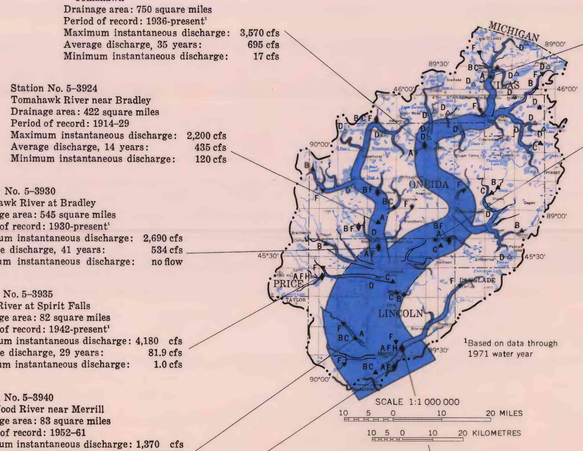
SURFACE WATER

Streams and lakes in the upper Wisconsin River basin contain abundant water of generally good quality. However, man's use of this water has locally altered streamflow characteristics and water quality. About 631.6 billion gallons of water leave the basin yearly as streamflow.

Surface water in the basin is used in numerous ways. The major uses are for power generation, recreation, fish and wildlife habitat, industrial processing, and transportation of industrial and municipal wastes. Minor uses include fish-hatchery operation and irrigation.



Station No. 5-3910
Wisconsin River at Rainbow Lake, near Lake Tomahawk
Drainage area: 750 square miles
Period of record: 1936-present[1]
Maximum instantaneous discharge: 3,570 cfs
Average discharge, 35 years: 695 cfs
Minimum instantaneous discharge: 17 cfs

Station No. 5-3924
Tomahawk River near Bradley
Drainage area: 422 square miles
Period of record: 1914-29
Maximum instantaneous discharge: 2,200 cfs
Average discharge, 14 years: 435 cfs
Minimum instantaneous discharge: 120 cfs

Station No. 5-3930
Tomahawk River at Bradley
Drainage area: 545 square miles
Period of record: 1930-present[1]
Maximum instantaneous discharge: 2,690 cfs
Average discharge, 41 years: 534 cfs
Minimum instantaneous discharge: no flow

Station No. 5-3935
Spirit River at Spirit Falls
Drainage area: 82 square miles
Period of record: 1942-present[1]
Maximum instantaneous discharge: 4,180 cfs
Average discharge, 29 years: 81.9 cfs
Minimum instantaneous discharge: 1.0 cfs

Station No. 5-3940
New Wood River near Merrill
Drainage area: 83 square miles
Period of record: 1952-61
Maximum instantaneous discharge: 1,370 cfs
Average discharge, 9 years: 72.7 cfs
Minimum daily discharge: 1 cfs

Station No. 5-3950
Wisconsin River at Merrill
Drainage area: 2,780 square miles
Period of record: 1902-present[1]
Maximum instantaneous discharge: 49,400 cfs
Average discharge, 68 years: 2,677 cfs
Minimum instantaneous discharge: 90 cfs
[1]Based on data through water year 1971.

[1]Based on data through 1971 water year

Station No. 5-3945
Prairie River near Merrill
Drainage area: 181 square miles
Period of record: 1914-31; 1939-present[1]
Maximum instantaneous discharge: 5,800 cfs
Average discharge, 49 years: 180 cfs
Minimum instantaneous discharge: 34 cfs

Station No. 5-3991.8
Wisconsin River at Conover
Drainage area: 176 square miles
Period of record: 1966-present[1]
Maximum instantaneous discharge: 532 cfs
Average discharge, 5 years: 175 cfs
Minimum instantaneous discharge: 84 cfs

Station No. 5-3920
Wisconsin River at Whirlpool Rapids, near Rhinelander
Drainage area: 1,200 square miles
Period of record: 1905-61
Maximum instantaneous discharge: 5,590 cfs
Average discharge, 56 years: 1,108 cfs
Minimum instantaneous discharge: no flow

EXPLANATION

Width of pattern indicates approximate average discharge of stream, in cubic feet per second

Measurement site symbol[1]	Parameter measured	Frequency of measurement
$A_{\blacktriangle}$	Stream discharge	Continuous
$B_{\blacktriangle}$	Low-flow stream discharge	Intermittent
$C_{\blacktriangle}$	Flood-flow stream discharge	Intermittent
$D_{\blacktriangle}$	Lake stage	Periodic
$F_{\blacktriangledown}$	Chemical quality	Intermittent
$H_{\blacktriangledown}$	Sediment	Intermittent

[1]Letter to left indicates present measurement; letter to right indicates discontinued measurement. Solid symbol indicates site operated by U.S. Geological Survey. Open symbol indicates operation by Wisconsin Valley Improvement Company

Surface-water divide

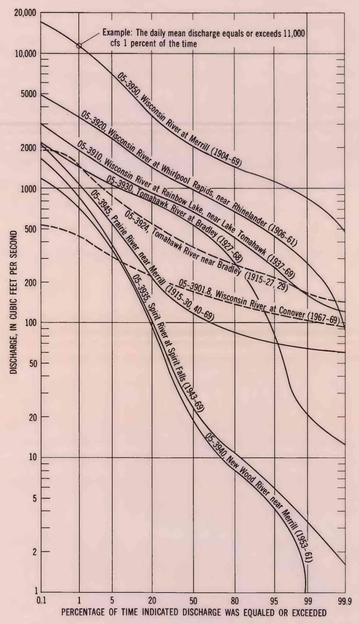
DATA NETWORK AND AVERAGE STREAMFLOW

The surface-water monitoring system in the basin consists of 58 sites. Of these, 38 are U.S. Geological Survey sites, and the remainder are sites of the Wisconsin Valley Improvement Company.

Streamflow (including flood and low flows) and reservoir and lake-stage fluctuations are or have been monitored at 47 sites. Streamflow is continuously monitored at six sites. Continuous records also are available for three sites where streamflow measurements have been discontinued. Intermittent low-flow and flood-flow measurements are made at 14 and nine sites, respectively. The stages of 21 lakes and reservoirs are measured periodically. In addition to the monitoring system, 52 one-time low-flow measurements in the basin are presented in the "Low Flow" section.

Chemical quality of streams is monitored intermittently at 20 sites. Sediment concentrations in streamflow are monitored intermittently at two sites. These data and chemical-quality data on lakes are presented in the "Water Quality" section.

The average discharge pattern represents amounts that hypothetically would yield continuous, unvarying flow through the period of record.



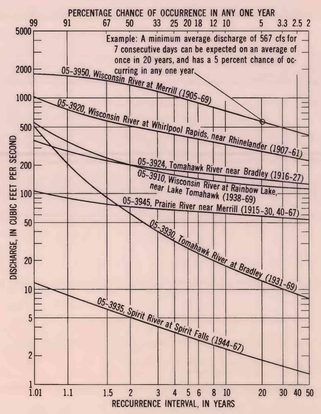
FLOW DURATION

A flow-duration curve shows the percentage of time that the discharge of a stream equals or exceeds a given rate. A duration curve is useful in appraising the hydrologic and geologic characteristics of a drainage basin, which are indicated by the shape and slope of the curve.

Most streams in the basin have flow-duration curves of similar slope but differing magnitude commensurate with drainage area size. These similar slopes may represent similar ground-water discharge conditions or similar regulation of streamflow by release from impoundments. Each has an effect on the shape and slope of the flow-duration curves.

Steep curves, especially the lower ends, for the Spirit River at Spirit Falls and the New Wood River near Merrill (both unregulated streams) indicate little ground-water runoff from the till moraine that covers most of their basins above the gages. The curve for the Prairie River near Merrill, an unregulated stream, is flat at the lower end, indicating substantial ground-water runoff from end moraine and outwash.

The other curves represent regulated streams. The difference in the curves for the Tomahawk River at Bradley and the Tomahawk River near Bradley results from the streamflow regulation at the outlet of Lake Nokomis and the relocation of the gage from above to below the lake. The flattened curve for the Wisconsin River near Conover reflects controlled release from impoundments and sustained ground-water discharge from outwash.



LOW-FLOW FREQUENCY

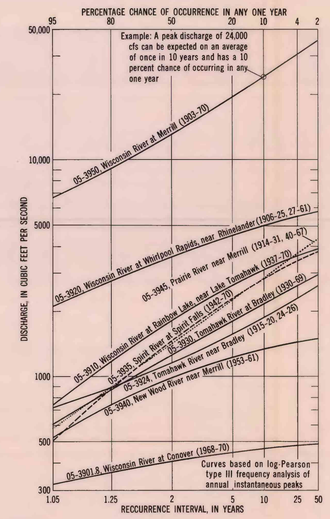
A knowledge of low-flow characteristics of a stream is useful to determine adequacy to supply minimum needs; to design and manipulate reservoirs; to estimate ground-water discharge; and to assess the stream's capacity to assimilate, dilute, and transport waste. Streamflow during the low-flow period is the amount of water released from underground and surface storage.

The 7-day low-flow frequency of streams in the basin ranges from 5 cfs (cubic feet per second) every 2 years for the Spirit River at Spirit Falls to 1,380 cfs for the same interval for the Wisconsin River at Merrill. The curves for streams in the basin are generally parallel and plot in descending order related to drainage area.

The Spirit River at Spirit Falls and the Tomahawk River at Bradley are exceptions to this general relationship. The Spirit River at Spirit Falls drains 82 square miles, mainly till moraine, which supplies little ground water to streamflow. Low flow at this site is relatively small at all recurrence intervals. The flow of the Tomahawk River at Bradley has been influenced by the regulation of Lake Nokomis.

FLOODS

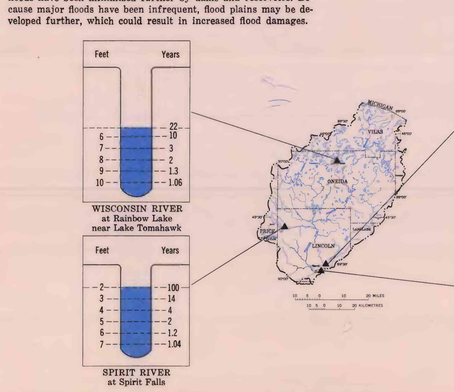
The basin has a low flood risk because extensive plant cover and generally high soil permeability reduce rapid overland flow, and there is little development on flood plains. Damages from floods have been minimized further by dams and reservoirs. Because major floods have been infrequent, flood plains may be developed further, which could result in increased flood damages.

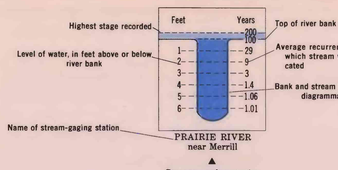


FLOOD-DISCHARGE FREQUENCY

The magnitude of flood flows depends mainly upon the size of the drainage area—the largest area receives the most rainfall or snowmelt and has the most runoff. However, intensity and duration of rainfall, rate of snowmelt, land slope, soil permeability, plant cover, and frost effects also influence the magnitude of flood flows. In general, curves on the graph above are in descending order with decreasing drainage area. An exception is the transposed curves for the New Wood River near Merrill and the Wisconsin River at Conover, which is attributed to the dissimilar periods of record for these sites.

Similar curves indicate similar stream conditions. The relatively low slopes of most of the curves reflect the temporary storage of flood waters by lakes, wetlands, and reservoirs. The curves for the Spirit River at Spirit Falls and the Prairie River near Merrill are steeper, representing flows of unregulated streams.





FLOOD-STAGE FREQUENCY

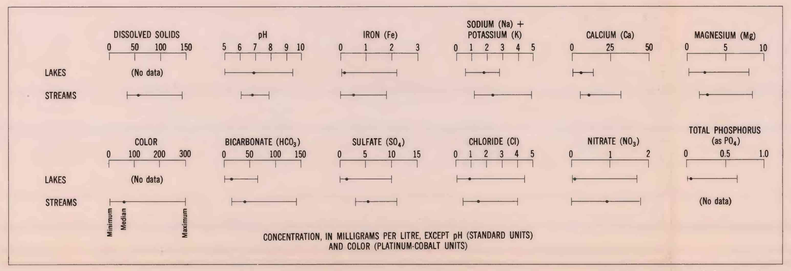
The diagrams above illustrate the recurrence frequency of several high-water stages at long-term stream-gaging sites in the basin. The zero point on the diagram represents bank-full stage at the site and is not a staff-gage reading. The diagrams are schematic and do not represent the stream cross section at the gaging station. They can be used to estimate high-water risks only at the gage because controlling factors differ from site to site. Controlling factors include channel width and depth; velocity of streamflow within the channel and on the flood plain; and channel controls, such as bridges, dams, ice or debris jams, and natural constrictions.

SURFACE-WATER QUALITY

Surface water in the basin generally is of good quality and is suitable for most purposes. The water is commonly soft, containing 0-60 mg/l (milligrams per liter) hardness as $CaCO_3$. Chemical constituents and sediment do not restrict the use of surface water for recreation or most industries.

Water color of lakes and streams in the basin ranges from clear to dark brown. The colored water is due to organic materials derived from wetland vegetation. As a result, streams draining wetlands and the lakes into which they flow are commonly colored. Statistically, the smaller lakes are more commonly colored and the large lakes clear (Black and others, 1963, p. 184).

Pollution of surface water is minor, although the quality of the Wisconsin River at Rhinelander, Tomahawk, and Merrill has been degraded (Wisconsin Department of Natural Resources, 1970, p. 6-9, 27-29). Ninety-four percent of the suspended solids discharged into streams is from pulp and paper mills; 94 percent of the biological oxygen demand (BOD) is caused by this discharge (Wisconsin Department of Natural Resources, 1970, p. 42). Because the area is comparatively undeveloped, there is little pollution of streams from municipal or other industrial wastes. Fertilization of lakes because of shoreline development of homes is a condition of increasing seriousness.



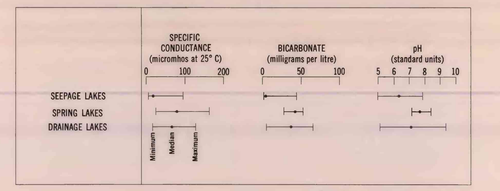
Based on analyses by U.S. Geological Survey and on analyses compiled by Poff (1967)

RANGE IN QUALITY OF STREAM AND LAKE WATER

The illustration above compares the quality of water in lakes and streams. Lake analyses represent a cross section of all lake types. Stream analyses include the mainstems of major rivers and tributaries. The number of samples for each parameter ranges from 11 to 170 for lakes and from 19 to 24 for streams.

Nitrogen and phosphorus are important nutrients in surface water, but excessive concentrations may accelerate weed and algal growth in streams and lakes. The critical concentrations given by Sawyer (1947) are 1.3 mg/l inorganic nitrogen, as NO_3, and 0.03 mg/l inorganic phosphorus, as PO_4.

In general, streams in the basin are slightly more mineralized than lakes. Concentrations of all chemical constituents in lakes and streams are low, and the water is suitable for most uses.



Based on analyses compiled by Andrews and Threinen (1966), Black, Andrews, and Threinen (1963), and Poff (1967)

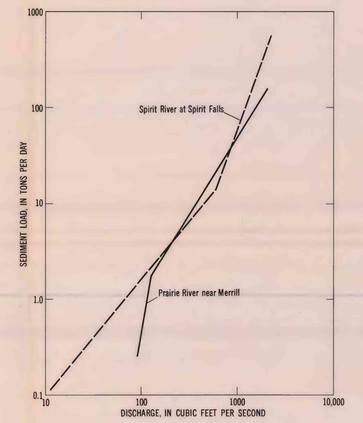
RANGE IN QUALITY OF LAKE WATER

This diagram shows the range and median values of some chemical constituents in lake water in the basin. The lakes are considered in three categories, spring, seepage, and drainage, used by the Wisconsin Department of Natural Resources. Andrews and Threinen (1966) define them as follows: A spring lake seldom has an inlet but has an outlet of substantial flow. It is fed by ground water rather than surface drainage. A seepage lake has no inlet or outlet, although it may have an intermittent outlet. Lake level is maintained by the water table or by a well-sealed lake bottom. A drainage lake has an outlet and at least one inlet. Its main water source is from stream drainage.

Specific conductance values were determined for 160 seepage lakes, 82 drainage lakes, and 28 spring lakes. Conductance is related to mineralization by the general relationship for the area: specific conductance × 0.7 = dissolved solids. The highest conductance and, therefore, the highest mineralization is in spring lakes, which receive the greatest amount of ground water. Drainage lakes are less mineralized than spring lakes. In this basin many seepage lakes are bog lakes and have only slightly mineralized water.

Bicarbonate is related to alkalinity, which is sometimes used as an index of fish productivity (Andrews and Threinen, 1966, p. 160). The median values of bicarbonate for spring and drainage lakes are similar. Both lake types are excellent for fish. Seepage lakes generally are not considered good fish habitat, probably due in part to low bicarbonate content.

The pH of water is a measure of its acidity (low pH) or basicity (high pH). Drainage lakes show the greatest range in pH values, although the median value is nearly neutral (pH 7). Water in spring lakes is similar to ground water. The range within seepage lakes is wide, but the low median value of 6.3 probably results from the low pH in shallow bog ponds.



STREAM DISCHARGE-SEDIMENT RELATION

The capacity of a stream to carry sediment depends upon stream velocity and discharge, but the actual sediment load depends also upon the availability of sediment. Concentrations of sediment usually peak during storm runoff, shortly before the stream reaches peak discharge.

The graph at left shows the suspended-sediment load, in tons per day, related to discharge based on samples from two stream sites. The relationship is only approximate; for example, at a discharge of about 130 cfs, the sediment load in the Spirit River at Spirit Falls has been measured to be 0.7 ton per day at one time and 10 tons per day at another. This variation occurs because less sediment is available at one time than another, possibly due to seasonal changes in vegetation or agricultural practices, land clearing and excavations, or road and other construction.

Streams in the upper Wisconsin River basin have low sediment loads ranging from less than 10 to 25 tons of suspended sediment per square mile of drainage area per year (Hindall and Flint, 1970). These streams are in a relatively undeveloped, forested region, where outwash soils have high infiltration rates. Lakes and reservoirs act as stilling ponds where sediment is trapped and retained.

Stream sediment is not a major problem in the basin. However, it diminishes the trout habitat in some tributary streams because of streambank clearing by beavers and subsequent siltation behind their dams (Andrews and Threinen, 1966, p. 185).

SUMMARY

Large amounts of good quality water are available in the upper Wisconsin River basin. Most areas have adequate supplies of water for future growth. The amount of surface water withdrawn in the basin is three times that of ground water, although the total withdrawal use is only about 2 percent of the streamflow leaving the basin. Ninety-one percent of the surface water used in the basin is for pulp and paper processing. Nonwithdrawal uses of surface water are power generation, recreation, fish and wildlife habitat, cranberry culture, and fish hatcheries. Ground water is used for all community and most rural supplies and for some irrigation.

Ground water, which is more widespread than surface water, is available principally from glacial sand and gravel deposits, although a few wells tap crystalline bedrock. Domestic and stock supplies are available everywhere in the basin. The sand and gravel commonly yields several hundred gallons per minute to wells in many places.

Controlled release from a network of 20 reservoirs regulates streamflow for power generation on the Wisconsin and Tomahawk Rivers. Supplemental benefits of the network are flood control and the development of recreational areas.

The northern part of the basin is a favorite recreation area. Forests cover more than 80 percent of Vilas and Oneida Counties, and the basin contains more than 2,000 lakes and 1,500 miles of streams. The lakes and streams contain trout and many species of game and pan fish.

Water quality in the basin is good. Most surface water is soft, and ground water is soft to moderately hard. There is little pollution, and stream sediment loads are low.

Water problems are minor and are related primarily to water quality. High iron content is a local problem in ground water. Reaches of the Wisconsin River are polluted by industrial wastes. Some small lakes may have an algae problem because of overfertilization, which may contribute to winterkill of fish.

SUMMARY OF WATER AVAILABILITY AND SUITABILITY FOR VARIOUS USES

Source / Use and considerations	SURFACE WATER: Wisconsin, Tomahawk, Pelican, and Eagle Rivers	SURFACE WATER: Prairie River	SURFACE WATER: Spirit, New Wood, Copper and, Somo Rivers	SURFACE WATER: Headwaters and small tributary streams	SURFACE WATER: Large lakes and reservoirs	SURFACE WATER: Small lakes and wetlands	GROUND WATER: Glacial drift: Ground and end moraine	GROUND WATER: Glacial drift: Outwash and ice-contact sand and gravel	GROUND WATER: Bedrock
Municipal and industrial supply Quantity: 100,000 gpd (gallons per day) for a population of 1,000 or a small industry Quality: Cost of sanitary treatment of surface water for municipal use	Adequate discharge Soft water Strong flow maintained by release from reservoirs Some reaches polluted by municipal and paper mill wastes Sanitary treatment necessary	Adequate discharge Good chemical quality; mostly soft water Very little pollution Sanitary treatment necessary	Good chemical quality; mostly soft water Very little pollution Discharge inadequate during dry seasons Sanitary treatment necessary Colored	Good chemical quality; mostly soft water Very little pollution Discharge may be inadequate during dry seasons Sanitary treatment necessary Colored where wetland drainage is present	Adequate quantity Good chemical quality; mostly soft water Very little pollution Sanitary treatment necessary May be colored	Lakes have good chemical quality; mostly soft water Very little pollution Quantity may be inadequate Sanitary treatment necessary Small lakes commonly colored	Good chemical quality; mostly moderately hard water Not commonly subject to pollution Well yields may be inadequate May be high in iron	Adequate well yields Good chemical quality; mostly soft to moderately hard water May be high in iron Easily polluted	Good chemical quality; mostly soft to moderately hard water Not commonly subject to pollution Well yields inadequate
Rural domestic and stock supply Quantity: 5 gpm (gallons per minute), adequate for pressure system Quality: Cost of sanitary treatment of surface water for domestic use	Adequate discharge Soft water Strong flow maintained by release from reservoirs Some reaches polluted by municipal and paper mill wastes Sanitary treatment necessary for domestic use Available only to shorelands	Adequate discharge Good chemical quality; moderately hard water Very little pollution Sanitary treatment necessary for domestic use Available only to shorelands	Adequate discharge Good chemical quality; mostly soft water Very little pollution Sanitary treatment necessary for domestic use Colored Available only to shorelands	Adequate discharge Good chemical quality; mostly soft water Very little pollution Widespread distribution Sanitary treatment necessary for domestic use Colored where wetland drainage is present Available only to shorelands	Adequate quantity Good chemical quality; mostly soft water Very little pollution Sanitary treatment necessary for domestic use Available only to shorelands May be colored	Adequate quantity in lakes Lakes have good chemical quality; mostly soft water Very little pollution Excessive fertilization from nearshore sewage disposal may contribute to a local algae problem Sanitary treatment necessary for domestic use Small lakes commonly colored Available only to shorelands	Adequate well yields Good chemical quality; mostly moderately hard water Not commonly subject to pollution May be high in iron	Adequate well yields Good chemical quality; mostly soft to moderately hard water May be high in iron	Good chemical quality; mostly soft to moderately hard water Not commonly subject to pollution Well yields may be inadequate
Recreation Adequate public access and user facilities Attractive physical setting Water free from pollution, excessive weed growth, odor, and high sediment load	Public access at many points State and county parks Good boating on lower reaches Good fishing for pan fish and game fish Strong flow maintained by release from reservoirs Little sediment Fishing degraded by pollution in some reaches of the Wisconsin River	Public access at many points Trout stream Very little pollution Large low flows Little sediment County park	Headwaters are trout streams Very little pollution Little sediment Limited public access in headwaters of New Wood and Copper Rivers Small low flows	Several are trout streams Very little pollution Little sediment Limited public access in the northern part of the basin Small low flows on some streams	Good public access Numerous resorts, boat rental facilities and campgrounds Good boating; boat trips can be made through several "lake chains" Good fishing for pan fish and game fish Good swimming Very little pollution	Numerous resorts, boat-rental facilities, and campgrounds Good fishing for pan fish and game fish Very little pollution About half the lakes have no public access Excessive fertilization from nearshore sewage disposal may contribute to a local algae and winterkill problem			
Fish and wildlife habitat Adequate depth and quality for fish Adequate flow for stream fish Adequate cover for wildlife in or around streams and wetlands	Adequate depth Strong flow maintained by releases from reservoirs Good cover in adjacent wetlands and forests Habitat degraded by pollution in some reaches of the Wisconsin River	Very little pollution Large low flows Good cover in adjacent wetlands and forest	Very little pollution Good cover in adjacent wetlands and forest Depth inadequate in headwaters Small low flows	Very little pollution Good cover in adjacent wetlands and forest Depth commonly inadequate Small low flows on some streams	Adequate depth Very little pollution Good cover in adjacent wetlands and forest	Depth commonly adequate Wetlands provide good cover Very little pollution Good cover in wetlands and forest adjacent to lakes Excessive fertilization from nearshore sewage disposal may contribute to a local algae and winterkill problem Low fish productivity common			

EXPLANATION

Good chemical quality; mostly soft water
Very little pollution
} Advantages for use

Discharge inadequate during dry seasons
Sanitary treatment necessary
Colored
} Limitations for use

General suitability for use: Good, Fair, Poor

This table lists advantages and limitations of sources without regard for legal limitations. Water withdrawals from streams, lakes, and high-capacity wells (capacity to yield more than 100,000 gpd) require permits from the Wisconsin Department of Natural Resources.

AGENCIES HAVING ADDITIONAL INFORMATION

Information source \ Information category	Geology	Soils	Topography and drainage	Land use	Water budget	Ground- and surface-water relationships	Surface water	Surface-water quality	Pollution	Ground water	Ground-water quality	Water use	Recreation and fish and wildlife
U.S. Environmental Protection Agency (formerly Federal Water Quality Administration), 88th St. and 40th Ave. South, Minneapolis, Minn. 55450								■	■				
U.S. Army Corps of Engineers, Chicago District, 219 South Dearborn St., Chicago, Ill. 60607				■			■						
U.S. Department of Agriculture, Soil Conservation Service, 4601 Hammersley Rd., Box 4248, Madison, Wis. 53711		■		■			■					■	
U.S. Department of the Interior, Bureau of Outdoor Recreation, 3853 Research Park Dr., Ann Arbor, Mich. 48104													■
U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, Room 630, Federal Building, Fort Snelling, Minneapolis, Minn. 55111							■						■
U.S. Forest Service, 633 West Wisconsin Avenue, Milwaukee, Wis. 53403				■									■
U.S. Geological Survey, Water Resources Division, 1815 University Ave., Madison, Wis. 53706	■		■	■	■	■	■	■	■	■	■	■	■
Wisconsin Department of Natural Resources, 4610 University Ave., Box 450, Madison, Wis. 53701				■				■	■	■	■	■	■
Wisconsin Geological and Natural History Survey, 1815 University Ave., Madison, Wis. 53706	■	■	■		■	■	■	■		■	■		■
Wisconsin Public Service Commission, 432 Hill Farms State Office Bldg., Madison, Wis. 53702													■
Wisconsin Valley Improvement Company, 501 Jefferson St., Wausau, Wis. 54402							■			■			■
University of Wisconsin Water Resources Center, Hydraulic and Sanitary Laboratory, Madison, Wis. 53706							■	■	■	■	■	■	■

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Wisconsin Department of Natural Resources, 1968, Wisconsin trout streams: Madison, Div. Conserv. Pub. 213-68, 75 p.
——— 1970, Upper Wisconsin River pollution investigation survey: Madison, 103 p.
Wisconsin Valley Improvement Company [no date], The Wisconsin River—namesake of a state: Wausau, 18 p.

Base from U.S. Geological Survey
1:500,000 1968

WATER RESOURCES OF WISCONSIN—UPPER WISCONSIN RIVER BASIN

By
E. L. Oakes and R. D. Cotter
1975

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1975