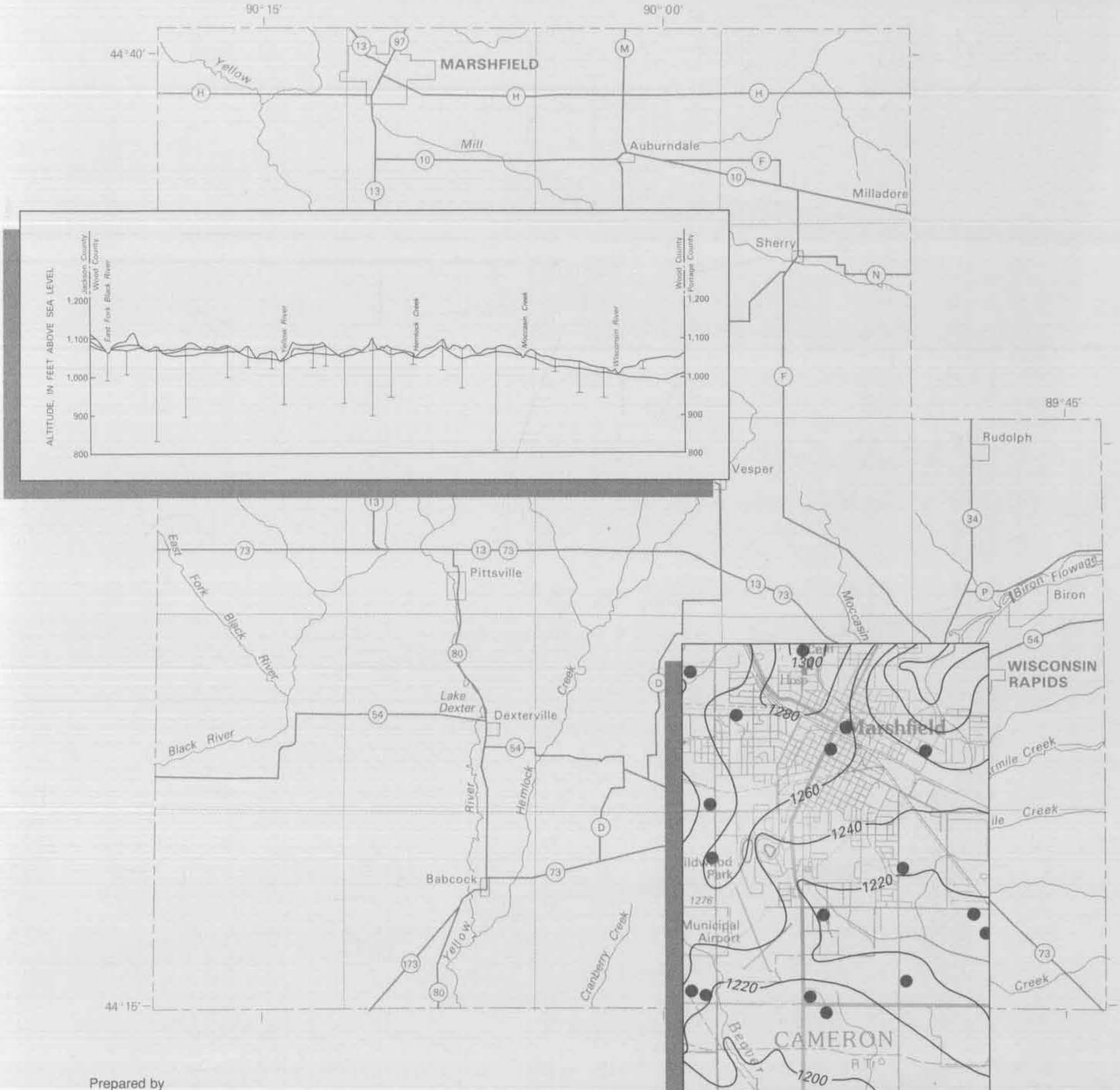
University of Wisconsin—Extension
WISCONSIN GEOLOGICAL and NATURAL HISTORY SURVEY

Information Circular 60
1989

# Hydrogeology of Wood County, Wisconsin

By
W. G. Batten
U.S. Geological Survey




Prepared by
Department of the Interior
United States Geological Survey
In cooperation with the
University of Wisconsin–Extension,
Geological and Natural History Survey,
and
Wood County

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University of Wisconsin–Extension, Geological and Natural History Survey,
M. E. Ostrom, Director and State Geologist,
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Wood County

This report is a product of the U.S. Geological Survey Water-Resources Division and the University of Wisconsin–Extension Geological and Natural History Survey.

The Wisconsin Geological and Natural History Survey Water Resources Program includes: systematic collection, analysis, and cataloging of basic water data; impartial research and investigation of Wisconsin's water resources and problems; publication of technical and popular reports and maps; and public service and information. This report for the Survey's Water Resources Program is accomplished throught state-federal cooperative cost sharing with the U.S. Geological Survey Water Resources Division.

This report is available at: Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin, 53705.

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## CONVERSION FACTORS AND ABBREVIATIONS

For the use of readers who prefer metric (International System) units, rather than the inch-pound terms used in this report, the following conversion factors may be used:

| Multiply inch-pound unit | By | To obtain metric unit |
|---|---|---|
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| acre | 4,047 | square meter ($m^2$) |
| gallon (gal) | 3.785 | liter (L) |
| gallon per day (gal/d) | 0.003785 | cubic meter per day ($m^3/d$) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second ($m^3/s$) |
| gallon per minute (gal/min) | 0.06308 | liter per second (L/s) |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| gallon per minute per foot [(gal/min)/ft] | 0.2070 | liter per second per meter [(L/s)/m] |

The stratigraphic nomenclature used in this report is that of the Wisconsin Geological and Natural History Survey and does not necessarily follow usage of the U.S. Geological Survey.

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

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## ABSTRACT

The presence of low-permeability Precambrian rocks near land surface limits ground-water availability in the northern two-thirds of Wood County. Sand and gravel deposits provide large amounts of water (more than 500 gallons per minute) to some wells in the southeastern part of the county. Fine-grained unconsolidated deposits generally are less than 20 feet thick in the northern two-thirds of the county, but sand and gravel deposits 40- to 100-feet thick underlie the extreme southeastern part of the county. Horizontal hydraulic conductivity of the sand and gravel deposits ranges from about 155 to about 280 feet per day. The horizontal hydraulic conductivity of fine-grained unconsolidated deposits in the northern part of the county ranges from about 0.02 to 2 feet per day. Where unconsolidated deposits do not yield dependable water supplies, wells are finished in Precambrian rocks. Fractures occurring at shallow depths are the primary source of water for wells finished in Precambrian rocks. Because the number of fractures tends to decrease with depth, the horizontal hydraulic conductivity of these rocks generally decreases from about 11 feet per day in wells less than 50-feet deep to about 0.02 foot per day in wells greater than 160 feet deep.

Estimates of ground-water recharge to sand and gravel deposits in the southeastern part of the county range from about 7 to 12 inches per year. Recharge estimates for the central and northern parts of the county range from about 1 to 4 inches per year.

The total dissolved-solids concentration in ground water in Wood County is relatively low. Concentrations in water samples from 124 wells ranged from 21 to 578 milligrams per liter, with a median concentration of about 190 milligrams per liter. Major dissolved constituents are calcium, magnesium, and bicarbonate; sodium, potassium, chloride, and sulfate are present in low concentrations. The most common water-quality problem in Wood County is elevated iron concentrations. Iron concentrations greater than 300 micrograms per liter were found in 54 of 124 samples, and 15 samples contained iron concentrations greater than 5,000 micrograms per liter.

Nitrate as nitrogen concentrations exceeded Wisconsin's drinking-water standard (10 milligrams per liter) in water from just 4 of 124 wells. The pesticide aldicarb was detected in 7 of 36 samples, and various volatile organic compounds were detected in 24 of 102 ground-water samples collected by the Wisconsin Department of Natural Resources since 1980. Wells in which these chemicals were detected are near irrigated agricultural fields and in commercially developed areas where buried gasoline-storage tanks and chemical spills are more likely to occur.

A reconnaissance approach combining electromagnetic surveys and sampling for water-quality indicators was used to assess effects of leachate on ground water near seven landfills. Results of the electromagnetic surveys were used to site water-quality observation wells. Total dissolved-solids concentrations and concentrations of volatile organic compounds, chloride, sulfate, iron, chemical oxygen demand, and organic carbon are some of the chemical constituents analyzed in samples collected from these wells.

The average rate of ground-water pumpage in Wood County in 1985 was 9.7 million gallons per day. Of this rate, about 6 million gallons per day is pumped from municipal-supply wells in seven communities.

An additional 1.08 million gallons per day is pumped for agricultural irrigation.

# INTRODUCTION

## BACKGROUND

Ground water supplies virtually all municipal, residential, and irrigation water needs in Wood County. However, ground-water availability is limited in large areas of the northern two-thirds of Wood County where the only source of ground water is low-permeability Precambrian rock.

Degradation of water quality is a major concern in the southern part of the county. The development of subdivisions with individual septic systems and wells near established dairy farms and irrigated cropland are potential sources of water-quality problems. The major aquifer in this area is composed of shallow, very permeable, sand and gravel that allow rapid flow of water with little attenuation of contaminants.

## PURPOSE AND SCOPE

This report describes the hydrogeology of Wood County–specifically, the occurrence, movement, availability, and quality of the ground water. Drillers' well-construction and aquifer-test data were used to determine water-table conditions, directions of ground-water flow, and aquifer characteristics. Geological data are presented in enough detail to help determine the extent of aquifers. Domestic and test wells were sampled to define general chemical characteristics of ground water throughout the county. Analyses included several chemical constituents of use as indicators of possible ground-water-quality problems. These indicator constituents were also used in testing a reconnaissance method for assessing ground-water quality near abandoned landfills.

## ACKNOWLEDGMENTS

Marvin Krzykowski, Wood County Zoning Administrator, was instrumental in conducting this study. His efforts in locating wells, landfills, and areas of interest are appreciated. The cooperation of landowners who allowed access to their wells for sampling is also appreciated.

## DESCRIPTION OF STUDY AREA

### Location and Physical Setting

Wood County has an area of 812 mi² (square miles) and is located near the geographic center of Wisconsin (fig. 1). The population has steadily increased from about 26,000 in 1900, to 65,000 in 1970, and to about 75,500 in 1985. The cities of Marshfield and Wisconsin Rapids (fig. 1), each with about 19,000 residents, plus several smaller communities, presently account for 47,000 of the 75,500 total. Agriculture, including cranberry growing and irrigated cash cropping, in addition to dairy farming, is balanced by an industrial base that includes large paper mills and a major regional health and medical research facility.

Wood County can be divided into three general physiographic areas based on topography and type of underlying unconsolidated deposits. The first area contains the Wisconsin River and its flood plain in the southeastern part of the county (fig. 2). The area on either side of the Wisconsin River is characterized by gently sloping topography and well-drained sandy soils. Land use in this area is urban and suburban residential. About 4 to 5 mi² of this area are irrigated agricultural cropland. Several square miles of this area also are devoted to growing trees for paper production.

The second physiographic area contains the southwestern part of the county and is dominated by a low-lying marshy area with poorly drained soils. Most of this area is county- and State-owned recreational land with limited access. In the 1890's, growers began taking advantage of these soil and surface-water conditions for growing cranberries. Today, this area contains a network of drainage ditches, check dams, and reservoirs, and is one of the major cranberry-producing regions in the United States.

The third physiographic area covers the northern two-thirds of the county and is characterized by broad rolling uplands and some areas of low-lying poorly drained wetlands. Several isolated hills rise 100 to 300 ft (feet) above the surrounding area in this part of the county. Dairy farming is the major land use in northern Wood County. However, poor drainage during wet years may limit crop yields in some areas.

Overall surface-water drainage is to the south. Surface runoff drains locally east and west into streams such as the Yellow River, Hemlock Creek, and Mill Creek (pl.1). These streams flow generally south and east as tributaries to the Wisconsin River (pl. 1). Drainage is to the west into the Wisconsin River in extreme southeastern Wood County. Surface water in the southwestern part of the county moves west into the Black River basin. In the extreme northeast, small streams flow north and east out of the county (pl. 1).

### Geologic Setting

The rock and unconsolidated deposits in Wood County range in age from more than 2,800 million years old to modern stream deposits (Socha, 1983).

The oldest rocks are part of the Canadian Shield–the large area of ancient rocks that underlie (at shallow depths) much of northern North America. These Precambrian igneous and metamorphic rocks are directly overlain by sandstone of Cambrian age or by unconsolidated deposits. Figure 3 is a geologic section through the center of the county and shows the vertical (stratigraphic) relation between these different rock types. Characteristics of these rocks and unconsolidated deposits influence the occurrence, availability, and movement of ground water in the county.

## BEDROCK GEOLOGY

Precambrian-age rocks (older than 600 million years) in Wood County were produced by volcanic activity, intrusion of large bodies of granitic rock, and by the melting and recrystallization of these rocks under extreme pressure and heat. This tectonic activity also caused complex faulting, fracturing, and deformation of these rocks after they were in place (Socha, 1983). Precambrian rock-types include granite, gneiss, quartzite, schist, and metamorphosed volcanic rock. In this report, the Precambrian rocks are not differentiated.

Overlying the Precambrian rocks is Cambrian sandstone. This sandstone is locally interlayered with shale layers and is very coarse-grained near its contact with underlying Precambrian rock.

This sandstone was left exposed to erosion prior to any known glacial advances into the area. The most significant result of this period of erosion was the removal of all sandstone deposits in large areas of northern Wood County and in the present-day stream valleys. The sandstone varies in thickness from less than 10 ft to a maximum known thickness of about

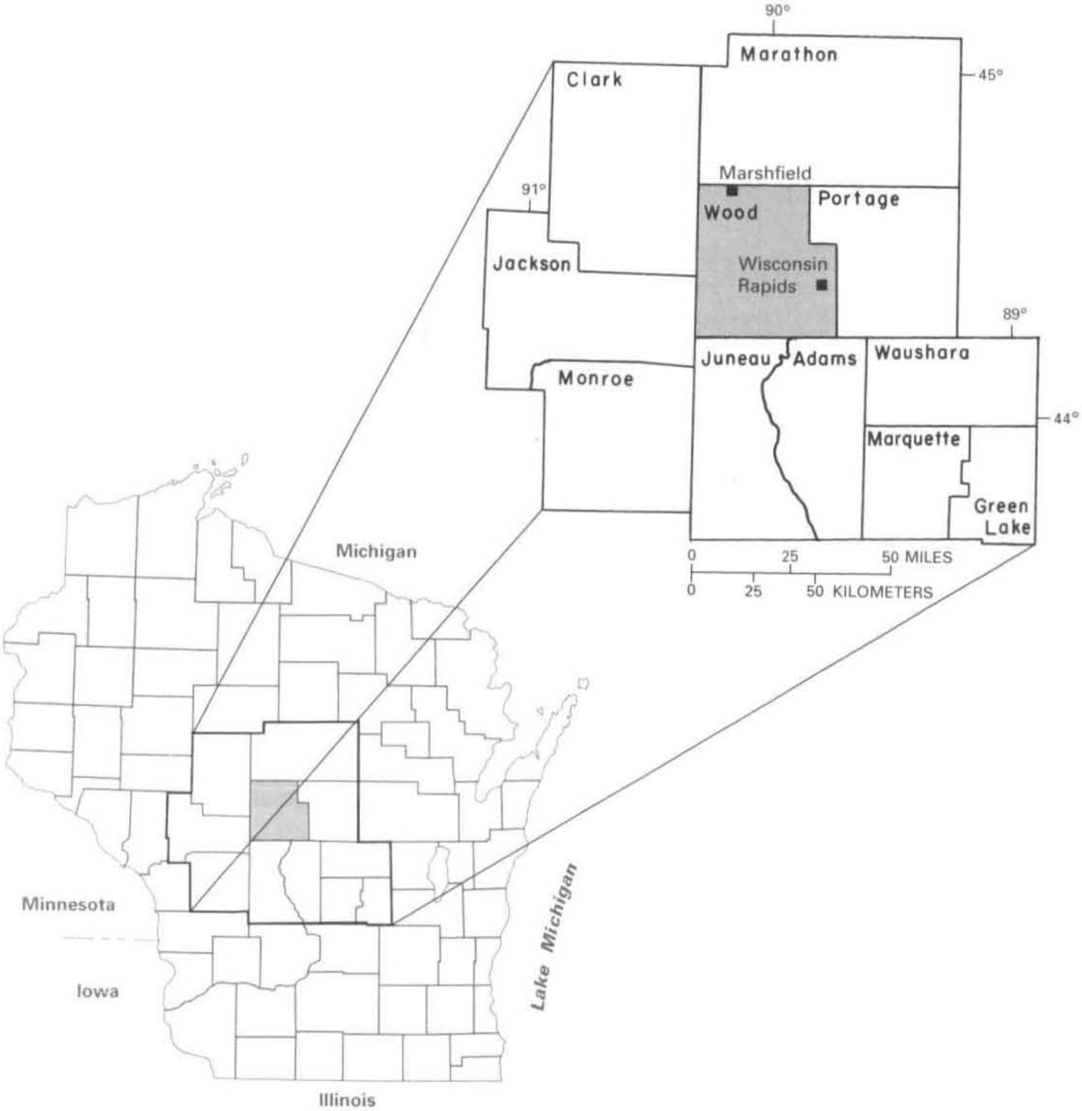


**Figure 1.** Location of Wood County in Wisconsin.

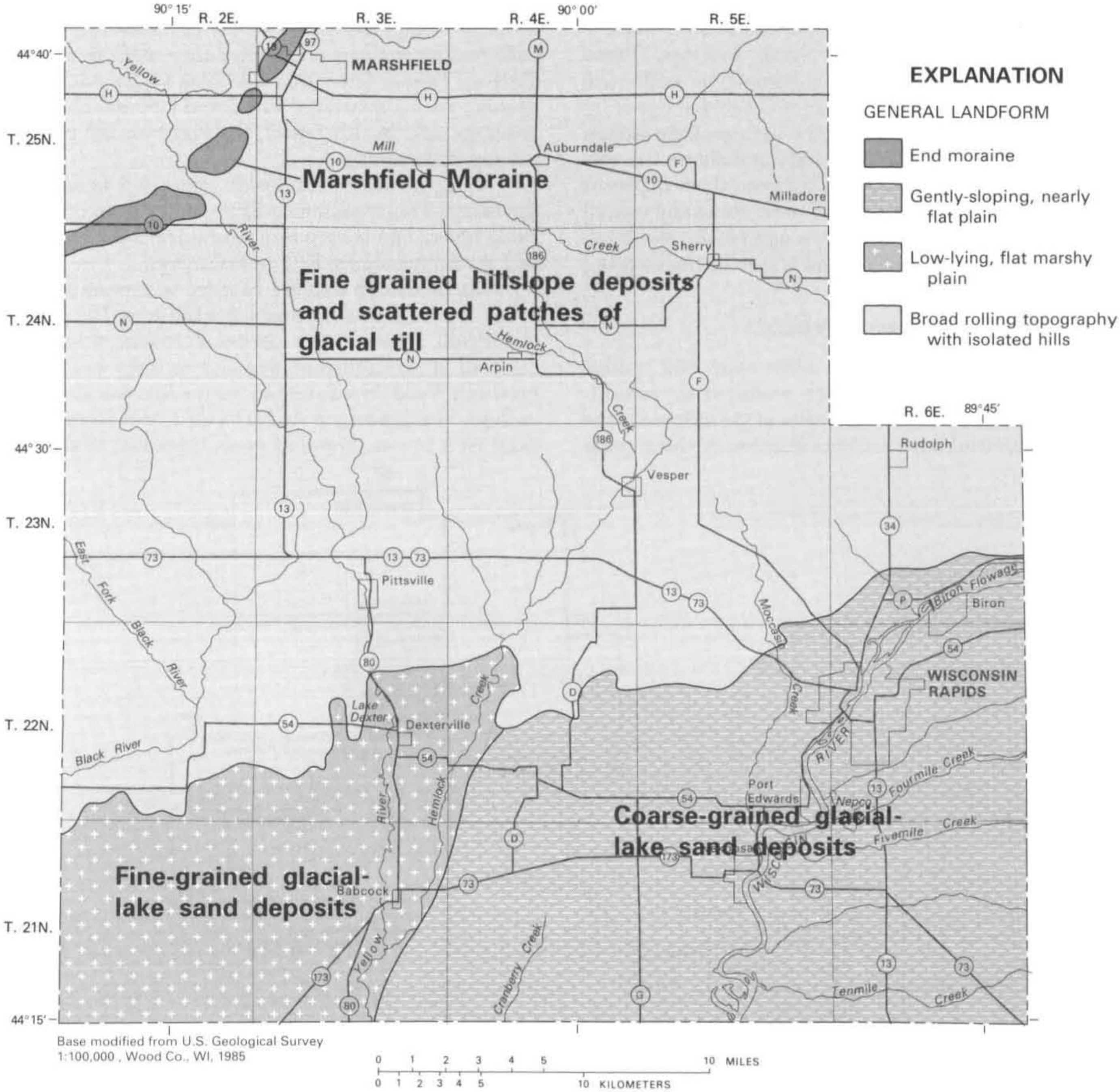


**Figure 2.** Generalized landforms and associated glacial deposits.

180 ft (Lee Clayton, Wisconsin Geological and Natural History Survey, written commun., 1988). It generally is 20- to 40-ft thick over the areas where present.

Figure 4 shows the bedrock geology of Wood County. It is a somewhat simplified version of a detailed bedrock map of the county compiled by Brown and Greenberg (1986, pl.1). It shows what type of rock would be encountered if all overlying glacial and stream deposits were removed. Sandstone is the uppermost bedrock unit over more than half of the area. In northeastern Wood County, there exists a Precambrian high. Sandstone has been completely removed by erosion in this area (fig. 4).

The bedrock surface (fig. 5) is relatively smooth and gently rolling and has broad, shallow, stream valleys. Powers Bluff, in T. 24 N., R. 4 E. (pl. 1), and several minor bluffs scattered throughout the county are the only striking features in an otherwise featureless bedrock surface. The bedrock surface slopes gently from about 1,200 ft above sea level in northern parts of the county to just less than 900 ft

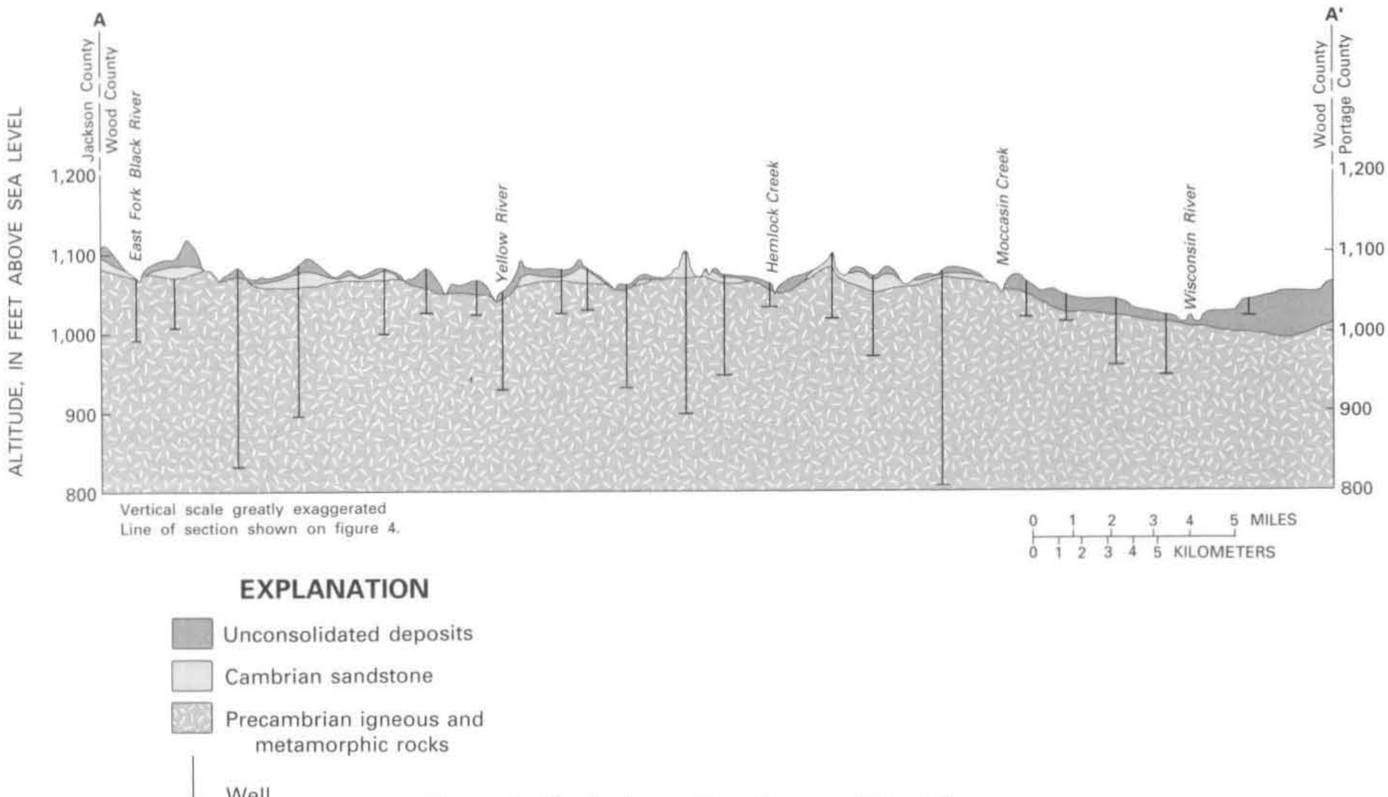


**Figure 3.** Geologic section through Wood County.

in the Wisconsin River valley in the extreme southeast (fig. 5).

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits in Wood County can be separated into three groups that coincide with the three physiographic areas discussed earlier. These deposits are distinguished by type and texture of material and the mode of deposition (fig. 2).

The first group of deposits underlies the southern third of the county. These are lacustrine sands deposited as lake-bottom deposits in Glacial Lake Wisconsin (Lee Clayton, Wisconsin Geological and Natural History Survey, oral commun., 1987)—a large shallow lake that received glacial meltwater until it dried up about 15,000 years ago. Lake-bottom deposits in the eastern half of this area are medium- to coarse-grained sand and were derived from sources east of Wood County (Lee Clayton, Wisconsin Geological and Natural History Survey, oral commun., 1987). The flood plains of the Wisconsin River and larger tributary streams also are underlain by sand and gravel deposited by these present-day streams.

A second group of lake deposits in the western part of this area consists of slightly finer-grained sand deposits; they were derived from sources further north in the county (Lee Clayton, Wisconsin Geological and Natural History Survey, oral commun., 1987). The lake deposits are commonly covered by peat, muck, and stream sediments. The overall thickness of unconsolidated deposits in this area typically is less than 30 ft and commonly less than 10 ft. Both areas that contain lake-bottom deposits are underlain at a depth of 10 to 20 ft by a continuous 5- to 10-ft-thick layer of clayey silt. This layer probably is a lake deposit laid down during a quiet-water period (Lee Clayton, Wisconsin Geological and Natural History Survey, oral commun., 1987).

The third group of unconsolidated deposits is present over the northern two-thirds of the county (fig. 2). These deposits generally are finer grained than the lake-bottom sediments in southern Wood County and differ in their mode of deposition. The tops of some hills are covered by till—a material deposited at the base of glacial ice that advanced into Wood County from the north and northwest. This till is possibly 1,000,000 years old or older (Lee Clayton, Wisconsin Geological and Natural History Survey, oral commun., 1987). However, most of northern Wood County is underlain by clayey soils and hillslope deposits (tens of feet thick in some areas) developed by weathering of underlying Precambrian rock. Similarly, sandier soils have developed in areas underlain by Cambrian sandstone. Some sand and gravel deposits of limited areal extent underlie a narrow bedrock valley in the Marshfield area (not shown) (Bell and Sherrill, 1974).

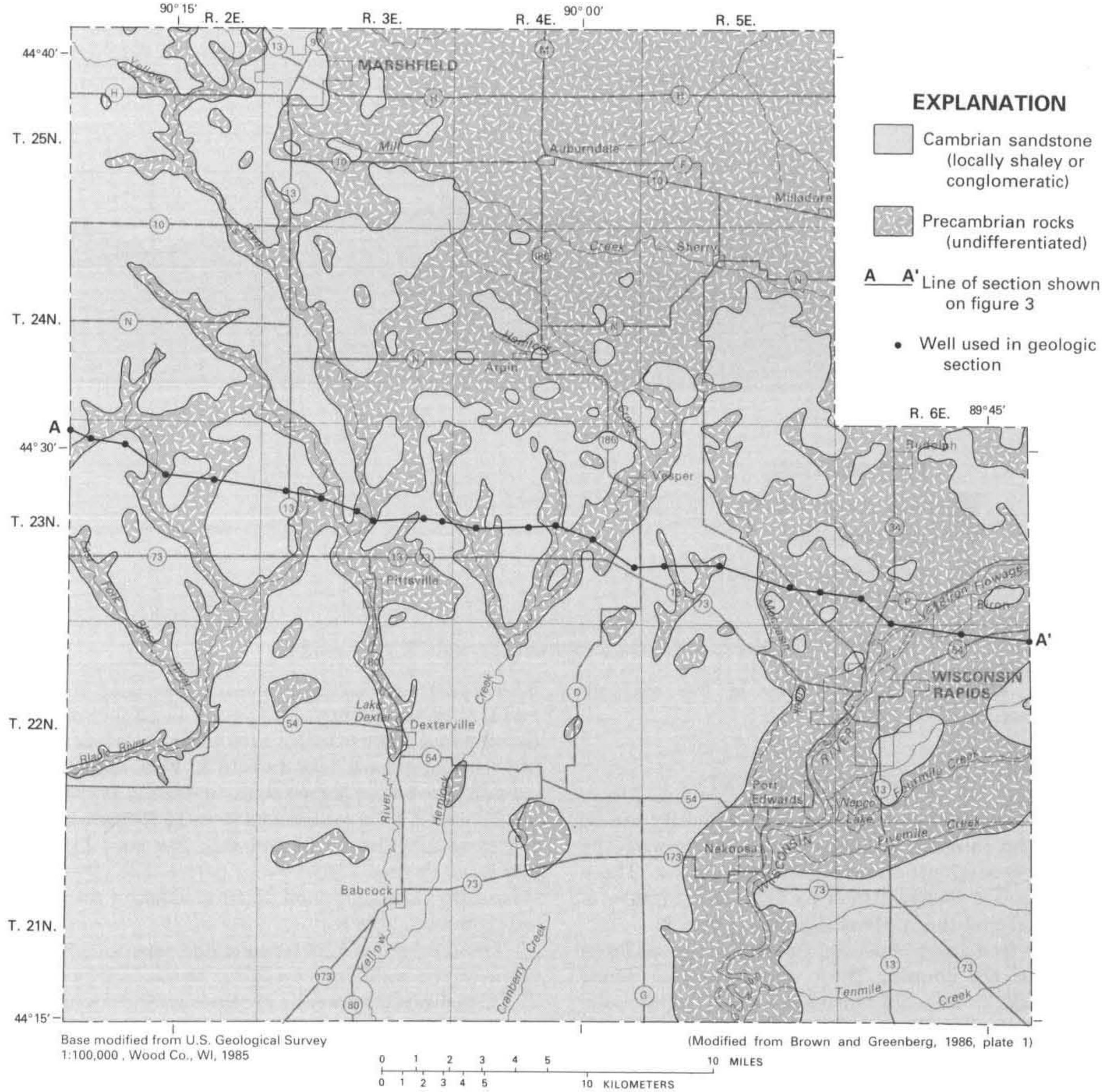


**Figure 4.** Bedrock geology of Wood County.

For the purposes of this report, the various types of unconsolidated deposits are grouped together, and their thickness is shown in figure 6. Thickness ranges from less than 20 ft over large areas (fig. 6) to a maximum known thickness of about 170 ft along a ridge in T. 24 and 25 N., R. 2 E. This ridge is called the Marshfield moraine (fig. 2). It consists of till deposited along the front edge of active glacial ice.

The sand deposits in the southeastern part of the county are commonly 50- to 60-ft thick. There is some evidence of a preglacially eroded bedrock valley tributary to the Wisconsin River valley in T. 21 N., R. 4 E. (figs. 5 and 6). The best evidence for this is a well in section 9 of this township that penetrates 155 ft of unconsolidated deposits; the top 85 ft is reported to be sand and the lower 70 ft, clay. Several other wells penetrate 70 to 90 ft of sand in this area. However, well data are insufficient to delineate this valley accurately or to determine whether similar valleys exist in the southwestern areas of the county.

With the exception of the areas discussed in the preceding paragraph, no other area in the county was

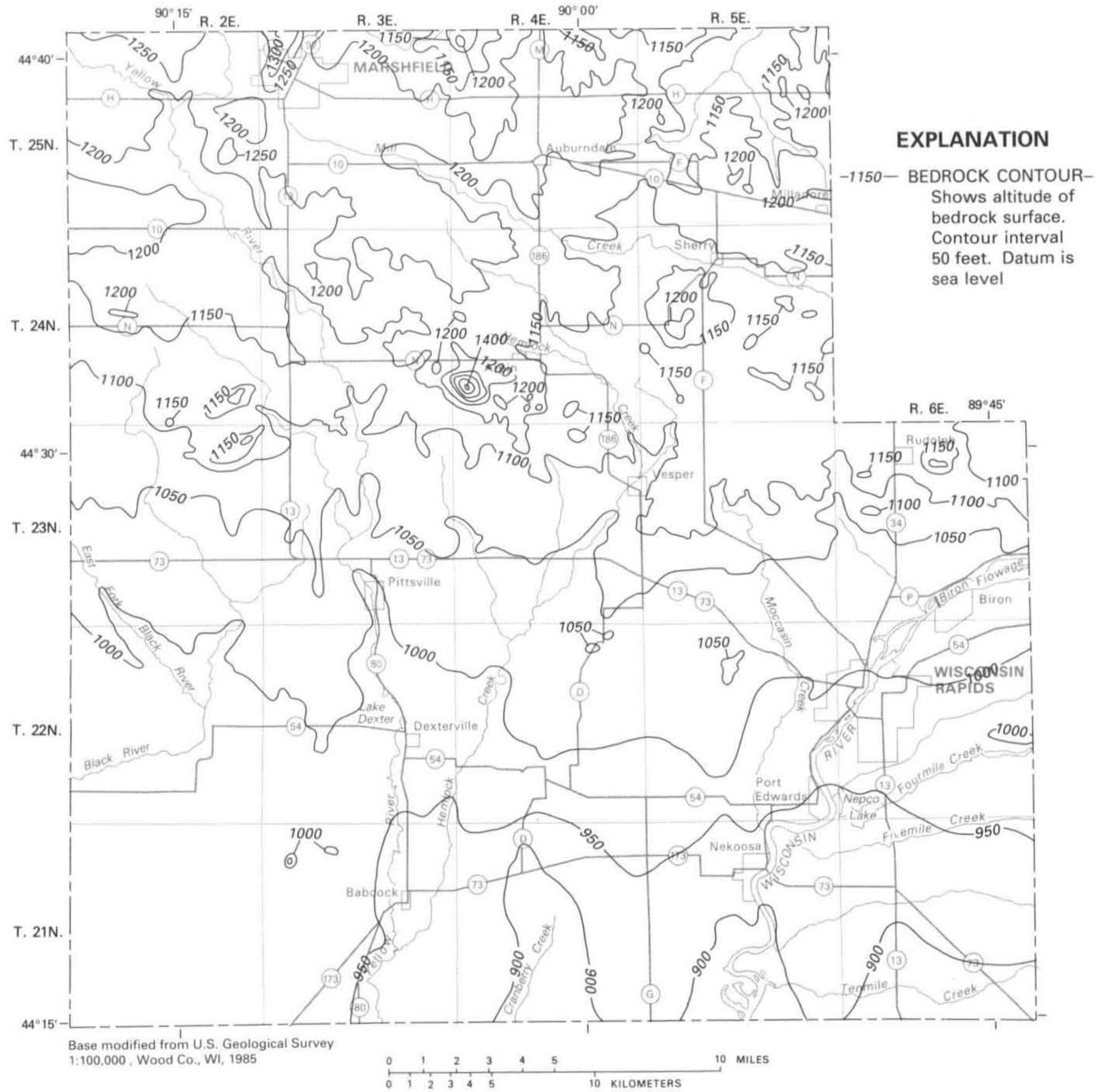


**Figure 5.** Altitude of the bedrock surface in Wood County.

found to have any mappable sand or sand and gravel deposits. The unshaded area in figure 6 shows the areas of the county where unconsolidated deposits are less than 20-ft thick and commonly less than 10 ft. The lack of significant thicknesses of sand and gravel deposits, particularly saturated deposits, in much of the county reduces the availability of ground water.

## HYDROGEOLOGY

Principal sources of ground water in the county are saturated sand and gravel deposits, fractured Precambrian rock, and, to a lesser extent, Cambrian sandstone. Most wells are finished in Precambrian rock. However, the highest yields are provided by wells finished in sand and gravel deposits.

## AQUIFERS

### Sand-and Gravel Aquifer

#### THICKNESS AND EXTENT

Use of sand and gravel as an aquifer for potable water supply is limited by the areal extent and

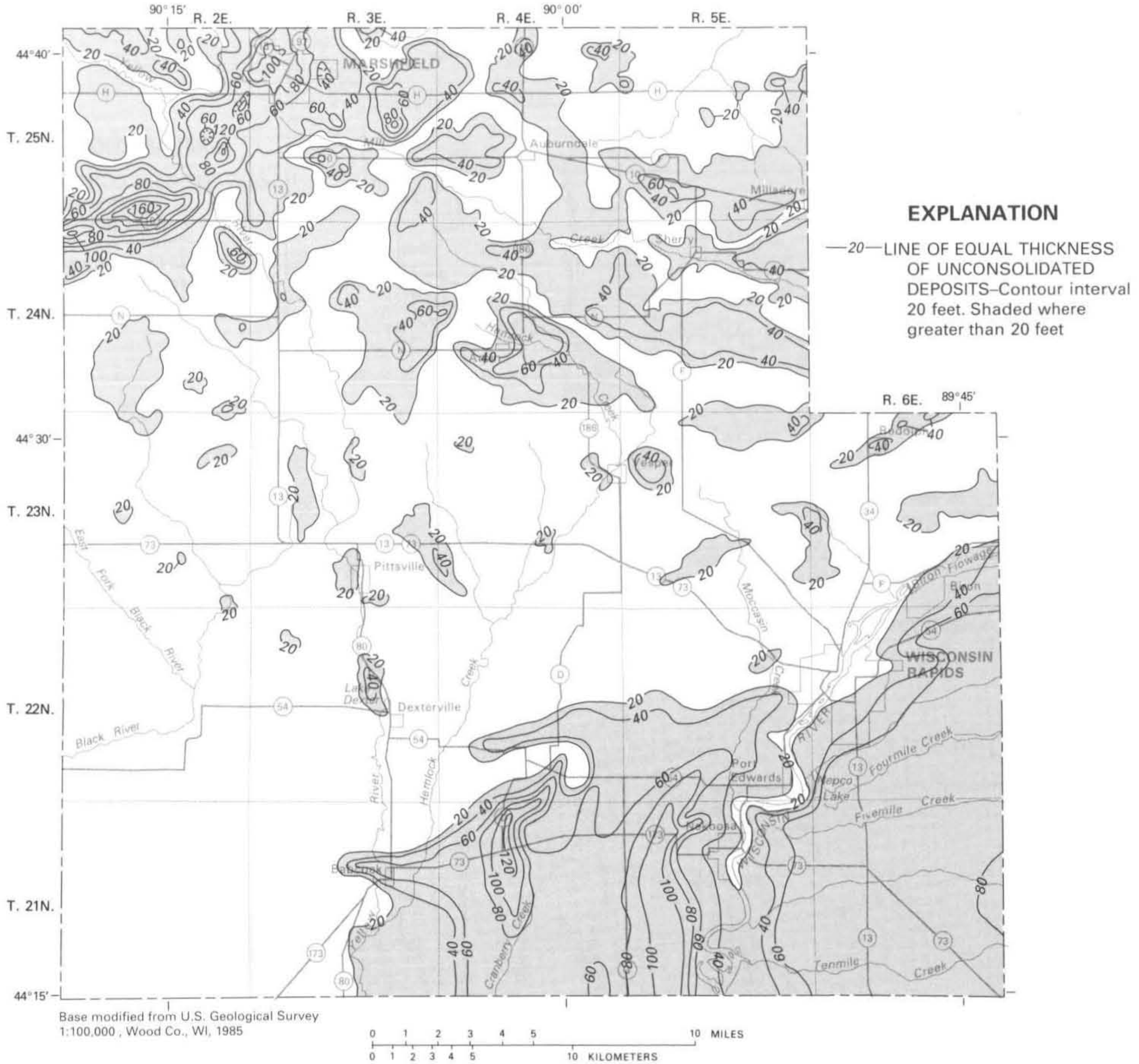


**Figure 6.** Thickness of unconsolidated deposits in Wood County.

saturated thicknesses of these deposits. The existence of sufficient saturated thicknesses of these deposits is limited to the southern third of the county. This is the area of coarser-grained lake sands discussed earlier (fig. 2).

The overall thickness of unconsolidated deposits is shown in figure 6. The saturated thickness of these deposits is shown in figure 7. Only the thickness that is saturated (all interconnected pore spaces filled with water) is of value as an aquifer. The shaded areas in figure 7 indicate those areas where the saturated thickness of sand and gravel exceeds 20 ft. These areas are outlined because they are areas where the sand and gravel can be used as an aquifer both for low-capacity [10 to 20 gal/min (gallons per minute)] domestic wells and possibly for higher-capacity wells used for municipal or irrigation supplies. The locations of all wells finished in the sand-and-gravel aquifer that were reported by well drillers through 1985 also are shown in figure 7. Drillers' well-construction data were used to compile the maps shown in figures 6 and 7.

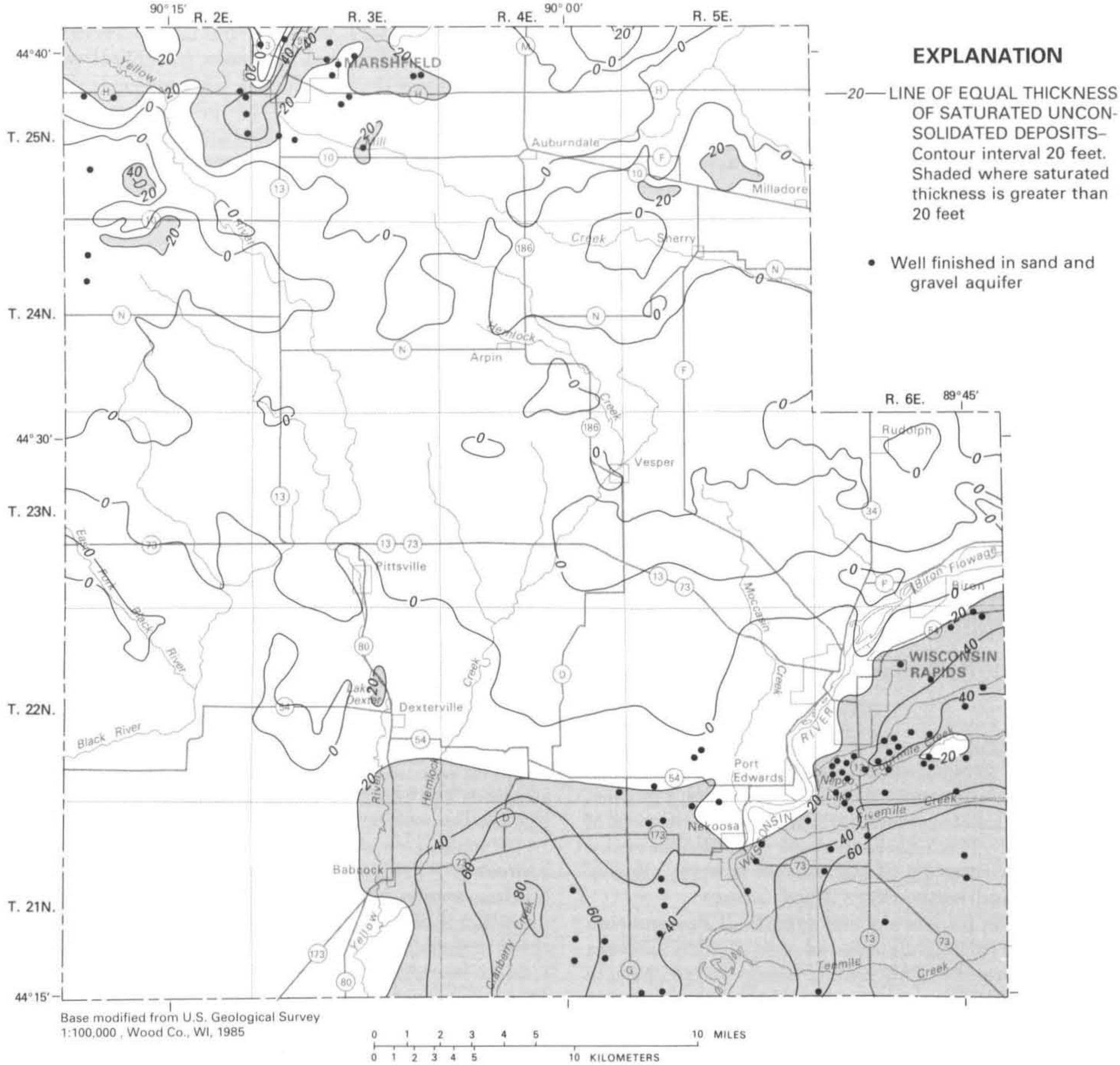


**Figure 7.** Saturated thickness of unconsolidated deposits and location of wells finished in the sand-and-gravel aquifer.

## AQUIFER PROPERTIES

The utility of unconsolidated deposits as an aquifer depends on the texture (grain size and sorting) of the deposits. Fine-grained materials, such as silt and clay, tend to be poorly sorted and have low permeability. This fine material can cause pump wear and clog well screens, thereby reducing the yield of the well. Wells finished in unconsolidated coarse-grained deposits tend to have large yields.

Drillers' well-construction data and data collected by other investigators in southeastern Wood County provide values for the horizontal hydraulic conductivity of the sand and gravel deposits in this area. Hydraulic conductivity is a measure of the volume of water an aquifer can transmit under a unit hydraulic gradient through a unit area measured at a right angle to the direction of ground-water flow. Values are greatest for coarse-grained materials with large, well-connected pore spaces, such as sand and gravel, and lowest for those with poorly connected pore spaces, such as silt or clay.

The horizontal hydraulic conductivity of the sand-and-gravel aquifer in southeastern Wood County was calculated from results of drillers' aquifer tests of irrigation wells in the area. Values ranged from 155 to 280 ft/d (feet per day), with an average of about 210 ft/d for all wells. This compares with an average of about 230 ft/d, as determined by previous studies in the area (Karnauskas, 1977).

The horizontal hydraulic conductivities of finer-grained deposits in northern areas of the county were determined from slug tests of three test wells finished in weathered bedrock material. The three values range from about 0.1 to 1.6 ft/d. These values compare with an average value of about 0.02 ft/d calculated for similar till in Marathon County (not shown) just north of Wood County (Maureen Muldoon, Wisconsin Geological and Natural History Survey, oral commun., 1987). The combination of greater thicknesses and hydraulic conductivity of sand and gravel deposits in the southern part of the county accounts for the larger number of sand and gravel wells in the southern part of the county and the lack of sand and gravel wells in the northern part of the county.

### Precambrian Bedrock Aquifer

#### EXTENT

Precambrian rocks of various types are the only source of ground water in much of the county. The low hydraulic conductivity of these rocks, however, severely limits ground-water availability in most of the county. Precambrian bedrock underlies the entire county. It crops out at land surface in many areas of central and northeastern Wood County.

For the purposes of this report, all Precambrian rocks are collectively referred to as the Precambrian bedrock aquifer. This aquifer also is defined here to include "broken, weathered, or soft" Precambrian rock reported by drillers.

#### AQUIFER PROPERITES

Wells finished in Precambrian rocks derive water from one of two sources. The first is the upper 10 to 30 ft where chemical and physical weathering has broken up the rock and created interconnected spaces through which water can move. The second source is fractures or joints in the rock that are intersected by the well borehole. These fractures or joints can be present at any depth, although their number tends to decrease with depth. Wells that intercept water that moves along these fractures typically are uncased for more than 100 ft of the total well depth, and the borehole acts as a reservoir for water that enters the well. Half of all 1,350 wells that tap the Precambrian aquifer are less than 84-ft deep, and only 10 percent are greater than 163-ft deep. This indicates that the upper weathered zone is the primary source of water in wells that tap the Precambrian aquifer.

Results of drillers' specific-capacity tests of the 1,350 wells finished in Precambrian rocks were analyzed to estimate the horizontal hydraulic conductivity of this aquifer. The specific capacity of a well is the rate of discharge in gallons per minute per foot of decline in the water level in the well caused by pumping at that discharge rate. Specific capacity is directly related to the hydraulic conductivity of the aquifer material surrounding the well.

The median horizontal hydraulic conductivity value for the Precambrian aquifer as determined from 1,350 drillers' well reports in Wood County was 0.7 ft/d compared to 220 ft/d for wells finished in sand and gravel. A decrease in hydraulic conductivity with depth in the Precambrian aquifer also was apparent. Ten percent of all wells tapping Precambrian rocks in the county are less than 47-ft deep and, therefore, tap only the uppermost part of the aquifer. The median horizontal hydraulic conductivity determined from the specific-capacity tests of these shallow wells was 11.4 ft/d. The median value of hydraulic conductivity continually decreased with depth to about 0.02 ft/d for the deepest 10 percent (greater than 163-ft deep) of all wells finished in the Precambrian aquifer. This decrease in hydraulic conductivity with depth suggests less weathering and fewer fractures intercepting the well borehole.

In some areas of the country where Precambrian bedrock is the only source of ground water, well yield has been shown to be inversely related to topographic elevation (LeGrand, 1954). LeGrand found that, in areas underlain by crystalline bedrock aquifers, wells located in valleys yielded more water than wells drilled on hillsides or hilltops. This is because valleys typically are formed by streams that erode relatively soft, nonresistive rock that has been broken down by physical and chemical weathering. This rock tends to have a high permeability, which promotes ground-water flow. These areas also tend to be associated with fractures or joints in the near-surface bedrock. Conversely, adjacent hills are underlain by relatively hard, crystalline rock resistant to erosion and chemical weathering. These rocks provide little water to wells.

The locations of high-capacity Precambrian aquifer wells in Wood County were plotted and compared to their topographic position and proximity to areas of possibly fractured bedrock. Socha (1983) examined areal photographs of central Wisconsin that included Wood County to identify linear features on the ground surface that might be associated with bedrock fractures or joints. Socha plotted locations of all wells finished in Precambrian rocks that have large specific capacities and the locations of fracture traces. No relation was found to exist between the well locations and their topographic position or proximity to possible fracture traces on the ground surface. In this present study, locations of Precambrian aquifer wells with hydraulic conductivities in the upper 10 percent of values in the county were also plotted against Socha's fracture-trace locations. Again, no relation was found to exist. However, very few wells are actually drilled along the fracture traces. Additional study and more data may determine if increased well production is possible near fracture traces.

## GROUND WATER

### Flow

Movement of ground water in Wood County can best be described by referring to plate 1, a map of the water table. This map shows the altitude above sea level of the top of the saturated zone. Within the saturated zone, all interconnected openings (pore spaces) in the glacial material or bedrock are filled by water. The contour lines on plate 1 connect points of equal water-table altitude. The map is based on altitudes of static water levels in wells and elevations of streams and wetlands. The altitude of the water table ranges from more than 1,280 ft in northwestern Wood County to less than 930 ft in the southeastern part of the county.

The water table is a subdued replica of the land surface. The altitude of the water table usually is higher under topographic highs such as the Marshfield moraine in the northwest (fig. 2). It usually is lower but closer to land surface in topographically low areas, such as wetlands or areas adjacent to streams and rivers. Wetlands, rivers, and lakes generally occupy low areas where the water table intersects the land surface.

Regional ground-water flow in central Wood County generally is from the north to the south into the low-lying wetland in the southwest. Flow is out of the county along the northeastern and western edges of the county. In the extreme southeast, flow is into the county from the east toward the Wisconsin River and toward several small streams that are tributary to the river.

This concept of regional flow suggests that ground water moves several miles or more from the point where it enters the ground-water system to the point where it discharges to a stream or wetland. However, ground water in Wood County typically moves along much shorter (less than 1-mi long) flow paths from the point where it enters the ground-water system to where it discharges to nearby streams or low-lying wetland areas.

### Recharge and Discharge

The source of recharge to aquifers in the county is precipitation that seeps down through the soil column and reaches the water table. The average annual precipitation rate for the Wood County area is about 31 in/yr (inches per year). Only a part of this actually recharges to the water table. Most precipitation is taken up by plant roots or evaporates into the atmosphere (evapotranspiration). Some runs off the land surface into streams and lakes.

Recharge to the water table in Wood County varies by physiographic region (fig. 2) and depends on the soil and aquifer types within each region. The coarse, sandy soils of the southeast facilitate aquifer recharge from precipitation. Weeks and Strangland (1971) estimated that about 11 to 12 in/yr of the annual total precipitation recharges the water table in southeastern Wood County. Holt (1965) estimated that recharge for this same area ranges from about 6.8 in/yr during dry periods to about 10.3 in/yr during wet years. Ground-water recharge in the low-lying, marshy area of southwestern Wood County is considerably less than these amounts. Evaporation from the many surface-water bodies and water transpired by wetland vegetation reduces recharge in southwestern Wood County.

Hamilton (1971) calculated a reduction in ground-water storage in the Cranberry Creek drainage basin located in south-central Wood County (pl. 1). This "negative" recharge was estimated by summing evapotranspiration, surface-water flow out of the area, and ground-water flow out of the area as part of a water budget for this marshy wetland. The sum of these three items exceeded the average precipitation for the area by 1.1 in/yr (32.7 in/yr compared to 31.6 in/yr). To balance this budget, he determined that the additional 1.1 in/yr was derived from a reduction in ground-water storage in this area. Although calculation of a water budget is an indirect and somewhat inaccurate method of determining recharge, it is reasonable, in a wetland area, for ground-water recharge to be near zero over a short (1- to 2-year) period.

Recharge for the northern part of the county was calculated by another indirect method. This method involves separating streamflow into its base-flow component (the contribution from ground water) and its surface-water component. Streamflow in the Yellow

River has been monitored by the U.S. Geological Survey since 1944 at a gaging station located near Babcock (pl. 1). Figure 8 shows hydrographs of average daily flows for the 12-month periods (water years) ending September 30, 1977 (water year 1977), and September 30, 1986 (water year 1986). Water year 1977 was a period of below-normal precipitation and water year 1986 was a period of above normal precipitation. The shaded area in each hydrograph is the ground-water component of streamflow as determined by hydrograph separation (Linsley and others, 1975). The water year 1977 separation shows that about 36 percent of the total $1.18 \times 10^9$ gal (gallon) of streamflow passing the gaging station was ground-water runoff. About 23 percent of the total $8.87 \times 10^9$ gal of streamflow during water year 1986 was ground-water runoff. It can be assumed that the amount of ground water that discharges to a stream is approximately equal to the amount of ground-water recharge in the ground-water basin contributing to that stream. Calculated ground-water recharge rates for the Yellow River basin in central Wood County were about 0.9 in/yr during the 1977 water year and about 4.2 in/yr during the 1986 water year. The recharge

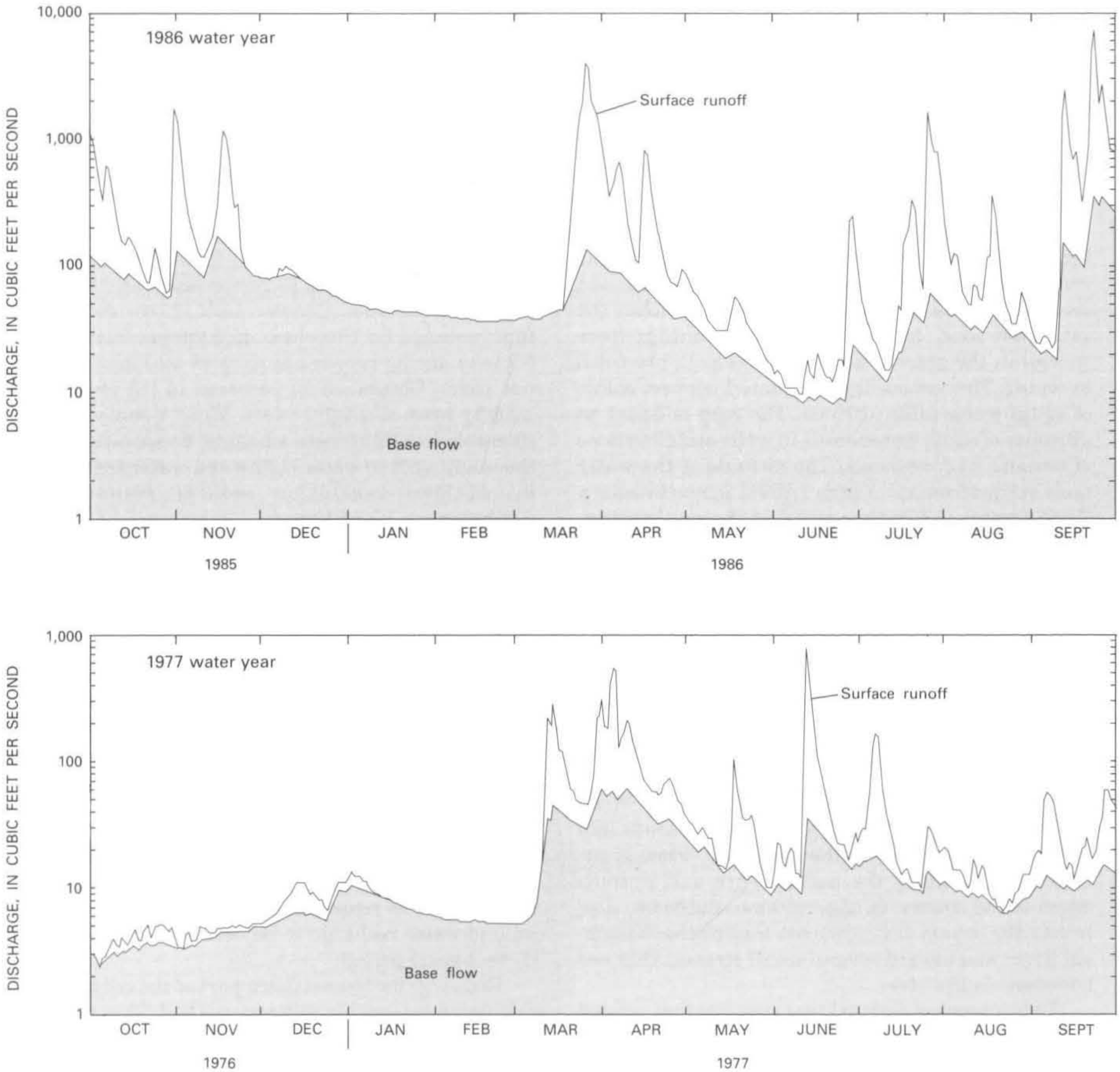


**Figure 8.** Hydrographs of base flow and surface runoff for the Yellow River, 1977 and 1986 water years.

rate in this area of the county is lower than that of the southeast because of the relatively low-permeability fine-grained materials that cover the land surface and a generally steep-sloped topography that tends to decrease the amount of precipitation that infiltrates to the water table.

### Availability

Most wells in Wood County are finished in Precambrian rocks. About 85 percent of all Wood County wells (1,350 of 1,622) for which construction reports are on record at the Wisconsin Geological and Natural History Survey have uncased boreholes open to this aquifer. Of the remaining wells, 149 have boreholes open to Cambrian sandstone and 123 wells have screens open to sand and gravel. An estimated (unreported) 200 to 300 shallow domestic wells in sand and gravel are in the southeastern part of the county. These wells were drilled or driven prior to enactment of the State requirement that drillers submit a construction report upon completion of a well.

Wells in sand and gravel are concentrated in the southeast (fig. 7) and tap the permeable sand deposits in that area. Municipal wells in the Wisconsin Rapids and Nekoosa areas tap water in sand and gravel deposited by the Wisconsin River. About 20 agricultural irrigation wells capable of discharging 500 to 1,000 gal/min also are located in the southeast. The area around the city of Marshfield also has some wells in sand and gravel. Wells in the Marshfield area are finished in sand and gravel deposits just east, south, and west of the city and beneath the Marshfield moraine (fig. 2).

Wells finished in Cambrian sandstone are scattered throughout the central and northwestern parts of the county. These wells typically are cased through overlying unconsolidated deposits and have uncased boreholes open to 15 to 30 ft of sandstone.

Table 1 is a comparison of well depths and production data by aquifer for the entire county. These data show that the sand-and-gravel aquifer is the most productive aquifer, followed by the sandstone and the Precambrian aquifers. This is best shown by comparing the specific capacities of wells by aquifer. As previously discussed, the specific capacity of a well is directly related to the horizontal hydraulic conductivity of the aquifer. The median specific capacity of the Precambrian aquifer wells is 0.2 (gal/min)/ft (gallon per minute per foot) of drawdown and that of the sand-and-gravel aquifer wells is 1.9 (gal/min)/ft of drawdown. In terms of actual well performance, this comparison means that, for a typical domestic well pumping 10 gal/min, the water level in the sand and gravel well will be drawn down about 5 ft but the water level in the Precambrian aquifer well will be drawn down 50 ft. The larger drawdown may result in additional costs for pump installation and additional pump wear. Some "dry" holes are encountered in the Precambrian rock. These wells are not capable of producing a sustained discharge of even 1 gal/min for rural domestic supply. When this occurs the driller typically will destroy such a well and drill another nearby.

### Quality

#### OBJECTIVES AND METHODS OF WATER-QUALITY ASSESSMENT

Ground water was sampled and analyzed to define the general water quality and determine, by analyzing for indicators of contamination, the existence of water-quality problems in the county. An attempt was made to correlate elevated concentrations of these indicator parameters with land use and well construction. All water-quality data are summarized by aquifer. Ground water also was sampled and analyzed

**Table 1**—*Comparison of well depth and production, by aquifer, in Wood County*
[All figures are median values for all wells]

| | Precambrian aquifer | Cambrian sandstone aquifer | Sand-and-gravel-aquifer | |
|---|---|---|---|---|
| | | | Domestic wells | High-capacity irrigation wells |
| Well depth (feet) | 84 | 55 | 55 | 56 |
| Well discharge (gallons per minute) | 6 | 10 | 15 | 645 |
| Specific capacity (gallons per minute per foot of drawdown) | .2 | .7 | 1.9 | 26.7 |

at abandoned landfill sites to help evaluate the effectiveness of a reconnaissance approach for detecting ground-water contamination near landfills.

Samples were collected from 124 domestic wells in 21 of 23 townships (22 civil townships) in the county. Sampling sites were chosen for uniformity of areal coverage of data points throughout the county. Analyses of common dissolved mineral constituents were performed on 16 of the 124 samples to determine the chemical characteristics of ground water in the county. All samples were analyzed for hardness, iron, chloride, and nitrate. Very hard water and elevated iron concentrations can cause water-quality problems. Relatively high concentrations of chloride and nitrate may indicate ground-water contamination from human and animal waste or road salt because of their presence in these sources and because of their usually low concentration in natural ground water.

Existing water-quality data from other sources also were summarized. This includes water-quality data collected in Wood County as part of a cooperative ground-water education program conducted by the University of Wisconsin at Stevens Point and the University of Wisconsin-Extension. Data from analyses of volatile organic compounds (VOCs) and pesticides in samples collected by the Wisconsin Department of Natural Resources (WDNR) since 1983 also were summarized.

## GENERAL GROUND-WATER QUALITY

The major dissolved constituents in ground water in Wood County are calcium, magnesium, and bicarbonate. Sodium, potassium, chloride, and sulfate are present in relatively smaller concentrations. Together, these constituents comprise almost all dissolved solids in ground water in the county. The results of all 124 analyses are summarized, by aquifer, in table 2. The locations of sampled wells are shown on plate 2. Samples were collected in 93 wells finished in Precambrian rock, 9 wells in sand and

Table 2—*Summary of chemical analyses of ground water in Wood County, by aquifer*

[All units are in milligrams per liter unless otherwise indicated; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; a dash indicates data unavailable]

| | | *Precambrian aquifer* | | | | |
|---|---|---|---|---|---|---|
| | | | Percentage of wells where indicated value was equaled or exceeded | | | |
| Constituent | Number of wells | Maximum concentration | 25 | 50 (median) | 75 | Minimum concentration |
| Temperature (°C) | 93 | 14.5 | 12.0 | 11.0 | 10.0 | 9.0 |
| Specific conductance (µS/cm @ 25 °C) | 93 | 825 | 412 | 310 | 218 | 50 |
| pH (units) | 93 | 7.9 | 7.2 | 6.7 | 6.4 | 4.9 |
| Alkalinity as $CaCO_3$ | 93 | 351 | 152 | 102 | 76 | 3 |
| Hardness as $CaCO_3$ | 93 | 390 | 170 | 125 | 87 | 1 |
| Noncarbonate hardness as $CaCO_3$ | 93 | 160 | 36 | 12 | 0 | 0 |
| Calcium, dissolved | 93 | 120 | 42 | 31 | 20 | .1 |
| Magnesium, dissolved | 93 | 33 | 16 | 11 | 8 | .01 |
| Sodium, dissolved | 10 | 58 | 11 | 6.2 | 4.6 | 4 |
| Potassium, dissolved | 10 | 31 | 3.2 | 2 | .8 | .7 |
| Chloride, dissolved | 93 | 130 | 28 | 13 | 3.3 | .4 |
| Sulfate, dissolved | 10 | 37 | 10.8 | 5.2 | 2.9 | .8 |
| Fluoride, dissolved | 10 | .4 | .2 | .2 | .1 | <.1 |
| Silica, dissolved as $SiO_2$ | 10 | 25 | 19 | 17 | 15 | 12 |
| Dissolved solids (residue @ 180 °C) | 93 | 563 | 278 | 208 | 144 | 28 |
| Nitrate, dissolved as N | 93 | 33 | 1.6 | <.1 | <.1 | <.1 |
| Ammonia, dissolved as N | 10 | .13 | .07 | .04 | .03 | <.01 |
| Phosphorus, dissolved as P | 10 | .11 | .06 | .04 | .02 | .01 |
| Iron, dissolved (µg/l) | 93 | 25,000 | 3,100 | 350 | 28 | 5 |
| Manganese, dissolved (µg/l) | 10 | 1,000 | 230 | 155 | <1 | <1 |
| Strontium, dissolved (µg/l) | 10 | 520 | 225 | 86 | 56 | .6 |
| Barium, dissolved (µg/l) | 10 | 330 | 76 | 51 | 26 | 11 |

gravel, 12 wells in Cambrian sandstone, and in 10 wells that have uncased boreholes open to both sandstone and Precambrian rock.

The concentration of dissolved solids is a good measure of general ground-water quality and how it differs throughout the county. The concentration of dissolved solids depends on the chemical composition and solubility of the rock and soil through which the water moves and the length of time that the water is in contact with these materials. Elevated concentrations of total dissolved solids generally do not impair drinking-water quality. However, the Wisconsin Department of Natural Resources (1978) recommends that water with a dissolved-solids concentration greater than 500 mg/L (milligrams per liter) not be used for drinking water. This is based on aesthetic (taste) considerations.

Elevated concentrations of dissolved solids is not a problem in Wood County. Dissolved-solids concentrations exceeded 500 mg/L in only 4 of 124 ground-water samples. Concentrations ranged from 21 to 563 mg/L (table 2) and the median concentration for all 124 samples was 186 mg/L. The median dissolved-solids concentration differed by aquifer. The median dissolved-solids concentration in water from wells finished in Precambrian rocks was 208 mg/L compared to 108 mg/L in water from wells in sand and gravel and 156 mg/L in water from wells in sandstone (table 2). The median dissolved-solids concentrations in water from wells open to both Precambrian rocks and sandstone was 84 mg/L.

Ground water in the county has low pH and alkalinity. That is, Wood County ground water tends to be slightly acidic. More than 60 percent of samples collected had pH values of 6.0 to 7.0. The median pH by aquifer in samples was about 6.5 (table 2). Alkalinity is a measure of the ability of the water to neutralize acid, and in Wood County it essentially is a measure of the concentration of dissolved bicarbonate ions (or carbonate minerals) in the ground

**Table 2**—*Summary of chemical analyses of ground water in Wood County, by aquifer—Continued*

[All units are in milligrams per liter unless otherwise indicated; μS/cm, microsiemens per centimeter; μg/L, micrograms per liter; a dash indicates data unavailable]

| Constituent | Number of wells | Maximum concentration | Cambrian sandstone aquifer — Percentage of wells where indicated value was equaled or exceeded: 25 | 50 (median) | 75 | Minimum concentration |
|---|---|---|---|---|---|---|
| Temperature (°C) | 12 | 16.5 | 12.5 | 11.5 | 10.0 | 9.5 |
| Specific conductance (μS/cm @ 25 °C) | 12 | 690 | 463 | 235 | 88 | 30 |
| pH (units) | 12 | 7.4 | 7.2 | 6.5 | 6.2 | 5.0 |
| Alkalinity (as $CaCO_3$) | 12 | 250 | 126 | 41 | 4 | 2 |
| Hardness as $CaCO_3$ | 12 | 210 | 170 | 76 | 32 | 19 |
| Noncarbonate hardness as $CaCO_3$ | 12 | 60 | 46 | 15 | 6 | 0 |
| Calcium, dissolved | 12 | 60 | 36 | 22 | 7.2 | 4 |
| Magnesium, dissolved | 12 | 23 | 15 | 4.5 | 2.2 | 2 |
| Sodium, dissolved | 2 | 35 | -- | -- | -- | 1.4 |
| Potassium, dissolved | 2 | 2.6 | -- | -- | -- | 1.1 |
| Chloride, dissolved | 12 | 200 | 7.2 | 3.9 | 1.5 | .3 |
| Sulfate, dissolved | 2 | 12 | -- | -- | -- | 2 |
| Fluoride, dissolved | 2 | .2 | -- | -- | -- | <.1 |
| Silica, dissolved as $SiO_2$ | 2 | 21 | -- | -- | -- | 7.6 |
| Dissolved solids (residue @ 180 °C) | 12 | 470 | 313 | 156 | 54 | 21 |
| Nitrate, dissolved as N | 12 | 6 | 3.7 | 2.3 | 0.3 | <.1 |
| Ammonia, dissolved as N | 2 | .01 | -- | -- | -- | <.01 |
| Phosphorus, dissolved as P | 2 | .1 | -- | -- | -- | .04 |
| Iron, dissolved (μg/l) | 12 | 9,000 | 130 | 16 | 9 | 7 |
| Manganese, dissolved (μg/l) | 2 | 26 | -- | -- | -- | 23 |
| Strontium, dissolved (μg/l) | 2 | 85 | -- | -- | -- | 22 |
| Barium, dissolved (μg/l) | 2 | 67 | -- | -- | -- | 47 |

water. Although bicarbonate is one of the major ions in ground water in the county, alkalinities are somewhat low. This is because carbonate minerals are scarce in rock underlying the county; some carbonate minerals are present in glacial till in the northern part of the county. Median alkalinity concentrations for water from aquifers in Wisconsin range from about 160 to 260 mg/L (Kammerer, 1981). This compares with median alkalinity concentrations of 34 to 102 mg/L in aquifers in Wood County. In some instances, the combination of low pH, alkalinity, and low hardness can cause the water to be corrosive and to dissolve copper pipes in water systems.

## GENERAL WATER-QUALITY PROBLEMS

Elevated concentrations of several constituents listed in table 2 can cause, or are indicators of, water-quality problems. Elevated concentrations of iron and manganese and hard water are aesthetic nuisances but are not harmful to health. Elevated chloride concentration is not a serious health problem by itself, but may indicate more serious ground-water contamination problems. Nitrate, like chloride, also is an indicator of possible contamination. However, unlike chloride, elevated concentrations of nitrate can cause health problems for very young children.

These four constituents plus barium, fluoride, sulfate, and dissolved solids are included in the list of constituents under Wisconsin's State drinking-water standards (Wisconsin Department of Natural Resources, 1978) shown in table 3. Elevated concentrations of constituents shown in table 3 can limit the use of the water. Primary standards represent minimum standards for protection of health and secondary standards are established for aesthetic reasons that do not affect health.

*Hardness.*—A common ground-water-quality problem in Wood County is hard water. Hardness is caused by the presence of calcium and magnesium, which are two of the major dissolved constituents in

**Table 2**—*Summary of chemical analyses of ground water in Wood County, by aquifer—Continued*

[All units are in milligrams per liter unless otherwise indicated; μS/cm, microsiemens per centimeter; μg/L, micrograms per liter; a dash indicates data unavailable]

*Cambrian sandstone and Precambrian aquifer (well open to both units)*

| Constituent | Number of wells | Maximum concentration | Percentage of wells where indicated value was equaled or exceeded: 25 | 50 (median) | 75 | Minimum concentration |
|---|---|---|---|---|---|---|
| Temperature (°C) | 10 | 17.5 | 13.0 | 11.0 | 10.5 | 10.0 |
| Specific conductance (μS/cm @ 25 °C) | 10 | 538 | 232 | 130 | 83 | 50 |
| pH (units) | 10 | 7.3 | 6.8 | 6.5 | 5.8 | 5.4 |
| Alkalinity as $CaCO_3$ | 10 | 279 | 97 | 34 | 24 | 5 |
| Hardness as $CaCO_3$ | 10 | 270 | 112 | 47 | 26 | 18 |
| Noncarbonate hardness as $CaCO_3$ | 10 | 31 | 19 | 6 | 0 | 0 |
| Calcium, dissolved | 10 | 69 | 29.2 | 10.5 | 6.8 | 4 |
| Magnesium, dissolved | 10 | 23 | 10.5 | 4 | 2 | 2 |
| Sodium, dissolved | 2 | 5.6 | -- | -- | -- | 1 |
| Potassium, dissolved | 2 | 2.9 | -- | -- | -- | 1.6 |
| Chloride, dissolved | 10 | 8.7 | 4 | 2.6 | 1 | .6 |
| Sulfate, dissolved | 2 | 4.7 | -- | -- | -- | 4.3 |
| Fluoride, dissolved | 2 | <.1 | -- | -- | -- | <.1 |
| Silica, dissolved as $SiO_2$ | 2 | 16 | -- | -- | -- | 13 |
| Dissolved solids (residue @ 180 °C) | 10 | 365 | 154 | 84 | 51 | 28 |
| Nitrate, dissolved as N | 10 | 7.5 | 3 | 1.6 | .1 | <.1 |
| Ammonia, dissolved as N | 2 | .02 | -- | -- | -- | <.01 |
| Phosphorus, dissolved as P | 2 | .02 | -- | -- | -- | .02 |
| Iron, dissolved (μg/l) | 10 | 6,000 | 2,225 | 56 | 10 | 4 |
| Manganese, dissolved (μg/l) | 2 | 200 | -- | -- | -- | 43 |
| Strontium, dissolved | 2 | 160 | -- | -- | -- | 36 |
| Barium, dissolved | 2 | 66 | -- | -- | -- | 24 |

ground water in Wood County. Hard water forms hard scales and other insoluble residues that build up in plumbing and can cause deterioration of plumbing and appliances.

The U.S. Geological Survey uses the following classification scheme to evaluate and compare hardness of water from different sources (Durfor and Becker, 1964, p. 27). This classification is:

0–60 mg/L as $CaCO_3$—soft
greater than 60–120 mg/L as $CaCO_3$—moderately hard
greater than 120–180 mg/L as $CaCO_3$—hard
greater than 180 mg/L as $CaCO_3$—very hard

Hardness values ranged from 1 to 390 mg/L with a median value of 110 mg/L. Twenty-nine of the 122 samples (24 percent) analyzed for hardness had concentrations less than 60 mg/L thus classifying them as soft and 24 (20 percent) had concentrations greater than 180 mg/L.

Hardness differs by aquifer and areally throughout the county. This is indicated by comparing the hardness values by aquifer (table 2). The median hardness in water from wells finished in Precambrian rock is about twice that in the sand-and-gravel and sandstone aquifers. Therefore, ground water tends to be hardest in the northern parts of the county where almost all wells are finished in Precambrian rocks and softest in southern parts of the county where most wells are finished in sand and gravel. Lower hardness in ground water in southern parts of the county corresponds to generally lower concentrations of calcium and magnesium in the sand-and-gravel aquifer (table 2).

*Iron and manganese.*—Elevated concentrations of iron and manganese in ground water impart an objectionable taste to the water and cause staining of laundry and plumbing fixtures. Elevated iron and manganese concentrations pose no known health hazard. However, recommended maximum concentra-

**Table 2**—*Summary of chemical analyses of ground water in Wood County, by aquifer—Continued*

[All units are in milligrams per liter unless otherwise indicated; μS/cm, microsiemens per centimeter; μg/L, micrograms per liter; a dash indicates data unavailable]

| | | *Sand-and-gravel aquifer* | | | | |
|---|---|---|---|---|---|---|
| | | | Percentage of wells where indicated value was equaled or exceeded | | | |
| Constituent | Number of wells | Maximum concentration | 25 | 50 (median) | 75 | Minimum concentration |
| Temperature (°C) | 9 | 15.0 | 12.5 | 11.5 | 10.0 | 10.0 |
| Specific conductance (μS/cm @ 25 °C) | 9 | 725 | 258 | 165 | 120 | 105 |
| pH (units) | 9 | 8.2 | 7.7 | 6.5 | 6.4 | 5.9 |
| Alkalinity as $CaCO_3$ | 9 | 113 | 64 | 47 | 37 | 22 |
| Hardness as $CaCO_3$ | 8 | 190 | 104 | 58 | 48 | 33 |
| Noncarbonate hardness as $CaCO_3$ | 8 | 140 | 20 | 10 | 7 | 4 |
| Calcium, dissolved | 9 | 45 | 20 | 13 | 9 | .1 |
| Magnesium, dissolved | 9 | 19 | 9 | 6 | 4 | 1 |
| Sodium, dissolved | 2 | 39 | -- | -- | -- | 1.4 |
| Potassium, dissolved | 2 | .5 | -- | -- | -- | .2 |
| Chloride, dissolved | 9 | 120 | 20 | 4.2 | 1.6 | .8 |
| Sulfate, dissolved | 2 | 12 | -- | -- | -- | 8.2 |
| Fluoride, dissolved | 2 | <.1 | -- | -- | -- | <.1 |
| Silica, dissolved as $SiO_2$ | 2 | 16 | -- | -- | -- | 8.8 |
| Dissolved solids (residue @ 180 °C) | 9 | 494 | 172 | 108 | 77 | 66 |
| Nitrate, dissolved as N | 9 | 14 | 2.8 | .5 | <.1 | <.1 |
| Ammonia, dissolved as N | 2 | <.01 | -- | -- | -- | <.01 |
| Phosphorus, dissolved as P | 2 | .06 | -- | -- | -- | .04 |
| Iron, dissolved (μg/l) | 9 | 6,000 | 2,065 | 150 | 40 | 25 |
| Manganese, dissolved (μg/l) | 2 | 4 | -- | -- | -- | <1 |
| Strontium, dissolved (μg/l) | 2 | 16 | -- | -- | -- | <.5 |
| Barium, dissolved (μg/l) | 2 | 17 | -- | -- | -- | 11 |

tions of 300 μg/L (micrograms per liter) (0.3 mg/L) for iron and 50 μg/L for manganese are included in State drinking-water standards (table 3) because of taste and staining problems.

There is a wide range of iron and manganese concentrations in ground water in all aquifers in Wood County. Iron concentrations ranged from 4 to 25,000 μg/L in water from wells sampled during this study. Iron concentrations in 54 of 124 samples exceeded 300 μg/L; the median concentration was 150 μg/L. Forty-seven of these 54 samples with concentrations greater than 300 μg/L were from Precambrian aquifer wells. The median concentration of iron in samples from the Precambrian aquifer also was significantly higher than that in the other aquifers (table 2). Manganese concentrations ranged from less than 1 to 1,000 μg/L in water from 16 wells sampled during this study; the median concentration was 44 μg/L. Manganese concentrations exceeded the State drinking-water standard of 50 μg/L in 7 of the 16 samples. All seven samples with elevated manganese concentrations were from wells finished in the Precambrian aquifer. Kammerer (1984) also found that wide ranges of iron and manganese concentrations are present in all

**Table 3**—*Summary of Wisconsin's drinking-water standards*[1]

[All concentrations in milligrams per liter; micrograms per liter in parentheses unless otherwise indicated; a dash indicates data unavailable]

| Constituent | Maximim recommended level: Primary (health) standard | | Secondary (aesthetic) standard | |
|---|---|---|---|---|
| Inorganic chemicals: | | | | |
| Arsenic | 0.05 | (50) | | |
| Barium | 1 | (1,000) | | |
| Cadmium | .01 | (10) | | |
| Chromium | .05 | (50) | | |
| Fluoride | 2.2 | -- | | |
| Lead | .05 | (50) | | |
| Mercury | .002 | (2) | | |
| Nitrate (as N) | 10 | -- | | |
| Selenium | .01 | (10) | | |
| Silver | .05 | (50) | | |
| Chloride | | | 250 | |
| Color | | | 15 units | |
| Foaming agents (MBAS) | | | .5 | |
| Hydrogen sulfide | | | not detectable | |
| Iron | | | .3 | (300) |
| Manganese | | | .05 | (50) |
| Odor | | | 3 threshold number | |
| Sulfate | | | 250 | |
| Total residue | | | 500 | |
| Zinc | | | 5 | (5,000) |
| Organic chemicals: | | | | |
| Chlorinated hydrocarbons | | | | |
| Endrin | .0002 | (.2) | | |
| Lindane | .004 | (4) | | |
| Methoxychlor | .1 | (100) | | |
| Toxaphene | .005 | (5) | | |
| Chlorophenoxy herbicides | | | | |
| 2,4-D | .1 | (100) | | |
| 2,4,5-TP (Silvex) | .01 | (10) | | |

[1]From Wisconsin Department of Natural Resources, 1978.

aquifers in Wisconsin. His statewide summary shows that concentrations of both iron and manganese exceed the drinking-water standards in water from more than 25 percent of all wells from all aquifers in Wisconsin.

Elevated concentrations of iron and manganese are present in Wisconsin's rocks and soils. The amount of iron and manganese in ground water is governed by complex chemical and biological processes. Because of this, iron and manganese concentrations differ locally and are difficult to explain or predict.

*Chloride.*–The concentration of chloride in rocks and soil generally is low (Hem, 1970, p. 173) and its concentration in natural ground water in the Wood County area also is low. The Wisconsin Department of Natural Resources (1978) recommends that water with a chloride concentration greater than 250 mg/L not be used for drinking water. In previous summaries of ground-water quality in Wisconsin, Kammerer (1981) found that chloride concentrations exceeded 18 mg/L only in 10 percent of 819 samples from sand-and-gravel wells throughout the State. Kammerer found that concentrations exceeded 22 mg/L in 10 percent of 1,164 wells finished in Cambrian sandstone and exceeded 33 mg/L in 10 percent of 43 wells finished in Precambrian rocks in northern Wisconsin.

Chloride concentrations in well water sampled during this study ranged from 0.3 to 200 mg/L with a median of 7.6 mg/L (table 2). Thirty percent of all samples had concentrations greater than 22 mg/L, and 15 samples had chloride concentrations of 50 mg/L or greater. The median concentration of chloride in water from wells finished in Precambrian rocks was somewhat higher than in water from wells finished in the other aquifers (table 2).

Chloride concentrations greater than 50 mg/L in Wood County ground water may indicate ground-water contamination from road salt or human or animal waste. This value, though somewhat arbitrary, is significantly higher (about six times higher) than the median value found in this study. It is also about twice as high as values exceeded by only 10 percent of all existing ground-water analyses in the State as determined by Kammerer.

*Nitrate.*—Natural and human activities can increase nitrate concentrations in ground water. Nitrate can be introduced into the soil naturally from plant decay. However, elevated nitrate concentrations generally are caused by contamination from animal-waste disposal, septic systems, and from nitrogen fertilizer applied to agricultural fields. Rural areas and unsewered subdivisions are therefore most likely to have elevated concentrations of nitrate in ground water.

The State drinking-water standard for nitrate is 10 mg/L as nitrogen (table 3). Like chloride, elevated concentrations of nitrate may indicate the presence of other contaminants from such sources as septic systems, barnyards, or other animal-waste disposal sites.

Nitrate concentrations in Wood County ground water are low. Nitrate concentrations in samples collected during this study ranged from less than 0.1 to 33 mg/L (table 2). The median concentration was 0.11 mg/L. Only four samples had a nitrate concentration that exceeded the State drinking-water standard of 10 mg/L.

Twenty-seven samples or 22 percent of the total of 124 samples collected had a nitrate concentration greater than 3.0 mg/L. This 3.0 mg/L value is significant because an evaluation of nitrate concentrations in ground water throughout the country has indicated that concentrations of nitrate at or above 3.0 mg/L may result from human acticities. Wells that yield water with nitrate concentrations greater than 3.0 mg/L are scattered throughout Wood County. There is a slightly greater number of these wells in the northern and north-central parts of the county. This is indicated by the median nitrate concentrations in T. 25 N. in table 4. Precambrian bedrock, which is the principal aquifer, is at or near land surface in much of this area. Vertical fractures in this shallow rock likely provide direct conduits for agricultural runoff and septic-system leachate to enter the aquifer.

Well-casing depth has been correlated with the amount of nitrate or other contaminants in ground water in some areas. In a study of ground-water quality in Barron County, Wis., Zaporozec (1986) found that 17 of 22 wells that had water with nitrate concentrations greater than 10 mg/L had much shallower well casings then the average well in the area. Nitrate, like many contaminants, enters the ground water from the surface. For this reason, drilling and casing wells to depths below the zone of nitrate contamination is a common practice in areas where nitrate or other contaminants are widespread in shallow ground water. Nitrate data were compared against well and casing depth. No statistical correlation was found between nitrate data and well depth or casing depth. This lack of correlation may be related to the small range of casing depths of wells sampled during this study. Eighty percent of the wells sampled were cased at depths of 30 to 55 ft below land surface.

Table 4 is a summary, by township, of several chemical constituents that are indicators of water-quality problems. The table indicates that dissolved-solids concentrations are somewhat greater in northern townships than in southern townships. Iron concentrations have a wide range of values within most townships but there appears to be an overall higher iron concentration in ground water in the southern area of the county. Nitrate concentrations and hardness differ considerably within individual townships but are somewhat higher in northern parts of the county.

## WATER-QUALITY DATA FROM OTHER SOURCES

More than 350 domestic-well owners submitted samples of their well water as part of a ground-water education program by the University of Wisconsin at Stevens Point and the University of Wisconsin-Extension program in 1984 and 1985. Samples were analyzed at the University of Wisconsin at Stevens Point Environmental Task Force Lab for hardness, nitrate, chloride, sulfate, and specific conductance as indicators of general water-quality problems. Results of these analyses are summarized, by township and range, in table 5 (Byron Shaw, University of Wisconsin at Stevens Point, written commun., 1986). Sampling sites are concentrated in the southeastern and northeastern parts of the county; about 75 percent of all sites are located in T. 21 N., R. 5 E. and T. 22 N., R. 6 E. Locations of sampling sites are shown

**Table 4**—*Summary of water-quality data, by township and range, collected by the U.S. Geological Survey*

[Twn, township; Rng, range; µg/L, micrograms per liter; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celcius; a dash indicates data unavailable]

| | | | Well depth (feet) | | Specific conductance (µS/cm) | | Iron (µg/L) | | Chloride (mg/L) | | Nitrate (mg/L) | | Hardness as $CaCO_3$ (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Twn N. | Rng E. | Number of analyses | range | median | range | median | range | median | range | median | range | median | range | median |
| 21 | 2 | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 21 | 3 | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 21 | 4 | 1 | 58 | 58 | 140 | 140 | 930 | 930 | 1.3 | 1.3 | 0.72 | .72 | 52 | 52 |
| 21 | 5 | 5 | 57-300 | 72 | 130-430 | 225 | 27- 6,000 | 840 | 1.9- 28 | 3.9 | <.1 | .15 | 58-170 | 110 |
| 21 | 6 | 1 | 45 | 45 | 105 | 105 | 53 | 53 | .8 | .8 | .49 | .49 | 7 | 7 |
| 22 | 2 | 3 | 40-220 | 44 | 30-390 | 102 | 17- 9,000 | 150 | 1.4- 62 | 2.8 | <.1-1.8 | .11 | 19- 36 | 31 |
| 22 | 3 | 4 | 68-160 | 78 | 169-230 | 178 | 18- 5,500 | 3,350 | 2.1- 9.8 | 6.7 | <.1-7.5 | <.1 | 55- 97 | 66 |
| 22 | 4 | 9 | 35-420 | 85 | 75-690 | 305 | 14- 5,100 | 1,600 | 1.2-200 | 5.8 | <.1-3.8 | <.1 | 15-220 | 140 |
| 22 | 5 | 6 | 58-83 | 75 | 78-350 | 185 | 83- 5,500 | 2,500 | .8- 24 | 3.4 | <.1-3.5 | .08 | 26-140 | 81 |
| 22 | 6 | 5 | 46-128 | 55 | 110-425 | 220 | 100- 3,200 | 2,200 | 4.2- 47 | 10 | <.1-4.5 | <.1 | 33-180 | 74 |
| 23 | 2 | 6 | 60-188 | 89 | 103-480 | 295 | 6- 3,800 | 270 | 2.4- 26 | 9 | <.1-2.9 | <.1 | 34-200 | 110 |
| 23 | 3 | 6 | 62-143 | 79 | 109-413 | 252 | 9- 8,400 | 2,450 | 1.0- 29 | 8.3 | <.1-.53 | <.1 | 29-170 | 104 |
| 23 | 4 | 6 | 40-325 | 70 | 55-825 | 440 | 9- 5,300 | 41 | 1.4-120 | 32 | <.1- 33 | .73 | 13-370 | 130 |
| 23 | 5 | 7 | 41-194 | 110 | 100-620 | 370 | 29-18,000 | 720 | 1.2- 82 | 29 | <.1- 2.8 | <.1 | 36-240 | 160 |
| 23 | 6 | 8 | 67-206 | 103 | 50-620 | 335 | 33-25,000 | 1,235 | .9-130 | 17 | <.1- 1.9 | <.1 | 13-200 | 114 |
| 24 | 2 | 9 | 52-150 | 80 | 50-295 | 203 | 7- 1,300 | 50 | .3- 4.3 | 1.8 | <.1- 6 | .19 | 18-120 | 79 |
| 24 | 3 | 9 | 63-300 | 98 | 142-410 | 236 | 6- 3,300 | 60 | .5- 17 | 2.6 | <.1- 4.5 | <.1 | 1-200 | 95 |
| 24 | 4 | 7 | 60-353 | 220 | 145-475 | 340 | 21-13,000 | 120 | 4.3- 70 | 26 | <.1- 7.4 | .11 | 39-190 | 120 |
| 24 | 5 | 6 | 70-130 | 89 | 195-510 | 378 | 820- 5,500 | 1,650 | 1.3- 66 | 20 | <.1- <.1 | <.1 | 83-230 | 145 |
| 25 | 2 | 6 | 67-156 | 82 | 85-480 | 383 | 4- 1,100 | 12 | 1.1- 40 | 4 | <.1- 8.1 | 2.7 | 24-240 | 165 |
| 25 | 3 | 6 | 60-100 | 76 | 185-548 | 514 | 6- 6,000 | 41 | 2.3-120 | 6.3 | <.1- 5.6 | 2.4 | 71-270 | 220 |
| 25 | 4 | 7 | 68-360 | 104 | 260-445 | 340 | 5- 96 | 14 | 7.8- 52 | 17 | 1.5- 6.1 | 3.3 | 110-220 | 140 |
| 25 | 5 | 7 | 85-290 | 103 | 260-775 | 375 | 9 - 47 | 21 | 13 - 50 | 27 | .84-17 | 6.8 | 110-390 | 140 |
| All wells | | 124 | 35-420 | 86 | 30-825 | 280 | 4-25,000 | 150 | .3-200 | 7.65 | <.1 -33 | .11 | 1-390 | 110 |

on plate 2. Much of this southeastern area consists of unsewered subdivisions where each home has its own water well finished in shallow sand and gravel deposits. Almost all irrigated agricultural fields in Wood County also are located in this area.

The overall results of this sampling program are similar to those from this project in areas where data from both programs are sufficient to permit comparison. Table 5 shows higher specific conductance (related to total dissolved solids) in the northern townships, as shown in table 4. The ranges of hardness, chloride, and nitrate concentrations and median values of these constituents also are similar. Median chloride and hardness concentrations are greater in the northern townships than in the southern townships. Median nitrate concentrations tend to be slightly higher than data in table 4. This may be explained by the large number of samples collected from wells finished in shallow sand and gravel located in southeastern areas of the county where there is a high density of individual septic systems. Nitrate concentrations exceeded 3.0 mg/L in 56 of 172 wells (32 percent) and exceeded the State drinking-water standard of 10.0 mg/L in 7 wells (4 percent) in T. 22 N., R. 6 E. Chloride concentrations exceeded 50 mg/L in only 11 of 172 wells (6 percent) sampled in this township. Nitrate concentrations exceeded 3.0 mg/L in 16 of 76 wells (21 percent) and exceeded 10.0 mg/L in 11 wells (14 percent) in T. 21 N., R. 5 E. Chloride exceeded 50 mg/L in just 1 well sampled in this township.

Samples were also collected from 68 wells in 4 rural northeastern townships (locations shown on plate 2). This group represents wells in rural agricultural areas where water quality can be affected by feedlot runoff, fertilizer application, or septic-system leachate that reaches the water table. Nitrate concentrations exceeded 3.0 mg/L in 35 of 68 wells (51 percent) and exceeded the State drinking-water standard of 10 mg/L in 10 wells (15 percent). Chloride concentrations exceeded 50 mg/L in 15 wells (22 percent) in this area.

The Wisconsin Department of Natural Resources has been sampling wells throughout the State for VOCs and pesticides since 1980. A total of 138 wells in Wood County have been sampled for 46 different VOCs and 10 different pesticides (Al Lulloff, Wisconsin Department of Natural Resources, written commun., 1987). Private wells were selected where contamination was suspected to occur. All municipal-supply wells were sampled. Sampled wells that could be accurately located with the location information provided are plotted on plate 2. Samples were analyzed for pesticides primarily in wells near irrigated cropland in the southeastern part of the county (pl. 2). Likely sources of VOCs include leaking underground gasoline storage tanks, landfills, and chemical-storage facilities. Therefore, VOC-sampling sites were concentrated in southeastern Wood County in areas where most potential sources are present.

A total of 36 wells were sampled for pesticides. The pesticide aldicarb was the only pesticide detected in wells sampled for pesticides. All seven wells with detected aldicarb are located in T. 21 N., R. 5 E. in areas near irrigated potato fields (pl. 2).

Water samples from 102 wells in Wood County have been analyzed for VOCs. Water from 11 wells

**Table 5**—*Summary of water-quality data, by township and range, collected by the University of Wisconsin-Stevens Point and the University of Wisconsin-Extension*

[Twn, township; Rng, range; μg/L, micrograms per liter; mg/L, milligrams per liter; μS/cm, microsiemens per centimeter at 25 degrees Celcius; a dash indicates data unavailable]

| Twn N. | Rng E. | Number of samples | Well depth (feet) range | Well depth (feet) median | Specific conductance (μS/cm at 25°) range | Specific conductance (μS/cm at 25°) median | Iron (μg/L) range | Iron (μg/L) median | Chloride (mg/L) range | Chloride (mg/L) median | Nitrate (mg/L) range | Nitrate (mg/L) median | Hardness as $CaCO_3$ (mg/L) range | Hardness as $CaCO_3$ (mg/L) median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 4 | 9 | 15-46 (8) | 20 | 43- 146 | 128 | -- | | <1- 8.8 | 3.1 | <0.2- 4 | <0.2 | <1- 72 | 24 |
| 21 | 5 | 76 | 4.0-90 (50) | 28 | 35- 452 | 135 | -- | | <1- 70.5 | 6.4 | <.2-31.5 | 1 | 0-160 | 34 |
| 21 | 6 | 3 | 14 (1) | 14 | 142- 251 | 212 | -- | | 8- 28 | 13 | 9 -11 | 10 | 32- 80 | 36 |
| 22 | 5 | 20 | 10-56 (13) | 24 | 45- 390 | 128 | -- | | 4- 78.9 | 9 | <.2- 6.5 | .4 | 4- 92 | 24 |
| 22 | 6 | 172 | 10-80 (113) | 24 | 42- 966 | 122 | -- | | <1-247 | 10 | <.2-32.5 | 1.5 | <2-208 | 40 |
| 23 | 5 | 1 | -- | -- | 263 | 263 | -- | | 27 | 27 | 8.8 | 8.8 | 112 | 112 |
| 23 | 6 | 6 | 15-20 (2) | 17.5 | 149- 352 | 196 | -- | | 7- 18 (5) | 10 | <.2-18.8 | 1.1 | 1.0-136 | 84 |
| 24 | 4 | 28 | 12-263 (21) | 80 | 136- 601 | 316 | 0 -46 | 9.0 | 2.2-142 | 18.6 | <.2-15.5 | 1.5 | <.1-441 | 115 |
| 24 | 5 | 21 | 28-175 (18) | 60 | 107- 589 | 388 | 1 -24.5 | 10 | 4.4-104 | 29.9 | <.2-25 | 4.0 | <.1-214 | 141 |
| 25 | 4 | 6 | 43-110 (5) | 100 | 176- 719 | 390 | 12 -43 | 28 | 12.6-43.5 | 17.6 | 1 -17.5 | 4.1 | <.1-382 | 135 |
| 25 | 5 | 13 | 28-100 (11) | 63 | 251-1,258 | 548 | 2.5-38.5 | 1 | 2.7-203 | 33.8 | <.2-11.5 | 2.0 | <.1-616 | 224 |

had detectable amounts of at least one type of compound; these wells were resampled. Water from some wells contained detectable concentrations of VOCs in second samplings but others did not. A total of 46 different compounds were included in these analyses. However, only 16 of these 46 were ever detected in any single well. Benzene was the most commonly detected compound; it was detected in nine wells. Xylene was detected in eight wells and toluene was detected in seven wells. Seven of the 11 wells with detected VOCs are located in T. 22 N., R. 6 E. in residential and commercial areas where potential sources are common. Only sampling sites with accurate location information are plotted on plate 2.

Actual results of pesticide and VOC analyses are not included in this report. However, these data are summarized in three publications by the Wisconsin Department of Natural Resources (1985, 1986, and 1987).

### WATER QUALITY NEAR ABANDONED LANDFILLS

Changes in ground-water quality caused by leachate from landfills has become a major concern for well owners. Leachate is formed by percolation of water through waste in landfills. If the leachate reaches underlying aquifers, it can adversely affect the quality of the ground water.

The characteristics of underlying rocks and unconsolidated material influence the movement of the leachate away from a landfill. The presence of low-permeability materials, such as clay deposits, and a thick unsaturated zone that separates the landfill from underlying aquifers typically impedes the migration of leachate from landfill sites. Sorption of chemical compounds in the leachate onto soil particles or degradation of these compounds can impede leachate migration. Biological decay is a natural process that can limit or prevent the movement of leachate to the water table. Coarse-grained material such as sand and gravel or fractured bedrock and a shallow water table are factors that allow leachate to move down to the water table with little opportunity for degradation or removal of the contaminants.

Locations of landfills and sludge lagoons have been identified in Wood County (pl. 2). The majority (29) of these landfills formerly received domestic refuse from farm and village residences within the individual townships in which the landfills are located. Several received construction and demolition materials, and others contain unspecified wastes from the cranberry and paper industries.

A reconnaissance approach was used to study seven landfills that received domestic waste. Each landfill site covers an area of about 1 to 2 acres. The locations of these landfills are shown on plate 2. The objectives of studying these sites were to determine, by the use of water-quality indicators and electromagnetic surveys, if landfill leachate presently is affecting the chemical quality of shallow ground water in the immediate vicinity of each site and to evaluate the method of study. The use of electromagnetic surveys also was chosen to determine their utility as a cost-effective way of identifying contaminated ground water.

Electomagnetic surveys were first conducted at each site. These surveys were used as reconnaissance tools to select the most favorable sites for water-quality observation wells. This procedure measures the apparent ability of the underlying mixture of earth material and ground water to transmit an electrical signal. If it is assumed that the earth material is homogeneous over a relatively small area, any changes in the apparent electrical conductivity are then attributable to the electrical conductance of the ground water, which, in turn, is related to the amount of dissolved solids present in the ground water. It was assumed that increased dissolved-solids concentrations (as indicated by increased electrical-conductivity measurements) would likely be the result of leachate contribution to ground water. Observation wells were installed on the perimeter of each landfill at locations where high electromagnetic readings indicated that ground water might be affected by leachate. A single observation well also was installed near each site where electromagnetic data indicated that ambient (background) water-quality conditions prevailed; that is, ground water did not appear to be affected by leachate.

As many as four observation wells were installed around the perimeter of each landfill site. The number of wells at any site was determined by electromagnetic data and also by the access to each site. A total of 20 water-quality observation wells (pl. 2) were installed at the 7 landfill sites.

Water samples were collected once from each of the 20 observation wells for chemical analysis of constituents that might indicate the presence of leachate in ground water. Samples were analyzed for the same chemical constituents and water-quality indicators that were analyzed for in samples from domestic wells in the county (tables 2, 4, and 5). Each sample was also analyzed for chemical oxygen demand, total organic carbon, and for the presence of VOCs. The results of these analyses are shown in table 6. The first well listed in table 6 for each of the seven landfill sites was selected, prior to sampling, to be representative of background water quality in the immediate area of the landfill. This selection was based on direction of ground-water flow in the vicinity of the landfill and on results of the electromagnetic survey at each site. Other wells were located where electromagnetic-survey data indicated that ground water might be affected by leachate from the landfill.

Results of water analyses varied by site. At some sites, there were apparent differences in ground-water quality at wells that monitored background water quality and wells that were affected by leachate. At other sites, differences were unclear or not apparent. The first three sites listed in table 6 are located in the southern part of the county where the total dissolved-solids concentration in natural ground water is relatively low (generally less than 200 mg/L). The dissolved-solids concentrations in samples from wells considered to have background water quality were less than 100 mg/L at each of these sites. Total dissolved-solids concentrations in samples considered to be representative of background water quality generally were similar to dissolved-solids concentrations in ground water in the northern part of the county. In general, the concentrations of constituents in samples from background water-quality wells compared closely with data from domestic wells sampled in the same area of the county (tables 2, 4, and 5). However, samples from wells considered to represent background water quality apparently do not reflect background water quality at sites 4 and 5. At site 4, concentrations of chloride and manganese were considerably higher than the medians for the county, and the VOC concentration of 790 μg/L was more than 10 times what might be considered background. At site 5, the "background" sample had concentrations of VOCs, sulfate, and chloride considerably higher than expected. Analyses of water from sites 1, 2, and 3 showed higher concentrations of several constituents than background concentrations (table 6). The highest VOC concentration (1,300 μg/L) occurred in a sample from a well at site 3; a sample from a well at site 2 had an iron concentration of 37,000 μg/L. All 3 samples from site 5 had VOC concentrations at or above 100 μg/L. The sample from well Wd–1255 at site 5 had a dissolved-solids concentration of 2,920 mg/L. Water from this well had concentrations of several constituents that were considerably higher than those at any other well sampled in this study. Samples from three wells at site 7 showed some indication that they were affected by leachate. Elevated concentrations of manganese, VOC, and chemical oxygen demand were present in water from all three wells at this site.

In summary, samples from sites 1 and 6 do not show definite evidence of leachate in observation wells. Samples from at least one well at each of the other 5 sites show some indication that leachate has affected the water quality. The objective of this reconnaissance approach was to determine, in a cost-effective way, whether leachate affects shallow ground-water quality in the immediate vicinity of these landfills. Results indicate that this approach, using electromagnetic data and a limited number of observation wells, was useful in identifying the presence of leachate in ground water at five of seven sites. It also provided a water-quality data base by which to compare any future data. Limitations to this approach are the low number of sampled wells and samples. Also, poor access hindered installation of wells near some sites. This approach does not determine how far or at what rate leachate has moved away from the individual site. More data are needed to determine the full extent and degree of leachate in ground water in the areas surrounding these landfills.

### Ground-Water Use

The average daily rate of ground-water pumpage in Wood County during 1985 was about 9.7 Mgal (million gallons) (table 7). This is equivalent to a total annual pumpage of slightly more than 3.5 billion gallons.

The cities of Wisconsin Rapids, Marshfield, Nekoosa, and Pittsville, and the villages of Biron, Port Edwards, and Vesper are served by public-supply systems. About 5.99 Mgal/d (million gallons per day) is pumped from wells serving these communities. About 5.8 Mgal/d of this 5.99 Mgal/d public-supply total is pumped from shallow wells finished in the sand-and-gravel aquifer. Public-supply use includes water used by schools, commercial, and industrial customers as well as residential customers within each community.

Private residential use includes domestic supplies in homes in subdivisions and rural farm homes. This pumpage estimate is based on an average of 50 gal/d per person. Water used for stock watering also is an estimate based on standard consumptive values for farm animals—for example, 20 gal/d for a dairy cow (Lawrence and Ellefson, 1982). An average of about 1.08 Mgal/d was pumped from wells in sand and gravel for agricultural irrigation (table 7). Ground water for irrigation is pumped primarily during the months of June, July, and August. Use of ground water by industries not served by municipal supplies is minor (0.01 Mgal/d).

Large amounts of surface water are diverted from the Wisconsin River in the southeastern part of the county for use in paper mills, hydroelectric power-generation facilities and for use in cranberry production. These uses are not included in figures in table 7.

**Table 6**—*Chemical analyses of water from wells at selected landfill sites in Wood County, 1986*

[All concentrations in milligrams per liter unless otherwise indicated; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than]

| Landfill location (township, range, section)[1] | Well identifier | Date sampled | Specific conductance (µS/cm) | pH (units) | Temperature | Chemical oxygen demand | Hardness | Noncarbonate hardness | Calcium | Magnesium |
|---|---|---|---|---|---|---|---|---|---|---|
| T. 22 N., R. 2 E., sec. 4 | Wd-1233 (background) | 6-19-86 | 165 | 6.7 | 12.0 | 24 | 60 | 1 | 13 | 6.7 |
| | Wd-1234 | 6-19-86 | 185 | 6.7 | 12.5 | 22 | 39 | 0 | 12 | 2.2 |
| T. 22 N., R. 5 E., sec. 8 | Wd-1249 (background) | 6-20-86 | 40 | 5.0 | 11.0 | <10 | 11 | 8 | 2.7 | 1.0 |
| | Wd-1250 | 6-20-86 | 950 | 6.6 | 15.0 | 74 | 380 | 52 | 110 | 26 |
| | Wd-1251 | 6-20-86 | 545 | 6.1 | 15.0 | 25 | 210 | 100 | 59 | 15 |
| T. 23 N., R. 2 E., sec. 22 | Wd-1236 (background) | 6-19-86 | 37 | 5.3 | 12.0 | 28 | 7 | 4 | 1.6 | .66 |
| | Wd-1237 | 6-19-86 | 270 | 5.8 | 13.5 | 26 | 41 | 22 | 9.5 | 4.3 |
| | Wd-1238 | 6-19-86 | 205 | 5.2 | 12.5 | 85 | 33 | 30 | 6.3 | 4.2 |
| T. 24 N., R. 3 E., sec. 14 | Wd-1239 | 6-18-86 | 585 | 5.7 | 11.5 | 27 | 180 | 160 | 34 | 23 |
| | Wd-1240 | 6-18-86 | 810 | 5.1 | 12.5 | -- | 150 | 130 | 27 | 19 |
| T. 24 N., R. 4 E., sec. 28 | Wd-1253 | 6-17-86 | 580 | 5.3 | 10.0 | 14 | 160 | 150 | 31 | 19 |
| | Wd-1254 | 6-17-86 | 230 | 5.8 | 11.0 | 110 | 52 | 46 | 12 | 5.4 |
| | Wd-1255 | 6-17-86 | 3,770 | 5.8 | 9.5 | 44 | 1,300 | 1,300 | 240 | 180 |
| T. 24 N., R. 5 E., sec. 21 | Wd-1242 | 6-16-86 | 315 | 5.2 | 13.0 | 24 | 150 | 140 | 27 | 20 |
| | Wd-1243 | 6-16-86 | 315 | 6.5 | 11.5 | 110 | 110 | 8 | 32 | 7.4 |
| | Wd-1244 | 6-16-86 | 130 | 4.9 | 12.5 | 32 | 45 | 39 | 8.6 | 5.6 |
| T. 25 N., R. 3 E., sec. 22 | Wd-1245 | 6-18-86 | 290 | 6.7 | 9.5 | 36 | 140 | 0 | 36 | 12 |
| | Wd-1246 | 6-18-86 | 680 | 7.2 | 11.0 | 210 | 180 | 0 | 45 | 16 |
| | Wd-1247 | 6-18-86 | 370 | 7.0 | 9.0 | 22 | 170 | 9 | 42 | 16 |
| | Wd-1248 | 6-18-86 | 225 | 7.1 | 11.0 | 390 | 92 | 0 | 23 | 8.5 |

**Table 6**—*Chemical analyses of water from wells at selected landfill sites in Wood County, 1986—Continued*

[All concentrations in milligrams per liter unless otherwise indicated; μS/cm, microsiemens per centimeter; μg/L, micrograms per liter; <, less than]

| Well identifier | Sodium | Potassium | Alkalinity | Sulfate | Chloride | Dissolved solids | Nitrate | Iron (μg/L) | Magnesium (μg/L) | Organic carbon | Volatile organic compounds, unspecified (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wd-1233 (background) | 2.7 | 2.8 | 59 | 9.5 | 1.7 | 85 | <0.10 | 550 | 120 | 5.6 | 32 |
| Wd-1234 | 1.2 | 2.6 | 41 | .7 | 1.1 | 80 | <.10 | 18,000 | 1,100 | 9.0 | 42 |
| Wd-1249 (background) | 1.0 | 1.3 | 3 | 12 | 1.1 | 31 | <.10 | 120 | 38 | 3.9 | 43 |
| Wd-1250 | 16 | 35 | 330 | 100 | 14 | 551 | <.10 | 37,000 | 710 | 25 | 210 |
| Wd-1251 | 10 | 17 | 106 | 130 | 9.7 | 314 | <.10 | 3,400 | 360 | 10 | 77 |
| Wd-1236 (background) | .6 | 1.4 | 3 | 9.2 | .7 | 25 | <.10 | 1,100 | 44 | 9.3 | 84 |
| Wd-1237 | 6.5 | 5.0 | 19 | 5.4 | 27 | 109 | <.10 | 4,600 | 130 | 18 | 1,300 |
| Wd-1238 | 12 | 4.0 | 3 | 8.0 | 38 | 111 | <.10 | 7,600 | 81 | 29 | — |
| Wd-1239 | 36 | 2.5 | 15 | 11 | 180 | 385 | <.10 | 4,700 | 1,500 | 6.5 | 790 |
| Wd-1240 | 88 | 15 | 15 | 55 | 220 | 506 | <.10 | 5,800 | 800 | 9.3 | -- |
| Wd-1253 | 26 | .9 | 10 | 130 | 59 | 293 | <.10 | 6,400 | 48 | 10 | 330 |
| Wd-1254 | 18 | 1.2 | 6 | 64 | 9.0 | 145 | .13 | 460 | 35 | 44 | 280 |
| Wd-1255 | 300 | 27 | 57 | 1,500 | 370 | 2,920 | <.10 | 5,100 | 4,100 | 48 | 100 |
| Wd-1242 | 16 | 2.1 | 6 | 170 | 9.9 | 287 | .14 | 83 | 330 | 10 | 64 |
| Wd-1243 | 6.1 | 4.5 | 102 | 28 | 9.1 | 161 | <.10 | 5,800 | 290 | 30 | 34 |
| Wd-1244 | 5.4 | 2.0 | 6 | 46 | 3.5 | 92 | .31 | 330 | 140 | 4.5 | 23 |
| Wd-1245 | 6.4 | 1.3 | 151 | 11 | 1.1 | 171 | <.10 | 45 | 290 | 23 | 45 |
| Wd-1246 | 8.5 | 3.3 | 204 | 3.4 | 1.4 | 215 | <.10 | 130 | 1,000 | -- | 350 |
| Wd-1247 | 7.2 | 2.6 | 162 | 8.5 | 13 | 222 | <.10 | 28 | 990 | 110 | 130 |
| Wd-1248 | 7.3 | 2.0 | 107 | 5.4 | 4.2 | 133 | <.10 | 150 | 1,000 | 42 | 60 |

[1]Landfill locations are shown on plate 2.

**Table 7**—*Ground-water pumpage by use, 1985*
[A dash indicates less than 1 percent of total]

| Use | Quantity used (millions of gallons per day) | Percentage of total pumpage |
|---|---|---|
| Public supply | 5.99 | 62 |
| Private residential | 1.63 | 17 |
| Irrigation | 1.08 | 11 |
| Stock watering | .99 | 10 |
| Private industrial | .01 | — |
| **Total** | 9.70 | 100 |

## SUMMARY


Precambrian rock, unconsolidated sand and gravel deposits, and Cambrian sandstone provide virtually all ground water used in Wood County. The extent and aquifer characteristics of these deposits were determined from drillers' well-construction data. Saturated thicknesses of permeable sand and gravel deposits adequate for water supply occur only in the southeastern part of the county and in an isolated area in the northwestern part of the county. These deposits are capable of yielding 500 gal/min or more in some areas. Residents in more than two-thirds of the county area depend on fractured or weathered Precambrian rock for ground-water supplies. However, limited amounts (generally less than 5 gal/min) of water generally are available from this rock; this causes a water-availability problem in much of the county.

The horizontal hydraulic conductivity of sand and gravel deposits in the southeastern part of the county averages about 210 ft/d; values range from about 0.02 to 2 ft/d in finer-grained tills in the northern two-thirds of the county. The effective horizontal hydraulic conductivity of Precambrian rocks ranged from 0.02 ft/d in deeper wells to about 11 ft/d in more weathered or fractured shallow Precambrian rocks.

Elevated hardness, iron, and manganese concentrations are the most common water-quality problems in the county. Ground water has relatively low alkalinity because of small amounts of carbonate minerals in rocks and unconsolidated deposits in the county.

Ground-water samples were analyzed for concentrations of chloride and nitrate as indicators of contamination resulting from septic systems, animal wastes and agricultural fertilizers. Only 4 of 124 samples contained nitrate in concentrations greater than the State drinking-water standard of 10 mg/L. Twenty-two percent of the samples had nitrate concentrations in the 3.0 to 10.0 mg/L range. This may indicate that some contamination is occurring. The median chloride concentration was 7.6 mg/L. Chloride concentrations in 15 of 124 samples exceeded 50 mg/L. Chloride concentrations above 50 mg/L also may indicate some contamination of ground water. No chloride value exceeded the 250 mg/L drinking-water standard of the State.

A reconnaissance approach using electromagnetic surveys to site water-quality observation wells was used to determine if ground water is affected by leachate near seven landfill sites. Ground-water samples from observation wells installed around the perimeters of these landfills showed that leachate from waste affects ground-water quality at five of the seven landfills. Dissolved solids, chloride, iron, manganese, sulfate, chemical-oxygen demand, total organic carbon, and volatile organic compounds were found in concentrations higher than probable background concentrations in samples from most observation wells. However, the full areal extent of leachate migration was not determined during this study.

The average daily ground-water pumpage in Wood County is about 9.7 Mgal. Public-supply wells in seven communities pump about 6.0 Mgal/d. Wells finished in sand and gravel deposits provide about 5.8 Mgal/d of this total. Agricultural irrigation wells finished in sand and gravel supply another 1.08 Mgal/d in southeastern parts of the county.


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