HYDROGEOLOGY OF HURON COUNTY, MICHIGAN

By M.J. Sweat

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.004047	square kilometer
acre	0.4047	hectare
square foot (ft^2)	0.09294	square meter
square mile (mi^2)	2.590	square kilometer
square mile	259.0	hectare
	Volume	
gallon (gal)	3.785	liter
gallon	0.003785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
	Flow	
foot per second (ft/s)	0.3048	meter per second
foot per day (ft/d)	0.1524	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second	28.32	liter per second
cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$	0.09291	cubic meter per day per square meter times meter of aquifer thickness
gallon per minute (gal/min)	0.06308	liter per second

Temperature: Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = (1.8 \times °C) + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance: Specific conductance is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is identical to micromhos per centimeter at 25 degrees Celsius, formerly used by the U.S. Geological Survey.

Dissolved solids concentration: Dissolved solids concentration is reported as residue on evaporation.

Chemical concentration: Chemical concentration in water is given in milligrams per liter (mg/L) and micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Radionuclide concentration: Radionuclide concentration in water is expressed as picoCuries per liter (pCi/L).

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By Michael J. Sweat

ABSTRACT

This report presents the results of a study by the U.S. Geological Survey, in cooperation with Huron County and the Michigan Department of Natural Resources, Geological Survey Division, to evaluate and describe the ground-water resources of Huron County. Huron County is a mostly agricultural county of 36,000 residents, and is located in east-central Michigan.

Inland surface waters of the county are not reliable sources of water supply. Thick, water-bearing glacial sand and gravel deposits are absent from much of the county. Bedrock, in many places, either yields insufficient amounts of water for domestic supplies or yields only saline water. The Napoleon Sandstone Member of the Marshall Formation is the source of most ground water used in Huron County. Sandstones in the lower part of the Marshall Formation are used as a source of ground water where the Napoleon Sandstone Member is absent.

The only alternative sources of ground water are surficial deposits. Surficial deposits are primarily till, glacial and lacustrine clay, and lenses of sand and gravel. Water levels and quality in the surficial deposits are susceptible to seasonal change.

Water from some of the wells sampled during this study exceeded the maximum contaminant levels for drinking water established by the U.S. Environmental Protection Agency for arsenic, cadmium, nitrate, and selenium. Pesticides were present in water from two wells. The predominant dissolved ions in ground water from the Napoleon Sandstone Member are calcium and bicarbonate. Underlying the Napoleon Sandstone Member are three sandstones in the lower part of the Marshall Formation in which water quality is similar to that of the Napoleon Sandstone Member.

Ground-water recharge may be occurring in the south-central part of the county to surficial and bedrock aquifers. Tritium concentrations in ground water are below the detection limit, which is 26 picoCuries/liter, for 38 of 39 samples analyzed; the absence of tritium indicates that residence time of water now in the flow system is greater than 40 years. Ground-water flow in the county is from southeast to northwest toward Saginaw Bay.

The Michigan Formation and Coldwater Shale act as confining units, and the Saginaw and Michigan Formations limit the rate of recharge to the Marshall Formation. Horizontal hydraulic conductivities of the Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation in Huron County range from 0.25 to 1.5 foot per day, and transmissivities range from 7 to 50 cubic feet per day per square foot times foot of aquifer thickness. Horizontal hydraulic conductivities in overlying deposits are 2 and 3 orders of magnitude less than horizontal hydraulic conductivities in the Marshall Formation. Horizontal hydraulic conductivities were not measured in the Coldwater Shale.

Potentiometric surface maps were drawn to identify areas where flowing wells might be encountered. It is possible that ground-water withdrawals could be expanded in these areas without adverse effects on existing supplies. Data collected during this study indicate that increased withdrawals from the Marshall Formation could potentially cause migration of water with elevated dissolved-solids concentrations from overlying and underlying formations and could also cause depletion of the aquifer in places.

INTRODUCTION

In Huron County, as in several other Michigan counties, the use of ground water and surface water for irrigation has increased in recent years. The extent to which additional water resources can be developed and agricultural activity can be expanded without a serious effect on existing water users and deterioration of water quality is a major concern. Increased use of water can affect not only its quality and availability to other potential users but also the esthetic value of streams and lakes.

In the western part of the county, wells are commonly completed in the Michigan Formation. These wells yield water in which dissolved-sulfate concentrations[1] are elevated (greater than 250 mg/L), probably because of the abundance of gypsum in the Michigan Formation. Deeper wells in the western and central parts of the county that are completed in sandstone of the upper Marshall Formation (Napoleon Sandstone Member) yield potable water. In the southeastern part of the county, wells in the Coldwater Shale or in sandstones of the lower Marshall Formation yield water in which chloride concentrations are high.

Existing information on the hydrogeology of Huron County is not adequate to determine if supplies of potable ground water are sufficient to meet long-term needs. This lack of information has prevented development of sound ground-water-management plans by county planners and water-resource managers. To provide the information needed by planners and water-resource managers, the U.S. Geological Survey (USGS), in cooperation with Huron County and the Geological Survey Division of the Michigan Department of Natural Resources, conducted an investigation of the ground-water resources of Huron County.

Purpose and Scope

This report describes the general hydrogeologic conditions in Huron County, and identifies areas from which additional ground-water resources might be available. The investigation required an assessment of the water available from underground and surface sources. To do this required a thorough understanding of the hydrology and geology of the study area, extensive water-quality sampling countywide, and making numerous aquifer tests in the principal aquifers and confining layers of the study area.

The report is based on data collected during 1987-90. Data on geology, hydrology, and water quality, which provide the necessary basis for interpretations, also were collected and evaluated.

Previous Studies

Hydrologic and geologic characteristics of the county were described by Winchell (1861), Rominger (1876), Lane (1893, 1899a, 1899b, and 1900), Lane

[1]Selected terms and water-quality units are defined in the definitions of terms at the back of the report.

and others (1897), and Leverett and others (1907). A report by Monnett (1948) includes a discussion of the rocks of the Marshall Formation and Coldwater Shale. The Chester Engineers (1976), Hendrix and Yocum (1984), U.S. Department of Agriculture (1986, 1987a, 1987b), and Williams, Osminski, Little and Associates (1989) discuss agricultural issues relating to the availability of water. Reports by Vugrinovich (1986) and Mandle and Westjohn (1989) describe regional ground-water flow in the western part of the county.

Acknowledgments

The author wishes to thank James LeCureux of the Huron County Cooperative Extension Service for providing information on irrigation and agricultural practices and on the quantity of ground-water withdrawals for agricultural practices in the county. The Huron County Health Department provided existing partial chemical analyses of ground water. The Geological Survey Division of the Michigan Department of Natural Resources provided access to well logs. The Michigan Department of Public Health analyzed water from 30 observation wells installed by the USGS. Many county and local officials and citizens provided data and took an active interest in the project.

GENERAL DESCRIPTION OF STUDY AREA

Huron County is in the east-central part of Michigan's Lower Peninsula (fig. 1). The county, shaped roughly like a semicircle, is bounded along the north by 91 mi of Great Lakes shoreline (Lake Huron and Saginaw Bay) and along the south by Sanilac and Tuscola Counties. Most streams start within the county and flow to the lake or bay. Land surface is flat to rolling; elevations range from 580 ft above sea level along the lakeshore to more than 800 ft near Ubly (fig. 2). The county has an area of 830 mi^2, most of which is pasture and cropland.

The estimated population of the county in 1985 was 36,000 (Michigan Department of Management and Budget, 1985). The community with the largest population is Bad Axe (fig. 1 and plate 1), which had a population of 3,184 in 1985 (table 1); Sebewaing Township has the largest township population (3,259) (fig. 3). Tourism and shoreline development are expected to increase because of the county's proximity to large population centers (Detroit, Saginaw, Bay City and Midland) and easy access to Lake Huron. These increases are likely to increase demands on water resources as the population increases.

The western half of the county is in the Saginaw Lowlands (Newcombe, 1933), and the eastern half is in the Thumb Uplands (fig. 2). The entire county is in the Lake Huron basin. The land surface of the south-central part of the county is rolling and is part of the Port Huron end moraine (fig. 4) of the Saginaw lobe of the Wisconsinan stage glaciation. The remainder of the county is nearly flat and slopes toward Lake Huron and Saginaw Bay. This broad plain developed as sediments accumulated in the many proglacial lakes that formed as the Saginaw lobe retreated about 10,000 to 13,000 years ago.

Average annual precipitation ranges from 34 in. to 29 in. Average annual rainfall ranges from 27 in. along the shore to 24 in. at some inland areas (National Oceanic and Atmospheric Administration, 1988-90); average annual

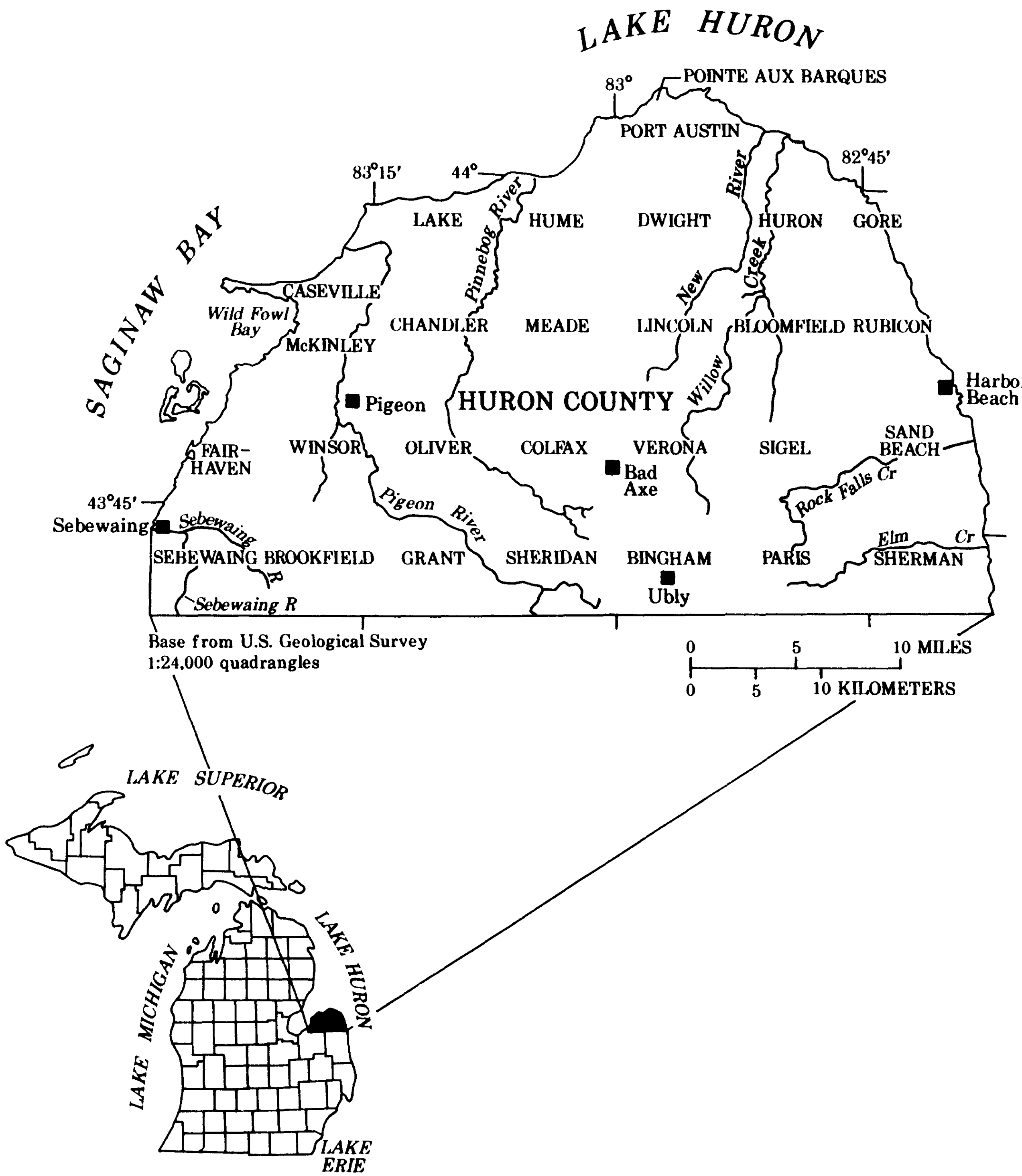
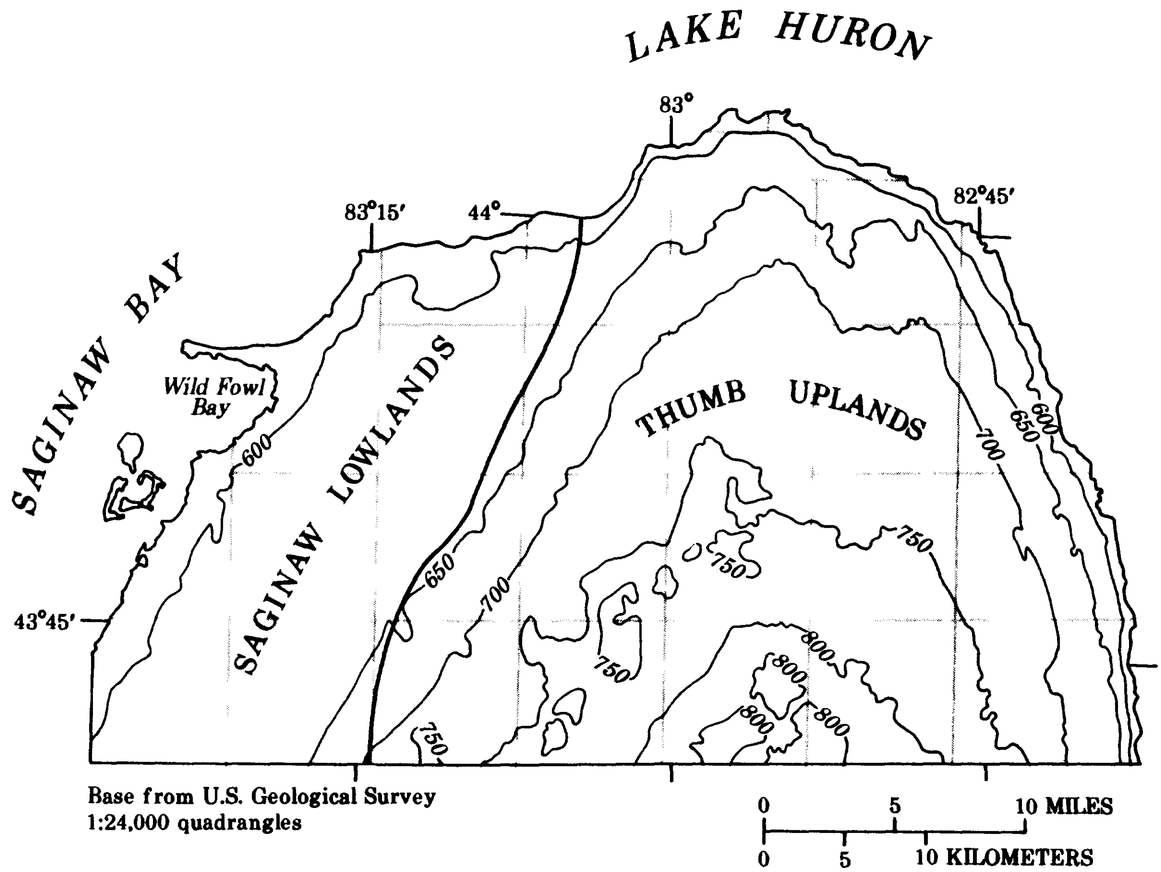


Figure 1.--Location of Huron County.



EXPLANATION

—700— TOPOGRAPHIC CONTOUR--Shows elevation of land surface. Contour interval 50 feet. Datum is sea level

——— PHYSIOGRAPHIC BOUNDARY

Figure 2.--Elevation of land surface and physiographic subdivisions of Huron County (physiography modified from Newcombe, 1933).

Table 1.--Population of communities in Huron County, Michigan, 1985

[Population data from Michigan Department of Management and Budget, 1985]

Community	Population	Community	Population
Bad Axe	3,184	Pigeon	1,247
Caseville	851	Pointe Aux Barques	15
Elkton	953	Port Austin	839
Harbor Beach	2,000	Port Hope	369
Kinde	600	Sebewaing	2,046
Owendale	308	Ubly	862

snowfall ranges from 50 to 72 in. Extreme temperatures range from -25 °F to 100 °F; mean monthy temperatures range from 22 °F to 69 °F.

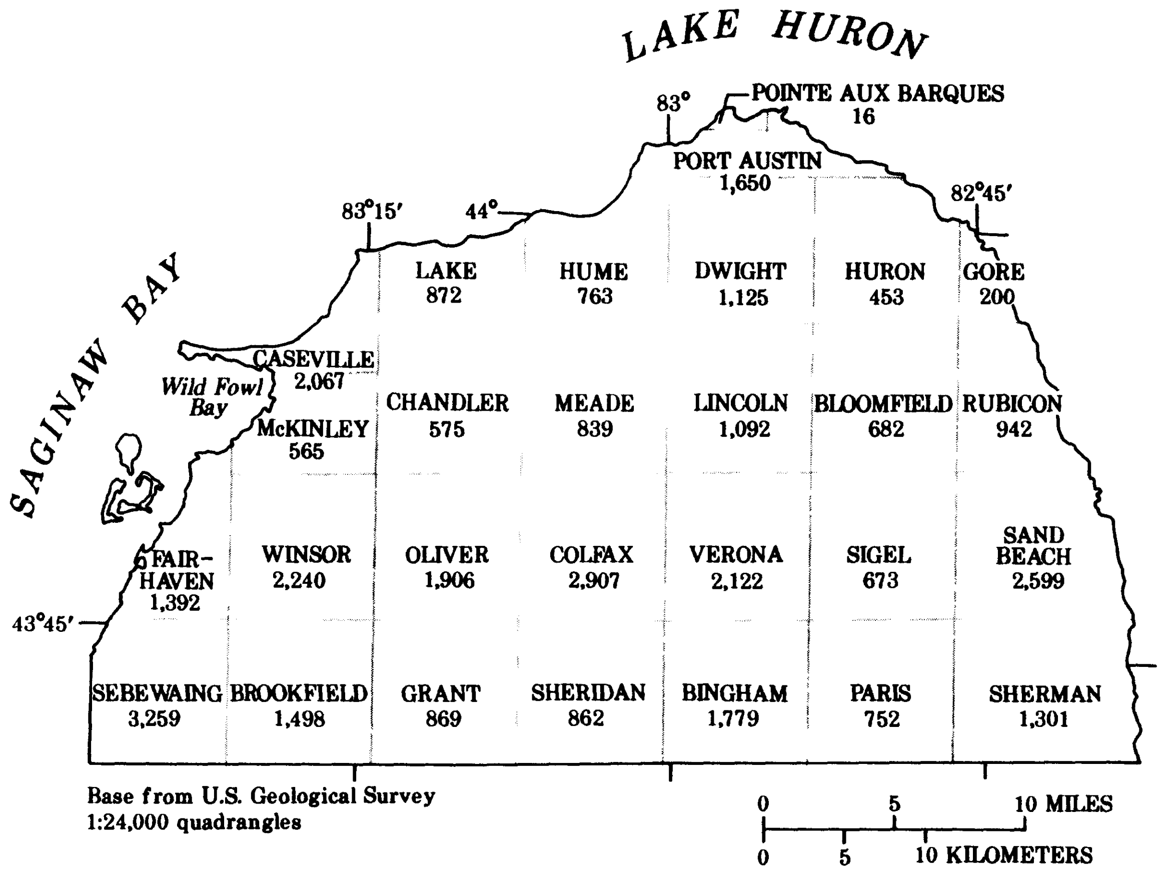
GEOLOGIC SETTING

The geology of Huron County consists of consolidated strata of Mississippian and Pennsylvanian age and unconsolidated surficial deposits of Pleistocene age. Lithologic characteristics of these deposits at observation wells installed by the USGS, as inferred from drill cuttings, are listed in table 2 (at back of report); well locations are shown on plate 1. Additional lithologic data were obtained from well logs on file with the Michigan Department of Natural Resources in Lansing, Michigan.

Description of Bedrock Units

Bedrock units that are uppermost in Huron County were deposited between 350 and 320 million years ago. From oldest to youngest and from east to west, they include the Coldwater Shale, the Marshall Formation, the Michigan Formation, the Bayport Limestone and the Saginaw Formation (figs. 5, 6, and 7). The first four units were deposited during the Mississippian Period; the Saginaw Formation was deposited during the Pennsylvanian Period. Delineation of the contacts between three of these units in Huron County is difficult. The upper part of the Coldwater Shale and lower part of the Marshall Formation sandstones are transitional. The upper part of the Marshall Formation and the lower Michigan Formation represent another transitional zone in which there are no clear breaks in lithology. The contact between the Michigan Formation and the Bayport Limestone was recognizable in cuttings from test holes drilled during this investigation.

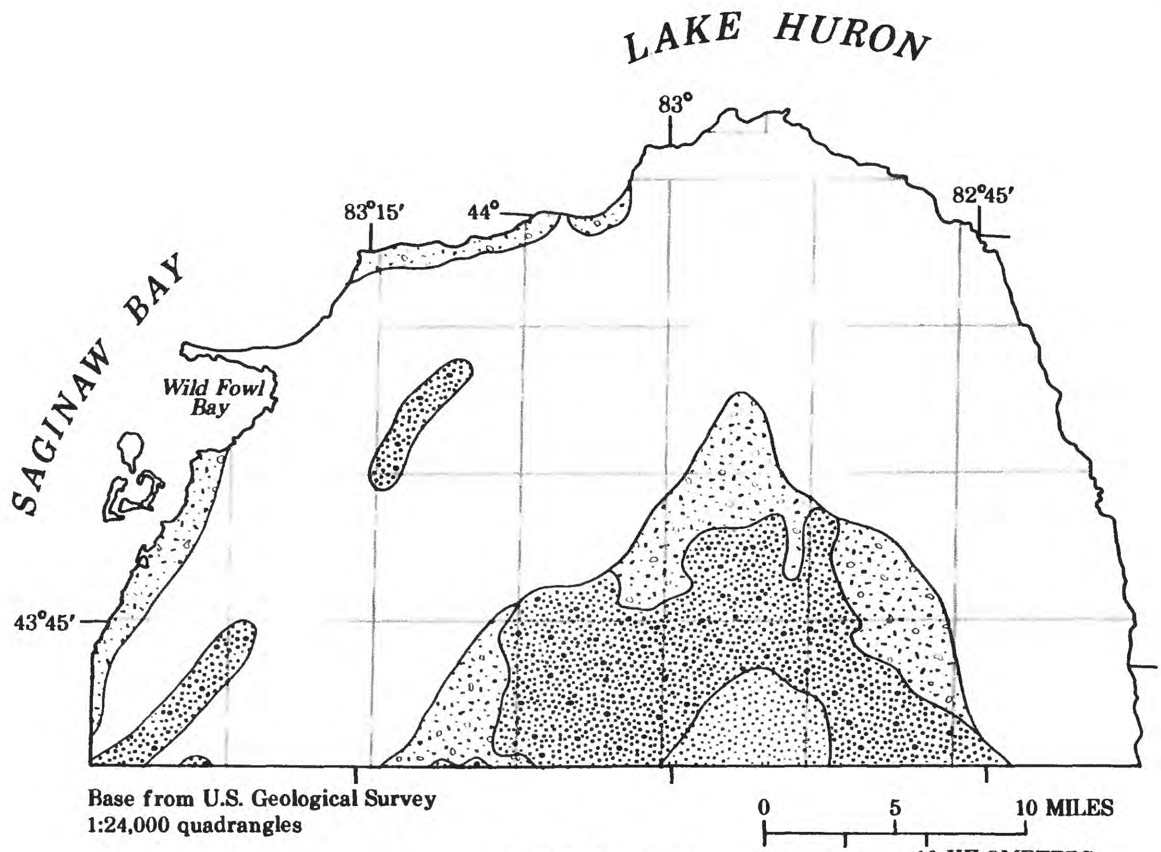
Bedrock exposures are present at many places along the shoreline. Low cliffs (10 to 20 ft high), stacks, and arches rise above the water just off shore. Throughout the county, bedrock underlies lake and glacial deposits at depths of as much as 80 ft in the southeast and as much as 120 ft in the southwest (fig. 8).



EXPLANATION

GRANT (869) TOWNSHIP NAME --Number in parentheses indicates Township population

Figure 3.--Population in 1985, by township.



EXPLANATION

DESCRIPTION OF UNITS

Lacustrine clay and silt

Lacustrine sand and gravel

Port Huron end moraine--Fine- to coarse-grained till interbedded with sand and gravel lenses

Glacial outwash and post-glacial alluvium

Figure 4.--Areal distribution of surficial deposits.

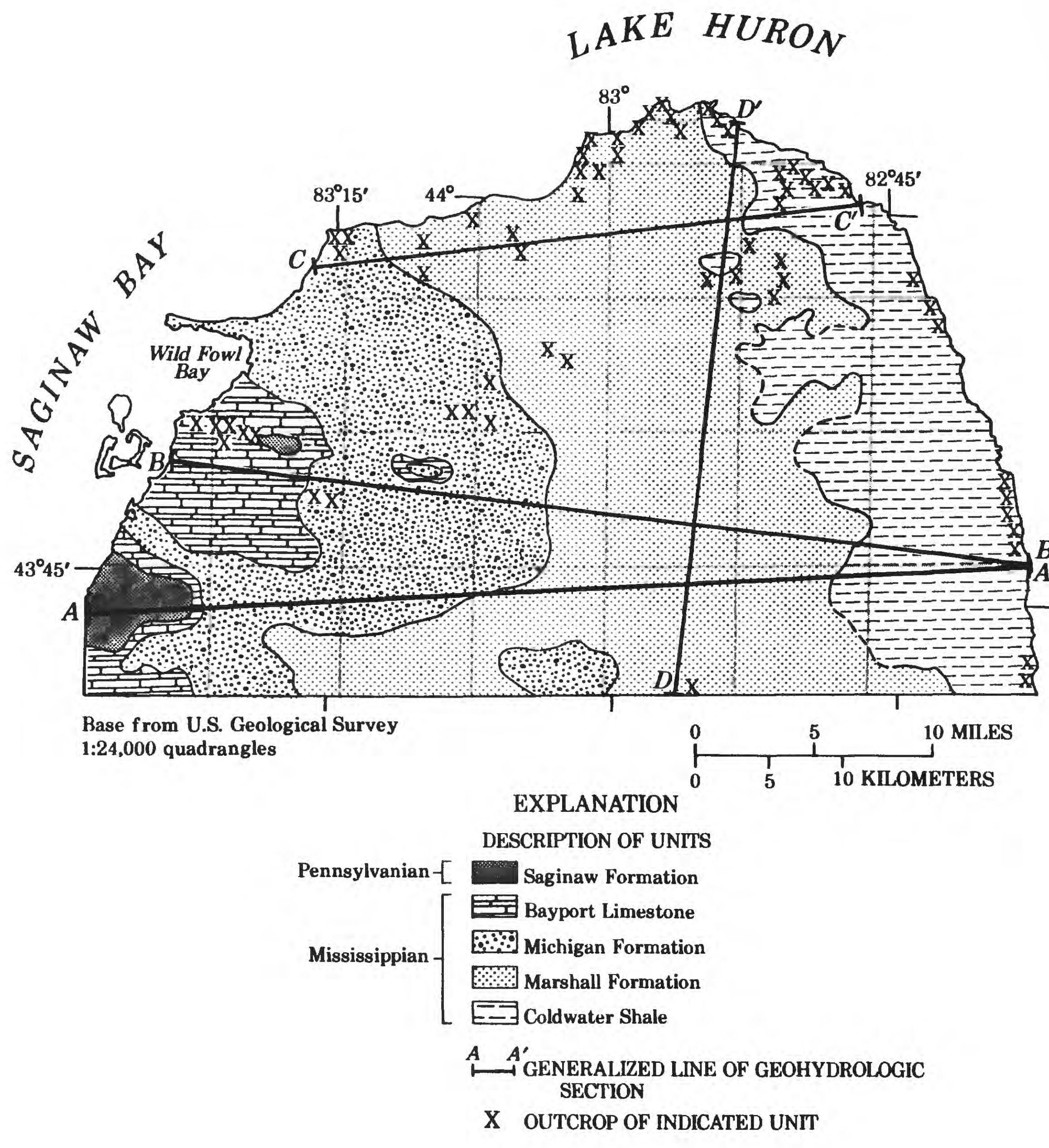


Figure 5.--Areal distribution of bedrock.

ERATHEM	SYSTEM	SERIES	GROUP	STRATIGRAPHIC UNIT	HYDROGEOLOGIC UNIT	THICKNESS (feet)
CENOZOIC	Quaternary	Pleistocene		Glacial and lacustrine deposits	Surficial deposits (aquifer)	0-10
				Glacial deposits		0-130
	Unconformity					
PALEOZOIC	Pennsylvanian	Middle		Saginaw Formation	Confining unit	0-100
		Lower				
	Unconformity					
	Mississippian	Meramecian	Grand Rapids	Bayport Limestone	Confining units	0-100
				Michigan Formation		0-175
		Osagean		Marshall Formation	Napoleon Sandstone Member of Marshall Formation (aquifer)	0-120
					Sandstones in lower part of Marshall Formation (aquifer)	0-225
		Kinderhookian		Coldwater Shale	Confining unit	1,000-1,200

Figure 6.--Stratigraphic succession and aquifer nomenclature in Huron County (stratigraphy modified from Milstein, 1987).

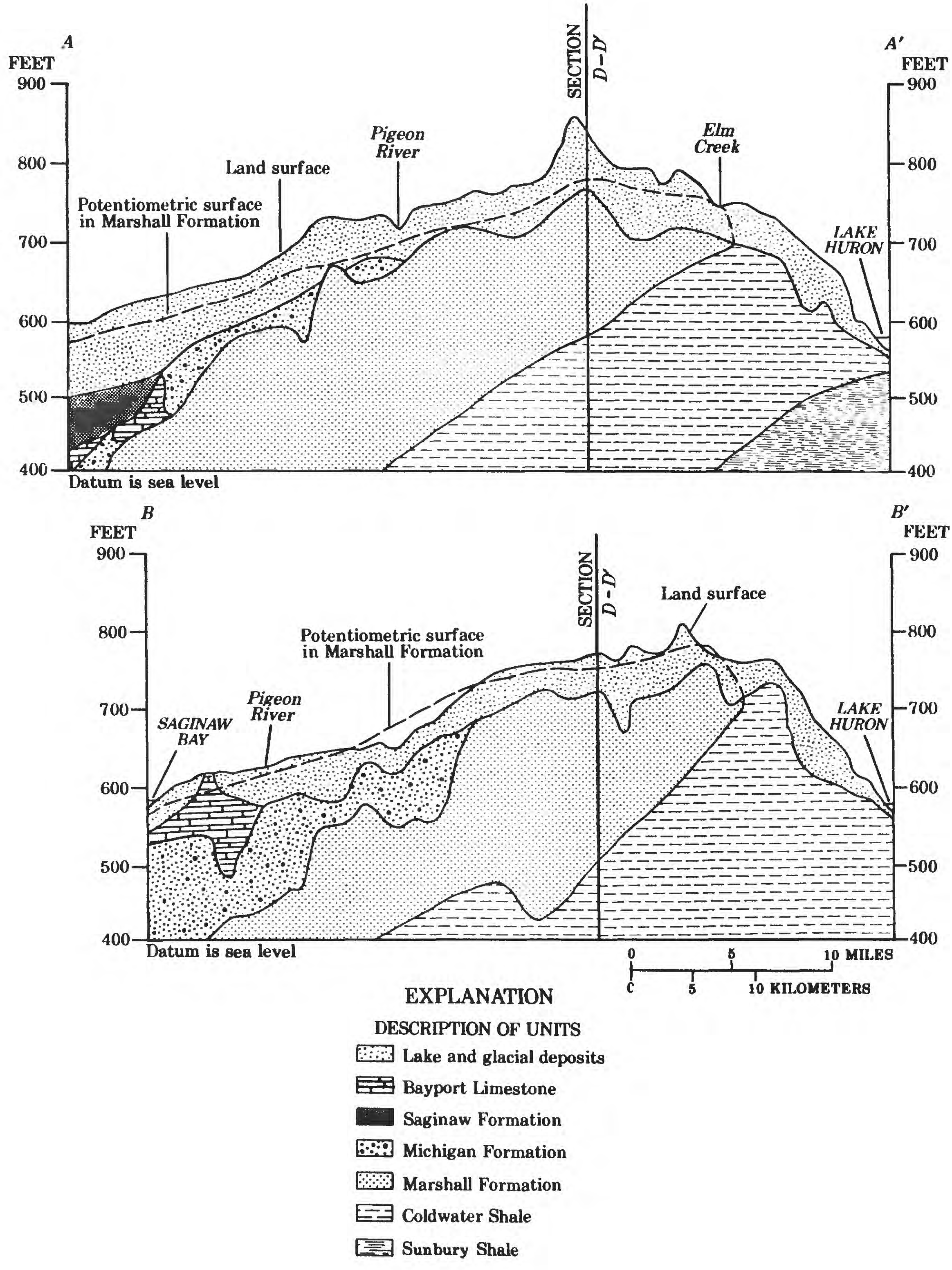
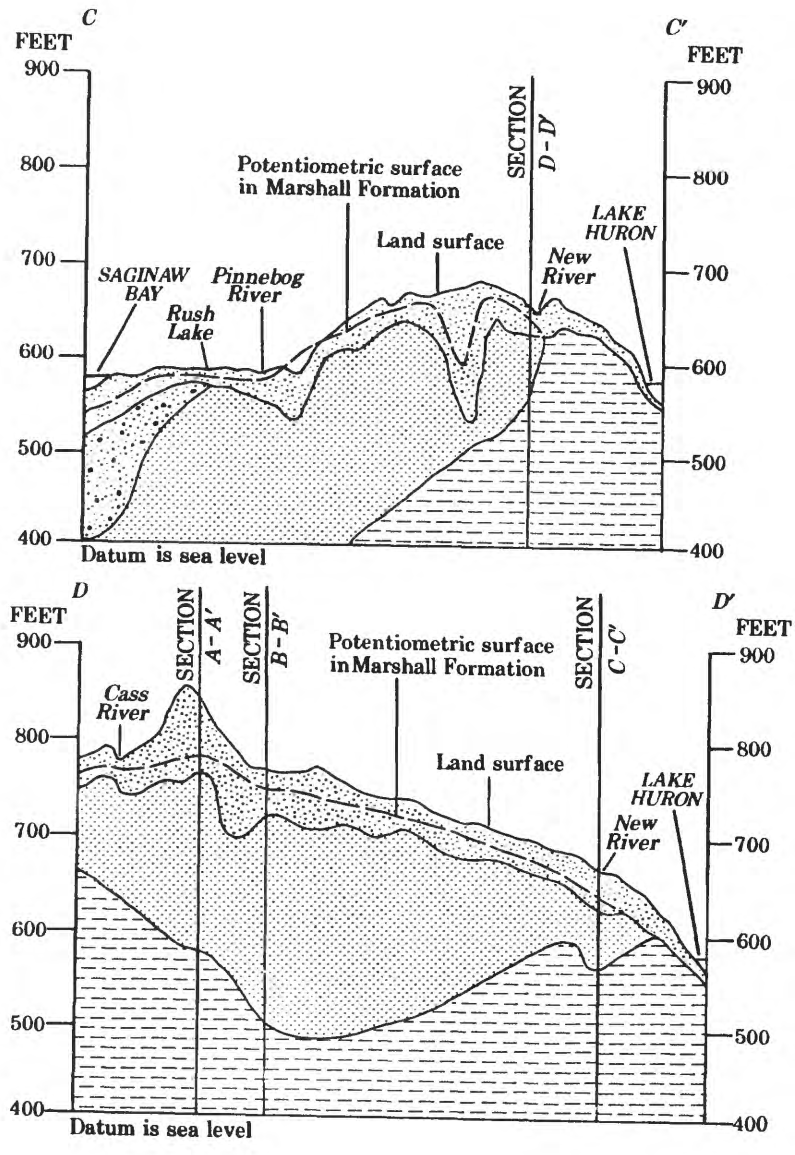


Figure 7.--Generalized geohydrologic sections showing stratigraphic section shown on figure 5;



relations of surficial deposits and bedrock units (Line of vertical scale greatly exaggerated).

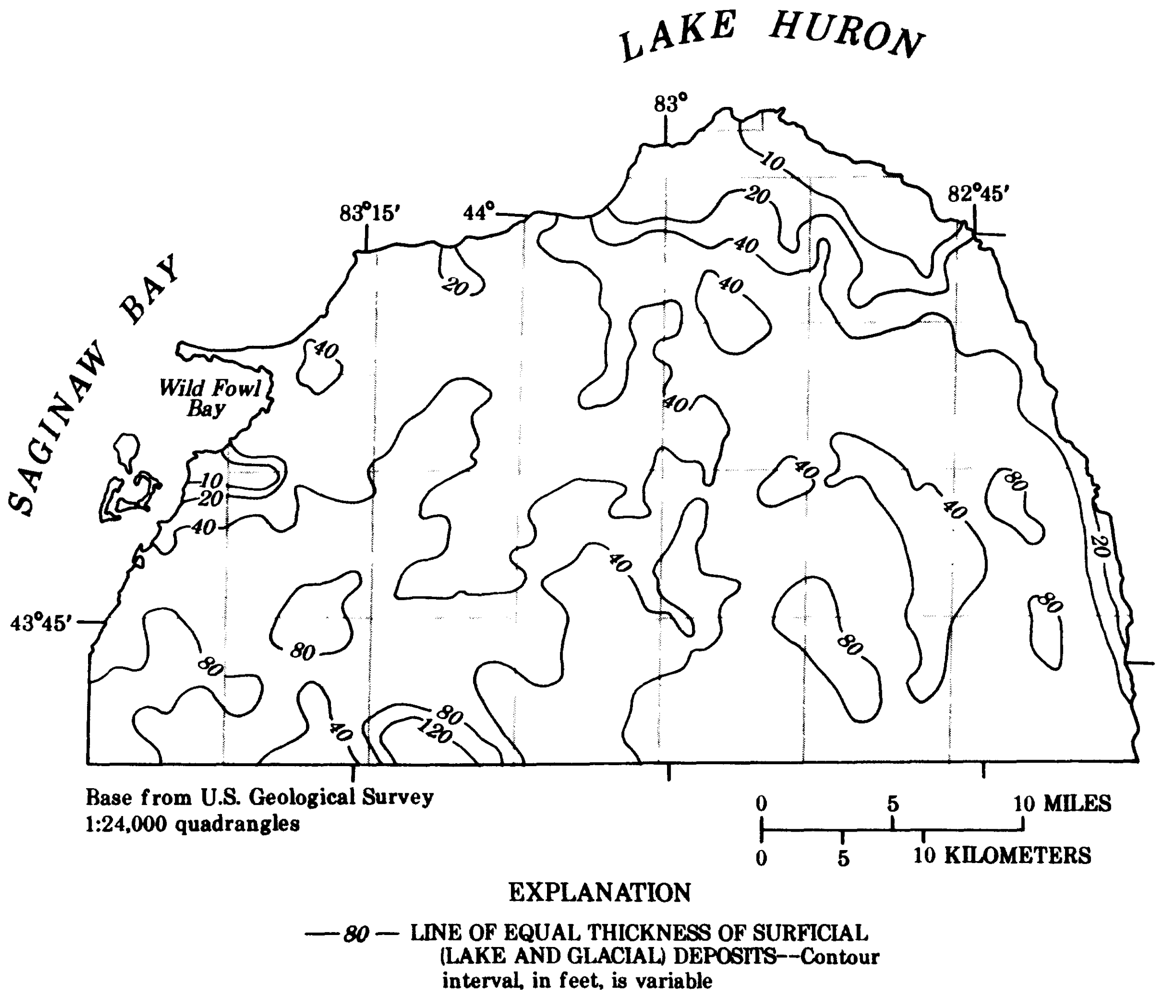


Figure 8.--Thickness of surficial deposits.

Coal beds as much as 3 ft thick are present at depths ranging from 75 to 120 ft below land surface in the Saginaw Formation in northwestern Sebewaing Township. Coal mining began about 1840 and continued into the early 1900's. Well-cemented sandstones in the lower part of the Marshall Formation near Grind Stone City were used to make grinding wheels and whetstones. Brine was produced in the 1800's from the Berea Sandstone, which underlies the county at depths ranging from 700 to 1,800 ft below land surface.

Bedrock materials and most surficial deposits in Huron County were deposited in water. Hence, plate-shaped grains in the sediments tend to be deposited with their flat surfaces oriented parallel to the bedding plane. This orientation reduces vertical permeability (Lohman, 1979).

Coldwater Shale

The Coldwater Sale is mostly gray and blue shale, but it includes lenses of slaty sandstone and conglomerate. Under the eastern third of the county, and where exposed along the western shore of Lake Huron, the upper part of the Coldwater Shale consists of silty, fine-grained sandstone interbedded with siltstone and shale. Near the upper contact with the overlying Marshall Formation, the Coldwater Shale contains discontinuous layers of conglomerate. Lane (1893, 1900) called this the "peanut conglomerate," and proposed its use as a marker horizon in the upper part of the Coldwater Shale. Monnett (1948, p. 676-677), however, concluded that there is little evidence for any type of marker horizon between the Coldwater Shale and Marshall Formation. The thickness of the Coldwater Shale in Huron County is 1,000 to 1,200 ft (Monnett, 1948; Moser, 1963; Cohee, 1965; and Chung, 1973).

Marshall Formation

The Marshall Formation can be divided into a lower and an upper part on the basis of lithology. The lower part contains three transitional, silty sandstones. The upper part is a medium- to coarse-grained, friable sandstone that has been named the Napoleon Sandstone Member (Winchell, 1861, p. 81; and Rominger, 1876, p. 80). Sandstones of the lower part of the Marshall Formation crop out throughout the county, mainly along the Lake Huron shoreline and in streambeds (fig. 5).

Sandstones in the lower part of the Marshall Formation

The lowermost of three sandstones in the lower part of the Marshall Formation is exposed along the northeastern shore of the county (fig. 5), in quarries near Grind Stone City, and along the western bluff of the New River valley in Huron Township. The sandstone is fine grained and well cemented. Bedding structures are not apparent, although the sandstone does contain pebbles and silty lenses in places.

A middle, distinct sandstone unit in the lower part of the Marshall Formation is exposed at Pointe Aux Barques and west of Port Austin to Flat Rock Point, just north of Jenks County Park. This sandstone is coarse grained and crossbedded; it is probably the Port Austin-Pointe Aux Barques sandstone described by Lane (1900, p. 92). This layer is separated from the lowest sandstone by silty shales and fine-grained sandstones.

An upper sandstone unit in the lower part of the Marshall Formation is exposed in the northwest near Hat Point, west of Phillips County Park. This sandstone is less distinct than the lower two units, but is identifiable in drill cuttings because it is usually separated from overlying and underlying layers by a fine-grained, silty sandstone interbedded with shale.

These three sandstone units form the lower part of the Marshall Formation as described by Lane (1900, p. 89-96). Some large-scale structure is evident in these beds, notably a shallow synclinal trough and associated anticline that trends northwest-southeast along the northeastern edge of the Marshall Formation. Contact with the underlying Coldwater Shale is transitional.

Napoleon Sandstone Member

The uppermost sandstone of the Marshall Formation was named the "Napoleon Sandstone Member" by Winchell (1861) after the type locality in quarries at the east edge of Napoleon, Michigan. In Huron County the Napoleon Sandstone Member is medium to coarse grained, very friable, crossbedded, and contains grains of limonite throughout the exposures. Toward its base, the Napoleon Sandstone Member becomes more fine grained; near its top, it is less crossbedded. Beds of small quartz pebbles are present throughout, and grains of black carbonaceous materials are present toward its base. Its color is buff to tan, although color grades to greenish-gray and green laterally and vertically.

A thickness of 300 ft in the Napoleon Sandstone Member in Huron County was measured by Lane (1900, p. 19); however, he also noted that the unit was only 135 ft thick at a well near Bayport and only 110 ft thick at a well near Pigeon. Monnett (1948, p. 676) concluded that the Napoleon Sandstone Member is only about 120 ft thick. Investigation during this study indicates a thickness of 110 to 120 ft.

Michigan Formation

The Michigan Formation contains quartzose sandstones, greenish-gray to dark-gray shale, thin limestone, and sporadic dolomite. Gypsum and anhydrite are present throughout the Michigan Formation (McGregor, 1953, p. 36). Gypsum grades laterally into shale and in many places is interbedded with shale. Gypsum and anhydrite are most prevalent in the lower part of the formation (Newcombe, 1933, p. 57) and are common in the western part of the State. Mineralogy of sands in the Michigan Formation does not differ appreciably from that of the Napoleon Sandstone Member (Stearns and Cook, 1932, p. 433); contact with the underlying Napoleon Sandstone Member is conformable (Cook, 1914, p. 64; Hard, 1938, p. 169; Hake, 1938, p. 404; Addison, 1940, p. 1967; and Monnett, 1948, p. 663).

Bayport Limestone

The Bayport Limestone is principally a fossiliferous, cherty limestone, often intermixed with sandstone. Where present, the sandstone is typically crossbedded and appears to have been deposited as sandbars (Rominger, 1876, p. 109; Lane, 1899a, p. 80). Limestone is quarried from this formation east of Bay Port. The contact with underlying Michigan Formation is conformable.

Saginaw Formation

The Saginaw Formation is the uppermost bedrock unit in the western part of the study area. This formation, which underlies lake and glacial deposits in the southwest corner of the study area, ranges from only a few feet to about 100 ft in thickness and is primarily shale and silty shale. It contains beds of siltstone and fine-grained sandstone and thin beds of coal (a few inches to 3 ft). It is difficult, and in most areas impossible, to trace specific beds for any distance. The contact between the Saginaw Formation and the Bayport Limestone is unconformable.

Glacial Deposits

Glacial deposits cover the south-central part of Huron County. They consist primarily of till deposited as end moraines (fig. 4). The till is interspersed with kames and eskers. Thickness of the glacial deposits ranges from less than 10 to about 130 ft (fig. 8); the deposits are thickest along the crest of end moraines.

Landforms are the result of geologic processes at the end of the last glacial stage, the Wisconsinan. At times during Wisconsinan stage glaciation, Michigan was covered by several thousand feet of ice (Dorr and Eschman, 1970, p. 161). About 16,000 years ago, glaciers began to retreat. After the last major retreat, two minor advances and retreats occurred (Zumberge and Potzger, 1955; and Zumberge, 1956, 1960). The second minor advance, referred to as the Greatlakean by Martin (1955), covered much of the study area and was responsible for shaping many of the landforms in south-central Huron County. Ice advanced to a position a few miles inland from the present Lake Huron shore and deposited the Port Huron end moraine (fig. 4).

Terminal and recessional moraines form hills in south-central Huron County. These moraines consist of a variety of sediment types. The cores of the moraines probably contain material deposited by glacial ice before the last minor ice advance. Overlying the moraines are brown, clay-rich tills deposited during the glaciations, sand and gravel deposited by superglacial and supraglacial streams, and sand deposited by wind.

Lacustrine Deposits

Final retreat of ice resulted in large variations in the level of water in Lake Huron. At high levels, the lake extended inland and flooded some areas (Bretz, 1951, 1953, and 1964; and Hough, 1958, 1963, and 1966). Thick, laterally extensive deposits of glacially derived clays and other sediments were laid down under these lake-derived flood waters between morainal deposits and the current shoreline (fig. 8). Lake deposits consist primarily of lacustrine clay and silt (fig. 4) and lacustrine sand and gravel (Martin, 1955). Lacustrine and riverine deposits are thickest in shallow buried valleys that cut diagonally southeastward across Grant Township and along the end moraines in Bingham and Verona Townships (fig. 8).

Small sand dunes are present in the northwest edge of the county along Saginaw Bay. These dunes are at or near the shoreline of Saginaw Bay and inland for a few hundred yards. Some of these dunes are intermittently active and move east-southeast (Kelley, 1962).

HYDROGEOLOGY

An average of about 30 in. of precipitation falls annually in Huron County. The amount that is evaporated and transpired and the amount that is discharged by streams cannot be determined from available data. On the basis of records available, about 30 percent of the precipitation is discharged by streams (Blumer and others, 1990, p. 187-190); of the remainder, most is either evaporated or transpired, and some is recharged to ground water. The southwestern part of the county is hydrologically, topographically, and geologically different from other parts of the county; hence, runoff may differ appreciably. Lake Huron, Saginaw Bay, and streams are the principal sources of surface water in the county. Lake Huron and Saginaw Bay are the sources of water for communities that use only surface water for their water supply (table 3).

Table 3.--Sources of water for selected communities in Huron County

[Information from Huron County Health Department, 1990]

Community	Source of water	Community	Source of water
Bad Axe	Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation	Pigeon	Napoleon Sandstone Member
		Pointe Aux Barques	Marshall Formation
		Port Austin	Lake Huron
Caseville	Lake Huron (Saginaw Bay)	Port Hope	Lake Huron
		Sebewaing	Napoleon Sandstone Member
Elkton	Marshall Formation		
Harbor Beach	Lake Huron	Ubly	Sandstones in the lower part of the Marshall Formation
Kinde	Marshall Formation		
Owendale	Napoleon Sandstone Member		

Thick, water-bearing glacial sand and gravel deposits are absent from much of the county; bedrock, in many places, either yields insufficient amounts of water to wells or yields only saline water (greater than 1,000 mg/L of dissolved solids). Aquifers consist of two types--bedrock and surficial. The Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation are sources of water for communities that use ground water in Huron County (table 3).

Nearly 80 percent of soils in the county are classified as being poorly or very poorly drained, as having low or very low infiltration capacity, and as having a high shrink-swell potential because of their clay content (Linsemier, 1979, p. 58, 90, 139-142). When saturated, these soils have a very low capacity for transmitting water vertically; precipitation collects in shallow surface depressions or flows overland and does not recharge aquifers.

This ponding effect also places surface water in extended contact with surface-applied chemicals and decaying plant matter.

Surface Water

Huron County is drained by rivers, small creeks, and drainage ditches. Two lakes exceed 50 acres; both are shallow and eutrophic. Mud Lake (57 acres) is primarily a reed swamp with no open water (plate 1). Rush Lake (100 acres) is primarily a reed swamp with little open water (plate 1).

Nearly all rivers, creeks, and surface drains start in the county, except for State Drain (also known as Sebewaing River) and Shebeon Creek, which start in Tuscola County. Drainage-basin areas are generally less than 150 mi^2. The largest stream, Pinnebog River, drains more than 160 mi^2; the smallest stream, Elm Creek, drains 2.4 mi^2. Stream discharge and water-quality measurements were made periodically at 11 sites on 9 streams and drains (plate 1).

Availability

Daily discharge data were collected for the Columbia Drain near Sebewaing from 1940-54, and data collection was started again in 1988 (USGS gaging station 04158000). Daily discharge data also have been collected for the Pigeon River near Caseville since 1987 (USGS gaging station 04159010). The maximum discharge observed at Pigeon River near Caseville was 1,800 ft^3/s in October 1986, and the maximum discharge observed at Columbia Drain near Sebewaing was 1,720 ft^3/s in March 1952. Both streams were dry several days each year. Quarterly measurements of discharge and water quality were made at nine other sites. Maximum and minimum discharges for 1987 through 1990 are listed in table 4.

Generally, streams in Huron County are not reliable sources of water supply because flows are not sustained during the summer months. Only during periods of high runoff are flows sufficient as a source of water supply.

Quality

Water-quality data were collected periodically at 11 sampling sites in Huron County from April 1988 through April 1989. Water at all 11 sites was analyzed for nitrogen and phosphorus; pesticide concentrations were determined for samples from 10 of the sites. At five sites, water was collected for analysis of common dissolved constituents and trace metals.

The concentration of dissolved solids in water is indicated by the specific conductance. From regression analysis, the following relation of laboratory measurements of dissolved solids and measurements of specific conductance was determined for selected streams in Huron County:

$$\text{Dissolved-solids concentration (mg/L)} = 44.9 + 0.56 \times \text{specific conductance (in } \mu\text{S/cm)}$$

Table 4.--Maximum and minimum discharge of streams in Huron County on days that discharge and water quality were measured

[Gaging station locations are shown on plate 1. ft^3/s, cubic feet per second]

Gaging station number	Stream name	Date	Maximum and minimum discharge (ft^3/s)
04158000	Columbia Drain near Sebewaing	April 14, 1989 July 13, 1988	20 0
04159010	Pigeon River near Caseville	April 12, 1989 July 13, 1988	137 .03
04159012	Pinnebog River near Elkton	April 14, 1989 July 13, 1988	65 0
04159037	Bad Axe Creek near Elkton	April 13, 1989 July 13, 1988	31 0
04159063	Taft Drain near Pinnebog	April 13, 1989 July 14, 1988	40 .43
04159069	New River near Huron City	April 13, 1989 July 13, 1988	19 0
04159075	East Branch Willow Creek near Redman	April 13, 1989 July 14, 1988	38 0
04159077	Willow Creek near Redman	April 13, 1989 July 14, 1988	86 0
04159078	Willow Creek near Huron City	April 13, 1989 July 14, 1988	83 .01
04159096	Rock Falls Creek near Harbor Beach	April 12, 1989 July 14, 1988	36 .26
04159104	Elm Creek near White Rock	April 12, 1989 July 14, 1988	20 .44

The specific conductance of water at 11 sites ranged from 525 μS/cm at Taft Drain near Pinnebog during a period of low flow to 1,160 μS/cm at Bad Axe Creek near Elkton during a period of median flow (table 5, at back of report). The countywide mean for all sites was 796 μS/cm.

Mean values of pH ranged from 8.1 at three sites (Bad Axe Creek near Elkton, Elm Creek near White Rock, and Willow Creek near Redman) to 8.4 at two sites (Pigeon River near Caseville and Willow Creek near Huron City). These values are somewhat higher than the mean pH values of 7.3 to 8.3 reported for sites in Van Buren County (Cummings and others, 1984, p. 42) and the mean pH values of 7.5 to 8.2 reported for sites in Kalamazoo County (Rheaume, 1990, p. 46). Mean concentrations of dissolved oxygen ranged from 9.9 mg/L at Elm Creek near White Rock to 14.1 mg/L at Columbia Drain near Sebewaing.

Calcium bicarbonate is the predominant dissolved ion in water from streams and drains in Huron County. Occasionally, sulfate concentrations are higher than calcium bicarbonate concentrations. Stream water is very hard[2] in Huron County, as it is throughout much of the State. Mean values of selected physical properties and dissolved substances measured in selected streams are listed in table 6.

Five stream sites were sampled for trace elements (table 5) during 1988-89. None of the trace elements exceeded maximum contaminant levels (MCL's) for drinking water established by the U.S. Environmental Protection Agency (USEPA); however, concentrations of manganese did exceed USEPA secondary

Table 6.--Mean values of selected constituents and properties of selected streams in Huron County, Michigan, 1988-89

[Mean values are concentrations in milligrams per liter]

Constituent or property	Mean value	Constituent or property	Mean value
Silica (SiO_2)	11.5	Chloride (Cl)	48
Calcium (Ca)	102	Fluoride (F)	.2
Magnesium (Mg)	32	Hardness (as $CaCO_3$)	385
Sodium (Na)	19	Dissolved solids	
Potassium (K)	4.5	Sum	468
Sulfate (SO_4)	95	Residue at 180 degrees Celsius	479

[2] The U.S. Geological Survey (Durfor and Becker, 1964) classifies the hardness of water as follows: 0 to 60 mg/L, soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/L, hard; and 181 mg/L or greater, very hard.

maximum contaminant levels (SMCL's) at two sites (Pigeon River near Caseville and Taft Drain near Pinnebog) during a period of low flow in July, 1988. Total dissolved-solids concentrations were near or exceeded the SMCL's at all sites where measured. The USEPA MCL's and SMCL's for chemical constituents and properties of interest in this study are listed in table 7.

During 1988-89, 32 analyses for nitrogen and phosphorus were done on water collected at 11 sites (table 8). Mean total nitrogen concentration, based on the total concentrations of each nitrogen species (table 8), was 7.55 mg/L. This mean concentration is higher than the 1.7 mg/L for the St. Joseph River basin reported by Cummings (1978), the 1.5 mg/L in Van Buren County reported by Cummings and others (1984), and the 1.46 mg/L in Kalamazoo County reported by Rheaume (1990).

Table 7.--U.S. Environmental Protection Agency drinking-water regulations for trace elements, water properties, and dissolved solids

[µg/L, micrograms per liter; mg/L, milligrams per liter; --, no level set. Data from U.S. Environmental Protection Agency, 1986a and 1986b]

Constituent or property	Maximum contaminant levels for inorganic chemicals	Secondary maximum contaminant levels
Arsenic (As)	50 µg/L	--
Barium (Ba)	1 mg/L	--
Cadmium (Cd)	10 µg/L	--
Chloride (Cl)	--	250 mg/L
Chromium (Cr)	50 µg/L	--
Color (units)	--	15 units
Copper (Co)	--	1 mg/L
Fluoride (F)	4 mg/L	2 mg/L
Iron (Fe)	--	300 µg/L
Lead (Pb)	50 µg/L	--
Manganese (Mn)	--	50 µg/L
Mercury (Hg)	2 µg/L	--
Nitrate (NO_3 as N)	10 mg/L	--
pH (standard units)	--	6.5 to 8.5 units
Selenium (Se)	10 µg/L	--
Silver (Ag)	50 µg/L	--
Sulfate (SO_4)	--	250 mg/L
Zinc (Zn)	--	5 mg/L
Dissolved solids	--	500 mg/L

Table 8.--Nitrogen and phosphorus concentrations of selected streams in Huron County, Michigan, 1988-89

[Analyses by U.S. Geological Survey. Gaging station locations shown on plate 1. mg/L, milligrams per liter; <, less than; --, no analysis done]

Gaging station number and name	Date	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrite, total (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate, total (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, organic, total (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
04158000 Columbia Drain near Sebewaing	July 19, 1988	0.03	0.02	6.17	6.38	0.05	0.05	0.65	0.02	0.04	<0.01
	Oct. 10, 1988	.04	.04	5.66	6.26	.03	--	--	.02	.02	<.01
	Apr. 14, 1989	.03	.03	13.0	--	.05	.04	.96	.01	.02	<.01
04159010 Pigeon River near Caseville	Apr. 19, 1988	--	.03	--	6.57	--	.03	--	.02	--	--
	July 13, 1988	<.01	<.01	.23	--	.05	.03	.77	.40	.41	.32
	Oct. 18, 1988	.04	.04	8.76	8.96	.04	.03	1.4	.06	.08	.04
	Apr. 12, 1989	.05	.04	13.1	13.0	.24	.22	1.1	.07	.12	.07
04159012 Pinnebog River near Elkton	Apr. 21, 1988	.02	.02	3.78	3.88	.12	.14	1.1	.40	.46	.33
	Oct. 20, 1988	.03	.02	14.0	13.0	.03	.03	.87	.02	.04	.01
	Apr. 14, 1989	.02	.02	8.78	--	.14	.13	1.8	.19	.25	.17
04159037 Bad Axe Creek near Elkton	Apr. 21, 1988	.06	.06	5.34	5.54	.17	.16	.84	.08	.10	.05
	Oct. 18, 1988	.36	.37	6.94	7.23	.04	--	--	.11	.14	.08
	Apr. 13, 1989	.65	.62	10.4	9.38	.12	.11	1.9	.05	.09	.04
04159063 Taft Drain near Pinnebog	Apr. 19, 1988	.03	.02	5.17	5.18	.03	.03	.47	.02	.02	<.01
	July 14, 1988	<.01	<.01	<.10	--	.02	<.01	--	.02	.07	<.01
	Oct. 18, 1988	.06	.06	10.0	10.9	.05	--	--	.03	.04	<.01
	Apr. 13, 1989	.02	.02	7.98	8.68	.04	.04	1.4	.02	.03	<.01
04159069 New River near Huron City	Apr. 20, 1988	.02	.02	3.78	3.78	.06	--	--	.03	.04	.01
	Oct. 19, 1988	.18	.18	13.8	14.8	.33	.32	2.2	.10	.13	.06
	Apr. 13, 1989	.03	.03	11.0	--	.05	.04	.96	.03	.03	.03
04159075 East Branch Willow Creek near Redman	Apr. 20, 1988	.02	.02	3.88	3.88	.05	.06	.74	.04	.04	.02
	Oct. 20, 1988	.06	.05	14.9	15.0	.02	.02	1.6	.05	.06	.03
	Apr. 13, 1989	.03	.03	11.0	9.97	.05	.04	1.5	.02	.03	.01
04159077 Willow Creek near Redman	Apr. 20, 1988	.02	.02	2.78	2.78	.10	.10	.8	.03	.05	.01
	Oct. 19, 1988	.16	.16	7.24	7.34	.04	.03	2.3	.23	.26	.14
	Apr. 13, 1989	.03	.03	9.67	--	.05	.04	1.7	.02	.08	.01
	Apr. 12, 1989	.09	.08	13.9	12.9	.07	.07	.93	.02	.04	<.01
04159078 Willow Creek near Huron City	Apr. 20, 1988	.03	.03	2.97	2.97	.07	.02	1.2	.04	.06	<.01
	July 14, 1988	<.01	<.01	<.10	--	.02	<.01	--	.03	.04	<.01
	Oct. 19, 1988	.13	.13	7.97	8.37	.02	.04	1.2	.02	.03	.01
	Apr. 13, 1989	.02	.02	9.48	--	.04	.07	.93	.04	.04	<.01
04159096 Rock Falls Creek near Harbor Beach	Apr. 20, 1988	.01	.01	4.09	4.19	.04	<.01	--	.01	.03	<.01
	July 14, 1988	<.01	<.01	<.10	--	.01	.03	.67	.02	.02	<.01
	Oct. 19, 1988	.02	.02	3.38	3.38	--	.07	.73	.02	.02	.01
	Apr. 12, 1989	.03	.03	11.0	9.97	.08	.04	.56	.02	.03	<.01
04159104 Elm Creek near White Rock	Apr. 20, 1988	.02	.02	4.18	4.18	.04	.05	.45	.02	.02	<.01
	July 14, 1988	<.01	<.01	<.10	--	.03	--	--	.05	.10	<.01
	Oct. 19, 1988	.42	.43	3.28	3.37	.40	--	--	.03	.05	.02

Fertilizer applications in the county are similar to those in other parts of the State (Jim LeCureux, Huron County Cooperative Extension Service, written commun., 1990) and are probably not the sole reason that total nitrogen concentrations are higher than those found in surface waters elsewhere. These high concentrations may be related to the clay content of the soils. The clay content results in low permeability and thus low infiltration rates; under these conditions, surface runoff will normally transport more nutrients after precipitation events than it would if the soils were permeable.

Water was collected at 10 sites for the analysis of 16 pesticides. Analyses were done for pesticides listed in table 9. Eight pesticides were detected in surface waters in Huron County (table 10). The greatest number of pesticides (six) was detected in water from Willow Creek near Redman. Concentrations ranged from 0.1 to 1.3 µg/L. The number of sites at which each pesticide was detected is listed in table 9. Concentrations of pesticides in surface water from Huron County are similar to those elsewhere in Michigan's surface water (Cummings and others, 1984; Rheaume, 1990). The highest concentrations of pesticides in surface water in the county are in areas with the most agricultural activity (fig. 9), the central and north-central parts of the county.

Table 9.--Pesticides analyzed for in selected surface waters of Huron County, Michigan, and the number of sites where they were detected

Pesticide	Number of sites where detected	Pesticide	Number of sites where detected
Alachlor, total	0	Propazine, total	0
Ametryne, total	0	Silvex, total	0
Atrazine, total	9	Simazine, total	2
Cyanazine, total	3	Simetryne, total	0
Metolachlor, total	5	Trifluralin, total	0
Metribuzin, total	1	2,4-D, total	4
Prometone, total	2	2,4-DP, total	2
Prometryne, total	0	2,4,5-T, total	0

Ground Water

The Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation are the source of most of the ground water used in Huron County. Many private domestic wells are supplied by these units. Glacial deposits are the only other source of ground water. Glacial deposits are a source of ground water in the west central, southern and east central parts of the county and locally in other parts of the county. Rocks overlying the Napoleon Sandstone Member and underlying sandstones in the lower part of the Marshall Formation are not considered to be aquifers because of low yields and water of poor quality (i.e., water with one or more chemical qualities that exceeds values listed in table 7).

Table 10.--Pesticide concentrations of selected streams in Huron County, Michigan, 1988

[Analyses by U.S. Geological Survey. Gaging station locations shown on plate 1. µg/L, micrograms per liter; <, less than; --, no analysis done]

Gaging station number and name	Date	Alachlor, total (µg/L)	Ametryne, total (µg/L)	Atrazine, total (µg/L)	Cyanazine, total (µg/L)	Metolachlor, total (µg/L)	Metribuzin, total (µg/L)	Prometone, total (µg/L)	Prometryne, total (µg/L)	Propazine, total (µg/L)
04158000 Columbia Drain near Sebewaing	Oct. 18, 1988	<0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1
04159010 Pigeon River near Caseville	Oct. 18, 1988	<.1	<.1	.3	<.1	<.1	<.1	<.1	<.1	<.1
04159012 Pinnebog River near Elkton	Oct. 20, 1988	<.1	<.1	.7	<.1	<.1	<.1	<.1	<.1	<.1
04159037 Bad Axe Creek near Elkton	Oct. 18, 1988	<.1	<.1	.9	.1	<.1	<.1	.1	<.1	<.1
04159063 Taft Drain near Pinnebog	July 14, 1988	--	--	--	--	--	--	--	--	--
	Oct. 18, 1988	<.1	<.1	1.3	<.1	.1	<.1	<.1	<.1	<.1
04159069 New River near Huron City	Oct. 19, 1988	<.1	<.1	.7	<.1	.2	<.1	<.1	<.1	<.1
04159075 East Branch Willow Creek near Redman	Oct. 20, 1988	--	--	--	--	--	--	--	--	--
04159077 Willow Creek near Redman	Oct. 19, 1988	<.1	<.1	.6	.9	.2	.1	.1	<.1	<.1
04159096 Rock Falls Creek near Harbor Beach	Oct. 19, 1988	<.1	<.1	.2	<.1	<.1	<.1	<.1	<.1	<.1
04159104 Elm Creek near White Rock	Oct. 19, 1988	<.1	<.1	.3	<.1	.2	<.1	<.1	<.1	<.1

Gaging station number and name	Silvex, total (µg/L)	Simazine, total (µg/L)	Simetryne, total (µg/L)	Trifluralin, total (µg/L)	2,4-D, total (µg/L)	2,4-DP, total (µg/L)	2,4,5-T, total (µg/L)
04158000 Columbia Drain near Sebewaing	--	<0.1	<0.1	<0.1	--	--	--
04159010 Pigeon River near Caseville	<0.01	<.1	<.1	<.1	0.21	<0.01	<0.01
04159012 Pinnebog River near Elkton	<.01	<.1	<.1	<.1	.08	<.01	<.01
04159037 Bad Axe Creek near Elkton	<.01	.1	<.1	<.1	.03	.04	<.01
04159063 Taft Drain near Pinnebog	<.01	--	--	--	<.01	<.01	<.01
	--	<.1	<.1	<.1	--	--	--
04159069 New River near Huron City	--	<.1	<.1	<.1	--	--	--
04159075 East Branch Willow Creek near Redman	<.01	--	--	--	.08	.05	<.01
04159077 Willow Creek near Redman	--	.1	<.1	<.1	--	--	--
04159096 Rock Falls Creek near Harbor Beach	--	<.1	<.1	<.1	--	--	--
04159104 Elm Creek near White Rock	--	<.1	<.1	<.1	--	--	--

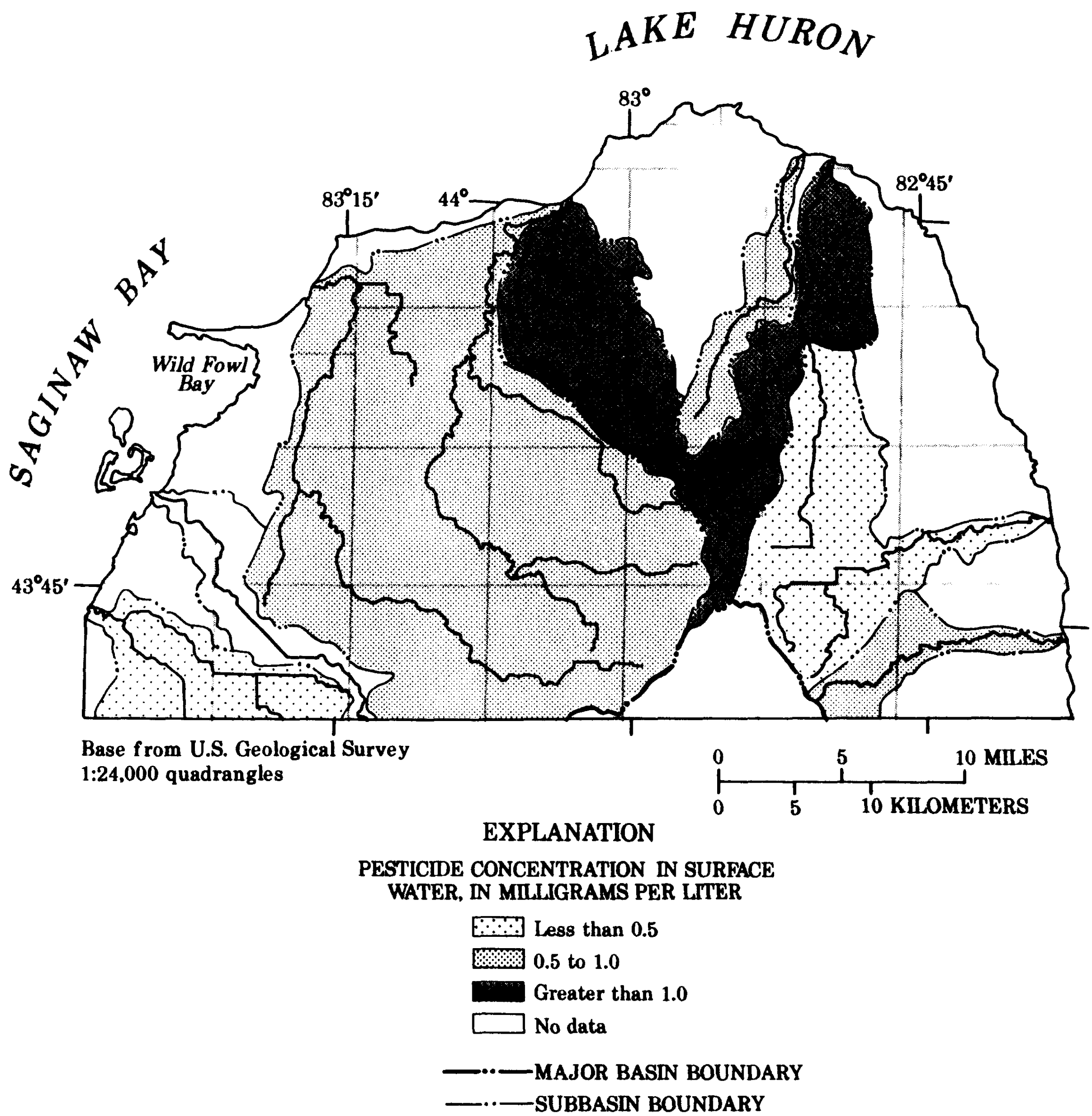


Figure 9.--Areal distribution of pesticides in surface water.

Surficial Aquifers

In the northern two-thirds of the county, many shallow wells, some more than 50 years old, are completed in surficial aquifers consisting of lacustrine clay and glacial till. Seasonal fluctuations affect the water level in the clay and till. In most of the southern part of the county, aquifers consisting of glacial sands and gravels yield sufficient quantities of water for domestic and small agricultural supplies throughout the year.

Bedrock Aquifers and Confining Units

Most wells that tap bedrock aquifers are completed in the Napoleon Sandstone Member of the Marshall Formation. Some bedrock wells from along the eastern shoreline and several miles inland are in Coldwater Shale. In western and southwestern parts of the county some wells are completed in either the Michigan Formation or the Saginaw Formation. Locally, the Bayport Limestone may provide small quantities of potable water. In general, however, the Coldwater Shale, the Michigan Formation, the Saginaw Formation, and the Bayport Limestone are not considered to be aquifers in Huron County; they function instead as confining units. The Coldwater Shale functions as the lowest confining unit in Huron County.

Communities that depend on ground water for their public water supplies obtain it from the Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation (table 3). Most domestic users also obtain ground water from the Napoleon Sandstone Member or sandstones in the lower part of the Marshall Formation.

Saginaw Formation (confining unit)

The Saginaw Formation generally consists of shale and silty shale. In some places, thin, lenticular, fine-grained sandstones yield small amounts of water. Water from wells in this formation is usually hard and commonly of marginal quality. Most water-bearing lenticular sandstones, siltstones, and coal beds are confined by shale or silty shale. Many domestic wells tap the Saginaw Formation in the Caseville area; elsewhere in the county, however, it does not produce potable water.

Michigan Formation (confining unit)

Sandstones and limestones of the Michigan Formation generally will not yield sufficient quantities of water to be considered aquifers in Huron County, though they do yield water to wells in some areas. In general, water from the Michigan Formation is saline and unsuitable for use. The Michigan Formation is considered to be a confining unit. Because of high dissolved-solids concentrations, water from the Michigan Formation is a potential source of elevated dissolved solids to the underlying Marshall Formation.

Napoleon Sandstone Member (aquifer)

The Napoleon Sandstone Member is the principal aquifer in Huron County. It is identified by its lithology and water quality. Some wells that are drilled to this aquifer in Huron County flow at land surface.

Statewide, the yield of wells in the Marshall Formation generally ranges from 100 to 500 gal/min; locally, yields can exceed 1,500 gal/min (Twenter, 1966a, and Grannemann and others, 1985, p. 33). Yields in the Napoleon Sandstone Member were determined from aquifer tests done during this project (plate 1) and from observations made when municipal wells at Bad Axe, Caseville, Elkton, Owendale, Pigeon, and Sebewaing were installed. Yields ranged from 1 gal/min in small (4 in.) diameter wells to 300 gal/min in large (12 in.) diameter municipal wells. Public water supplies for Bad Axe, Elkton, Pigeon, Owendale, and Sebewaing are obtained from the Napoleon Sandstone Member. Caseville withdrew water from this aquifer from 1940 to 1989, at which time the Caseville municipal supply was changed to lake water from Saginaw Bay (Baltusis and others, 1991, p. 47). The Napoleon Sandstone Member also supplies water for irrigation, livestock, crop processing, commercial and industrial use, and domestic use.

Sandstones in the lower part of the Marshall Formation (aquifer)

Sandstones in the lower part of the Marshall Formation underlie the western two-thirds of the county. Potable ground water is generally available from sandstones in the lower part of the Marshall Formation where present. These sandstones are not as widely used as aquifers as is the Napoleon Sandstone Member. The quality of water worsens as depth to the sandstones in the lower part of the Marshall Formation increases near the southern and western edges of the county. Ubly withdraws water from these sandstones, as did Port Austin from 1919 to 1967 (Baltusis, 1991, p. 28). Yields of five wells installed for this project and of municipal wells at Pointe Aux Barques, Port Austin, and Ubly, range from 8 gal/min (three wells) to 290 gal/min (one of the Ubly municipal wells).

Coldwater Shale (confining unit)

The Coldwater Shale is not a source of municipal water supply in the county. Along the county's eastern shore, and inland 7 to 9 mi, wells are locally completed in Coldwater Shale. The wells yield small quantities of water with a high dissolved-solids concentration; for the most part, this water is suitable only for livestock.

Throughout Huron County, the Coldwater Shale is present either at the surface or buried beneath lake clays, till, and sandstones in the lower part of the Marshall Formation. The horizontal hydraulic conductivity of the Coldwater Shale was not determined. Freeze and Cherry (1979, p. 29), however, report that the horizontal hydraulic conductivity of shales is two to four orders of magnitude less than that of sandstones. It is therefore likely that the Coldwater Shale functions as an underlying confining layer to the Marshall Formation. In places, water from sandstones and conglomerates in the Coldwater Shale is used; however, water generally has a high dissolved-solids concentration, making the Coldwater Shale unsuitable as a source of water.

Water from the Coldwater Shale may also be a source of dissolved solids to overlying sandstones in the lower part of the Marshall Formation where pumping draws saline water upward from shales. In the late 1800's and early 1900's, deep wells in the Coldwater Shale and the Berea Sandstone were drilled for the production of brine, particularly in an area from Harbor Beach to an area north of Port Hope. These wells are of concern if improperly abandoned because they can be conduits for the upward migration of brine. Although improperly abandoned brine-production wells may be present in the county, their locations are unknown.

Availability

The availability of ground water from surficial aquifers (fig. 10) was determined from an analysis of well logs and aquifer tests. Aquifer tests (pumping tests and slug tests) of 17 wells were done at 15 locations (plate 1) to determine hydraulic properties of the different sandstones in the Marshall Formation. These tests were done at different depths and pumping rates. Results of aquifer tests made when municipal wells were installed at Elkton, Sebewaing, and Ubly were also used to determine the hydraulic conductivity and transmissivity of aquifers in the Marshall Formation. Results of these tests were used to determine the general availability of ground water from bedrock throughout the county (fig. 11).

Water Levels

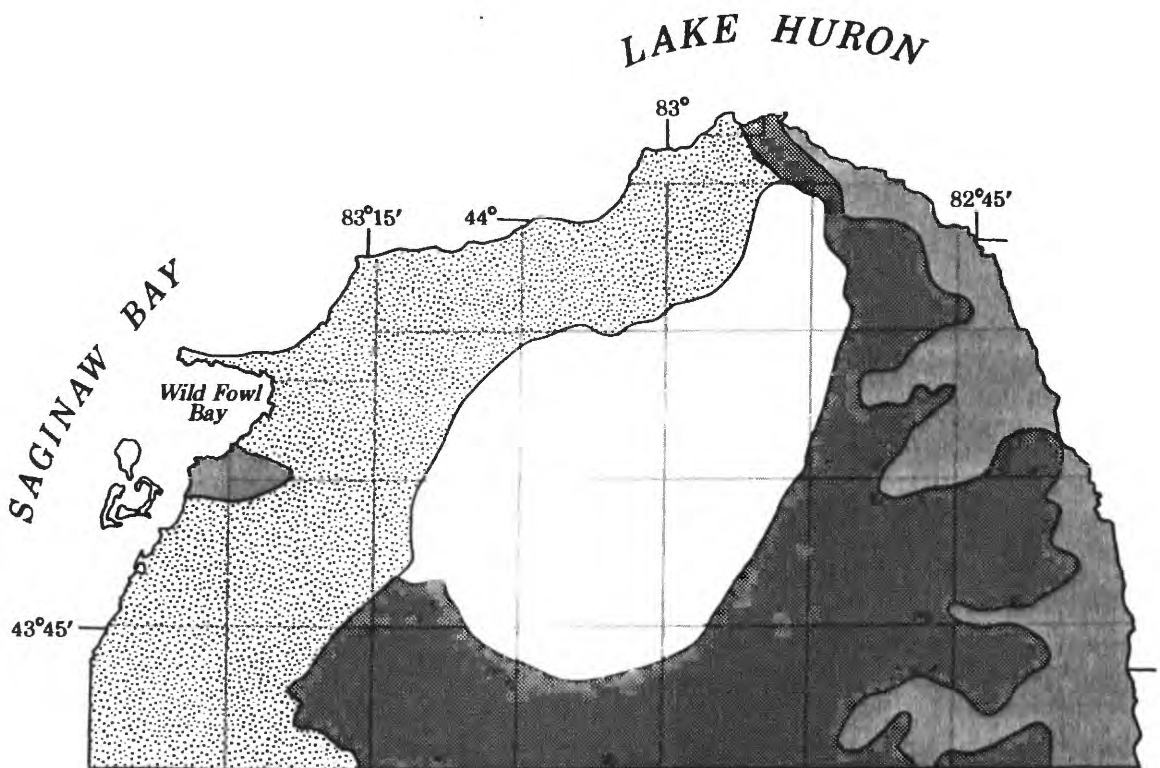
Ground-water levels were measured in 42 wells in Huron County from May 1988 through March 1990. Water levels in 33 of these wells are listed in table 11 (at back of report). In some areas wells flow at land surface; at others, water may be 5 to 100 ft below land surface. Depth to water tends to be least in areas of bedrock highs and greater in areas of bedrock lows.

Where ground water is confined, the depth to water in wells is not indicative of how deep a well must be drilled to obtain water. In such places, the well must be drilled through the confining unit into the aquifer to obtain water; the depth to water in the well indicates how far below land surface a pump must be set in order to withdraw water. The range and average depth of wells drilled in each township are shown in figure 12. Depths of wells installed by the USGS are listed in table 2.

Depth to water in 31 observation wells installed by the USGS ranged from 1 to 117 ft below land surface. At most places, the depth to water in wells is generally less than 55 ft. In general, water levels indicate confined conditions. Water levels in a few wells in the Napoleon Sandstone Member and in surficial deposits indicate water-table conditions. The average depth to water in wells, by township, is shown in figure 13.

Water levels in five wells and precipitation during the period October 1988 through March 1990 are shown in figure 14. Water levels in wells H25A, H25B, and H25C, and H27, generally declined from January through March 1989. In early April, the water levels in the wells increased as precipitation increased, and water levels continued to increase through the end of June. As precipitation decreased, water levels declined.

The relation of precipitation to the water level in well H5 is less pronounced. Large variations in water levels in well H5 are principally caused by withdrawals from wells that supply Ubly. Rotation of pumping amongst the town wells affected the water level in well H5. When the nearest well was being pumped, the water level declined in well H5. When pumping was changed to a more distant well, the water level in well H5 increased. This was particularly evident in July 1989, when the nearest well became the sole



Base from U.S. Geological Survey
1:24,000 quadrangles

0 5 10 MILES
0 5 10 KILOMETERS

EXPLANATION

DESCRIPTION OF UNITS

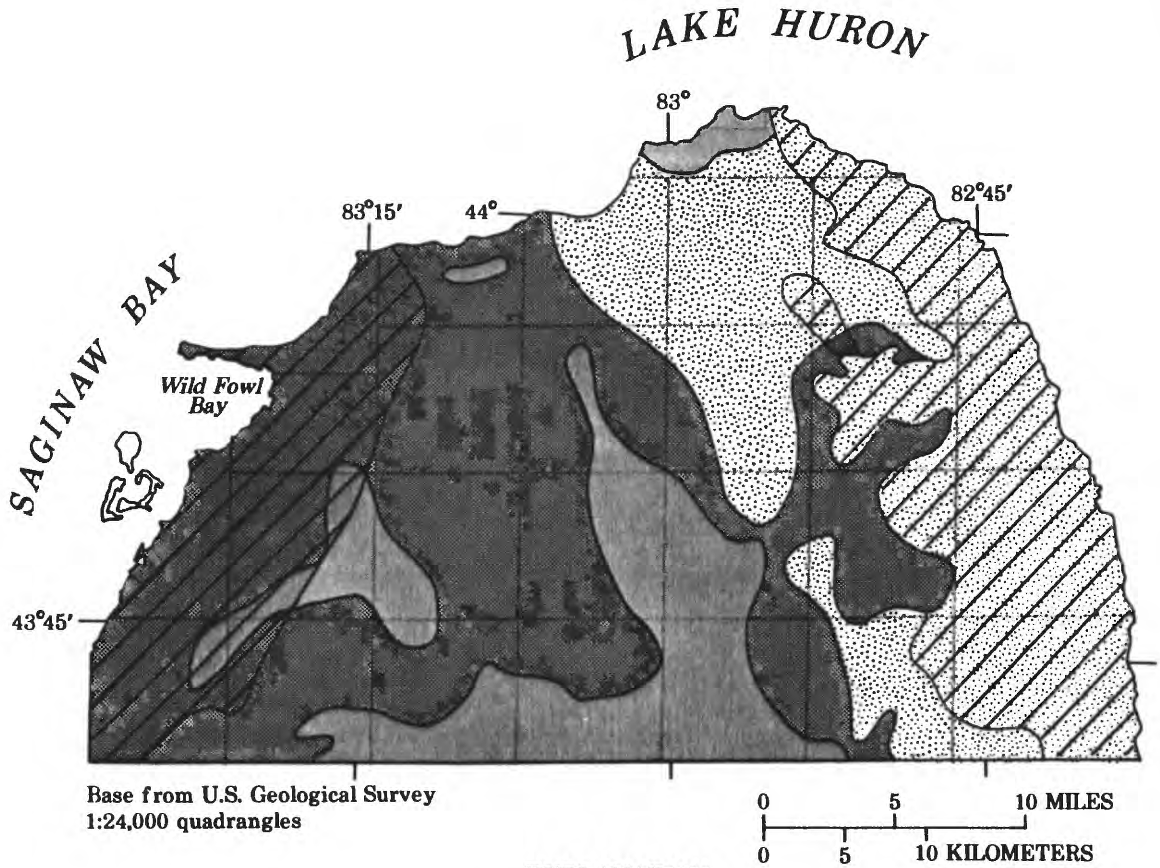
Well yields are generally less than 10 gallons per minute. Locally, wells in shallow sand or gravel deposits may yield more than 10 gallons per minute

Well yields are generally from 10 to 50 gallons per minute. Locally, wells may yield less than 10 gallons per minute or more than 50 gallons per minute

Well yields are generally from 50 to 100 gallons per minute. Locally, wells may yield significantly less than 500 gallons per minute or more than 100 gallons per minute

Data are too sparse to accurately describe the hydrologic properties of the deposits; hence, it is not possible to describe and classify the potential of wells installed in this area

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



EXPLANATION

DESCRIPTION OF UNITS

Well yields are generally less than 10 gallons per minute. Locally, wells 6 inches or more in diameter may yield more than 10 gallons per minute

Well yields are generally from 10 to 100 gallons per minute. Locally, wells may yield less than 10 gallons per minute or more than 100 gallons per minute

Well yields are generally from 100 to 200 gallons per minute. Locally, wells may yield greater than 200 gallons per minute

Wells will generally yield water that is too saline for domestic or public supplies. Locally, the water may be potable. In general, the dissolved-solids concentration of water increases as well depth increases

Figure 11.--Availability of ground water in bedrock (water quality from Twenter, 1966a).

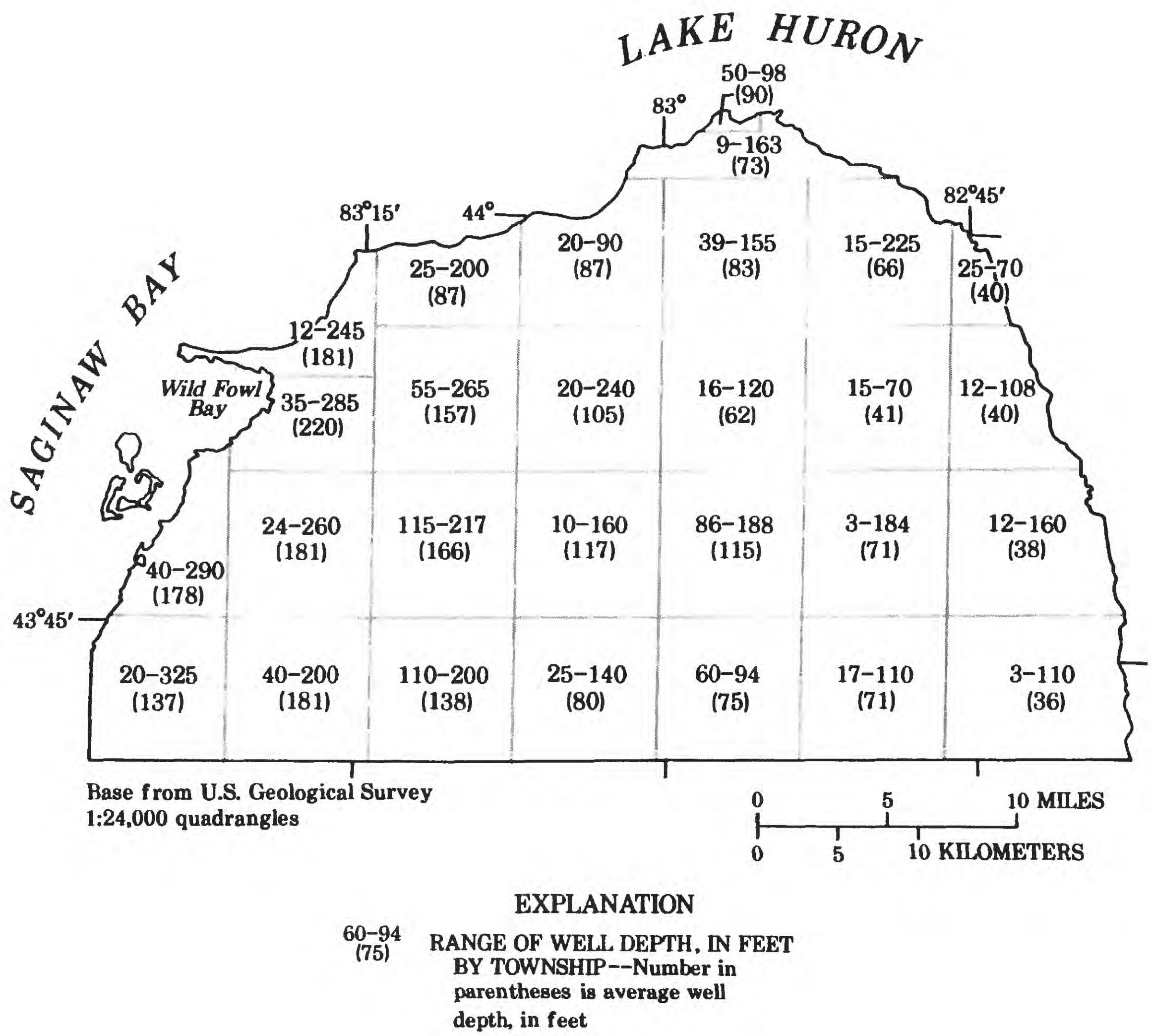


Figure 12.--Range and average depth of domestic wells, by township.

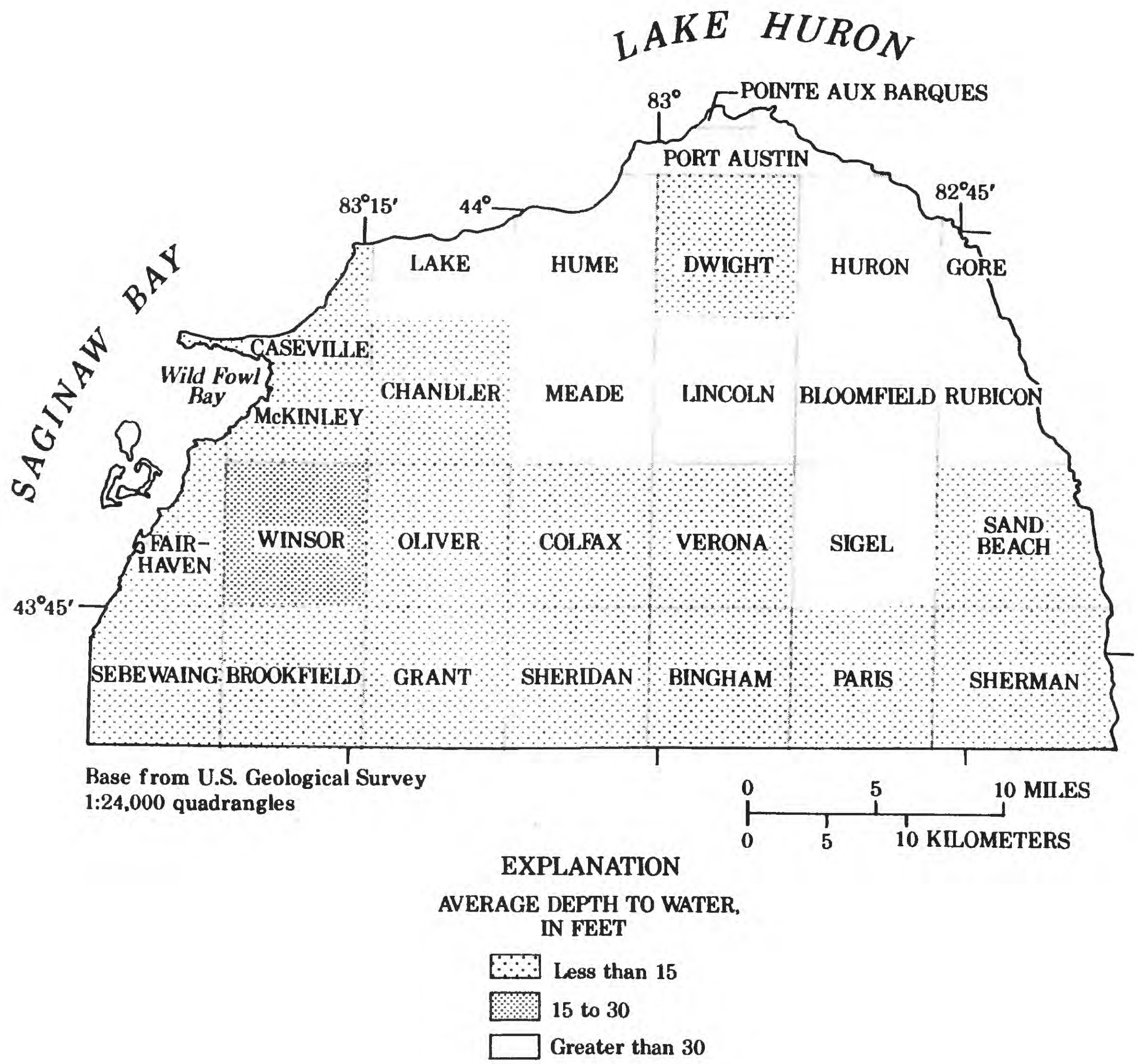


Figure 13.--Average depth to water in wells, by township.

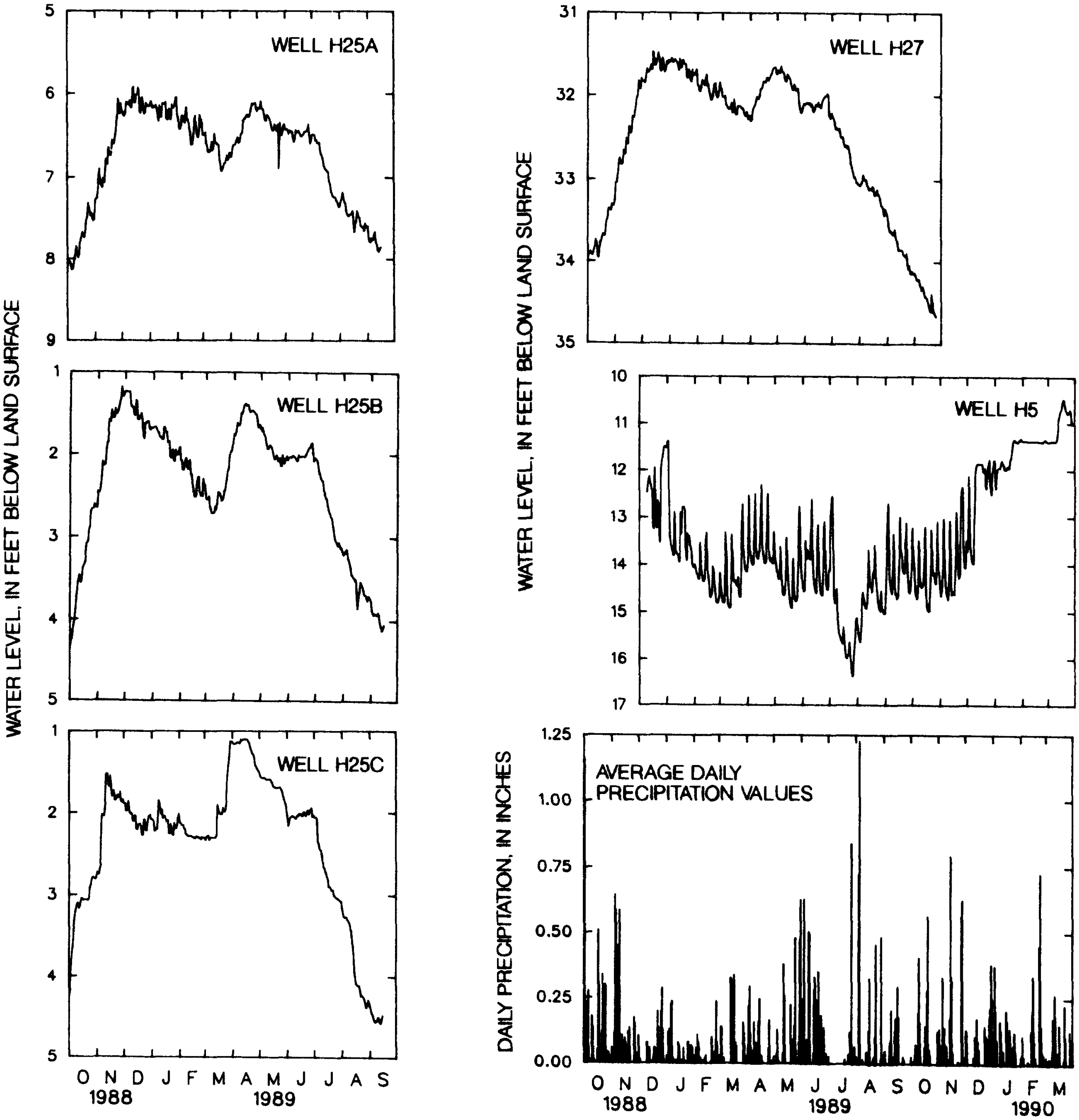


Figure 14.--Hydrographs of selected wells and daily precipitation for Huron County, Michigan, October 1988 through March 1990.

source for the water supply for Ubly because the more distant well was out of service for maintenance. However, noticeable rises in the water level of well H5 did follow intense precipitation on June 19 and July 2, 1989. Also, the water-level in well H5 increased when use of the nearby city well was discontinued in December 1989.

Three wells (H25A, H25B, and H25C) were drilled to bedrock at site H25 (plate 1). The wells were completed at different depths (table 12, at back of report). Water levels were slightly higher in well H25C than in well H25B; however, water levels in both wells are about 5 ft higher than the water level in well H25A. The difference in water levels indicates that water in the bedrock is moving slowly downward.

Water levels shown in figure 15 represent the water table in surficial deposits. Water levels shown in figures 16, 17, and 18, represent confined conditions, except in areas of municipal or irrigation withdrawals. In these areas, the potentiometric surface is below the top of the aquifer. Both the water table and potentiometric-surface maps represent water levels that were measured over an extended period of time. Water levels measured as part of this study indicate that water levels have not differed significantly over time.

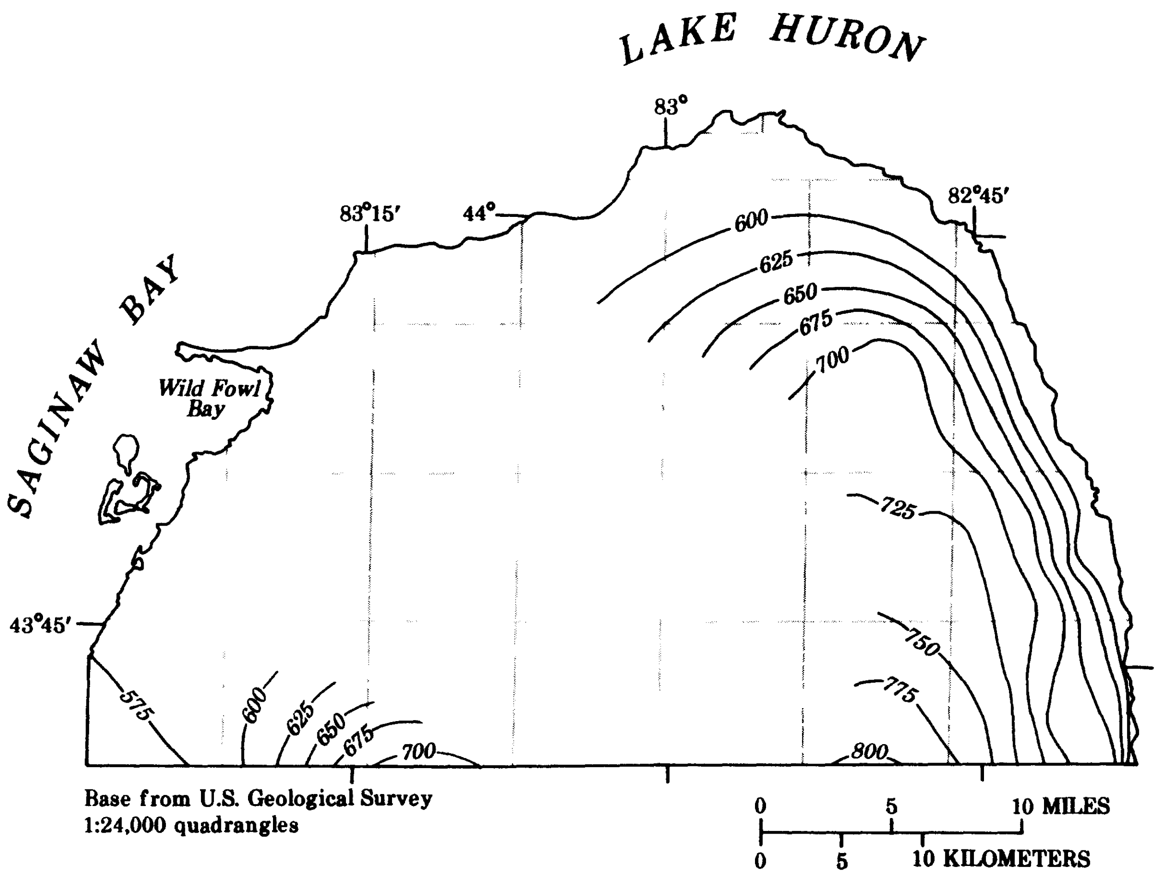
Quality

Chemical and physical characteristics of water from 31 USGS and 4 domestic wells were measured. Locations of these wells are shown on plate 1, and analyses of major dissolved substances, properties, and trace metals are listed in table 12 (at back of report). Principal cations and anions are listed in table 13.

Dissolved-solids concentrations in ground water ranged from 181 to 39,200 mg/L. In water from the Marshall Formation, dissolved-solids concentrations ranged from 181 to 2,440 mg/L. The mean dissolved-solids concentration for the county was 555 mg/L. The relation of dissolved-solids concentration to specific conductance of ground water is shown in figure 19. Waters from two of the formations appear to be identifiable by the relation

Table 13.--Principal ions in ground water in Huron County, Michigan

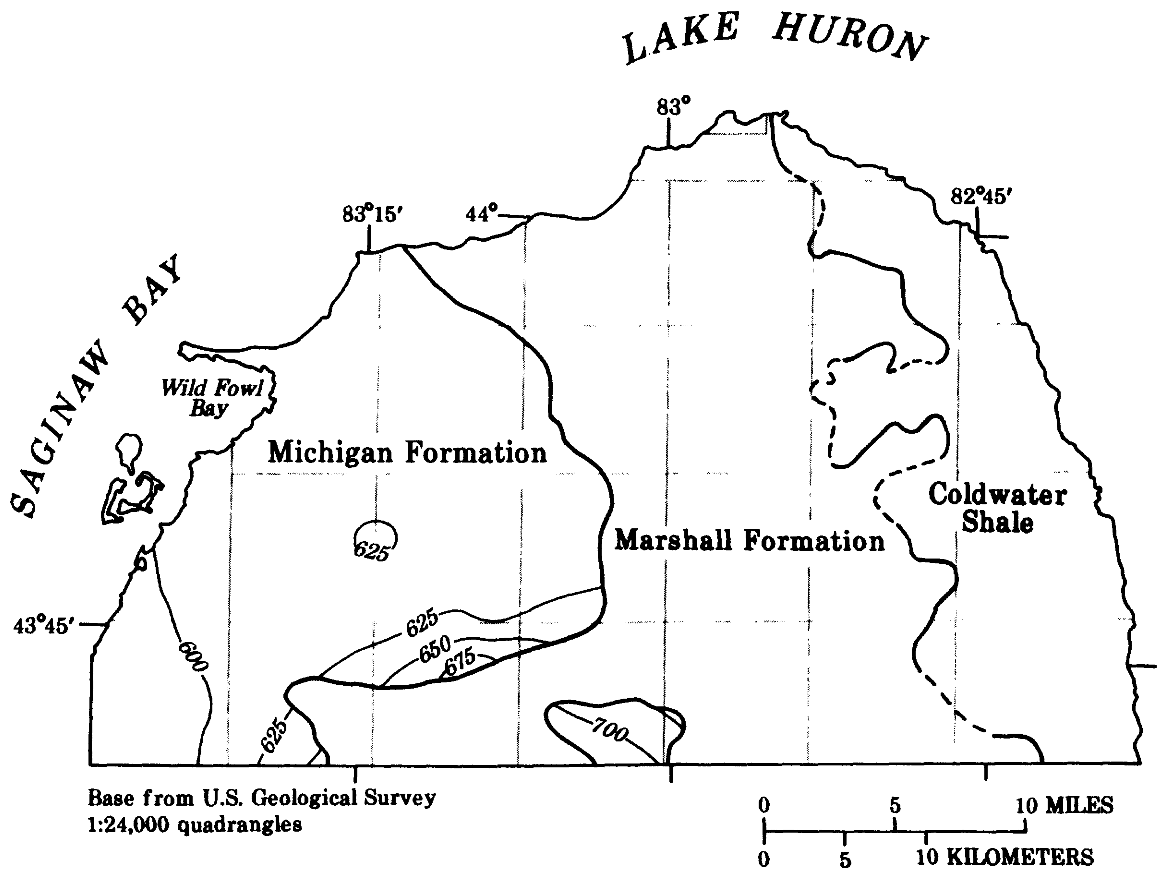
Formation	Principal ions	
	Cations	Anions
Surficial deposits	calcium, sodium	sulfate
Bayport Limestone	calcium, sodium	sulfate
Michigan Formation	calcium, sodium	sulfate
Napoleon Sandstone Member	calcium, magnesium	sulfate
Sandstones in the lower part of the Marshall Formation	calcium, sodium	chloride, sulfide
Coldwater Shale	calcium, sodium	chloride



EXPLANATION

—*700*— WATER-TABLE CONTOUR--Shows altitude of water table, 1980-90. Contour interval 25 feet. Datum is sea level. Uncontoured areas of map indicate insufficient data available to determine the water table

Figure 15.--Water table in the surficial deposits. (Water levels used to generate this figure were obtained from drill logs filed with the Michigan Department of Natural Resources (since 1980) and from data collected for this study).

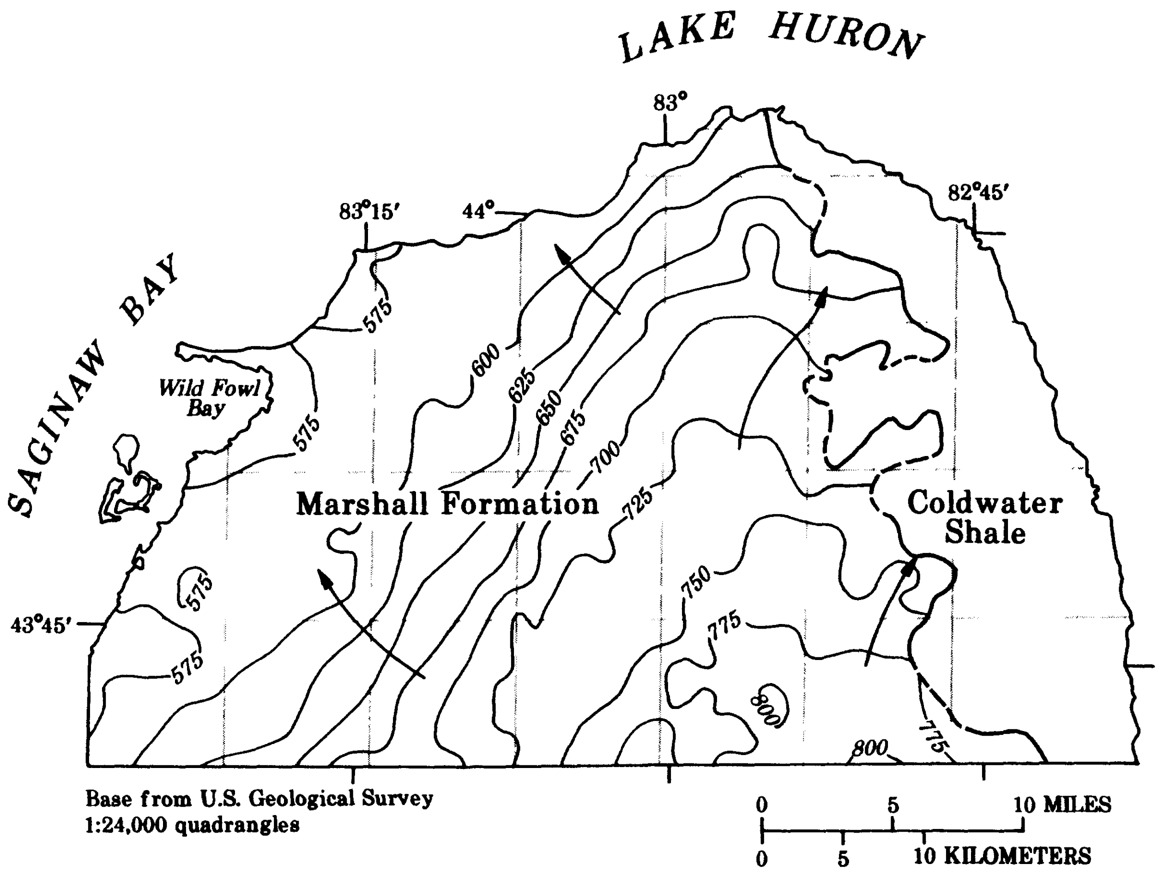


EXPLANATION

—*700*— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased well, 1980-90. Contour interval 25 feet. Datum is sea level

——— LINE OF GEOLOGIC CONTACT--Contact between the Michigan Formation, the Coldwater Shale and the Marshall Formation

Figure 16.--Potentiometric surface in the Michigan Formation. (Water levels used to generate this figure were obtained from drill logs filed with the Michigan Department of Natural Resources (since 1980) and from data collected for this study).



Base from U.S. Geological Survey
1:24,000 quadrangles

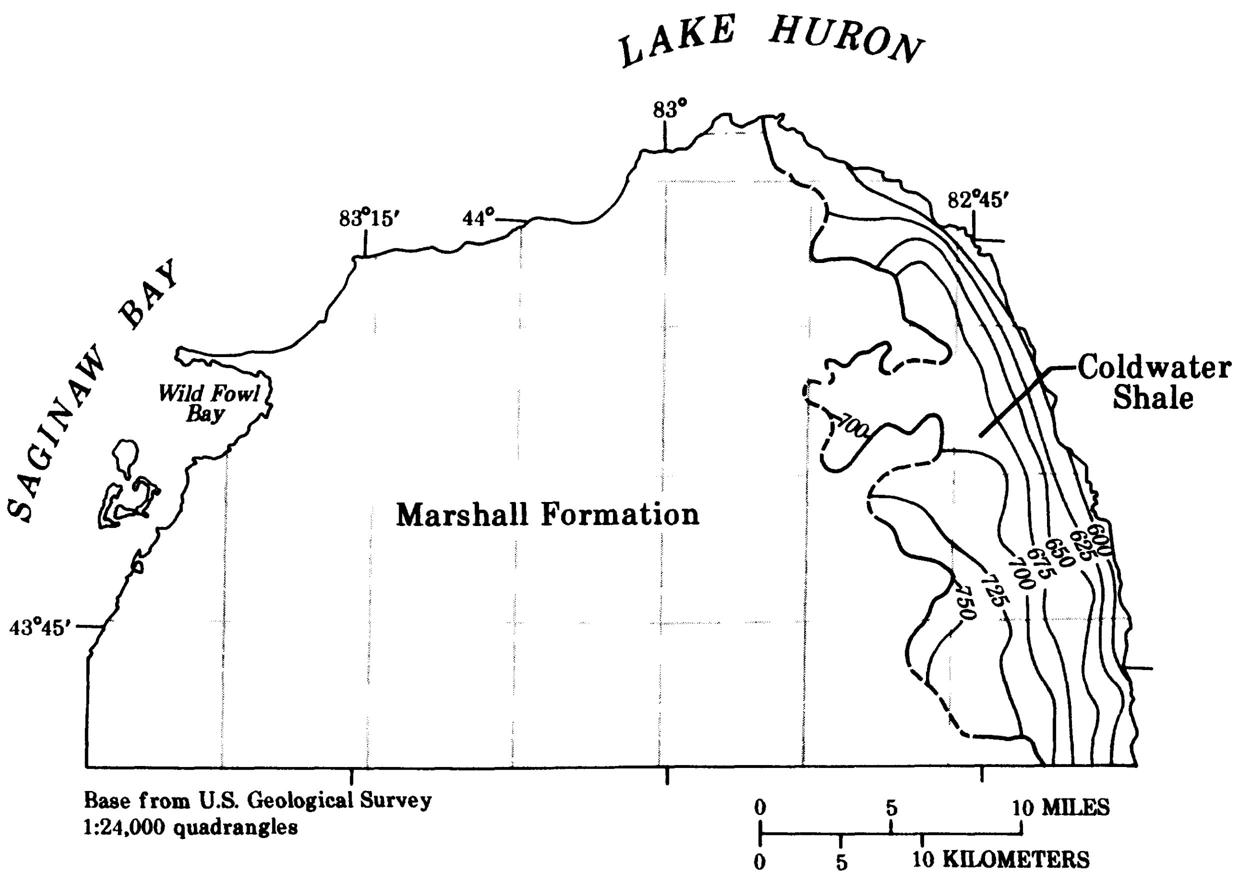
EXPLANATION

— *700* — POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased well, 1980-90. Contour interval 25 feet. Datum is sea level

——► GROUND-WATER FLOW--Arrow indicates direction of flow in the Marshall Formation

———— LINE OF GEOLOGIC CONTACT--Contact between the Marshall Formation and the Coldwater Shale. Dashed where approximately located

Figure 17.--Potentiometric surface and generalized ground-water flow directions in the Marshall Formation. (Water levels used to generate this figure were obtained from drill logs filed with the Michigan Department of Natural Resources (since 1980) and from data collected for this study).



EXPLANATION

—*700*— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased well, 1980-90. Contour interval 25 feet. Datum is sea level

——— LINE OF GEOLOGIC CONTACT--Contact between the Coldwater Shale and the Marshall Formation. Dashed where approximately located

Figure 18.--Potentiometric surface in the Coldwater Shale. (Water levels used to generate this figure were obtained from drill logs filed with the Michigan Department of Natural Resources (since 1980) and from data collected for this study).

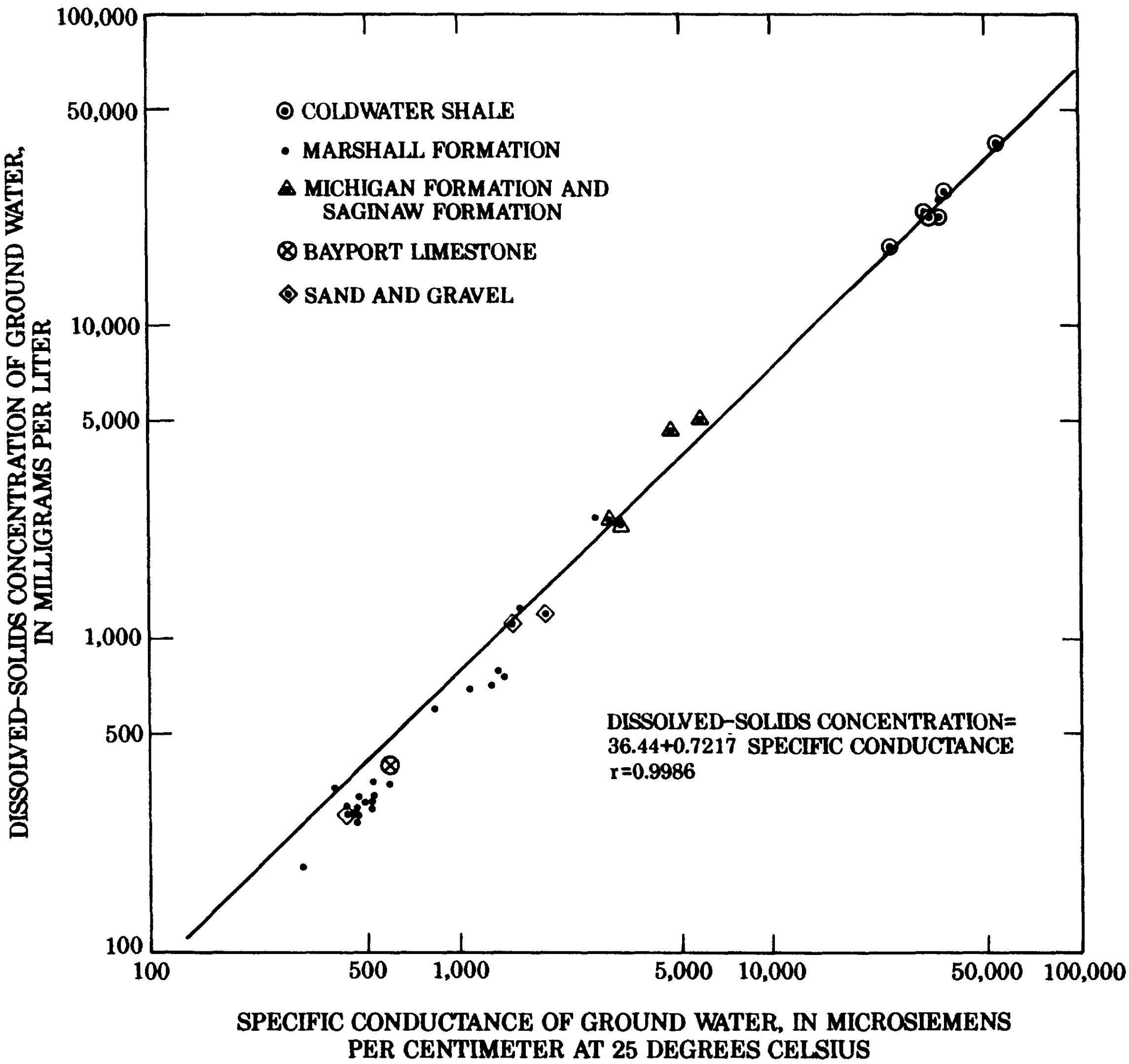


Figure 19.--Relation of dissolved-solids concentrations to specific conductance of ground water.

between the specific conductance and dissolved solids. This relation is especially strong for water from the Marshall Formation, in which dissolved-solids concentrations are generally less than 1,000 mg/L and specific conductances are generally less than 2,000 µS/cm. Water from the Coldwater Shale has dissolved-solids concentrations greater than 20,000 mg/L and specific conductances greater than 20,000 µS/cm. The relation is not as clear for water from the Michigan Formation and Saginaw Formation.

Dissolved-solids concentrations increase as a function of well depth, particularly in sandstones in the lower part of the Marshall Formation. The highest dissolved-solids concentration (39,200 mg/L) was measured in water from well H23. Well H23 is completed in the Coldwater Shale. The lowest dissolved-solids concentration (180 mg/L) was measured in water from well H22. Well H22 is completed in the Napoleon Sandstone Member.

Specific conductance ranges from 308 to 52,700 µS/cm. The variation of specific conductance of ground water by township is shown in figure 20. If figure 20 is compared to figure 5, the influence of geology on chemical characteristics of the ground water can be seen; if compared to figure 12, the variation of specific conductance with well depth can be seen. In general, the specific conductance is highest either in areas where wells are completed in fine-grained materials or in aquifers overlain or underlain by a unit containing saline water. Specific conductance also tends to increase with well depth, particularly in the western two-thirds of the county.

Median values of chemical and physical characteristics of ground water based on data in table 12 were compared to median values found by Cummings (1989) in a survey of natural ground-water quality for the entire state. Comparisons for 28 selected constituents and properties are listed in table 14. The quality of water in Huron County is not substantially different from that considered to be "natural" statewide. Some trace metals and other dissolved substances are higher when compared to statewide values, however, even if a dissolved concentration is compared to a total recoverable concentration reported by Cummings (1989).

Chemical analyses (table 12) indicate that most ground water is suitable for human consumption. The exceptions are samples from wells H4, H15A, and H15B (which exceeded the USEPA MCL for arsenic), wells H7, H18, and H24 (which exceeded the USEPA MCL for cadmium), well H28 (which exceeded the USEPA MCL for mercury), and well H30 (which exceeded the USEPA MCL for selenium). Wells H7, H18, H24, and H30 are completed in the Coldwater Shale, which is not considered to be an aquifer.

In addition, 25 wells yielded water that exceeded USEPA SMCL's for one or more of the following constituents or properties--chloride, color, iron, manganese, pH, sulfate, zinc, and dissolved solids. These 25 wells are completed in aquifers and confining units of Huron County.

Public concern has been expressed regarding nitrate concentrations in ground water. Mean nitrate concentrations in ground water by township in the county are shown in figure 21. The USEPA has set an MCL of 10 mg/L for nitrate. All nitrate concentrations in water from domestic wells and wells installed by the USGS were less than the USEPA MCL.

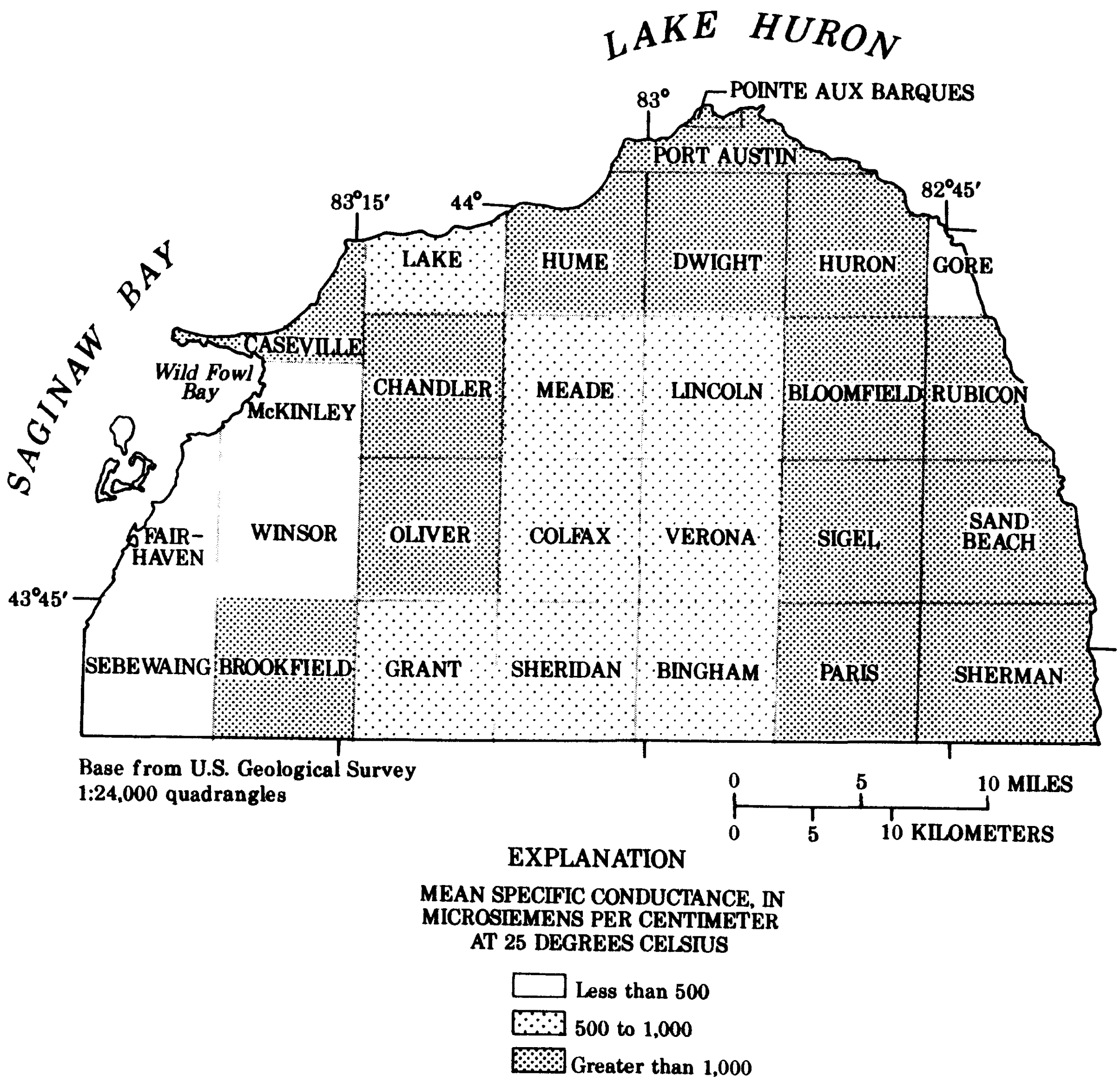


Figure 20.--Mean specific conductance of ground water, by township.

Table 14.--Relation of ground-water quality in Huron County to statewide ground-water quality

[Analyses by U.S. Geological Survey. mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than]

Constituent or property	Median value	
	[a]Statewide	[b]Huron County
Alkalinity (mg/L as $CaCO_3$)	155	188
Arsenic, total (µg/L as As)	1	[c]9
Calcium, dissolved (mg/L as Ca)	50	96
Chloride, dissolved (mg/L as Cl)	4.4	140
Chromium, total recoverable (µg/L as Cr)	<20	[c]1
Fluoride, dissolved (mg/L as F)	.1	.6
Hardness, total (mg/L as $CaCO_3$)	200	330
Iron, total recoverable (µg/L as Fe)	560	[c]330
Manganese, total recoverable (µg/L as Mn)	22	[c]36
Magnesium, dissolved (mg/L as Mg)	17	26
Mercury, total recoverable (µg/L as Hg)	<.50	[c]<.10
Nitrogen, ammonia, total (mg/L as N)	.05	.38
Nitrogen, nitrite, total (mg/L as N)	<.01	<.01
Nitrogen, organic, total (mg/L as N)	.13	<.01
pH (standard units)	7.7	7.45
Phosphorus, total (mg/L as P)	<.01	.01
Phosphorus, ortho, total (mg/L as P)	<.01	<.01
Potassium, dissolved (mg/L as K)	1.4	3.0
Selenium, total (µg/L as Se)	<1	[c]<1
Silica, dissolved (mg/L as SiO_2)	11	11
Silver, total recoverable (µg/L as Ag)	<1	[c]<1
Sodium, dissolved (mg/L as Na)	6.8	150
Solids, residue at 180 °C, dissolved (mg/L)	244	779
Specific conductance (µS/cm)	426	811
Strontium, total recoverable (µg/L as Sr)	150	[c]1,400
Sulfate, dissolved (mg/L as SO_4)	13	150
Temperature (°C)	9.5	11.0
Zinc, total recoverable (µg/L as Zn)	60	[c]140

[a]From Cummings (1989).

[b]Data collected during this investigation.

[c]Dissolved constituent.

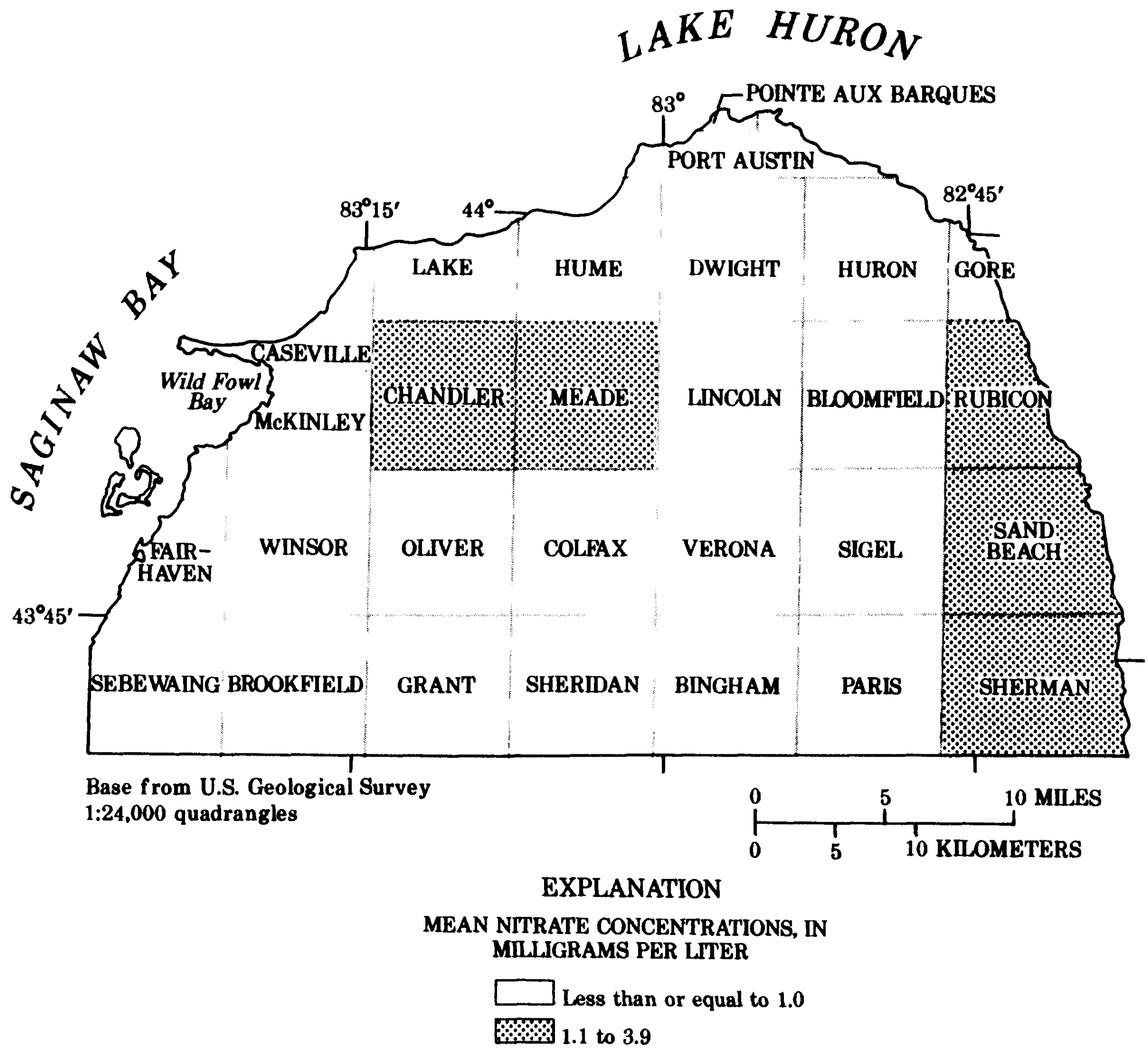


Figure 21.--Nitrate concentrations in ground water, by township.

Water was collected at 12 USGS wells in July 1988 and May 1989 and was analyzed by the USGS for the following pesticides:

- Alachlor, total
- Ametryne, total
- Atrazine, total
- Cyanazine, total
- Methomyl, total
- Metolachlor, whole water
- Metribuzin, whole water
- Prometone, total
- Prometryne, total
- Propazine, total
- Propham, total
- Sevin, total
- Silvex, dissolved
- Silvex, total
- Simezine, total
- Simetryne, total
- Trifluralin, total
- 2,4-D, dissolved
- 2,4-D, total
- 2,4-DP, dissolved
- 2,4-DP, total
- 2,4,5-T, dissolved
- 2,4,5-T, total

Results of pesticide analyses are listed in table 15. One compound, 2,4,5-T, was detected in water from wells H2 and H11.

Radon-222 concentrations were measured in water from 32 wells (table 16). The USEPA has not issued regulations for the amount of radon-222 allowed in drinking water; however, the USEPA has found that the average content of radon-222 in ground water in the United States is between 200 and 600 pCi/L (Hess and others, 1985). Radon-222 concentrations in ground water in Huron County ranged from less than 80 pCi/L to 710 pCi/L. The median concentration was 130 pCi/L.

Tritium concentrations were measured in water from 22 wells (table 16). The bulk of tritium in the environment is the result of nuclear testing, which began in 1952. Because tritium has a relatively short radiometric half-life (12.3 years), the concentration of this radionuclide in ground water indicates the age of the water. The absence of this radionuclide indicates a water residence time that exceeds 40 years (Freeze and Cherry, 1979, p. 136-137). Except for well H20, tritium in water from wells was not detectable. This indicates that the ground water sampled in Huron County has not been recently recharged and has a residence time greater than 40 years.

Recharge and Discharge

Areas of probable recharge to the Marshall Formation, shown in figure 22, are based on differences between the water table and (or) potentiometric surfaces of aquifers and confining units. Small areas under glacial moraines coincide with surface areas of parallel glacial ridges and valleys and a bedrock high on the Marshall Formation. Surficial troughs in this area are perennial swamps and marshes and receive a large part of the runoff in the area. The water table in these areas is at a higher altitude than the potentiometric surface of the Marshall Formation. In the area beneath the Michigan Formation, the potentiometric surface of the Michigan Formation is above that of the Marshall Formation. The two areas overlying the Coldwater Shale are areas where the potentiometric surface of the Coldwater Shale is greater than that of the Marshall Formation; hence, water from the Coldwater Shale may be slowly moving upward into the Marshall Formation. In this area, however, the Marshall Formation is not thick enough to be a significant source of water.

Table 15.--Pesticide concentrations of ground water in Huron County, Michigan, 1988-89

[Analyses by U.S. Geological Survey. Well locations shown on plate 1. µg/L, micrograms per liter; <, less than; --, no analysis done]

Well number	Date of sample	Alachlor, total recoverable (µg/L)	Ametryne, total (µg/L)	Atrazine, total (µg/L)	Cyanazine, total (µg/L)	Methomyl, total (µg/L)	Prometone, total (µg/L)	Prometryne, total (µg/L)	Propazine, total (µg/L)	Propham, total (µg/L)	Sevin, total (µg/L)	Silvex, dissolved (µg/L)
H2	May 23, 1989	<0.01	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.5	<0.5	<0.01
H4	May 23, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H9	May 24, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H11	July 14, 1988	--	--	--	--	--	--	--	--	--	--	--
H11	May 24, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H15B	July 14, 1988	--	--	--	--	--	--	--	--	--	--	--
H15B	May 24, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H16	July 14, 1988	--	--	--	--	--	--	--	--	--	--	--
H16	May 24, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H21	May 25, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H22	July 14, 1988	--	--	--	--	--	--	--	--	--	--	--
H22	May 25, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H25A	May 25, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H25B	May 25, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01
H26	July 15, 1988	--	--	--	--	--	--	--	--	--	--	--
H28	May 26, 1989	<.01	<.1	<.1	<.1	<.5	<.1	<.1	<.1	<.5	<.5	<.01

Well number	Silvex, total (µg/L)	Simazine, total (µg/L)	Simetryne, total (µg/L)	Trifluralin, total recoverable (µg/L)	2,4-D, dissolved (µg/L)	2,4-D, total (µg/L)	2,4-DP, dissolved (µg/L)	2,4-DP, total (µg/L)	2,4,5-T, dissolved (µg/L)	2,4,5-T, total (µg/L)
H2	--	<0.1	<0.1	<0.1	<0.01	--	<0.01	--	<0.1	--
H4	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H9	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H11	<0.01	--	--	--	--	<0.05	--	<0.05	--	0.06
H11	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H15B	<.01	--	--	--	--	<.05	--	<.05	--	<.01
H15B	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H16	<.01	--	--	--	--	<.05	--	<.05	--	<.01
H16	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H21	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H22	<.01	--	--	--	--	<.05	--	<.05	--	<.01
H22	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H25A	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H25B	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--
H26	<.01	--	--	--	--	<.05	--	<.05	--	<.01
H28	--	<.1	<.1	<.1	<.01	--	<.01	--	<.1	--

Table 16.--Radon-222 and tritium concentrations of ground water in Huron County, Michigan, 1988

[Analyses by U.S. Geological Survey. Well locations shown on plate 1. pCi/L, picoCuries per liter; <, less than; --, no analysis done]

Well number	Date	Depth of well, total (feet)	Radon-222, total (pCi/L)	Tritium, total (pCi/L)
H1B	July 13, 1988	76	130	<26
H1C	July 13, 1988	243	<80	<26
H1D	July 13, 1988	70	<80	<26
H2	July 13, 1988	91	100	<26
H3	July 13, 1988	120	130	--
H4	July 13, 1988	80	380	--
H5	July 19, 1988	172	250	<26
H6	July 15, 1988	90	240	--
H7	July 19, 1988	140	<80	<26
H8	July 19, 1988	18	<80	<26
H9	July 13, 1988	180	120	<26
H10	July 13, 1988	150	<80	<26
H12	July 14, 1988	280	310	--
H13	July 14, 1988	120	--	<26
H13	July 19, 1988	120	160	--
H13	July 19, 1988	120	210	--
H14	July 14, 1988	100	--	<26
H14	July 19, 1988	100	90	--
H15A	July 14, 1988	102	300	<26
H15B	July 14, 1988	99	710	<26
H16	July 14, 1988	160	160	<26
H17	July 18, 1988	80	<80	<26
H18	July 18, 1988	160	120	<26
H19	July 18, 1988	100	<80	--
H20	July 18, 1988	60	130	64
H21	July 19, 1988	80	150	--
H22	July 14, 1988	150	<80	<26
H24	July 19, 1988	100	<80	--
H25A	July 15, 1988	200	--	<26
H25A	July 18, 1988	200	150	--
H25B	July 15, 1988	160	--	<26
H25B	July 18, 1988	160	200	--
H25C	July 15, 1988	40	--	<26
H25C	July 18, 1988	40	300	--
H26	July 18, 1988	60	110	--
H27	July 18, 1988	80	<80	--
H28	July 14, 1988	75	--	<26
H28	July 19, 1988	75	<80	--
H30	July 18, 1988	80	190	--

A water budget for the Saginaw Bay area of Michigan, which includes Huron County, was calculated by Vieux and He (1990). For the Pigeon River near Owendale, base flow was calculated to be 4.30 in., recharge was 1.31 in., and net discharge from the ground-water system was 2.99 in. The calculations indicate a net loss of ground water from the county of 1.68 in.

Many streams in the county (Cass River, Pigeon River, Pinnebog River, Willow River, Rock Falls Creek and Elm Creek) originate in swamps and marshes. Most of the streams start at about 750 ft above sea level, the approximate elevation of the potentiometric surface in the south-central part of the county. A potentiometric surface greater than land-surface elevation can cause underlying bedrock aquifers to discharge water at land surface if vertical hydraulic conductivity is great enough to allow flow to the surface. Surface discharge of ground water is sufficient to maintain flow in Rock Falls Creek and Elm Creek throughout most of the year. Most other streams, however, are above the potentiometric surface throughout much of their lengths; hence, periods of no flow occur in late summer and early fall, when surface runoff and ground-water discharge are insufficient to maintain flow.

Tritium concentrations in ground water indicate that infiltration of precipitation is slow and that recharge of precipitation to aquifers requires more than 40 years. Use of other isotopic water-dating techniques would be required to further identify the age of ground water and the rate at which it recharges the aquifers.

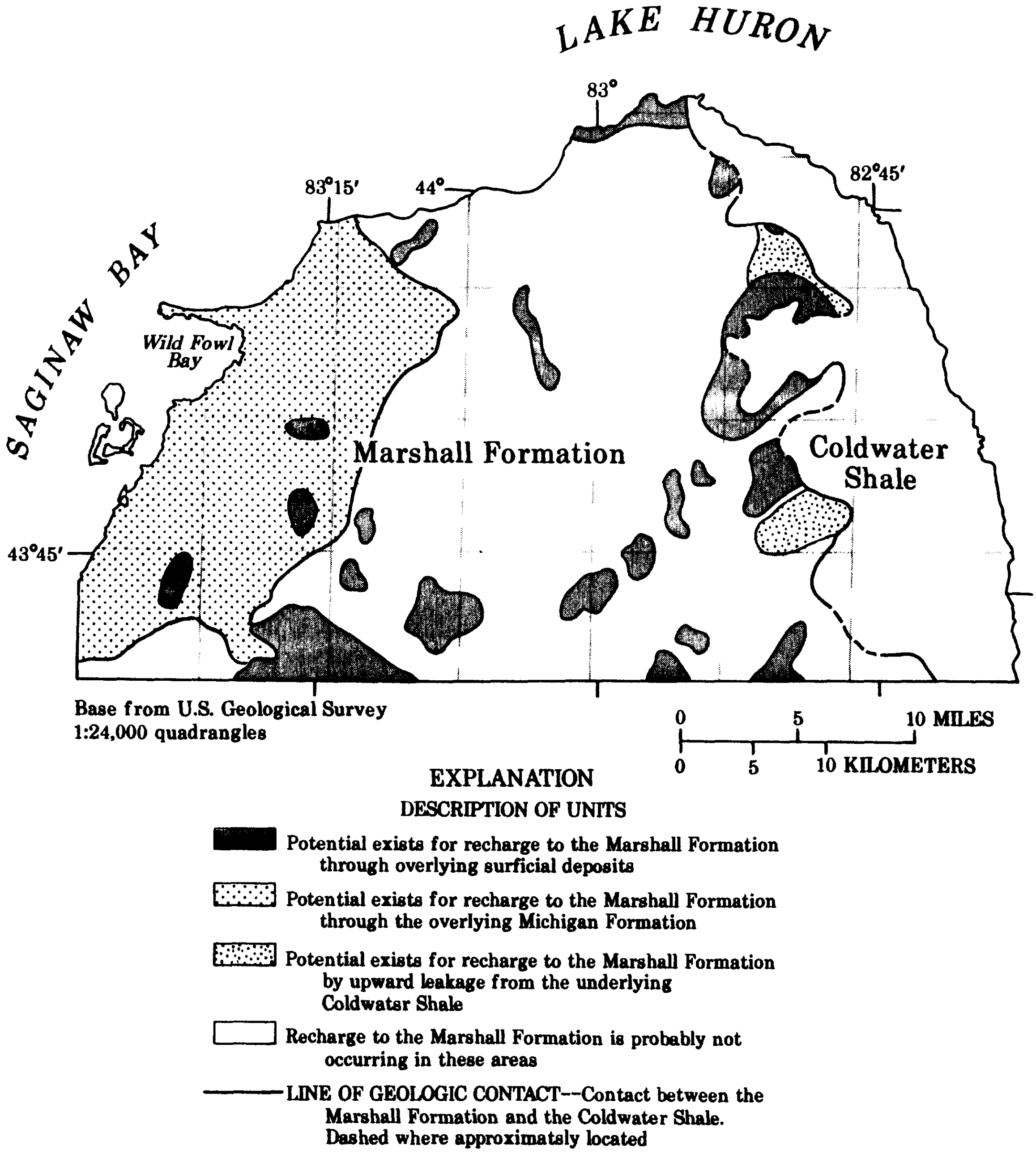


Figure 22.--Areas of probable ground-water recharge to the Marshall Formation.

Direction of Flow

Data collected by Mandle and Westjohn (1989, p. 95-105), and data obtained during this project, indicate that ground-water flow in Huron County is from the southeastern part of the county to the northwest, toward Saginaw Bay. The generalized ground-water-flow pattern in the Marshall Formation is shown in figure 17.

Availability of Water Resources for Development

On the basis of analysis of data obtained during this study, areas where further ground- or surface-water sources are available are not obvious. Areas of probable ground-water recharge may be areas where additional ground water is available; these areas are shown on figure 23. These areas coincide with (1) areas where the potentiometric surface of the Marshall Formation is greater than the elevation of land surface, and (2) areas where the water-table surface of surficial deposits, which are in direct contact with the Marshall Formation, is higher than the potentiometric surface in the Marshall Formation.

Aquifer tests (pumping tests and slug tests) indicate that the ability of the Marshall Formation to yield water is related to the degree of cementation, grain size, pore size, and fracturing. Transmissivities range from 7 to 50 $[(ft^3/d)/ft^2]ft$[3] for the freshwater bearing Marshall Formation and generally increase from east to west as the sandstones become thicker and more coarse grained. These transmissivities correspond to hydraulic conductivities of 0.25 to 1.5 ft/d. Bear (1979, p. 68) and Driscoll (1986, p. 75) cite similar hydraulic conductivities for friable, unfractured sandstone. Westjohn and others (1990, p. 11-12) cite similar values for matrix-controlled hydraulic conductivities in Mississippian sandstones in the Michigan basin. These transmissivities were compared to those found for the same formation in Battle Creek, Michigan. Grannemann and Twenter (1985, p. 25) calculated transmissivities ranging from 3,000 to 27,000 ft^2/d in the lower part of the Marshall Formation at the Verona well field, and 0 to 15,000 ft^2/d in the upper Marshall Formation. These values correspond to hydraulic conductivities of 55 and 150 ft/d, respectively, and are representative of fractured sandstone. Westjohn and others (1990, p. 9) report matrix-controlled horizontal hydraulic conductivities at the Verona well field of 0.08 to 1.9 ft/d, and for Mississippian sandstones in general, horizontal hydraulic conductivities of 0.4 to 1.62 ft/d. This comparison shows that the hydraulic conductivity of the Marshall Formation in Huron County is matrix controlled and similar to that of the Marshall Formation in other parts of the State. An increase of water supplies from the Marshall Formation is thus likely to be difficult without the use of aquifer-enhancement techniques.

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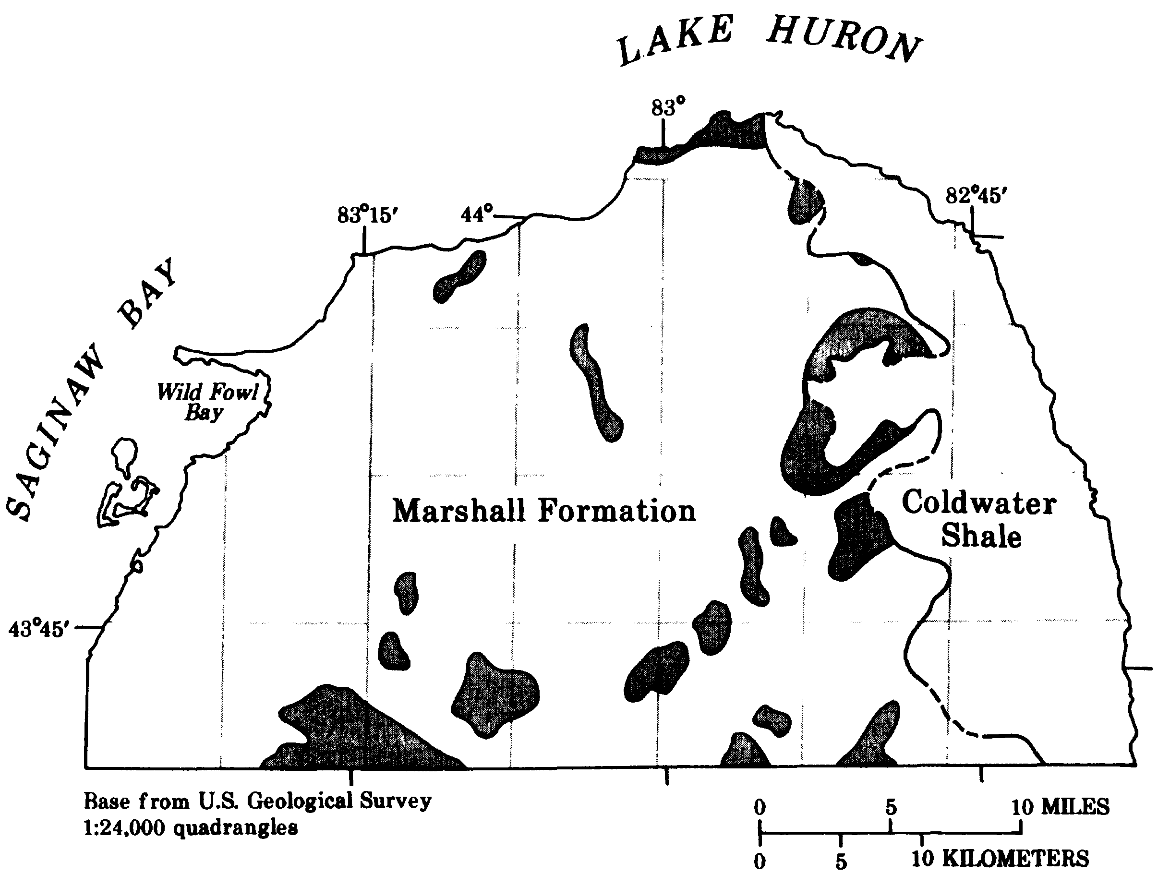
[3]This relation reduces to foot squared per day (ft^2/d), and this reduced form is used hereafter.



EXPLANATION

DESCRIPTION OF UNITS

Area in which additional ground water may be available from the Marshall Formation

LINE OF GEOLOGIC CONTACT--Contact between the Marshall Formation and the Coldwater Shale. Dashed where approximately located

Figure 23.--Areas where additional ground-water resources may be available from the Marshall Formation.

The Marshall Formation yields less water in Huron County than it does in other parts of the State. Increases in ground-water withdrawal from the Marshall Formation may induce flow from rock units containing saline water or may impinge on the area of supply of existing wells. The effect will be greatest where the hydraulic conductivity and transmissivity of the Marshall Formation are lowest.

The availability of ground water throughout the county is shown in figures 10 and 11. In general, ground water is most readily available in the south-central and western parts of the county; availability decreases to the north and east. The lack of availability is particularly acute in the eastern part of the county where bedrock aquifers are either absent or very thin. In the north, aquifers are not thick enough to yield significant amounts of water. Water-supply problems along the western and south-western shore of the county are related to the depth to the aquifer and the salinity of the ground water.

Additional large withdrawals of water at some locations could cause upward migration of brine from the Coldwater Shale (fig. 22). Recharge from the overlying Michigan and Saginaw Formations might also be induced (fig. 22). An increase in withdrawals may be possible locally, but more intensive local study would be needed to determine their effects in many areas. Areas where increased withdrawals of ground water from the Marshall Formation may be possible are shown on figure 23.

SUMMARY

Industry and agriculture are placing increasing demands on the water resources in Huron County. The extent to which water resources can be developed and agricultural activity can be expanded without negative effects on water resources is of concern to county officials, residents and businesses.

Generally, surface water from streams is not a reliable source of water supply because most streams lack sustained flows during summer months. Surface-water records indicate that there is a net discharge of ground water from the aquifers into the streams of Huron County.

Thick, highly productive glacial sand and gravel deposits are absent from much of the county. In many places, bedrock yields insufficient water for domestic supplies or yields only saline water. The principal aquifers in the county are sandstones of the Marshall Formation. Surficial deposits are used as a resource where present, but they yield only small quantities of water (1 to 10 gal/min).

Yields from the Napoleon Sandstone Member and sandstones in the lower part of the Marshall Formation typically range from 1 to 300 gal/min. Depth to water in wells is variable, but it is generally less than 55 ft. Water levels in wells completed in sandstones in the lower part of the Marshall Formation indicate confined conditions; water levels in a few wells completed in the Napoleon Sandstone Member and the surficial deposits indicate water-table conditions.

The Michigan Formation, the Bayport Limestone, and the Saginaw Formation overlie the Napoleon Sandstone Member. Potable water can be obtained from each of these units in places, but they are primarily confining units. The Michigan Formation may be a source of elevated dissolved solids to the Napoleon Sandstone Member because of induced recharge. The Coldwater Shale underlies sandstones in the lower part of the Marshall Formation, and is generally considered to be a lower confining unit. Locally, the Coldwater Shale yields small amounts of potable water, but it is generally considered to be a source of dissolved constituents to sandstones in the lower part of the Marshall Formation.

The predominant dissolved ions in water from the Napoleon Sandstone Member are calcium and bicarbonate. Water quality in Huron County does not differ appreciably from that found across the State. Water from three wells completed in the Marshall Formation had arsenic concentrations that exceeded USEPA MCLs; in one well, water had cadmium concentrations exceeding the USEPA MCL. Water from two wells contained pesticides.

For the most part, water levels throughout the county are unaffected by pumping. Exceptions are in areas of municipal or irrigation pumpage, where there may be depressions in the potentiometric surface. Water levels in wells indicate that water in bedrock is moving slowly downward. In all but one well sampled, tritium concentrations were below the detection limit (an indication that ground-water recharge rates in Huron County are low). Regional ground-water flow in the Marshall Formation is from the southeast to the northwest.

The ability to expand water production in the Marshall Formation is restricted by hydraulic characteristics of the aquifer and the apparently low recharge rate of the aquifer. Transmissivities range from 7 to 50 ft^2/d in the Napoleon Sandstone Member, and hydraulic conductivities are in the range of 0.25 to 1.5 ft/d. These values are similar to those in the Marshall Formation in other parts of the State. Additional large-volume increases in production from the Marshall Formation could increase the risk of water-quality degradation by flow of saline water from above and below the aquifer.

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DEFINITIONS OF TERMS

The following are definitions of selected technical terms as they are used in this report; they are not necessarily the only valid definitions for these terms.

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

Bedrock. A general term for consolidated rock that underlies unconsolidated material.

Concentration. The weight of dissolved solids or sediment per unit volume of water expressed in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Consolidated. Solidified earth materials that were deposited in a loose, soft, or liquid form.

Crossbedded. Layers within a deposit that are at angles to the main orientation of the deposit.

Cubic feet per second. A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

Discharge. The rate of flow of a stream; reported in cubic feet per second (ft^3/s).

Dissolved solids. Substances present in water that are in true chemical solution.

Elevation. Vertical distance of a point or line above or below a specified datum. In this report, elevations are referenced to the National Geodetic Vertical Datum of 1929. The National Geodetic Vertical Datum of 1929 (NGVD of 1929) is a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Eutrophic. Referring to a lake or pond which is rich in nutrients, and in which excessive growth of aquatic plants occurs, consuming the available dissolved oxygen.

Ground water. Water that is in the saturated zone from which wells, springs, and ground-water inflow to streams are supplied.

Hydraulic conductivity. The volume of water at the prevailing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. In general terms, hydraulic conductivity is the ability of a porous medium to transmit water.

Lenticular. Resembling in shape the cross section of a lens.

NGVD of 1929. See Elevation.

Permeability. A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the fluid and of the force field.

Potable water. Water that is safe and palatable for human use; freshwater in which concentrations of pathogenic organisms and dissolved toxic constituents, if present, have been reduced to safe levels, and which is, or has been treated so as to be, tolerably low in objectionable taste, odor, color, or turbidity and of a temperature suitable for the intended use (Bates and Jackson, 1987, p. 523).

Potentiometric surface. A surface which represents the static head. As related to an aquifer, it is defined by the levels to which water will rise in tightly cased wells.

Recharge. The process by which water is infiltrated and added to the zone of saturation. It is also the quantity of water added to the zone of saturation.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to which an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

Specific conductance. A measure of the ability of water to conduct an electric current, expressed in microsiemens per centimeter (µs/cm) at 25 degrees Celsius [formerly termed micromhos (µmhos)]. Because the specific conductance is related to the amount and the type of dissolved material, it is used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in milligrams per liter) to specific conductance (in microsiemens per centimeter) is in the range 0.5 to 0.8.

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

Unconsolidated. Earth materials that are loosely arranged or whose particles are not cemented together, occurring either at the surface or at depth.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells. No water table exists where the upper surface of the water body is confined by low permeability materials.

TABLES OF DATA

Table 2.--Generalized lithologic data for observation wells installed in Huron County, Michigan, by the U.S. Geological Survey

[Well locations are shown on plate 1]

Well number	Lithology	Depth to bottom (feet)	Well number	Lithology	Depth to bottom (feet)
[a]H1A	Clay	61	H5	Shale	112
	Sand and gravel	86		Sandstone	160*
	Clay	89			
	Gravel	91	H6	Clay	34
	Clay	93		Sand	37
	Gravel	95		Clay	52
	Clay	100		Sandstone	90*
	Sandy limestone	119*			
			H7	Clay	14
H2	Clay	11		Sand	18
	Shale	13		Clay	50
	Clay	22		Sandy shale	55
	Sand	24		Shale	140*
	Clay	85			
	Sand	91*	H8	Gravel	6
				Clay	16
H3	Sand	24		Sandstone	18*
	Clay	64			
	Gravel	66	H9	Clay	26
	Shale	70		Limestone	28
	Limestone and shale	78		Clay	34
	Sandy limestone	88		Sand	36
	Sandstone	120*		Sandstone	41
				Limestone	46
H4	Clay	10		Shale	50
	Sand	18		Sandstone	55
	Clay	35		Shale	116
	Sand	37		Gypsum and limestone	128
	Sandstone	63		Shale	132
	Limestone	65		Gypsum and limestone	135
	Sandstone	80*		Shale	140
				Sandstone	152
H5	Gravel	14		Shale	159
	Clay	20		Sandy limestone	162
	Sand	23		Shale	164
	Clay	30		Sandy shale	167
	Sand	38		Sandy limestone	181*
	Shale	45			
	Limestone	48	H10	Clay	30
	Sandstone	51		Limestone	36
	Limestone	58		Shale	99
	Sandstone	100*		Gypsum	101

Table 2.--Generalized lithologic data for observation wells installed in Huron County, Michigan, by the U.S. Geological Survey--Continued

Well number	Lithology	Depth to bottom (feet)	Well number	Lithology	Depth to bottom (feet)
H10	Shale	112	H16	Blue shale	126
	Limestone	114		Sandstone	160*
	Shale	130			
	Sandy shale	142	H17	Sand	5
	Limestone	150*		Clay	7
				Sand	10
H13	Clay	66		Clay	20
	Shale	68		Shale	69
	Limestone	72		Sandstone	80*
	Shale	79			
	Limestone	82	H18	Sand	12
	Shale	86		Clay	86
	Limestone	89		Sand	106
	Sandstone	120*		Clay	120
				Sandy shale	160*
H14	Clay	8			
	Gravel	10	H19	Clay	28
	Clay	18		Shale	38
	Limestone	21		Gypsum	40
	Shale	32		Shale	41
	Limestone	35		Limestone	42
	Shale	55		Gypsum	43
	Limestone	70		Shale	68
	Shale	78		Sandy limestone	70
	Limestone	90		Shale	80
	Sandstone	100*		Shale and gypsum	100*
H15B	Sand and gravel	6	H20	Clay	37
	Clay	22		Shale	42
	Sand	23		Limestone	43
	Clay	37		Sandstone	44
	Sandstone	72		Limestone	45
	Sandy shale	74		Shale	51
	Sandstone	100*		Sandy shale	53
				Shale	55
H16	Sand	14		Limestone	60*
	Clay	24			
	Sand	38	H21	Clay	6
	Clay	57		Sand	9
	Shale	59		Clay	36
	Sandstone	61		Sandstone	40
	Limestone	63		Limestone	45
	Shale	68		Sandstone	80*
	Sandy shale	106			

Table 2.--Generalized lithologic data for observation wells installed in Huron County, Michigan, by the U.S. Geological Survey--Continued

Well number	Lithology	Depth to bottom (feet)	Well number	Lithology	Depth to bottom (feet)
H22	Sand and gravel	9	H25A	Sandy shale	120
	Clay	15		Sandstone	140
	Sand	19		Sandy shale	180
	Clay	27		Sandstone	200*
	Gravel	30			
	Clay	36	H26	Clay	23
	Sandstone	85		Sandstone	55
	Shale	101		Sandy shale	60*
	Sandstone	102			
	Sandy shale	118	H27	Gravel	5
	Gray shale	122		Clay	12
	Sandy shale	144		Sand	16
	Green shale	145		Clay	30
	Brown shale	149		Sandy shale	36
	Sandstone	150*		Shale	70
				Sandstone	71
H23	Sand and gravel	16		Shale	72
	Clay	63		Sandstone	80*
	Sandstone	68			
	Shale	81	H28	Sand	12
	Sandstone	82		Clay	42
	Shale	115		Shale	55
	Sandy shale	130		Sandy shale	59
	Shale	132		Shale	65
	Sandy shale	150*		Sandstone	75*
H24	Sand	7	H29	Clay	6
	Clay	10		Shale	39
	Sand	12		Sandstone	44
	Clay	64		Shale	70*
	Sandstone	66			
	Sandy shale	80	H30	Clay	7
	Shale	90		Sand	9
	Sandy shale	100*		Clay	16
				Sandstone	33
[b]H25A	Clay	18		Sandy shale	42
	Sandstone	86		Shale	80*

[a]Deepest of two wells installed at this site.

[b]Deepest of three wells installed at this site.

*Indicates bottom of hole. All depths are from land surface.

Table 5.--Chemical and physical characteristics of selected streams in Huron County, Michigan, 1988-89

[Analyses by U.S. Geological Survey. Gaging station locations shown on plate 1. ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; NTU, nephelometric turbidity units; mg/L, milligram per liter; µg/L, micrograms per liter; <, less than; --, no analysis done]

Gaging station number and name	Date sampled	Discharge, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Barometric pressure (mm of Hg)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
04158000 Columbia Drain near Sebawaing	Apr. 19, 1988	11	774	8.2	6.5	740	8.9	13	410	170	234
	Oct. 18, 1988	4.90	796	8.4	14.0	740	4.5	15	410	210	197
04159010 Pigeon River near Caseville	Apr. 19, 1988	58	762	8.3	6.0	740	2.1	14	410	150	255
	July 13, 1988	.03	757	8.6	20.0	741	1.1	--	350	160	193
	Oct. 18, 1988	26	937	8.2	10.5	740	2.5	7.7	470	200	274
	Apr. 12, 1989	137	950	8.2	4.5	750	6.0	12	470	210	254
04159012 Pinnebog River near Elkton	Apr. 21, 1988	35	854	8.4	5.0	739	--	13	--	--	295
	Oct. 20, 1988	42	897	8.2	7.0	747	--	10	--	--	268
	Apr. 14, 1989	65	901	8.2	4.5	744	--	13	--	--	264
04159037 Bad Axe Creek near Elkton	Apr. 21, 1988	13	786	8.0	3.5	740	--	14	--	--	269
	Oct. 18, 1988	12	1,160	8.0	11.5	744	--	9.1	--	--	281
	Apr. 13, 1989	31	834	8.2	7.0	749	--	13	--	--	250
04159063 Taft Drain near Pinnebog	Apr. 19, 1988	11	671	8.2	5.0	740	1.4	15	360	110	250
	July 14, 1988	.43	525	8.2	31.5	746	1.4	8.6	270	12	258
	Oct. 18, 1988	16	765	8.2	11.5	744	6.0	10	390	170	217
04159069 New River near Huron City	Apr. 20, 1988	5.3	706	8.2	5.5	735	--	13	--	--	245
	Oct. 19, 1988	5.3	802	8.1	10.0	745	--	8.8	--	--	230
	Apr. 13, 1989	19	752	8.2	4.0	748	--	13	--	--	238
04159075 East Branch Willow Creek near Redman	Apr. 20, 1988	9.2	842	8.3	6.0	732	--	13	--	--	264
	Oct. 20, 1988	8.5	927	8.2	7.0	747	--	--	--	--	247
	Apr. 13, 1989	38	831	7.9	2.5	751	--	14	--	--	239
04159077 Willow Creek near Redman	Apr. 20, 1988	26	593	8.1	6.0	732	--	12	--	--	259
	Oct. 19, 1988	16	853	8.1	10.0	745	--	8.2	--	--	211
	Apr. 13, 1989	86	777	8.0	3.5	751	--	14	--	--	228
04159078 Willow Creek near Huron City	Apr. 20, 1988	29	654	8.2	6.5	735	2.7	13	350	100	250
	July 14, 1988	.01	623	8.5	24.0	739	1.3	6.0	280	74	208
	Oct. 19, 1988	14	913	8.4	10.5	745	2.8	12	440	220	223
04159096 Rock Falls Creek near Harbor Beach	Apr. 20, 1988	10	774	8.4	6.0	735	--	13	--	--	274
	July 14, 1988	.26	608	8.2	25.5	744	--	10	--	--	209
	Oct. 19, 1988	2.8	796	8.1	9.0	745	--	9.9	--	--	233
	Apr. 12, 1989	36	825	8.3	4.0	748	--	15	--	--	258
04159104 Elm Creek near White Rock	Apr. 20, 1988	6.4	872	7.9	5.5	735	2.9	13	410	140	274
	July 14, 1988	.44	570	7.9	22.5	742	.5	7.4	300	110	190
	Oct. 19, 1988	2.20	982	8.3	9.0	750	1.6	9.3	460	170	286

Table 5.--Chemical and physical characteristics of selected streams in Huron County, Michigan, 1988-89--Continued

Gaging station number and name	Alkalinity, total, field (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 °C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, dissolved, field (mg/L as HCO_3)	Carbonate, dissolved, field (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
04158000 Columbia Drain	--	482	481	110	32	12	2.3	--	--	110	47
near Sebewaing	--	492	--	110	33	17	3.7	--	--	130	52
04159010 Pigeon River	260	454	498	110	32	13	3.2	317	0	100	41
near Caseville	189	480	496	82	36	27	3.5	228	1	150	53
	271	577	611	130	36	19	5.5	331	0	120	57
	248	566	581	130	34	24	3.6	302	0	95	60
04159012 Pinnebog River	--	--	--	--	--	--	--	--	--	--	--
near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159037 Bad Axe Creek	--	--	--	--	--	--	--	--	--	--	--
near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159063 Taft Drain	--	402	417	99	27	9.1	2.7	--	--	60	30
near Pinnebog	--	341	330	60	29	18	5.1	--	--	32	32
	--	458	405	110	27	11	5.5	--	--	71	48
04159069 New River	--	--	--	--	--	--	--	--	--	--	--
near Huron City	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159075 East Branch	--	--	--	--	--	--	--	--	--	--	--
Willow Creek near	--	--	--	--	--	--	--	--	--	--	--
Redman	--	--	--	--	--	--	--	--	--	--	--
04159077 Willow Creek	--	--	--	--	--	--	--	--	--	--	--
near Redman	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159078 Willow Creek	--	412	425	100	25	11	3.0	--	--	77	32
near Huron City	--	357	406	55	35	26	3.0	--	--	54	51
	--	577	568	120	35	27	10	--	--	140	74
04159096 Rock Falls	--	--	--	--	--	--	--	--	--	--	--
Creek near Harbor	--	--	--	--	--	--	--	--	--	--	--
Beach	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159104 Elm Creek	--	484	496	110	33	18	3.4	--	--	90	44
near White Rock	--	353	385	78	26	25	2.5	--	--	61	37
	--	587	606	120	38	28	11	--	--	130	68

Table 5.--Chemical and physical characteristics of selected streams in Huron County, Michigan, 1988-89--Continued

Gaging station number and name	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Aluminum, dissolved (µg/L as Al)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
04158000 Columbia Drain near Sebewaing	0.2	0.8	<10	<1	34	<0.5	<1	<1	<3	1	9
	.2	2.2	20	1	27	.9	1	<1	<3	3	31
04159010 Pigeon River near Caseville	.2	.9	<10	1	41	<.5	<1	<1	<3	1	15
	.2	10	<10	8	17	<.5	<1	<1	<3	<1	13
	.2	5.6	10	1	56	<.5	5	<1	<3	7	31
	.2	4.4	<10	<1	47	<.5	<1	<1	<3	<1	9
04159012 Pinnebog River near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159037 Bad Axe Creek near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159063 Taft Drain near Pinnebog	.2	.8	<10	1	31	<.5	<1	<1	<3	1	15
	.4	9.1	<10	7	41	<.5	<1	<1	<3	<1	19
	.2	6.1	<10	1	37	<.5	4	<1	<3	3	31
04159069 New River near Huron City	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159075 East Branch Willow Creek near Redman	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159077 Willow Creek near Redman	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159078 Willow Creek near Huron City	.2	.6	<10	1	47	<.5	<1	2	<3	1	18
	.3	7.3	<10	10	62	<.5	<1	<1	<3	1	51
	.2	.6	10	1	48	<.5	4	<1	<3	3	58
04159096 Rock Falls Creek near Harbor Beach	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159104 Elm Creek near White Rock	.2	1.7	<10	2	48	<.5	<1	<1	<3	1	24
	.3	8.7	<10	4	110	<.5	<1	<1	<3	1	8
	.3	2.6	<10	2	78	<.5	4	1	<3	3	76

Table 5.--Chemical and physical characteristics of selected streams in Huron County, Michigan, 1988-89--Continued

Gaging station number and name	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Molyb-denum, dis-solved (µg/L as Mo)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Stron-tium, dis-solved (µg/L as Sr)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)
04158000 Columbia Drain	<5	9	7	<0.1	<10	1	2	<1.0	270	<6	8
near Sebewaing	<5	12	4	.2	<10	2	2	<1.0	300	<6	18
04159010 Pigeon River	<5	6	22	<.1	<10	2	1	<1.0	270	<6	3
near Caseville	<5	16	440	.9	<10	<1	<1	<1.0	490	<6	9
	<5	12	10	<.1	<10	2	<1	<1.0	320	<6	14
	<5	10	19	<.1	<10	<1	2	<1.0	300	<6	12
04159012 Pinnebog River	--	--	--	--	--	--	--	--	--	--	--
near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159037 Bad Axe Creek	--	--	--	--	--	--	--	--	--	--	--
near Elkton	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159063 Taft Drain	<5	6	29	.2	<10	2	<1	<1.0	190	<6	<3
near Pinnebog	<5	14	150	<.1	<10	<1	<1	<1.0	410	<6	<3
	<5	8	4	.2	<10	<1	1	<1.0	180	<6	20
04159069 New River	--	--	--	--	--	--	--	--	--	--	--
near Huron City	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159075 East Branch	--	--	--	--	--	--	--	--	--	--	--
Willow Creek near	--	--	--	--	--	--	--	--	--	--	--
Redman	--	--	--	--	--	--	--	--	--	--	--
04159077 Willow Creek	--	--	--	--	--	--	--	--	--	--	--
near Redman	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159078 Willow Creek	<5	7	24	<.1	<10	1	<1	<1.0	220	<6	<3
near Huron City	<5	8	24	.1	<10	<1	<1	<1.0	280	<6	6
	<5	13	6	.1	<10	<1	<1	<1.0	360	<6	13
04159096 Rock Falls	--	--	--	--	--	--	--	--	--	--	--
Creek near Harbor	--	--	--	--	--	--	--	--	--	--	--
Beach	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
04159104 Elm Creek	<5	11	44	<.1	<10	3	<1	<1.0	320	<6	8
near White Rock	<5	15	49	<.1	<10	<1	<1	<1.0	290	<6	6
	<5	17	16	<.1	<10	1	<1	<1.0	430	<6	12

Table 11.--Elevation of water in wells installed in Huron County, Michigan, by the U.S. Geological Survey, 1988-90

The well-location system for Michigan indicates the location of wells within a rectangular subdivision of land with reference to the Michigan meridian and base line. The first two segments of the well-location designation indicate township and range, either north (N), south (S), east (E), or west (W). The number in the third segment designates the section, and the letters A through D designate successively smaller subdivisions of the section. Thus, a well designated as 15N 9E 30ABAD 01 is one of many wells at a site located to the nearest 2.5 acres and is within section 30.

Well number	Location	Date	Elevation of water table (feet)
H1A	15N 9E 30ABAD 01	May 24, 1988	482
		June 27, 1988	502
		July 13, 1988	510
		July 15, 1988	483
		July 18, 1988	486
		Aug. 4, 1988	496
		Sept. 28, 1988	522
		Oct. 18, 1988	529
		Nov. 9, 1988	535
H1B	15N 9E 30ABAD 02	May 24, 1988	573
		June 27, 1988	570
		July 13, 1988	569
		Aug. 4, 1988	580
		Sept. 28, 1988	571
		Oct. 14, 1988	572
		Nov. 9, 1988	572
H2	15N 11E 32BBCB	June 2, 1988	710
		June 29, 1988	712
		July 13, 1988	712
		Aug. 4, 1988	711
		Sept. 28, 1988	712
		Oct. 20, 1988	712
		Dec. 7, 1988	714
		Mar. 16, 1989	713
		May 23, 1989	714
		June 28, 1989	714
		Sept. 13, 1989	712
		Mar. 29, 1990	714
H3	15N 11E 22CCBB	May 23, 1988	702
		June 28, 1988	700
		July 13, 1988	699
		Aug. 4, 1988	699
		Sept. 28, 1988	700
		Oct. 20, 1988	701
		Dec. 7, 1988	702
		Mar. 16, 1989	702
H4	15N 12E 18AAAA	May 28, 1988	737
		June 28, 1988	737
		July 13, 1988	736
		Aug. 4, 1988	737
		Sept. 28, 1988	737
		Oct. 20, 1988	738
		Dec. 8, 1988	739
		Mar. 16, 1989	738
		May 23, 1989	738
		June 28, 1989	739
		Oct. 24, 1989	737
		Mar. 29, 1990	739
H5	15N 13E 22BBBC	May 28, 1988	782
		June 28, 1988	779
		July 15, 1988	779
		Aug. 3, 1988	781
		Sept. 28, 1988	780
		Oct. 20, 1988	781
		Dec. 8, 1988	782
		Mar. 16, 1989	781
		June 28, 1989	781
		Sept. 14, 1989	780
H6	15N 14E 5DDDA	June 3, 1988	765
		June 28, 1988	766
		July 15, 1988	766
		Aug. 3, 1988	765
		Sept. 28, 1988	765
		Oct. 20, 1988	764
		Dec. 8, 1988	767
		Mar. 16, 1989	767
		June 28, 1989	768
		Sept. 14, 1989	765
		Mar. 29, 1990	769
H7	15N 15E 34ABAB	May 18, 1988	589
		June 28, 1988	709
		July 19, 1988	709
		Aug. 3, 1988	708
		Sept. 28, 1988	709
		Dec. 8, 1988	708
		Mar. 16, 1989	709
		June 28, 1989	709
		Oct. 25, 1989	709
H8	15N 16E 6AAAC	June 10, 1988	590
		June 28, 1988	590
		July 19, 1988	590
		July 19, 1988	587
		Aug. 3, 1988	589
		Sept. 29, 1988	589
		Dec. 6, 1988	592
		Mar. 16, 1989	592
		June 28, 1989	592
		Oct. 25, 1989	590
H9	16N 9E 2CDCA	June 2, 1988	570
		June 27, 1988	570
		July 13, 1988	571
		Aug. 4, 1988	570
		Sept. 29, 1988	570
		Oct. 18, 1988	570
		Dec. 9, 1988	572
		Mar. 16, 1989	573
		May 24, 1989	573
		June 29, 1989	573
		Sept. 14, 1989	573

Table 11.--Elevation of water in wells installed in Huron County, Michigan, by the U.S. Geological Survey, 1988-90--Continued

Well number	Location	Date	Elevation of water table (feet)
H10	16N 10E 9BBBB	May 25, 1988	591
		June 27, 1988	592
		July 13, 1988	591
		Aug. 4, 1988	591
		Sept. 29, 1988	591
		Oct. 18, 1988	591
		Dec. 9, 1988	591
		Mar. 16, 1989	592
		June 29, 1989	592
		Oct. 25, 1989	591
		Jan. 25, 1990	593
H11	16N 10E 33AAAD	July 14, 1987	595
		Aug. 14, 1987	585
		Sept. 1, 1987	581
		June 28, 1988	588
		July 14, 1988	583
		Aug. 4, 1988	583
		Sept. 29, 1988	596
		Oct. 19, 1988	598
		Dec. 9, 1988	600
		Mar. 16, 1989	602
		May 24, 1989	603
		June 29, 1989	602
H12	16N 10E 27CDCC	July 14, 1987	602
		Aug. 14, 1987	576
		June 28, 1988	552
		Aug. 4, 1988	554
		July 14, 1988	546
		Sept. 29, 1988	591
		Oct. 19, 1988	595
		Dec. 9, 1988	595
		Mar. 16, 1989	597
		June 29, 1989	596
H13	16N 11E 18AAAA	June 8, 1988	606
		June 27, 1988	607
		July 14, 1988	604
		Aug. 4, 1988	603
		Sept. 28, 1988	606
		Oct. 19, 1988	606
		Dec. 9, 1988	609
		Mar. 16, 1989	610
		Oct. 26, 1989	607
H14	16N 11E 13AADD	June 8, 1988	664
		June 27, 1988	674
		July 14, 1988	673
		Aug. 4, 1988	673
		Sept. 27, 1988	674
		Oct. 19, 1988	675
		Dec. 8, 1988	677
		Mar. 16, 1989	676
		June 29, 1989	676
		Sept. 13, 1989	675
		Jan. 25, 1990	678
H15B	16N 12E 23BCDB	May 17, 1988	735
		June 28, 1988	729
		July 14, 1989	727
		Aug. 3, 1989	729
		Sept. 28, 1989	731
		Oct. 20, 1989	732
		Dec. 8, 1989	735
		Jan. 10, 1989	735
		Feb. 23, 1989	734
		Mar. 16, 1989	733
		Apr. 12, 1989	733
		May 24, 1989	734
		June 28, 1989	734
		Oct 25, 1989	733
H16	16N 13E 16DBCA	May 17, 1988	745
		June 28, 1988	742
		July 13, 1988	741
		Aug. 3, 1988	740
		Sept. 28, 1988	741
		Oct. 20, 1988	742
		Dec. 8, 1988	744
		Mar. 16, 1989	744
		May 24, 1989	743
		June 28, 1989	744
H17	16N 14E 21AADC	May 23, 1988	740
		June 28, 1988	743
		July 18, 1988	742
		Aug. 3, 1988	736
		Sept. 28, 1988	737
		Oct. 20, 1988	741
		Dec. 8, 1988	744
		Mar. 16, 1989	744
		June 28, 1989	744
		Oct. 24, 1989	743
H18	16N 15E 27BDCC	May 26, 1988	563
		June 28, 1988	675
		July 18, 1988	676
		Aug. 3, 1988	675
		Sept. 28, 1988	675
		Dec. 8, 1988	675
		Mar. 16, 1989	676
		June 28, 1989	676
		Oct. 25, 1989	675
H19	17N 10E 24CCBB	June 27, 1988	606
		July 18, 1988	606
		Aug. 4, 1988	607
		Sept. 26, 1988	607
		Oct. 18, 1988	608
		Dec. 9, 1988	608
		Mar. 16, 1989	608
		June 29, 1989	606
H20	17N 11E 16DDDD	May 25, 1988	617
		June 27, 1988	616
		July 13, 1988	616
		Aug. 4, 1988	615
		Sept. 28, 1988	615
		Oct. 18, 1988	614
		Dec. 7, 1988	616
		Mar. 16, 1989	615
		June 20, 1989	616
		Oct. 26, 1989	615

Table 11.--Elevation of water in wells installed in Huron County, Michigan, by the U.S. Geological Survey, 1988-90--Continued

Well number	Location	Date	Elevation of water table (feet)	Well number	Location	Date	Elevation of water table (feet)
H21	17N 12E 11DADD	May 31, 1988	690	H25C	18N 11E 27AADD 03	June 27, 1988	597
		June 27, 1988	691			July 15, 1988	596
		July 15, 1988	690			Aug. 4, 1988	595
		Aug. 3, 1988	689			Sept. 27, 1988	596
		Sept. 28, 1988	689			Oct. 18, 1988	597
		Oct. 20, 1988	691			Dec. 7, 1988	598
		Dec. 8, 1988	693			Mar. 16, 1989	598
		Mar. 16, 1989	691			May 25, 1989	599
		May 25, 1989	692			June 29, 1989	598
		June 28, 1989	693			Aug. 15, 1989	596
		Oct. 24, 1989	689				
				H26	18N 12E 34ACDC	June 1, 1988	644
H22	17N 13E 28CBCC	May 17, 1988	683			June 27, 1988	659
		June 28, 1988	680			July 17, 1988	656
		July 14, 1988	680			Sept. 28, 1988	655
		Aug. 3, 1988	678			Oct. 20, 1988	655
		Sept. 28, 1988	678			Dec. 8, 1988	659
		Oct. 20, 1988	679			Mar. 16, 1989	657
		Dec. 6, 1988	682			June 28, 1989	658
		Mar. 16, 1989	681			Oct. 25, 1989	654
		May 25, 1989	682				
		Oct. 28, 1989	682				
				H27	18N 13E 26CAAD	May 19, 1988	680
						May 19, 1988	684
H23	17N 14E 15BAAA	May 19, 1988	578			June 28, 1988	682
		June 28, 1988	711			July 14, 1988	682
		July 15, 1988	710			Aug. 3, 1988	681
		Aug. 3, 1988	710			Sept. 28, 1988	681
		Sept. 28, 1988	711			Oct. 20, 1988	681
		Oct. 20, 1988	710			Dec. 8, 1988	683
		Dec. 8, 1988	711			Mar. 16, 1989	683
		Mar. 16, 1989	711			June 28, 1989	683
		June 28, 1989	711			Oct. 25, 1989	680
H24	17N 15E 18DDDD	May 27, 1988	598	H28	18N 14E 29DCCC	June 28, 1988	671
		June 28, 1988	662			July 14, 1988	670
		July 19, 1988	664			Aug. 3, 1988	669
		Aug. 3, 1988	661			Sept. 28, 1988	669
		Sept. 28, 1988	663			Oct. 20, 1988	670
		Oct. 20, 1988	664			Dec. 8, 1988	673
		Dec. 8, 1988	665			Mar. 16, 1989	672
		Mar. 16, 1989	666			May 26, 1989	672
		June 28, 1989	666			June 28, 1989	672
H25A	18N 11E 17AADD 01	June 27, 1988	593	H29	18N 14E 12CBCB	May 27, 1988	663
		July 15, 1988	592			June 28, 1988	606
		Aug. 4, 1988	592			July 14, 1988	606
		Sept. 27, 1988	592			Aug. 3, 1988	606
		Oct. 18, 1988	592			Sept. 28, 1988	605
		Dec. 7, 1988	594			Oct. 20, 1988	606
		Mar. 16, 1989	593			Dec. 8, 1988	607
		May 25, 1989	594			Mar. 16, 1989	606
		June 29, 1989	593			June 28, 1989	606
		Aug. 15, 1989	593				
				H30	19N 13E 25DCDD	June 1, 1988	535
H25B	18N 11E 27AADD 02	June 27, 1988	598			June 28, 1988	602
		July 15, 1988	597			July 18, 1988	606
		Aug. 4, 1988	596			Aug. 3, 1988	604
		Sept. 27, 1988	596			Sept. 28, 1988	606
		Oct. 18, 1988	597			Oct. 20, 1988	606
		Dec. 7, 1988	598			Dec. 8, 1988	606
		Mar. 16, 1989	596			Mar. 16, 1989	606
		May 25, 1989	598			June 28, 1989	607
		June 29, 1989	598				
		Aug. 15, 1989	596				

Table 12.--Chemical and physical characteristics of ground water in Huron County, Michigan, 1988-89

[Analyses by U.S. Geological Survey. Well locations shown on plate 1. µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, no analysis done; NTU, nephelometric turbidity units; 112GRVL, gravel; 112SAND, sand; 324SGMG, Saginaw-Michigan Formations; 324SGNW, Saginaw Formation; 333BPMG, Bayport-Michigan Formations; 333BPRT, Bayport Limestone; 337CLDR, Coldwater Shale; 337NPLN, Napoleon Sandstone Member of Marshall Formation; 337MRSLL, Marshall Sandstone, Lower]

Well number	Date of sample	Aquifer	Depth of well, total (feet)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Color (platinum cobalt units)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)
H1B	July 13, 1988	112GRVL	76	1,830	7.4	11.0	<1	4.6	0.5	460
H1C	July 13, 1988	324SGMG	243	3,240	7.3	11.5	1	31	.1	890
H1D	July 13, 1988	112GRVL	70	1,430	7.9	12.0	2	8.2	.4	420
H2	July 13, 1988	112SAND	91	431	8.2	12.0	<1	32	6.3	180
H3	July 13, 1988	337NPLN	120	452	8.0	12.5	<1	3.2	4.4	210
H4	July 13, 1988	337NPLN	80	585	7.1	11.0	<1	64	.6	330
H4	May 23, 1989	337NPLN	80	572	7.2	10.5	--	--	.0	--
H5	July 19, 1988	337NPLN	172	513	7.2	12.0	1	23	.0	280
H6	July 15, 1988	337NPLN	90	453	7.6	11.0	1	2.2	.0	200
H7	July 19, 1988	337CLDR	140	34,100	6.9	11.0	1	400	.0	2,200
H8	July 19, 1988	337MRSLL	18	1,240	7.8	11.5	15	76,000	.4	150
H9	July 13, 1988	324SGMG	180	5,740	7.4	11.5	<1	13	.0	1,800
H9	May 24, 1989	324SGMG	180	5,770	7.5	11.0	--	--	.0	--
H10	July 13, 1988	333BPMG	150	4,610	7.6	11.0	1	110	.0	1,400
H11	July 14, 1988	337MRSLL	280	811	10.4	12.5	2	3.5	.0	1,100
H12	July 14, 1988	337MRSLL	280	1,310	7.5	11.0	1	3.9	.0	350
H13	July 14, 1988	333BPRT	120	608	7.8	12.0	1	7.7	.0	290
H14	July 14, 1988	337MRSLL	100	1,520	7.8	11.0	<1	13	.0	470
H15A	July 14, 1988	337NPLN	102	518	7.1	17.5	--	4.5	.4	270
H15A	May 24, 1989	337NPLN	102	516	7.5	12.5	--	--	.1	--
H15B	July 14, 1988	337NPLN	99	506	7.1	10.0	--	27	.0	260
H15B	May 24, 1989	337NPLN	99	516	7.2	10.0	--	--	.0	--
H16	July 14, 1988	337NPLN	160	465	8.1	11.5	--	.4	.0	310
H17	July 18, 1988	337MRSLL	80	1,340	8.4	11.0	1	1.1	.1	310
H18	July 18, 1988	337CLDR	160	31,700	8.7	11.5	<1	9.8	.0	4,200
H19	July 18, 1988	337MRSLL	100	1,050	8.3	11.5	1	2.4	.0	330
H20	July 18, 1988	324SGNW	60	2,940	6.7	10.5	2	2.7	.0	1,700
H21	July 15, 1988	337NPLN	80	486	8.7	10.5	1	3.4	.2	270
H22	July 14, 1988	337NPLN	150	308	8.5	14.0	--	5.3	6.0	150
H22	May 25, 1989	337NPLN	150	461	7.2	10.5	--	--	.0	--
H23	July 15, 1988	337CLDR	150	52,700	8.7	10.5	<1	4.1	.0	5,300
H24	July 19, 1988	337CLDR	100	24,000	7.2	11.5	2	5.2	.0	3,300
H25A	July 15, 1988	337MRSLL	200	2,640	7.4	10.0	<1	9.6	.0	1,300
H25A	May 25, 1989	337MRSLL	200	2,690	7.3	10.0	--	--	.0	--
H25B	July 15, 1988	337NPLN	160	506	8.2	10.0	<1	3.7	.2	310
H25B	May 25, 1989	337NPLN	160	598	7.4	10.0	--	--	.0	--
H25C	July 15, 1988	337NPLN	40	420	7.0	9.5	<1	4.8	.2	320
H26	July 15, 1988	337NPLN	60	451	7.7	11.0	1	2.9	.0	240
H27	July 14, 1988	337NPLN	80	438	7.8	11.5	<1	580	3.9	170
H28	July 14, 1988	337MRSLL	75	801	7.3	15.5	1	34	.1	420
H28	May 26, 1989	337MRSLL	75	315	9.1	8.5	--	--	.0	--
H29	July 14, 1988	337CLDR	80	31,000	7.8	14.5	1	4,200	9.0	3,100
H30	July 18, 1988	337CLDR	80	36,000	7.2	11.5	1	8.6	.2	3,300

Table 12.--Chemical and physical characteristics of ground water in Huron County, Michigan, 1988-89--Continued

Well number	Alka-linity, lab (mg/L as $CaCO_3$)	Solids, residue at 180 °C, dis-solved (mg/L)	Solids, sum of consti-tuents, dis-solved (mg/L)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)
H1B	111	1,210	1,180	130	32	210	3.5	550	170	0.8
H1C	54	2,360	2,160	260	57	400	5.7	820	570	.6
H1D	106	1,120	1,100	110	33	190	3.3	520	160	1.0
H2	217	278	273	40	18	38	2.2	26	4.6	1.1
H3	233	279	275	54	19	26	2.0	15	4.0	.7
H4	324	--	344	83	29	8.2	1.7	6.7	.7	.6
H4	--	--	--	--	--	--	--	--	--	--
H5	265	--	300	66	27	10	1.6	17	1.6	.9
H6	203	267	248	44	21	29	1.9	7.0	6.7	1.0
H7	167	23,000	22,500	480	240	7,900	35	760	13,000	.3
H8	232	721	691	38	14	200	4.6	70	210	.9
H9	91	5,090	4,900	490	130	880	10	2,800	520	.8
H9	--	--	--	--	--	--	--	--	--	--
H10	103	4,640	4,480	400	100	710	7.5	3,000	180	1.3
H11	22	2,040	1,330	280	85	150	6.4	1,200	52	.7
H12	179	810	748	98	25	150	3.0	150	200	.7
H13	316	377	357	78	22	29	2.4	18	5.2	.6
H14	211	--	1,270	130	34	210	4.8	730	21	1.1
H15A	268	316	306	67	24	14	1.9	17	3.8	.6
H15A	--	--	--	--	--	--	--	--	--	--
H15B	260	299	291	65	24	13	2.3	12	3.1	.6
H15B	--	--	--	--	--	--	--	--	--	--
H16	280	311	307	81	25	7.6	1.2	7.1	.8	.4
H17	219	779	739	84	24	160	2.3	59	270	.5
H18	25	--	22,300	1,000	400	6,900	20	1,900	12,000	.4
H19	224	--	703	90	26	110	3.5	180	150	.6
H20	228	2,470	2,450	590	46	110	2.8	1,400	140	.8
H21	277	--	305	64	26	14	1.8	14	3.5	.8
H22	165	181	180	35	16	15	1.7	5.5	1.6	.5
H22	--	--	--	--	--	--	--	--	--	--
H23	45	39,200	39,000	1,300	490	12,000	39	3,100	22,000	.2
H24	127	18,000	17,700	430	540	5,100	22	1,800	9,300	.4
H25A	146	2,440	2,320	480	18	150	4.1	1,400	160	.5
H25A	--	--	--	--	--	--	--	--	--	--
H25B	225	358	305	96	17	18	1.4	19	3.3	.4
H25B	--	--	--	--	--	--	--	--	--	--
H25C	154	292	276	80	29	2.4	.8	54	5.5	.2
H26	205	289	248	62	21	13	1.9	7.6	1.7	.8
H27	188	--	279	53	8.1	35	2.2	51	1.9	.8
H28	182	607	561	130	21	37	2.3	220	21	.9
H28	--	--	--	--	--	--	--	--	--	--
H29	141	23,000	22,800	910	200	6,800	24	3,800	11,000	.5
H30	82	27,100	26,400	920	230	8,200	30	3,900	13,000	.3

Table 12.--Chemical and physical characteristics of ground water in Huron County, Michigan, 1988-89--Continued

Well number	Silica, dis- solved (mg/L as SiO_2)	Nitro- gen, nitrite, total (mg/L as N)	Nitro- gen, nitrate, total (mg/L as N)	Nitro- gen, ammonia, total (mg/L as N)	Nitro- gen, organic, total (mg/L as N)	Phos- phorus, total (mg/L as P)	Phos- phorus, ortho, total (mg/L as P)	Alu- minum, dis- solved (µg/L as Al)	Arsenic, dis- solved (µg/L as As)	Barium, dis- solved (µg/L as Ba)
H1B	12	<0.01	<0.10	0.66	0.34	0.02	<0.01	<10	13	8
H1C	9.3	<.01	<.10	.87	.23	<.01	<.01	<10	<1	12
H1D	12	<.01	<.10	.62	.4	<.01	<.01	<10	10	14
H2	10	<.01	<.10	.10	.1	.07	<.01	<10	14	220
H3	12	<.01	<.10	.03	.37	.01	<.01	<10	<1	190
H4	18	<.01	<.10	.16	.04	.02	<.01	<10	63	280
H4	--	--	--	--	--	--	--	--	48	--
H5	16	<.01	<.10	.14	.26	.05	<.01	20	31	140
H6	14	<.01	<.10	.25	.25	.01	<.01	<10	23	270
H7	8.2	<.01	<.10	8.40	5.3	.04	.01	<10	3	210
H8	13	--	--	--	17	.03	--	220	15	120
H9	5.9	<.01	<.10	1.40	1.1	<.01	<.01	10	51	9
H9	--	--	--	--	--	--	--	--	15	--
H10	7.4	<.01	<.10	.75	.05	.01	<.01	10	1	8
H11	6.4	<.01	<.10	.25	.65	.06	<.01	10	1	6
H12	11	<.01	<.10	.30	.5	.02	<.01	<10	5	22
H13	11	<.01	<.10	.16	.24	.42	<.01	<10	<1	97
H14	8.7	<.01	<.10	.40	<.2	<.01	<.01	<10	20	4
H15A	15	<.01	<.10	.60	.3	.03	.02	<10	360	210
H15A	--	--	--	--	--	--	--	--	91	--
H15B	13	<.01	<.10	.72	.18	.04	<.01	<10	190	240
H15B	--	--	--	--	--	--	--	--	97	--
H16	14	<.01	<.10	.02	.18	<.01	<.01	<10	1	80
H17	5.8	<.01	<.10	.05	<.2	.02	<.01	<10	<1	34
H18	5.0	<.01	<.10	5.30	.20	<.01	<.01	20	<1	200
H19	5.5	<.01	<.10	<.01	.7	.01	<.01	<10	2	110
H20	18	<.01	<.10	.38	.52	<.01	<.01	<10	19	8
H21	14	<.01	<.10	.21	.09	.01	<.01	<10	9	60
H22	4.1	<.01	<.10	<.01	<.2	.01	<.01	<10	<1	26
H22	--	--	--	--	--	--	--	--	--	--
H23	.98	<.01	<.10	7.50	6.3	<.01	<.01	30	<1	50
H24	400	<.01	<.10	5.20	4.5	.01	<.01	<10	2	74
H25A	11	<.01	<.10	.58	.22	<.01	<.01	<10	2	6
H25A	--	--	--	--	--	--	--	--	--	--
H25B	13	<.01	<.10	.06	.14	.04	.02	<10	3	26
H25B	--	--	--	--	--	--	--	--	--	--
H25C	11	<.01	<.10	.04	.26	<.01	.01	<10	4	32
H26	16	<.01	<.10	.30	.5	.03	<.01	40	15	49
H27	12	<.01	<.10	.06	1.84	.11	<.01	<10	1	16
H28	13	<.02	<.10	.31	.3	<.01	<.01	<10	14	30
H28	--	--	--	--	--	--	--	--	--	--
H29	5.2	<.01	<.10	1.10	4.5	.02	<.01	60	1	30
H30	3.9	<.01	<.10	6.50	3.1	.58	<.01	50	1	48

Table 12.--Chemical and physical characteristics of ground water in Huron County, Michigan, 1988-89--Continued

Well number	Beryllium, dissolved (μg/L as Be)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Cobalt, dissolved (μg/L as Co)	Copper, dissolved (μg/L as Cu)	Cyanide, dissolved (mg/L as Cn)	Iron, dissolved (μg/L as Fe)	Lead, dissolved (μg/L as Pb)	Lithium, dissolved (μg/L as Li)	Manganese, dissolved (μg/L as Mn)
H1B	<0.5	<1	1	<3	3	<0.01	510	<5	35	72
H1C	<.5	<1	2	<3	2	<.01	1,300	<5	54	36
H1D	<.5	<1	<1	<3	<1	<.01	1,100	<5	32	41
H2	<.5	<1	1	<3	9	<.01	12	<5	16	41
H3	<.5	<1	<1	<3	2	<.01	6	<5	16	21
H4	<.5	<1	1	<3	1	<.01	840	<5	17	33
H4	--	--	--	--	--	--	--	--	--	--
H5	<.5	<1	10	<3	6	<.01	320	<5	20	22
H6	<.5	<1	1	<3	1	<.01	210	<5	15	28
H7	<50	100	2	<300	1	<.01	<300	<5	420	<100
H8	<.5	<1	<1	<3	9	<.01	340	<5	32	130
H9	<.5	<1	4	<3	1	<.01	750	<5	140	97
H9	--	--	--	--	--	--	--	--	--	--
H10	<30	9	3	<9	<1	<.01	620	<5	140	51
H11	<.5	<1	2	<3	1	<.01	770	<5	83	49
H12	<.5	<1	1	<3	<1	<.01	510	<5	25	17
H13	<.5	<1	1	<3	<1	<.01	48	<5	17	25
H14	<.5	<1	1	<3	<1	<.01	400	<5	43	18
H15A	<.5	<1	3	<3	<1	<.01	120	<5	14	77
H15A	--	--	--	--	--	--	--	--	--	--
H15B	<.5	<1	2	<3	1	<.01	460	<5	15	84
H15B	--	--	--	--	--	--	--	--	--	--
H16	<.5	<1	1	<3	1	<.01	520	<5	20	22
H17	<.5	<1	<1	<3	<1	<.01	4	<5	32	21
H18	<50	150	2	<300	7	<.01	<300	<5	770	<100
H19	<.5	<1	1	<3	2	<.01	330	<5	24	17
H20	<.5	2	4	4	2	<.01	1,500	<5	70	36
H21	<.5	<1	<1	<3	1	<.01	150	<5	21	31
H22	<.5	<1	<1	<3	3	<.01	8	<5	19	3
H22	--	--	--	--	--	--	--	--	--	--
H23	<.5	<1	10	<3	1	<.01	94	<5	800	190
H24	<.5	1,600	1	20	<1	<.01	26	<5	210	170
H25	<.5	<1	3	<3	1	<.01	1,300	<5	72	72
H25A	--	--	--	--	--	--	--	--	--	--
H25B	.6	<1	<1	<3	1	<.01	86	<5	20	17
H25B	--	--	--	--	--	--	--	--	--	--
H25C	.5	<1	<1	<3	1	<.01	570	<5	11	29
H26	<.5	<1	<1	<3	2	<.01	150	<5	17	30
H27	<.5	<1	<1	<3	1	<.01	7	<5	28	10
H28	<.5	<1	<1	<3	2	<.01	420	<5	43	20
H28	--	--	--	--	--	--	--	--	--	--
H29	<.5	<1	2	10	3	<.01	79	<5	440	190
H30	<5	<10	6	<30	<1	<.01	150	<5	570	170

Table 12.--Chemical and physical characteristics of ground water in Huron County, Michigan, 1988-89--Continued

Well number	Mercury, dis- solved (µg/L as Hg)	Molyb denum, dis- solved (µg/L as Mo)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, dis- solved (µg/L as Se)	Silver, dis- solved (µg/L as Ag)	Stron- tium, dis- solved (µg/L as Sr)	Vana- dium, dis- solved (µg/L as V)	Zinc, dis- solved (µg/L as Zn)	Carbon, organic, total (mg/L as C)	Phenols, total, (µg/L)
H1B	<0.10	10	<1	<1	<1.0	5,100	<6	84	0.6	4
H1C	<.10	<10	3	<1	1.0	1,000	<6	33	3.6	110
H1D	<.10	20	2	<1	1.0	4,400	<6	13	.6	1
H2	<.10	10	3	<1	1.0	1,400	<6	890	11	22
H3	<.10	<10	4	<1	1.0	900	<6	1,600	1.5	--
H4	<.10	<10	3	<1	1.0	480	<6	90	1.5	--
H4	--	--	--	--	--	--	--	--	--	--
H5	<.10	<10	1	<1	<1.0	550	<6	69	1.4	4
H6	<.10	20	<1	--	<1.0	980	<6	62	--	--
H7	<.10	<1,000	7	<1	<1.0	18,000	<600	110	3.9	--
H8	<.10	30	3	<1	<1.0	800	<6	110	80	--
H9	.5	<10	4	<1	<1.0	7,800	<6	140	.4	--
H9	--	--	--	--	--	--	--	--	--	--
H10	<.10	<30	1	<1	<1.0	6,100	<6	430	1.6	--
H11	<.10	<10	4	<1	<1.0	6,400	<6	11	2.7	--
H12	<.10	<10	<1	<1	<1.0	2,400	<6	23	.6	--
H13	<.10	<10	1	<1	1.0	1,200	<6	<3	3.7	--
H14	.2	<10	<1	<1	<1.0	2,000	<6	120	1.3	--
H15A	4.8	<10	2	<1	<1.0	1,200	<6	89	11	--
H15A	<.1	--	--	--	--	--	--	--	--	--
H15B	<.10	10	1	<1	<1.0	1,200	<6	230	9.1	--
H15B	--	--	--	--	--	--	--	--	--	--
H16	<.10	<10	2	<1	<1.0	510	<6	450	1.0	4
H17	<.10	<10	<1	<1	<1.0	970	<6	130	.8	3
H18	.4	<1,000	<1	<1	<1.0	22,000	<600	1,100	1.1	2
H19	<.10	<10	1	<1	<1.0	960	<6	1,500	3.0	--
H20	<.10	<10	<1	<1	<1.0	5,100	<6	960	.9	--
H21	<.10	<10	<1	<1	<1.0	720	<6	290	2.4	--
H22	<.10	<10	2	<1	1.0	1,200	<6	140	1.8	28
H22	--	--	--	--	--	--	--	--	--	12
H23	1.5	10	<1	<1	1.0	31,000	<6	2,200	9.1	--
H24	<.10	20	16	<1	1.0	12,000	<6	5	1.2	2
H25A	.4	<10	<1	<1	<1.0	6,300	<6	350	.1	5
H25A	--	--	--	--	--	--	--	--	--	6
H25B	<.10	<10	1	<1	<1.0	1,600	<6	710	.9	5
H25B	--	--	--	--	--	--	--	--	--	3
H25C	<.10	<10	1	<1	<1.0	180	<6	95	1.4	2
H26	<.10	20	<1	<1	<1.0	810	<6	110	4.4	--
H27	<.10	<10	<1	<1	<1.0	730	<6	1,400	12	--
H28	6.2	<10	2	<1	<1.0	5,500	<6	320	1.6	--
H28	<.1	--	--	--	--	--	--	--	--	--
H29	.8	<10	7	<1	1.0	17,000	<6	800	1.0	--
H30	1.7	<100	<1	13	<1.0	18,000	<60	14,000	1.5	--

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