LOW-FLOW CHARACTERISTICS OF STREAMS IN THE KISHWAUKEE RIVER BASIN, ILLINOIS

By Howard E. Allen, Jr. and Ellen A. Cowan

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

For use of those readers who may prefer to use the International System of Units (SI), the factors for converting terms used in this report are listed below:

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
gallon (gal)	0.03785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second-day [$(ft^3/s)\cdot d$]	0.02832	cubic meter per second-day [$(m^3/s)\cdot d$]
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
gallon per day (gal/d)	0.003785	cubic meter day day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

GLOSSARY

Average standard error of estimate (SE). An indicator of the reliability of a regression. It is a measure of the distribution of the residuals about a regression line.

Climatic year. A 12-month period, April 1 through March 31, during which a complete annual runoff cycle occurs, arbitrarily selected for presentation of data relative to hydrologic or meteorologic phenomena.

Continuous-record gaging station. A particular site on a stream where systematic observations of gage height or discharge are obtained continuously.

Drainage area (A). The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Partial-record gaging station. A particular site on a stream where limited observations of gage height or discharge are obtained systematically.

$Q_{7,2}$ low flow. The $Q_{7,2}$ low flow is the minimum 7-day mean discharge that has a 2-year recurrence interval and is calculated from the frequency curve of annual minimum values of the mean low flow for 7 consecutive days.

$Q_{7,10}$ low flow. The $Q_{7,10}$ low flow is the minimum 7-day discharge that has a 10-year recurrence interval and is calculated from the frequency curve of annual minimum values of the mean low flow for 7 consecutive days.

$Q_{7A,2}$. The 7-day, 2-year low-flow estimate adjusted to represent 1981 streamflow conditions by adding the 1981 7-day mean effluent from wastewater-treatment plants during low-flow periods.

$Q_{7A,10}$. The 7-day, 10-year low-flow estimate adjusted to represent 1981 streamflow conditions by adding the 1981 7-day mean effluent from wastewater-treatment plants during low-flow periods.

Q_{7E}. The 7-day mean effluent from wastewater-treatment plants during normal periods of low flow for streams.

$Q_{7E,1981}$. The 7-day mean effluent from wastewater-treatment plants during the low-flow period in 1981.

Q_{7N}. The annual 7-day mean natural low flow at a gaging station. Q_{7N} is computed by subtracting the amount of wastewater effluent (Q_{7E}) from the annual 7-day low flow.

$Q_{7N,2}$. The 7-day, 2-year natural low-flow estimate.

$Q_{7N,10}$. The 7-day, 10-year natural low-flow estimate.

Q_{7R}. The annual 7-day mean low flow, including wastewater effluent, at a continuous-record gaging station.

Recurrence interval. The average interval of time within which one occurrence of streamflow will be equal to or less than a given value. Also called return period.

Return period. See recurrence interval.

Streamflow-recession index (G). The average number of days on a streamflow-recession hydrograph during which streamflow declines one log cycle when plotted on semilogarithmic graph paper, with discharge, in cubic feet per second, on the logarithmic scale, and time, in days, on the arithmetic scale.

Water year. A 12-month period from October 1 to September 30, for which streamflow data are compiled and reported.

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ABSTRACT

The 7-day, 2-year and 7-day, 10-year ($Q_{7N,2}$ and $Q_{7N,10}$) natural low flows are estimated at five long-term continuous-record gaging stations in the Kishwaukee River basin using a probability distribution based on daily discharge records and records of wastewater effluent furnished by treatment plants. The $Q_{7N,2}$ and $Q_{7N,10}$ are also estimated at 22 partial-record gaging stations based on the relation of concurrent natural low flows at the long-term stations and the partial-record stations. The natural low flows were defined by low-flow discharge measurements minus the daily wastewater effluent from treatment plants. The standard error of estimates for the 27 gaged sites averaged 33 percent for the $Q_{7N,2}$ estimates and 51 percent for the $Q_{7N,10}$ estimates.

Estimates of the $Q_{7N,2}$ and $Q_{7N,10}$ at ungaged stream sites may be made based on drainage area and indexes of streamflow recession. Streamflow-recession indexes were used to account for the effects of geology on low flows. Relations of low-flow estimates to drainage area and streamflow-recession indexes were defined by multiple-regression analyses.

The locations of wastewater-treatment plants and the amount of effluent discharged from each plant during 7-day low-flow periods in 1981 are given for adjusting natural low-flow estimates at gaged and ungaged sites to represent 1981 streamflow conditions.

INTRODUCTION

Ever-changing land and water uses cause an increasing need for reliable estimates of streamflow during low-flow periods. Estimates of low flow are frequently used to evaluate whether streamflows are adequate for navigable waterways, municipal or industrial water supplies, agricultural uses, maintenance of fish and wildlife habitat, and production of hydropower. Water-quality standards are commonly based on a streamflow characteristic designated as the 7-day, 10-year low flow ($Q_{7,10}$). The $Q_{7,10}$ low flow is the minimum 7-day mean discharge that has a 10-year recurrence interval and is calculated from the frequency curve of annual values of the lowest mean flow for 7 consecutive days.

Low flow is usually ground-water discharge to the stream. Base flow, ground-water runoff, or natural-base discharge are terms used to describe the condition when streamflow is almost totally composed of ground-water discharge. Probability of occurrence and a time period (such as the $Q_{7,10}$) can be specified for a more precise definition of the occurrence of low flow.

Effluent from wastewater-treatment plants can be a significant portion of the low flows in many streams. During low-flow periods in 1981, the 7-day mean effluent to the South Branch Kishwaukee River, upstream from the gaging station at Fairdale (05439500) (fig. 1), was 7.6 ft^3/s (cubic feet per second) which is about 65 percent of the computed $Q_{7,10}$ low flow. At the most downstream gaging station in the basin, the Kishwaukee River near Perryville (05440000) (fig. 1), the 1981 7-day mean effluent during low-flow periods was 14 ft^3/s, about 20 percent of the computed $Q_{7,10}$ low flow.

The purpose of this report is to describe the low-flow characteristics of streams in the Kishwaukee River basin at gaged sites where streamflow data have been collected, and to present techniques for estimating low-flow characteristics at ungaged sites.

The scope of the project included determining natural low flows of streams by subtracting the amount of wastewater effluent from measured stream discharge. The natural streamflows were used for computing the 7-day, 2-year ($Q_{7N,2}$) and the 7-day, 10-year ($Q_{7N,10}$) low-flow estimates at gaging stations. The $Q_{7N,2}$ and $Q_{7N,10}$ estimates at gaging stations were related to basin characteristics to develop estimating equations for determining $Q_{7N,2}$ and $Q_{7N,10}$ natural low-flow estimates at ungaged sites. Procedures are given for adjusting the $Q_{7N,2}$ and $Q_{7N,10}$ estimates for the amount of effluent based on wastewater-effluent records, or the relation of effluent to population.

The report includes estimates of the $Q_{7N,2}$ and the $Q_{7N,10}$ at gaged sites; the 7-day mean effluent ($Q_{7E,1981}$) from wastewater-treatment plants during the 7-day low-flow periods in 1981; and estimates of the 7-day, 2-year ($Q_{7A,2}$) and the 7-day, 10-year ($Q_{7A,10}$) low flows adjusted to represent 1981 streamflow conditions. The adjusted 1981 low-flow estimates include the 7-day mean effluent ($Q_{7E,1981}$) from wastewater-treatment plants. The report also includes equations to estimate the $Q_{7N,2}$ and $Q_{7N,10}$ at ungaged stream sites in the basin.

Low-flow estimates in the Kishwaukee River basin are based on data collected by the U.S. Geological Survey through the 1981 climatic year ending March 31, 1982, as part of a cooperative program with the Illinois Department of Transportation, Division of Water Resources; the Rock Island District, U.S. Army Corps of Engineers; and other State and Federal agencies. The locations of wastewater-treatment plants (fig. 1) that discharge to streams in the Kishwaukee River basin were provided by Illinois Environmental Protection Agency (IEPA) offices in Maywood and Rockford. IEPA also supplied copies of monthly operation reports submitted by treatment-plant operators. Daily wastewater-effluent records were obtained directly from the treatment plants.

BASIN DESCRIPTION

The Kishwaukee River basin is in northern Illinois, and includes all or parts of Boone, De Kalb, Kane, McHenry, Ogle, and Winnebago Counties, Illinois, and Walworth County, Wisconsin (fig. 1). The total drainage area of the basin is 1,257 mi^2 (square miles), including 32 mi^2 in Wisconsin.

The Kishwaukee River has its headwaters in McHenry County and flows westerly about 64 miles to join the Rock River just south of Rockford. Major streams in the basin are listed in table 1. The basin is mostly rural and in 1980 had a population of about 133,000. Nine communities, with boundaries completely within the basin, have populations of 1,000 or more (table 2).

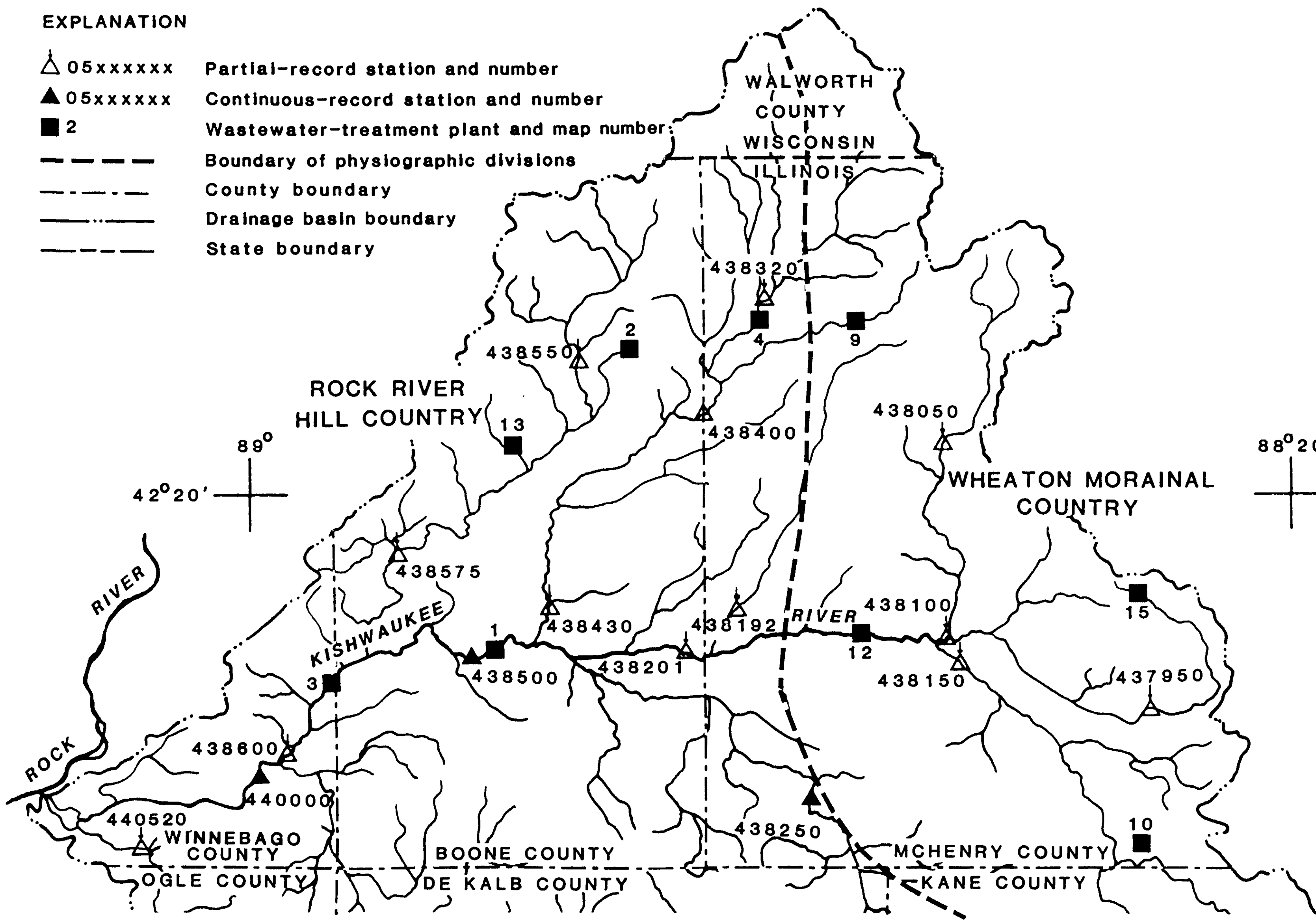
Average annual precipitation at De Kalb, reported by the U.S. Weather Service (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1981) is 35.5 inches, of which about 64 percent occurs during the growing season (April through September). About 10 percent of the annual precipitation occurs as snow. Average yearly runoff from the basin, based on 42 years of record at the gaging station on the Kishwaukee River near Perryville (05440000) (U.S. Geological Survey, 1982, p. 277), is 8.6 inches. The drainage area at the Perryville gage is 1,099 mi^2.

The basin is located in the physiographic divisions of the Wheaton Morainal Country, Bloomington Ridged Plain, and Rock River Hill Country (Leighton and others, 1948) (fig. 1). The three physiographic divisions have different topographic characteristics that are due to morphology and age of the surficial glacial deposits.

The Wheaton Morainal Country is characterized by rolling, hilly topography, broad morainic ridges, and numerous lakes and swamps. The Bloomington Ridged Plain is characterized by low, broad morainic ridges with intervening wide reaches of almost featureless ground moraines. The Rock River Hill Country has areas of the oldest glacial drift (Altonian) within the basin and is characterized by a rolling, hilly topography. Throughout most of the Rock River Hill Country, the glacial drift is thin and the topography follows that of the underlying bedrock surface.

Unconsolidated glacial deposits, mainly of Wisconsinan age, overlie the bedrock in most of the basin. The unconsolidated deposits range in thickness from zero, at several locations where bedrock crops out in the western part of the basin, to more than 400 feet along the southern boundary of the basin. The underlying bedrock is dolomite of Ordovician and Silurian age.

Gradients of major streams range from moderate in the southern part of the basin to moderately steep in the northern part. The approximate gradient for the Kishwaukee River main stem is 4.2 ft/mi (feet per mile). The South Branch Kishwaukee River has the lowest gradient at about 2.9 ft/mi, whereas the North Branch Kishwaukee River has the highest gradient at about 9.5 ft/mi.


EXPLANATION
05xxxxxx Partial-record station and number
05xxxxxx Continuous-record station and number
2 Wastewater-treatment plant and map number
Boundary of physiographic divisions
County boundary
Drainage basin boundary
State boundary
WALWORTH COUNTY
WISCONSIN
ILLINOIS
ROCK RIVER HILL COUNTRY
WHEATON MORAINAL COUNTRY
89°
42°20'
88°20'
ROCK RIVER
KISHWAUKEE
RIVER
438320
438550
438400
438050
438575
438430
438192
438100
438500
438201
438150
437950
438600
440000
440520
438250
1
2
3
4
9
10
12
13
15
WINNEBAGO COUNTY
OGLE COUNTY
BOONE COUNTY
DE KALB COUNTY
MCHENRY COUNTY
KANE COUNTY

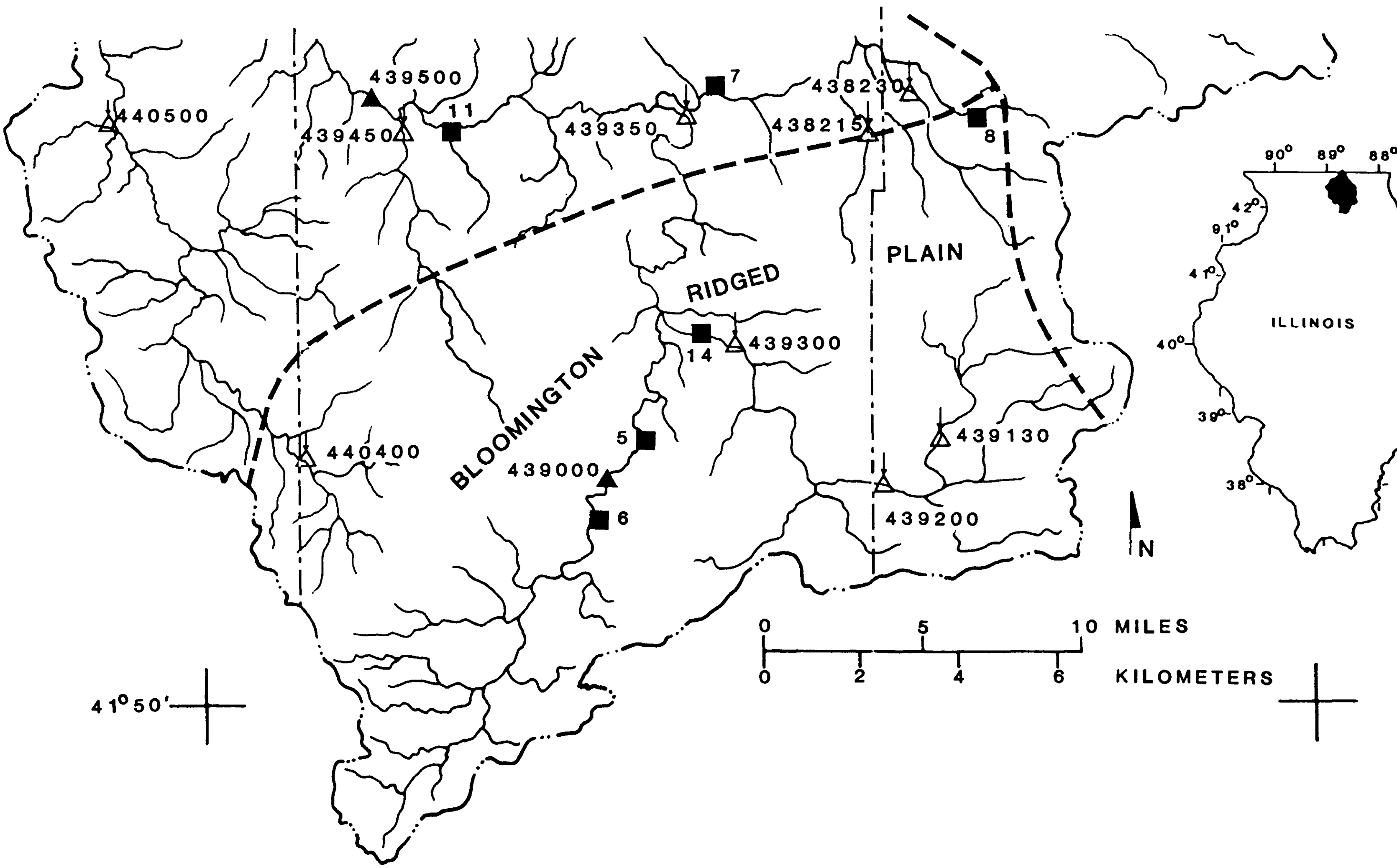


Figure 1.--Location of Kishwaukee River basin, data-collection sites, wastewater-treatment plants, and physiographic divisions.

Table 1.--Major streams in the Kishwaukee River basin

Stream name	River mile at mouth[1] (mi)	Length (mi)	Drainage area (mi^2)
Kishwaukee River	[2]130.0	64.2	1,257
Killbuck Creek	2.1	36.4	139
South Branch Kishwaukee River	11.0	67.7	441
East Branch of South Branch Kishwaukee River	[3]39.0	9.1	122
Beaver Creek	16.7	31.4	70.4
Piscasaw Creek	24.9	32.2	128
Coon Creek	26.5	29.1	156
South Branch Kishwaukee River (East)	43.7	19.2	74.5
North Branch Kishwaukee River	44.1	18.9	40.3

1 River miles on Kishwaukee River.
2 River miles on Rock River.
3 River miles on South Branch Kishwaukee River.

Table 2.--Communities in the Kishwaukee River basin with populations greater than 1,000 in the 1980 census

Community	County	Population
De Kalb	De Kalb	33,099
Belvidere	Boone	15,176
Sycamore	De Kalb	9,219
Harvard	McHenry	5,126
Marengo	McHenry	4,361
Genoa	De Kalb	3,276
Hampshire	Kane	1,735
Huntley	McHenry	1,646
Kirkland	De Kalb	1,155

PREVIOUS WORK

Mitchell (1957) describes the flow duration of streams in Illinois based on streamflow records at continuous-record gaging stations through the 1950 water year. Lara (1970) presents low-flow data for gaging stations based on streamflow records through March 1956. Lara also describes a technique for extrapolating short-term low-flow records based on relations empirically developed between low-flow and flow-duration parameters. Singh and Stall (1973) used streamflow records through the 1969 water year as the primary data to derive $Q_{7,10}$ low-flow estimates for streams in Illinois.

Methods for data collection, analysis, and reporting of low-flow characteristics are described by Riggs (1972). Equations and graphs are presented for evaluating the accuracy of low-flow characteristics in reports by Hardison (1969) and Hardison and Moss (1972). Regionalization of low-flow characteristics using basin characteristics is discussed by Thomas and Benson (1970).

Rorabaugh and others (1966) related recession hydrographs of ground-water levels to base flow of streams in the Columbia River basin. Bingham (1982) used the results of their research to develop streamflow-recession indexes for estimating low flows of streams in Alabama. Bingham showed that streamflow-recession indexes are indicative of the storage and transmissivity characteristics of the geologic materials. He used geologic maps to assign recession indexes and used the index as a basin characteristic for deriving low-flow estimating equations.

METHODS OF STUDY

The approach was to determine natural low flow at gaging stations by subtracting the amount of wastewater effluent upstream of the station from measurements of streamflow at the station. Low-flow frequency characteristics were determined using the natural low flows, and these low-flow characteristics were regionalized based on their relation to selected physical characteristics of the basins. Low-flow characteristics were then adjusted to account for wastewater effluents during 1981. Procedures were developed to estimate the wastewater-effluent adjustment for other years based on population of communities served by treatment plants.

Streamflow records from five long-term continuous-record gaging stations and 22 low-flow partial-record gaging stations (fig. 1) were used in this study. Low-flow partial-record stations are sites at which measurements of low flow were made to define a relation with concurrent flows at a nearby continuous-record station.

Low-flow measurements were made for this study during the 1979-81 water years. Measurements were also made in the eastern part of the basin during the 1961-64 water years as part of a statewide data-collection program and are included in the analyses for this report. Daily streamflow records at continuous-record stations and low-flow measurements at partial-record stations are published in the annual series of the U.S. Geological Survey Water-Data Reports for Illinois.

Computing Natural Low Flows

The amount of wastewater effluent entering a stream, upstream of a gaging station, had to be computed or estimated in order to compute natural flows from measurements of stream discharge. Effluent records from 13 municipal and 2 industrial wastewater-treatment plants (fig. 1) were available to determine the wastewater-effluent contribution to streams during low-flow periods. Effluents from the two industrial plants were small or zero during low-flow periods in 1979-81 because of their seasonal operation and were assumed to be zero during the low-flow period for years prior to 1981 for purposes of computing natural low flows.

The amount of daily effluent from each treatment plant was tabulated for those days when measurements of low flow were made at gaging stations in order to compute the natural low flow of the streams at the time of the measurements. Although the variation in the daily effluent from each of the treatment plants was small, the distances between treatment-plant outfalls and the gaging stations were taken into consideration in order to account for traveltime of the effluent.

The 7-day mean low-flow effluents (Q_{7E}) for communities during past years were estimated by interpolating yearly populations of communities based on census data from 1940 to 1980 and using a relation between effluent and population based on data for 1981. The 7-day mean low-flow effluents in 1981 ($Q_{7E,1981}$) were determined from daily records furnished by the treatment plants for the period August through November, the normal period of low flow for streams in the Kishwaukee River basin. The Q_{7E} for community populations of past years were determined after shifting the curve defined for 1981 to pass through the point representing each community, following the method used by Singh and Stall (1973). Using these shifted curves, the annual 7-day mean low-flow effluents (Q_{7E}) from each wastewater-treatment plant were estimated for the period from 1941 to 1980.

Continuous-Record Gaging Stations

The annual 7-day mean natural low flows of streams at continuous-record gaging stations were determined by frequency analyses of recorded annual 7-day low flows adjusted for wastewater effluent. The relation for calculating 7-day natural low flow is:

$$Q_{7N} = Q_{7R} - Q_{7E}. \qquad (1)$$

The 7-day, 2-year ($Q_{7N,2}$) and 7-day, 10-year ($Q_{7N,10}$) natural low flows for the five continuous-record gaging stations were estimated from the annual 7-day mean natural low flows (Q_{7N}) for the period of daily discharge record at each station using a log-Pearson Type III probability distribution.

The low-flow estimates from the log-Pearson Type III probability distribution ($Q_{7N,2}$ and $Q_{7N,10}$) were adjusted to represent 1981 streamflow conditions ($Q_{7A,2}$ and $Q_{7A,10}$) by adding the 7-day 1981 mean effluent ($Q_{7E,1981}$) from wastewater-treatment plants during 7-day low-flow periods in 1981:

$$Q_{7A,2} = Q_{7N,2} + Q_{7E,1981} \qquad (2)$$

$$Q_{7A,10} = Q_{7N,10} + Q_{7E,1981} \qquad (3)$$

Low-Flow Partial-Record Gaging Stations

The low-flow estimates for partial-record gaging stations were determined by relating discharge measurements at a partial-record station to concurrent discharge at a nearby long-term continuous-record station (Riggs, 1972). Measured discharges were adjusted by subtracting the daily wastewater effluent in order to obtain natural low flow. A relation line, determined by regression, was drawn through the pairs of concurrent adjusted discharges plotted on logarithmic paper. Estimates of the $Q_{7N,2}$ and $Q_{7N,10}$ at the continuous-record stations were then transformed to estimates of $Q_{7N,2}$ and $Q_{7N,10}$ at the partial-record station by using the relation line.

Estimates of $Q_{7N,2}$ and $Q_{7N,10}$ at the partial-record stations were adjusted to actual 1981 streamflow conditions ($Q_{7A,2}$ and $Q_{7A,10}$) by adding the 7-day wastewater effluent ($Q_{7E,1981}$) discharged upstream from each station during the 1981 low-flow periods.

Regionalization of Natural Low-Flow Characteristics

Step-backward regression analyses, using procedures outlined by Thomas and Benson (1970), were used to determine the relation between a natural low-flow estimate (dependent variable) and basin characteristics (independent variables). The analyses provide an equation, or series of equations, relating the dependent variable to independent variables. All variables significant at the 95 percent confidence level were retained in the equations. These analyses defined mathematical equations of the form:

$$Q_T = a\ A^x B^y \ldots D^z , \qquad (4)$$

where: Q_T is a low-flow estimate having a T-year recurrence interval;

a is the regression constant defined by the regression analysis;

A, B, ...D are drainage-basin characteristics; and

x, y, ...z are regression coefficients defined by the regression analysis.

Several basin characteristics were tested as independent variables in step-backward regression analyses (Thomas and Benson, 1970) with the dependent variables $Q_{7N,2}$ and $Q_{7N,10}$ to provide equations for estimating low flow at ungaged sites. The independent variables that were tested included drainage area, streamflow-recession index, and main-channel length. Climatic characteristics that would be significant in broader, regional areas vary little in the Kishwaukee River basin and were excluded from the analyses.

The drainage area (A) of a watershed is the most significant characteristic in explaining differences in streamflow between sites. Low flows in streams are mostly ground-water discharge and the contributing area extends to the ground-water divide of a basin, which can be determined from potentiometric maps. Detailed potentiometric maps are not available for much of the Kishwaukee River basin; however, under most water-table conditions the topographic divide closely corresponds to the ground-water divide. For this report, the topographic divide was used to define contributing drainage area. Drainage areas are routinely determined by the U.S. Geological Survey for all gaging stations. Drainage areas for many sites in the Kishwaukee River basin were tabulated by Healy (1979).

Main-channel length (L), in conjunction with drainage area of the basin, is a landform characteristic that indicates basin shape. In estimating ground-water discharge to the stream, main-channel length may be considered as one dimension of the vertical cross-sectional area of the porous material through which ground-water discharge occurs. Channel lengths were obtained from topographic maps by measuring the total indicated length. River mileages listed in the report by Healy (1979) may be used to determine many of the desired channel lengths.

The streamflow-recession index (G) is the average number of days on the streamflow-recession hydrograph during which streamflow declines one complete log cycle when plotted on semilogarithmic graph paper (Bingham, 1982), with discharge, in cubic feet per second, on the logarithmic scale, and time, in days, on the arithmetic scale. The peak discharge during a period of rainfall runoff was used as the first plotting point for the streamflow-recession curve. The plotting of stream discharge for each successive day continued until the streamflow-recession curve became apparently straight. The straight-line part of the curve, extended through one log cycle of discharge, was used to define the streamflow-recession index.

The methods outlined by Bingham (1982) for determining streamflow-recession indexes were applied to the daily streamflow records for six gaging stations in the Kishwaukee River basin including the South Branch Kishwaukee River at De Kalb (05439000) which had 7 years of record and is treated as a partial-record station elsewhere in this report. Streamflow hydrographs for 8 of the lowest-flow years for five continuous-record stations, and all hydrographs for the station with only 7 years of record, were reviewed to find the periods of straight-line streamflow recession. All indexes were determined from streamflow hydrographs during August through October, the normal period of annual minimum flow. Streamflow during this period is affected by evaporation and transpiration; however, the effect is assumed to be nearly constant. During winter, when evaporation and transpiration are low, streamflow records are less reliable due to backwater from ice cover. Figure 2 illustrates the method of determining the streamflow-recession index.

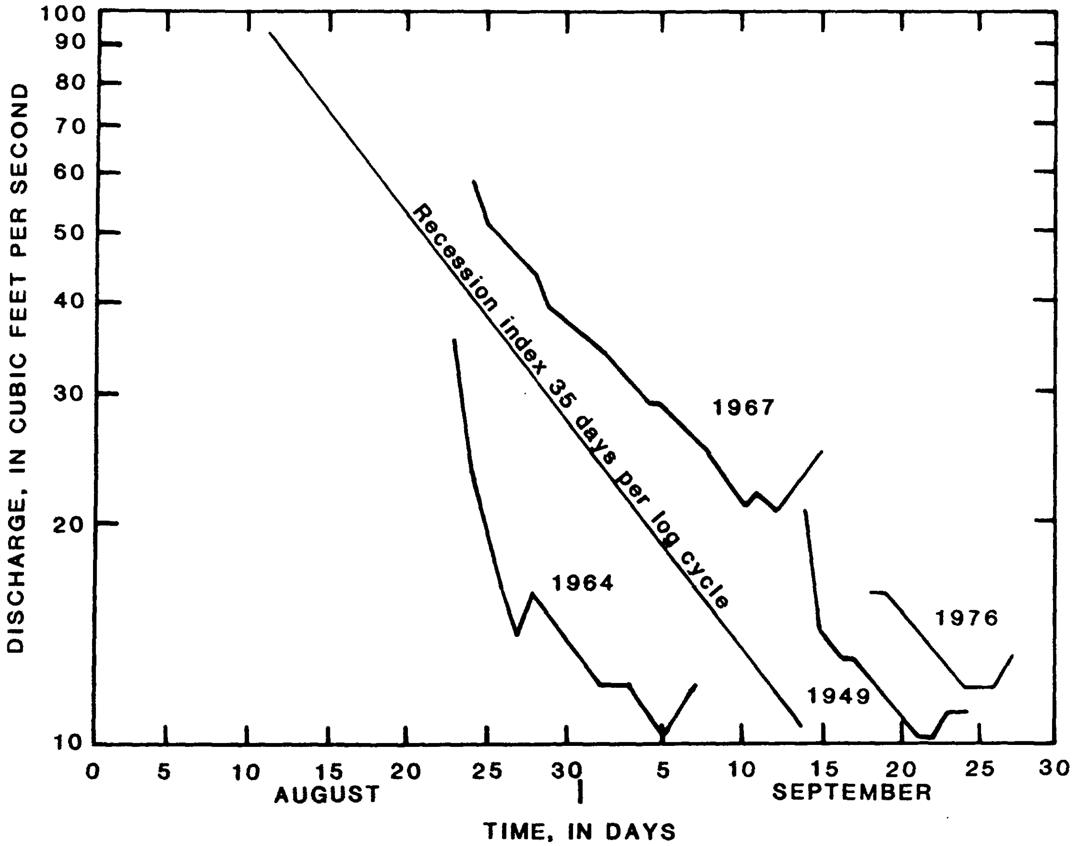


Figure 2.--Streamflow-recession hydrographs and index for South Branch Kishwaukee River near Fairdale.

The recession indexes for the partial-record stations were estimated from the relation between the indexes at the continuous-record stations and the types of geologic materials the streams traverse. Surficial deposits in the Kishwaukee River basin (Lineback, 1979) are of glacial origin and may be grouped into two general compositional types that relate to water transmitting characteristics. Glacial tills generally consist of poorly sorted clay, silt, and sand having low transmissivity. Outwash or glacial-contact deposits of sand and gravel have relatively high transmissivities. Most of the sand and gravel in the Kishwaukee River basin is in the Henry Formation in which the major stream valleys are formed.

The boundaries of the sand and gravel deposits (Henry Formation) from Lineback's (1979) map were delineated on a drainage map of the Kishwaukee River basin (fig. 3). Reports by Block (1960), Anderson and Block (1962), and Anderson (1964), describing sand and gravel resources of De Kalb, Kane, and McHenry Counties, were also used to help delineate the boundaries of the sand and gravel deposits. The area of sand and gravel deposits within the drainage area of each gaging station was determined from figure 3.

RESULTS

Low-Flow Estimates at Gaged Sites

The gaging station on the South Branch Kishwaukee River near Fairdale (05439500) is used as an example to describe the computation of Q_{7N} at continuous-record stations. The value of the recorded 7-day mean low flow (Q_{7R}) during the 1981 climatic year was 75 ft^3/s. The Q_{7E} discharged into the stream, upstream from the gaging station, was 5.4 ft^3/s at De Kalb; 1.6 ft^3/s at Sycamore; 0.4 ft^3/s at Genoa; and 0.2 ft^3/s at Kirkland, for a total of 7.6 ft^3/s (table 3, fig. 4). Using equation 1, the Q_{7N} for 1981 at the Fairdale gaging station is 75 - 7.6 = 67.4 ft^3/s or 67 ft^3/s rounded to publication standards.

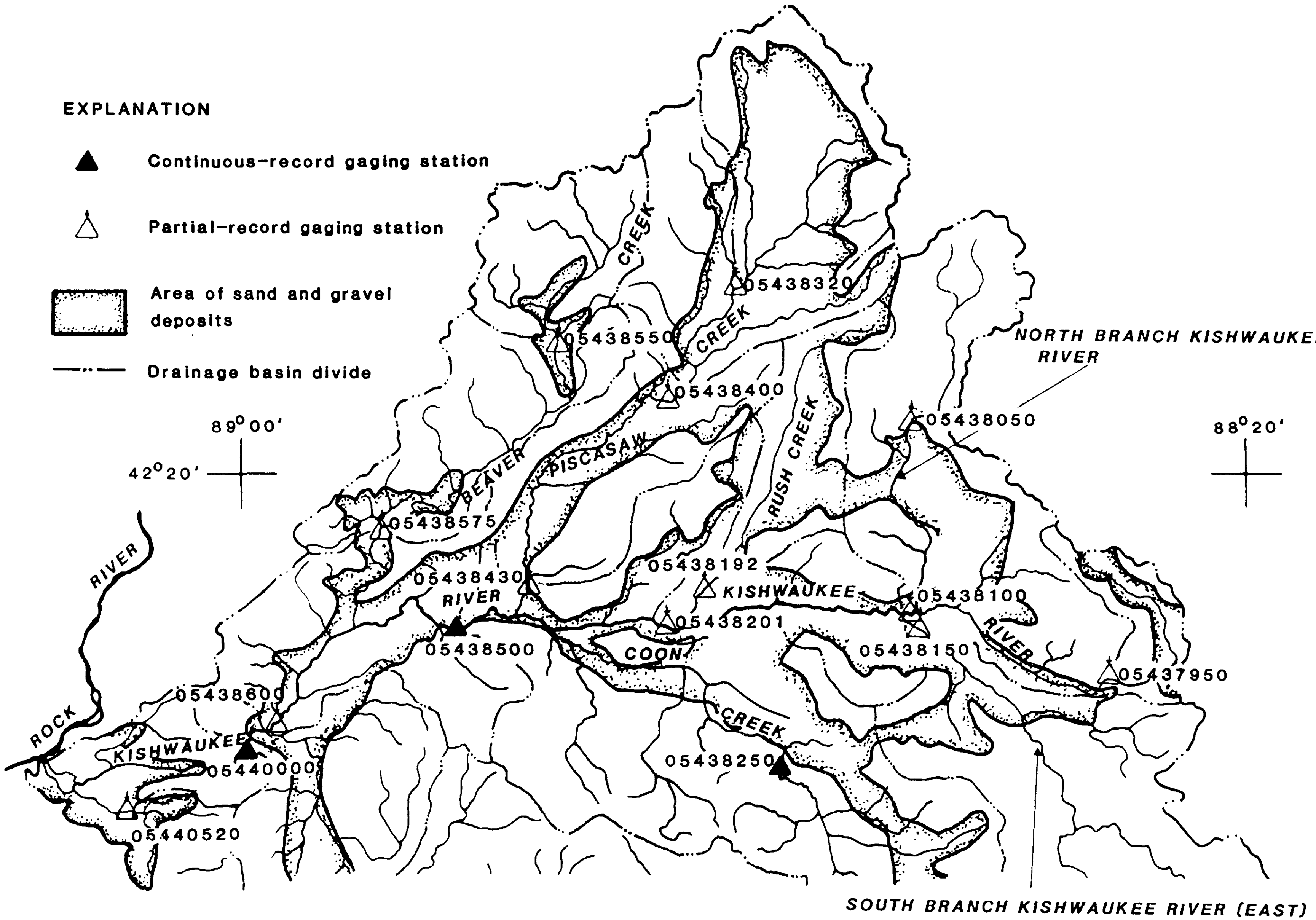
Wastewater effluents in 1981 at 15 treatment plants (fig. 1, table 3) in the Kishwaukee River basin are related (fig. 4) to the 1980 census population by the equation:

$$Q_{7E,1981} = 56.21\ (P)^{1.074} \times 10^{-6} \qquad (5)$$

where: $Q_{7E,\ 1981}$ is the 7-day mean low-flow effluent, in million gallons per day (Mgal/d), discharged to receiving streams during the 1981 low-flow periods; and

(P) is the population of the communities served by the treatment plants.

The relation has an average standard error of 33 percent and a correlation coefficient of 0.97.


EXPLANATION
Continuous-record gaging station
Partial-record gaging station
Area of sand and gravel deposits
Drainage basin divide
89°00'
42°20'
88°20'
NORTH BRANCH KISHWAUKEE RIVER
SOUTH BRANCH KISHWAUKEE RIVER (EAST)
ROCK
RIVER
KISHWAUKEE
KISHWAUKEE
RIVER
RIVER
BEAVER
CREEK
PISCASAW
CREEK
CREEK
RUSH CREEK
COON
CREEK
05438320
05438550
05438400
05438050
05438575
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05440000
05438250
05440520

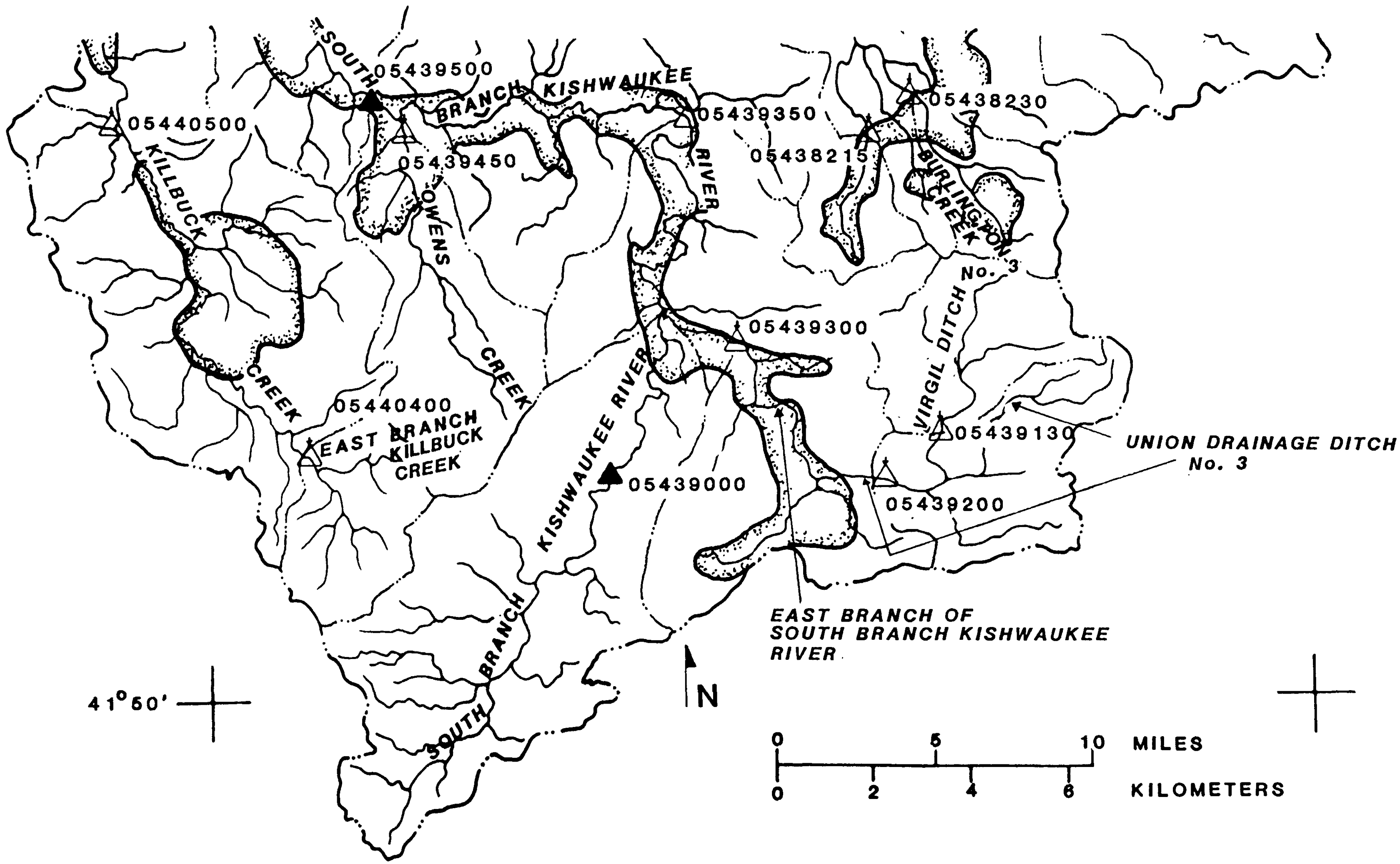


Figure 3.--Areal distribution of sand and gravel deposits in the Kishwaukee River basin.

Table 3.--Seven-day wastewater effluent during 1981 low-flow periods

Map number[1]	Name of plant	Population served by plant in 1980	7-day wastewater effluent during 1981 low-flow period ($Q_{7E,1981}$): Million gallons per day (Mgal/d)	Cubic feet per second[2] (ft^3/s)
1	Belvidere	15,176	2.3267	3.6
2	Capron	678	.0650	.1
3	Cherry Valley	946	.1616	.2
4	Dean Foods, Chemung[3]	---	.1422	.2
5	De Kalb	33,099	3.4901	5.4
6	Del Monte, De Kalb[3]	---	0	.0
7	Genoa	3,276	.2585	.4
8	Hampshire	1,735	.0969	.2
9	Harvard	5,126	.7110	1.1
10	Huntley	1,646	.1551	.2
11	Kirkland	1,155	.1290	.2
12	Marengo	4,361	.3490	.5
13	Poplar Grove	818	.0540	.1
14	Sycamore	9,219	1.0341	1.6
15	Woodstock, South Plant	3,000	.3749	.6

[1] See figure 1 for location of the wastewater-treatment plants.
[2] Rounded to the nearest 0.1 ft^3/s.
[3] Industrial plant.

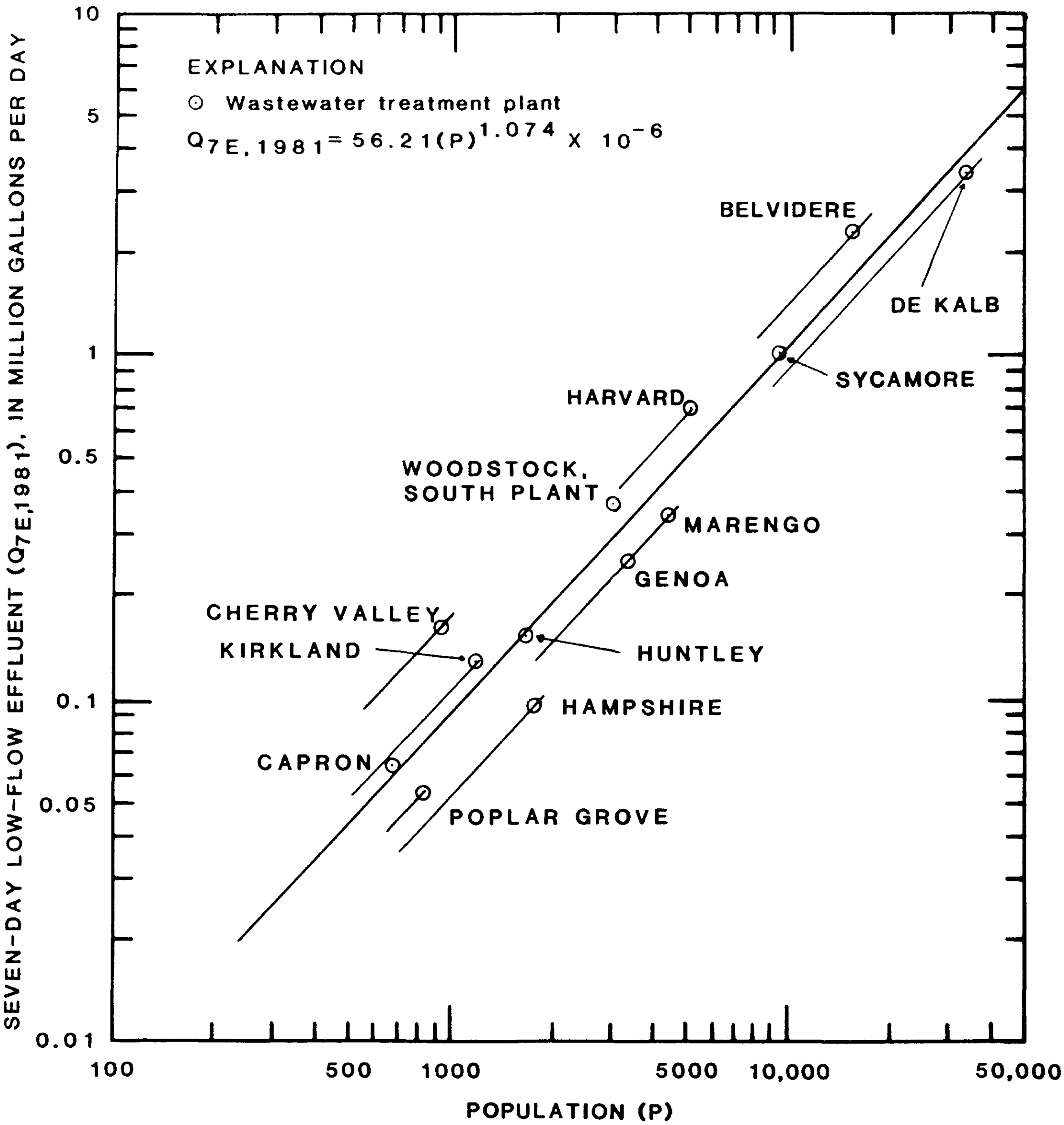


Figure 4.--Relation of 7-day mean wastewater effluent during low-flow periods to population of communities served by the treatment plants.

The regression line in figure 4 or equation 5 would be useful for estimating effluent from a new treatment plant or from an existing plant if no records were available. However, communities have differing water-use and effluent characteristics depending on socio-economic factors and conditions of sewer systems. Following the method of Singh and Stall (1973), lines were drawn parallel to the regression line in figure 4 and passing through the point for each community; each parallel line being more representative for changing populations in a particular community. The Q_{7N} for the gaging station Kishwaukee River near Fairdale (05439500) (table 4), during past years, was determined from the Q_{7R} values minus the Q_{7E} values from the shifted lines adjusted for community populations based on census data from 1940 to 1980. Table 4 includes the annual 7-day mean low flows (Q_{7R}, Q_{7E}, and Q_{7N}) for the period of record at the gaging station.

The log-Pearson Type III probability distribution of the Q_{7N} values in table 4 (fig. 5) yields $Q_{7N,2}$ and $Q_{7N,10}$ estimates of 12 ft^3/s and 3.8 ft^3/s, respectively. Adjusting the natural low-flow estimates to 1981 streamflow conditions using equations 2 and 3 yields estimates of 20 ft^3/s for $Q_{7A,2}$ and 11 ft^3/s for $Q_{7A,10}$.

Figure 6 shows the logarithmic relation of natural low flow at one partial-record station (05439200) to the natural low flow at a continuous-record station (05439500) based on 10 pairs of concurrent discharge measurements. The relation is used to determine the $Q_{7N,2}$ and $Q_{7N,10}$ at the partial-record station from previously determined values at the continuous-record station. There are no wastewater-treatment plants upstream from the partial-record station used in this example, Union Drainage ditch No. 3 near Maple Park.

The natural and adjusted low-flow estimates for all continuous and partial-record stations are given in table 5.

Sampling and Analytical Errors at Gaged Sites

Low-flow estimates at gaging stations, made during this study, are based on past conditions. Given similar conditions, they should be expected to occur in the future with predictable frequencies. Each estimate has an error associated with it, depending on the amount and kind of data, and the analytical method. The time-sampling error in streamflow records and the error in the analytical method are two major sources of error.

The average standard error of estimate (SE) at gaging stations for the $Q_{7N,2}$ and the $Q_{7N,10}$ low flows (table 5) is an indicator of accuracy of the low-flow estimates. Standard error is defined such that 67 percent of the estimates of $Q_{7N,2}$ or $Q_{7N,10}$ at a station are within one standard error, plus or minus, of the true values; 95 percent are within two standard errors of the true values; and 99.7 percent are within three standard errors. The standard error, SE, is the average of the positive departure in percent and absolute value of the negative departure in percent (Hardison, 1969, p. D210). Standard errors should be used only as a guide to indicate a general level of confidence.

Table 4.--Annual 7-day mean low flows at the gaging station on South Branch Kishwaukee River near Fairdale (05439500)

Year	7-day mean low flows, in cubic feet per second		
	Recorded value, Q_{7R}	Wastewater effluent, Q_{7E}	Natural flow (Q_{7R} - Q_{7E}), Q_{7N}
1941	8.2	2.4	5.8
1942	15	2.4	13
1943	33	2.6	30
1944	18	2.6	15
1945	6.4	2.7	3.7
1946	19	2.7	16
1947	11	2.9	8.1
1948	11	3.0	8.0
1949	9.7	3.0	6.7
1950	10	3.1	6.9
1951	18	3.2	15
1952	37	3.3	34
1953	15	3.5	12
1954	9.6	3.6	6.0
1955	21	3.7	17
1956	12	3.8	8.2
1957	8.8	3.9	4.9
1958	16	4.1	12
1959	15	4.2	11
1960	9.5	4.3	5.2
1961	22	4.5	18
1962	18	4.9	13
1963	11	5.3	5.7
1964	6.8	5.5	1.3
1965	11	5.8	5.2
1966	29	6.0	23
1967	12	6.4	5.6
1968	23	6.6	16
1969	55	6.9	48
1970	32	7.2	25
1971	37	7.2	30
1972	11	7.3	3.7
1973	123	7.4	116
1974	29	7.4	22
1975	24	7.4	17
1976	18	7.5	10
1977	9.9	7.5	2.4
1978	25	7.5	18
1979	41	7.5	34
1980	49	7.6	41
1981	75	7.6	67

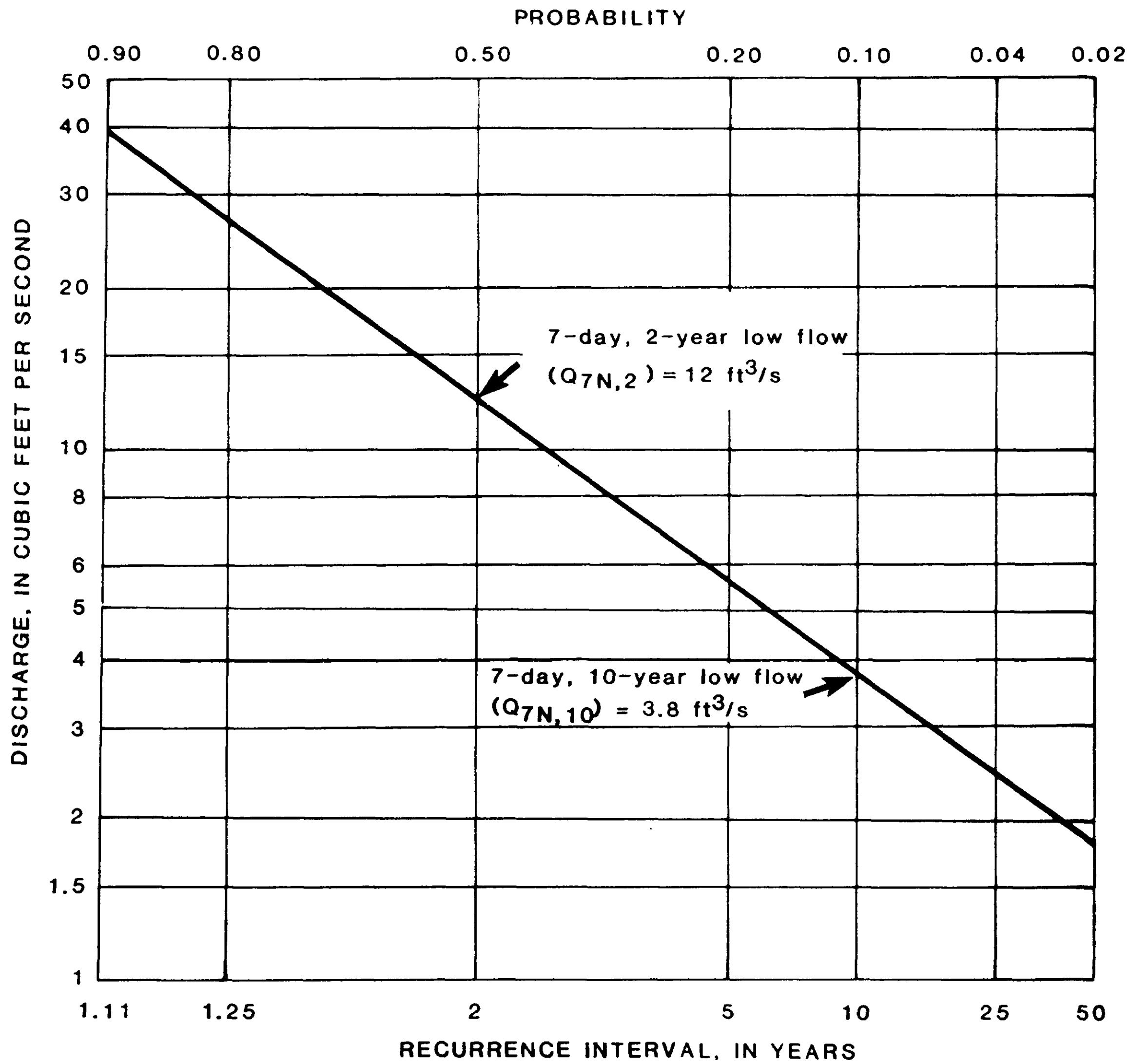


Figure 5.--Low-flow frequency curve of the annual lowest 7-day natural mean discharge, South Branch Kishwaukee River near Fairdale.

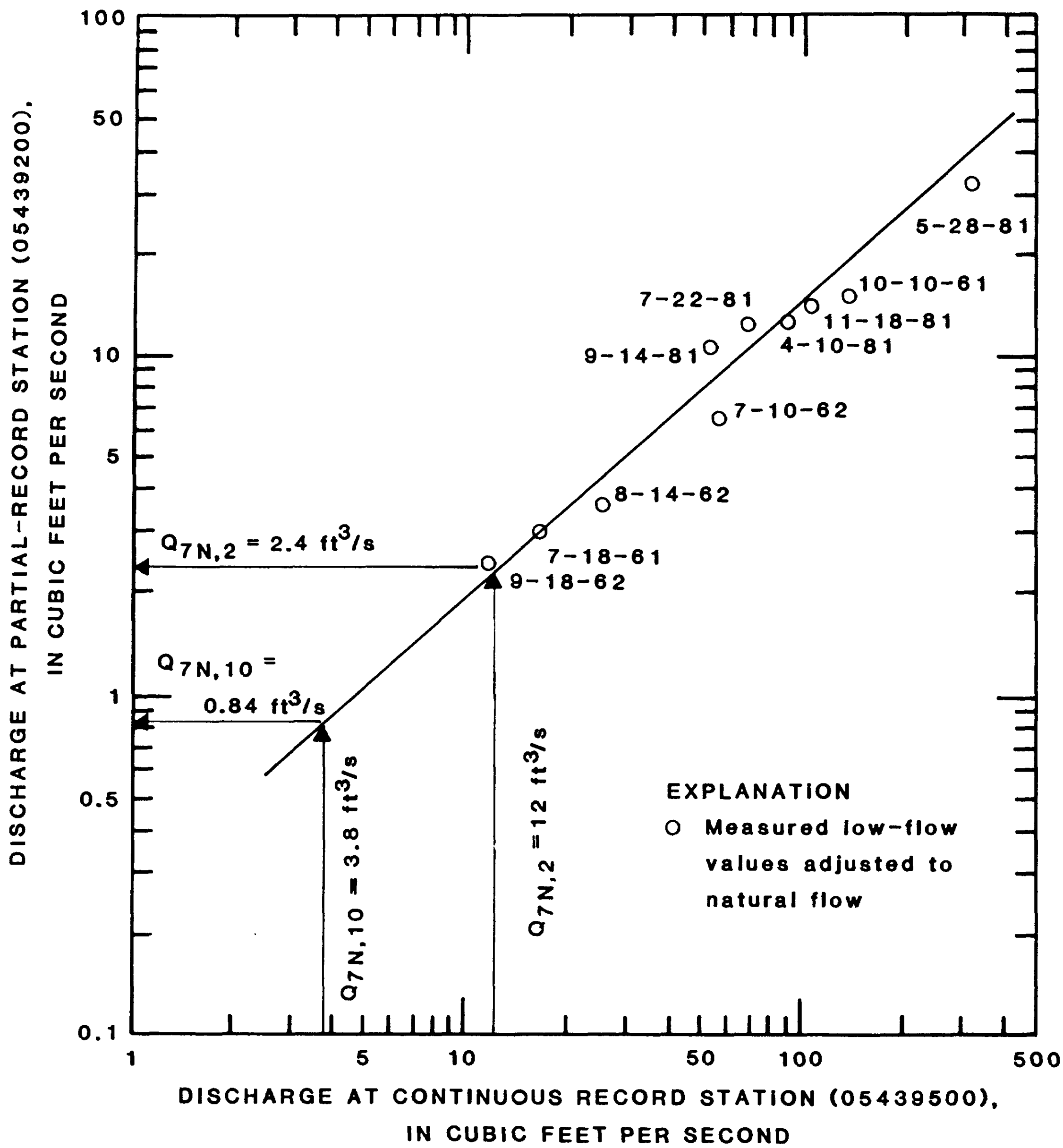


Figure 6.--Relation of low flows at a partial-record station to concurrent flows at a continuous-record station.

Table 5.--Estimates of low flow at gaging stations in the Kishwaukee River basin

[The $Q_{7N,2}$ and $Q_{7N,10}$ values represent natural low flows. The $Q_{7A,2}$ and $Q_{7A,10}$ values are the $Q_{7N,2}$ and $Q_{7N,10}$ low flows plus the 1981 7-day wastewater effluent ($Q_{7E,1981}$) discharged by treatment plants into the upstream system. Dashes shown in the $Q_{7A,2}$ and $Q_{7A,10}$ columns indicate there were no treatment plants discharging during 7-day low-flow periods in 1981.]

Station No.	Station name	Type of station[1]	Drainage area (mi^2)	Low-flow estimates: 7-day, 2-year $Q_{7N,2}$ (ft^3/s)	7-day, 2-year $Q_{7A,2}$ (ft^3/s)	7-day, 10-year $Q_{7N,10}$ (ft^3/s)	7-day, 10-year $Q_{7A,10}$ (ft^3/s)	Average std. error $SE_{7N,2}$ (in percent)	Average std. error $SE_{7N,10}$ (in percent)
05437950	Kishwaukee River near Huntley	PR	14.4	1.3	1.9	0.69	1.3	27	39
05438050	North Branch Kishwaukee River near Harvard	PR	21.1	.44	--	.14	--	41	66
05438100	Kishwaukee River near Marengo	PR	89.7	12	12	6.6	7.2	11	16
05438150	South Branch Kishwaukee River (East) below Union	PR	73.5	3.0	3.2	1.2	1.4	21	31
05438192	Rush Creek near Garden Prairie	PR	29.5	3.6	--	2.0	--	27	40
05438201	Kishwaukee River at Garden Prairie	PR	222	24	26	13	14	11	15
05438215	Coon Creek at New Lebanon	PR	16.3	.51	--	.14	--	34	56
05438230	Burlington Creek near Hampshire	PR	15.2	.45	--	.11	--	30	45
05438250	Coon Creek at Riley	R	85.1	6.7	6.9	2.8	3.0	16	21
05438320	Piscasaw Creek at Chemung	PR	52.9	7.9	--	4.5	--	48	72
05438400	Piscasaw Creek near Capron	PR	90.7	13	15	8.7	10	9.2	13
05438430	Piscasaw Creek near Belvidere	PR	128	17	18	9.7	11	37	55
05438500	Kishwaukee River near Belvidere	R	538	62	65	33	36	7.4	10
05438550	Beaver Creek near Poplar Grove	PR	26.1	2.4	--	1.3	--	54	84
05438575	Beaver Creek near Belvidere	PR	64.2	3.6	3.8	1.8	2.0	73	118
05438600	Kishwaukee River above South Branch near Perryville	PR	655	79	86	49	47	18	26
05439000	South Branch Kishwaukee River at De Kalb	R[2]	77.7	.47	--	.07	--	54	103
05439130	Virgil ditch No. 3 at Virgil	PR	25.7	.54	--	.15	--	62	106

Table 5.--Estimates of low flow at gaging stations in the Kishwaukee River basin--Continued

Station No.	Station name	Type of station[1]	Drainage area (mi^2)	Low-flow estimates: 7-day, 2-year $Q_{7N,2}$ (ft^3/s)	7-day, 2-year $Q_{7A,2}$ (ft^3/s)	7-day, 10-year $Q_{7N,10}$ (ft^3/s)	7-day, 10-year $Q_{7A,10}$ (ft^3/s)	Average std. error $SE_{7N,2}$ (in percent)	Average std. error $SE_{7N,10}$ (in percent)
05439200	Union Drainage ditch No. 3 near Maple Park	PR	58.0	2.4	--	.84	--	18	26
05439300	East Branch of South Branch Kishwaukee River at Sycamore	PR	107	5.6	--	2.1	--	26	40
05439350	South Branch Kishwaukee River at Genoa	PR	249	8.8	16	2.7	9.7	27	42
05439450	Owens Creek near Kirkland	PR	44.5	.47	--	.09	--	53	87
05439500	South Branch Kishwaukee River near Fairdale	R	387	12	20	3.8	11	10	14
05440000	Kishwaukee River near Perryville	R	1,099	105	118	57	71	7.4	9.9
05440400	East Branch Killbuck Creek near Creston	PR	31.4	.25	--	.08	--	146	200
05440500	Killbuck Creek near Monroe Center	PR[3]	117	6.0	--	3.0	--	9.7	13
05440520	Killbuck Creek near New Milford	PR	136	10	--	5.6	--	19	26

[1] PR - Low-flow partial-record station; R - Continuous-record station.

[2] Operated as a continuous-record station from July 1925 to September 1933, October 1979 to current year. There was less than 10 years of record at the time of this report. Treated as a partial-record station for estimates of low flow.

[3] Operated as a continuous-record station 1940-70, and as a partial-record station 1979-82. Treated as a continuous-record station for estimates of low flow.

The standard error of the low-flow estimates at continuous-record gaging stations were determined by a method developed by Hardison (1969). An average SE of 10 percent for the $Q_{7N,2}$ and 14 percent for the $Q_{7N,10}$ was computed for low-flow estimates at the five continuous-record stations. The SE for these stations ranged from 7.4 to 16 percent for the $Q_{7N,2}$ and from 9.9 to 21 percent for the $Q_{7N,10}$.

The standard error of low-flow estimates at partial-record stations were determined by a method developed by Hardison and Moss (1972). Average SE of 38 percent for the $Q_{7N,2}$ and 59 percent for the $Q_{7N,10}$ were computed for the low-flow estimates at the 22 partial-record stations in the Kishwaukee River basin. The average standard errors for these stations ranged from 9.2 to 146 percent for the $Q_{7N,2}$ and from 13 to 200 percent for the $Q_{7N,10}$.

The SE for all gaged sites averaged 33 percent for the $Q_{7N,2}$ low-flow estimates and 51 percent for the $Q_{7N,10}$ estimates.

Low-Flow Estimates at Ungaged Sites

Drainage area (A) and streamflow-recession index (G) were the most significant basin characteristics in explaining the differences in low flow. Main-channel length (L) dropped out of the analyses as insignificant at the 95 percent level, probably because of the interrelation with drainage area.

Basin characteristics for the continuous-record gaging stations are given in table 6. Because there is no direct means of measuring recession indexes for partial-record stations, the relation shown in figure 7

$$G = 14.1 + 1.77 \, PSG \qquad (6)$$

was used to estimate the recession index from the percent of the drainage area underlain by sand and gravel (PSG). Most of the major stream channels are developed in the Henry Formation as mapped by Lineback (1979) and shown as sand and gravel deposits in figure 3. The main stem of the streams, upstream of stations 05438250 and 05440500, are contrary to the general pattern in that the channel is located outside or against the boundary of the sand and gravel deposits (fig. 3). Because long reaches of the streams are not in contact with the sand and gravel, ground-water discharge to streams is less stable and the recession indexes are lower. Streamflow-recession indexes determined for the partial-record stations from the relation shown in figure 7 ranged from 14 days for zero percent sand and gravel to 118 days for 59 percent sand and gravel (table 7). The relation projects to 191 days for a drainage basin of 100 percent sand and gravel which is near the streamflow-recession index of 250 days reported by Bingham (1982) for streams draining sand and gravel deposits in Alabama.

The low-flow estimating equations determined by regression analyses are:

$$Q_{7N,2} = 6.58 \times 10^{-4} \, A^{1.11} \, G^{1.04} \qquad (7)$$

$$Q_{7N,10} = 6.17 \times 10^{-5} \, A^{1.16} \, G^{1.37} \qquad (8)$$

Table 6.--Basin characteristics for continuous-record gaging stations in the Kishwaukee River basin

Station No.	Station name	Drainage area (mi^2)	Area of basin underlain by sand and gravel (mi^2)	Area of basin underlain by sand and gravel (percent)	Recession index (in days)
05438250	Coon Creek at Riley	85.1	20.6	24	49
05438500	Kishwaukee River at Belvidere	538	183	34	82
05439000	South Branch Kishwaukee River at De Kalb[1]	77.7	0	0	20
05439500	South Branch Kishwaukee River near Fairdale	387	39.4	10	35
05440000	Kishwaukee River near Perryville	1,099	264	24	58
05440500	Killbuck Creek near Monroe Center[2]	117	15.9	14	28

[1] Operated as a continuous-record station from July 1925 to September 1933, October 1979 to current year. This station was treated as a partial-record station elsewhere in this report.

[2] Operated as a continuous-record station from 1940-70, and as a partial-record station from 1979-82.

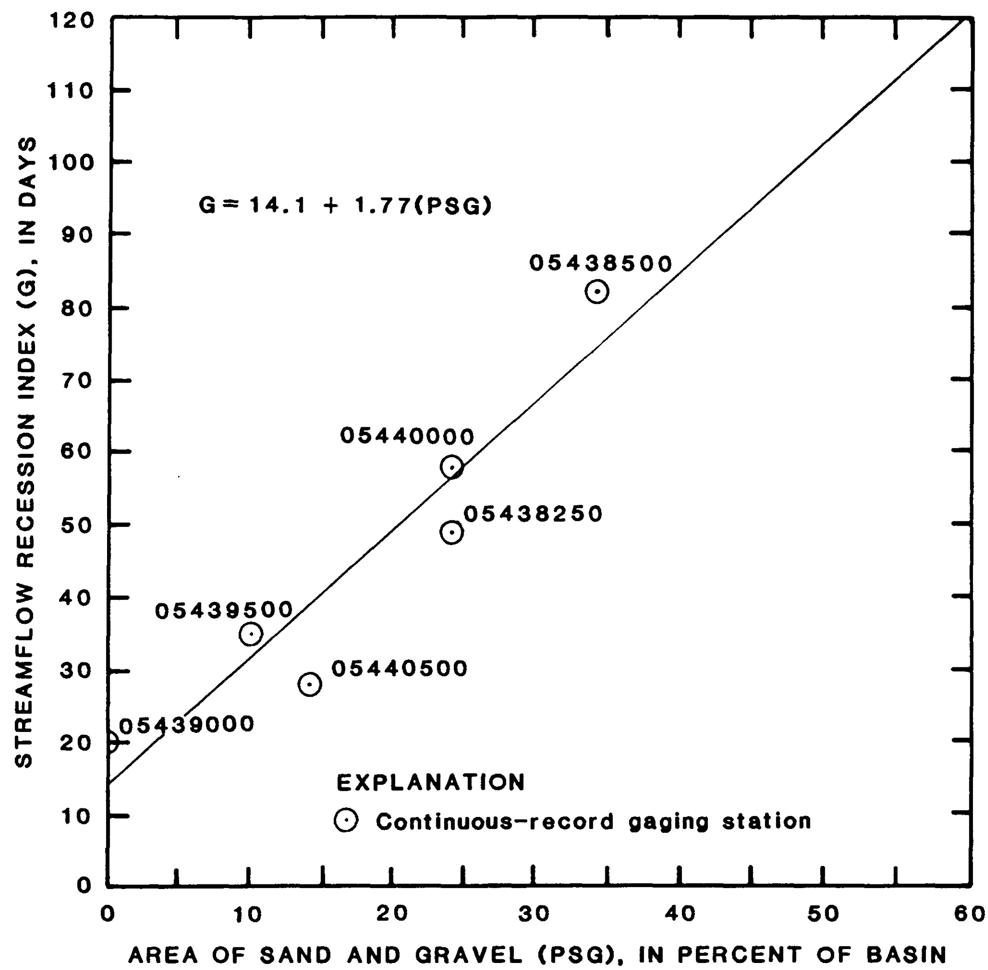


Figure 7.--Relation between percent sand and gravel and streamflow-recession index.

Table 7.--Basin characteristics for low-flow partial-record gaging stations in the Kishwaukee River basin

Station No.	Station name	Drainage area (mi^2)	Area of basin underlain by sand and gravel (mi^2)	Area of basin underlain by sand and gravel (percent)	Recession index (in days)
05437950	Kishwaukee River at Huntley	14.4	4.3	30	67
05438050	North Branch Kishwaukee River near Harvard	21.1	0	0	14
05438100	Kishwaukee River near Marengo	89.7	28.3	32	71
05438150	South Branch Kishwaukee River (East) below Union	73.5	9.6	13	37
05438192	Rush Creek near Garden Prairie	29.5	17.4	59	118
05438201	Kishwaukee River at Garden Prairie	222	80.8	36	78
05438215	Coon Creek at New Lebanon	16.3	2.81	17	44
05438230	Burlington Creek near Hampshire	15.2	4.34	29	65
05438320	Piscasaw Creek near Chemung	52.9	23.4	44	92
05438400	Piscasaw Creek near Capron	90.7	46.0	51	104
05438430	Piscasaw Creek near Belvidere	128	52.4	41	87
05438550	Beaver Creek near Poplar Grove	26.1	2.77	11	34
05438575	Beaver Creek near Belvidere	64.2	6.49	10	32
05438600	Kishwaukee River above South Branch near Perryville	655	210	32	71

Table 7.--Basin characteristics for low-flow partial-record gaging stations in the Kishwaukee River basin--Continued

Station No.	Station name	Drainage area (mi^2)	Area of basin underlain by sand and gravel (mi^2)	Area of basin underlain by sand and gravel (percent)	Recession index (in days)
05439130	Virgil ditch No. 3 at Virgil	25.7	0	0	14
05439200	Union Drainage ditch No. 3 near near Maple Park	58.0	0	0	14
05439300	East Branch of South Branch Kishwaukee River at Sycamore	107	12.9	12	35
05439350	South Branch Kishwaukee River at Genoa	249	22.3	9	30
05439450	Owens Creek near Kirkland	44.5	4.59	10	32
05440400	East Branch Killbuck Creek near Creston	31.4	0	0	14
05440520	Killbuck Creek near New Milford	136	18.5	14	39

where: $Q_{7N,2}$ is the 7-day, 2-year natural low flow, in cubic feet per second;

$Q_{7N,10}$ is the 7-day, 10-year natural low flow, in cubic feet per second;

A is the drainage area of the basin, in square miles; and

G is the streamflow-recession index, in days per log cycle of discharge depletion.

Limitations of Estimating Equations

Equations 7 and 8 may be used to estimate natural low-flow characteristics ($Q_{7N,2}$ and $Q_{7N,10}$) for most ungaged streams in the Kishwaukee River basin. The equations are based on data from watersheds with drainage areas ranging from 14.4 to 1,099 mi^2, $Q_{7N,2}$ from 0.25 to 105 ft^3/s, and $Q_{7N,10}$ from 0.07 to 57 ft^3/s (table 5). Use of the equations outside of the observed ranges of data is not recommended.

Adjusting Low-Flow Estimates for Wastewater Effluents

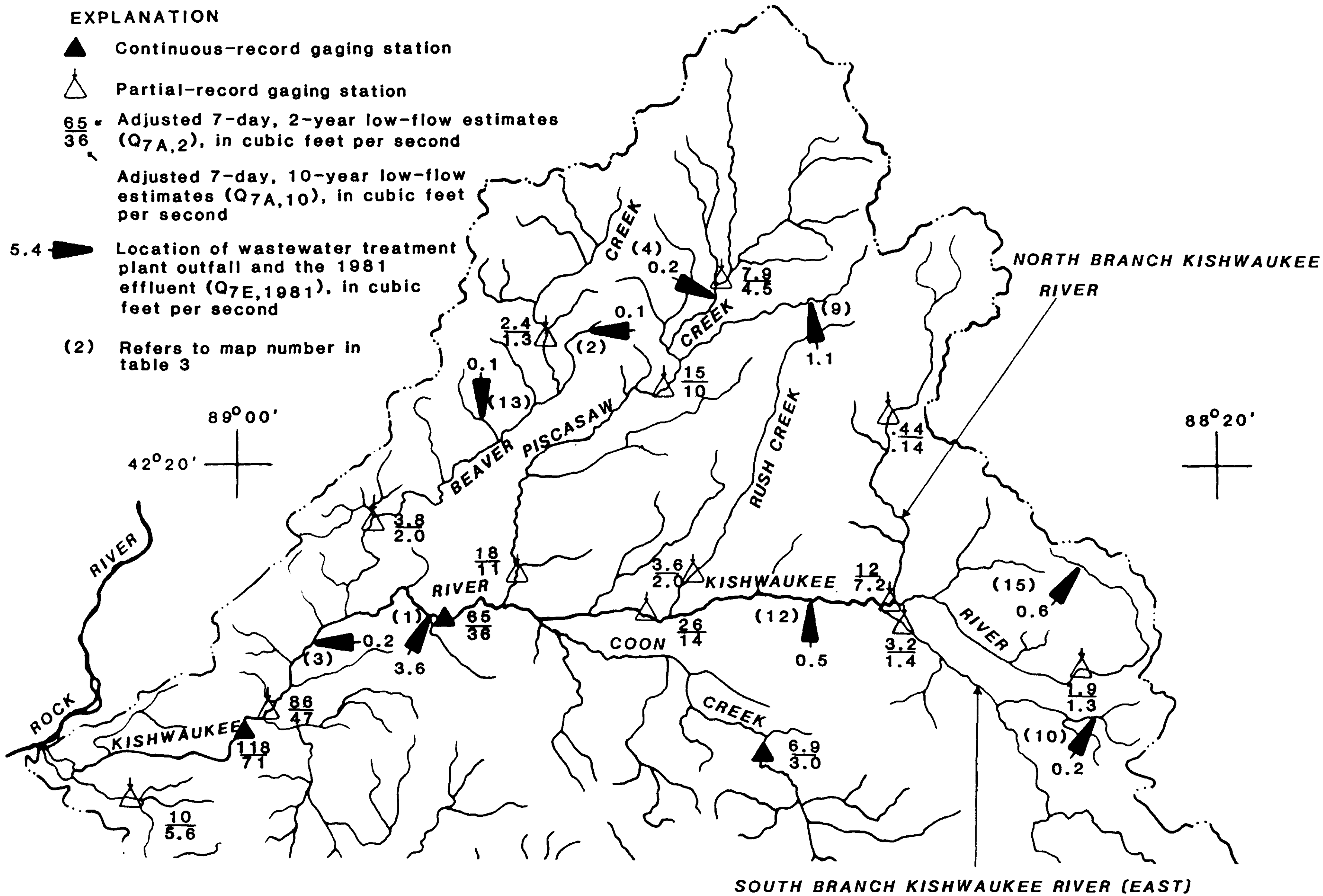
The amount of wastewater effluents discharged to receiving streams must be considered in estimating total low flow. The addition of effluents to a perennial-flowing stream increases the low flow by the amount of effluent. Effluents added to an intermittent stream could be partly or completely absorbed before reaching a perennial stream. The discharge outfalls of wastewater-treatment plants presently operating in the Kishwaukee River basin are all located on perennial streams except for the Capron and Poplar Grove plants.

The location of discharge outfalls for the wastewater-treatment plants operating in the basin, as of September 1982, are shown in figure 8 along with the 7-day mean effluent discharged during the 1981 low-flow period ($Q_{7E,1981}$). The $Q_{7E,1981}$ values from figure 4 or table 3 can be used to adjust $Q_{7N,2}$ and $Q_{7N,10}$ natural low-flow estimates at ungaged sites to represent 1981 streamflow conditions. Figure 4 may be used to estimate Q_{7E} values for future years based on expected changes in population of the communities served by the treatment plants.

EXAMPLES

The method of estimating low flows described in this report is demonstrated by the following two examples:

Example 1. Estimate the $Q_{7A,2}$ low flow at a site on an ungaged stream with no wastewater-treatment plants in upstream basin.


EXPLANATION
Continuous-record gaging station
Partial-record gaging station
65/36 Adjusted 7-day, 2-year low-flow estimates ($Q_{7A,2}$), in cubic feet per second
Adjusted 7-day, 10-year low-flow estimates ($Q_{7A,10}$), in cubic feet per second
5.4 Location of wastewater treatment plant outfall and the 1981 effluent ($Q_{7E,1981}$), in cubic feet per second
(2) Refers to map number in table 3
89°00'
42°20'
88°20'
NORTH BRANCH KISHWAUKEE RIVER
SOUTH BRANCH KISHWAUKEE RIVER (EAST)
ROCK RIVER
KISHWAUKEE RIVER
BEAVER CREEK
PISCASAW CREEK
RUSH CREEK
COON CREEK
RIVER
CREEK
CREEK
(1) (2) (3) (4) (9) (10) (12) (13) (15)
0.1 0.1 0.2 0.2 0.2 0.5 0.6 1.1 3.6
7.9/4.5 2.4/1.3 15/10 .44/.14 3.8/2.0 18/11 3.6/2.0 12/7.2 65/36 26/14 3.2/1.4 1.9/1.3 86/47 118/71 6.9/3.0 10/5.6

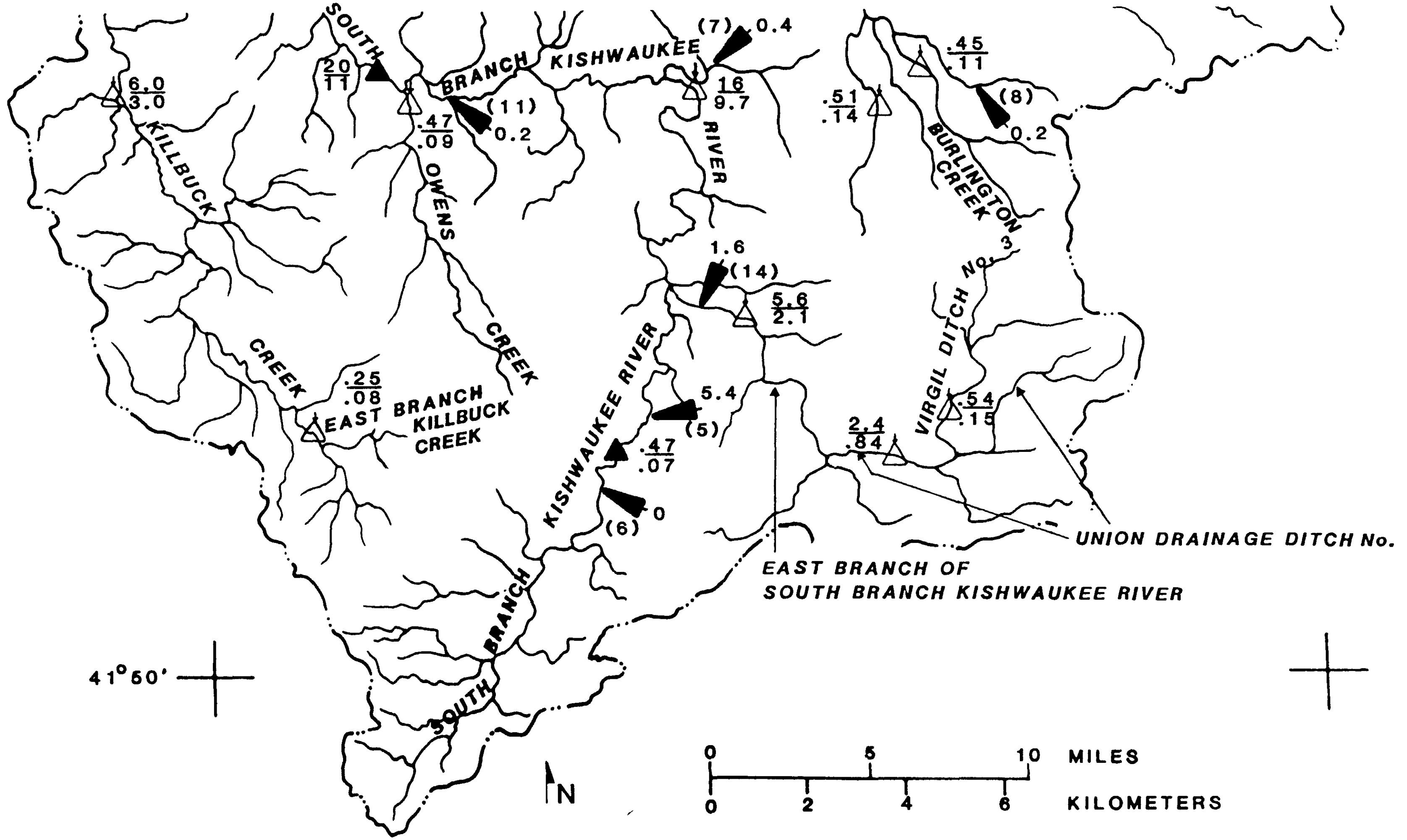


Figure 8.--Seven-day low-flow estimates at gaging stations and wastewater-treatment-plant effluents.

(a) Determine the size of the contributing drainage area (A), in square miles. The drainage area is measured on maps with sufficient features to accurately delineate the basin boundary. For this example, assume A = 88.1 mi^2.

(b) Determine the area of sand and gravel in the basin for the ungaged site from figure 3, from Lineback's (1979) map of Quaternary Deposits, or from other available maps of sand and gravel deposits. For this example, assume the area of sand and gravel in the ungaged basin is 33.8 mi^2, or 38.4 percent of the total drainage area.

(c) Convert percentage sand and gravel in the basin to streamflow-recession index using equation 6 or figure 7. For this example, G = 82.

(d) Use equation 7 to compute the natural 7-day, 2-year ($Q_{7N,2}$) low flow.

$$Q_{7N,2} = 6.58 \times 10^{-4} A^{1.11} G^{1.04}$$

$$= (6.58 \times 10^{-4}) (88.1)^{1.11} (82)^{1.04}$$

$$= (6.58 \times 10^{-4}) (144) (97.8)$$

$$= 9.3 \text{ ft}^3/\text{s}$$

(e) There are no wastewater-treatement plants in the stream system upstream from the site; therefore, no adjustment is necessary to the $Q_{7N,2}$ value computed: $Q_{7A} = Q_{7N,2} = 9.3$ ft^3/s.

Example 2. Estimate the $Q_{7A,10}$ low flow at a site on the South Branch Kishwaukee River just upstream from the junction with the East Branch, 2-1/2 miles northeast of Sycamore.

(a) The drainage area (A) and streamflow recession index (G) are determined as described in example 1. For this site, the drainage area (A) = 98.5 mi^2 from the report by Healy (1979).

(b) The area of sand and gravel as determined from the areas delineated in figure 3 is 2.0 mi^2 or 2 percent of the ungaged basin.

(c) The streamflow-recession index (G) from figure 7 is 18.

(d) Use equation 8 to compute the natural 7-day, 10-year ($Q_{7N,10}$) low flow.

$$Q_{7N,10} = 6.17 \times 10^{-5} A^{1.16} G^{1.37}$$

$$= (6.17 \times 10^{-5}) (98.5)^{1.16} (18)^{1.37}$$

$$= (6.17 \times 10^{-5}) (205) (52.4)$$

$$= 0.66 \text{ ft}^3/\text{s}$$

(e) The only wastewater-treatment plant discharging into the stream during the 1981 7-day low-flow period is the De Kalb plant (fig. 8). From figure 8 or table 3, the $Q_{7E,1981}$ for the De Kalb plant is 5.4 ft^3/s. Thus,

$$Q_{7A,10} = Q_{7N,10} + Q_{7E,1981} = 0.66 + 5.4 = 6.1 \ ft^3/s$$

(the 7-day, 10-year natural low flow adjusted to account for the wastewater effluent discharged during the 1981 low-flow period).

SUMMARY

The 7-day, 2-year ($Q_{7N,2}$) and the 7-day, 10-year ($Q_{7N,10}$) natural low flows were estimated at five continuous-record gaging stations and 22 low-flow partial-record gaging stations in the Kishwaukee River basin. The $Q_{7N,2}$ and $Q_{7N,10}$ estimates were adjusted to represent the 1981 streamflow conditions at each gaging station. Methods used in estimating low flows at gaging stations in the basin were dependent on the type of streamflow data available.

The $Q_{7N,2}$ and $Q_{7N,10}$ estimates at five continuous-record stations with at least 10 years of streamflow record were determined from the natural 7-day annual mean low flows (Q_{7N}) for the period of streamflow record at each station by using a log-Pearson Type III probability distribution. The annual Q_{7N} values for each station were computed by subtracting the wastewater effluent (Q_{7E}) discharged by treatment plants upstream from a particular station during a 7-day low-flow period from the recorded 7-day annual mean low flow (Q_{7R}) as determined from the daily discharge records ($Q_{7N} = Q_{7R} - Q_{7E}$). The average standard errors of estimate (SE) determined for low-flow estimates at the five continuous-record stations ranged from 7.4 to 16 percent for the natural 7-day, 2-year low flows and 9.9 to 21 percent for the natural 7-day, 10-year low flows.

The low-flow estimates at 21 partial-record stations and one continuous-record station with less than 10 years of record were determined from a relation established by regression analysis of computed natural low flows at a partial-record station and concurrent natural low flows at one of the five long-term continuous-record stations. The natural low flows were determined by subtracting the amount of daily wastewater effluent from the discharge measured at the partial-record and continuous-record stations. The average standard errors of estimate (SE) for low flows at the 22 stations treated as partial-record stations, ranged from 9.2 to 146 percent for the $Q_{7N,2}$ and from 13 to 200 percent for the $Q_{7N,10}$.

The $Q_{7N,2}$ and $Q_{7N,10}$ low-flow estimates at all gaging stations were adjusted to represent 1981 streamflow conditions by adding the 7-day effluent ($Q_{7E,1981}$) discharged upstream from a particular station during the 1981 low-flow periods.

Multiple-regression analyses using drainage area and streamflow-recession index as independent variables provided equations that can be used to estimate the $Q_{7N,2}$ and $Q_{7N,10}$ low flows at ungaged sites in the basin. Streamflow-recession indexes are dependent on the storage and transmissivity of geologic materials. In the Kishwaukee River basin, they are related to the percentage of sand and gravel in a particular subbasin as determined from geologic maps.

The location of wastewater-treatment plants operating in the Kishwaukee River basin in 1981 and the 7-day mean effluent discharged from each plant during the 1981 low-flow periods ($Q_{7E,1981}$) are provided in order to adjust the natural low-flow estimates ($Q_{7N,2}$ and $Q_{7N,10}$) at ungaged sites in the basin to represent 1981 streamflow conditions.

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