# INTRODUCTION

## PURPOSE AND SCOPE

The purpose of this report is to describe the physical environment of the Chippewa River basin, emphasizing the availability, distribution, movement, and quality of water. In addition, use of water and water problems are summarized to give an understanding of man's management of water within the basin.

This atlas is the fourth in a series of river-basin studies that will describe, in general terms, the water resources of the State. The report presents general information on the basin that was derived from data obtained from many Federal, State, and local agencies. Additional data were collected for areas where available data were scarce. Detailed studies of problem areas may be necessary in the future as the need for specific information increases. The reader is referred to the sections titled "Agencies Having Additional Information" and "Selected References" on sheet 4 for sources of further information.

## ACKNOWLEDGMENTS

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

## GEOGRAPHY

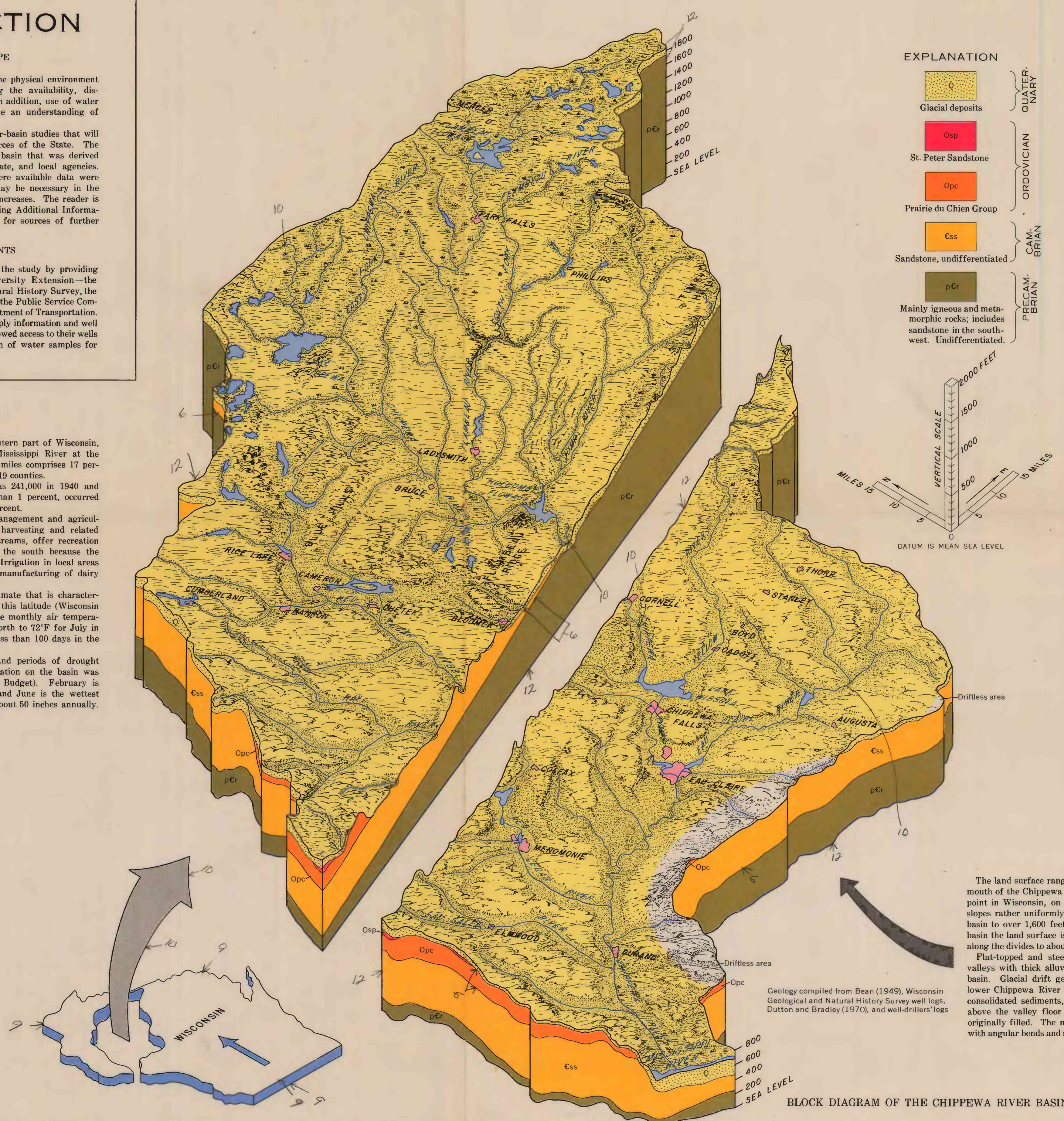
The Chippewa River basin, in the northwestern part of Wisconsin, extends 175 miles from Michigan to the Mississippi River at the Minnesota border. Its area of 9,495 square miles comprises 17 percent of the State and consists of all or parts of 19 counties.

The estimated population of the basin was 241,000 in 1940 and 243,000 in 1960. This small growth, less than 1 percent, occurred while the State's population increased by 26 percent.

Major land uses are recreation, forest management and agriculture. In the north, forests provide wood harvesting and related manufacturing and, along with lakes and streams, offer recreation opportunities. Agriculture is dominant in the south because the growing season is longer than in the north. Irrigation in local areas increases the agricultural economy as does manufacturing of dairy products.

Wisconsin has a temperate, continental climate that is characterized by marked seasonal changes common to this latitude (Wisconsin Statistical Reporting Service, 1967). Average monthly air temperatures range from 10°F for January in the north to 72°F for July in the south. The average growing season is less than 100 days in the north and greater than 140 days in the south.

Precipitation is abundant on the basin and periods of drought occur infrequently. Average annual precipitation on the basin was 31.2 inches during 1931-60 (see Hydrologic Budget). February is normally the driest month (about 1 inch), and June is the wettest month (about 5 inches). Snowfall averages about 50 inches annually.




BLOCK DIAGRAM OF THE CHIPPEWA RIVER BASIN

The land surface ranges from 670 feet above mean sea level at the mouth of the Chippewa River to 1,952 feet at Tims Hill, the highest point in Wisconsin, on the eastern basin divide. The land surface slopes rather uniformly from about 1,100 feet in the center of the basin to over 1,600 feet in the northeast. In the south part of the basin the land surface is irregular and ranges from about 1,200 feet along the divides to about 700 feet in the stream channels.

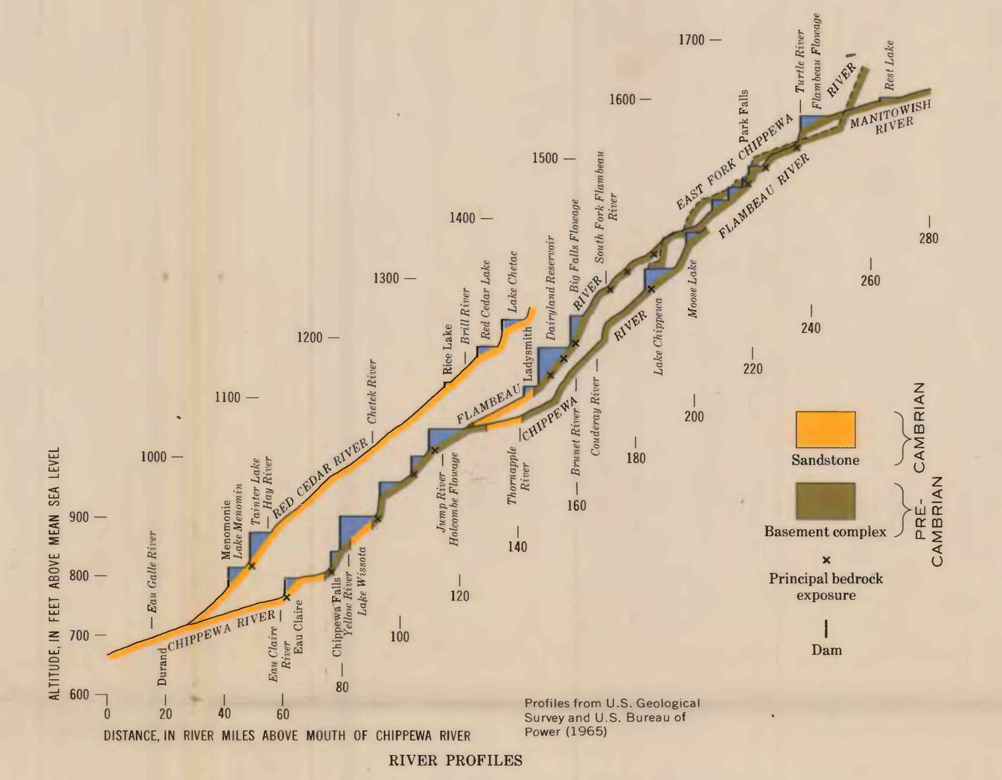
Flat-topped and steep-sided hills and deeply entrenched stream valleys with thick alluvial fill characterize the southern part of the basin. Glacial drift generally is very thin except in valleys. The lower Chippewa River valley is filled with 100 to 200 feet of unconsolidated sediments, and erosional terraces more than 100 feet above the valley floor indicate the depth to which the valley was originally filled. The main stems of streams are relatively straight with angular bends and short tributaries.

The northeastern half of the basin has low to moderate relief and many swamps and lakes. The crystalline bedrock surface, generally a plain, is covered with thick glacial deposits, ground moraine and outwash, that form the topography and control the drainage patterns. Northeast-oriented hills (drumlins) in the Jump River area and the discontinuous arc of hills (end moraine) across the basin create local relief. The most prominent drainage pattern is formed by the closely spaced streams parallel to the drumlins, as exhibited by the Jump River and its tributaries. In much of the area of ground moraine and outwash the drainage is disordered and poorly developed. Lakes are abundant in the north and east.

Topography of the central area, between Chippewa Falls and Rice Lake, is characterized by flat outwash plains and low hills of sandstone. Because of the high permeability of the outwash, the plains have poorly developed surficial drainage. Runoff to streams that cross the plains is mainly ground water.

# PHYSICAL SETTING

## DRAINAGE




RIVER PROFILES

The overall gradient of the main streams, the Chippewa and Flambeau Rivers, generally is 4 to 5 feet per mile and is controlled by the general surface of the resistant crystalline bedrock. The lowest gradient are in the lower- and upper-most reaches of these streams and in 15-mile reaches of the Chippewa and Flambeau Rivers above their confluence. Numerous rapids and several falls, controlled by bedrock, characterize the rivers and create local areas of steep gradient. Dams for generating electric power are located at many of these steep gradient reaches; however, many rapids remain for the canoeist.

The lower course of the Chippewa River below Eau Claire has a very uniform gradient of about 1.5 feet per mile and meanders broadly over its 1- to 2-mile wide flood plain. The present valley floor has developed from erosion of thick glacial outwash that partly fills the deep preglacial valley in the sandstone.

The low gradient reaches of the Chippewa and Flambeau Rivers immediately above their confluence are due mainly to preglacial erosion of the sandstone bedrock underlying these reaches. Above and below these reaches the bedrock is resistant crystalline rock, and the streams have maintained uniform gradients as the sandstone was eroded.

The principal headwater stream of the Flambeau River (Manitowish River) drains an outwash plain and has a flat gradient of only 1.3 feet per mile. This low gradient is controlled by crystalline bedrock near Flambeau Flowage.

The East Fork Chippewa River drains end and ground moraine and has a steep gradient of almost 12 feet per mile except for its central reach where it flows in outwash and has a gradient of 5 feet per mile.

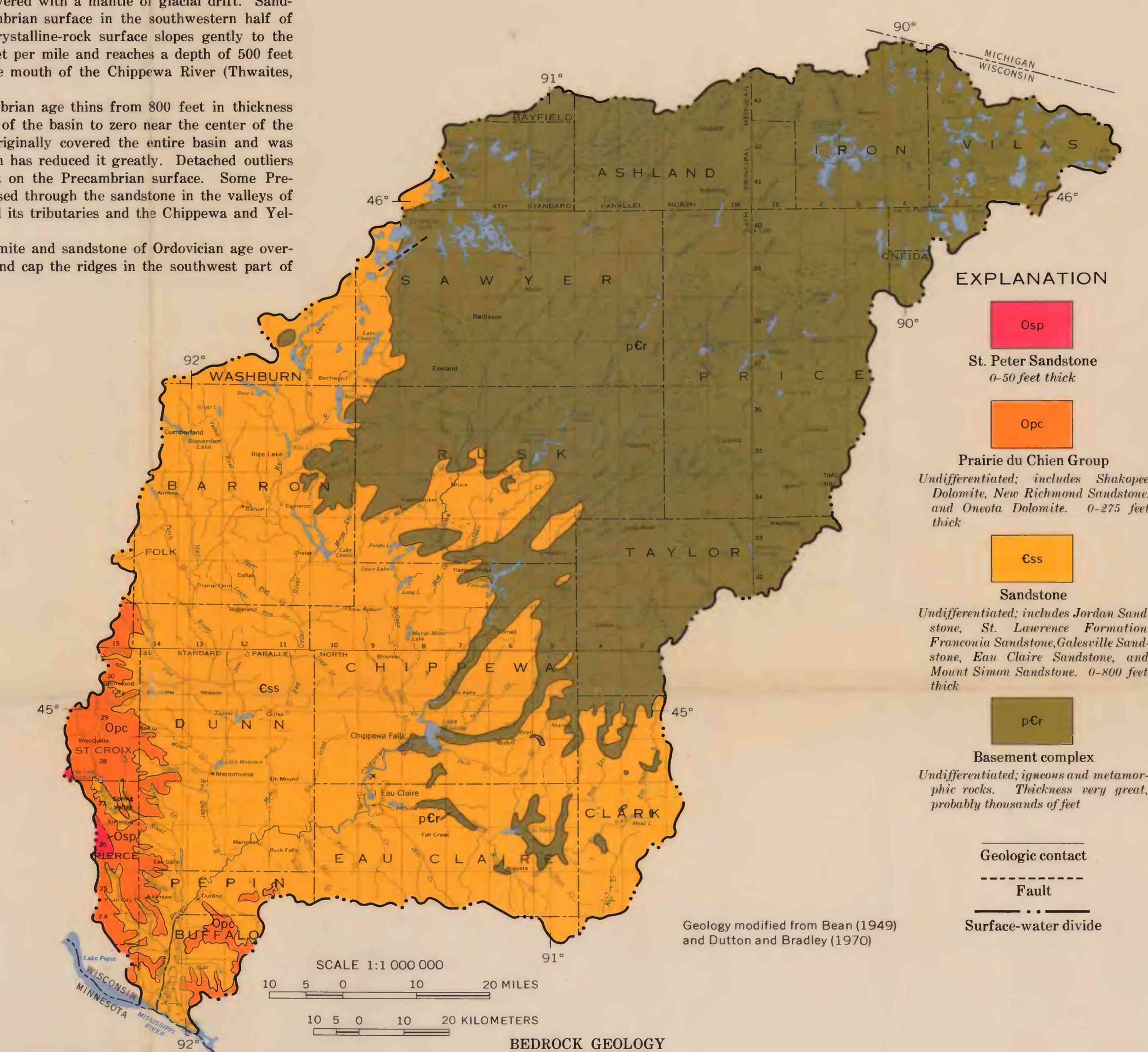
The Red Cedar River is the only main tributary of the Chippewa River that is wholly underlain by sandstone. Its overall gradient is rather uniform, about 4.5 feet per mile from Red Cedar Lake to the river mouth. The river reach above the lake has short, steep changes in gradient as it flows through a series of natural lakes in end moraine.

## GEOLOGY AND SOILS

Igneous and metamorphic rocks of Precambrian age underlie the basin. These rocks form the bedrock surface in the northeastern half and are generally covered with a mantle of glacial drift. Sandstone overlies the Precambrian surface in the southwestern half of the basin. The eroded crystalline-rock surface slopes gently to the southwest at about 15 feet per mile and reaches a depth of 500 feet below land surface at the mouth of the Chippewa River (Thwaites, 1957).

The sandstone of Cambrian age thins from 800 feet in thickness at the southwestern edge of the basin to zero near the center of the basin. The sandstone originally covered the entire basin and was much thicker, but erosion has reduced it greatly. Detached outliers of sandstone are present on the Precambrian surface. Some Precambrian rocks are exposed through the sandstone in the valleys of the Eau Claire River and its tributaries and the Chippewa and Yellow Rivers.

Small amounts of dolomite and sandstone of Ordovician age overlie the Cambrian rocks and cap the ridges in the southwest part of the basin.

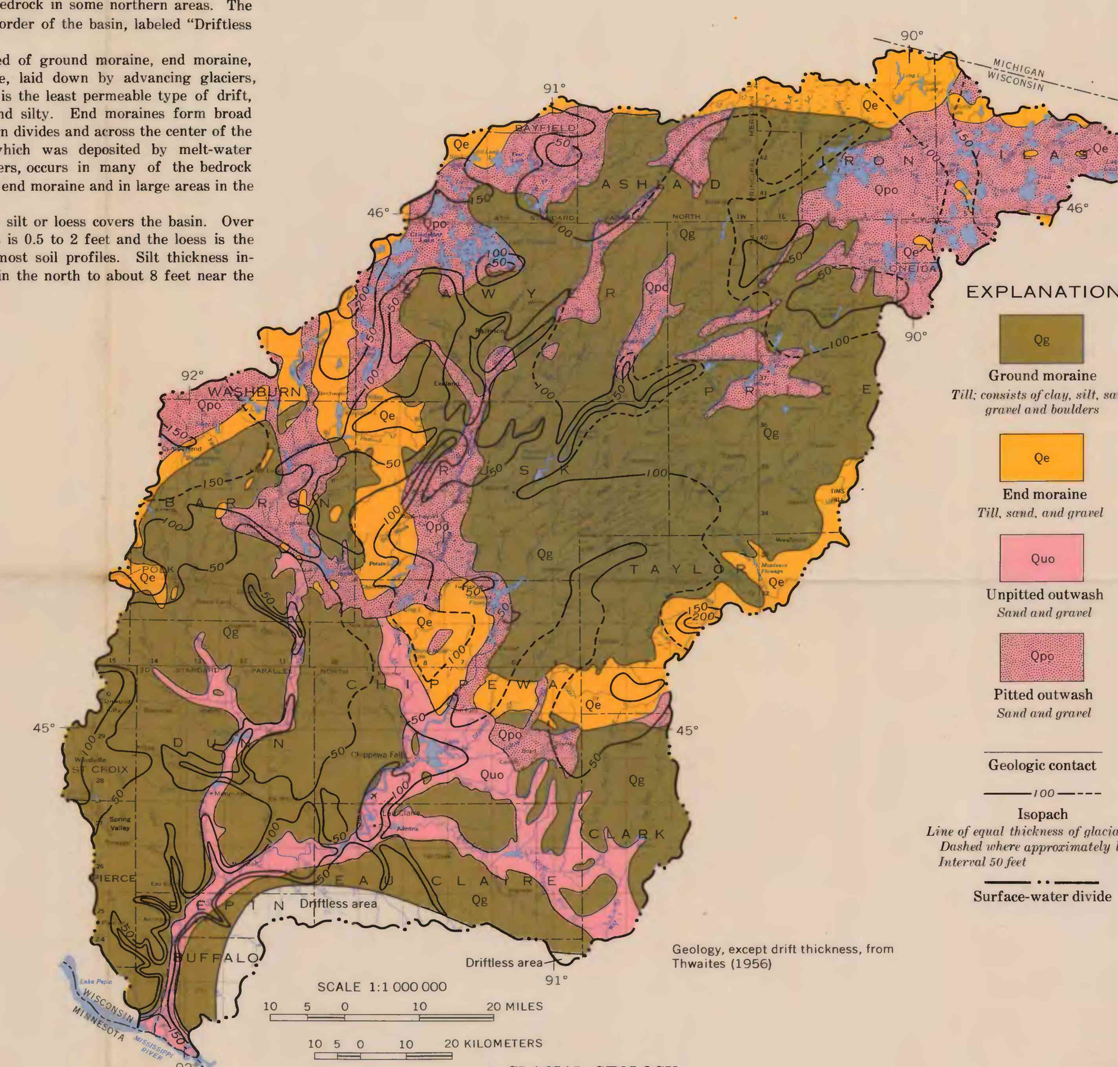



BEDROCK GEOLOGY

Glacial drift forms an almost continuous mantle, as much as 150 feet in thickness, over the bedrock. Drift is thickest in preglacial bedrock valleys and in areas of end moraine and outwash. Drift is thin to absent over crystalline bedrock in some northern areas. The small area along the southern border of the basin, labeled "Driftless area," has no drift cover.

Drift in the basin is composed of ground moraine, end moraine, and outwash. Ground moraine, laid down by advancing glaciers, overlies much of the basin and is the least permeable type of drift, especially where it is clayey and silty. End moraines form broad belts along the north and western divides and across the center of the basin. Permeable outwash, which was deposited by melt-water streams from stagnating glaciers, occurs in many of the bedrock valleys southwest of the central end moraine and in large areas in the north.

A thin blanket of windblown silt or loess covers the basin. Over most of the basin the thickness is 0.5 to 2 feet and the loess is the parent material for topsoil in most soil profiles. Silt thickness increases from less than 0.5 foot in the north to about 8 feet near the Mississippi River (Hole, 1950).




GLACIAL GEOLOGY

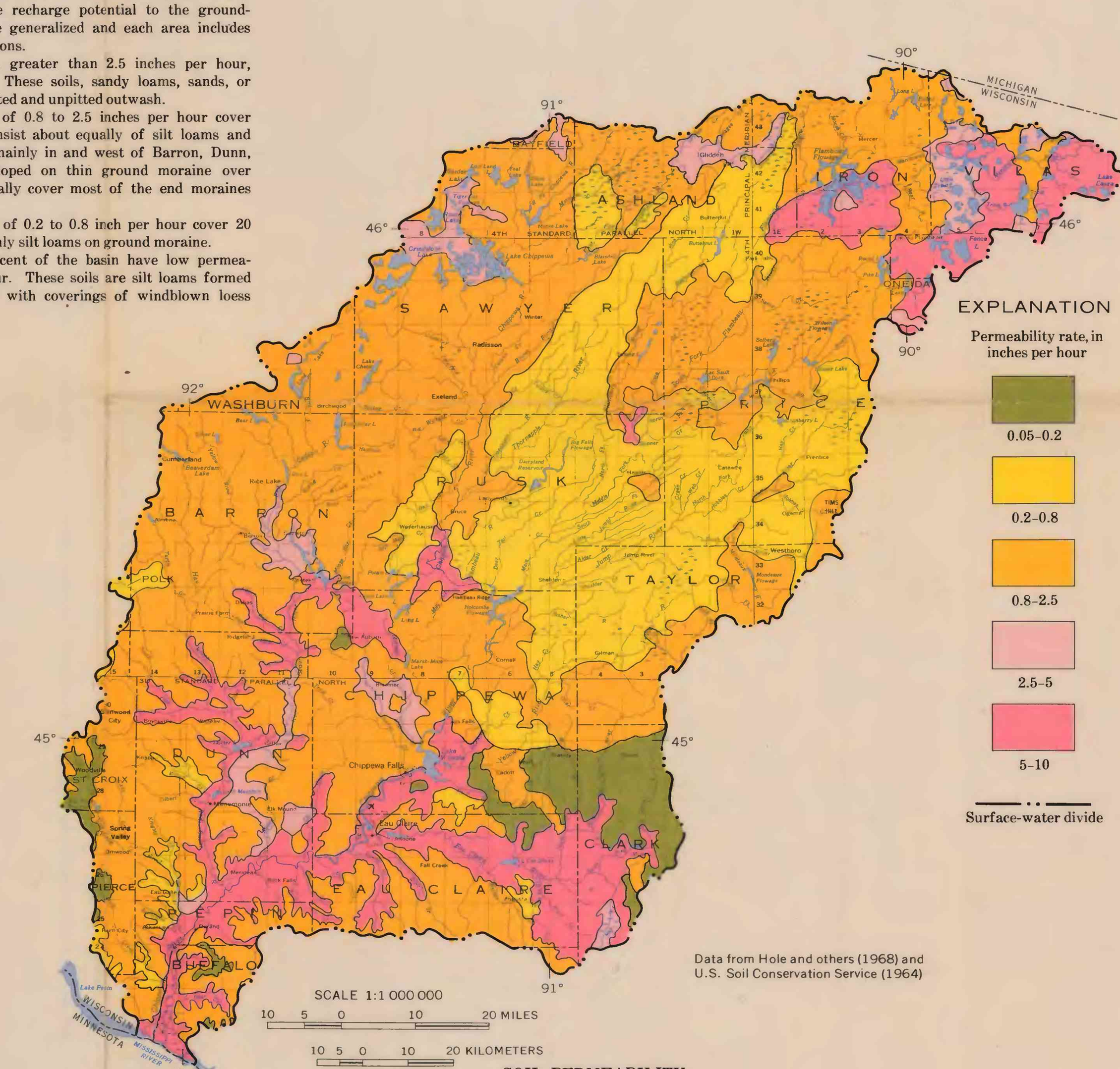
The soil permeability map shows areas of permeability rates that can be expected from the least permeable horizon in saturated soils. Permeability is an important factor that determines the rate of infiltration of precipitation into the soil. Soil-moisture content, vegetative cover, land slope, depth to the water table, and frequency and duration of precipitation are additional factors. These permeability rates are representative of the recharge potential to the ground-water reservoir. The areas are generalized and each area includes many soil types and soil associations.

Soils with high permeability, greater than 2.5 inches per hour, cover 24 percent of the basin. These soils, sandy loams, sands, or alluvium, are formed on both pitted and unpitted outwash.

Soils with permeability rates of 0.8 to 2.5 inches per hour cover 52 percent of the basin and consist about equally of silt loams and sandy loams. The silt loams, mainly in and west of Barron, Dunn, and Pepin Counties, are developed on thin ground moraine over sandstone. Sandy loams generally cover most of the end moraines and much of the outwash areas.

Soils with permeability rates of 0.2 to 0.8 inch per hour cover 20 percent of the basin and are mainly silt loams on ground moraine.

Soils in the remaining 4 percent of the basin have low permeability, less than 0.2 inch per hour. These soils are silt loams formed on both sandstone and granite with coverings of windblown loess and older glacial till.




SOIL PERMEABILITY

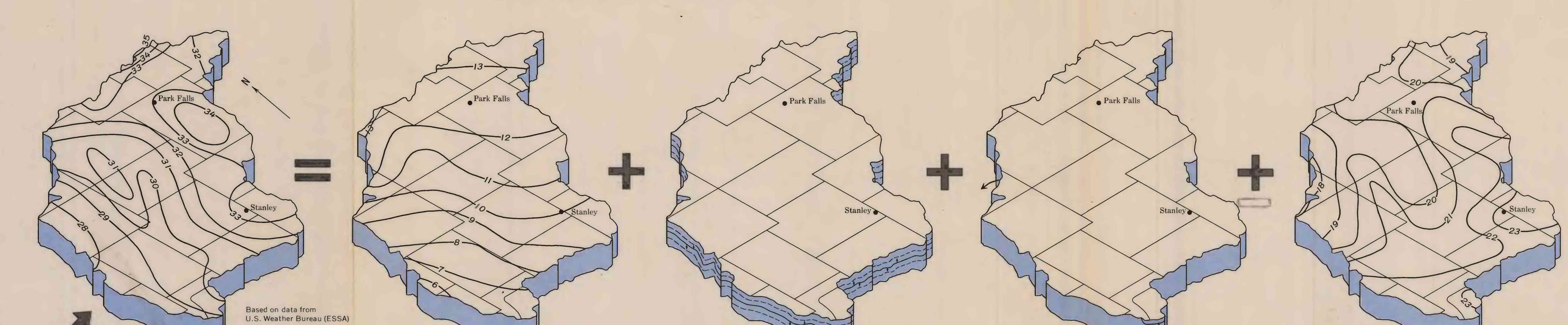
# WATER SYSTEM

## HYDROLOGIC BUDGET

Precipitation, the source of all water in the basin, falls on the land surface, streams, and lakes and starts the cycle of circulation called the hydrologic cycle. Some of the water runs rapidly off the land surface to nearby streams and lakes (surface runoff); some water evaporates immediately from the soil surface and plants (evaporation); some water enters the soil but is used by plants (transpiration); and some water seeps down through the soil, eventually recharging ground water (recharge), which contributes base flow to streams and discharge to lakes (ground-water runoff). The cycle is not complete within an area as small as a river basin; usually large parts of continents are involved.

The hydrologic budget is a simplified equation of the basic components of the hydrologic cycle. Water input to the basin, or the precipitation on the basin, equals the algebraic sum of water output and change in storage. Water output includes surface runoff, ground-water underflow, evapotranspiration, and consumptive use by man. Changes in storage occur in ground and surface water as well as soil moisture. The quantities of these budget items fluctuate from year to year, but major variations occur only in precipitation, runoff, and evapotranspiration. Man's effect on these quantities is almost negligible in the Chippewa basin. A very small part of the ground and surface water withdrawn by man is consumed, and a part of the water he stores on the surface is evaporated.

Average conditions for the period 1931-60 are illustrated on the budget maps. Average budget quantities are presented for that period, and extremes are given for a very dry year (1948) and for a very wet year (1938).




PRECIPITATION
21.3 INCHES 1948 (DRY)
31.2 INCHES 1931-60 (AVERAGE)
45.1 INCHES 1938 (WET)

Average annual precipitation is greatest in the east and northeast (34 inches) and lowest in the west (28 inches). Annual precipitation on the basin is variable, ranging from 9.9 inches below normal in 1948 to 13.9 inches above normal in 1938. Droughts occur occasionally but are seldom widespread. From one-half to two-thirds of the annual precipitation falls during the growing season. Average winter snowfall, which is about one-fifth of the annual precipitation, ranges from 40 inches along the Mississippi River to 100 inches in the northeast.

RUNOFF
5.9 INCHES 1948 (DRY)
10.7 INCHES 1931-60 (AVERAGE)
14.8 INCHES 1938 (WET)

Average runoff from the basin, 7,431 cfs (cubic feet per second), equals 10.7 inches per year on the basin. Runoff varies with precipitation and evapotranspiration, increasing from about 6 inches in the south to over 13 inches in the north. Runoff varied 4 to 5 inches from average in the extremely wet and extremely dry years illustrated. The map of average annual runoff is based on streamflow records of 30 U.S. Geological Survey gaging stations in and near the basin.

CHANGE IN STORAGE
-0.5 INCHES 1948 (DRY)
0.0 INCHES 1931-60 (AVERAGE)
+1.0 INCHES 1938 (WET)

The long-term net change in ground- and surface-water storage in the basin is negligible. Annual gains and losses of water, as shown by lake-stage and ground-water hydrographs, are balanced over a long-term period. The amount of stored surface water is very small compared to the amount of stored ground water; thus, net change in the water table indicates net change in basin storage.

A study of water-level records for the wet and dry years shows that the water table generally, but not everywhere, responded to the extremes in precipitation. The resulting net annual rise or fall of the water table during these years is estimated to be about 6 inches and 3 inches, respectively. Assuming a storage coefficient of 0.15, these changes in water level equal about 1 and 0.5 inch of water, respectively.

UNDERFLOW
0 INCHES 1948 (DRY)
0 INCHES 1931-60 (AVERAGE)
0 INCHES 1938 (WET)

Subsurface underflow from the basin is very small and takes place principally along the western edge of the basin, where the ground-water divide does not coincide with the surface-water divide (see water-table map, sheet 2). Elsewhere along the basin boundary inflow approximates outflow because the ground- and surface-water divides usually coincide, and areas of ground-water inflow balance areas of ground-water outflow. Additional underflow leaves the basin through valley fill at the mouth of the Chippewa River. The net amount of underflow from the basin is estimated to be about 0.02 inch per year around the basin boundary and 0.006 inch per year at the river mouth. Therefore, total underflow, as well as changes in underflow during years of precipitation extremes, are negligible.

EVAPOTRANSPIRATION
15.9 INCHES 1948 (DRY)
20.5 INCHES 1931-60 (AVERAGE)
29.3 INCHES 1938 (WET)

Evapotranspiration, the return of water to the atmosphere by evaporation and plant transpiration, is the difference between precipitation and the sum of runoff, change in storage, and underflow. Evaporation from open-water surfaces accounts for about 1 inch of the 20.5 inches of average annual evapotranspiration. Man's consumptive use of water has been included in evapotranspiration but is less than 0.5 percent of that figure.

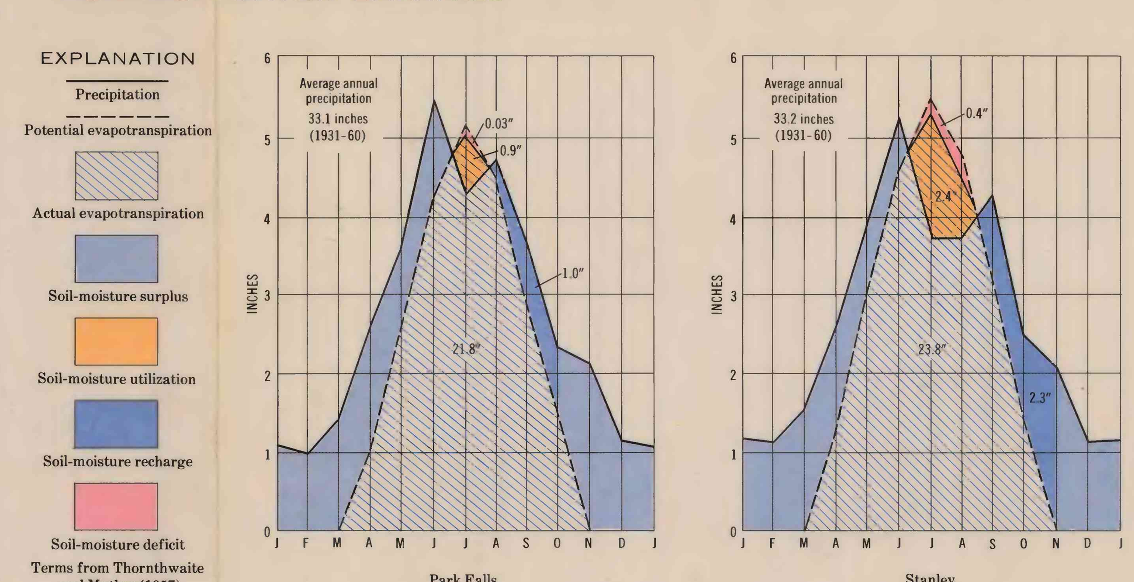
Evapotranspiration is greatest in the south and east and generally decreases northward with decreasing air temperatures and westward with decreasing precipitation. In the very dry year evapotranspiration decreased just 4.4 inches from the average, but in the very wet year it increased by 8.8 inches.

## MONTHLY WATER BALANCE

The relation of soil-moisture to evapotranspiration and precipitation varies throughout the year, as shown for two areas of the basin. An empirical method (Thornthwaite and Mather, 1957) for estimating monthly values of "actual" and "potential" evapotranspiration illustrates the monthly water balance in the northern and southern parts of the basin at Park Falls and Stanley.

Winter snow accumulation and spring rainfall maintain a soil moisture surplus through spring. The monthly surplus decreases as evapotranspiration increases during the spring, until evapotranspiration exceeds precipitation in midsummer and soil moisture is withdrawn from storage. A moisture deficit, or a moisture demand that cannot be supplied, exists when the soil-moisture in storage is depleted and the potential evapotranspiration is greater than actual evapotranspiration during the moisture utilization period. In the fall, as the temperature declines and transpiration by vegetation decreases, precipitation recharges soil-moisture until the winter phase of surplus moisture starts again.

Soil moisture deficit and utilization from storage are less in the northern part of the basin than in the southern part because the air temperature is lower and the growing season is shorter in the north.




WATER BALANCE, AVERAGE 1931-60

COMPARISON OF MONTHLY WATER BALANCE TO THE ANNUAL HYDROLOGIC BUDGET

| Station | Runoff (inches) Hydrologic budget | Soil-moisture surplus (inches) Water balance | Evapotranspiration (inches) | |
|---|---|---|---|---|
| | | | Hydrologic budget | Water balance |
| Park Falls. . | 12.5 | 11.3 | 20.7 | 21.8 |
| Stanley. . . | 10.0 | 9.4 | 23.0 | 23.8 |

Runoff and evapotranspiration values by the Thornthwaite method compare closely with those in the hydrologic budget. For both methods evapotranspiration is lower and runoff and soil-moisture surplus are higher at Park Falls, in the north, than at Stanley, in the south. Soil-moisture surplus is comparable to average annual runoff.

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

# WATER RESOURCES OF WISCONSIN—CHIPPEWA RIVER BASIN

By
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1972