WATER RESOURCES ACTIVITIES

IN MICHIGAN, 1991

Compiled by R.M. Corey

U.S. GEOLOGICAL SURVEY

Open-File Report 92-157

Prepared in cooperation with

State and Federal Agencies

Lansing, Michigan
1992

U.S. DEPARTMENT OF THE INTERIOR

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INTRODUCTION

This report was compiled to provide information on the water resources activities of the U.S. Geological Survey in Michigan.

The U.S. Geological Survey

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

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

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the USGS remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate unbiased information about the natural resources of the Nation.

Water Resources Division's Mission and Program

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization and management of the Nation's water resources for the overall benefit of the people of the United States. This is accomplished, in large part, through cooperation with other Federal and non-Federal agencies by:

* Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.
* Conducting analytical and interpretive water-resource appraisals describing the occurrence, the availability, and the physical, chemical, and biological characteristics of surface and ground water.
* Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related fields of science to improve the scientific basis for investigations and measurement techniques, and to understand hydrologic systems sufficiently well to quantitatively predict their response to natural and human caused stress.
* Disseminating water data and results of these investigations and research through reports, maps, computerized information services, and other forms of public releases.
* Providing scientific and technical assistance in hydrology to other Federal agencies, to State and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.

WATER RESOURCES ACTIVITIES IN MICHIGAN

The water-resources program in Michigan is, in part, planned and funded with local and state agencies through cooperative programs. If a proposed project is mutually advantageous to the U.S. Geological Survey and to a state or local agency, the U.S. Geological Survey may enter into a formal cooperative agreement to collect needed information. In most cases, costs are shared equally between the U.S. Geological Survey and the cooperator. These cooperative programs are reviewed annually, and thus, are responsive to the current needs in the State. In Michigan, the program is conducted in cooperation with the following agencies or units of government:

Michigan Department of Natural Resources (MDNR)
  Fisheries Division
  Geological Survey Division
  Land and Water Management Division
  Surface Water-Quality Division

Michigan Department of Transportation

City of Adrian
City of Ann Arbor
City of Battle Creek
City of Cadillac
City of Clare

City of Coldwater
Village of Elsie
City of Flint
Genesee County
Huron County

Huron-Clinton Metropolitan Authority
Imlay City
City of Kalamazoo
Kalamazoo County
City of Lansing

Macomb County
Monroe County
City of Negaunee
City of Norway
Oakland County Drain Commission

Otsego County Road Commission
City of Portage
City of Portland
Tri-County Regional Planning
Wayne County
City of Ypsilanti

The U.S. Geological Survey also performs work for other Federal agencies, the cost of which is borne by the requesting agency. Currently work is underway for the following:

U.S. Air Force

U.S. Environmental Protection Agency

U.S. Army Corps of Engineers

U.S. Bureau of Indian Affairs

District Office Organization

The Michigan District office of the U.S. Geological Survey's Water Resources Division is located in Lansing, Michigan; field headquarters are located in Escanaba and Grayling (fig. 1).

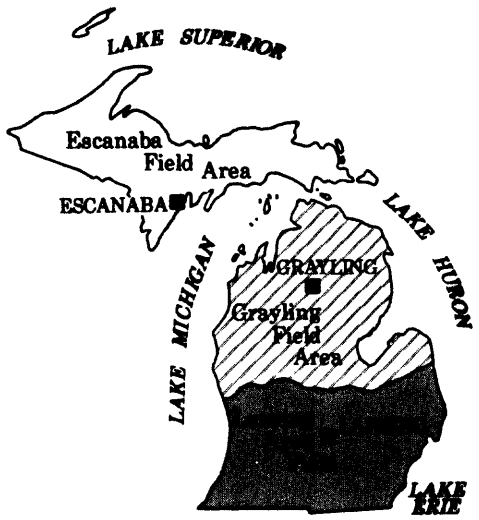
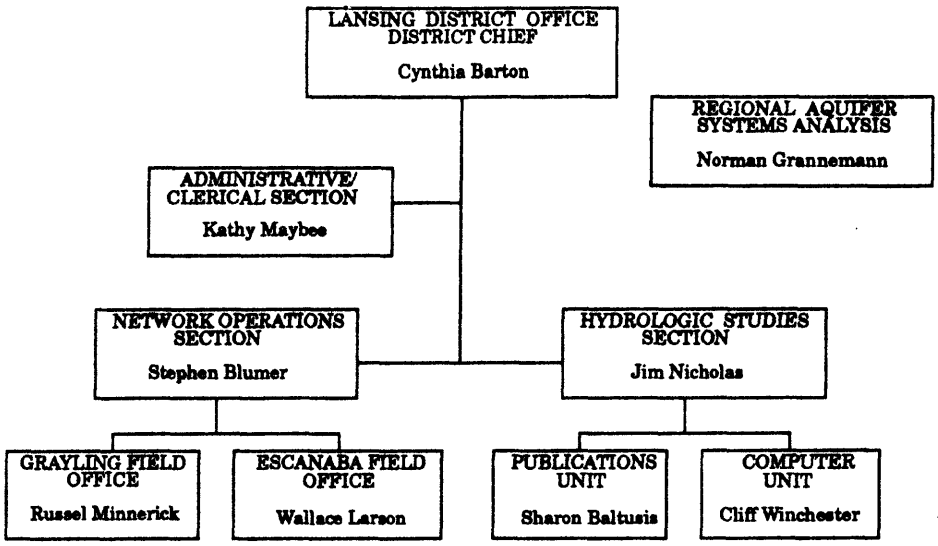


Figure 1.--U.S. Geological Survey Water Resources Division offices in Michigan.

The District has 34 employees. The employees consist of professional hydrologists that represent a variety of scientific backgrounds, including engineering, chemistry, biology, geology, environmental science, and mathematics. The hydrologists are supported by an experienced staff of hydrologic technicians and clerical and administrative personnel.

District operations are grouped into three sections--Administrative/ Clerical, Hydrologic Studies, and Network Operations (fig. 2). The function and major purpose of each section are described in the following paragraphs.



Office	Phone	Address
Lansing	(517) 377-1608	6520 Mercantile Way, Suite 5 Lansing, Michigan 48911-5971
Escanaba	(906) 786-0714	205 State Office Building Escanaba, Michigan 49829
Grayling	(517) 348-8291	P.O. Box 485 Grayling, Michigan 49738

Figure 2.--Michigan District organization chart and office addresses.

Administrative/Clerical Services Section

This section provides the District guidance and support services for financial planning, analysis, and management; manpower development and utilization; acquisition procedures and property management; general clerical procedures; and compliance with federal regulations and operating policies.

Hydrologic Studies Section

This section analyzes and interprets hydrologic data as it relates to the problems of water-resources management and development. Present activities include studies of surface- and ground-water conditions in specified areas, investigations of the chemical, physical, and biological properties of water, studies related to ground-water contamination, land-use studies, and miscellaneous investigations to assist community and state planning agencies in management decisions. This section also conducts hydrologic investigations to determine availability, quantity, quality, and use of water within the State; these investigations generally are of short duration, areal in nature, and require a thorough understanding of hydrology.

In addition to the above work, reports on the results of hydrologic investigations are processed within this section prior to publication. Several different publication outlets are used to accommodate the diversity of subject matter. Most reports are published in a formal series of the U.S. Geological Survey or of a cooperating agency.

Network Operations Section

This section is responsible for the collection and publication of hydrologic data including records of stream discharge, ground-water levels, and quality of water. Data are collected as part of a statewide network, and are used in projects designed to appraise the water resources of the state. Reports containing these data are published annually. Hydrologic data are

also stored in the Survey's computer storage file called WATSTORE. Surface-water, ground-water, and quality of water data are available for tabular presentation, statistical manipulation, or graphical display.

Regional Aquifer Systems Analysis Office

The Regional Aquifer Systems Analysis (RASA) office has been established in Lansing to conduct a 9-year study of the major aquifers in the Michigan basin, and to define the occurrence of saline waters that underlie fresh waters throughout the Lower Peninsula. N.G. Grannemann, the RASA project chief, is supported by a staff of one full-time hydrologist and five part-time hydrologists headquartered at the Lansing District office.

Types of Funding

Funding for the water-resources programs falls into two broad categories. In the 1991 fiscal year, about 40 percent of the program is composed of hydrologic-data collection (fig. 3), i.e., operation of surface-water gaging stations, measurement of ground-water levels, and collection of samples for chemical and physical analysis. These data are collected largely on a routine basis at fixed sites. Periods of data collection vary from several months to many years. Areal appraisals and interpretive studies, which constitute about 60 percent of the program, consist of a variety of investigations. Some may be statewide in character, others address very localized problems. Such studies may range from complex, highly technical computer models of surface-water or ground-water systems, to reconnaissance appraisals of water resources.

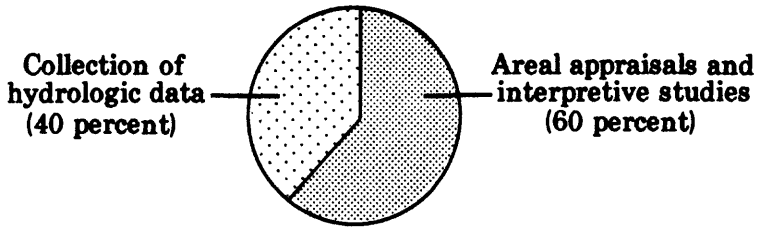


Figure 3.--Distribution of funding by category of work performed in fiscal year 1991, in Michigan

The water-resources program is supported by funds or services provided by State and local agencies. As part of the Federal-State Cooperative program, State and local funds are matched on a 50-50 basis by funds appropriated to the Geological Survey by Congress for that purpose. Other Federal agencies (OFA) also support data collection and studies; direct appropriations to the Geological Survey (Federal program) are also available. In fiscal year 1991, the financial support for work in Michigan amounts to about $3,180,000. It is distributed as shown in figure 4.

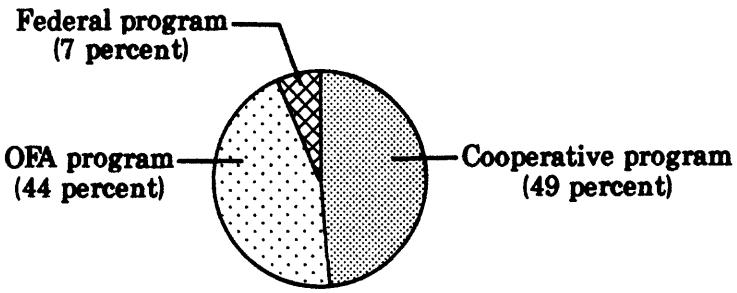


Figure 4.--Sources of funding for Michigan District 1991 water resources program.

INFORMATION IN THIS REPORT

This report consists of four sections: (1) current projects, (2) hydrologic conditions, (3) hydrologic-data stations, and (4) sources of information. The current-projects section contains information concerning the status of all projects that are presently active. The section on hydrologic-data stations gives locations where surface-water and ground-water data are collected and the types of records available. The hydrologic-conditions section provides general statewide information on water resources. The sources-of-information section contains a listing of publications resulting from work done by the U.S. Geological Survey and cooperating organizations.

(PAGE 11 follows)

CURRENT PROJECTS

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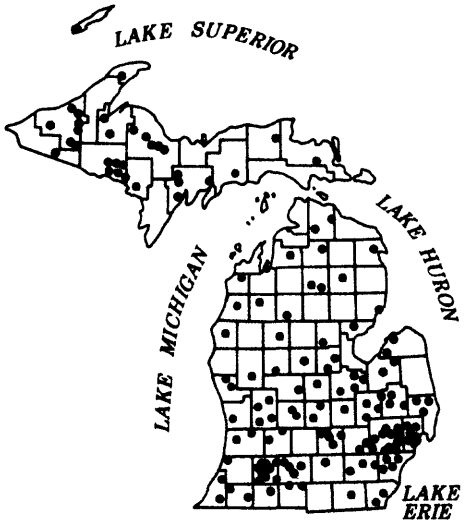
Surface-Water Stations (MI 001)



PROBLEM: Surface-water information is needed for purposes of surveillance, planning, design, hazard warning, water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. To provide this information, an appropriate data base is necessary.

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

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

RESULTS LAST YEAR: Data were collected at, and published for, the number of stations given in the following table:

Station classification	Number of stations
Stream stations	
Continuous record:	
Discharge and stage	146
Stage only	1
Partial record:	
Peak (maximum) flow only	45
Low (minimum) flow only	7
Peak and low flow	1
Lake and reservoir stations	
Stage and contents	5
Stage only	24
Total	229

PLANS THIS YEAR: Gaging-station network will continue in operation. New stations will be constructed as projects develop and existing stations will be relocated, reequipped, and modernized to improve quality of record, or discontinued to meet changing needs of projects and cooperators and to fulfill network-evaluation requirements.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

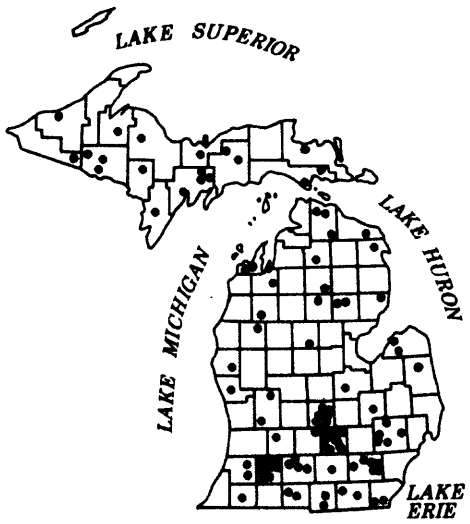
PROJECT CHIEF: Stephen P. Blumer

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES: Michigan Department of Natural Resources
Michigan Department of Transportation
Local units of government
U.S. Army Corps of Engineers

REPORTS COMPLETED: Data included in U.S. Geological Survey annual Water-Data Report "Water Resources Data--Michigan."

Ground-Water Stations (MI 002)



PROBLEM: Long-term water-level records are needed to evaluate the effects of climatic variations on the recharge to and discharge from ground-water systems, to provide a data base from which to measure the effects of development, to assist in the prediction of future supplies, and to provide data for management of the resource.

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

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

RESULTS LAST YEAR: Water levels were measured in, and published for, wells as follows:

Station classification	Number of stations
Observation wells:	
Recording	58
Nonrecording	49
Total	107

PLANS THIS YEAR: Continue to operate network and evaluate station requirements for most effective network.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

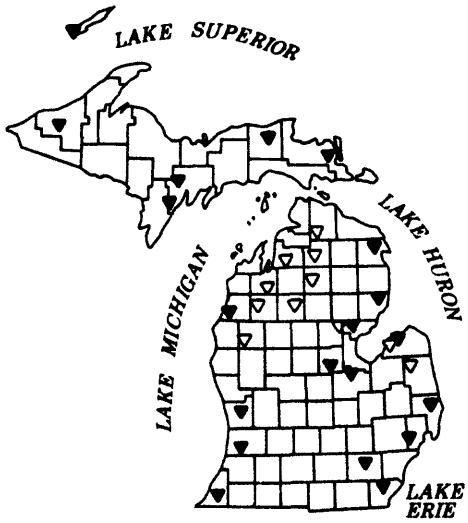
PROJECT CHIEF: Charles R. Whited

PERIOD OF PROJECT: Continuous

COOPERATING AGENCIES: Michigan Department of Natural Resources
Local units of government
Other Federal agencies

REPORTS COMPLETED: Data included in U.S. Geological Survey annual Water Data Report "Water Resources Data--Michigan" and Open-File Report "Ground-Water Data for Michigan."

Water-Quality Stations (MI 003)



EXPLANATION

▼ **Surface-water station**

▽ **Ground-water station**

PROBLEM: Water-resource planning and water-quality assessment require a nationwide base of information. To obtain this information, the chemical and physical quality of surface water and ground water must be defined and monitored. In addition, long-term sampling stations representing the numerous hydrological accounting units in Michigan must be operated to meet the objectives of the National Stream Quality Accounting Network (NASQAN).

OBJECTIVES: (1) Provide current and long-term data sufficient to describe water-quality conditions of surface and ground water in Michigan that are needed by planning and management agencies, (2) improve the water-quality data base in Michigan so that future assessments can be more effective, (3) operate the National Stream Quality Accounting Network, and (4) collect samples from wells throughout the State to establish a base against which future water-quality data can be compared and against which the effect of new and additional stresses can be evaluated.

APPROACH: Operate a network of water-quality stations to meet the needs of the State of Michigan and the objectives of national programs. Standard methods of data collection will be used.

RESULTS LAST YEAR: Data were collected at, and published for, the number of data types given in the following table:

Data classification	Number of sites
Surface water:	
Physical data (daily frequency):	
Water temperature	1
Chemical data:	
Inorganic constituents	20
Organic constituents	1
Pesticides	1
Radiochemical data	2
Biological data	20
Ground water:	
Physical data:	
Water temperature	5
Specific conductance	11
pH	11
Chemical data:	
Inorganic constituents	11
Organic constituents	11
Radiochemical data	11

Several types of data were collected at some sites.

PLANS THIS YEAR: Continue to operate network. Number of collection sites, frequency of data collection, and parameters to be measured will be adjusted if and as necessary, in consultation with cooperating agencies, to keep network in line with current needs for water-quality data.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Stephen P. Blumer

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources
U.S. Army Corps of Engineers
City of Ann Arbor

REPORTS COMPLETED: Data included in U.S. Geological Survey annual Water Data Report "Water Resources Data--Michigan" and Open-File Report "Ground-Water Data for Michigan."

Sediment Stations (MI 004)

PROBLEM: Water-resources planning and water-quality assessment require a nationwide base level of relatively standardized information. Sediment concentrations and discharges in rivers and streams must be defined and monitored.

OBJECTIVES: (1) Establish and operate a network of daily and periodic fluvial sediment stations to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and particle size of sediment being transported by streams. Define yields and transport characteristics for the principal drainage basins in the State, (2) contribute to a national bank of sediment data for use in broad federal planning and action programs, and (3) provide data for federal management of interstate and international waters.

RESULTS LAST YEAR: Sediment data were collected, analyzed and prepared for publication for several NASQAN and miscellaneous stream-measurement sites.

PLANS THIS YEAR: Sediment data will be collected at existing NASQAN stations and new stations will be established to meet the need of new projects.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Stephen P. Blumer

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Data included in U.S. Geological Survey annual Water Data Report "Water Resources Data--Michigan."

Water Use (MI 007)

PROBLEM: Michigan waters are under stress as a result of increasing demands by domestic, industrial, agricultural, and other users. Competition for water suggests that available supplies be matched to uses most beneficial to all citizens. Without accurate information on water use, addressing the wide range of problems is difficult. There has been little standardization of data or of methods used in collecting the data. Standards of accuracy vary over a wide range. Because water-use data are required for planning, long-range forecasting, and for estimating water availability, there is a need to coordinate and systematize data collection activities, and to develop standards of accuracy for data.

OBJECTIVES: (1) Provide water-use information for the optimum utilization and management of the State's water resources for the overall benefit of the people of Michigan and the Nation, (2) collect, store, and disseminate water-use data to complement data on availability and quality of the State's water resources, and (3) develop and operate a system to handle the data.

APPROACH: Responsibilities are divided between the State of Michigan and the U.S. Geological Survey to reflect the most efficient means of meeting the objectives of the program. Direction, management, and standards development to meet National needs are the responsibility of the U.S. Geological Survey. Field activities for the acquisition and storage of the data are the primary responsibility of the State.

RESULTS LAST YEAR: Compiled data for Michigan's contribution to the Estimated Use of Water in the United States in 1990.

PLANS THIS YEAR: Coordinate an orderly and timely transfer of water-use data from the State to the U.S. Geological Survey data base. Establish a site specific data base for data storage and retrieval using the current data supplied from the State.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Thomas E. Behrendt

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS IN PROGRESS: Estimated Use of Water in the United States in 1990.

REPORTS COMPLETED: Bedell, D.J., and Van Til, R.L., 1979, Irrigation in Michigan, 1977: Michigan Department of Natural Resources, Water Management Division, 44 p.

Bedell, D.J., 1982, Municipal water withdrawals in Michigan: Michigan Department of Natural Resources, Water Management Division, 43 p.

Van Til, R.L., and Scott, G., 1986, Water use for thermoelectric power generation in Michigan: Michigan Department of Natural Resources, Engineering and Water Management Division, 42 p.

Sweat, M.J., and Van Til, R.L., 1988, Water use and methods of data acquisition in Michigan, in, M. Waterstone and R.J. Burt, eds., Water-use data for water resources management, Tucson, 1988, Proceedings: American Water Resources Association, p. 133-141.

Sweat, M.J., and Van Til, R.L., 1989, Michigan--Water supply and use, in, National Water Summary 1987--Hydrologic events and water supply and demand: U.S. Geological Survey Water Supply Paper 2350, p. 305-312.

Ground-Water Study of Wurtsmith Air Force Base (MI 032)

PROBLEM: Volatile and semivolatile hydrocarbons have been found at several places in the ground-water system and on soils at Wurtsmith Air Force Base. Continued study of newly detected problems is required to permit Air Force management to assess present remedial actions and, if appropriate, institute new actions.

OBJECTIVES: (1) Determine the rate and direction of ground-water flow at Wurtsmith Air Force Base, (2) determine the extent and distribution of contaminants in the ground-water system, (3) investigate all suspected sources of ground-water contamination, including past and present landfill areas, (4) investigate sites for developing new Base water supplies, (5) refine previously developed mathematical ground-water-flow model, (6) design hydrologically efficient purge systems for removal of contaminants from the aquifer, (7) establish data base and statistically analyze historic data, and (8) conduct literature survey of ground-water-sampling methods.

APPROACH: (1) Conduct soil gas surveys at sites where ground-water contamination is known or suspected, (2) install water-quality monitoring wells and collect samples of soil for chemical analysis at seven sites, (3) assemble and summarize literature on sampling techniques, and (4) statistically analyze historic ground-water quality data using techniques developed by the U.S. Geological Survey.

RESULTS LAST YEAR: Study of newly detected contamination was continued, and an examination of potentially hazardous waste sites begun as part of the U.S. Air Force's Installation Restoration Program. Created a data base for historic water-quality data. Literature survey completed. Ground-water purge systems designed for two areas.

PLANS THIS YEAR: Continue investigations of contamination of water by fuel substances in western part of the Base, and define plume associated with Three Pipes Drain and redesign the purge system. Prepare Administrative and Open-File Reports for the U.S. Air Force.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Northeastern Lower Peninsula, Michigan

PROJECT CHIEF: John L. Gillespie

PERIOD OF PROJECT: April 1987 to September 1992

COOPERATING AGENCY: U.S. Air Force

REPORTS IN PROGRESS: None

REPORTS COMPLETED: Stark, J.R., Cummings, T.R., and Twenter, F.R., 1983, Ground-water contamination at Wurtsmith Air Force Base, Michigan: U.S. Geological Survey Water-Resources Investigations Report 83-4002, 93 p.

Cummings, T.R., and Twenter, F.R., 1986, Assessment of ground-water contamination at Wurtsmith Air Force Base, Michigan, 1982-85: U.S. Geological Survey Water-Resources Investigations Report 86-4188, 120 p.

Holtschlag, D.J., 1990, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: An environmental data-base system: U.S. Geological Survey Administrative Report.

Gillespie, J.L., 1990, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: Hydrogeology near Wurtsmith Air Force Base: U.S. Geological Survey Administrative Report.

Dumouchelle, D.H., Lynch, E.A., and Cummings, T.R., 1990, A literature survey of information on well installation and sample collection procedures used in investigation of ground-water contamination by organic compounds: U.S. Geological Survey Open-File Report 90-378, 60 p.

REPORTS COMPLETED--Continued

Cummings, T.R., and Gillespie, J.L., 1991, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 1, Wurtsmith Air Force Base, Michigan: Investigations of ground-water contamination at selected sites: U.S. Geological Survey Administrative Report.

Holtschlag, D.J., 1991, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: A sequential sampling design for Long-term, ground-water-quality monitoring: U.S. Geological Survey Administrative Report.

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Michigan Basin Regional Aquifer System Analysis (MI 041)

PROBLEM: About half of Michigan's population depends on ground water as the source of domestic and public supply. The potential for development of supplies in large areas of the Lower Peninsula, however, is not well defined. Additionally, saline water underlies the freshwater aquifers over the entire extent of the study area at an indeterminate depth. Migration of saline water resulting from excessive pumping or drilling boreholes too near the transition from freshwater to saline water has caused abandonment of wells. The two primary bedrock aquifers, the Marshall and Grand River-Saginaw, are used extensively where they contain freshwater. In the Lansing area, water levels have been as much as 160 feet below prepumping levels. A better understanding of the hydrogeology and the occurrence of fresh and saline water is necessary for effective management of the region's ground-water resources.

OBJECTIVES: (1) Describe the geologic, hydrologic, and chemical quality characteristics of water-bearing rocks in the central part of the Michigan basin, (2) delineate the vertical and areal extent of saline water and identify areas subject to saline-water contamination, (3) using computer models, simulate the three-dimensional movement of ground water through the aquifers under study, and (4) relate ground-water chemistry to rock mineralogy and ground-water movement through the use of geochemical models and laboratory analysis of rock and water chemistry.

APPROACH: (1) Develop a detailed work plan and review existing literature, (2) compile pertinent data from all sources, (3) using borehole geophysical and geologic logs, define the geologic framework, (4) using borehole geophysical logs, water-quality analyses, and surface geophysics, delineate transition from fresh to saline ground water, (5) develop a density-dependent ground-water flow model to simulate regional ground-water movement, (6) where appropriate, develop small-scale solute transport models to test hypotheses regarding movement of saline ground water, (7) collect ground-water samples for laboratory analysis to define regional ground-water chemistry, and (8) collect rock samples for laboratory analysis to define rock chemistry and mineralogy to define rock-water interactions that may be occurring.

RESULTS LAST YEAR: Maps showing thickness, structure, potentiometric surface, geochemical facies, and dissolved-ion distribution for each aquifer were updated. Reports on matrix-controlled hydraulic properties, physical and chemical properties of ground water, and municipal ground-water withdrawal were published.

PLANS THIS YEAR: Publish thickness and structure contour maps of aquifers and confining units. Begin work on reports that illustrate the potentiometric surfaces for the Marshall, Grand River-Saginaw, and Glacial-Drift aquifers in the study area. Continue evaluation of geochemistry of solid and aqueous phases using laboratory analysis, geochemical modeling, and statistical analysis. Continue ground-water-flow model development using reanalyzed geologic framework data to define physical extent to model layers.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Lower Peninsula, Michigan

PROJECT CHIEF: Norman G. Grannemann

PERIOD OF PROJECT: October 1985 to September 1994

REPORTS COMPLETED: Mandle, R.J., 1986, Plan of study for the Regional Aquifer-System Analysis of the Michigan Basin: U.S. Geological Survey Open-File Report 86-494, 23 p.

Mandle, R.J., and Westjohn, D.B., 1987, Preliminary interpretation of vertical electrical-resistivity soundings in the Saginaw Valley, Michigan: U.S. Geological Survey Open-File Report 87-474, 45 p.

Westjohn, D.B., and Carter, P.J., Jr., 1989, Direct-current vertical-electrical resistivity soundings in the Michigan basin: U.S. Geological Survey Open-File Report 89-244, 57 p.

REPORTS COMPLETED--Continued

Westjohn, D.B., Olsen, H.W., and Willden, A.T., 1990, Matrix-controlled hydraulic properties of Mississippian and Pennsylvanian sandstones from the Michigan basin: U.S. Geological Survey Open-File Report 90-104, 42 p.

Dannemiller, G.T., and Baltusis, M.A., Jr., 1990, Physical and chemical data for ground water in the Michigan basin, 1986-89: U.S. Geological Survey Open-File Report 90-368, 155 p.

Baltusis, M.A., Quigley, M.F., and Mandle, R.J., Municipal ground-water development and withdrawals in the central Lower Peninsula of Michigan, 1870-1987: U.S. Geological Survey Open-File Report 91-215, 89 p. [in press].

(PAGE 31 FOLLOWS)

Hydrogeology of K.I. Sawyer Air Force Base (MI 043)

PROBLEM: Information on the hydrogeology at K.I. Sawyer Air Force Base is inadequate for description and evaluation of potential problems, for management and protection of Base water resources, and for development of needed Base water-supply capacity. Volatile and aromatic hydrocarbons have been found in ground water at several locations on the Base, and in Silver Lead Creek. Additional information on the hydraulics of the ground-water system and movement and dispersion of contaminants are needed to trace contaminants to their origin and to predict movement of contaminants in ground water.

OBJECTIVES: (1) Determine geologic conditions at and near K.I. Sawyer Air Force Base, (2) determine direction and rate of ground-water flow, (3) determine chemical characteristics of ground water, including both organic and inorganic substances, (4) locate source or sources of contaminants, (5) determine extent and distribution of contaminants both on soils and in ground water, and (6) determine if there is a relation between contaminants detected in ground water and contaminants detected in Silver Lead Creek.

APPROACH: (1) Evaluate available geologic and hydrologic data, (2) using geophysical techniques, determine altitude of bedrock surface and lithologic characteristics of glacial deposits, (3) install wells on Base and in surrounding area, (4) make routine water-level measurements, either weekly, monthly, or with recording equipment, (5) conduct pumping tests on selected wells to determine hydraulic properties of the aquifer, and (6) collect water samples from wells for analysis of volatile and aromatic hydrocarbons

and common dissolved substances (make field measurements of specific conductance, pH, and temperature).

RESULTS LAST YEAR: A ground-water-flow model was developed to simulate ground-water movement on the Base. The model was used to evaluate remedial options for two of the sources of contamination. Ninety-seven new observation wells were drilled and water from 329 wells was sampled and analyzed. Water-levels were measured in all sampled and new wells and in wells that were suspected of containing floating fuel product.

PLANS THIS YEAR: Continue to evaluate data and prepare report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Central Upper Peninsula, Michigan

PROJECT CHIEF: John R. Brannen

PERIOD OF PROJECT: April 1985 to September 1992

COOPERATIVE AGENCY: U.S. Air Force

REPORTS IN PROGRESS: Cummings, T.R., Brannen, J.R., and Grannemann, N.G., 1991, Investigations of ground-water and soil contamination at selected sites: U.S. Geological Survey Administrative Report.

REPORTS COMPLETED: Grannemann, N.G., and Cummings, T.R., 1987, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 1, Hydrogeology of K. I. Sawyer Air Force Base, Michigan: U.S. Geological Survey Administrative Report.

Chemical and Physical Characteristics of Natural Ground Waters (MI 047)

PROBLEM: Detailed information on the chemical and physical characteristics of natural ground waters is inadequate. Substantial data need to be obtained to establish baseline conditions against which long-term changes in water quality can be judged, and for properly evaluating the degree and severity of contamination when it occurs. Information is also critical to support development of ground-water protection strategies, and to ensure their successful implementation. Systematic methods of integrating new data with those collected earlier, and of analyzing their significance, need to be developed.

OBJECTIVES: (1) To determine, evaluate, and describe the chemical and physical characteristics of natural ground waters in Michigan, (2) to establish a procedure for rapidly updating statistical summaries of file data, and to make the information available to users on request, and (3) to better understand the relation of ground-water quality to statewide geochemical conditions.

APPROACH: (1) Ground waters will be sampled at selected sites to define water-quality characteristics of aquifers statewide, (2) field analyses of specific conductance, temperature, dissolved oxygen, pH and alkalinity will be made, (3) laboratory analyses will be performed for common substances, trace metals, and pesticides, and isotopes (tritium, O^{18}/O^{16}, N^{15}/N^{14}, S^{34}/S^{32}, C^{14}, C^{13}/C^{12}, deuterium/protium, and radon 222), (4) isotopic analyses of rainfall will be made by Michigan State University, (5) results of chemical analyses will be stored in a dedicated file and updated as new

results become available. P-STAT or IMSL will be used to update statistical summaries, graphically display results, and provide hard copy, and (6) analyze and evaluate data; write and publish report.

RESULTS LAST YEAR: Samples of the analysis of stable isotopes were collected in the Upper Peninsula and northern part of the Lower Peninsula. A contract was let with Michigan State University to analyze for isotopes in precipitation.

PLANS THIS YEAR: Continue collection of stable isotope data on natural ground water; complete the analysis of precipitation.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: John L. Gillespie

PERIOD OF PROJECT: January 1986 to September 1991

COOPERATIVE AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Cummings, T.R., 1980, Chemical and physical characteristics of natural ground waters in Michigan: A preliminary report: U.S. Geological Survey Open-File Report 80-953, 34 p.

Cummings, T.R., 1989, Natural ground-water quality in Michigan, 1974-87: U.S. Geological Survey Open-File Report 89-259, 50 p.

Hydrogeology of Huron County (MI 048)

PROBLEM: A shortage of ground water of good quality has caused serious problems in Huron County. In part, problems are related to geologic conditions. Thick sands and gravels are absent in much of the county; at places, bedrock yields insufficient water or only highly mineralized water. Pumping of irrigation and municipal wells in the western part of the county seems to cause salty water to migrate upward. Hydrogeologic information is inadequate to determine if enough good-quality water is available to meet long-term needs. Lack of information precludes development of sound ground-water management policies for the county.

OBJECTIVES: (1) Determine geologic, hydrologic, and cultural factors that influence the quantity and quality of ground water, and its direction and rate of flow, (2) define areal and vertical distribution of major chemical constituents in aquifers that are, or could be, sources of supply, (3) evaluate conditions in existing problem areas and suggest, if possible, alternative sources or approaches for obtaining supplies, and (4) provide the water-resources information and data needed for county officials and water managers to plan for future industrial, commercial, and agricultural development, and for the expansion of tourism.

APPROACH: (1) Evaluate available hydrologic and geologic data contained in State, county, and U.S. Geological Survey files, (2) install about forty 4-inch wells, (3) collect water-quality data from about 50 wells, (4) collect ground-water level data at about 50 sites, (5) install digital recorders on two wells, (6) conduct pumping tests as needed, (7) use geophysical techniques to aid in determining lithologic and stratigraphic

features of the glacial deposits and bedrock, (8) make discharge measurements at about 10 stream sites approximately three times per year during low flow, (9) collect samples for chemical analysis at the time discharge measurements are made, and (10) analyze and evaluate data; write and publish report.

RESULTS THIS YEAR: Prepared water table map, bedrock top map, aquifer thickness maps, and geologic sections showing relation of aquifers to each other and to confining beds. Conducted pumping tests. Report completed.

PLANS THIS YEAR: Publish report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Eastern Lower Peninsula, Michigan

PROJECT CHIEF: Michael J. Sweat

PERIOD OF PROJECT: May 1987 to July 1991

COOPERATING AGENCIES: Huron County
Michigan Department of Natural Resources

REPORTS COMPLETED: Sweat, M.J., 1991, Hydrogeology of Huron County, Michigan: U.S. Geological Survey Water-Resources Investigations Report 91-4133, 76 p.

Ground Water at the Verona Well Field, Battle Creek (MI 049)

PROBLEM: Organic chemicals were detected in the City of Battle Creek's Verona well field in 1981. Studies by various agencies defined the major problems and, based on the studies, a series of existing water-supply wells were converted to purge wells to intercept contaminated water moving to the well field. Although the purge system is functioning as planned, the reduced number of production wells has created a water-supply problem. In addition, contaminants from a gasoline spill are moving toward three of the city's most used production wells. If these wells are taken out of service, the water-supply shortage will become especially acute.

OBJECTIVES: (1) Re-evaluate the effect of water-supply pumping on ground-water flow and evaluate the possibility of expanding water-production capacity of the well field, (2) determine the feasibility of moving the purge system to a new location, (3) determine the rate and direction of ground-water flow in the area of gasoline contamination, and (4) collect and analyze additional data on secondary permeability of the principal aquifers.

APPROACH: (1) Assemble and evaluate geologic and hydrologic data in State, county, and USGS files, (2) drill about 10 wells at selected locations to obtain lithologic, fracture, and water-level data, (3) measure water levels periodically in observation, domestic, and production wells, (4) measure discharge of the Battle Creek River, (5) recalibrate existing ground-water flow model based on new data and utilize the model to evaluate the effects of proposed pumping stresses, (6) analyze data, and write and publish report.

RESULTS LAST YEAR: All data was compiled and a draft copy of the report was prepared except for the section on ground-water-flow modeling. Recalibration of the existing model continued.

PLANS THIS YEAR: Complete recalibration of ground-water-flow model. Finish writing and publish report.

FIELD LOCATION: Southwestern Lower Peninsula, Michigan

PROJECT CHIEF: Erin A. Lynch

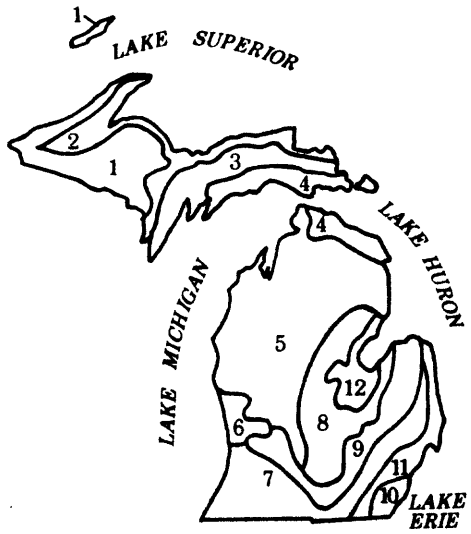
PERIOD OF PROJECT: January 1989 to March 1991

COOPERATING AGENCY: City of Battle Creek, Michigan

REPORTS IN PROGRESS: Lynch, E.A., and Grannemann, N.G., 1992, Assessment of geohydrology and ground-water flow at Verona well field, Battle Creek, Michigan: U.S. Geological Survey Water-Resources Investigations Report.

REPORTS COMPLETED: Grannemann, N.G., and Twenter, F.R., 1985, Geohydrology and ground-water flow at Verona well field, Battle Creek, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4056, 54 p.

Hydrologic Provinces of Michigan (MI 050)



PROBLEM: Currently there is no generalized description of the hydrology of the State of Michigan that can be referred to by planners and managers when confronted with decisions affecting the State as a whole. Although generalized glacial and bedrock deposit maps are available, maps delineating hydrologic characteristics and how these characteristics vary have not been prepared. In setting priorities for investigations, and in justifying priorities to legislative bodies, presentations are hampered by the absence of visual aids. At present there is no map or report that clearly demonstrates the disadvantages, when they exist, of using study boundaries based on political subdivisions.

OBJECTIVES: (1) To identify and describe generalized areal variations in the hydrology of Michigan based on published reports and unpublished file data, and (2) to delineate, hydrologic provinces and subprovinces as may be appropriate.

APPROACH: (1) Assemble and evaluate geologic and hydrologic data contained in Michigan Department of Natural Resources and U.S. Geological Survey files. Information used in the study will include data on aquifer thickness, lithologic and hydraulic characteristics, water levels, yield, recharge, flow direction, streamflow, lakes, and water quality, (2) analyze and summarize data, and delineate province boundaries based on similarities in aquifer properties and streamflow characteristics, water quality, and regional ground-water flow and ground-water divides, and (3) write and publish report.

RESULTS LAST YEAR: Completed analysis of hydraulic characteristics, surface and ground-water-quality data, and delineated twelve hydrologic provinces on plate size map. Report completed.

PLANS THIS YEAR: Publish report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Stephen J. Rheaume

PERIOD OF PROJECT: June 1989 to January 1991

COOPERATIVE AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Rheaume, S.J., 1991, Hydrologic provinces of Michigan: U.S. Geological Survey Water-Resources Investigations Report 91-4120, 73 p.

Impacts of Drought on Water Resources of Monroe County (MI 051)

PROBLEM: The water resources of Monroe County have been seriously affected by droughts in recent years. During the summer of 1988, many domestic wells went dry or had abnormally low water levels. The relation of low ground-water levels, periods of drought, and ground-water pumpage, especially agriculturally related pumpage, is not well understood. The quality of ground water is also a concern in much of the county. Water from many wells has objectionable concentrations of hydrogen sulfide, particularly during periods of drought. Highly mineralized water from deeper bedrock formations has, in places, been induced into shallow aquifers by pumpage from wells and quarries. Other water-quality problems may be the result of waste disposal in quarries and sinkholes, septic field operations, and operation of oil, mineral, and disposal wells. Streamflow was significantly diminished during the 1988 drought.

OBJECTIVES: (1) Evaluate the impact of droughts on Monroe County's surface- and ground-water resources, (2) evaluate the impacts of pumpage on ground-water levels, (3) determine the extent, thickness, and hydraulic properties of the most significant aquifers in the county, (4) evaluate the relation of geology to the quantity and quality of surface and ground water, (5) investigate the occurrence of mineralized water in shallow aquifers, (6) analyze the extent and causes of hydrogen sulfide in ground water, and (7) determine, where significant, the impacts of major land-use practices on the quality of surface and ground water.

APPROACH: (1) Assemble and evaluate hydrologic and geologic data in State, county, and USGS files, (2) install and analyze data from about thirty observation wells to determine lithology and directions of ground-water flow, (3) collect water-quality data from about 40 wells, (4) analyze selected core samples, obtained during installation of observation wells, to determine their organic content, (5) use geophysical techniques to aid in determining lithologic and stratigraphic features of the glacial deposits and bedrock, (6) make discharge measurements at 15 sites three times each year during low flow, (7) develop and use mathematical models, as appropriate, to aid in assessing effects of drought on the availability of ground water, and (8) analyze and evaluate data; write and publish report.

RESULTS LAST YEAR: Thirty-three observation wells were drilled, and two ground-water level recorders installed. Slug-test to determine aquifer properties were conducted on twenty-five observation wells. Surface-water samples were collected and discharge measurements made at twenty-three sites.

PLANS THIS YEAR: Collect ground-water and surface-water samples for chemical analysis. Conduct borehole logging on observation wells. Conduct multi-well aquifer test.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Southeastern Lower Peninsula, Michigan

PROJECT CHIEF: John L. Gillespie

PERIOD OF PROJECT: June 1989 to May 1992

COOPERATING AGENCIES: Michigan Department of Natural Resources
Monroe County

Determination of the Feasibility of using Transfer-Function Models for Estimating Daily Streamflow (MI 052)

PROBLEM: Portions of streamflow records are lost each year at many of the U.S. Geological Survey's 7,100 gaging stations because of malfunctions of sensing and recording equipment. A nationwide analysis of the U.S. Geological Survey streamflow network showed that missing record was the largest problem in providing accurate streamflow data. Although upgrading of equipment and development of strategies to minimize lost record might reduce the amount of missing streamflow data, it is not likely that all lost record could be entirely eliminated.

OBJECTIVES: (1) Increase the accuracy of estimated streamflow data by using statistical techniques, (2) provide a consistent method for developing statistical models needed to estimate streamflow data, (3) provide an objective estimate of model errors which accurately reflect the increase in uncertainty with time after the beginning of the period of missing record, and (4) account for seasonality of streamflow response.

APPROACH: (1) Review existing literature on estimation of missing streamflow data and development of transfer function models, (2) create data-base files containing daily flow values for selected stations, (3) investigate series for the occurrence of trends based on nonparametric trend detection and analysis procedures, (4) investigate the removal of the seasonal component of streamflow variation by development of a linear filter, seasonal differencing, and sinusoidal decomposition, (5) develop regression and transfer function models from detrended a deseasonalized streamflow data, (6) compare estimation errors among deseasonalizing procedures and between regression and transfer function models, and (7) write report.

RESULTS LAST YEAR: Analysis and report preparation completed. Results indicate that stochastic models reduce average estimation errors for intervals of missing record less than 30 days in duration.

PLANS THIS YEAR: Publish report entitled "Statistical models for estimating daily mean streamflow in Michigan" by D.J. Holtschlag and Habib Salehi.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: David J. Holtschlag

PERIOD OF PROJECT: May 1989 to September 1991

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Holtschlag, D.J., and Salehi, H., Statistical models for estimating daily streamflow in Michigan: U.S. Geological Survey Water-Resources Investigations Report 91-4194, 48 p.

EPA Superfund (MI 053)

PROBLEM: The Waste Management Division of U.S. Environmental Protection Agency (EPA), Region V, needs technical assistance from the Michigan District, Water Resources Division, to support the Superfund program. The EPA staff requires assistance in hydrogeology and geophysics to review or perform the large number of investigations that are underway or planned.

OBJECTIVES: (1) Perform technical review of work plans, reports, or other geologically related documents. (2) Provide field assistance by overseeing hydrogeologically related tasks, such as: performing or assisting in geophysical investigations, conducting tests of aquifer properties, assisting in modeling efforts, collectng of water-quality samples, or assisting in drilling activities.

APPROACH: (1) Technical reviews of written material will be performed in accordance with standard procedures used for internal colleague review. (2) Hydrogeologic and geophysical investigations will be conducted using approved methods and techniques of the U.S. Geological Survey (USGS). Assistance in modeling efforts will meet all standards used in USGS work.

RESULTS LAST YEAR: Conducted two investigations for the United States Environmental Protection agency.

PLANS THIS YEAR: Continue to collect data when requested and to make technical reviews of reports.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: John L. Gillespie

PERIOD OF PROJECT: October 1989 to September 1991

COOPERATING AGENCY: U.S. Environmental Protection Agency

REPORTS IN PROGRESS: None

REPORTS COMPLETED: None

Fractured Rocks (MI 054)

PROBLEM: Test wells have been drilled in several locations near Verona well field by the City of Battle Creek. For the wells that encountered interconnected fractures, higher hydraulic conductivities and yields were determined than those calculated for wells that encountered few fractures. Therefore, in order to plan for well field expansion it is critical to determine areas of interconnected fractures.

OBJECTIVES: (1) Identify extent, orientation, and degree of interconnection of fractures in the Marshall Sandstone in and near Verona well field, (2) relate fractures to well yield, (3) assess fractures as pathways for contamination of water supplies, and (4) analyze fractures on a regional scale to consider all potential locations for well fields and to allow drilling sites to be identified.

APPROACH: Construct maps of fracture networks at the outcrop near the dam on Battle Creek River and nearby quarries to determine the orientations of fractures. Drill twelve wells to be used for borehole and hydraulic testing. Use borehole geophysical methods to determine the nature and orientation of the fractures in as many boreholes as possible, particularly the twelve new boreholes. This will include televiewer, temperature, fluid resistivity, and long and short normal resistivity. Neutron logs may be used for a few boreholes. If equipment is available, acoustic waveform logs may also be made. Conduct borehole flow-meter logging to determine zones of contribution for water movement in the borehole. Conduct cross-hole pumping tests using packers in the pumped and observation wells to determine the hydraulic conductivity, storage coefficients (primary and secondary), and

vertical hydraulic conductivity of specific fractured zones at the scale of several tens of feet and several hundreds of feet. If a correlation between hydraulic properties and stratigraphic position in the sandstone can be appropriately made, changes will be made to an existing ground-water-flow model to reflect the influences of fracturing on regional ground-water flow. A particle-tracking model will be used to reanalyze the impacts of fractures on contaminant movement at Verona well field. Collect carbon-14, stable isotope, and tritium data for water from a few selected wells to determine the approximate age of water from the wells. Collect samples to analyze for priority pollutants at sites where new well fields are proposed.

RESULTS LAST YEAR: Preliminary interpretation of acoustic televiewer and other geophysical logs as well as flowmeter logs for fractures near Verona Well Field was completed.

PLANS THIS YEAR: Construct maps, drill new wells, run geophysical and flowmeter logs, conduct aquifer tests.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Southern Lower Peninsula, Michigan

PROJECT CHIEF: Erin A. Lynch

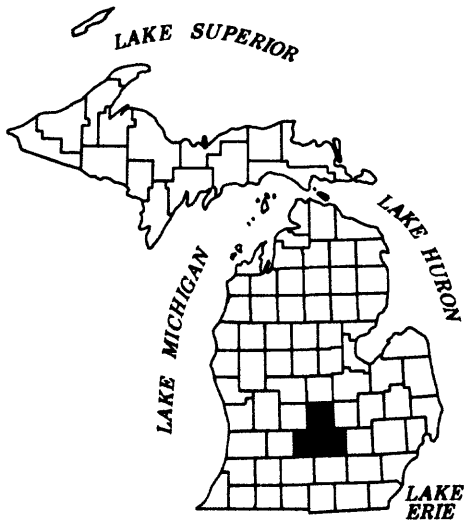
PERIOD OF PROJECT: October 1990 to June 1992

COOPERATING AGENCY: City of Battle Creek

REPORTS IN PROGRESS: Lynch, E.A., and Grannemann, N.G., 1992, Assessment of geohydrology and ground-water flow at Verona well field, Battle Creek, Michigan: U.S. Geological Survey Water-Resources Investigations Report.

REPORTS COMPLETED: Grannemann, N.G., and Twenter, F.R., 1985, Geohydrology and ground-water flow at Verona well field, Battle Creek, Michigan: U.S. Geological Survey Water-Resources Investigations Report 85-4056, 54 p.

Lansing Aquifers (MI 055)



PROBLEM: Management of the ground-water resources in Lansing and the surrounding area has become increasingly difficult as population and industrial development have expanded. Linking the major water systems into a single coordinated unit seems to offer a way of efficiently managing the resources in the future, but the hydrogeology in some areas is not understood well enough to support major changes in the existing water-supply system. Information is inadequate to determine the maximum yield of existing and new well fields, nor can realistic estimates of the long-term sustainable yield be made to guide planning. Because the water levels in the Saginaw Formation in the area have been drawn down as much as 160 feet, the technical feasibility of alternative courses of action needs to be carefully evaluated.

OBJECTIVES: (1) Define the geologic and hydrologic characteristics of aquifers in the Lansing area, (2) evaluate the relation of the quality of groundwater to geologic source, (3) define the impacts of large increases in withdrawals, (4) define areas favorable for developing new well fields, and (5) provide strategies for minimizing the impact of pumping on water levels.

APPROACH: (1) Assemble and evaluate geologic and hydrologic data in local, State, and USGS files, (2) develop a ground-water-flow model, (3) conduct surface geophysical surveys, (4) conduct borehole geophysical logging on selected wells, (5) drill observation wells in selected areas, (6) install recorders to augment existing ground-water-observation well network, (7) collect stable isotope data, (8) analyze and evaluate data and publish report.

RESULTS LAST YEAR: Installed 2 recorders to augment existing network of ground water observation wells.

PLANS THIS YEAR: Assemble existing hydrologic and geologic data, review literature and begin to develop preliminary ground-water-flow model.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: South-central Lower Peninsula, Michigan

PROJECT CHIEF: John R. Brannen

PERIOD OF PROJECT: May 1991 to April 1994

COOPERATING AGENCY: Tri-County Regional Planning Commission

REPORTS IN PROGRESS: None

REPORTS COMPLETED: None

Keweenaw Bay (MI 056)

PROBLEM: Analyses of water and sediments in Keweenaw Bay and tributary streams have identified areas where water quality has deteriorated. High coliform counts were found in several locations. High concentrations of metals, including lead and cadmium, were found in bottom sediments. Contamination by organic compounds has not been demonstrated, but is believed probable. Impairment of the quality of ground or surface water discharging to the Bay may be the result of land-use practices. Evidence suggests that there is an impact on tribal fisheries in the Bay. Additional information about the hydrology and the water quality in the Assinins Wetlands is also necessary to determine if plans to develop a fish farming and restocking program are feasible.

OBJECTIVES: (1) To describe hydrology of the Assinins Wetland area in the southwest corner of Keweenaw Bay, (2) to determine current water-quality conditions of the near shore area of Keweenaw Bay, its tributaries, and adjacent ground water.

APPROACH: Work in FY 1991 will be devoted to evaluating the Assinins Wetlands as a site for fish farming. Measurements of streamflow will be made at inlets and outlets to the wetland during high and low flow conditions. A lake gage will be installed on one small gravel pit located in the wetland. Analyses of water of streams, ponds, and wells will be made.

In FY 1992, work will continue in the Assinins Wetlands, but the major effort will be devoted to evaluating water quality in the near shore areas of Keweenaw Bay. Information from files of State, local, and other Federal

agencies will be assembled and evaluated. Water collected at selected sites in Keweenaw Bay, from tributary streams, and from wells will be analyzed. Analyses of bottom sediments also will be made at some sites. A Water-Resources Investigations Report will be prepared. The report will provide information needed to protect and enhance the Bay's fisheries that the Indian Community depends on.

RESULTS LAST YEAR: None.

PLANS THIS YEAR: Install wells and lake gage. Collect chemical analyses of water from streams, wetland, and wells.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Baraga and Houghton Counties

PROJECT CHIEF: Stephen J. Rheaume

PERIOD OF PROJECT: June 1991 to September 1992

COOPERATING AGENCY: Keweenaw Bay Indian Community

HYDROLOGIC CONDITIONS

Most of Michigan has sufficient water to meet present needs. Much of the State is bounded by water; annual precipitation ranges from 28 to 36 inches (fig. 5). Eight to 16 inches of precipitation becomes surface runoff (fig. 6) and 9 to 15 inches recharges ground-water bodies; the remainder is returned to the atmosphere by evapotranspiration. The discharge of streams is shown in figures 7 and 8; the availability of ground water is shown in figures 9 and 10. Freshwater withdrawals from both surface- and ground-water sources average about 15 billion gallons per day. Nearly 97 percent of withdrawal is from surface-water sources, particularly from the Great Lakes and connecting channels. Largest municipal withdrawals are in the heavily populated counties in the southern part of the State (fig. 11). Glacial deposits are the source of municipal ground-water supplies in most of the State (fig. 12). In some parts of the State, the base of fresh ground water is less than 200 feet deep (fig. 13); some wells produce salty water.

The Michigan Department of Natural Resources has identified about 2,000 sites where ground water has been contaminated or where contamination is suspected. A wide range of contaminants is involved. At many sites, chlorinated hydrocarbons and hydrocarbons that are contained in fuel substances are the contaminants. Nitrates from surface sources have contaminated domestic ground-water supplies in concentrations of as much as 30 milligrams per liter at some locations in the Lower Peninsula (Cummings and others, 1984).

The current program of the Michigan District of the Water Resources Division is effectively addressing many water-resource issues and is providing the hydrologic information needed for the best utilization and long-term management of the Nation's water resources. Hydrologic-data stations, at which data are collected for surface water, ground water, and water quality, are located throughout the State.

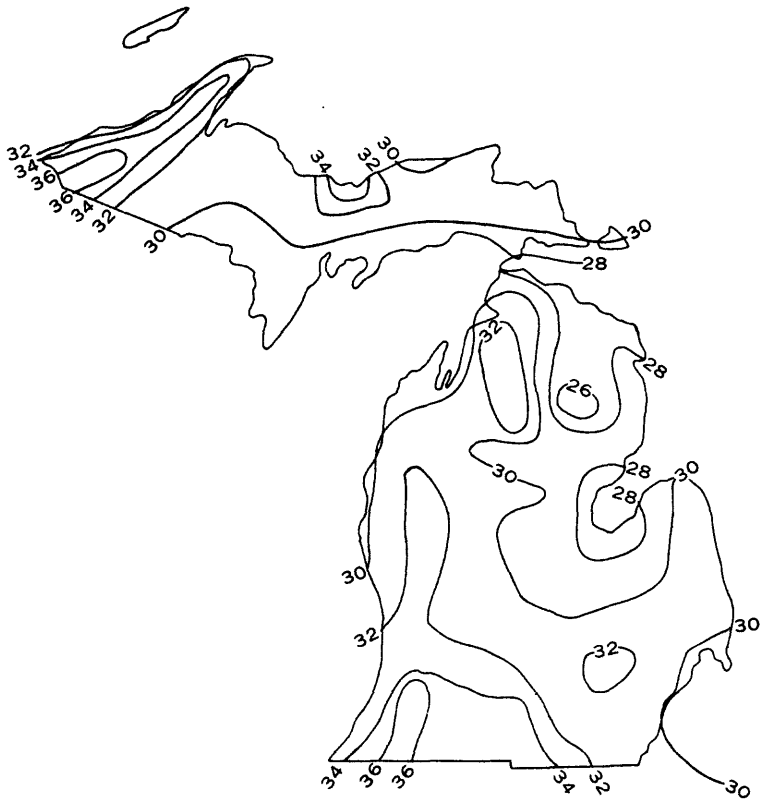


Figure 5.--Average annual precipitation (in inches) (Data from National Weather Service--NOAA).

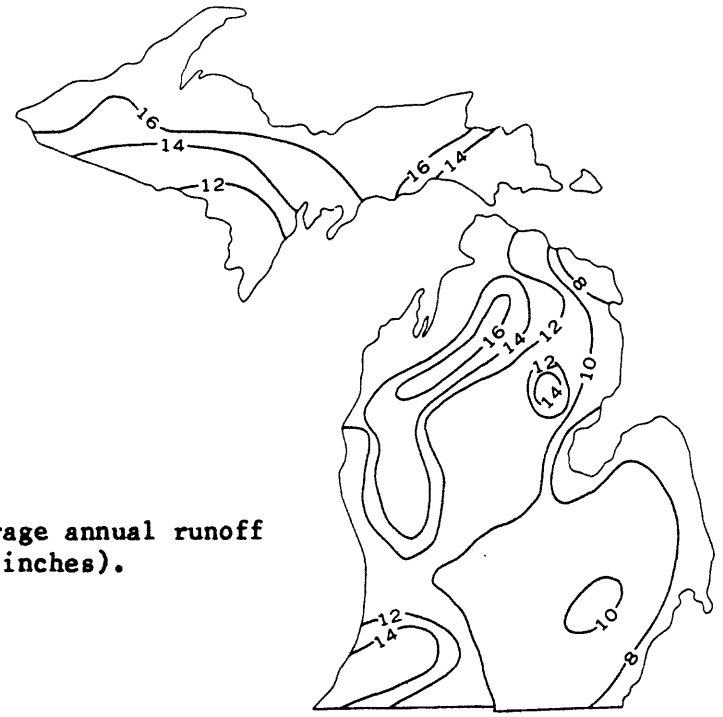


Figure 6.--Average annual runoff (in inches).

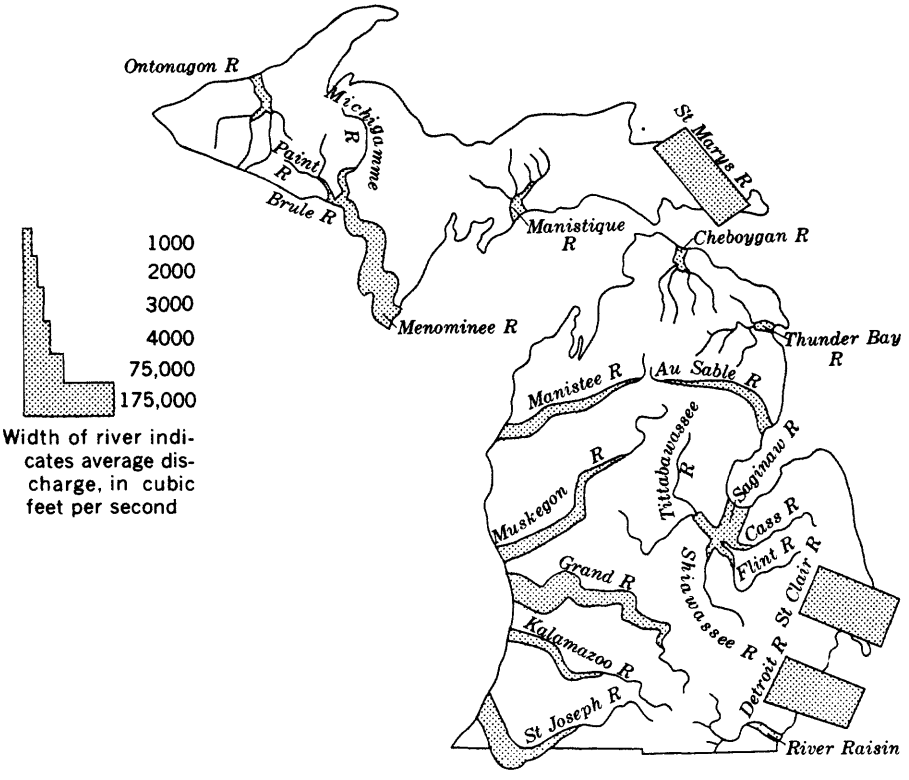
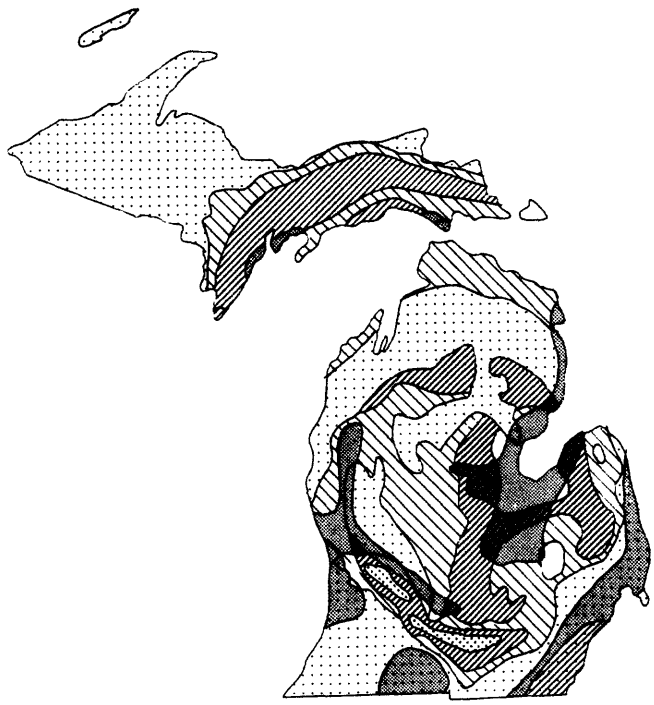


Figure 7.--Average discharge of streams (For streams draining an area of 1,000 square miles or more at mouth).

Figure 8.--Low-flow conditions.



Throughout most of these areas wells in bedrock will yield less than 10 gallons per minute. Locally, wells 6 inches or more in diameter may yield several tens of gallons per minute

Throughout most of these areas wells in bedrock 6 inches or more in diameter will yield from 10 to 100 gallons per minute. Locally, wells may yield less than 10 gallons per minute or more than 100 gallons per minute

Throughout most of these areas wells in bedrock 8 inches or more in diameter will yield from 100 to 500 gallons per minute. Locally, wells will yield less than 100 or more than 500 gallons per minute

Throughout most of these areas wells in bedrock 10 inches or more in diameter will yield more than 500 gallons per minute

Throughout most of these areas wells in bedrock will yield water that is too highly mineralized for domestic or public supplies-dissolved solids content of more than 1,000 milligrams per liter. Locally, the water may be of relatively good chemical quality. In general, the water becomes more mineralized with an increase in depth

As in the glacial drift the water in the bedrock is usually hard and may contain iron locally. With increasing depth water tends to become more mineralized

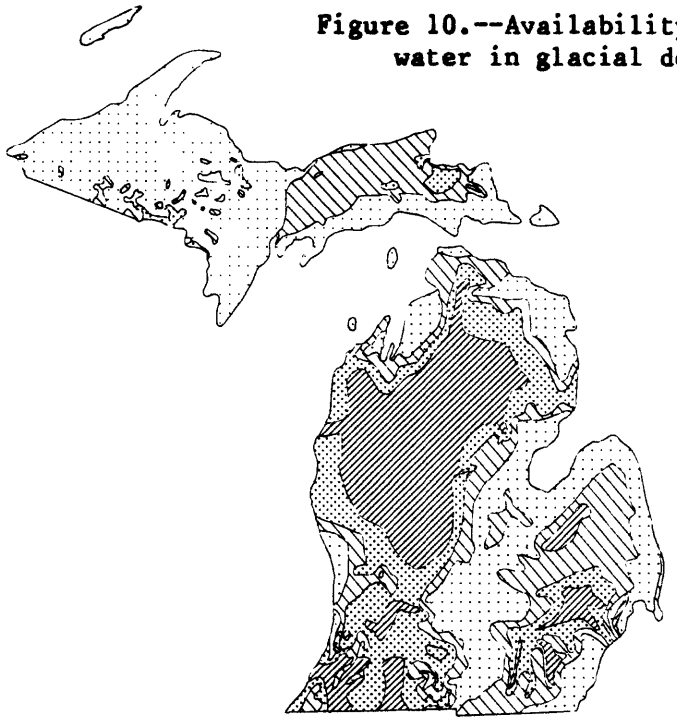
Figure 9.--Availability and quality of ground water in bedrock.

Throughout most of these areas wells in glacial deposits will yield less than 10 gallons per minute. Locally, wells 6 inches or more in diameter may yield several tens of gallons per minute and in places, especially where sand and gravel deposits occur along streams, will yield more than 100 gallons per minute

Throughout most of these areas wells 6 inches or more in diameter in glacial deposits will yield from 10 to 100 gallons per minute. Locally wells may yield less than 10 gallons per minute, and in places, especially where sand and gravel deposits occur along streams, will yield several hundred gallons per minute

Throughout most of these areas wells 8 inches or more in diameter in glacial deposits will yield from 100 to 500 gallons per minute. Locally, wells will yield less than 100 gallons per minute, and in places, especially where sand and gravel deposits occur along streams, will yield more than 500 gallons per minute

Throughout most of these areas wells 10 inches or more in diameter in glacial deposits will yield more than 500 gallons per minute



Water in the glacial deposits is of generally good quality although hard and may contain iron locally

Figure 10.--Availability of ground water in glacial deposits.

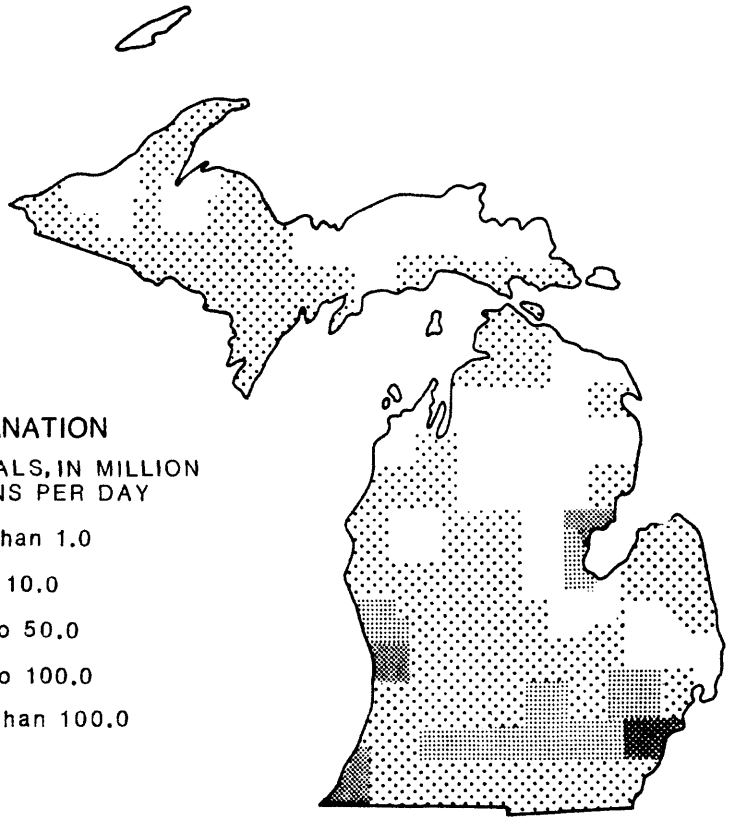


Figure 11.--Municipal water withdrawals, 1978.

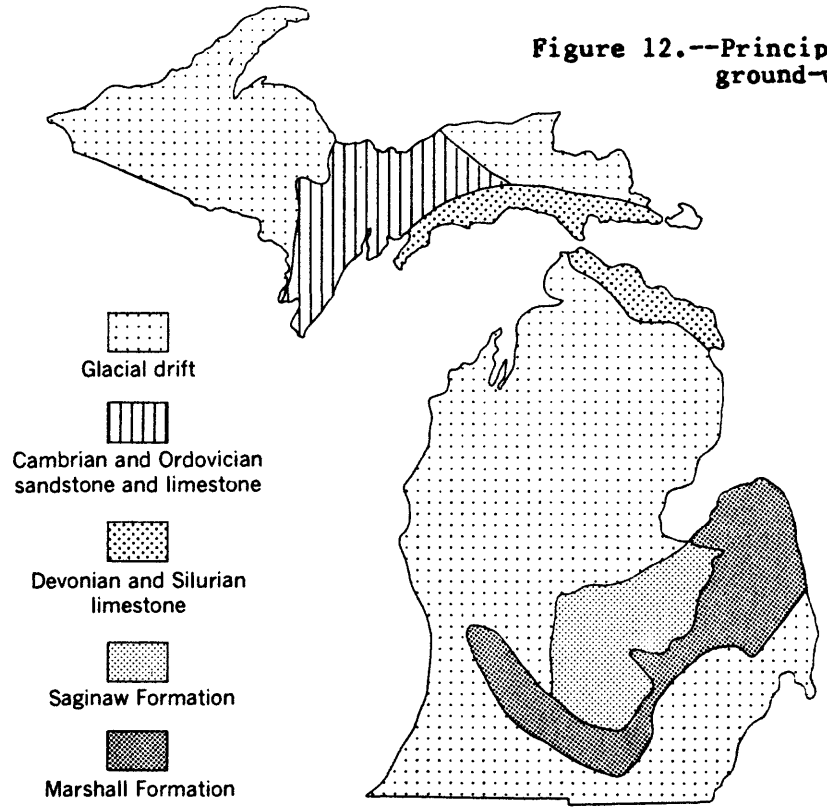


Figure 12.--Principal sources of public ground-water supplies.

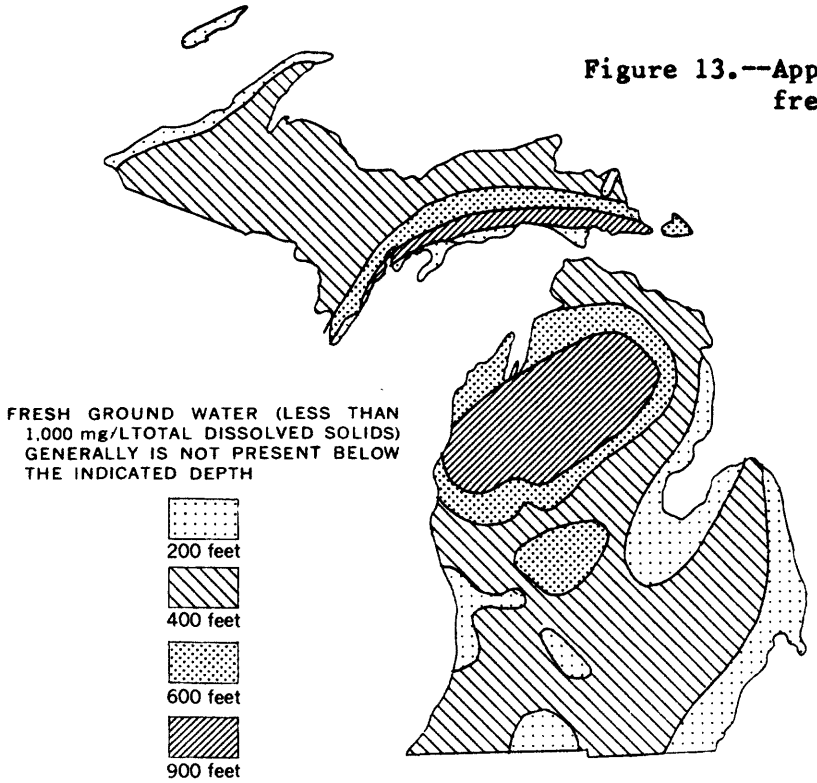


Figure 13.--Approximate depth to base of fresh ground water.

HYDROLOGIC-DATA STATIONS

Hydrologic-data stations are maintained by the U.S. Geological Survey at selected key locations throughout Michigan to constitute a basic data network for obtaining records on stream discharge or stage, reservoir and lake storage, ground-water levels, and the quality of surface and ground water. Every year some stations are added and others are terminated. Much of the information collected is stored in the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and is available to water planners and others involved in making decisions affecting the State's water resources.

Surface-Water Stations

The station number is a permanent numerical designation for surface-water stations that has been adopted on a nationwide basis by the U.S. Geological Survey (table 1). Stations are numbered and listed in a downstream direction along the main stem. All stations on the tributary entering above a main-stem station are listed before that station. A tributary entering between two main-stem stations is listed between them.

Table 1.--Surface water hydrologic data stations

Station number	Station name	Type of data[1]
04001000	Washington Creek at Windigo, MI	Q1CTR
04033000	Middle Branch Ontonagon River near Paulding, MI	Q1
04033500	Bond Falls Canal near Paulding, MI	Q1
04034000	Bond Falls Reservoir near Paulding, MI	14
04034500	Middle Branch Ontonagon River near Trout Creek, MI	Q1
04035500	Middle Branch Ontonagon River near Rockland, MI	Q1
04036000	West Branch Ontonagon River near Bergland, MI	Q1
04037500	Cisco Branch Ontonagon River at Cisco Lake Outlet, MI	Q1
04040000	Ontonagon River near Rockland, MI	Q1CS
04040500	Sturgeon River near Sidnaw, MI	Q1
04041000	Perch River near Sidnaw, MI	2
04041500	Sturgeon River near Alston, MI	Q1
04043050	Trap Rock River near Lake Linden, MI	Q1
04043800	McClure Storage Basin Release near Marquette, MI	Q1
04044200	Carp Creek at Ishpeming, MI	2
04044400	Carp Creek near Negaunee, MI	3
04044609	Sand River Wildlife Flooding at Sand River, MI	1
04044813	Two Hearted River near Paradise, MI	2
04045500	Tahquamenon River near Paradise, MI	Q1CS
04045538	West Branch Waiska River near Brimley, MI	2
04045559	East Branch Waiska River near Brimley, MI	2
04045580	St. Marys River above Sault Ste. Marie, MI	CR
04046000	Black River near Garnet, MI	2
04056500	Manistique River near Manistique, MI	Q1
04057510	Sturgeon River near Nahma Junction, MI	Q1
04057580	Whitefish River near Rapid River, MI	3
04057800	Middle Branch Escanaba River at Humboldt, MI	Q1
04057811	Greenwood Reservoir near Greenwood, MI	14
04057813	Greenwood Diversion near Greenwood, MI	Q1
04057814	Greenwood Release near Greenwood, MI	Q1
04057900	Black River near Republic, MI	2
04058100	Middle Branch Escanaba River near Princeton, MI	Q1
04058120	Green Creek near Palmer, MI	3
04058190	Schweitzer Reservoir near Palmer, MI	14
04058200	Schweitzer Creek near Palmer, MI	Q1
04058940	Escanaba River near St. Nicholas, MI	1
04059000	Escanaba River at Cornell, MI	Q1CS
04059034	Escanaba River near Wells, MI	3
04059400	Tenmile Creek at Perronville, MI	2
04059500	Ford River near Hyde, MI	Q1CS
04061000	Brule River near Florence, WI	Q1
04061500	Paint River at Crystal Falls, MI	Q1
04062000	Paint River near Alpha, MI	Q1
04062011	Brule River near Commonwealth, WI	Q1
04062300	Michigamme River at Republic, MI	2
04062500	Michigamme River near Crystal Falls, MI	Q1
04063000	Menominee River near Florence, WI	Q1
04063500	Menominee River at Twin Falls near Iron Mountain, MI	Q1
04065722	Menominee River near Vulcan, MI	Q1

Table 1.--Surface water hydrologic data stations--Continued

Station number	Station name	Type of data
04096272	Beebe Creek near Hillsdale, MI	2
04096340	St. Joseph River at Clarendon, MI	2
04096400	St. Joseph River near Burlington, MI	Q1
04096515	South Branch Hog Creek near Allen, MI	Q1
04096517	South Branch Hog Creek tributary near Allen, MI	3
04096900	Nottawa Creek near Athens, MI	Q1
04097170	Portage River near Vicksburg, MI	2
04097195	Gourdneck Canal near Schoolcraft, MI	Q1
04097540	Prairie River near Nottawa, MI	Q1
04099000	St. Joseph River at Mottville, MI	Q1
04101500	St. Joseph River at Niles, MI	Q1CS
04101800	Dowagiac River at Sumnerville, MI	Q1
04102500	Paw Paw River at Riverside, MI	Q1
04102700	South Branch Black River near Bangor, MI	Q1
04103010	Kalamazoo River near Marengo, MI	Q1
04105000	Battle Creek at Battle Creek, MI	Q1
04105500	Kalamazoo River near Battle Creek, MI	Q1
04105700	Augusta Creek near Augusta, MI	Q1
04106000	Kalamazoo River at Comstock, MI	Q1
04106180	Portage Creek at Portage, MI	Q1
04106300	Portage Creek near Kalamazoo, MI	Q1
04106320	West Fork Portage Creek near Oshtemo, MI	Q1
04106400	West Fork Portage Creek at Kalamazoo, MI	Q1
04108500	Kalamazoo River near Fennville, MI	Q1CS
04108600	Rabbit River near Hopkins, MI	Q1
04108645	Rabbit River at Hamilton, MI	2
04108800	Macatawa River near Zeeland, MI	Q1
04109000	Grand River at Jackson, MI	Q1
04111500	Deer Creek near Dansville, MI	Q1
04112000	Sloan Creek near Williamston, MI	Q1
04112500	Red Cedar River at East Lansing, MI	Q1
04112700	Sycamore Creek near Mason, MI	2
04113000	Grand River at Lansing, MI	Q1
04113090	Carrier Creek near Grand Ledge, MI	2
04114000	Grand River at Portland, MI	Q1
04114500	Looking Glass River near Eagle, MI	Q1
04114594	Maple River near St. Johns, MI	3
04115000	Maple River at Maple Rapids, MI	Q1
04115265	Fish Creek near Crystal, MI	Q1
04116000	Grand River at Ionia, MI	Q1
04117000	Quaker Brook near Nashville, MI	2
04117500	Thornapple River at Hastings, MI	Q1
04118000	Thornapple River near Caledonia, MI	Q1
04118500	Rogue River near Rockford, MI	Q1
04119000	Grand River at Grand Rapids, MI	Q1
04119055	Plaster Creek at Grand Rapids, MI	2
04119160	Buck Creek at Grandville, MI	2
04119300	Grand River near Eastmanville, MI	MCS
04120295	Black Creek near Muskegon, MI	23
04121239	Clam River at Cadillac, MI	3
04121300	Clam River at Vogel Center, MI	Q1
04121500	Muskegon River at Evart, MI	Q1
04121900	Little Muskegon River near Morley, MI	Q1

Table 1.--Surface water hydrologic data stations--Continued

Station number	Station name	Type of Data
04122000	Muskegon River at Newaygo, MI	Q1
04122100	Bear Creek near Muskegon, MI	Q1
04122200	White River near Whitehall, MI	Q1
04122230	North Branch Pentwater River near Pentwater, MI	2
04122500	Pere Marquette River at Scottville, MI	Q1
04124000	Manistee River near Sherman, MI	Q1
04124500	East Branch Pine River near Tustin, MI	2
04126000	Manistee River near Manistee, MI	Q1
04126520	Manistee River at Manistee, MI	MCS
04126600	Betsie River near Benzonia, MI	2
04126740	Platte River at Honor, MI	Q1
04127565	Intermediate River at Bellaire, MI	Q1
04127800	Jordan River near East Jordan, MI	Q1
04127850	Boyne River near Boyne City, MI	2
04127918	Pine River near Rudyard, MI	Q1
04128000	Sturgeon River near Wolverine, MI	Q1
04129000	Pigeon River near Vanderbilt, MI	Q1
04130500	Black River near Tower, MI	Q1
04135000	Thunder Bay River near Alpena, MI	Q1CS
04135500	Au Sable River at Grayling, MI	Q1
04135700	South Branch Au Sable River near Luzerne, MI	Q1
04136500	Au Sable River at Mio, MI	Q1
04137500	Au Sable River near Au Sable, MI	Q1CS
04140200	Klacking Creek near Selkirk, MI	2
04140500	Rifle River at Selkirk, MI	2
04142000	Rifle River near Sterling, MI	Q1CS
04143900	Shiawassee River at Linden, MI	Q1
04144500	Shiawassee River at Owosso, MI	Q1
04145000	Shiawassee River near Fergus, MI	Q1
04146000	Farmers Creek near Lapeer, MI	Q1
04146020	South Branch Flint River near Millville, MI	2
04146063	South Branch Flint River near Columbiaville, MI	Q1
04146450	North Branch Flint River near Columbiaville, MI	2
04147000	Holloway Reservoir near Otisville, MI	14
04147500	Flint River near Otisville, MI	Q1
04148140	Kearsley Creek near Davison, MI	Q1
04148500	Flint River near Flint, MI	Q1
04149000	Flint River near Fosters, MI	Q1
04150500	Cass River at Cass City, MI	Q1
04150800	Cass River at Wahjamega, MI	Q1
04151500	Cass River at Frankenmuth, MI	Q1
04152238	South Branch Tobacco River near Beaverton, MI	Q1
04154000	Chippewa River near Mount Pleasant, MI	Q1
04155000	Pine River at Alma, MI	Q1
04155500	Pine River near Midland, MI	Q1
04156000	Tittabawassee River at Midland, MI	Q1
04156100	Tittabawassee River near Midland, MI	MCS
04157000	Saginaw River at Saginaw, MI	Q1CS
04159010	Pigeon River near Caseville, MI	Q1CS
04159130	St. Clair River at Port Huron, MI	MCS
04159500	Black River near Fargo, MI	Q1

Table 1.--Surface water hydrologic data stations--Continued

Station number	Station name	Type of data
04159900	Mill Creek near Avoca, MI	Q1
04160350	Pine River near Rattle Run, MI	2
04160570	North Branch Belle River at Imlay City, MI	Q1
04160600	Belle River at Memphis, MI	Q1
04160800	Sashabaw Creek near Drayton Plains, MI	Q1
04160900	Clinton River near Drayton Plains, MI	Q1
04161000	Clinton River at Auburn Heights, MI	2
04161100	Galloway Creek near Auburn Heights, MI	Q1
04161500	Paint Creek near Lake Orion, MI	Q1
04161540	Paint Creek at Rochester, MI	Q1
04161580	Stony Creek near Romeo, MI	Q1
04161760	West Branch Stony Creek near Washington, MI	2
04161790	Stony Lake near Washington, MI	14
04161800	Stony Creek near Washington, MI	Q1
04163400	Plum Brook at Utica, MI	Q1
04164000	Clinton River near Fraser, MI	Q1
04164010	North Branch Clinton River at Almont, MI	2
04164050	North Branch Clinton River near Romeo, MI	2
04164100	East Pond Creek at Romeo, MI	Q1
04164150	North Branch Clinton River near Meade, MI	2
04164200	Coon Creek near Armada, MI	2
04164300	East Branch Coon Creek at Armada, MI	Q1
04164350	Highbank Creek near Armada, MI	2
04164360	East Branch Coon Creek near New Haven, MI	2
04164400	Deer Creek near Meade, MI	2
04164450	McBride Drain near Macomb, MI	2
04164500	North Branch Clinton River near Mount Clemens, MI	Q1
04164600	Middle Branch Clinton River near Macomb, MI	2
04164800	Middle Branch Clinton River at Macomb, MI	2
04165200	Gloede Ditch near Waldenburg, MI	2
04165500	Clinton River at Mount Clemens, MI	Q1CS
04166000	River Rouge at Birmingham, MI	Q1
04166100	River Rouge at Southfield, MI	Q1
04166200	Evans Ditch at Southfield, MI	Q1
04166300	Upper River Rouge at Farmington, MI	Q1
04166500	River Rouge at Detroit, MI	Q1
04167000	Middle River Rouge near Garden City, MI	Q1
04168000	Lower River Rouge at Inkster, MI	Q1
04168660	Frank and Poet Drain at Trenton, MI	2
04168800	Huron River near Andersonville, MI	2
04170000	Huron River at Milford, MI	Q1
04170500	Huron River near New Hudson, MI	Q1
04172000	Huron River near Hamburg, MI	Q1
04173250	Mill Creek near Lima Center, MI	2
04174050	Huron River at Delhi Mills, MI	P
04174500	Huron River at Ann Arbor, MI	Q1
04174800	Huron River at Ypsilanti, MI	Q1
04174950	Willow Run near Rawsonville, MI	Q1
04175600	River Raisin near Manchester, MI	Q1
04175957	South Branch River Raisin at Adrian, MI	Q1
04175960	South Branch River Raisin near Adrian, MI	2
04176000	River Raisin near Adrian, MI	Q1

Table 1.--Surface water hydrologic data stations--Continued

Station number	Station name	Type of data	Station number	Station name	Type of data
04176400	Saline River near Saline, MI	2	04176605	Otter Creek at LaSalle, MI	Q1C
04176500	River Raisin near Monroe, MI	Q1CS			

[1]TYPE OF DATA:

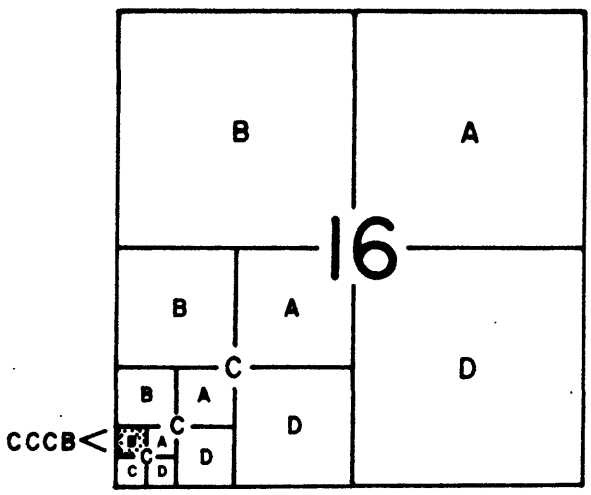
Surface-water data:
- Q - Daily discharge.
- 1 - Stage.
- 2 - Peak stage and discharge.
- 3 - Low flow.
- 4 - Reservoir contents.
- M - Miscellaneous.

Quality analyses:
- C - General chemical, organic, and biological analyses.
- S - Sediment analyses.
- P - Pesticide.
- T - Temperature.
- R - Radiochemical.

Ground-Water Stations

Table 2 lists the ground-water stations established as part of the State-wide observation network. In addition to ground-water information collected at sites listed in table 2, chemical analyses of ground water have been collected at other locations in the State. Further information is available upon request.

The well-numbering system for Michigan indicates the location of wells within the rectangular subdivision of the land with reference to the Michigan meridian and base line. The first two segments of the well number designate township and range, the third segment of the number designates the section, and the letters A through D designate successively smaller subdivisions of the section as shown below. Thus, a well designated as 32N 6E 16CCCB would be located to the nearest 2.5 acres (1 hectare) and would be within the shaded area in section 16.



For many wells in this report, locations are only given to the nearest 40-acre (16 hectares) tract, for example, 16CC. In the event that two or more wells are located in the same tract, a sequential number designation is added--for example, 16CC1, 16CC2, 16CC3, etc.

Table 2.--Ground-water hydrologic data stations

County	Well number[1]	Name of well	Depth (ft)	Aquifer[2]	Type of data[3]
Alger	45N 19W 25BDCD1	CCC	66	GLCL	Q,QC
Alpena	32N 06E 23DDDA1	Alpena State Forest	88	GLCL	R,QC
Arenac	19E 05E 07DABA1	Omer, D	185	SGNW	M,QC
	07DABA2	Omer, S	21	GLCL	M,QC
Baraga	48N 32W 12DD	WEP 14	10	GLCL	M
Barry	04N 09W 05DA	Solomon Road	131	GLCL	Q
Bay	17N 04E 22DCAA1	Pinconning Twp.	110	SGNW	M,QC
Branch	06S 06W 18CCCD1	Coldwater Twp.	56	GLCL	M,QC
	22CABA1	Coldwater Test 4	113	GLCL	R
Calhoun	01S 07W 10BB	Sabin	12	GLCL	W
	32BDCC1	Penfield Twp.	95	MRSL	R,QC
	32DABD	Battle Creek	127	MRSL	D
	02S 06W 25AA	Marshall	59	MRSL	M
Cass	08S 14W 17BA	Little	55	GLCL	M
Cheboygan	33N 01W 26DABB1	Pigeon River CCC	164	GLCL	R,QC
	39N 03W 29CBCB1	Mackinaw, D	125	DUND	M,QC
	39N 03W 29CBCB2	Mackinaw, S	55	GLCL	M,QC
Chippewa	46N 04W 24DAAD1	Raco	54	GLCL	R
Clare	17N 04W 34DCAD	Clare	91	GLCL	R
Clinton	05N 02W 32DC	Quarantine Farm	135	SGNW	M
	06N 01W 3BB2	Sleepy Hollow 5	62	GLCL	A
	06N 02W 16DDAD1	MDOT, U.S. 27	23	GLCL	M
	07N 01W 34CC	Sleepy Hollow 7	32	GLCL	A
Crawford	25N 01W 15DDCD1	Eldorado	56	GLCL	R,QC
Delta	39N 23W 28AC	Schemmel	530	MNSG	R
	41N 18W 31CD	Isabella	250	LMSN	M
	42N 19W 20AA	Pollack CCC	134	GLCL	Q
	43N 19W 24BB	Clarage	405	TBRV	Q
Dickinson	43N 28W 32ADAB1	Felch	31	GLCL	M,QC
Eaton	03N 03W 02BA	Lansing, Stiefel	66	GLCL	R
	04N 03W 12CD	Robins Road	381	SGNW	R
Grand Traverse	26N 09W 14ABAA1	Fife Lake State Forest	80	GLCL	R,QC
Hillsdale	07S 02W 10BDDD1	Pittsford Game Area	20	GLCL	R,QC
	07S 02W 15BCBA1	Osseo	150	OTSH	R,QC
Huron	15N 11E 32BBCB	Grant Twp.	91	SAND	R
	16N 09E 02CDCA	Fairhaven Twp.	180	SGNW	R
Ingham	02N 01E 34DB	Dansville Game Area	87	GLCL	Q
	03N 01E 07DDCA1	Lotte	184	SGNW	M
	02W 06ACAD	Lansing, Davis	--	SGNW	R
	23BCBD	Holt	188	SGNW	R
	04N 01W 16DAD	Meridian Twp.	398	SGNW	M
	28BCAD1	Okemos	125	SGNW	R
	02W 05CDDD	Lansing, Muskegon	418	SGNW	R
	9BD	Lansing, Seymour	401	SGNW	R
	16DA	Lansing, Cedar	417	SGNW	R
	17AB	Lansing, Logan	424	SGNW	R
	21BA3	Lansing, Scott Park	400	SGNW	R

Table 2.--Ground-water hydrologic data stations--Continued

County	Well number	Name of well	Depth (ft)	Aquifer	Type of data
Ingham (cont.)	04N 02W 22BC	Lansing, P-5	338	SGNW	M
	24CA	Spartan Village	453	SGNW	R
	27BB	Fenner Arboretum	215	SGNW	R
	02W 31CC	Maybell Street	204	SGNW	M
Iosco	24N 07E 13ADAD1	Oscoda	69	GLCL	M,QC
Iron	43N 35W 11AD	WEP 23	47	GLCL	M
	20DC	WEP 25	48	GLCL	M
	44N 37W 14BB	CCC Camp	102	GLCL	Q
Jackson	03S 01W 11AA1	Jackson - 4a, Belden	360	SGNW MRSL	D
Kalamazoo	02S 10W 04D	Kalamazoo, Campbell	13	GLCL	R
	26BBCC	Kalamazoo, Morrow	27	GLCL	R
	02S 11W 20BB2	Kalamazoo, Kendall	106	GLCL	R
	28AA	Kalamazoo, Maple	245	GLCL	R
	31CD	Kalamazoo, Colony	226	GLCL	R
	36CB	Kalamazoo, Emerald	226	GLCL	R
	03S 11W 04ABAD1	Kalamazoo, K325	36	GLCL	R
	04ABAD2	Kalamazoo, K32D	144	GLCL	R
	14AA	Upjohn 28	233	GLCL	R
	22BBCD	Portage	102	GLCL	R
	12W 11BD	Kalamazoo, Atwater	248	GLCL	R
	04S 11W 11AD1	Kalamazoo,Sabo, D	300	GLCL	R
Kalamazoo	04S 11W 11AD2	Kalamazoo,Sabo,S	38	GLCL	R
	03CDDA1	Prairie View Park	190	GLCL	R,QC
Kent	05N 12W 04DCCD1	Wyoming, Wobma	86	GLCL	R,QC
	10N 12W 13DD	Rogue River Game Area	30	GLCL	Q
Lake	20N 13W 13ACAC1	Irons	58	GLCL	M,QC
Leelanau	28N 14W 08DDCA1	Sleeping Bear,D	138	GLCL	M,QC
	18BABB1	Sleeping Bear,S	60	GLCL	M,QC
Lenawee	05S 01E 12DDBD1	Onstead Game Area	39	GLCL	M
Livingston	01N 06E 13DBAB1	American Aggregate	29	GLCL	R,QC
Mackinac	41N 05W 23BC	Round Lake CCC	47	SLINT	Q
	42N 02W 07AABB1	Pontchartrain CCC	102	MNSQ	R,QC
Marquette	47N 28W 03CCDC1	Ely Township	75	GLCL	R,QC
	49N 30W 22AC	WEP 13	17	GLCL	M
Menominee	37N 26W 19DADA1	Carney	17	GLCL	Q,QC
Monroe	07S 06E 15ACAA1	Petersburg, rock	73	DRRV	R,QC
	15ADBB1	Petersburg Game Area	17	GLCL	M
Oakland	02N 07E 05BA	Honeywell Lake Road	44	GLCL	R
	08E 18DBAD1	Proud Lake Park	45	GLCL	R,QC
	03N 07E 05DA	Fish Lake Road	49	GLCL	R
	10E 13AC	Oakland Univ.	183	GLCL	R
	05N 08E 08ACAC1	Holly Recreation Area	42	GLCL	M
Oceana	13N 15W 18AAAA1	Hesperia	79	OTSH	R,QC

Table 2.--Ground-water hydrologic data stations--Continued

County	Well number	Name of well	Depth (ft)	Aquifer	Type of data
Ogemaw	23N 01E 02BAAA1	Rose City Road,D	105	GLCL	Q
	02BAAA2	Rose City Road,S	20	GLCL	Q,QC
Ontonagon	51N 41W 08BDBC1	Silver City	100	FRED	Q,QC
Otsego	30N 03W 19ABBB1	Gaylord	90	OTSH	M,QC
Presque Isle	33N 06E 8BBBB1	Styma	61	TRVR	Q,QC
Roscommon	24N 02W 20BABA1	Exp. Station	14	GLCL	R,QC
Saginaw	10N 01E 22DADA1	Marion Springs,D	210	SGNW	R,QC
Sanilac	13N 13E 12ADAA1	Minden Game Area	130	MRSL	R,QC
Schoolcraft	45N 13W 16CCCB1	Seney	154	LMSN	R,QC
	47N 16W 30BBBB1	Cusino CCC	57	PRDC	R,QC
Van Buren	02S 13W 02BBCD1	Almena, D	108	GLCL	M
	02BBCD2	Almena, S	44	GLCL	M
Washtenaw	02S 03E 09DAAB2	Waterloo Park	48	GLCL	R,QC
	03S 06E 16BCCD1	Ann Arbor	55	GLCL	R,QC
	07E 05BB	Ypsilanti, Superior	69	GLCL	R
	09ADBC1	Ypsilanti,Gilbert	94	GLCL	R
	24CD	Ypsilanti Township 117	75	GLCL	R
Wexford	22N 12W 13BA	Harrietta Fish Hatchery	141	GLCL	R

[1]Local well number: For explanation of well numbers see introduction to table.

[2]Aquifer:

GLCL - Glacial deposits; Pleistocene
OTSH - Outwash; Pleistocene
SGNW - Saginaw Formation; Middle Pennsylvanian
MRSL - Marshall Formation; Lower Mississippian
TRVR - Traverse Group; Middle and Upper Devonian
DUND - Dundee Formation; Middle Devonian
DRRV - Detroit River Group; Lower Devonian
SLINT - Saline Formation; Middle and Upper Silurian
MNSQ - Manistique Group Middle Silurian
LMSN - Upper Ordovician limestones
TBRV - Black River and Tenton Groups; Middle Ordovician
PRDC - Prairie du Chien Group; Lower Ordovician
MNSG - Munising Sandstone; Upper Cambrian
FRED - Freda Sandstone; Precambrian

[3]Type of data:

Ground-water levels: R - Continuous record
D - Daily measurement
W - Weekly measurement
M - Monthly measurement
Q - Quarterly measurement
A - Annual measurement

Quality analyses: QC - General chemical, organic, and pesticide analyses

SOURCES OF INFORMATION

The U.S. Geological Survey publishes an annual series of reports, "Water Resources Data--Michigan," in which hydrologic data collected for each water year (October 1 to September 30) are included. The Survey publishes another annual series of reports, "Ground-Water Data for Michigan", in which ground-water data collected for each calendar year are included. These reports are available upon request to the District Chief. Topographic maps showing flood prone areas are available from the District office. Additional information on surface- and ground-water conditions in Michigan is given in the reports listed in table 3. Some of the reports listed in table 3 are available for viewing at:

Water Resources Division
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48911
Telephone: (517) 377-1608
(FTS) 374-1608

Inquires concerning the availability of these reports should be addressed to:

Books and Open-File Reports Section
Branch of Distribution
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225-0425

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