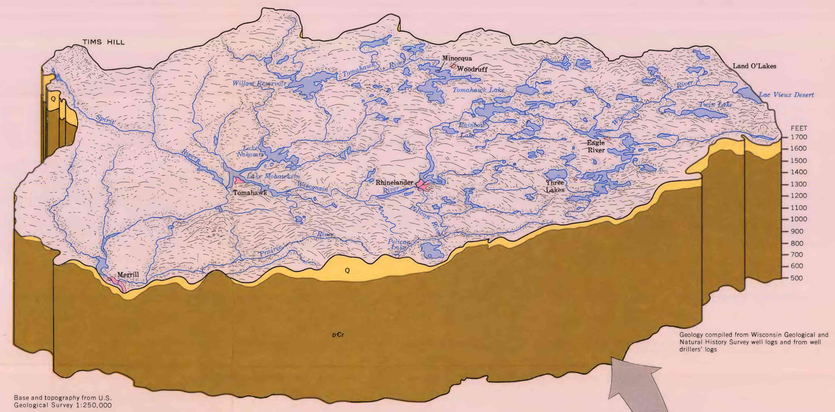
INTRODUCTION

This report describes the physical environment, availability, distribution, movement, quality, and use of water in the upper Wisconsin River basin as an aid in planning and water management. The report presents general information on the basin derived from data obtained from Federal, State, and local agencies. New field data were collected in areas where information was lacking. More detailed studies of problem areas may be required in the future, as water needs and related development increase.

The upper Wisconsin River basin is the headwaters of the Wisconsin River drainage and includes about 2,730 square miles in northern Wisconsin (upstream from the gage on the Wisconsin River at Merrill). An additional 50 square miles of the basin lies in Michigan and is not covered by this report. The report area includes parts of Forest, Langlade, Lincoln, Marathon, Oneida, Price, Taylor, and Vilas Counties.

Many organizations and persons assisted the study by providing data. Among the contributors were the University of Wisconsin-Extension, Geological and Natural History Survey, the Wisconsin Department of Natural Resources, the Public Service Commission of Wisconsin, and the Wisconsin Valley Improvement Company. Municipal water officials furnished water-supply information and well records. Many individuals allowed access to their wells for water-level measurements and collection of water samples for chemical analysis.

PHYSICAL SETTING



Base and topography from U.S. Geological Survey 1:250,000

Geology compiled from Wisconsin Geological and Natural History Survey well logs and from well drillers' logs

The basin has an irregular glacial landscape. Rolling ground moraine and hills and ridges of end moraine cover all but the central part of the southern one-half. The pitted outwash plains and rugged ice-contact topography of the south-central and northern parts are dotted by more than 2,000 lakes.

The basin has a poorly developed drainage network, as indicated by the numerous lakes. The Wisconsin River meanders southward through the center of the basin, and major tributaries feed it from east and west.

The altitude of the land surface ranges from about 1,240 feet along the Wisconsin River at Merrill to 1,952 feet atop Tims Hill in southern Price County. Tims Hill is the highest point in Wisconsin. Local relief exceeds 200 feet in several areas of end moraines.

The bedrock is part of a Precambrian crystalline area that is the southern extension of the Precambrian Canadian Shield. Throughout most of the basin the bedrock surface has an altitude between 1,400 and 1,600 feet and slopes generally towards the south. Locally, buried bedrock hills have 200-300 feet of relief and altitudes ranging from less than 1,200 feet to more than 1,700 feet.

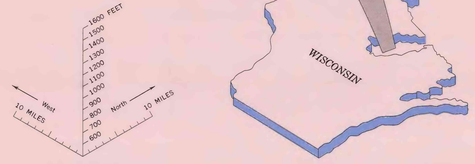
Bedrock is Precambrian igneous or metamorphic rock. Known rock types include granite, diorite, schist, gneiss, quartzite, slate, and greenstone (Dutton and Bradley, 1970, p. 9, 11, 12, and sheet 1). The occurrence and distribution of these rock types have not been well defined because outcrops are sparse and few wells are completed in bedrock.

EXPLANATION

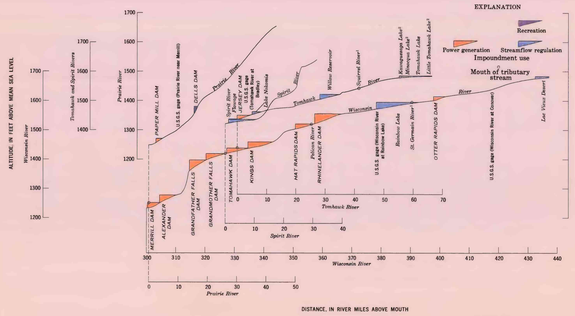
QUATERNARY
- Q — Glacial deposits

PRECAMBRIAN
- pCr — Crystalline rocks

Contact



BLOCK DIAGRAM OF THE UPPER WISCONSIN RIVER BASIN



¹ Too small to be named on base map
² Lakes not named on base map but all part of a single reservoir

STREAM PROFILES

Profiles of streams in the upper Wisconsin River basin reflect the character of the land over which the streams flow. The Tomahawk River and the Wisconsin River above Rainbow Lake flow over relatively flat outwash sand and gravel and have low gradients, about 3 feet per mile. Between Rainbow Lake and Merrill the gradient of the Wisconsin River is 3–4 feet per mile, except at Grandfather Falls Dam, where the river falls 120 feet in less than 10 miles. The gradient of the river above this steep fall is maintained by bedrock in the channel. The Spirit and Prairie Rivers have gradients averaging about 10 feet per mile. The headwaters of both are in end moraine.

There are many bodies of water in the basin whose outflow is controlled by dams. Some are natural lakes; others are man-made. As used in this report, impoundment refers to any body of water whose discharge is regulated by a control structure. One type of impoundment is a reservoir, from which water is released to maintain streamflow rather than to generate power.

Of the numerous impoundments, many have multiple purposes. The primary purpose of 18 of these is shown on the illustration. Eleven produce hydroelectric power for pulp and paper mills and for utilities. There are 20 storage reservoirs used for streamflow regulation. All are used for recreation, and Della Dam impoundment is used only for that purpose.

WATER USE

WITHDRAWAL USE OF WATER IN 1970

[Million gallons per day]

Use	Source and type of supply				Total
	Ground water			Surface water	
	Public supply		Private supply	Private supply	
	Municipal	Other			
Domestic	1.0	0.1	2.3	0	3.4
Industrial and commercial	1.6	0	.3	24.4	26.3
Irrigation	0	0	.5	0	.5
Stock	0	0	.3	.1	.4
Other	1.5	0	0	1.3	2.8
Subtotal	4.1	.1	3.4		
Total	7.6			25.8	33.4

About 12 billion gallons of water was withdrawn for use in the upper Wisconsin River basin in 1970. About 77 percent of this amount was water from streams, lakes, and reservoirs. The remainder was from wells.

Of the surface water withdrawn, more than 91 percent was used for pulp and paper manufacturing at five plants on the Wisconsin and Tomahawk Rivers. Most such water was returned to the streams within a short time.

Ground water supplies all communities and most rural and small industrial needs. Public supply is that used by municipalities, civil townships, sanitary districts, and schools. In the use column, "other" includes losses from the distribution systems, street washing, water-main flushing, and use in public buildings. Private supply is that used for all other purposes, including rural farm and nonfarm, industries, commerce, resorts, and irrigation.

Withdrawal use of water in 1970 was equal to about 2 percent of the average streamflow leaving the basin. However, because most of the water is discharged into the nearest stream after use, it is available for reuse downstream. Therefore, data on withdrawals of surface water include an undetermined amount of reuse of water.

NONWITHDRAWAL USE

Major nonwithdrawal uses of water in the basin are for power generation, fish and wildlife habitat, and recreation. Eleven dams are used for hydroelectric-power generation; nine are located on the Wisconsin River, and there is one each on the Tomahawk and Prairie Rivers. In 1970 the power plants of these dams generated about 440 megawatt hours daily, passing an average of 8,000 cfs (cubic feet per second) (1,000 billion gallons per year) of water through their turbines. This amount is about three times the average runoff from the basin. This reuse of water is not consumptive; water discharged at a power plant is available for use downstream.

The basin is noted for its fish and wildlife habitat. It contains more than 2,000 lakes and 1,600 miles of streams, of which 548 miles are trout streams. Most common species of game and pan fish are abundant in the lakes (Wisconsin Department of Natural Resources, 1968). Cover is provided for game by forests (70 percent of the area).

The upper Wisconsin basin is one of the most popular recreation centers in the State and is used extensively in the summer for fishing, boating, camping, and swimming. In Vilas County, the resident-water ratio is 1 person to 10 acres. In the peak summer season, the resident-plus-tourist-water ratio is 1 person to 0.32 acre (Black and others, 1965, p. 198). In addition to summer-based recreation, fall hunting and winter snowmobiling are popular.

The use of water in fish hatcheries and for cranberry culture is considered as nonwithdrawal, although surface water is diverted from natural courses. Fish-hatchery use was estimated to have been 7 mgd (million gallons per day) in 1970 and cranberry-culture use to have been 0.3 mgd. The major use of water in cranberry culture is for frost protection rather than irrigation.

COMMUNITY WATER USE IN 1970

[Pumpage and use data from Public Service Commission of Wisconsin]

Community	County	Population 1970	Average daily pumpage (mgd)	Maximum daily pumpage (mgd)	Use (million gallons per year)			
					Domestic	Industrial and commercial		
							Public	Other
City of Eagle River	Vilas	1,326	0.32	0.56	20	60	5	32
Land O'Lakes Sanitary District	Vilas	¹400	.05	.16	--	--	--	--
City of Merrill	Lincoln	9,502	1.40	2.41	121	201	102	86
Town of Minocqua	Oneida	¹1,500	²22	.5	17	22	6	²35
City of Rhinelander	Oneida	8,218	1.67	3.16	140	233	31	207
Three Lakes Sanitary District	Oneida	²700	.06	.13	6	6	1	9
City of Tomahawk	Lincoln	3,419	.39	.83	42	43	5	51
Woodruff Sanitary District	Oneida	¹1,000	².06	--	5	11	2	4
Total		26,065	4.11	--	351	576	152	402

¹ Estimated.
² Figures for Minocqua include 0.06 mgd (22 mgy) in resales of water to Woodruff.

All eight communities in the basin having distribution systems use ground water from glacial sand and gravel. About 75 percent of the 1970 pumpage was at Merrill and Rhinelander. Thirty-nine percent of the water use by these eight communities was for industrial and commercial purposes, and 24 percent was domestic; the remainder was used for public buildings, street washing, and main flushing, or was lost in distribution.

EXPLANATION

Use, in million gallons per day
0.1–0.5 | 0.5–1 | 1–5 | 5–10 | 10–50

WITHDRAWAL USE
Ground water ○ Surface water
Community
Self-supplied industrial for paper and pulp manufacturing □
Irrigation ◐

NONWITHDRAWAL USE
Fish hatchery △
Cranberry culture △
Individual sites use less than 0.1 mgd
Trout stream
Large lake or impoundment 2.8
Number is area, in square miles
Hydroelectric power plant 370 (8252)
Upper number is 1970 water use, in million gallons per day. Lower number is 1970 power output, in megawatt hours.
Surface-water divide

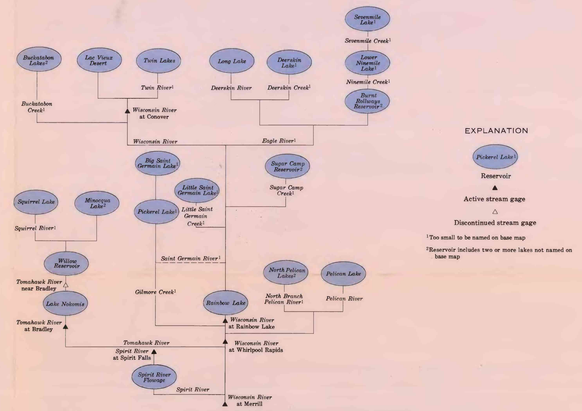
DISTRIBUTION OF USE

Major centers of water use for municipal purposes, pulp and paper manufacturing, and hydropower generation are along the Wisconsin River. Three of the four community supplies shown are near the river, and three of the four paper-manufacturing plants, as well as nine of the power-generation dams, are on this river.

Water is used for recreation throughout the basin. Most lakes and impoundments are in the northern two-thirds. Trout streams are scattered throughout, and, except for the Prairie River, are mostly small headwater tributaries.

The four fish hatcheries and eight cranberry-growing areas shown are widely spaced, and all use surface water.

Ground water is used throughout the basin for domestic, agricultural, and small industrial supplies. Although individual quantities are too small and scattered to show on the map, the total use is more than 3 mgd.



EXPLANATION
- Pickerel Lake — Reservoir
- ▲ Active stream gage
- △ Discontinued stream gage

¹Too small to be named on base map
²Reservoir includes two or more lakes not named on base map

SYSTEM OF STREAMFLOW REGULATION RESERVOIRS

A reservoir management system has developed over the years to provide a more uniform streamflow than that provided by nature because of the water and power requirements of the paper mills. The system was created under a legislative act for the purpose of producing as nearly a uniform flow of water as practicable in the Wisconsin and Tomahawk Rivers. The primary aim of the system is to augment low flows for power generation, and the secondary aim is flood control. Corollary advantages of the system are recreation and the assimilation of wastes.

The streamflow-regulation system consists of 20 reservoirs, with a total of surface area of 59,604 acres, a controlled drainage area of 981,760 acres, and a total usable-contents storage capacity of 13 billion cubic feet (Wisconsin Valley Improvement Company, written commun., 1972). Sixteen of these reservoirs were built to take advantage of natural lakes and old logging dams. These 16 have a combined storage of approximately 38 percent of the total storage of the system. The other 62 percent of storage is provided by four reservoirs expressly built for streamflow regulation. These four are the Spirit River Flowage, Willow Reservoir, Rainbow Lake, and Lake Nokomis (Carlson and others, 1968, p. 4).

The usual cycle of reservoir operation is to fill in the spring, release some water during summer dry periods, partly refill in autumn, and lower during the winter. An important aspect of reservoir operation is "routing" the high flows. This is the procedure by which the Wisconsin Valley Improvement Company regulates storage and release between their 20 reservoirs to reduce flooding.

During high flow, reservoir storage has reduced the flow at Merrill from a calculated natural rate of 7,000 cfs to a measured 4,000 cfs. Release from storage can increase a natural low flow of 800 cfs to 1,600 cfs (Wisconsin Valley Improvement Company, undated written commun.).

Geology after Thwaites (1956)
Drift thickness from well records

EXPLANATION

STRATIFIED DRIFT
- Qo — Outwash and ice-contact deposits
  Sand, sand and gravel, includes pitted and unpitted outwash, and ice-contact features on the flank of end moraines. Small patches of ground moraine may occur in this area

UNSTRATIFIED DRIFT
- Qg — Ground moraine
  Till, consists of clay, silt, sand, pebbles, cobbles, and boulders
- Qe — End moraine
  Till, includes some minor ice-contact stratified drift

QUATERNARY

Contact
200 — Line of equal thickness of glacial drift
Interval 50 feet
Surface-water divide

SURFICIAL GEOLOGY

Glacial drift overlies bedrock in the basin and stores water for release to wells and streams. It is the only significant source of ground water.

Drift is either stratified or unstratified, depending on the method of deposition. Most stratified drift consists of ice-contact deposits or outwash laid down by melt water during glacial stagnation. Outwash generally occurs in areas of lakes and impoundments in the Wisconsin River headwaters. Unstratified drift consists either of ground moraine (a sheet of unsorted sandy clay till laid down directly by ice) or of end moraine (ridges of bouldery, sandy clay till laid down by ice during pauses in glacial advance or retreat). End moraines usually include some stratified ice-contact features and outwash. Ground moraine may overlie or underlie outwash or may include outwash deposits.

Drift thickness ranges from almost 0 to 240 feet and averages about 100 feet over much of the basin. With some exceptions, the drift is thickest in areas of end moraine and thinnest in areas of ground moraine. The surficial outwash commonly ranges in thickness from 20 to 100 feet.

Data from Hole and others (1968) and U.S. Soil Conservation Service (1964)

EXPLANATION

Permeability rate, in inches per hour (under a 0.5 inch head)
- 0.05–0.2
- 0.2–0.8
- 0.8–2.5
- 2.5–5
- 5–10

Surface-water divide

SOIL PERMEABILITY

Soils determine, in part, how much rainfall or snowmelt directly runs off to streams and how much infiltrates the ground. Soils with low permeability allow rapid surface runoff and little infiltration of precipitation; highly permeable soils allow rapid infiltration and little surface runoff.

Soil permeability in the basin is related to the deposits from which the soils were derived. Soils with a permeability rate of 0.05–0.2 inch-per-hour are either peat or muck; the 0.2–0.8 inch-per-hour soils are mostly developed on clay-till ground moraine; the 0.8–2.5 inch-per-hour soils are developed on sandier areas of mixed outwash and ground and end moraines; the 2.5–5.0 inch-per-hour soils are developed on sand and gravel ice-contact deposits on the flanks of end moraine and outwash sand mixed with ground moraine; and 5–10 inch-per-hour soils are developed on very permeable outwash sand. The greater soil permeability is generally associated with the more sandy parent material.

The map of soil permeability is based on the least permeable soil horizon (U.S. Soil Conservation Service, 1964).

Soil data from Hole and others (1968) and Hole (written communications, 1968)

EXPLANATION

Suitability	Qualifications	Parent material
Good	Soil is level and permeable; water table is more than 4 feet below land surface	Sand and gravel and some sandy till; both with discontinuous thin silt cover
Fair	Terrain is undulating to rolling and contains wetlands needing drainage	Sand and gravel and sandy till; both with discontinuous thin silt cover; organic materials
Good on the few level areas		
Poor	Terrain is hilly and stony, or water table is less than 1 foot below land surface	Silt; sand and gravel; sandy till; organic material

Surface-water divide

SOIL SUITABILITY FOR IRRIGATION

Water for irrigation is available nearly everywhere in the basin; however, the suitability of soils for irrigation differs greatly and depends upon topography, soil permeability, and depth to the water table. Soils in this basin are grouped above according to topographic setting and the parent material from which the soil was formed (F. D. Hole, written commun., 1968). The soil suitability shown above does not consider the important factors of soil fertility and climate.

Soils have good suitability for irrigation where the topography is level, to allow uniform distribution of water and to prevent excessive water runoff; the soil is permeable, so that water can infiltrate and percolate to the root zone; and the depth to the water table is 4 feet or more, so that plant roots remain in the zone of aerated soil for proper utilization of oxygen and nutrients. Soil suitability is good in areas of flat outwash and on level alluvial areas in end moraine. Soils have fair suitability for irrigation where the topography is uneven and runoff is great. Suitability is fair in an extensive outwash area and near lakes and streams in less extensive areas of end and ground moraines. Suitability is good in level, drained wetlands and small, level uplands within these areas.

Soils are poor for irrigation in hilly areas of coarse, bouldery sand and gravel, in semipermeable end and ground moraines, and in undrainable wetlands.

HYDROLOGIC BUDGET

A hydrologic budget is a quantitative accounting of the balance between total water gains and losses for a given period in a given area. The budget indicates that precipitation (the principal water source) either leaves the basin as streamflow or returns to the atmosphere as evapotranspiration. Minor adjustments to the budget may be made for changes in storage. Underflow is not significant and is not considered in the budget.

The average annual budget for a 30-year period (calendar years 1931–60) indicates that, of the 31.3 inches of precipitation on the basin, 12.4 inches left as streamflow. This flow was equivalent to 2,546 cfs, or 1,646 mgd. The largest quantity of water that left the basin was 18.9 inches of evapotranspiration.

Single-year budgets are shown for the dry (1948) and wet (1951) years.

PRECIPITATION

(INCHES)	
Dry year (1948)	23.7
Average (1931-60)	31.3
Wet year (1951)	40.1

Annual precipitation in the basin during 1931–60 averaged 31.3 inches. The average is slightly more than 33 inches in the southwestern part and slightly less than 31 inches in the eastern part. Precipitation of 40.1 inches made 1951 a wet year, and 23.7 inches made 1948 a dry year.

RUNOFF

(INCHES)	
Dry year (1948)	6.7
Average (1931-60)	12.4
Wet year (1951)	18.2

Runoff is the most accurately measured of all the budget items. A stream gage at Merrill continuously monitors the stage of the Wisconsin River. The stage is converted to flow, in cubic feet per second. The average flow of 2,546 cfs equals 12.4 inches for the basin for the budget period. The average flow in the dry year (1948) was 6.7 inches and in the wet year (1951), 18.2 inches.

CHANGE IN STORAGE

(INCHES)	
Dry year (1948)	LOSS 0.6
Average (1931–60)	0
Wet year (1951)	GAIN 2.3

Water for storage occurs as ground water, soil moisture, or in lakes, reservoirs, and wetlands. Storage changes are assumed to equal zero on a long-term basis. A storage gain estimated to have been 2.3 inches in the wet year (1951) was based on a ground-water-storage increase of 1.56 inches (from analysis of six observation-well hydrographs) and a surface-water-storage increase of 0.77 inch (from records of the Wisconsin Valley Improvement Company). In the dry year (1948) storage loss was estimated to have been 0.6 inch, based on a 0.7 inch ground-water storage decrease and a 0.1 inch surface-water-storage increase.

EVAPOTRANSPIRATION

(INCHES)	
Dry year (1948)	17.6
Average (1931-60)	18.9
Wet year (1951)	19.6

Evapotranspiration is the return of water to the atmosphere by evaporation from open water, plant surfaces, and bare ground, and plant transpiration. The figures above are derived as a residual amount after all other measured and estimated amounts have been subtracted from precipitation. The annual average evapotranspiration for 1931–60 was 18.9 inches. The bulk of evaporation and transpiration takes place during the summer, when temperatures are high and plant growth most active. Evapotranspiration is highest in the southern part of the basin, which has fewer lakes but higher average temperatures and a longer growing season. Evapotranspiration was 19.6 inches in the wet year (1951) and 17.6 inches in the dry year (1948).

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

For sale by U.S. Geological Survey, Reston, Virginia 22092, price $2.25 per set