# WATER RESOURCES ACTIVITIES

# IN MICHIGAN, 1989

Compiled by T. J. Spicer

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U.S. GEOLOGICAL SURVEY

Open-File Report 89-270

Prepared in cooperation with

State and Federal agencies

Lansing, Michigan
1989

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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# Foreword

For the past 89 years, the U.S. Geological Survey has collected data on the water resources of Michigan. During the winter of 1900-01, a Survey employee visited the State to measure the flow of streams, and to select sites for establishing 13 gaging stations. For the next quarter of a century the program remained small, and much of the Survey's work was related to municipal needs and water-power requirements. State agency cooperation in the data-collection effort began in 1930, and with it began the development of a close and unique Federal-State relationship. Although early programs were largely related to the flow of streams, subsequent interest resulted in the collection of ground-water and water-quality information, as well as interpretive studies of water resources locally and statewide. In recent years, the discovery of the pervasiveness of ground-water contamination has resulted in increased activity in identifying and defining such problems. Interest in this area of water resources work is likely to remain strong for many years, and be a major part of program activity.

T. Ray Cummings

District Chief

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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 employer of the largest number 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. One of the Nation's

most important natural resources is water.

## 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 stress, either natural or manmade.
- 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 an 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)
  Geological Survey Division
  Land and Water Management Division
  Surface Water-Quality Division

Michigan Department of Transportation

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
City of Mason
Monroe County
City of Negaunee
City of Norway
Oakland County Drain Commission
Otsego County Road Commission
City of Portage
City of Ypsilanti
Wayne County

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

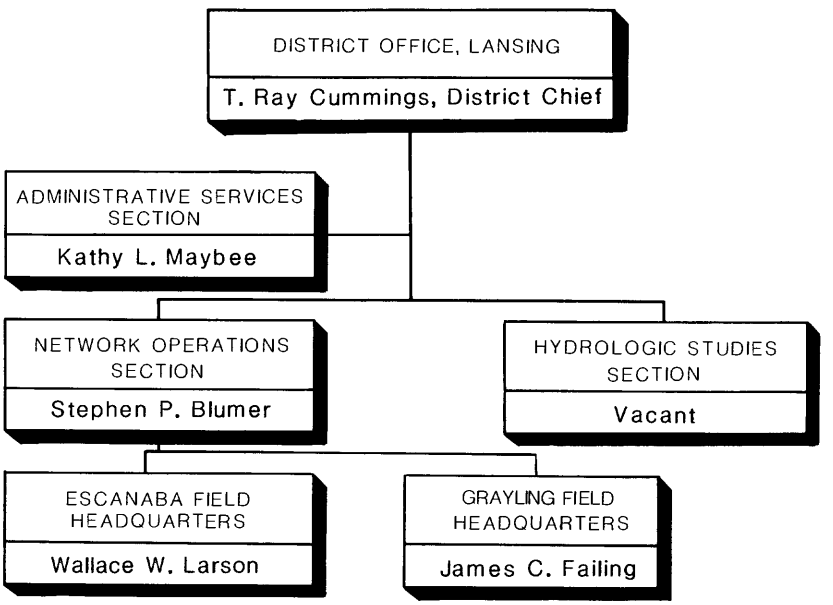
## District Office Organization

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, geology, 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 services, 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<br>Lansing, Michigan 48911 |
| Escanaba | (906) 786-0714 | 205 State Office Building<br>Escanaba, Michigan 49829 |
| Grayling | (517) 348-8291 | P.O. Box 485<br>Grayling, Michigan 49738 |

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

## Administrative Services Section

This section provides administrative support to the Michigan District office and is responsible for:

- Budget formulation and execution,
- Preparation of financial summaries of cooperative programs,
- Assistance in personnel management of the District,
- Maintenance of all administrative files, vehicle control, and property records,
- Insuring that staff members are familiar with regulations pertaining to administrative functions of the Geological Survey.

## Hydrologic Studies Section

This section analyzes and interprets hydrologic data as they relate 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

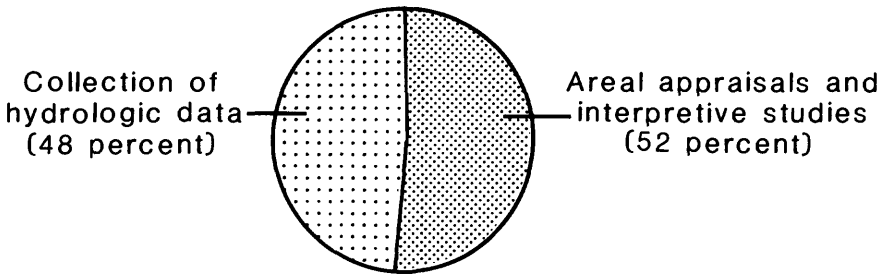
are used in projects designed to appraise the water resources of the state. Reports containing these data are published annually. Hydrologic data are also stored in the Survey's computer storage file called WATSTORE. Surface-water, ground-water, and quality of water data are available for tabular presentation, statistical manipulation, or graphical display.

### Regional Aquifer Systems Analysis Office

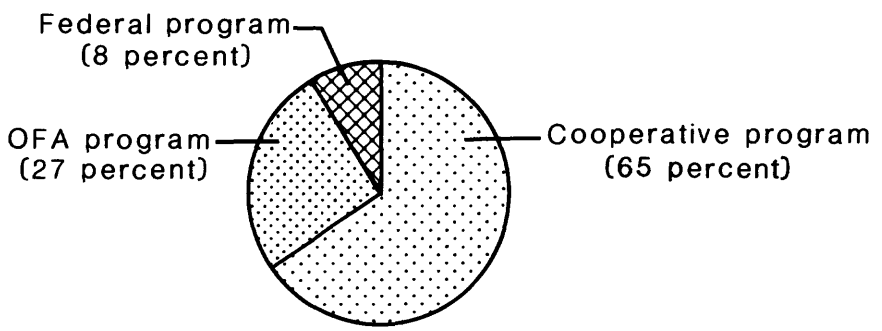
In addition to activities described above, a Regional Aquifer Systems Analysis (RASA) office has been established in Lansing to conduct a 5-year study of the major aquifers in the Michigan Basin, and to define the occurrence of saline waters that underlie fresh waters throughout the Lower Peninsula. R. J. Mandle, the RASA project chief, is supported by a staff of two hydrologists and four hydrologic technicians headquartered at the Lansing District office. Mr. Mandle can be reached at (517) 377-1608.

## Types of Funding

Funding for the water-resources programs falls into two broad categories. In the 1989 Fiscal Year, about half of the program is composed of hydrologic-data collection, 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 slightly more than half 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.




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 1989, the financial support for work in Michigan amounts to about $2,400,000. It is distributed as follows:



## INFORMATION IN THIS REPORT

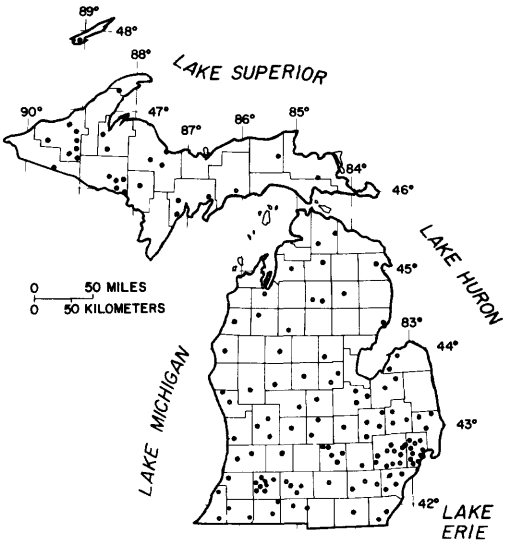
This report consists of four sections: (1) current projects, (2) hydrologic conditions, (3) hydrologic-data stations, and (4) sources of information. The current-projects section contains information concerning the status of all projects that are presently active. The section on hydrologic-data stations 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.


(p. 11 follows)

## CURRENT PROJECTS


(p. 13 follows)

SURFACE-WATER STATIONS




PROJECT NO. - 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 | 199 |
| Continuous record: | |
| Discharge and stage | 138 |
| Stage only | 1 |
| Partial record: | |
| Peak (maximum) flow only | 51 |
| Low (minimum) flow only | 8 |
| Peak and low flow | 1 |
| Lake and reservoir stations | 29 |
| Stage and contents | 5 |
| Stage only | 24 |
| Total | 228 |

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

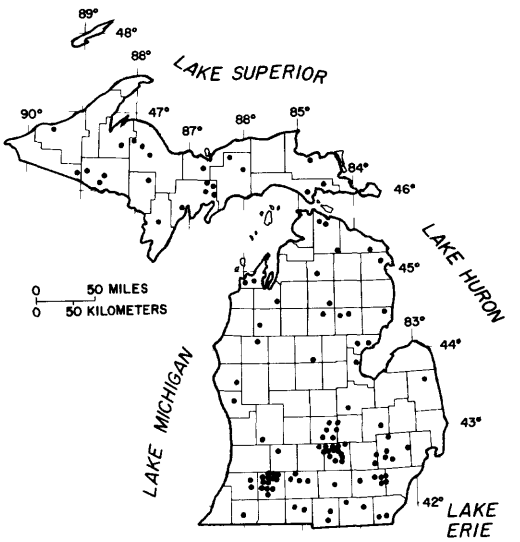
PROJECT CHIEF: Stephen P. Blumer

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 hydrologic-data report "Water Resources Data for Michigan."

GROUND-WATER STATIONS




PROJECT NO. - 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, the wells as follows:

| Station classification | Number of stations |
|---|---|
| Observation wells: | |
| Recording | 60 |
| Nonrecording | 52 |
| Total | 112 |

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

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

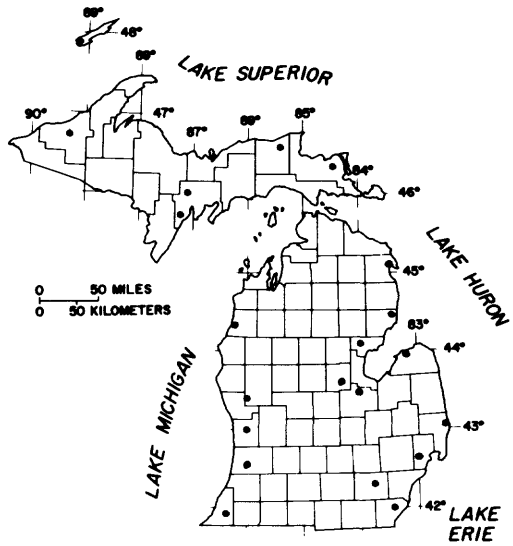
PROJECT CHIEF: Charles R. Whited

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 hydrologic-data reports "Water Resources Data for Michigan" and "Ground-Water Data for Michigan."

WATER-QUALITY STATIONS




PROJECT NO. - MI 003

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:

Surface water:

| Data classification | Number of sites |
|---|---|
| Physical data (daily frequency): | |
| Water temperature | 1 |
| Specific conductance | 0 |
| 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 | 13 |
| pH | 13 |
| Chemical data: | |
| Inorganic constituents | 13 |
| Organic constituents | 13 |
| Radiochemical data | 13 |

Several types of data were collected at some sites.

PLANS THIS YEAR: Continue network in operation. 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

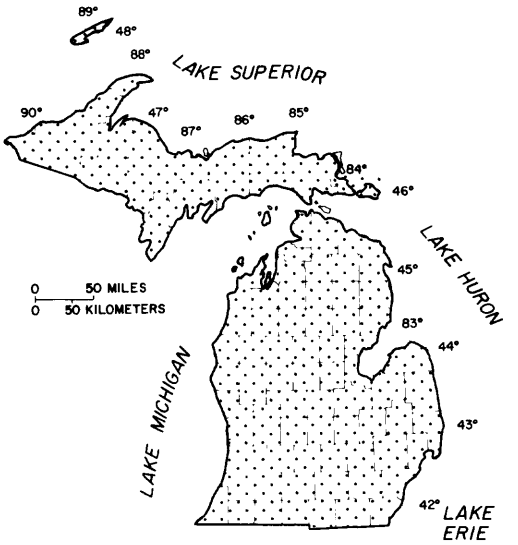
PROJECT CHIEF: Stephen P. Blumer

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Data included in U.S. Geological Survey annual hydrologic-data reports "Water Resources Data for Michigan" and "Ground-Water Data for Michigan."

SEDIMENT STATIONS




PROJECT NO. - 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

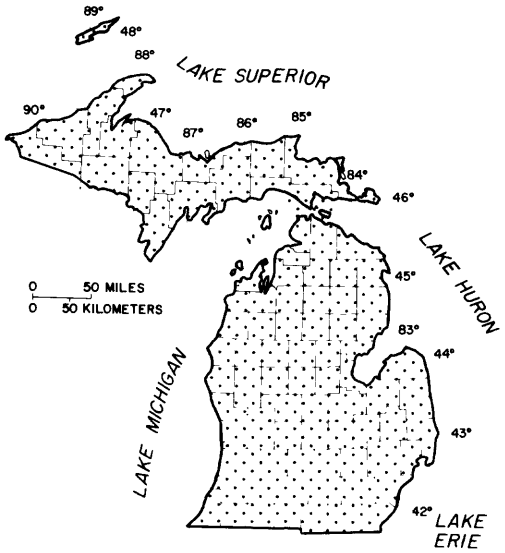
PROJECT CHIEF: Stephen P. Blumer

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS COMPLETED: Data included in U.S. Geological Survey annual hydrologic-data report "Water Resources Data for Michigan."

FLOOD INSURANCE STUDIES




PROJECT NO. - MI 006

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: To conduct the necessary hydrologic and hydraulic evaluations to define flood plains, and to present the results in an appropriate format.

APPROACH: To conduct the necessary evaluation or to conduct surveys by ground or photogrammetic methods. Determine flood-discharge frequency relationships using local historical information, gaging-station records, step-backwater models, or by other acceptable methods, and furnish the results in reports prepared to FEMA specifications.

RESULTS LAST YEAR: No studies conducted.

PLANS THIS YEAR: No flood insurance studies are planned.

HEADQUARTERS OFFICE: Lansing, Michigan

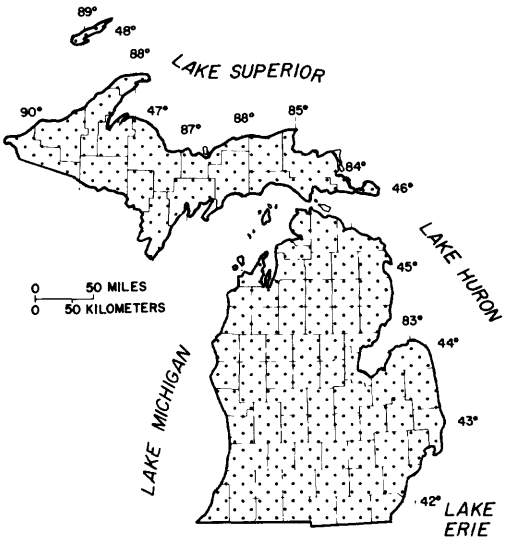
FIELD LOCATION: Statewide

PROJECT CHIEF: David J. Holtschlag

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Federal Emergency Management Agency

WATER USE




PROJECT NO. - MI 007

PROBLEM: Michigan waters are under stress as a result of increasing demands by domestic, industrial, agricultural, and other users, and because of the need to protect water quality. 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: Presented overview of Michigan's water-use data collection and data-bases at an American Water Resources Association conference. Published paper in conference proceedings.

PLANS THIS YEAR: Complete a public water supply data base. Develop framework for county level water-use data compilation. Re-inventory irrigators to update irrigation water use report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: Michael J. Sweat

PERIOD OF PROJECT: Continuous

COOPERATING AGENCY: Michigan Department of Natural Resources

REPORTS IN PROGRESS: Revisions of reports on irrigation in Michigan and municipal water withdrawals have been started.

REPORTS COMPLETED: (1) Bedell, D. J., and Van Til, R. L., 1979, Irrigation in Michigan, 1977: Michigan Department of Natural Resources, Water Management Division

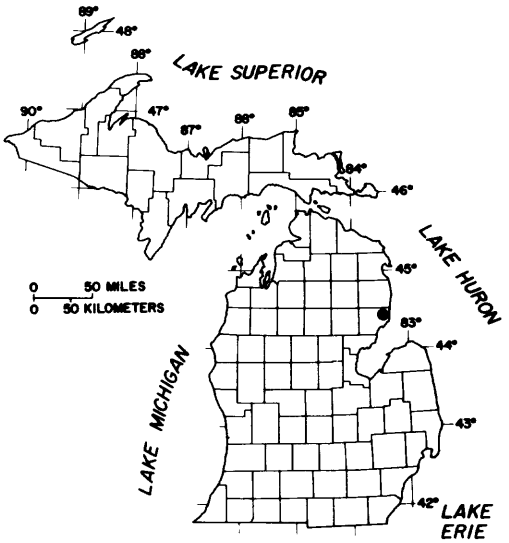
Bedell, D. J., 1982, Municipal water withdrawals in Michigan, Michigan Department of Natural Resources, Water Management Division

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

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 (In press).

GROUND-WATER STUDY OF
WURTSMITH AIR FORCE BASE, MICHIGAN




PROJECT NO. - MI 032

PROBLEM: Volatile hydrocarbons have been found at several places in the ground-water system 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) establish data base and statistically analyze historic data, and (7) 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.

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.

PLANS THIS YEAR: Continue investigations of contamination of water by fuel substances in western part of the Base, and define plume associated with fire training area. Complete statistical analysis of water quality data. Prepare Administrative and Open-File Reports for the U.S. Air Force.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Northeastern Lower Peninsula, Michigan

PROJECT CHIEF: T. Ray Cummings

PERIOD OF PROJECT: April 1987 to September 1989

COOPERATING AGENCY: U.S. Air Force

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., 1 pl., 43 figs.

T. R. Cummings and F. R. Twenter, 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., 3 pls., 55 figs.

REPORTS IN PROGRESS: Cummings, T. R., and Gillespie, J. L., 1989, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Investigations of ground-water contamination at selected sites. [Water-Resources Investigations Report.]

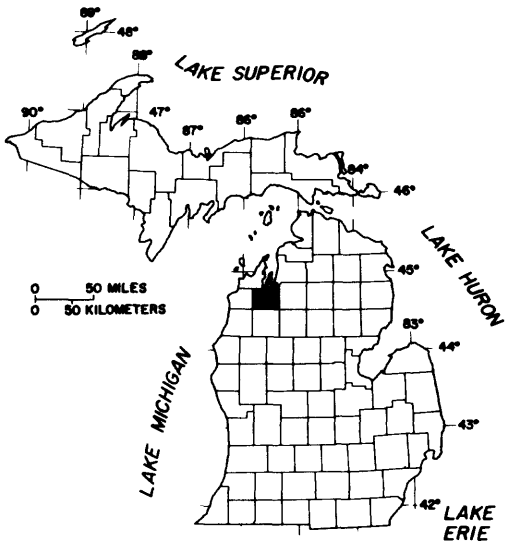
Dumouchelle, D. H., Lynch, E., and Cummings, T. R., 1989, Techniques in the investigation of ground-water contamination: A literature survey: U.S. Geological Survey Open-File Report.

Holtschlag, D. J., 1989, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: An environmental data base system.

Holtschlag, D. J., 1989, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: A strategy for long-term ground-water quality monitoring. [Publication as a Journal article.]

Gillespie, J. L., 1989, Installation Restoration Program, Phase II, Confirmation/Quantification, Stage 2, Wurtsmith Air Force Base, Michigan: Geology and ground water. [Publication as a Water-Resources Investigations Report.]

WATER RESOURCES OF GRAND TRAVERSE COUNTY, MICHIGAN




PROJECT NO. - MI 040

PROBLEM: An increased demand for water by irrigators, municipalities, and industries is affecting economic development in parts of Grand Traverse County, the world's largest producer of cherries. Irrigation alone has increased by more than 300 percent since 1970. The effect of this expansion is unknown, and available information is inadequate to provide a basis for solving problems when they occur. Deteriorating ground-water quality at some places is likely related to use of fertilizer. Studies have shown that nitrate levels in heavily irrigated areas have made water unsuitable for domestic use.

OBJECTIVES: (1) Determine the quantity and quality of ground water and surface water, with particular attention to the use of water for irrigation, and the causes of contamination, (2) evaluate the chemical characteristics of precipitation and integrate this information into hydrologic assessments, (3) relate quality of ground water to land use, with emphasis on agricultural use, and (4) relate, if possible, the transport of dissolved and sorbed substances and suspended sediment by streams to agricultural practices and land use.

APPROACH: (1) Evaluate available data contained in State, county, and USGS files, (2) make routine discharge measurements at 15 stream sites 10 to 12 times per year, at 10 miscellaneous sites three times per year, and at several sites as needed during high flow, (3) measure ground-water levels at about 50 sites and install twenty 4-inch, twenty-five 2-inch, and two 6-inch wells, (4) install recording rain gages at two sites, (5) collect water-quality data from about 250 wells, 15 lakes, and 25 streams, (6) measure quality of precipitation, (7) develop mathematical models for assessing local ground-water conditions, and (8) analyze and evaluate data; write and publish report.

RESULTS LAST YEAR: All field data collected, and analysis begun.

PLANS THIS YEAR: Complete data analysis; write and publish Water-Resources Investigations Report.

HEADQUARTERS OFFICE: Lansing, Michigan.

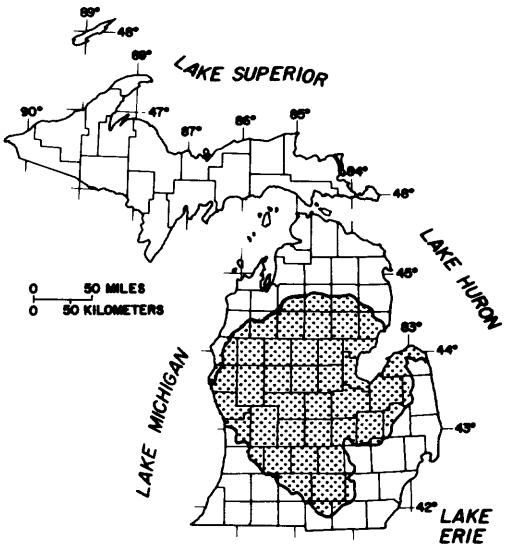
FIELD LOCATION: Northwest Lower Peninsula, Michigan

PROJECT CHIEF: Norman G. Grannemann

PERIOD OF PROJECT: May 1984 to October 1989

COOPERATING AGENCIES: Michigan Department of Natural Resources
Grand Traverse County

MICHIGAN BASIN REGIONAL
AQUIFER SYSTEM ANALYSIS




PROJECT NO. - 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 glacial deposits and bedrock aquifers in the Lower Peninsula, however, is not well defined. Additionally, saline water underlies the freshwater aquifers over the entire extent 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 are 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, (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, (5) develop a computer data base for appropriate data describing the aquifer systems, and (6) using results of this study, evaluate future management of the fresh ground-water resources of the study area.

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: Collected 81 ground-water samples for complete inorganic analysis. Oxygen-18 and deuterium were sampled and analyzed. An additional 18 ground-water samples were collected for carbon-13, carbon-14, tritium, sulfur-34 (sulfate and sulfide), deuterium, oxygen-18, and complete inorganic analysis. At 25 of the 99 sample sites, ground-water samples were collected and analyzed for strontium 87/86. Preliminary isotope and dissolved ion distribution maps were constructed for each aquifer. Preliminary geochemical model simulations were made for 100 ground-water quality analyses (out of 468 total analyses). Top and thickness maps were constructed for each hydrostratigraphic unit. Whole-rock chemical analysis, scanning electron microscope (SEM) and microprobe mineral analysis of matrix and cement of sedimentary rock were completed. Thin sections of sandstone samples from the Marshall and Grand River-Saginaw aquifers were made and examined for mineral analysis. Three test wells, down to the top of the Coldwater Shale, were completed. Multiple ground-water samples were collected through the use of inflatable pockets and submersible pump. The history, rate and distribution of municipal pumping throughout the study area were determined. Hydrographs showing long-term ground-water level trends throughout the study area, and maps showing predevelopment equivalent freshwater head in both bedrock aquifers were constructed. A preliminary, steady-state ground-water flow model has been developed. DC resistivity vertical-electrical soundings were analyzed.

PLANS THIS YEAR: Continue geochemical model and statistical analysis of ground-water quality data. Complete solid-phase chemical and mineral analysis. Continue hydrogeologic framework definition. Analyze and interpret geophysical data used in mapping saline-water/freshwater interface. Refine regional ground-water flow model. Document municipal well abandonment due to saline water encroachment.

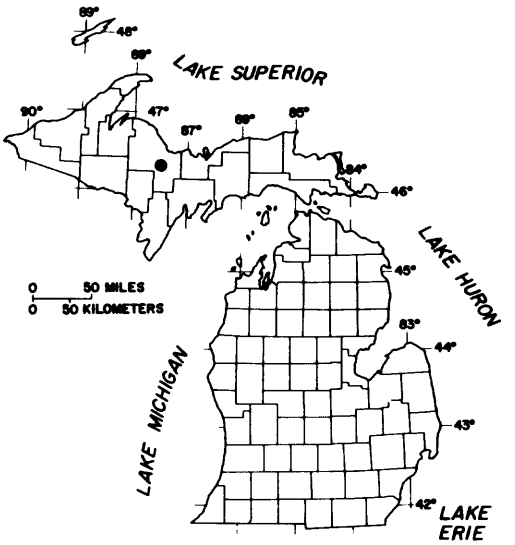
HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Lower Peninsula, Michigan

PROJECT CHIEF: Richard J. Mandle

PERIOD OF PROJECT: October 1985 to September 1991

HYDROGEOLOGY OF
K.I. SAWYER AIR FORCE BASE,
MICHIGAN




PROJECT NO. - 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: Soil-gas chromatographs were obtained at about 100 locations. Based on the soil-gas chromatography and analysis of data from the Phase II, Stage 1 study, 92 new observation wells were drilled. Water from 153 wells was sampled and analyzed for organic compounds. Soils from borings were analyzed for potential contamination. Water samples from Silver Lead Creek were collected and analyzed. Water-levels were measured in all new wells and most other wells on the Base.

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

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Central Upper Peninsula, Michigan

PROJECT CHIEF: Norman G. Grannemann

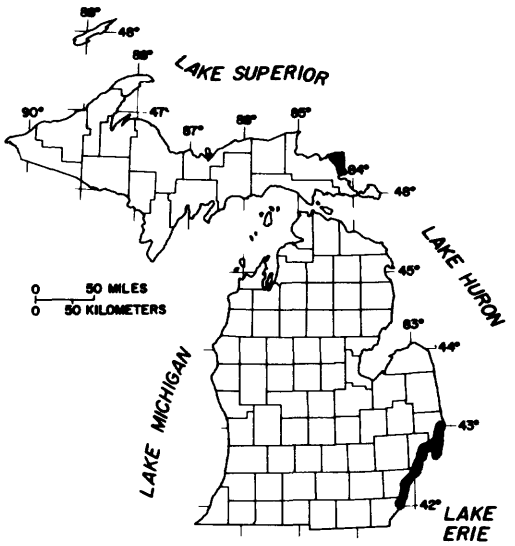
PERIOD OF PROJECT: April 1985 to September 1989

COOPERATIVE AGENCY: U.S. Air Force

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.

REPORTS IN PROGRESS: Grannemann, N. G., and Cummings, T. R., 1989, Groundwater contamination at K. I. Sawyer Air Force Base: U.S. Geological Survey Water-Resources Investigations Report.

GROUND-WATER MOVEMENT NEAR UPPER GREAT LAKES CONNECTING CHANNELS




PROJECT NO. - MI 045

PROBLEM: Information on the movement of ground water to the upper Great Lakes connecting channels in Michigan is inadequate for an evaluation of its impact on the water quality of the channels. Contaminants from landfills, waste-disposal sites, and areas of known ground-water contamination could be a significant factor in determining water quality of the Great Lakes. In areas adjacent to the St. Marys River, Lake St. Clair, the St. Clair River, and the Detroit River, more than 100 hazardous-waste sites lie within 10 miles of the channels. Five of these sites are on the National Priority List. Upward movement of chemical substances from deep geologic strata, either from natural sources or from areas where deep injection of wastes has occurred, is also a possibility.

OBJECTIVES: (1) Determine the geologic conditions near connecting channels, (2) determine configuration of the water table and direction of ground-water flow, (3) determine the chemical and physical characteristics of ground water, with particular attention to the characteristics near known hazardous-waste sites, (4) assess the movement of dissolved substances from deep geologic strata to the connecting channels, and (5) assess the ground-water contribution of contaminants and natural occurring substances in the connecting channels.

APPROACH: Data collection and analyses activities were conducted in three phases to meet the requirements of the United States-Canada agreements developed by the project Management and Activities Integration Committees. Phase I was concerned with assembling data and identifying sites where ground-water contamination is suspected or known; phase II consisted of a preliminary designation of potentially hazardous sites; and phase III consisted of site specific investigation for prioritizing waste sites and calculating loading.

PLANS THIS YEAR: Consider and evaluate recent recommendations of the Upper Great Lakes Connecting Channels Study Management Committee regarding additional investigations near deep wastes disposal sites along the St. Clair River.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Eastern Upper Peninsula and southeastern Lower Peninsula

PROJECT CHIEFS: John L. Gillespie and Denise H. Dumouchelle

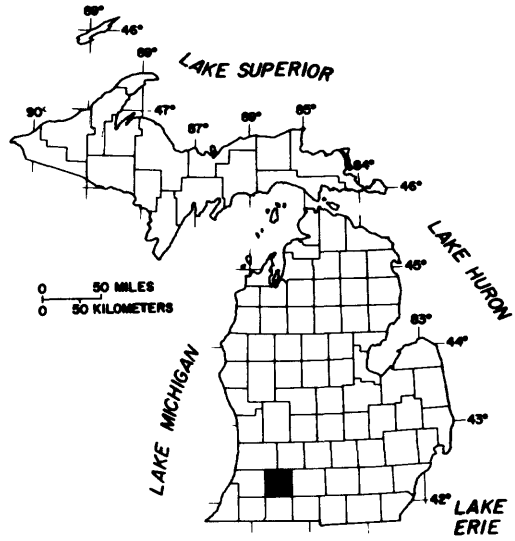
PERIOD OF PROJECT: July 1985 to December 1989

COOPERATING AGENCY: U.S. Environmental Protection Agency

REPORTS COMPLETED: Gillespie, J. L., Dumouchelle, D. H., and Cummings, T. R., 1988, "Ground-water flow and quality near the upper Great Lakes connecting channels, Michigan", Administrative Report to the U.S. Environmental Protection Agency, 50 p., 10 pl., 42 figs., 23 tabs.

Gillespie, J. L., and Dumouchelle, D. H., 1989, Ground-water flow and quality near the upper Great Lakes connecting channels, Michigan, U.S. Geological Survey Water-Resources Investigations Report 88-4232, 82 p., 5 pl., 28 figs., 9 tabs.

GROUND-WATER PROTECTION IN
KALAMAZOO COUNTY, MICHIGAN




PROJECT NO. - MI 046

PROBLEM: Studies by the State of Michigan have identified 46 sites in Kalamazoo County where ground-water contamination has or is likely to occur. Many of the compounds contaminating ground water are chlorinated hydrocarbons, fuel substances, or plating wastes. Irrigation increased about 400 percent in the 1970's, with a commensurate increase in the use of fertilizers and pesticides. Relations between geology, hydrology, land and water use, and ground water have not been established. The source of recharge for specific ground-water reservoirs is not well known. Strategies for protecting ground water cannot be developed until such relationships are understood.

OBJECTIVE: (1) To determine the geologic and hydrologic conditions that influence the quality and quantity of ground water, (2) to relate information on ground-water quality to land and water use, cultural activity, and surface-water resources, (3) to relate, to the extent possible, the movement of chemical substances in the ground-water system to the hydrology of the area, (4) to delineate recharge areas and identify areas susceptible to ground-water contamination from surface and subsurface sources, and (5) to better define location, extent, and character of confining beds and determine their relation to the vertical and horizontal movement of ground water and contaminants.

APPROACH: (1) Evaluate available hydrologic and geologic data contained in State, county, and USGS files, (2) collect ground-water level data routinely at about 50 sites, (3) install approximately thirty five 4-inch wells, (4) install digital recorders on three wells, (5) collect water-quality data from about 50 wells, (6) install Belfort rain gage at one site, (7) collect precipitation and dry fallout samples at two sites, (8) make discharge measurements at about 20 stream sites approximately three times per year, (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: Completed analysis of surface and ground water-quality data, and mapped the susceptibility of the ground water to contamination county wide.

PLANS THIS YEAR: Transmit report for colleague review; obtain Director's approval for publication of a Water-Resources Investigations Report.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Southwest Lower Peninsula, Michigan

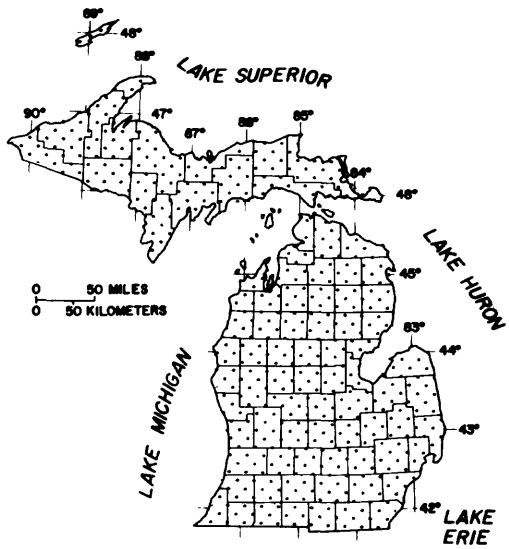
PROJECT CHIEF: Stephen J. Rheaume

PERIOD OF PROJECT: March 1986 to July 1989

COOPERATING AGENCIES: Michigan Department of Natural Resources
Kalamazoo County

REPORT IN PROGRESS: Rheaume, S. J., 1989, Ground-water protection in Kalamazoo County, Michigan: U.S. Geological Survey Water-Resources Investigations Report.

CHEMICAL AND PHYSICAL CHARACTERISTICS
OF NATURAL GROUND WATERS IN MICHIGAN




PROJECT NO. - 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) approximately 30 samples will be collected each year, (3) field analyses of specific conductance, temperature, dissolved oxygen, pH and alkalinity will be made, (4) laboratory analyses will be performed for common substances, trace metals, pesticides, and tritium, (5) results of chemical analyses, and analyses made prior to 1986, will be stored in a separate 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: Chemical analyses of water from selected wells were made; open-file report on natural water quality completed.

PLANS THIS YEAR: Publish natural water-quality report. Collect samples for the analysis of isotopes.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: T. Ray Cummings

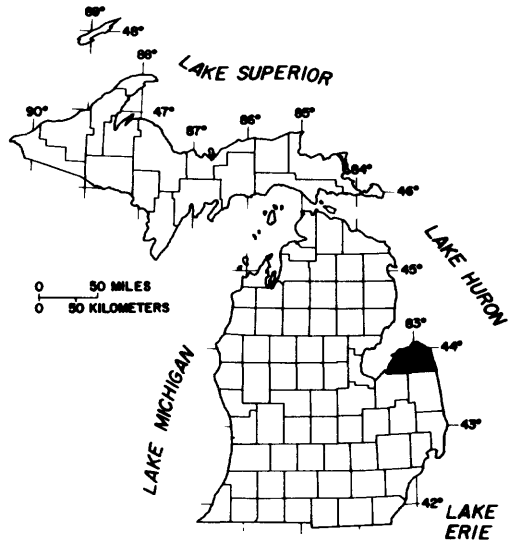
PERIOD OF PROJECT: January 1986 to September 1991

COOPERATIVE AGENCY: Michigan Department of Natural Resources
Geological Survey Division

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., 12 figs.

Cummings, T. R., 1989, Natural ground-water quality in Michigan, 1974-87: U.S. Geological Survey Open-File Report 89-259, 50 p., 15 figs., 4 tabs.

HYDROGEOLOGY OF
HURON COUNTY, MICHIGAN




PROJECT NO. - 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: Thirty-one ground water wells were drilled, and eight ground-water level recorders were installed. Surface-water and ground-water samples were collected. Seven DC-resistivity measurements were made, and forty-one geophysical logs of wells were made.

PLANS THIS YEAR: Prepare water table map, bedrock top map, aquifer thickness maps, and geologic cross-sections showing relation of aquifers to each other and to confining beds. Conduct pumping tests.

HEADQUARTERS OFFICE: Lansing, Michigan

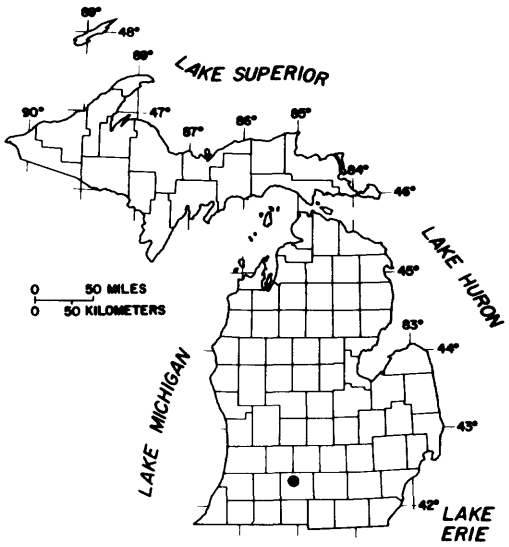
FIELD LOCATION: Eastern Lower Peninsula, Michigan

PROJECT CHIEF: Michael J. Sweat

PERIOD OF PROJECT: May 1987 to April 1990

COOPERATING AGENCIES: Huron County
Michigan Department of Natural Resources

GROUND WATER AT THE
VERONA WELL FIELD,
BATTLE CREEK, MICHIGAN




PROJECT NO. - 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 the 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.

PLANS THIS YEAR: Begin review and evaluation of data. Install wells, and begin recalibration of ground-water flow model.

FIELD LOCATION: Southwestern Lower Peninsula, Michigan

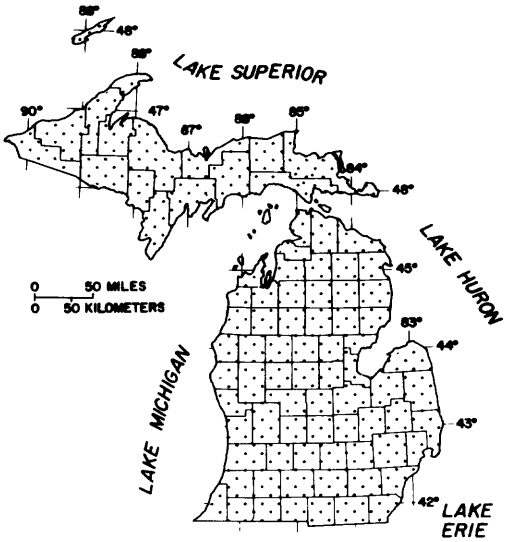
PROJECT CHIEF: Norman G. Grannemann

PERIOD OF PROJECT: January 1989 to March 1990

COOPERATING AGENCY: City of Battle Creek, Michigan

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.

HYDROLOGIC PROVINCES IN MICHIGAN




PROJECT NO. - 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, on two 1:500,000 scale maps, 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 being collected by the Regional Aquifer Systems Analysis study in Michigan also will be used. 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: None

PLANS THIS YEAR: Begin assembling and analyzing data

HEADQUARTERS OFFICE: Lansing, Michigan

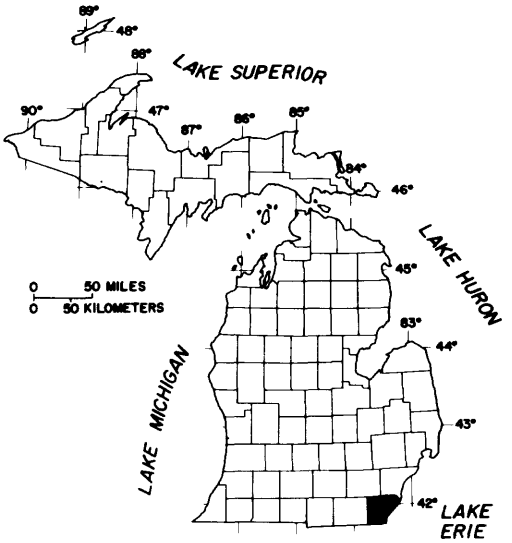
FIELD LOCATION: Statewide

PROJECT CHIEF: Stephen J. Rheaume

PERIOD OF PROJECT: June 1989 to September 1990

COOPERATIVE AGENCY: Michigan Department of Natural Resources

IMPACTS OF DROUGHT ON WATER RESOURCES
OF MONROE COUNTY, MICHIGAN




PROJECT NO. - 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 routine 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.

PLANS THIS YEAR: Assemble existing hydrologic and geologic data, review literature, and begin collection of hydrologic data.

HEADQUARTERS OFFICE: Lansing, Michigan

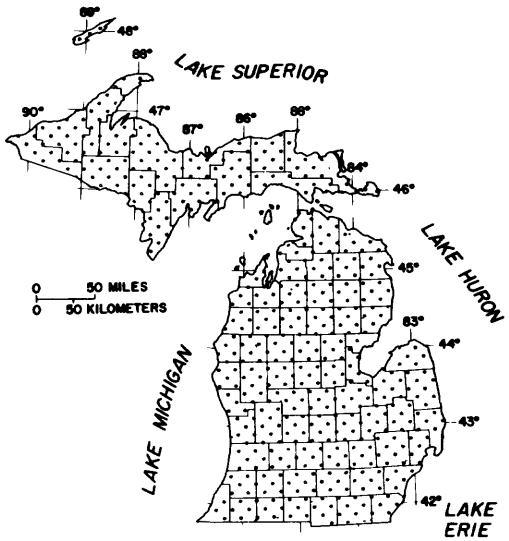
FIELD LOCATION: Southeastern Lower Peninsula, Michigan

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




PROJECT NO. - 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.

PLANS THIS YEAR: Conduct literature survey, develop data base, analyze data for trends and use deseasonalizing procedures. Begin development of regression and transfer function models.

HEADQUARTERS OFFICE: Lansing, Michigan

FIELD LOCATION: Statewide

PROJECT CHIEF: David J. Holtschlag

PERIOD OF PROJECT: May 1989 to September 1990

COOPERATING AGENCY: Michigan Department of Natural Resources

## 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. 3). Eight to 16 inches of precipitation becomes surface runoff (fig. 4) 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 5 and 6; the availability of ground water is shown in figures 7 and 8. 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 waters. Largest municipal withdrawals are in the heavily populated counties in the southern part of the State (fig. 9). Glacial deposits are the source of municipal ground-water supplies in most of the State (fig. 10). In some parts of the State, the base of fresh ground water is less than 200 feet deep (fig. 11); 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 mg/L (milligrams per liter) at some locations in the Lower Peninsula (Cummings and others, 1984).

The current program of the Michigan District of the U.S. Geological Survey 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.

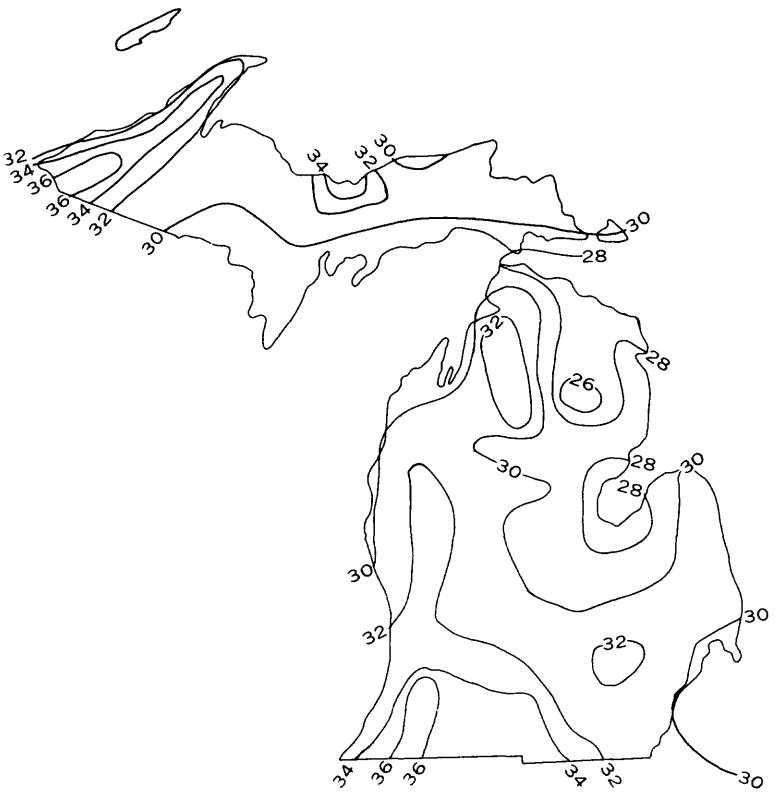



Figure 3.--Average annual precipitation (in inches) (Date from National Weather Service--NOAA).

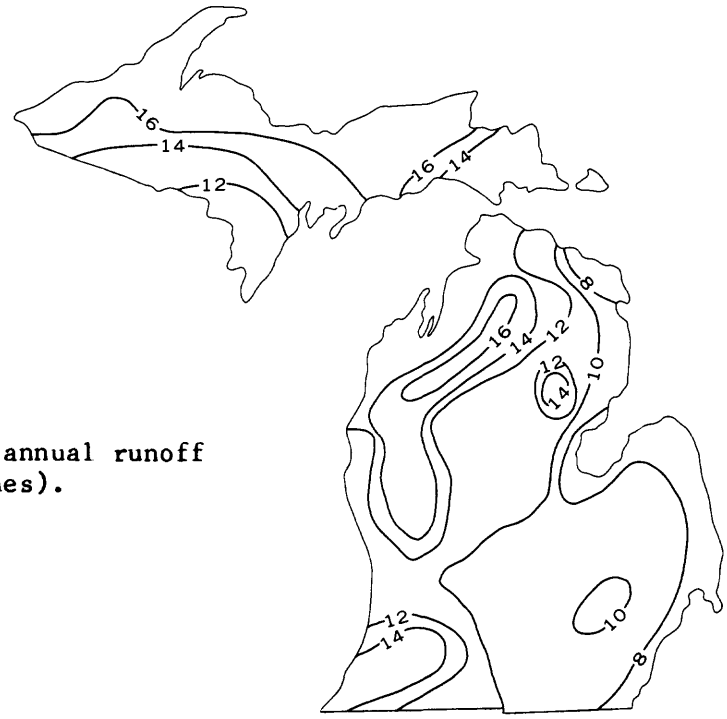



Figure 4.--Average annual runoff (in inches).

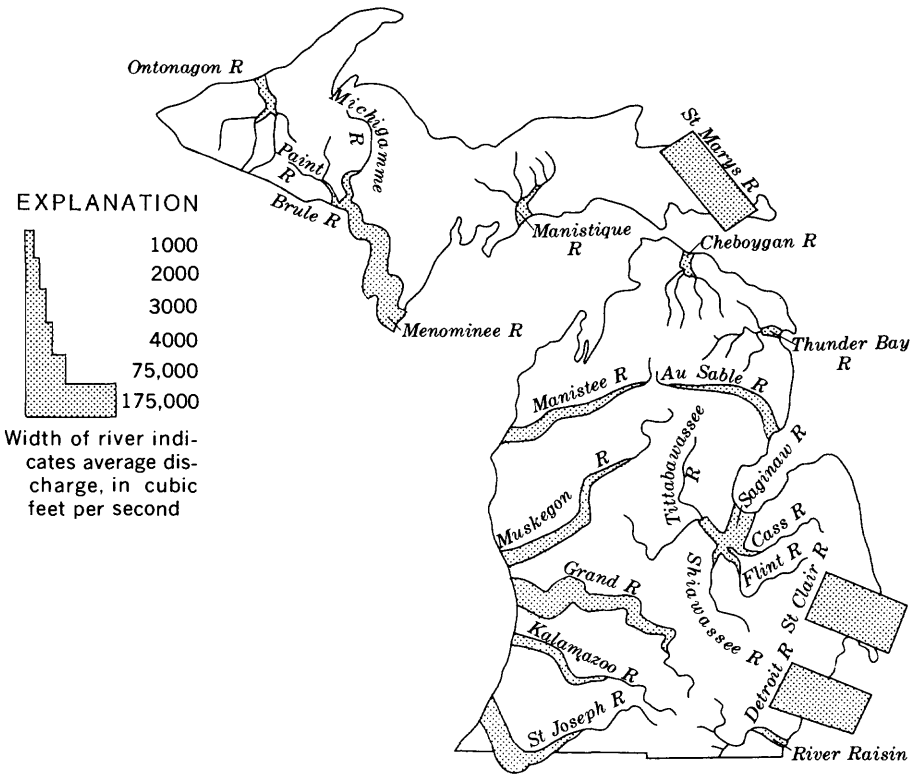



Figure 5.--Average discharge of streams (For streams draining an area of 1000 square miles or more at mouth).

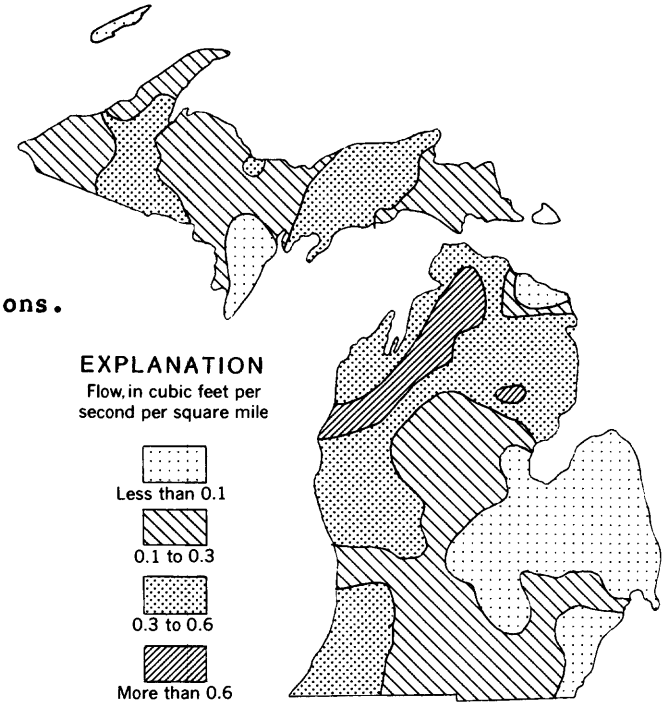



Figure 6.--Low-flow conditions.


Figure 7.--Availability and quality of ground water in bedrock.

EXPLANATION

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 8.--Availability of ground water in glacial deposits.**

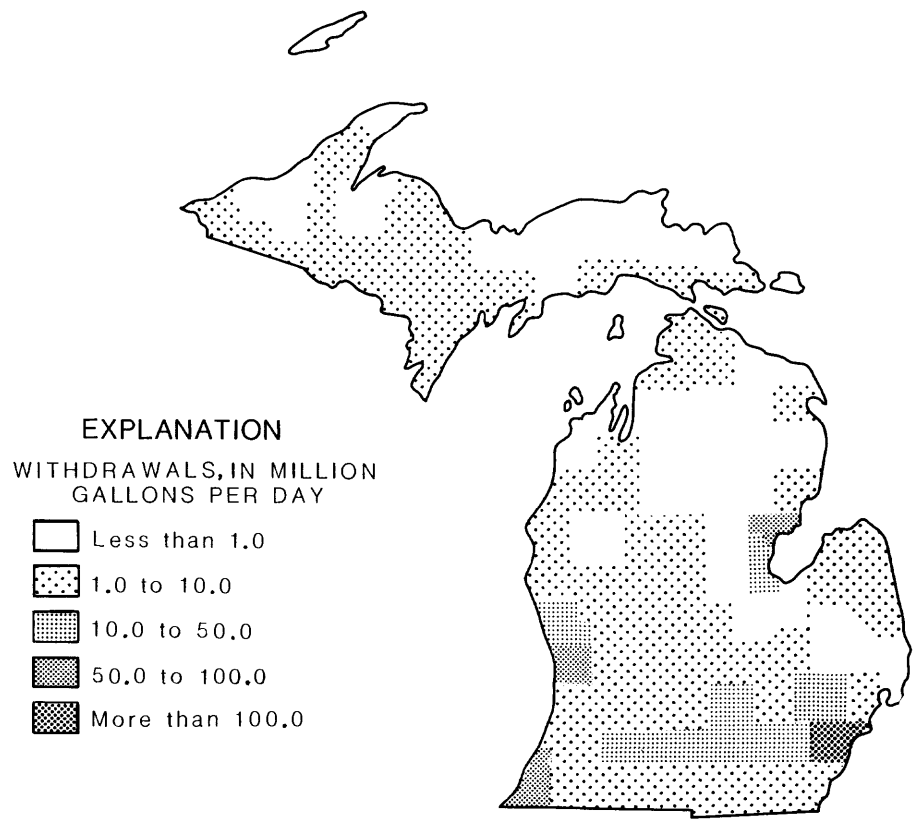



**Figure 9.--Municipal water withdrawals, 1978.**

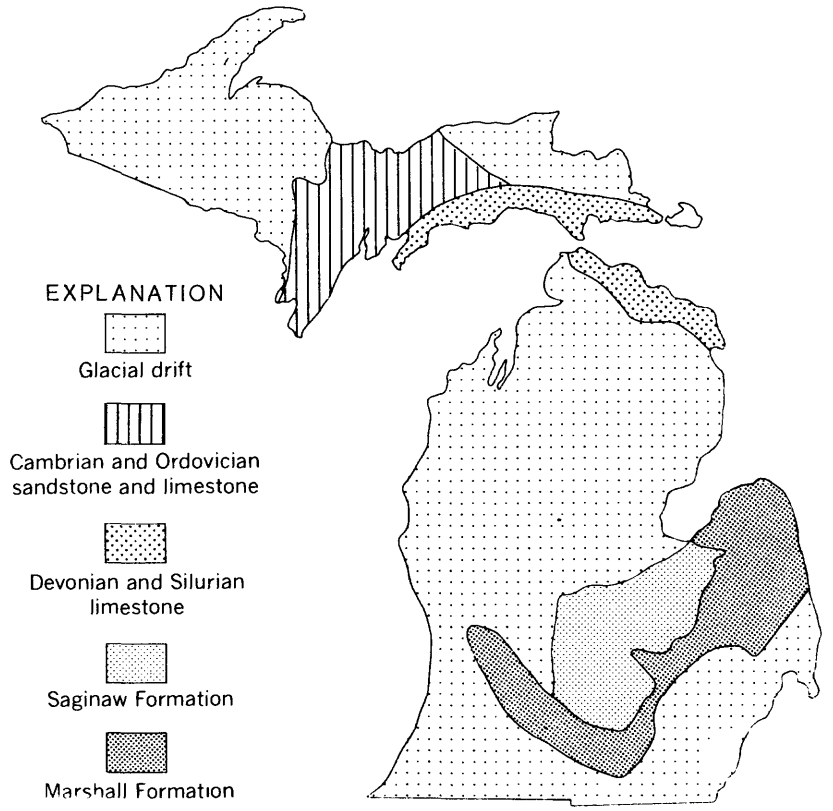
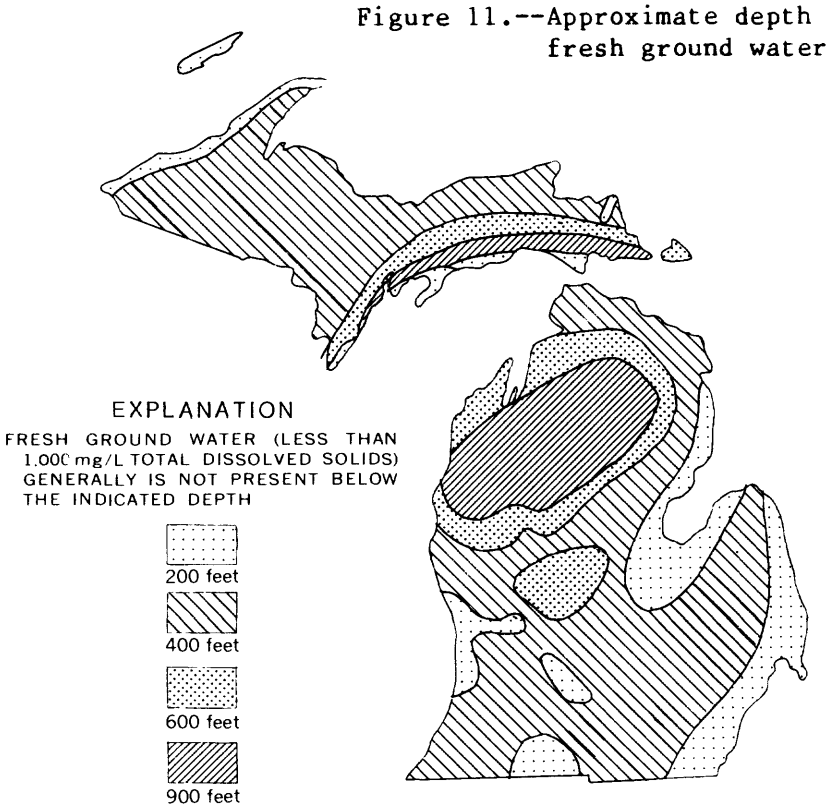



Figure 10.--Principal sources of public ground-water supplies.

Figure 11.--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

In table 1, 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. 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 | Q1CPTR |
| 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 |
| 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 Tahquamenon 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 | MCSR |
| 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 |
| 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 |
| 04062300 | Michigamme River at Republic, MI | 2 |
| 04062500 | Michigamme River near Crystal Falls, MI | Q1 |
| 04063000 | Menominee River near Florence, WI | Q1 |
| 04065722 | Menominee River near Vulcan, MI | Q1 |
| 04096272 | Beebe Creek near Hillsdale, MI | 2 |
| 04096340 | St. Joseph River at Clarendon, MI | 2 |

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

| Station number | Station name | Type of data |
|---|---|---|
| 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 |
| 04096600 | Coldwater River near Hodunk, MI | Q1 |
| 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 |
| 04111379 | Red Cedar River near Williamston, 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 |
| 04112850 | Sycamore Creek near Holt, MI | Q1 |
| 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 |

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

| Station number | Station name | Type of Data |
|---|---|---|
| 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 |
| 04122000 | Muskegon River at Newaygo, MI | Q1 |
| 04122030 | Muskegon River near Bridgeton, MI | MCS |
| 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 |
| 04127000 | Boardman River near Mayfield, 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 | Q1 |
| 04139000 | Houghton Creek near Lupton, MI | 2 |
| 04140200 | Klacking Creek near Selkirk, MI | 2 |
| 04140500 | Rifle River at Selkirk, MI | 2 |
| 04141100 | Shepards Creek near Selkirk, MI | 2 |
| 04142000 | Rifle River near Sterling, MI | Q1C |
| 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 |

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

| Station number | Station name | Type of data |
|---|---|---|
| 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 |
| 04158000 | Columbia Drain near Sebewaing, 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 |
| 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 | |
| 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 |

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

| Station number | Station name | Type of data | Station number | Station name | Type of data |
|---|---|---|---|---|---|
| 04168800 | Huron River near Andersonville, MI | 2 | 04174950 | Willow Run near Rawsonville, MI | Q1 |
| 04170000 | Huron River at Milford, MI | Q1 | 04175600 | River Raisin near Manchester, MI | Q1 |
| 04170500 | Huron River near New Hudson, MI | Q1 | 04175960 | South Branch River Raisin near Adrian, MI | 2 |
| 04172000 | Huron River near Hamburg, MI | Q1 | 04176000 | River Raisin near Adrian, MI | Q1 |
| 04173250 | Mill Creek near Lima Center, MI | 2 | 04176400 | Saline River near Saline, MI | 2 |
| 04174050 | Huron River at Delhi Mills, MI | P | 04176500 | River Raisin near Monroe, MI | Q1CS |
| 04174500 | Huron River at Ann Arbor, MI | Q1 | 04176605 | Otter Creek at LaSalle, MI | Q1 |

1/ TYPE OF DATA:

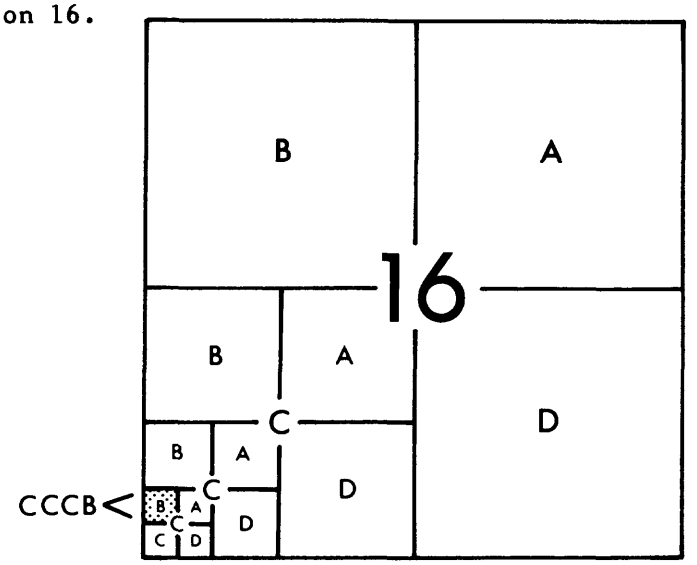
Surface-water data:
- Q - Daily discharge.
- 1 - Stage.
- 2 - Peak stage and discharge.
- 3 - Low flow.
- 4 - Reservoir contents.
- M - Miscellaneous.

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 | I |
| | 06N 02W 16DDAD1 | MSHD, U.S. 27 | 23 | GLCL | M |
| | 07N 01W 34CC | Sleepy Hollow 7 | 32 | GLCL | I |
| 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 |
| Genesee | 06N 07E 09DCCC1 | Fisher Body No.2 | 385 | SGNW | R,QC |
| 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 |
| Ingham | 02N 01E 34DB | Dansville Game Area | 87 | GLCL | Q |
| | 02N 01W 05BCAB1 | Mason | 210 | SGNW | R,QC |
| | 03N 01E 07DDCA1 | Lotte | 184 | SGNW | M |
| | 02W 23BCBD | Holt | 188 | SGNW | R |
| | 04N 01W 16DAD | Meridian Twp. | 398 | SGNW | M |
| | 28BCAD1 | Okemos | 125 | SGNW | R |
| | 02W 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 |
| | 22BC | Lansing, P-5 | 338 | SGNW | M |

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

| County | Well number | Name of well | Depth (ft) | Aquifer | Type of data |
|---|---|---|---|---|---|
| Ingham (cont.) | 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 | WMP 23 | 47 | GLCL | M |
| | 20DC | WMP 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 | Rouge 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 |
| | 06S 04E 08DDBA1 | Fisher Body | 81 | GLCL | R,QC |
| 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 | WMP 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 |

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

| County | Well number | Name of well | Depth (ft) | Aquifer | Type of data |
|---|---|---|---|---|---|
| Oceana | 13N 15W 18AAAA1 | Hesperia | 79 | OTSH | R,QC |
| 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 |
| | 24CA1 | Ypsilanti Township 104 | 87 | 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
I - Intermittently

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 for 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 areas inundated by 100-year floods are available from the District office. Additional information on surface- and ground-water conditions in Michigan is given in the reports listed. Inquires concerning the availability of these reports should be addressed to:

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

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