites.

No limits have been set for the concentrations of boron, lithium, and strontium in water to be used for public supply. The concentrations of boron, lithium, and strontium generally increase downstream in concentrations proportional to the increase of dissolved solids in the stream. The greatest increases occur after the water draining from the mountains is diverted for irrigation of lowland areas. Thus, streams in the lowland areas generally contain the largest concentrations of boron, lithium, and strontium.



EXPLANATION

▲3 CONTINUOUS-RECORD GAGING STATION AND SITE NUMBER (SEE TABLE 6.7-1 AND SECTION 10.0)

Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Figure 6.7-1 Location of gaging station where surface water was sampled for trace-element analyses.

Table 6.7-1 Concentrations of trace elements in water from selected surface-water sites.

[Constituents are dissolved and values are reported in micrograms per liter.]

Site No. (see figure 6.7-1)		Arsenic (As)	Boron (B)	Chromium (Cr)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Selenium (Se)	Strontium (Sr)
3	Number of samples	31	18	31	31	31	0	31	1
	Minimum-Maximum	1-4	20-170	0-20	10-80	0-51*	—	1-23*	1,900
10	Number of samples	12	23	12	23	12	7	12	7
	Minimum-Maximum	0-1	0-3,600	0-20	10-200	0-410*	4-30	0-1	3-190
11	Number of samples	17	26	17	25	17	11	17	11
	Minimum-Maximum	0-2	2-180	0-20	10-210	0-30	4-20	0-1	110-260
20	Number of samples	6	17	6	17	6	6	6	6
	Minimum-Maximum	2-3	60-180	0-10	10-80	0-2	20-40	1-3	350-1,100
21	Number of samples	6	17	6	17	6	6	6	6
	Minimum-Maximum	1-3	20-610	0-20	10-30	0-5	7-30	0-3	300-630
22	Number of samples	3	13	3	13	3	2	3	2
	Minimum-Maximum	0-3	210-700	10-30	20-60	1-2	160-180	3-20*	1,200-1,300
24	Number of samples	10	15	10	15	10	9	10	9
	Minimum-Maximum	1-4	70-230	0-20	10-86	0-19	20-50	0-4	470-720
25	Number of samples	11	16	11	16	11	9	11	9
	Minimum-Maximum	0-3	40-310	0-0	0-140	0-18	20-60	0-3	340-630
26	Number of samples	6	11	6	11	6	5	6	5
	Minimum-Maximum	1-2	7-150	0-0	10-20	0-4	10-30	0-1	320-400
29	Number of samples	2	2	2	2	2	2	2	2
	Minimum-Maximum	1-1	300-400	40-50	70-100	40-50	190-240	4-7	2,100-2,500
31	Number of samples	16	27	15	26	16	16	16	15
	Minimum-Maximum	1-3	20-370	0-40	10-60	0-55*	4-80	0-1	260-5,000
32	Number of samples	8	16	8	16	8	9	8	9
	Minimum-Maximum	0-2	20-490	0-20	0-110	0-47	7-630	0-5	720-2,000
35	Number of samples	31	18	31	31	31	0	31	0
	Minimum-Maximum	1-5	80-240	0-20	10-190	0-70*	—	1-3	—
45	Number of samples	9	14	9	14	9	8	9	8
	Minimum-Maximum	0-2	0-60	0-20	10-40	0-19	6-30	0-1	200-260
46	Number of samples	9	20	9	20	9	9	9	9
	Minimum-Maximum	0-2	0-160	0-20	10-110	0-1	4-30	0-1	110-170
61	Number of samples	9	14	9	14	9	8	9	8
	Minimum-Maximum	0-2	20-200	0-10	10-30	0-130*	10-40	1-1	300-390
62	Number of samples	4	79	2	2	3	3	4	2
	Minimum-Maximum	1-1	0-120	0-0	10-10	0-2	10-10	1-2	290-310
67	Number of samples	5	8	3	3	5	5	5	4
	Minimum-Maximum	1-2	20-50	0-7	20-30	2-21	20-30	1-1	730-820
70	Number of samples	4	73	3	3	4	4	4	3
	Minimum-Maximum	1-4	20-710	0-40	40-80	2-40	190-260	2-8	2,200-3,200
95	Number of samples	4	7	2	4	5	5	4	4
	Minimum-Maximum	1-2	4-30	0-5	20-30	2-11	20-20	1-1	410-460
98	Number of samples	3	8	3	8	3	2	3	2
	Minimum-Maximum	0-3	150-310	0-10	10-20	0-2	20-30	0-0	500-550
99	Number of samples	11	22	11	22	11	11	11	11
	Minimum-Maximum	0-2	20-700	0-20	0-50	0-38	40-180	2-7	780-4,800
100	Number of samples	11	22	11	22	11	11	11	11
	Minimum-Maximum	1-2	130-590	0-20	10-60	0-59*	90-370	3-60*	850-3,400
101	Number of samples	6	15	3	8	7	7	8	8
	Minimum-Maximum	1-2	160-620	0-60*	10-130	2-60*	180-440	7-16*	1,900-4,100
Mandatory maximum concentration for public water supply		50	—	50	—	50	—	10	—

* Exceeds mandatory maximum concentration for public supply.

Natural Sediment Yields Estimated

Sediment yields vary from less than 0.2 to about 3 acre-feet per square mile per year.

The estimated sediment yields shown in figure 6.8-1 are based largely on the geology of the study area. The sediment yields vary from less than 0.2 to about 3 acre-feet per square mile per year. The smaller yields generally are from the higher parts of the Wasatch Plateau and Book Cliffs where the rocks mainly are limestone and dolomite. The larger yields generally are from the lowlands where the rocks are predominantly shale and sandstone. A large percentage of the total sediment yield occurs during infrequent large intensity storms.

Clay minerals constitute less than about 20 percent (by weight) of the bed material of streams in the higher parts of the Wasatch Plateau and Book Cliffs (sites A, C, and E, figure 6.8-2). In the same stream several miles from the mountains, clay minerals often constitute more than 20 percent of the bed material (sites B, D, and F, figure 6.8-2) (Waddell and others, 1981, p. 29-32).

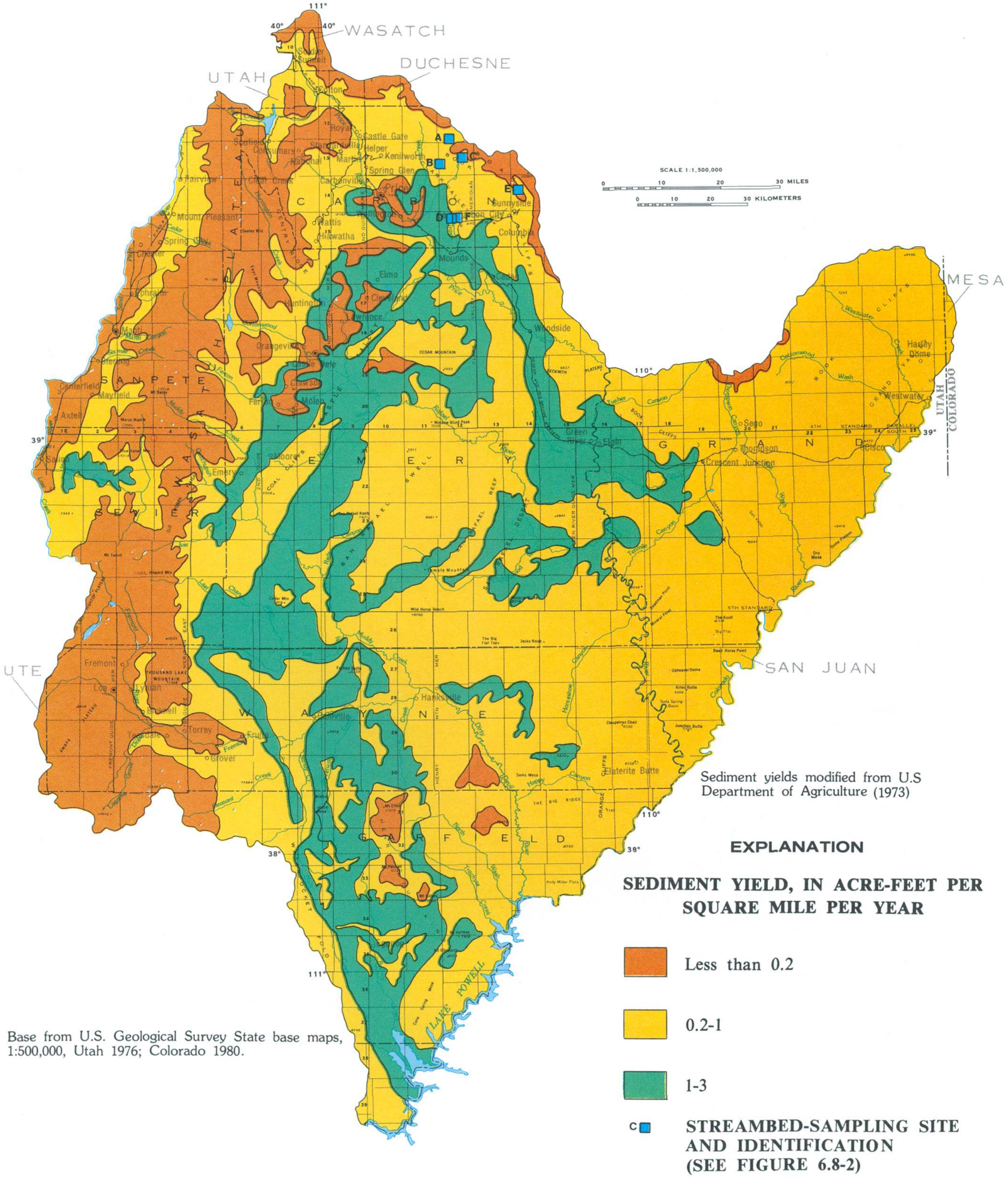


Figure 6.8-1 Estimated natural sediment yields.

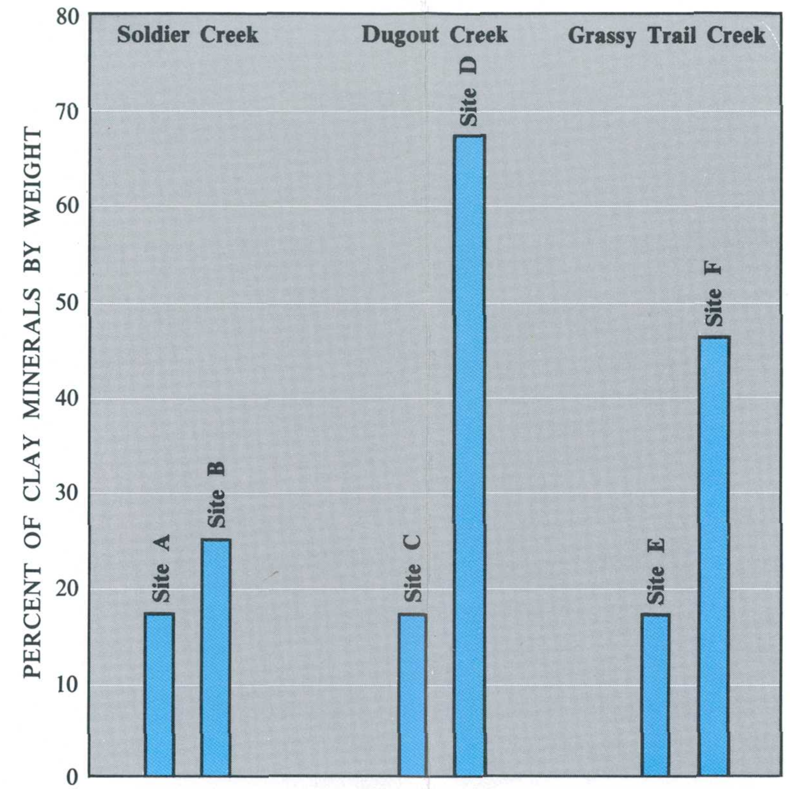


Figure 6.8-2 Percentage of clay minerals in bed material along three streams.

Water Levels in Some Wells Measured Since 1935

Water levels were measured in 41 wells during 1981, most of which were in agricultural areas.

As part of the U.S. Geological Survey's statewide observation-well network, water levels were measured in 41 wells in the area during 1981 and 2 wells were sampled for chemical analyses. The observation-well network in the area during 1981 is shown in figure 7.1-2.

The aquifer in which each well is finished, the period of record, and the frequency of measurements are listed in table 7.1-1. Hydrographs of water levels in two wells are shown in figure 7.1-1.

Most of the observation wells are in the populated agricultural areas and are privately owned. Water levels are measured once or twice a year, and water-level data for some wells are available since 1935.

The water-level data are stored in the National Water Data Storage and Retrieval System (WATSTORE). This computerized system is described in section 8.3.

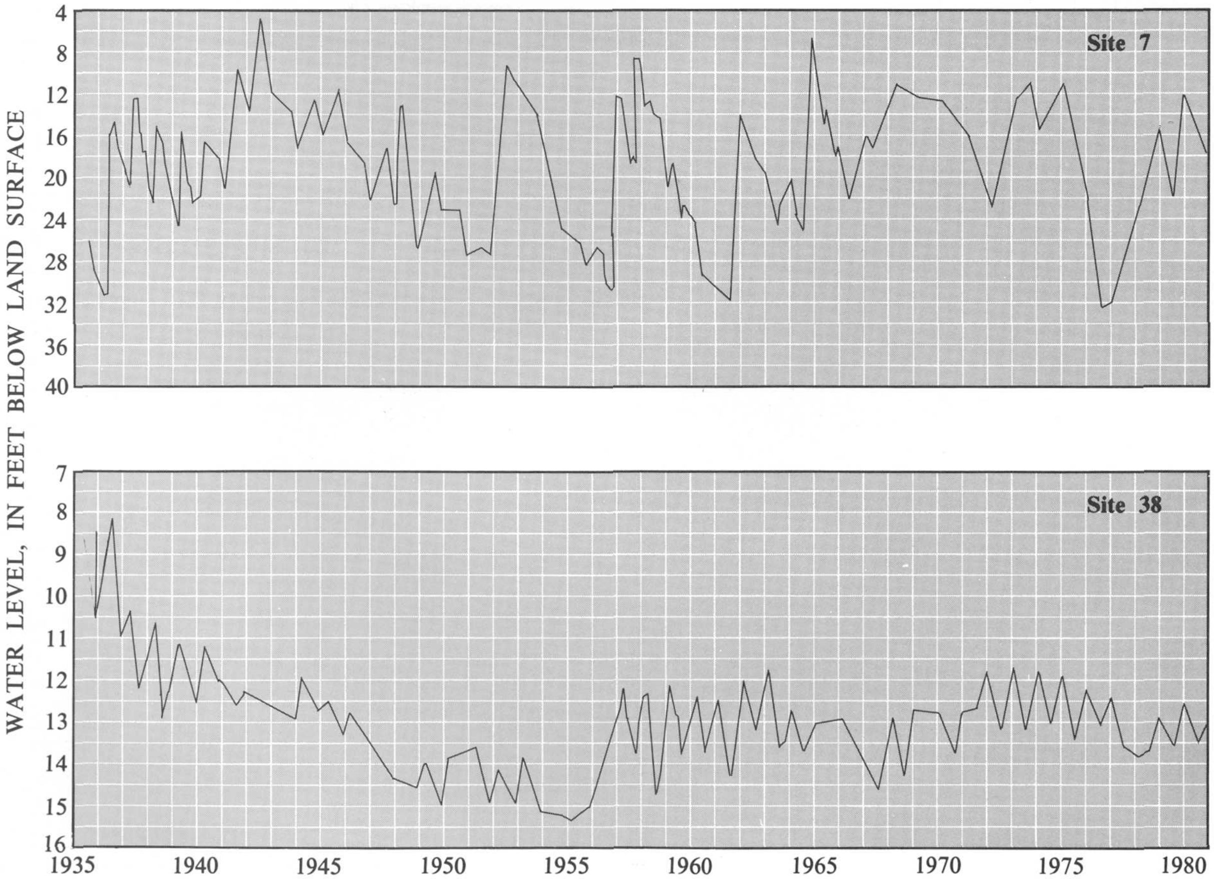
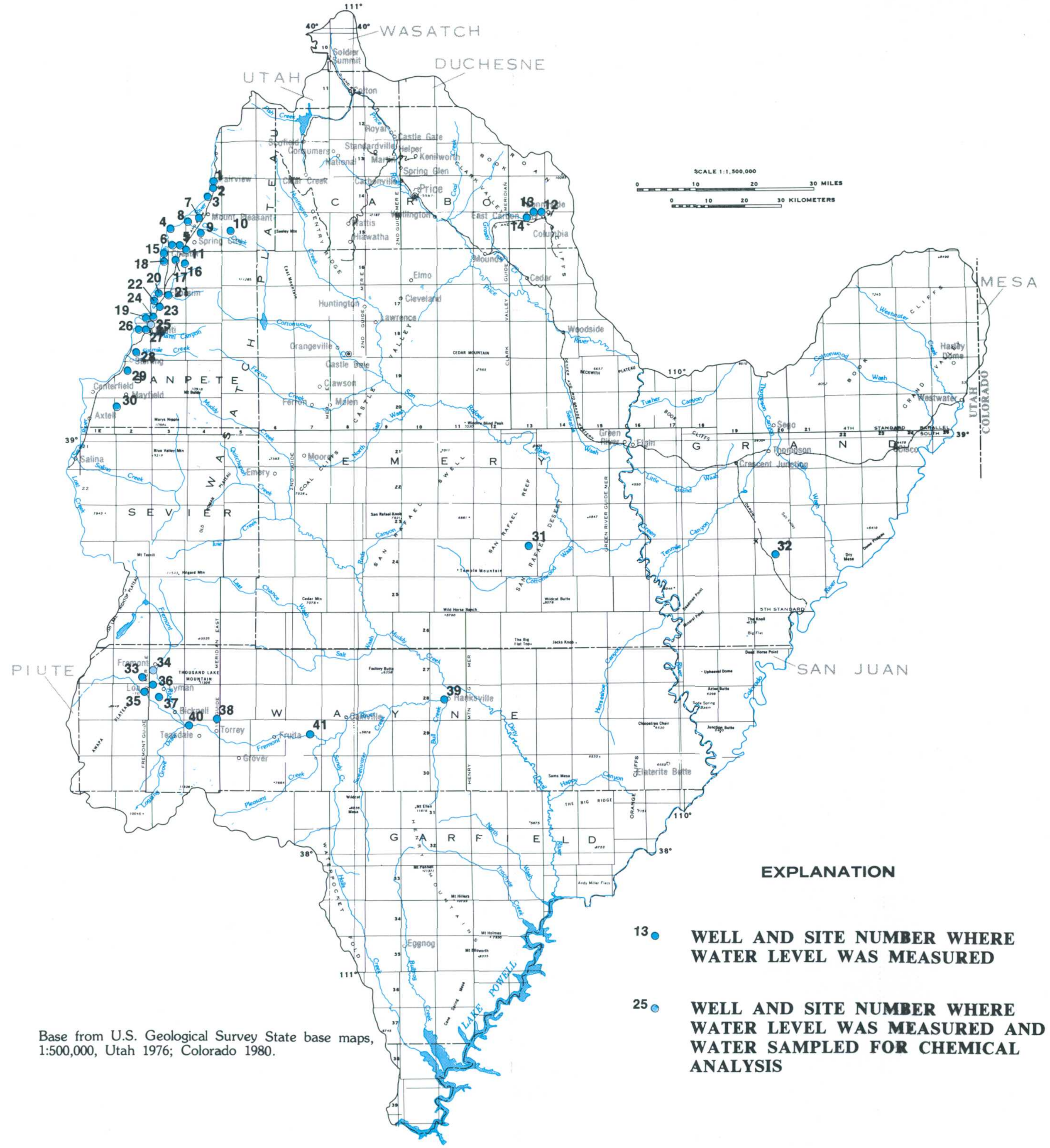


Figure 7.1-1 Water levels in two observation wells.



EXPLANATION

13● WELL AND SITE NUMBER WHERE WATER LEVEL WAS MEASURED

25● WELL AND SITE NUMBER WHERE WATER LEVEL WAS MEASURED AND WATER SAMPLED FOR CHEMICAL ANALYSIS

Base from U.S. Geological Survey State base maps, 1:500,000, Utah 1976; Colorado 1980.

Figure 7.1-2 Observation well network, 1981.

Table 7.1-1 Summary of observation-well network.

Aquifer: 100VLFL, valley fill; 100ALVM, alluvium; 124GRRV, Green River Formation; 220NVJO, Navajo Sandstone; 221ENRD, Entrada Sandstone; 221JRSC, rocks of Jurassic age.
Frequency of water-level measurements: A, annual; S, semiannual.

Site No. (figure 7.1-1)	Site-identification No.	Local No.	Aquifer	Period of record	Frequency of water-level measurements
1	393228111262702	(D-14-4) 2dbc-2	100VLFL	1971-81	S
2	393654111254201	(D-14-4) 12cdd-1	100VLFL	1964-81	S
3	393447111271901	(D-14-4) 27aab-1	100VLFL	1965-81	A
4	392912111334701	(D-15-3) 27ada-1	100VLFL	1964-81	A
5	392832111324001	(D-15-3) 35aaa-1	100VLFL	1965-81	A
6	392751111323701	(D-15-3) 35dda-1	124GRRV	1970-81	A
7	393220111282701	(D-15-4) 4dda-1	100VLFL	1935-81	S
8	393113111294501	(D-15-4) 17abb-1	100VLFL	1964-81	A
9	392940111283901	(D-15-4) 21cda-1	100VLFL	1967-68, 72, 74-81	A
10	392923111205801	(D-15-4) 29bac-1	100VLFL	1935-81	S
11	392805111303201	(D-15-4) 31dab-1	100VLFL	1935, 65-68, 70-72, 74-81	A
12	393249110251501	(D-15-13)2dad-2	110ALVM	1973-81	S
13	393248110263101	(D-15-13)3dac-1	110ALVM	1973-81	S
14	393230110280201	(D-15-13)9baa-1	110ALVM	1973-81	S
15	392740111345301	(D-16-3) 4aaa-1	100VLFL	1935-56, 58-81	S
16	392517111312901	(D-16-3) 13dda-1	124GRRV	1965-68, 70-81	A
17	392516111325201	(D-16-3) 14dca-1	100VLFL	1938-56, 58-62, 65-81	S
18	392510111341201	(D-16-3) 15dcb-1	100VLFL	1964-81	S
19	391726111385501	(D-17-2) 36cba-1	100VLFL	1935-56, 58-62, 65-81	S
20	392129111364001	(D-17-3) 8bab-1	100VLFL	1935-40, 65-81	A
21	392056111353901	(D-17-3) 9cbd-1	100VLFL	1935-56, 58-81	S
22	392023111360501	(D-17-3)17adb-1	100VLFL	1938-56, 58-61, 64-81	A
23	391920111361901	(D-17-3) 20acc-1	100VLFL	1956-62, 64-81	A
24	391816111371901	(D-17-3) 30dbd-1	100VLFL	1938-56, 58-62, 65-81	A
25	391634111380701	(D-18-2) 1daa-2	100VLFL	1962-81	S
26	391648111401301	(D-18-2)11bcc-2	100VLFL	1958-59, 62, 65-81	A
27	391610111384501	(D-18-2) 12bab-1	100VLFL	1935-56, 58-61, 64-68, 72-81	A
28	391249111401901	(D-18-2) 27ccc-1	100VLFL	1958-60, 62, 65-81	A
29	390943111422002	(D-19-2) 17aac-2	100VLFL	1935-37, 56, 61-81	S
30	390436111432201	(D-20-2)18aaa-1	100VLFL	1958-60, 65-81	A
31	384430110271802	(D-24-13)11adb-1	221JRSC	1979-81	S
32	384251109420101	(D-24-20)22bac-1	110ALVM	1971-81	S
33	382540111392801	(D-27-2) 26ddc-1	110ALVM	1965-81	S
34	372717111365601	(D-27-3)19aaa-1	110ALVM	1966-81	S
35	382319111383401	(D-28-2) 12dbc-1	110ALVM	1965-81	S
36	382441111372901	(D-28-3) 6baa-1	110ALVM	1966-81	S
37	382240111353001	(D-28-3) 16bdb-1	110ALVM	1966-81	S
38	381940111253501	(D-28-4) 36cdb-1	110ALVM	1936-42, 44-56, 58-81	S
39	382220110424601	(D-28-11)16dad-1	221ENRD	1964-81	S
40	381820111300501	(D-29-4) 8bbd-1	110ALVM	1948-56, 58-64, 68-81	S
41	381706111084201	(D-29-7)15dbd-1	220NVJO	1978-81	S

Most Geologic Units Contain Water

Water moves through the ground-water system from areas of recharge to areas of manmade and natural discharge.

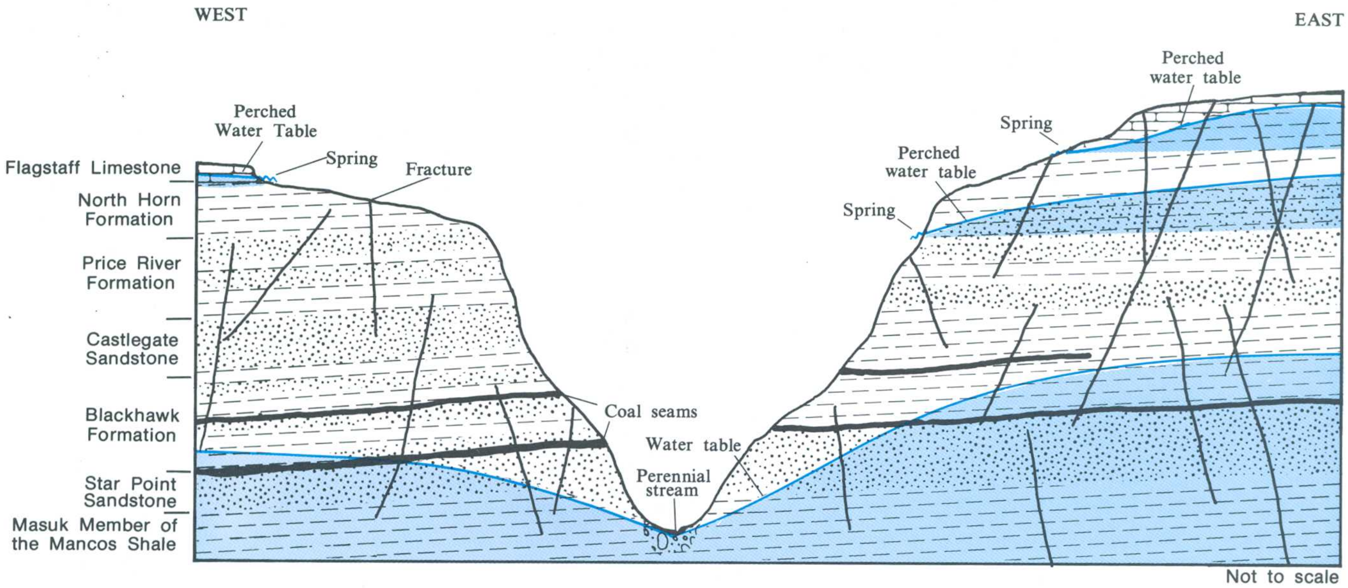
Most geologic units in the area contain water, although none are saturated everywhere. Water occurs in unconsolidated and consolidated rocks under both unconfined and confined conditions. Perched zones of water (underlain by an unsaturated zone) are common in consolidated rocks, particularly in mountainous areas.

The general occurrence of ground water in the Wasatch Plateau and Emery coal fields is shown in cross sections A and B of figure 7.2-1. Cross section A also depicts general ground-water occurrence in the Book Cliffs coal field, except that the Star Point Sandstone is not present in the eastern part of the field.

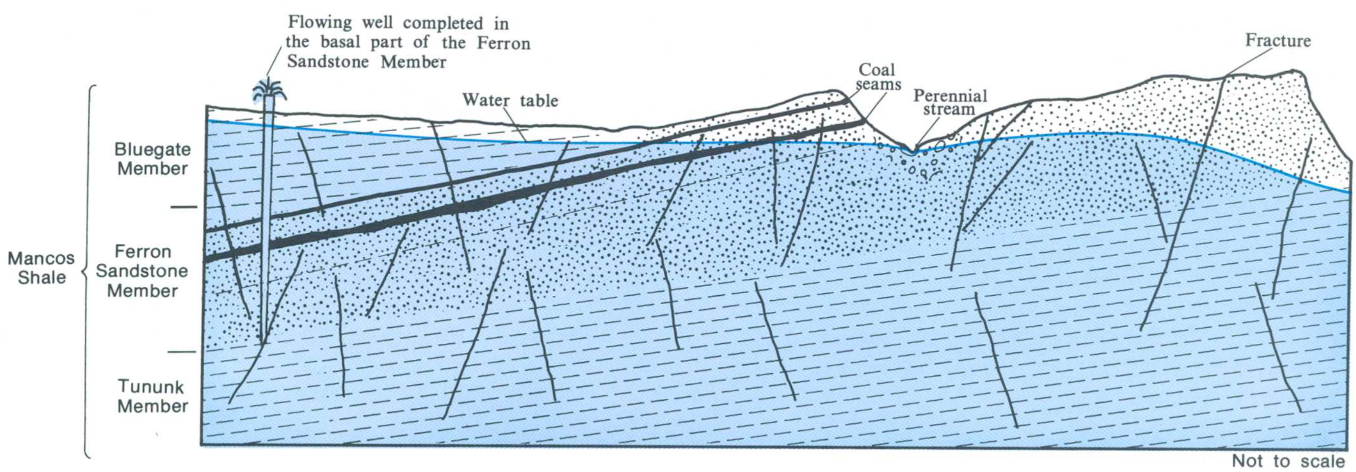
Studies in the Wasatch Plateau and Book Cliffs indicate that most recharge to the ground-water system is due to infiltration of rainfall and snowmelt at the higher altitudes. Much of the water is discharged by springs that issue from the Flagstaff Limestone and North Horn Formation short distances from the recharge areas. Water in the Flagstaff and North Horn is depicted as perched in cross section A of figure 7.2-1, but this may not be the case everywhere.

In addition to infiltration of rainfall and snowmelt in outcrop areas, the coal-bearing Blackhawk Formation also is recharged by downward percolation of water from overlying water-bearing rocks, mainly through fractures. Large quantities of water flow into underground mines in the Wasatch Plateau and Book Cliffs, and mine discharges were the largest sources of manmade discharge from the Blackhawk during 1980. Mines that have encountered no ground water usually have extended only a short distance underground from the edges of deeply incised canyons where the Blackhawk is drained naturally.

The largest source of recharge to the coal-bearing Ferron Sandstone Member in the Emery coal field is subsurface inflow from the Wasatch Plateau to the west (Lines and Morrissey, 1981, p. 58). Much of the water is transmitted in the subsurface along a permeable fault zone along the west side of the Emery field. Water in the Ferron moves from areas of subsurface recharge toward the Ferron outcrop area, where it is discharged mainly by leakage to alluvium along streams and by leakage to adjoining rocks in the Mancos Shale. Dewatering of an underground coal mine was the largest manmade discharge from the Ferron during 1979, and it averaged 0.7 cubic foot per second.



A. Wasatch Plateau coal field



B. Emery coal field

Figure 7.2-1 Diagrammatic cross sections showing occurrence of ground water in coal fields.

Well Yields Generally Small

Only locally in major stream valleys can individual wells yield several hundred gallons per minute; elsewhere potential well yields are generally less than 50 gallons per minute.

Potential well yields in most places generally are less than 50 gallons per minute (figure 7.3-1). However, there are some areas in which well yields exceed 100 gallons per minute and locally exceed 1,000 gallons per minute. The most extensive of these latter areas are Sanpete Valley and the upper Fremont River valley. In Sanpete Valley, a number of existing large-yield wells are completed in unconsolidated valley fill (Robinson, 1968, table 1). In the upper Fremont River valley, several large-yield wells are completed in both unconsolidated valley fill and igneous rocks (Bjorklund, 1969, table 4).

Alluvium along some of the larger perennial streams and glacial deposits in the high plateaus and mountains probably would yield more than 100 gallons per minute of water to individual wells. However, the deposits, in most instances, are too thin and have limited areal extent to sustain such yields for long periods.

Water also is available for development by wells completed in consolidated rocks, which consist chiefly of shale, siltstone, sandstone, and limestone. The consolidated rocks characteristically transmit water slowly; and, therefore, they generally yield water slowly to wells. Locally, however, rock permeability has been significantly increased by fracturing and faulting, and the rocks can yield several hundred to more than a thousand gallons per minute to individual wells. This is especially true of the extensive brittle sandstones, such as the Navajo Sandstone, where the rock has been shattered along faults and of some limestones, where fractures have been enlarged by solution. The Navajo (and associated sandstones) is considered an important aquifer in adjacent parts of Utah and is known to yield several hundred to more than a thousand gallons per minute locally to wells in the lower Dirty Devil River basin (Hood and Danielson, 1981, table 6).

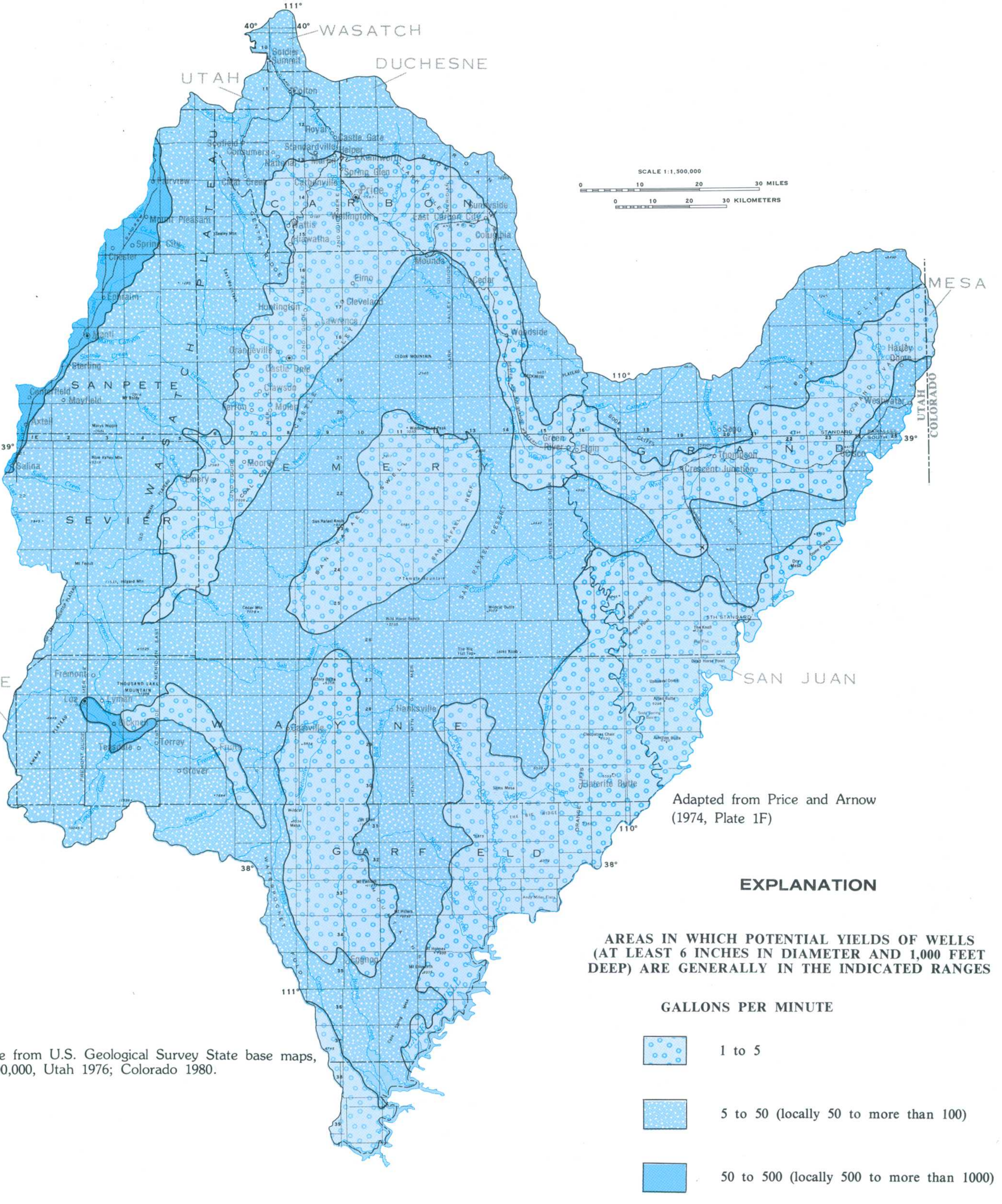


Figure 7.3-1 Potential well yields.

Springs are Important Sources of Water Supply

Spring discharges normally peak during the snowmelt period and recede until the next period of recharge.

Springs are important sources of water supply, particularly in the Wasatch Plateau and Book Cliffs. Several springs are used for public water supplies. Spring water, the major source of the base flow of streams, also is used for irrigation, for cooling coal-fired powerplants, and for watering of livestock and wildlife. Spring water also enhances instream uses such as fishing. Few, if any, springs in the area have no beneficial use.

Spring discharges vary from a trickle to about 1,000 gallons per minute. Most of the larger springs in the Wasatch Plateau and Book Cliffs coal fields are associated with faulting or folding whereby aquifer permeability has been increased by fracturing. A spring that issues from the Blackhawk Formation in a faulted area in the Wasatch Plateau is shown in figure 7.4-1. Discharge of the spring was about 170 gallons per minute when the photograph was taken.

Many springs, such as most of those in the Flagstaff Limestone and North Horn Formation, issue from permeable rock at the contact with underlying relatively impermeable rock. The less permeable rock retards or prevents the downward movement of water, and the water is deflected and discharged at the land surface. A small spring that issues at the contact between the Ferron Sandstone and Tununk Members of the Mancos Shale in the Emery coal field is shown in figure 7.4-2. Discharge of the spring was about 1 gallon per minute when the photograph was taken.

The discharge of most springs in the Wasatch Plateau and Book Cliffs usually peaks in May or June during the snowmelt period and recedes until the next period of ground-water recharge. The rate at which the spring discharge recedes is dependent on the transmissivity and storage of the aquifer. As shown in figure 7.4-3, the discharge recession varies markedly. Danielson, ReMillard, and Fuller (1981, p. 39) suggest that the rate of discharge recession is duplicated after each period of recharge. They also point out that changes in the rate of recession may indicate unnatural changes in the ground-water system, such as those caused by mine dewatering or by fracturing associated with subsidence.

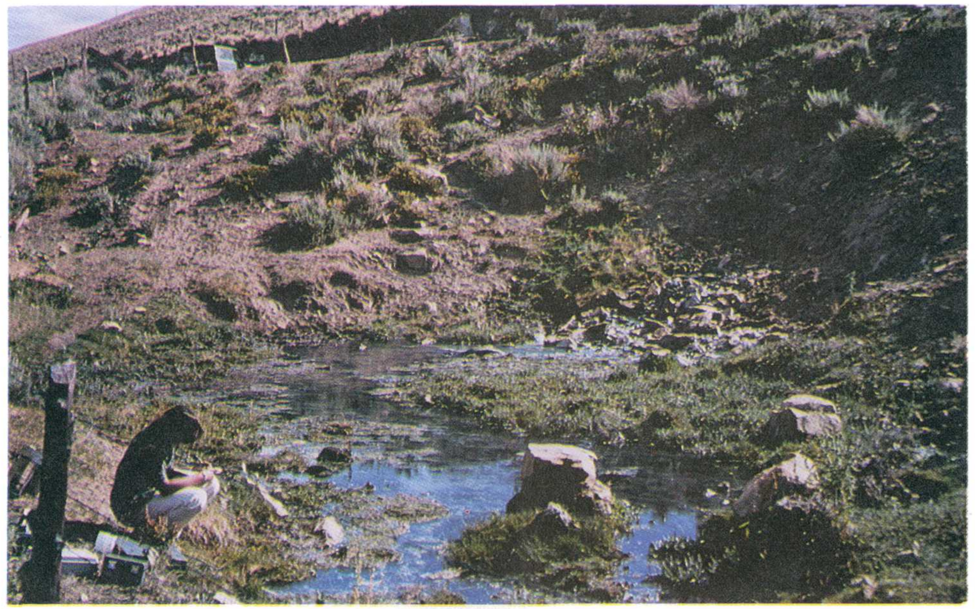


Figure 7.4-1 Spring that issues from the Blackhawk Formation in the Wasatch Plateau coal field (photograph by Kidd M. Waddell).

Figure 7.4-2 Small spring in the Emery coal field that issues at the contact between the Ferron Sandstone and Tununk Members of the Mancos Shale. The water issues about a foot above and below the contact between the light colored sandstone and the underlying black shale (photograph by Daniel J. Morrissey).

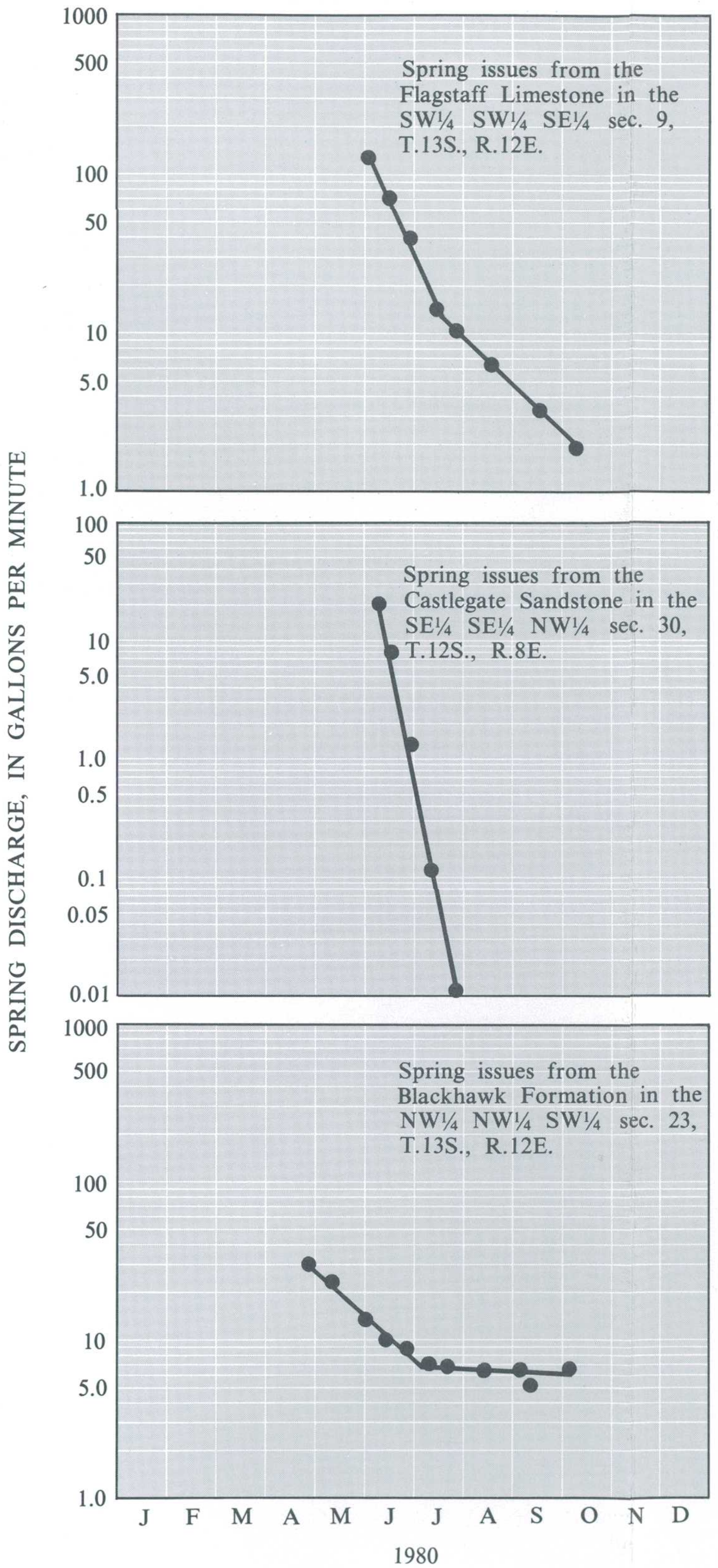


Figure 7.4-3 Discharge recession of three springs in the Book Cliffs.

Dissolved Solids in Ground Water Varies

The concentration of dissolved solids in ground water in the coal fields varies from less than 250 milligrams per liter to greater than 8,000 milligrams per liter.

The concentration of dissolved solids and chemical composition of ground water generally reflect the solubility and kinds of rocks through which the water moves and the length of time that the water is in the rocks. In the Star Point Sandstone and younger formations, the chemical composition of water is primarily affected by limestone and dolomite. The concentrations of dissolved solids in such water generally vary from less than 250 to 1,000 milligrams per liter, and the principal chemical constituents are calcium, magnesium, and bicarbonate.

In formations older than the Star Point Sandstone, such as the Mancos Shale, the chemical composition of ground water is affected by more readily soluble minerals, such as gypsum ($CaSO_4 \cdot 2H_2O$), mirabilite ($Na_2SO_4 \cdot 10H_2O$), and thenardite (Na_2SO_4), which are contained in the shales and sandstones. The ground water in these areas generally has concentrations of dissolved solids greater than 1,000 milligrams per liter, and the principal chemical constituents generally are sodium, calcium, sulfate, and bicarbonate.

Although of marginal quality for public supply, probably the most suitable water in formations older than the Star Point Sandstone is in the Ferron Sandstone Member of the Mancos Shale. The concentrations of dissolved solids in the Ferron vary from less than 500 to more than 8,000 milligrams per liter (Lines and Morrissey, 1981, table 6).

The concentration of dissolved solids in ground water is shown in figure 7.5-1. Because the quality varies with depth, especially in the lowlands, only the concentration of dissolved solids in the shallowest aquifer is shown.

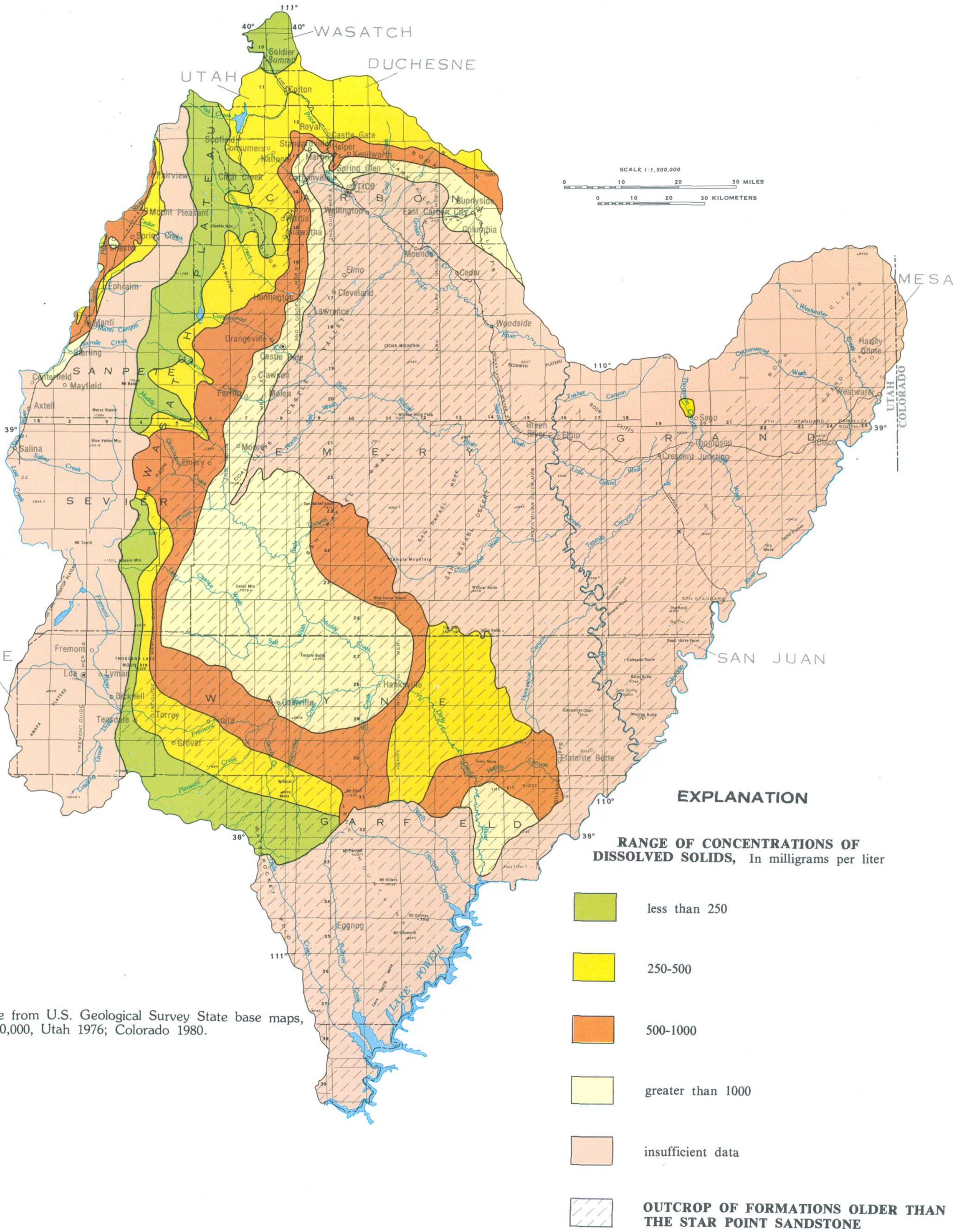


Figure 7.5-1 Dissolved solids in ground water.

Small Concentrations of Trace Elements are Found in Ground Water of the Area

The concentrations of most trace elements in ground water are within standards for public supply.

The concentration of dissolved trace elements were determined in water samples collected from coal-bearing aquifers at 14 sites during 1975-82 (figure 7.6-1). The concentrations of eight selected elements are shown in table 7.6-1 for samples from the Blackhawk Formation and the Ferron Sandstone Member of the Mancos Shale, together with the mandatory maximum limits for public supply (U.S. Environmental Protection Agency, 1976, p. 5).

The concentrations of arsenic, chromium, lead, and selenium did not exceed the maximum mandatory limits for public supply at any site. The concentrations of iron in two water samples from the Blackhawk Formation exceeded the recommended limit of 300 micrograms per liter.

No limits have been set for the concentrations of boron, lithium, and strontium in water to be used for public supply. The greatest concentrations of boron, lithium, and strontium were in a sample of water from a mine in the Ferron Sandstone Member (site M). Water from a nearby well that is completed in the Ferron (site N) also had relatively large concentrations of boron and strontium.

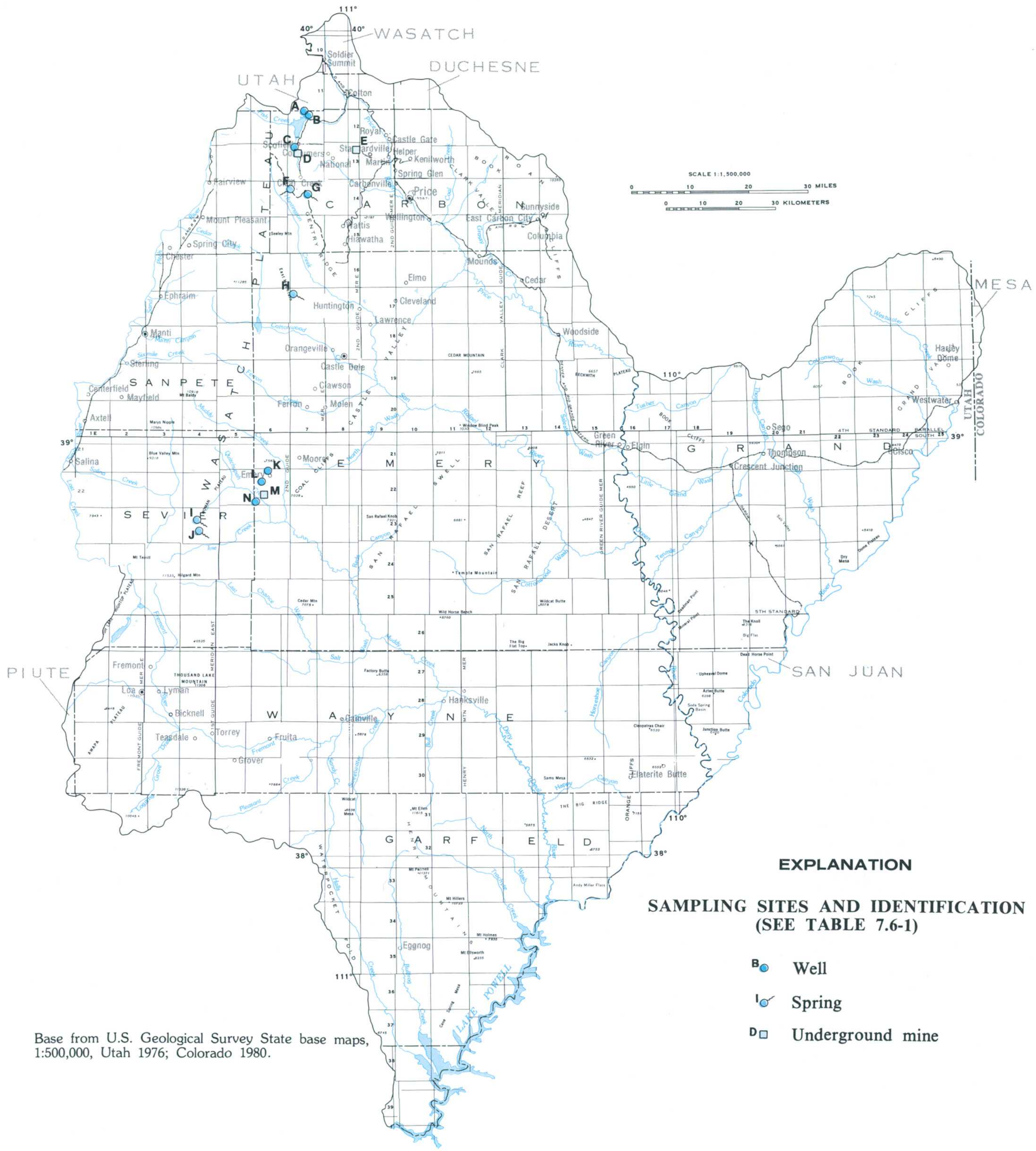


Figure 7.6-1 Ground-water sites sampled for analyses of trace-element concentrations.

Table 7.6-1 Concentrations of trace elements in ground water in coal-bearing aquifers.
[Constituents are dissolved and values are reported in micrograms per liter.]

Site identification (see figure 7.6-1)	Arsenic (As)	Boron (B)	Chromium (Cr)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Selenium (Se)	Strontium (Sr)
Blackhawk Formation								
A	0	30	—	20	2	10	2	—
B	0	80	—	1,300*	4	20	0	—
C	0	30	—	620*	7	10	0	—
D	1	70	—	20	4	10	0	—
E	0	120	0	30	0	30	0	680
F	0	10	10	10	6	0	1	120
G	0	40	0	20	4	0	0	60
H	—	0	—	10	—	—	—	—
I	0	40	0	10	10	10	0	290
J	1	40	0	10	11	0	2	220
Ferron Sandstone Member of the Mancos Shale								
K	—	80	—	—	—	—	—	—
L	1	190	—	—	4	40	0	—
M	1	770	0	10	0	250	0	9,300
N	0	280	10	120	0	50	0	2,300
Mandatory maximum concentration for public water supply	50	—	50	—	50	—	10	—

* Exceeds mandatory maximum concentration for public supply.

NAWDEX, WATSTORE, OWDC Have Water Data Information

Water data are collected in coal areas by a large number of organizations in response to a wide variety of missions and needs.

Within the U.S. Geological Survey there are three activities that help to identify and improve access to the vast amount of existing water data.

(1) The National Water Data Exchange (NAWDEX), which indexes the water data available from over 400 organizations and serves as a central focal point to help those in need of water data to determine what information already is available.

(2) The National Water Data Storage and Retrieval System (WATSTORE), which serves as the central repository of water data collected by the U.S. Geological Survey and which contains large volumes of data on the quantity and quality of both surface and ground waters.

(3) The Office of Water Data Coordination (OWDC), which coordinates Federal water-data acquisition activities and maintains a "Catalog of Information on Water Data." To assist in identifying available water-data activities in coal provinces of the United States, special indexes to the Catalog are being printed and made available to the public.

A more detailed explanation of these three activities is given in sections 8.2, 8.3, and 8.4.

NAWDEX Simplifies Access to Water Data

The National Water Data Exchange (NAWDEX) is a nationwide program managed by the U.S. Geological Survey to assist users of water data or water-related data in identifying, locating, and acquiring needed data.

NAWDEX is a national confederation of water-oriented organizations working together to make their data more readily accessible and to facilitate a more efficient exchange of water data.

Services are available through a Program Office at the U.S. Geological Survey's National Center in Reston, Va. and a nationwide network of Assistance Centers in 45 States and Puerto Rico, which provide local and convenient access to NAWDEX facilities (See figure 8.2-1.) A directory, which is available on request, provides names of organizations and persons to contact and addresses, telephone numbers, and office hours for each of the organizations [Directory of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist any organization or individual in identifying and locating needed water data and referring the requester to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (figure 8.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. A Water Data Sources Directory (figure 8.2-3), which also is maintained, identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition, NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

Charges for NAWDEX services are assessed at the option of the organization providing the requested data or data service. Search-assistance services are provided free by NAWDEX to the greatest extent possible. Charges are assessed, however, for those requests requiring computer cost, extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In all cases, charges assessed by NAWDEX Assistance Centers will not exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in all cases where costs are anticipated to be substantial.

For additional information concerning the NAWDEX program or its services contact:

Program Office
National Water Data Exchange (NAWDEX)
U.S. Geological Survey
421 National Center
12201 Sunrise Valley Drive
Reston, VA 22092
Telephone: (703) 860-6031
FTS 928-6031
Hours: 7:45 - 4:15 Eastern Time
or
NAWDEX ASSISTANCE CENTER
UTAH
Room 1016, Administration Bldg.
1745 West 1700 South
Salt Lake City, UT 84104
Telephone: (801) 524-5654
FTS: 588-5654
Hours: 8:00 to 4:30 Mountain Time

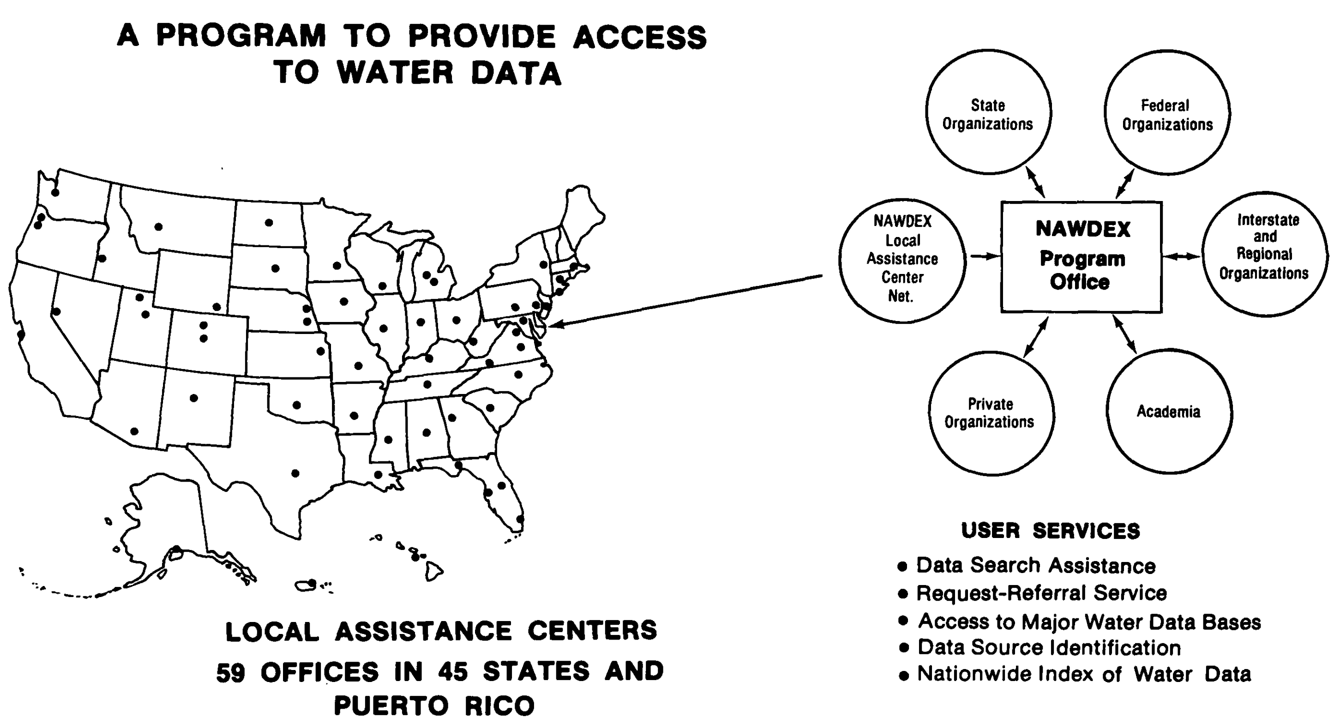


Figure 8.2-1 Access to water data.

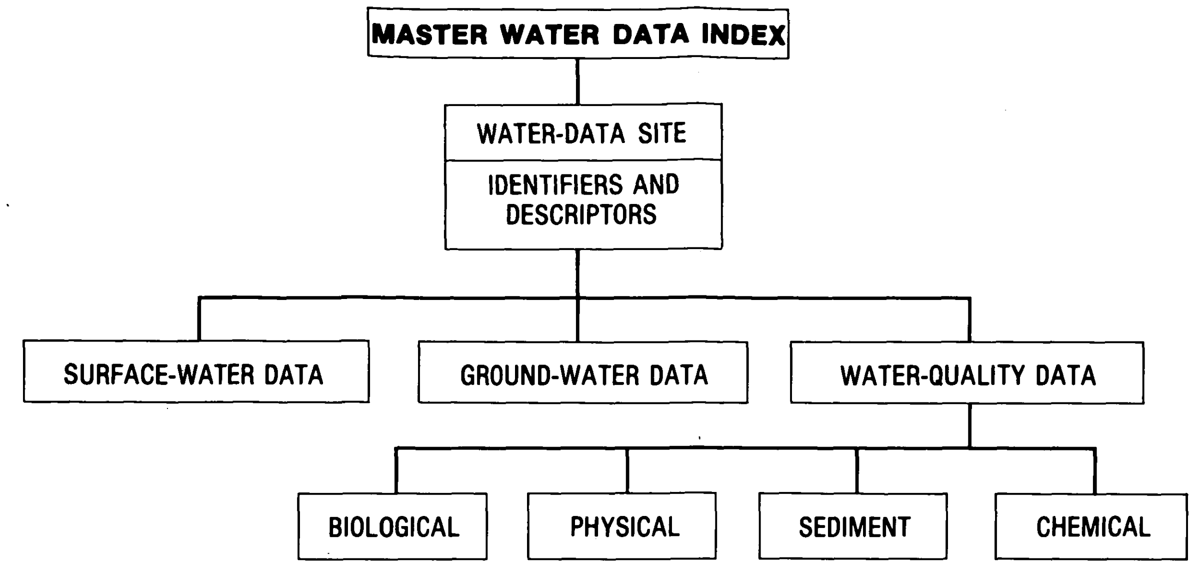


Figure 8.2-2 Master Water-Data Index.

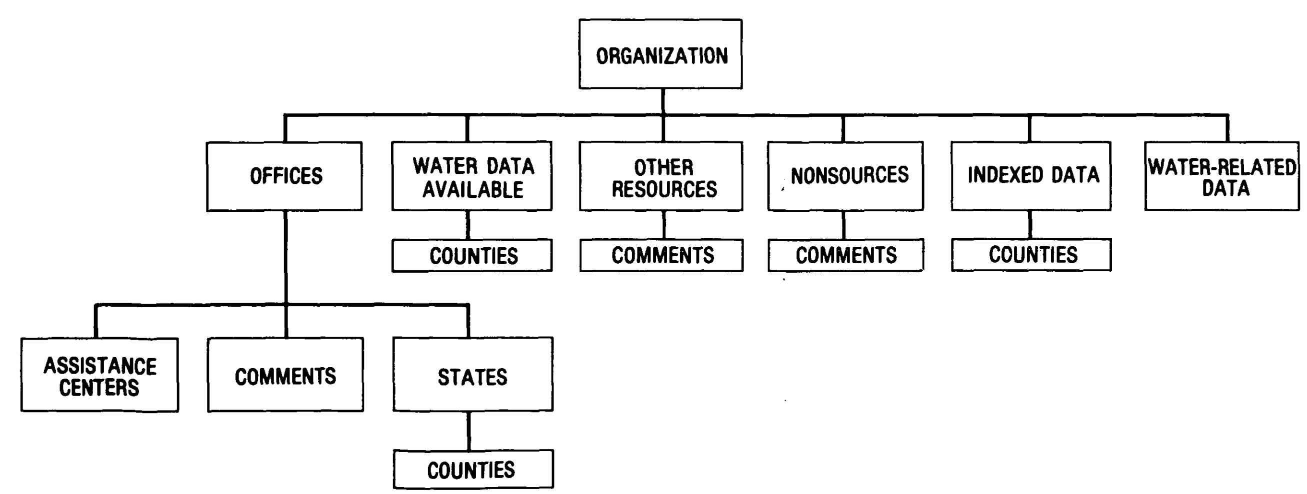


Figure 8.2-3 Water-Data Sources Directory.

WATSTORE Automated Data System

The National Water Data Storage and Retrieval System (WATSTORE) of the U.S. Geological Survey provides computerized procedures and techniques for processing water data and provides effective and efficient management of data-releasing activities.

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to computerize the U.S. Geological Survey's existing water-data system and to provide for more effective and efficient management of its data-releasing activities. The system is operated and maintained on the central computer facilities of the Survey at its National Center in Reston, Va. Data may be obtained from WATSTORE through the Water Resources Division's 43 district offices. General inquiries about WATSTORE may be directed to:

Chief Hydrologist
U.S. Geological Survey
437 National Center
Reston, VA 22092
or
U.S. Geological Survey
Water Resources Division
Room 1016, Administration Building
1745 West 1700 South
Salt Lake City, UT 84104

The Geological Survey currently (1980) collects data at approximately 16,000 stream-gaging stations, 1,000 lakes and reservoirs, 5,200 surface-water quality stations, 1,020 sediment stations, 30,000 water-level observation wells, and 12,500 ground-water quality wells. Each year, many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data-collection activities.

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system also is designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of: (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (figure 8.3-1). A brief description of each file is as follows:

Station-Header File: All sites for which data are stored in the files for Daily Values, Peak Flow, Water Quality, and Unit Values of WATSTORE are indexed in this file. It contains information pertinent to the identification, location, and physical description of nearly 220,000 sites.

Daily-Values File: All water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values are stored in this file. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 200 million daily values including data on streamflow, river stages, reservoir contents, water temperatures, specific conductance, sediment concentrations, sediment discharges, and ground-water levels.

Peak-Flow File: Annual maximum (peak) streamflow (discharge) and gage-height (stage) values at surface-water sites constitute this file, which currently contains over 400,000 peak observations.

Water-Quality File: Results of over 1.4 million analyses of water samples that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters are contained in this file. These analyses contain data for 185 different constituents.

Unit-Values File: Water parameters measured on a schedule more frequent than daily are stored in this file. Rainfall, stream discharge, and temperature data are examples of the types of data stored in the Unit-Values File.

Ground-Water Site-Inventory File: This file is maintained within WATSTORE independent of the files discussed above, but it is cross-referenced to the Water-Quality File and the Daily-Values File. It contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, one-time field measurements such as water temperature. The file is designed to accommodate 255 data elements, and it contained data for about 700,000 sites in 1980.

Water-Use File: This file is also an independent file maintained within WATSTORE. It contains aggregated estimates of water use by county and hydrologic unit.

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center. However, data may be entered into or retrieved from WATSTORE at a number of locations that are part of a nationwide telecommunication network.

Remote Job-Entry Sites: Almost all the Water Resources Division's district offices are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals allow each site to put data into or retrieve data from the system within several minutes to overnight, depending upon the priority placed on the request. The number of remote job-entry sites is increased as the need arises.

Digital-Transmission Sites: Digital recorders are used at many field locations to record values for parameters such as river stage, conductivity, water temperature, turbidity, wind direction, and chloride. Data are recorded on 16-channel paper tape, which is removed from the recorder and the data then transmitted over telephone line to the receiver at Reston, Va. The data are recorded on magnetic tape for use on the central computer. Extensive testing of satellite data-collection platforms indicates their feasibility for collecting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 200 data-relay stations were operated during 1980.

Central Laboratory System: The Water Resources Division's water-quality laboratories in Denver, Colo., and Atlanta, Ga. analyze more than 150,000 water samples per year. These laboratories are equipped to automatically perform chemical analyses ranging from determinations of simple inorganic compounds, such as chlorides, to complex organic compounds, such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and transmitted via a computer terminal to the central computer facilities to be stored in the Water-Quality File of WATSTORE.

Water data are used in many ways by decision makers for the management, development, and monitoring of water resources. In addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple data tables to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requester.

Computer-Printed Tables: Users most often request data from WATSTORE in the form of tables printed by the computer. These tables may contain lists of actual data or condensed indexes that indicate the availability of data stored in the files. A variety of formats is available to display the many types of data.

Computer-Printed Graphs: Computer-printed graphs for the rapid analysis or display of data are another capability of WATSTORE. Computer programs are available to produce bar graphs (histograms), line graphs, frequency-distribution curves, X-Y point plots, site-location-map plots, and other similar items by means of line printers.

Statistical Analyses: WATSTORE interfaces with a proprietary statistical package (SAS) to provide extensive analyses of data such as regression analyses, and the analysis of variance, transformations, and correlations.

Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral offline plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency distribution curves, X-Y point plots, contour plots, and three-dimensional plots.

Data in Machine-Readable Form: Data stored in WATSTORE can be obtained in machine-readable form for use on other computers or for use as input to user-written computer programs. These data are available in the standard-storage format of the WATSTORE system or in the form of punched cards or card images on magnetic tape.

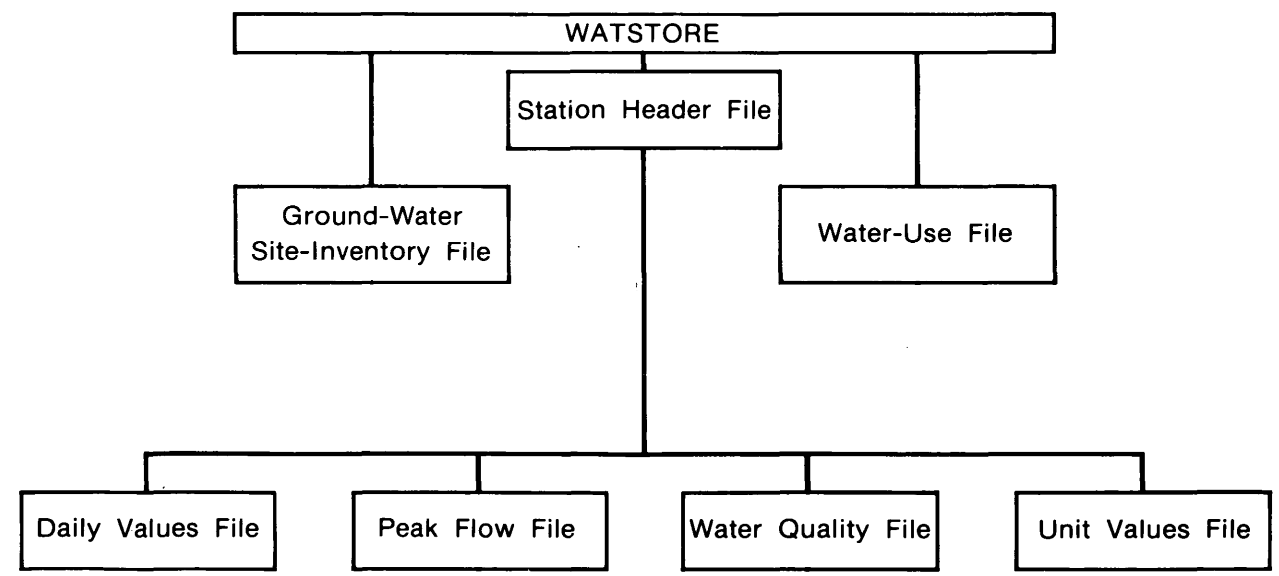


Figure 8.3-1 Index-file of stored data.

Water Data Indexed for Coal Provinces

A special index, "Index to Water-Data Activities in Coal Provinces of the United States," has been published by the U.S. Geological Survey's Office of Water Data Coordination (OWDC).

The "Index to Water-Data Activities in Coal Provinces of the United States" was prepared to assist those involved in developing, managing, and regulating the Nation's coal resources by providing information on the availability of water-resources data in the major coal provinces of the United States. It is derived from the "Catalog of Information on Water Data," which is a computerized information file about water-data acquisition activities in the United States and its territories and possessions, with some international activities included.

This special index consists of five volumes (figure 8.4-1): volume I, Eastern Coal province; volume II, Interior Coal province; volume III, Northern Great Plains and Rocky Mountain Coal provinces; volume IV, Gulf Coast Coal province; and volume V, Pacific Coast and Alaska Coal provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

Each volume of this special index consists of four parts: Part A, Streamflow and Stage Stations; Part B, Quality of Surface-Water Stations; Part C, Quality of Ground-Water Stations; and Part D, Areal Investigations and Miscellaneous Activities. Information given for each activity in Parts A-C includes: (1) the identification and location of the station, (2) the major types of data collected, (3) the frequency of data collection, (4) the form in which the data are stored, and (5) the agency or organization reporting the activity. Part D summarizes areal hydrologic investigations and water-data activities not included in the other parts of the index. The agencies that submitted the information, agency codes, and the number of activities reported by type are shown in a table.

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (See section 8.2).

Further information on the index volumes and their availability may be obtained from:

U.S. Geological Survey
Water Resources Division
Room 1016 Administration Bldg.
1745 West 1700 South
Salt Lake City, UT 84104
Telephone: (801) 524-5654
FTS 588-5654
or
Office of Surface Mining
U.S. Department of the Interior
Brooks Towers
Denver, CO 80202
Telephone: (303) 827-5511
FTS 327-5511

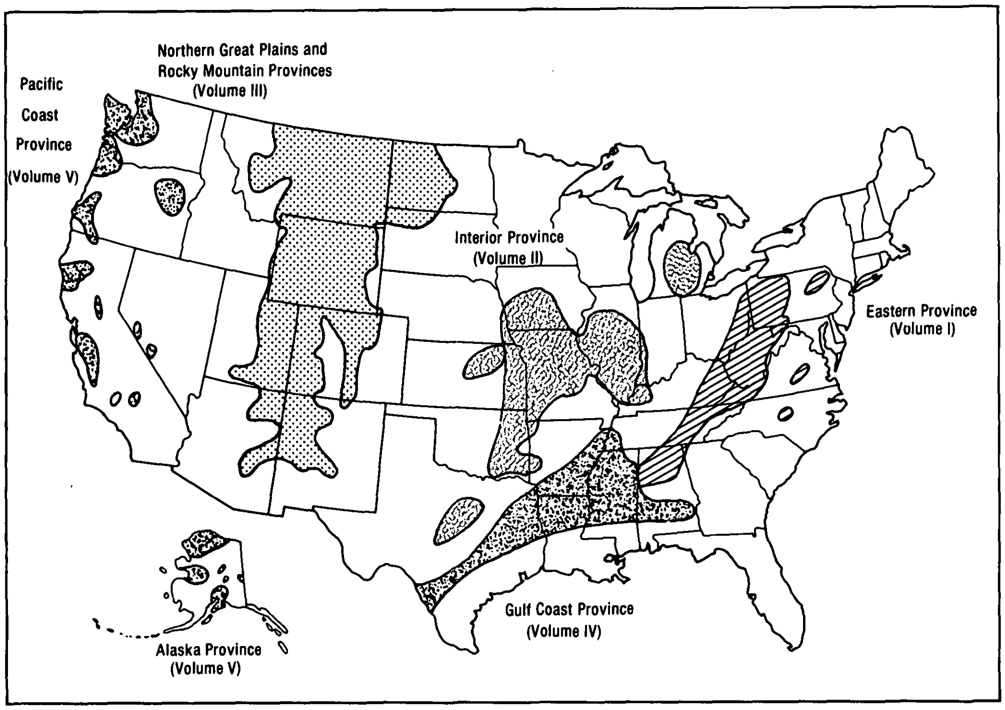


Figure 8.4-1 Index volumes and related provinces.

9.0 REFERENCES CITED

Benson, M. A., and Carter, R. W., 1973, A national study of the streamflow data-collection program: U.S. Geological Survey Water-Supply Paper 2028, 44 p.

Berwick, V. K., 1962, Floods in Utah, magnitude and frequency: U.S. Geological Survey Circular 457, 24 p.

Bjorklund, L. J., 1969, Reconnaissance of the ground-water resources of the upper Fremont River valley, Wayne County, Utah: Utah Department of Natural Resources Technical Publication 22, 54 p.

Butler, Elmer, and Cruff, R. W., 1971, Floods in Utah, magnitude and frequency characteristics through 1969: U.S. Geological Survey open-file report, 34 p.

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

Cordova, R. M., 1963, Hydrogeologic reconnaissance of part of the headwaters area of the Price River, Utah: Utah Geological and Mineralogical Survey Water-Resources Bulletin 4, 26 p.

Covington, H. R., 1972a, Map showing length of freeze-free season in the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591-E, scale 1:250,000.

_______1972b, Map showing springs in the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591-G, scale 1:250,000.

Covington, H. R., and Williams, P. L., 1972a, Map showing normal annual and monthly precipitation in the Salina Quadrangle: U.S. Geological Survey Miscellaneous Investigations Map I-591-D, scale 1:250,000.

_______1972b, Surface water map of the Salina Quadrangle: U.S. Geological Survey Miscellaneous Investigations Map I-591-F, scale 1:250,000.

Danielson, T. W., ReMillard, M. D., and Fuller, R. H., 1981, Hydrology of the coal-resource areas in the upper drainages of Huntington and Cottonwood Creeks, central Utah: U.S. Geological Survey Water-Resources Investigations 81-539, 85 p.

Danielson, T. W., and Sylla, D. A., 1983, Hydrology of coal-resource areas in the southern Wasatch Plateau, central Utah: U.S. Geological Survey Water-Resources Investigations 82-4009, 66 p.

Dunrud, C. R., 1976, Some engineering geologic factors controlling coal mine subsidence in Utah and Colorado: U.S. Geological Survey Professional Paper 969, 39 p.

Edwards, M. D., 1977, Directory of local assistance centers of the National Water Data Exchange (NAWDEX): U.S. Geological Survey Open-File Report 76-880, 11 p.

Eychaner, J. H., 1976, Estimating runoff volumes and flood hydrographs in the Colorado River Basin, sourthern Utah: U.S. Geological Survey Water-Resources Investigations 102-76, 18 p.

Feltis, R. D., 1966, Water from bedrock in the Colorado Plateau of Utah: Utah State Engineer Technical Publication 15, 82 p.

Fenneman, N. M., 1946, Physical divisions of the United States: U.S. Geological Survey map, scale 1:7,000,000.

Fields, F. K., 1975, Estimating streamflow characteristics for streams in Utah using selected channel-geometry parameters: U.S. Geological Survey Water-Resources Investigations 34-74, 19 p.

Goode, H. D., and Olson, Eric, 1977, Reconnaissance appraisal of the water resources of the Henry Mountains coal field, Wayne and Garfield Counties, Utah, 1975-77: University of Utah Research Report, Salt Lake City, Utah, 90 p.

Graham, M. J., Tooley, J. E., and Price, Don, 1981, Preliminary hydrologic evaluation of the North Horn Mountain coal-resource area, Utah: U.S. Geological Survey Open-File Report 81-141, 33 p.

Hackman, R. J., and Williams P. L., 1972, Map showing drainage basins and historic cloudburst floods in the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591-N, scale 1:250,000.

Hintze, L. F., 1980, Geologic map of Utah: Utah Geological and Mineral Survey, 2 sheets, scale 1:500,000.

Hood, J. W., and Danielson, T. W., 1979, Aquifer tests of the Navajo Sandstone near Caineville, Wayne County, Utah: Utah Department of Natural Resources Technical Publication 66, 69 p.

_______1981, Bedrock aquifers in the lower Dirty Devil River basin area, Utah, with special emphasis on the Navajo Sandstone: Utah Department of Natural Resources Technical Publication 68, 143 p.

Iorns, W. V., Hembree, C. H., Phoenix, D. A., and Oakland, G. L., 1964, Water resources of the Upper Colorado River Basin--basic data: U.S. Geological Survey Professional Paper 442, 1036 p.

Iorns, W. V., Hembree, C. H., and Oakland, G. L., 1965, Water resources of the Upper Colorado River Basin--technical report: U.S. Geological Survey Professional Paper 441, 370 p.

King, N. J., and Mace, M. N., 1953, Sedimentation in small reservoirs on the San Rafael Swell, Utah: U.S. Geological Survey Circular 256, 21 p.

Lines, G. C., 1981, Hydrologic studies of the U.S. Geological Survey in major coal-resource areas of Utah through 1980: U.S. Geological Survey Open-File Report 81-216, 20 p.

Lines, G. C., and Morrissey, D. J., 1981, Hydrology of the Ferron sandstone aquifer and effects of proposed surface-coal mining in Castle Valley, Utah, *with a section on* Stratigraphy by T. A. Ryer and *a section on* Leaching of overburden by R. H. Fuller: U.S. Geological Survey Open-File Report 81-535, 108 p. (to be printed as U.S. Geological Survey Water-Supply Paper 2195).

Lines, G. C., and Plantz, G. G., 1981, Hydrologic monitoring in coal fields of central Utah, August 1978-September 1979: U.S. Geological Survey Water-Resources Investigations 81-138, 56 p.

Marine, I. W., 1962, Water-supply possibilities at Capitol Reef National Monument, Utah: U.S. Geological Survey Water-Supply Paper 1475-G, p. 201-208.

Morrissey, D. J., Lines, G. C., and Bartholoma, S. D., 1980, Three-dimensional digital-computer model of the Ferron sandstone aquifer near Emery, Utah: U.S. Geological Survey Water-Resources Investigations 80-62, 101 p.

Mundorff, J. C., 1968, Fluvial sediment in Utah, 1905-65, a data compilation: Utah Department of Natural Resources Information Bulletin 20, 400 p.

_______1971, Nonthermal springs of Utah: Utah Geological and Mineralogical Survey Water-Resources Bulletin 16, 70 p.

_______1972, Reconnaissance of chemical quality of surface water and fluvial sediment in the Price River basin, Utah: Utah Department of Natural Resources Technical Publication 39, 55 p.

_______1979, Reconnaissance of chemical quality of surface water and fluvial sediment in the Dirty Devil River basin, Utah: Utah Department of Natural Resources Technical Publication 65, 132 p.

Mundorff, J. C., and Thompson, K. R., 1980, Reconnaissance of the quality of surface water in the San Rafael River basin, Utah: U.S. Geological Survey Open-File Report 80-574, 54 p. (to be printed as Utah Department of Natural Resources Technical Pubication 72).

Price, Don, 1972a, Map showing general availability of ground water in the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591-M, scale 1:250,000.

Price, Don, 1972b, Map showing general chemical quality of ground water in the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591-K, scale 1:250,000.

Price, Don, and Arnow, Ted, 1974, Summary appraisals of the Nation's ground-water resources--upper Colorado Region: U.S. Geological Survey Professional Paper 813-C, 40 p.

Price, Don, and Waddell, K. M., 1973, Selected hydrologic data in the Upper Colorado River Basin: U.S. Geological Survey Hydrologic Investigations Atlas HA-477, 2 sheets, scale 1:250,000.

Riggs, H. C., 1973, Regional analysis of streamflow characteristics: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter B3, 15 p.

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

______1971, Ground-water hydrology of the San Pitch drainage basin, San Pete County, Utah: U.S. Geological Survey Water-Supply Paper 1896, 80 p.

Sumsion, C. T., 1979, Selected coal-related ground-water data, Wasatch Plateau-Book Cliffs area, Utah: U.S. Geological Survey Open-File Report 79-915 (duplicated as Utah Hydrologic-Data Report 32), 25 p.

U.S. Bureau of Land Management, 1973, Utah public lands guide: U.S. Bureau of Land Management map of Utah, scale about 1:2,000,000.

U.S. Department of Agriculture, 1973, Estimating sediment yield rates for the State of Utah: Western United States Water-Plan Map, scale 1:500,000.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: Washington, D. C., U.S. Government Printing Office, 159 p.

U.S. Geological Survey, issued annually since 1975, Water resources data for Utah: Water Resources Division, Salt Lake City.

______1980, Index to topographic maps of Utah: map of Utah, scale 1:1,000,000.

U.S. Weather Bureau, [1963], Normal annual and May-September precipitation (1931-60) for the State of Utah: Map of Utah, scale 1:500,000.

Utah Department of Agriculture, 1981, Utah agricultural statistics, 1981: Utah Department of Agriculture duplicated report, 95 p.

Utah Geological and Mineral Survey, 1975, Energy resources map of Utah: Map 36, scale 1:500,000.

Waddell, K. M., Contratto, P. K., Sumsion, C. T., and Butler, J. R., 1981, Hydrologic reconnaissance of the Wasatch Plateau-Book Cliffs coal-fields area, Utah: U.S. Geological Survey Water-Supply Paper 2068, 45 p.

Waddell, K. M., Vickers, H. L., Upton, R. T., and Contratto, P. K., 1978, Selected hydrologic data, 1931-77, Wasatch Plateau-Book Cliffs coal-fields area, Utah: U.S. Geological Survey Open-File Report 78-121 (duplicated as Utah Basic-Data Release 31), 33 p.

Waring, G. A., 1935, Ground water in part of southeastern Utah and southwestern Colorado *with a chapter on* Moab and Spring Valleys by M. M. Knechtel: U.S. Geological Survey open-file report, 119 p.

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

10.0 LIST OF SURFACE-WATER STATIONS

Site No. (see figure 6-1.1)	Station No.	Station Name	Location Latitude ° ′ ″	Location Longitude ° ′ ″	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
1	09163550	Harley Dome Wash near Harley Dome, Utah	39 09 25	109 08 40	3.1	[1]1959-68	–
2	09163700	Cisco Wash near Cisco, Utah	38 57 50	109 20 10	29	[1]1959-74	–
3	09180500	Colorado River near Cisco, Utah	38 48 38	109 17 34	24,100	1895-1981	1928-81
4	09182600	Salt Wash near Thompson, Utah	38 57 10	109 39 30	3.9	[1]1959-74	–
5	09309500	Fairview ditch near Fairview, Utah (Transmountain diversion)	39 39 36	111 19 38	–	1949-67	–
6	09309600	Fairview tunnel near Fairview, Utah (Transmountain diversion)	39 40 03	111 18 41	–	1967-81	–
7	09309800	Gooseberry Creek near Fairview, Utah	39 40 27	111 18 15	7.9	1959-69	–
8	09310000	Gooseberry Creek near Scofield, Utah	39 42 57	111 17 58	16.8	1930-31, 1940-81	–
9	09310500	Fish Creek above reservoir, near Scofield, Utah	39 46 28	111 11 25	60.1	1931-32, 1938-81	–
10	09310600	Eccles Canyon near Scofield, Utah	39 41 07	111 09 22	5.5	1979-81	1979-81
11	09310700	Mud Creek below Winter Quarters Canyon, at Scofield, Utah	39 43 18	111 09 38	29.1	1978-81	1978-81
12	09311000	Scofield Reservoir near Scofield, Utah	39 47 15	111 07 30	154	1941-81	–
13	09311500	Price River (Fish Creek) near Scofield, Utah	39 47 13	111 07 10	155	1917-21, 1925-31, 1938-69	–
14	09311700	Price River near Soldier Summit, Utah	39 49 40	111 00 30	180	1961-63	–
15	09312000	North Fork White River near Soldier Summit, Utah	39 56	111 04	23.3	1942-47	–
16	09312500	White River near Soldier Summit, Utah	39 55 20	111 03 25	53	1938-67	–
17	09312600	White River below Tabbyune Creek, near Soldier Summit, Utah	39 52 33	111 02 12	75.6	1967-81	–
18	09312700	Beaver Creek near Soldier Summit, Utah	39 49 50	110 58 07	26.1	1960-81	–
19	09312800	Willow Creek near Castle Gate, Utah	39 46 37	110 47 30	62.8	1962-81	–
20	09312900	Willow Creek at Castle Gate, Utah	39 43 37	110 51 41	77.4	1979-81	1979-81

Site No. (see figure 6-1.1)	Station No.	Station Name	Location Latitude ° ' "	Location Longitude ° ' "	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
21	09313000	Price River near Heiner, Utah	39 43 08	110 51 55	415	1934-69, 1979-81	1979-81
22	09313040	Spring Canyon below Sowbelly Gulch, at Helper, Utah	39 41 19	110 53 09	23.0	1978-81	1978-81
23	09313500	Price River near Helper, Utah	39 39 05	110 51 25	530	1904-34	–
24	09313965	Coal Creek near Helper, Utah	39 42 09	110 40 38	25.3	1978-81	1978-81
25	09313975	Soldier Creek below mine, near Wellington, Utah	39 41 43	110 36 52	17.7	1978-81	1978-81
26	09313985	Dugout Creek near Sunnyside, Utah	39 40 47	110 32 52	5.8	1979-81	1979-81
27	09314000	Price River near Wellington, Utah	39 30 40	110 40 50	850	1949-58	–
28	09314200	Miller Creek near Price, Utah	39 32	110 49	62	[1]1960-74	–
29	09314250	Price River below Miller Creek, near Wellington, Utah	39 26 59	110 37 38	956	1972-81	–
30	09314280	Desert Seep Wash near Wellington, Utah	39 25 16	110 38 44	191	1972-81	–
31	09314340	Grassy Trail Creek at Sunnyside, Utah	39 33 20	110 22 46	40.1	1978-81	1978-81
32	09314374	Horse Canyon near Sunnyside, Utah	39 27 26	110 21 33	12.5	1978-81	1978-81
33	09314400	Coleman Wash tributary near Woodside, Utah	39 23	110 24	3.6	[1]1959-68	–
34	09314500	Price River at Woodside, Utah	39 15 50	110 20 45	1,540	1909-11, 1945-81	1946-49, 1951-81
35	09315000	Green River at Green River, Utah	38 59 10	110 09 02	44,850	1894-1899, 1904-81	1928-81
36	09315150	Saleratus Wash tributary near Woodside, Utah	39 08	110 20	10	[1]1959-74	–
37	09315200	Saleratus Wash tributary No. 2 near Woodside, Utah	39 06	110 19	4.4	[1]1959-74	–
38	09315400	Saleratus Wash above Cottonwood Wash, near Green River, Utah	39 01	110 18	120	[1]1959-68	–
39	09315500	Saleratus Wash at Green River, Utah	38 58 53	110 14 46	180	1948-70	–
40	09315900	Browns Wash tributary near Green River, Utah	38 59	110 06	3.89	[1]1959-74	–

Site No. (see figure 6-1.1)	Station No.	Station Name	Location Latitude ° ' "	Location Longitude ° ' "	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
41	09316000	Browns Wash near Green River, Utah	38 59 10	110 07 45	75	1949-68	—
42	09317000	Boulger Creek near Fairview,Utah	39 38	111 16	1.9	1938-49	—
43	09317500	Candland ditch near Mount Pleasant, Utah (Transmountain diversion)	39 33	111 19	—	1949-58	—
44	09317919	Crandall Canyon at mouth, near Huntington, Utah	39 27 48	111 08 54	5.7	1978-81	1978-81
45	09317920	Tie Fork Canyon near Huntington, Utah	39 27 31	111 08 11	11.7	1978-81	1978-81
46	09317997	Huntington Creek near Huntington, Utah	39 23 07	111 05 15	181	1979-81	1979-81
47	09318000	Huntington Creek near Huntington, Utah	39 22 17	111 03 47	190	1909-73, 1974-76, 1977-79	1978-79
48	09318500	Huntington Creek near Castle Dale, Utah	39 12 30	110 55 00	325	1911-17, 1919-21	—
49	09319000	Ephraim tunnel near Ephraim, Utah (Transmountain diversion)	39 19 47	111 25 51	—	1949-81	—
50	09319500	Beck Creek near Ephraim, Utah	39 19 00	111 25 00	5	1931-32	—
51	09320000	Horseshoe tunnel near Ephraim, Utah (Transmountain diversion)	39 22 00	111 27 00	—	1949-58	—
52	09320500	Larsen tunnel near Ephraim, Utah (Transmountain diversion)	39 21 00	111 27 00	—	1949-58	—
53	09321000	Coal Fork ditch near Mount Pleasant, Utah (Transmountain diversion)	39 30 00	111 19 00	—	1949-58	—
54	09321500	Twin Creek tunnel near Mount Pleasant, Utah (Transmountain diversion)	39 28 00	111 20 00	—	1949-58	—
55	09322000	Black Canyon ditch near Spring City, Utah (Transmountain diversion)	39 27 00	111 20 00	—	1949-58	—
56	09322500	Cedar Creek tunnel near Spring City, Utah (Transmountain diversion)	39 27 00	111 20 00	—	1949-58	—
57	09323000	Spring City tunnel near Spring City, Utah (Transmountain diversion)	39 25 34	111 21 51	—	1949-81	—

Site No. (see figure 6-1.1)	Station No.	Station Name	Location Latitude ° ′ ″	Location Longitude ° ′ ″	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
58	09323500	Reeder ditch near Spring City, Utah (Transmountain diversion)	39 23 00	111 23 00	—	1949-58	—
59	09323900	Joes Valley Reservoir near Orangeville, Utah	39 17 20	111 16 10	146	1965-81	—
60	09324000	Seely Creek near Orangeville, Utah	39 17 00	111 16 00	150	1953-57	—
61	09324200	Cottonwood Creek above Straight Canyon, near Orangeville, Utah	39 18 26	111 11 02	21.9	1978-81	1978-81
62	09324500	Cottonwood Creek near Orangeville, Utah	39 16 00	111 07 45	208	1909-27, 1932-70, 1975-81	1975-81
63	09325000	Cottonwood Creek near Castle Dale, Utah	39 10 12	110 56 15	261	1947-58	—
64	09325100	San Rafael River above Ferron Creek, near Castle Dale, Utah	39 09 00	110 54 30	680	1964-70	—
65	09325500	John August ditch near Ephraim, Utah (Transmountain diversion)	39 18 00	111 27 00	—	1949-58	—
66	09326000	Madsen ditch near Ephraim, Utah (Transmountain ditch)	39 19 00	111 27 00	—	1949-58	—
67	09326500	Ferron Creek (Upper station) near Ferron, Utah	39 06 15	111 12 47	138	1911-23, 1947-81	—
68	09327000	Ferron Creek near Ferron, Utah	39 06 00	111 11 00	159	1909-11	—
69	09327500	Ferron Creek near Castle Dale, Utah	39 06 20	111 01 25	210	1911-14, 1947-58	—
70	09327550	Ferron Creek below Paradise Ranch, near Clawson, Utah	39 07 09	110 59 20	221	1975-81	1975-81
71	09327600	Ferron Creek tributary near Ferron, Utah	39 04 00	111 02 00	.96	[1]1959-74	—
72	09328000	San Rafael River near Castle Dale, Utah	39 08 37	111 53 50	930	1947-64, 1972-81	—
73	09328050	Dry Wash near Moore, Utah	38 56 00	111 04 00	14	[1]1959-74	—
74	09328100	San Rafael River at San Rafael Bridge Campground, near Castle Dale, Utah	39 04 51	110 39 56	1,284	1975-81	1975-81
75	09328200	Buckhorn Draw tributary near Castle Dale, Utah	39 10	110 43	5.7	[1]1959-68	—
76	09328300	Sids Draw near Castle Dale, Utah	38 59	110 40	17.6	[1]1959-74	—
77	09328500	San Rafael River near Green River, Utah	38 51 30	110 22 10	1,628	1909-20, 1945-81	1946-81

Site No. (see figure 6-1.1)	Station No.	Station Name	Latitude ° ′ ″	Longitude ° ′ ″	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
78	09328600	Georges Draw near Hanksville, Utah	38 49 00	110 42 00	6.63	[1]1959-74	–
79	09328700	Temple Wash near Hanksville, Utah	38 39	110 33	38.2	[1]1959-68	–
80	09328720	Old Woman Wash near Hanksville, Utah	38 41	110 32	17.6	[1]1959-68	–
81	09328900	Crescent Wash at Crescent Junction, Utah	38 56 32	109 49 14	23.3	[1]1959-68	–
82	09329000	Fremont River (Head of Dirty Devil River) below Fish Lake, near Fremont, Utah	38 35 30	111 40 30	27	1939-45	–
83	09329050	Seven Mile Creek near Fish Lake, Utah	38 37 40	111 38 50	24.0	1964-81	–
84	09329500	Fremont River near Fremont, Utah	38 29 07	111 34 34	205	1949-58	–
85	09329800	Tommy Hollow near Bicknell, Utah	38 17	111 37	3.3	[1]1959-68	–
86	09329900	Pine Creek near Bicknell, Utah	38 16 10	111 35 00	104	1964-80	–
87	09330000	Fremont River near Bicknell, Utah	38 18 25	111 31 03	751	1909-12, 1937-58, 1976-81	–
88	09330100	Sulphur Creek near Torrey, Utah	38 20	111 22	7.86	[1]1959-68	–
89	09330120	Sulphur Creek near Fruita, Utah	38 18	111 16	56.7	[1]1959-74	–
90	09330200	Pleasant Creek at Notom, Utah	38 14	111 07	80.6	[1]1959-73	–
91	09330210	Pleasant Creek near Caineville, Utah	38 16 20	111 05 30	115	1969-72	–
92	09330230	Fremont River near Caineville, Utah	38 16 40	111 04 00	1,208	1967-81	1967-72, 1977-81
93	09330300	Neilson Wash near Caineville, Utah	38 22	110 53	22.3	[1]1959-74	–
94	09330400	Fremont River near Hanksville, Utah	38 22 00	110 45 00	1,900	[1]1959-74	–
95	09330500	Muddy Creek near Emery, Utah	38 58 55	111 14 55	105	1909-14, 1949-81	–
96	09331000	Muddy Creek (Lower station) near Emery, Utah	38 57	111 12	114	1911-14	–
97	09331500	Ivie Creek above diversions, near Emery, Utah	38 45 30	111 25 15	50	1950-61, [1]1962-74	–
98	09331850	Convulsion Canyon near Emery, Utah	38 54 23	111 24 40	21.5	1980-81	1980-81
99	09331900	Quitchupah Creek near Emery, Utah	38 51 33	111 15 41	104	1978-81	1978-81

Site No. (see figure 6-1.1)	Station No.	Station Name	Location Latitude ° ′ ″	Location Longitude ° ′ ″	Drainage area (square miles)	Period and type of record: Discharge	Period and type of record: Water quality
100	09331950	Christiansen Wash near Emery, Utah	38 51 41	111 15 07	13.6	1978-81	1978-81
101	09332100	Muddy Creek below Interstate Highway I-70, near Emery, Utah	38 48 44	111 11 53	418	1973-81	–
102	09332500	Muddy Creek below Ivie Creek, near Emery, Utah	38 46	111 08	440	1950-61, [1]1962-68	–
103	09332700	Muddy Creek at Delta Mine, near Hanksville, Utah	38 33 47	110 57 13	841	1975-81	1975-81
104	09332800	Muddy Creek at mouth, near Hanksville, Utah	38 24 10	110 42 00	1,552	1975-80	1975-80
105	09333000	Dirty Devil River near Hanksville, Utah	38 24	110 41	3,490	1945-48	1947-48
106	09333500	Dirty Devil River above Poison Spring Wash, near Hanksville, Utah	38 05 50	110 24 27	4,159	1948-81	–
107	09333900	Butler Canyon near Hite, Utah	38 00	110 30	14.7	[1]1959-74	–
108	09334000	North Wash near Hanksville, Utah	37 53 55	110 26 55	136	1950-70	–
109	09335000	Colorado River at Hite, Utah	37 48 30	110 26 55	76,600	1947-58	–
110	10205030	Salina Creek near Emery, Utah	38 54 43	111 31 47	51.8	1963-81	–
111	10205070	Cottonwood Creek near Salina, Utah	38 55	111 42	7.8	[1]1959-68	–
112	10205100	Sheep Creek near Salina, Utah	38 46 41	111 40 48	.30	1957-58	–
113	10205200	West Fork Sheep Creek near Salina, Utah	38 47 22	111 41 18	.43	1957-58	–
114	10205300	Sheep Creek at mouth, near Salina, Utah	38 48 00	111 40 58	1.47	1957-58	–
115	10205500	Salina Creek near Salina, Utah	38 56	111 47	–	1900-01	–
116	10205700	Salina Creek above diversions, near Salina, Utah	38 56	111 49	280	[1]1959-74	–
117	10206000	Salina Creek at Salina, Utah	38 57 24	111 51 58	292	1914-19, 1942-55, 1960-81	–
118	10208500	Oak Creek near Fairview, Utah	39 40 26	111 24 30	11.8	1964-81	–
119	10210000	Pleasant Creek near Mount Pleasant, Utah	39 32 35	111 23 00	16.4	1954-75	–
120	10211000	Twin Creek near Mount Pleasant, Utah	39 29 30	111 24 25	5.9	1954-66	–
121	10215700	Oak Creek near Spring City, Utah	39 26 52	111 25 29	8.35	1964-74, 1979-81	–
122	10215900	Manti Creek below Dugway Creek, near Manti, Utah	39 15 33	111 34 45	26.4	1964-74, 1978-81	–
123	10216000	Manti Creek near Manti, Utah	39 15	111 37	–	1900	–
124	10216200	Gunnison Reservoir near Sterling, Utah	39 12 23	111 42 37	672	1965-81	–
125	10216210	San Pitch River near Sterling, Utah	39 12 20	111 42 37	672	1964-80	–
126	10216300	Sixmile Creek near Sterling, Utah	39 12	111 40	29	[1]1959-73	–
127	10216400	Twelvemile Creek near Mayfield, Utah	39 06 02	111 38 44	59.4	1959-80	–

[1] Annual maximums only.

10.0 LIST OF SURFACE-WATER STATIONS--Continued