WATER-RESOURCES ACTIVITIES of the U.S. GEOLOGICAL SURVEY in MINNESOTA, 1991

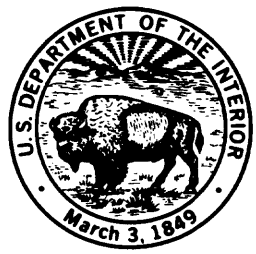
Compiled by G.L. Amos and T. A. Winterstein

U.S. GEOLOGICAL SURVEY

Open-File Report 93-65

Mounds View, Minnesota

1993



U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
702 Post Office Building
St. Paul, Minnesota 55101

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FORWARD

Since the U.S.Geological Survey began water-resources activities in Minnesota in 1903, a large amount of hydrologic data has been collected and many areal investigations and research projects have been completed. Over the years, these activities have reflected the need for water-resource information on priority issues of the time. I am gratified by these past accomplishments and pleased to be part of the current program. This report contains brief summaries of our current activities, which are being conducted in cooperation with many local, State, and other Federal agencies. Future activities undoubtedly will be oriented toward ground-water and surface-water quality issues and the increasing need for real-time data. I look forward to continuation of a challenging cooperative program that will aid resolution of water-resources issues in Minnesota.

George Garklavs
District Chief

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ILLUSTRATIONS

CONVERSION FACTORS AND DEFINITION OF TERMS

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.09290	meter squared per day
cubic foot per second (ft^3/s)	2.831	cubic meter per second
acre	0.4047	hectacre
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second
degrees Fahrenheit (^oF)	5/9 x (^oF-32)	degrees Celsius

A water year begins October 1 and ends September 30 the following year. The water year is named for the calendar year in which it ends. For example, the 1991 water year begins October 1, 1990 and ends September 30, 1991.

Use of brand/firm/trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

WATER-RESOURCES ACTIVITIES OF THE U.S. GEOLOGICAL SURVEY IN MINNESOTA, 1991

Compiled by G. L. Amos and Thomas A. Winterstein

INTRODUCTION

The Geological Survey was established as an agency in the Department of the Interior by an Act of Congress in 1879. The growth of its scientific investigations has paralleled the growth of the United States and has contributed to that development. Initially, the mission of the Geological Survey was to assess the mineral resources of the United States. However, as need arose, the Survey mission expanded and the organization eventually was divided into several operating Divisions and Offices, each addressing specific aspects of natural resources. As a result of its expanding research and fact-finding role, the Geological Survey has become the Nation's largest earth-science research agency, the largest civilian-mapmaking agency, the primary source of data on the Nation's surface-water and ground-water resources, and the employer of the largest number of professional earth scientists. Today's programs, which serve a diversity of needs and users, 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-resources 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 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

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-resources appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface water 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 measurements 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 water.

*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.

*Acquiring, developing, and disseminating information on water-related natural hazards such as droughts, floods, landslides, land subsidence, mudflows, and volcanoes.

*Administering the provisions of the Water Resources Research Act of 1984, which include the State Water Resources Research Institutes and the Research Grants and Contracts Programs.

*Supporting the provisions of the National Environmental Policy Act of 1969 and managing the Geological Survey conduct of natural resources surveys in response to the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act) of 1980.

ORGANIZATION OF THE MINNESOTA DISTRICT

Water Resources Division
U.S. Geological Survey
Mounds View, Minnesota
February 1993

A description of the functions of each organizational unit in the Minnesota District is given below. An organizational chart is given in figure 1.

Office of the District Chief

The long-term and intermediate responsibilities of the Office of the District Chief are to stay abreast of the status, trends, and problems of water resources in the District. The District Chief promotes, develops, and maintains the technical proficiency of the District Office by participation in research and technical investigations with local, State, and Federal agencies. Technical proficiency is maintained by career development and training of personnel, which is encouraged and supported by the District Chief. Maintenance of quality scientific products, which result from research and investigations, are the highest priority of the District Chief.

The Office of the District Chief is comprised of the District Chief and a secretary. The District maintains communication with the Area Hydrologist and the Regional Chief Hydrologist to update them on all phases of water resources in the District. The Office of the District Chief is supported from within the District by Administrative Services Section, Information Management Section, Hydrologic Investigations Sections I & II, National Water-Quality Assessment (NAWQA) Program, Network Surveillance Section, and one Field Office. Section chiefs advise the District Chief and share in other duties.

Administrative Services Section

The responsibilities of the Administrative Services Section are the financial, human resource, and organizational management of the District. Specific responsibilities of the Administrative Services Section are (1) preparation and maintenance of District program documents such as project proposals, financial management, and joint-funding agreements; (2) processing of personnel actions and other personnel management and administrative matters; (3) managing the controlled property data base, and (4) obtaining office services, supplies, and equipment.

The Administrative Services Section is comprised of an Administrative Officer, Administrative Operations Assistant, and three administrative technicians. The Administrative Officer makes specific recommendations about all District-wide administrative concerns.

Information Management Section

The responsibility of the Information Management Section is to provide support for the production of high-quality scientific products and to manage informational data bases. Computer support is provided by the Computer Applications Unit. Land-surface information is provided by

Geographic Information Systems Unit. Report publication is provided by the Scientific Publications Unit. These three units work together to produce high-quality scientific products.

Computer Applications Unit

The responsibility of the Computer Applications Unit is computer operations for the District. The Computer Applications Unit services the automatic data processing needs of the District and its principal cooperators. This is accomplished by (1) maintaining a library of computer programs, (2) aiding in the storage, management, and retrieval of data, (3) staying abreast of procedures to access the U.S. Geological Survey national computer system, and (4) procuring new automatic data processing equipment.

The Computer Applications Unit is comprised of the Unit Chief, one computer programmer analyst, and one student trainee in computer science. The Unit Chief advises the District on computer applications to hydrologic problems, and serves as a contact for the District's Local Area Network (LAN). The Computer programmer analyst develops, debugs, and runs scientific and research programs, manages the District's PRIME mini-computer, and writes specific computer programs to aid in the operation and management of the District.

Geographic Information System Unit

The responsibility of the Geographic Information System (GIS) Unit is maintenance of the District GIS data base. A Geographic Information System is a computer system capable of holding and using data that describes the land surface. The GIS Unit provides support services to the District which include (1) providing guidance on using GIS in a project, (2) building GIS coverages, (3) constructing maps and illustrations, and (4) geographic analysis.

The GIS Unit is comprised of one hydrologist and one cartographic technician. The Unit Chief is the District GIS specialist and maintains quality control for the District GIS data bases.

Scientific Publications Unit

The responsibility of the Scientific Publications Unit is to process and publish high-quality scientific reports in a timely manner. Authors are assisted through all stages of report production, which include (1) preparation of report outline and illustration plan, (2) review, (3) approval, (4) publication, and (5) distribution of printed reports.

The Scientific Publications Unit is comprised of two cartographic technicians, one technical publications editor, and two office automation clerks. The Unit Chief oversees the production of reports by the District.

Hydrologic Investigations Section I & II

The responsibility of the Hydrologic Investigations Sections is to appraise the water resources of specific areas in the State through research and investigations. Emphasis is placed on the collection and interpretation of hydrologic data required for planning, developing, and managing the State's water resources.

Each Hydrologic Investigations Sections is comprised of one supervisory Hydrologist, about six hydrologists, and two hydrologic technicians. Hydrologists initiate and conduct research and technical investigations.

Hydraulic Investigations Unit

The responsibility of the Hydraulic Investigations Unit is to conduct complex technical research and investigations in open-channel hydraulics and streamflow characteristics. Research and investigation activities are (1) magnitude and frequency of floods, (2) low-flow frequency and duration, (3) streamflow duration, (4) stream sediment transport, (5) bridge scour, (6) relation of flow to channel and basin characteristics, and (7) streamflow time-of-travel.

The Hydraulic Investigations Unit is comprised of two hydrologists, who serve the District as specialists in surface water research and investigations.

National Water-Quality Assessment Program--Red River of the North Study Unit

The long-term responsibilities of the NAWQA (National Water-Quality Assessment) program are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources; and provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. The Red River of the North basin is 1 of 20 studies currently underway in 1992. The project team is comprised of specialists from St. Paul, Minnesota and field experts from Grand Forks, North Dakota. The project chief and specialists in stream hydrology, data-base management and geographical information systems, chemistry, aquatic biology, hydrogeology, and data collection comprise the St. Paul interdisciplinary team.

Communication and coordination between U.S. Geological Survey personnel and other interested scientists and water-management organizations are critical components of the NAWQA program. The Red River of the North study-unit investigation has a local liaison committee consisting of representatives that have water-resources responsibilities from Federal, State, and local agencies, universities, and the private sector. Activities of the liaison committee include (1) information exchange about water-quality issues of regional and local interest, (2) identification of data and information sources, (3) assistance in design and scope of the project products, and (4) the review of project planning documents and reports.

Network Surveillance Section

The responsibility of the Network Surveillance Section is to supervise the design and operation of hydrologic-data networks and review hydrologic records and the operations of the Water Quality Unit and the Grand Rapids Field Headquarters. Particular emphasis is placed on collection, verification, and compilation of surface- and ground-water records for publication of the District's annual report.

The Network Surveillance Section is comprised of the Section Chief, two hydrologists, and nine hydrologic technicians. The Section Chief monitors the compilation of the District's annual report, and also ensures that adequate technical guidance, supervision and training are provided to the assigned staff. Hydrologists design and manage hydrologic data networks, and review hydrologic records to develop a better understanding of surface water and water quality of the State.

Water Quality Unit

The responsibility of the Water Quality Unit is to provide quality assurance for District water-quality activities. Responsibilities of the Water Quality Unit include (1) ordering supplies for the District laboratory, (2) maintaining the Water-Quality data base, (3) making periodic data retrievals of laboratory data for review and distribution the Project Chiefs and the annual report, and (4) maintaining the lab for determination of selected constituents and physical properties.

The Water Quality Unit is comprised of one hydrologist and one hydrologic technician. The hydrologist is responsible for the District Laboratory. The hydrologic technician serves as Water-Quality data base manager for data retrieval.

Grand Rapids Field Headquarters

The responsibilities of the Grand Rapids Field Headquarters are surface-water, ground-water, and water quality hydrologic records for the northern region of the District. Specific responsibilities include collection, computation, analysis, review and assembly of hydrologic records for publication in the District's annual report.

The Grand Rapids Field Headquarters is comprised of the Technician-in-Charge, and four hydrologic technicians. The supervisory hydrologic Technician, or Unit Chief, ensures that the data are complete, accurate, and timely. The Grand Rapids Field Headquarters provides support to the Network Surveillance Section in the collection, verification, and compilation of data for the District's annual report.

MINNESOTA DISTRICT

DISTRICT OFFICE

U.S. Geological Survey

2280 Woodale Drive

Mounds View, Minnesota 55112

(612) 783-4600

District Chief ..... George Garklavs

Chief, Hydrologic Investigations Section I ..... James R. Stark

Chief, Hydrologic Investigations Section II ..... Donald S. Hansen

Chief, Hydraulic Investigations Unit ..... George H. Carlson

Chief, National Water-Quality Assessment Program--

Red River of the North Study Unit ..... Jeffrey D. Stoner

Chief, Network Surveillance Section ..... Mark R. Have

Chief, Information Management Section ..... Allan D. Arntson

Chief, Geographic Information System Unit ..... Thomas A. Winterstein

Chief, Scientific Publications Unit ..... Rebecca A. Miller

Chief, Administrative Services Section ..... Marre Jo Sager

FIELD HEADQUARTERS

415 South Pokegama Avenue

Grand Rapids, Minnesota 55744

(218) 326-1297

Technician-in-charge ..... James L. Zirbel

ORGANIZATIONAL CHART
MINNESOTA DISTRICT
APRIL 1992

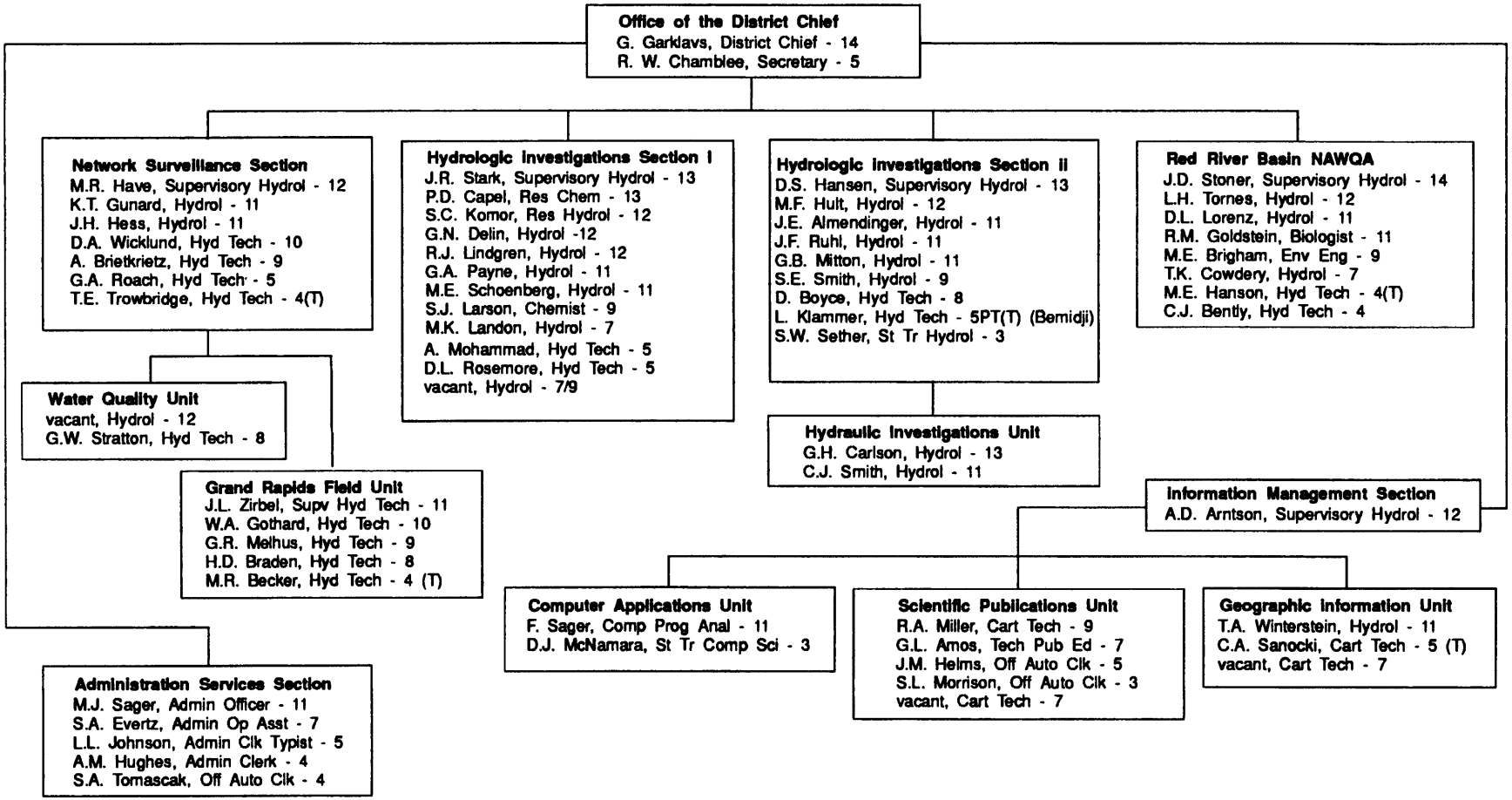


Figure 1.--Geological Survey organizational chart for the Minnesota District, April 1992.

COOPERATING AGENCIES--1991

The U.S. Geological Survey and local, State, and other Federal agencies have had joint agreements for the systematic collection of water records or for interpretive studies and research since 1903. Organizations that participated through cooperative or interagency agreements with the Survey during 1991 are:

Beltrami County Soil and Water Conservation District
City of St. Paul
Dakota County Soil and Water Conservation District
Elm Creek Watershed Management Commission
Grand Portage Band of Chippewa Indians
Iron Range Resources and Rehabilitation Board
Leech Lake Reservation
Legislative Commission on Minnesota Resources
Lower Red River Watershed Management Board
Metropolitan Waste Control Commission
Mille Lacs Band of Chippewa Indians
Minnesota Department of Health
Minnesota Department of Natural Resources
Minnesota Department of Transportation
Minnesota Geological Survey
Minnesota Pollution Control Agency
National Park Service
Northwestern Minnesota Ground Water Steering Commission
Red Lake Indian Reservation Tribal Council
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Soil Conservation Service
University of Minnesota
Vadnais Lake Watershed Management Organization
Whitewater Joint Powers Board

SURFACE-WATER STATIONS

MN001

DATE PROJECT BEGAN: May 1903

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Minnesota Statewide

PRINCIPAL COOPERATING AGENCIES: Minnesota Department of Natural Resources, Minnesota Department of Transportation, Metropolitan Waste Control Commission, Elm Creek Watershed Management Commission, and Lower Red River Watershed Management Board.

PROBLEM: Surface-water information is needed for surveillance, planning, design, hazard warning, operation, and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, contamination abatement, flood-plain management, and water resources development.

OBJECTIVES: Collect data on the surface waters of Minnesota for public needs such as assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and control of contamination, evaluation of water-quality data, compacts and legal requirements, and research or special studies. Collect data for analytical studies, planning, and design that will define statistical properties and trends in the occurrence of water at any location in Minnesota streams, lakes, reservoirs, and estuaries.

APPROACH: Maintain a statewide network of gaging stations (fig.2). 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 better serves the required purpose.

RESULTS LAST YEAR: The 1989 and 1990 Water-Resources Data-Minnesota reports were completed. The last volume of the 1990 report was sent to the government printing office on July 19, 1991. The surface-water network consisted of the following: 85 continuous-record discharge stations, 81 high-flow partial-record stations, approximately 600 low-flow partial-record stations, 6 continuous-record stage stations on streams, and 13 continuous-record stage stations on lakes. Water year 1991 began with below normal flow in most of the northern part of the state and normal flow in the rest of the state. This condition generally continued until May when much of the southern two thirds of the state began receiving rain storms that caused above normal flows in large areas. By July, most of the state, including parts of the northwest, had above normal streamflows. At the end of the water year, most of the state had normal to above normal flows with a few

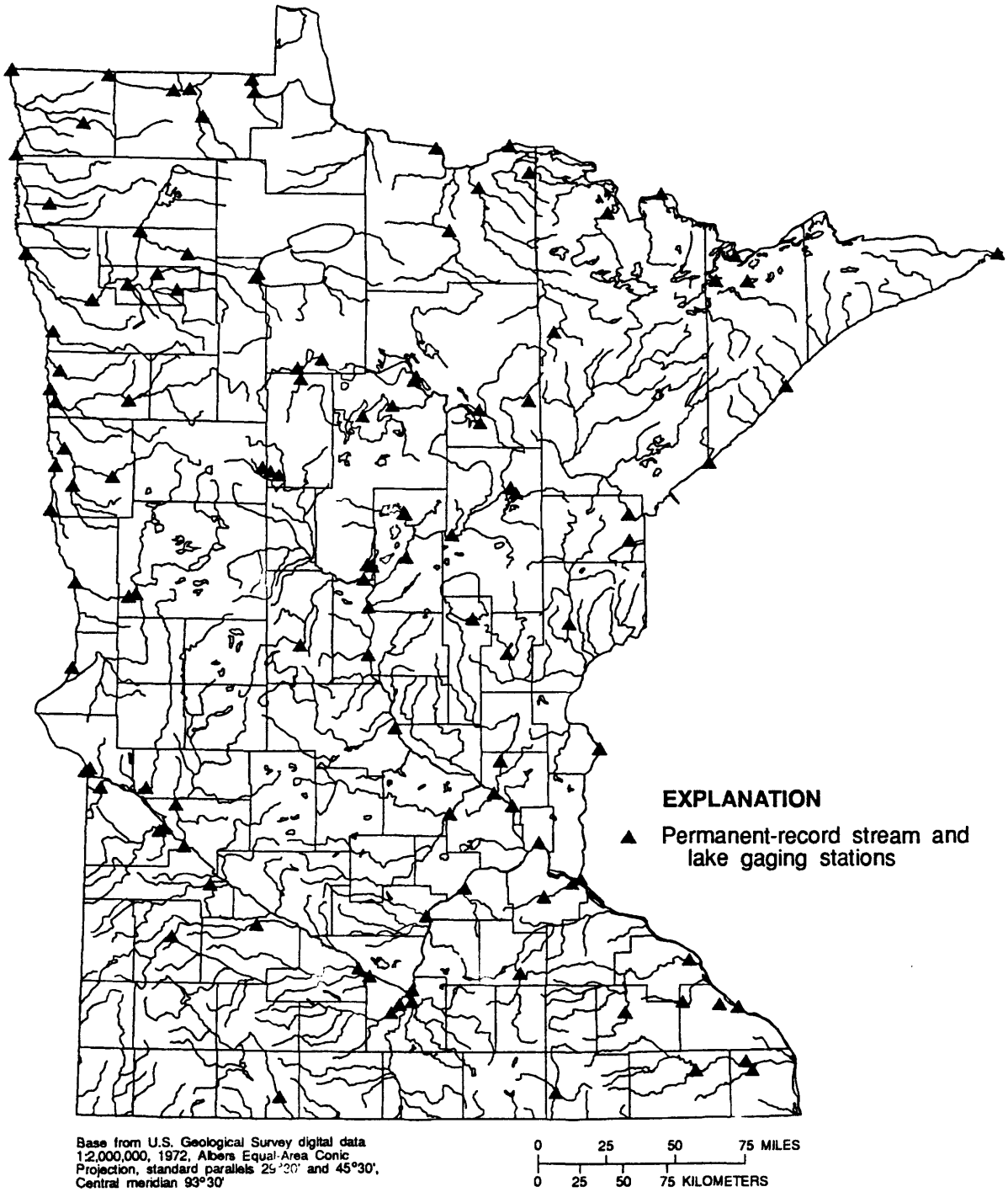


Figure 2.--Surface-water network (MN001) operated during water year 1991.

isolated areas of deficient flows in the north. Preparation of Open-File reports that contain drainage basin boundary maps and river basin characteristics for major Minnesota River and Mississippi River tributaries continued. Reports that describe stream subbasins in the Watonwan and Le Sueur River basins were published, and preparation of similar reports for Blue Earth, Pomme de Terre, and Lac qui Parle River drainage basins were completed. Data from low-flow measurements were entered into the data base. High-flow measurements were made at high-flow partial record stations, especially in the southern third of the state. Streamflow discharge measurements were collected on the Zumbro and Pomme de Terre Rivers for the bridge-scour project.

PLANS NEXT YEAR: Continue the surface water program at about the same level as in 1991. Complete data analysis and compilation for water year 1991. Publish the Water-Resources Data-Minnesota Water Year 1991 and maintain the data in the U.S. Geological Survey data base (WATSTORE). The low-flow and high-flow programs will be continued as in the previous year. A list of sites needing low-flow measurements will be developed. The program of preparing drainage-basin reports will continue.

PUBLISHED REPORTS IN 1991:

Lorenz, D.L. and Payne, G.A., 1991, Selected data for stream subbasins in the LeSueur River basin, south-central Minnesota: U.S. Geological Survey Open-File Report 91-62, 8 p., 1 pl.

Lorenz, D.L. and Payne, G.A., 1991, Selected data for stream subbasins in the Watonwan River basin, south-central Minnesota: U.S. Geological Survey Open-File Report 91-61, 7p., 1 pl.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

GROUND-WATER STATIONS

MN002

DATE PROJECT BEGAN: July 1947

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Brietkrietz, Alex

LOCATION: Minnesota Statewide

PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources, Minnesota Department of Health, and Beltrami Soil and Water Conservation District.

PROBLEM: Climatic variations directly affect recharge to and discharge from the 14 principal aquifer systems in Minnesota. Long-term water-level records will provide water resource managers a data base to aid in assessing the effects of long term climatic variation and on Minnesota's principle aquifers.

OBJECTIVES: Collect and tabulate water-level data from 14 principal aquifers in Minnesota. Provide the data base necessary for effective development and management of ground-water resources.

APPROACH: Measure and maintain a network of observation wells screened in the principal aquifers in Minnesota (fig. 3).

RESULTS LAST YEAR: The hydrologic-data report for the 1990 water year was published. Data for the 1991 water year were transmitted to Minnesota Department of Natural Resources. The observation-well network included 124 wells, of which 16 were equipped with recorders. Water levels in wells screened in the surficial aquifers declined 6 ft from October 1991 to May 1992, and rose 1 ft from June 1992 to September 1992. Levels were 1 to 2 ft below seasonal averages in the north and 1/2 to 3 ft above the seasonal averages in the south at the close of water year 1991. Water levels in the Prairie du Chien-Jordan aquifer in the Minneapolis-St. Paul area rose during October 1990 through March 1991 then declined from April 1991 through August 1991, and rose in September. In October 1990, water levels were 11 feet above average in the St. Paul area and 14 feet above average in the Minneapolis area. Water levels in the deeper Mount Simon-Hinckley aquifer declined near the close of the 1991 water year, and were 13 ft below average in St. Paul and 25 ft below average in Minneapolis.

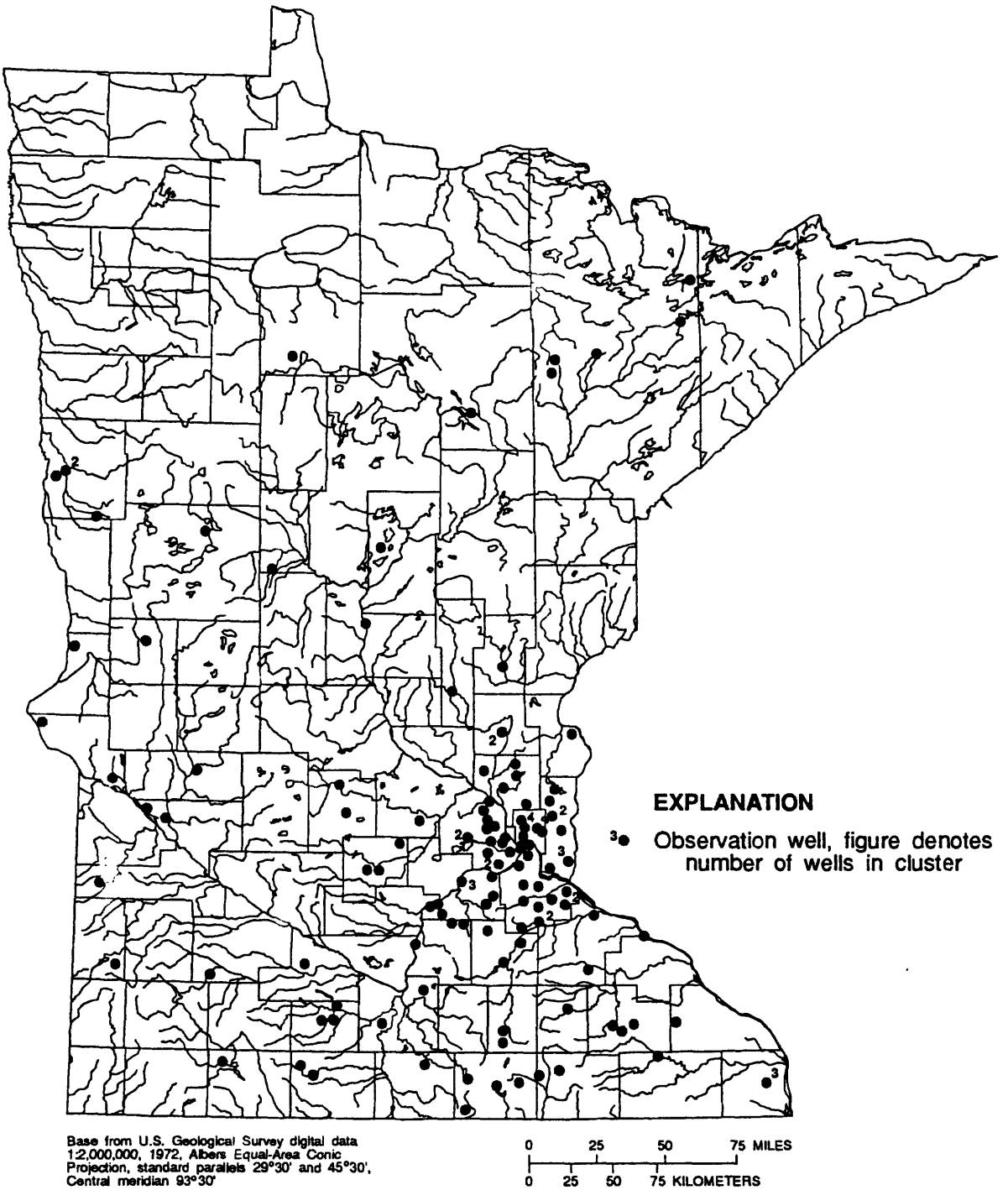


Figure 3.--Observation-well network (MN002) operated during water year 1991.

PLANS NEXT YEAR: Water-level measurements will be maintained on selected wells in the program. Data for the 1992 water year will be prepared for transmittal to Minnesota Department of Natural Resources, and the 1991 annual data report will be prepared.

PUBLISHED REPORTS IN 1991:

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

WATER-QUALITY STATIONS

MN003

DATE PROJECT BEGAN: June 1955

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Minnesota Statewide

PRINCIPAL COOPERATING AGENCIES: Minnesota Department of Transportation, Metropolitan Waste Control Commission, University of Minnesota, and Elm Creek Watershed Management Commission.

PROBLEM: Water-quality assessments for water-resources planning and development require a regional and national water-quality data base. To provide this data base, a network of groundwater and surface-water stations must be maintained and additional sites must be selected for synoptic sampling to obtain representative data that describe water-quality conditions at the time of collection.

OBJECTIVE: Provide water-quality data for local, State, and Federal planning and for the management of interstate and intrastate water resources.

APPROACH: Maintain a network of stations to provide water-quality data of both a continuing and synoptic basis, including concentrations, loads, and time trends, for water-resource planning and management (fig. 4).

RESULTS LAST YEAR: Water quality data for 1990 were published in the Water-Resources Data-Minnesota Water Year 1990. Nitrite plus nitrate nitrogen concentrations in samples collected in 1990 showed some notable differences from historical monthly medians. For example, the Minnesota River near Jordan was sampled in October 1990, February, May, and September 1991. The nitrite plus nitrate nitrogen concentrations from the samples collected during these months were <0.10, 0.4, 7.6, and 3.5 mg/L, respectively. The historical monthly median concentrations for these months were 2.7, 2.5, 2.8, and 1.7 mg/L, respectively. The North Fork Whitewater River near Elba was sampled in November 1990, January, April, May, July, and August 1991. The nitrite plus nitrate nitrogen concentrations for the samples collected during these months were 2.6, 3.1, 3.0, 2.8, 4.3, and 2.9 mg/L, respectively. The historical monthly median concentrations for these months were 3.1, 4.1, 3.9, 3.0, 2.2, and 2.7 mg/L, respectively. Water samples were collected and analyzed at the eight NASQAN (National Stream Quality Accounting Network) and two Benchmark sites. Samples from Elm Creek were collected in cooperation with the Elm Creek Watershed Management Commission. Three sets of flow samples were also collected.

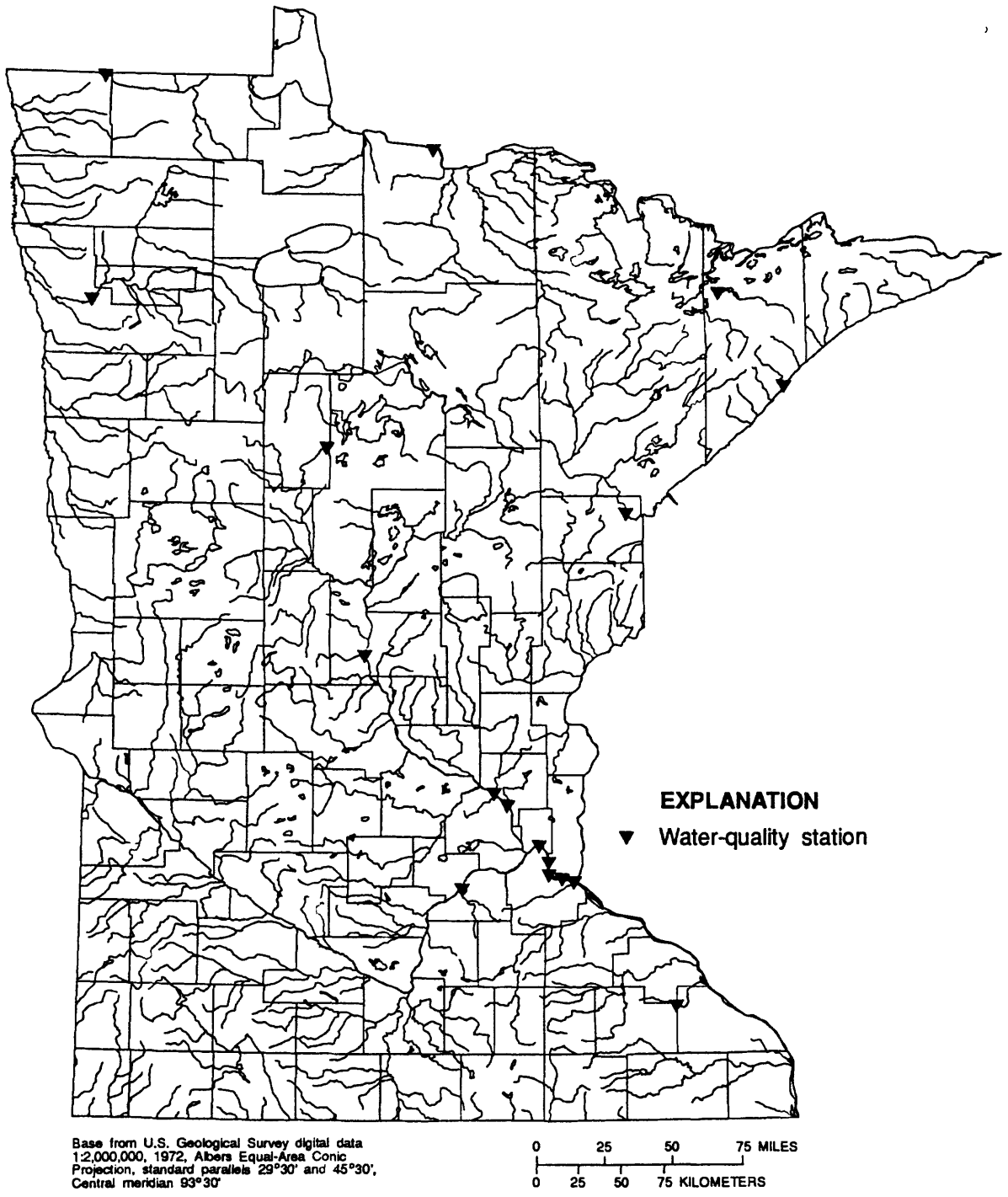


Figure 4.–Water-quality network (MN003) operated during water year 1991.

PLANS NEXT YEAR: Continue the NASQAN and Benchmark stations, and the station on Elm Creek where an automatic sampler has been sampling storm flows. Check and review 1991 data for the Water-Resources Data-Minnesota Water Year 1991.

PUBLISHED REPORTS IN 1991:

Have, M.R., 1991, Selected water-quality characteristics of the upper Mississippi River basin Royalton of Hastings, Minnesota: U.S. Geological Survey Water Resources Investigations Report 88-4053, 152p.

Mitton, G.B., 1991, Water-quality data for Sauk Lake and tributaries near Sauk Centre, Minnesota, 1988-89: U.S. Geological Survey Open-File Report 91-456, 57p.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

SEDIMENT STATIONS

MN004

DATE PROJECT BEGAN: March 1967

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, Mark R.

LOCATION: Minnesota Statewide

PRINCIPAL COOPERATING AGENCY: Whitewater Joint Powers Board.

PROBLEM: Water-resources planning and development require data on suspended-sediment concentrations, suspended-sediment load, total-sediment load and particle-size distribution of suspended sediment and bed material.

OBJECTIVES: Provide standardized sediment data for broad Federal and State planning and action programs and provide data for Federal management of interstate and international waters.

APPROACH: Maintain a network of sediment stations to determine trends in sediment concentration, discharge, and particle size of sediment transported by selected streams in Minnesota (fig. 5).

RESULTS LAST YEAR: Data for the 1989 and 1990 water years were published in Water-Resources Data-Minnesota. Daily records for the Minnesota River at Mankato and the Mississippi River near Anoka were completed for the 1990 water year. A suspended-sediment load of 138,668 tons was transported past the Anoka station in water-year 1990, with 26 percent transported during March and 32 percent transported during June. A suspended-sediment load of 524,495 tons was measured at the Mankato station in 1990, with ninety percent of the load transported during June, July, and August. Sediment stations operated during 1991 included two daily stations (on the Minnesota River at Mankato and on the Mississippi River near Anoka), 10 periodic stations, and three stations in the Whitewater River watershed that had automatic suspended-sediment samplers for storm-flow sampling. Size data for suspended sediment were collected at all stations and size data for bed material were collected at the two stations for which daily records were computed. Water year 1991 was wetter than 1990 and, as a result, more storm-event samples were collected in the Whitewater River watershed during 1991.

PLANS NEXT YEAR: Publish the 1991 data. Operate the automatic samplers in the Whitewater basin one more year.

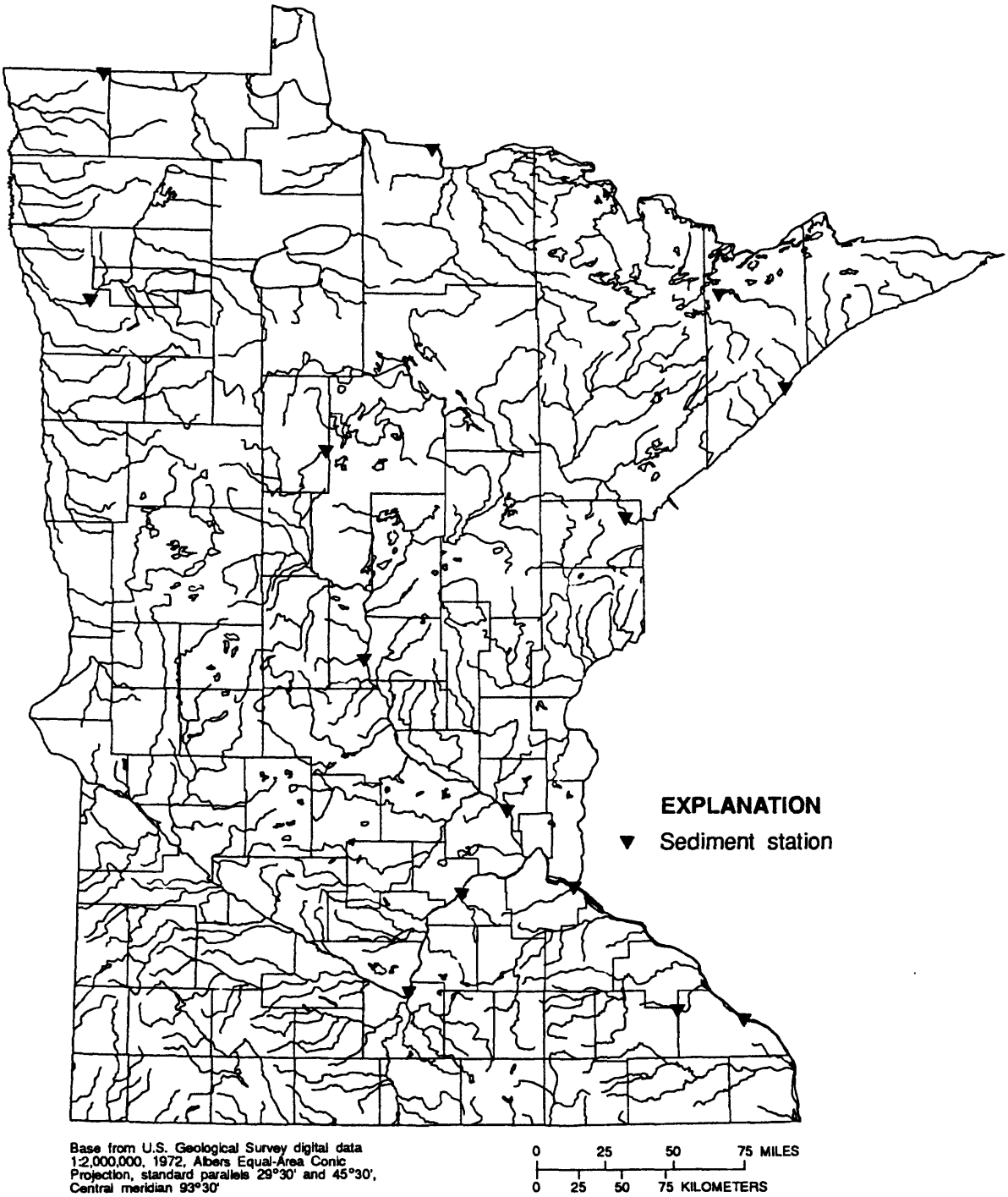


Figure 5.--Suspended-sediment network (MN004) operated during water year 1991.

REPORTS PUBLISHED IN 1991:

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

PRECIPITATION STATIONS

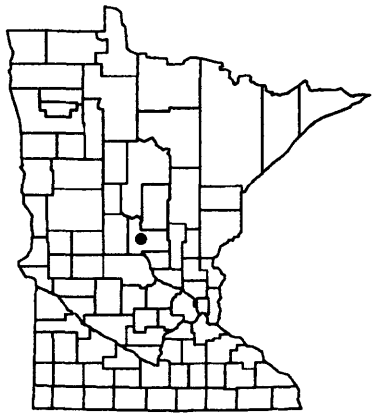
MN005

DATE PROJECT BEGAN: August 1983

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Have, M.R.

LOCATION: Central Minnesota



PROBLEM: Human activities have greatly increased the abundance of chemical substances dispersed into the atmosphere. These substances can be deposited by precipitation and adversely affect plants, surface water, and ground water. Spatial and temporal trends in the chemical composition of atmospheric deposition require better definition to determine the affects.

OBJECTIVE: Establish a record that will allow detection of spatial and temporal trends in the chemical composition of atmospheric deposition. This record will better define the sources, movement, and transformation of materials contributing to or associated with acidic atmospheric deposition in the United States and its effects on the biosphere.

APPROACH: Construct a site at Camp Ripley as part of about 150 sites nationwide. The site will have a wet-fall/dry-fall collector and a recording rain and snow gage. The wet fall collector will be changed and the recording raingage will be serviced once a week. The dry-fall collector will be changed every 8 weeks. Chemical analyses will be done by the Illinois State Water Survey.

RESULTS LAST YEAR: Analytical results for samples collected during the 1990 water year were published in the Water-Resources Data-Minnesota Water Year 1990. Weekly precipitation during 1990 ranged from 0.0 to 2.40 inches and pH ranged from 4.5 to 6.1. The median pH was 5.1. Sulfate concentrations ranged from 0.22 to 4.24 mg/L, and nitrate concentrations (as NO_3) ranged from 0.22 to 4.7 mg/L.

PLANS NEXT YEAR: Continue operating the site the same as before. Publish the 1991 data in the Water-Resources Data-Minnesota Water Year 1991.

REPORTS PUBLISHED IN 1991:

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

FLOOD INVESTIGATIONS
MN006

DATE PROJECT BEGAN: September 1980

DATE PROJECT ENDS: September 1991

PROJECT CHIEF: Carlson, George H.

LOCATION: Minnesota Statewide

PROBLEM: The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 provide for the operation of a flood insurance program. The Federal Emergency Management Agency (FEMA) needs flood studies in selected areas to determine applicable flood insurance premium rates.

OBJECTIVE: Determine flood-discharge frequency relations.

APPROACH: Determine water-surface profiles using step-backwater models or by other acceptable methods and furnish the results in reports prepared to FEMA specifications.

RESULTS LAST YEAR: Review of the preliminary flood insurance study report for St. Louis County was completed and the report of review submitted to FEMA.

PLANS NEXT YEAR: None, project is complete.

WATER USE

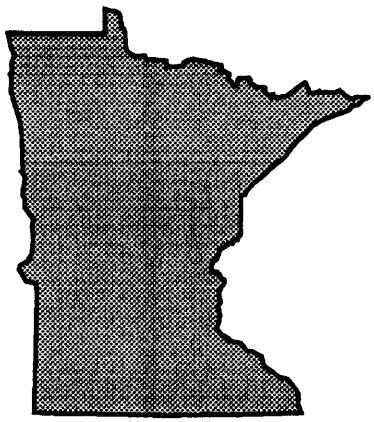
MN007

DATE PROJECT BEGAN: October 1986

DATE PROJECT ENDS: Continuous

PROJECT CHIEF: Mitton, Greg B.

LOCATION: Minnesota Statewide



PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources (MNDNR).

PROBLEM: Decisions by water planners and managers depend on accurate, current, systematically collected water use data.

OBJECTIVE: Maintain a statewide system to collect, store, and disseminate information on water use in Minnesota that is compatible with the U.S Geological Survey's National Water-Use Data System.

APPROACH: Compilation of data will be conducted by the Minnesota Department of Natural Resources, Division of Waters, and the U. S. Geological Survey. Direction, management, and development standards will be the responsibility of the U.S. Geological Survey. Acquisition, storage and dissemination of data will be the responsibility of the Minnesota Department of Natural Resources. Water-use data will be compiled from the files of local, State, and Federal agencies, followed by field inventories and development of a State water-use reporting system.

RESULTS LAST YEAR: The 1990 national water-use data compilation was the major effort during the water year. As of Sept. 30, 1991 all water-use data have been collected from the U.S. Geological Survey National Water-Use program office; U.S. Bureau of Census; and State agencies including the Energy Agency, Department of Agricultural Statistics, Pollution Control Agency, Office of Demographer, and the Minnesota Department of Natural Resources. Data were entered into Aggregated Water-Use Data System (AWUDS); about one-half of the data obtained from the Minnesota Department of Natural Resources Waters Well Permit data base is in the final stages of being formatted for loading into AWUDS. Documentation of data sources and data collection methods used in the 1990 compilation was completed. A major change from the 1985 compilation was the compilation of water-use by aquifer, which required that all site-specific data in the DNR-Water data base have aquifer codes assigned. The assignment of aquifer designations was a combined effort of DNR-Waters and District personnel and was completed.

PLANS NEXT YEAR: The 1990 compilation will be finished. Analysis of the compiled data will begin in the first quarter.

REPORTS PUBLISHED IN 1991:

Trotta, L.C., 1991, Water Use in Minnesota: Minnesota Department of Natural Resources Water Map Series.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 1. Great Lakes & Souris-Red-Rainy River basins: U.S. Geological Survey Annual Report, p. 128.

Gunard, K.T., Hess, J.H., Zirbel, J.L. and Cornelius, C.E., 1991, Water Resources Data-Minnesota Water Year 1990, Volume 2. Upper Mississippi and Missouri River basins: U.S. Geological Survey Annual Report, p. 351.

WATER-QUALITY INVESTIGATIONS IN VOYAGEURS NATIONAL PARK, MINNESOTA

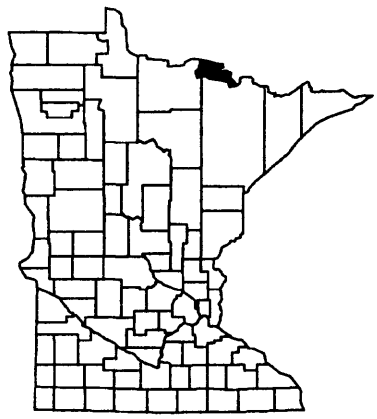
MN068

DATE PROJECT BEGAN: October 1978

DATE PROJECT ENDED: May 1984

PROJECT CHIEF: Payne, Gregory A.

LOCATION: Northern Minnesota



PRINCIPAL COOPERATING AGENCY:
National Park Service

PROBLEM: Voyageurs National Park, established in 1976, is a wilderness area in northern Minnesota adjacent to the Boundary Waters Canoe Area. Most lakes and streams in the Park are oligotrophic and dissolved solids generally are less than 50 mg/L. The National Park Service is concerned about the potential for degradation of water quality by runoff from Park facilities and campgrounds.

OBJECTIVE: Monitor water quality in areas of proposed park development, with emphasis on definition of natural water-quality characteristics and the effects on quality of recreational use and waste disposal in the park.

APPROACH: Collect water samples for chemical and biological analyses at 10 sites in the principal bays and inlet areas during spring overturn and during summer maximum biological productivity. The sites will be selected to assess potential degradation of quality from sources outside the Park and the potential for degradation from activities within the Park. Sampling for chemical constituents for which water-quality standards have been established will be conducted every 4 years beginning in water year 1980. Annual sampling and analysis will be conducted for any constituents that exceed the standards.

RESULTS LAST YEAR: The investigation was completed and published. Major findings showed differences in water quality in six interconnected lakes that comprise most of the surface area of Voyageurs National Park. Three large lakes: Sand Point, Namakan, and Rainy, near the eastern and northern boundaries of the Park, are oligotrophic to mesotrophic, having lower dissolved solids and alkalinity, and dimictic circulation than Kabetogama Lake, Black Bay, and Sullivan Bay, near the western and southern boundaries of the Park, which were eutrophic, having higher dissolved solids and alkalinity, and polymictic circulation. Concentrations of the three lakes along the eastern and northern boundary were similar to those of the Namakan River --a major source of inflow that drains an extensive area of exposed bedrock and thin, noncalcareous glacial drift east of the Park. The lake and embayments along the western and southern boundary receive inflow from two streams that drain an area west and south of the Park that is overlain by

calcareous glacial drift. Samples from one of these streams contained dissolved-solids concentrations about five times, and total alkalinity about eight times that of concentrations measured in the Namakan River. The nutrient-enriched lakes and embayments had algal productivity that produced blooms of blue-green algae during some years. Annual fluctuation in the concentration of trophic-state indicators showed that the shallow, polymictic lakes showed seasonal increases in total phosphorus concentrations in their euphotic zones that did not occur in the deeper, dimictic lakes. This indicates a link between the frequent recirculation of these lakes and internal cycling of phosphorus. Secchi-disk transparency was limited by organic color in Sand Point, Namakan, and Rainy Lakes, and resuspended bottom material reduced transparency in Black Bay. Waters in the large lakes and embayments met nearly all U.S. Environmental Protection Agency criteria for protection of freshwater aquatic life, recreation, and drinking water. Some sites exceeded criteria because of oil and grease, phenols, sulfide, and ammonia. Reconnaissance sampling of 19 small lakes in remote areas of the Park indicated that most of them are sharply stratified and had small dissolved solids (16 mg/L to 49 mg/L) and alkalinity concentrations (4.0 to 29mg/L total alkalinity). Thirteen of the lakes could be classified as moderately sensitive to acid precipitation, and two could be classified extremely sensitive. Fifty percent of the interior lakes had nutrient concentrations that ranged from 10 µg/L to 30 µg/L total phosphorus, and low algal productivity (0.1-2.0 µg/L chlorophyll *a*). Five of the lakes had a reduction in trophic state from spring to summer. The Namakan River is the largest source of inflow to the Park and was better quality than its receiving waters based on dissolved solids and nutrient concentrations, algal productivity, and transparency.

PLANS NEXT YEAR: None, project is complete.

PUBLISHED REPORTS IN 1991:

Payne, G.A. 1991, Water quality of lakes and streams in Voyageurs National Park, northern Minnesota, 1977-84: U.S. Geological Survey Water Resources Investigations Report 88-4016, 95 p.

WATER-QUALITY ASSESSMENT OF EXISTING AND PLANNED IMPOUNDMENTS IN THE COTEAU DES PRAIRIE--UPPER MISSISSIPPI RIVER BASIN

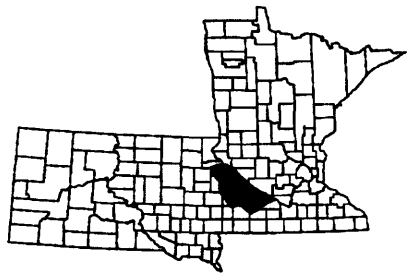
MN069

DATE PROJECT BEGAN: June 1979

DATE PROJECT ENDED: November 1991

PROJECT CHIEF: Smith, Charles J.

LOCATION: Upper Minnesota River basin



PRINCIPAL COOPERATING AGENCIES:
U.S. Army Corps of Engineers and U.S Soil Conservation Service.

PROBLEM: Flooding, bank erosion, and sediment movement have increased on the Coteau des Prairie, Minnesota River basin. The construction of about 70 impoundments has been proposed for streams in the basin to reduce flooding, erosion, and movement of sediment. Information about streamflow, discharge, suspended sediment concentration, nutrients, and concentration of selected water-quality constituents in water from the streams is needed to estimate the effects of the impoundments.

OBJECTIVE: Assess the quality of water in streams and existing imoundments in the Coteau des Prairie. Estimate the effects of proposed impoundments on water quality.

APPROACH: This assessment will be made by determining the water quality at existing impoundment sites and comparing it to water-quality data for sites where similar type impoundments will be built. Water-quality data will be related to land use, storm runoff, topography, and soil type. Water-quality and streamflow data from the Coteau des Prairie region of southwestern Minnesota and eastern South Dakota will be collected. During the reconnaissance part of the study (Phase 1), impoundments, lakes, and proposed impoundment sites will be visited; water-quality samples will be collected, and photographs will be taken. During Phase II, impoundments and four proposed sites will be instrumented for monitoring stage height and precipitation and for collecting samples for sediment and chemical analyses. Specific conductance, pH, water temperature, and dissolved oxygen will be measured in the impoundments to determine variability in vertical profiles. Water transparency will be measured. Samples will be collected for phosphorus analysis. Monthly samples will be collected for analysis of phytoplankton, chlorophyll, major cations, anions and nutrients. Specific conductance, pH, water temperature, dissolved oxygen, selected cations and anions, selected nutrients, and suspended sediment will be measured in the streams.

RESULTS LAST YEAR: Water was collected and analyzed at 66 stream sites, 24 impoundment sites, and 21 inlets and outlets. Water-quality data at four stream sites, four impoundment sites, and nine inlet and outlet sites varied widely. Maximum and median suspended-sediment concen-

trations were lower in impounded streams than in unimpounded streams. Peak daily suspended-sediment discharges were lower at impoundment outlets relative to the sediment discharge at inlets. The impoundments had no effect on stream temperature and dissolved oxygen, dissolved solids, and major ion concentrations. Elevated concentrations of fecal bacteria were found in unimpounded streams throughout the study area and the impoundments did not reduce the number of bacteria transported. Elevated concentrations of nitrate, ammonia, and phosphorus were measured during the summer in all the impoundments. Productivity levels were not related to concentrations of total phosphorus in the euphotic zone. Bacteria productivity varied among the impoundments and was affected by the occurrence and duration of thermal stratification. Periods of summer stratification and accumulation of late winter snow on pool ice were related to depletion of dissolved oxygen. During summer stratification the concentration of ammonia increased with time in the lower part of the water column in some impoundments.

PLANS NEXT YEAR: None, project was completed.

PUBLISHED REPORTS IN 1991:

Smith, C.J., Payne, G.A. and Tornes, L.H., 1991, Effects of impoundments on water-quality of streams in the Coteau Des Prairie--upper Minnesota River basin: U.S. Geological Survey Water Resources Investigations Report 90-4033, 67 p.

THERMAL-ENERGY STORAGE IN THE IRONTON-GALESVILLE AQUIFER, ST. PAUL, MINNESOTA

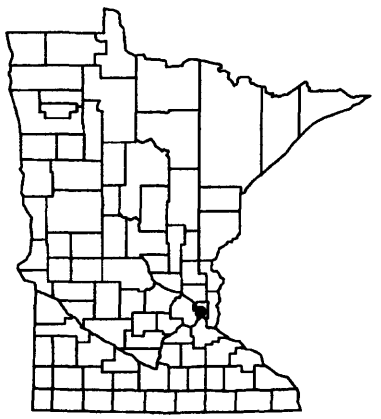
MN077

DATE PROJECT BEGAN: May 1980

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Delin, Geoffrey N.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES:
Minnesota Geological Survey and University of Minnesota.

PROBLEM: Aquifer thermal-energy storage (ATES) is believed to be a cost-effective method of energy conservation because it employs a natural reservoir for storage of waste heat from power plants. However, demonstration projects are needed to prove the feasibility of such systems. A site on the St. Paul Campus of the University of Minnesota has been selected by the U.S. Department of Energy (DOE) and Battelle Pacific Northwest Laboratories for an ATES demonstration. Hydrologic modeling for the aquifer system is needed to aid the design of field-testing experiments and evaluation of the aquifer-system response to injection and withdrawal of heated water.

OBJECTIVES: Develop a method to evaluate flow and thermal energy-transport during annual variations of injection and withdrawal cycles under real heating loads. Assist in the collection of hydraulic and thermal data during pilot testing of real injection/withdrawal cycles and process data for analysis. Determine effects of hot-water injection/withdrawal on hydraulic properties of the Ironton-Galesville aquifer near an injection well.

APPROACH: Construct three numerical simulation models of the project area. These will be a three-dimensional flow model, a two-dimensional axially-symmetric radial-flow and thermal-energy transport model, and a three-dimensional flow and energy-transport model. Simulation models will be used to accomplish the first three objectives of the study. The results of three other studies in the Twin Cities area that involve simulation models of the aquifer system also will be used for model construction and calibration. Record simultaneous pressure and temperature data at predetermined time intervals using multi-channel automatic data recorders. These data will be entered into computer storage for retrieval, analysis, and manipulation. Data also will be used for testing and calibration of the numerical simulation models.

RESULTS LAST YEAR: The interpretive report documenting preliminary modeling at the ATES site was published as an U.S. Geological Survey Open-File Report, pending publication as a U.S. Geological Survey Professional Paper. The interpretive report documenting the short-term test cycles was revised following colleague review. The first draft of the report documenting modeling of the long-term test cycles was written.

PLANS NEXT YEAR: The interpretive report documenting the short-term test cycles will be approved for publication and the report printed. The report documenting modeling of the long-term test cycles will be completed and processed through colleague review. The project is complete except report.

PUBLISHED REPORTS IN 1991:

Miller, R.T., 1991, Cyclic injection, storage, and withdrawal of heated water in a sandstone aquifer at St. Paul, Minnesota--Field observations, preliminary model analysis, and aquifer thermal efficiency,: U.S. Geological Survey Open-File Report 89-261, 97 p.

WATER AND SEDIMENT DISCHARGE FROM TACONITE-TAILINGS BASINS IN NORTHERN MINNESOTA

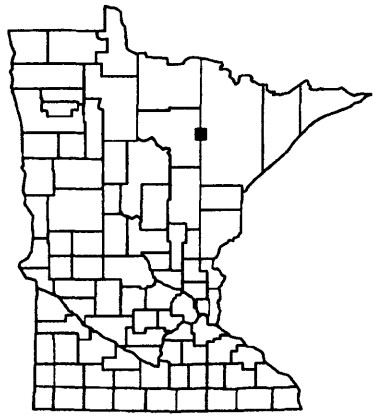
MN087

DATE PROJECT BEGAN: June 1982

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Stark, James R.

LOCATION: Northeastern Minnesota



PRINCIPAL COOPERATING AGENCIES: Iron Range Resources and Rehabilitation Board and the Minnesota Pollution Control Agency.

PROBLEM: Minnesota regulations require that disposal of taconite tailings be on land in man-made holding basins. Once a basin is filled with tailings, regulations require that the abandoned basin not impound natural water and that it be incorporated into the natural ecosystem. State regulatory agencies need data on the yield and quality of water and sediment on which to base criteria for proper abandonment and reclamation of filled basins. Mining companies need information on which to base engineering design of outlet structures and to plan revegetation.

OBJECTIVES: Determine water and sediment yield from a taconite-tailings basin that has been temporarily abandoned. Determine the response of surface- and ground-water flow to rainfall and snowmelt. Determine the impact of a tailings basin on the flow and chemical quality of ground water. Determine the chemical quality of water and sediment discharging to downstream areas.

APPROACH: A 2.5 square mile tailings basin near Keewatin, Minnesota will be instrumented for research. Primary emphasis will be on defining the rainfall-runoff response by monitoring rainfall, changes in pond storage and ground-water storage, outflow of surface water and sediment through a breach in the dike, discharge of ground water through evapotranspiration, vertical leakage into the underlying glacial deposits and seepage through the dike. A secondary emphasis will be on the quality of surface and ground water. Data on surface-water quality will be compared to previously published data on atmospheric depositions, the only source of water to the basin. Ground-water quality will be compared to State standards for domestic consumption.

RESULTS LAST YEAR: The report was published.

PLANS NEXT YEAR: None, project complete.

PUBLISHED REPORTS IN 1991:

Myette, C.F., 1991, Hydrology, water quality, and simulation of ground-water flow at a taconite-tailings basin near Keewatin, Minnesota: U.S. Geological Survey Resources Investigations Report 88-4230, 61 p.

CRUDE-OIL CONTAMINATION OF GROUND-WATER NEAR BEMIDJI, MINNESOTA

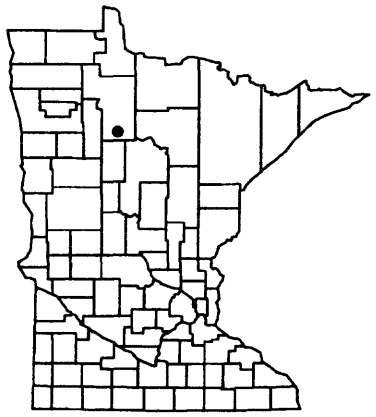
MN095

DATE PROJECT BEGAN: March 1983

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Hult, Marc F.

LOCATION: North-central Minnesota



PROBLEM: About 10,000 barrels of crude petroleum spilled from a broken pipeline near Bemidji on August 20, 1979. Although regulatory and remedial actions have been completed, as much as 4 ft of crude petroleum is floating on the water table in the outwash aquifer. Ground water is dissolving the oil, and residual organic compounds in the unsaturated zone are being leached downward.

OBJECTIVE: Understand the mobilization, transport, and fate of petroleum derivatives in the subsurface and use this understanding to develop predictive models of contaminant behavior in the ground-water system.

APPROACH: The project will require a comprehensive interdisciplinary approach coordinated between the District, National Research Program (NRP), and University groups involved in specialized research. The District will describe the geologic, hydrologic, and natural-geochemical framework, develop and maintain chemical and hydrologic monitoring networks, provide logistical support for separately funded research by staff of the National Research Program, and conduct research. Although conventional techniques may be adequate for many purposes, new field, laboratory, and modeling techniques will need to be developed and applied.

RESULTS LAST YEAR: Five journal articles, 13 abstracts, 12 conference proceedings papers, and five theses were completed by project participants from the District, National Research Program, Geologic Division, and universities. Of these, one journal article, 3 abstracts, and 5 conference proceedings papers were authored by District personnel. M.K. Landon and M.F. Hult determined the loss of volatile hydrocarbon constituents of field samples and samples of oil that were artificially aged in the laboratory. A method was developed using measurements of refractive index to determine the amount of oil that has been mobilized by vaporization and dissolution from a drop-size oil sample. The method allows for estimation of the total amount of oil that has entered ground water as solutes or vapors. This information is needed for quantitative modeling. A new analytical method was developed to measure vapor phase permeability. The method showed that fine-grained zones within the generally uniform outwash in the unsaturated zone strongly influenced vapor and gas movement. Vapor-sampling and pressure-measurement tubes, neutron access tubes, thermocouples, and moisture blocks were installed to determine the effect of the heterogeneities in unsaturated zone transport. M.F. Hult, in collaboration with R.W. Healy and

R.G. Streigl (National Research Program, Denver), used real-time mass-spectroscopy in the field to conduct tracer tests in the unsaturated zone using helium, argon and carbon dioxide.

PLANS NEXT YEAR: A publication updating site hydrologic and geochemical data will be completed and an interpretive summary report on the hydrology of the site submitted for processing for Director's approval. It is anticipated that at least one additional thesis will be prepared. Field work will include continued refinement of sampling techniques for multiphase systems, measurements to define the geochemical and biologic evolution of the plume, and characterization of physical parameters that control transport in the saturated and unsaturated zones.

PUBLISHED REPORTS IN 1991:

Aiken, G.R., Capel, P.D., Furlong, E.T., Hult, M.F., and Thorn, K.A., 1991, Mechanisms controlling the transport of organic chemicals in subsurface environment, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

Baehr, A.L. and Hult, M.F., 1991, Evaluation of unsaturated zone air permeability through pneumatic tests: Water Resources Research, V. 27, No. 10, p. 2605-17.

Bennett, P.C., 1991, Quartz dissolution in organic-rich aqueous systems.Geochim. Cosmochim. Acta 49, p. 1781-1797.

Capel, P.D., 1991, Mechanisms controlling the transport of organic chemicals in subsurface environments, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the technical meeting, Monterey, California, March 11-15, 1991.

Hult, M.F., 1991, Field validation of conceptual models of mobilization and transport of volatile petroleum derivatives in the unsaturated zone, Bemidji, Minnesota, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

Hult, M.F., 1991, Overview of research on contaminants of the subsurface by crude oil at the Bemidji, Minnesota, toxic substances research site, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

Landon, M.K. and Hult, M.F., 1991, Evolution of source term properties at an oil spill site, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

Stark, J.R., Busch, J.P. and Deters, M.H., 1991, Hydrogeology and water quality of a glacial drift aquifer in the Bemidji-Bagley area, Beltrami, Clearwater, Cass, and Hubbard Counties, Minnesota: U.S. Geological Survey Water Resources Investigations Report, 89-4136, 135 p.

IMPACT OF AGRICULTURE AND RURAL-RESIDENTIAL DEVELOPMENT OF GROUND-WATER QUALITY IN THE ANOKA SAND PLAIN, EASTERN MINNESOTA

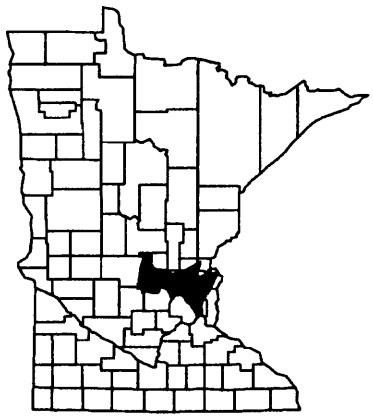
MN096

DATE PROJECT BEGAN: July 1983

DATE PROJECT ENDED: September 1986

PROJECT CHIEF: Stark, James R.

LOCATION: East-central Minnesota



PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources (MNDNR)

PROBLEM: Degradation of ground-water quality in the Anoka Sand Plain by non-point source contamination is of concern to residents and to local and State agencies. Potential sources of ground-water contamination in the Anoka Sand Plain are agricultural chemicals, manure produced in feedlots, lawn fertilizer, and septic-system effluent in residential areas. Current data are inadequate to evaluate the effects of these contaminants historically, seasonally, or areally.

OBJECTIVES: Assess areal and seasonal water quality variations in the Anoka Sand Plain aquifer in relation to hydrogeologic and climatic conditions, and land use. Determine the degree of horizontal and vertical mixing of water in the aquifer. Determine long-term trends in water quality and effects due to land-use practices. Provide baseline water-quality data. Establish a regional network of wells in each aquifer that may be incorporated into a statewide water-quality-monitoring network.

APPROACH: About 100 wells at 75 sites will be selected for sampling based on ground-water flow and land use. At 25 of the 75 sites, shallow and deep pairs of wells will be installed to determine stratification of water quality. All wells will be sampled for baseline quality during May 1984. The wells will be resampled the following winter for indicator constituents. Constituents to be measured are sulfate, chloride, nitrate, and ammonia. In May 1985 40 to 50 selected wells will be sampled again for sulfate, chloride, nitrate, and ammonia. Constituent concentrations will be evaluated for relations with land use, seasonal change, and long-term trends. This project also will include annual sampling for indicator constituents from about 20 wells in networks established as part of two previous similar projects.

RESULTS LAST YEAR: The project is complete except report.

PLANS NEXT YEAR: The final report will be printed.

GROUND-WATER AND SURFACE-WATER RELATIONS IN THE VICINITY OF VADNAIS LAKE, RAMSEY COUNTY, MINNESOTA

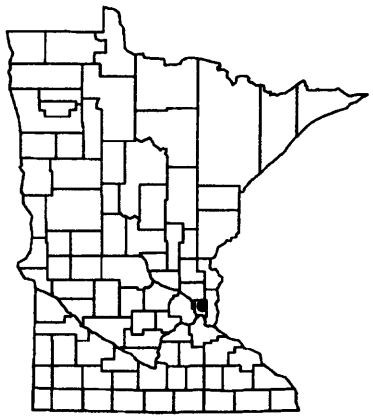
MN101

DATE PROJECT BEGAN: April 1984

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Ruhl, James F.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES: St. Paul Water Utility and Vadnais Lake Watershed Management Organization.

PROBLEM: The St. Paul Water Utility (SPWU) withdraws water from a series of lakes for the city's water supply. Water taken from the lakes during the summer has had an undesirable taste and odor caused by factors related to eutrophication of the lakes, which is caused by sediment and nutrient discharge from tributary streams. Transport of nutrients from ground water to the lake is not well understood.

OBJECTIVES: Determine nutrient loadings to the St. Paul water-supply lakes. Determine the quality of water in the surficial aquifer in the vicinity of Vadnais Lake and selected watersheds. Determine the potential for transport of nutrients from the surficial aquifer into the Vadnais Lake watershed.

APPROACH: Monitoring wells will be installed to complete a network of about 25 wells in the surficial sand and gravel aquifer that will be used to measure seasonal variations in potentiometric surfaces. Ten of these wells will be sampled quarterly to determine concentrations of major nutrients and annually to determine concentrations of major ions. Precipitation and discharge data will be collected in three tributary watersheds. Discharge will be measured using stage-recording data loggers on Parshall flumes. Water will be sampled manually and with automatic samplers triggered by changes in stream stage. Samples will be analyzed by the St. Paul Water Utility for major plant nutrients and for suspended solids.

RESULTS LAST YEAR: The ground-water component of the hydrologic budget of Vadnais Lake is small compared to the other components. The influence of the lake on quality of ground water is greater than the influence of the ground water on the quality of the lake. The project is complete except the report.

PLANS NEXT YEAR: Project complete except report.

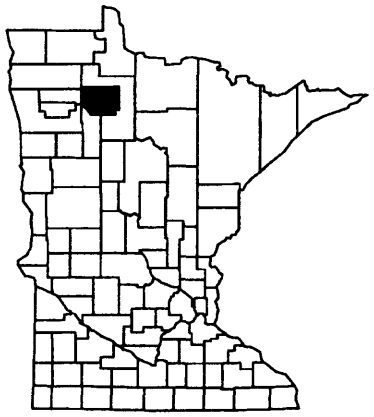
HYDROLOGY OF RED LAKE INDIAN RESERVATION IN MINNESOTA
MN103

DATE PROJECT BEGAN: October 1984

DATE PROJECT ENDED: September 1989

PROJECT CHIEF: Ruhl, James F.

LOCATION: Northwestern Minnesota



PRINCIPAL COOPERATING AGENCY: Red Lake Indian Reservation Tribal Council

PROBLEM: Tribal officials need water resource information to manage the water resource of the reservations and to plan future development. An assessment of water resources of Indian Reservations is presently underway throughout the United States. The Bureau of Indian Affairs (BIA) requested appraisal-level studies as a basis for review of Indian water claims. The Minnesota Tribes requested the U.S. Geological Survey to conduct water-resources appraisals and prepare map-type reports on the hydrology of the major reservations in the state. This report, the third in the series, covers the Red Lake Indian Reservation.

OBJECTIVE: Determine streamflow characteristics, availability of ground and surface water, quality of ground and surface water, water use, seasonal and annual fluctuations of streamflow, ground-water levels, water quality, and the annual water budget of the Red Lake Indian Reservation.

APPROACH: The hydrogeology of the glacial drift aquifers and peat deposits will be determined from well logs, test drilling, and seismic refraction and reflection surveys. Water-level data will be collected periodically from a network of observation wells, and used to determine potentiometric surfaces and flow directions. Streamflow characteristics will be determined from previously collected discharge data and stage discharge relationships determined on several smaller streams. Water quality will be determined from samples collected from ground- and surface-water.

RESULTS LAST YEAR: Mean annual precipitation in the study area was 22.7 inches. Approximately 90 percent of this precipitation returned to the atmosphere by evapotranspiration; the remainder became runoff. Recharge to ground water ranged from 0.5 to 1.35 inches per year. Long-term changes in ground water storage was zero. Confined-drift aquifers were the major source of ground water in the Red Lake Indian Reservation. The confined-drift aquifers were discontinuous lenses of sand and gravel, 50 to 150 feet below land surface. Estimated yields of wells screened in these aquifers ranged from about 20 to 240 gallons per minute. Most of the streams drained into Lower and Upper Red Lakes, and the lakes discharged into the Red Lake River.

Spring snowmelt caused peak flows in the streams. Low-flow conditions occurred during mid-summer to early fall and winter. Based on U.S. Environmental Protection Agency criteria, the quality of ground water was suitable for drinking and other household uses, and the quality of the surface waters was suitable for the maintenance of aquatic life. The primary chemical constituents in water from the aquifers and streams were calcium, magnesium, and bicarbonate. Lower and Upper Red Lakes were eutrophic to mesotrophic. Secchi disk-transparency readings ranged from 2.6 to 8.2 feet. Total organic carbon concentration in samples from Lower and Upper Red Lakes and four streams was less than 30 milligrams per liter. The sample with the largest organic carbon concentration was collected from a stream that drained peatlands, which were probably sources of organic matter in the runoff. Nitrite plus nitrate concentrations in water from Lower and Upper Red Lakes in late summer was less than 0.01 milligrams per liter. Total phosphorus concentrations from these lakes ranged from 0.01 to 0.02 milligrams per liter. Phosphorus was in the particulate organic fraction because of the abundance of phytoplankton.

PLANS NEXT YEAR: None, project is completed.

PUBLISHED REPORTS IN 1991:

Ruhl, J. F.,1991, Water resources of the Red Lake Indian Reservation, northwestern Minnesota; U.S. Geological Survey Water Resources Investigations Report 90-4163, 49 p.

GROUND-WATER RESOURCES OF LEECH LAKE INDIAN RESERVATION, MINNESOTA

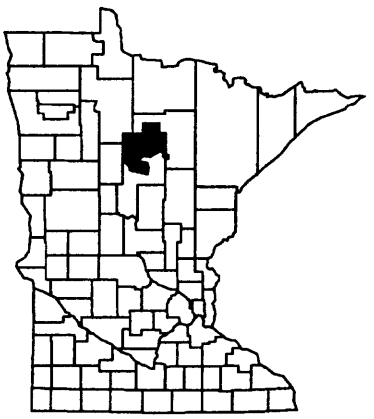
MN109

DATE PROJECT BEGAN: July 1987

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: North-central Minnesota



PRINCIPAL COOPERATING AGENCY: Leech Lake Indian Reservation

PROBLEM: Tribal officials need water resource information to manage the water resources of the reservation and to plan future development. The Bureau of Indian Affairs (BIA) requested appraisal-level studies as a basis for review of Indian water claims. The BIA requested the U.S. Geological Survey to conduct water resource appraisals and prepare map-type reports on the hydrology of the major reservations in the state. The Leech Lake Reservation has a program to evaluate their surface-water resources. The Leech Lake Business Committee requested that the U.S. Geological Survey conduct a study to provide the data and analyses needed to define the presence, availability, and quality of ground-water resources on the Reservation.

OBJECTIVES: Describe the availability of water from unconfined and confined aquifers in the glacial drift. Define baseline quality of ground water. Relate ground-water quality to major land uses.

APPROACH: The hydrogeology of the glacial-drift aquifers in the study area will be defined on the basis of drillers' logs, test drilling, and numerical modeling. Hydraulic properties of aquifers will be estimated using well-log data and pumping tests. Water-level data will be collected from a network of observation wells, and used to describe potentiometric surfaces and flow directions in the aquifers. Recharge and discharge areas will be located by comparing potentiometric-surface maps, analyzing stream base-flow data, and conducting mini-piezometer surveys in major lakes. Water quality will be evaluated on the basis of existing data and samples collected from ground-water sources. Ground-water and land use relations will be studied by analyzing water samples for chemical species indicative of land use practices.

RESULTS LAST YEAR: Water-level measurements were made five times (November 1990, February, March, May, and June 1991) in 31 observation wells screened in the unconfined-drift aquifer and in three wells screened in the uppermost confined-drift aquifer. Ten streamflow measurements made during February 1991 at base-flow conditions indicated ground-water discharges of 3.3 to 7.0 ft^3/mi for the Mississippi River, 0.4 ft^3/mi for the Leech Lake River, and 1.2 ft^3/mi for the Boy River. Maps showing the extent, thickness, transmissivity, theoretical maximum well

yield, and potentiometric surface for the unconfined-drift and uppermost confined-drift aquifers were completed. Maps showing the altitude of the top of the uppermost confined-drift aquifer and the thickness of the uppermost confining unit also were completed. The saturated thickness of the unconfined-drift aquifer ranges from 15 to 30 ft over most of the study area, but is as much as 106-ft thick. The thickness of the uppermost confined-drift aquifer ranges from 5 to 50 ft. Theoretical maximum well yields in the unconfined-drift aquifer range from less than 10 to about 2,000 gal/min and in the uppermost confined-drift aquifer range from less than 10 to about 2,600 gal/min. Chemical analyses of water from the unconfined-drift and uppermost confined-drift aquifers indicate that calcium and bicarbonate are the predominant chemical constituents in water from both aquifers. Water from wells in urban and recreational land-use areas had concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and cyanide equal to or less than 6 µg/L. Concentrations of organic-acid herbicides in water from three wells in managed-forest land-use areas were all below detection limits. Concentrations of U.S. Environmental Protection Agency priority pollutants in water collected from three wells screened in the unconfined-drift aquifer and from one well screened in the uppermost confined-drift aquifer were all below detection limits. The first draft of the interpretive report was completed.

PLANS NEXT YEAR: Project is complete except report.

GROUND-WATER FLOW IN THE ST. PETER-PLATTEVILLE AND DRIFT AQUIFER SYSTEM RELATED TO CONTAMINATION BY COAL-TAR DERIVATIVES ST. LOUIS PARK, MINNESOTA

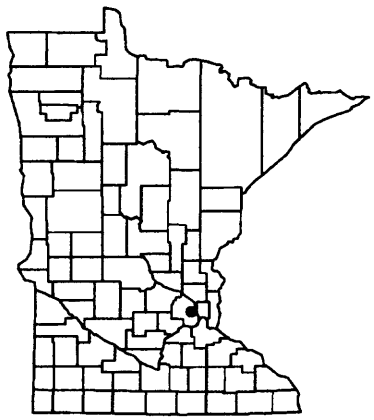
MN112

DATE PROJECT BEGAN: April 1987

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCY: U.S. Environmental Protection Agency

PROBLEM: Ground-water contaminants from a coal-tar distillation and wood preserving plant that operated from 1918-72 have degraded the quality of water in several aquifers in the vicinity of St. Louis Park, Minnesota. The upper aquifers in the glacial drift and the Platteville Limestone and the St. Peter Sandstone, have been contaminated by coal-tar compounds that percolated to the water table from ponds and wetlands that received runoff and process water from the plant. Previous studies have dealt primarily with understanding ground-water flow and contaminant transport in the Prairie du Chien-Jordan aquifer because it is the major water-supply aquifer in the area. Gradient-control and water-treatment measures currently are being implemented in this aquifer. An appraisal is needed to evaluate gradient-control measures and previous simulations of gradient-control measures in the Prairie du Chien-Jordan aquifer and to provide information for regulators to design gradient-control measures for the drift and Platteville and St. Peter aquifers.

OBJECTIVES: Determine the direction and rate of movement of ground water in the St. Peter aquifer under past and current pumping conditions and under proposed gradient-control conditions. Obtain an understanding of the hydrogeology and ground-water flow in the drift and Platteville aquifer system.

APPROACH: Models from previous studies will be refined and used to simulate the effects of past pumping conditions on the movement of contamination in the St. Peter aquifer, including the effects of multiaquifer wells. The models will be used to evaluate effectiveness of several proposed gradient-control options in the St. Peter aquifer. Logs of wells and test holes in the area will be used to determine the hydrology, ground-water movement, and stratigraphic framework of the drift and Platteville aquifer in the vicinity of the former plant site. A three-dimensional, ground-water-flow model of the drift and Platteville aquifer will be constructed to evaluate options for controlling hydraulic gradients in the aquifer. The effectiveness of gradient-control measures in the Prairie du Chien-Jordan aquifer will be evaluated. Results from previous model simulations of proposed gradient-control scheme will be compared to evaluate the accuracy of past predictions beyond 1990.

RESULTS LAST YEAR: The interpretive report on the hydrogeology of the drift and Platteville aquifer system was completed. The report was processed through editorial and colleague reviews.

PLANS NEXT YEAR: Project is complete except report.

EFFECTS OF GROUND WATER WITHDRAWALS ON THE TEMPERATURE AND QUALITY OF THE STRAIGHT RIVER, MINNESOTA

MN114

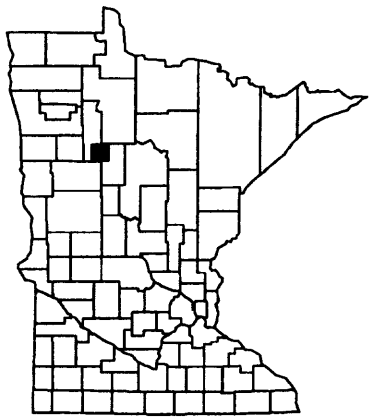
DATE PROJECT BEGAN: January 1988

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Stark, James R.

LOCATION: North-central Minnesota

PRINCIPAL COOPERATING AGENCY: Minnesota Department of Natural Resources



PROBLEM: Trout require cold, high-quality water as habitat. Agricultural land-use changes reduce trout habitat by degradation of stream-water quality and quantity. Recreation managers are concerned that contamination from nutrients, pesticides, and reduced oxygen-carrying capacity because of higher stream-water temperatures will reduce trout habitat. These factors may affect the ability of the river to maintain a stable population of trout. The Straight River is a designated trout stream, having clear, cold water in an area where trout streams are not common. Production of processed potato products is an important industry in the area. The sandy soils are ideal for growing potatoes but require irrigation. Irrigation development has increased during the last decade and about 1.5 billion gallons of ground water was withdrawn in 1984 from wells screened in glacial-drift aquifers. Intensive use of agricultural chemicals and the subsequent degradation of ground- and surface-water quality because of irrigation has not been clearly established. An understanding of the fate and movement of pesticides, particularly as related to changes in stream quality, needs to be established.

OBJECTIVES: Evaluate the effect of ground-water withdrawals on water temperatures and water quality of a trout stream. Explore the feasibility of water-use-management techniques to balance the need for ground-water use with the need to maintain river and ground-water quality.

APPROACH: A three-year project will be conducted in cooperation with the Minnesots Depsrtmenrt of Natural Resources. The major work elements will be conducted to accomplish the following objectives: describe the hydrogeologic framework of the aquifer system and bottom sediments of the trout stream; measure baseflow of the stream and pumping for irrigation to determine seasonal change and areal distribution of outflow from the aquifer system; measure the temperature of water in the stream, streambed, and aquifer to determine seasonal and diurnal fluctuations and temperature distribution as related to aquifer-stream flux; sample stream and ground waters for constituents that could indicate seasonal loading effects from the local agricultural practices; construct a preliminary three-dimensional ground-water flow model to determine which parameters and properties require additional data collection to understand the aquifer-

stream system; and use results of the calibrated flow model to build a model to test concepts of heat transport through the hydrologic system.

RESULTS LAST YEAR: Hydrogeologic data indicate hydraulic connection between the river and the unconfined-drift aquifer. Discharge of the Straight River increased from about 25 ft^3/sec at the outfall from a reservoir near the headwaters to about 51 ft^3/sec near its mouth. The rate of gain in streamflow during summer decreased downriver, possibly as a result of ground-water withdrawal for irrigation. The hydraulic conductivity of the unconfined and confined-drift aquifers averaged about 530 and 580 ft/d, respectively. The storage coefficient of the unconfined and confined-drift aquifers averaged 0.2 and 0.00003, respectively. The water table and potentiometric surface of the aquifers slope toward the Straight River at a gradient of about 10 ft/ mi and decline as much as 5 ft from spring to summer. Daily fluctuations of river temperature are caused by daily fluctuations of air temperature, and are as much as 15°C during the summer. Ground-water discharge decreases the river temperature during the summer. Results from a river-temperature model indicate that daily changes in river temperature are caused by solar radiation, wind speed, river depth, and ground water inflow. Nitrate concentrations in water from shallow wells screened at the water table are elevated and are greater than the limit set by the Minnesota Pollution Control Agency. Nitrate concentrations in water from deeper wells, and in the river, are less than 1.0mg/L. Results from ground-water-flow and river-temperature models developed for the study indicate that a significant decrease in ground-water flow may result from ground-water withdrawal at rates similar to those during 1988, and that this reduction in discharge to the river could result in a change in river temperatures by as much as 1.5° C.

PLANS NEXT YEAR: Project is complete except report.

GROUND-WATER FLOW AT THREE AREAS NEAR THE MISSISSIPPI AND MINNESOTA RIVERS, TWIN CITIES METROPOLITAN AREA, MINNESOTA

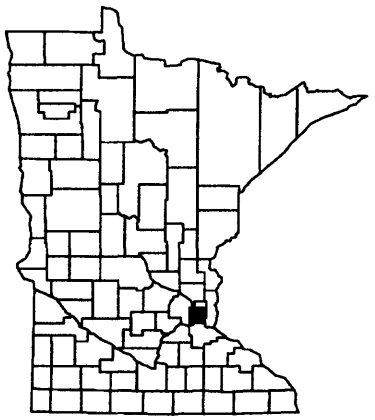
MN115

DATE PROJECT BEGAN: October 1987

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Schoenberg, Michael E.

LOCATION: Twin Cities Metropolitan Area



PRINCIPAL COOPERATING AGENCIES:
Legislative Commission on Minnesota Resources and Minnesota Department of Natural Resources.

PROBLEM: The rate of flow and degree of hydraulic connection between aquifers and rivers in the Twin Cities Metropolitan Area is not well defined. This information is needed to manage and to estimate the availability of ground water flowing into surface waters.

OBJECTIVES: Determine the spatial and hydraulic properties of the valley-fill deposits along selected transects through deep and shallow buried valleys. Determine the vertical and horizontal hydraulic connections between aquifers and valley fill along the transects.

APPROACH: The distribution and hydraulic properties of the valley-fill deposits in the Mississippi and Minnesota River valleys will be determined along three transects by the compilation of hydraulic data, the construction of test holes and observation wells, the collection of geologic samples for laboratory analysis, conducting aquifer tests to determine the hydraulic properties of valley fill, and using geophysical surveys. Models will be constructed at one transect to simulate ground-water flow and to obtain an understanding of the relation between aquifers and the river.

RESULTS LAST YEAR: Data from test holes, geophysical surveys, aquifer tests, and geotechnical tests defined the distribution of alluvium, glacial drift, interstadial deposits, and preglacial deposits separating the bedrock from the stream at each transect. At the Fridley/Brooklyn Center transect, alluvial sands fill a valley cut into older glacial drift and, in places, through. a rubble zone that separates the St. Peter and Prairie du Chien-Jordan aquifers. Older drift underlies terrace deposits. Along this transect most ground-water flow is through hydraulic connections between river and bedrock where coarse-grained, alluvial, and interstadial fill directly overlies the Prairie du Chien-Jordan aquifer. At the Minneapolis transect, alluvial sands fill a valley incised into the St. Peter aquifer. The Mississippi River and bedrock are hydraulically connected directly through the riverbed. At the Eagan/Bloomington transect, organic-rich, alluvial sands and peat fill a post-glacial valley incised into older interstadial fill. The interstadial fill lies in a broader valley cut into still older glacial deposits. River and bedrock are separated by confining units within the river channel, forcing ground water to discharge along the sides of the valley. Alluvium in the Missis-

sippi River valley from that confluence to the vicinity of St. Anthony Falls is clean sand. Along this stretch, the river and bedrock are directly connected with no intervening confining units. The transport of sand down the Mississippi River caused alluvium at the confluence of the Minnesota and Mississippi Rivers to be deposited as a sand bar across the mouth of the slower moving Minnesota River. Alluvium or interstadial fill or both in the Minnesota River valley, from Carver Falls to the confluence of the Minnesota and Mississippi Rivers, impedes the vertical flow of ground water between bedrock and the Minnesota River.

PLANS NEXT YEAR: The project is complete except the report.

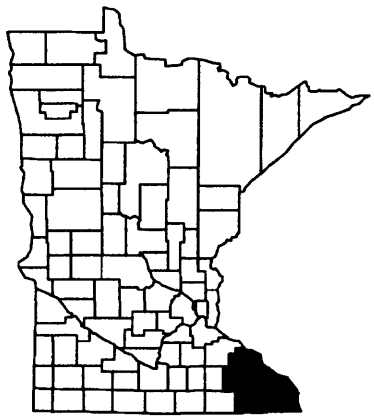
GROUND-WATER FLOW IN THE KARST AREA OF SOUTHEASTERN MINNESOTA
MN116

DATE PROJECT BEGAN: October 1987

DATE PROJECT ENDED: September 1990

PROJECT CHIEF: Ruhl, James F.

LOCATION: Karst area of southeastern Minnesota



PRINCIPAL COOPERATING AGENCY:
Minnesota Department of Natural Resources

PROBLEM: Contamination of ground water from point sources such as landfills, feedlots, and septic systems, and non-point sources such as agricultural chemicals is a recognized problem in the karst area of southeastern Minnesota. Rate of contaminant movement is dependent on size, orientation, and degree of interconnection between fractures and solution channels in the carbonate rocks on which karst terrain has developed. A better understanding of flow is needed that incorporates data on fracture and solution-channel occurrence and orientation with other hydrogeologic conditions in the karst area.

OBJECTIVES: Determine if the fractures and solution channels in the Prairie du Chien Group of carbonate rocks in southeastern Minnesota are aligned along principal and minor axes of orientation. Evaluate the effect of the fractures and solution channels on ground-water flow.

APPROACH: Surface lineaments will be mapped using aerial photographs. The lineament maps will be compared with known orientation of fractures and sinkholes determined from previous and ongoing studies. Principal watersheds will be investigated to determine whether the joint systems correlate with base-flow characteristics. A smaller watershed will be selected for simulating the effects of fractures on sub-regional ground-water flow and contaminant migration. Mathematical models will be used to conceptualize the sensitivity of fracture density, orientation, and permeability on ground-water flow. Hydrologic and chemical data will be analyzed to test the effectiveness of the preliminary flow models in improving the understanding of local and regional flow systems.

RESULTS LAST YEAR: Analyses of fracture direction measurements were grouped by 30-degree increments. Rose diagrams were constructed for ten exposure sites (quarries, road cuts, and natural outcrops) in the Prairie du Chien Group. The data showed directional trends at eight of the sites. The trend for these eight sites was defined by a sixty-degree arc centered along an east-west line. Linear terrain features for 100 square mile areas were identified on 1:80,000 aerial photographs of the exposure sites. Orientations of the linear trend features were compared to the directional trends of the fractures. The linear terrain features showed directional trends in areas

that surround four of the ten sites, which included three of the sites where the fractures also showed directional trends. Data from the other sites and surrounding areas did not validate this approach. Horizontal anisotropy in Prairie du Chien Group, determined from an aquifer test, indicated that the major axis of horizontal transmissivity was along a line W 10° N. This axis was within the resultant trend of fractures in Prairie du Chien Group rocks estimated from field measurements. The major axis of horizontal transmissivity is determined by the principal axes of joint fractures, which control the direction of ground-water flow. Base flow at six stream reaches incised into Prairie du Chien Group was measured. These streams were Crow Creek and Middle Fork of the Whitewater River, Duschee Creek, Middle Fork of the Zumbro River, South Branch of the Root River, South Branch of the Zumbro River, and Riceford Creek. Data from five of the stream reaches did not support the relation of linear terrain features, stream reach alignments, and seepage rates. The linear terrain features mapped in the areas surrounding the Middle Fork of the Zumbro River, the South Branch of the Root River, and the South Branch of the Zumbro River, did not indicate directional trends. Directional trends of linear terrain features did not correlate with ground-water-flow direction. Linear terrain features in areas surrounding Crow Creek and the Middle Fork of the Whitewater River, and Duschee Creek, did have significant directional trends. The seepage measurements along these stream reaches generally were higher along alignments that were correlated or nearly correlated with the major directional trends of the linear terrain features, and lower along reaches that were orthogonal or nearly orthogonal with the major directional trends. Data from Riceford Creek, however, was consistent with the relation that ground-water-flow direction was related to linear terrain features. The stream reaches at this site that received the highest rates of ground-water discharge were approximately orthogonal to the principal directional trends of linear terrain features. These results indicated that the dominant ground-water-flow directions were along the major axes of fractures. The approaches used in this study to investigate the hydrogeology of Prairie du Chien Group rocks appeared to be generally inadequate for prediction of local ground-water-flow directions on the basis of estimated fracture patterns. Some of the findings of the study indicated; however, that where linear terrain features had statistically significant directional trends, this approach was reasonable for a reconnaissance-level evaluation, provided that the uncertainty of the results and the underlying assumptions were understood and accepted.

PLANS NEXT YEAR: Project is complete except report.

SOURCES AND TRANSPORT OF SEDIMENT, NUTRIENTS, AND OXYGEN-DEMANDING SUBSTANCES IN THE MINNESOTA RIVER

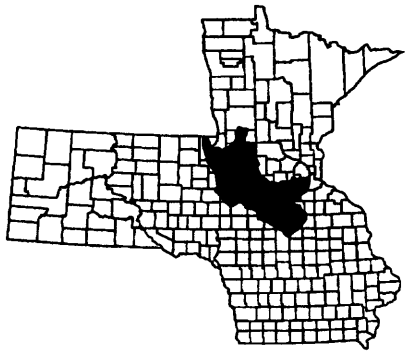
MN120

DATE PROJECT BEGAN: July 1989

DATE PROJECT ENDS: September 1993

PROJECT CHIEF: Payne, Gregory A.

LOCATION: South-central Minnesota



PRINCIPAL COOPERATING AGENCY:
Minnesota Pollution Control Agency

PROBLEM: The Minnesota River is affected by point source and non-point source contaminants. The extent of contamination by these sources and how the quality will change as point sources are controlled or as agricultural practices change is not known. Point source discharges have been identified, but interest now is being directed towards controlling non-point sources that could substantially improve the quality of the river and enhance its resources. The sources, transport, and fate of non-point source contaminants need to be understood so that best-management practices can be implemented.

OBJECTIVES: Determine the sources and determine loading of suspended sediment, nutrients, BOD, and organic carbon in selected reaches and tributaries of the Minnesota River and ground water. Determine the effects of specific sources on river water quality. Determine the relation between suspended sediment and nutrients, BOD, and organic carbon. Identify areas of bank erosion and sediment deposition to determine if in-stream loading could have an more adverse effect on river quality than non-point off-stream loading.

APPROACH: This study encompasses most of the Minnesota River drainage basin, focusing primarily on the mainstem and several major tributaries. Water-quality samples will be collected at 12 mainstem, 10 tributary, and 15 seep sites. Two sites will be sampled monthly, supplemented by weekly sampling March-July. Daily suspended sediment samples will be collected at two sites. Water samples will be analyzed to determine concentrations of nitrogen, phosphorus, suspended sediment, COD, BOD, bacteria, and chlorophyll. Bottom material also will be sampled. Stream discharges will be measured and sediment and chemical loads are calculated. The relation between suspended sediment concentration and concentrations of other constituents will be determined. Transport between segments of the main stem will be assessed on the basis of differences in load.

RESULTS LAST YEAR: Nitrate concentrations in the western (upstream) part of the Minnesota River basin range from 3-7 mg/L. In the eastern (downstream) part of the basin, nitrate concentrations range from 10-25 mg/L. Nitrate comprises about 90 percent of total nitrogen in most sam-

ples. Nitrate concentrations increase when streamflow increases. Total phosphorus concentrations in the Minnesota River and tributaries ranged from 0.2-0.5 mg/L during runoff. Dissolved orthophosphate comprised 30-50 percent of total phosphorus in most samples. Suspended-sediment concentrations in tributary streams increased during runoff, rising from less than 100 mg/L during low-flow periods to 700-1000 mg/L during snowmelt and rainfall. Suspended sediment was comprised of clay- and silt-size particles. Five-day BOD was less than 5 mg/L, but increased to 10-16 mg/L during snowmelt. BOD also increased during July and August to 8-10 mg/L. The BOD rise coincided with stable flow, elevated stream temperature, and increased algal productivity.

PLANS NEXT YEAR: The Minnesota River and tributaries will be sampled during runoff and during periods of stable flow. Emphasis will be placed on sampling for nonpoint-source contaminants. Priority will be given to gaining understanding of processes affecting the transport and fate of nonpoint-source substances as they enter the mainstem channel and travel to the mouth of the Minnesota River. The relative contribution of channel-bank erosion to the total sediment load will be investigated. Characterization of nonpoint-source loading from major tributaries will continue, with the objective of documenting regional differences in the type and quantity of loads originating from the various land-use areas in the basin.

PUBLISHED REPORTS IN 1991:

Payne, G.A., 1991, Sediments, Nutrients, and Oxygen-demanding Substances in the Minnesota River--Selected Water-Quality Data, 1989-90: U.S. Geological Survey Open-File Report 91-498, 37 p.

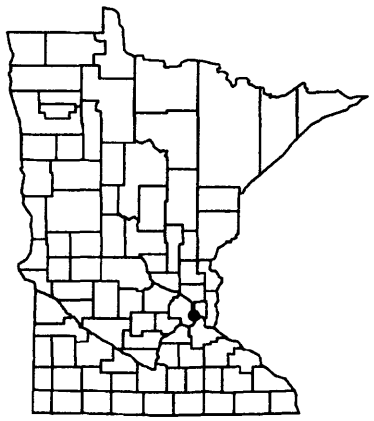
ATMOSPHERIC TRANSPORT AND DEPOSITION OF HERBICIDES
MN121

DATE PROJECT BEGAN: March 1990

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Capel, Paul D.

LOCATION: St. Paul



PROBLEM: Anthropogenic organic chemicals, including herbicides, can be transported long distances through the atmosphere and deposited in aquatic and terrestrial ecosystems through wet and dry processes. It has been measured that between 2 and 20 percent of the herbicides are lost from agricultural fields after application through volatilization, but less than 0.5 percent is returned through precipitation. This indicated that either the herbicides are being removed through dry deposition, vapor phase chemical reaction or are accumulating in the atmosphere.

OBJECTIVES: Examine and quantify the processes controlling the atmospheric transport and deposition of agricultural herbicides. Determine the seasonal fluctuations in the mass of herbicides stored in the atmosphere.

APPROACH: Rain and snow samples were collected from a site in St. Paul for one year. The rain samples are wet-only samples collected on an event basis. The snow samples also were collected on an event basis. Herbicide analyses were performed by gas chromatography/mass spectrometry or high performance liquid chromatography, depending on the analyte. Atrazine, alachlor, and their metabolites were the target compounds.

RESULTS LAST YEAR: The herbicides, alachlor, atrazine, and cyanazine, have been detected in rain and snow during 1989 and 1990 in St. Paul and Rosemount, Minnesota. Maximum concentration of alachlor was 22 µg/L, atrazine was 1.6 µg/L, and cyanazine was 3.9 µg/L in rain during spring. During one 24-hour storm in June 1990, 43 sequential samples were collected. Maximum concentration of all three herbicides was present in the first millimeter of rain. Alachlor and atrazine were detected throughout most of the event, but cyanazine was detected in only the first three samples (about 4 mm rain). Yearly fluxes of the three herbicides, alachlor, atrazine, and cyanazine, to the state of Minnesota are estimated to 40, 20, 20 megagrams per year, respectively. Although this is less than one percent of their total agricultural application in Minnesota, the atmospheric deposition of atrazine potentially could have a harmful effect on aquatic and terrestrial ecosystems.

PLANS NEXT YEAR: None, project is completed.

PUBLISHED REPORTS:

Capel, P.D., 1991, Atmospheric deposition of herbicides in the mid-continental United States, *in* EOS, Transactions, American Geophysical Union, Vol. 71, No. 43, p. 1163-1754, Proceedings of the 1990 fall meeting, San Francisco, California, December 3-7, 1990.

Capel, P.D., 1991, Atmospheric deposition of herbicides in the mid-continental United States, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

Capel, P.D., 1991, Atmospheric deposition of herbicides in the mid-continental United States, in EOS, Transactions, American Geophysical Union, Vol. 71, No. 43, p. 1163-1754, Proceedings of the 1990 fall meeting, San Francisco, California, December 3-7, 1990.

Schottler, S.P., Eisenreich, S.J. and Capel, P.D., 1991, Hydrologic and chemical controls on atrazine, alachor, and cyanazine in a major agricultural watershed, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991.

HYDROGEOLOGIC SENSITIVITY OF THE PRAIRIE DU CHIEN-JORDAN AQUIFER, MINNESOTA

MN122

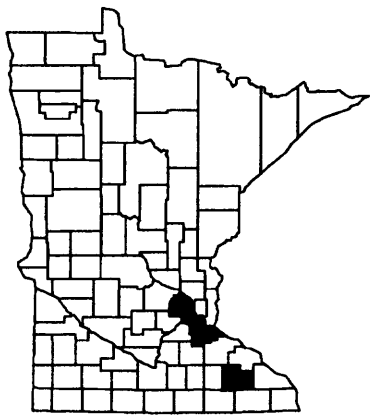
DATE PROJECT BEGAN: October 1989

DATE PROJECT ENDS: September 1992

PROJECT CHIEF: Smith, Shannon E.

LOCATION: Southeastern Minnesota

PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources and the Legislative Commission on Minnesota Resources.



PROBLEM: The Prairie du Chien-Jordan is a principal aquifer over large parts of southeastern Minnesota and is the principal source of ground water in the Minneapolis-St. Paul Metropolitan Area. The aquifer comprises a fractured and solution-channeled dolomite underlain by quartz sandstone. Both stratigraphic units yield significant quantities of water to wells. Vertical differences in natural ground-water quality and contamination between the Prairie du Chien Group and the Jordan Sandstone have been measured. Contamination of the Prairie du Chien by various industrial and agricultural practices is widespread; however, contamination underlying Jordan Sandstone is not known. The factors that cause water quality variation in the aquifer and in the degree of contamination must be better defined in order to allow evaluation of the sensitivity of the aquifer to contamination and to effectively manage large-scale withdrawal of water from this aquifer.

OBJECTIVES: Describe the susceptibility of the Jordan Sandstone to contamination by land-use practices. Characterize in water quality variations between the Prairie Du Chien dolomite and the Jordan Sandstone of the Prairie du Chien-Jordan aquifer. Determine the geologic and hydrogeologic factors that could cause water quality variations.

APPROACH: A 2 1/2-year study will be conducted to evaluate ground-water chemistry and hydraulics along regional flow paths in the Prairie du Chien-Jordan aquifer. Available hydrologic, geologic, and chemical data will be reviewed to select ground-water flow paths in Olmsted, Dakota, and Hennepin Counties. Six study areas will be selected to represent a broad spectrum of land use, water use, and hydrogeologic conditions. Aquifer geometry, hydraulic properties, and existing water levels will be compiled for each study area. Information relative to areas of confinement, areas of fractures, lithology, thickness, and stratigraphy of the Prairie du Chien and Jordan aquifers and overlying units also will be compiled. Hydrologic and land-use data will be compiled from data available from files of the U.S. Geological Survey, the Minnesota Geological Survey, the State Planning Agency, and local agencies. Water samples will be collected from 150 wells for analysis.The data will be used to determine the relation between water quality and

hydrologic and geologic conditions in each area. Conceptually-based, cross-section, ground-water flow models will be used to aid in understanding the flow system of the Prairie du Chien-Jordan aquifer.

RESULTS LAST YEAR: Analyses of water data collected from 103 wells from July to September of 1990 have been tabulated and reviewed. Concentrations of chloride, nitrite plus nitrate, and tritium isotopes in the water from the aquifer were used as water-quality indicators to compare water from different parts of the aquifer and to indicate regions where the aquifer could be hydraulically connected to land surface. Geologic sections perpendicular to the flow were compared with water-quality data to show the distribution of indicator constituents. These comparisons indicate that several factors may be important in explaining differences in water quality. These factors include thickness of the glacial drift, presence of bedrock or drift confining layers overlying the aquifer, vertical location of the open interval of wells in the aquifer, presence of a water table in the aquifer, and proximity of the well to buried bedrock valleys. Forty-six wells were selected for sampling during July and August of 1991. An immunoassay screen for triazine herbicides has been completed for water from each of the sites. Twenty-seven of the sample herbicide concentrations were greater than 0.1 part per billion. Additional samples from these wells were sent to the U.S. Geological Survey's Water-Quality Laboratory for gas chromatography and mass spectrometry (GCMS) analysis. Water-levels were measured were at 70 wells and a potentiometric surface of the Prairie du Chien-Jordan aquifer was prepared. The potentiometric surface map and geologic sections of the flowpaths will be used for development of the conceptual models.

PLANS NEXT YEAR: Results from statistical analyses of the water-quality data will be used to correlate aquifer water-quality and hydrogeology. The final project report will be written.

PUBLISHED REPORTS IN 1991:

Smith, S.E., 1991, Water-quality indicators in the Prairie du Chien-Jordan aquifer, southeastern Minnesota: U.S. Geological Survey Open File Report 91-480. 2 p.

RELATION OF WATER QUALITY TO SELECTED PHYSICAL FACTORS IN DAKOTA COUNTY, MINNESOTA, 1990-91

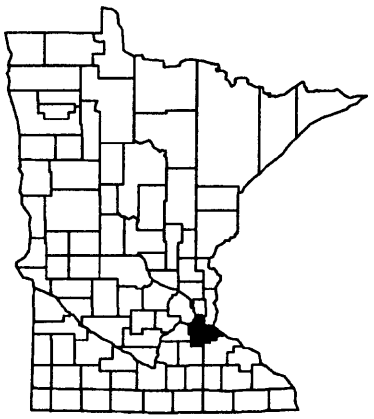
MN123

DATE PROJECT BEGAN: November 1989

DATE PROJECT ENDED: September 1991

PROJECT CHIEF: Almendinger, James E.

LOCATION: Southeastern Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources, Legislative Commission on Minnesota Resources and Dakota County Soil and Water Conservation Distri.

PROBLEM: The headwaters area of the Vermillion River basin in Dakota County is undergoing rapid urbanization while other areas of the basin are used for agriculture. Information is needed on how the water resources are affected by urbanization, agriculture, water table depth, and soil type. The Prairie du Chien-Jordan aquifer underlies the glacial drift in Dakota County and is susceptible to contamination from land-use practices where the water table is at or near land surface.

OBJECTIVES: Describe surface- and ground-water quality in Dakota County as related to land use, surficial geology, bedrock geology, water-table depth, and soil type. Compare regional depth-to-water-table mapping methods that are used to assess ground-water susceptibility to surface contamination.

APPROACH: A file search will be done to retrieve existing streamflow and water-quality data. Five combination surface- and ground-water sites for water-quality sampling will be established in the Vermillion River basin. Streamflow data also will be collected at these sites. Water quality sampling will be done from January 1990 through June 1991 and samples will be analyzed for specific conductance, pH, water temperature, dissolved oxygen, major cations and anions, bacteria, nutrients, organics, U.S. Environmental Protection Agency priority pollutants, and triazines. Twenty domestic wells also will be sampled twice during 1990-91. The hydrologic data will be correlated with selected physical factors to determine causes for differences in the water-quality data. Geographic Information Systems software will be used for depth-to-water-table mapping.

RESULTS LAST YEAR: Collection and analysis of all water-quality data and physical factors was completed. Two methods of producing a county-wide map of depth to water table were compared and results published in a Water Fact Sheet (U.S. Geological Survey Open-File Report 91-245). A Water Fact Sheet (U.S. Geological survey Open-File Report 91-235) was prepared to describe how nitrate concentrations in ground water in Dakota County were related to both the percentage of agricultural land use and the soil type around the well. Ground water from wells

located in areas of highly leachable soil had nitrate concentrations proportional to the percentage of agricultural land use around the well. Ground water from wells located in areas of soil with low potential for leaching had low nitrate concentrations, regardless of the percentage of agricultural land use around the well. None of the constituents in the U.S. Environmental Protection Agency's list of Priority Pollutants were detected, and no triazine concentrations, determined by immunoassay, were greater than two micrograms per liter.

PLANS NEXT YEAR: Project is complete except report.

PUBLISHED REPORTS IN 1991:

Almendinger, J.E., 1991, Relation of nitrate concentrations in water to agricultural land use and soil type in Dakota County, Minnesota, 1990: U.S. Geological Survey Open-File Report 91-235, 2 p.

Lorenz, D.L. and Trotta, L.C., 1991, Preparation and comparison of maps showing the depth to the water table, Dakota County, Minnesota: U.S. Geological Survey Open-File Report 91-245, 2 p.

SPATIAL AND TEMPORAL VARIABILITY OF BASE FLOW OF A PERENNIAL STREAM, STRAIGHT RIVER, MINNESOTA

MN124

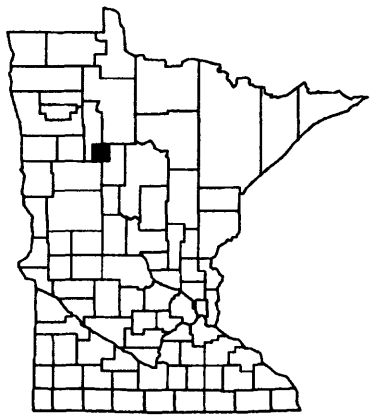
DATE PROJECT BEGAN: December 1989

DATE PROJECT ENDS: September 1992

PROJECT CHIEF: Armstrong, David S.

LOCATION: North-central Minnesota

PRINCIPAL COOPERATING AGENCY:
Minnesota Department of Natural Resources.



PROBLEM: Spatial and temporal variability in ground-water discharge to streams is complex. There is a need to understand the distribution of ground-water flow to streams and the interaction between streams and aquifers. Streamflow cannot be routinely and efficiently measured with sufficient detail and frequency to accurately determine the ground-water component of discharge to streams.

OBJECTIVES: Categorize valley reaches of similar geomorphic features (slope, sinuosity, and streambed and alluvial materials) and zones of similar hydraulic gradient between the stream and the aquifer. Determine the affect of these geomorphic features on base flow. Develop numerical models and make detailed and frequent measurements of ground-water flow to a stream to test correlations between ground-water flow and readily mapped geomorphic and sedimentologic features.

APPROACH: Two principal hypotheses will be tested during the study. The first hypothesis is that a correlation exists between geomorphic characteristics of a stream valley or channel (slope and sinuosity), and the spatial distribution of alluvial materials that resist ground-water flow between an underlying alluvial aquifer and a stream. The second hypothesis is that a correlation exists between these same geomorphic characteristics and base flow in the stream. This study will develop general conceptual models and conduct field experiments at regional and local scales to determine factors controlling spatial and temporal variability of base flow from glacial aquifers to a perennial stream. The field approach to this study will be to compare the base-flow changes between selected reaches of the river. Stream reaches of 4,000 to 7,000 ft will be selected for analysis of base flow. The test reach will have different geomorphic characteristics. For each reach, physical factors will be mapped into zones of relative base-flow potential. Base-flow gain will be measured when aquifer head and stream stage are not changing, and correlated to factors that vary within and among the reaches. Changes in base-flow gain through time caused by changes in hydraulic gradient across the streambed will be measured. General conceptual numerical models of streambed and groundwater gradients along the Straight River will be developed and used to

test stream-ground-water interactions observed during field investigations.

RESULTS LAST YEAR: Alluvial sediments were mapped using sediment cores and electromagnetic data. The distribution of fine-grained sediments appears to be better correlated with reaches of low slope, wide valley and channel width, and significant meander migration, than to channel sinuosity. Vertical hydraulic-head and stream-temperature surveys were used to classify reaches of the river where ground-water discharge occurs mainly through the streambed and reaches where discharge occurs mainly through bank seeps and springs. Water levels measured in piezometers installed near and in the river bed indicate that fine-grained alluvial-valley deposits may influence the flow path of ground-water into the river to a greater degree than was initially estimated. Data from baseflow-discharge measurements obtained at half-mile increments along the river indicate that the rate of gain of discharge varies on different scales. The river gains flow along its entire length, and the rate of gain decreases downstream. Rate of gain appears to be related to basin geometry, distribution of pumping, and flow around a dam. The rate of gain appears to differ slightly between reaches with low valley slope and fine-grained alluvial sediments, as compared with reaches to higher valley slope and coarser alluvial sediments.

PLANS NEXT YEAR: Cores will be analyzed for grain-size distribution and organic content. Additional geophysical data from seismic reflection and electromagnetic surveys will be collected along transects across the river valley. Discharge measurements will be made during a seepage run. An elevation survey of the river valley will be completed. River-valley and channel geomorphology data will be analyzed. Ground-water-level data will be analyzed along flow lines. Hypothetical ground-water models will be prepared.

AVAILABILITY AND QUALITY OF WATER FROM DRIFT AQUIFERS IN MARSHALL, PENNINGTON, POLK, AND RED LAKE COUNTIES, NORTHWESTERN MINNESOTA

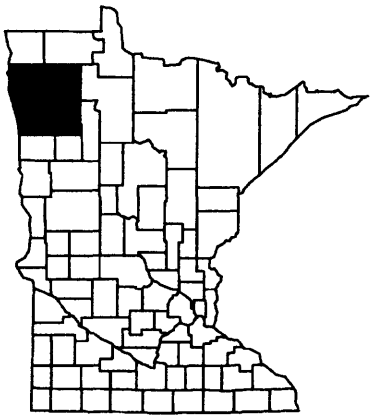
MN125

DATE PROJECT BEGAN: December 1989

DATE PROJECT ENDS: September 1993

PROJECT CHIEF: Lindgren, Richard J.

LOCATION: Northwestern Minnesota



PRINCIPAL COOPERATING AGENCIES:
Minnesota Department of Natural Resources and the Northwestern Minnesota Ground Water Steering Committee.

PROBLEM: Ground-water withdrawals are increasing in Marshall, Pennington, Polk, and Red Lake Counties where surficial aquifers are limited to scattered beach deposits formed by the ancient glacial Lake Agassiz and surface water is not a reliable source of drinking water. The glacial drift ranges from 200 to 300 ft in thickness, but little is known about the presence and availability of water from confined aquifers interbedded within the drift. The surficial (beach-ridge) aquifers, which are susceptible to land-surface contamination, could be significant areas of recharge for the underlying confined sand and gravel aquifers. High-salinity water from underlying Paleozoic and Cretaceous sedimentary rocks is believed to have migrated into the drift aquifers, resulting in some water-quality problems. The Minnesota Department of Natural Resources and a local ground-water steering committee made up of county, city, water and soil district representatives have requested the U.S. Geological Survey to study water-supply potential and water quality of the sand and gravel aquifers in the four counties to help manage the increasingly scarce ground-water resources.

OBJECTIVES: Describe the areal extent, thickness, and water-bearing characteristics of confined-drift aquifers. Estimate the water-supply potential from the surficial and uppermost confined-drift aquifers. Describe trends in water quality along regional ground-water flow paths from areas of recharge to discharge.

APPROACH: A 3 1/2-year study will be conducted under two overlapping phases. Phase I will concentrate on regional mapping and description of the confined sand and gravel aquifers in Marshall, Pennington, Polk, and Red Lake Counties. Phase II involves a more detailed study of water resource potential of the surficial aquifers (especially the beach-ridge deposits), the interaction between the surficial and confined aquifers, and ground-water quality in an area smaller than the area for phase I of the study. Data from water-well logs, field inventory of wells, and subsequent test drilling will be used to map the distribution of the uppermost confined-drift aquifers and to estimate the direction of flow in the aquifer system. Seismic-geophysical data collected by the Minnesota Department of Natural Resources will be used to further refine estimates of aquifer

distribution and depth to bedrock. A mathematical model will be constructed to test concepts of ground-water flow and recharge to the aquifer system and to guide additional data collection. Water-use data will be compiled to describe the distribution and intensity of ground-water withdrawals. Aquifer tests will be run to determine transmissivity, storage coefficients, and the effects of aquifer boundaries to water supply potential. Water levels will be measured continuously in unconfined and confined aquifers to estimate seasonal recharge, relative hydraulic connection between aquifers, and the impacts of ground-water withdrawals. Water samples will be collected from wells and analyzed for major inorganic constituents to establish baseline water-quality conditions and to define water-quality trends along regional flow paths. Water samples will also be collected from surficial aquifers and analyzed for U.S. Environmental Protection Agency priority pollutants that might be related to local land-surface activities. Specific conductance measurements of well water will be made to estimate the depth to saline ground water, especially near the Red River of the North.

RESULTS LAST YEAR: A well inventory was completed and well-log information entered into a relational data base. Fifty-five test holes were drilled to better define the extent and thickness of the unconfined-drift aquifer underlying a beach ridge near the Crookston city well field in Polk County. Unconfined-drift aquifers in the study area generally are limited to scattered beach deposits formed by the glacial Lake Agassiz. Nine observation wells were installed in the unconfined-drift aquifers to determine potentiometric surfaces and to measure water-level fluctuations. Test drilling indicated that the saturated thickness of the unconfined-drift aquifer underlying this beach ridge generally is less than 10 ft, with a maximum saturated thickness of about 30 ft. Fifty-two test holes were drilled in beach ridges in Marshall County. The test drilling indicated the saturated thickness of the unconfined-drift aquifers underlying these beach ridges generally was less than 10 ft. A part of the unconfined-drift aquifer underlying a beach ridge located east of Stephen, Minn. has a saturated thickness of from 10 to 15 ft and covers an area of about 10 square miles. Water-level fluctuations were measured monthly in 14 wells screened in the unconfined-drift aquifer and in 8 wells screened in the uppermost confined-drift aquifer in Polk and Red Lake Counties. Water samples were collected from 13 wells screened in the unconfined- drift aquifer and from 18 wells screened in the uppermost confined-drift aquifer to establish baseline water-quality conditions in the drift aquifers in the study area. All samples were analyzed for major inorganic ions, metallic elements, and dissolved organic carbon. Six of the samples collected from wells screened in the unconfined-drift aquifer also were analyzed for nutrient concentrations, including concentrations of nitrogen and phosphorus species.

PLANS NEXT YEAR: Additional test holes will be drilled and geophysical surveys conducted to better define the extent and thickness of the drift aquifers. Observation wells will be installed and periodic water-level measurements will be made in selected wells. A numerical ground-water-flow model will be constructed to develop a better understanding of the concepts of ground-water flow, boundary effects, and recharge to the aquifer system underlying a typical beach ridge in the study area. Additional water samples will be collected and analyzed to establish baseline water-quality conditions, determine possible trends in water quality relative to age and position of the water in the flow system, and determine possible effects of land-use activities on water quality.

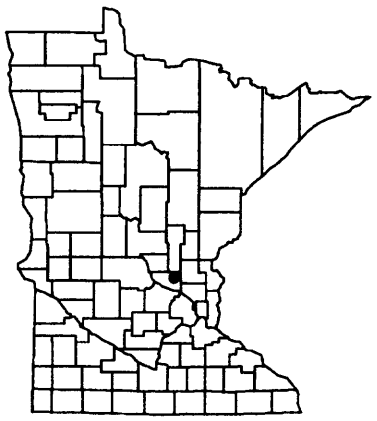
PLANNING FOR MID-CONTINENT HERBICIDE INITIATIVE
MN126

DATE PROJECT BEGAN: October 1989

DATE PROJECT ENDS: September 1993

PROJECT CHIEF: Delin, Geoffrey N.

LOCATION: East-central Minnesota



PROBLEM: Agricultural chemicals are applied most frequently in light soils with low organic content, commonly underlain by surficial sand-and-gravel aquifers. These aquifers are hydrogeologically vulnerable because they have hydraulic conductivities greater than till. To better understand the fate and transport of agricultural chemicals through the environment, a multiscale study is needed.

OBJECTIVES: Determine the fate and mobilization of agricultural chemicals in sand-plain aquifers and specifically the Anoka Sand-Plain Management System Evaluation Area (MSEA) in collaboration with the Agricultural Research Service for integrated research.

APPROACH: Concentrations of agricultural chemicals and their metabolites will be quantified, spatially and temporally, downgradient of the research plots. Research activities by U.S. Geological Survey and U.S. Environmental Protection Agency researchers at the MSEA site will be coordinated and logistical support provided. Hydrologic and chemical data of common interest to participating scientists will be collected and synthesized into a data base. The hydrology and water quality at the research farm will be described.

RESULTS LAST YEAR: The primary Minnesota MSEA research site was selected near the town of Princeton, Minn. The agricultural research plots were established, crops planted, and chemicals applied beginning in April. A numerical model was constructed using MODFLOW and used to evaluate regional ground-water flow at the site. The research plots were oriented within the field, based in part, on these model analyses. A total of 33 observation wells and 11 multiport samplers were installed at the MSEA site during 1991. A ground-penetrating radar survey was used to help characterize the site and provide stratigraphic information between the core holes. Detailed surveying was conducted to define land, water, and water-table surfaces. Preliminary hydrogeologic maps were constructed. Neutron access tubes, thermocouples, rain gages, shaft encoders, and dataloggers were installed in selected locations along the perimeter of the field and within the recharge plot. Staff gages were installed in three locations on Battle Brook. Water levels were measured daily in wells equipped with dataloggers and monthly in all other observation wells. Water samples were collected from all wells, multiports, and from Battle Brook during May (before the application of chemicals), June, and August. Concentrations of nitrate in ground water during June ranged from 0.04 to 24.58 mg/L with a mean concentration of 11.66 mg/L com-

pared to a mean of 8.22 mg/L during May. A sharp vertical gradient in nitrate concentrations was detected in 8 of the 11 multiports. About 50 percent of all ground-water samples tested positive for triazine herbicides during the June sampling period using immunoassay techniques. Water from Battle Brook tested positive for alachlor and trazine and had nitrate concentrations less than 1.0 mg/L. Results of slug tests performed on 16 observation wells at the site indicate that hydraulic conductivities range between about 90 and 160 ft/day. The average ground-water velocity at the site was calculated to be about 0.17 ft/day. Numerical modeling with the VS2D code indicated that recharge water may take between one week and 8 months to travel to the water table, which is about 3 meters below land surface. A tracer test was conducted in depression and upland areas at the recharge research site to evaluate the preferential movement of water and agrichemicals through the unsaturated zone.

PLANS NEXT YEAR: Observation wells, Battle Brook, and an irrigation well will be sampled four times. Synoptic measurements of water levels in all observation wells will be completed monthly. Sixteen additional multiport samplers will be constructed and installed prior to spring planting. The 'Integrated Workplan' and 'Site Characterization' reports will be completed. A trench will be dug in the tracer-test areas and water-flow patterns (zones of dye adsorption) will be examined during October. Soil samples will be collected from the walls of each trench, in cooperation with Rick Healy (National Research Program, Denver) and Hal Olson (Geologic Division, Denver), to determine soil moisture, bulk density, hydraulic conductivity, and dye concentration. Laboratory tracer experiments will be completed. The MODFLOW model will be used to evaluate three-dimensional movement of conservative agricultural chemicals downgradient from the research plots.

PUBLISHED REPORTS:

Anderson, J.L., Dowdy, R.H. and Delin, G.N., 1991, Ground-water impacts from irrigated ridge-tillage, *in* Ritter, W.F., ed., Irrigation and Drainage--Proceedings of the 1991 National conference sponsored by the Irrigation and Drainage Division of the America Society of Civil Engineers and the Hawaii section of the American Society of Civil Engineers, Honolulu, Hawaii, July 22-26, 1991.

Delin, G.N., 1991, Aquifer research at the management systems evaluation areas, *in* The President's water quality initiative--Inter-agency Progress and Perspectives Proceedings, Arlington, Virginia, February 6-7, 1991.

Delin, G.N., 1991, Integrated hydrologic research at the northern cornbelt sand-plain management system evaluation area, Minnesota: U.S. Geological Survey Open-File Report 91-88, 15 p.

Delin, G.N., 1991, Integrated hydrologic research at the northern cornbelt sand-plain management system evaluation area, Minnesota, *in* Mallard, G.E. and Aronson, D.A., compilers, U.S. Geological Survey Toxic Substances Hydrology Program--Proceeding of the technical meeting, Monterey, California, March 11-15, 1991 and U.S. Geological Survey Open-File Report 91-88, p.15.

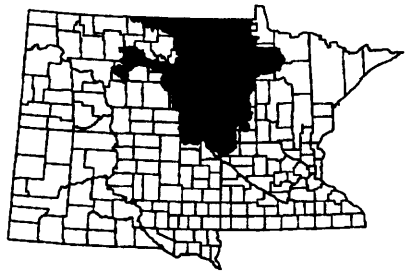
Delin, G.N., 1991, Effects of differing agricultural practices on concentrations of nitrate and atrazine in a sand-plain aquifer, western Minnesota, *in* EOS, Transactions, American Geophysical Union, Vol. 71, No. 43, p. 1163-1754, Proceedings of American Geophysical Union fall meeting, San Francisco, California, December 3-7, 1990.

NATIONAL WATER-QUALITY ASSESSMENT--RED RIVER OF THE NORTH BASIN
MN127

DATE PROJECT BEGAN: December 1990

PROJECT ENDS: September 1996

PROJECT CHIEF: Stoner, Jeffrey D.



LOCATION: Northwestern Minnesota and eastern North Dakota.

PROBLEM: Federal, State, and local governments and industry have made significant commitments to the protection of water quality over the past two decades. Large financial investments have been made for water-quality management and protection over the past 20 years and future expenditures are anticipated to abate and control water contamination. Nationally consistent information is needed to make valid regional comparisons and national statements about current water-quality conditions and about changes in these conditions. The U.S. Geological Survey began implementing a full-scale National Water-Quality Assessment (NAWQA) program in 1990 to address this need for national water-quality information. Because it would be impractical to assess water quality in every area of the Nation, major activities of the NAWQA program will take place within a set of hydrologic systems called study units. The Red River of the North basin was selected as 1 of 60 study units because the basin represents an important hydrologic region where good-quality water is a valued resource vital to the region's economy. The quality of the Red River of the North, which flows north into Manitoba, Canada, is of international concern. In keeping with the President's Water-Quality Initiative, the basin represents a significant agricultural area and provides opportunities to study sediment, nutrients, and pesticides through the national-assessment part of NAWQA. The northern location and potential interaction of surface and ground water in the Red River of the North basin are essential physical factors necessary for a complete national assessment of water quality.

OBJECTIVES: Describe the status and trends in the quality of a large, representative part of the basin surface- and ground-water resources and provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. Identify the regional physical, chemical, and biological constituents of water quality (herein called target constituents) that are of concern in the Red River of the North study unit. Estimate the distribution and annual stream load of selected nutrients, sediment, and pesticides in the basin. Describe the relation of water quality to regional land-use practices in surficial and confined aquifers within the glacial drift and major streams. Identify the predominant natural and human factors that affect the load and concentration of target constituents measured in water and aquatic animals. Describe seasonal variability of selected target constituents in major streams from agricultural runoff and from natu-

ral sources. Describe the long-term regional and subregional trends of target constituents in surface water and ground water. Design schemes for sampling surface water, ground water, and aquatic animals to effectively monitor for long-term trends in water quality.

APPROACH: Project activities will be cyclic to accomplish the water-quality status and trend components of the study. The first two years will focus on planning and analysis of available data. Years 3 through 5 will emphasize data collection and analysis followed by the 6th year for report preparation. A lower level of data collection will continue for the subsequent 5 to 6 years to evaluate long-term trends in water quality after which the more intensive data-collection cycle will be repeated. Project planning will be coordinated through a liaison committee made up of local, state, and other Federal agencies, and some Canadian agencies and private industries who will help identify key water-quality issues of the basin and sources of data, and will assist with the project design. Available water-quality and ancillary data will be compiled into computer data bases, including geographical information systems, for spatial comparisons and statistical analysis. Information from the available data will be used to design data collection networks needed to accomplish a comprehensive assessment of the basin water quality. Water will be sampled from networks of time-series and synoptic stream stations and wells, and analyzed for target constituents. Suspended and bottom sediments will be collected from major streams and analyzed for grain-size distribution and selected chemical constituents. Algae and tissues of fish and macroinvertebrates will be sampled and analyzed for selected target constituents.

PLANS NEXT YEAR: Available water-quality data will be collated and entered into a computer data base. Available ancillary data, such as land use, vegetation, climate, chemical applications, soils, hydrogeology, runoff, basin characteristics, water wells, and aquatic ecology will be obtained and, where possible, entered into a geographical information system. The available data will be analyzed for identifying the spatial occurrence of chemical and biological constituents and time trends within the basin. Bottom sediments and biological tissues will be collected from numerous stream sites and analyzed for a large suite of inorganic and organic constiuents.These data also will be used to refine specific approaches and define sampling networks to collect water-quality data. Ecological surveys will be conducted on the major streams. Communication of project plans and preliminary findings, as well as information exchange, will continue through the liaison-committee process.

PUBLISHED REPORTS IN 1991:

Stoner, J.D.,1991, National Water-Quality Assessment Program--Red River of the North: U.S. Geological Survey Open-File Report 90-151, 2 p.

GROUND-WATER RESOURCES OF THE MILLE LACS INDIAN RESERVATION IN MINNESOTA

MN128

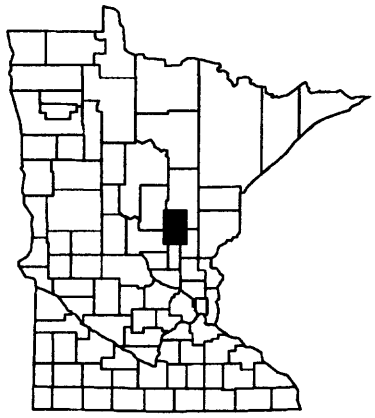
DATE PROJECT BEGAN: October 1990

PROJECT ENDS: September 1992

PROJECT CHIEF: Cowdrey, Timothy K.

LOCATION: Central Minnesota

PRINCIPAL COOPERATING AGENCY: Mille Lacs Band of Chippewa Indians



PROBLEM: In 1978, the President re-emphasized the Federal government's commitment to water-resources appraisals of Indian Reservations by directing the Bureau of Indian Affairs to develop a plan for the review of Indian water claims. The plan sets forth a strategy to gather, organize, and present information about the water resources of Indian reservations through a series of appraisal-level studies. Results from these studies are used by tribal officials for the management of water resources of the reservation. Information about the water resources of the 12 Indian reservations in Minnesota is limited, and a review of Indian water claims in Minnesota, as outlined in the Bureau of Indian Affairs plan, presently is not feasible. The Mille Lacs Reservation Band Government has requested that the U.S. Geological Survey conduct a study to provide the data and analyses needed to define the occurrence, availability, and quality of ground-water resources on the Reservation. Water managers from the Mille Lacs Reservation are interested in the potential for development of ground-water supplies and the protection of ground water from human activities on the land. In addition, the levels of smaller lakes in the area are critical to the production of wild rice and favorable waterfowl habitat, both of which are important to the economy of the Reservation.

OBJECTIVES: Determine water availability from the uppermost confined-drift aquifers. Describe the potential for contamination of the uppermost confined-drift aquifer from land-use activities. Describe potential interaction between ground water and Lake Onamia.

APPROACH: A three-year study will be conducted. Data collection and analysis will be completed during the first two years. Data interpretation and report preparation will be planned for the third year. Seismic surveys will be conducted to identify the depth to sand and gravel layers and depth to bedrock. Maps and hydrogeologic sections showing the areal extent and thickness of the uppermost confined-drift aquifer will be prepared from drill-log data and geophysical surveys. A test-drilling program will be implemented to define aquifer boundaries in areas lacking sufficient data. The presence and movement of water in the glacial aquifers will be defined by mapping the potentiometric surface from reported and measured water levels in wells. Temporal variations of

the water surface will be investigated by synoptic well water-level surveys and monthly and continuous well water-level measurements. Hydraulic properties of the aquifers will be estimated from well-log descriptions and aquifer tests. Recharge areas to the uppermost aquifers will be mapped by combining areas of high ground-water table elevation and areas of permeable overlying materials. Ground-water withdrawals will be estimated by tabulating the principal ground-water uses in the area. Water quality of the glacial aquifers will be determined by reviewing existing water-quality data bases and collecting new water from the aquifers for analyses. Areas of ground-water-pollution susceptibility will be mapped by reviewing well-log data for grain-size distribution, clay and organic content, and unit thickness. Water from the aquifer located in high-susceptibility areas will then be collected and analyzed for priority pollutants indicative of local land-use activities. Water levels in wells around Lake Onamia and staff-gage readings of the lake will be measured for one year. The potentiometric surface of shallow aquifers adjacent to the lake will be compared to the lake level to determine potential ground-water interaction with Lake Onamia. A mini-piezometer survey will be conducted in late summer to improve the understanding of this interaction.

RESULTS LAST YEAR: Well-log data from U.S. Geological Survey files and the files of the Minnesota Geological Survey were reviewed and entered into an ARC-INFO data base. This data base/geographic information system now contains (1) information from 736 wells drilled in the drainage basin of Mille Lacs Lake, (2) maps showing the thickness and extent of glacial-drift aquifers, (3) potentiometric surfaces of the aquifers, and (4) the elevation of the bedrock surface. Available geologic and hydrologic information have been used to select sites for test drilling. A drilling contract was prepared and awarded, and drilling test holes and installation of monitoring wells is complete. Two test wells were drilled, and 11 observation wells installed. At least two wells were drilled along ground-water flow lines on the south, north, east, and west sides of Mille Lacs Lake. Two additional test holes were completed on the east and south sides of the lake. Analysis of data from existing driller's logs and from test holes drilled for this project indicated that a continuous confined-drift aquifer probably does not exist within the ground-water basin for Mille Lacs Lake. These data also indicate that the glacial stratigraphy in the area is more complex that has been previously thought. This complicated stratigraphic sequence indicates that continuous, extensive glacial aquifers are not likely to be present in the area. Several discontinuous aquifers probably exist. Data also show that the bedrock surface is at a low elevation on the east and south sides of the lake. The material directly overlying bedrock consists of a weathered clay-rich regolith in some areas. Potentiometric-surface data show that the ground- and surface-water basins are nearly identical, except in the area south of the lake, where lake water may discharge to the ground-water system.

PLANS NEXT YEAR: Observation wells will be developed. Water from the observation wells and selected domestic wells will be sampled for chemical analysis. Water-level recorders will be installed on selected wells. A synoptic measurement of water levels in wells will be completed. Aquifer tests will be conducted. Soil samples from test drilling will be analyzed for grain-size distribution and for pebble lithology, to determine the sequence of glacial stratigraphy in the area. A report outline and list of illustrations will be completed. Plans for geophysical surveys also will be completed.

HYDROGEOLOGY OF THE GRAND PORTAGE INDIAN RESERVATION, NORTHEASTERN MINNESOTA

MN129

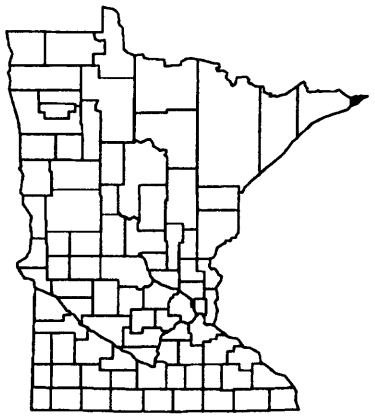
DATE PROJECT BEGAN: April 1991

DATE PROJECT ENDS: September 1994

PROJECT CHIEF: Ruhl, James F.

LOCATION: Northeastern Minnesota

PRINCIPAL COOPERATING AGENCY: Grand Portage Band of Chippewa Indians



PROBLEM: The Grand Portage Band of Chippewa Indians has identified two critical issues regarding the management, use, and protection of ground water at the Reservation. First, the efficient development of ground-water supplies for commercial and residential use. Second, the potential migration of contaminants from on-land waste-disposal sites to aquifers used as sources of drinking water. Information about the hydrogeology and water quality of the aquifers at the Reservation currently is limited to regional-scale descriptions determined from reconnaissance-level investigations. Reservation officials have expressed a need for more information about local ground-water conditions to better deal with these issues.

OBJECTIVES: Determine the general availability and quality of ground water with special emphasis at designated development areas. Evaluate the potential for aquifer contamination from on-land waste disposal sites.

APPROACH: Stream-discharge data will be collected at gaging stations on the Reservation River and Grand Portage Creek. Approximately three monitoring wells will be installed. Water-level changes in monitoring wells will be compared to stream discharge data to estimate aquifer properties. Aquifer properties also will be evaluated on the basis of specific capacity tests conducted on the monitoring wells.

RESULTS LAST YEAR: A continuous-record stream gage was installed along the Reservation River at Highway 61 and a staff gage was constructed on Grand Portage Creek, at Grand Portage, during late April. Streamflow measurements were made at these sites approximately every month. Sites were selected for installation of monitoring wells. One site is near a landfill and the other two sites are in areas where the uppermost bedrock formations are used as sources of ground-water supply. Selection of the site near the landfill was made because of the potential for ground-water contamination. Selection of the other two sites was made because of the opportunity to gain useful hydrogeologic information about the principal bedrock units that are used as aquifers. The bedrock formations in the study area that are known or potential sources or ground-water supply are the Middle-Proterozoic North Shore Volcanic Group, which consists of basaltic and rhyolitic

lava flows; Middle-Proterozoic Keweenawan, which consists of undivided intrusive gabbro; and Puckwunge Sandstone. Another potential source of ground water are alluvial sand and gravel deposits, although information about existing wells indicate this source currently is untapped. Available drillers' logs indicate existing wells in the study area are completed in the North Shore Volcanic Group and Keweenawan in approximately equal numbers. Transmissivities of these bedrock units, estimated from data on about 20 drillers' longs, varies over 3 orders of magnitude, from 5 to 480 feet squared per day. Most values are between 15 and 40 feet squared per day.

PLANS NEXT YEAR: Collect water-quality data and conduct aquifer testing on the test wells. Continue operation of stream gages.

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