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Low-Flow Characteristics at Gaging Stations on the Wisconsin, Fox, and Wolf Rivers, Wisconsin

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Low-flow characteristics are presented at 11 gaging stations on the main stem of the Wisconsin, Fox, and Wolf Rivers. To provide accurate and consistent low-flow characteristics for uniform evaluation of waste effluent, a long-term period of streamflow record (1915-75) was used for the analyses. The annual minimum 7-day mean flow that occurs on the average of once in 10 years ($Q_{7,10}$) on the Wisconsin River ranged from 140 cubic feet per second at the gaging station at Rainbow Lake to 2,790 cubic feet per second at the Muscoda gaging station. On the Fox-Wolf Rivers, the $Q_{7,10}$ ranged from 360 cubic feet per second at Fox River at Berlin to 950 cubic feet per second at Fox River at Rapide Croche dam. The analyses showed that the severe drought of the 1930's makes a substantial change in the $Q_{7,10}$ discharge while the effect of regulation apparently makes little difference in the $Q_{7,10}$ discharge at the Merrill gaging station.

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Low-Flow Characteristics at Gaging Stations on the Wisconsin, Fox, and Wolf Rivers, Wisconsin

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and
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ABSTRACT

Low-flow characteristics are presented at eleven gaging stations on the main stem of the Wisconsin, Fox, and Wolf Rivers in this report. The low-flow characteristics presented are the annual minimum 7-day mean flow below which the flow will fall on the average of once in 2 years ($Q_{7,2}$) and the annual minimum 7-day mean flow below which the flow will fall on the average of once in 10 years ($Q_{7,10}$).

To provide accurate and consistent low-flow characteristics for uniform evaluation of waste effluent, a long-term period of streamflow record was used for the analyses. The record selected for the study was 1915-75. This was found to be the most representative that included long-term streamflow conditions and various degrees of regulation by storage reservoirs.

The $Q_{7,10}$ discharge on the Wisconsin River ranged from 140 cubic feet per second at the Wisconsin River at Rainbow Lake near Lake Tomahawk gaging station to 2,790 cubic feet per second at the Wisconsin River at Muscoda gaging station. On the Fox-Wolf Rivers, the $Q_{7,10}$ ranged from 360 cubic feet per second at Fox River at Berlin to 950 cubic feet per second at Fox River at Rapide Croche dam near Wrightstown.

Low-flow characteristics that reflect unregulated and regulated conditions on the upper Wisconsin River were compared. This analysis showed no apparent difference in $Q_{7,10}$ discharge values due to regulation at the Wisconsin River at Merrill gaging station, although a more detailed study is warranted to fully evaluate the effect of storage.

The magnitude of the low-flow characteristics are in some instances affected by the period of record. These characteristics can vary as much as ±30 percent at some gaging stations depending on whether or not the severe drought of the 1930's was included in the analysis.

INTRODUCTION

The purpose of this report is to describe the low-flow characteristics at selected gaging stations on the main stem of the Wisconsin, Fox, and Wolf Rivers. The study was done in cooperation with the Wisconsin Department of Natural Resources.

Water-quality standards for streams in Wisconsin are based on the annual minimum 7-day mean flow below which the flow will fall on the average of once in 10 years ($Q_{7,10}$). An accurate and consistent definition of the $Q_{7,10}$ discharge is required at various sites along the major rivers in the State to evaluate the stream's ability to assimilate waste.

Long-term streamflow records are available at 11 gaging stations along these rivers for the required low-flow analyses. Although the number and location of gaging stations provide data that could be used to define the low-flow characteristics near the required locations, the results would not be uniform or consistent because the stations were operated for different periods of record.

The difference in the period of record is especially important because it may cause a significant difference in the results due to several other factors. Upstream reservoirs have regulated streamflow since the early 1900's. The amount of regulation has varied over the years as additional storage reservoirs were constructed. Most of the major storage reservoirs were completed by 1936.

Climatic difference also has been a major factor in the recorded streamflow data. The most severe drought of record occurred during the 1930's. This was also a period when some of the gaging stations were not being operated.

To remove these differences, a uniform period of record was selected for analysis. The selection of a period was based on the longest time sample of recorded discharge at most gaging stations and also included the same degree of regulation and climatic conditions.

To evaluate water-quality standards, it may be necessary to consider $Q_{7,10}$ values for time periods other than annual events. A combination of minimum 7-day mean flow for some other period combined with maximum stream temperature may produce a more critical water-quality condition in the stream. Therefore, this report presents low-flow characteristics for the periods: April 1-March 31; June 1-October 31; December 1-March 31 at all sites; and for July, August, September, and October at some sites.

This report presents low-flow characteristics for the above periods at eight gaging stations on the Wisconsin River, two gaging stations on the Fox River, and at one gaging station on the Wolf River. The locations of these gaging stations are shown on figure 1. The low-flow characteristics determined for the Wisconsin River stations are for the period 1915-75, except for the station Wisconsin River at Rainbow Reservoir (05391000) which is based on the period 1938-75. For the gaging stations on the Fox and Wolf Rivers, the 1915-75 period also was used.

The low-flow characteristics presented are the minimum 7-day mean flow at the 2-year ($Q_{7,2}$) and 10-year ($Q_{7,10}$) recurrence intervals.

To document when the annual minimum 7-day mean flow occurs, the date of the event is listed for four gaging stations.

A comparison between regulated and unregulated flows on the upper Wisconsin River is presented to illustrate the effect of regulation on low flows. The comparison is based on two unregulated streams in northern Wisconsin and the upper Wisconsin River, which is regulated.

For the convenience of readers who may want to use metric units, the data in the report may be converted by using the following conversion factors:

Multiply	By	To obtain
miles (mi)	1.609	kilometers (km)
feet (ft)	.3048	meters (m)
square miles (mi^2)	2.59	square kilometers (km^2)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
feet per mile (ft/mi)	.1894	meters per kilometer (m/km)
inches (in)	2.54	centimeters (cm)
cubic feet per second per square mile {$(ft^3/s)/mi^2$}	.01093	cubic meters per second per square kilometer {$(m^3/s)/km^2$}

GAGING STATIONS

Low-flow characteristics were obtained at 11 gaging stations. The location, drainage area, period of record, amount of regulation, and other related problems are presented. Also included is a discussion of how the records were extended when necessary to obtain a uniform period for the analyses. Regression relations with streamflow records at other gaging stations were used only when the estimated data would improve the accuracy of the low-flow characteristics. Fiering (1963) has shown that generally a regression relationship has to have a correlation coefficient greater than 0.8 to improve the estimates.

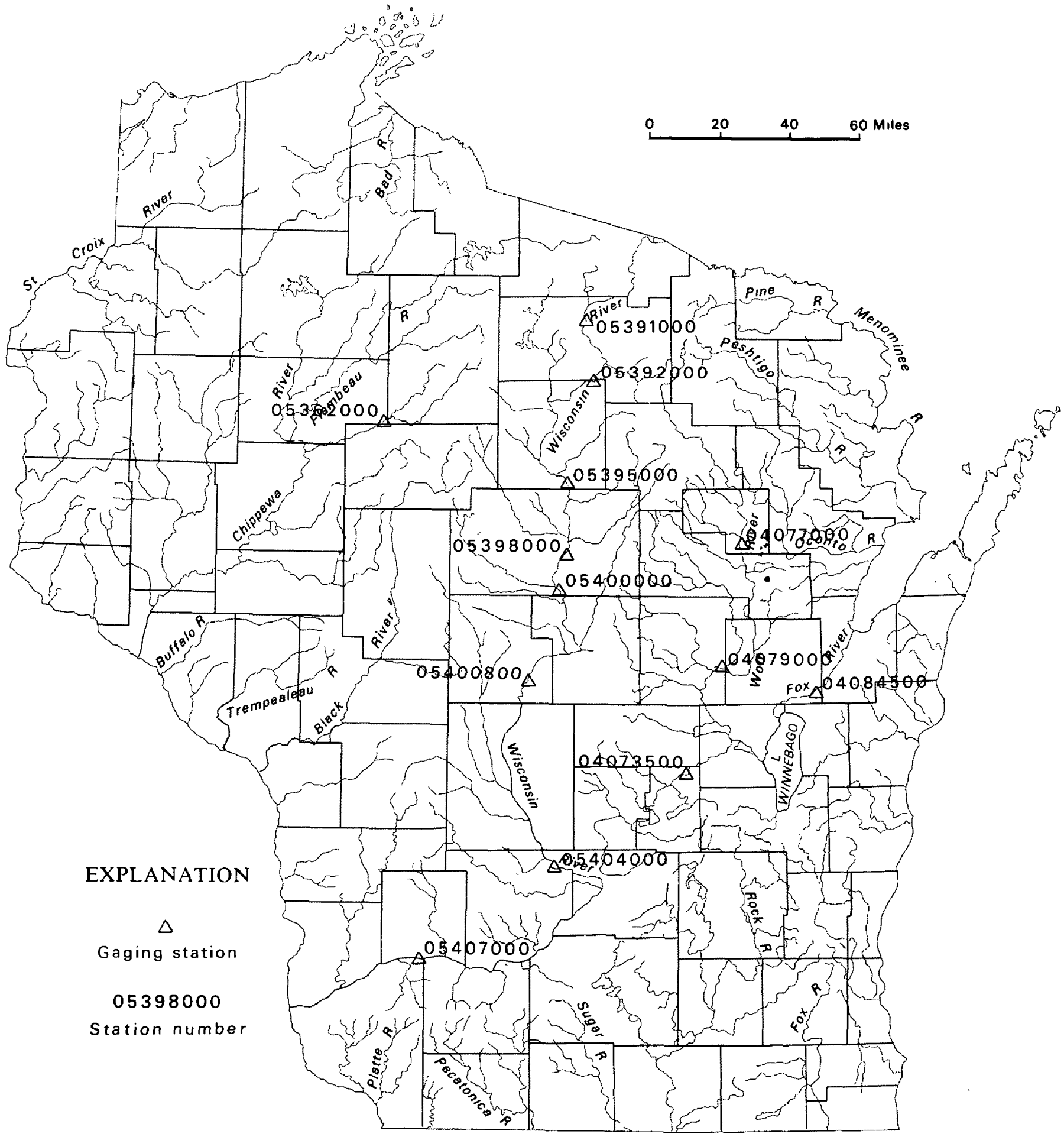

Figure 1. Location of gaging stations included in this report.

Wisconsin River at Rainbow Lake near Lake Tomahawk, Wis. (05391000)

Location.--Lat 45°49'58", long 89°32'51", in S½SW¼ sec. 30, T. 39 N., R. 8 E., Oneida County, 400 ft upstream from Gilmore Creek, 0.3 mi downstream from Rainbow Lake, and 2.5 mi northeast of Lake Tomahawk.

Drainage area.--744 mi^2, includes Gilmore Creek drainage.

Period of record.--July 1936 to March 1975.

Period used for low-flow analysis.--April 1937 to March 1975. The period was not extended to April 1914 because the regression relation with stations that had longer record of discharge had a correlation coefficient less than 0.8.

Remarks.--The recorded streamflow data generally are rated[1] good except for winter periods, which are fair. The flow is regulated by Rainbow Lake and 12 smaller reservoirs upstream (U.S. Geological Survey, 1976).

Wisconsin River at Whirlpool Rapids near Rhinelander, Wis. (05392000)

Location.--Lat 45°33'15", long 89°30'25", in NW¼ sec. 4, T. 35 N., R. 8 E., Lincoln County, at head of Whirlpool Rapids, 0.6 mi downstream from outlet of Crescent Lake and 10 mi southwest of Rhinelander.

Drainage area.--1,220 mi^2.

Period of record.--October 1905 to September 1961.

Period used for low-flow analysis.--April 1914 to March 1975. Low-flow data for the required periods were estimated from regression relations with the recorded discharge at the Wisconsin River at Merrill gaging station. Correlation coefficients ranged from 0.81 to 0.90 for the three regressions that were developed.

Remarks.--Records are rated good except for winter periods, which are fair. Flow is regulated by 12 reservoirs beginning in 1908, 13 reservoirs 1909-34, 15 reservoirs since 1935, and 3 powerplants upstream from this station.

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[1]Rating of streamflow records states the degree of accuracy of the records. Excellent means that about 95 percent of the daily discharge is within 5 percent; good within 10 percent; and fair within 15 percent. Poor means that daily discharges have less than fair accuracy.

Wisconsin River at Merrill, Wis. (05395000)

Location.--Lat 45°10'41", long 89°40'52", on line between secs. 12 and 13, T. 31 N., R. 6 E., Lincoln County, 300 ft downstream from U.S. Highway 51 bridge at east end of Merrill, and 0.5 mi downstream from the Prairie River.

Drainage area.--2,760 mi^2.

Period of record.--November 1902 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975.

Remarks.--Records are rated good except for winter months, which are fair. Flow is regulated by 13 reservoirs beginning in 1908, 14 reservoirs in 1909, 15 reservoirs 1910-11, 16 reservoirs 1912-22, 17 reservoirs 1923-27, 18 reservoirs 1927-34, 20 reservoirs since 1935, and 9 powerplants upstream from this station.

Wisconsin River at Rothschild, Wis. (05398000)

Location.--Lat 44°53'09", long 89°38'05", in sec. 26, T. 28 N., R. 7 E., Marathon County, at Rothschild, 0.5 mi downstream from Rothschild Dam, 1.7 mi upstream from U.S. Highway 51 bridge, 2.0 mi downstream from Eau Claire River.

Drainage area.--4,020 mi^2.

Period of record.--October 1944 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975. Low-flow data for required periods were estimated from regression relations with the recorded discharge at the Wisconsin River at Merrill gaging station. Correlation coefficients ranged from 0.92 to 0.97 for the three regressions that were developed.

Remarks.--Records are rated good except for winter periods or discharges below 1,500 ft^3/s, which are fair. Flow is regulated by 20 reservoirs since 1944 and 12 powerplants upstream from this station.

Wisconsin River at Knowlton, Wis. (05400000)

Location.--Lat 44°42', long 89°42', in N½ sec. 29, T. 26 N., R. 7 E., Marathon County, on combination railroad and highway bridge at Knowlton and 1.5 mi downstream from Big Eau Pleine River.

Drainage area.--4,530 mi^2.

Period of record.--October 1920 to September 1942.

Period used for low-flow analysis.--April 1914 to March 1975. Low-flow data for required periods were estimated from regression relations with the recorded discharge at the Wisconsin River at Wisconsin Rapids gaging station. Correlation coefficients ranged from 0.92 to 0.96 for the three regressions that were developed.

Remarks.--Records are rated good except for winter periods, which are fair. This site has been inundated by Lake DuBay which was constructed in 1942. Flow was regulated by 16 reservoirs before 1923, 17 reservoirs 1923-26, 18 reservoirs 1927-34, 20 reservoirs 1935-36, 21 reservoirs since 1937, and many powerplants upstream from this station.

Wisconsin River at Wisconsin Rapids, Wis. (05400800)

Location.--Lat 44°22'05", long 89°51'30", in SW¼ sec. 24, T. 22 N., R. 5 E., Wood County, at Centralia Powerplant of Nekoosa-Edwards Paper, Inc., 1.6 mi downstream from Chicago and Northwestern Railway bridge in Wisconsin Rapids.

Drainage area.--5,430 mi^2.

Period of record.--May 1914 to March 1950, October 1957 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975. Low-flow data for the period March 1950 to October 1957 were estimated from Centralia Powerplant records on the basis of load-discharge rating of hydroelectric units. Rating of units and spillway is based on theoretical formulae and discharge measurements that were made after October 1957.

Remarks.--Records are rated good. Discharge was computed from powerplant records as described above since 1957. Before March 1950, the gaging station was located 1.5 mi downstream from Nekoosa. Drainage area for that site is approximately 5,500 mi^2. Records for the period 1914 to 1950 are rated good except for winter periods which are rated fair.

Flow is regulated by 16 reservoirs before 1923, 17 reservoirs 1923-26, 18 reservoirs 1927-34, 20 reservoirs 1935-36, 21 reservoirs 1937-42, 22 reservoirs since 1943, and many powerplants upstream from this station.

Water is diverted periodically from the pond of the Wisconsin Rapids Powerplant 2.6 mi upstream into Cranberry Creek for cranberry culture.

Diversion generally occurs during July and August or October and November and is about 100 ft^3/s.

Wisconsin River near Wisconsin Dells, Wis. (05404000)

Location.--Lat 43°36'22", long 89°45'25", in NW¼ sec. 14, T. 13 N., R. 6 E., Sauk County, 0.5 mi downstream from Dell Creek and 3.0 mi downstream from Wisconsin Dells.

Drainage area.--8,090 mi^2.

Period of record.--October 1934 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975. Low-flow data for the period April 1914 to October 1934 were estimated from regression relations with the recorded discharge at the Wisconsin River at Muscoda gaging station. Correlation coefficients ranged from 0.88 to 0.91 for the regressions that were developed.

Remarks.--Records are rated good. Flow is regulated by 20 reservoirs 1935-36, 21 reservoirs 1937-42, 22 reservoirs 1943-49, 24 reservoirs since 1950, and many powerplants upstream from this station.

Wisconsin River at Muscoda, Wis. (05407000)

Location.--Lat 43°11'54", long 90°26'26", in NW¼ sec. 1, T. 8 N., R. 1 W., Grant County, at bridge on State Highway 80, 0.5 mi upstream from Eagle Mill Creek and 1.0 mi north of Muscoda.

Drainage area.--10,450 mi^2.

Period of record.--December 1902 to December 1903, October 1913 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975.

Remarks.--Records are rated good except for winter periods which are fair. Flow is regulated by 16 reservoirs before 1923, 17 reservoirs 1923-26, 18 reservoirs 1927-34, 20 reservoirs 1935-36, 21 reservoirs 1937-42, 22 reservoirs 1943-49, 24 reservoirs since 1950, and many powerplants upstream from this station.

Fox River at Berlin, Wis. (04073500)

Location.--Lat 43°57'14", long 88°57'08", in NE¼ sec. 16, T. 17 N., R. 13 E., Green Lake County, 0.4 mi downstream from Government Dam, 1.0 mi south of Huron Street bridge in Berlin, 2.5 mi upstream from Barnes Creek.

Drainage area.--1,400 mi^2, approximately.

Period of record.--January 1898 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975.

Remarks.--Records computed by U.S. Army Corps of Engineers and reviewed by Geological Survey from 1898 to 1939. The records for this period were based on a rating curve developed from 18 discharge measurements. Records for this period are rated fair for the open water seasons because of the small number and timing of the discharge measurements. The winter records for this period are rated poor because no discharge measurements were made during the winter period to determine backwater effect from ice. Adjustments for ice were made based on dam tender's estimate of ice thickness. Attempts to improve winter records based on regression relations with climatic and other streamflow data in the area were not successful.

Records for the period 1940 to present are rated good except for the winter periods which are fair.

A diversion of usually less than 5.0 ft^3/s is made from the Wisconsin River at the Portage Canal into the Fox River basin.

Wolf River at New London, Wis. (04079000)

Location.--Lat 44°23'32", long 88°44'25", in NE¼SE¼ sec. 12, T. 22 N., R. 14 E., Waupaca County, at Pearl Street bridge in New London, 0.2 mi downstream from the Embarrass River.

Drainage area.--2,200 mi^2, approximately.

Period of record.--March 1896 to March 1975. Before October 1913 monthly discharges only.

Period used for low-flow analysis.--April 1914 to March 1975.

Remarks.--Records are rated good except for winter periods which are fair.

Fox River at Rapide Croche Dam near Wrightstown, Wis. (04084500)

Location.--Lat 44°19'03", long 88°11'50", in SE¼ sec. 4, T. 21 N., R. 19 E., Outagamie County, at Rapide Croche Dam, 2.0 mi upstream from Wrightstown and 18 mi upstream from mouth.

Drainage area.--6,200 mi^2, approximately.

Period of record.--March 1896 to September 1917 (monthly discharge only), October 1917 to March 1975.

Period used for low-flow analysis.--April 1914 to March 1975.

Remarks.--Records furnished by Corps of Engineers and reviewed by the U.S. Geological Survey.

LOW-FLOW CHARACTERISTICS

Low-flow characteristics for the 11 gaging stations are presented in table 1. The low-flow characteristics determined are the $Q_{7,2}$ and $Q_{7,10}$ discharge. The characteristics were determined for the following periods: April 1 through March 31; June 1 through October 31; and December 1 through March 31 for all sites; and for July, August, September, and October for selected sites.

The low-flow frequency characteristics were determined from the daily discharge records using a Log Pearson Type III probability distribution. The results of these analyses then were compared to a graphical plot of the 7-day annual minimum flows (Riggs, 1972). If the two curves did not agree, a graphical interpretation was made to determine the low-flow characteristics.

Effect of Regulation and Period of Record Used for Analysis

A comparison of regulated and unregulated low flows was made for the upper Wisconsin River. This was done by determining low-flow frequency characteristics at a gaging station that is regulated and at two gaging stations that are unregulated. The regulated conditions were represented by the Wisconsin River at Merrill gaging station and natural or unregulated conditions were determined for the Jump River near Sheldon (05362000) and the Wolf River at Keshena Falls (04077000) gaging stations. The Merrill station was selected because it has continuous record for the desired period (1915-75) and reflects any changes that may have been caused by regulation in the upper Wisconsin River basin. The Jump River and Wolf River stations were selected because they are the only stations in or near the upper Wisconsin River basin that are unregulated and have been operated for the period 1915-75.

Low-flow characteristics were compared for three different periods: the period selected for uniform analyses at all 11 gaging stations (1915-75); the period before completion of Rainbow Lake near Lake Tomahawk which is the major upstream storage reservoir (1915-36), this is also the period that contains the minimum flows of record; and the period after the completion of Rainbow Lake (1937-75).

Low-flow frequency curves are shown in figure 2 for the three periods at the three gaging stations. The $Q_{7,10}$ discharge values determined from these analyses are presented in table 2. The comparison shows that for the upper Wisconsin River basin the selected period for uniform analysis provides a reasonable estimate of long-term, low-flow conditions. As shown in table 2, the 1915-75 period represents a good average of the $Q_{7,10}$ discharge for the other two periods at all three stations.

The $Q_{7,10}$ values for the 1915-36 period are significantly lower than those for the 1915-75 period. Because all three stations show the same characteristics, it appears that the drought of the early 1930's, causing extreme low flow, is the reason for this decrease.

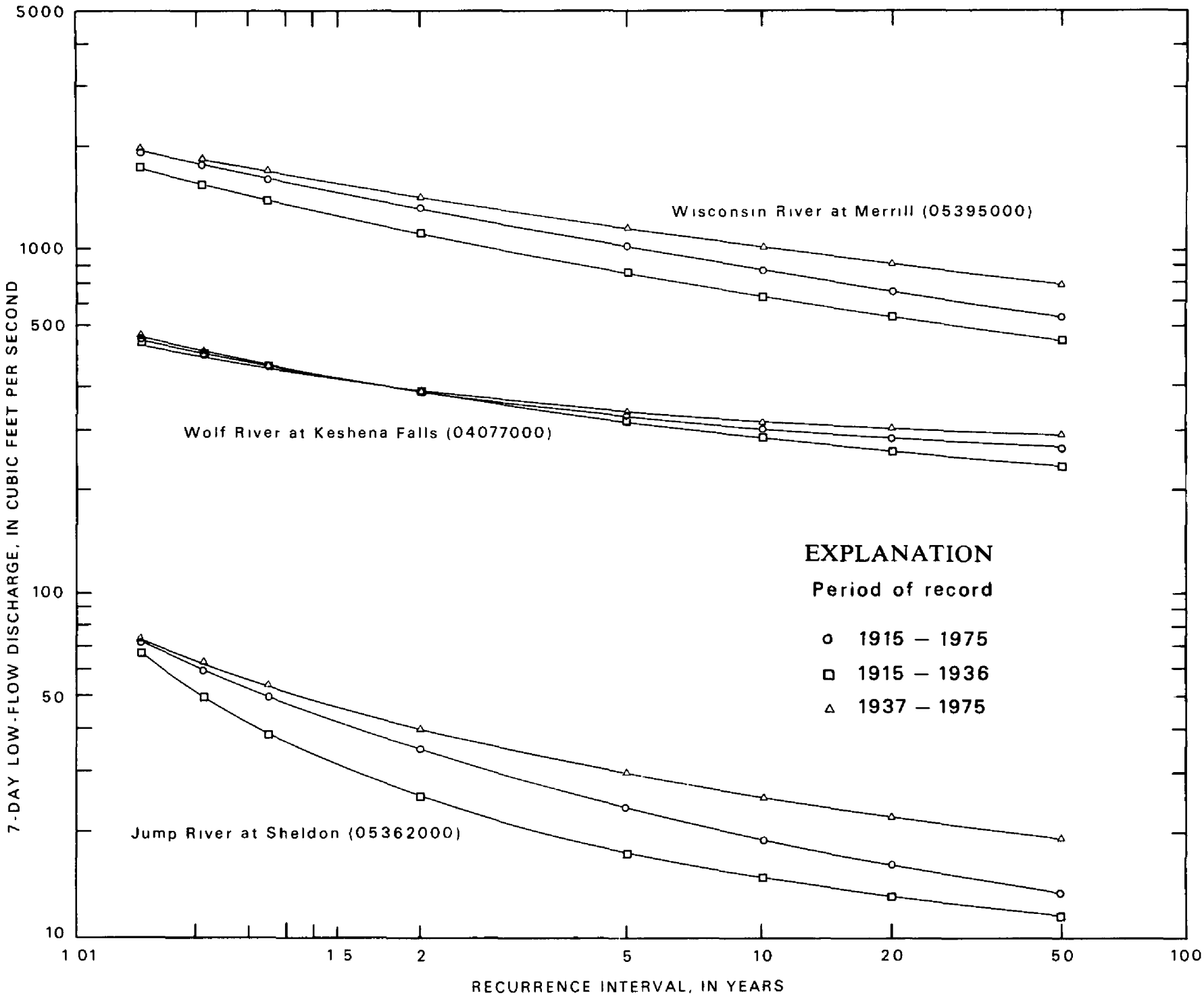

Figure 2. 7-day low-flow frequency curves showing differences of annual low-flow characteristics at three gaging stations for different periods of time

Table 1.--Low-flow characteristics at gaging stations on the Wisconsin, Fox, and Wolf Rivers

Station name and number	Low-flow characteristics determined	Low-flow characteristics (cubic feet per second)						
		Apr. 1 to Mar. 31	June 1 to Oct. 31	Dec. 1 to Mar. 31	July	Aug.	Sept.	Oct.
Wisconsin River at Rainbow Lake near Lake Tomahawk (05391000)	$Q_{7,2}$	210	380	470				
	$Q_{7,10}$	140	220	270				
Wisconsin River at Whirlpool Rapids near Rhinelander (05392000)	$Q_{7,2}$	590	640	710				
	$Q_{7,10}$	360	380	480				
Wisconsin River at Merrill (05395000)	$Q_{7,2}$	1,330	1,440	1,530	1,730	1,660	1,640	1,690
	$Q_{7,10}$	880	930	1,030	1,150	1,050	1,120	1,100
Wisconsin River at Rothschild (05398000)	$Q_{7,2}$	1,460	1,580	1,720				
	$Q_{7,10}$	950	990	1,170				
Wisconsin River at Knowlton (05400000)	$Q_{7,2}$	1,640	1,790	1,960				
	$Q_{7,10}$	1,020	1,050	1,310				
Wisconsin River at Wisconsin Rapids (05400800)	$Q_{7,2}$	1,870	2,060	2,230	2,490	2,330	2,320	2,470
	$Q_{7,10}$	1,280	1,360	1,510	1,670	1,450	1,590	1,620
Wisconsin River near Wisconsin Dells (05404000)	$Q_{7,2}$	2,690	2,910	3,360				
	$Q_{7,10}$	1,910	1,980	2,350				
Wisconsin River at Muscoda (05407000)	$Q_{7,2}$	3,770	4,100	4,420				
	$Q_{7,10}$	2,790	2,950	3,120				
Fox River at Berlin (04073500)	$Q_{7,2}$	480	540	520				
	$Q_{7,10}$	360	390	380				

Wolf River at New London (04079000)	$Q_{7,2}$	670	750	750				
	$Q_{7,10}$	470	480	560				
Fox River at Rapide Croche dam near Wrightstown (04084500)	$Q_{7,2}$	1,660	1,770	2,870	2,530	2,000	1,860	2,060
	$Q_{7,10}$	950	950	1,880	1,440	1,110	1,010	1,080

Table 2.--Annual minimum 7-day mean flows below which the flow will fall on the average of once in 10 years ($Q_{7,10}$) at three gaging stations for different periods of record

Station number	Station name	$Q_{7,10}$ discharge in cubic feet per second for indicated periods		
		1915-75	1915-36	1937-75
04077000	Wolf River at Keshena Falls	310	290	320
05362000	Jump River at Sheldon	20	16	24
05395000	Wisconsin River at Merrill	880	750	1,000

The 1937-75 $Q_{7,10}$ values show a similar characteristic, only the $Q_{7,10}$ values are significantly larger than those for the 1915-75 period. This increase reflects higher annual minimum 7-day flows during 1937-75 than the entire period. While the effect of adding a significant upstream storage reservoir, Rainbow Lake, does not seem to have affected the $Q_{7,10}$ discharge at Merrill, a more detailed study is required to fully evaluate the effect of storage.

In summary, the period 1915-75 is considered a more representative period for analysis than either of the others (1915-36 or 1937-75 periods).

To illustrate the need for selecting a uniform period of record for the analyses, a comparison was made between $Q_{7,10}$ discharges at two stations on the Wisconsin River. Using the period of record at each gaging station the $Q_{7,10}$ at Wisconsin River at Rothschild (1946-72) is 1,090 ft^3/s but at the next station downstream, Wisconsin River at Knowlton (1922-42) the $Q_{7,10}$ is 798 ft^3/s. This comparison shows a decrease in discharge of 292 ft^3/s. Using the uniform period (1915-75) the $Q_{7,10}$ discharge increased 180 ft^3/s between the two stations which is consistent with known hydrologic behavior of the river.

Date of Low-Flow Occurrence

The dates that the annual minimum 7-day mean flows occurred were determined at four gaging stations to illustrate when low-flow events occur on regulated streams and to observe any difference between upstream and downstream conditions. The four gaging stations selected are: Wisconsin River at Whirlpool Rapids; Wisconsin River at Muscoda; Fox River at Berlin; and Fox River at Rapide Croche Dam. The dates of the annual low-flow event for the climatic years 1915-75 are shown in table 3.

The two Wisconsin River stations have distinctly different annual minimum 7-day mean flows. At the Whirlpool Rapids station, the annual minimum 7-day mean flow occurred in every month but at the Muscoda station the annual minimum 7-day mean flow never occurred during April, May, or June. At both stations the June 1-October 31 period had the highest percentage of annual minimum 7-day mean flows, 47 percent at Whirlpool Rapids and 55 percent at Muscoda.

The two stations on the Fox River had even a more distinct difference in the date of occurrence. At the Berlin station, 54 percent of the events occurred during the December 1-March 31 period and 43 percent during the June 1-October 31 period. This is in contrast to the Rapide Croche Dam which had only 2 percent of the annual minimum 7-day mean flow occurring during the December 1-March 31 period and 87 percent during the June 1-October 31 period. This difference is probably caused by either the operation of Lake Winnebago or reflects the water loss that occurs as evaporation during the summer on the Lake Winnebago pool.

SUMMARY AND CONCLUSIONS

The low-flow characteristics determined for this study are well defined by the available streamflow records. The $Q_{7,10}$ discharge of the Wisconsin River ranged from 140 ft^3/s at the Rainbow Lake gaging station to 2,790 ft^3/s at the Muscoda gaging station. On the Fox-Wolf River, the $Q_{7,10}$ discharge ranged from 360 ft^3/s at the Berlin gaging station to 950 ft^3/s at Rapide Croche Dam.

Low-flow characteristics for the climatic year were lower than those determined for the June 1-October 31 period; December 1-March 31 period; and July, August, September, and October. In comparing the June 1-October 31 period and the December 1-March 31 period, the low-flow characteristics were lower for the June 1-October 31 period except for two stations. The $Q_{7,2}$ and $Q_{7,10}$ discharges were both higher at the Berlin station for the June 1-October 31 period and the $Q_{7,2}$ was the same at the New London station.

The period of record used for the analyses appears to be satisfactory for consistent and representative determination of low-flow characteristics. A longer period could not be used because streamflow records are not available to extend the period of record at all sites.

The comparison of shorter periods 1915-36 and 1937-75 shows a definite bias for the difference in climatic conditions. The inclusion or exclusion of the data from the early 1930's makes a difference of ±5 percent to ±30 percent for the three stations that were analyzed. The comparison of low-flow characteristics for two unregulated stations and one regulated showed the same trends for the three periods analyzed.

Table 3.--Annual minimum 7-day low flow and date of occurrence at selected gaging stations on the Wisconsin River

Climatic year (April 1-March 31)	05392000 Wisconsin River at Whirlpool Rapids near Rhinelander		05407000 Wisconsin River at Muscoda	
	7-day low flow (ft^3/s)	Date of 7-day low flow	7-day low flow (ft^3/s)	Date of 7-day low flow
1915	685	Dec. 11-17, 1914	4,020	Jan. 1- 7, 1915
1916	478	Feb. 12-18, 1916	4,080	July 15-21, 1915
1917	627	Dec. 13-19, 1916	3,830	Feb. 27-Mar. 5, 1917
1918	481	Sept. 16-22, 1917	2,950	Feb. 18-24, 1918
1919	549	July 17-23, 1918	4,160	Oct. 12-18, 1918
1920	702	Sept. 23-29, 1919	4,690	Feb. 1- 7, 1920
1921	377	Nov. 14-20, 1920	3,870	Oct. 20-26, 1920
1922	493	Jan. 17-23, 1922	3,210	Jan. 15-21, 1922
1923	638	June 9-15, 1922	3,470	Feb. 2- 8, 1923
1924	413	Feb. 26-Mar. 3, 1924	2,880	Feb. 18-24, 1924
1925	464	Dec. 31, 1924-Jan. 6, 1925	3,670	Jan. 8-14, 1925
1926	430	Aug. 25-31, 1925	3,830	Mar. 3- 9, 1926
1927	601	Apr. 4-10, 1926	4,770	July 24-30, 1926
1928	740	Sept. 1- 7, 1927	4,860	Aug. 31-Sept. 6, 1927
1929	844	Feb. 11-17, 1929	3,890	Jan. 20-26, 1929
1930	644	Jan. 8-14, 1930	3,710	Feb. 3- 9, 1930
1931	232	Sept. 22-28, 1930	2,650	Jan. 9-15, 1931
1932	340	June 2- 8, 1931	2,730	Sept. 7-13, 1931
1933	352	July 30-Aug. 5, 1932	2,530	Dec. 9-15, 1932
1934	211	Aug. 27-Sept. 2, 1933	2,950	Feb. 19-25, 1934
1935	252	July 29-Aug. 4, 1934	2,600	Aug. 25-31, 1934
1936	568	Jan. 15-21, 1936	3,870	Feb. 3- 9, 1936
1937	410	Aug. 5-11, 1936	2,450	July 20-26, 1936
1938	431	July 4-10, 1937	2,870	Sept. 15-21, 1937
1939	921	Dec. 22-28, 1938	5,200	Dec. 28, 1938-Jan. 3, 1939

1940	714	Mar. 24-30, 1940	3,240	Jan. 15-21, 1940
1941	679	Sept. 22-28, 1941	5,270	Oct. 6-12, 1940
1942	472	Aug. 4-10, 1941	3,540	Aug. 26-Sept. 1, 1941
1943	858	Aug. 14-20, 1942	4,740	Nov. 30-Dec. 6, 1942
1944	677	Mar. 18-24, 1944	4,020	Dec. 13-19, 1943
1945	565	Apr. 16-22, 1944	3,640	Dec. 15-21, 1944
1946	659	Aug. 10-16, 1945	5,440	Aug. 16-22, 1945
1947	594	Mar. 11-17, 1947	4,540	Aug. 30-Sept. 5, 1946
1948	502	Dec. 9-15, 1947	4,160	Feb. 11-17, 1948
1949	326	Sept. 3- 9, 1948	2,530	Sept. 13-19, 1948
1950	427	May 28-June 3, 1949	3,010	Oct. 13-19, 1949
1951	665	Nov. 9-15, 1950	3,570	Oct. 28-Nov. 3, 1950
1952	921	Mar. 23-29, 1952	6,140	Sept. 6-12, 1951
1953	729	Nov. 12-18, 1952	4,170	Nov. 10-16, 1952
1954	748	May 10-16, 1953	3,430	Oct. 24-30, 1953
1955	779	Aug. 23-29, 1954	4,560	Sept. 6-12, 1954
1956	443	Mar. 22-28, 1956	3,500	Sept. 29-Oct. 5, 1955
1957	730	June 7-13, 1956	3,770	Oct. 28-Nov. 3, 1956
1958	470	Aug. 12-18, 1957	3,270	Oct. 8-14, 1957
1959	510	Mar. 22-28, 1959	2,470	Sept. 1- 7, 1958
1960	555	June 18-24, 1959	3,600	Aug. 9-15, 1959
1961	755	Apr. 5-11, 1960	5,140	Dec. 29-Jan. 4, 1961
1962			3,820	July 17-23, 1961
1963			4,150	Aug. 16-22, 1962
1964			2,930	Dec. 27, 1963- Jan. 2, 1964
1965			2,510	Aug. 7-13, 1964
1966			3,870	July 27-Aug. 2, 1965
1967			3,620	Sept. 22-28, 1966
1968			4,110	Jan. 2- 8, 1968
1969			4,740	Aug. 30-Sept. 5, 1968
1970			4,490	Dec. 17-23, 1969
1971			3,550	Aug. 28-Sept. 3, 1970
1972			4,320	Sept. 20-26, 1971
1973			4,790	July 5-11, 1972
1974			5,610	Aug. 1- 7, 1973
1975			4,710	Oct. 16-22, 1974

Table 4.--Annual minimum 7-day low flow and date of occurrence at selected gaging stations on the Fox River

Climatic year (April 1-March 31)	04073500 Fox River at Berlin		04084500 Fox River at Rapide Croche dam near Wrightstown	
	7-day low flow (ft^3/s)	Date of 7-day low flow	7-day low flow (ft^3/s)	Date of 7-day low flow
1915	394	Dec. 9-15, 1914	1,620	Aug. 24-30, 1914
1916	557	Jan. 15-21, 1916	1,700	Sept. 6-12, 1915
1917	550	Jan. 21-27, 1917	2,660	Aug. 29-Sept. 4, 1916
1918	506	Jan. 1- 7, 1918	2,440	Oct. 17-23, 1917
1919	609	Sept. 4-10, 1918	1,730	Oct. 16-22, 1918
1920	559	Jan. 3- 9, 1920	2,430	Sept. 28-Oct. 4, 1919
1921	637	Aug. 6-12, 1920	2,160	Oct. 4-10, 1920
1922	489	Jan. 23-29, 1922	1,000	Aug. 13-19, 1921
1923	581	Feb. 4-10, 1923	2,530	Oct. 1- 7, 1922
1924	406	Jan. 21-27, 1924	1,720	Aug. 11-17, 1923
1925	675	Dec. 27, 1964-Jan. 2, 1925	3,760	Dec. 21-27, 1924
1926	535	Aug. 28-Sept. 3, 1925	1,970	Apr. 18-24, 1925
1927	539	July 18-24, 1926	2,720	Aug. 10-16, 1926
1928	545	Jan. 3- 9, 1928	1,810	Sept. 2- 8, 1927
1929	598	Aug. 14-20, 1928	2,330	July 27-Aug. 2, 1928
1930	521	Jan. 9-15, 1930	2,060	Oct. 18-24, 1929
1931	452	Nov. 28-Dec. 4, 1930	935	Sept. 29-Oct. 5, 1930
1932	507	Aug. 21-27, 1931	870	Aug. 26-Sept. 1, 1931
1933	370	Dec. 17-23, 1932	669	Oct. 14-20, 1932
1934	378	Feb. 23-Mar. 1, 1934	499	Sept. 20-26, 1933
1935	366	June 4-10, 1934	762	Aug. 20-26, 1934
1936	368	Jan. 26-Feb. 1, 1936	2,290	Oct. 27-Nov. 2, 1935
1937	333	Feb. 1- 7, 1937	700	Sept. 2- 8, 1936
1938	421	Jan. 8-14, 1938	934	Oct. 10-16, 1937
1939	701	Aug. 31-Sept. 6, 1938	3,050	Sept. 3- 9, 1938

1940	364	Jan. 16-22, 1940	1,770	Sept. 4-10, 1939
1941	720	Feb. 27-Mar. 5, 1941	2,230	Apr. 6-12, 1940
1942	470	Aug. 28-Sept. 3, 1941	1,480	Aug. 26-Sept. 1, 1941
1943	708	Apr. 25-May 1, 1942	2,960	Sept. 7-13, 1942
1944	521	Dec. 23-29, 1943	1,820	Oct. 22-28, 1943
1945	447	Aug. 11-17, 1944	1,520	Sept. 2- 8, 1944
1946	609	July 25-31, 1945	2,110	Sept. 10-16, 1945
1947	496	Aug. 25-31, 1946	1,850	Oct. 12-18, 1946
1948	530	Aug. 28-Sept. 3, 1947	1,770	Oct. 21-27, 1947
1949	385	Sept. 12-18, 1948	1,120	Oct. 14-20, 1948
1950	416	Sept. 24-30, 1949	1,530	Oct. 25-31, 1949
1951	500	Feb. 1- 7, 1951	2,000	Sept. 11-17, 1950
1952	759	Aug. 8-14, 1951	2,290	Aug. 7-13, 1951
1953	500	Feb. 6-12, 1953	1,420	Oct. 14-20, 1952
1954	450	Feb. 1-7, 1954	1,580	Oct. 30-Nov. 5, 1953
1955	573	Feb. 6-12, 1955	1,400	Apr. 17-23, 1954
1956	367	Feb. 23-29, 1956	1,380	Oct. 2- 8, 1955
1957	463	Jan. 15-21, 1957	1,830	Oct. 17-23, 1956
1958	403	Feb. 15-21, 1958	1,290	Oct. 21-27, 1957
1959	300	Jan. 17-23, 1959	1,080	Aug. 22-28, 1958
1960	339	Sept. 13-19, 1959	1,530	Sept. 12-18, 1959
1961	503	Jan. 28-Feb. 3, 1961	1,930	Feb. 11-17, 1961
1962	501	Aug. 25-31, 1961	2,240	July 11-17, 1961
1963	451	Jan. 30-Feb. 5, 1963	1,980	Aug. 31-Sept. 6, 1962
1964	405	Aug. 20-26, 1963	1,130	Sept. 4-10, 1963
1965	332	Aug. 14-20, 1964	1,430	Aug. 12-18, 1964
1966	391	July 28-Aug. 3, 1965	1,560	Aug. 31-Sept. 6, 1965
1967	403	Nov. 29-Dec. 5, 1966	1,160	Oct. 14-20, 1966
1968	394	Aug. 19-25, 1967	1,430	Oct. 5-11, 1967
1969	479	Jan. 12-18, 1969	1,470	Apr. 9-15, 1968
1970	443	Sept. 24-30, 1969	1,220	Sept. 24-30, 1969
1971	347	Aug. 19-25, 1970	1,020	Apr. 9-15, 1970
1972	389	Sept. 14-20, 1971	1,530	Sept. 11-17, 1971
1973	564	June 7-13, 1972	1,860	July 4-10, 1972
1974	663	Jan. 5-11, 1974	2,010	Sept. 15-21, 1973
1975	620	Feb. 6-12, 1975	1,290	Sept. 29-Oct. 5, 1974

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