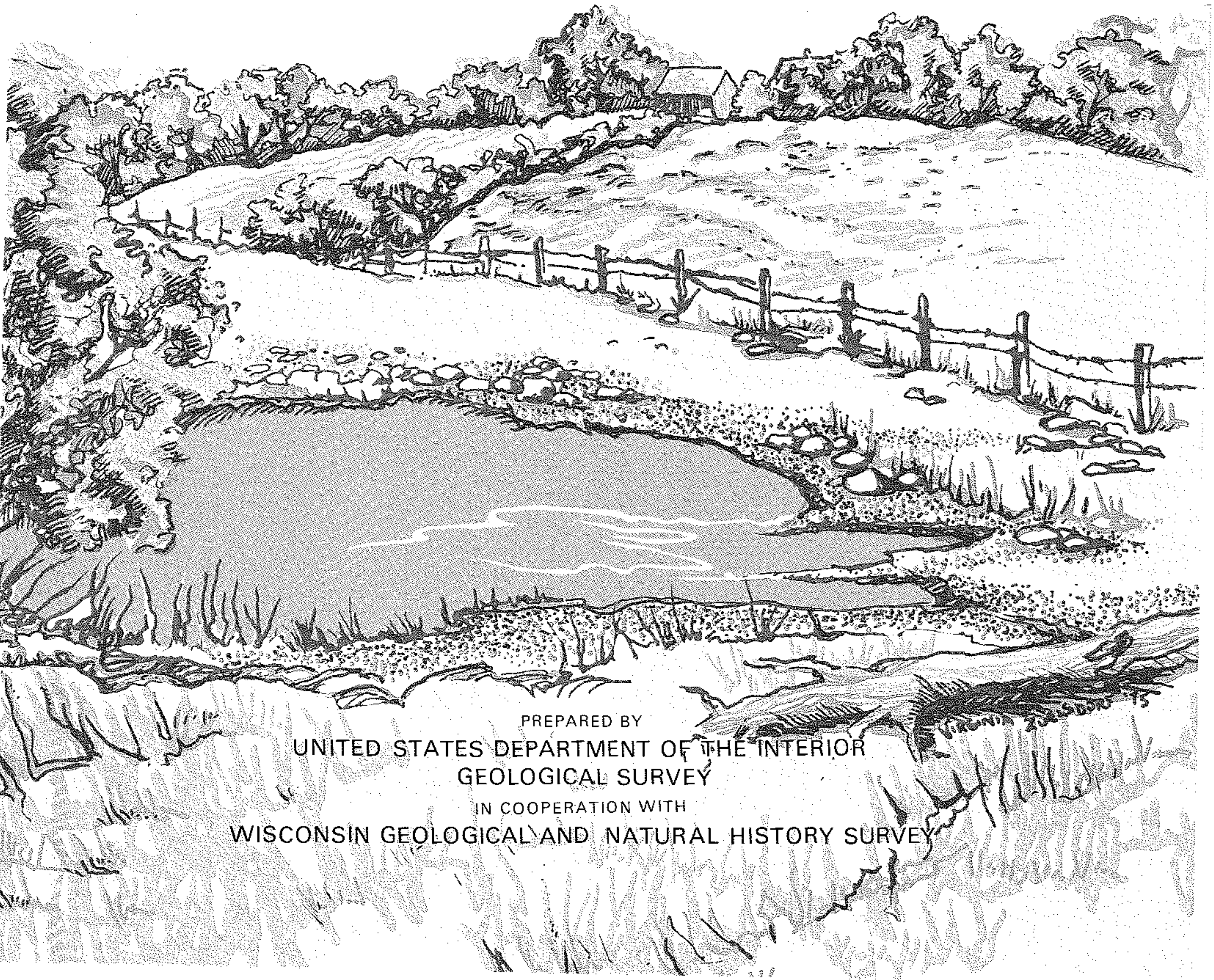
INFORMATION CIRCULAR
NUMBER 33
1975

UNIVERSITY OF WISCONSIN-EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY

Ground-Water Resources and Geology of Jefferson County, Wisconsin

by
R. G. Borman and L. C. Trotta
U.S. Geological Survey



PREPARED BY
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
IN COOPERATION WITH
WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

Ground-Water Resources and Geology of Jefferson County, Wisconsin

by
R. G. Borman and L. C. Trotta
U.S. Geological Survey

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

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

and

UNIVERSITY OF WISCONSIN–EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY
M. E. Ostrom, Director and State Geologist
Madison, Wisconsin
August 1976

Available from University of Wisconsin–Extension, Geological and Natural History Survey, 1815 University Avenue, Madison, Wisconsin 53706.

CONTENTS

ILLUSTRATIONS

Plate 1. Water-table map of Jefferson County, Wisconsin, 1973

TABLES

CONVERSION FACTORS

Multiply English units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
gallons per minute (gal/min)	.06309	liters per second (l/s)
million gallons per day (Mgal/d)	.04381	cubic meters per second (m^3/s)
feet per mile (ft/mi)	.1894	meters per kilometer (m/km)
gallons per day (gal/d)	3.785	liters per day (l/d)
feet per day (ft/d)	.3048	meters per day (m/d)

ABSTRACT

A steadily increasing population in Jefferson County, Wisconsin, is expanding the need for good-quality ground water. This need can be met by good-quality water available from the sand-and-gravel, Galena-Platteville, and sandstone aquifers. As much as 15 gallons per minute (0.95 liters per second) can be obtained from wells almost everywhere in the county. Yields of more than 1,000 gallons per minute (63 liters per second) are available from glacial drift where it contains a sufficient thickness of saturated sand and gravel. The Galena-Platteville aquifer is a dolomite that occurs mainly in the eastern one-half of the county and is locally more than 300 feet (90 meters) thick. Estimated well yields from this aquifer exceed 500 gallons per minute (32 liters per second). The sandstone aquifer underlies nearly the entire county except for small areas in the northwest corner. It is more than 1,100 feet (330 meters) thick in the southwest along the Dane-Jefferson County line. This aquifer is capable of yielding more than 1,000 gallons per minute (63 liters per second) to wells in much of the county and is the principal source of municipal water.

The chemical quality of water from the three aquifers is similar. The water is very hard, having a median hardness between 315 and 325 milligrams per liter. Median values for dissolved solids range between 325 and 349 milligrams per liter. Iron and manganese commonly are present in bothersome amounts (combined total exceeding 0.3 milligrams per liter.

About 13.0 million gallons per day (0.570 cubic meters per second) of ground water was pumped in the county in 1972, 87 percent from the sandstone aquifer. About 62 percent of the total water pumped was for industrial and commercial purposes, 26 percent for residential use, and 12 percent for municipal, irrigation, and institutional use.

INTRODUCTION

Jefferson County is in southeastern Wisconsin (fig. 1). Jefferson, the county seat, is approximately in the center of the county and is about 50 mi (80 km) west of Milwaukee and 40 mi (64 km) east of Madison. Jefferson County had a population growth of 19.9 percent from 1960 to 1970. Increasing population will require greater development of the water resources.

The purpose of this investigation is to describe the geology and the occurrence, movement, quality, and availability of ground water. It is intended as an information base to aid planning, development, and management of water supplies from the ground-water resources.

The scope of the project includes collection and analysis of ground-water samples, and well-log, water-level, water-use, pumpage, and aquifer-test data to describe the hydrology and geology of the county. The geology was studied only in enough detail to clarify the ground-water hydrology.

This study was a cooperative project between the U.S. Geological Survey and the University of Wisconsin-Extension, Geological and Natural History Survey.

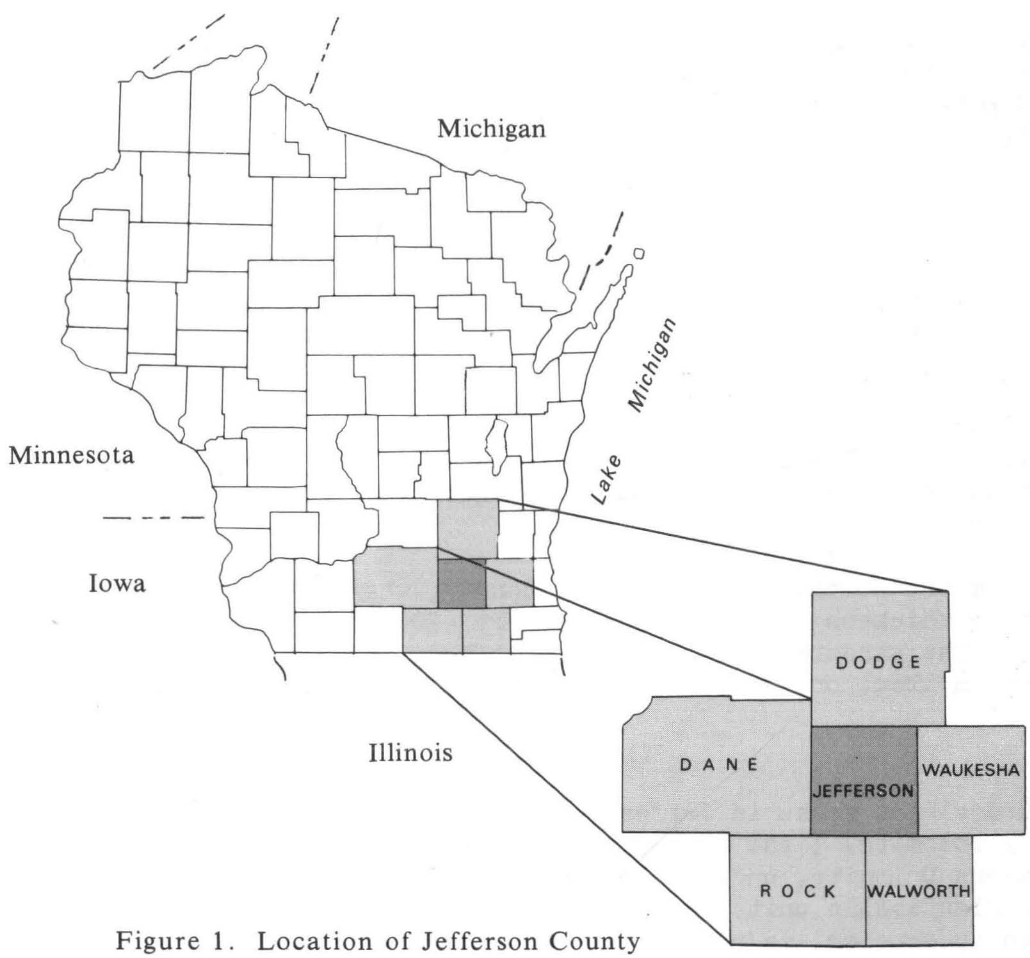


Figure 1. Location of Jefferson County in Wisconsin.

Thanks are given the many municipal and county officials, State agencies, drillers, and individual well owners who assisted this study by providing well and water information and to the many who allowed access to their wells for water-level measurement or for collecting water samples for chemical analysis. Special acknowledgment is made to the Wisconsin Department of Natural Resources for supplying well and pumpage records, to the Wisconsin State Laboratory of Hygiene for records of chemical analyses of ground water, and to the Wisconsin Public Service Commission for pumpage records.

GEOLOGY

The materials that control the movement and storage of ground water in Jefferson County range from the basement rocks of Precambrian age to the glacial deposits, alluvium, and soils of Pleistocene and Holocene ages. Bedrock is overlain by glacial drift in most of the county. The bedrock, from oldest to youngest, consists of Precambrian crystalline rock; Cambrian sandstone; and Ordovician dolomite, sandstone, and shale (table 1). Many of these rocks underlie only parts of the county.

PRECAMBRIAN ROCKS

Igneous and metamorphic rocks of Precambrian age underlie all of Jefferson County. They crop out more than 800 ft (240 m) above sea level in the northwest corner of the county and are less than 300 ft (90 m) below sea level (1,100 ft or 340 m below land surface) in the southwest corner of the county. The Precambrian rocks generally have low permeability and mark the lower limit of ground-water movement.

CAMBRIAN ROCKS

Cambrian rocks overlie the Precambrian rock and are present under the entire county except in two small areas in the northwest, where the Precambrian rocks are the uppermost bedrock unit. The Cambrian rocks are primarily sandstone but include some shale, siltstone, and dolomite. They consist of five formations, which are, from oldest to youngest: the Mount Simon, Eau Claire, Galesville, and Franconia Sandstones, and the Trempealeau Formation. In this report these formations are not differentiated, but are called the "Cambrian sandstone".

From the northwest part of the county, where it is absent, the Cambrian sandstone thickens to more than 1,000 ft (300 m) in the southwest corner of the county. The sandstone is the uppermost bedrock unit in deeply cut bedrock valleys in about one-fourth of the county, mostly in the western part (fig. 2).

ORDOVICIAN ROCKS

Ordovician rocks in Jefferson County include: the Prairie du Chien Group (mostly dolomite) ; the St. Peter Sandstone; the Platteville and Decorah Formations and Galena Dolomite, undifferentiated (mostly dolomite and herein called the Galena-Platteville unit); and the Maquoketa Shale. The Maquoketa Shale, largely removed by erosion, is present only in the eastern part of the county. The Galena-Platteville unit is the uppermost bedrock in about half the county. The

Table 1.--Stratigraphy of Jefferson County

System	Rock unit	Predominant lithology
QUATERNARY	Holocene deposits	Unconsolidated clay, silt, sand, gravel, and organic matter.
	Pleistocene deposits	Unconsolidated clay, silt, sand, gravel, cobbles, boulders, and organic matter.
ORDOVICIAN	Maquoketa Shale	Shale, dolomitic, blue-gray; contains dolomitic beds as thick 40 feet.
	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	Dolomite and some slightly shaly dolomite, light-gray to blue-gray.
	St. Peter Sandstone	Sandstone, dolomitic in some places, shaly at base in some places, white to light-gray, fine- to medium-grained.
	Prairie du Chien Group	Dolomite, gray or white; some sandstone and sandy dolomite.
CAMBRIAN	Trempealeau Formation	Sandstone, very fine- to medium-grained; dolomite interbedded with siltstone, light gray.
	Franconia Sandstone	Sandstone, very fine- to medium-grained; siltstone or dolomite; sandstone, dolomitic at base, medium- to coarse-grained.
	Galesville Sandstone	Sandstone, light-gray, fine- to medium-grained.
	Eau Claire Sandstone	Sandstone, dolomitic, light-gray to light-pink, fine- to medium-grained; some shale beds.
	Mount Simon Sandstone	Sandstone, white to light-gray, fine- to coarse-grained, mostly medium; some beds dolomitic, some interbedded shale.
PRE-CAMBRIAN	Precambrian rocks, undifferentiated	Crystalline rocks, mostly quartzite.

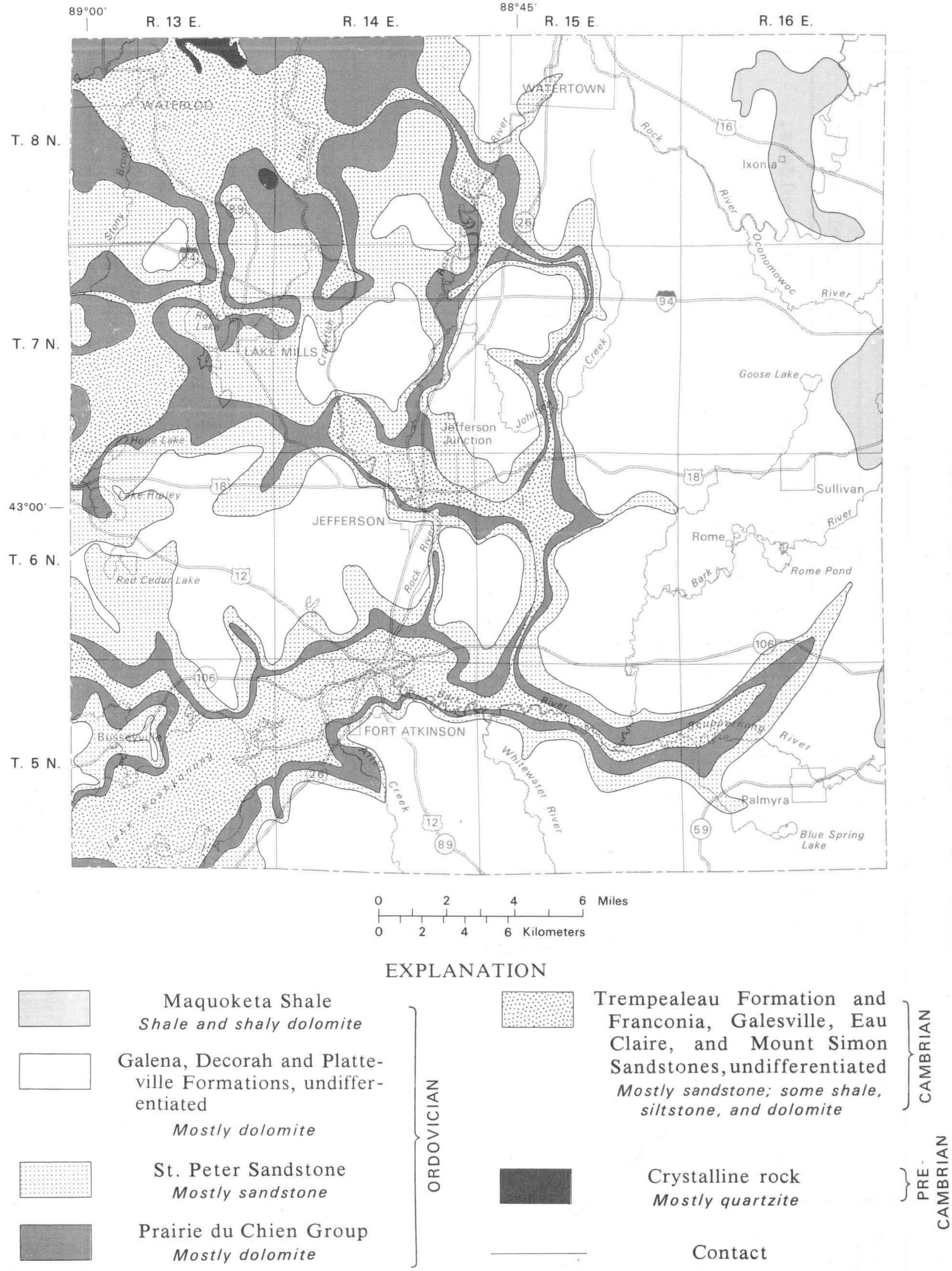


Figure 2. Bedrock geology.

St. Peter Sandstone and the Prairie du Chien Group together are the uppermost bedrock in about one-fourth of the county, primarily on the sides of valleys in the bedrock surface (fig. 2).

All of these rocks dip generally eastward. The upper surface of the St. Peter Sandstone ranges in altitude from more than 850 ft (260 m) along the western county line to less than 450 ft (140 m) in the southeast corner of the county. The base of the Prairie du Chien Group also dips to the east and ranges in altitude from about 750 ft (230 m) in the northwest corner of the county to less than 400 ft (120 m) in the northeast and southeast corners. The top of the Prairie du Chien Group was exposed to erosion before deposition of the St. Peter Sandstone. In places, the entire Prairie du Chien Group was removed, and the St. Peter Sandstone lies directly on the Cambrian sandstone.

BEDROCK SURFACE

The bedrock topographic surface (fig. 3) was formed by preglacial and glacial erosion. The most striking feature of the surface is the valley system that leaves the county in the southwest corner. These valleys were part of a preglacial stream system that drained much of the county and parts of Waukesha, Dodge, and Dane Counties. The valleys cut through the Galena-Platteville unit, the uppermost bedrock in much of the county, and the successively older St. Peter Sandstone, Prairie du Chien Group, and the youngest of the Cambrian sandstones (fig. 2).

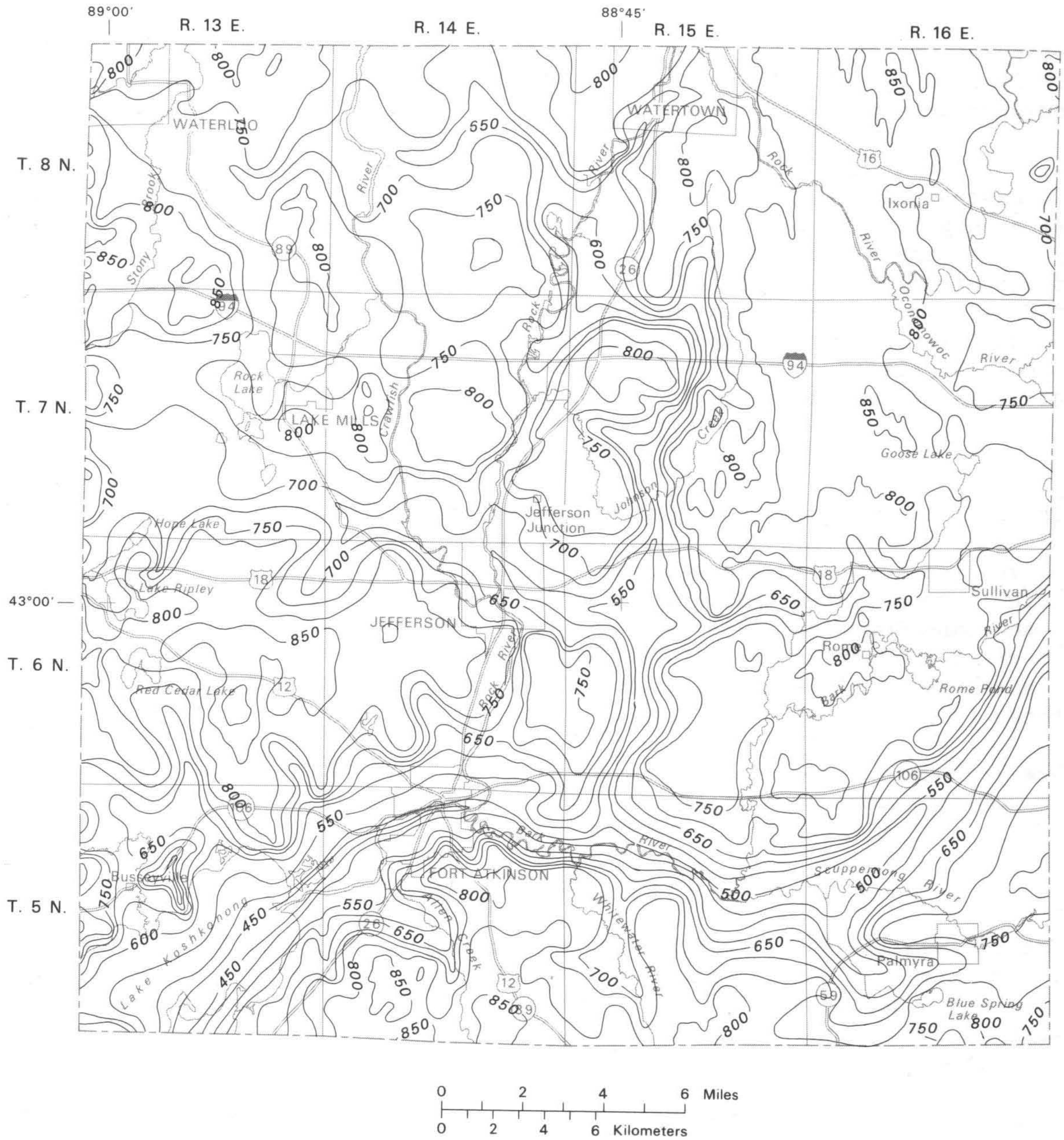
The bedrock surface ranges from an altitude of more than 900 ft (270 m) 4 mi (6 km) northwest of Fort Atkinson and 3 mi (5 km) south of Waterloo to less than 450 ft (140 m) at Lake Koshkonong.

QUATERNARY DEPOSITS

The unconsolidated Quaternary deposits overlying bedrock in Jefferson County are largely glacial sediments, but they also include some alluvium and surficial marsh deposits. Characteristic sediment types comprise the distinctive landforms (end moraine, ground moraine, outwash plains, and lake plains) resulting from glaciation (fig. 4).

End moraines are formed by deposition at the margin of a glacier when the rate of melting about equals the rate of glacier advance. They may form either at the point of maximum ice advance or during recession of the glacier. They consist of unsorted glacial material ranging in size from clay to boulders and may contain local stratified sand and gravel. An end moraine typically is a ridge with a rolling to hummocky surface, often with enclosed depressions called "kettles".

End moraines in Jefferson County were formed by the Green Bay glacier and the Delavan lobe of the Lake Michigan glacier, which were large lobes during Wisconsin Glaciation. The end moraine that marks the farthest advance of the Green Bay glacier is in the southeast corner of the county (fig. 4). In this area, the Green Bay glacier and the Delavan lobe met and formed an interlobate moraine known as the Kettle moraine. Several subparallel recessional moraines of the Green Bay glacier cross the county; the northernmost lies along an arc from Waterloo to Lake Mills, the city of Jefferson, and then northeast to the Jefferson-Waukesha County line.



EXPLANATION

—— 750 —— **Bedrock contour**

Shows altitude of bedrock surface. Dashed where approximately located. Contour interval 50 feet (15 meters). Datum is mean sea level

Figure 3. Bedrock topography.

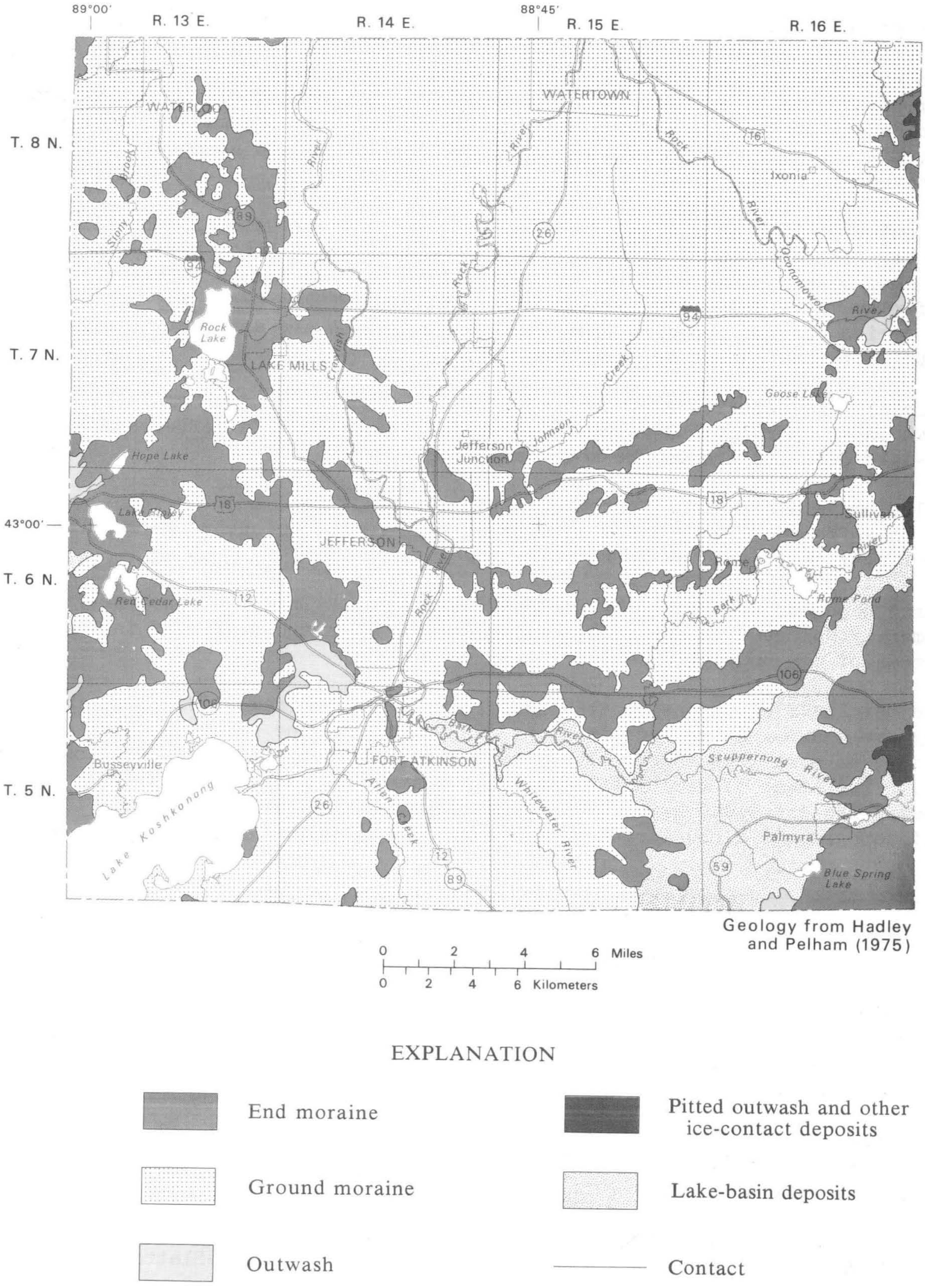


Figure 4. Glacial geology.

The ground moraine in much of Jefferson County is from the Green Bay glacier (fig. 4). Ground moraine is deposited by glacial ice as a blanket of unsorted rock debris, called till, ranging in size from clay to boulders. Ground moraine usually forms a gently undulating plain with moderate relief and no definite alinement of the undulation. In some parts of the county, however, elongate hills of ground moraine, called drumlins, are alined along the direction of ice movement.

An outwash plain is a stratified deposit laid down by water from melting ice fronts. It consists of stratified deposits of gravel, sand, silt, and clay. In Jefferson County outwash plains of sand and gravel, in places covered by a layer of clay, were deposited by melt water in front of the Green Bay ice front. Buried outwash deposits from earlier glaciation are apparent in drill-hole logs, but they cannot be mapped accurately.

Glacial-lake deposits are composed of materials derived from glaciers and laid down in ephemeral fresh-water lakes at the ice front. In Jefferson County glacial-lake deposits are in the southeast (fig. 4).

Alluvium is a deposit of unconsolidated materials laid down by running water. In Jefferson County minor amounts of alluvium of Holocene age ranging in size from clay to gravel are found along streams.

Marsh deposits are formed by decaying vegetation. In Jefferson County they are primarily Holocene in age. They are generally thin and are found in low-lying areas of the county.

The thickness of unconsolidated Quaternary deposits ranges from zero in a few very small areas where bedrock crops out, mainly in the northwest part of the county, to more than 400 ft (120 m) under the northeast part of Lake Koshkonong (fig. 5). The areas of zero thickness are too small to show in figure 5. Thicknesses are greatest where glacial materials fill bedrock valleys and in areas of topographic highs formed by end moraines.

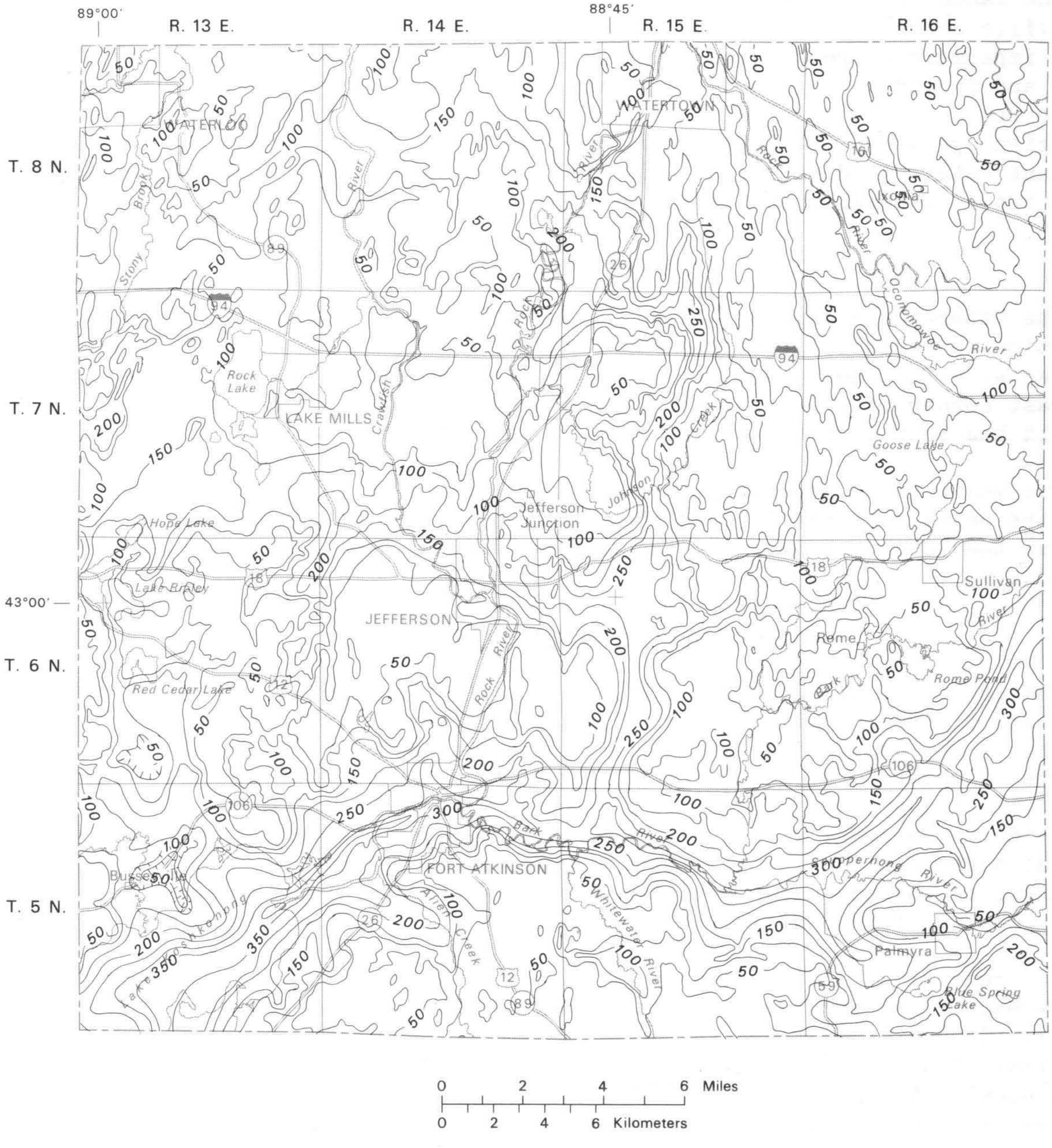
GROUND-WATER HYDROLOGY

PRINCIPAL AQUIFERS

Potable water supplies are obtained from ground-water bodies throughout Jefferson County. The principal sources of these supplies are, in general order of depth below land surface, the sand-and-gravel aquifer, the Galena-Platteville aquifer, and the sandstone aquifer.

The sand-and-gravel aquifer consists of unconsolidated sand-and-gravel deposits in glacial drift. These deposits occur either at land surface or buried by less permeable drift over about half the county.

The Galena-Platteville aquifer consists of the Galena-Platteville unit of Ordovician age. Many domestic wells are finished in the Galena-Platteville aquifer.



EXPLANATION

——— 150 ——— Line of equal thickness of unconsolidated materials

Interval 50 feet (15 meters)

Figure 5. Thickness of unconsolidated materials.

The sandstone aquifer includes all sedimentary bedrock below the Galena-Platteville unit (table 1). The bottom of the sandstone aquifer is the surface of the impermeable Precambrian rocks. The aquifer is nearly continuous over the county and includes, in ascending order from oldest to youngest, the sandstones of Cambrian age, and the Prairie du Chien Group and St. Peter Sandstone of Ordovician age. The St. Peter Sandstone and the Cambrian sandstone are the most important water-yielding rocks. The Prairie du Chien Group yields some water to wells, but it generally is not the primary water-yielding unit.

WATER TABLE

The water-table map (pl. 1) shows the altitude of the top of the zone of saturation in Jefferson County. For the most part, the water table lies within the glacial drift, and its altitude ranges from more than 900 ft (270 m) in the southeast corner of the county to less than 700 ft (210 m) at Jefferson Junction, where it has been lowered by pumping.

The water table generally is a subdued version of the land surface. Areas where the depth to water is less than 10 ft (3 m) for at least part of the year occur in the low-lying parts of the county (fig. 6) along streams, lakes and wetlands.

RECHARGE AND MOVEMENT

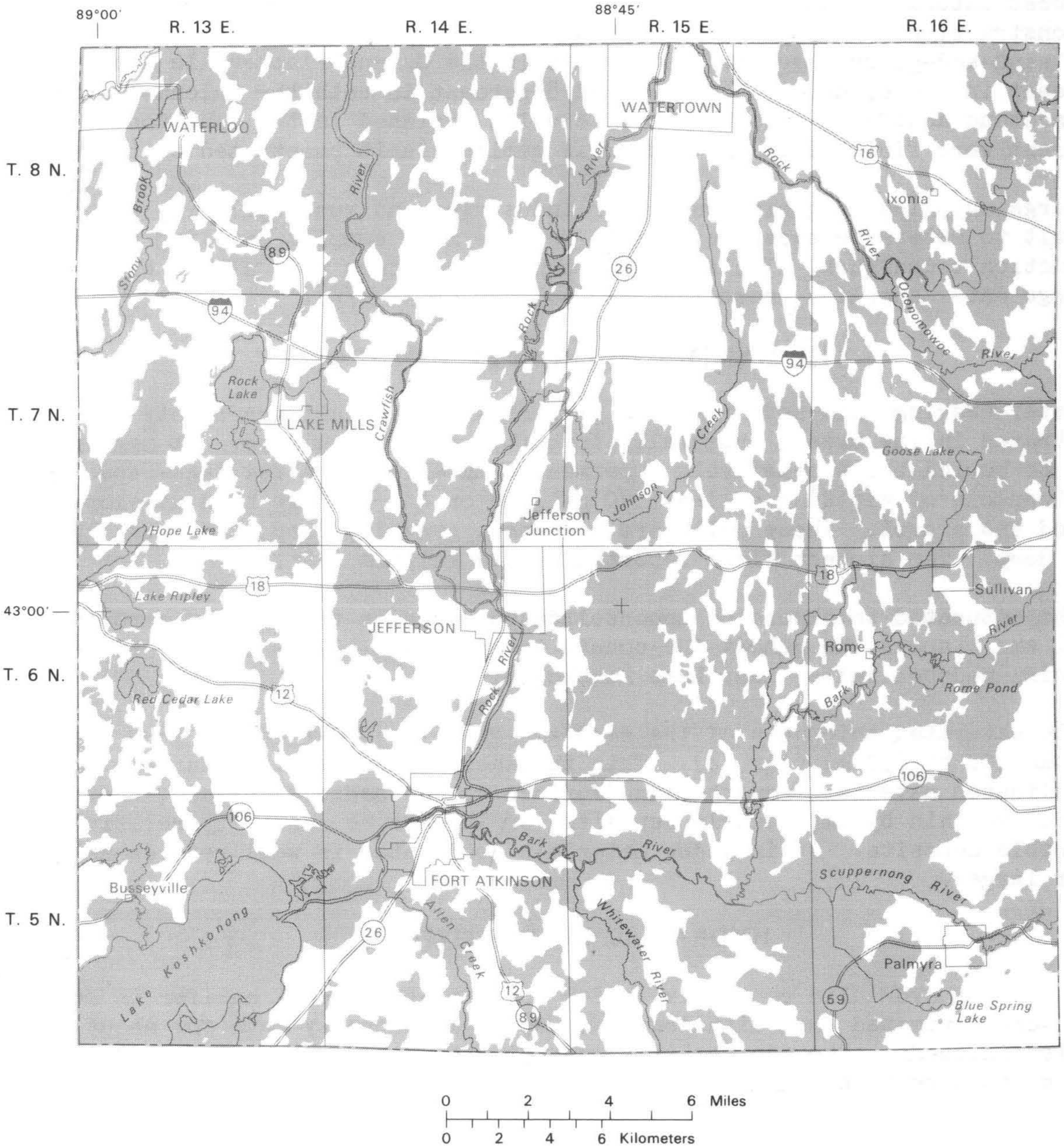
The source of all ground water is precipitation. Between 1 and 10 in (25.4 to 254 mm) of precipitation per year infiltrates and recharges the ground-water reservoir. The amount depends mainly on the rock material at the land surface. Recharge is least in areas covered by fine-grained clayey till, greater in silty sandy till, and greatest in sand and gravel. The amount of recharge received also tends to decrease with depth of the aquifer because most ground water circulates through the unconsolidated material or shallow bedrock units and then discharges to surface-water bodies. Ground-water interchange between rock units occurs because of head differences between them.

The general direction of ground-water flow within the glacial drift or the shallow bedrock at any locality can be determined from the water-table contours (pl. 1). Ground water flows in the direction of decreasing head and moves approximately at right angles to the contours. The movement is from recharge areas, usually topographic highs, to discharge areas, usually topographic lows, where water moves out of the aquifer to streams, lakes, and wetlands.

Local semiconfining layers form barriers to water interchange between and within aquifers. For example, clay confines ground water moving to the northwest from the Kettle moraine. Many wells that penetrate the clay flow.

GROUND-WATER AVAILABILITY

Ground water is available throughout the county, but individual well yields and well depths differ widely. Small yields of ground water, 15 gal/min (0.95 l/s), are obtained by drillers almost everywhere in the county. Most domestic wells are between 50 and 250 ft (15 to 76 m) deep, with some being as deep as 500 ft (150 m). Wells usually are completed in the sand-and-gravel aquifer or the



EXPLANATION

Area where depth to water is less than 10 feet (3 meters)

Figure 6. Areas where the depth to water is less than 10 feet (3 meters).

shallowest saturated bedrock. As determined by a representative sample of 1,100 well-construction reports, about 16 percent of the domestic wells are completed in the sand-and-gravel aquifer, 49 percent in the Galena-Platteville aquifer, 27 percent in the sandstone aquifer, and 8 percent in both the Galena-Platteville and sandstone aquifers. Of the domestic wells finished in the sandstone aquifer, 85 percent were finished in the uppermost geologic unit penetrated by the well.

Large supplies of ground water for industries and municipalities are more difficult to obtain because these wells require more complex drilling and construction techniques. The sandstone aquifer has been used almost exclusively for large water supplies (more than 500 gal/min or 32 l/s).

THE SAND-AND-GRAVEL AQUIFER

Water-bearing sand and gravel is present in about half the county and is concentrated in low areas, especially in buried bedrock valleys. It may crop out or be buried below relatively impermeable materials. A few high-capacity wells (capable of yielding at least 70 gal/min or 4 l/s) have been developed in the sand and gravel. These wells are screened, gravel packed, and about 100 ft (30 m) deep. The highest yield reported is 500 gal/min (32 l/s).

The saturated thickness of unconsolidated deposits ranges from zero in several small areas throughout the county to more than 400 ft (120 m) in the preglacial bedrock valley near Lake Koshkonong (fig. 7).

The saturated thickness of the sand-and-gravel aquifer ranges from zero to more than 300 ft (90 m) (fig. 8). This thickness includes all saturated permeable unconsolidated material from the land surface to the bedrock surface, whether exposed, overlain by impermeable deposits, or in beds separated by relatively impermeable deposits. It includes materials designated in well records as sand-size or larger.

HYDRAULIC CONDUCTIVITY

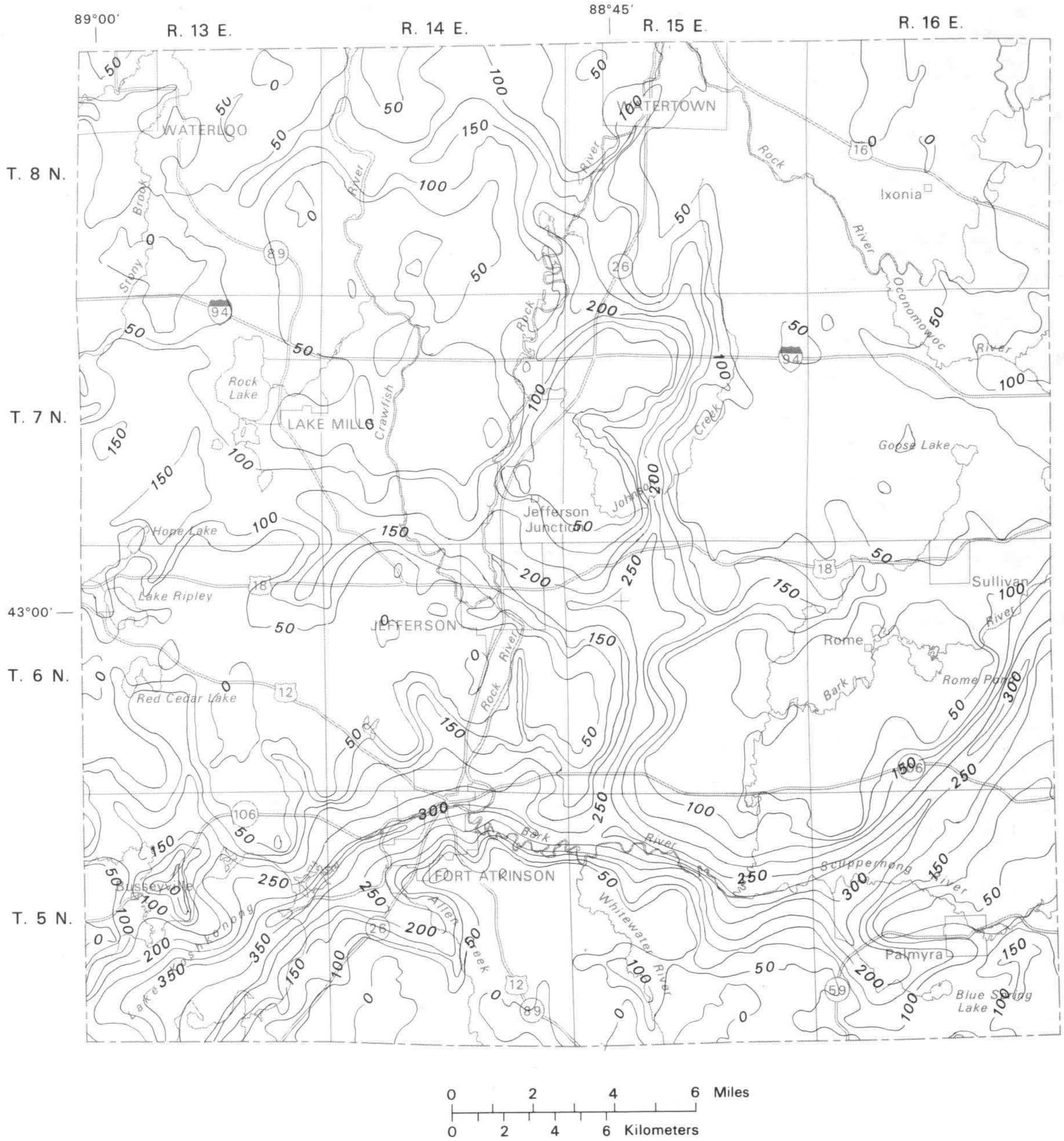
Values of hydraulic conductivity for the sand-and-gravel aquifer in Jefferson County were estimated from lithologic and specific-capacity data for about 60 wells finished in the aquifer. These estimates ranged from about 0.7 ft/d (0.2 m/d) to more than 1,300 ft/d (400 m/d).

PROBABLE WELL YIELDS

Well yields sufficient for domestic use are possible wherever the sand-and-gravel aquifer is present. Yields sufficient for industrial or municipal use are possible in parts of the county.

Figure 9 shows the probable well yields from the sand-and-gravel aquifer and is based on the hydraulic conductivity and saturated thickness of the aquifer. The map should be used with caution because the entire saturated section may have to be screened (which, in some wells, may not be economically feasible) for the indicated probable yield to be realized. Effective well diameters of 2 ft (0.6 m) may be required, especially for yields of more than 500 gal/min (32 l/s).

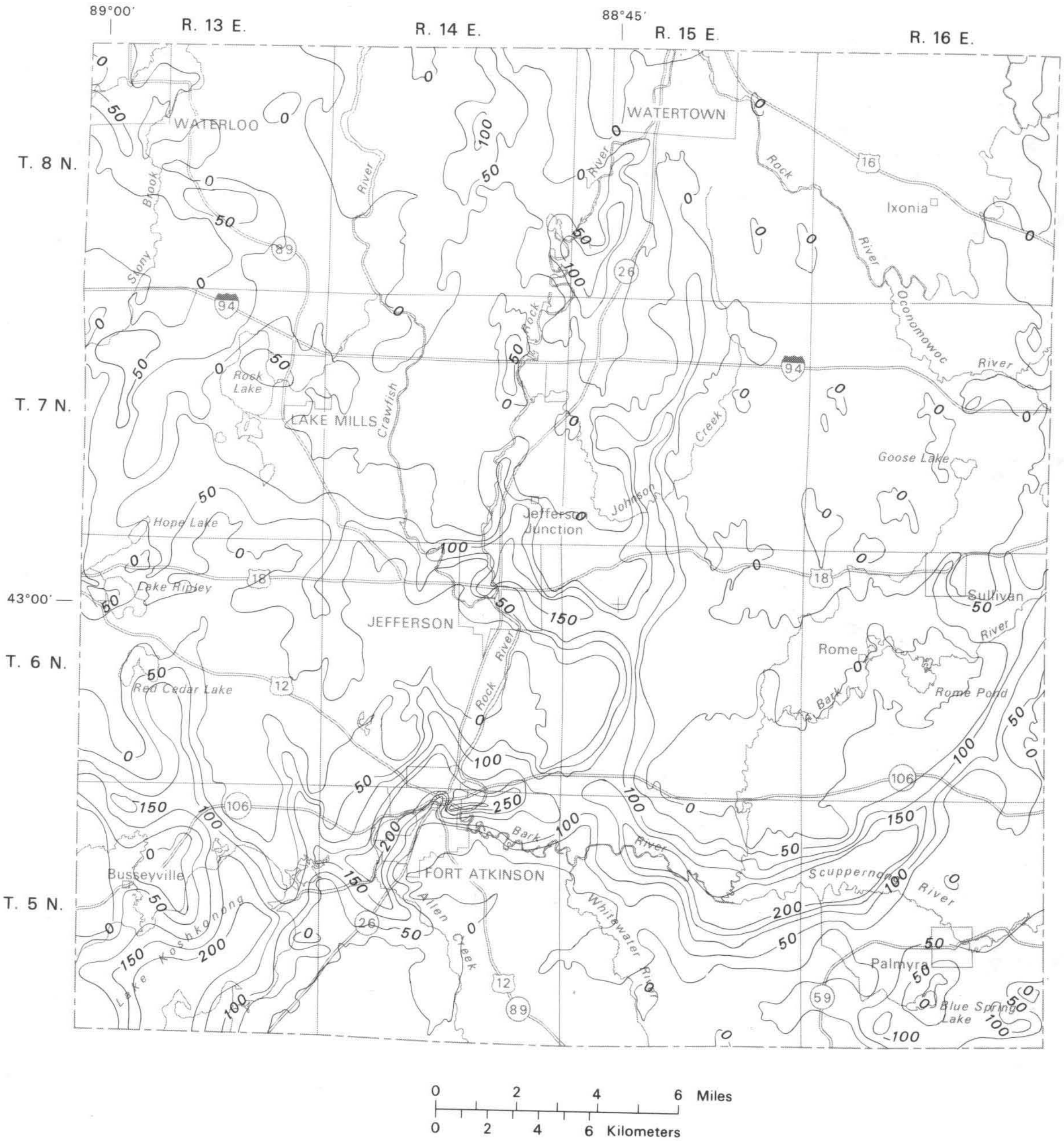
In preparing figure 9, drawdowns caused by pumping wells were limited to two-thirds of the total head (the total head is equal to the saturated thickness



EXPLANATION

——200—— Line of equal saturated thickness of unconsolidated materials
Interval 50 feet (15 meters)

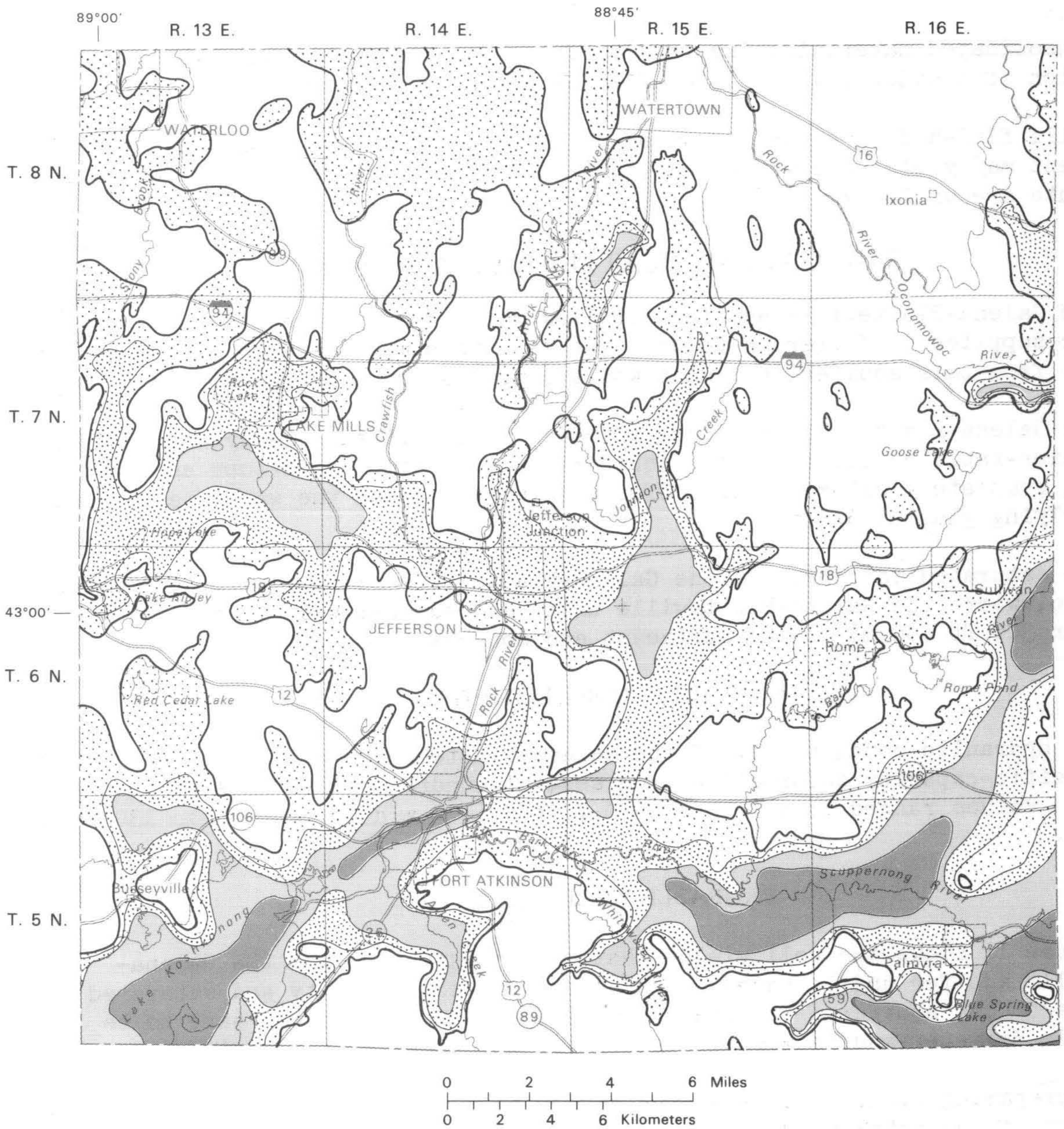
Figure 7. Saturated thickness of unconsolidated materials.



EXPLANATION

100 — Line of equal saturated thickness of the sand-and-gravel aquifer.
Interval 50 feet (15 meters)

Figure 8. Saturated thickness of the sand-and-gravel aquifer.



EXPLANATION

Probable well yields

- Chances of more than 100 gallons per minute (6.3 liters per second) are poor
- Chances of 100-500 gallons per minute (6.3-32 liters per second) are good
- Chances of 500-1,000 gallons per minute (32-63 liters per second) are good
- Chances of more than 1000 gallons per minute (63 liters per second) are good

Boundary of saturated sand-and-gravel aquifer

Contact

Figure 9. Probable well yields from the sand-and-gravel aquifer.

of unconsolidated materials, figure 7). This is a reasonable but arbitrary limitation of drawdown, which is useful for planning purposes.

Wells finished in saturated unconsolidated deposits where sand and gravel are absent may yield some water, but sustained yields of more than a few gallons per minute are unlikely.

THE GALENA-PLATTEVILLE AQUIFER

The Galena-Platteville aquifer supplies water for 49 percent of the private domestic supplies in Jefferson County. Wells have pumped as much as 300 gal/min (19 l/s) from this aquifer, but most wells pump less than 50 gal/min (3.2 l/s).

The Galena-Platteville aquifer, although semiconfined locally, is generally under water-table conditions. The aquifer is, with some exceptions as shown on plate 1, completely saturated in Jefferson County because the water table is in the overlying glacial drift.

The saturated thickness of the Galena-Platteville aquifer (fig. 10) ranges from zero, where the Galena-Platteville unit has been removed by erosion, to more than 300 ft (90 m) in the northeast and southeast corners of the county.

HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of the Galena-Platteville aquifer was estimated from specific-capacity information from several hundred wells finished in the aquifer. Values ranged from less than 0.7 ft/d (0.2 m/d) to more than 130 ft/d (40 m/d).

PROBABLE WELL YIELDS

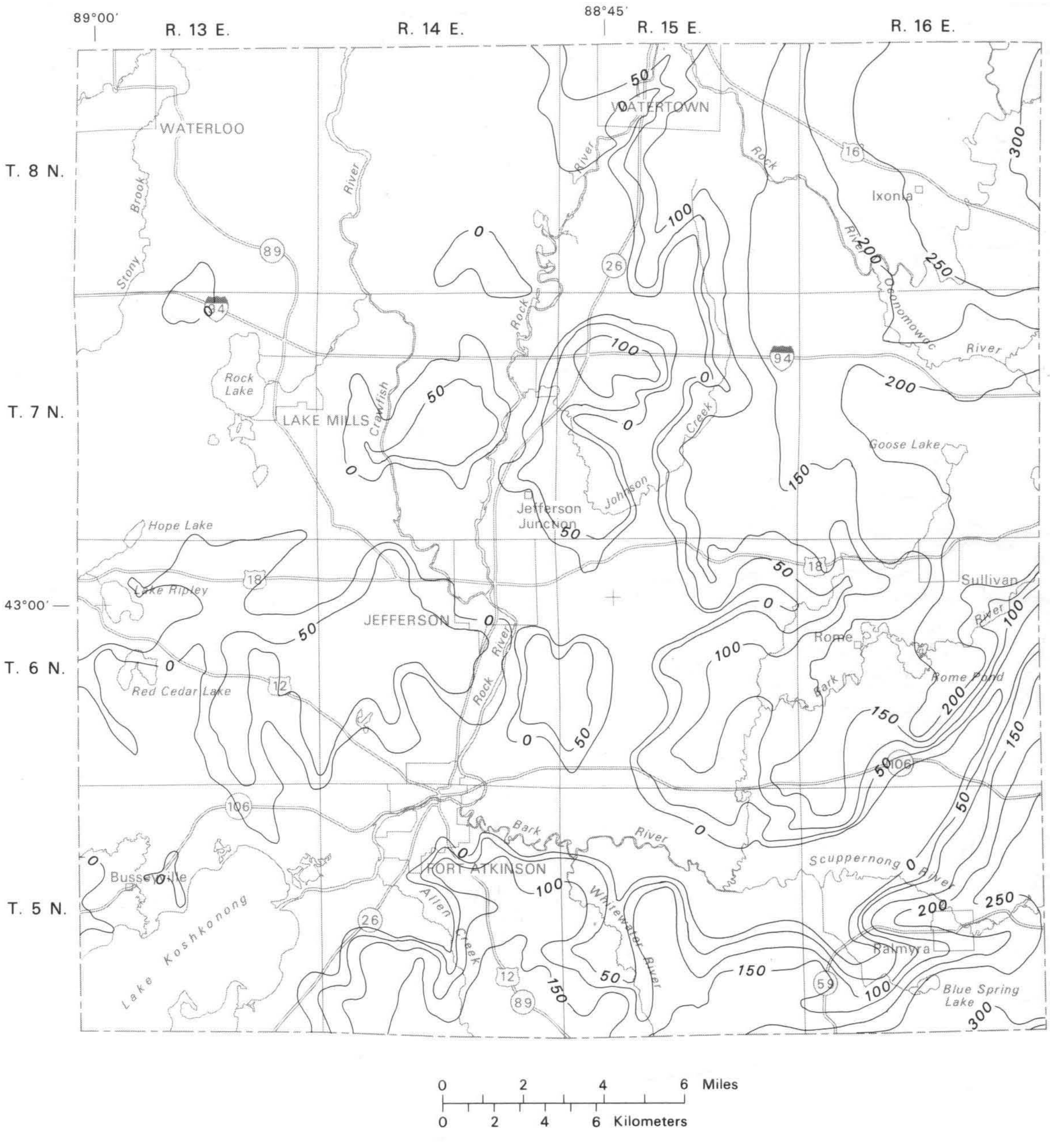
Figure 11 shows the well yields that may be expected from the Galena-Platteville aquifer and is based on the hydraulic conductivity and saturated thickness of the aquifer. To obtain the yields shown, wells may have to be 1 ft (0.3 m) in diameter and be open to the entire thickness of the aquifer.

In preparing figure 11, drawdowns caused by pumping wells were limited to 40 percent of the total head of the aquifer (fig. 12). This is a reasonable but arbitrary limitation of drawdown, which is useful for planning purposes.

THE SANDSTONE AQUIFER

The sandstone aquifer underlies southeastern Wisconsin and adjacent Illinois and is an important source of water. In Jefferson County it is the principal source for most municipal and industrial supplies, as well as many private domestic supplies. Most municipal or industrial wells pump between 250 gal/min (16 l/s) and 1,300 gal/min (82 l/s); yields as high as 2,000 gal/min (126 l/s) are reported.

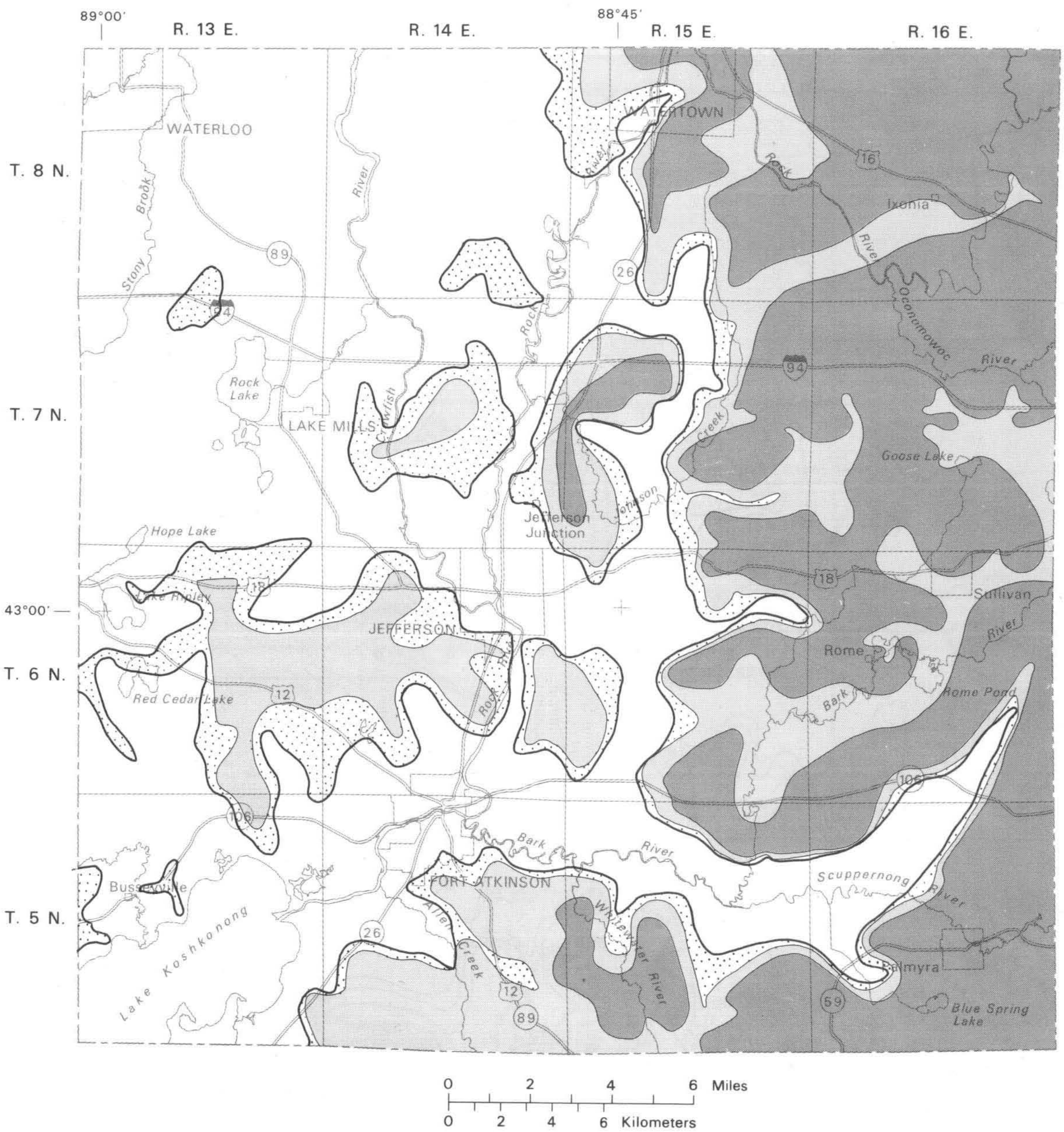
Water in the sandstone aquifer, although confined locally, is generally under water-table conditions. Water levels of wells in the aquifer are represented by the water-table map (pl. 1). The aquifer is, with few exceptions, completely saturated in Jefferson County because the water table is in the overlying glacial drift.



EXPLANATION

——— 150 ——— Line of equal saturated thickness of the Galena-Platteville aquifer
Interval 50 feet (15 meters)

Figure 10. Saturated thickness of the Galena-Platteville aquifer.



EXPLANATION

Probable well yields

Chances of more than 100 gallons per minute (6.3 liters per second) are poor

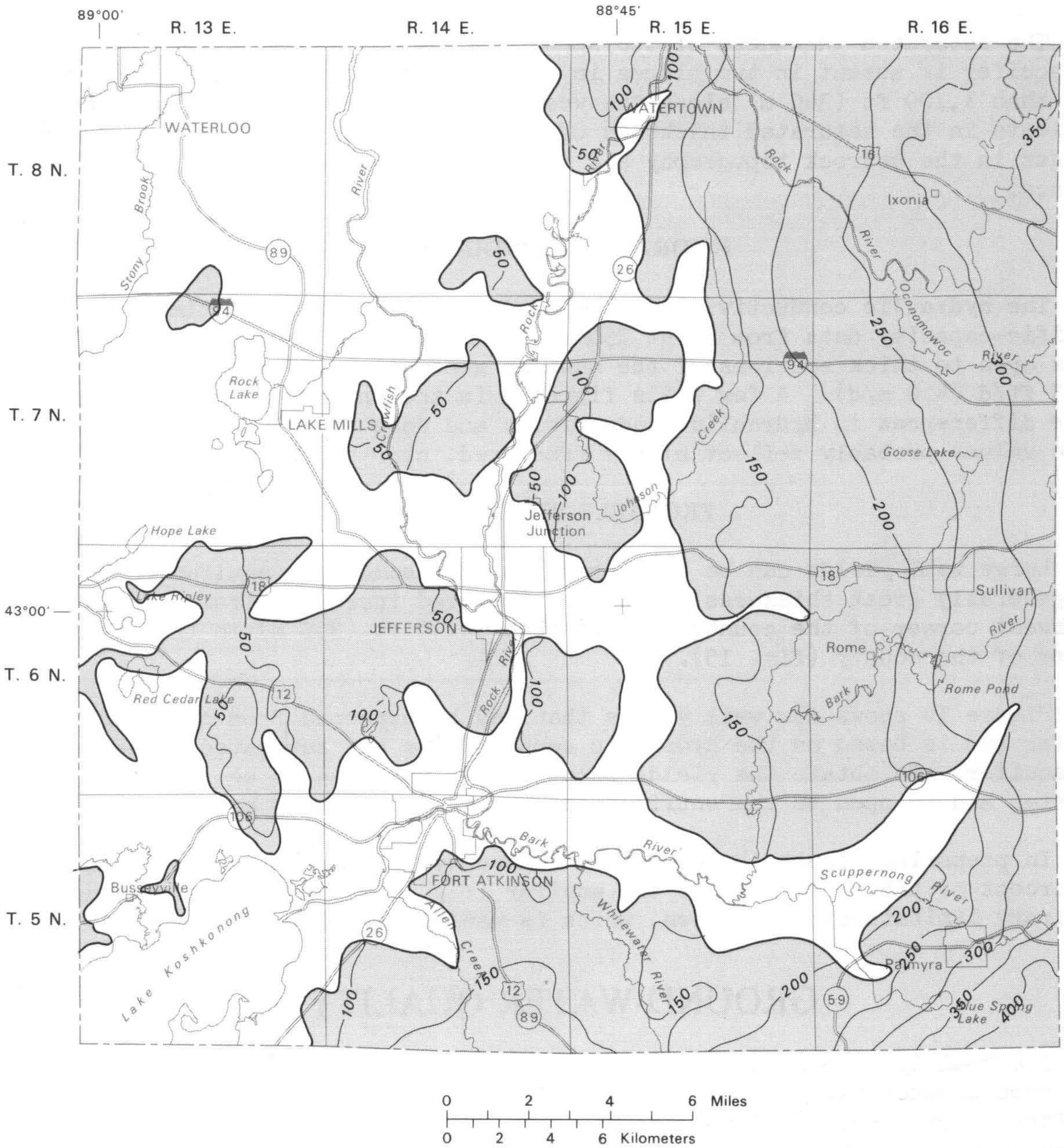
Chances of 100-500 gallons per minute (6.3-32 liters per second) are good

Chances of more than 500 gallons per minute (32 liters per second) are good

Boundary of saturated Galena-Platteville aquifer

Contact

Figure 11. Probable well yields from the Galena-Platteville aquifer.



EXPLANATION

200 — Line of equal total head
Shows head above the base of Galena-Platteville aquifer in 1973. Interval 50 feet (15 meters)

Boundary of Galena-Platteville aquifer

Figure 12. Total head for the Galena-Platteville aquifer

The saturated thickness of the sandstone aquifer ranges from zero, where the aquifer is absent in two places in the northwest corner of the county, to more than 1,100 ft (340 m) along the western county line (fig. 13). Steep gradients in the saturated thickness of the aquifer are due in places to rapid changes in the bedrock topography and in places to rapid changes in the Precambrian surface.

HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of the sandstone aquifer was estimated from specific-capacity data from about 250 wells finished in the aquifer. Values for wells open to thick sections of the aquifer generally ranged from 3 ft/d (0.9 m/d) to 13 ft/d (4.0 m/d). A few wells finished in the upper part of the aquifer had large differences in hydraulic conductivity and some exceeded 130 ft/d (40 m/d). These values probably reflect highly fractured, near-surface bedrock.

PROBABLE WELL YIELDS

Large well yields can be developed from the sandstone aquifer because of its generally great thickness and head. The head increases from zero in the northwest corner of the county to more than 1,150 ft (350 m) in the southwest corner of the county (fig. 15).

Figure 14 shows the well yields that may be expected from the sandstone aquifer and is based on the hydraulic conductivity and saturated thickness of the aquifer. To obtain the yields shown, wells may have to be 1 ft (0.3 m) in diameter and be open to the entire saturated section of the aquifer.

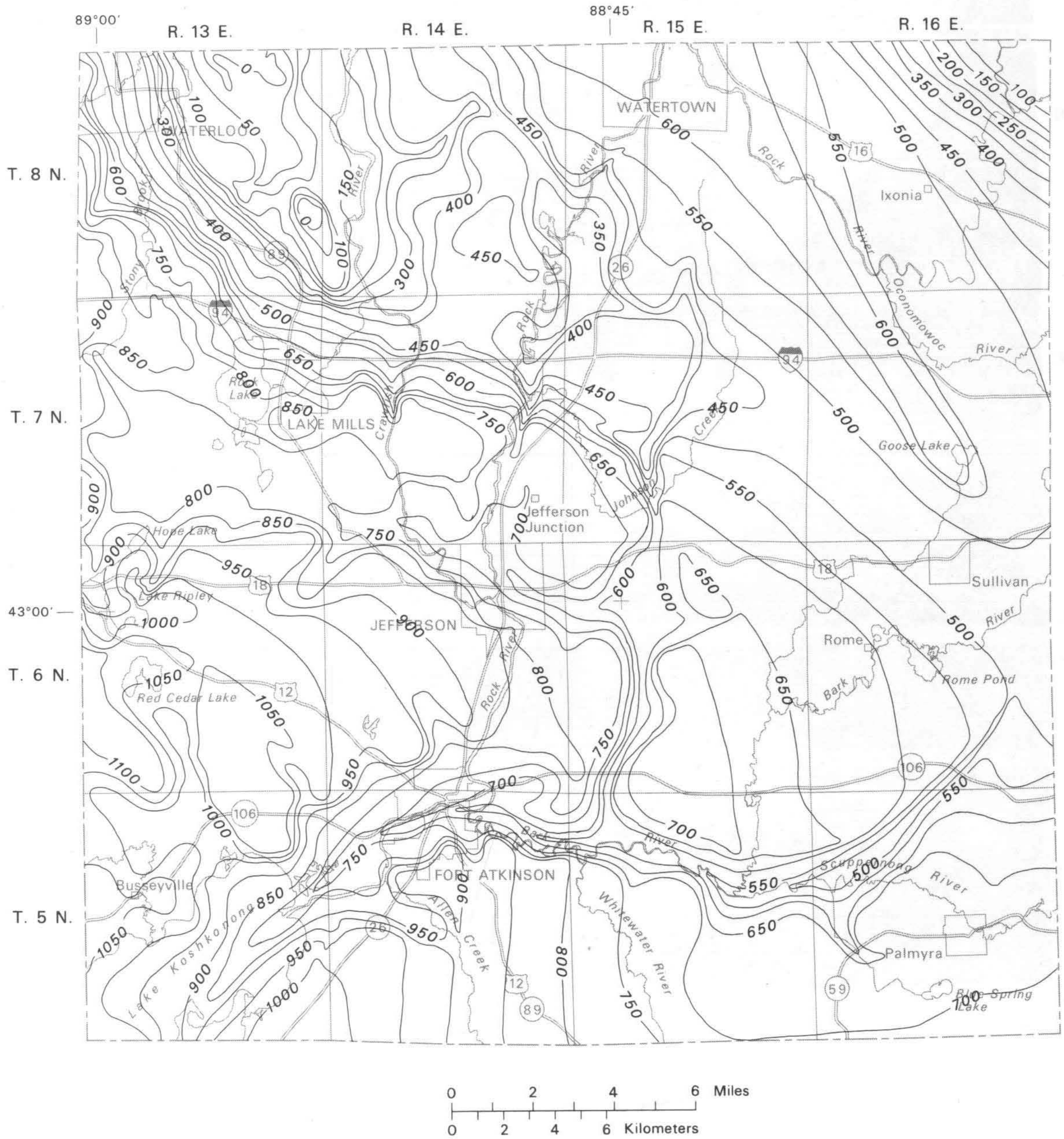
In preparing figure 14, drawdowns caused by pumping wells were limited to 40 percent of the total head of the aquifer (fig. 15). This is a reasonable but arbitrary limitation of drawdown, which is useful for planning purposes.

GROUND-WATER QUALITY

The quality of ground water in Jefferson County generally is good. However, some ground water has chemical characteristics that make it objectionable or unsuitable for domestic of industrial uses. Some chemical constituents that determine the quality of ground water and its suitability for use are dissolved-solids, iron, manganese, and nitrate concentrations. Hardness also determines the suitability of ground water for some uses. The known range of concentration of these constituents and hardness is shown for each aquifer in figure 16.

DISSOLVED SOLIDS

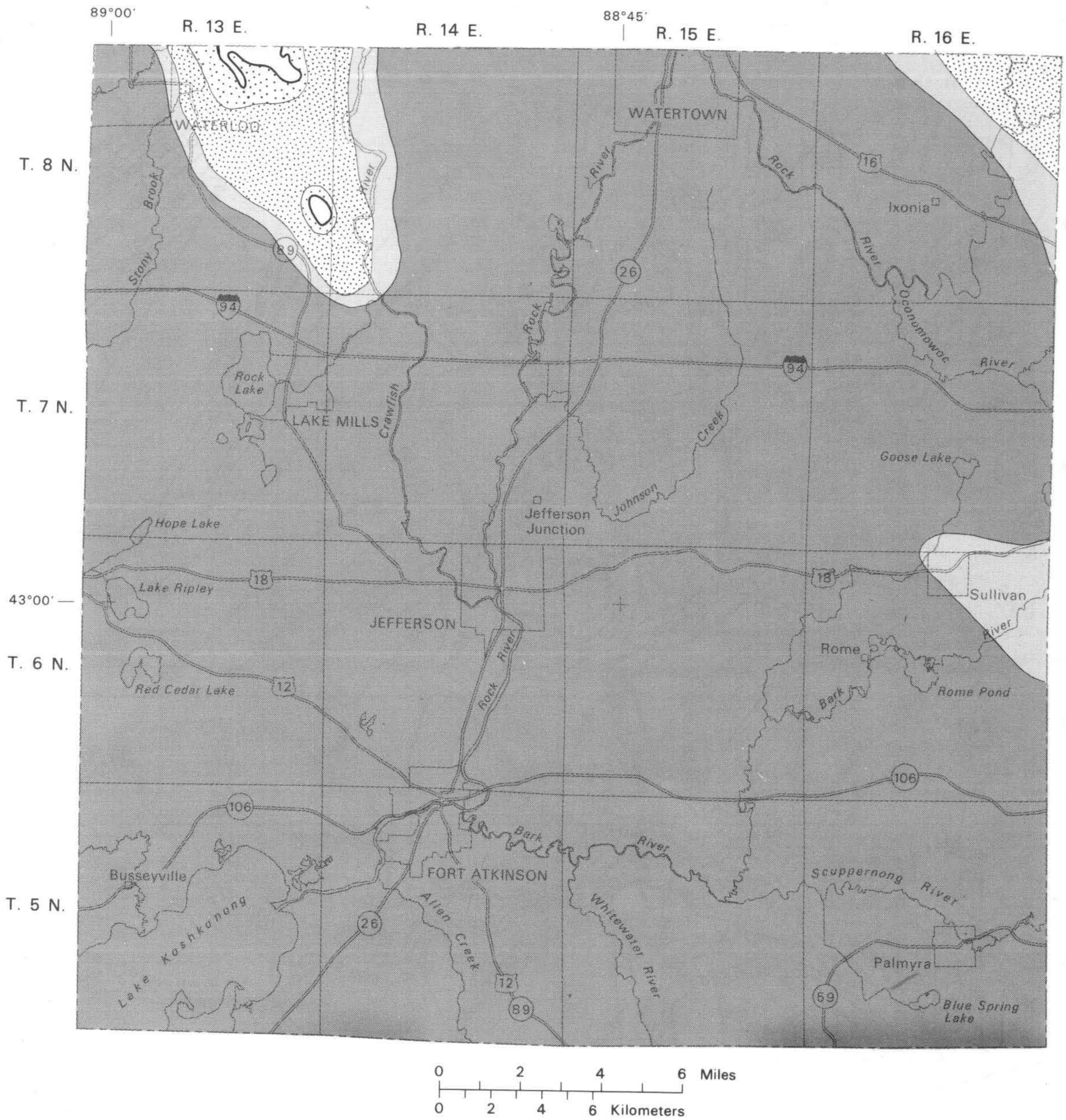
Dissolved-solids concentration is a measure of the total mineralization of water and is reported as milligrams per liter (mg/l). An upper limit of 500 mg/l for dissolved solids is recommended by the U.S. Public Health Service (1962, p. 7) because higher amounts create taste problems. These standards apply only to drinking water and water-supply systems used by interstate carriers and others subject to Federal quarantine regulations; however, they have been voluntarily accepted by the American Water Works Association and most state departments of public health as criteria for public-water supplies.



EXPLANATION

——— 700 ——— Line of equal saturated thickness of sandstone aquifer
Interval 50 feet (15 meters)

Figure 13. Saturated thickness of the sandstone aquifer.



EXPLANATION

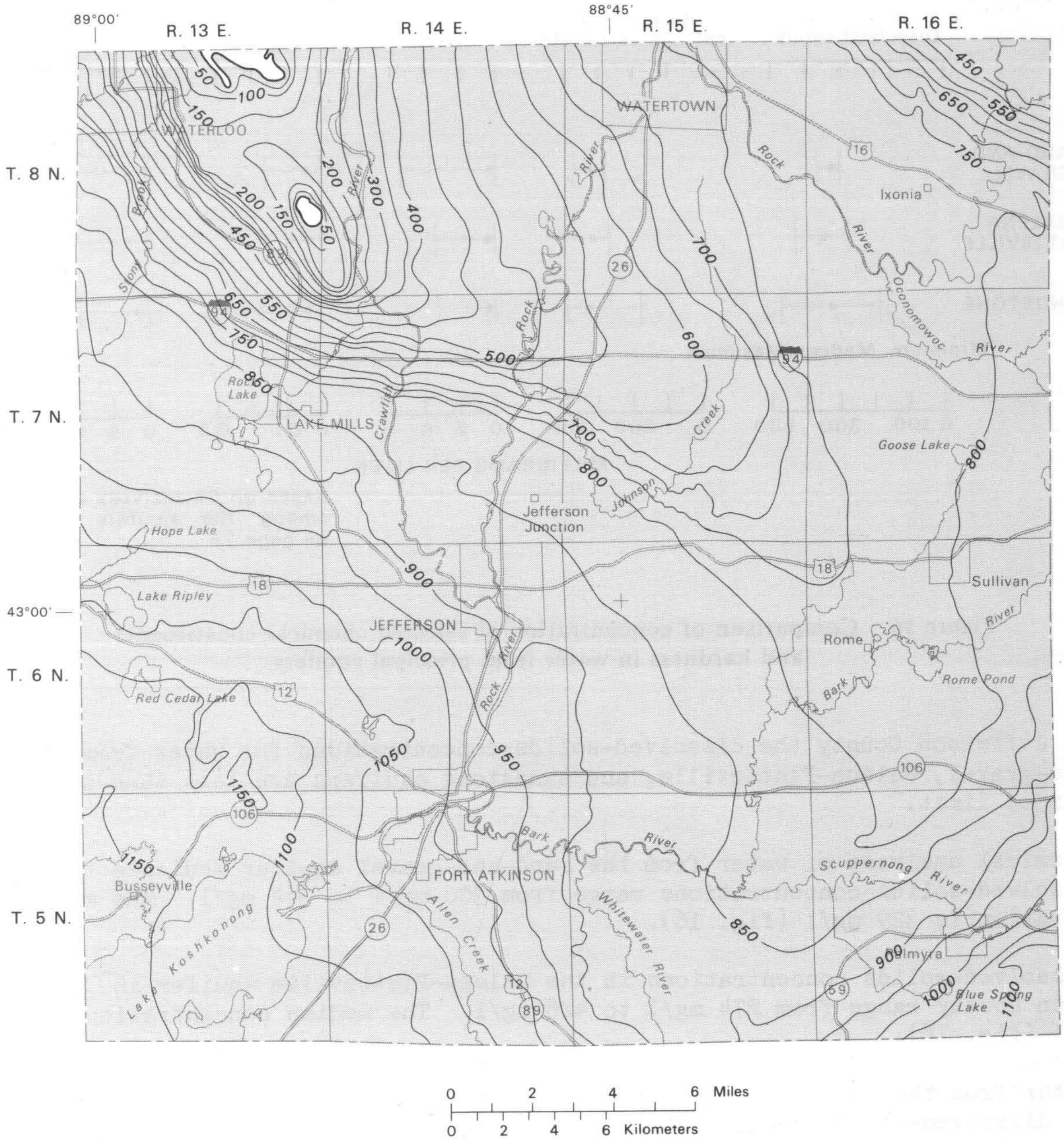
Probable well yields

- Chances of more than 100 gallons per minute (6.3 liters per second) are poor
- Chances of 100-500 gallons per minute (6.3-32 liters per second) are good
- Chances of 500-1,000 gallons per minute (32-63 liters per second) are good
- Chances of more than 1000 gallons per minute (63 liters per second) are good

Boundary of saturated sandstone aquifer

Contact

Figure 14. Probable well yields from the sandstone aquifer.



EXPLANATION

1100 — Line of equal total head
Shows total head above the base of the sandstone aquifer in 1973. Interval 50 feet (15 meters)

Area of saturated sandstone aquifer

Figure 15. Total head for the sandstone aquifer.

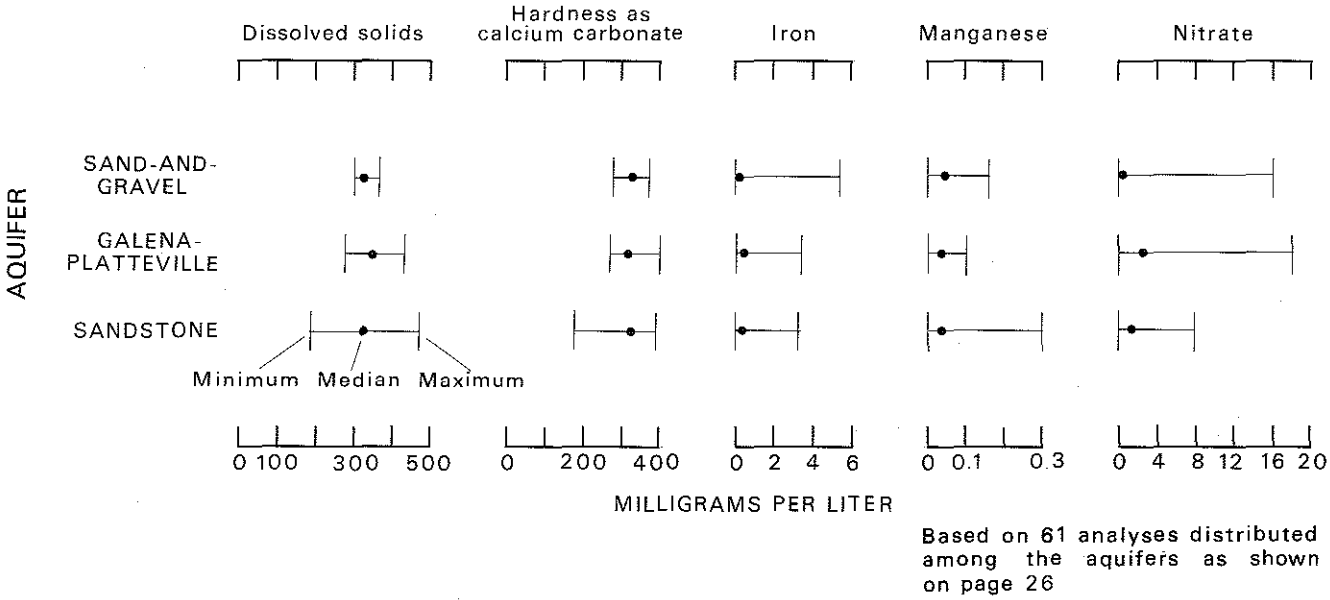


Figure 16. Comparison of concentration of selected chemical constituents and hardness in water from principal aquifers.

In Jefferson County the dissolved-solids concentrations for water from the sand-and-gravel, Galena-Platteville, and sandstone aquifers are less than the recommended limit.

Chemical analyses of water from the sand-and-gravel aquifer indicate that the dissolved-solids concentrations range from 300 mg/l to 364 mg/l. The median concentration is 329 mg/l (fig. 16).

Dissolved-solids concentrations in the Galena-Platteville aquifer in Jefferson County range from 274 mg/l to 428 mg/l. The median concentration is 349 mg/l (fig. 16).

Water from the sandstone aquifer has a larger range between minimum and maximum dissolved-solids concentrations, from 186 mg/l to 470 mg/l. The median value for dissolved solids is 326 mg/l, similar to the median values for the sand-and-gravel and Galena-Platteville aquifers (fig. 16).

HARDNESS

Hardness is that property of water that neutralizes soap; it is caused almost entirely by compounds of calcium and magnesium. Calcium and magnesium commonly are present in rocks and soils, but the highest dissolved concentrations usually are in water that has been in contact with limestone, dolomite, and gypsum. Dolomite is abundant in both the bedrock and glacial drift of Jefferson County.

The U.S. Geological Survey classifies hardness in terms of the amount of calcium carbonate or its equivalent that would be formed if the water were evaporated. This classification is:

0- 60 mg/l--soft,
61-120 mg/l--moderately hard,
121-180 mg/l--hard, and
more than 180 mg/l--very hard.

Hardness is often reported in grains per gallon in the water-softening industry. The conversion from milligrams per liter to grains per gallon is:

1 milligram per liter = 17.12 grains per U.S. gallon.

Hardness is objectionable because hard water leaves a scaly deposit on the insides of pipes, steam boilers, and hot-water heaters; it requires more soap than soft water to make a good lather; and it roughens clothes and hands.

In Jefferson County most ground water is very hard. Of the wells from which water was analyzed, only one had water classified as hard water, and none had water classified as moderately hard or soft. The dissolved constituents that are responsible for hardness constitute most of the total dissolved-solids concentration of ground water in the county.

Hardness of water sampled from the sand-and-gravel aquifer ranges from 276 mg/l to 370 mg/l. The median value is 325 mg/l (fig. 16).

In the Galena-Platteville aquifer hardness ranges from 270 mg/l in a well at Palmyra to 400 mg/l in a well south of Rome. Most values range from 300 mg/l to 350 mg/l, with a median value of 315 mg/l (fig. 16).

Hardness for the sandstone aquifer ranges from 176 mg/l southeast of Waterloo to 390 mg/l near Lake Ripley. Most values range from 300 mg/l to 350 mg/l, with a median value of 325 mg/l (fig. 16).

IRON AND MANGANESE

The concentrations of iron and manganese also affect the desirability of water for domestic and industrial uses. Iron is dissolved from many rocks and soils. On exposure to air, iron in nonacidic water oxidizes and settles out of solution. In concentrations as low as 0.3 mg/l iron causes reddish-brown stains on white porcelain or enameled water, fixtures, and on fabrics washed in the water. Manganese also is dissolved from rocks and resembles iron in its chemical behavior and occurrence in water. Manganese is especially objectionable in water used in laundries and in textile processing because small concentrations may cause dark brown or black stains on fabrics and porcelain fixtures. Appreciable quantities of manganese commonly accompany objectionable quantities of iron in water. Upper limits of 0.3 mg/l for iron and 0.05 mg/l for manganese have been recommended by the U.S. Public Health Service (1962, p. 7). Iron and manganese concentrations greater than these recommended limits occur in all aquifers in Jefferson County (fig. 16).

In the sand-and-gravel aquifer iron concentrations range from 0 to 5.4 mg/l, and manganese concentrations range from 0 to 0.16 mg/l. The median iron concentration of 0.04 mg/l is well below the 0.3 mg/l recommended limit, but the median manganese concentration of 0.05 mg/l is at the recommended limit.

Table 2.--Additional constituents and properties of water from the sand-and-gravel, Galena-Platteville, and sandstone aquifers

(Chemical constituents, in milligrams per liter, except pH, as shown)

Aquifer		Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Noncarbonate hardness as calcium carbonate	pH (standard units)
Sand-and-gravel	Minimum	0	252	0.0	1.0	0.0	0	7.4
	Median	0	365	26	5.0	.2	39	7.6
	Maximum	4	394	42	21	.4	66	8.4
Galena-Platteville	Minimum	0	303	8.0	1.3	.1	4	7.6
	Median	0	333	31	2.8	.2	40	7.6
	Maximum	0	400	44	11	.3	72	8.1
Sandstone	Minimum	0	188	2.4	.5	.0	0	7.3
	Median	0	365	14	3.7	.2	19	7.6
	Maximum	10	432	47	74	.2	76	8.6

Iron concentrations in the Galena-Platteville aquifer range from 0.01 to 3.3 mg/l. The median concentration of 0.35 mg/l is above the 0.3 mg/l recommended limit.

Manganese concentrations in the Galena-Platteville aquifer range from 0 to 0.10 mg/l. The median concentration of 0.04 mg/l is less than the recommended limit of 0.05 mg/l.

Iron concentrations in the sandstone aquifer range from 0 to 3.2 mg/l. The median concentration of 0.34 mg/l is above the recommended upper limit of 0.3 mg/l.

Manganese concentrations in the sandstone aquifer range from 0 to 0.30 mg/l. The median concentration of 0.04 mg/l is below the recommended limit of 0.05 mg/l.

NITRATE

Nitrate (NO_3) in water is considered a final oxidation product of nitrogen-containing matter. Nitrate concentrations of several milligrams per liter may indicate contamination by sewage or other organic matter. The effect of nitrate on industrial use of water is practically negligible. However, many studies by health officers and medical research scientists have shown that excess nitrate in drinking water is a contributing factor or perhaps the main cause of methemoglobinemia. The U.S. Public Health Service has set 45 mg/l (1962, p. 7) as the upper limit for nitrate.

In Jefferson County nitrate is not a problem, although some degradation of ground water is suggested by nitrate concentrations exceeding the background concentration of 3.0 mg/l. As used here, the background concentration is the upper limit of the modal range, as determined by Cotter and others (1969) for the Rock-Fox River basin. Water from none of the sampled wells exceeded the recommended upper limit of 45 mg/l, although water from some wells in each aquifer exceeded the background concentration of 3.0 mg/l. Median concentrations for all aquifers are less than the background concentration of 3.0 mg/l (fig. 16).

OTHER CHEMICAL CHARACTERISTICS

In addition to those described above, several other chemical constituents and properties were measured. Table 2 summarizes these analyses, by aquifer, and is based on analyses from the U.S. Geological Survey and the Wisconsin State Laboratory of Hygiene. There were analyses from 8 wells in the sand-and-gravel aquifer, 10 wells in the Galena-Platteville aquifer, and 43 wells in the sandstone aquifer.

GROUND-WATER PUMPAGE AND USE

About 13.0 Mgal/d (0.570 m^3/s) of water was pumped from the three aquifers in Jefferson County in 1972. This water was used for residential, industrial, commercial, institutional, irrigation, and municipal purposes.

PUMPAGE

In 1972 pumpage from the sandstone aquifer was about 87 percent of the county's total pumpage. Pumpage from the Galena-Platteville aquifer and from wells open to both the Galena-Platteville aquifer and sandstone aquifer was about 11 percent. Pumpage from the sand-and-gravel aquifer was only 2 percent. The pumpages are tabulated below.

Aquifer	1972 pumpage (Mgal/d)	1972 pumpage Percent
Sand-and-gravel	0.3	2
Galena-Platteville	.9	7
Sandstone	11.3	87
Combination of Galena-Platteville and sandstone	.5	4
	13.0	100

Ten municipalities and corporations pumped 10.91 Mgal/d (0.478 m^3/s) or 84 percent of all ground water pumped in the county in 1972. The average daily pumpages were:

Organization	1972 pumpage (Mgal/d)
Ladish Malting Co., Jefferson Junction	2.82
City of Fort Atkinson	2.41
City of Watertown	2.01
City of Jefferson	.87
Northwest Malting Co., Waterloo	.83
City of Lake Mills	.73
Albers Milling Co., Jefferson	.59
City of Waterloo	.39
Village of Johnson Creek	.13
Village of Palmyra	.13
Total	10.91

USE

The amount of ground water used daily in 1972 for residential, commercial, industrial, institutional, irrigation, and municipal purposes is shown below.

Use	Amount used (Mgal/d)	Percent
Residential, public supply	1.89	15
Residential, private supply	1.4	11
Commercial, public and private supply	.8	6
Industrial, public and private supply	7.3	56
Irrigation, private supply	.3	2
Institutional, private supply	.0	0
Municipal	1.27	10
Total	13.0	100

Residential water use includes all household uses. In addition, it includes farm uses, such as stock watering and equipment washing. Public-supply residential use is water used by residences on a public or private water-distribution system serving five or more homes. Water used by homes and farms with their own source of supply is considered private-supply residential use. Residential use by aquifer is tabulated as follows:

Aquifer	Public supply (Mgal/d)	Private supply (Mgal/d)
Sand-and-gravel	0	0.2
Galena-Platteville	0	.7
Sandstone	1.79	.4
Combination of Galena-Platteville and sandstone	.1	.1
Total	1.9	1.4

This tabulation shows the relative importance of each aquifer for public and private residential supplies.

The sand-and-gravel and Galena-Platteville aquifers are relatively shallow and are capable of yielding sufficient water for residential use. Where the Galena-Platteville aquifer is absent, the sandstone aquifer is the bedrock aquifer used for private residential supplies. The sandstone aquifer is capable of yielding large water supplies and is the only aquifer used for public distribution systems in the county. Some sandstone wells are also open to the Galena-Platteville aquifer.

Commercial use refers to water used by business establishments that do not fabricate or produce a product, filling stations, retail stores, and restaurants, For example. Commercial water use accounted for 6 percent of the ground water pumped in 1972.

Industrial use refers to water used in plants that manufacture or fabricate products. Industrial water may be used to cool machinery, to provide sanitary facilities for employees, to air-condition the plant, or to water the lawn at the plant. Industrial water use was 56 percent of the ground water used in Jefferson County in 1972.

Irrigation use is water used for sprinkling golf courses and irrigating crops. In Jefferson County most irrigation is for sod farms and nurseries. Some public-supply water is used for lawn sprinkling, but is included under municipal use.

Institutional use refers to water used in the maintenance and operation of institutions such as schools, hospitals, rest homes, and prisons. Institutions may be privately or public owned. Private-supply institutional use is the only type tabulated. Use by institutions served by public supplies is included under municipal water use. Self-supplied institutional use accounted for less than 0.5 percent of the ground water used in Jefferson County in 1972.

Municipal water use is water pumped by municipalities but not sold to customers. It includes use in flushing water lines, fire fighting, sprinkling, use in municipal buildings and institutions, and water lost in the distribution system. In 1972, 10 percent of the ground water used in the county was for municipal use.

SELECTED REFERENCES

Alden, W. C., 1918, The Quaternary geology of southeastern Wisconsin: U.S. Geol. Survey Prof. Paper 106, 356 p.

Bean, E. F., 1949, Geologic map of Wisconsin: Wisconsin Geol. and Nat. History Survey map.

Chamberlin, T. C., 1878, Geology of eastern Wisconsin, in Geology of Wisconsin: Wisconsin Geol. and Nat. History Survey, v. 2, pt. 2, p. 93-405.

Cotter, R. D., Hutchinson, R. D., Skinner, E. L., and Wentz, D. A., 1969, Water resources of Wisconsin--Rock-Fox River basin: U.S. Geol. Survey Hydrol. Inv. Atlas HA-360.

Devaul, R. W., 1967, Trends in ground-water levels in Wisconsin through 1966: Wisconsin Geol. and Nat. History Survey Inf. Circ. 9, 109 p.

Erickson, R. M., 1972, Trends in ground-water levels in Wisconsin, 1967-71: Wisconsin Geol. and Nat. History Survey Inf. Circ. 21, 40 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, p. 69-174.

Hackett, J. E., 1952, The occurrence and movement of ground water in the Jefferson Junction area, Wisconsin: Thesis for degree of master of science (geology) at the Univ. of Wisconsin, 97 p.

Hadley, D. W., and Pelham, J. H., 1975, Glacial deposits of Wisconsin: Wisconsin Geol. and Nat. History Survey map.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 2nd ed., 393 p.

Holt, C. L. R., Jr., and Skinner, E. L., 1973, Ground-water quality in Wisconsin through 1972: Wisconsin Geol. and Nat. History Survey Inf. Circ. 22, 147 p.

Lohman, S. W., 1972, Ground-water hydraulics: U.S. Geol. Survey Prof. Paper 708, 70 p.

Lohman, S. W., and others, 1972, Definitions of selected ground-water terms--revisions and conceptual refinements: U.S. Geol. Survey Water-Supply Paper 1988, 21 p.

Martin, Lawrence, 1916, The physical geography of Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 36, 608 p.

Milfred, C. J., and Hole, F. D., 1970, Soils of Jefferson County, Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 86, Soil Series No. 61, 172 p.

U.S. Department of Commerce, 1971, 1970 census of population, number of inhabitants, Wisconsin: U.S. Bur. Census Rept. PC (1)-A51 Wis., 46 p.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.

Walton, W. C., 1962, Selected analytical methods for well and aquifer evaluation: Illinois State Water Survey Bull. 49, 81 p.

Weidman, Samuel, and Schultz, A. R., 1915, The underground and surface-water supplies of Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 35, 664 p.

Wisconsin Legislative Reference Bureau {compilers}, 1973, The State of Wisconsin 1973 blue book: Madison, Wisconsin Dept. Adm., 900 p.