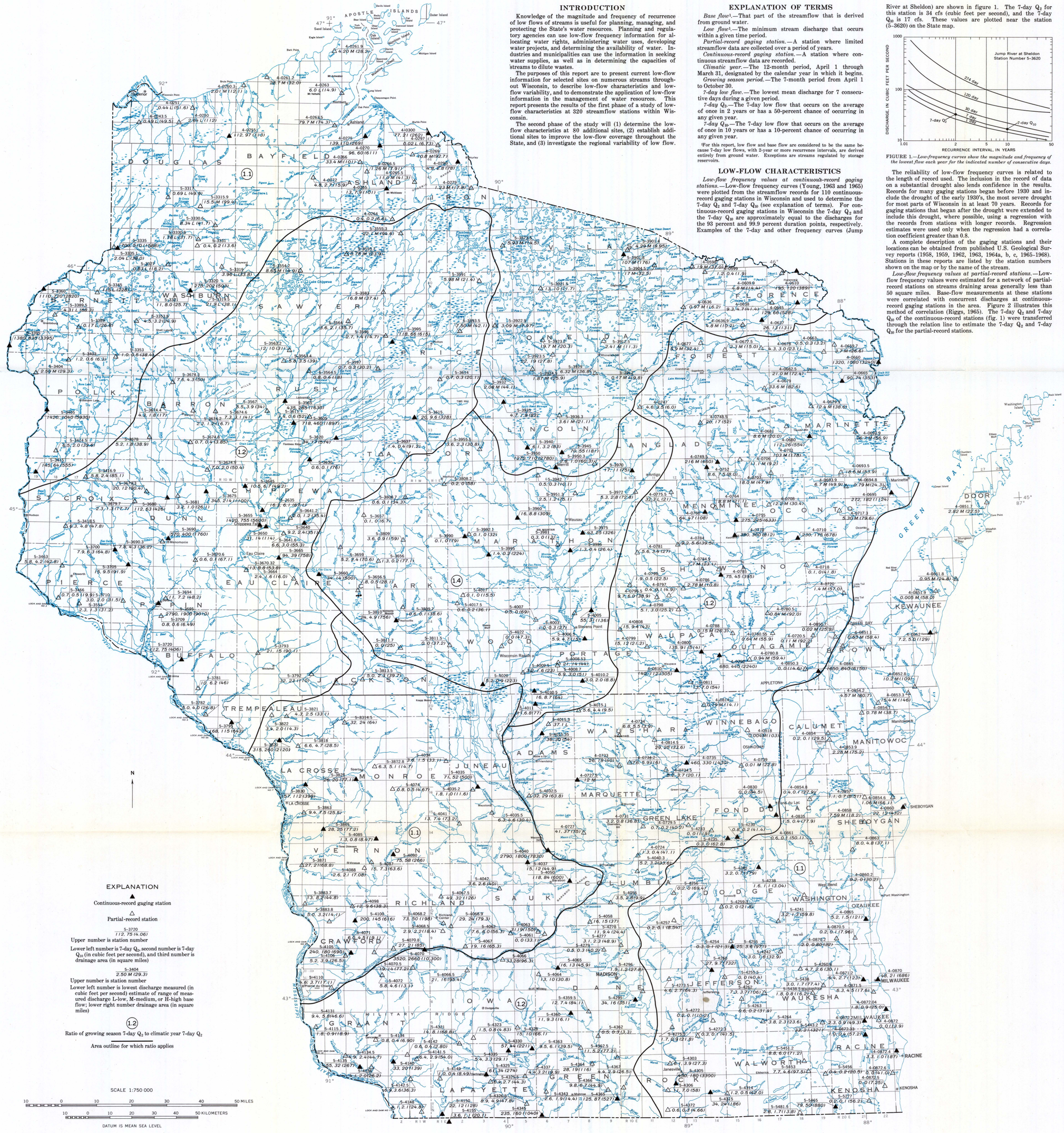
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

HYDROLOGIC INVESTIGATIONS
ATLAS HA-390



INTRODUCTION

Knowledge of the magnitude and frequency of recurrence of low flows of streams is useful for planning, managing, and protecting the State's water resources. Planning and regulatory agencies can use low-flow frequency information for allocating water rights, administering water uses, developing water projects, and determining the availability of water. Industries and municipalities can use the information in seeking water supplies, as well as in determining the capacities of streams to dilute wastes.

The purposes of this report are to present current low-flow information for selected sites on numerous streams throughout Wisconsin, to describe low-flow characteristics and low-flow variability, and to demonstrate the application of low-flow information in the management of water resources. This report presents the results of the first phase of a study of low-flow characteristics at 320 streamflow stations within Wisconsin.

The second phase of the study will (1) determine the low-flow characteristics at 80 additional sites, (2) establish additional sites to improve the low-flow coverage throughout the State, and (3) investigate the regional variability of low flow.

EXPLANATION OF TERMS

Base flow[1].—That part of the streamflow that is derived from ground water.

Low flow[1].—The minimum stream discharge that occurs within a given time period.

Partial-record gaging station.—A station where limited streamflow data are collected over a period of years.

Continuous-record gaging station.—A station where continuous streamflow data are recorded.

Climatic year.—The 12-month period, April 1 through March 31, designated by the calendar year in which it begins.

Growing season period.—The 7-month period from April 1 to October 30.

7-day low flow.—The lowest mean discharge for 7 consecutive days during a given period.

7-day Q_2.—The 7-day low flow that occurs on the average of once in 2 years or has a 50-percent chance of occurring in any given year.

7-day Q_{10}.—The 7-day low flow that occurs on the average of once in 10 years or has a 10-percent chance of occurring in any given year.

[1]For this report, low flow and base flow are considered to be the same because 7-day low flows, with 2-year or more recurrence intervals, are derived entirely from ground water. Exceptions are streams regulated by storage reservoirs.

LOW-FLOW CHARACTERISTICS

Low-flow frequency values at continuous-record gaging stations.—Low-flow frequency curves (Young, 1963 and 1965) were plotted from the streamflow records for 110 continuous-record gaging stations in Wisconsin and used to determine the 7-day Q_2 and 7-day Q_{10} (see explanation of terms). For continuous-record gaging stations in Wisconsin the 7-day Q_2 and the 7-day Q_{10} are approximately equal to the discharges for the 93 percent and 99.9 percent duration points, respectively. Examples of the 7-day and other frequency curves (Jump River at Sheldon) are shown in figure 1. The 7-day Q_2 for this station is 34 cfs (cubic feet per second), and the 7-day Q_{10} is 17 cfs. These values are plotted near the station (5-3620) on the State map.

FIGURE 1.—*Low-frequency curves show the magnitude and frequency of the lowest flow each year for the indicated number of consecutive days.*

The reliability of low-flow frequency curves is related to the length of record used. The inclusion in the record of data on a substantial drought also lends confidence in the results. Records for many gaging stations began before 1930 and include the drought of the early 1930's, the most severe drought for most parts of Wisconsin in at least 70 years. Records for gaging stations that began after the drought were extended to include this drought, where possible, using a regression with the records from stations with longer records. Regression estimates were used only when the regression had a correlation coefficient greater than 0.8.

A complete description of the gaging stations and their locations can be obtained from published U.S. Geological Survey reports (1958, 1959, 1962, 1963, 1964a, b, c, 1965–1968). Stations in these reports are listed by the station numbers shown on the map or by the name of the stream.

Low-flow frequency values at partial-record stations.—Low-flow frequency values were estimated for a network of partial-record stations on streams draining areas generally less than 50 square miles. Base-flow measurements at these stations were correlated with concurrent discharges at continuous-record gaging stations in the area. Figure 2 illustrates this method of correlation (Riggs, 1965). The 7-day Q_2 and 7-day Q_{10} of the continuous-record stations (fig. 1) were transferred through the relation line to estimate the 7-day Q_2 and 7-day Q_{10} for the partial-record stations.

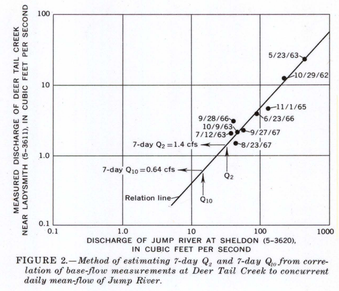


FIGURE 2.—*Method of estimating 7-day Q_2 and 7-day Q_{10} from correlation of base-flow measurements at Deer Tail Creek to concurrent daily mean-flow of Jump River.*

Many partial-record stations on the map do not have low-flow frequencies shown because of insufficient data to define a relationship with a continuous-record gaging station. For these stations the lowest measured discharges are shown on the map.

A complete description of the location of the partial-record stations can be obtained from published U.S. Geological Survey annual reports (1962, 1963, 1964c, 1965–1968). Stations in these reports are listed by the station numbers, which are shown on the map.

Low-flow frequency values at miscellaneous sites.—Additional low-flow information is collected at miscellaneous sites throughout the State by the Water Resources Division for other cooperative projects. This information is not on the map but is available from the Madison district office of the Water Resources Division. Miscellaneous low-flow information, when compared with the low-flow frequencies of nearby gaging stations, may be used to estimate low-flow frequency values for ungaged sites.

LOW-FLOW VARIABILITY

Factors that influence low flow.—The principal factors that influence low flow are precipitation, geology, soils, evapotranspiration, storage in lakes and swamps, drainage patterns, and man's development of the area. To illustrate the wide variation in low flows, frequency curves are shown in figure 3 for five continuous-record gaging stations. Cedar Creek has a low discharge and a high variability of low flow because it drains a clay till area and receives little ground-water flow.

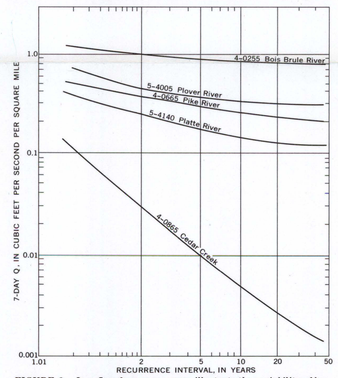


FIGURE 3.—*Low-flow frequency curves illustrate the variability of low flows.*

Bois Brule and Plover Rivers have high discharges and a low variability because they drain sand areas that store and release uniformly large ground-water discharge. Pike and Platte Rivers have intermediate low flows and drain a swamp and sand area and a sandstone and dolomite area, respectively. The average 7-day Q_2 in Wisconsin is 0.20 cfs per sq mi (square mile), and the average 7-day Q_{10} is 0.14 cfs per sq mi. Low flows range from 0 to 0.99 cfs per sq mi for the 7-day Q_2 and from 0 to 0.86 cfs per sq mi for the 7-day Q_{10}. Some areas of the State have high, stable low flows during droughts; other areas have zero flow during droughts.

Seasonal variation in low flow.—Minimum low flows of streams in Wisconsin generally occur during the winter, but periods of low flow are common also in the summer. The low-flow frequency values on the map for the climatic year were developed from flows that occurred during the winter.

From an agricultural, recreational, or aesthetic standpoint the low flow during the growing season is especially important. The scale of the map prohibits complete presentation of low-flow data for this season; however, an approximate value for the growing season 7-day Q_2 may be estimated from the ratios shown on the map. The ratios should be used to estimate only the 7-day Q_2 low flows. This relationship does not hold for other time periods or recurrence intervals.

APPLICATION OF LOW-FLOW FREQUENCY INFORMATION IN THE MANAGEMENT OF WATER RESOURCES

The following example suggests how low-flow information from the map can be applied in the management of water resources.

Example: A water supply of 2 cfs is needed for irrigation on Spring Creek near Antigo (station 5-3972). The relation of the required seasonal water supply to the low-flow characteristics of the stream is shown by the following analyses. The minimum flow on the average of once in 2 years for 7 days (shown on the map) is 5.3 cfs, and the minimum flow on the average of once in 10 years for 7 days is 2.8 cfs. The growing season 7-day Q_2 is 7.4 cfs, as determined by multiplying the climatic year 7-day Q_2 (5.3 cfs) by the map ratio of 1.4.

The low-flow frequencies on the map are estimates for specific sites and cannot be transferred to ungaged sites without supplemental information and hydrologic interpretation. To estimate the low-flow frequencies at an ungaged site, a few measurements of base flow should be made at the ungaged site and at a nearby gaged site to define a relationship between the two.

REFERENCES

Riggs, H. C., 1965, Estimating probability distributions of drought flow: Water and Sewage Works, v. 112, no. 5, p. 153–157.

U.S. Geological Survey, 1958, Compilation of records of surface waters of the United States through 1950, pt. 4, St. Lawrence River basin: U.S. Geol. Survey Water-Supply Paper 1307, 389 p.

_____1959, Compilation of records of surface waters of the United States through September 1950, pt. 5, Hudson Bay and Upper Mississippi River basins: U.S. Geol. Survey Water-Supply Paper 1308, 696 p.

_____1962, Surface water records of Wisconsin, 1961: Madison, U.S. Geol. Survey ann. rept., 140 p.

_____1963, Surface water records of Wisconsin, 1962: Madison, U.S. Geol. Survey ann. rept., 136 p.

_____1964a, Compilation of records of surface waters of the United States, October 1950 to September 1960, pt. 4, St. Lawrence River basin: U.S. Geol. Survey Water-Supply Paper 1727, 371 p.

_____1964b, Compilation of records of surface waters of the United States, October 1950 to September 1960, pt. 5., Hudson Bay and Upper Mississippi River basins: U.S. Geol. Survey Water-Supply Paper 1728, 566 p.

_____1964c, Surface water records of Wisconsin, 1963: Madison, U.S. Geol. Survey ann. rept., 150 p.

_____1965, Surface water records of Wisconsin, 1964: Madison, U.S. Geol. Survey ann. rept., 193 p.

_____1966, Water resources data for Wisconsin, 1965, pt. 1 and 2: Madison, U.S. Geol. Survey ann. rept., 212 p.

_____1967, Water resources data for Wisconsin, 1966, pt. 1 and 2: Madison, U.S. Geol. Survey ann. rept., 215 p.

_____1968, Water resources data for Wisconsin, 1967, pt. 1 and 2: Madison, U.S. Geol. Survey ann. rept., 215 p.

Young, K. B., 1963, Flow characteristics of Wisconsin streams: Madison, U.S. Geol. Survey open-file rept. 151 p.

_____1965, Supplement to report on flow characteristics of Wisconsin streams: Madison, U.S. Geol. Survey open-file rept., 81 p.

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LOW-FLOW FREQUENCY OF WISCONSIN STREAMS

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