WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN NORTH DAKOTA, FISCAL YEAR 1985

Compiled by Cathy R. Martin

U.S. GEOLOGICAL SURVEY

Open-File Report 85-558

Bismarck, North Dakota

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN NORTH DAKOTA, FISCAL YEAR 1985

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MESSAGE FROM THE DISTRICT CHIEF

The North Dakota District of the U.S. Geological Survey, Water Resources Division, has had a long-standing and ambitious cooperative program with the North Dakota State Water Commission, the North Dakota Geological Survey, and the counties of the State to develop a statewide inventory of ground-water resources. This year, the last of the county reports, McKenzie County, will be published, thus ending a farsighted program to provide a reconnaissance-level data base (framework) on which the U.S. Geological Survey and the North Dakota State Water Commission can build and which can be used to manage the ground-water resources of North Dakota. North Dakota should be proud to be one of only a few states to complete such a program.

Having completed the county ground-water studies, the Survey and the North Dakota State Water Commission have started another cooperative effort to advance the knowledge of hydrologic processes in the State--the mechanics of ground-water recharge from snowmelt. This project was selected as one of the WRD "Merit Fund" projects for fiscal year 1985 based on its scientific merits.

Also this year, the District and the North Dakota Geological Survey will complete a multiyear study addressing the geochemical impacts of strip mining of lignite. This project was a WRD "Merit Fund" project in 1983.

The District also prepared a report summarizing the water resources of North Dakota for the Garrison Diversion Study Commission. Projects assisting the U.S. Bureau of Reclamation and the State develop plans for water management consistent with the Commission's recommendations comprise many of the District's current activities.

During the year, the District has continued the development of a statewide data-collection network with the support of various Federal, State, and local agencies. This network continues to provide the core of information necessary for management activities, flood forecasting, and interpretive studies.

The next few years promise a growth of new projects oriented toward assisting the State and Federal agencies in their management of our finite water resources. I look forward to an active role of the U.S. Geological Survey in these activities.

L. Grady Moore
District Chief
U.S. Geological Survey, WRD
Bismarck, N. Dak.

U.S. GEOLOGICAL SURVEY ORIGIN

The U.S. Geological Survey was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific 'classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain.' An integral part of that original mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nation's energy, land, mineral, and water resources.

Since 1879, the research and fact-finding role of the U.S. Geological Survey has grown and been modified to meet the changing needs of the Nation it serves. As part of that evolution, the U.S. Geological Survey has become the Federal Government's largest earth-science research agency, the Nation's largest civilian mapmaking agency, the primary source of data on the Nation's surface- and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs serve a diversity of needs and users. Programs include:

--Conducting detailed assessments of the energy and mineral potential of the Nation's land and offshore areas;
--Investigating and issuing warnings of earthquakes, volcanic eruptions, landslides, and other geologic and hydrologic hazards;
--Conducting research on the geologic structure of the Nation;
--Studying the geologic features, structure, processes, and history of the other planets of our solar system;
--Conducting topographic surveys of the Nation and preparing topographic and thematic maps and related cartographic products;
--Developing and producing digital cartographic data bases and products;
--Collecting data on a routine basis to determine the quantity, quality, and use of surface and ground water;
--Conducting water-resource appraisals in order to describe the consequences of alternative plans for developing land and water resources;
--Conducting research in hydraulics and hydrology and coordinating all Federal water-data acquisition;
--Using remotely sensed data to develop new cartographic, geologic, and hydrologic research techniques for natural resources planning and management;
--Providing earth-science information through an extensive publications program and a network of public access points.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the U.S. Geological Survey remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation--providing 'Earth Science in the Public Service.'

WATER RESOURCES DIVISION

Basic Mission and Program

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization and management of the Nation's water resources for the overall benefit of the people of the United States.

This is accomplished, in large part, through cooperation with other Federal and non-Federal agencies, by:

--Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources;

--Conducting analytical and interpretive water-resource appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water;

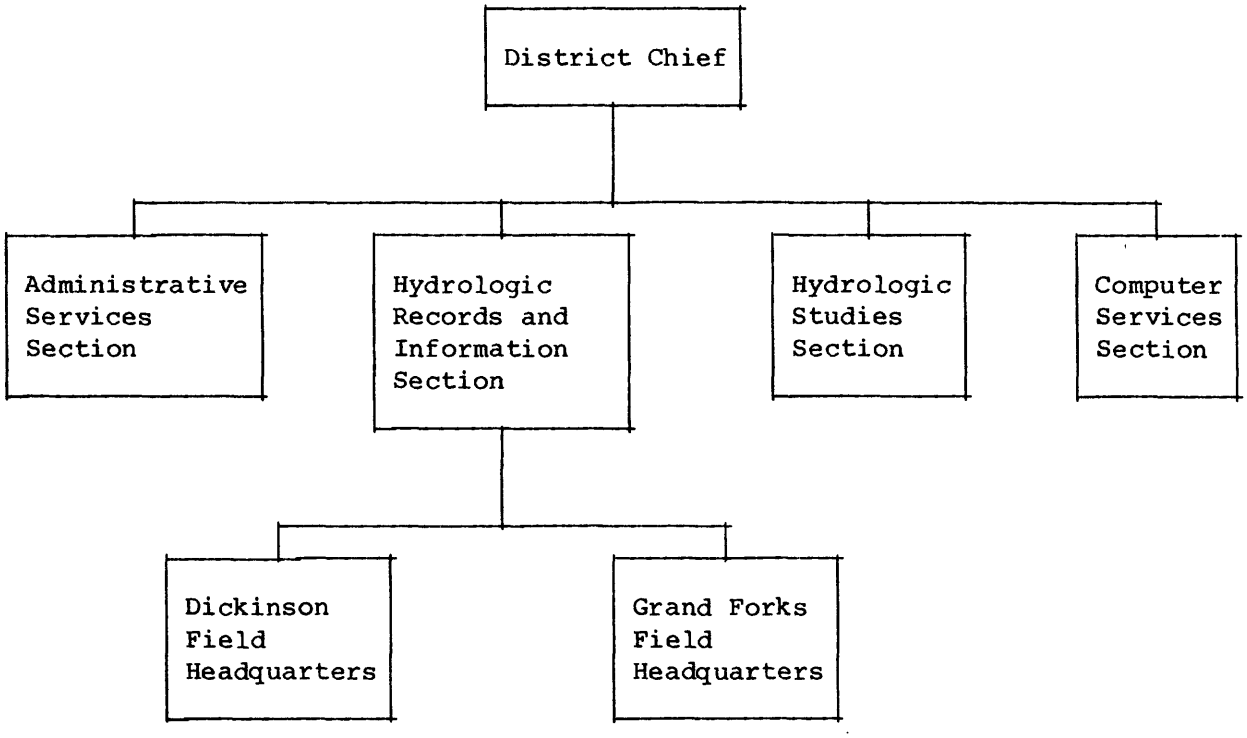
--Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade;

--Disseminating the water data and the results of these investigations and research through reports, maps, computerized information services, and other forms of public releases;

--Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters;

--Providing scientific and technical assistance in hydrologic fields to other Federal, State, and local agencies, to licensees of the Federal Power Commission, and to international agencies on behalf of the Department of State.

NORTH DAKOTA DISTRICT ORGANIZATION
L. Grady Moore, District Chief



North Dakota District Office Addresses

District Office	(701) 255-4011 Extensions 601, 610 FTS 783-4601	U.S. Geological Survey 821 East Interstate Bismarck, ND 58501
Dickinson Field Headquarters	(701) 225-2051 FTS 783-5771, ask for 225-2051	U.S. Geological Survey Water Resources Division 669 12th Street SW Dickinson, ND 58601
Grand Forks Field Headquarters	(701) 775-7221 FTS 783-0325	U.S. Geological Survey Water Resources Division P.O. Box 1437 Grand Forks, ND 58206-1437

TYPES OF FUNDING

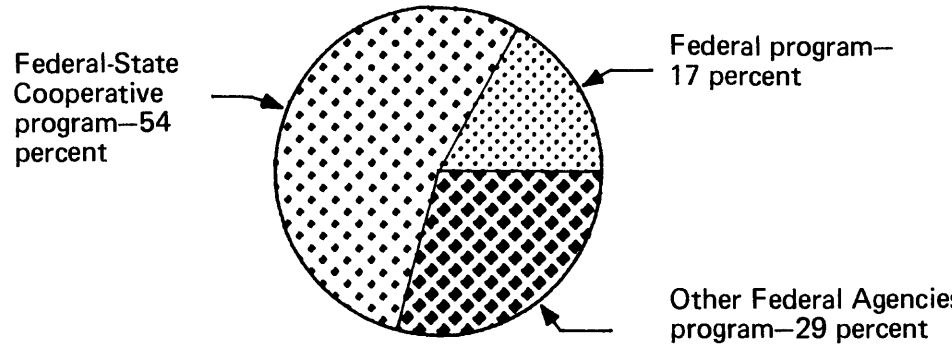
Funds to support the water-resources activities of the North Dakota District are derived from three principal sources:

(1) Federal Program--Funds are appropriated by Congress and are specifically identified. In fiscal year 1985, Federal funding for North Dakota District program activities was $436,825.

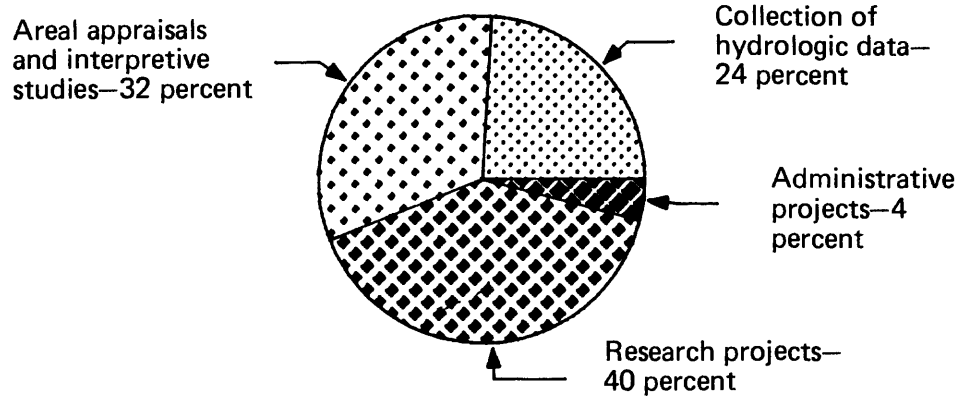
(2) Federal-State Cooperative Program--Federal funds are appropriated by Congress and used to match those furnished by State and other tax-supported agencies on a 50-50 basis. These funds are used for a variety of hydrologic data-collection activities and water-resources investigations in which the U.S. Geological Survey represents the national interest and the cooperating agencies represent State and local interests. In fiscal year 1985, Federal-State Cooperative funding for the North Dakota District was $1,410,780.

(3) Other Federal Agencies (OFA) Program--In this program, the funds are transferred to the U.S. Geological Survey as reimbursement for work performed at the request of another Federal agency. In fiscal year 1985, OFA funding was $741,555.

The total budget for fiscal year 1985 is $2,589,160.



The diagram below shows the percentage of the investigations for fiscal year 1985 in each of the broad categories of research projects, areal appraisals and interpretive studies, collection of hydrologic data, and administrative projects.



LIST OF COOPERATORS

Agencies supporting water-resources investigations during fiscal year 1985 are listed below.

Federal agencies

U.S. Department of Agriculture
  Soil Conservation Service
U.S. Department of the Army
  Corps of Engineers
    St. Paul District
    Omaha District
U.S. Department of Commerce
  National Weather Service
U.S. Department of Energy
  Western Area Power Administration
U.S. Department of the Interior
  Bureau of Indian Affairs
  Bureau of Land Management
  Bureau of Reclamation
  Fish and Wildlife Service
  National Park Service
U.S. Department of State
  International Joint Commission
    Waterways Treaty
U.S. Environmental Protection Agency

Local agencies

Burleigh County Water Resource District
City of Dickinson
Lower Heart Water Resource District
Oliver County Board of Commissioners

State agencies

North Dakota Geological Survey
North Dakota Public Service Commission
North Dakota State Department of Health
North Dakota State University
North Dakota State Water Commission

SUMMARY OF MAJOR WATER PROBLEMS

Water has been a subject of major concern to the agricultural State of North Dakota. Testimonial to this is the fact that the North Dakota State Water Commission, the chief State water agency, has been one of the largest State agencies over the years and generally has received adequate funding from the State Legislature. It has regulatory authority over all water use within the State and carries out a program of water-related activities with Federal, other State, and local agencies.

The water problems are related mostly to natural conditions of geology and climate but are socioeconomic as well. They are discussed herein under the broad headings of quantity and quality.

Quantity

Precipitation in North Dakota (fig. 1) is erratic. Periods of surplus water alternate with periods of deficiency. No regular cyclic pattern has been demonstrated, but the periods generally extend over several years. During the surplus periods, flooding is common. All major rivers in the State (fig. 2) are subject to flooding; but for some rivers, such as the Missouri, the risks are low because their flows are regulated by dams and reservoirs.

The Red River valley is particularly vulnerable to flooding because of extremely flat topography and small channel capacity. Since 1950, 10 serious floods have occurred along the Red River main stem in North Dakota and Minnesota. The Souris River, which enters northwestern North Dakota from Canada and eventually flows back into Canada from North Dakota, also is flood prone. Since 1950, seven serious floods have occurred along the Souris River main stem.

Studies to date indicate that the natural tendencies toward flooding in the Red River valley and along the Souris River are being affected by man's activities. However, these effects are very difficult to quantify because of insufficient long-range records. It is known that large tracts of formerly noncontributing wetlands in and on both sides of the Red River valley have been drained for agricultural purposes. Drainage of the wetlands has added to the contributing basin of the Red River. Also, it is known that a large number of individual dike systems have been built for flood protection. These systems tend to aggravate flood conditions in that they locally cause higher than normal flood crests.

Wetland drainage affects water resources in other ways. Wetlands constitute valuable habitat for waterfowl and other wildlife. North Dakota normally produces more waterfowl than any other state in the contiguous United States. Some of the deeper wetlands are used for stock-watering purposes, particularly in the Coteau du Missouri. Finally, wetlands may be important sources of ground-water recharge. To date, little quantitative work has been done in North Dakota regarding ground-water recharge. During the 1985 fiscal year, however, a cooperative project with the North Dakota State Water Commission was begun to address snowmelt recharge to shallow aquifers.

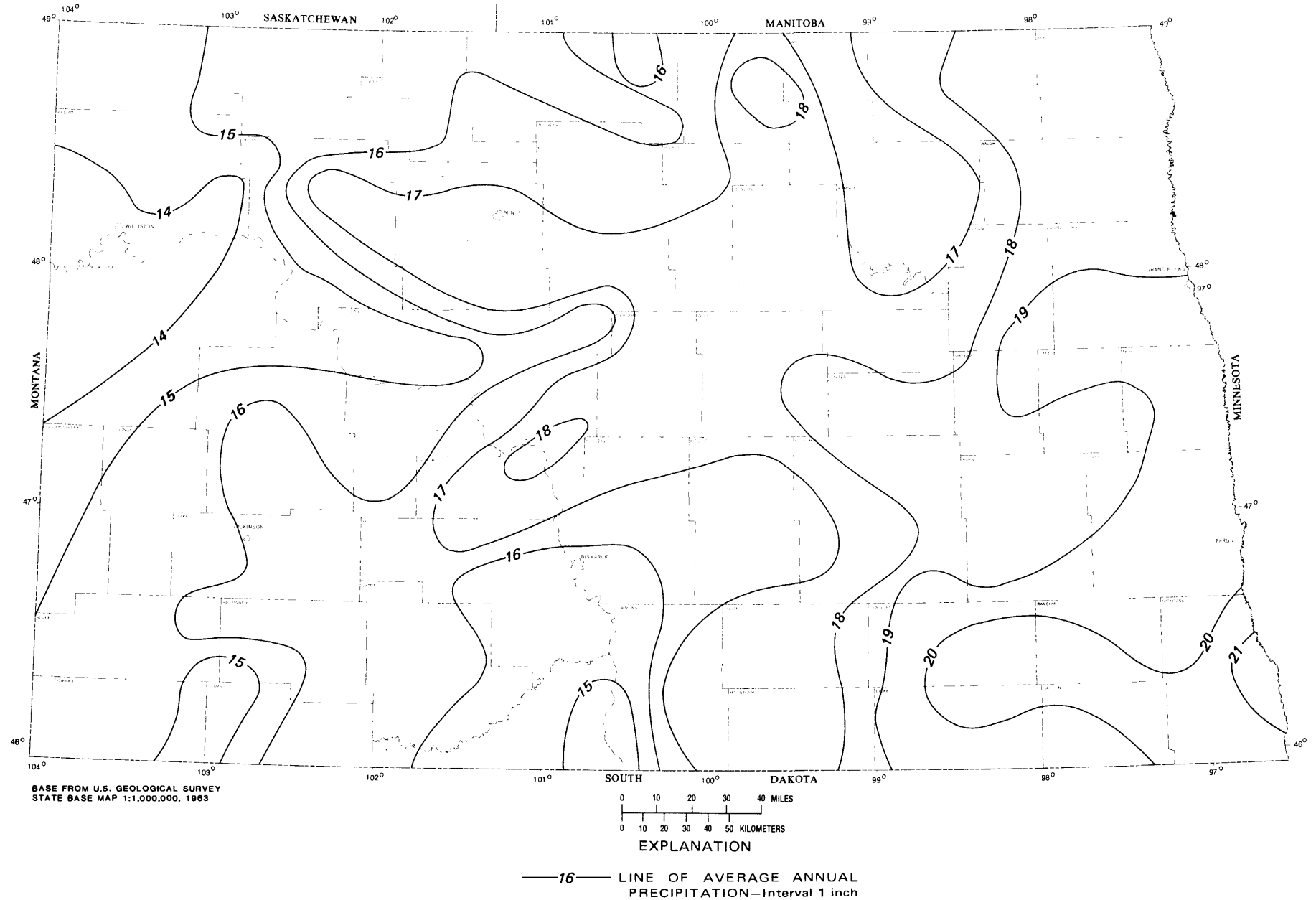


FIGURE 1.—Average annual precipitation (1951-80), in inches (John W. Enz, North Dakota State University, written commun., 1984).

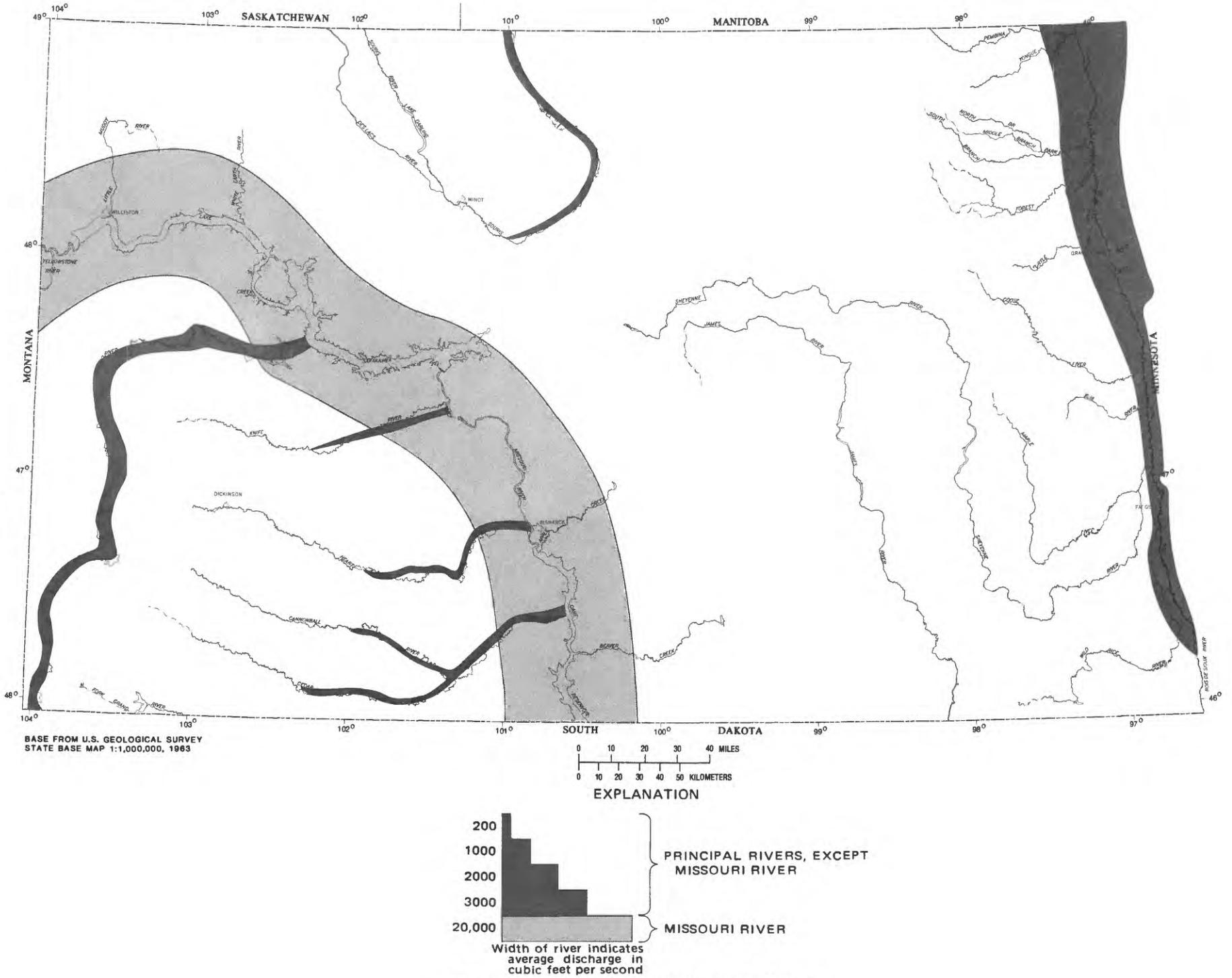


Figure 2.—Average discharge of the principal rivers.

Generally, the first problems that arise during the water-deficiency period are associated with inadequate streamflow. Municipalities dependent on surface-water sources may have to curtail water use. Ironically, these may include the cities that were damaged by flood waters only a few years earlier. Such has been the case with Fargo on the Red River and Minot on the Souris River. Irrigators may be forced to reduce their irrigated acreages and put part of their crop into dryland farming. This reduction, in turn, may affect cattle-feeder operations, beef prices, etc.

Fish and wildlife resources are severely impacted during prolonged periods of water deficiencies. Severely depleted streams and lakes result in fish kills, some to the point where complete restocking is necessary. Wetlands dry up during these periods, greatly reducing the production of waterfowl and other wildlife that use the wetlands for habitat.

Water levels in shallow aquifers, most of which occur in glacial deposits (fig. 3), decline during periods of water deficiency because evapotranspiration losses exceed recharge. Also, as surface-water sources are depleted, more dependency is placed on ground water, and withdrawals increase. Irrigation, which in North Dakota is supplemental to rainfall, increases during the water-deficiency period placing added stresses on aquifers. In the case of shallow aquifers, the additional water pumped may be salvage derived from evapotranspiration losses. However, water from deeper, confined aquifers is pumped from storage that is not replaced within comparable time frames. Future ground-water studies in the State will need to focus on both types of ground-water occurrence. Information is needed regarding rates of evapotranspiration from and rates of recharge to shallow aquifers as well as sources and rates of recharge (leakage from confining beds) to the deeper aquifers.

Quality

High salinity is the most serious water-quality problem in the State, particularly in the western part. Except for the Missouri River and its reservoirs, salinity in both surface- and ground-water sources in western North Dakota commonly exceeds 1,000 mg/L and at times and in places exceeds 2,000 mg/L (fig. 4). Salinity in the Missouri River and its reservoirs generally is near 500 mg/L with little variation. The high salinity limits use of the water resources in the western part of the State. Generally, salinity and sodium hazards prohibit use of the water for irrigation. Also, the high salinity as well as high concentrations of certain chemical constituents (fig. 5) limits the desirability of the water for domestic use.

Greatly expanded energy development poses a potential threat to water quality in western North Dakota. Leachates from lignite mine spoil piles are several times as saline as water in the undisturbed environment. In addition, because the lignite has a high water content, it cannot economically be hauled great distances for commercial use. Consequently, it must be utilized (burned) within the State, and preliminary studies indicate the ash contains significant quantities of hazardous materials such as arsenic, molybdenum, selenium, and phenols that under certain conditions could be released into the environment.

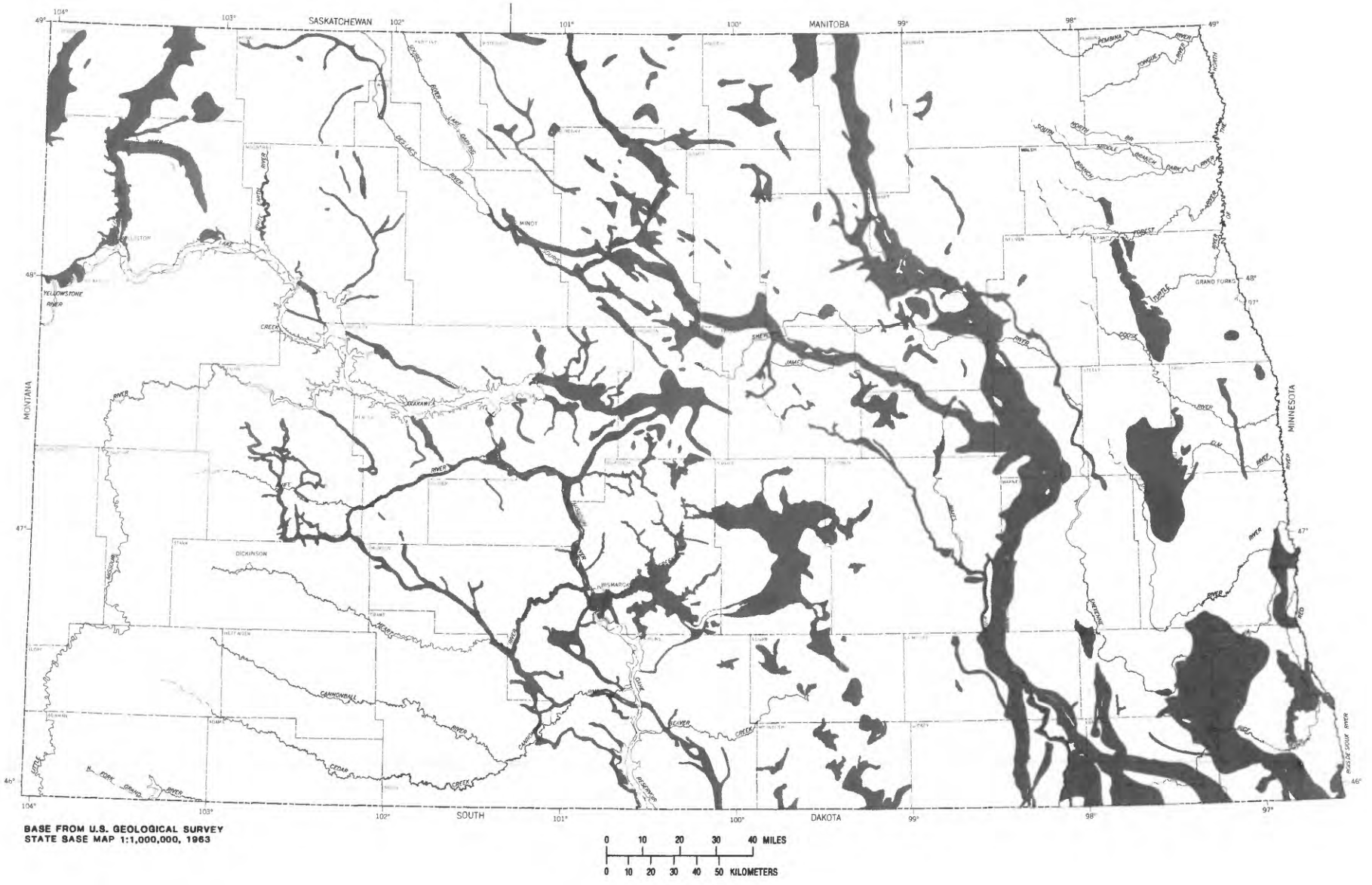


Figure 3.—Locations of major glacial-drift aquifers. (Modified from North Dakota State Water Commission, 1982. Map showing glacial-drift aquifers in North Dakota and estimated potential yields. North Dakota State Water Commission, scale 1:500,000, 1 sheet).

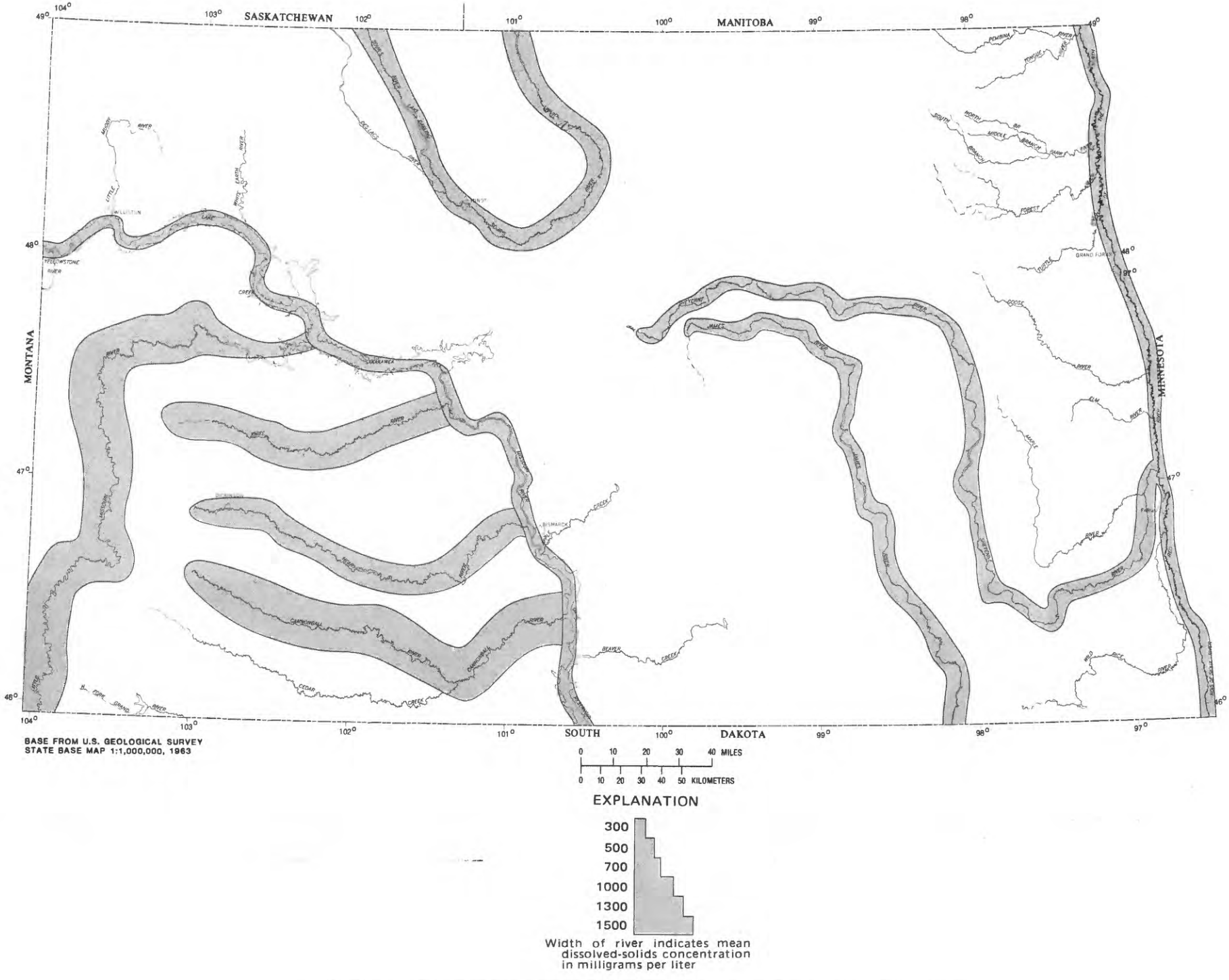


Figure 4.—Mean dissolved-solids concentration of the principal rivers of North Dakota.

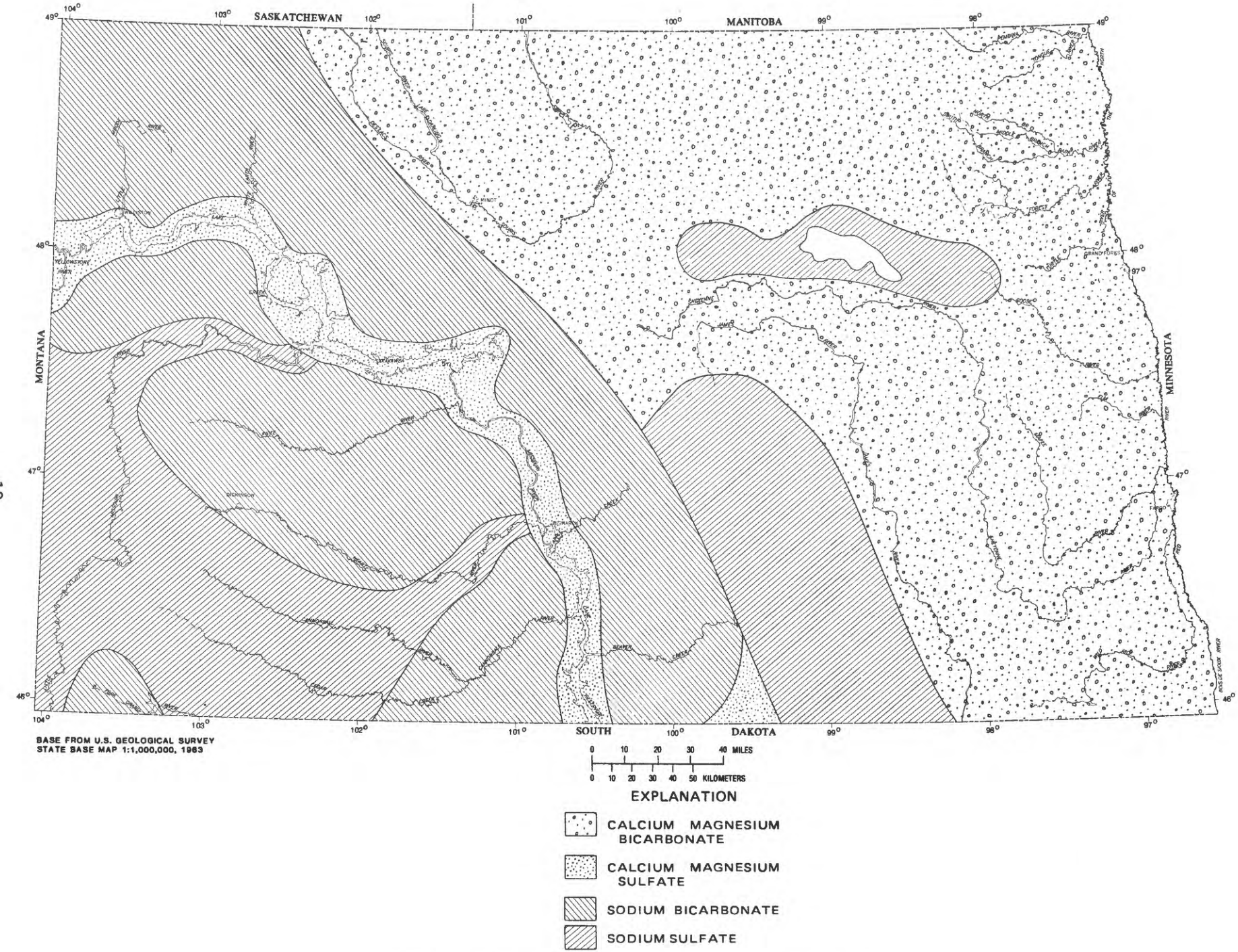


Figure 5.—Prevalent principal dissolved constituents in surface waters.

Certain lignite deposits in western North Dakota contain relatively high concentrations of uranium, ranging up to 2.5 percent. During the 1950's and 1960's, a process was developed for further concentrationg the uranium through in situ burning. Although mining is no longer active, there are at least nine unreclaimed uranium mines, ranging in size from 40 to 200 acres, that the U.S. Environmental Protection Agency has designated potential hazardous waste sites. Few hydrologic data are available for these sites, and additional work is being undertaken to determine the hydrologic changes in the area, if any, due to the mining and processing activities.

Extensive oil and gas exploration and extraction have been going on since the first oil discovery in 1951. Impacts of these activities are showing up in the hydrologic environment in two ways: (1) Air emissions of acid-forming sulfur compounds due to flaring of gas and leakage of sour gas from oil wells and (2) underground migration of salts and hazardous wastes from drilling-mud pits and brine-disposal pits. The practice of brine disposal in pits has been discontinued since 1972 when legislation was put into effect requiring underground injection to deep-lying formations. Some work has been done by State agencies to investigate the extent of the impacts, and at least two projects were conducted last year by investigators with the North Dakota Water Resources Research Institute. These studies will add to our knowledge of the magnitude of impacts due to these disposal practices.

Another byproduct of expanded energy development may be acid rain and other deteriorations of precipitation quality. Since 1980, precipitation in the State has been characterized by mean annual volume-weighted pH values less than 4.8 and by elevated concentrations of mercury, selenium, and molybdenum relative to regional soils. Although most of the State is characterized by calcareous soils and alkaline waters that offer some buffering protection against acidification, wetlands situated on noncalcareous glacial till in the Coteau du Missouri and Turtle Mountains may be vulnerable to acidification. Monitoring of water quality in potholes in both areas suggests snowmelt enrichments in trace metals such as mercury, selenium, and molybdenum and minor snowmelt depressions in pH of about 0.7-1.6 units. There is a suggestion in current data that precipitation acidity may be increasing surface-water alkalinity and nutrient loading due to increased dissolution of carbonate minerals and nutrients in bottom materials, adding to eutrophication of some small lakes.

SURFACE WATER

Surface-water discharge (streamflow), stage (water level), and water-quality data are collected for assessment of water resources, areal analyses, determination of long-term trends, research and special studies, or for management and operational purposes. In North Dakota, data on discharge and stage currently are obtained at the number of stations given in the following table.

Station classification		Number of stations
Stream stations		142
Continuous record:		
Discharge and stage	103	
Stage only	18	
Stage and peak flow	5	
Partial record:		
Peak (maximum) flow only	2	
Peak and low flow	8	
Discharge and stage (seasonal)	6	
Lake and reservoir stations		15
Stage and contents	13	
Stage only	2	
Total		157

All stations listed above are shown in figure 6.

Water-quality data are obtained at 129 of the surface-water stations listed in the preceding table and also at 14 other surface-water sites where discharge and stage are not measured routinely. In addition to monitoring the quality of surface water in North Dakota, nine of these stations also are part of a U.S. Geological Survey nationwide network known as the National Stream Quality Accounting Network (NASQAN), which is used to detect nationwide trends in water quality. The types of data determined at these sites are given in the following table. Inasmuch as several types of data may be determined at a particular site and not all types of data are determined at each site, the numbers given in the following table will not equal the total number of stations given earlier.

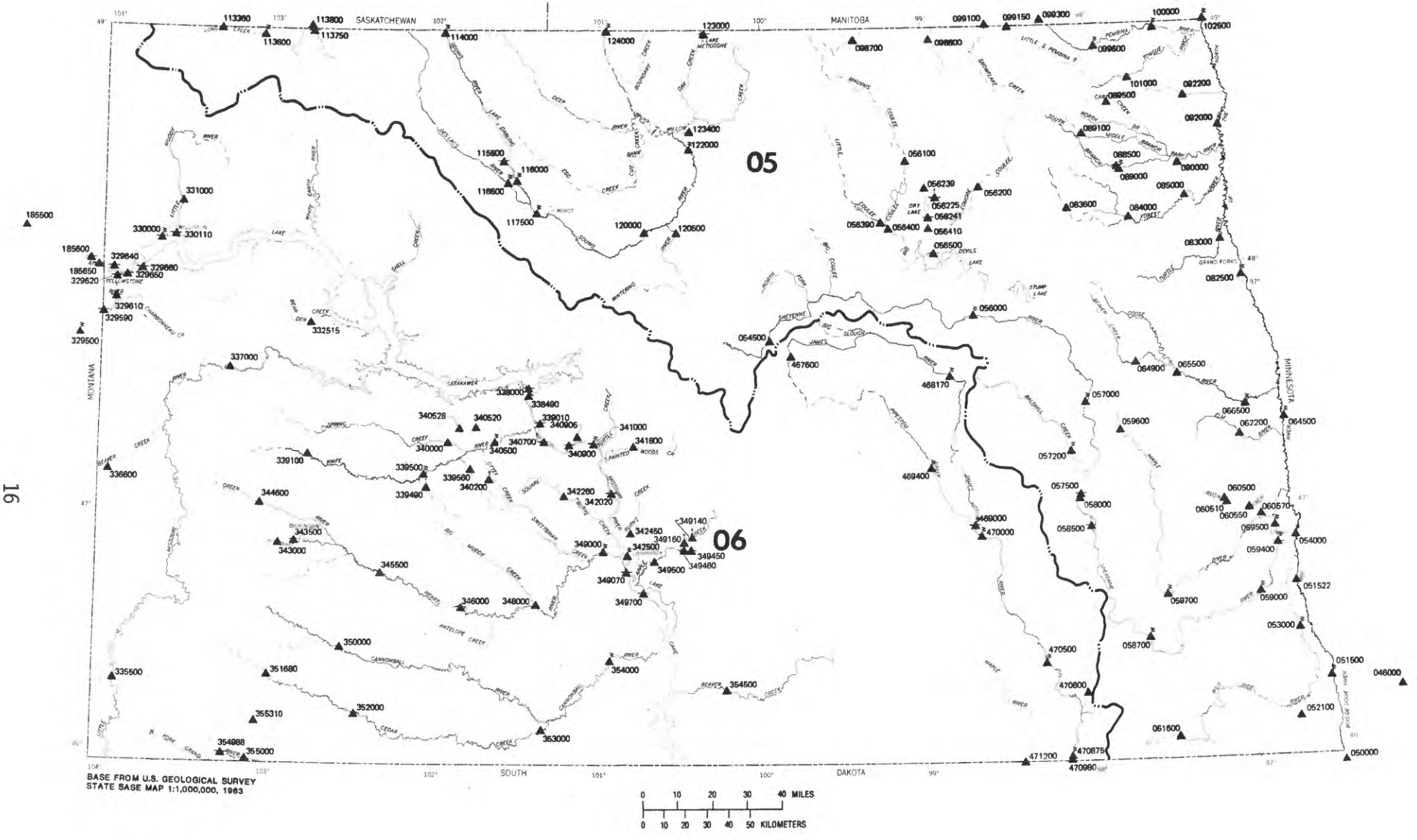


Figure 6.—Locations of lake, crest-stage, and stream-gaging stations.

Data classification		Number of sites
Physical data:		
Water temperature		129
Specific conductance		129
pH		129
Sediment data:		
Inorganic constituents		129
Organic constituents		25
Pesticides	5	
Radiochemical data		21
Biological data		13
Precipitation quality		1

All surface-water stations where water-quality data are collected are shown in figure 7.

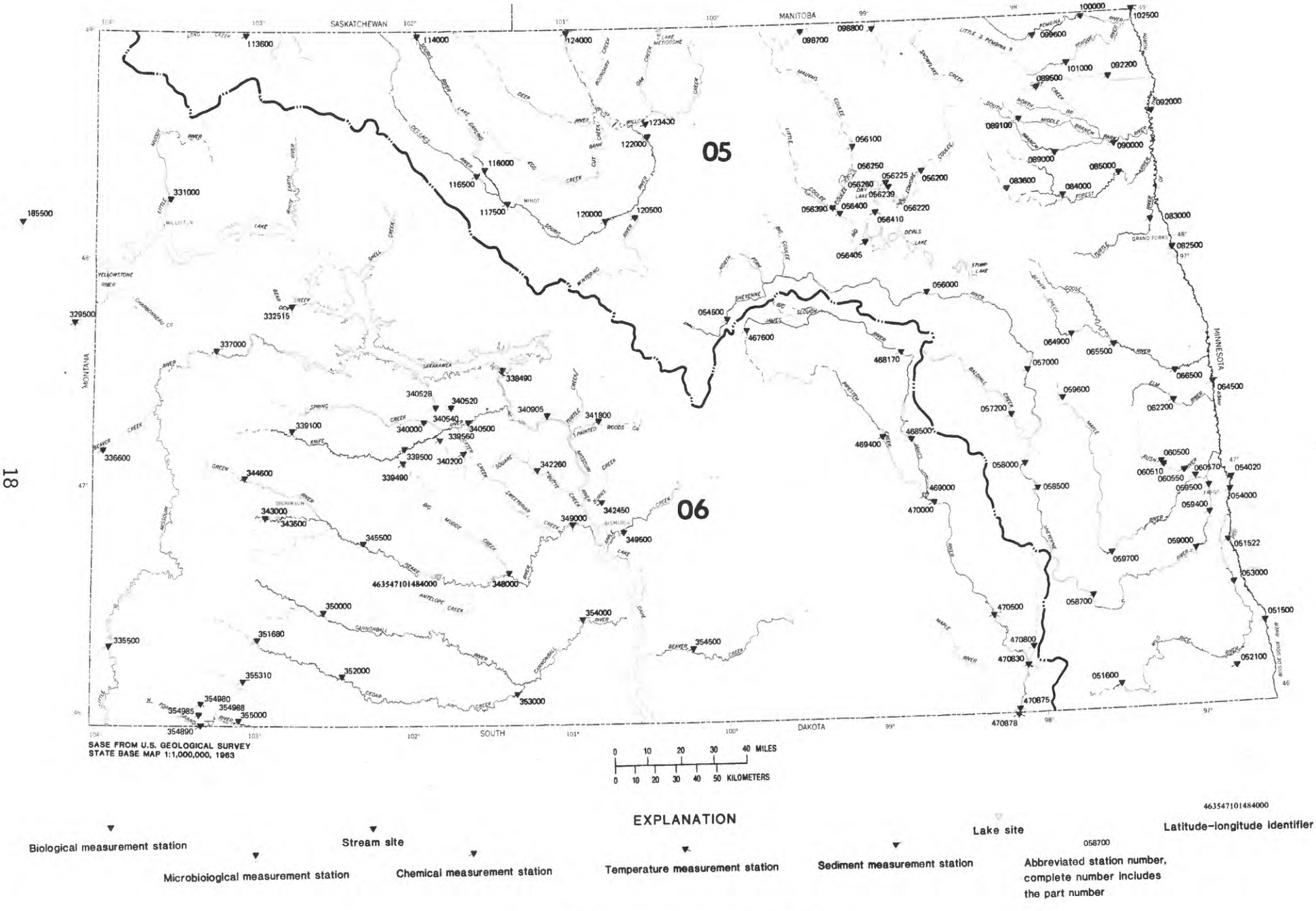


Figure 7.—Locations of water-quality stations.

GROUND WATER

Water levels in wells, discharge of springs and wells, and water-quality data are key characteristics in monitoring ground-water trends; however, these hydrologic characteristics must be integrated with other observation and ground-water system studies in order to have the fullest meaning and usefulness. In North Dakota, the U.S. Geological Survey regularly monitors a number of wells (called observation wells). Other wells, which are known as project wells, are used for specific (generally short-term) studies and, although they are not part of the observation-well program, data obtained from them also are made available. The number of wells currently being measured is given in the following table.

Station classification	Number of stations
Observation wells: Water levels	867
Project wells	83

Measurements are made quarterly or more frequently at 440 ground-water sites. Water-level records also are available for 427 additional ground-water sites that are measured annually and for several hundred observation wells that have been discontinued. Only the data from a skeleton network of observation wells (see fig. 8) is published annually; however, water-level data and other information about all current and past monitoring sites are available from manual and computer files.

Water-quality data are obtained at 40 to 60 observation wells annually. Physical data collected include water temperature, specific conductance, and pH. The water samples collected are analyzed primarily for inorganic constituents. The number of wells and the locations sampled vary from year to year. Wells and locations sampled this year are shown in figure 8.

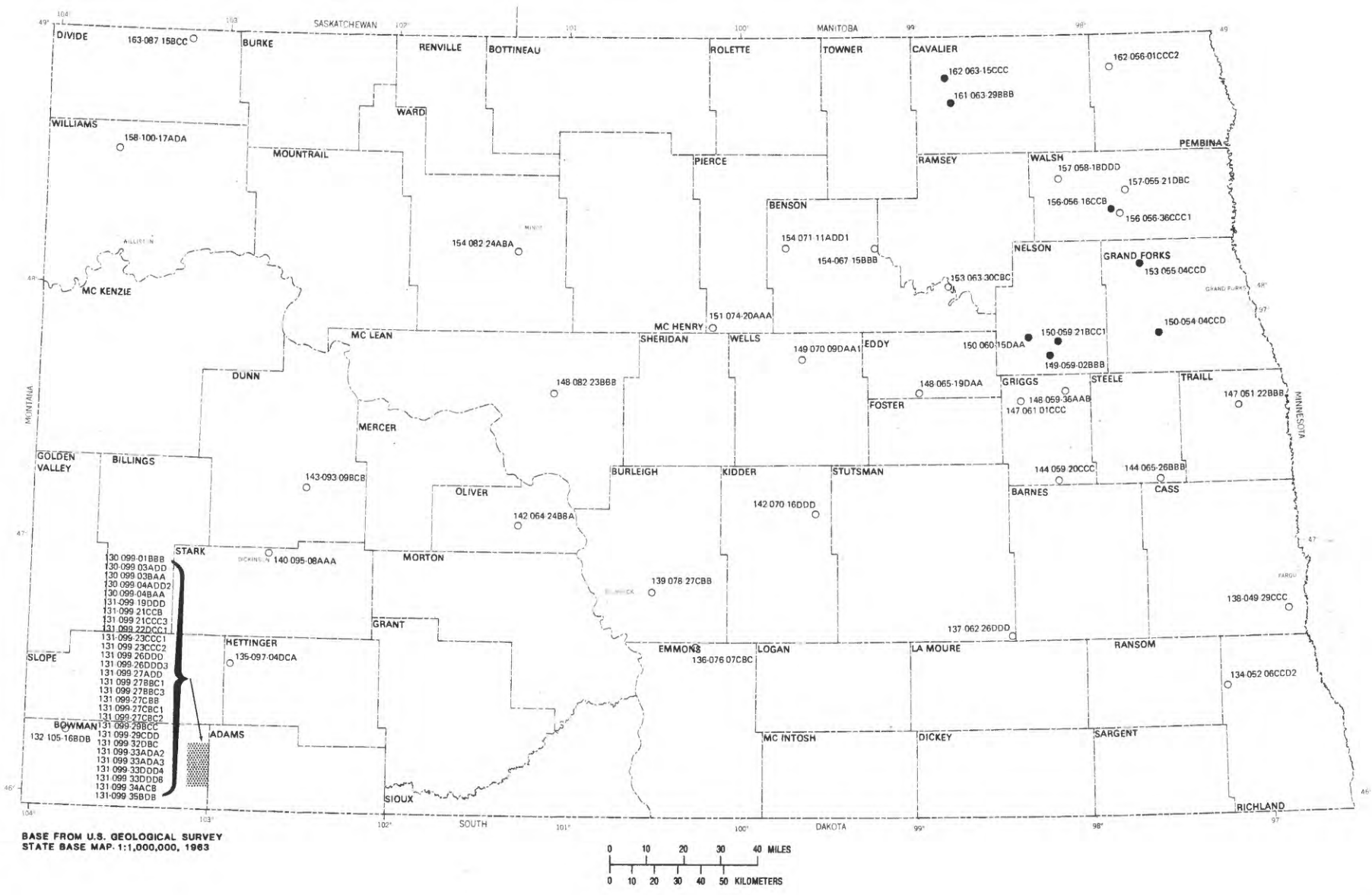


Figure 8.—Locations of ground-water observation wells.

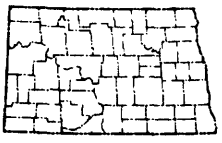
DATA-COLLECTION PROGRAM

The U.S. Geological Survey continually records stage, discharge, quality of water, sediment concentrations, and ground-water levels at selected sites throughout North Dakota. Some of the sites are operated on a long-term basis to sample trends in the gross water supply, and others are operated for short terms for correlation with long term to gain wider areal coverage or for specific purposes. The information is published annually in water-data reports and stored in computer files for retrieval and processing.

PROJECT TITLE: Surface-Water Stations
(ND 00-001)

LOCATION: Statewide

PERIOD OF PROJECT: Continuous



STATEWIDE

PROJECT CHIEF: Russell E. Harkness

COOPERATING AGENCIES:
Burleigh County Water Resource District
City of Dickinson
Lower Heart Water Resource District
North Dakota Public Service Commission
North Dakota State Water Commission
Oliver County Board of Commissioners
U.S. Department of Agriculture
  Soil Conservation Service
U.S. Department of the Army
  Corps of Engineers
U.S. Department of the Interior
  Bureau of Reclamation
  Fish and Wildlife Service
U.S. Department of State
  International Joint Commission
Other Federal agencies of the U.S.
  Department of the Interior for the
  development of the Missouri River
  basin

PROBLEM: Operation of current water projects and planning future works requires the availability of accurate and unbiased streamflow and water-level data. The information must be available in a timely manner in order to assure efficient and effective operation of existing projects. The data also must be available over a wide range of space and time in order to provide statistically accurate projections used for planning.

OBJECTIVES: Specific objectives are (1) to collect surface-water data sufficient to satisfy needs for current purpose uses, such as assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and pollution controls, discharge data to accompany water-quality measurements, compact and legal requirements, and research or special studies and (2) to collect data necessary for analytical studies to define for any location the statistical properties of, and trends in, the occurrence of water in streams, lakes, etc., for use in planning and design.

APPROACH: Standard methods of data collection will be used as described in the series, "Techniques of Water-Resources Investigations of the United States Geological Survey." Partial-record gaging will be used instead of complete-record gaging where it serves the required purpose.

PROGRESS IN 1984: All network (fig. 6) data were collected on schedule and the water-year records are being prepared for publication. Six former coal-lease monitoring stations were discontinued. One former streamflow-gaging station was reinstalled with a new sheet-pile control. Extensive repairs were made to the control at one other streamflow station.

The Interim National Water Data Storage and Retrieval System (WATSTORE) was installed on the District's PRIME computer. All digital recorder data for the 1984 water year were processed on the PRIME system.

PLANS FOR 1985: Two streamflow gages will be converted to crest-stage gages and one crest-stage gage will be discontinued. One lake gage will be turned over for operation by another agency and a new lake gage will be installed. One former streamflow-gaging station will be reinstated. Five new streamflow gages will be installed during the summer and will be ready for data collection during the 1986 spring snowmelt period. Five existing short-term seasonal gages will be discontinued. Control rehabilitation will continue with new sheet-pile controls planned for three stations. The conversion to the 12-volt power system will be completed.

The National Water Information System (NWIS) will replace the Interim WATSTORE system on the PRIME computer. Improved data-management capabilities and experience with the system should result in more current processing of streamflow records and an earlier publication date of the annual report.

REPORT PRODUCTS: U.S. Geological Survey, 1984, Water-resources data, North Dakota, Water year 1983: U.S. Geological Survey Water-Data Report ND-83-1, 382 p.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1984 (planned).

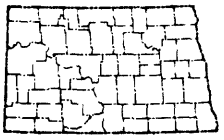
PROJECT TITLE: Ground-Water Stations
(ND 00-002)

LOCATION: Statewide

PERIOD OF PROJECT: Continuous

PROJECT CHIEF: Russell E. Harkness

COOPERATING AGENCIES: North Dakota Public Service Commission
North Dakota State Water Commission
U.S. Department of the Army
Corps of Engineers



STATEWIDE

PROBLEM: Planning for management and development of ground-water resources requires extensive knowledge of the occurrence and availability of ground water, the stresses on the system, and the ability of the system to recover when stress ceases.

OBJECTIVES: Specific objectives are (1) to collect water-level data sufficient to provide a minimum long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known and potential problems can be defined early enough to allow proper planning and management and (2) to provide a data base against which the short-term records acquired in areal studies can be analyzed. This analysis must (1) provide an assessment of the ground-water resources, (2) allow prediction of future conditions, (3) detect and define pollution and supply problems, and (4) provide the data base necessary for management of the resources.

APPROACH: Evaluation of regional geology allows broad, general definition of aquifer systems and their boundary conditions. Within this framework and with some knowledge of the stress on the system in time and space and the hydrologic properties of the aquifers, a subjective decision can be made on the most advantageous locations of observation wells to determine long-term system behavior. This network can be refined as records become available and detailed areal studies of the ground-water system more closely define the aquifers, their properties, and the stresses to which they are subjected.

PROGRESS IN 1984: All network (fig. 8) data were collected on schedule. The data were tabulated and stored in District and WATSTORE files.

PLANS FOR 1985: Plans are to continue to operate the data network and to conduct a Beta test (initial field application and testing) of the ground-water software for NWIS on the District PRIME computer.

REPORT PRODUCTS: U.S. Geological Survey, 1977, Ground-water levels in the United States, 1972-74, north-central states: U.S. Geological Survey Water-Supply Paper 2163, p. 57-61.

Ground-water data for the basic network have been and will continue to be published in the annual report series, "U.S. Geological Survey, Water-resources data, North Dakota."

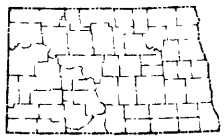
PROJECT TITLE: Water-Quality Stations (ND 00-003)

LOCATION: Statewide

PERIOD OF PROJECT: Continuous

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCIES: North Dakota Public Service Commission
North Dakota State Water Commission
U.S. Department of the Army
Corps of Engineers
U.S. Department of the Interior
Bureau of Reclamation
Fish and Wildlife Service



STATEWIDE

PROBLEM: Water-resource planning and water-quality assessment require a nationwide base level of relatively standardized information. For proper planning and assessment of the water resource, the chemical and physical qualities of surface water and ground water must be defined and monitored.

OBJECTIVES: Specific objectives are (1) to provide a national bank of water-quality data for broad Federal planning and action programs and (2) to provide data for Federal management of interstate and international waters.

APPROACH: A network of water-quality stations will be operated to provide average chemical concentrations, loads, and time trends as required by planning and management agencies.

PROGRESS IN 1984: All network (fig. 7) data were collected on schedule and records are being prepared for publication.

PLANS FOR 1985: The network will continue to operate with a few cooperator-requested modifications. Water-quality sampling frequency and constituents for analysis will be expanded at all main-stem stations on the James River.

REPORT PRODUCTS: U.S. Geological Survey, 1984, Water-resources data, North Dakota, Water year 1983: U.S. Geological Survey Water-Data Report ND-83-1, 382 p.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1984 (planned).

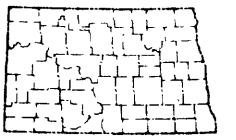
PROJECT TITLE: Sediment Stations (ND 00-004)

LOCATION: Statewide

PERIOD OF PROJECT: Continuous

PROJECT CHIEF: Russell E. Harkness

COOPERATING AGENCIES: North Dakota Public Service Commission
U.S. Department of the Interior
Bureau of Reclamation
Other Federal agencies of the U.S. Department of the Interior for the development of the Missouri River basin



STATEWIDE

PROBLEM: Water-resources planning for intrastate as well as interstate waters requires a standardized data base containing sediment transport information. The information must be accurate, unbiased, and available to the user.

OBJECTIVES: Specific objectives are (1) to provide a national bank of sediment data for use in broad Federal and State planning and action programs and (2) to provide data for Federal management of interstate and international waters.

APPROACH: A network of sediment stations will be established and operated to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and particle size of sediment being transported by rivers and streams.

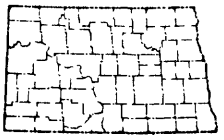
PROGRESS IN 1984: Data were collected and analyzed for 21 partial-record stations (fig. 7). Records are being prepared for publication.

PLANS FOR 1985: Plans are to continue to operate the network.

REPORT PRODUCTS: U.S. Geological Survey, 1984, Water-resources data, North Dakota, Water year 1983: U.S. Geological Survey Water-Data Report ND-83-1, 382 p.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1984 (planned).

PROJECT TITLE: National Trends Network for Atmospheric Deposition (ND 00-005)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: Continuous since November 1983

PROJECT CHIEF: Robert L. Houghton

PROBLEM: In order to determine atmospheric fluxes to the hydrologic system and man's influences on these fluxes, it is necessary to establish and operate a nationwide, long-term monitoring network for atmospheric deposition.

OBJECTIVES: The objectives of the project are (1) to establish and operate a nationwide long-term monitoring network to detect and measure levels of atmospheric deposition and (2) to determine variations in atmospheric deposition that occurs on a week-to-week basis by collection of wet- and dry-deposition products for analysis of elements and constituents that can contribute to the chemical composition of surface waters.

APPROACH: Monitoring stations are to be set up as part of the National Trends Network (NTN). Stations will be maintained, on-site measurements made, samples processed, and samples submitted to the analytical laboratory. Data will be stored in NWIS and verified. Results will be reported to the national program coordinator.

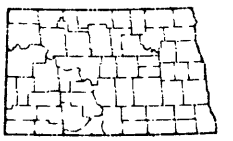
PROGRESS IN 1984: Two atmospheric deposition stations were operated. Records for the first year's precipitation and quality are being prepared for publication. Collection of dry fall was terminated in August 1984.

PLANS FOR 1985: Stations will continue to be monitored. Data will be stored in NWIS files. Digitally recording rain gages will be installed at each station. Field operators will receive training from the National Atmospheric Deposition Program.

REPORT PRODUCTS: Houghton, R. L., 1984, Differences in composition of wet fall collected on weekly and event basis in North Dakota: National Atmospheric Deposition Program Technical Committee Meeting, Abstract of Papers, October 31-November 2, 1984, p. 11-12.

U.S. Geological Survey, Water-resources data, North Dakota, Water year 1984 (planned).

PROJECT TITLE: Water-Use Data Acquisition and Dissemination Program (ND 00-007)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: Continuous

PROJECT CHIEFS: Jon C. Patch, North Dakota State Water Commission, and Edwin A. Wesolowski, U.S. Geological Survey

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: The water resources of North Dakota are being used more extensively with each succeeding year. Competition among users for available water resources--both those parts of the resources that have not been used and those parts that are available for reuse--in the State has greatly increased. Increased energy development during the next decade will place an even greater stress on the hydrologic system. In order to control the development of the resources and to project future trends, planners and managers must be aware of existing patterns of use. The types of analyses that must be made to evaluate the availability of the water resources require more detailed water-use information than currently is available from Federal and State agencies.

OBJECTIVES: This study will establish a program to provide water-use information for the optimum utilization and management of the State's water resources. The program will collect, store, and disseminate water-use data to complement data on availability and quality of the State's water resources.

APPROACH: Withdrawal uses can be evaluated quantitatively because they require removal of the water from the ground, stream, lake, or reservoir. The categories that would be applicable for obtaining the total withdrawals are irrigation, municipal use, industrial self-supply, agricultural (nonirrigation), withdrawn can be obtained by adding together the known amounts of withdrawals. Two nonwithdrawal uses that need to be considered are recreation and preservation. For each of these categories, not only the record of withdrawal would be collected but other pertinent information that would be useful in water-use analysis.

PROGRESS IN 1984: The major cooperator, North Dakota State Water Commission, continued to collect water-use data and to store these data in their site-specific oriented data base. The water-use data are obtained through contact with individuals who have permission to withdraw water for consumptive use. Field investigators were used to verify and supplement the user-supplied data.

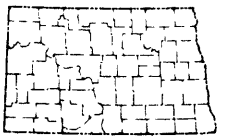
In 1982, North Dakota used an estimated 371 billion gallons of water. The largest user was thermoelectric, 77.2 percent; followed by irrigation, 13.2 percent; municipal/rural, 9.2 percent; and industrial, 0.4 percent.

PLANS FOR 1985: (1) The North Dakota State Water Commission will continue to update and maintain the detailed water-use data base. (2) A computerized system that can retrieve the water-use data from the detailed state-level water-use data base and transfer these data to the National Water-Use Data System's (NWUDS) national-level aggregated data base will be developed and implemented. (3) In order to improve data collection, various techniques for obtaining accurate discharge information will be tested.

REPORT PRODUCTS: Patch, J. C., and Haffield, N. D., 1982, Estimated use of water for North Dakota, 1982: North Dakota State Water Commission Information Series No. 33 (map).

Smith, M. L., and Harkness, R. E., 1982, Water use in North Dakota, 1980: North Dakota State Water Commission Information Series No. 31 (map).

PROJECT TITLE: Evaluation of the Streamflow Collection Network for North Dakota (ND 90093)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: October 1983 to September 1986

PROJECT CHIEF: Gerald L. Ryan

PROBLEM: Changes in the streamflow data-collection network are being made in a somewhat indiscriminate manner based on individual agency needs. The changes or cutbacks are necessary due to severe restraints on funds and manpower and increased cost of operation. The tendency is to collect selective data to meet immediate requirements with little thought to future needs.

OBJECTIVES: The purpose of this study is to make a systematic review of the network to determine how best to serve the immediate and long-term Federal and State needs. The specific objectives of the study are (1) to define the purpose of the data collection at each site, (2) to make a comparative merit evaluation for all sites, (3) to identify alternative ways to supply data requirements and the changes that could be made in the network to effect savings in funds and manpower, and (4) to identify requirements for periodic or continuous network evaluation.

APPROACH: The study will be conducted in two phases. Phase 1 will be to answer objectives 1 and 2. Phase 2 will be to answer objectives 3 and 4. A questionnaire will be prepared and distributed to cooperators and other interested agencies to ascertain individual station interest. The data from the questionnaire will be compiled and manipulated to develop a relative merit for each existing station as well as any that might be proposed. Phase 2 will lend itself to statistical manipulation to effect network efficiency. This can be accomplished by one or more of several methods. A method that might be used effectively in improving data-collection activities and reducing funding and manpower costs is the "Kalman Filter Cost Effective Resource Allocation (K-CERO)."

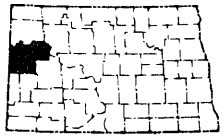
PROGRESS IN 1984: A general questionnaire was formulated and circulated and data compiled to develop a relative merit for each station. The report containing the results of the first phase of the investigation was written and began the review process.

PLANS FOR 1985: Alternative ways to supply data requirements and the changes that could be made in the network to effect savings in funds and manpower will be identified. A start will be made on the statistical evaluation of data operation. Publication of the report containing the results of the first phase of the investigation is planned.

REPORT PRODUCTS: Ryan, G. L., 1985, Data uses and funding of the streamflow-gaging program in North Dakota: U.S. Geological Survey Open-File Report 85-349, 29 p. (in press).

COUNTY GROUND-WATER STUDIES

The U.S. Geological Survey has for many years had a continuing program in cooperation with State and other Federal agencies to investigate the ground-water resources of the counties in North Dakota. The studies are connected under county or multicounty boundaries and every county has a study completed or in progress (fig. 9). In 1985, the report on the final remaining county will be published.



PROJECT TITLE: Ground-Water Resources of McKenzie County, North Dakota (ND 79-086)

LOCATION: Western North Dakota

PERIOD OF PROJECT: October 1978 to September 1983

PROJECT CHIEF: Mack G. Croft

COOPERATING AGENCIES: North Dakota Geological Survey
North Dakota State Water Commission
U.S. Department of the Interior
Bureau of Land Management
National Park Service

PROBLEM: To plan the safe and intelligent development of water supplies for farms, industry, and cities, information is needed on the sources of recharge and discharge, quantities of water in storage, potential yield, and chemical quality of water in aquifers in McKenzie County.

OBJECTIVES: The purpose of the investigation is to determine the quantity and quality of ground water available for municipal, domestic, livestock, industrial, and irrigation uses. Specifically, the objectives are (1) to determine the location, extent, and nature of the major aquifers and confining beds; (2) to evaluate the occurrence and movement of ground water, including the sources of recharge and discharge; (3) to estimate the quantities of water stored in the aquifers; (4) to estimate the potential yields to wells tapping the major aquifers; and (5) to determine the chemical quality of the ground water.

APPROACH: This is a relatively comprehensive study of the ground-water resources. The methods of study are categorized by the following activities: (1) Project planning, (2) water records, (3) geologic mapping, (4) test drilling, (5) chemical quality of water sampling and analyses, (6) aquifer tests and special studies, (7) data compilation and analysis, and (8) report preparation.

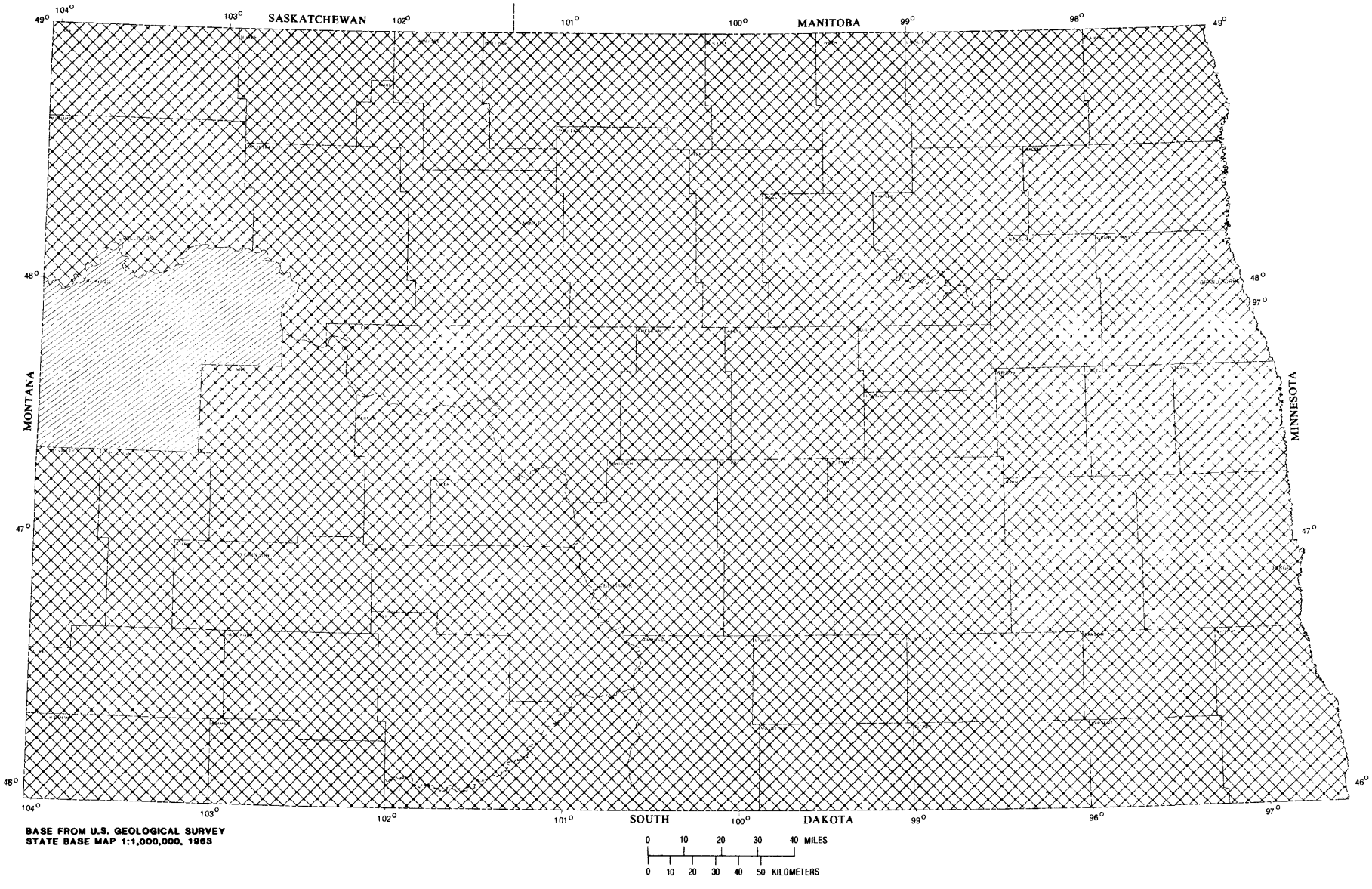


Figure 9.—Locations of county ground-water studies.

PROGRESS IN 1984: Five test holes ranging from 1,600 to 2,100 feet deep were drilled to the Pierre Shale. Thirty test wells were drilled to the base of the Tongue River Formation. Glacial channels, some containing gravel, were outlined in the northern part of the county and about 100 test wells were drilled into them. The well canvass was completed. About 150 water samples were collected and analyzed. The basic-data report was published and the interpretive report was written.

PLANS FOR 1985: Plans are to process reviews for the interpretive report and obtain approval for publication.

REPORT PRODUCTS: Croft, M. G., 1985, Ground-water data for McKenzie County, North Dakota: North Dakota State Water Commission County Ground-Water Studies 37, part II, and North Dakota Geological Survey Bulletin 80, part II, 455 p.

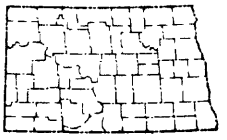
Croft, M. G., 1985, Ground-water resources of McKenzie County, North Dakota: North Dakota State Water Commission County Ground-Water Studies 37, part III, and North Dakota Geological Survey Bulletin 80, part III, 58 p.

Geology and ground-water resources of McKenzie County, North Dakota, part I, Geology (planned).

REGIONAL STUDIES

In anticipation of water demands on a scale unlimited by political boundaries or local problems, the U.S. Geological Survey is conducting studies of regional ground-water systems. Some of these studies are in cooperation with other agencies. The studies are directed toward definition of the systems and prediction of the effects of stresses that could be imposed by present and future management plans.

PROJECT TITLE: Changes in Precipitation Chemistry Resulting from Coal-Fired Energy Conversion Plants in North Dakota (ND 82-106/108)



STATEWIDE

LOCATION: North Dakota

PERIOD OF PROJECT: October 1981 to September 1984

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: North Dakota State Department of Health

PROBLEM: Little data have been collected on precipitation quality in relatively pristine areas of the country not presently receiving large pollutant loads from the atmosphere. Of the western energy-producing states, North Dakota may be the most vulnerable to serious environmental damage in the future. The State is currently undergoing a rapid expansion of population, lignite mining, petroleum and synfuel production, and energy production by coal-fired powerplants. With the known energy development projects proposed for operation within North Dakota by 1985, the total statewide emissions of sulfur and nitrogen oxides are expected to exceed 1,300 tons per day. Considering additional input from increased emissions in upwind regions of Montana and Saskatchewan, the potential also exists for an adverse or episodic acid rain problem on a regional scale in North Dakota by the mid-1980's.

OBJECTIVES: Detailed geochemical investigations will be made (1) to determine baseline concentrations of certain elements in aerosol, precipitation, soil, and water prior to large-scale development of fuel resources; (2) to examine this baseline data for evidence of current influences by coal-fired generating facilities; (3) to determine the variation in composition of atmospheric precipitation both temporally and spatially; (4) to identify and evaluate mechanisms by which elements transfer within the ecosystem among atmosphere, water, and soil components; and (5) to determine the impact of changes in precipitation chemistry on surface- and ground-water quality. The results of these studies should provide the necessary basis (1) to develop a conceptual model of the processes controlling the composition of atmospheric deposition and (2) to follow with a mathematical model for quantitative predictions of future changes in precipitation quality and network design required to determine long-term changes in the quality of precipitation.

APPROACH: Representative receptor locations will be chosen within and downwind of the energy development area in western North Dakota. Meteorological data and chemical data for wet and dry deposition collected at each receptor location will be statistically evaluated to determine the covariance of properties measured. Parameters indicative of differing types of energy development will be identified and monitored on an event or weekly basis. Stable isotopes will be monitored periodically to determine the proportion of acidic substances in precipitation contributed by biogenic processes and fossil-fuel combustion. A mass-balance flux-type model will be used to evaluate the effects of changing precipitation composition on the hydrologic system. An atmospheric model developed by the North Dakota State Department of Health may be used to evaluate the effects of powerplant emissions on precipitation quality and predict future impacts. The composition of streams and lakes in the vicinity of precipitation stations will be monitored to measure the effects of precipitation chemistry on local surface waters. If impacts of degraded atmospheric deposition are recognized in local surface waters, regional surface- and ground-water quality data collected as part of the statewide network will be evaluated to determine the extent of these impacts.

PROGRESS IN 1984: The quality of water in potholes adjacent to precipitation-collection stations at Canfield Lake and Woodworth and a small-basin headwater stream near Dunn Center was determined monthly to determine the hydrologic consequences of changing precipitation chemistry. During snowmelt, these surface-water quality determinations were supplemented by daily samplings and snow cores to identify snowmelt enrichments in the volatile trace metals. An area of apparent acidification in the Turtle Mountains of northern North Dakota also was monitored on a monthly basis. After a year's lapse, the Canfield Lake precipitation chemistry station was reestablished in 1984 and the North Dakota State Department of Health continued to operate stations at Dunn Center and Woodworth. This network was supplemented by two NTN stations operated by the U.S. Geological Survey, a third NTN station operated by the U.S. Park Service, and 10 new weekly stations geographically distributed across North Dakota and operated by the North Dakota State Department of Health.

PLANS FOR 1985: Monitoring of pothole quality on a monthly basis will be continued in Canfield Lake Pothole No. 1 and Woodworth Pothole No. 14. These samplings will be supplemented by a daily monitoring during initial snowmelt and snow cores. Canfield Lake precipitation-collection station will be operated on an event basis. A within-event precipitation pH, specific conductance, and temperature monitor will be installed at Canfield Lake and operated between April and October. An improved automated digital meteorological monitoring system will be installed and operated at Canfield Lake commencing May 1985.

REPORT PRODUCTS: Houghton, R. L., 1983, Acidification of North Dakota surface water: Proceedings, Symposium on Acid Rain in Western Canadian Provinces, Regina, Saskatchewan, May 26-27, 1983, p. 16.

Houghton, R. L., 1983, Composition of atmospheric deposition in western North Dakota: Proceedings, 75th Annual Meeting of the North Dakota Academy of Science, Grand Forks, N. Dak., April 28-30, 1983, p. 59.

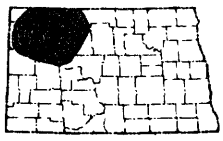
Houghton, R. L., 1984, Differences in composition of wet fall collected on weekly and event basis in North Dakota: National Atmospheric Deposition Program Technical Committee Meeting, Abstract of Papers, October 31-November 2, 1984, p. 11-12.

Houghton, R. L., Berger, M. E., Zander, N., and Dutchuk, S. K., 1984, Atmospheric deposition: Sample handling, storage, and analytical procedures for chemical characterization of event-based samples in North Dakota: U.S. Geological Survey Water-Resources Investigations 83-4205, 71 p.

Houghton, R. L., and Briel, L. I., 1985, Chemistry of precipitation in rural North Dakota: Proceedings, International Conference on Acidic precipitation, Muskoka, Ontario, Canada, September 15-20, 1985 (in press).

Houghton, R. L., and Foss, J. E., 1985, Snowmelt trace-element enrichments in prairie potholes and soils of central North Dakota: Proceedings, International Conference on Acidic Precipitation, Muskoka, Ontario, Canada, September 15-20, 1985 (in press).

PROJECT TITLE: Hydrology of Area 46, Northern Great Plains Coal Province, North Dakota (ND 83-112)



LOCATION: Northwestern North Dakota

PERIOD OF PROJECT: October 1982 to September 1983

PROJECT CHIEF: Mack G. Croft

PROBLEM: Because of the rapidly developing energy resources (i.e., coal and oil), water availability and protection of water resources are significant problems in coal area 46. Expected energy development included surface mining, powerplants, and coal conversion plants. Mining companies are required by law to analyze the hydrologic effects of proposed activities and to take appropriate measures to minimize adverse effects. There was, therefore, a need for comprehensive and easily understood information about the water resources in coal area 46.

OBJECTIVES: The purpose was to describe the hydrology of area 46 in a format readily usable by the coal-mining industry, the regulatory agencies, interest groups (such as environmental organizations), and the general public. The specific objectives of the study were to present (1) a description of the area in a hydrologic framework, (2) a quantitative assessment of the occurrence and availability of water, (3) an assessment of the present quality of available water, and (4) an identification of current and planned utilization of water.

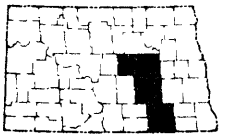
APPROACH: A topic outline was developed based on previous reports. Only existing data were utilized to establish an information framework for the study area. All available data were used to prepare graphs, maps, and text to fulfill the objectives of the study. The report was prepared in accordance with the Sequential Thematic Organization of Publications (STOP) format.

PROGRESS IN 1984: The report was completed and approved for publication.

PLANS FOR 1985: Publication of the report is anticipated.

REPORT PRODUCTS: Croft, M. G., and Crosby, O. A., 1985, Hydrology of area 46, northern Great Plains and Rocky Mountain coal provinces, North Dakota: U.S. Geological Survey Open-File Report 84-467, 135 p. (in press).

PROJECT TITLE: Generation of a Data Base for the James River Salinity Model, North Dakota and South Dakota (ND 85-135)



LOCATION: James River Basin of Eastern North Dakota and South Dakota

PERIOD OF PROJECT: April 1985 to December 1986

PROJECT CHIEF: Lawrence I. Briel

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Reclamation

PROBLEM: Operation of the Garrison Diversion Unit will bring Missouri River water into the James River basin to augment flows in the James River sufficiently to permit expanded irrigation and provide new supply for municipalities and industry. Increased irrigation may increase river salinity beyond acceptable limits. Before the U.S. Bureau of Reclamation can model unit impact on river salinity, model inputs must be estimated in a hydrochemically sound manner.

OBJECTIVE: The purpose of this investigation is (1) to generate the input data required by the river salinity model of the U.S. Bureau of Reclamation to evaluate a variety of different management options and (2) to index the effect of each option on water quality in the James River.

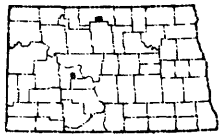
APPROACH: Successive reaches of the James River will be defined for purposes of the model. For each reach, input of water-quality and quantity data is required for surface-water, ground-water, and irrigation return flows. Most information on surface-water contribution will be taken from the historical gaged record. Ungaged surface-water inflows will be estimated from residuals in the flow model and assigned salinities according to equations correlating tributary salinity to land use, drainage area, and flow. Ground-water data will be estimated from seepage information. Irrigation return flow quality will be estimated from extract or reaction-model data.

PLANS FOR 1985: The historical data base will be screened to eliminate erroneous data. Equations relating surface-water salinity to land use, drainage area, and flow will be developed for each stream reach and tributary. Monthly mean or monthly period-of-record data bases will be developed. Ground-water and irrigation return flow qualities will be developed based on available ground-water and extract quality data. Documentation of the methods used to develop the data base will begin.

REPORT PRODUCTS: Development of a water-quality data base to arm the U.S. Bureau of Reclamation's salinity model of the James River in North and South Dakota (planned).

SPECIAL INVESTIGATIONS

Special hydrologic investigations often are needed to supplement the ongoing program. These special investigations include water-supply problems, drainage problems, ground-water and surface-water relationships, ground-water recharge, water-quality problems, geochemical studies, and water management. The objective is to assist State and Federal agencies in solving water-resources problems on short notice.



PROJECT TITLE: Feasibility of Aerial Snow Surveys to Determine the Variation of Snow Cover on Snow Courses of 1 Mile or Less on the Northern Plains of North Dakota (ND 81-093)

LOCATION: North-Central North Dakota

PERIOD OF PROJECT: October 1980 to September 1982

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCIES: U.S. Department of Commerce
National Weather Service
U.S. Department of the Interior
Bureau of Land Management

PROBLEM: Snow-cover data in terms of water equivalents were needed by Federal, State, and local agencies, and private groups who have the responsibility of managing snow cover for maximum crop production, maintaining transportation routes, and determining runoff for flood predictions and reservoir storage. Most of these uses require information on variations in snow-cover distribution. There has always been difficulty in obtaining data on the variations in snow-cover distributions on the northern plains.

OBJECTIVE: The objective of this investigation was to evaluate the feasibility of using aerial surveys to obtain information on the snow water equivalents of the snow cover on small selected land use/terrain type units in order to minimize the necessity of labor intensive ground snow surveys.

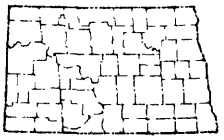
APPROACH: Two methods of making snow surveys were used to obtain the objective of the study. The first method was a ground snow-survey technique based on stratified sampling. This technique was based on the research relating snow accumulation to terrain, vegetation, and land use. The second method was an aerial snow-survey technique used by the U.S. National Weather Service that measured the attenuation of natural terrestrial gamma radiation to determine snow water equivalent. The delineation of the aerial snow survey data into smaller segments to determine the variation of snow cover was examined.

PROGRESS IN 1984: Data were collected and analyzed. One aerial snow-survey pass was found to be adequate for measuring the snow cover over a 1-mile snow course. Aerially measuring snow cover for multiple single land use units and extrapolating the data over an area to obtain the variations of snow cover appeared to be feasible.

PLANS FOR 1985: None.

REPORT PRODUCTS: Emerson, D. G., Carroll, T. R., and Steppuhn, H., 1985, Small-area snow surveys on the northern plains of North Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4026, 22 p. (in press).

PROJECT TITLE: Pumping Techniques Bias in Chemistry of Ground-Water Samples (ND 81-096)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: October 1980 to September 1982

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: One of the most common sources of error in the chemical analysis of ground water is bias introduced by chemical alteration during sampling. The largest source of alteration is believed to result from air entrainment during pumping. Therefore, if the nature and magnitudes of the biases of different common pumping techniques were known, it would be possible to determine which ground-water data currently on file are usable in future studies. Current quantitative studies would not be hampered by historical data of questionable accuracy.

OBJECTIVE: The objective of this investigation was to determine the nature and magnitude of chemical biases introduced during the sampling of ground water by several different common pumping methods. Pumps that were investigated included air-lift, gas-squeeze, gas-driven reciprocating, peristaltic, and submersible centrifugal pumps and Kemmerer-type and conventional bailers. Analyses of ground water sampled by these techniques provided a basis for evaluating historical ground-water data and determining preferred methods for future sampling.

APPROACH: In phase 1 of the project, only wells of similar construction were studied, thus minimizing water-quality alteration due to well conditions. During phase 2, randomly selected wells were sampled without regard to construction design, but only water from wells of similar construction and composition was considered in each statistical group. To fully assess the affected properties, deep, intermediate, and shallow wells were included. To assure applicability of the results to all water types, wells yielding sulfate-, bicarbonate-, and chloride-type waters were studied. Additionally, adjacent wells to the same aquifer depth but cased in different materials were sampled to evaluate the effect of well construction on apparent ground-water quality.

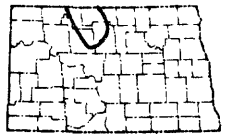
PROGRESS IN 1984: The project was summarized in a report presented at the National Water Well Association's Fourth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring. The draft final report remained in the review process.

PLANS FOR 1985: Publication of the final report is anticipated.

REPORT PRODUCTS: Houghton, R. L., and Berger, M. E., 1984, Effects of well-casing composition and sampling methods on apparent quality of ground water: Proceedings, Fourth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring, Columbus, Ohio, May 23-25, 1984, National Water Well Association, p. 203-213.

Houghton, R. L., and Berger, M. E., 1985, Effect of sampling method on apparent quality of ground water (in progress).

PROJECT TITLE: Water-Quality Assessment of the Souris River within North Dakota (ND 82-103)



LOCATION: Souris River within North Dakota

PERIOD OF PROJECT: October 1981 to September 1985

PROJECT CHIEF: Edwin A. Wesolowski

COOPERATING AGENCY: North Dakota State Department of Health

PROBLEM: The water-quality degradation of the Souris River has resulted in both intrastate dispute and international concern. The source and movement of contaminants are of concern to Saskatchewan and Manitoba, the municipalities and State agencies of North Dakota, and several Federal agencies. The North Dakota State Department of Health and the U.S. International Joint Commission's Souris River Pollution Control Board have requested that a study be undertaken to determine the cause of water-quality degradation on the Souris River. Potential sources of water-quality degradation include inadequately treated municipal and industrial wastes, urban and rural runoff, feedlots, and several large wildlife refuges.

OBJECTIVES: Specific objectives of the study are (1) to define the hydrologic system and the current water-quality problems; (2) to determine time-of-travel, dispersion, and reaeration characteristics; (3) to quantitatively evaluate water-quality processes; and (4) to develop conceptual and digital models to evaluate the waste load and water-quality relationships and to predict the effect of waste discharges on the river at various flows and at selected reaches of the river.

APPROACH: Existing data will be used to identify seasonal water-quality and hydrologic trends and conditions when the river is susceptible to degradation. At these critical periods, additional data will be collected to isolate the processes that degrade the stream. A one-dimensional steady-state water-quality model will evaluate these processes using the new data and field determined times-of-travel and dispersion and reaeration coefficients.

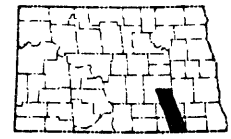
PROGRESS IN 1984: A meeting early in the year with the cooperator resulted in a decision to produce two reports-"Reaeration, traveltime, and dispersion characteristics of the Souris River from Lake Darling to J. Clark Salyer Refuge" and "Analysis of waste-load assimilation capacity of the Souris River from Lake Darling to J. Clark Salyer Refuge." Data processing for the modeling aspect of the report was terminated and a concentrated effort was made to produce the reaeration, traveltime, and dispersion (TRACER) report. Illustrations, figures, and tables were sketched and the first draft of the TRACER report was completed shortly after the end of the year. In the test reaches, reaeration coefficients ranged from 0.5-2.1 day^{-1}, traveltime (10-mile reach) ranged from 54 to 293 hours, test reach velocities ranged from 0.06-0.35 feet per second, and dispersion coefficients ranged from <10 to 60 feet squared per second.

PLANS FOR 1985: The precipitation received and the intermittent releases from Minot's lagoon during the 1983 synoptic sampling may necessitate using an unsteady-state model instead of the planned steady-state model. Data used with the steady-state model will be reformatted for use with the unsteady-state model. Plans are to process the 1983 data, calibrate the model, prepare the illustrations, and begin writing the report.

REPORT PRODUCTS: Wesolowski, E. A., Reaeration, traveltime, and dispersion characteristics of the Souris River from Lake Darling to J. Clark Salyer Refuge (in progress).

Analysis of waste-load assimilation capacity of the Souris River from Lake Darling to J. Clark Salyer Refuge (planned).

PROJECT TITLE: Hydrology of the Lower James River Basin in North Dakota (ND 82-104)



LOCATION: Southeastern North Dakota

PERIOD OF PROJECT: October 1981 to September 1984

PROJECT CHIEFS: Jeffrey E. Miller and Paul K. Christensen

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: A significant relationship was noted by previous investigators between the local glacial-drift aquifers, the terrace aquifers, and the lower James River in North Dakota. Irrigation and other developments in the James River basin were increasing their demands on the ground-water and surface-water system. As development of the water resources of the basin increased, concerns also increased regarding the impact of development or proposed development on low flows and water quality in both the James River and the connected aquifers. Before the North Dakota State Water Commission could begin to allow additional use of the water in the basin, the system needed to be defined so that the effects of further development could be predicted.

OBJECTIVES: The objectives of this study were (1) to define the hydrology of the ground-water and surface-water system and (2) to develop quantitative capabilities for the evaluation of water-use impacts.

APPROACH: The project was done in a series of stages over a 3-year period. The ground-water and surface-water system was defined as far as possible with available data. Based on this definition, a data-collection procedure was designed so that the system could be redefined in detail. Ground-water levels, flow data, and ground-water and surface-water quality differences were used to define the system. A preliminary report was prepared. Additional data needs again were determined and the data collected before the final system definition was completed. Based on the system and approach, a model was developed, tested, and described in the final report.

PROGRESS IN 1984: The data report was prepared. Final data development for the digital ground-water and surface-water model was completed and the modeling system was calibrated and simulation runs made. A draft final report was begun.

PLANS FOR 1985: Review of report products will continue. Final publication of the report is planned by year-end.

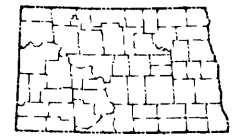
REPORT PRODUCTS: Christensen, P. K., and Miller, J. E., Progress report for the cooperator on the ground-water and surface-water system of the lower James River basin, North Dakota (not published).

Christensen, P. K., Miller, J. E., and Patten, E. P., 1985, Spiritwood aquifer and James River system: Synopsis of the system and an evaluation of a management scheme, southeastern Stutsman and north-central LaMoure Counties, North Dakota (in progress).

Miller, J. E., 1985, User's manual for a model for simulating interconnected ground-water and surface-water systems (in progress).

Wald, J. D., and Christensen, P. K., 1985, Water-resources data for the lower James River, Dickey, LaMoure, and Stutsman Counties, North Dakota (in progress).

PROJECT TITLE: Inventory and Analysis of Information for Flood Plain Management in North Dakota (ND 83-118/119)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: October 1982 to September 1985

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCIES: North Dakota State Water Commission
U.S. Department of the Army
Corps of Engineers

PROBLEM: The North Dakota State Engineer identified governmental units (i.e., cities, townships, and counties) in North Dakota that have flood hazard areas but do not have detailed base flood (100-year flood) information available from the U.S. Federal Emergency Management Agency Flood Insurance Studies, U.S. Soil Conservation Service Flood Hazard Analyses, or U.S. Army Corps of Engineers Flood Plain Information Reports. To be in compliance with the standards of the National Flood Insurance Program, these governmental units are required to use the "best available data" to regulate new development or expansion of existing development in flood-prone areas.

OBJECTIVES: The objectives of this investigation were (1) to determine all data available regarding flood hazards, hydraulics, and hydrology for particular areas; (2) to analyze these data to determine their adequacy for flood-plain management purposes; (3) to present these data, if adequate, in a format usable to local flood plain administrators; and (4) to determine, if inadequate, the effort necessary to produce "best engineering judgment" flood elevations.

APPROACH: A systematic and comprehensive data search was conducted for each site. The data search included files of the U.S. Geological Survey, other Federal agencies, and the State agencies. Direct contact was made with governmental units responsible for the area under consideration. The data obtained through the systematic search were analyzed for adequacy in defining flood information. If found adequate, data were put into a format that can be used by managers. If the data were found inadequate, an attempt was made to establish the fieldwork and analytical work necessary to provide at least a minimal base for flood management decisions.

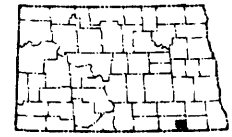
PROGRESS IN 1984: The data search was completed for 126 governmental units.

PLANS FOR 1985: Publication of the supplemental report is anticipated.

REPORT PRODUCTS: Emerson, D. G., and Wald, J. D., 1983, Inventory and analyses of information for flood plain management in North Dakota: U.S. Geological Survey Open-File Report 84-053, 201 p.

Emerson, D. G., and Wald, J. D., 1985, Supplement to inventory and analyses of information for flood plain management in North Dakota (in progress).

PROJECT TITLE: Application of Unsaturated Zone Monitoring and Modeling Techniques to the Determination of Ground-Water Recharge (ND 83-120)



LOCATION: Southeastern North Dakota

PERIOD OF PROJECT: October 1983 to September 1986

PROJECT CHIEF: William F. Horak

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: A review of the hydrologic literature indicated that little precedent was available for direct, quantitative approaches to studying ground-water recharge and evapotranspiration (ET). Most geohydrologic studies have involved either loosely defined water budgets or water-level time-series analyses to estimate ground-water recharge or ET or both. Neither of these approaches was suitable for the intensive management of North Dakota's heavily developed glacial-drift aquifers. Attempts to simulate the effects of additional ground-water withdrawals on these aquifers have been frustrated by the lack of data regarding recharge and ET. It was essential to the responsible management of the aquifers, therefore, that reliable estimates of the magnitudes of recharge and ET be made available.

OBJECTIVES: The specific objectives were (1) to measure the hydraulic properties, including the functional relations of hydraulic conductivity and of matric potential to moisture content, for the major soil groups in the study area; (2) to evaluate the areal variability of those data; (3) to select a physically-based model(s) for simulation of unsaturated or variably saturated flow; (4) to use the model to test the sensitivity of the flow system to variations in soil hydraulic properties and assumed boundary conditions; (5) to collect the data required for use of the Penman combination method of estimating potential evapotranspiration (PET); and (6) to make recommendations as to the optimum manner in which to interface the information output by the recharge and ET process model(s) with the ground-water flow model.

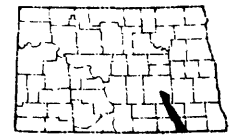
APPROACH: The important emphasis of this study was the field collection of soil hydrologic data. Tensiometers and neutron moisture measurements were used to define the soil-moisture characteristics for the major soils in the study area. The instantaneous profile method of determining unsaturated hydraulic conductivity also was used. The acquired soil-moisture, moisture potential, and hydraulic conductivity data were used with an unsaturated or variably saturated flow model to determine probable rates of ground-water recharge. Estimates of ET from the water table were derived from the PET, moisture content, and moisture potential data.

PROGRESS IN 1984: The draft report was prepared.

PLANS FOR 1985: Publication of the final report is anticipated.

REPORT PRODUCTS: Horak, W. F., 1985, Evaluation of the theory and methodology for quantifying recharge and evapotranspiration for shallow glacial aquifers in North Dakota (in progress).

PROJECT TITLE: Evaluation of Streamflow-Gaging Methods for Application to Rivers with Flat Slopes, North Dakota (ND 83-121)



LOCATION: Southeastern North Dakota

PERIOD OF PROJECT: October 1982 to September 1985

PROJECT CHIEF: Gregg J. Wiche

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Reclamation

PROBLEM: The James River, like many rivers in eastern North Dakota and other Plains states, has a flat slope and, therefore, experiences variable backwater conditions, slow velocities, and reverse flows. These conditions make accurate discharge measurements difficult to obtain and eliminate the usefulness of the standard single-value rating curve for streamflow-gaging applications.

OBJECTIVES: The objectives of this study are (1) to test and compare the feasibility, cost effectiveness, and accuracy of acoustical velocity meters, stage-fall discharge ratings, and unsteady-state flow models for gaging stream discharge and (2) to collect adequate field data to develop streamflow records at a site near Hecla, S. Dak.

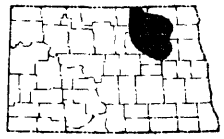
APPROACH: The stage data necessary to drive the unsteady flow model have been collected by constructing and operating three gaging stations. These stage data will be used to develop the unsteady-state flow model for a 4-mile section of the river ending at the downstream site. Discharge will be computed by the flow model at the downstream site. A stage-fall discharge rating will be developed at the downstream site. Discharge also is being collected at the downstream site using an acoustic velocity flow meter. The accuracy, feasibility, and cost effectiveness of the three methods used to collect discharge will be compared. In addition, a stage-discharge relationship has been developed at the upstream site (a low-head dam) and this discharge will be compared with the discharge at the downstream site.

PROGRESS IN 1984: A new acoustic velocity flow meter was installed and calibrated at the downstream site. All other work was suspended because funds were withheld pending the outcome of the Garrison Commission hearings.

PLANS FOR 1985: The cross-section data, required as input to the unsteady flow model, will be compiled, and the initial calibration will be conducted. Development of the stage-fall discharge relationship will continue. Initial comparisons of discharge at the upstream and downstream sites will be undertaken.

REPORT PRODUCTS: A comparison of gaging methods on the lower James River, North Dakota (planned).

PROJECT TITLE: An Investigation of the Hydrologic and Climatologic Mechanisms Controlling the Water-Surface Elevation of Devils Lake, North Dakota (ND 83-124)



LOCATION: Northeastern North Dakota

PERIOD OF PROJECT: October 1983 to September 1984

PROJECT CHIEF: Gregg J. Wiche

COOPERATING AGENCY: U.S. Department of the Army
Corps of Engineers

PROBLEM: The current high water-surface elevations of Devils Lake pose an immediate flood threat to the city of Devils Lake. The U.S. Army Corps of Engineers has developed a draft report detailing a flood-control project at Devils Lake. In this project, four structural and nonstructural flood-control plans have been developed to prevent flooding. Implementation of any of these plans should be based on knowledge of the hydrologic and climatologic relationships of the Devils Lake system. The purpose of this study is to gain an understanding of the interaction of the hydrologic and climatologic mechanisms controlling the water-surface elevation of Devils Lake.

OBJECTIVES: There are two objectives that will be investigated to meet the purpose of the study. First, a literature review will be conducted to see what previous studies have been completed on other terminal lakes. The second objective will be to conduct a statistical comparability analysis of Devils Lake basin to other streams and basins.

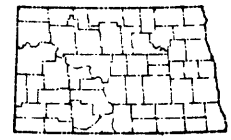
APPROACH: A literature review will be conducted to see what studies have been undertaken that may provide ideas and methods that can be incorporated in the present study. These findings from previous studies will provide guidelines as to what statistical techniques may show promising results. A statistical analysis of Devils Lake basin and other streams and basins will be conducted using multiple linear regression. In addition, correlations will be made using the climatological indices of temperature and precipitation.

PROGRESS IN 1984: The literature review and the hydrologic and climatologic analyses were completed. The draft report has had inhouse review.

PLANS FOR 1985: Plans are to prepare the final report.

REPORT PRODUCTS: Investigation of Devils Lake water-level fluctuations (planned).

PROJECT TITLE: Evaluation of the Theory and Methodology for Quantifying Recharge and Evapotranspiration for Shallow Glacial Aquifers in North Dakota (ND 83-127)



STATEWIDE

LOCATION: Statewide

PERIOD OF PROJECT: October 1982 to September 1983

PROJECT CHIEF: William F. Horak, Jr.

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: Several of North Dakota's shallow glacial aquifers are developed extensively for irrigation and municipal water supplies. Requests for new ground-water use permits for these aquifers are evaluated with regard to the impact of the proposed use on prior appropriators and on the overall water budget of the geohydrologic system. The evaluation procedure, particularly for the aquifers that are already heavily appropriated, generally includes the use of ground-water flow models. The models frequently have given unsatisfactory results, however, because reliable data concerning recharge and evapotranspiration magnitudes for North Dakota aquifers are lacking. This study was designed, therefore, to provide information concerning recharge and evapotranspiration that will strengthen the credibility of aquifer management decisions.

OBJECTIVES: Specifically, the study objectives were (1) to review the hydrologic literature dealing with the determination of ground-water recharge and evapotranspiration; (2) to review the theory and methodology for the determination and estimation of the critical soil and meteorological parameters; (3) to consider the relative merits of a rigorous, data-intensive approach versus an estimation, parametric approach; and (4) to review the agronomic research, past and present, in North Dakota for applicability of the research and the data generated to the study of recharge and evapotranspiration.

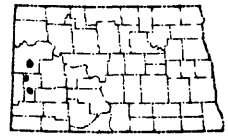
APPROACH: This study involved no original data collection. Rather, achievement of the objectives involved an extensive study of the literature and a canvassing of appropriate scientific agencies and institutions. The study had application to all shallow glacial aquifers in North Dakota. The study provided the background research, preliminary planning, and sound approach for a subsequent project in which the data actually were acquired and the analyses and interpretations necessary for quantifying recharge and evapotranspiration actually were made.

PROGRESS IN 1984: The project was cancelled at the request of the cooperating agency. The investigation will be completed by the cooperating agency.

PLANS FOR 1985: None.

REPORT PRODUCTS: None.

PROJECT TITLE: Flood Analysis Along the Little Missouri River Within and Adjacent to Theodore Roosevelt National Park, North Dakota (ND 84-006)



LOCATION: Little Missouri Badlands

PERIOD OF PROJECT: April 1984 to September 1984

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCY: U.S. Department of the Interior
National Park Service

PROBLEM: The U.S. National Park Service needed information on flood potential as part of a general management plan for the Theodore Roosevelt National Park.

OBJECTIVES: The objectives of the study were (1) to determine water-surface elevations for the 100- and 500-year flood discharges for selected reaches of the Little Missouri River; (2) to determine water-surface elevations for the 100-year flood discharge for the areas near the mouths of Knutson, Paddock, and Squaw Creeks; and (3) to evaluate the effects of ice jams on flood elevations.

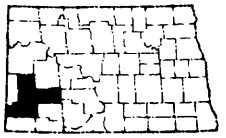
APPROACH: Peak flow frequency analysis described by the U.S. Geological Survey (1982, Guidelines for determining flood flow frequency: Interagency Advisory Committee on Water Data, Office of Water Data Coordination, 28 p.) were used to determine the flood discharges at the gaging stations, 06336000 and 06337000. The 100- and 500-year flood discharges for the Elkhorn Ranch Site were determined by using the drainage area ratio method. The 100-year flood discharges for the mouths of Knutson, Paddock, and Squaw Creeks were determined by using a regression equation developed to determine flood-peak discharges for small drainage areas in North Dakota. Water-surface elevations were determined by using step-backwater computations.

PROGRESS IN 1984: Cross-section data were obtained and flood profiles were determined.

PLANS FOR 1985: Publication of the report is anticipated.

REPORT PRODUCTS: Emerson, D. G., and Macek-Rowland, K. M., 1985, Flood analysis along the Little Missouri River within and adjacent to Theodore Roosevelt National Park, North Dakota (in progress).

PROJECT TITLE: Hydrogeochemical Controls on the Mobility of Radiogenic Constituents in Uraniferous Lignite and Ash in North Dakota (ND 84-125/126)



LOCATION: Billings, Stark, and Slope Counties, North Dakota

PERIOD OF PROJECT: June 1983 to September 1987

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: North Dakota Public Service Commission

PROBLEM: During operation of lignitic uranium mines in western North Dakota, airborne fugitive dust from the ashing of mined lignite was deposited on rangeland surrounding the sites. Adjacent to the kiln sites where the greatest amount of ashing occurred, soil became highly contaminated with radioactive and trace-metal residuals. After the abandonment of North Dakota lignitic uranium mines, most mine pits filled with ground water, providing a potential for mobilization of metals and radioactive components concentrated in ash and unburned lignite remaining in pit bottoms. Aquifers hydrologically connected with mine pits locally are used for domestic and livestock supply.

OBJECTIVES: The objectives are (1) determination of the physiochemical conditions that promote the mobility of radiogenic, select trace metal, and other potentially hazardous chemical constituents from uraniferous lignite and its ash throughout the hydrologic system; (2) prediction of the mobility of these constituents at each of the abandoned mine sites in western North Dakota; (3) comparison of predicted and observed ground-water, pore-water, and surface-water compositions affected by mine-derived solutes; (4) development of reclamation methods that might limit hazardous waste mobility from the sites; and (5) evaluation of reclamation practices adopted by the North Dakota Public Service Commission to restore the sites to maximum safe usefulness.

APPROACH: The study consists of three phases. Phase 1 is designed to provide the geohydrologic and geohydrochemical data at all eight sites necessary to develop initial reclamation plans. Phase 2 will determine the geochemical processes controlling radiochemical mobility in the hydrologic system. Specifically, one uranium mining and ashing site that intersects the water table, a second uranium mining and ashing site remote from the water table, and a kiln processing site will be selected for extensive study. Phase 3 will determine the transference value of information gathered in phase 2 to the remaining phase 1 sites. Proof of transference is requisite before the simulation can be utilized to help develop standards for reclamation of mine sites.

PROGRESS IN 1984: All existing hydrogeologic data in the vicinity of the mine sites have been evaluated to look for evidence of mobility of radiogenic constituents from the sites. Seepage surveys were conducted on area streams and samples of baseflow and stream sediments taken for analysis for radiogenic and selected trace-element components. Domestic- and livestock-supply wells in the vicinity of mine sites were sampled and the collected ground water analyzed for the same constituents as surface water. During the fall, ground-water wells, pressure-vacuum lysimeters, and radon-etch detectors were emplaced in and near mine sites. Ground and pore water were sampled seasonally. Cores obtained during drilling operations were subjected to leaching and soxholet extraction experiments to determine the mobility of hazardous constituents occurring in the solid phase.

PLANS FOR 1985: Monitoring and water-quality sampling will continue. One mine pit will be reclaimed by the North Dakota Public Service Commission using methods believed to minimize deterioration of the aquifer. Monitoring sites destroyed will be reestablished in the reclaimed site. Monthly ground-water levels and drilling information will be used to develop flow models at the phase 2 sites. Solute transport equations may be applied if errors in the flow model are sufficiently low.

REPORT PRODUCTS: Houghton, R. L., Wald, J. D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents at uraniferous lignite mines in southwestern North Dakota [abs.]: Proceedings, 76th Annual Meeting of the North Dakota Academy of Science, Fargo, N. Dak., v. 38, p. 59.

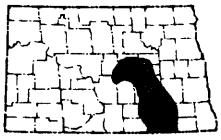
Houghton, R. L., Wald, J. D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents in mine spoils and uraniferous lignite ash in southwestern North Dakota [abs.]: Proceedings of the 1984 Rocky Mountain Ground-Water Conference, Great Falls, Mont., April 8-11, 1984, Montana Bureau of Mines and Geology Special Publication 91, p. 26-27.

Houghton, R. L., Wald, J. D., and Anderson, Garth, 1984, Hydrogeochemical controls on the mobility of radiogenic constituents in the coal-bearing Fort Union Formation and in lignite mines in western North Dakota: Proceedings of the 1984 Rocky Mountain Coal Symposium, Bismarck, N. Dak., p. 89-113.

Houghton, R. L., Hall, R. L., Unseth, J. D., Wald, J. D., Burgess, Jeff, Mount, Dana, Patrick, Dale, and Anderson, Garth, 1985, Prevention of ground-water quality degradation during reclamation of a uraniferous lignite mine, North Dakota: Proceedings of the 1985 U.S. Department of Energy, Low-Level Radioactive Waste Symposium, Las Vegas, September 10-13, 1985 (in progress).

Distribution and hydrogeochemical mobility of radioactive and associated constituents in the coal-bearing Fort Union Formation of western North Dakota (planned).

PROJECT TITLE: Data Development and Analysis for Use in the U.S. Bureau of Reclamation Model on the James River (ND 84-128)



LOCATION: Southeastern North Dakota

PERIOD OF PROJECT: October 1983 to September 1984

PROJECT CHIEF: Gregg J. Wiche

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Reclamation

PROBLEM: The James River planning model that will be developed by the U.S. Bureau of Reclamation will require as input data the nonregulated and regulated discharges at a number of locations along the James River. A combination of water-balance and statistical procedures will be used to synthesize the necessary input data. The purpose of this study will be to compile and analyze the monthly discharge data needed as input to the planning flow model that will be developed by the U.S. Bureau of Reclamation.

OBJECTIVES: Specific objectives are (1) to compute a regulated discharge for the period 1953-82 at the North Dakota-South Dakota State line, (2) to compute unregulated discharge for six James River locations, (3) to characterize the period of record in terms of the recorded climatological record, and (4) to compute revised drainage area figures for the James River basin.

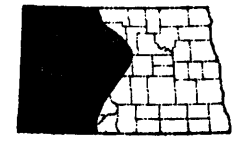
APPROACH: Two methods will be used to compute the regulated discharge at the North Dakota-South Dakota line. The first method of record reconstruction is the drainage area ratio technique outlined by Hirsch (Hirsch, R. M., 1979, An evaluation of some record reconstruction techniques: Water Resources Research, v. 15, no. 6, p. 1781-1790). The second method will be to develop log-log regression between the monthly flows of James River at LaMoure and the monthly flows of James River at Ludden Dam, which is within a mile of the North Dakota-South Dakota line. The unregulated flows will be computed by determining the effect of Jamestown and Pipestem Reservoirs and then subtracting or adding the monthly effect to the regulated flows at stations downstream of the reservoirs.

PROGRESS IN 1984: The objectives of the study were completed and a draft of the report written.

PLANS FOR 1985: Plans are to obtain Director's approval for report publication.

REPORT PRODUCTS: James River model data (planned).

PROJECT TITLE: Hydraulic Characteristics of Aquifers and Confining Units in the Fort Union Formation (ND 84-129)



LOCATION: West-Central North Dakota and Eastern Montana

PERIOD OF PROJECT: October 1983 to September 1985

PROJECT CHIEF: Thomas B. Reed

PROBLEM: Previous studies of the hydrogeology of lignite deposits in North Dakota generally have not provided the areally distributed hydraulic data that are required for use in ground-water flow models. Without this type of data, the areal and temporal distribution of drawdown in the vicinity of a strip mine cannot be projected accurately. Furthermore, without valid, calibrated flow models, solute transport processes cannot be modeled quantitatively.

OBJECTIVES: The objectives will be (1) to evaluate the available methodologies appropriate for the in situ determination of hydraulic conductivity (or transmissivity), specific storage, and specific yield of fractured rock aquifers and for the determination of vertical hydraulic conductivity and specific storage of confining beds; (2) to establish and execute a systematic procedure for the collection and analysis of data required for the determination of the hydraulic properties of the lignite and sandstone aquifers and confining beds; (3) to examine the data for correlative relationships between lignite hydraulic conductivity and various physical or geologic parameters such as depth of burial or lignite bulk density; and (4) to compare values of aquifer hydraulic conductivity derived from slug testing with those derived from pumping tests to evaluate the validity of the slug test method for fractured rock and granular aquifers.

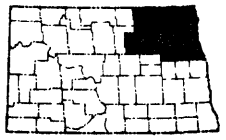
APPROACH: Accomplishment of the study objectives will require a drilling program that will provide the production and observation wells necessary for the pumping and slug tests. Aquifer testing by pumping methods will require production wells to be drilled in several different locations, each fully penetrating the aquifer and each accompanied by several observation wells placed at varying distances and directions from the production well. Each of the wells completed in aquifer zones also will be used for slug testing. Additional wells will be completed in the confining beds.

PROGRESS IN 1984: Test holes and wells were drilled. The literature review was completed.

PLANS FOR 1985: Plans are to conduct aquifer tests, analyze data, and write the report.

REPORT PRODUCTS: Hydraulic parameters in the Fort Union Formation (planned).

PROJECT TITLE: Effects of Fallowed Land on Soil Erosion, Northeastern North Dakota (ND 85-130)



LOCATION: Northeastern North Dakota

PERIOD OF PROJECT: July 1983 to September 1986

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: North Dakota State University

PROBLEM: Each year, large tracts of agricultural land in North Dakota are left fallowed. Recent Federally-sponsored programs have increased this acreage greatly. Because ground cover commonly is not used or is planted mid-summer, early summer rains have a great potential to cause significant soil erosion. Currently, no easily applicable means of remotely determining the magnitude of this soil erosion are available.

OBJECTIVES: The objectives are (1) to make semiquantitative estimates of soil erosion from farmlands managed with differing agricultural practices, (2) to determine the effect of land laid fallow on the magnitude of soil erosion, and (3) to determine the effect of expected increase in soil erosion on sediment loads in major rivers and their tributaries draining eastern North Dakota.

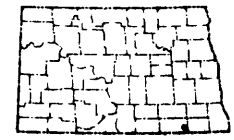
APPROACH: Low-level aerial photography of fallow fields will be employed before and after the major summer rain period. Soil erosion will be estimated from rill patterns on the photographs and calibrated against ground-truth surveys. Calculated soil losses will be compared to suspended-sediment loads at stations in the small basins being investigated.

PROGRESS IN 1984: Tracts identified for survey were flown and ground-truth measurements taken. Data evaluation was begun.

PLANS FOR 1985: Three new tracts will be added to represent different slope characteristics. Aerial and ground-truth measurements will be repeated.

REPORT PRODUCTS: Aerial determination of soil erosion in northeastern North Dakota (planned).

PROJECT TITLE: Heat and Water Transport Model for Seasonally Frozen Soils in North Dakota (ND 85-131)



LOCATION: Eastern Dickey County, Southeastern North Dakota

PERIOD OF PROJECT: January 1985 to September 1987

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCY: North Dakota State Water Commission

PROBLEM: Snow cover is an important manageable water resource of the northern prairies. To take full advantage of this water resource, an understanding of the processes of runoff and water movement into and through seasonally frozen soils and an operational procedure to quantify these processes are needed.

OBJECTIVES: The objectives of this investigation are (1) to develop a physically-based model for simulation of flow through seasonally frozen soils, (2) to measure the hydraulic properties of soil types in a study area and collect meteorological and hydrological data for verification of the model, (3) to use the model concurrently with the data-collection process to evaluate the sensitivity of the model's flow system to variations in soil hydraulic properties and driving variables, and (4) to couple the model to the U.S. Geological Survey's precipitation-runoff model system.

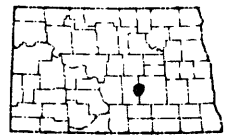
APPROACH: A physically-based heat and water transport model for seasonally frozen soils will be developed. Data collection will consist of measuring the necessary parameters to verify the snow accumulation and melt, soil freezing and thawing, and soil water content.

PROGRESS IN 1984: New project.

PLANS FOR 1985: Plans are to develop a model and collect data.

REPORT PRODUCTS: Emerson, D. G., 1985, Heat and water transport model for seasonally frozen soils in North Dakota: Study Plan; in Proceedings, Workshop/Symposium: Snow Management for Agriculture.

PROJECT TITLE: Ground-Water Flow in the Marstonmoor Aquifer in the Vicinity of Chase Lake, North Dakota (ND 85-134)



LOCATION: Stutsman and Kidder Counties, North Dakota

PERIOD OF PROJECT: April 1985 to September 1986

PROJECT CHIEF: Thomas B. Reed

COOPERATING AGENCY: U.S. Department of the Interior
Fish and Wildlife Service

PROBLEM: Chase Lake National Wildlife Refuge is the sole nesting area for the white pelican. Irrigation wells have been installed near the refuge, and refuge officials fear that pumpage will cause lake-level declines and threaten the nesting area.

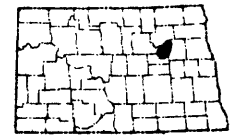
OBJECTIVES: The purpose of this project is to determine whether nearby irrigation pumpage can effect a decline in the level of Chase Lake. The specific objectives are to ascertain ground-water gradients and relative transmissivities adjacent to the lake.

APPROACH: Ground-water wells and meteorological stations will be installed to measure aquifer gradients around the lake and hydrologic impacts to the system. A ground-water flow model may be used to determine whether irrigation pumpage is likely to affect lake levels.

PLANS FOR 1985: Ground-water wells and meteorological stations will be installed in the vicinity of Chase Lake. Monitoring of water levels in the wells and precipitation at the meteorological stations will commence. The framework for a ground-water flow model of the Marstonmoor aquifer in the vicinity of Chase Lake will be developed.

REPORT PRODUCTS: Ground-water flow in the Marstonmoor aquifer in the vicinity of Chase lake, North Dakota (planned).

PROJECT TITLE: Ground-Water Flow in the Warwick Aquifer, North Dakota (ND 85-136)



LOCATION: Benson, Eddy, and Ramsey Counties, North Dakota

PERIOD OF PROJECT: April 1985 to December 1986

PROJECT CHIEF: Thomas B. Reed

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Indian Affairs

PROBLEM: It has been proposed to use the Warwick aquifer to irrigate land on the Fort Totten Indian Reservation. However, it is not known if the aquifer can sustain the required withdrawals.

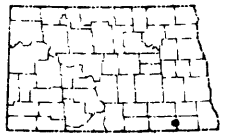
OBJECTIVE: The purpose of the project is to augment existing hydrologic knowledge of the Warwick aquifer so that it may be determined if the aquifer will sustain planned irrigation withdrawals.

APPROACH: Most hydrologic properties of the aquifer are known. Additional wells will be installed to determine leakage from East Devils Lake into the aquifer and seepage from the aquifer to the Sheyenne River. This information will be sufficient to complete input requirements for a simple ground-water flow model to evaluate irrigation potential.

PLANS FOR 1985: All drilling and data collection will be completed. A preliminary ground-water flow model will be developed to evaluate irrigation potential.

REPORT PRODUCTS: Irrigation potential from the Warwick aquifer, north-central North Dakota (planned).

PROJECT TITLE: Effects of Irrigation and Ground-Water Recharge Practices on the Quantity and Quality of Shallow Ground Water and on Soil Productivity along the James River, North Dakota (ND 85-137)



LOCATION: Dickey and Sargent Counties, North Dakota

PERIOD OF PROJECT: May 1985 to September 1987

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Reclamation

PROBLEM: The Garrison Diversion project includes plans to irrigate approximately 46,000 acres of land in the Oakes area. To assure sufficient water supply for irrigation, a proposal was made by the 12-member Garrison Diversion Commission to supply irrigation water from the Oakes aquifer and to recharge the aquifer with James River water during peak flows. The purpose of the investigation is to provide the means to evaluate the effects of an irrigation/ground-water recharge management plan for the Oakes aquifer on ground-water quantity and quality prior to its implementation.

OBJECTIVES: Objectives include (1) determination of aquifer thickness and hydraulic properties; (2) development of a regional, two-dimensional ground-water flow model for the Oakes aquifer; (3) development of a three-dimensional ground-water flow model of a single recharge pit; (4) evaluation of the feasibility of other recharge designs; and (5) determination of the effect of recharge design on water quality in the aquifer.

APPROACH: Observation wells will be installed in the Oakes aquifer to provide information on hydraulic heads and water quality. Aquifer tests, core samples, and geophysical logs will be evaluated to determine the hydraulic properties of the aquifer. A two-dimensional ground-water flow model of the aquifer will be developed. Based on design plans for the Garrison Diversion project, a three-dimensional ground-water flow model will be developed to evaluate the operation of a ground-water recharge pit and determine its optimum dimensions. Based on the two models developed, a network of recharge pits necessary to produce the required recharge will be designed and its effects on the aquifer evaluated by another ground-water flow model.

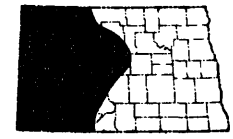
PLANS FOR 1985: The observation-well network will be designed, installed, and sampled. Aquifer tests will be completed. Initial design and evaluation of the effectiveness of recharge pits using a three-dimensional ground-water flow model will commence.

REPORT PRODUCTS: No report products are planned for 1985.

ENERGY-RELATED STUDIES

The expanding domestic energy demand has resulted in increased coal production and associated development in North Dakota. To meet the requirements for coal leasing and environmental protection, the U.S. Geological Survey has developed a program to evaluate the water resources in areas of current and planned development. This program is effected through the cooperation of interested agencies and the U.S. Geological Survey.

PROJECT TITLE: Hydrologic Changes Due to Lignite Mining in North Dakota, Part 1--Reconnaissance of Strippable Lignite Deposits (ND 75-070)



LOCATION: Western North Dakota

PERIOD OF PROJECT: July 1974 to June 1977

PROJECT CHIEF: William F. Horak, Jr.

PROBLEM: There is a lack of reliable and detailed geologic and hydrologic data for the assessment of the hydrologic effects of strip mining the lignite coal in North Dakota. The mining will, in some areas, affect the availability of water for shallow wells. The quality of water will be changed through displacement and mixing of overburdened materials. Sediment yields from the areas will be changed. The ground-water interrelationship with surface water will be altered. None of these effects could be evaluated without a thorough knowledge of present hydrologic conditions.

OBJECTIVES: The project objectives were to define for each strippable lignite deposit (as identified in publications of the U.S. Bureau of Mines and the U.S. Geological Survey) the following information: (1) A summary of local geologic conditions; (2) description of the local ground-water flow system; (3) flow characteristics of the streams; (4) chemical quality of water from streams, lakes, and aquifers; (5) stream sediment loads; and (6) recommendations for more intensive hydrologic studies in probable problem areas.

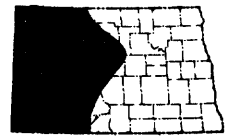
APPROACH: A field reconnaissance was made to evaluate the deposit areas in regard to geology, topography, and land use. A literature and data search was made and all hydrologic and geologic data computerized. Conceptual models were developed for each site through preliminary analysis and interpretation of available data. Additional data needs were defined and a program of data collection instituted. These data then were used to further develop and test the conceptual models. The probable hydrologic changes due to mining were evaluated for each deposit, and recommendations for areas of future intensive hydrologic study were made.

PROGRESS IN 1984: The ground-water aspects of the lignite deposit areas have been completed. These are being incorporated into second-generation reports. One area, the Avoca deposit, is being reported on separately.

PLANS FOR 1985: Publication of the report is anticipated.

REPORT PRODUCTS: Horak, W. F., and Crosby, O. A., 1985, Geohydrologic reconnaissance of the Avoca lignite deposit area near Williston, northwestern North Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4024, 23 p. (in press).

PROJECT TITLE: Surface-Water Resources, Fort Union Coal Region of Western North Dakota (ND 77-107)



LOCATION: West-Central North Dakota

PERIOD OF PROJECT: October 1977 to September 1982

PROJECT CHIEF: Norman D. Haffield

COOPERATING AGENCIES: Other Federal agencies

PROBLEM: Because of the increasing demands for energy, the coal resources in the Fort Union coal region of western North Dakota have been undergoing extensive development. The mining and associated activities will put a demand on the water resources and could alter the characteristics of the streams. Because it will be necessary for resource developers to make decisions in order to use and protect the available water resources, there is a need for a comprehensive and easily understood source of data that describes the existing hydrologic system.

OBJECTIVES: The purpose of the study is to describe the surface-water resources of the Fort Union coal region of western North Dakota in a readily usable format. The specific objectives are (1) to determine the streamflow and water-quality characteristics for the streams located in the region and (2) to describe seasonal and areal variations that occur within the various stream systems.

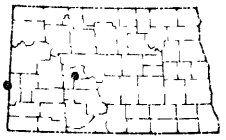
APPROACH: All existing data will be condensed and analyzed in order to define the characteristics of the various components of the streamflow systems that are located within the region.

PROGRESS IN 1984: A limited amount of data analysis work was done.

PLANS FOR 1985: As time permits, work will continue on data analysis.

REPORT PRODUCTS: Haffield, N. D., Streamflow and water quality for streams in Fort Union coal region in North Dakota (in progress).

PROJECT TITLE: Evaluation Through Modeling of Probable Surface-Water Hydrologic Effects of Future Lignite Mining and Reclamation Activities in the Antelope Creek Area, Mercer County, North Dakota, and the Wibaux-Beach Deposit Area, Wibaux County, Montana, and Golden Valley County, North Dakota (ND 80-087)



LOCATION: Mercer County, North Dakota, and Wibaux County, Montana

PERIOD OF PROJECT: October 1979 to September 1982

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Land Management

PROBLEM: The U.S. Bureau of Land Management has the responsibility of evaluating the leasing applications for mining of Federal coal. Their evaluations evaluations must address environmental impacts, which include those of hydrology. Therefore, a basic problem to be addressed in this investigation was the assessment of impacts of surface mining on the surface-water hydrology of mined and adjacent unmined areas.

OBJECTIVES: The objectives of this investigation were (1) to determine premining hydrologic conditions in a small representative drainage basin, (2) to provide historical data with which to compare the magnitude of change with mining, and (3) to develop the capability of making reasonably accurate projections of hydrologic effects resulting from the various land treatments imposed by surface mining.

APPROACH: This was a very comprehensive study of two small representative watersheds. A surface-water model was developed through coupling of snowmelt-rainfall runoff models. A modular-design program was used with each element of the hydrologic system being defined by a subroutine. This program has the capability of combining subroutines to best fit a particular problem. A distribution-parameter approach was used by having the basin partitioned into subunits based on slope, aspect, vegetation type, soil type, and snow distribution. Each subunit was considered homogeneous with respect to these parameters. Partitioning into subunits helped define the temporal and spatial variations of the hydrologic characteristics, climatic variables, and overall system response.

PROGRESS IN 1984: For two watersheds, data were collected and analyzed, and a watershed model was calibrated for snowmelt runoff.

PLANS FOR 1985: Publication of the analysis report is anticipated.

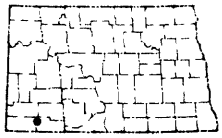
REPORT PRODUCTS: Emerson, D. G., 1981, Progress report on the effects of surface mining on the surface-water hydrology of selected basins in the Fort Union coal region, North Dakota and Montana: U.S. Geological Survey Open-File Report 81-678, 28 p.

Emerson, D. G., 1982, Hydrologic analysis of high flow from snowmelt on small basins in the Fort Union coal region: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., April 22-24, 1982, v. 36, p. 42.

Emerson, D. G., Norbeck, S. W., and Boespflug, K. L., 1983, Data from the surface-water hydrologic investigations of the Hay Creek study area, Montana, and the West Branch Antelope Creek study area, North Dakota, October 1976 through April 1982: U.S. Geological Survey Open-File Report 83-136, 273 p.

Emerson, D. G., 1985, Hydrologic analyses of Hay Creek, Montana, and West Branch Antelope Creek, North Dakota (in progress).

PROJECT TITLE: Geochemistry of the Upper Fort Union Group as Related to Impacts of Strip Mining of Lignite in the Gascoyne Area, North Dakota (ND 80-089)



LOCATION: Southwestern North Dakota

PERIOD OF PROJECT: October 1979 to September 1985

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCIES:
North Dakota Geological Survey (1980-83)
North Dakota Public Service Commission (1983-85)
U.S. Department of the Interior
Bureau of Land Management (1980-82)
U.S. Environmental Protection Agency (1981-82)

PROBLEM: Simultaneous demands for expanded surface-mining activity, agricultural production, and urban development are placing ever-increasing strains on the land and water resources of the region. Investigations of the environmental effects of surface mining have begun to provide the data base required to make these land-use decisions, but failure to understand the geochemistry of water-rock interactions may seriously limit the options for future coal development in the Fort Union coal region. Definition of these reaction mechanisms and rate-controlling factors could lead to the recognition of critical parameters governing probable water-rock interactions at other and projected mine sites within the Fort Union lignite region.

OBJECTIVES: The purpose of this investigation is to quantitatively describe major controls on the movement of critical solutes in local and regional ground-water systems within the Fort Union Group affected by surface mining of lignite in western North Dakota. Specific objectives at the Gascoyne site are to define the hydrogeologic and hydrogeochemical character of the shallow ground-water system in the area and to ascertain the source of observed anomalous sulfate concentrations. The effects of discharge of mine-impacted ground water on the surface-water system in the area also are of concern.

APPROACH: The first phase was to establish a clear and complete understanding of the hydrologic regime. Next, the mineralogy and mineral chemistry of the Fort Union Group was determined. Thirdly, determinations of formation cation-exchange rates and constants were determined. Fourth, oxidation-reduction reactions were defined for important species pairs. Finally, the solute flux from mine to locations of water use must be defined as mining expands.

PROGRESS IN 1984: Continued monitoring of 22 ground-water wells and one surface-water station on a tributary of Buffalo Creek draining the mine area provided additional data on temporal hydrochemical changes in the vicinity of the Gascoyne mine. Review of the data base to identify which chemical parameters in ground and surface water best indicate mine impact was initiated. Five new cores were obtained in the mine area to provide material for stable and radiogenic carbon analyses in cooperation with D. C. Thorstenson and H. A. Haas, Northeast Region Research staff. These carbon-isotopic data are expected to constrain the number of possible organic reactions involved in water-quality evolution at the site to a small number, permitting refinement of preliminary solute transport simulations.

PLANS FOR 1985: Four new wells in mine spoils will be added to the ground-water network. Monitoring of the ground-water wells and one surface-water station will continue. A summary of the existing hydrochemical data will be developed. Work will continue on the reports.

REPORT PRODUCTS: Houghton, R. L., 1982, Hydrochemistry of shallow ground water from the Fort Union Group near the Peerless lignite strip mine, Gascoyne, southwestern North Dakota [abs.]: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., p. 40.

Houghton, R. L., 1982, Hydrogeochemical consequences of strip mining in the Fort Union Group of southwestern North Dakota: Proceedings of the 1982 National Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation, Lexington, Ky., December 6-10, 1982, p. 79-86.

Houghton, R. L., 1982, Trace-element enrichments in waters associated with strip mining of lignite in the Fort Union Group of southwestern North Dakota [abs.], in Gough, L. P., and Severson, R. C., eds., Trace-element mobilization in western energy regions: Colorado School of Mines Research Institute, Golden, Colo., p. 46.

Houghton, R. L., 1982, Weathering of coal scoria--a source for diagenetic silica cements? [abs.]: Proceedings of the U.S. Geological Survey Workshop on Diagenesis, Denver, Colo., March 1982, p. 36.

Houghton, R. L., and Davison, D., 1982, Stratigraphy and paleoenvironment of the Paleocene Fort Union Group of the Williston basin near Gascoyne, southwestern North Dakota [abs.]: Proceedings, 74th Annual Meeting of the North Dakota Academy of Science, Bismarck, N. Dak., p. 15.

Houghton, R. L., Thorstenson, D. C., Fisher, D. W., and Groenewold, G. H., 1984, Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota: U.S. Geological Survey Open-File Report 84-131, 184 p.

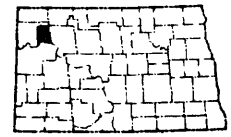
Houghton, R. L., 1985, Inverse modeling of solute transport in shallow ground water, With an example of sulfate movement around a lignite mine in southwestern North Dakota: Proceedings, 77th Annual Meeting of the North Dakota Academy of Science, Minot, N. Dak., v. 39, p. 53.

Fisher, D. W., Thorstenson, D. C., and Houghton, R. L., Geochemical processes in the Gascoyne lignite mining area, Bowman County, North Dakota (in progress).

Houghton, R. L., Probable and observed hydrologic consequences of lignite strip mining in the Fort Union Group near Gascoyne in southwestern North Dakota (in progress).

Houghton, R. L., Thorstenson, D. C., Fisher, D. W., and Groenewold, G. H., Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota (in progress).

PROJECT TITLE: Evaluation of Probable Hydrologic Effects of Future Lignite Mining and Subsequent Reclamation Activities in the M & M Deposit, Williams County, North Dakota (ND 81-091)



LOCATION: Northwestern North Dakota

PERIOD OF PROJECT: October 1980 to September 1983

PROJECT CHIEF: William F. Horak, Jr.

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Land Management

PROBLEM: There is a lack of reliable and detailed geologic and hydrologic data for the assessment of the hydrologic effects of strip mining the lignite coal in North Dakota. The mining will, in some areas, affect the availability of water for shallow wells. The quality of water will be changed through displacement and mixing of overburdened materials. Sediment yields from the areas will be changed. The ground-water interrelationship with surface water will be altered. None of these effects could be evaluated without a thorough knowledge of present hydrologic conditions.

OBJECTIVES: The project objectives were (1) to define the hydrologic regime in the greatest possible detail consistent with the duration of the study and funding, including assessment of the ground-water flow system and its chemical characteristics, determination of flow frequencies and magnitude, chemical quality, and sediment concentration and load of the larger streams; (2) to establish a historical data base; and (3) to develop the capability for projecting the hydrologic effect of physical treatments imposed by surface mining.

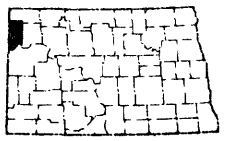
APPROACH: Data were assembled and collected for use in conjunction with digital models to define the ground-water flow system. The surface-water system was defined through available records, data collection, and regionalized equations. Quality of water was defined through an intensive sampling program. Methods for estimating the hydrologic effects of various land treatments imposed by mining were developed.

PROGRESS IN 1984: The draft report was completed and the review was initiated.

PLANS FOR 1985: Plans are to complete review through Director's approval and publish the report.

REPORT PRODUCTS: Crosby, O. A., Horak, W. F., and Randich, P. G., 1985, Hydrologic characteristics and possible effects of surface mining in the M & M lignite deposit area, North Dakota (in progress).

PROJECT TITLE: Evaluation of the Hydrologic System in the Sand Creek-Hanks Coal Area, Williams County, North Dakota (ND 83-109)



LOCATION: Northwestern North Dakota

PERIOD OF PROJECT: October 1982 to September 1983

PROJECT CHIEF: Clarence A. Armstrong

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Land Management

PROBLEM: The need for the proposed investigation came about as a response to the Interior Department's request for hydrologic information concerning Federal coal lands leased and eligible for lease within the Sand Creek-Hanks coal area. Probably the most obvious effect of coal development in the study area was the disruption of aquifers existing in the lignite beds and overburden material. The majority of farmsteads in the area (virtually all rely on ground water for their water supply) draw water from wells 200 feet or less in depth. Depending on the hydraulic properties and the areal continuity of the lignite and adjacent aquifer, many of these water supplies could have been diminished or obliterated. Any coal-development-induced diminuation of streamflow, increase in dissolved chemical constituents, or increase in sediment load could have had an effect on the usability of water in Sand, Painted Woods, Willow, and Cottonwood Creeks.

OBJECTIVES: The primary objective was to define the hydrologic regime in the greatest possible detail consistent with the project duration and funding. This included assessment of the ground-water flow system and chemical characteristics and determination of surface-water flow magnitudes, chemical quality, sediment concentration, and sediment load. By defining the hydrologic regime of the study area, a second objective was satisfied--the establishment of a historical data base with which to monitor changes in the system as mining proceeds.

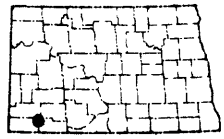
APPROACH: Existing geologic and hydrologic data were assembled and used to establish an information framework of the study area. Limited surface-runoff, water-level, and quality-of-water information was collected in the field. Where possible, regionalized information was used to define the hydrology. The final report assesses the available information and makes recommendations as to whether further study is needed for leasing purposes.

PROGRESS IN 1984: The draft report was completed and began the review process.

PLANS FOR 1985: Publication of the report is anticipated.

REPORT PRODUCTS: Armstrong, C. A., 1985, The geohydrologic system and probable effects of mining in the Sand Creek-Hanks lignite area, Williams County, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4089, 38 p. (in press).

PROJECT TITLE: Evaluation of the Hydrologic System in the New England-Mott Coal Area, Adams and Hettinger Counties, North Dakota (ND 83-110)



LOCATION: Southwestern North Dakota

PERIOD OF PROJECT: October 1982 to December 1983

PROJECT CHIEF: Mack G. Croft

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Land Management

PROBLEM: The need for the proposed investigation came about as a response to the Interior Department's request for hydrologic information concerning Federal coal lands leased and eligible for lease within the New England-Mott lignite deposit. Probably the most obvious effect of coal development in the study area will be the disruption of aquifers existing in the lignite beds and overburden material. The majority of farmsteads in the area (virtually all rely on ground water for their water supply) draw water from wells 400 feet or less in depth. Depending on the hydraulic properties and the areal continuity of the lignite and adjacent aquifer, many of these water supplies could be diminished or obliterated. Any coal-development-induced diminuation of streamflow, increase in dissolved chemical constituents, or increase in sediment load could have an effect on the usability of water in Thirty Mile Creek and the Cannonball River.

OBJECTIVES: The primary objective will be to define the hydrologic regime in the greatest possible detail consistent with the project duration and funding. This includes assessment of the ground-water flow system and chemical characteristics and determination of surface-water flow magnitudes, chemical quality, sediment concentration, and sediment load. By defining the hydrologic regime of the study area, a second objective will be satisfied--the establishment of a historical data base with which to monitor changes in the system as mining proceeds.

APPROACH: Existing geologic and hydrologic data will be assembled and used to establish an information framework of the study area. Limited surface-runoff, water-level, and quality-of-water information will be collected in the field. Where possible, regionalized information will be used to define the hydrology. The final report will assess the available information and make recommendations as to whether further study is needed for leasing purposes.

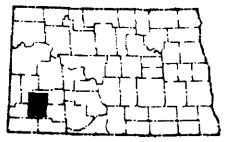
PROGRESS IN 1984: A detailed project proposal and work plan was prepared. A limited canvass of wells and collection of additional water samples was completed in the area. Data were assembled and illustrations and text prepared. The report is ready for colleague review.

PLANS FOR 1985: Plans are to process reviews and obtain Director's approval for publication.

REPORT PRODUCTS: Wald, J. D., and Norbeck, S. W., 1983, Ground-water data for selected coal areas in western North Dakota: U.S. Geological Survey Open-File Report 83-219, 229 p.

Croft, M. G., 1985, Hydrology of New England-Mott coal area, North Dakota (in progress).

PROJECT TITLE: Evaluation of the Hydrologic System in the Dickinson Coal Area, Stark County, North Dakota (ND 83-111)



LOCATION: Western North Dakota

PERIOD OF PROJECT: October 1982 to September 1983

PROJECT CHIEF: Clarence A. Armstrong

COOPERATING AGENCY: U.S. Department of the Interior
Bureau of Land Management

PROBLEM: The need for the proposed investigation came about as a response to the Interior Department's request for hydrologic information concerning Federal coal lands leased and eligible for lease within the Dickinson lignite area. Probably the most obvious effect of coal development in the study area was the disruption of aquifers existing in the lignite beds and overburden material. The majority of farmsteads in the area (virtually all rely on ground water for their water supply) draw water from wells 200 feet or less in depth. Depending on the hydraulic properties and the areal continuity of the lignite and adjacent aquifer, many of these water supplies could have been diminished or obliterated. Any coal-development-induced diminuation of streamflow, increase in dissolved chemical constituents, or increase in sediment load could have had an effect on the usability of water in Sand Creek and Painted Woods Creek.

OBJECTIVES: The primary objective was to define the hydrologic regime in the greatest possible detail consistent with the project duration and funding. This included assessment of the ground-water flow system and chemical characteristics and determination of surface-water flow magnitudes, chemical quality, sediment concentration, and sediment load. By defining the hydrologic regime of the study area, a second objective was satisfied--the establishment of a historical data base with which to monitor changes in the system as mining proceeds.

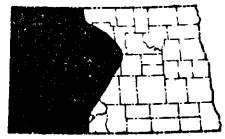
APPROACH: Existing geologic and hydrologic data were assembled and used to establish an information framework of the study area. Limited surface-runoff, water-level, and quality-of-water information was collected in the field. Where possible, regionalized information was used to define the hydrology. The final report assesses the available information and makes recommendations as to whether further study is needed for leasing purposes.

PROGRESS IN 1984: The report was completed and processed through Director's approval.

PLANS FOR 1985: Publication of the report is anticipated.

REPORT PRODUCTS: Armstrong, C. A., 1985, Evaluation of the hydrologic system and potential effects of mining in the Dickinson lignite area, eastern Slope and western Stark and Hettinger Counties, North Dakota: U.S. Geological Survey Water-Resources Investigations Report 84-4194, 41 p. (in press).

PROJECT TITLE: Hydrochemical Impacts of Surface Mining of Lignite--The Sulfur Cycle (ND 83-113/114)



LOCATION: Fort Union Coal Region, North Dakota

PERIOD OF PROJECT: October 1983 to September 1984

PROJECT CHIEF: Robert L. Houghton

COOPERATING AGENCY: North Dakota Geological Survey

PROBLEM: Hydrogeochemical studies of the impacts of surface mining of lignite in recharge areas of the northern Great Plains have not unambiguously defined the sulfur cycle. As sulfate is the principal cause of ground-water deterioration in the vicinity of mines, it is vital that the sulfur cycle be defined so that appropriate reclamation procedures may be developed to mitigate sulfate generation.

OBJECTIVES: Detailed geochemical investigations will be made to quantitatively describe the sulfur sources that contribute to ground-water sulfate in strip mines situated in recharge zones and to determine the hydrogeochemical processes that control the sulfur path to the ground water. Isotopic studies will be employed (1) to trace sulfur transformations among solid and aqueous species present throughout the sulfur cycle, (2) to quantify the relative magnitude of each transformation as a contributor to ground-water sulfate concentrations, and (3) to determine which transformations are affected by biological activity.

APPROACH: Cores and ground- and pore-water samples will be obtained from two active strip mines and one potential mine site. Sulfur species present at various depths will be identified and the sulfur isotopic ratios will be used to determine transformation paths. Samples also will be obtained with minimal contamination for determination of the presence and activity of sulfur-metabolizing microorganisms. Comparison of organism distributions and isotopic ratios will be used to determine the stages at which biological activity affects the sulfur cycle. Observations will be simulated in the laboratory as a control check.

PROGRESS IN 1984: All samples were collected and processed. The contractor continued isotopic analysis of collected samples while the project chief completed soxholet and microbiological studies. Preliminary project results were presented at the Practical Applications of Ground-Water Geochemistry Workshop sponsored by the Alberta Research Council and National Water Well Association.

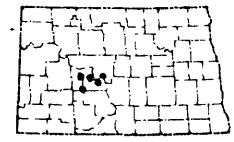
PLANS FOR 1985: The contractor will complete isotopic analysis of all samples. The final report will be prepared and processed for publication.

REPORT PRODUCTS: Houghton, R. L., Koob, R. D., and Groenewold, G. H., 1985, Progress report on the geochemistry of the sulfur cycle in northern Great Plains coal mines: U.S. Geological Survey Water-Resources Investigations Report 85-4016, 70 p.

Houghton, R. L., Koob, R. D., and Groenewold, G. H., 1985, Sulfur cycle in western coal mines, in Hitchon, Brian, and Wallick, E. I., eds., Proceedings of the First Canadian/American Conference on Hydrogeology--Practical Applications of Ground-Water Geochemistry, Banff, Alberta, Canada, June 22-26, 1984: Worthington, Ohio, National Water Well Association, p. 306-314.

Houghton, R. L., Koob, R. D., Groenewold, G. H., and Brekke, Dave, 1985, Geochemistry and microbiology of sulfur in shallow ground-water systems associated with lignite deposits, North Dakota (in progress).

PROJECT TITLE: Evaluation of Effects of Ongoing and Future Mining and Reclamation Activities in Western North Dakota (ND 83-115)



LOCATION: Western North Dakota

PERIOD OF PROJECT: October 1982 to September 1985

PROJECT CHIEF: Douglas G. Emerson

COOPERATING AGENCY: North Dakota Public Service Commission

PROBLEM: The North Dakota Public Service Commission serves as the State regulatory authority to administer this agreement as well as the regulations for State and privately-owned lands. Although the obligation for hydrologic monitoring to determine the effects of mining falls to the mining company, the North Dakota Public Service Commission needs unbiased information to effectively assure adherence to the regulations.

OBJECTIVES: The purpose of the study is to provide the capability to assess and predict the effects of mining and energy development on the hydrologic system. Specific objectives are (1) to monitor the variations in the quantity and quality of surface water below active energy development sites, (2) to use the data collected to augment and refine predictive models presently available, and (3) to verify the transferability of a calibrated watershed model.

APPROACH: The study includes the operation of five river stream-gaging and water-quality sites, one complete weather station, and three precipitation sites. The U.S. Geological Survey's Precipitation-Runoff Modeling System has been selected as the predictive model. The model has not been completely calibrated for the site where the model was developed; this is one of the five sites to be operated under this project. The plans are to collect enough data at the sites to check verification of the model. The present plans are to collect data for 3 years, but it could depend on runoff conditions.

PROGRESS IN 1984: Data were collected on a continuing basis. Streamflow data are being published in the annual water-resources data report.

PLANS FOR 1985: Collection of streamflow, chemical quality, and meteorological data will continue.

REPORT PRODUCTS: Data report of streamflow, chemical quality, and meteorological data (planned).

PROJECT TITLE: Effects of Energy Development on Trace-Element Concentrations in Hydrologic Benchmark Streams (ND 83-122)

MULTISTATE

LOCATION: Nationwide

PERIOD OF PROJECT: April 1983 to September 1983

PROJECT CHIEF: Robert L. Houghton

PROBLEM: Combustion of fossil fuels releases many substances to the atmosphere. In regions where snowmelt constitutes a major source of stream water, trace-metal enrichments may be further augmented by the physics of the melt process. Relatively volatile elements such as mercury and silver are leached from the entire snowpack during the initial phases of snowmelt and may be concentrated by several orders of magnitude. These enrichments can restrict water use for some purposes and, in the case of mercury, even be a health hazard. Recognition of such enrichments thus is an important responsibility of water-resources agencies.

OBJECTIVES: The purpose of this investigation was to evaluate existing hydrochemical data from Hydrologic Benchmark Network sites for evidence of snowmelt enrichments in atmospherically-derived trace constituents. On the basis of the relationship of such enrichments to the hydrograph, it was possible to develop guidelines for future sampling procedures at these sites that would enhance our ability to monitor snowmelt enrichments.

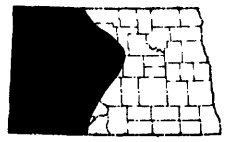
APPROACH: Trace-element data from benchmark sites within the snow belt were evaluated for enrichments during snowmelt periods. Once enrichments were identified with respect to the hydrograph, these enrichments were statistically quantified relative to the mean concentration for nonsnowmelt periods. Standard statistics for each property summed over all stations were used to determine the significance of observed enrichments.

PROGRESS IN 1984: The draft report continued in the review process.

PLANS FOR 1985: Publication of the final report is planned.

REPORT PRODUCTS: Houghton, R. L., and Schimke, LeAnn, 1985, Volatile trace-element concentrations in snowmelt contributions to streams monitored by hydrologic bench-mark network stations in the conterminous United States where average snowfall exceeds 12 inches: U.S. Geological Survey Water-Resources Investigations Report 85-4104, 20 p. (in press).

PROJECT TITLE: Hydrogeologic and Geochemical Data Base for Coal Areas in North Dakota (ND 85-132/133)



LOCATION: Fort Union Coal Region, North Dakota

PERIOD OF PROJECT: October 1984 to September 1986 (Preproject--May 1984 to October 1984)

PROJECT CHIEF: Lawrence I. Briel

COOPERATING AGENCIES: U.S. Department of the Interior
Bureau of Land Management
(Preproject--North Dakota Public Service Commission

PROBLEM: Models of the principal geochemical processes controlling water quality in North Dakota and the effects of mining on these processes have been developed during investigations. Overburden chemical characteristics are determined routinely on overburden and spoils both prior to and during mining as part of the permitting requirements and also have been collected during scientific investigations of the hydrochemical consequences of mining. Accordingly, a large and growing body of data exists to arm the chemical models. Although the data generally are in existence, data collected by the various industry and governmental groups are not readily accessible.

OBJECTIVES: The purpose of this project is to develop a geochemical data base capable of centrally storing all the data required to arm the model that has been developed to predict the hydrochemical consequences of mining. Specific objectives include (1) designing a data base for storage of overburden geochemical data required to run models to predict the hydrochemical consequences of mining, (2) initiating data transfer from other data files to this data base, and (3) providing access to the data base by all participating industries and agencies while protecting the propriety of provisional data.

APPROACH: Design of the data base will be undertaken in a tiered fashion. Individual samples will be identified uniquely by geographic location, depth, date and time of collection, and medium type. Numerical parameter codes will be used to identify individual sample constituents or properties, analytical methods, and collecting and analyzing agencies for which data values are stored. To facilitate rapid development of the data base and ease of use by others, the data base will be designed around the existing U.S. Geological Survey WATSTORE data base. WATSTORE control code will be modified to extend sample identification to include the depth parameter.

PROGRESS IN 1984: As part of a preproposal investigation, the conceptual design of the data base and the project proposal were developed.

PLANS FOR 1985: The data base manager will be developed by modifying existing WATSTORE code. Population of the data base will commence with machine-readable files.

REPORT PRODUCTS: User manual and documentation for hydrogeologic and geochemical data base management system (planned).

BOARDS AND COMMISSIONS

To coordinate water-resources activities with International, other Federal, State, and local agencies, District personnel must participate actively on numerous boards and commissions. Participation frequently includes compilation, publication, and dissemination of meeting minutes or researching special concerns of participating agencies.

PROJECT TITLE: Boards and Commissions (ND00-064)

LOCATION: Bismarck, North Dakota

PERIOD OF PROJECT: Continuous

PROJECT CHIEF: L. Grady Moore

COOPERATING AGENCIES: Other Federal agencies

PROBLEM: Coordination of water-data collection activities and supporting information planning.

OBJECTIVES: The primary objectives of this project are (1) to assure impartial Federal representation on the Yellowstone River Compact Commission and the Souris River Board of Control and (2) to supply accurate, unbiased information to boards and commissions.

APPROACH: Chair the meetings and provide administrative support to the Yellowstone River Compact Commission. Act as alternate member for the United States to the Souris River Board of Control. Furnish information requested by members of the International Souris-Red River Engineering Board.

PROGRESS IN 1984: The 1983 Annual Report of the Souris River Board of Control was printed and distributed. Meetings of the Board were held February 2, 1984, and June 7, 1984. Information was routinely furnished to parties concerned with Souris River streamflow.

PLANS FOR 1985: All meetings of the Souris River Board of Control will be attended. The Annual Report for 1984 will be prepared and distributed.

All meetings of the Yellowstone River Compact Commission and the Administration Committee will be attended. The Annual Report for 1984 will be prepared and distributed.

SOURCES OF WRD PUBLICATIONS AND INFORMATION

Publications Program

Professional papers, water-supply papers, and bulletins are sold by the U.S. Geological Survey, Eastern Distribution Branch, 604 South Pickett Street, Alexandria, VA 22304; single copies of circulars still in print are available upon request from that address. Hydrologic investigations atlases, hydrologic unit maps, and other maps pertaining to North Dakota are sold by U.S. Geological Survey, Western Distribution Branch, Box 25286, Federal Center, Denver, CO 80225.

U.S. Geological Survey water-resources investigations reports and open-file reports are available for inspection at the North Dakota District Office, Water Resources Division, U.S. Geological Survey, 821 East Interstate Avenue, Bismarck, ND 58501; information on their availability also may be obtained from the District Chief at the above address. In addition, those reports having an alpha-numeric designation in parentheses at the end of the citation may be purchased as paper copy or microfiche from Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225--these numbers are required when ordering from OFSS.

The series of reports entitled "Water-Resources Data for (State) for (Year)," covering surface water, ground water, and water quality in each state, must be purchased from the National Technical Information Service but can be inspected in U.S. Geological Survey libraries and in Water Resources Division District Offices in the region of the report.

New reports are announced monthly in "New Publications of the Geological Survey," subscriptions to which are available upon request from the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Water-Data Program

Water-data stations at selected locations throughout the Nation are used by the U.S. Geological Survey to obtain records on stream discharge (flow) and stage (height), reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. These data provide a continuing record of the quantity and quality of the Nation's surface- and ground-water resources and thus provide the hydrologic information needed by Federal, State, and local agencies and the private sector for the development and management of land and water resources. All data collected are stored in the Survey's National Water Data Storage and Retrieval System (see section "WATSTORE" for additional information on this system) and also are published by water year for each state in a publication series entitled "U.S. Geological Survey Water-Resources Data Reports (see section "Publications Program" for availability of these reports). Information about the Water-Data Program can be obtained from the Assistant Chief Hydrologist for Operations or from the District Chief of the state of interest.

NAWDEX

The Water Data Sources Directory (WDSD) is a computerized data base developed and maintained by the National Water Data Exchange (NAWDEX) Program Office that contains information about organizations that collect, store, and disseminate water data. This information includes the type of each organization; the major orientation of water-data activities conducted by each organization; the names, addresses, and telephone numbers of offices within each organization from which water-data may be obtained; the types of data held by each organization and the geographic locations within which these data have been collected; and alternate sources of an organization's data.

WATSTORE

The WATer data STOrage and REtrieval system, which has remained basically unchanged for about 10 years, is in the process of being downloaded from a central computer located in Reston, Va., to PRIME minicomputers located in the district offices. At the same time, the software is being enhanced to streamline the data processing, allow for direct entry of data relayed via satellite, and permit processing of variable-interval data (as opposed to fixed-interval data; i.e., 15-minute punch tape).

All of the surface-water streamflow and stage data were downloaded to the North Dakota PRIME during 1984. All 1984 water year data processing for surface-water data was done on the District PRIME computer. Although the conversion delayed the publication of the 1983 water year report, the 1984 water year report should be available before the end of the 1985 water year and earlier completion dates should be attained in subsequent years.

In May 1985, the ground-water software was installed on the District PRIME and all ground-water site information and water levels were downloaded from Reston. The North Dakota District is acting as one of the test sites for the new ground-water software.

The water-quality data have not been downloaded to the District PRIME, but downloading is planned for 1985. Several utility programs such as the Log-Pearson Flood Frequency Analysis and Daily Values Duration also are not available at this time.

The new system, when complete, will be called the National Water Information System (NWIS). Results so far appear encouraging. The data management has become easier and data can be handled more quickly. Significant improvements in timeliness of data availability are expected to occur in the near future as software is developed.

ADDITIONAL INFORMATION ON U.S. GEOLOGICAL SURVEY PROGRAMS IN NORTH DAKOTA

Additional information on U.S. Geological Survey programs in North Dakota may be obtained from the Public Inquiries Office, U.S. Geological Survey, 169 Federal Building, 1961 Stout Street, Denver, CO 80294, or from "A Guide to Obtaining Information from the U.S. Geological Survey, 1982," Geological Survey Circular 777.

PUBLICATIONS BY PERSONNEL OF THE U.S. GEOLOGICAL SURVEY, NORTH DAKOTA DISTRICT

Date published	Report title	Author	Publication media	Number of pages	Report availability
1961	Artesian water in the Spiritwood buried valley complex, North Dakota	Huxel	Professional paper 424-D	3	Available
1961	Flood stages and discharges for small streams in North and South Dakota, July 1, 1954, to September 30, 1961	Crosby and West	Administrative report	122	--
1962	Artesian water from glacial drift near Lehr, Logan and McIntosh Counties, North Dakota	Adolphson	North Dakota Ground-Water Studies 38	22	Available
1962	Current studies of the hydrology of prairie potholes	Shjeflo and others	Circular 472	11	Available
1962	Geology and ground-water resources of Kidder County, North Dakota, Ground-water basic data	Randich, Petri, and Adolphson	North Dakota Geological Survey Bulletin 36	134	Out of print[1/]
1962	Geology and ground-water resources of Tioga and Hofflund Flats areas, Williams and Mountrail Counties, North Dakota	Paulson and Powell	North Dakota Ground-Water Studies 43	65	Available

1/May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1962	Geology and occurrence of ground water near Bowbells, Burke and Ward Counties, North Dakota	Jensen	North Dakota Ground-Water Studies 42	65	Available
1962	Ground water--A vital North Dakota resource	Paulson	North Dakota Geological Survey Miscellaneous Series 16	25	Available
1962	Ground water in the Hatton area, Traill and Steele Counties, North Dakota	Adolphson	North Dakota Ground-Water Studies 39	23	Available
1962	Ground-water near Hoople, Walsh and Pembina Counties, North Dakota	Jensen and Bradley	North Dakota Ground-Water Studies 49	19	Available
1962	Ground water near Reynolds, Grand Forks and Traill Counties, North Dakota	Jensen	North Dakota Ground-Water Studies 47	26	Available
1962	Ground-water resources in the Lakota area, Nelson County, North Dakota	Powell and Jones	North Dakota Ground-Water Studies 48	68	Available
1962	Ground-water resources in the vicinity of Leeds, Benson County, North Dakota	Randich and Bradley	North Dakota Ground-Water Studies 44	27	Available
1962	Test drilling near Beulah, Mercer County, North Dakota	Bradley and Jensen	North Dakota Ground-Water Studies 40	19	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1963	Geology and ground-water resources near Berthold, Ward County, North Dakota	Randich	North Dakota Ground-Water Studies 46	26	Available
1963	Geology and ground-water resources of Kidder County, North Dakota, Ground water and chemical quality of water	Bradley, Petri, and Adolphson	North Dakota Geological Survey Bulletin 36	38	Available
1963	Geology and ground-water resources of Stutsman County, North Dakota, Ground-water basic data	Huxel and Petri	North Dakota Geological Survey Bulletin 41	339	Available
1963	Geology and ground-water resources of the Linton-Strasburg area, Emmons County, North Dakota	Randich	North Dakota Ground-Water Studies 50	53	Available
1963	Ground water in the Crosby-Mohall area, North Dakota	LaRocque, Swenson, and Greenman	North Dakota Ground-Water Studies 54	57	Available
1963	Ground water in the vicinity of Hillsboro, Traill County, North Dakota	Jensen and Bradley	North Dakota Ground-Water Studies 55	19	Available
1963	Ground-water resources near Max, McLean and Ward Counties, North Dakota	Armstrong	North Dakota Ground-Water Studies 45	24	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1964	Geohydrology of the Spiritwood aquifer, Stutsman and Barnes Counties, North Dakota	Kelly	Professional paper 501-D	5	Out of print[1/]
1964	Geologic factors affecting discharge of the Sheyenne River in southeastern North Dakota	Paulson	Professional paper 501-D	5	Out of print[1/]
1964	Ground-water resources of the Devils Lake area, Benson, Ramsey, and Eddy Counties, North Dakota	Paulson and Akin	North Dakota Ground-Water Studies 56	211	Available
1964	Map of Burleigh County, North Dakota, showing the location of aquifers and potential yields	Randich	Open file	1	Superseded
1964	North Dakota's ground-water resources	Paulson	North Dakota Economic Commission	7	--
1965	Exploration and development of glacial-drift aquifers in North Dakota	Paulson	American Geophysical Union, Abstract	1	--
1965	Geohydrology of the Souris River valley in the vicinity of Minot, North Dakota, Ground-water basic data	Pettyjohn and Hills	North Dakota Ground-Water Studies 65	89	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1965	Geology and ground-water resources of Barnes County, North Dakota, Ground-water basic data	Kelly	North Dakota Geological Survey Bulletin 43	156	Available
1965	Geology and ground-water resources of Burleigh County, North Dakota, Ground-water basic data	Randich	North Dakota Geological Survey Bulletin 42	273	Out of print[1/]
1965	Geology and ground-water resources of Divide County, North Dakota, Ground-water basic data	Armstrong	North Dakota Geological Survey Bulletin 45	112	Available
1965	Geology and ground-water resources of Stutsman County, North Dakota, Ground water and its chemical quality	Huxel and Petri	North Dakota Geological Survey Bulletin 41	58	Available
1965	Ground-water conditions at control site Foxtrot (F), Minot minuteman complex, North Dakota	Randich and Brown	Administrative report	24	--
1965	Ground-water conditions at control site Nemo (N), Minot minuteman complex, North Dakota	Brown and Randich	Administrative report	29	--
1966	Color variations within glacial till, east-central North Dakota--A preliminary investigation	Kelly and Baker	Journal of Sedimentary Petrology	6	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1966	Eocene paleosol in the northern Great Plains	Pettyjohn	Professional paper 550-C	5	Out of print[1/]
1966	Floods of June 24-25, 1966, in southwest-central North Dakota	Crosby	Open file	15	Available
1966	Geohydrologic use of lithofacies maps in glaciated areas	Pettyjohn and Randich	Water Resources Research	11	Available
1966	Geology and ground-water resources of Barnes County, North Dakota, Ground-water resources	Kelly	North Dakota Geological Survey Bulletin 43	67	Available
1966	Geology and ground-water resources of Burleigh County, North Dakota, Ground-water resources	Randich and Hatchett	North Dakota Geological Survey Bulletin 42	92	Available
1966	Geology and ground-water resources of Cass County, North Dakota, Ground-water basic data	Klausing	North Dakota Geological Survey Bulletin 47	158	Available
1966	Geology and ground-water resources of Eddy and Foster Counties, North Dakota, Ground-water basic data	Trapp	North Dakota Geological Survey Bulletin 44	243	Available
1966	Geology and ground-water resources of Richland County, North Dakota, Ground-water basic data	Baker	North Dakota Geological Survey Bulletin 46	170	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1966	Minimum and maximum water-level recording devices	Kelly	WRD Bulletin, January-March 1966	2	Available
1966	Preliminary ground-water availability map of Williams County, North Dakota	Armstrong	Open file	1	Superseded
1966	Report of water-loss study from pool above Minot water plant dam on the Souris (Mouse) River	Crosby	Open file	8	Available
1966	The Milnor channel, an ice-marginal course of the Sheyenne River, North Dakota	Baker	Professional paper 550-B	3	Out of print[1/]
1967	Accurate test-tube rain gages	Kelly	WRD Bulletin, July-December 1967	2	Available
1967	Artificial recharge at Valley City, North Dakota, 1932-65	Kelly	Ground Water	6	Available
1967	Availability of shallow ground water at control sites HO, IO, and KO, Grand Forks Air Force Base minuteman complex, North Dakota	Buturla and Kelly	Administrative report	30	--

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1967	Development of a ground-water supply, Badlands National Monument, South Dakota	Randich	Administrative report	18	--
1967	Dump ridges and collapsed sub-ice channels in Ward County, North Dakota	Pettyjohn	North Dakota Geological Survey Miscellaneous Series 30	3	Available
1967	Geohydrology of the simulated nuclear explosion test site near Valley City, North Dakota (USAF HEST III)	Brown and Randich	Administrative report	28	--
1967	Geohydrology of the Souris River valley in the vicinity of Minot, North Dakota	Pettyjohn	Water-supply paper 1844	53	Out of print[1/]
1967	Geology and ground-water resources of Barnes County, North Dakota, Geology	Kelly and Block	North Dakota Geological Survey Bulletin 43	51	Available
1967	Geology and ground-water resources of Divide County, North Dakota, Ground-water resources	Armstrong	North Dakota Geological Survey Bulletin 45	56	Available
1967	Geology and ground-water resources of Richland County, North Dakota, Geology	Baker	North Dakota Geological Survey Bulletin 46	45	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1967	Geology and ground-water resources of Richland County, North Dakota, Ground-water resources	Baker and Paulson	North Dakota Geological Survey Bulletin 46	45	Available
1967	Geology and ground-water resources of Traill County, North Dakota, Ground-water basic data	Jensen	North Dakota Geological Survey Bulletin 49	103	Available
1967	Geology and ground-water resources of Williams County, North Dakota, Ground-water basic data	Armstrong	North Dakota Geological Survey Bulletin 48	132	Available
1967	Hydrologic applications of lithofacies clastic-ratio maps	Pettyjohn and Randich	Society of Petroleum Engineers	11	Available
1967	Multiple drift sheets in southwestern Ward County, North Dakota	Pettyjohn	North Dakota Geological Survey Miscellaneous Series 30	9	Available
1967	New observations on the Sheyenne delta of glacial Lake Agassiz	Baker	Professional paper 575-B	7	Out of print[1/]
1967	Pleistocene diversion of streams in central North Dakota	Kelly and Buturla	North Dakota Geological Survey Miscellaneous Series 30	5	Available
1967	Portable recorder shelter	Randich	WRD Bulletin, July-December 1967	1	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1967	Preliminary ground-water availability map of Cass County, North Dakota	Klausing	Open file	1	Superseded
1967	Preliminary ground-water availability map of Eddy and Foster Counties, North Dakota	Trapp	Open file	1	Superseded
1967	Preliminary ground-water availability map of Grand Forks County, North Dakota	Kelly	Open file	1	Superseded
1967	Preliminary ground-water availability map of Wells County, North Dakota	Buturla	Open file	1	Superseded
1967	Preliminary map showing the estimated potential yields of the Little Muddy aquifer, Williams County, North Dakota	Ackroyd	Open file	1	Superseded
1967	Quality of water	Hatchett	4-H lesson	2	--
1968	Design and construction of a dual recharge system at Minot, North Dakota	Pettyjohn	Ground Water	5	Available
1968	Evapotranspiration and the water budget of prairie potholes in North Dakota	Shjeflo	Professional paper 585-B	49	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1968	Geology and ground-water resources of Cass County, North Dakota, Geology	Klausing	North Dakota Geological Survey Bulletin 47	39	Out of print[1/]
1968	Geology and ground-water resources of Cass County, North Dakota, Hydrology	Klausing	North Dakota Geological Survey Bulletin 47	77	Available
1968	Geology and ground-water resources of Eddy and Foster Counties, North Dakota, Ground-water resources	Trapp	North Dakota Geological Survey Bulletin 44	110	Available
1968	Geology and ground-water resources of Grand Forks County, North Dakota, Ground-water basic data	Kelly	North Dakota Geological Survey Bulletin 53	117	Out of print[1/]
1968	Geology and ground-water resources of Renville and Ward Counties, North Dakota, Ground-water basic data	Pettyjohn	North Dakota Geological Survey Bulletin 50	302	Available
1968	Geology and ground-water resources of Wells County, North Dakota, Ground-water basic data	Buturla	North Dakota Geological Survey Bulletin 51	118	Available
1968	Ground-water levels in North Dakota, 1966	Randich	North Dakota Ground-Water Studies 74	117	Available

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1968	Late Pliocene lagomorphs of the San Pedro valley, Arizona	Downey	Professional paper 600-D	5	Available
1968	Long-term trends of ground-water levels in selected wells in North Dakota	Jensen and Brown	Open file	1	Available
1968	Low-cost packer for measuring flowing wells	Downey	WRD Bulletin, April-June 1968	1	Available
1968	Notes on the geohydrology of the Dakota Sandstone, eastern North Dakota	Kelly	Professional paper 600-C	7	Available
1968	Preliminary ground-water availability map of Kidder County, North Dakota	Brown	Open file	1	Superseded
1968	Safety markers on cableway for warning aircraft	Brostrom	WRD Bulletin, January-March 1968	2	Available
1969	A method of calculating permeability from electric logs	Croft	WRD Bulletin, January-June 1969	3	Available
1969	Flood stages and discharges for small streams in North Dakota, July 1, 1954, to September 30, 1969	Crosby	Administrative report	152	--

Date published	Report title	Author	Publication media	Number of pages	Report availability
1969	Geology and ground-water resources of Burke and Mountrail Counties, North Dakota, Ground-water basic data	Armstrong	North Dakota Geological Survey Bulletin 55	282	Available
1969	Geology and ground-water resources of Williams County, North Dakota, Hydrology	Armstrong	North Dakota Geological Survey Bulletin 48	82	Out of print[1/]
1969	Ground-water resources at Fort Union Trading Post National Historic Site, North Dakota-Montana	Armstrong	Administrative report	28	--
1969	Guide sheave for float line	Shjeflo	WRD Bulletin, January-June 1969	1	Available
1969	Souris-Red-Rainy River basins framework study, ground-water section, appendix B	Anderson	National Water Assessment	46	--
1970	A proposed streamflow data program for North Dakota	Crosby	Open file	68	Available
1970	Channel-scarp formation in western North Dakota	Hamilton	Professional paper 700-C	4	Available

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1970	Geology and ground-water resources of Grand Forks County, North Dakota, Ground-water resources	Kelly and Paulson	North Dakota Geological Survey Bulletin 53	58	Available
1970	Geology and ground-water resources of Wells County, North Dakota, Ground-water resources	Buturla	North Dakota Geological Survey Bulletin 51	57	Available
1970	Ground-water basic data, Mercer and Oliver Counties, North Dakota	Croft	North Dakota Geological Survey Bulletin 56	268	Available
1970	Ground-water resources of Nelson County, northeastern North Dakota	Downey	Hydrologic Investigations Atlas HA-428	1	Available
1970	Middle Pleistocene Leporidae from the San Pedro valley, Arizona	Downey	Professional paper 700-B	6	Available
1970	Transmissivity and storage coefficient of aquifers in the Fox Hills Sandstone and the Hell Creek Formation, Mercer and Oliver Counties, North Dakota	Croft and Wesolowski	Professional paper 700-B	6	Available
1971	A method of calculating permeability from electric logs	Croft	Professional paper 750-B	5	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1971	Evaluation of proposal to form a lake at a highway borrow site, Richland County, North Dakota	Paulson	Administrative release to Federal Highway Administration	7	--
1971	Geology and ground-water resources of Traill County, North Dakota, Ground-water resources	Jensen and Klausing	North Dakota Geological Survey Bulletin 49	40	Available
1971	Ground-water basic data, Benson and Pierce Counties, North Dakota	Randich	North Dakota Geological Survey Bulletin 59	360	Out of print[1/]
1971	Ground-water basic data, Hettinger and Stark Counties, North Dakota	Trapp	County Ground-Water Studies 16	455	Available
1971	Ground-water basic data, McLean County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 60	468	Available
1971	Ground-water basic data, Nelson and Walsh Counties, North Dakota	Downey	North Dakota Geological Survey Bulletin 57	459	Out of print[1/]
1971	Ground-water resources of Burke and Mountrail Counties, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 55	86	Available
1971	Ground-water resources of Renville and Ward Counties, North Dakota	Pettyjohn and Hutchinson	North Dakota Geological Survey Bulletin 50	100	Out of print[1/]

[1/]May be available for inspection at U.S. Geological Survey libraries.

Date published	Report title	Author	Publication media	Number of pages	Report availability
1971	Ground-water resources of Walsh County, northeastern North Dakota	Downey	Hydrologic Investigations Atlas HA-431	1	Available
1971	Thermal study of the Missouri River in North Dakota using infrared imagery	Crosby	Open file	46	Available
1972	An inventory of published and unpublished surface-water quality data for North Dakota, 1905-72	Hanson	Open file	--	--
1972	Flood stages and discharges for small streams in North Dakota, July 1, 1954, to September 30, 1971	Crosby and Pewe	Open file	160	Available
1972	Ground-water resources of Benson and Pierce Counties, north-central North Dakota	Randich	Hydrologic Investigations Atlas HA-476	1	Available
1972	Ground-water resources of McLean County, west-central North Dakota	Klausing	Hydrologic Investigations Atlas HA-475	1	Available
1972	Mineral and water resources of North Dakota, with a section on water resources	Crosby, Armstrong, and Paulson	--	112	--

Date published	Report title	Author	Publication media	Number of pages	Report availability
1973	Ground-water basic data for Griggs and Steele Counties, North Dakota	Downey, Hutchinson, and Sunderland	North Dakota Geological Survey Bulletin 64	468	Available
1973	Ground-water basic data of Cavalier and Pembina Counties, North Dakota	Hutchinson	North Dakota Geological Survey Bulletin 62	606	Out of print[1/]
1973	Ground-water resources of Mercer and Oliver Counties, North Dakota	Croft	North Dakota Geological Survey Bulletin 56	81	Out of print[1/]
1973	Ground-water resources of Nelson and Walsh Counties, North Dakota	Downey	North Dakota Geological Survey Bulletin 57	67	Out of print[1/]
1974	An investigation of basin effects on flood discharges in North Dakota	Crosby	Open file 74-346	49	Available
1974	Effects of strip mining on water quality at the Gascoyne lignite mine, Bowman County, North Dakota	Croft and Downey	GSA abstract	1	Available
1974	Ground-water basic data for Adams and Bowman Counties, North Dakota	Croft	North Dakota Geological Survey Bulletin 65	294	Out of print[1/]

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1974	Ground-water conditions at launch control facility B-O, Cavalier County, northeastern North Dakota	Hutchinson	Administrative report	17	--
1974	Ground-water resources of McLean County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 60	73	Available
1974	Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota	Downey and Paulson	Water-resources investigations 30-74	22	Available
1974	Preliminary map showing availability of ground water from major glacial-drift aquifers in Griggs and Steele Counties, North Dakota	Downey	Open file	1	Superseded
1974	Water supply at Painted Canyon Overlook, Theodore Roosevelt National Memorial Park (South Unit), southwestern North Dakota	Croft	Open file 74-136	35	Available
1975	Geology and ground-water resources of Hettinger and Stark Counties, North Dakota	Trapp and Croft	County Ground-Water Studies 16	51	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1975	Ground-water availability in the Belcourt area, Rolette County, North Dakota	Randich	Open file 75-104	36	Available
1975	Ground-water basic data for Emmons County, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 66	375	Available
1975	Ground-water basic data for Grant and Sioux Counties, North Dakota	Randich	North Dakota Geological Survey Bulletin 67	303	Out of print[1/]
1975	Ground-water investigation for U.S. Air Force launch control facility O-O, Griggs County, North Dakota	Sunderland and Downey	Open file 75-345	13	Available
1975	Magnitude and frequency of floods in small drainage basins in North Dakota	Crosby	Water-resources investigations 19-75	24	Available
1975	Results of aquifer testing in the Belcourt area, Rolette County, North Dakota	Randich and Ghering	Open file 75-396	31	Available
1975	Water-resources investigations in the Fort Union coal region, North Dakota, 1974-75	U.S. Geological Survey	Open file	43	Available

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1976	Ground-water basic data for Dunn County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 68	501	Out of print[1/]
1976	Preliminary map showing availability of ground water from glacial aquifers in Ramsey County, northeastern North Dakota	Hutchinson	Open file 76-569	1	Superseded
1976	Pressurized filtration unit	Ghering	WRD Bulletin, April-June 1976	2	Available
1976	Water-resources investigations in the Fort Union coal region, North Dakota, 1975-76	U.S. Geological Survey	Open file	43	Available
1977	Ground-water basic data for Morton County, North Dakota	Ackerman	North Dakota Geological Survey Bulletin 72	592	Available
1977	Ground-water basic data for Ramsey County, North Dakota	Hutchinson	North Dakota Geological Survey Bulletin 71	344	Available
1977	Ground-water investigation at U.S. Air Force launch control facility E-0, Ramsey County, North Dakota	Randich	Open file 77-619	23	Available
1977	Ground-water levels in the United States, 1972-74, north-central states	U.S. Geological Survey	Water-supply paper 2163	5	Available

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1977	Ground-water resources of Benson and Pierce Counties, North Dakota	Randich	North Dakota Geological Survey Bulletin 59	76	Available
1977	Ground-water resources of Cavalier and Pembina Counties, North Dakota	Hutchinson	North Dakota Geological Survey Bulletin 62	68	Available
1977	Ground-water resources of Griggs and Steele Counties, North Dakota	Downey and Armstrong	North Dakota Geological Survey Bulletin 64	33	Available
1977	Preliminary map showing availability of ground water from glacial-drift aquifers in Dunn County, North Dakota	Klausing	Open file 77-273	1	Superseded
1977	Water-resources investigations in the Fort Union coal region, North Dakota, 1976-77	U.S. Geological Survey	Open file	43	Available
1978	Cation-exchange characteristics of Tongue River sediments at the Gascoyne strip mine, North Dakota	Crawley and Croft	GSA abstract	1	Available
1978	Ground-water basic data for Dickey and LaMoure Counties, North Dakota	Armstrong and Luttrell	North Dakota Geological Survey Bulletin 70	557	Out of print 1/

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1978	Ground-water resources of Adams and Bowman Counties, North Dakota	Croft	North Dakota Geological Survey Bulletin 65	54	Out of print[1/]
1978	Ground-water resources of Emmons County, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 66	43	Available
1978	Preliminary map showing availability of ground water from glacial-drift aquifers in Dickey and LaMoure Counties, southeastern North Dakota	Armstrong	Open file 78-501	1	Superseded
1979	An appraisal of pumping effects on the Edgeley aquifer, LaMoure County, North Dakota, as determined by a digital model	Burkart	Open file 79-748	22	Available
1979	Ground-water basic data for McIntosh County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 73	458	Available
1979	Ground-water basic data for Ransom and Sargent Counties, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 69	637	Available
1979	Ground-water resources of Dunn County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 68	48	Available

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1979	Ground-water resources of Grant and Sioux Counties, North Dakota	Randich	North Dakota Geological Survey Bulletin 67	49	Out of print[1/]
1980	Current water-resources investigations of the U.S. Geological Survey in North Dakota, Fiscal year 1980	U.S. Geological Survey	Open file	58	Available
1980	EMRIA project--Data acquisition and reduction system, Part I, Data acquisition	Reid and Ghering	WRD Bulletin, July-December 1980	6	Available
1980	Ground-water basic data for Billings, Golden Valley, and Slope Counties, North Dakota	Anna	North Dakota Geological Survey Bulletin 76	241	Available
1980	Ground-water data for Sheridan County, North Dakota	Burkart	North Dakota Geological Survey Bulletin 75	302	Available
1980	Ground-water resources of Dickey and LaMoure Counties, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 70	61	Available
1980	Ground-water resources of Morton County, North Dakota	Ackerman	North Dakota Geological Survey Bulletin 72	51	Available
1980	Ground-water resources of Ramsey County, North Dakota	Hutchinson and Klausing	North Dakota Geological Survey Bulletin 71	36	Available

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Date published	Report title	Author	Publication media	Number of pages	Report availability
1980	Preliminary map showing availability of ground water from glacial-drift aquifers in Ransom and Sargent Counties, southeastern North Dakota	Armstrong	Open file 80-505W	1	Superseded
1980	Preliminary map showing availability of ground water from glacial-drift aquifers in Sheridan County, central North Dakota	Burkart and Randich	Open file 80-504W	1	Superseded
1980	Preliminary map showing availability of water from glacial-drift aquifers in McHenry County, north-central North Dakota	Randich	Open file 80-562	1	Superseded
1980	Water-quality reconnaissance of the Middle and North Branch Park River watersheds, northeastern North Dakota	Ackerman	Open file 80-449	27	Available
1981	Applicability of kinematic-wave models	Miller	American Society of Civil Engineers, Journal article	--	--
1981	Current water-resources investigations of the U.S. Geological Survey in North Dakota, Fiscal year 1981	Martin and Albright	Open file 81-923	50	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1981	Gagehouse electrification	Ghering	WRD Bulletin, April-September 1981	4	Available
1981	Ground-water data for McHenry County, North Dakota	Randich	North Dakota Geological Survey Bulletin 74	446	Available
1981	Ground-water resources of Billings, Golden Valley, and Slope Counties, North Dakota	Anna	North Dakota Geological Survey Bulletin 76	56	Available
1981	Ground-water resources of McHenry County, North Dakota	Randich	North Dakota Geological Survey Bulletin 74	47	Available
1981	Ground-water resources of McIntosh County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 73	37	Available
1981	Ground-water resources of Sheridan County, North Dakota	Burkart	North Dakota Geological Survey Bulletin 75	32	Available
1981	Hydrologic characteristics and possible effects of surface mining in the northwestern part of West Branch Antelope Creek basin, Mercer County, North Dakota	Crawley and Emerson	Water-resources investigations 81-79	73	Available
1981	Progress report on the effects of surface mining on the surface-water hydrology of selected basins in the Fort Union coal region, North Dakota and Montana	Emerson	Open file 81-678	28	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1981	Statistical summaries of streamflow and water-quality data for streams of western North Dakota, 1977-80	Haffield	Open file 81-1066	78	Available
1981	Supplement to predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, south-eastern North Dakota	Armstrong	Open file 81-646	15	Available
1982	A plate-tectonic origin for the Williston basin, North Dakota	Houghton	North Dakota Academy of Science, Proceedings	1	Available
1982	Changes in flood response of the Red River of the North basin, North Dakota-Minnesota	Miller and Frink	Open file 82-774	158	Available
1982	Estimated use of water for North Dakota, 1982	Patch and Haffield	North Dakota State Water Commission Information Series No. 33	1	Available
1982	Evaluation of the hydrologic system in the New Leipzig coal area, Grant and Hettinger Counties, North Dakota	Armstrong	Open file 82-698	41	Available
1982	Ground-water basic data for Logan County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 77	299	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1982	Ground-water data for Bottineau and Rolette Counties, North Dakota	Kuzniar and Randich	North Dakota Geological Survey Bulletin 78	742	Available
1982	Ground-water resources of Ransom and Sargent Counties, North Dakota	Armstrong	North Dakota Geological Survey Bulletin 69	51	Available
1982	Hydrochemistry of shallow ground water from the Fort Union Group near the Peerless lignite strip mine, Gascoyne, southwestern North Dakota	Houghton	North Dakota Academy of Science, Proceedings	1	Available
1982	Hydrogeochemical consequences of strip mining in the Fort Union Group of southwestern North Dakota	Houghton	1982 National Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation, Proceedings	8	Available
1982	Hydrogeology and geochemistry of the Wibaux-Beach lignite deposit area, eastern Montana and western North Dakota	Horak	North Dakota Academy of Science, Proceedings	1	Available
1982	Hydrologic analysis of high flow from snowmelt on small basins in the Fort Union coal region	Emerson	North Dakota Academy of Science, Proceedings	1	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1982	Preliminary map showing availability of ground water from glacial-drift aquifers in Logan County, south-central North Dakota	Klausing	Open file 82-515	1	Superseded
1982	Preliminary map showing availability of water from glacial-drift aquifers in Towner County, north-central North Dakota	Randich and Kuzniar	Open file 82-767	1	Superseded
1982	Stratigraphy and paleoenvironment of the Paleocene Fort Union Group of the Williston basin near Gascoyne, southwestern North Dakota	Houghton and Davison	North Dakota Academy of Science, Proceedings	1	Available
1982	Trace-element enrichments in waters associated with strip mining of lignite in the Fort Union Group of southwestern North Dakota	Houghton	Symposium on Trace-Element Mobilization, Colorado School of Mines Research Institute, Abstract	1	Available
1982	Water use in North Dakota, 1980	Smith and Harkness	North Dakota State Water Commission Information Series No. 31	1	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1982	Weathering of coal scoria--a source for diagenetic silica cements?	Houghton	U.S. Geological Survey Workshop on Diagenesis, Proceedings	1	Available
1983	Acidification of North Dakota surface water	Houghton	Symposium on Acid Rain in Western Canadian Provinces, Proceedings	1	Available
1983	Chip recorders for weighing-type precipitation gages	Schwappach and Emerson	WRD Bulletin, September 1982-April 1983	1	Available
1983	Composition of atmospheric deposition in western North Dakota	Houghton	North Dakota Academy of Science, Proceedings	1	Available
1983	Data from the surface-water hydrologic investigations of the Hay Creek study area, Montana, and the West Branch Antelope Creek study area, North Dakota, October 1976 through April 1982	Emerson, Norbeck, and Boespflug	Open file 83-136	273	Available
1983	Evaluation of the effects of Lake Audubon on ground- and surface-water levels in the Lake Nettie area, eastern McLean County, North Dakota	Armstrong	Water-resources investigations 83-4242	41	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1983	Ground-water data for selected coal areas in western North Dakota	Wald and Norbeck	Open file 83-219	229	Available
1983	Ground-water data for Towner County, North Dakota	Kuzniar and Randich	North Dakota Geological Survey Bulletin 79	280	Available
1983	Ground-water resources of Logan County, North Dakota	Klausing	North Dakota Geological Survey Bulletin 77	42	Available
1983	Guide to North Dakota's ground-water resources	Paulson	Water-supply paper 2236	25	Available
1983	Hydrology of the Wibaux-Beach lignite deposit area, eastern Montana and western North Dakota	Horak	Water-resources investigations 83-4157	89	Available
1983	Inventory and analyses of information for flood plain management in North Dakota	Emerson and Wald	Open file 84-053	201	Available
1983	Water-resources investigations in North Dakota, Fiscal year 1983	Lankford and Albright	Open file 83-220	51	Available
1983	Water resources of the Rattlesnake Butte area, a site of potential lignite mining in west-central North Dakota	Horak	Water-resources investigations 83-4228	53	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1984	Atmospheric deposition: Sample handling, storage, and analytical procedures for chemical characterization of event-based samples in North Dakota	Houghton, Berger, Zander, and Dutchuk	Water-resources investigations 83-4205	71	Available
1984	Basic concepts of kinematic-wave models	Miller	Professional paper 1302	29	Available
1984	Changes in flood response of the Red River of the North basin, North Dakota-Minnesota	Miller and Frink	Water-supply paper 2243	103	Available
1984	Differences in composition of wet fall collected on weekly and event basis in North Dakota	Houghton	National Atmospheric Deposition Program Technical Committee Meeting, Abstract	2	Available
1984	Effects of well-casing composition and sampling methods on apparent quality of ground water	Houghton and Berger	Fourth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring, Proceedings	11	Available
1984	Ground-water resources of Bottineau and Rolette Counties, North Dakota	Randich and Kuzniar	North Dakota Geological Survey Bulletin 78	41	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1984	Hydrogeochemical controls on the mobility of radiogenic constituents at uraniferous lignite mines in southwestern North Dakota	Houghton, Wald, and Anderson	North Dakota Academy of Science, Proceedings	1	Available
1984	Hydrogeochemical controls on the mobility of radiogenic constituents in mine spoils and uraniferous lignite ash in southwestern North Dakota	Houghton, Wald, and Anderson	1984 Rocky Mountain Ground-Water Conference, Proceedings	2	Available
1984	Hydrogeochemical controls on the mobility of radiogenic constituents in the coal-bearing Fort Union Formation and in lignite mines in western North Dakota	Houghton, Wald, and Anderson	1984 Rocky Mountain Coal Symposium, Proceedings	25	Available
1984	Hydrogeochemistry of the upper part of the Fort Union Group in the Gascoyne lignite strip-mining area, North Dakota	Houghton, Thorstenson, Fisher, and Groenewold	Open file 84-131	184	Available
1984	Synopsis of ground-water and surface-water resources of North Dakota	Winter, Benson, Engberg, Wiche, Emerson, Crosby, and Miller	Open file 84-732	127	Available
1984	Water-resources investigations in North Dakota, Fiscal year 1984	Hall and Kuzniar	Open file 84-429	52	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	Chemistry of precipitation in rural North Dakota	Houghton and Briel	International Conference on Acidic Precipitation, Proceedings	1	In press
1985	Data uses and funding of the streamflow-gaging program in North Dakota	Ryan	Open file 85-349	29	In press
1985	Evaluation of the hydrologic system and potential effects of mining in the Dickinson lignite area, eastern Slope and western Stark and Hettinger Counties, North Dakota	Armstrong	Water-resources investigations 84-4194	41	In press
1985	Geohydrologic reconnaissance of the Avoca lignite deposit area near Williston, northwestern North Dakota	Horak and Crosby	Water-resources investigations 85-4024	23	In press
1985	Ground-water data for McKenzie County, North Dakota	Croft	North Dakota Geological Survey Bulletin 80	455	Available
1985	Ground-water resources of McKenzie County, North Dakota	Croft	North Dakota Geological Survey Bulletin 80	58	Available
1985	Heat and water transport model for seasonally frozen soils in North Dakota: Study plan	Emerson	Workshop/Symposium: Snow Management for Agriculture	17	Available

Date published	Report title	Author	Publication media	Number of pages	Report availability
1985	Hydrologic effects of withdrawal of ground water on the West Fargo aquifer system, eastern Cass County, North Dakota	Armstrong	Water-resources investigations 83-4279	30	In press
1985	Hydrology of area 46, northern Great Plains and Rocky Mountain coal provinces, North Dakota	Croft and Crosby	Open file 84-467	135	In press
1985	Hydrology of area 47, northern Great Plains and Rocky Mountain coal provinces, North Dakota, South Dakota, and Montana	Crosby and Klausing	Water-resources investigations 83-221	150	In press
1985	Inverse modeling of solute transport in shallow ground water, With an example of sulfate movement around a lignite mine in southwestern North Dakota	Houghton	North Dakota Academy of Science, Proceedings	1	Available
1985	National Water Summary 1984--North Dakota ground-water resources	Crosby	Water-supply paper 2275	6	Available
1985	Progress report on the geochemistry of the sulfur cycle in northern Great Plains coal mines	Houghton, Koob, and Groenewold	Water-resources investigations 85-4016	70	Available
1985	Small-area snow surveys on the northern plains of North Dakota	Emerson, Carroll, and Steppuhn	Water-resources investigations 85-4026	22	In press

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1985	Snowmelt trace-element enrichments in prairie potholes and soils of central North Dakota	Houghton and Foss	International Conference on Acidic Precipitation, Proceedings	1	In press
1985	Sulfur cycle in western coal mines	Houghton, Koob, and Groenewold	National Water Well Association	9	Available
1985	The geohydrologic system and probable effects of mining in the Sand Creek-Hanks lignite area, Williams County, North Dakota	Armstrong	Water-resources investigations 85-4089	38	In press
1985	Use of chemical test papers to semiquantitatively determine mercury-vapor concentrations	Houghton	Water-resources investigations 85-4012	15	Available
1985	Volatile trace-element concentrations in snowmelt contributions to streams monitored by hydrologic bench-mark network stations in the conterminous United States where average snowfall exceeds 12 inches	Houghton and Schimke	Water-resources investigations 85-4104	20	In press
--	U.S. Geological Survey surface-water project activities related to energy development in North Dakota	Moore	Reclamation-Research Conference Speech	--	--