SURFACE WATER

Streams and lakes in the Rock-Fox basin contain abundant, good quality water, although man's use of this water alters its quality and its streamflow characteristics. About 550 billion gallons of surface water leave the basin as streamflow each year. Along its way this water passes through power generating turbines and cooling systems, it receives waste, and a small amount is taken for irrigation and other uses. Many dams store water and alter flow characteristics; however, there is very little regulation of the dams. One of the largest uses of lakes and streams is for recreation and fish and wildlife habitat; this use sometimes conflicts with other uses.

Conflicts of interest are likely to become more numerous as the population and water use within the basin increase. In order to plan intelligently and resolve conflicts, we must increase our knowledge of the quality and flow characteristics of the lakes and streams.

Station No. 5-4230
West Branch Rock River near Waupun
Drainage area: 41.4 square miles
Period of record: 1949-present
Maximum instantaneous discharge: 949 cfs
Average discharge, 17 years: 21.0 cfs
Minimum instantaneous discharge: 0 cfs

Station No. 5-4235
South Branch Rock River at Waupun
Drainage area: 62.8 square miles
Period of record: 1948-present
Maximum instantaneous discharge: 1,500 cfs
Average discharge, 18 years: 25.0 cfs
Minimum instantaneous discharge: 0 cfs

Station No. 5-4240
East Branch Rock River near Mayville
Drainage area: 179 square miles
Period of record: 1949-present
Maximum instantaneous discharge: 3,400 cfs
Average discharge, 17 years: 87.4 cfs
Minimum instantaneous discharge: 0.1 cfs

Station No. 5-4255
Rock River at Watertown
Drainage area: 971 square miles
Period of record: 1931-present
Maximum instantaneous discharge: 5,030 cfs
Average discharge, 35 years: 426 cfs
Minimum daily discharge: 0.9 cfs

Station No. 5-4295
Yahara River near McFarland
Drainage area: 351 square miles
Period of record: 1930-present
Maximum instantaneous discharge: 867 cfs
Average discharge, 36 years: 150 cfs
Minimum instantaneous discharge: 1.0 cfs

Station No. 5-4260
Crawfish River at Milford
Drainage area: 732 square miles
Period of record: 1931-present
Maximum instantaneous discharge: 6,140 cfs
Average discharge, 35 years: 335 cfs
Minimum instantaneous discharge: 0.2 cfs

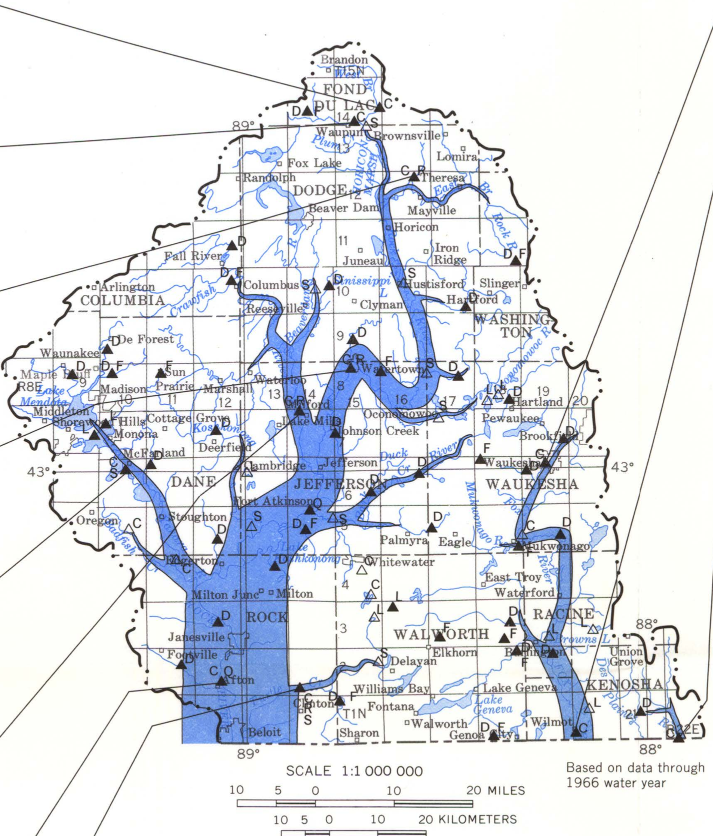
Station No. 5-4305
Rock River at Afton
Drainage area: 3,300 square miles
Period of record: 1914-present
Maximum instantaneous discharge: 13,000 cfs
Average discharge, 52 years: 1,715 cfs
Minimum instantaneous discharge: 22 cfs

Station No. 5-4315
Turtle Creek near Clinton
Drainage area: 186 square miles
Period of record: 1939-present
Maximum instantaneous discharge: 6,560 cfs
Average discharge, 27 years: 103 cfs
Minimum instantaneous discharge: 8 cfs

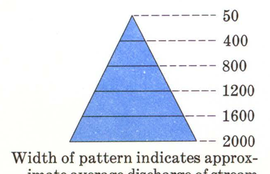
Station No. 5-5438.3
Fox River at Waukesha
Drainage area: 127 square miles
Period of record: 1963-present
Maximum instantaneous discharge: 1,240 cfs
Minimum instantaneous discharge: 3.0 cfs

Station No. 5-5465
Fox River at Wilmot
Drainage area: 880 square miles
Period of record: 1939-present
Maximum instantaneous discharge: 7,520 cfs
Average discharge, 27 years: 453 cfs
Minimum instantaneous discharge: 0 cfs

Station No. 5-5278
Des Plaines River at Russell, Ill.
Drainage area: 124 square miles
Period of record: 1962-present



EXPLANATION



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

Active station

Discontinued station

Symbol	Parameter measured	Frequency of measurement
C	Discharge	Continuous
D	Low-flow discharge	Periodic
F	Flood-flow discharge	Periodic
L	Lake stage	Periodic
Q	Chemical quality	Monthly[1]
R	Chemical quality, complete analysis	Once
S	Chemical quality, partial analysis	Once

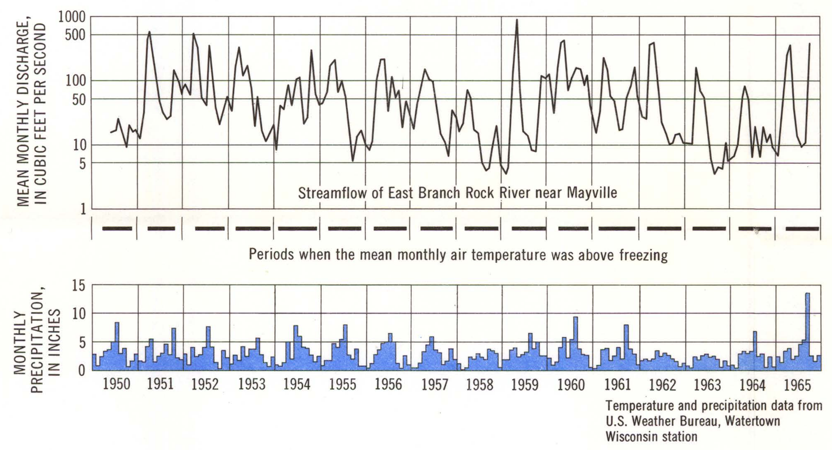
[1]Operated by Wisconsin Department of Natural Resources

Surface-water divide

DATA NETWORK AND AVERAGE STREAMFLOW

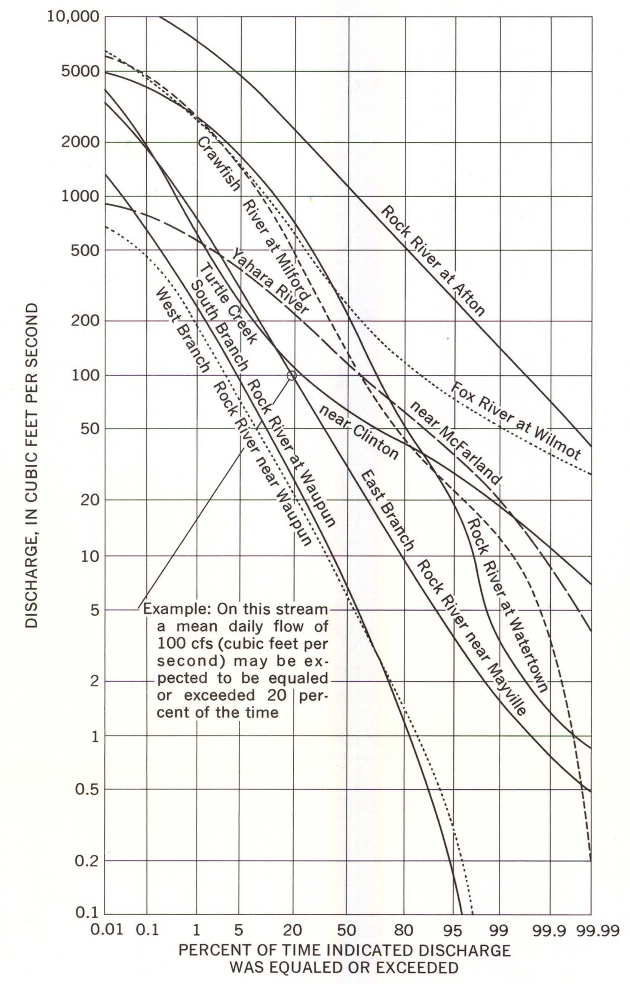
Streamflow is continuously monitored at 11 points within the basin. Frequency and duration curves and stream hydrographs have been constructed from these records. The above map shows the average streamflow of major rivers and sites where flood flow, low flow, lake stage, or chemical quality are measured. Miscellaneous gaging sites are not shown.

The average flow rate of streams in the basin, represented by the width of patterns on the above map, is the discharge that could be sustained if the runoff was totally regulated. Total regulation is impractical, however, because of the large and expensive storage reservoirs required to adjust for differences in weather and because of the losses from evaporation and transpiration that would take place. Sites for storage reservoirs exist in the basin and provide an opportunity for more regulation of streamflow as the need increases.



CHANGE IN STREAMFLOW IN RELATION TO TEMPERATURE AND PRECIPITATION

The natural flow of a stream varies greatly throughout the year; it depends mainly on precipitation and temperature. High runoff generally occurs when the mean monthly air temperature is above freezing in response to heavy rainfall. There is usually a peak flow in the spring from snowmelt and rain.



FLOW DURATION

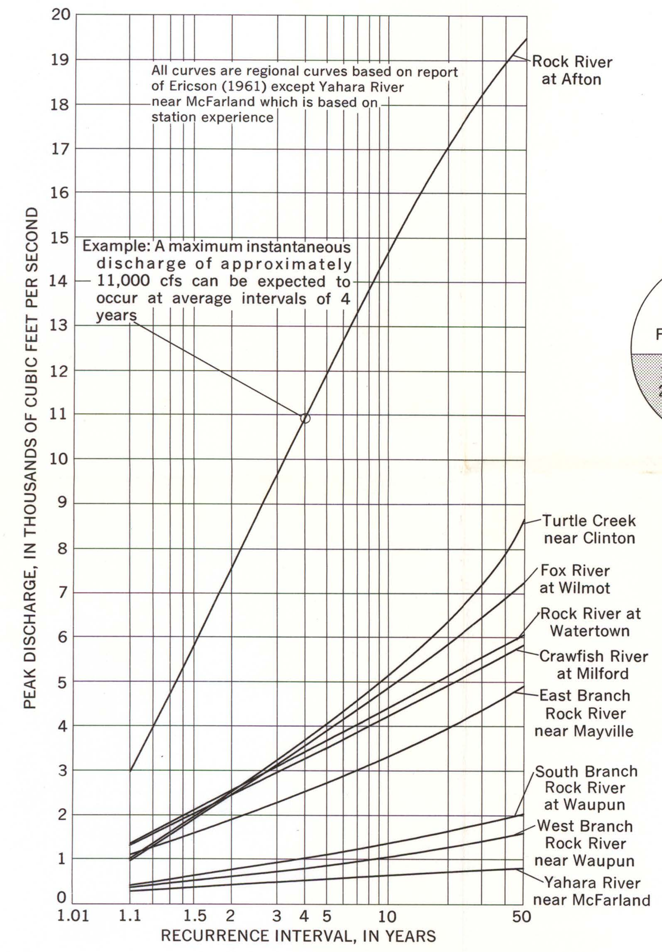
A flow-duration curve shows the percentage of time that the discharge of a stream equals or exceeds a given rate. Duration curves are useful in appraising the hydrologic and geologic characteristics of a drainage basin, and in comparing the characteristics of one basin with another. A basin with a large ground- or surface-water storage capacity provides a high rate of flow during dry periods, and its duration curve has a gentle slope.

The gentle slope of the duration curve for Turtle Creek below 100 cfs, for example, is due to the large quantities of ground water released from storage within the basin. The gentle slope of the duration curve for the Yahara River is due to the release of water from upstream lakes having artificial controls. The data have been adjusted to a common period.

FLOOD FLOW

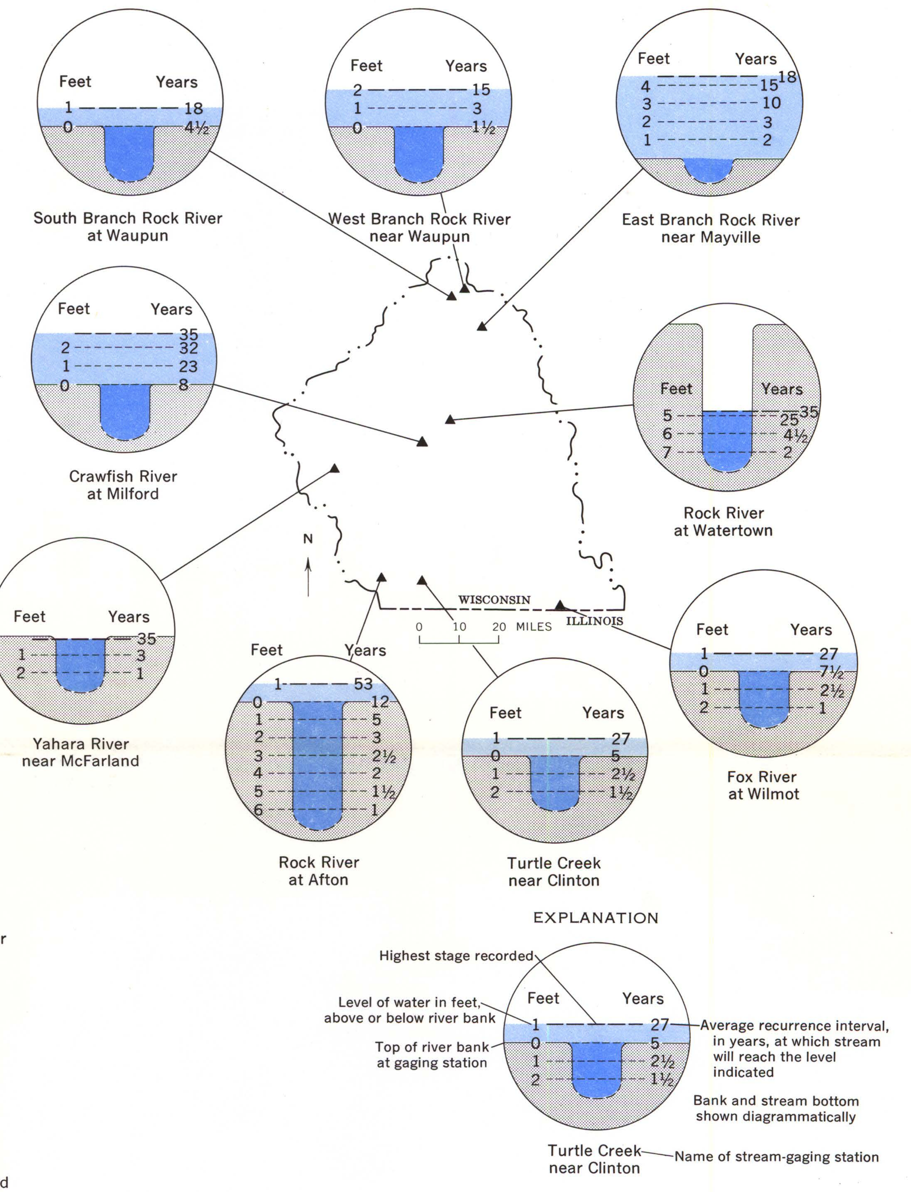
The low relief of the basin, large lakes and wetlands, locally high infiltration capacities, and present land-use practices combine to make flood risks in the Rock-Fox River basin among the lowest in the State. On the main stem of the Rock River floods are low in peak discharge but long in duration.

Because major floods have been infrequent in most parts of the basin, there has been increased occupancy of the flood plains. Although most of the flood plains in the basin are presently unoccupied, a continued increase in occupancy will result in a significant increase in flood damage.



FLOOD-DISCHARGE FREQUENCY

The magnitude of flood flows depends largely upon the size of the drainage area. The largest drainage area collects the most rainfall and has the largest runoff. Curves in this graph fall in order of their drainage area size, with two exceptions. The curve for Turtle Creek falls high in the grouping according to its drainage area, except for very low recurrence intervals. This is because the stream has a steep gradient and few flat, marshy areas adjacent to it to retard rapid runoff. The Yahara River's curve is low in the grouping because lake basins provide temporary storage for flood waters.



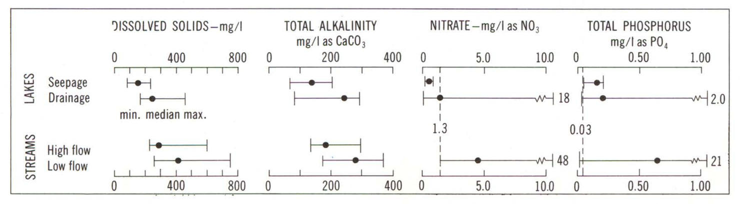
FLOOD-STAGE FREQUENCY

Flood stage or height depends upon numerous factors including width, depth, and velocity of flow within the stream channel and on the flood plain; and channel controls such as bridges, dams, ice jams, or natural constrictions. The diagrams shown above illustrate the frequency of various high water stages at long term stream-gaging stations in the basin. Because the controlling factors are different at each site on the stream, these stage diagrams can be used to estimate flood risks only in the vicinity of the gaging stations.

WATER QUALITY

Surface water in the Rock-Fox basin is generally of good quality, but it is commonly very hard (181 mg/l (milligrams per liter) or greater hardness). Hardness does not restrict the use of water for recreation and most industries; surface water is not used for municipal supplies in the basin.

The water quality of some lakes and reaches of some streams has been degraded by pollution.



QUALITY OF STREAM AND LAKE WATER

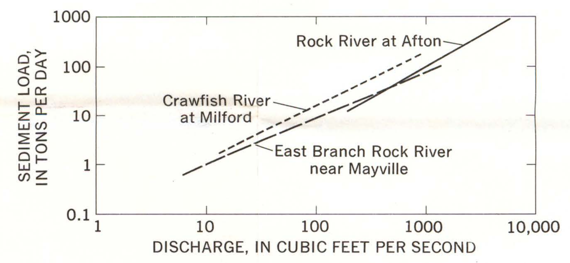
This diagram shows the range of mineralization in streams and lakes within the basin. Dissolved solids, the total mineralization, including that introduced with waste water. Alkalinity represents mainly bicarbonate and is largely natural in origin. Nitrate and total phosphorus (commonly referred to as nutrients) are at least partly introduced through sewage and fertilizers.

Total mineralization is generally higher in streams than in lakes and is highest at low streamflow. Total mineralization is higher in drainage lakes (lakes with surface outlets) than in seepage lakes (lakes with no surface outlets). Natural mineralization (contributed largely from ground water) in streams is also highest at low streamflow and higher in drainage lakes than in seepage lakes. However, the relation between lakes and streams is not the same for natural mineralization as for total mineralization: the natural mineralization during high flow generally lies between that of seepage lakes and drainage lakes.

Seepage lakes are fed by slightly mineralized direct surface runoff during periods of rainfall and snowmelt and by ground water. In addition to these sources, drainage lakes generally receive perennial streamflow, which may be highly mineralized due to waste-water discharge.

Nitrogen and phosphorus are important nutrients in surface waters, but excessive concentrations may cause weed-choked channels in streams and obnoxious algal blooms and weed-choked areas along lakeshores. 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 the Rock-Fox basin the nutrients in streams are much higher than nutrients in lakes, and seepage lakes generally have slightly lower nutrient concentrations than drainage lakes.

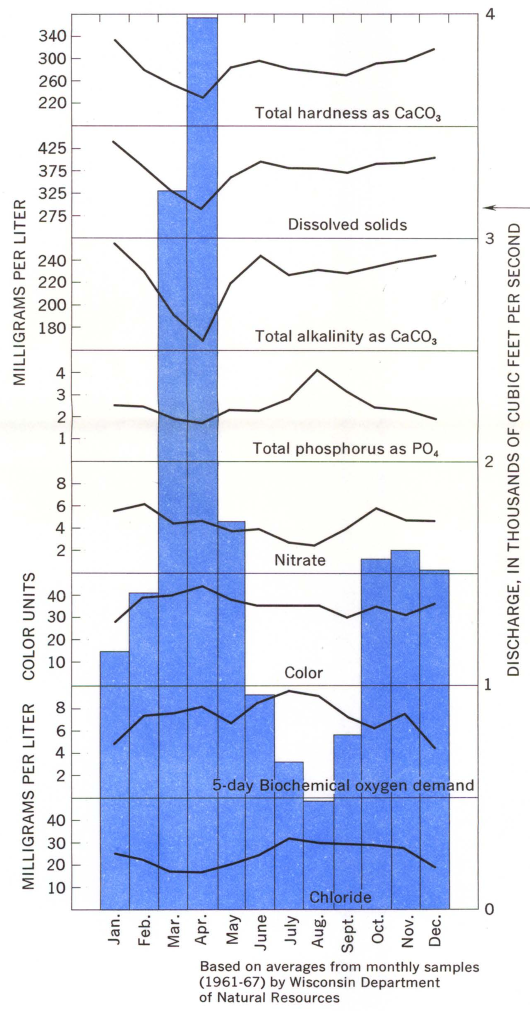


STREAM SEDIMENT LOAD RELATED TO DISCHARGE

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. The peak concentration of sediment usually occurs during storm runoff, shortly before the stream reaches peak discharge. Fine-grained or buoyant sediments tend to remain suspended longer and reach peak concentrations at or shortly after peak stream discharge.

The graph above shows the suspended sediment load, in tons per day, related to discharge based on a few samples from three streams in the basin. The relationship is only approximate; for example, at a discharge of 50 cfs the East Branch Rock River near Mayville has been measured carrying 1 ton per day at one time and carrying 30 tons per day at another. This variation is a result of less sediment being available at one time than at another. Land clearing, road cuts, and excavations increase the availability of sediments.

Streams in the Rock-Fox basin carry relatively little sediment, and stream sediment does not create any major problems.



RELATIONSHIP OF WATER QUALITY TO MONTHLY DISCHARGE OF THE ROCK RIVER AT AFTON

The average chemical quality of streamflow varies seasonally with discharge. Total hardness, dissolved solids, and alkalinity vary directly with each other but generally inversely to flow. However, during the fall season these parameters vary directly with flow.

Total phosphorus varies inversely to flow. The input is primarily sewage effluent and is relatively constant; therefore, dilution is the governing factor that regulates its concentration.

Nitrate concentrations show no trend that can be related to flow. The concentration is generally dependent upon the discharge from sewage treatment plants and upon agricultural fertilization (Schraufnagel and others, 1963a and b, 1967a and b).

During spring months color readings vary directly with flow. This is attributed to flush-out of swamps where dead organic matter collected during the winter. Color concentrations are erratic during the fall and early winter months.

BOD (biochemical oxygen demand) varies directly with flow from January until May, after which it varies inversely with flow.

Chloride concentrations vary inversely with flow. Because chlorides are introduced in sewage and industrial wastes, the concentrations are determined by the amount of water available for dilution.

SURFACE-WATER POLLUTION

Common sources of contamination of surface water in the basin are municipalities and industries (treated and partially treated wastes), power generating plants (heated water), and farms and unsewered homes (agricultural and untreated animal and domestic wastes).

Overloading a stream with inadequately treated wastes may result in fish kill, unsightly appearance, odor, and a resultant decrease in the value of the resource. The uptake of oxygen by chemical or biological wastes discharged into the streams lowers the amount of dissolved oxygen in the streams and limits animal life to species tolerant of oxygen-poor water. This demand for oxygen is measured as BOD.

The State has set high standards of water quality and the Department of Natural Resources is continuing a program of pollution detection and abatement. The department inventories sources of pollution in river basins throughout the State. The Rock River basin was most recently studied in 1961-63 (Schraufnagel and other, 1963a and b), and the Fox and Des Plaines River basins were studied in 1966-67 (Schraufnagel and others, 1967a and b). Of course, efforts to improve the quality of waste water discharged to streams in the basin must continually increase to meet the expected expansion of population and industry.

Chemical quality of streamflow during the period of low flow (Aug. 14-15, 1967) shows that conductance generally ranged between 500 and 1,000 micromhos. Water quality of streams was similar to that of ground water in most of the basin, but streams were influenced locally by quality changes in lakes and by pollution.

Specific conductance of the water is related to the amounts and kinds of minerals dissolved in the water. In this basin it can be related to dissolved solids by the equation:

Dissolved solids = specific conductance x 0.57.

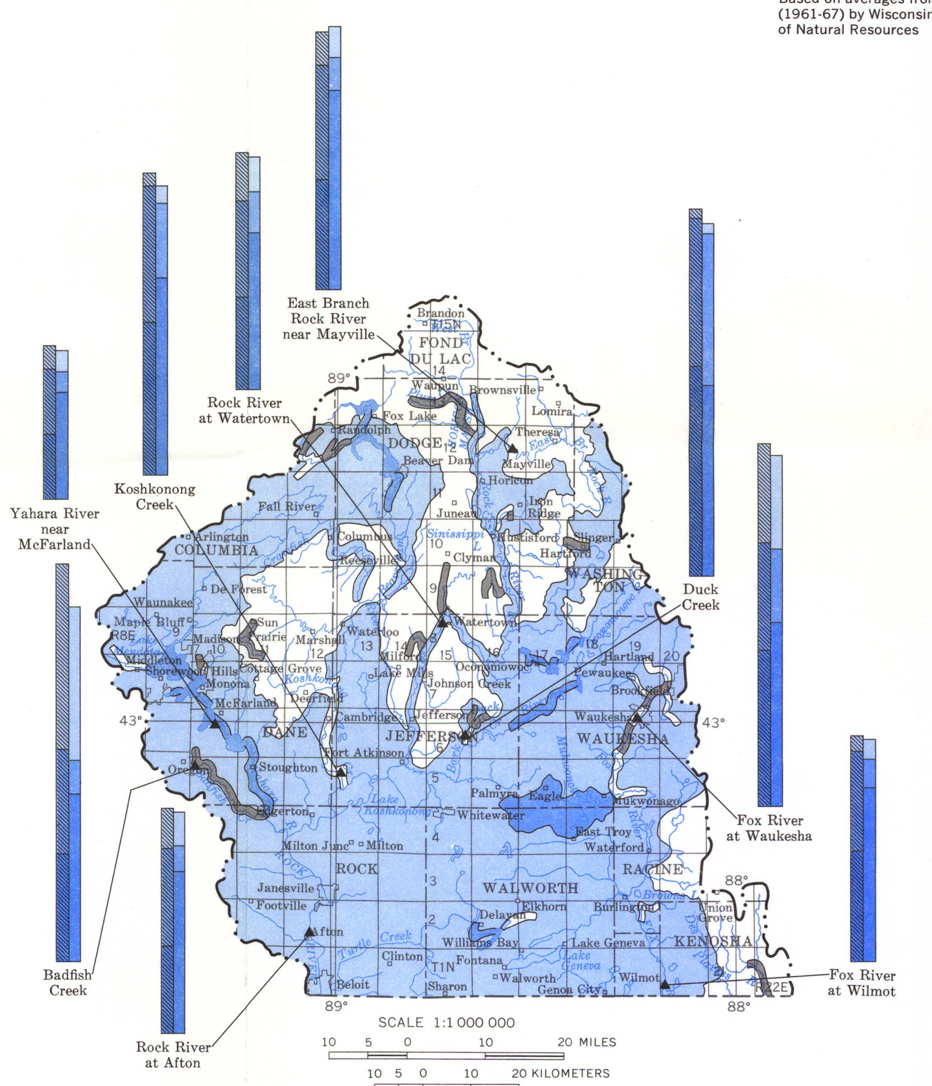
Streamflow, which was maintained largely by ground water during this period, had a specific conductance between 500 and 750 micromhos over about two-thirds of the basin. Most analyses of ground water from wells in shallow aquifers within the basin also fall within this range. Conductance of streamflow in a large area in the north-central part of the basin was between 751 and 1,000 micromhos. This higher conductance is probably due to the solution of dolomite in the drift and in the Platteville-Galena aquifer. The Platteville-Galena aquifer produces the most highly mineralized water in the basin west of the Maquoketa Shale (see sheet 3).

Many individual streams or stream segments within the basin have a higher or lower conductance than that common to the area. Streams discharging from large lakes generally have a conductance under 500 micromhos. Dissolved solids are lower because biologic activity and chemical precipitation within the lakes remove some of the minerals. Also, overland runoff, which is relatively low in dissolved solids, enters the lakes during high flow and is discharged slowly during dry periods. These factors reduce the conductance for several miles downstream to a value below that of the regional ground-water inflow.

Most conductances above 1,000 micromhos are a result of contamination by waste-water discharge, and the areas of contamination extend downstream from the source (Schraufnagel and others, 1963a and b, 1967a and b). The high conductance of water in Plum Creek is probably natural.

The subbasin of the Mukwonago River yields water low in dissolved solids because it is in an area of highly permeable glacial deposits that allow insufficient time for water to dissolve large amounts of minerals. Also, the basin has a large number of lakes and few sources of pollution.

Specific analyses representing low-flow quality are shown by the bar diagrams. Waste water from Madison and sources in the headwaters of the Fox River raise the sodium and chloride contents of both Badfish Creek and of the Fox River at Waukesha. Effluent from Madison and numerous municipalities on the Rock River produce a moderately high sodium chloride content in the Rock River at Afton. Some small tributaries, such as Duck and Koshkonong Creeks, receive water high in calcium and sulfate. Biologic activity and chemical precipitation in lakes and slow moving streams reduce mineralization downstream (see Yahara River at McFarland and the Rock River at Watertown).



SURFACE-WATER QUALITY DURING LOW FLOW

EXPLANATION

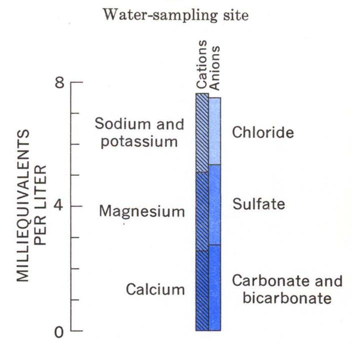
Conductivity, in micromhos at 25° C	Dissolved solids in milligrams per liter
Less than 500	Less than 280
500-750	280-430
750-1000	430-570
More than 1000	More than 570

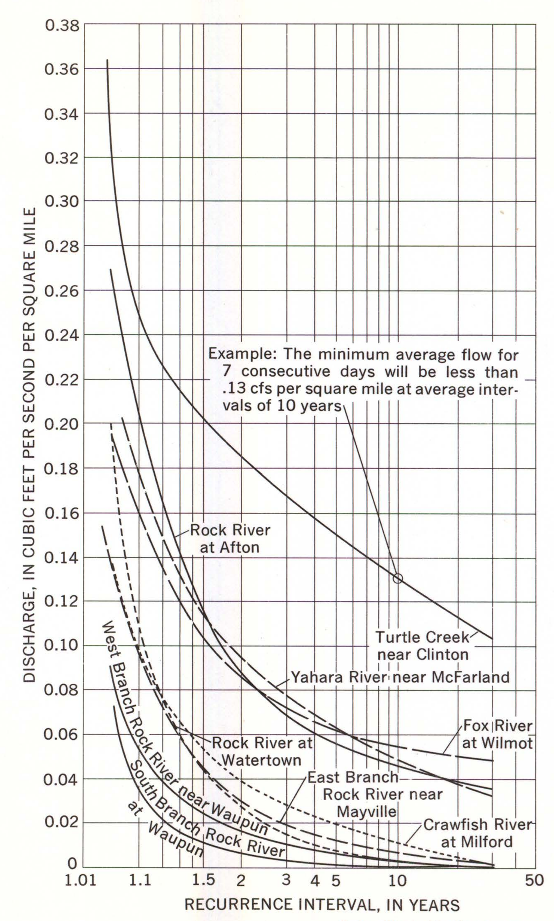
Dissolved solids derived by empirical relationship from conductivity

Area boundary

Surface-water divide

Water-sampling site





LOW-FLOW FREQUENCY

A knowledge of low flow of a stream is necessary to determine adequacy of streamflow for minimum supply needs, to maintain reservoir storage, to estimate ground-water discharge, and to estimate a stream's capacity to accommodate and transport waste. The stream discharge on the graph, a 7-day low flow, is given in cubic feet per second per square mile for comparison purposes. Approximate discharges can be obtained by multiplying the unit area discharge by the drainage area (in sq mi) shown beside the data-network map.

The low-flow frequencies of streams in the basin range from the high discharge of Turtle Creek at Clinton to the low discharge of the South Branch of the Rock River at Waupun. Turtle Creek maintains the highest discharge per unit area because of the release of ground-water storage from outwash deposits. The Rock River at Afton and the Fox River at Wilmot sustain high runoff from similar sources, and their flows are stabilized by the composite effect of tributaries that have varying discharge characteristics. The Yahara River's flow is maintained at a level similar to these two by the controlled release of stored lake water. The discharge rates per unit area at the remaining stations are relatively low because of evapotranspiration losses and because, in the headwaters of the streams, many channels are above the local water table and the flows are not sustained by ground-water discharge.

LOW FLOW

These subbasins, the headwaters of the south and west branches of the Rock River and the Crawfish River, have very little runoff during dry weather. They contain small headwater streams, many of which flow intermittently.

Runoff is low because much of the ground water recharged in this area of ground moraine is discharged in marshy areas adjacent to the streams, where it is lost by evapotranspiration, and never reaches the streams. Also, a small part of the ground water in these subbasins discharges to streams northwest of the Rock-Fox River basin.

Streamflow did not increase within the Madison area of the Yahara River subbasin, so its runoff per square mile was zero. This lack of increase in flow was partly because of high evapotranspiration losses from the large percentage of lake and wetland areas. Also, part of the ground water that normally would discharge into streams within the subbasin is intercepted and withdrawn by Madison wells. Most of this water, about 34 cfs, is later discharged as sewage effluent and diverted out of the subbasin. Upstream regulation of lake levels may also have reduced the flow during the measurement period.

The lower parts of the Rock and Yahara Rivers have comparatively high base flows. The flow in the Rock River is the summation of the flows of all upstream tributaries, and it represents a variety of sources. A major contribution to the high base flow is ground water from the glacial outwash that underlies the valley south of Lake Koshkonong. A minor contribution is from surface storage release and sewage effluent.

The high discharges of Badfish Creek, and to a lesser degree the lower part of the Yahara River, are due to the addition of about 34 cfs of sewage effluent from the city of Madison.

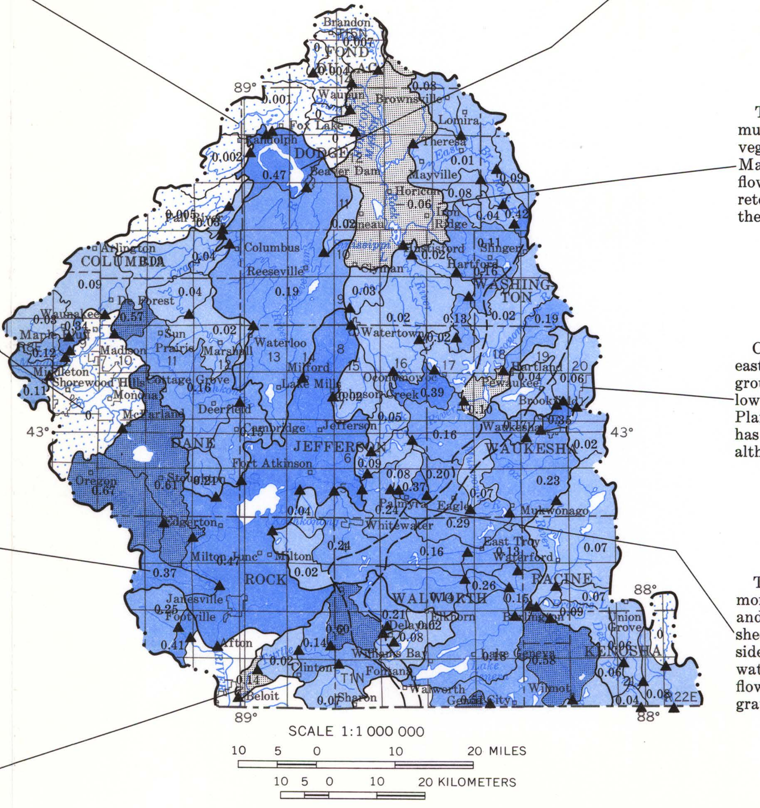
Turtle Creek shows a decreasing runoff per square mile in a downstream direction below its headwater subbasins. Upstream segments receive ground water, but in lower reaches the stream is higher than the adjacent water table and it loses water to the underlying thick and very permeable glacial outwash deposits (LeRoux, 1963, p. 26).

Beaver Dam River subbasin had an atypical runoff of 0.47 cfs per square mile due to drainage of Beaver Dam Lake, which was being lowered for fish management purposes. This drainage also raised the runoff for Crawfish River from about 0.05 to 0.19 cfs per square mile. The 0.05 cfs per square mile runoff of the Crawfish River was estimated from previous periods of similar low flow.

The upper Rock River subbasin loses much water by evapotranspiration from vegetation and water surfaces in Horicon Marsh and Lake Sinissippi. Loss of streamflow within the subbasin is also due to the retention of part of the flow by dams below the marsh and the lake.

Clayey soils in the Des Plaines River and eastern Fox River subbasins allow little ground-water recharge; therefore, there is low "fair-weather" streamflow. The Des Plaines River at the State line, for example, has no flow during 25 percent of the time, although it drains 143 square miles.

The Kettle Moraine and related end moraines are ground-water recharge areas and have high infiltration rates (see Soils, sheet 1). Headwaters of streams on both sides of the moraine are fed by ground water discharging from springs, seeps, and flowing wells from permeable sand and gravel.



EXPLANATION

Runoff, in cubic feet per second per square mile of subbasin

Negative

0-0.01

0.01-0.1

0.1-0.3

0.3-0.5

0.5-0.7

Boundary of subbasin

Boundary of end moraine

Boundary of subbasin(s) described in text

Streamflow-measurement site

Surface-water divide

RUNOFF PATTERN DURING LOW-FLOW AUGUST 14-15, 1967

Large differences in the amount of streamflow from subbasins within the Rock-Fox basin occur during periods of low flow. These differences are caused by: variations in geology and soil cover, evapotranspiration, the number and size of lakes and marshes, the amount and type of vegetation, and by manmade impoundments and diversions within the ground-water drainage area. Ninety-three discharge measurements were made during August 14-15, 1967, when the flow was sustained by the slow release of water from storage (about 90 percent on the flow-duration curves). To aid in the comparison of the contributions from the many subbasins, streamflow is presented on the above map as runoff per square mile. The runoff per square mile for a subbasin will not typify every small area within that subbasin.

The median streamflow for the 93 subbasins was 0.08 cfs per square mile during August 14-15, 1967. The text relating to several selected subbasins explains the causes of comparatively high or low runoff per square mile.

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

WATER RESOURCES OF WISCONSIN—ROCK-FOX RIVER BASIN

By
R. D. Cotter, R. D. Hutchinson, E. L. Skinner, and D. A. Wentz

1969