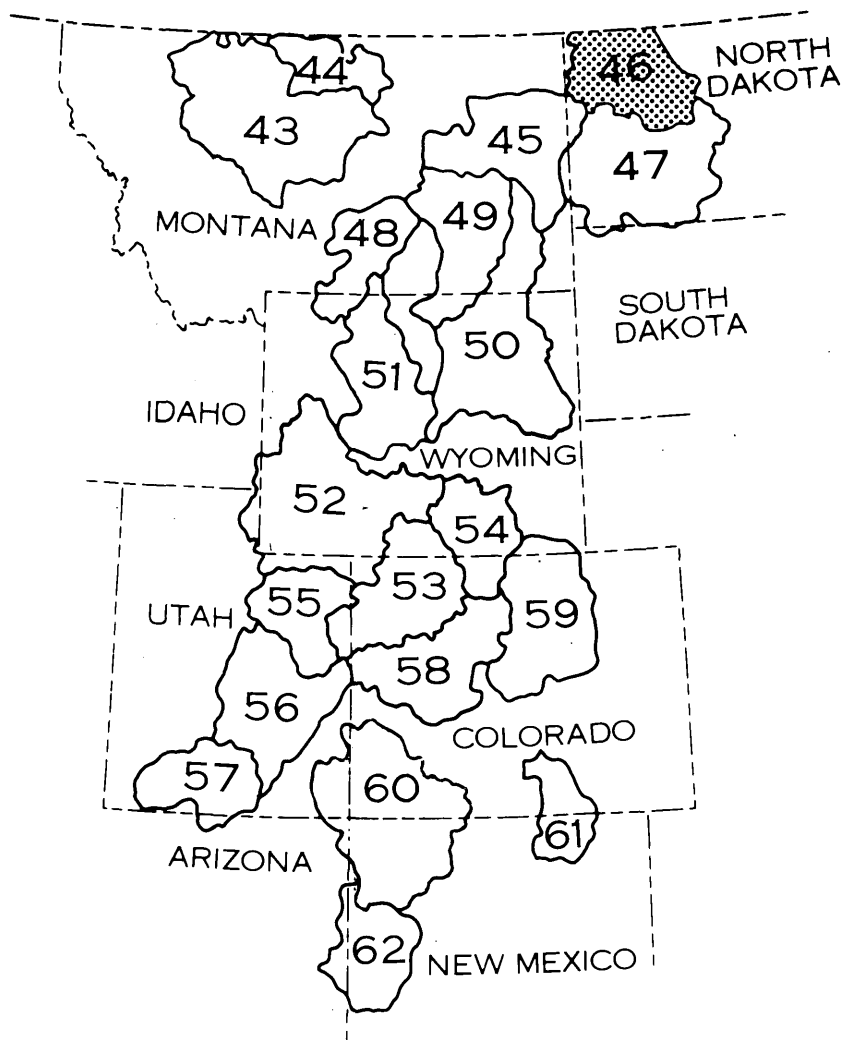


HYDROLOGY OF AREA 46, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, NORTH DAKOTA



- MISSOURI RIVER
- SOURIS RIVER
- DES LACS RIVER
- WHITE EARTH RIVER
- LITTLE MUDDY RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 84-467

HYDROLOGY OF AREA 46, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, NORTH DAKOTA

**BY
M. G. CROFT AND ORLO A. CROSBY**

U. S. GEOLOGICAL SURVEY

**WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 84-467**



**BISMARCK, NORTH DAKOTA
MARCH 1987**

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

	Page
Abstract.....	1
1.0 Introduction	
1.1 Objective.....	2
1.2 Study area.....	4
1.3 Hydrologic problems.....	6
2.0 Definition of terms.....	8
3.0 General features	
3.1 Geography.....	10
3.2 Surface drainage.....	12
3.3 Geology	
3.3.1 Rocks of Tertiary age.....	14
3.3.2 Quaternary deposits.....	16
3.4 Soils.....	18
3.5 Land use.....	20
3.6 Climate	
3.6.1 Precipitation.....	22
3.6.2 Temperature.....	24
4.0 Coal resources	
4.1 Coal production.....	26
4.2 Coal ownership.....	28
5.0 Water use.....	30
6.0 Hydrologic data-collection networks	
6.1 Surface-water quantity.....	32
6.2 Surface-water quality.....	34
6.3 Ground-water observation wells.....	36

7.0 Surface water	
7.1 Streamflow	
7.1.1 Mean annual flow.....	38
7.1.2 Duration of flow.....	40
7.1.3 Floods.....	42
7.2 Surface-water storage.....	44
7.3 Surface-water quality	
7.3.1 Dissolved solids.....	46
7.3.2 pH.....	48
7.3.3 Dissolved sulfate.....	50
7.3.4 Dissolved boron.....	52
7.3.5 Suspended sediment.....	54
8.0 Ground water	
8.1 Availability of ground-water reports.....	56
8.2 Extent of aquifers.....	58
8.3 Ground-water quality.....	60
9.0 Water-data sources	
9.1 Introduction.....	62
9.2 National Water-Data Exchange (NAWDEX).....	64
9.3 WATSTORE.....	66
9.4 Office of Water-Data Coordination (OWDC).....	68
10.0 Supplementary information	
10.1 Streamflow-quantity stations.....	70
10.2 Streamflow water-quality stations.....	72
10.3 Ground-water observation wells.....	73
10.4 Selected reservoirs and lakes.....	75
11.0 List of references.....	78

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 data may be converted by using the following factors:

<u>Multiply inch-pound units</u>	<u>By</u>	<u>To obtain SI units</u>
acre	4,047	square meter
acre-foot	1,233	cubic meter
acre-foot per square mile	476.2	cubic meter per square kilometer
cubic foot	0.02832	cubic meter
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
foot squared per day	0.0929	meter squared per day
gallon	3.785	liter
gallon per minute	0.06309	liter per second
gallon per second	3.785	liter per second
inch	25.40	millimeter
inch per hour	25.40 2.54	millimeter per hour centimeter per hour
micromho per centimeter at 25°C	1.00	microsiemens per centimeter at 25°C
mile	1.609	kilometer
million gallons per day	0.04381 3,785	cubic meter per second cubic meter per day
square mile	2.590	square kilometer
ton (short, 2,000 pounds)	0.9072	metric ton

To convert degrees Fahrenheit (°F) to degrees Celsius (°C) use the following formula:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9.$$

HYDROLOGY OF AREA 46, NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES, NORTH DAKOTA

BY

M. G. CROFT AND ORLO A. CROSBY

ABSTRACT

This report is one of a series that describes the hydrology of coal provinces nationwide. The Northern Great Plains and Rocky Mountain Coal Provinces are divided into 20 separate reporting areas which are numbered 43 to 62. This report provides general hydrologic information for Area 46 using a brief text with accompanying maps, charts, or graphs. This information may be used to describe the hydrology of the general area of any existing or proposed mine. Some of the more obvious hydrologic problems of coal development that will need to be addressed before development are disruption of aquifers and potential contamination of streams, aquifers, and the atmosphere.

Area 46 is in northwestern North Dakota and is composed of parts or all of 14 hydrologic units based on surface-water drainage basins. The area is drained by the Missouri and Souris Rivers.

Lignite-bearing rocks of late Paleocene age underlie nearly all of Area 46. The thickest and most continuous lignite beds occur in the Sentinel Butte and Tongue River Members of the Fort Union Formation. Alluvial deposits and a veneer of glacial drift of late Pleistocene age overlie the lignite-bearing rocks.

The climate of the area is semiarid. Mean annual precipitation ranges from 13.9 to 17.8 inches.

Mean annual temperatures range from 37.7°F at Bowbells to 40.9°F at Williston. Mean monthly temperatures at Williston range from 8.3°F to 70°F. The growing season is about 125 days.

A fairly comprehensive data base for streamflow and water quality in streams is available for Area 46. Many of the small-stream monitoring sites have been operated during the last few years to provide a data base before coal development. With the exception of the Missouri River, which is controlled by several dams, both the quantity and quality of water varies greatly in all streams.

A ground-water observation network for water levels and water quality has been established through county ground-water resource investigations and other ground-water studies and provides an adequate data base.

Three activities within the U.S. Geological Survey identify and provide access to hydrologic data. These are the National Water-Data Exchange (NAWDEx), the National Water-Data Storage and Retrieval System (WATSTORE), and the Office of Water-Data Coordination (OWDC).

1.0 INTRODUCTION

1.1 Objective

Report Summarizes Available Hydrologic Information

Existing hydrologic conditions and sources of information are identified to aid in leasing decisions and in preparation of environmental-impact studies and mine-permit applications.

Hydrologic information (fig. 1.1-1) and analyses are necessary to aid in decisions to lease federally owned coal and for the preparation of the required environmental assessments and impact-study reports. The need for information and analysis has become even more critical with the enactment of Public Law 95-87, the "Surface Mining Control and Reclamation Act of 1977." This act requires an appropriate regulatory agency to issue mining permits based on the review of permit-application data supplied to assess hydrologic impacts. The need for data is partly fulfilled by this report, which generally characterizes the hydrology of a part of the Northern Great Plains Coal Province (Area 46). This report is one of a series that describes coal provinces nationwide.

General hydrologic information for Area 46 is provided by means of a brief text with accompanying maps, charts, graphs, or other illustrations

for each of a series of water-resources-related topics. The topical discussions of the report provide a description of the geology and the hydrology of the area. The information contained herein will be useful to Federal agencies in the leasing and management of Federal coal lands; surface-mine owners, operators, and others preparing permit applications; and regulatory authorities evaluating the adequacy of the applications.

The hydrologic information presented herein or available through sources identified in this report will be useful in describing the hydrology of the "general area" of any proposed mine. This hydrologic information may be supplemented by specific-site data as well as data from other sources to provide a detailed appraisal of the hydrology of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.



A. Will development change stream discharge?



B. What will the aquifers yield?

Figure 1.1-1 Hydrologic information is needed for decision making.

1.0 INTRODUCTION--Continued

1.2 Study Area

The Area Includes 10,900 Square Miles in the Northern Great Plains Coal Province

Area 46 is in the Williston structural basin in northwestern North Dakota.

Area 46 is a subarea of the Northern Great Plains Coal Province (fig. 1.2-1). It is in the Williston structural basin, the center of which is south of the area. The area includes about 10,900 square miles in all or part of Burke, Divide, Dunn, McHenry, McKenzie, McLean, Mountrail, Renville, Ward, and Williams Counties in northwestern North Dakota (fig. 1.2-1).

The area is drained on the south by the Missouri River and its tributaries. Lake Sakakawea was formed by damming the Missouri River in the early 1950's. The area on the east is drained by the Souris River and its tributaries. The Souris River flows into Hudson Bay by way of Lake Winnipeg.

NORTHERN GREAT PLAINS AND ROCKY MOUNTAIN COAL PROVINCES

Numbers represent project areas

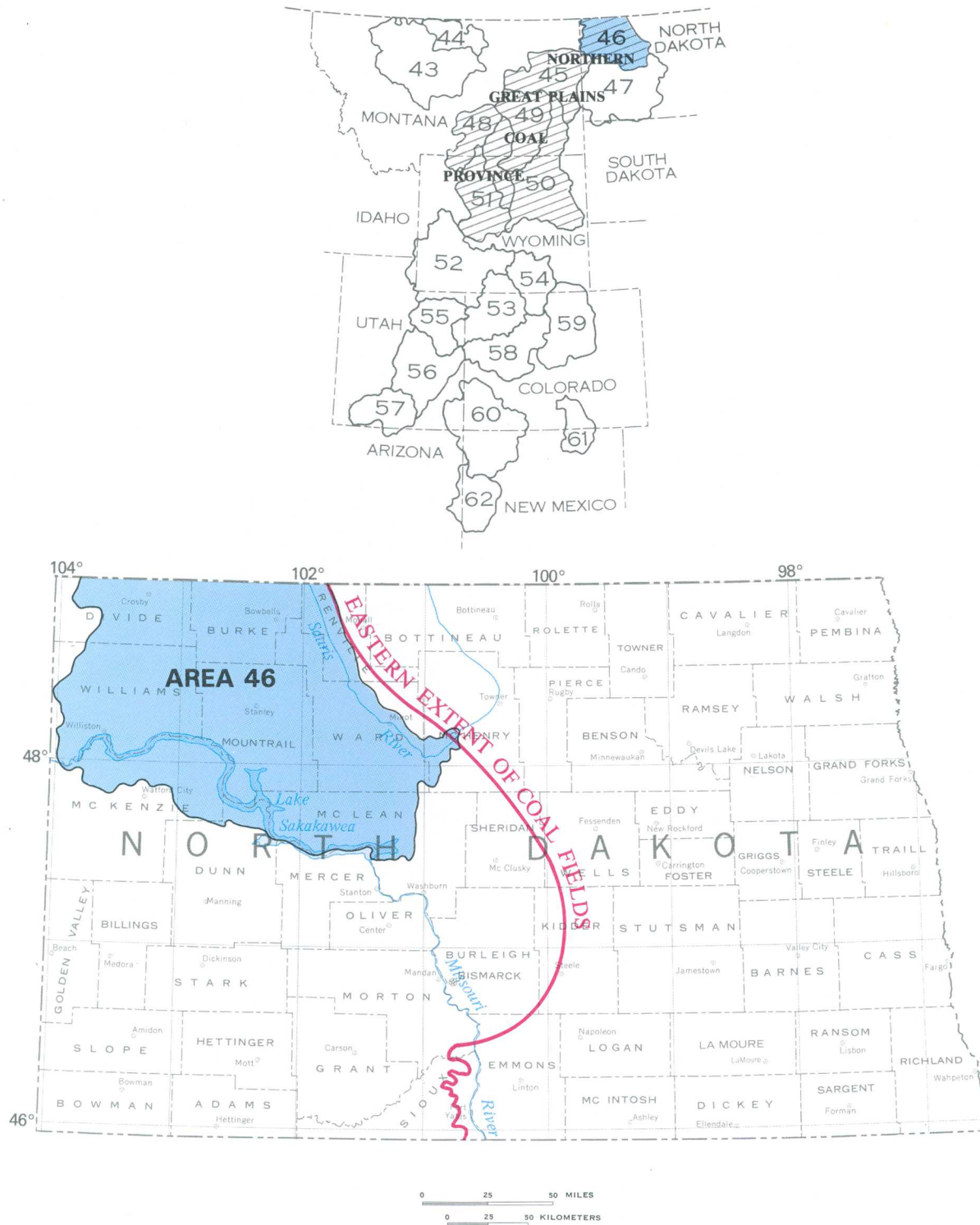


Figure 1.2-1 Location of study area.

1.0 INTRODUCTION--Continued

1.3 Hydrologic Problems

Hydrologic Problems Described for Area 46

Surface mining may cause water problems such as increased sedimentation, degradation of water quality, and local disruption of aquifers.

The use of coal as a source of energy has increased dramatically in the United States in the last decade because of the shortage of oil and gas. Development of coal will require expansion of surface mining, which can cause detrimental changes in the environment. Surface-mining activities, such as removal of vegetation and excavation of overburden, create spoil piles which erode easily and, if not controlled, contribute additional sediment to streams. Soluble minerals, such as gypsum, are exposed in spoil piles and may be dissolved by ground water and surface runoff, producing a highly mineralized effluent.

The net effects of increased sedimentation and increased mineralization will affect lakes and streams and could cause severe water problems (fig. 1.3-1). These problems include limitations on the domestic, municipal, industrial, and recreational use of water because of poor quality. Other effects include the local disruption or even loss of aquifers and air-quality problems. In addition, a decline of ground-water levels can occur in and near strip-mining areas where excavation extends below the water table. The decline in ground-water levels may cause some wells and springs to go dry.

The quality of ground water near mines also can be affected. Effects on ground-water quality at points remote from mining activities may take much longer to determine because of the slow movement of water in the subsurface. Surface mining has seriously affected water quality in many areas of the United States and the impact, especially in coal-mining areas in the eastern United States, is well documented in the literature where acid mine drainage has been studied. In North Dakota, oxidation of pyrite and marcasite in lignite beds of Tertiary age will result in the formation of sulfuric acid. However, calcium carbonate and bentonite in the soil buffers the acid and the resultant product downgradient from the mine is a water moderately high in dissolved solids (M. G. Croft, D. W. Fisher, and D. C. Thorstenson, written commun., 1979).

This report summarizes the geohydrology of part of the Northern Great Plains Coal Province. It provides a general framework for more detailed and site-specific studies that will be needed for a mining permit applicant to satisfy the requirements of the Surface Mining Control and Reclamation Act of 1977.



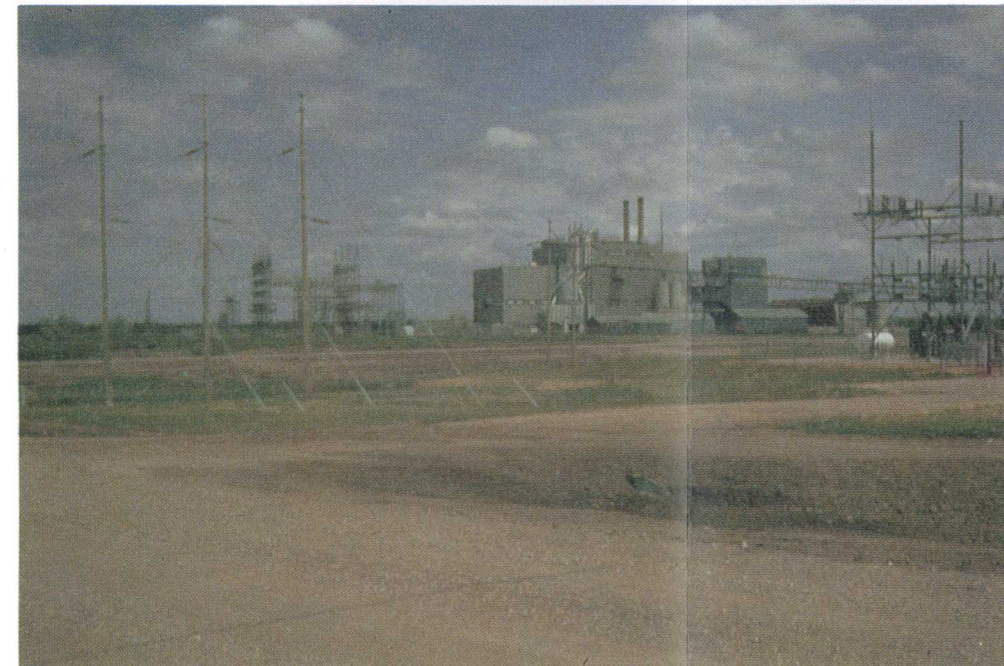
A. Abandoned mines are unsightly, decrease runoff, and limit land use.



B. Water has a high specific conductance in lakes at abandoned mines due to leaching spoils materials.



C. Unreclaimed spoils change runoff patterns and alter water chemistry.



D. Atmospheric emissions from generating plants may change the chemistry of precipitation and surface water.

Figure 1.3-1 Problems associated with lignite mining.

2.0 DEFINITION OF TERMS

Terms Used in Hydrologic Reports Defined

Technical terms that occur in this hydrologic report are defined.

Acre-foot—the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or about 326,000 gallons.

Aquifer—a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield a significant quantity of water to wells and springs.

Bedrock—consolidated or semiconsolidated rock underlying glacial and alluvial deposits of Pleistocene or Holocene age.

Crest-stage station—a particular site on a stream equipped with a device which will register the peak stage occurring between inspections of the gage.

Cubic foot per second—the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second or 449 gallons per minute.

Cubic foot per second per square mile—the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly in time and area.

Discharge—the volume of water (or more broadly, volume of fluid plus suspended material), that passes a given point within a given period of time.

Dissolved—refers to a substance in true chemical solution. In practice, however, the term includes all forms of substance that will pass through a 0.45-micrometer membrane filter and thus may include some very small (colloidal) suspended particles.

Drainage area—drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation may drain by gravity into the stream from areas upgradient from the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas within the area, unless otherwise noted.

Drainage basin—a part of the land surface that is occupied by a drainage system, which consists of a stream or a body of impounded surface water together with all tributary area, streams, and bodies of impounded surface water.

Gaging station—a particular site on a stream, canal, lake, or reservoir where systematic observations of hydraulic data are obtained.

Hydrologic unit—a geographic area representing part or all of a surface drainage basin as delineated by the U.S. Geological Survey, Office of Water-Data Coordination, on the State Hydrologic Unit Maps; each hydrologic unit is identified by an 8-digit number.

Instantaneous discharge—the discharge at a particular instant of time.

Mean discharge—the arithmetic mean of individual daily mean discharges during a specific period.

Micrograms per liter—a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter.

Milligram equivalents per liter (meq/L)—a unit

expressing the relative concentration of a chemical constituent in solution. It is calculated by dividing concentration values expressed in milligrams per liter by the combining weight (atomic or molecular weight of ion divided by the ionic charge) of the ion in question. In equivalents, unit concentrations of all ions are chemically equivalent.

Milligrams per liter—a unit expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of water. In dilute solutions 1 milligram per liter is equivalent to 1 part per million.

National Geodetic Vertical Datum of 1929 (NGVD of 1929)—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.

pH—indicates the degree of acidity or alkalinity of water and is expressed in terms of pH units. The pH value of a solution is the negative logarithm of the concentration of hydrogen ions, in moles per liter. A pH of 7.0 indicates that the water is neither acid nor alkaline. Values of pH progressively less than 7.0 denote increasing acidity and those progressively greater than 7.0 denote increasing alkalinity. A pH change from 7.0 to 6.0 corresponds to a tenfold increase in acidity and a pH change from 7.0 to 5.0 corresponds to a hundredfold increase in acidity. The pH of most natural surface waters ranges between 6 and 8.

Saturation—that condition of a solution in which the concentration of dissolved minerals can exist in equilibrium with the solid mineral phase.

Sediment—solid material that originates primarily from disintegrated rocks and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material, such as humus.

Specific conductance—electrical conductance or conductivity is the ability of a substance to conduct an electric current. The electrical conductivity of water is related to the ions in the water. Standard laboratory measurements report the conductivity of water in micromhos per centimeter at 25°C.

Streamflow—the discharge that occurs in a natural channel. Although the term “discharge” can be applied to the flow of a canal, the word “streamflow” uniquely describes the discharge in a surface stream course.

Stream order—a method of numbering streams as part of a drainage-basin network. The smallest unbranched mapped tributary is called first order, the stream receiving the tributary is called second order, and so on.

Transmissivity—the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Undersaturation—that condition of a solution which would result in dissolution on a solid mineral phase.

3.0 GENERAL FEATURES

3.1 Geography

Area 46 In Two Physiographic Provinces

The area is within the Great Plains and Central Lowland Provinces.

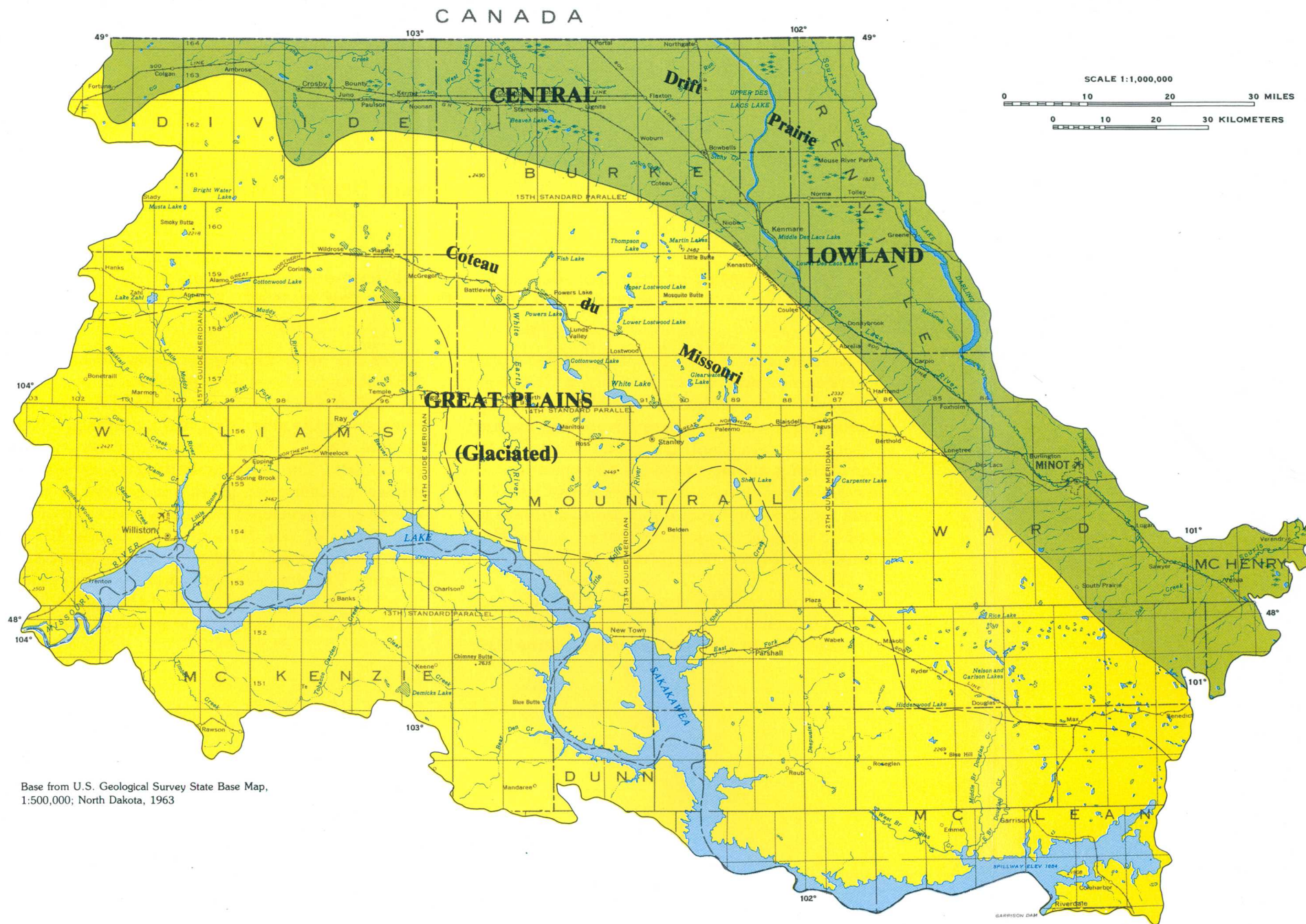
The study area is in the Great Plains Province and the Drift Prairie section of the Central Lowland Province. The Coteau du Missouri, a part of the Great Plains Province (fig. 3.1-1), is a series of elongated hills, ridges, sloughs, and prairie potholes that is bounded on the north by a scarp that grades into the Drift Prairie.

The topography of the glaciated Great Plains south of the Coteau is that of a slightly elevated plateau. Streams drain into the Missouri River. For several miles parallel to the river they are entrenched several hundred feet below the upland surface. The "badland" terrain bordering the river

is rugged and commonly referred to as the Missouri River escarpment.

The northeastern part of the area lies within the Drift Prairie section and is characterized by a northeastward sloping plain with a few low rounded hills and shallow depressions. The bedrock is deeply mantled with glacial debris. Streams drain into the Souris River.

The population of the area is about 100,000. Minot has a population of about 32,800 and Williston has a population of about 13,300 (U.S. Bureau of the Census, 1982).



Modified from Fenneman (1946).

Figure 3.1-1 Physiographic divisions.

3.0 GENERAL FEATURES--Continued

3.2 Surface Drainage

Missouri and Souris Rivers Drain Area 46

Most of the major tributaries of the Missouri and Souris Rivers in Area 46 drain areas with known coal reserves.

Area 46 is drained by the Missouri and Souris Rivers and several of their tributaries. The major tributaries draining the area are the Little Muddy, White Earth, and Des Lacs Rivers and Beaver, Tobacco Garden, Shell, Long, and Short Creeks. The drainage boundaries of the streams and some lower-order tributaries important to coal development are shown in figure 3.2-1. Drainage areas for specific sites on streams are given in the Supplementary Information (section 10.1).

The Missouri River drains about 7,400 square miles of Area 46, about 4 percent of the total drainage area at Garrison Dam where the river

leaves the area. The Souris River drains about 3,500 square miles of Area 46, about 31 percent of the total drainage area near Verendrye where the river leaves the area. Most of the drainage basins include large areas noncontributing to the streamflow. The noncontributing areas contain numerous undrained lakes and prairie potholes and have no developed stream systems. All of the tributaries of the Missouri and Souris Rivers shown in figure 3.2-1 drain areas with known coal reserves. Current development of the reserves has taken place at the upper ends of the basins, near basin divides, or along moraine scarps.

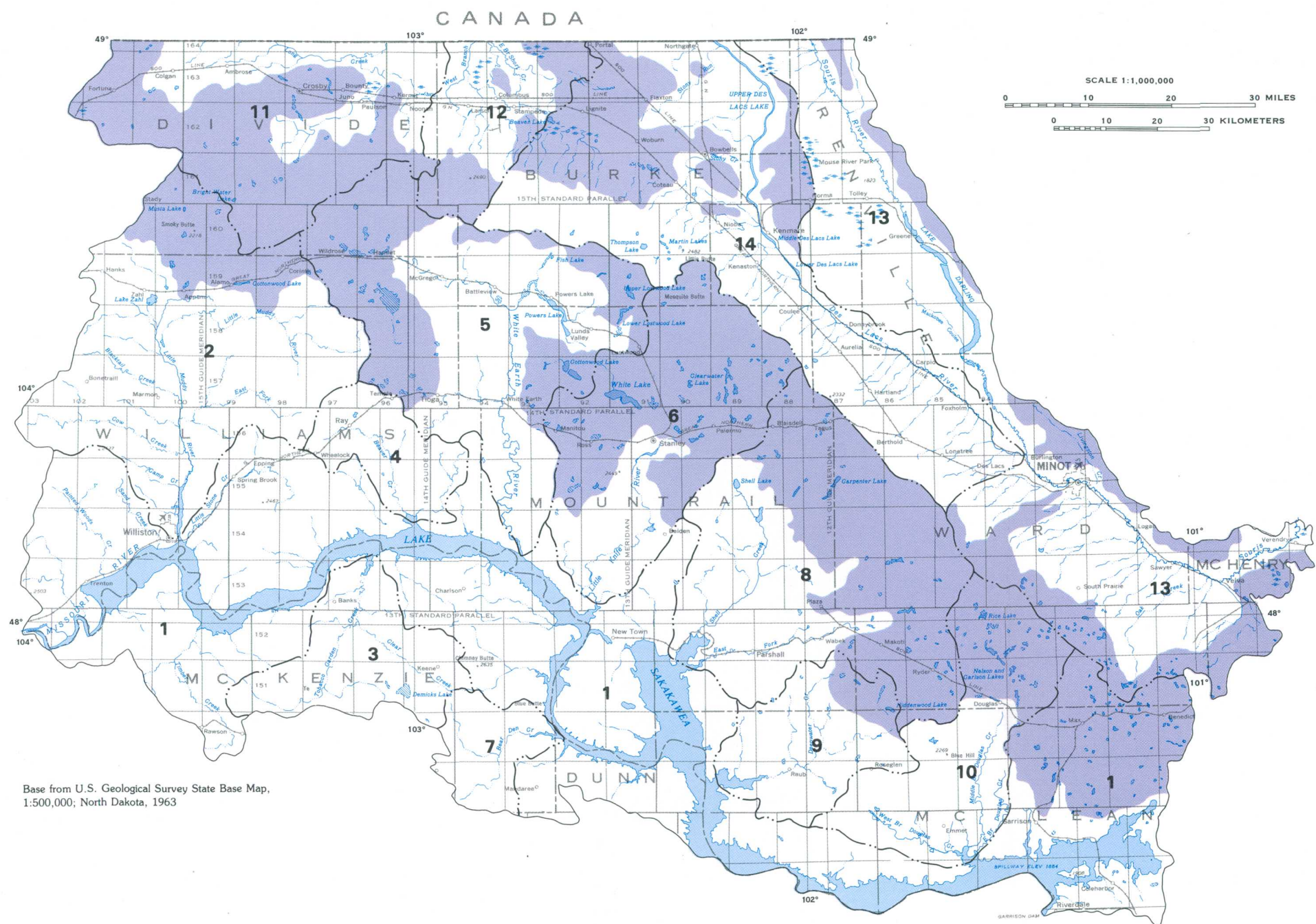


Figure 3.2-1 Drainage basins.

EXPLANATION

NONCONTRIBUTING AREA

BASIN BOUNDARY

DRAINAGE BASINS

- 1 Missouri River (mainstem)
- 2 Little Muddy River
- 3 Tobacco Garden Creek
- 4 Beaver Creek
- 5 White Earth River
- 6 Little Knife River
- 7 Bear Den Creek
- 8 Shell Creek
- 9 Deepwater Creek
- 10 Douglas Creek
- 11 Long Creek
- 12 Short Creek
- 13 Souris River (mainstem)
- 14 Des Lacs River

3.0 GENERAL FEATURES--Continued

3.3 Geology

3.3.1 Rocks of Tertiary Age

Coal-Bearing Rocks of Tertiary Age Exposed at the Surface

Rocks of Tertiary age consist of claystone, siltstone, sandstone, and lignite and will be disturbed by mining.

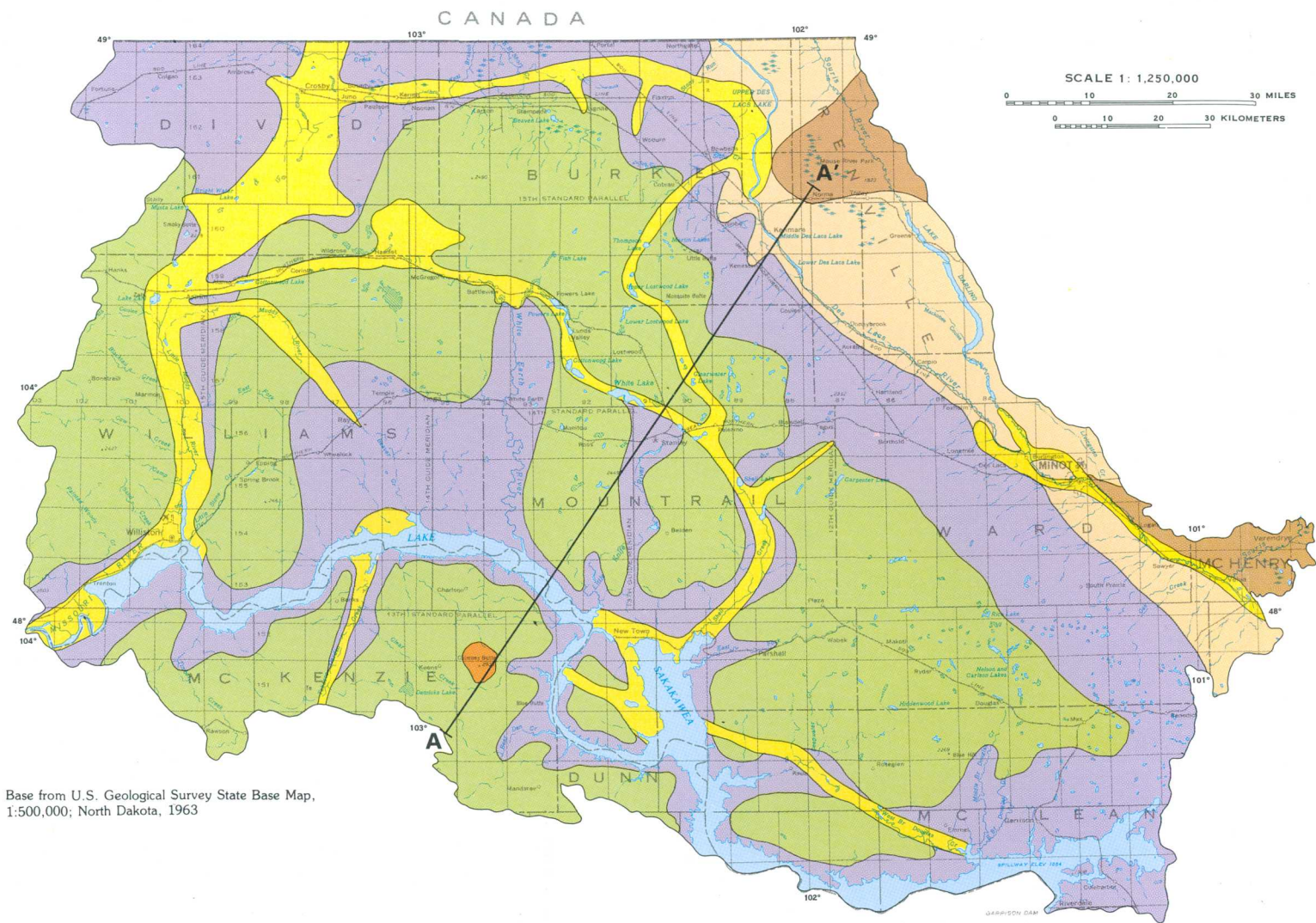
The coal-bearing rocks of Area 46 are in the Fort Union Formation (fig. 3.3.1-1) of late Paleocene age. Sedimentary rocks beneath the Fort Union Formation are about 12,000 feet thick (table 3.3.1-1). The Fort Union Formation, as much as 1,800 feet thick, is a deltaic and marine sequence of claystone, siltstone, sandstone, and lignite, 55 to 63 million years old. The thickest and most continuous beds of lignite are in the Tongue River and Sentinel Butte Members. Lignite beds may be as much as 20 feet thick. The Tongue River and Sentinel Butte Members will be disturbed by mining.

The Golden Valley Formation conformably overlies the Fort Union and is about 200 feet thick. It consists of sandstone, siltstone and claystone.

The Golden Valley Formation does not contain lignite. The White River Group and Arikaree Formation occur as thin deposits only on high buttes. Small, thin deposits of the Flaxville Formation¹, a terrace deposit of sand, gravel, and clay, overlie the Fort Union Formation high on the bluffs along the Missouri River south of Williston and on some stream divides elsewhere in the area.

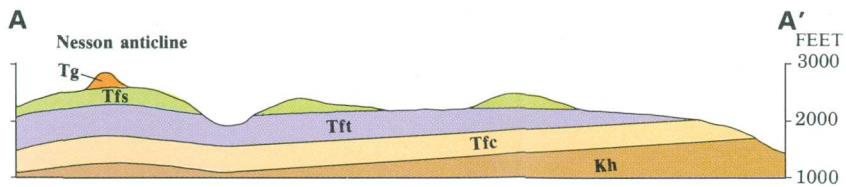
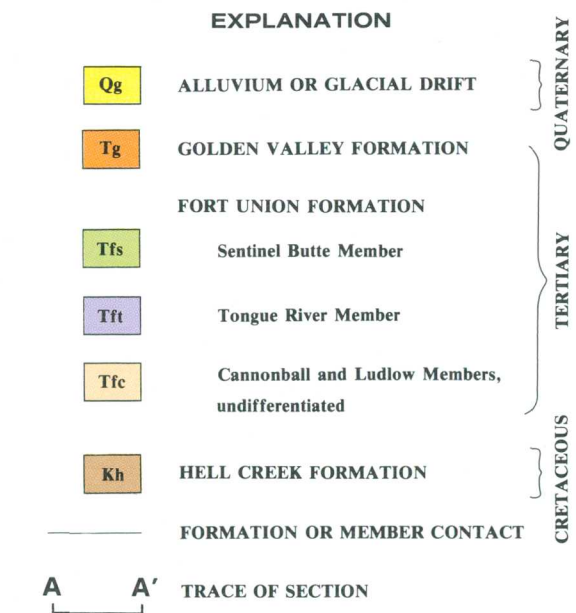
The rocks in Area 46 generally dip gradually to the south and southwest, except in the central part where they are folded into the Nesson anticline. The Nesson anticline is a large structural feature that is a prolific oil producer from rocks of Paleozoic age.

¹ Two small exposures of the Flaxville (?) Formation have been mapped north of Williston by Howard (1960, pl. 1). Also see Denson and Gill, 1965. Due to burial by till, and the dense vegetative cover, the Flaxville Formation is not widely exposed in North Dakota.



Base from U.S. Geological Survey State Base Map, 1:500,000; North Dakota, 1963

Modified from Carlson (1973).



Generalized geologic section A-A'.

Figure 3.3.1-1 Geologic map.

Table 3.3.1-1 Generalized stratigraphic column.

Erathem	System or series	Age estimates of boundaries (million years)	Geologic name	Maximum thickness (feet)	Lithology
Cenozoic	Quaternary	0.010		50	Alluvium: sand, gravel, and clay.
				300	Glacial drift: Sand, gravel, clay, and till.
	Tertiary	2	Cartwright Gravel	100	Sand, gravel, and clay on elevated terraces and above streams.
			Flaxville (?) Formation	100	Sand, gravel, and clay on highest terraces and benches.
		5	Arikaree Formation	50	Sandstone, siltstone, and shale.
		24	White River Group	50	Sandstone, siltstone, and shale.
		38	Golden Valley Formation	200	Sandstone, siltstone, and claystone.
	Paleocene	55	Sentinel Butte Member	600	Sandstone, siltstone, claystone, and lignite.
			Tongue River Member	600	Sandstone, siltstone, claystone, and lignite.
			Cannonball Member	200	Claystone and siltstone.
			Ludlow Member	400	Sandstone, siltstone, claystone, and lignite.
Mesozoic	Cretaceous	63	Hell Creek Formation	300	Sandstone, siltstone, claystone, and lignite.
			Fox Hills Sandstone	200	Sandstone, siltstone, and claystone.
			Pierre Shale	2,300	Shale, black, gray.
			Undifferentiated ¹	2,100	Shale and sandstone.
	Jurassic	138	Undifferentiated	1,100	Shale and sandstone.
Paleozoic	Triassic	205	Undifferentiated	450	Shale and sandstone.
		~240	Undifferentiated	5,500	Carbonates, shale, and sandstone; oil producing.
	Precambrian	~570			Crystalline rock.

¹ Undifferentiated for this report. The rocks are subdivided in reports of numerous oil and gas investigations.

3.0 GENERAL FEATURES--Continued

3.3 Geology--Continued

3.3.2 Quaternary Deposits

Glacial Drift and Alluvial Deposits of Quaternary Age Consist of Sand, Gravel, Silt, and Clay

Thick deposits of sand and gravel in stream and glacial valleys are major aquifers.

Overlying the Tertiary rocks are alluvial deposits in the stream valleys and a veneer of glacial drift in the uplands (fig. 3.3.2-1A). The drift deposits are the result of several successive glacial episodes late in the Pleistocene Epoch. In the uplands, much of the coarse glacial material is thin, and patches as much as 50 feet thick rarely

are found. The coarse upland deposits and the Cartwright Gravel deposits cannot be shown on the scale provided by figure 3.3.1-1. Outwash and alluvial deposits, as much as 200 feet thick, consist of sand and gravel and occur in many stream and glacial valleys, as shown in figure 3.3.2-1B.



A. Till overlying gravel deposit of Flaxville (?) Formation on upland surface.



B. Stream valley below the terrace of Cartwright Gravel contains thick alluvial material.

Figure 3.3.2-1 Glacial-drift and alluvial deposits are prominent features in Area 46.

3.0 GENERAL FEATURES--Continued

3.3 Geology--Continued

3.3.2 Quaternary Deposits

3.0 GENERAL FEATURES--Continued

3.4 Soils

Soils in Area 46 Developed on Three Types of Material

The soils in upland areas have dark-brown calcareous subhorizons and are highly productive.

The soils in the uplands of Area 46 are represented by the Chernozems and Chestnuts (fig. 3.4-1). They are derived from glacial debris, have black to dark-brown profiles several feet thick, and a calcareous C horizon. They are fertile, productive, and support a wide variety of native grasses. These soils are prized for crop production.

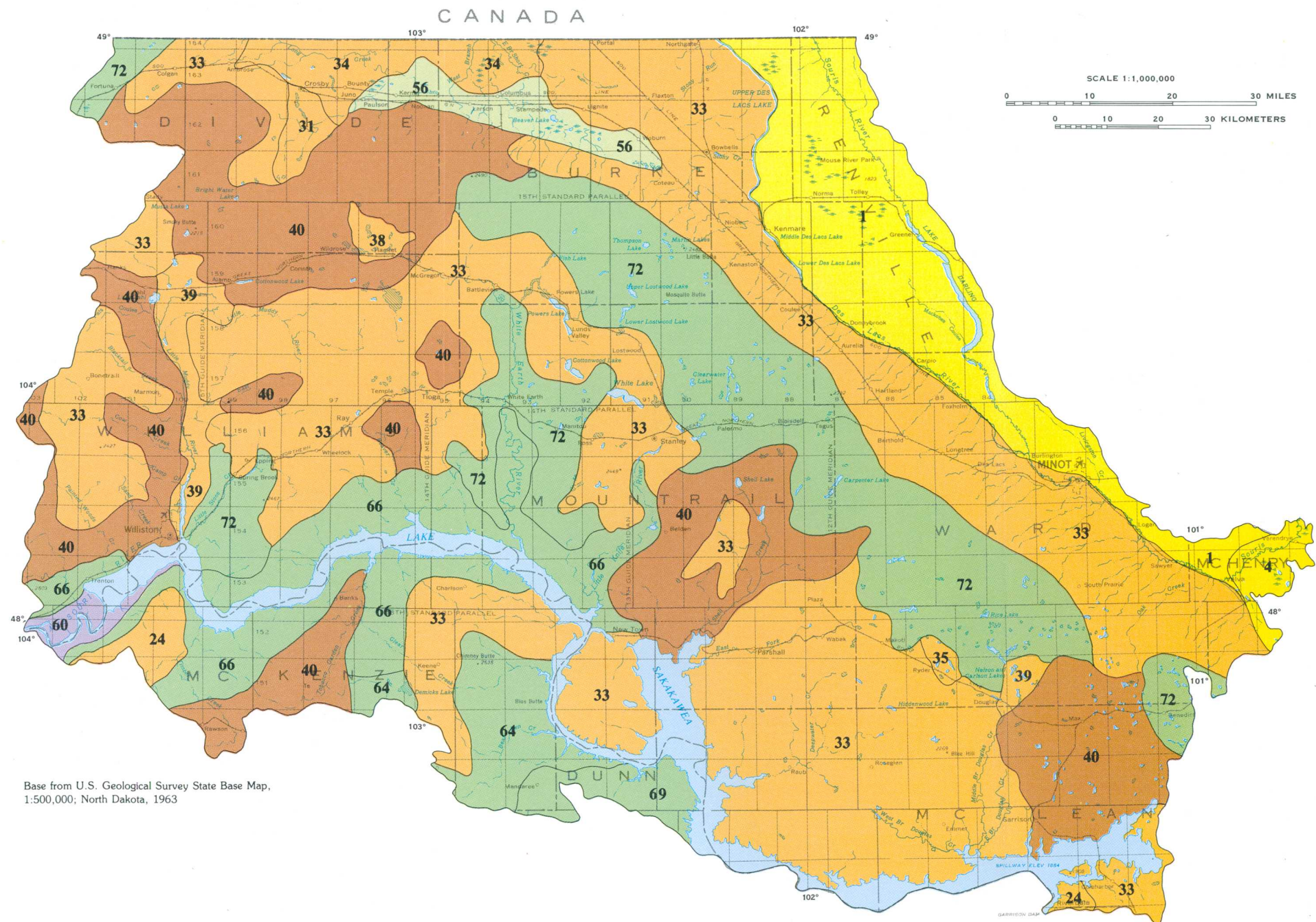
The Solonetz soils have developed in areas of restricted drainage and excessive sodium. Profiles are typically gray, crumbly, and the B horizon may contain gypsum and other soluble salts. Areas with these soils are used mainly as pasture.

Alluvial soils are in the bottomlands of most streams. Only in the Missouri River valley above Lake Sakakawea are they extensive enough to be shown at the scale of figure 3.4-1. Alluvial soils

have brown or grayish-brown calcareous profiles and generally are productive.

Regosol soils occur on steep slopes where runoff is rapid. They are derived mainly from the underlying rocks of Tertiary age. These soils have thin dark calcareous profiles and have limited productivity. They are used mainly for pastureland.

Soils derived from glacial materials generally are calcic, which makes revegetation of mine spoils relatively easy. Soils derived from bedrock materials are sodic and revegetation of spoils is more difficult. Strip-mining regulations require that the original soil material must be removed during the stripping process and saved for replacement because of the sodium problem.



Modified from Orndt and others (1968).

EXPLANATION

- CHERNOZEMS (Black soils of semihumid grasslands)**
- Loams and clay loams
- 1 Barnes
 - 4 Barnes-Svea
- CHESTNUTS (Black soils of semiarid grassland)**
- Loams and clay loams
- 24 Agar-Williams-Zahl
 - 31 Roseglen
 - 33 Williams
 - 34 Williams-Cresbard
 - 35 Parshall-Lihen
- Sandy loams and loams with sandy and gravelly substrata
- 38 Oahe-Roseglen
 - 39 Oahe-Sioux
- CHESTNUTS (Soils with thick dark-brown surface layers associated with steep slopes and thin regosols)**
- Loams
- 40 Williams-Zahl
- SOLONETZ (Alkali soil with gray claypan subsoil)**
- Loams and clay loams
- 56 Cresbard-Cavour
- ALLUVIAL (Soils of stream valleys)**
- Loams and sandy loams
- 60 Havre-Banks
- REGOSOLS (Hilly and steep land)**
- 64 Bainville-Morton
 - 66 Bainville-Zahl
 - 69 Flasher-Vebar
 - 72 Zahl-Williams

Figure 3.4-1 Soils map.

3.0 GENERAL FEATURES--Continued

3.5 Land Use

Range and Cropland are the Dominant Land Uses

Eighty-eight percent of Area 46 is used for range and cropland.

Area 46 includes about 10,900 square miles. About 28 percent of the land is used for rangeland and 60 percent is used for cropland. The main agricultural products are beef, milk, wheat, hay, oats, barley, and sunflowers. Of the remaining 12 percent, about 1 percent is used for pasture, 1 percent is woodland, 5 percent is other noncrop Federal land (includes national parks, rangeland, forests, and game refuges), and 5 percent is used for other purposes (includes urban and developed areas, small water areas including ponds and lakes of more than 2 acres but less than 40 acres in size,

rural nonresidences, farmsteads, farm roads, feedlots, and unused marshes). Large water areas are excluded from the total land use.

The distribution of land use per county is shown in figure 3.5-1. Land use in most counties is similar to land use on a statewide basis. No attempt was made to prorate land use for parts of counties in the area. The data were supplied by the U.S. Department of Agriculture, Soil Conservation Service (1970).

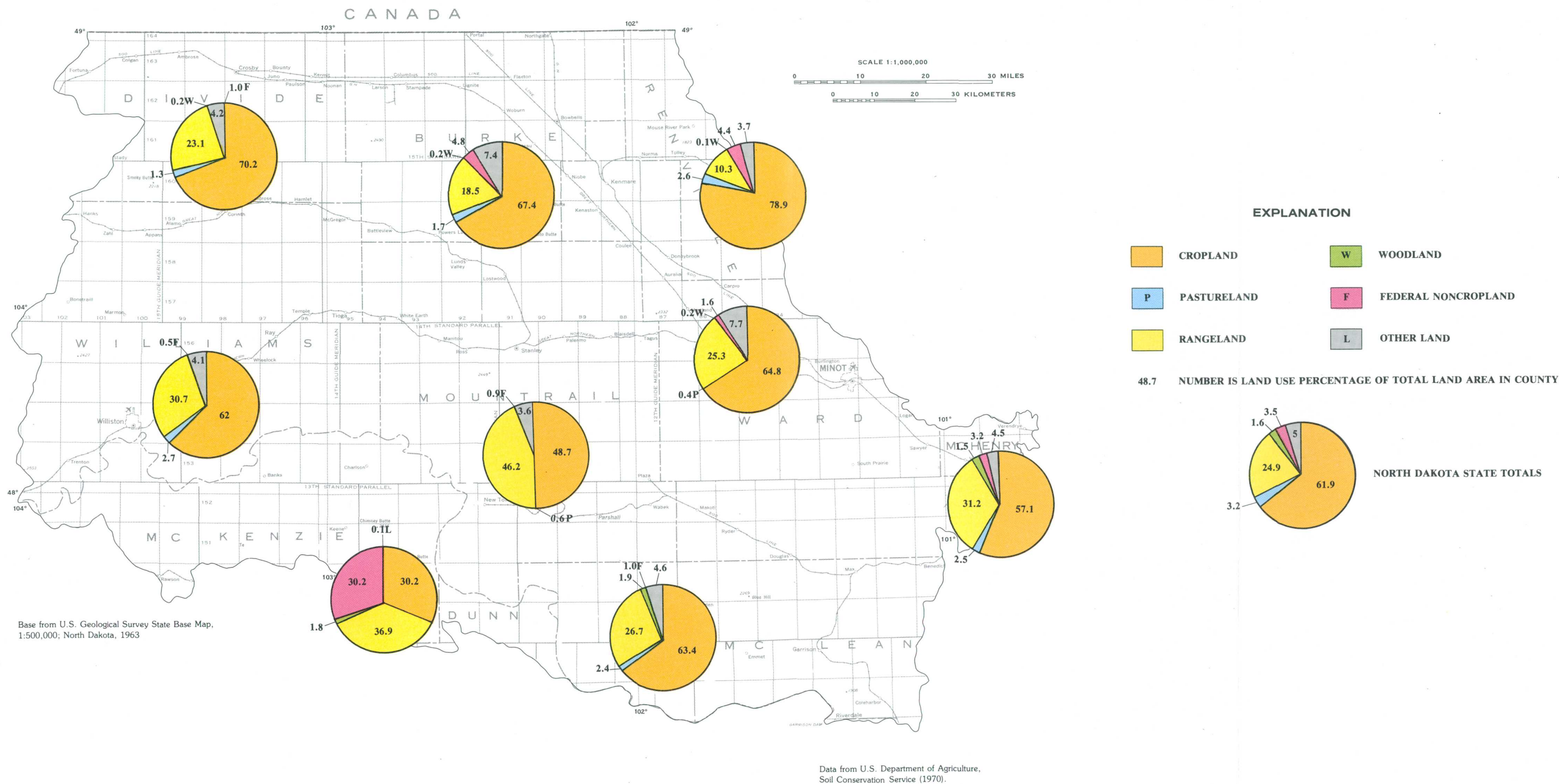


Figure 3.5-1 Land use.

3.0 GENERAL FEATURES--Continued

3.6 Climate

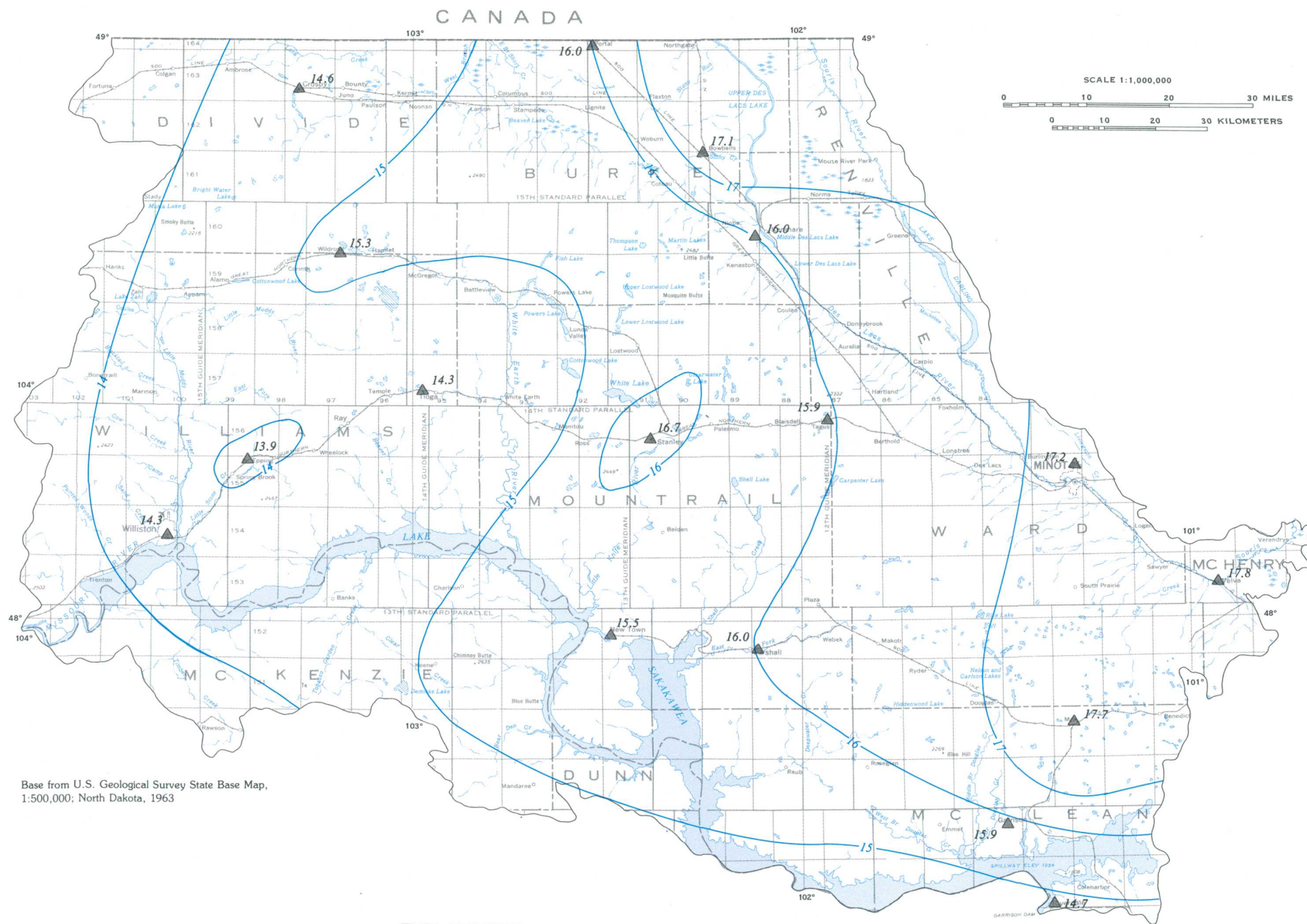
3.6.1 Precipitation

Most of the Precipitation Falls in the Spring and Summer

Mean annual precipitation in the study area ranges from 13.9 to 17.8 inches.

Area 46 is semiarid. The mean precipitation ranges from 13.9 inches per year in the western part of the area to 17.8 inches per year in the southeastern part (fig. 3.6.1-1). Monthly precipitation data at Williston show that about 70 percent falls in the spring and summer during the growing season. Much of the summer precipitation occurs as thunderstorms, which can be intense and accompanied by hail. Precipitation in the winter is light.

The precipitation data were compiled from the records of the National Weather Service precipitation recording stations in the area. Daily precipitation data are published monthly by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), U.S. Environmental Data Service, National Climatic Center, Asheville, N.C. Summary tables for this report were obtained from the U.S. Department of Commerce (1973).

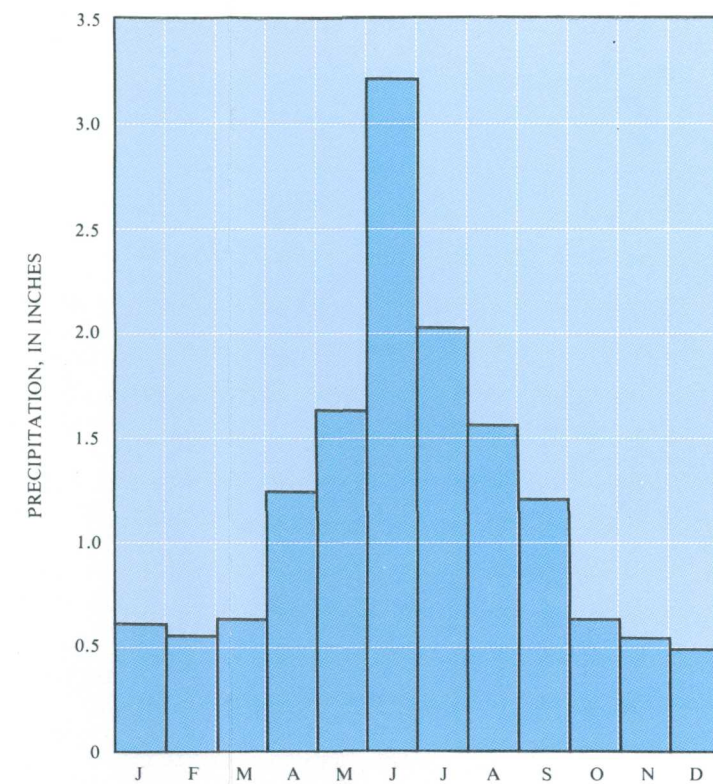


EXPLANATION

- 14— LINE OF EQUAL MEAN ANNUAL PRECIPITATION
Interval 1 inch
- ▲ 16.0 CLIMATOLOGICAL STATION
Number is mean annual precipitation

Data from U.S. Department of Commerce (1973).

Figure 3.6.1-1 Precipitation data.



Mean monthly precipitation at Williston, North Dakota.

3.0 GENERAL FEATURES--Continued

3.6 Climate--Continued

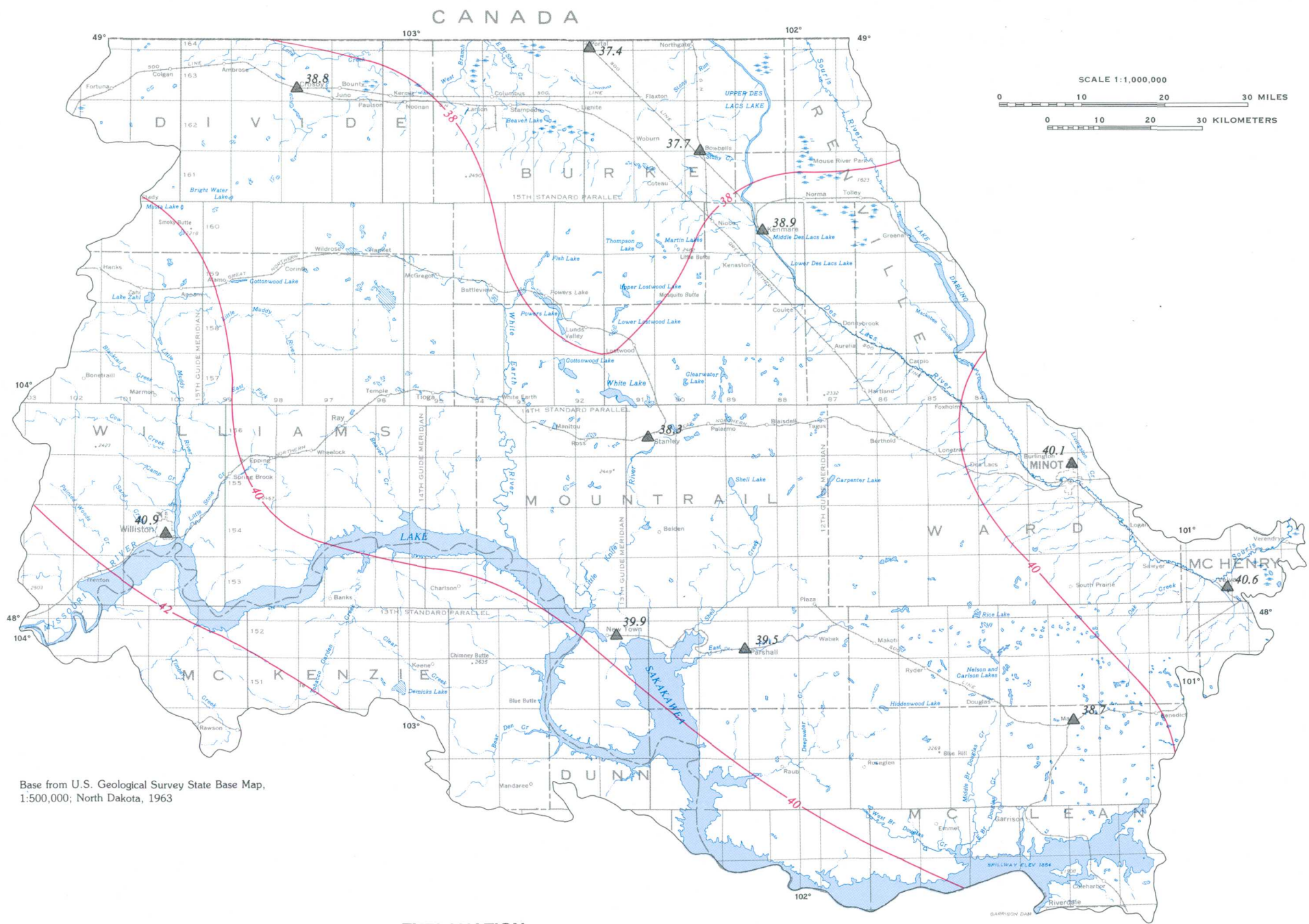
3.6.2 Temperature

Highest Temperatures Occur in July and Lowest in January

The mean annual temperature in the area ranges from 37.7°F to 40.9°F.

The mean annual temperatures in Area 46 are cool; they range from 37.7°F at Bowbells, in the northeastern part of the area, to 40.9°F at Williston, in the southwestern part (fig. 3.6.2-1). The mean monthly temperatures at Williston range from 8.3°F to 70.1°F. The highest temperatures occur in July, when extremes of

about 100°F occur, and the lowest in January, when extremes of -40°F are common. The growing season is about 125 days. The data were obtained from published records of the National Weather Service (U.S. Department of Commerce, 1973).



EXPLANATION

- 38 — LINE OF EQUAL MEAN ANNUAL TEMPERATURE
Interval 2°F
- ▲ 39.5 CLIMATOLOGICAL STATION
Number is mean annual temperature

Data from U.S. Department of Commerce (1973).

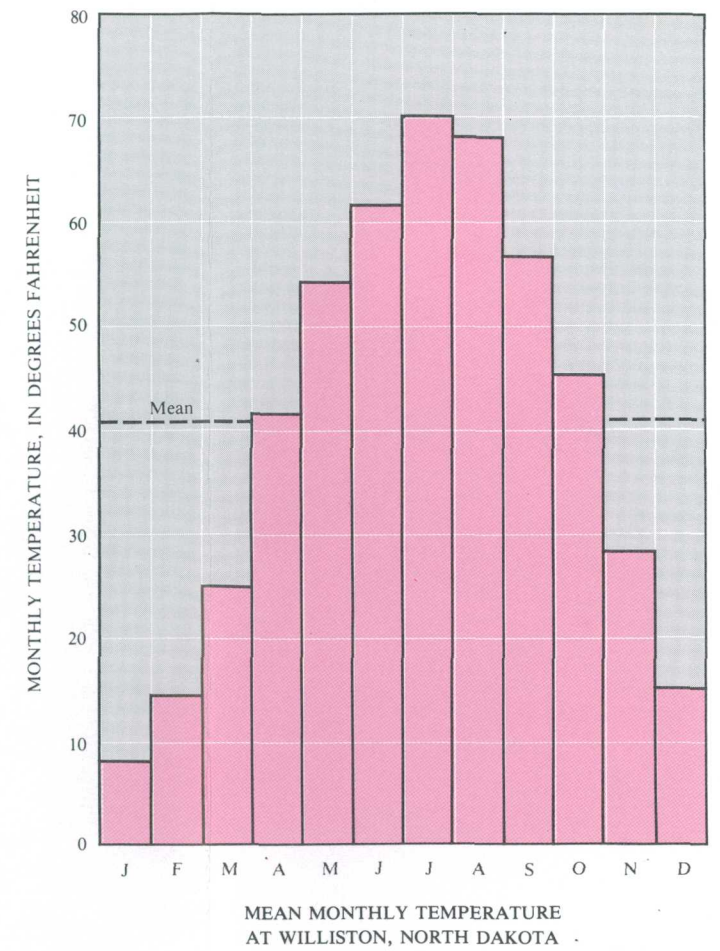


Figure 3.6.2-1 Temperature data.

4.0 COAL RESOURCES

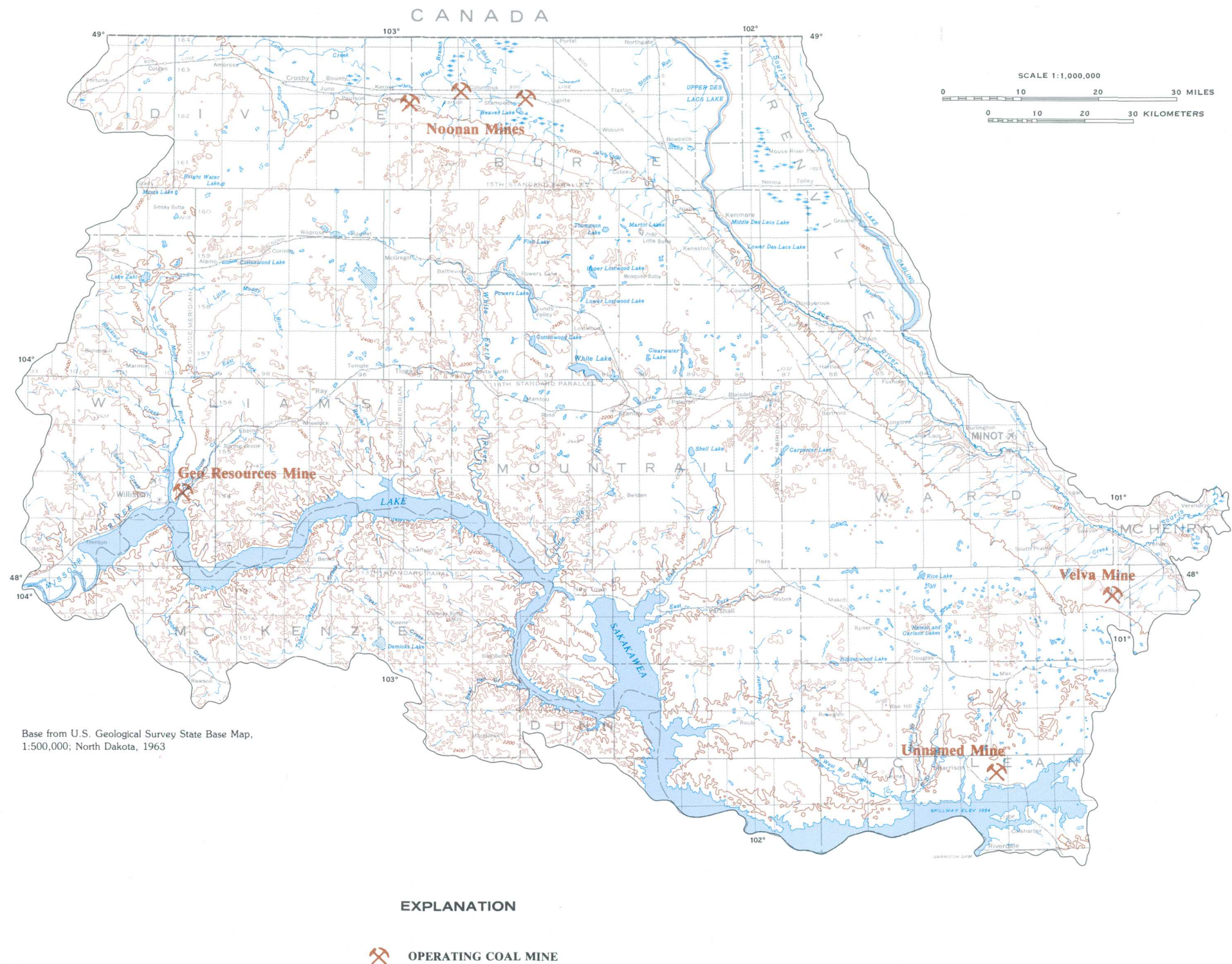
4.1 Coal Production

Production of Lignite is by Strip Mining

Production of lignite currently is a little more than one-half million tons per year in Area 46.

North Dakota is a major producer of lignite coal. The lignite has a low sulfur content, which makes it desirable for use in electric generating plants. Production is by stripping and tonnage varies considerably from year to year. On a state-wide basis, production increased rapidly from 8.2 million tons during July 1975 to June 1976 to 16.8 million tons during July 1979 to June 1980. However, during this period a decrease in coal production occurred in Area 46. In 1974, two mines

in Area 46, the Noonan and Velva, produced about 1,000,000 tons of lignite (fig. 4.1-1). In 1981, three mines, the Noonan, Velva, and Geo Resources, produced only 550,000 tons of lignite. Production was down from previous years due to a slump in the economy. Most of the lignite mined at Velva is burned locally in a generating plant. The production at the Geo Resources mine is mainly for leonardite (weathered lignite), which is valued for its high gypsum content.



Dragline removing overburden at Velva Mine.

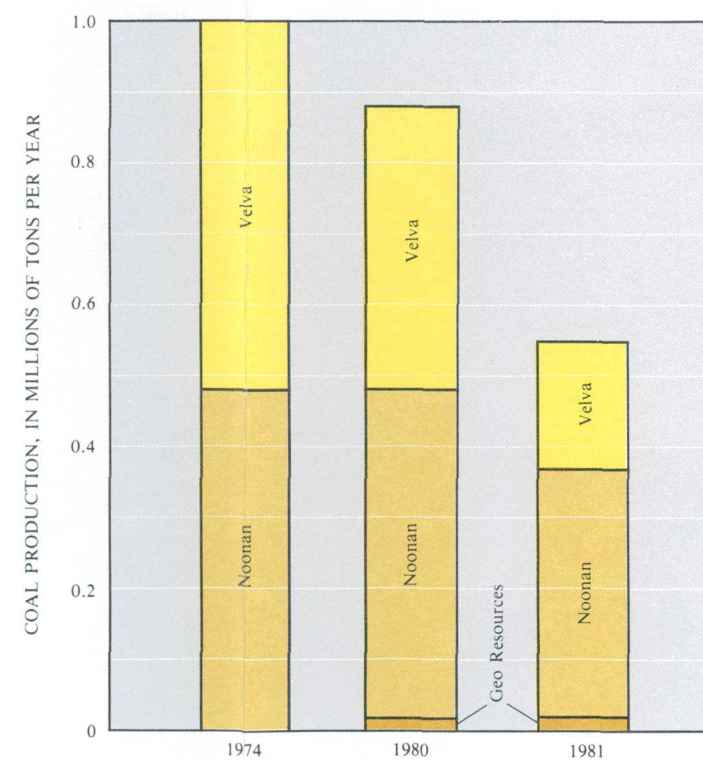


Figure 4.1-1 Coal production and mine locations.

4.0 COAL RESOURCES--Continued

4.2 Coal Ownership

Federal Ownership is in a Checkerboard Pattern

The Federal government owns approximately 23 percent of the lignite in Area 46.

Approximately 16 percent of the lignite coal deposits underlying 15.6 million acres in western North Dakota is federally owned. The State of North Dakota generally owns less than 1 percent of the coal. State ownership, for the most part, consists of school lands. The remainder of the coal is privately owned.

The Federal government owns coal rights in approximately 23 percent of the subsurface area in

Area 46 (fig. 4.2-1), but most of the land surface is in private ownership. Percentage of Federal ownership, by county, is greatest in the southwestern part of the area (fig. 4.2-1) and is least in the east. Federal ownership of coal is in a checkerboard pattern, as shown in figure 4.2-2.

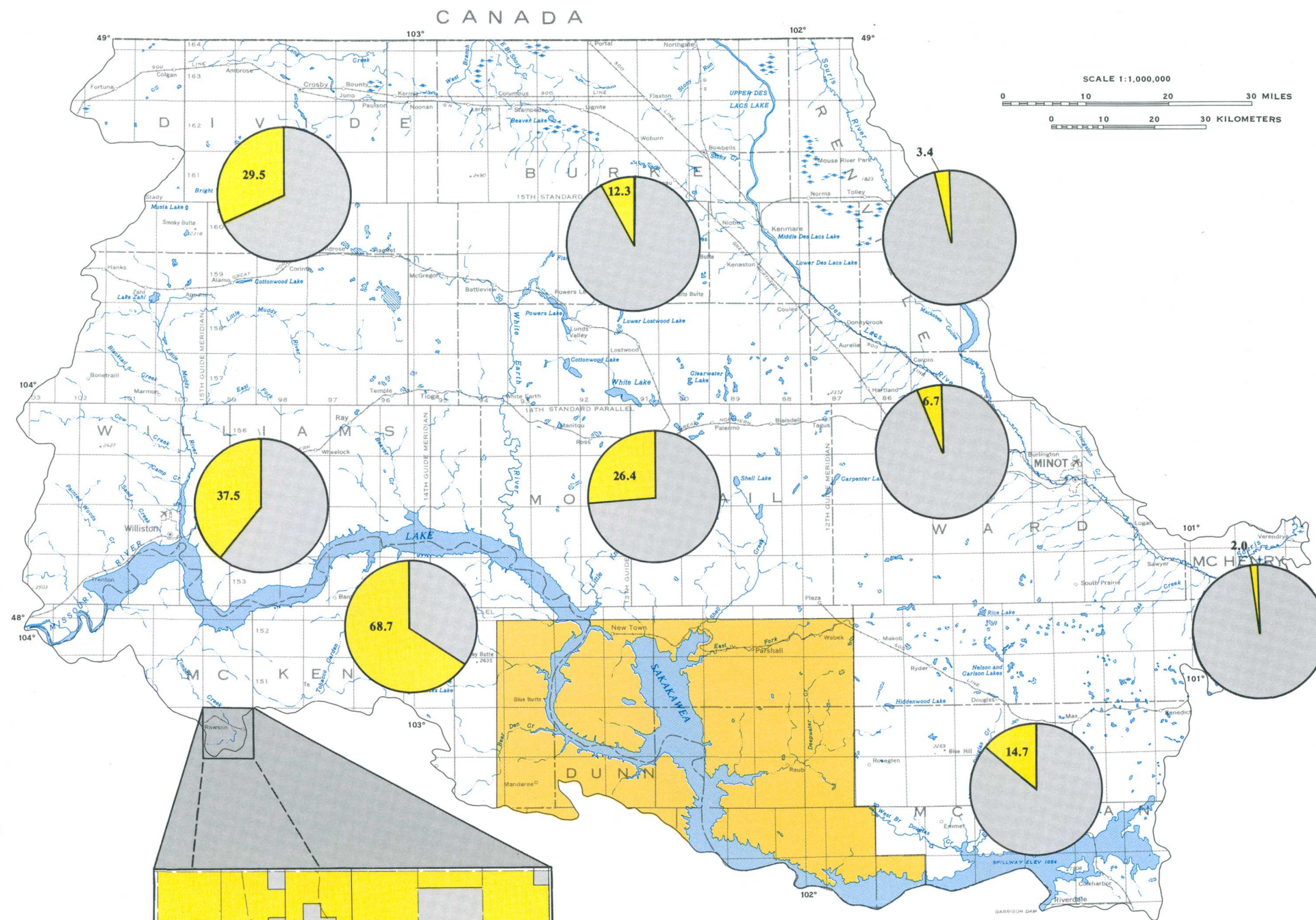


Figure 4.2-1 Federal ownership of coal.

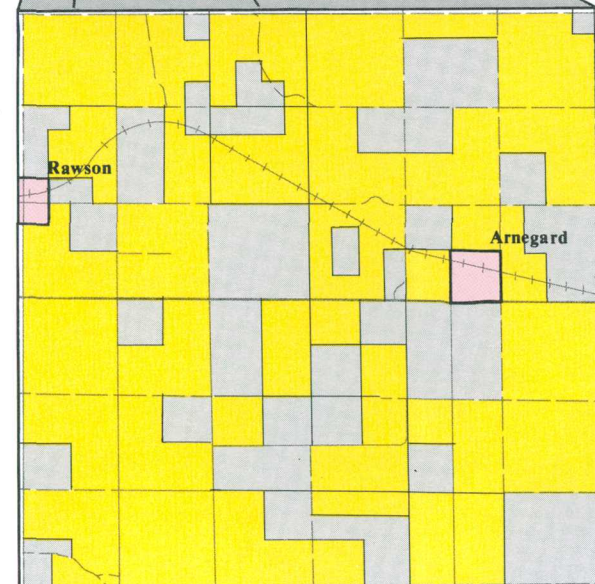


Figure 4.2-2 Typical checkerboard pattern of coal ownership, Township 150 N., Range 100 W.

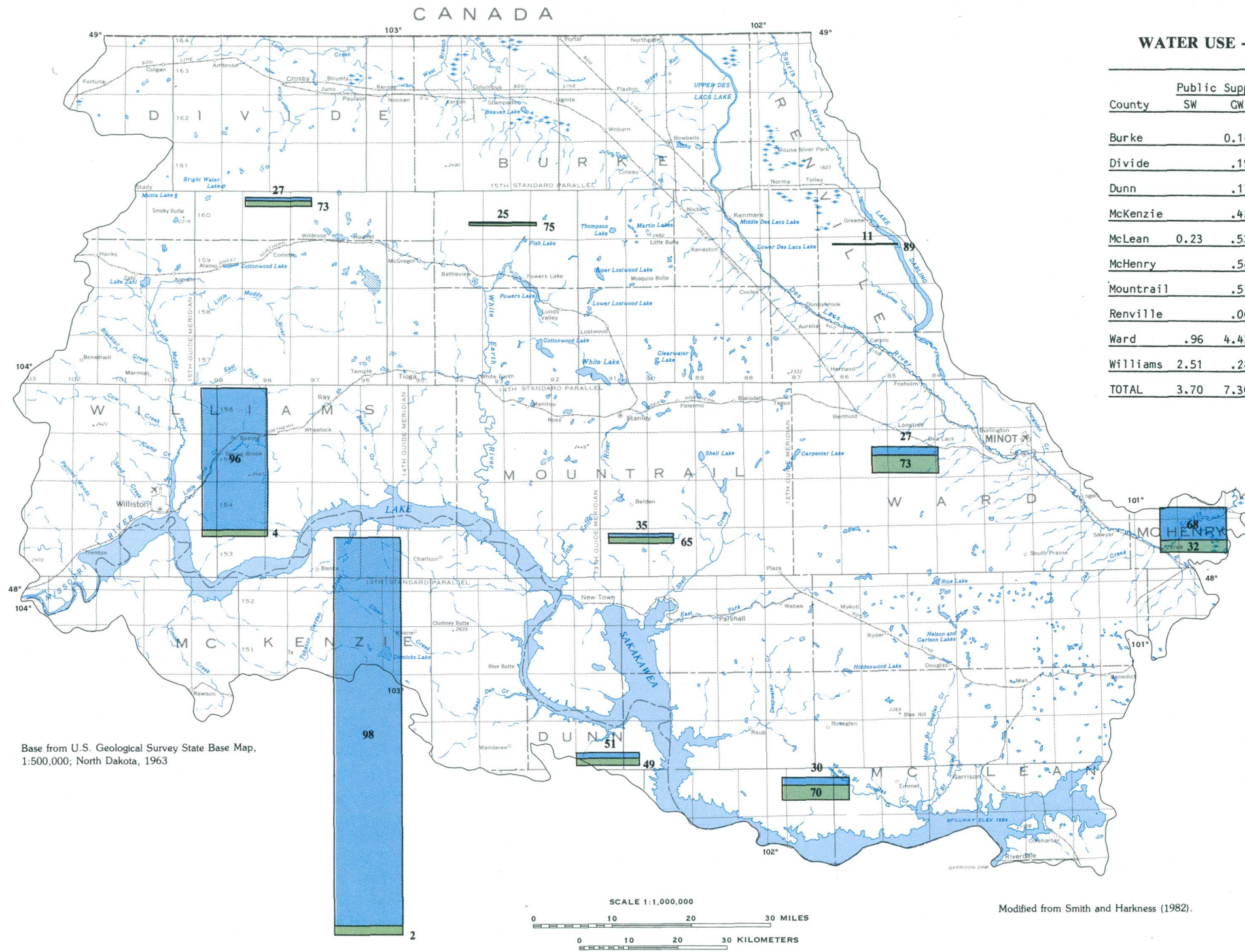
5.0 WATER USE

Principal Water Use is for Irrigation

Surface water supplies 89 percent of the total water use in Area 46.

About 210 million gallons of water per day is obtained from ground- and surface-water sources for use in Area 46. Most of the surface water is used for irrigation, as shown by the table in figure 5.0-1, and is obtained from the Missouri River and Lake Sakakawea. Ground water supplies only 11 percent of the total water used in the area. Areas that do

not border on Lake Sakakawea or the Missouri River depend on wells for about three-fourths of their water needs. The city of Williston obtains water from Lake Sakakawea, but most of the remaining cities and towns obtain water supplies from ground-water sources.

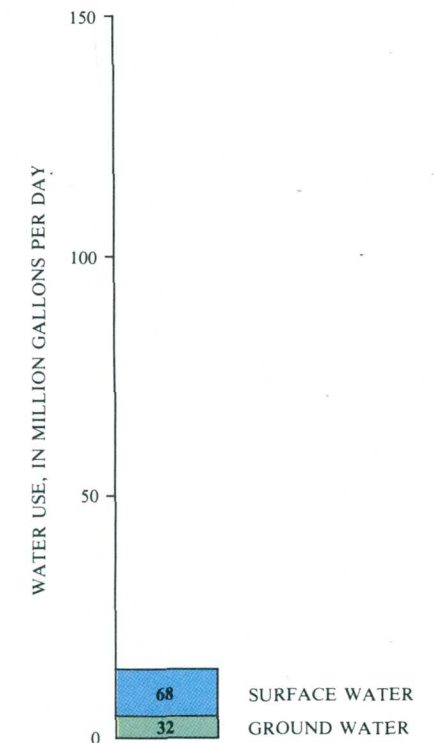


WATER USE - 1980 CALENDAR YEAR IN MILLION GALLONS PER DAY (Mgal/d).

County	Public Supply		Irrigation		Rural		Industrial		Total Use		Total
	SW	CW	SW	CW	SW	CW	SW	CW	SW	CW	
Burke		0.14	0.06		0.06	0.22			0.12	0.36	0.48
Divide		.19	.52	1.12	.06	.24			.58	1.55	2.13
Dunn		.17	.73	0.07	.43	.89	0.01	0.01	1.17	1.14	2.31
McKenzie		.42	¹ 123.13	.83	.29	.75	.03	.03	123.45	2.03	125.48
McLean	0.23	.52	1.85	3.7	.14	.73	.02	.18	2.24	5.13	7.37
McHenry		.58	8.93	2.87	.28	.82			9.21	4.27	13.48
Mountrail		.51	.43	.08	.16	.49			.59	1.08	1.67
Renville		.06			.04	.27			.04	.33	.37
Ward	.96	4.43	.92	.26	.17	1.14	.15	.12	2.20	5.95	8.15
Williams	2.51	.28	42.41	1.38	.15	.44	.46	.02	45.53	2.12	47.65
TOTAL	3.70	7.30	178.98	10.31	1.78	5.99	.67	.36	185.13	23.96	209.09

¹ 114.27 Mgal/d was imported from Montana for irrigation.

EXPLANATION



NUMBERS ARE PERCENTAGES OF TOTAL WATER USE SUPPLIED BY GROUND WATER AND SURFACE WATER

Figure 5.0-1 Water use in 1980.

6.0 HYDROLOGIC DATA-COLLECTION NETWORKS

6.1 Surface-Water Quantity

Streamflow Information is Available for 36 Locations

Surface-water data collected through the years has resulted in a fairly comprehensive data base.

The surface-water data-collection network in Area 46 started with the establishment of stations on the Souris, Des Lacs, and Little Muddy Rivers in 1903-04. A station was established on the Missouri River near Williston in April 1905. Though all are presently in operation, the only continuous record from 1903 to present is on the Souris River above Minot. The number of continuous-record stations has fluctuated, but generally increased with time to the present (1982) coverage (fig. 6.1-1 and section 10.1). The first stations were established as part of a water-accounting system on the mainstem Missouri and Souris Rivers and the major tributaries. Additional stations were subsequently established on these tributaries and other streams as demands on the supply of water increased. The early established stations provide a long-term record from which streamflow statistical information can be obtained. The long-term records also can be used to extend incomplete or short-term records using correlation techniques. However, regulation, storage, or diversion has occurred on many streams rendering invalid the use of parts of long-term records in defining streamflow characteristics.

Interest in low flow characteristics during the early 1950's resulted in a program of periodic measurements of low-flow discharge on many large and small streams for 1 or more years. Owing to the ephemeral nature of the streams and varied

sources of low-flow discharge, correlation of low flow between stations is poor and onsite measurements are the only dependable source of information.

From 1954 through 1973 a network of crest-stage stations was operated on a number of streams having drainage areas less than 100 square miles. The data from these stations, together with data from the continuous-record stations, were used to develop flood-frequency and magnitude relationships. Operation of the crest-stage stations also resulted in the collection of a large quantity of periodic discharge-measurement information.

Details about period of operation and type of data collected at 36 streamflow stations are shown in section 10.1. The actual data are available from computer storage through National Water-Data Exchange (NAWDEx), from the U.S. Geological Survey's WATSTORE, and in published annual U.S. Geological Survey reports.

The U.S. Geological Survey customarily uses an 8-digit number to identify stations and measurement sites. For simplicity, a smaller number for each gaging station or measurement site has been assigned in this report, as shown in figure 6.1-1 and section 10.1; henceforth, in this report, this is the station or site number referred to.

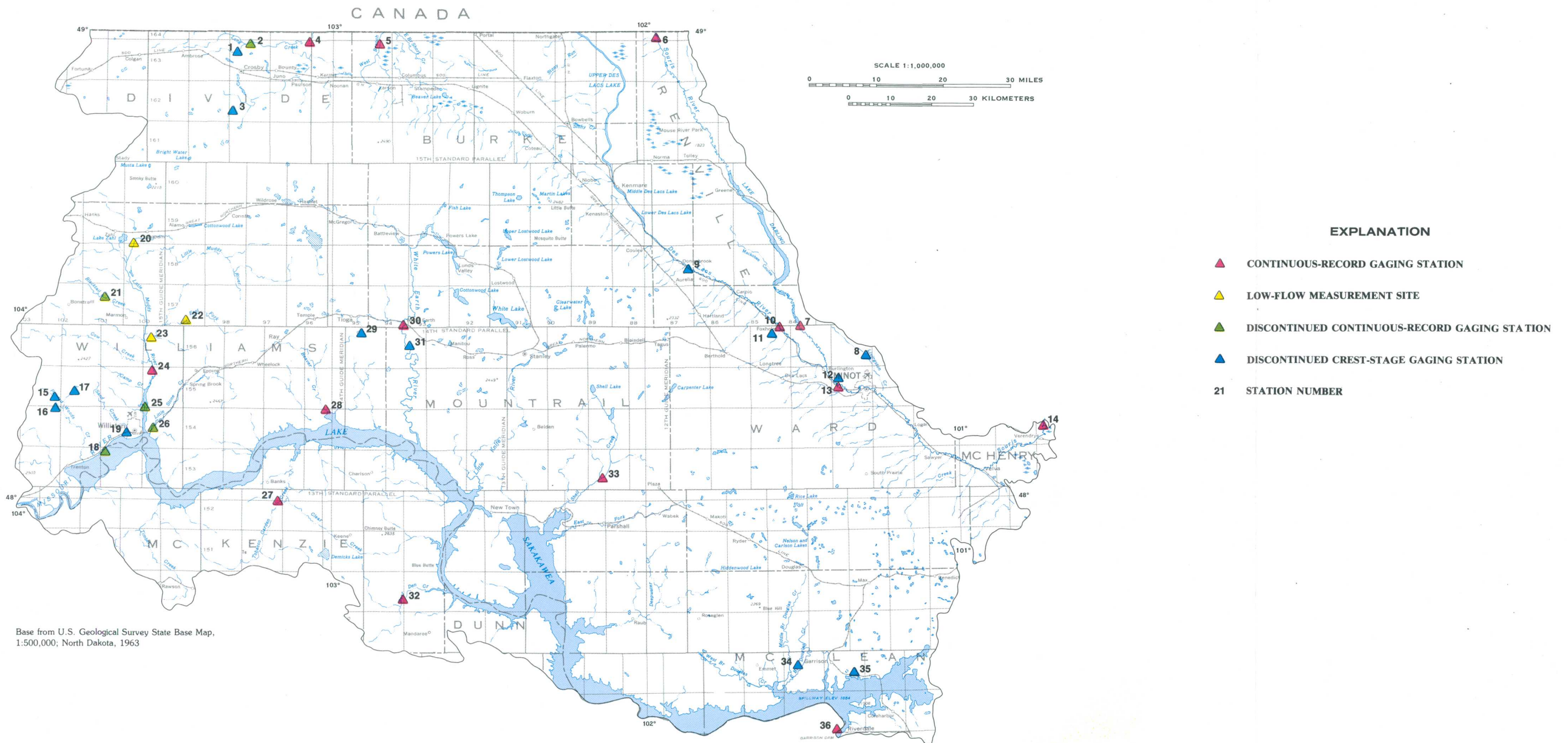


Figure 6.1-1 Location of gaging stations and discharge-measurement sites.

6.0 HYDROLOGIC DATA-COLLECTION NETWORKS--Continued

6.2 Surface-Water Quality

Water-Quality Information is Available for Many Locations

Surface-water-quality sampling programs provide a data base that characterizes the chemical composition of water in the major streams and many minor tributaries.

Water-quality sampling in Area 46 by the U.S. Geological Survey began with the collection of a single sample in 1946 on the Missouri River near Williston. The program to sample major streams for water-quality properties and common ions on a more or less routine basis began in 1950. The major effort to acquire a more complete water-quality data base was made during the 1970's and early 1980's. The locations where data are currently available as of 1982 are shown in figure 6.2-1. The data are widely spaced with regard to time and duration of collection. The period of record and the type of data available for each station are shown in section 10.2. The station numbers shown in figure 6.2-1 and section 10.2 are the same as those in figure 6.1-1 and section 10.1. There are additional scattered miscellaneous one-time sample data in the U.S. Geological Survey files. The data for stations listed in section 10.2 are available in published form in annual reports of the U.S.

Geological Survey; in the U.S. Environmental Protection Agency's STORET computer files; and, since about 1950, in the U.S. Geological Survey's WATSTORE computer files.

A common practice for several years has been for U.S. Geological Survey investigators to obtain water-temperature and specific-conductance measurements whenever a streamflow measurement is made. These data are not listed in section 10.2 unless a sample for chemical analyses also was obtained.

Data on water quality for Area 46 also can be obtained from the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, North Dakota State Department of Health, North Dakota State Water Commission, North Dakota Game and Fish Department, and the State universities.

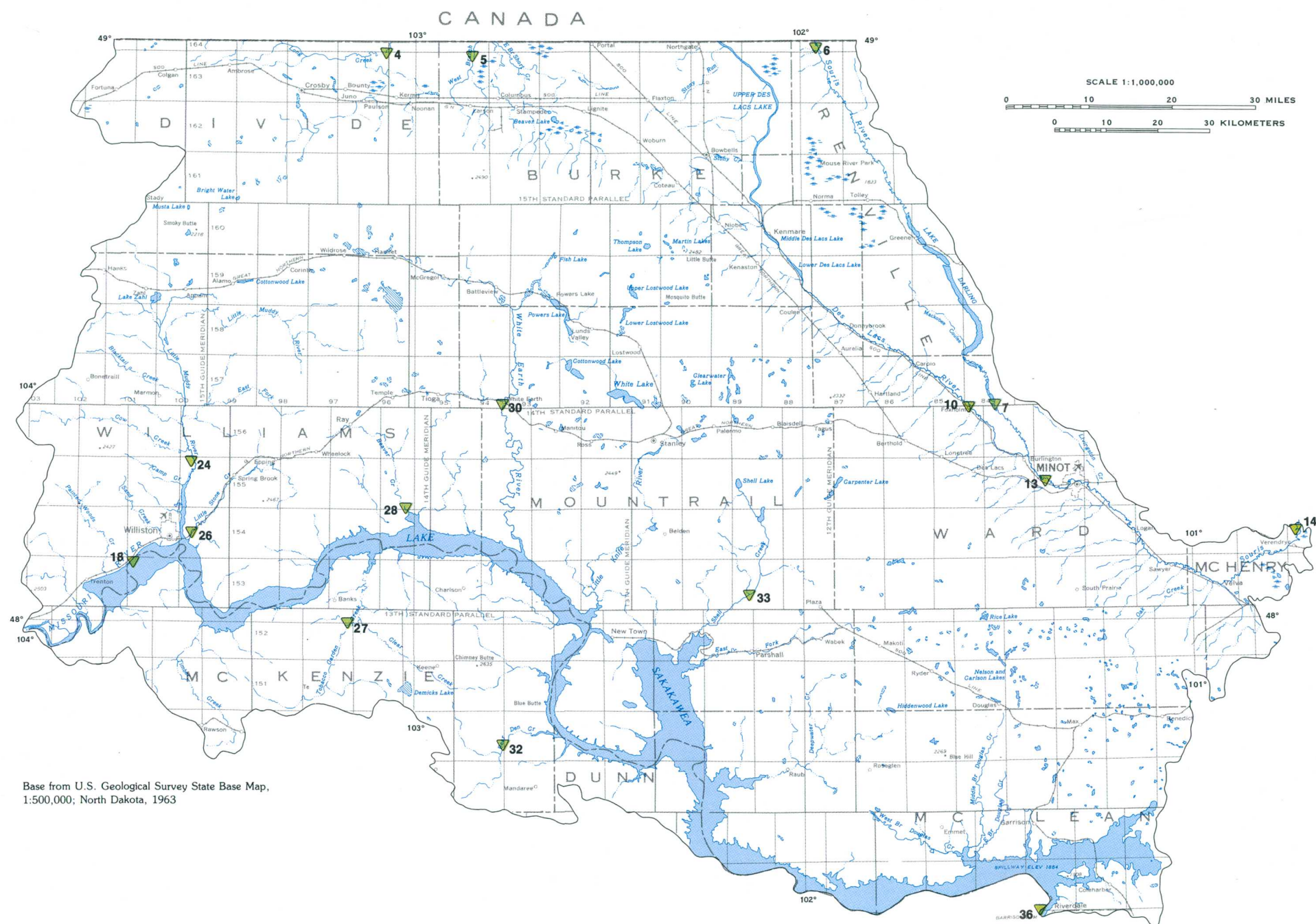


Figure 6.2-1 Location of surface water-quality stations.

6.0 HYDROLOGIC DATA-COLLECTION NETWORKS--Continued

6.3 Ground-Water Observation Wells

Information on Ground-Water Levels and Quality of Water is Available for Most of Area 46

*The ground-water network as of September 1982 included 113
observation wells in aquifers above the Pierre Shale.*

The ground-water network in Area 46 provides general water-level and ground-water quality data for most of the area. The network of observation wells being monitored is periodically reviewed and updated. The network as of September 30, 1982, is shown in figure 6.3-1. Information on location, aquifer, and period of record for each observation well is shown in section 10.3. Note that for this report a simpler numbering system is used than the local well-numbering system based on township, range, and section. The frequency of observation can vary from one annual measurement to a continuous record. Lithologic and

geophysical logs are available for all observation wells. At least one chemical analysis of water from the well is available for each site. Chemical quality is monitored at several key wells. Those wells for which a chemical analysis of the water was made during 1982 are identified in figure 6.3-1. Many other wells have been constructed by the U.S. Geological Survey and cooperators that are not a part of the network. Information on these wells is available from computer storage through the National Water-Data Exchange (NAWDEx) and in published reports.

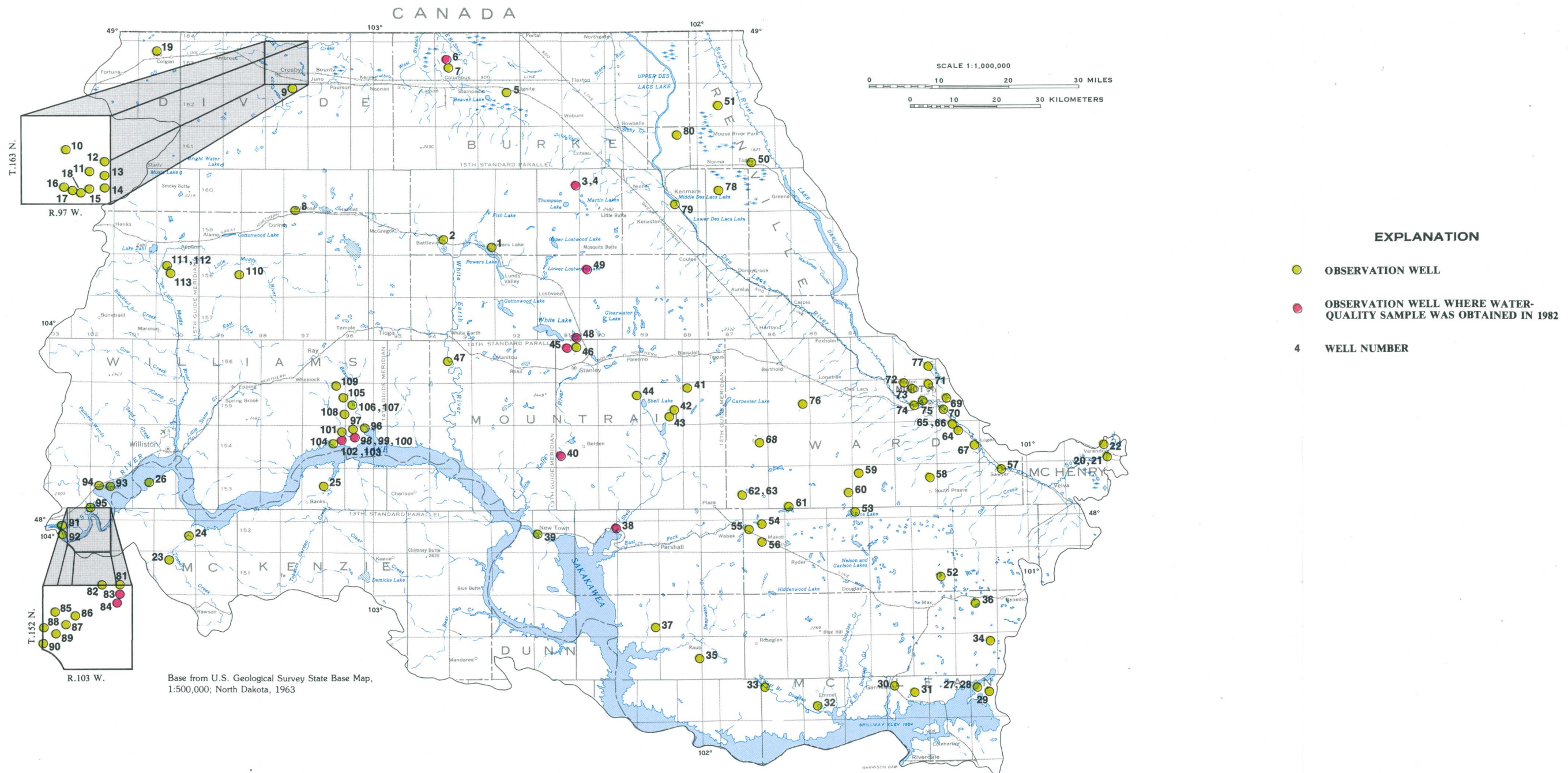


Figure 6.3-1 Location of ground-water observation wells, September 30, 1982.

7.0 SURFACE WATER

7.1 Streamflow

7.1.1 Mean Annual Flow

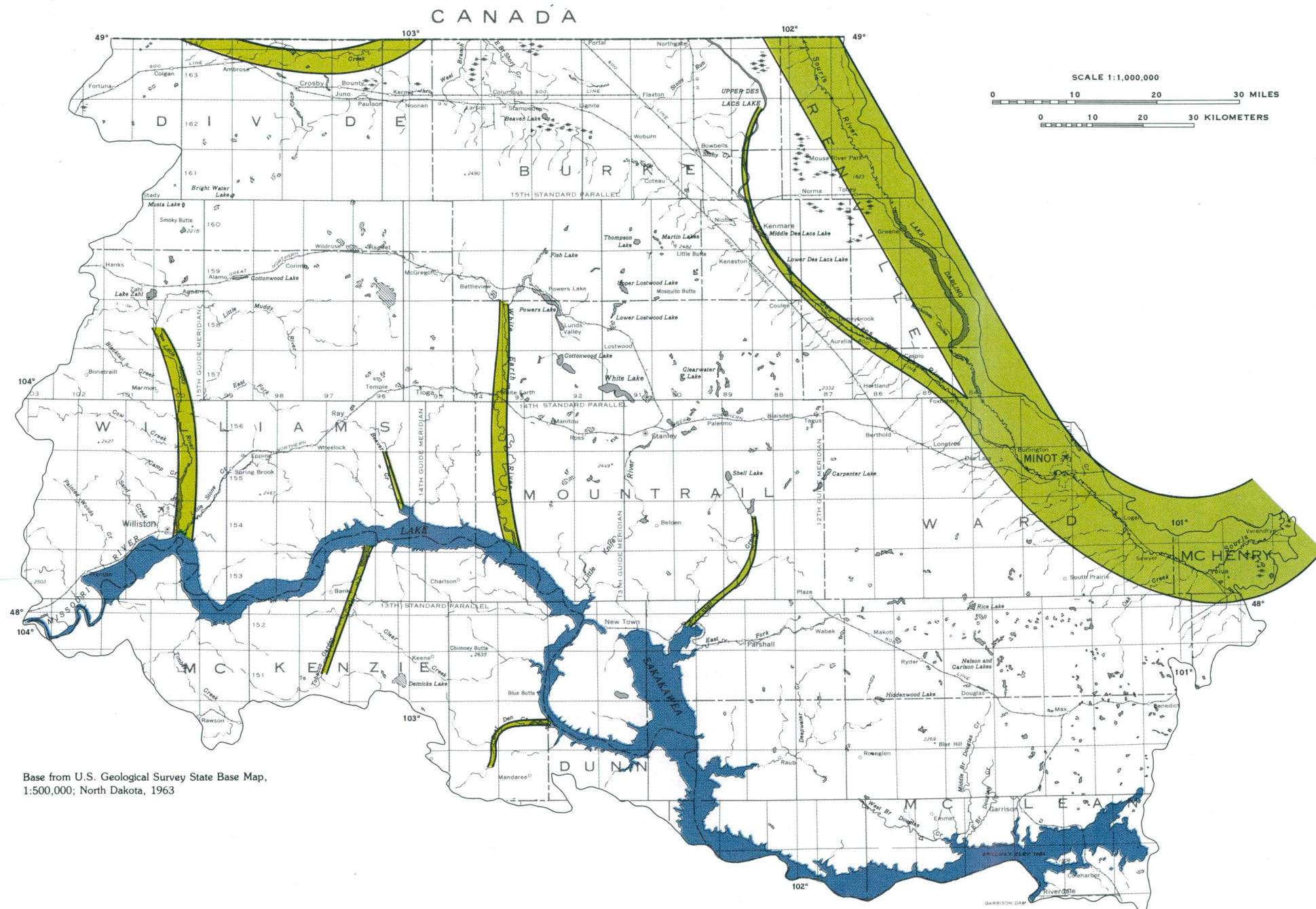
Mean Annual Flow Data are Available for All Stations Having 5 or More Years of Continuous Record

Mean annual flows in runoff per square mile show a wide areal variation.

The mean annual flow of a stream can be used to evaluate the availability of water for planned development. Data for mean annual flow are available for all gaging stations having 5 or more years of continuous record (see section 10.1). The mean annual flow varies from a high of 90 acre-feet per square mile for Bear Den Creek near Mandaree (station 32) to a low of 32 acre-feet per square mile for the Souris River above Minot (station 13). The mean annual flow results primarily from runoff from thunderstorms and spring snowmelt. The variation in runoff per square mile can be the result of weather patterns, differences in infiltration rates, surface storage, and diversion. The con-

tributing and noncontributing parts of the drainage areas cannot be accurately defined, as they vary with the magnitude of the runoff event; therefore, the runoff per square mile has been computed using an estimated contributing drainage area. Flow is approximately proportional to the contributing drainage area and increases downstream.

The mean annual inflow to Lake Sakakawea is about 17,000,000 acre-feet per year. The lake shows little change due to local precipitation, but responds to fluctuations of the inflow from the Missouri and Yellowstone Rivers.



EXPLANATION

- LAKE SAKAKAWEA (mean annual inflow, 17 million acre-feet)
- WIDTH PROPORTIONAL TO MEAN ANNUAL FLOW
(1 inch = 200,000 acre-feet)

Figure 7.1.1-1 Schematic of mean annual flows.

7.0 SURFACE WATER--Continued

7.1 Streamflow--Continued

7.1.2 Duration of Flow

Sustained Flow Occurs on Some Streams

The flow-duration curves indicate a variety of hydrologic and geologic characteristics in the area.

A flow-duration curve² can be used in appraising the geologic characteristics of a drainage basin, particularly as they affect low flows. It also can be used in waterpower, stream-pollution, and quality-of-water studies where discharge versus time is a crucial factor. Flow-duration curves for two of the smaller tributaries (stations 5 and 28) are shown in figure 7.1.2-1. The curves are based on the mean daily flows for the period of record at a site. For example, a discharge of about 0.10 cubic foot per second per square mile for station 28 (Beaver Creek near Ray) is expected to be equaled or exceeded about 9.7 percent of the time. The reliability of the duration curve for estimating the probability of future flows depends upon the length, accuracy, and consistency of the record and on how well the period of record represents the long-term climatic conditions of the basin.

The shape of the flow-duration curve is determined by the hydrologic and geologic char-

acteristics of the drainage basin. A curve that is nearly vertical (station 5, fig. 7.1.2-1) represents variable streamflows such as those derived from direct surface runoff and little or no base flow. A more gently sloping curve (station 24) is characteristic of streams whose flow is attenuated by surface storage or augmented by discharge from ground-water storage. Thus, the lower end of the curve (base flow) is a valuable means of studying the effect of geology on the ground-water discharge.

Discharges, in cubic feet per second, and selected corresponding percentages of time equaled or exceeded for stations in Area 46 are listed in table 7.1.2-1. Most of the curves will be similar to one or the other of the two types of curves shown in figure 7.1.2-1.

² The flow-duration curve is a cumulative frequency curve that shows the percent of time a specified discharge is equaled or exceeded during a given period.

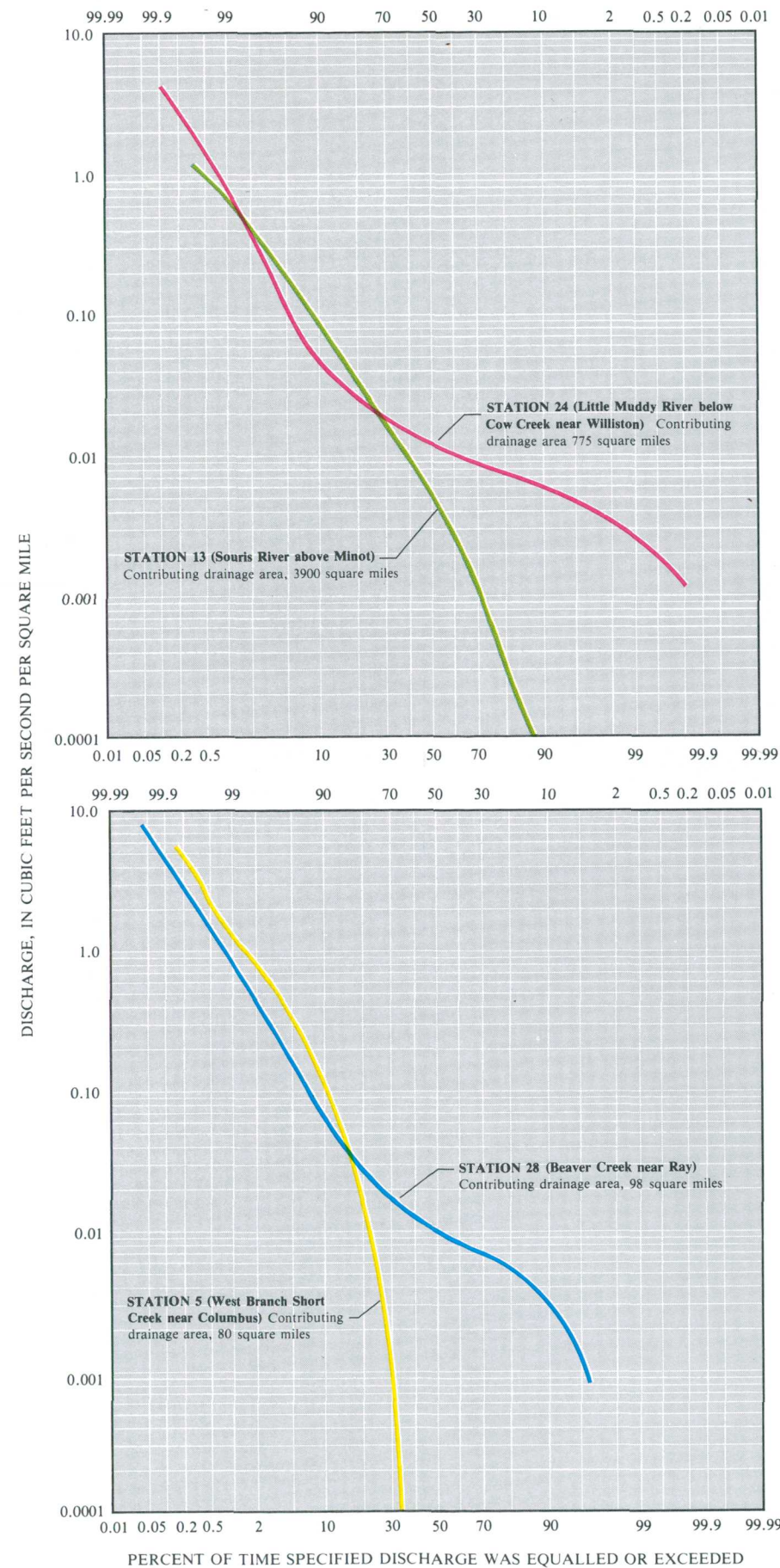


Figure 7.1.2-1 Duration of flow.

Table 7.1.2-1 Mean daily discharge flow-duration statistics, in cubic feet per second.

Station number	Contributing drainage area (square miles)	Percent of time specified discharge was equalled or exceeded				
		95	75	50	25	10
2	540	0	0	0.1	1.5	24
4	630	0	0	.6	6.3	66
5	80	0	0	0	.3	8.8
6	3,040	0	1.2	7.2	43	230
7	3,270	0	.8	20	81	270
10	539	0	.6	2.9	18	66
13	3,900	0	2.7	24	98	340
14	4,400	1.8	14	44	140	450
18	¹ 164,500	5,600	10,000	16,000	27,000	38,000
24	775	3.5	6.3	9.8	17	40
25	778	.9	6.2	10	20	59
26	146	0	0	.2	.6	4.2
27	135	.2	.4	.7	1.5	5.6
28	98	.1	.6	1.0	2.0	6.9
30	490	.5	1.8	3.5	12	44
32	74	0	.1	.3	.8	6.2
33	145	0	.3	1.6	5.7	19
36	¹ 181,400	15,000	21,000	25,000	30,000	37,000

¹ Total drainage area.

7.0 SURFACE WATER--Continued

7.1 Streamflow--Continued

7.1.3 Floods

Urban and Rural Flooding are a Problem

Flood estimates can be made from available data for gaged and ungaged streams in the area.

Most of the flood damage in Area 46 is to homes and businesses in small communities or to roads and bridges in rural areas. Flood-prone areas have been delineated by the U.S. Geological Survey for those topographic quadrangles indicated in figure 7.1.3-1. The mapped areas are not the only areas subject to flooding, but were given priority for mapping on the basis of need.

The most reliable estimators of the probabilities of future floods generally are the frequency analyses of streamflow-station records. Therefore, the estimating technique first includes a search for available flood-frequency data for a streamflow station at or near the desired site. Peak-flow data have been collected at many stations and for many years (see section 10.1). In the absence of such a record, estimates can be made by relating frequency analyses at long-term stations to an ungaged site based on basin characteristics and climatic factors. Information for estimating floods on ungaged streams draining less than 100 square miles is described by Crosby (1975). The regression equations to be used in computing floods from the 2-year to 50-year frequency are given in table 7.1.3-1. Information for estimating floods on ungaged streams draining 100 square miles or more is given in a report by Patterson (1966).

The maximum discharges on record for unregulated streams draining less than 500 square miles are plotted versus drainage area in figure 7.1.3-2. The plots also include significant maximum discharges at miscellaneous measurement sites. The wide spread (an order of magnitude) of flood peaks for a given drainage area indicates that adequate areal definition requires data at many sites.

Table 7.1.3-1—Summary of regression equations for estimating peak discharges for streams draining less than 100 square miles in Area 46.

[Standard error of estimate, in percent, is the average of the positive and negative percent error, within which lie two-thirds of the measured values.]

Region	Regression equation	Standard error of estimate (percent)
B	$Q_2 = 196A^{0.60}Si^{-1.74}$	74
	$Q_5 = 465A^{0.63}Si^{-1.66}$	64
	$Q_{10} = 626A^{0.64}Si^{-1.52}$	65
	$Q_{25} = 766A^{0.65}Si^{-1.30}$	74
	$Q_{50} = 848A^{0.65}Si^{-1.14}$	84
C	$Q_2 = 13A^{0.46}$	85
	$Q_5 = 34A^{0.51}$	72
	$Q_{10} = 54A^{0.53}$	67
	$Q_{25} = 86A^{0.54}$	67
	$Q_{50} = 115A^{0.54}$	70

Q_n Peak discharge, in cubic feet per second, with a recurrence interval of n years;

A Drainage area, in square miles; and

Si Soil-infiltration index, in inches

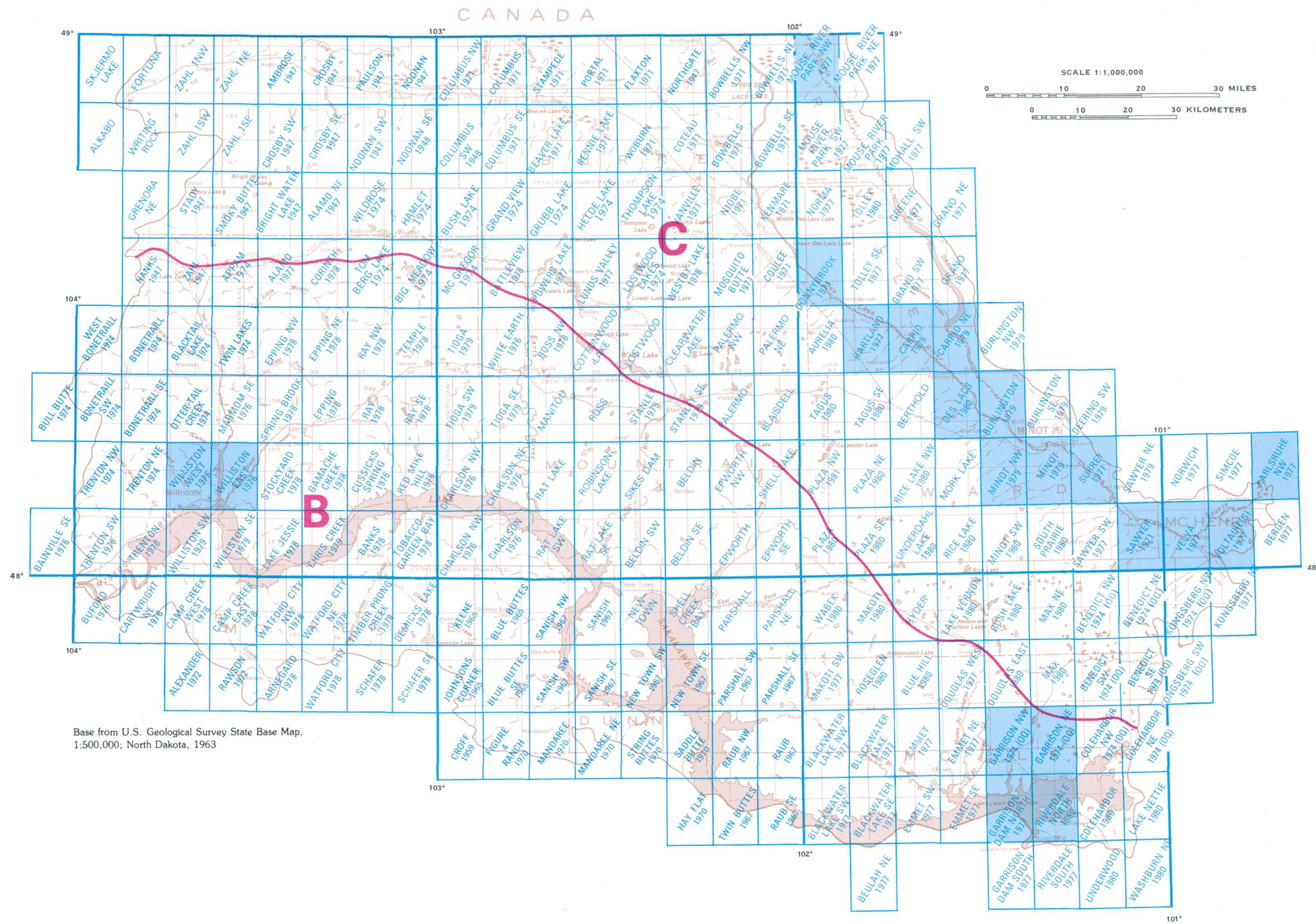
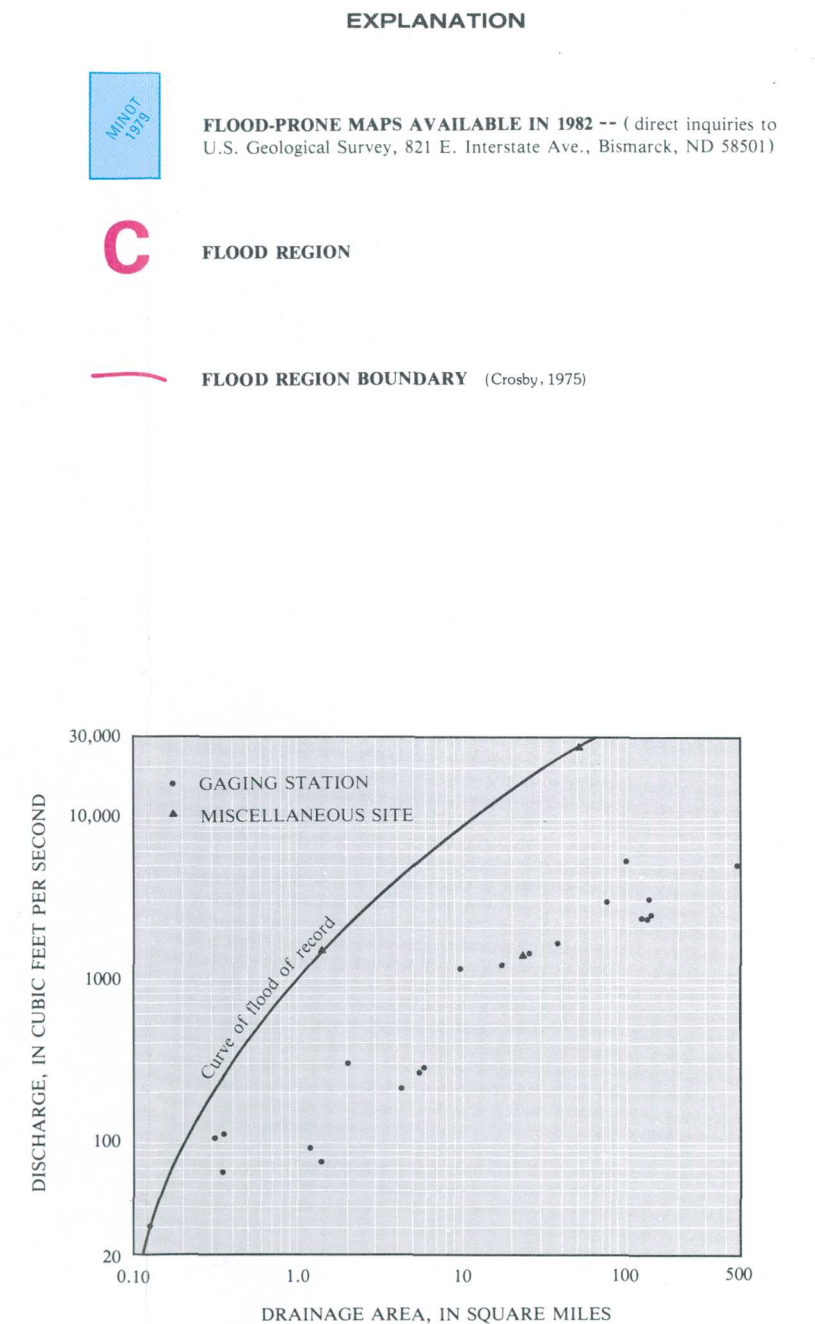


Figure 7.1.3-1 Available flood-prone area maps.



7.0 SURFACE WATER--Continued

7.2 Surface-Water Storage

Surface Storage Important to Use of Water Resources

Small reservoirs are vulnerable to adverse effects of mining.

Much of Area 46 is covered by a thick layer of glacial drift whose surface is pocketed by lakes and potholes. Most of these are small impoundments and have economic value in the production and propagation of wildlife. Some of the larger lakes have other water-based recreational value, but major economic development of the area has depended largely on the development of manmade storage in reservoirs. The location of selected reservoirs and lakes with storage capacities in excess of 50 acre-feet is shown in figure 7.2-1. The capacities of these reservoirs and lakes, where known, are listed in section 10.4. The storage generally has multiple uses; municipal and industrial supplies, irrigation, flood control, recreation, fish and wildlife, and livestock.

In addition to those listed, there are hundreds of smaller reservoirs created by dams for livestock

use. The small reservoirs and lakes may be especially vulnerable to adverse effects from surface mining such as drainage or water-quality deterioration. The shallow ephemeral ponds, which are used primarily for waterfowl production and small animal protection, may be difficult to replace if destroyed because of the hundreds of years it has taken to develop the present hydrologic and ecologic systems.

Some of the larger reservoirs and lakes already are impacted by demands related to energy development. Municipal demands are greater than available supplies in several localities. If distribution systems can be implemented, Lake Sakakawea, bordering the area on the south, is the one large source of water considered as a solution to many of the supply problems.

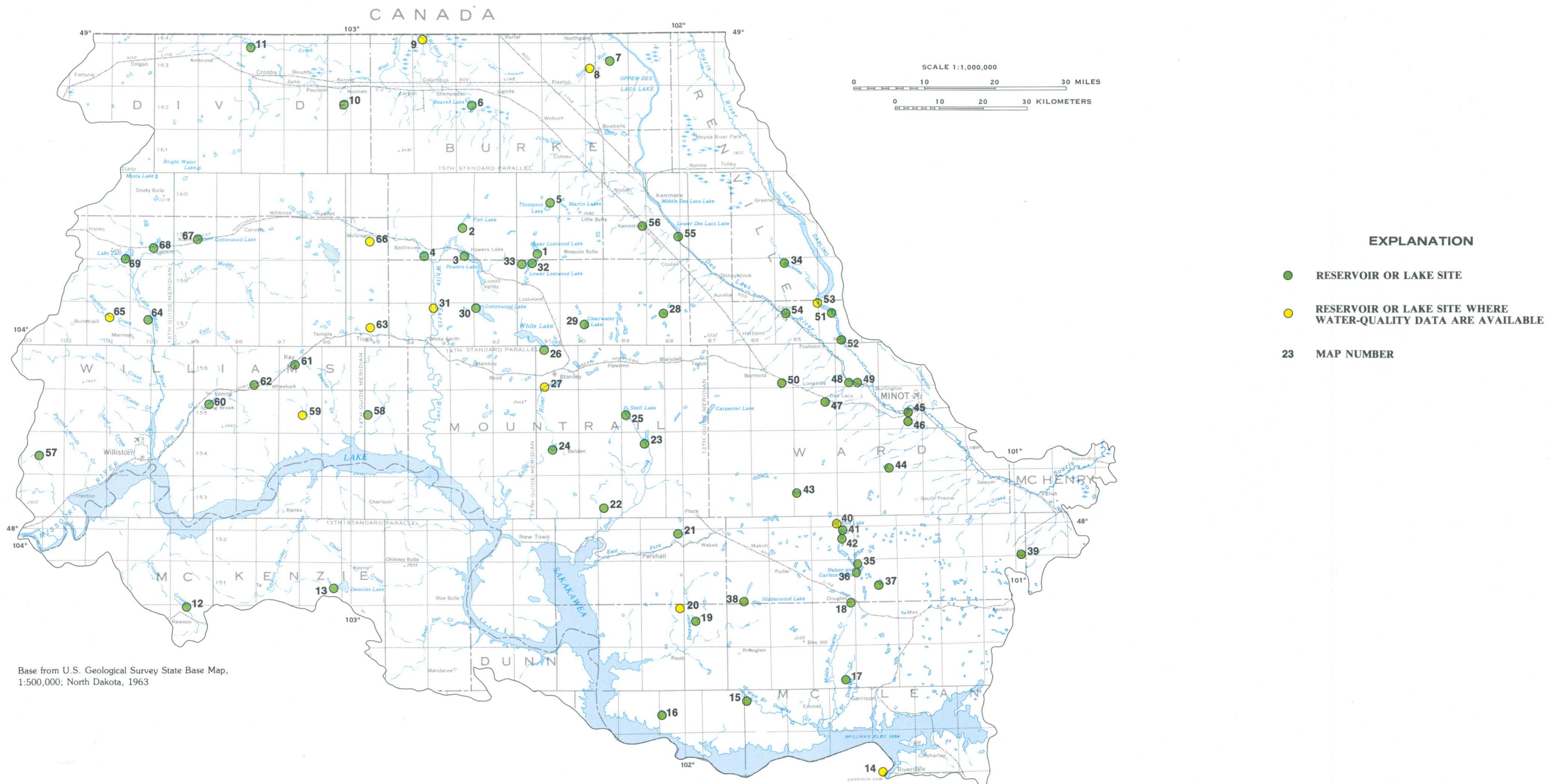


Figure 7.2-1 Location of selected reservoirs and lakes with storage capacity in excess of 50 acre-feet.

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality

7.3.1 Dissolved Solids

Dissolved-Solids Concentration of Most Streams Varies with Discharge as well as from Stream to Stream

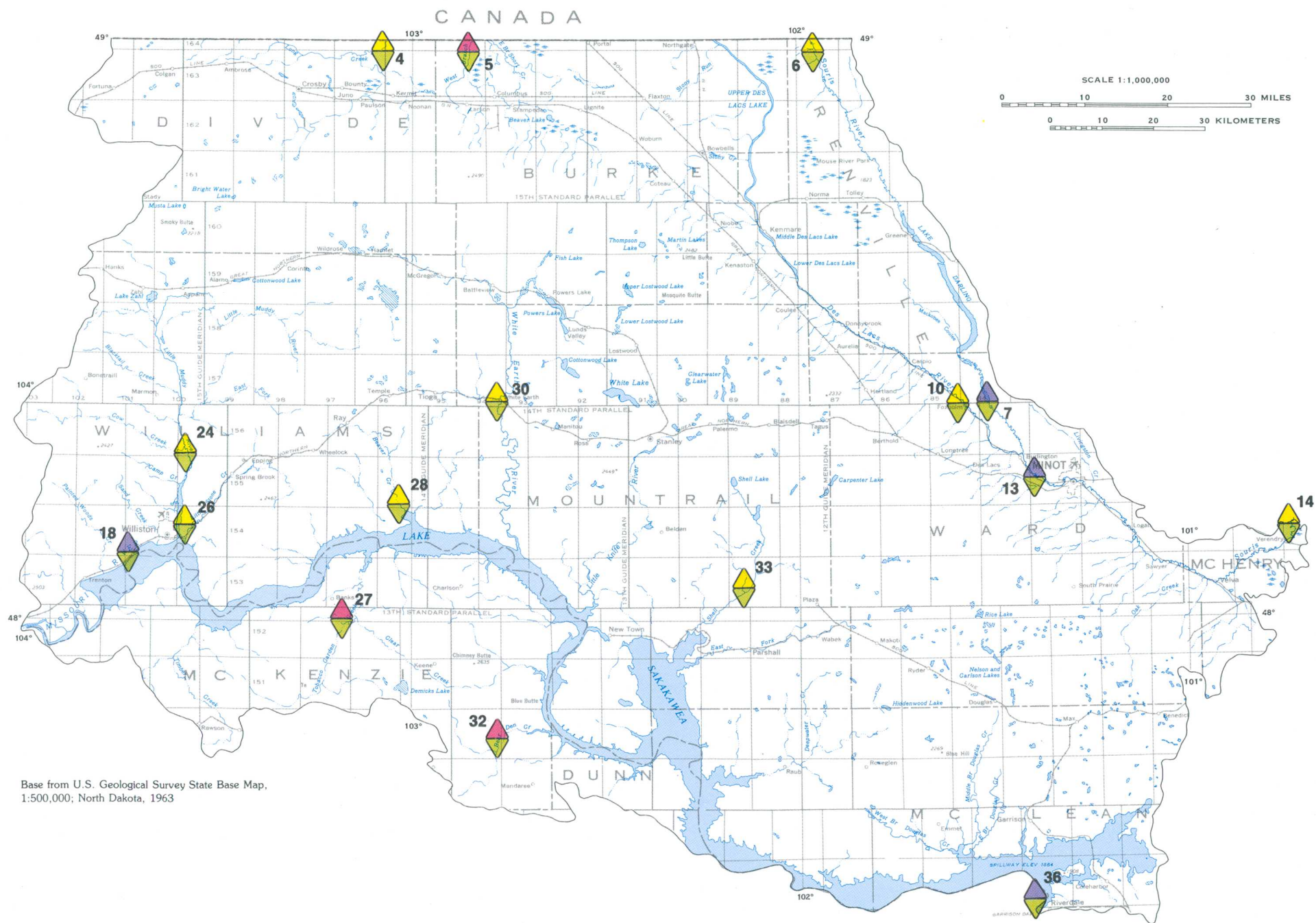
Changes in dissolved solids due to mining could be difficult to quantify because of the natural variability in the streams.

Dissolved-solids concentrations vary greatly with discharge and between streams in Area 46 (fig. 7.3.1-1). This variability could mask changes due to mining. The most common dominant cations are calcium, magnesium, and sodium and the dominant anions are bicarbonate, sulfate, and chloride. Large dissolved-solids concentrations can be objectionable because of possible physiological effects, mineral taste, or economic problems associated with their removal.

Numerous standards have been established for dissolved solids. Generally it is desirable to have less than 500 milligrams per liter for public water supplies. During snowmelt runoff or high flows resulting from rainstorms, most streams in the area have less than 500 milligrams per liter of

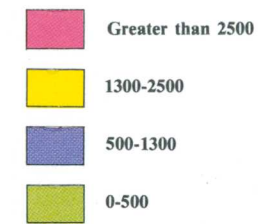
dissolved solids. During low flow, dissolved-solids concentrations in water from many of the streams will exceed 1,300 milligrams per liter, an approximate concentration at which the water will acquire a mineralized taste.

Water containing dissolved-solids concentrations in excess of 2,500 milligrams per liter has only limited use; however, livestock will tolerate as much as 4,500 milligrams per liter (McKee and Wolf, 1971). Dissolved-solids concentrations of water in many streams will exceed 2,500 milligrams per liter during extreme low flows when ground-water discharge is the primary source of water and water losses from evapotranspiration increase concentrations.

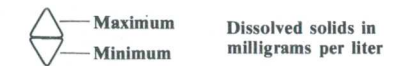


EXPLANATION

DISSOLVED-SOLIDS, IN MILLIGRAMS PER LITER



WATER-QUALITY STATION



30 STATION NUMBER

Figure 7.3.1-1 Dissolved-solids concentrations at selected stream locations.

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality

7.3.1 Dissolved Solids

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality--Continued

7.3.2 pH

Alkaline pH Values Characterize Most Streams

Coal mining in the area is unlikely to cause acid drainage.

Acidity and alkalinity generally are expressed in terms of pH units, which can range from 0–14. Neutral water has a pH of 7.0. Values less than 7.0 denote acidic water and those greater than 7.0 denote alkaline water. Atmospheric precipitation in equilibrium with average natural atmospheric-gas concentrations will have a pH of about 5.7 (Lerman, 1979). Bulk atmospheric-precipitation (includes dust) pH values have been measured as small as 4.0 and as large as 8.2 in North Dakota. The only observations in Area 46 (at Mandaree in 1977) showed a minimum of 5.9 and a maximum of 6.5 in four samples.

Unpolluted streams draining undisturbed basins in the Northern Great Plains generally will

have alkaline water. Values of pH in streams commonly range from about 7.5 to 8.5. Even though some basin disturbance due to mining has occurred in Area 46, the surface waters generally are still alkaline, as shown in figure 7.3.2–1. The surface waters are buffered by carbonate minerals in the prairie soils, and stream pH decreases to less than 7.0 only during major precipitation or immediately adjacent to acid sources such as coal outcrops. The oxidation of sulfur species in the coal mining areas generally will cause a decrease in pH. However, in Area 46, the prevalence of soils with moderate buffering capacity makes acid drainage unlikely.

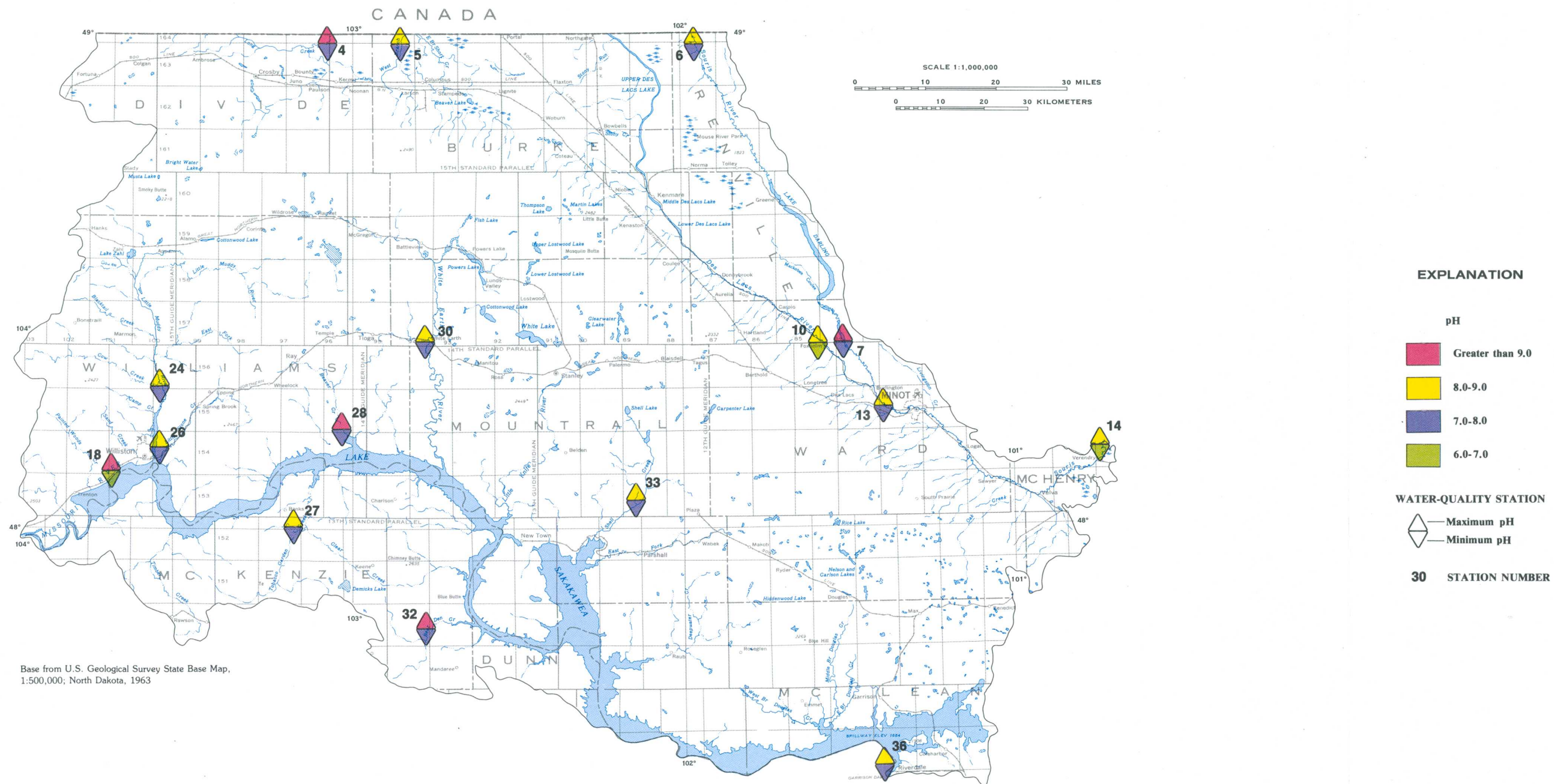


Figure 7.3.2-1 Values of pH at selected stream locations.

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality--Continued

7.3.3 Dissolved Sulfate

Dissolved-Sulfate Concentrations in Excess of 500 Milligrams per Liter Occur in Most Streams

*Dissolved sulfate is quite variable with concentrations usually less than
250 milligrams per liter during high flows and greater than
500 milligrams per liter during low flows.*

Dissolved-sulfate concentrations appear to vary greatly in the streams within the area, as shown in figure 7.3.3-1. Sulfate concentrations generally are discharge dependent, with concentrations on most streams less than 250 milligrams per liter during snowmelt runoff and runoff from intense rainstorms, and more than 500 milligrams per liter at low flows when streamflow is dominated by ground-water discharge. The U.S. Environmental Protection Agency National Secondary Drinking Water Regulations set an upper limit for sulfate concentrations in public water of 250 milligrams per liter (U.S. Environmental Protection Agency, 1977). Concentrations in excess of 250 milligrams per liter can impart a taste to the water for some

people, and concentrations in excess of about 500 milligrams per liter can have laxative effects in many people. McKee and Wolf (1971) recommend a threshold limit for cattle consumption at 1,000 milligrams per liter, which generally is not exceeded except at extreme low flows in some of the small drainage basins.

The variation of sulfate concentrations with discharge makes detection of changes due to mining difficult without a record of concentration variations through a wide range of discharges. The network of stations shown in figure 7.3.3-1 provides a limited data base for providing this background information.

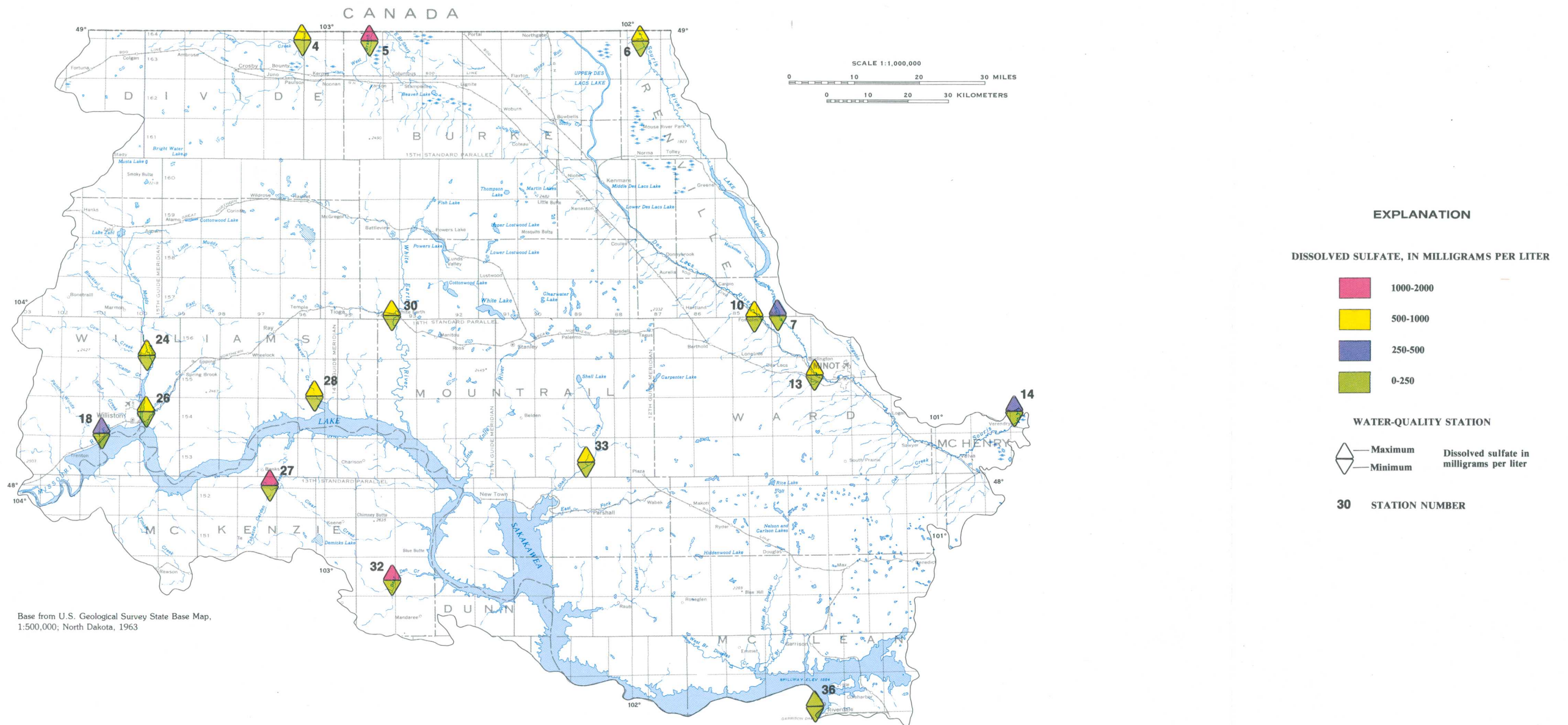


Figure 7.3.3-1 Dissolved-sulfate concentrations at selected stream locations.

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality--Continued

7.3.4 Dissolved Boron

Boron May Serve as an Indicator for Trace-Element Changes

Boron concentrations measured in Area 46 generally are less than 0.5 milligrams per liter and have not exceeded the maximum plant tolerance of 2.0 milligrams per liter.

Changes in the concentration of boron in stream water are suggested as an indicator of trace-element increase. Boron is an essential element for the growth of plants, but is needed only in very small concentrations. When small concentrations are exceeded, boron becomes toxic. Boron toxicity occurs in limited, scattered areas in arid or semiarid regions. Boron generally is not toxic at concentrations less than 0.5 milligrams per liter (McKee and Wolf, 1971). Sensitive plants can be damaged with concentrations ranging from 0.5 to 1.0 milligrams per liter. The maximum concentration recommended for semitolerant plants is 1.0 milligrams per liter and for tolerant plants it is 2.0 milligrams per liter (National Academy of Sciences-National Academy of Engineering, 1973).

Excess boron frequently is present in saline soils as a result of evaporative processes. New spoils from mine areas are commonly enriched in

carbonaceous material containing large amounts of boron and could be a source of increased boron concentrations in the streams.

Release of water which has had a significant residence time in ponds whose main source of discharge is through evaporation also could cause abrupt increases in boron. Boron concentrations have been less than 0.5 milligrams per liter, at least part of the time, at all stations (fig. 7.3.4-1). The small concentrations occur during high flows. During low flows, boron occasionally increases to almost 2.0 milligrams per liter at a few stations. These increases could be due to large boron concentrations in some ground-water discharges or sudden flushes from evaporative ponds during the initial part of a runoff event. A history of boron concentrations would be necessary to detect changes at a selected site.

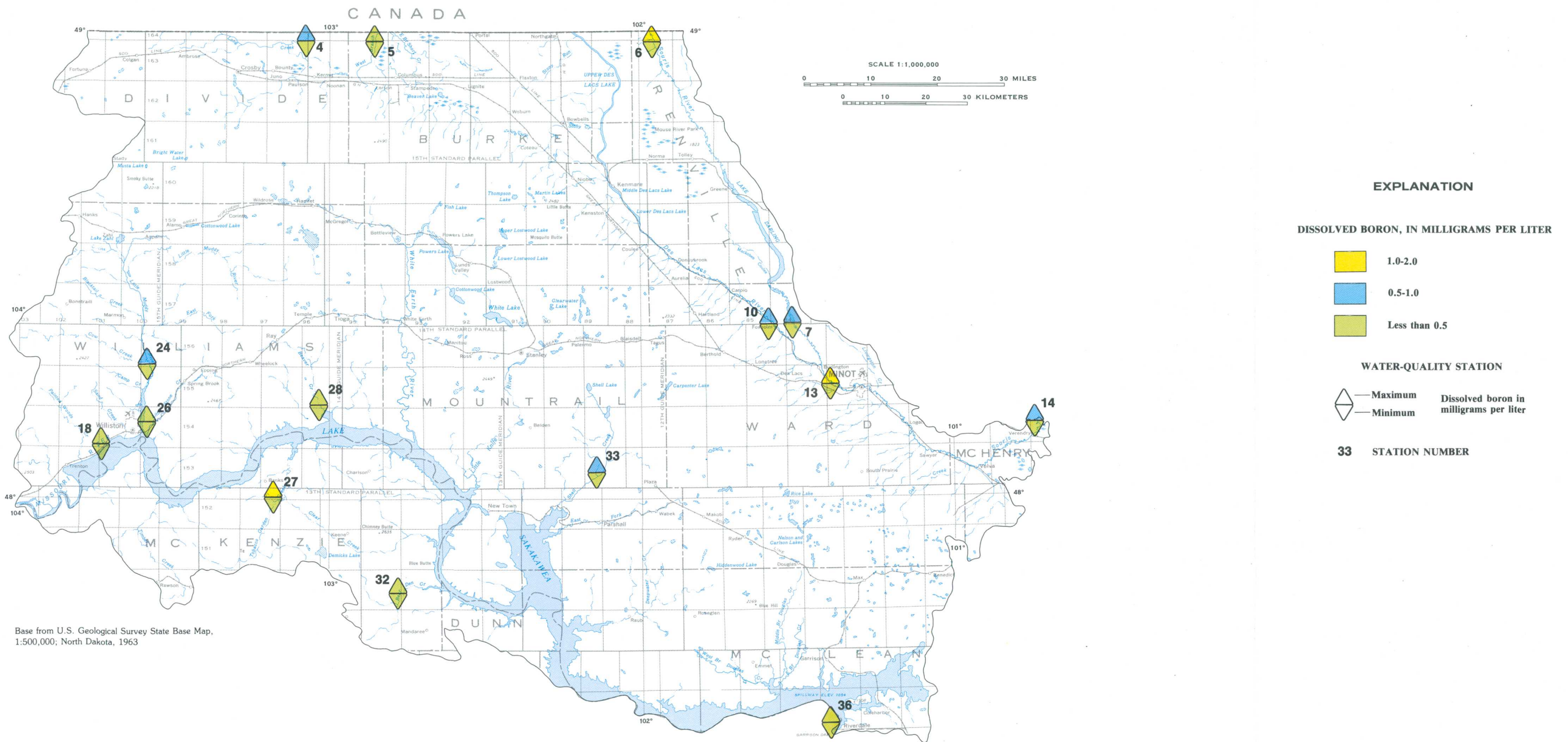


Figure 7.3.4-1 Dissolved-boron concentrations at selected stream locations.

7.0 SURFACE WATER--Continued

7.3 Surface-Water Quality--Continued

7.3.5 Suspended Sediment

Suspended-Sediment Data are Limited

Most sediment data have been collected in recent years.

The longest sediment-data record of the U.S. Geological Survey in Area 46 is for station 32 (Bear Den Creek near Mandaree; fig. 7.3.5-1). Sample collection started in March 1971 and is being continued in the ongoing water-quality program. This station was selected as a Hydrologic Benchmark Station; one of a group of stations in the United States representative of essentially pristine conditions. From 1975 to date, sediment samples have been collected at station 18 (Missouri River near Williston). The Corps of Engineers has long-term sediment records at this station because of data requirements relating to construction of Garrison Dam. Data have been collected on the Souris River (stations 6, 7, and 14) for several years in response to the need to maintain quality of water and to study flood control. Data have been collected at stations 5, 26, and 28 since 1977 in response to increased energy development.

The suspended-sediment data available generally are a determination of the concentration

at the time of streamflow measurements. In addition, occasional particle-size analyses are made. The relationship between the sediment concentration and measured discharge at station 28 (Beaver Creek near Ray) is shown in figure 7.3.5-2. There is no curve of relationship discernible from the plotted points. The data scatter is typical for small basins in the area. The lack of correlation is due to the great variability of factors such as soil types; soil conditions (frozen, thawed, degree of saturation, and tillage); land use; precipitation intensity; rapidity of snowmelt; and the time of sampling in relation to hydrologic events.

Except for station 5, the data available are from areas of undeveloped energy resources. It would be extremely difficult, if not impossible, to extrapolate the available data to estimate the effects of mining or other land-use changes. It is unlikely that cumulative effects of energy development will be detectable at the downstream stations on the major streams for many years.

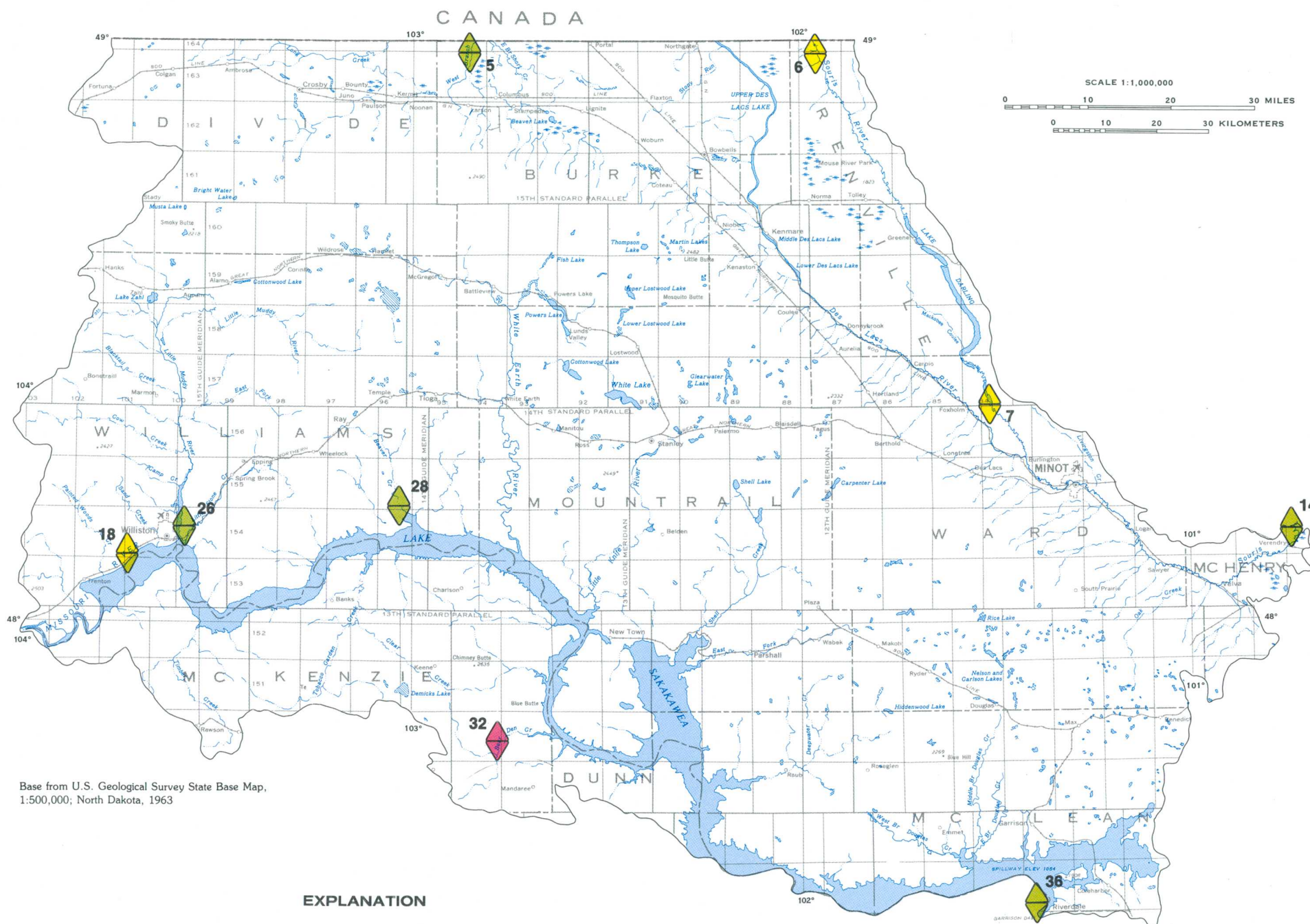


Figure 7.3.5-1 Suspended-sediment records at selected stream stations.

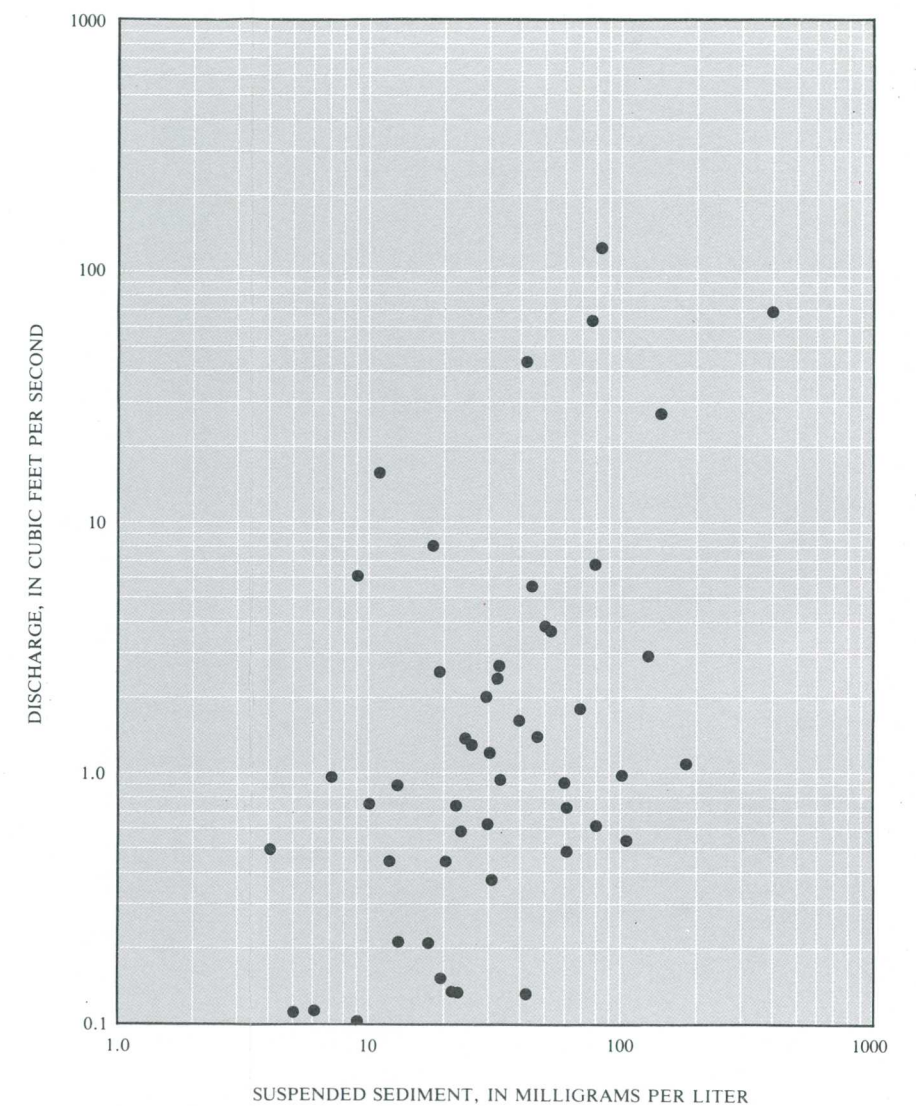


Figure 7.3.5-2 Variability of suspended-sediment concentrations with discharge, station 28 (Beaver Creek near Ray), October 1977 through September 1981.

8.0 GROUND WATER

8.1 Availability of Ground-Water Reports

Reports Describing Ground-Water Hydrology are Available for Most of Area 46

*Reports include results of chemical analysis of ground water,
well inventory, well yields, and test drilling.*

Surface mining and other land disturbances can alter the quality and quantity of ground water available to wells. Data on wells, ground-water availability, water quality, and well logs have been published in reports that include most of Area 46 (fig. 8.1-1). The reports, all of a reconnaissance nature, show the depth of wells, well logs, results

of test drilling, reported or measured water levels, yields of wells, aquifer boundaries, and ground-water quality. The ground-water hydrology is described for each area. Reports on the geology of the area are listed in the references. Long-term water-level information currently is available for selected wells in the area.

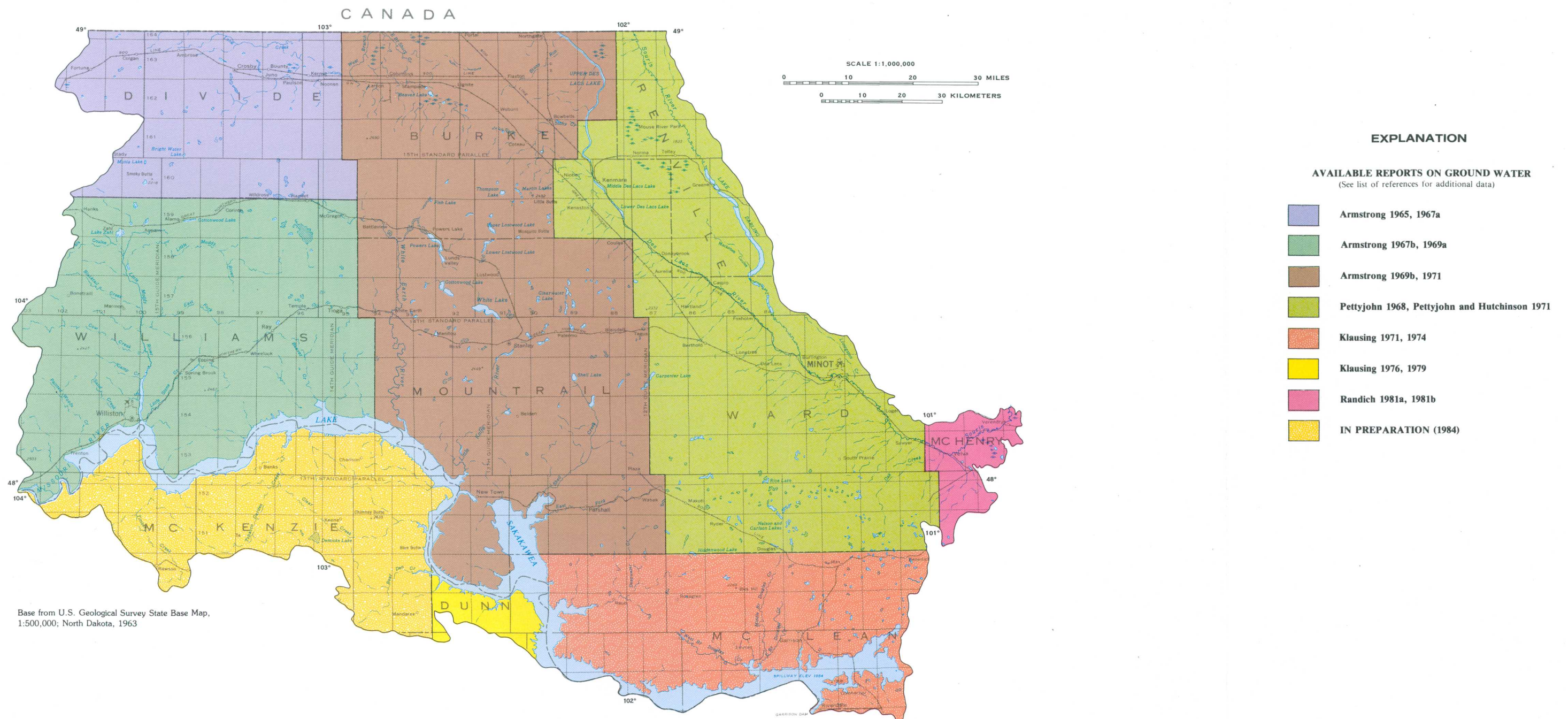


Figure 8.1-1 Available ground-water reports.

8.0 GROUND WATER

8.2 Extent of Aquifers

Glacial-Drift and Bedrock Aquifers Exist in Area 46

Important glacial-drift and alluvial aquifers consisting of sand and gravel underlie the valleys of the Missouri River, Little Muddy River, and other streams in the area.

Important glacial-drift aquifers, consisting of glacial and alluvial sand and gravel, underlie the valleys of the Missouri River, Little Muddy River, and other streams in Area 46 (fig. 8.2-1). The aquifers generally are less than 200 feet thick, but thicknesses of 300 feet are found in some areas. Values for aquifer transmissivity³ generally range from 200 to 15,000 feet squared per day. The aquifers in the valley of the Missouri River largely are a mixture of alluvial material and coarse outwash derived from mountain and continental glaciers. Elsewhere the aquifers largely are glacially derived backfill in outwash channels. Alluvium of Holocene age commonly overlies the glacial material and, where derived from the bedrock of the area, commonly is fine grained.

Bedrock aquifers, the Fox Hills and lower part of the Hell Creek Formation of Cretaceous age, and

the lower part of the Tongue River Member of the Fort Union Formation of Tertiary age, underlie all of Area 46. These aquifers consist of fine- to medium-grained semiconsolidated sandstone. Values for transmissivity range from 50 to 300 feet squared per day. Wells tapping the aquifer in the Fox Hills and lower part of the Hell Creek Formation in the valley of the Missouri River may be as much as 1,500 feet in depth and flow at land surface. Very few wells tap the aquifer in the Fox Hills and lower part of the Hell Creek Formation north of the Missouri River.

Many stock and farm wells in the area tap thin discontinuous beds of sandstone and lignite of Tertiary age at depths of less than 300 feet. These wells generally yield less than 20 gallons per minute.

³ Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

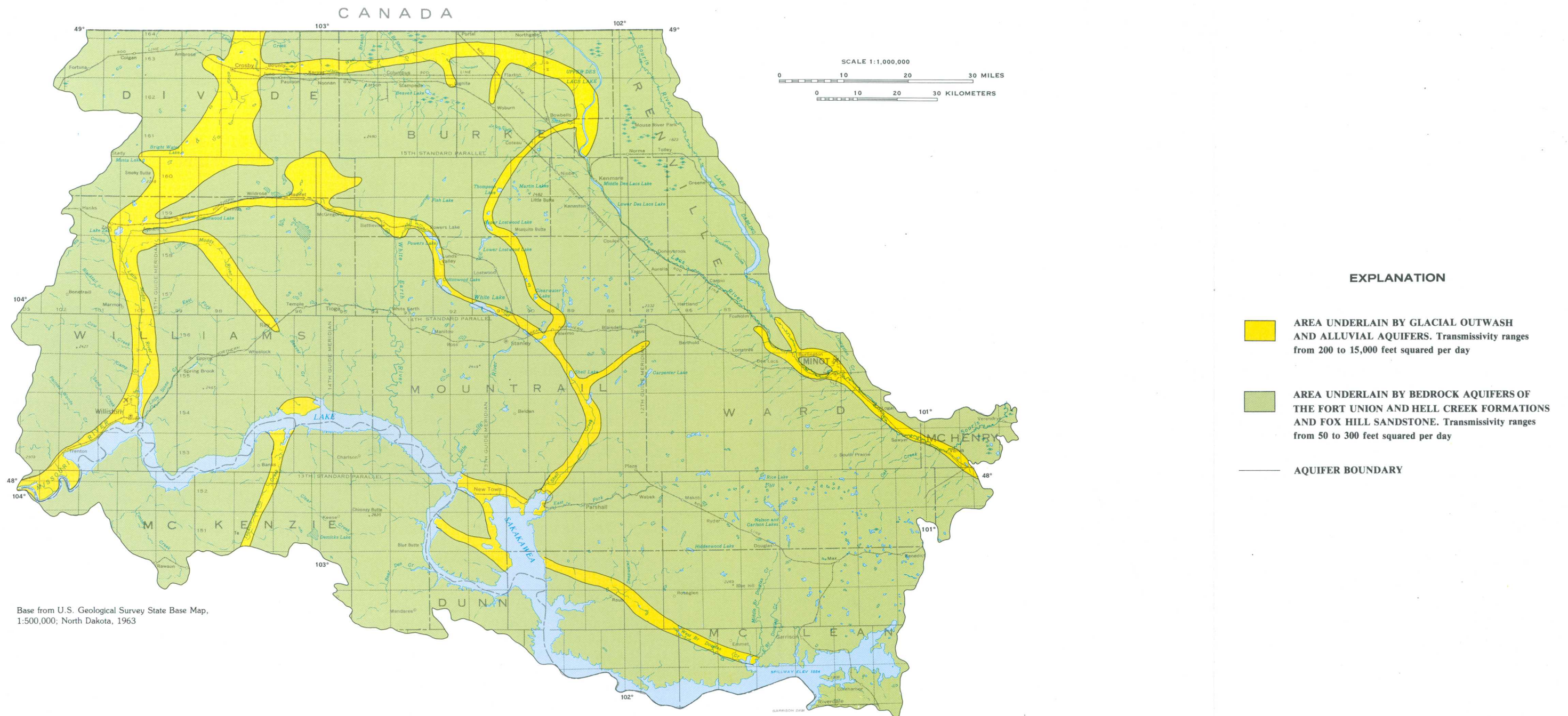


Figure 8.2-1 Extent of freshwater yielding formations.

8.0 GROUND WATER

8.3 Ground-Water Quality

Aquifers of Quaternary, Tertiary, and Cretaceous Age Contain Usable Water

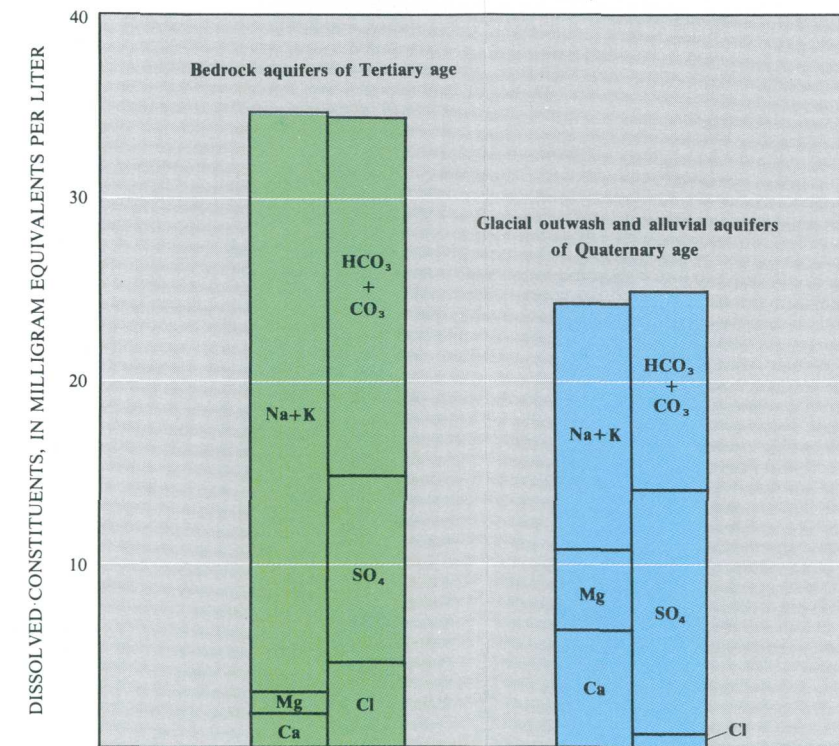
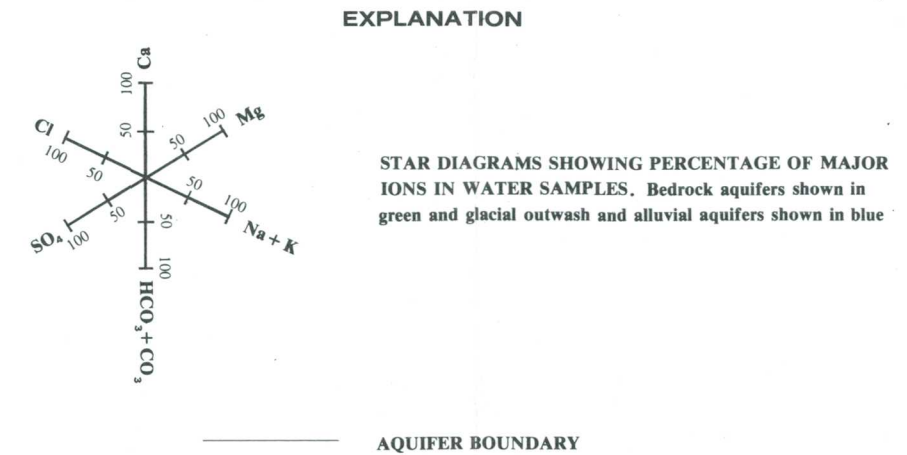
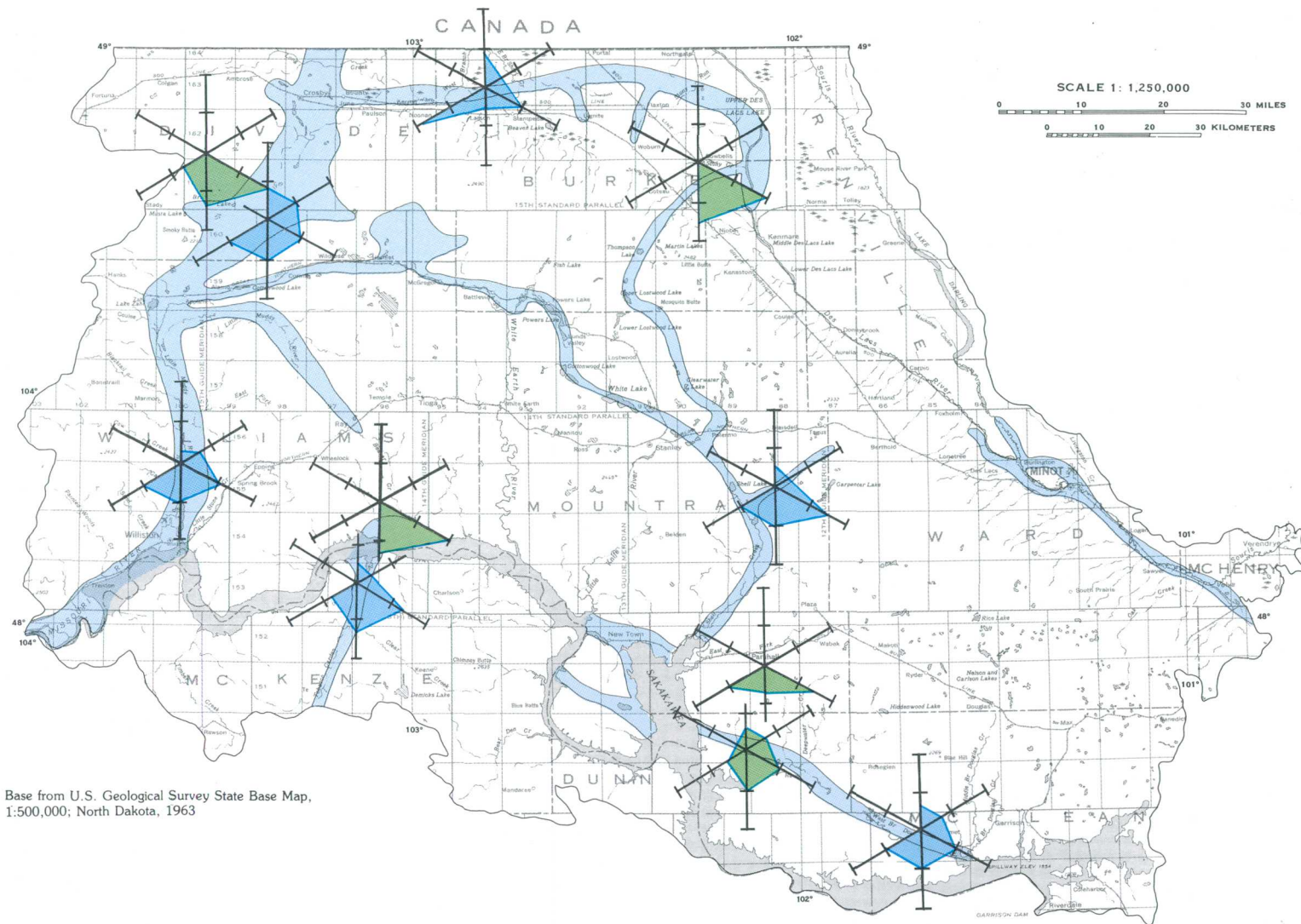
Water from glacial-outwash and alluvial aquifers is of better quality than water from the Tertiary or Cretaceous bedrock aquifers and is usable for most purposes.

Water in the shallow glacial-outwash and alluvial aquifers of Quaternary age is usable for most livestock, domestic, irrigation, and industrial purposes (fig. 8.3-1). Water samples collected from these aquifers contained about 25 milligram equivalents per liter dissolved solids (1,650 milligrams per liter), considerably less than the dissolved-solids concentration in water from the Tertiary bedrock aquifers (fig. 8.3-1). The star diagrams indicate that the percentages of individual dissolved constituents in the aquifers vary widely among wells. In the vicinity of mines, deteriorating ground-water quality may present a problem to water users (M. G. Croft, D. W. Fisher, and D. C. Thorstenson, written commun., 1979).

Water from beds of sandstone and lignite of Tertiary age is suitable for most livestock, and many municipal and industrial uses. The star diagrams in figure 8.3-1 show that constituent percentages are highly variable. The bar diagram shows that most samples from Tertiary aquifers are a sodium bicarbonate type and that the dissolved-solids concentration generally is greater than dissolved-solids concentration in water samples from the glacial and alluvial aquifers.

Water from the Fox Hills Sandstone and Hell Creek Formation is suitable for most livestock, municipal, and domestic uses. Few wells are found north of the Missouri River. South of the Missouri River typical samples contained about 2,000 milligrams per liter dissolved solids and were a sodium bicarbonate type. Samples contained about 400 milligrams per liter chloride.

Soluble sulfate minerals, such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), are abundant in soils and spoil piles. Precipitation percolating through the soil dissolves minerals and carries them to the water table (fig. 8.3-2). Ground water and surface runoff dissolve gypsum from spoils and may create a highly mineralized effluent downgradient from mine sites (M. G. Croft, D. W. Fisher, and D. C. Thorstenson, written commun., 1979). This effect has been shown by WATEQ (Truesdell and Jones, 1974), a computer analysis of water samples collected from the area (table 8.3-1). The WATEQ computer program calculates the solubility of minerals in water. The carbonate minerals calcite (CaCO_3) and aragonite (CaCO_3) are at saturation in the water and will not be dissolved.



Average composition of water samples from aquifers of Tertiary and Quaternary age.

Figure 8.3-1 Ground-water quality.

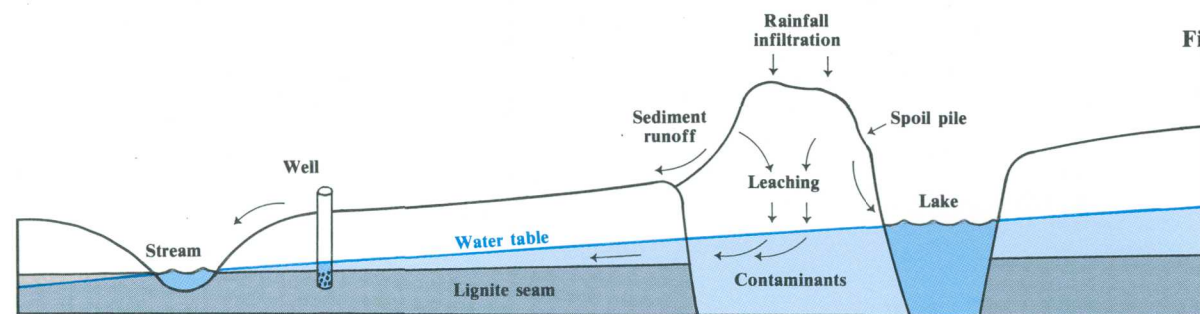


Figure 8.3-2 Sediments and leachates can contaminate streams and wells downgradient from spoils.

Table 8.3-1 WATEQ analyses of selected water samples.

Well number or location	Depth (feet)	Log ion-activity product/equilibrium constant ¹				
		Trona	Anhydrite	Gypsum	Aragonite	Calcite
Short Creek near Columbus		—	—	—	—	—
153-101-06ADB	96	-12.6	-2.1	-1.7	0.3	0.6
160-098-05CCC1	350	-12.6	-.9	-.5	.7	1.1
162-099-34DAB	508	-11.2	-2.2	-1.9	.4	.8
161-089-05AC	710	-10.0	-3.8	-3.4	.2	.5
161-089-05ADC	101	-10.9	-1.9	-1.5	.4	.7

¹ Positive values indicate over saturation and negative values indicate under saturation of the minerals in water samples.

9.0 WATER-DATA SOURCES

9.1 Introduction

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 9.2, 9.3, and 9.4.

9.0 WATER-DATA SOURCES--Continued

9.2 National Water-Data Exchange (NAWDEX)

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 more efficient exchange of water data.

Services are available through a Program Office located at the U.S. Geological Survey's National Center in Reston, Virginia, and a nationwide network of Assistance Centers located in 45 States and Puerto Rico, which provide local and convenient access to NAWDEX facilities (see fig. 9.2-1). A directory is available on request that provides names of organizations and persons to contact, addresses, telephone numbers, and office hours for each of these locations [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 requestor to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water-Data Index (fig. 9.2-2), 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 (fig. 9.2-3) also is maintained that 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
NORTH DAKOTA
U.S. Geological Survey
Water Resources Division
821 East Interstate Avenue
Bismarck, ND 58501
Telephone (701) 255-4011, extension 604
FTS 783-4604
Hours: 8:00-5:00 Central Time

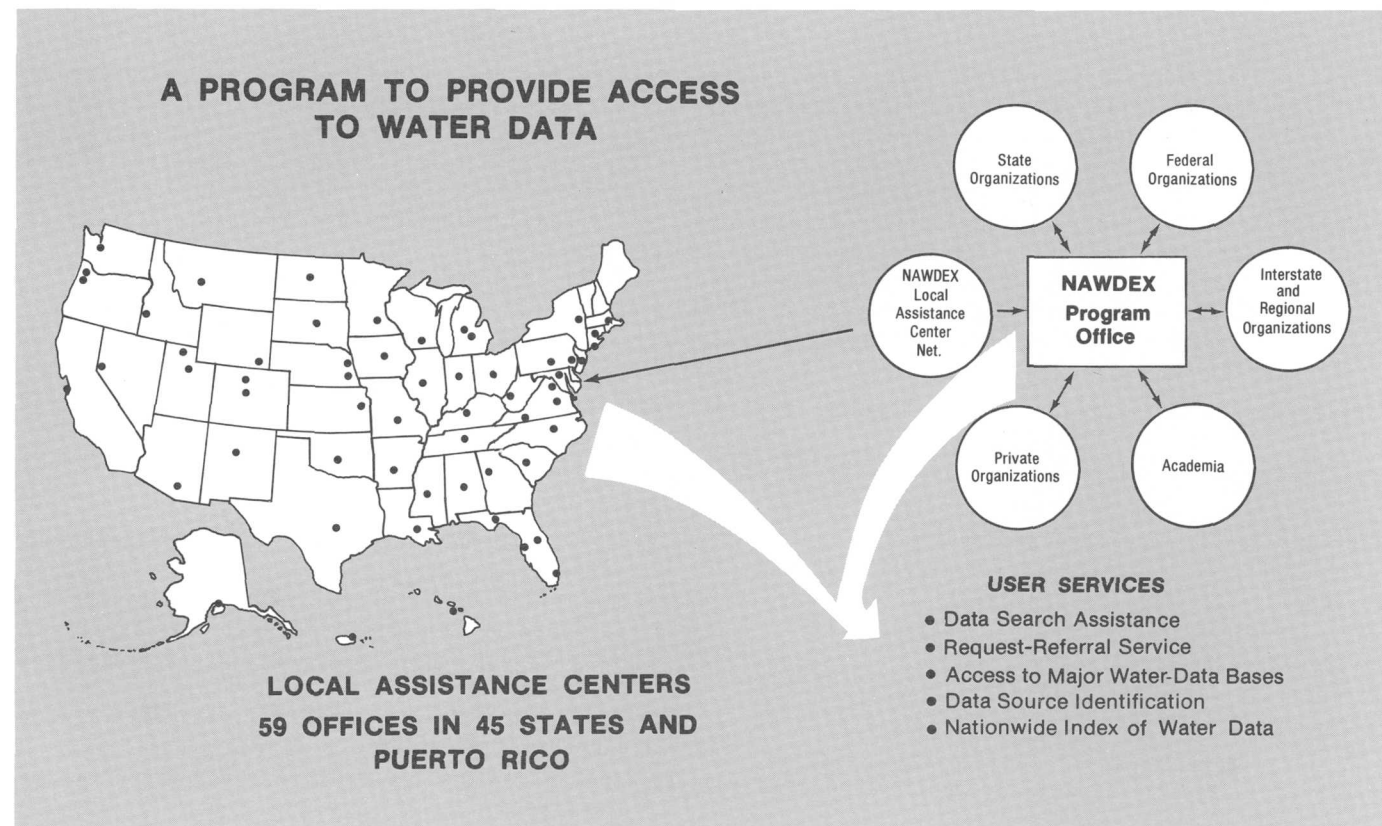


Figure 9.2-1 Access to water data.

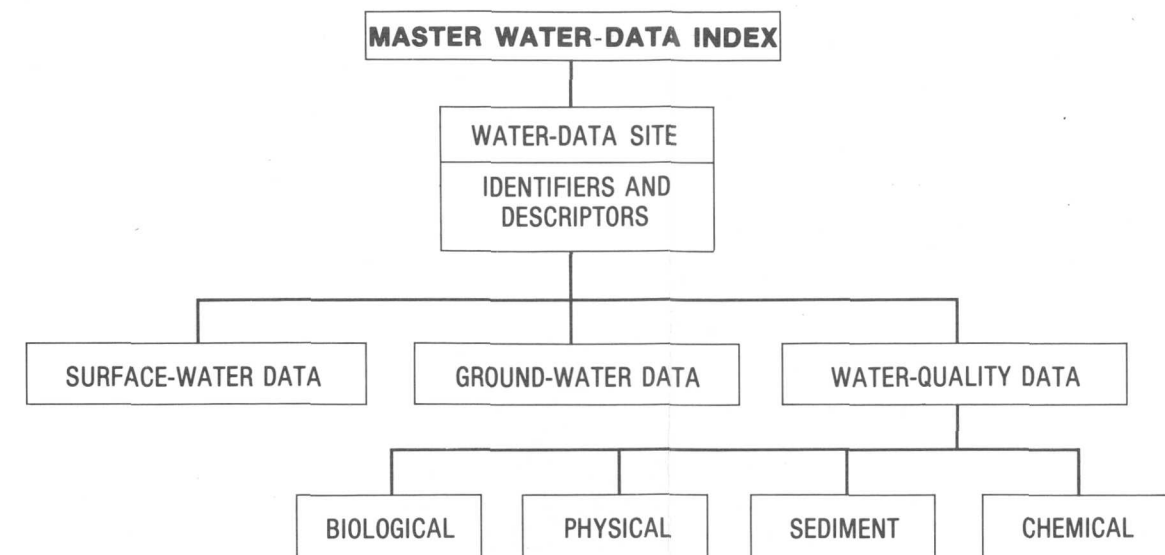


Figure 9.2-2 Master water-data index.

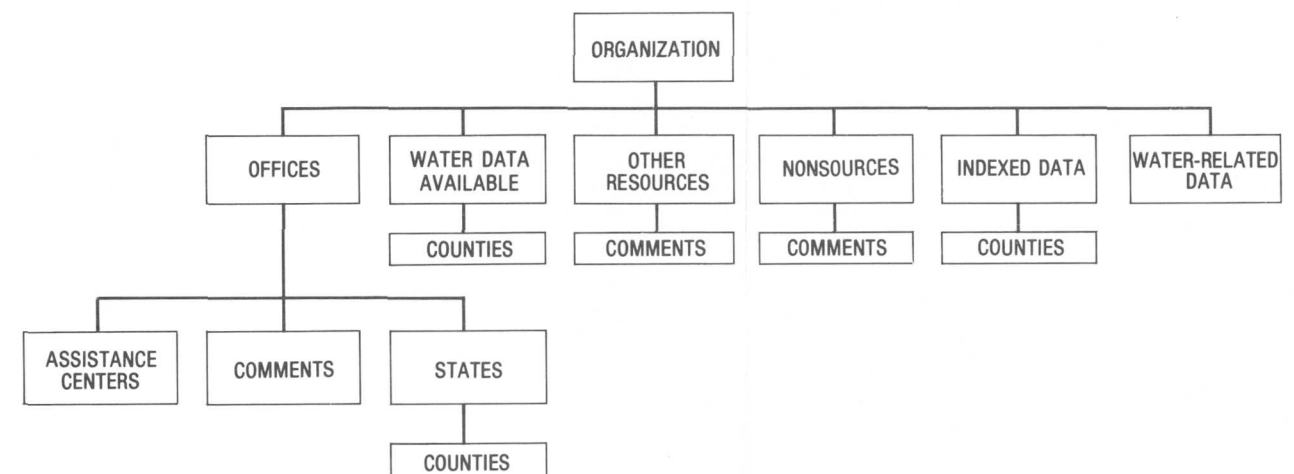


Figure 9.2-3 Water-data sources directory.

9.0 WATER-DATA SOURCES--Continued

9.3 WATSTORE

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 46 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
821 East Interstate Avenue
Bismarck, ND 58501
Telephone (701) 255-4011, extension 604
FTS 783-4604

The Geological Survey currently (1983) collects data at approximately 17,000 stage- or discharge-gaging stations, 5,200 surface-water quality stations, 27,000 water-level observation wells, and 7,400 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 (fig. 9.3-1). A brief description of each file is as follows:

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

Daily-Values File: All water-data parameters measured or observed either on a daily or 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 comprise this file, which currently contains over 400,000 peak observations.

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

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 ex-

amples 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, and one-time field measurements such as water temperature. The file is designed to accommodate 255 data elements and currently contains data for nearly 700,000 sites.

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 telecommunications network.

Remote Job Entry Sites: Almost all of 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 enter data into or retrieve data from the system within an interval of 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 stages, conductivity, water temperature, turbidity, wind direction, and chlorides. Data are recorded on 16-channel paper tape; the tape is removed from the recorder and the data are transmitted over telephone lines to the receiver at Reston, Va. The data are re-recorded on magnetic tape for use on the central computer. Extensive testing of satellite data-collection platforms indicates their feasibility for transmitting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication to link the satellite. About 500 data-relay stations are being operated currently (1983) by the Water Resources Division.

Central Laboratory System: The Water Resources Division's two water-quality laboratories located 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 com-

pounds, such as chloride, 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 our water resources. In addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple tables of data 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 capacity 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 called SAS (Statistical Analysis System, 1976) to provide extensive analyses of data such as regression analyses, 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.

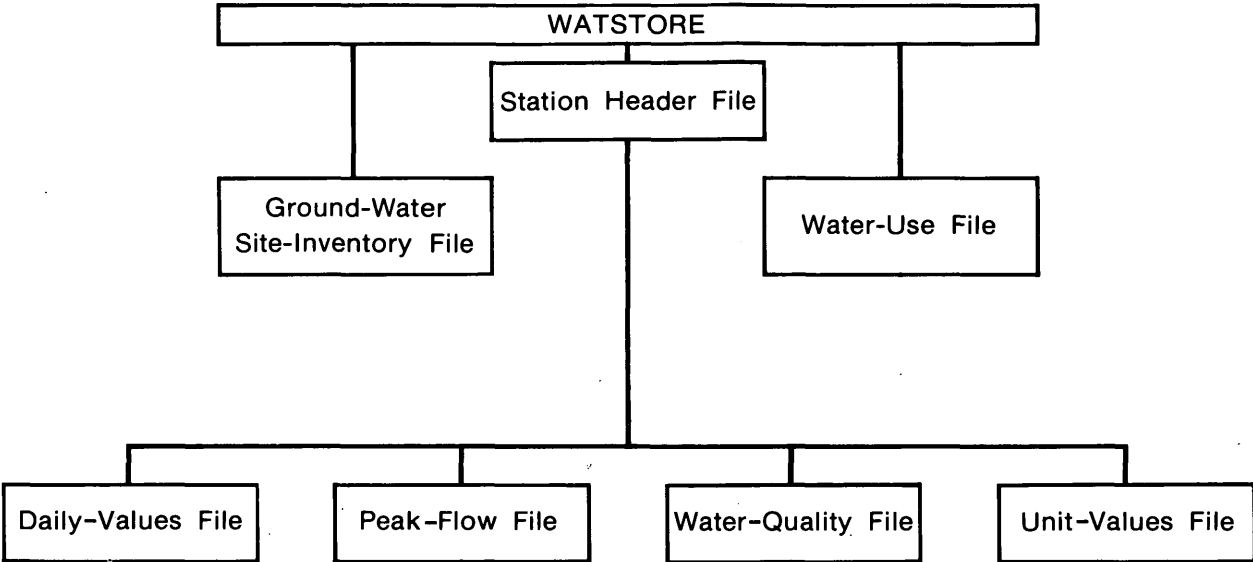


Figure 9.3-1 Index file stored data.

9.0 WATER-DATA SOURCES--Continued

9.4 Office of Water-Data Coordination (OWDC)

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 (fig. 9.4-1): 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 provinces; 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 9.2.)

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

U.S. Geological Survey
Water Resources Division
821 East Interstate Avenue
Bismarck, ND 58501
Telephone: (701) 255-4011, extension 604
FTS 783-4604

or

Office of Surface Mining
U.S. Department of the Interior
1st Floor, Thomas Hill Building
950 Kanawha Boulevard East
Charleston, WV 25301
Telephone: (304) 344-3481

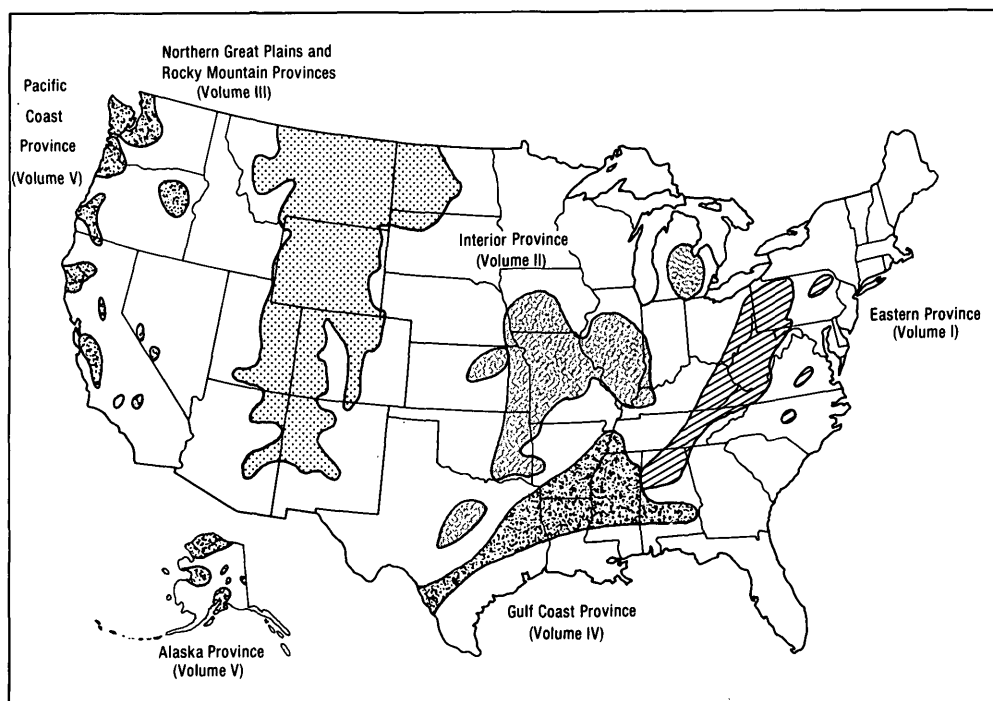


Figure 9.4-1 OWDC index. Volumes and related provinces.

10.0 SUPPLEMENTARY INFORMATION

10.1 Streamflow-Quantity Stations

Report station number	USGS station number	Station Name	Latitude (° ' ")	Longitude (° ' ")	Drainage area (square miles)		Periods of record		
					Total	Contributing	Daily or monthly values (calendar years)	Annual peaks and high-flow measurements (water years)	Low-flow measurements (water years)
1	0511340	Long Creek tributary No. 2 near Crosby	48 57 29	103 18 57	--	5.6	--	1960-73	--
2	05113500	Long Creek near Crosby	48 58 30	103 16 04	1,370	540	1943-65	--	--
3	05113520	Long Creek tributary near Crosby	48 50 11	103 19 19	--	.35	--	1960-73	--
4	05113600	Long Creek near Noonan	48 58 52	103 04 34	1,790	630	1959-82	--	--
5	05113700	West Branch Short Creek near Columbus	48 58 04	102 51 04	167	80	1977-82	--	--
6	05114000	Souris River near Sherwood	48 59 24	101 57 28	8,940	3,040	1930-82	--	--
7	05116000	Souris River near Foxholm	48 22 20	101 30 18	9,470	3,270	1905-05, 1936-82	--	--
8	05116100	Souris River tributary near Burlington	48 18 04	101 25 13	--	.13	--	1959-73	--
9	05116200	Des Lacs River tributary near Donnybrook	48 29 35	101 51 20	--	3.8	--	1956-73	--
10	05116500	Des Lacs River at Foxholm	48 22 14	101 34 11	939	539	1904-06, 1945-82	--	--
11	05116550	Fuller Coulee at Foxholm	48 24 45	101 34 00	--	5.9	--	1955-73	--
12	05117200	Souris River tributary No. 2 near Burlington	48 15 17	101 22 48	--	2.0	--	1960-73	--
13	05117500	Souris River above Minot	48 14 45	101 22 15	10,600	3,900	1903-82	--	--
14	05120000	Souris River near Verendrye	48 09 35	100 43 45	11,300	4,400	1937-82	--	--
15	06329700	Painted Woods Creek tributary near Williston	48 12 20	103 53 00	--	.37	--	1955-73	--
16	06329800	Painted Woods Creek near Williston	48 11 55	103 52 05	--	17	--	1955-73	--

17	06329900	Painted Woods Creek tributary No. 2 near Williston	48 13 55	103 49 10	--	8.3	--	1955-73	--
18	06330000	Missouri River near Williston	48 06 29	103 42 52	164,500	--	1897-1965	--	--
19	06330100	Sand Creek at Williston	48 08 50	103 39 10	--	38	--	1955-73	1955-56
20	06330200	Little Muddy River near Appam	48 32 48	103 37 57	268	--	--	--	1954-56
21	06330500	Blacktail Creek near Bonetrail	48 25 43	103 43 22	30	--	1955-60	--	--
22	06330600	East Fork Little Muddy River near Spring Brook	48 22 54	103 28 19	81	--	--	--	1953-56
23	06330700	East Fork Little Muddy River near Williston	48 21 09	103 34 58	125	--	--	--	1954-56
24	06331000	Little Muddy River below Cow Creek near Williston	47 17 04	103 34 21	875	775	1954-82	--	--
25	06331500	Little Muddy River near Williston	48 11 40	103 35 50	916	768	1904-09, 1932-33, 1945-54	--	--
26	06331570	Stony Creek near Williston	48 09 16	103 34 27	--	146	1977-81	--	--
27	06331680	Tobacco Garden Creek near Watford City	47 59 33	103 09 57	--	135	1976-82	--	--
28	06331850	Beaver Creek near Ray	48 10 52	103 01 26	--	98	1977-82	--	--
29	06331900	White Earth River tributary near Tioga	48 21 20	102 54 20	--	9.6	--	1960-73	--
30	06332100	White Earth River at White Earth	48 22 35	102 46 00	780	490	1954-82	--	--
31	06332150	White Earth River tributary near White Earth	48 19 55	102 45 10	--	.37	--	1960-73	--
32	06332515	Bear Den Creek near Mandaree	47 47 14	102 46 05	--	74	--	1960-73	--
33	06332520	Shell Creek near Parshall	48 03 11	102 08 10	465	145	1965-81	--	--
34	06337600	East Branch Douglas Creek tributary near Garrison	47 38 37	101 31 09	--	1.4	--	1957, 1959-73	--
35	06337900	Snake Creek tributary near Garrison	47 37 55	101 21 00	--	1.2	--	1959-73	--
36	06338490	Missouri River at Garrison Dam	47 30 08	101 25 60	181,400	--	1969-81	--	--

10.0 SUPPLEMENTARY INFORMATION--Continued
10.1 Streamflow-Quantity Stations

10.0 SUPPLEMENTARY INFORMATION--Continued

10.2 Streamflow Water-Quality Stations

[Type of data available: F indicates field determinations of conductance, pH, and water temperature; C indicates common ions; N indicates nutrients; T indicates trace elements; P indicates pesticides; R indicates radiochemical; S indicates sediment; M indicates microbiological; B indicates biological; O indicates organic compounds]

Report station number	USGS station number	Name	Period of record	Type of data available
4	05113600	Long Creek near Noonan	1972-82	F, C, N
5	05113700	West Branch Short Creek near Columbus	1978-81	F, C, N, T, R, S, M, B, O
6	05114000	Souris River near Sherwood	1970-82	F, C, N, T, P, S, M, B, O
7	05116000	Souris River near Foxholm	1977-82	F, C, N, T, P, S, M, B, O
10	05116500	Des Lacs River at Foxholm	1950-51, 1969-70, 1972-82	F, C, N
13	05117500	Souris River above Minot	1969-82	F, C, N
14	05120000	Souris River near Verendrye	1950-51, 1957-82	F, C, N, T, P, S, M, O
18	06330000	Missouri River near Williston	1946, 1951- 65, 1969-70, 1974-82	F, C, N, T, R, S, M, B, O
24	06331000	Little Muddy River below Cow Creek near Williston	1972-82	F, C, N
26	06331570	Stony Creek near Williston	1978-81	F, C, N, T, R, S, M, B, O
27	06331680	Tobacco Garden Creek near Watford City	1977-82	F, C
28	06331850	Beaver Creek near Ray	1978-82	F, C, N, T, R, S, M, B, O
30	06332100	White Earth River at White Earth	1969-70, 1972-82	F, C, N
32	06332515	Bear Den Creek near Mandaree	1966-82	F, C, N, T, P, R, S, M, O
33	06332520	Shell Creek near Parshall	1977-82	F, C, N
36	06338490	Missouri River at Garrison Dam	1971-82	F, C, N, T, R, S, M, B, O

10.0 SUPPLEMENTARY INFORMATION--Continued **10.3 Ground-Water Observation Wells**

Report well number	Local well number	Aquifer	Period of record	Report well number	Local well number	Aquifer	Period of record
<u>BURKE COUNTY</u>							
1	159-093-36AAA	Shell Creek	1971-	27	148-082-08CDC1	Lake Nettie	1980-
2	159-094-23DDC	Shell Creek	1965-	28	148-082-08CDC2	Lake Nettie	1980-
3	160-091-13ACD1	Kenmare	1966-	29	148-082-15BBB	Lake Nettie	1969-79, 1981-
4	160-091-13ACD2	Kanmare	1966-	30	148-084-08BCB	Garrison	1970-
5	162-092-02CBB	Lignite City	1966-	31	148-084-14BBC	Garrison	1970-
6	163-093-17DDD	Columbus	1967-	32	148-086-29AAA2	White Shield	1970-
7	163-093-20AAA	Columbus	1967-	33	148-087-07AAA2	White Shield	1968-
<u>DIVIDE COUNTY</u>							
8	160-097-32DAA	West Wildrose	1962-	34	149-082-12BAB2	Snake Creek	1969-
9	162-097-02BBB	Yellowstone System	1972-	35	149-089-24AAA	White Shield	1970-
10	163-097-15BCC	Yellowstone System	1972-	36	150-082-10CCD	Snake Creek	1969-
11	163-097-23DDD	Yellowstone System	1972-	37	150-090-36AAA	White Shield	1970-
<u>MOUNTAIN COUNTY</u>							
12	163-097-24AAA	Yellowstone System	1972-	38	152-090-18CCC	Shell Creek	1966-
13	163-097-25AA	Yellowstone System	1972-	39	152-092-19AAB	New Town	1967-
14	163-097-25DDD	Yellowstone System	1972-	40	154-091-30AAA	Buried glaciofluvial	1966-
15	163-097-26DDD	Yellowstone System	1976-	41	155-088-06DDD	Shell Creek	1966-
16	163-097-27CCC	Yellowstone System	1972-	42	155-049-25BCC	Shell Creek	1965-
17	163-097-34ABB	Yellowstone System	1972-	43	155-089-35AAA	Shell Creek	1966-
18	163-097-35BCC	Yellowstone System	1972-	44	155-090-12DDD	Shell Creek	1966-
19	163-100-09AAA	Buried Missouri Channel	1963-	45	156-091-05DAA	Shell Creek	1967-
<u>MCHENRY COUNTY</u>							
20	154-078-31BAA1	Fox Hills	1976-	46	156-091-10BBB	Shell Creek	1966-
21	154-078-31BAA2	Hell Creek	1976-	47	156-094-16DBA	Buried glaciofluvial	1966-
22	154-079-24DDD	New Rockford	1977-	48	157-091-36DDD	Buried glaciofluvial	1966-
<u>MCKENZIE COUNTY</u>							
23	151-101-09BAA	Charbonneau	1979-	49	158-090-17BBA	Buried glaciofluvial	1967-
24	152-101-24CBB	Charbonneau	1979-	<u>RENNVILLE COUNTY</u>			
25	153-097-15CCC	Tobacco Garden	1979-	50	161-086-33ABB	Buried glaciofluvial	1964-
26	153-101-16BAC	Yellowstone-Missouri	1980-	51	162-087-22AAA	Buried glaciofluvial	1965-
<u>WARD COUNTY</u>							
				52	151-083-26BAB	Buried glaciofluvial	1965-

10.3 Ground-Water Observation Wells

74

10.0 SUPPLEMENTARY INFORMATION--Continued

10.4 Selected Reservoirs and Lakes

[Capacity 50 acre-feet or more]

Map number	Name	Location of outlet	Capacity at spillway level (acre-feet)	Quality information available
BURKE COUNTY				
1	Upper Lostwood Lake	159-091-34BBD	--	No
2	Smishek Lake	159-093-11BBA	2,200	No
3	Powers Lake	159-093-35A	7,150	No
4	Sletten Lake	159-094-36DD	--	No
5	Thompson Lake	160-091-23DD	--	No
6	Beaver Lake	162-092-16BA	--	No
7	North Star Reservoir	163-089-15	270	No
8	Northgate Reservoir	163-089-19	1,300	Yes
9	East Branch Short Creek Reservoir	164-093-32BC	1,200	Yes
DIVIDE COUNTY				
10	Noonan Park Reservoir	162-095-16AAB	140	No
11	Country Club Reservoir	163-097-05ADD	112	No
MCKENZIE COUNTY				
12	Arnegard Reservoir	150-100-04CDA	320	No
13	Demicks Lake	151-097-24BC	--	No
MCLEAN COUNTY				
14	Lake Sakakawea	147-084-04DCC	22,700,000	Yes
15	Blackwater Lake	148-087-07BAA	--	No
16	Unnamed reservoir	148-089-19	69	No
17	Hager Reservoir	149-085-26DAD	223	No
18	Douglas Lake	150-085-01ADC	--	No
19	Lake Susie	150-088-16CCC	148	No
20	Peterson Lake	150-089-01DCC	50	Yes
MOUNTRAIL COUNTY				
21	Paulson Reservoir	152-089-13CBB	50	No
22	Unnamed reservoir	153-090-27CDC	50	No
23	Shell Lake	154-089-10CBA	--	No
24	Chocolate Drop Reservoir	154-091-16BCB	875	No

10.0 SUPPLEMENTARY INFORMATION--Continued

10.4 Selected Reservoirs and Lakes

Map number	Name	Location of outlet	Capacity at spillway level (acre-feet)	Quality information available
<u>MOUNTRAIL COUNTY, continued</u>				
25	Shell Lake	155-089-19DB	--	No
26	White Lake	156-091-05BAB	--	No
27	Stanley Reservoir	156-091-32ACC	1,550	Yes
28	Unnamed reservoir	157-088-09DD	80	No
29	Clearwater Lake	157-090-22DB	1,080	No
30	Cottonwood Lake	157-092-06DB	--	No
31	White Earth Reservoir	157-093-06ACC	1,600	Yes
32	Lower Lostwood Lake	158-091-04BDA	--	No
33	Unnamed reservoir	158-091-06B	50	No
<u>RENVILLE COUNTY</u>				
34	Plain Reservoir	158-085-05DDA	60	No
<u>WARD COUNTY</u>				
35	Nelson Lake	151-084-06	--	No
36	Carlson Lake	151-084-07	--	No
37	Rush Lake	151-084-22	--	No
38	Hiddenwood Lake	151-087-33DAA	--	No
39	Velva Sportsman Reservoir	152-081-36DDD	66	No
40	Rice Lake	152-085-10	1,430	Yes
41	Tangedahl Lake	152-085-14	--	No
42	Lake Vernon	152-085-23	--	No
43	Underdahl Lake	153-085-18	--	No
44	Schofield Reservoir	154-083-32DDA	100	No
45	Minot Water Supply Reservoir	155-083-23CCB	170	No
46	Unnamed reservoir	155-083-35ADB	50	No
47	Des Lacs City Reservoir	155-085-11ACC	220	No
48	Burlington Reservoir 2	156-084-32ADA	175	No
49	Burlington Reservoir 1	156-084-34DCC	200	No
50	Veghein Reservoir	156-086-35	50	No
51	Reservoir 87	157-084-08DDB	1,320	No

Map number	Name	Location of outlet	Capacity at spillway level (acre-feet)	Quality information available
<u>WARD COUNTY, continued</u>				
52	Reservoir 96	157-084-34DBB	2,800	No
53	Lake Darling	157-085-01AAC	112,000	Yes
54	Carpio Reservoir	157-085-07BBB	60	No
55	Des Lacs Lake	159-088-14DDD	49,000	No
56	Nelson-Landers Reservoir	159-089-13BDD	88	No
<u>WILLIAMS COUNTY</u>				
57	Unnamed reservoir	154-103-21CAC	55	No
58	Iverson Reservoir	155-095-19CDD	154	No
59	Kota Ra Reservoir	155-097-22BAD	375	Yes
60	Epping Reservoir	155-099-09CCC	1,580	No
61	McLeod Lake	156-097-16BCD	175	No
62	Olson Reservoir	156-098-33BAB	392	No
63	Tioga Reservoir	157-095-22CDB	620	Yes
64	Twin Lakes	157-100016ABB	143	No
65	Blacktail Lake	157-101-15BBB	2,640	Yes
66	McGregor Reservoir	159-095-22AAC	790	Yes
67	Cottonwood Lake	159-099-22BDD	2,130	No
68	Alkali Lake	159-100-17BBC	--	No
69	Lake Zahl	159-101-36CDD	2,980	No

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