

# **Techniques for Estimating Peak Flow on Small Streams in Minnesota**

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## CONVERSION FACTORS

Multiply	by	To obtain
inch (in.)	25.4	millimeter
square mile (mi <sup>2</sup> )	2.590	square kilometer
foot(ft)	.3048	meter
cubic foot per second (ft <sup>3</sup> /s)	.02832	cubic meter per second

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# Techniques for estimating peak flow on small streams in Minnesota

by D.L. Lorenz, G.H. Carlson, and C.A. Sanocki

## ABSTRACT

Two statistically-derived techniques, regional regression equation and region of influence regression, that estimate peak flow on small, ungaged streams in Minnesota were developed. Both techniques relate physical and climatic characteristics to peak flow for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals.

Regional regression equations were developed for each recurrence interval in each of six regions in Minnesota. The region of influence regression technique dynamically selects stations with characteristics similar to a site of interest. Thus, the region of influence regression technique allows use of a potentially unique set of stations for estimating peak flow at each site of interest. Two methods of selecting streamflow gaging stations, similarity and proximity, are recommended for use in the region of influence regression technique.

The regional regression equation technique is recommended as a first estimate of peak flow in regions C, E, and F. The similarity method of the region of influence regression technique should be used as a first estimate in regions A and D. The proximity method should be used as a first estimate in region B.

Tables showing the peak-flow-frequency data and basin characteristics for streamflow gaging stations, and regional peak-flow prediction equations, are documented.

## INTRODUCTION

Knowledge of the peak flow of floods of a given recurrence interval is essential for regulation and planning of water resources and bridge, culvert, and dam design along Minnesota's rivers and streams. Techniques are needed to estimate peak flow at ungaged sites because long-term streamflow records are available at relatively few places.

This report is one of a series of reports prepared in cooperation with the Minnesota Department of Transportation that discuss peak-flow frequency on small streams. This report supersedes previous reports by Prior (1949), Prior and Hess (1961), Wiitala (1965), Patterson and Gamble (1968), Guetzkow (1977), and Jacques and Lorenz (1987); all of which dealt with techniques for estimating peak flow in Minnesota. Analysis of annual peak-flow records for the first of these reports that employed the Log Pearson Type III method of analysis (Guetzkow, 1977) may not have included historical flood information in the analysis, and the period of record for many small streams was very short from the standpoint of flood history. Most of the long-term record stations included the low annual peaks from the 1930's drought and high annual peaks during the 1950's and 1960's.

Historical flood information was incorporated in the analysis done by Jacques and Lorenz (1987). Jacques and Lorenz (1987) also used fewer regions than Guetzkow (1977), which resulted in larger standard errors of estimate for the regional equations.

## Background

Continuous daily records for streamflow gaging stations in Minnesota span a relatively short time period. The longest record is for the Mississippi River at St. Paul, which is continuous from 1867 to present, except for 1871. Gaging of several streams to obtain daily streamflow records was started about 1909. The number of streamflow gaging stations decreased between 1912 and 1920. During the late 1920's and early 1930's, the number of streamflow gaging stations increased. Many of those streamflow gaging stations presently are in operation. Over the years, streamflow gaging stations were added where flow information was needed, and other stations were discontinued where additional data were not needed. Streamflow gaging stations operated to obtain daily records generally are located on streams that drain areas greater than 300 mi<sup>2</sup> and flow continuously.

In the 1950's, planners for the interstate highway system learned that little information was available about peak flow on small streams. This information was needed for determining the necessary size of bridges and culverts at road crossings. As a result of this need, small-stream flood investigation projects were initiated nationwide. The program in Minnesota began in 1958 and over the next 6 years about 150 streamflow gaging stations were established to determine annual peak flow and stage on streams draining about 60 mi<sup>2</sup> or less. Most of those stations were operated through the 1970's. In the 1980's, gaging for annual peak flow and stage for most of the drainage basins of less than 10 mi<sup>2</sup> was discontinued. Some new peak-flow gaging stations recently were established on streams draining areas from 10 mi<sup>2</sup> to several hundred square miles.

### **Purpose and scope**

This report (1) documents the analytical techniques used for annual series peak-flow-frequency computations, basin characterization, regionalization, and development of equations for estimating peak flow on small drainage basins; (2) presents peak-flow data and basin characteristics at streamflow gaging stations; and (3) discusses techniques for estimating peak flow at ungaged sites on small, unregulated streams in Minnesota.

Streamflow gaging stations on the Red Lake, Minnesota, Mississippi, Rainy, St. Louis, and Red River of the North Rivers that have drainage areas greater than 5,000 mi<sup>2</sup>, were not included in this analysis. Other streamflow gaging stations that were not included in this analysis had peak flows that were affected by controlled storage or regulated releases.

### **Acknowledgments**

The authors thank Steven K. Sando and David Eash, of the U.S. Geological Survey, for providing basin characteristics and peak flow analyses of streamflow gaging stations in South Dakota and Iowa. We thank Gary Tasker, of the U.S. Geological Survey, for his assistance in statistical analysis.

## **ANALYTICAL TECHNIQUES**

This section describes the analytical techniques and adjustments to analyses that were required to

develop the techniques for estimating the peak flow on small streams. It also presents preliminary computations required for regression analysis.

### **Frequency analysis of annual peak flow data at streamflow gaging stations**

An annual series peak-flow-frequency analysis at each streamflow gaging station (fig. 1) was prepared according to the procedures outlined in Bulletin 17B (U.S. Water Resources Council, 1982).

Many more streamflow gaging stations that have at least 25 years of record are available now than when the skew map of Bulletin 17B (U.S. Water Resources Council, 1982) was developed. Therefore, before computations of peak-flow frequency were begun, stations with 25 or more years of record in and near Minnesota were analyzed to determine the station skew coefficient and an updated generalized skew coefficient map was prepared and published (Lorenz, 1997). The resultant generalized skew coefficients were used in the Log-Pearson Type III peak-flow-frequency analysis used for this report.

Treatment of discontinuous periods of record (also called broken record) and the occurrence of large floods either within or outside the period of record, and considered "historic", are described below.

1. Where the record is not continuous and there is no indication of a historic flood, the record has been treated as though it was a continuous homogeneous record.

2. Where the flow of a large flood that occurred several years before the start of the record of annual peak flows is known, and that flood flow has not been exceeded, a historic period extending from the year of the large flood to 1995, or to the end of annual peak data, was used in the peak-flow frequency computation. For some streams where the record ended prior to 1995, and the large, historic flood flow has not been exceeded since the end of the record, the historic period was extended to 1995, if that extension improved the agreement between the observed peaks and the peak-flow-frequency analysis.

3. Where a large flood occurred before the start of the record of annual peak flows, but the flow is not known, the record was analyzed with a corresponding historic period if the record



contained a high outlier, as defined by U.S. Water Resources Council, 1982. If possible, that result was compared to peak-flow frequency analysis of nearby stations to support the valid use of the historic period.

4. Where the record was continuous for at least 50 years and there was a very large flood flow in the record, and there was evidence of a large regional flood outside of the period of record, the record was analyzed with and without use of a historic period. The results of both analyses were compared to the station data and the peak-flow frequency analysis of nearby stations, if possible. The analysis using the historic period was used if the comparison justified it.

The peak-flow frequency computations for streamflow gaging stations outside of Minnesota were obtained from a U.S. Geological Survey (USGS) office of the given state. The peak-flow frequency computations are listed table 1 (in the Supplemental Information at the end of this report).

### Estimating basin characteristics

Fourteen reports published by the USGS describe basin characteristics for gaged streams in the Minnesota and Crow River Basins (southern part of Minnesota). These reports list the drainage area, percent of the drainage area covered by lakes, percent drainage area covered by lakes and wetlands (storage), main-channel length, and main-channel slope.

For other gaged streams in Minnesota, drainage area boundaries were delineated on the basis of topographic contours and anthropogenic alterations to the landscape. Those alterations, such as the installation of storm sewers, the drainage of wetlands, and the diversion of streams can change the drainage area of a stream. Drainage basin delineation was done by the USGS, the Minnesota Department of Natural Resources Division of Waters, and Mankato State University Water Resources Center. Drainage area boundaries were drawn on USGS 1:24,000 topographic maps. The drainage area boundaries were digitized or scanned by the Minnesota Department of Natural Resources, Minnesota State Planning Land Management Information Center, Mankato State University, and the USGS and transferred to a geographic information system (GIS). The Canada Centre For Mapping, Department of Energy, Mines and Resources Canada 1:50,000 topographic maps

were used to obtain subbasin boundaries, main-channel length, contour elevation points, area of lakes, and area of wetlands within Canada.

Lake and wetland data were obtained from the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI). NWI data were extracted for each gaging station to identify the percentage of lake and percentage of storage (lake and wetland) area in the basin represented by each streamflow gaging station. The total area of lakes and wetlands in the basin represented by each streamflow gaging station was calculated using the GIS.

Main channels were defined from Basemap '97 (Minnesota Department of Transportation, 1997). Basemap '97 is a basic core of geographic data that cover the state of Minnesota. Extensions to the main channel through lakes and from the end of the mapped stream line to an endpoint within the drainage basin, generally at the divide, were added to the Basemap '97 data.

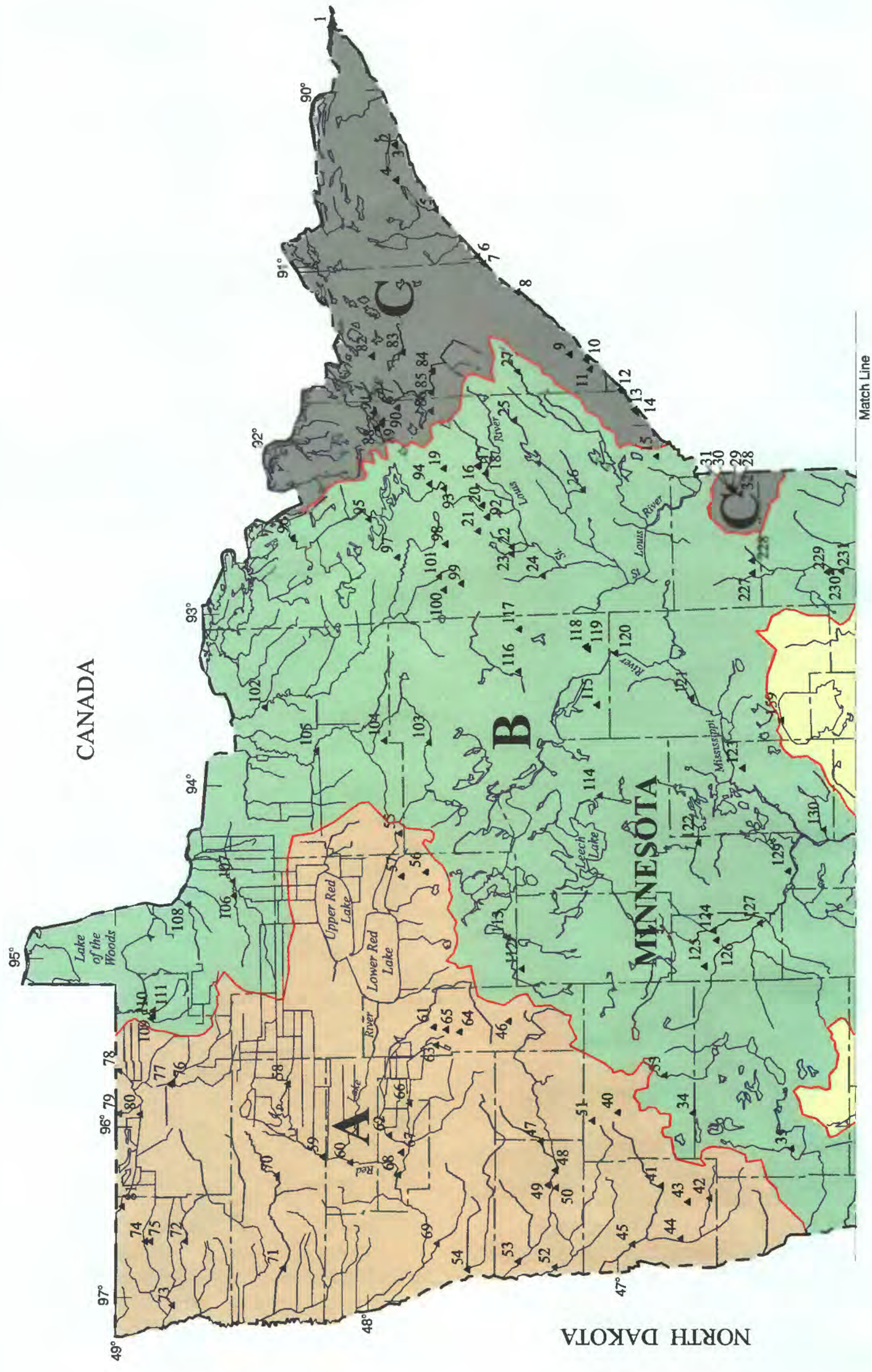
Elevations of intersections of topographic contour lines and main channels were digitized using the GIS. Two points on the main channel, at 10 percent and at 85 percent of the main-channel length from the streamflow gaging station to the endpoint of the extension, were located by the GIS. The elevations of these two points were interpolated from digitized elevation data. Main-channel slope was calculated by dividing the difference in elevation between those points by the distance along the main channel between those points.

The generalized runoff was based on the map of Gebert and others (1985) (fig. 2). The value of the generalized runoff for the basin was determined from the streamflow gaging station location using the surface interpolation function by Akima (1978). The basin characteristics are listed in table 2 (in the Supplemental Information section at the end of this report).

### Regression analysis

Tasker and others (1986) described the use of the generalized least squares (GLS) technique to estimate 100-year peak flow for an area in Arizona. They showed that the technique provided better estimates than the ordinary least squares technique. The GLS technique accounts for cross-correlated peak-flow data between stations having concurrent record. It also accounts for variance in estimated peak flow at each streamflow gaging station







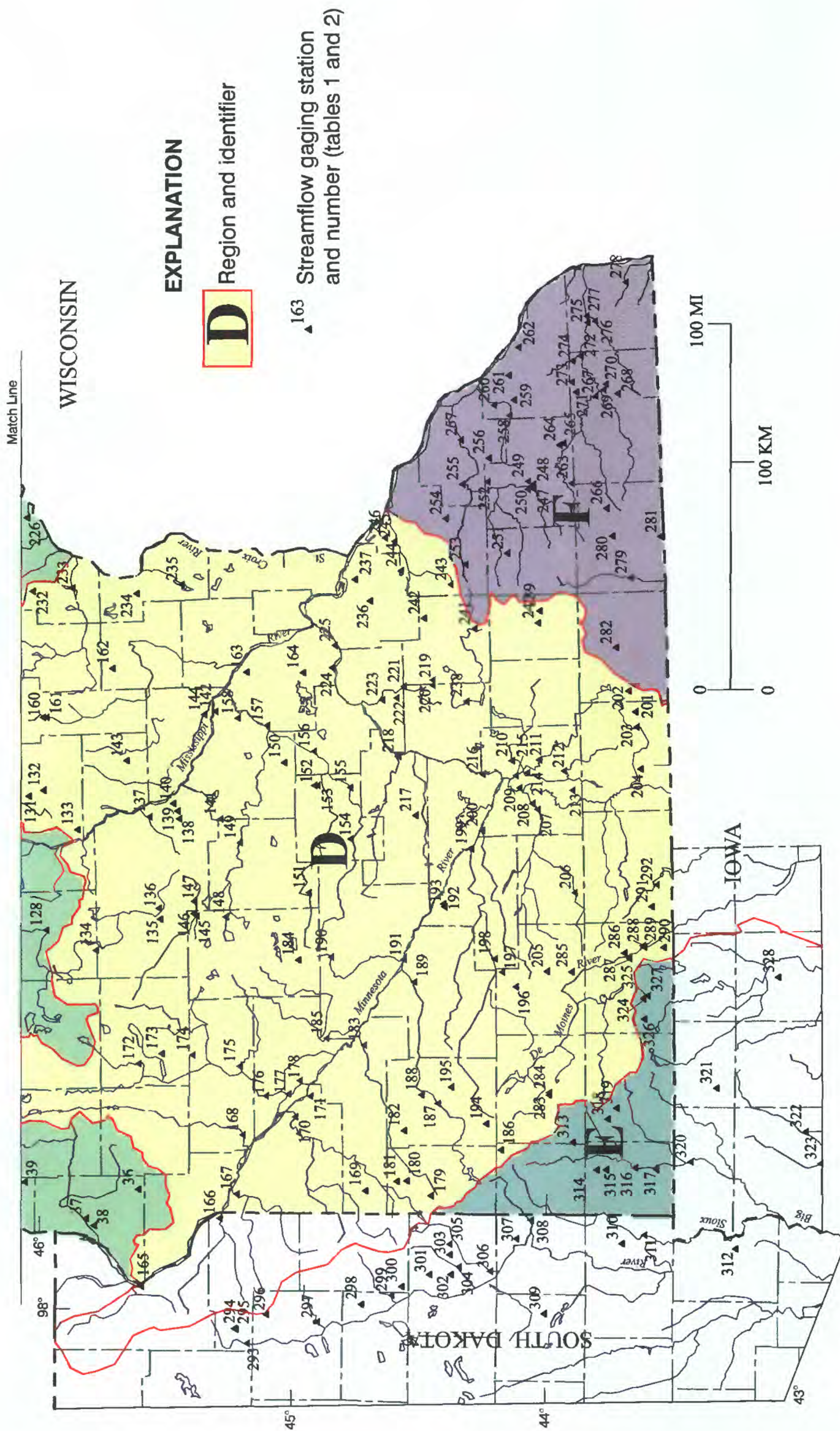
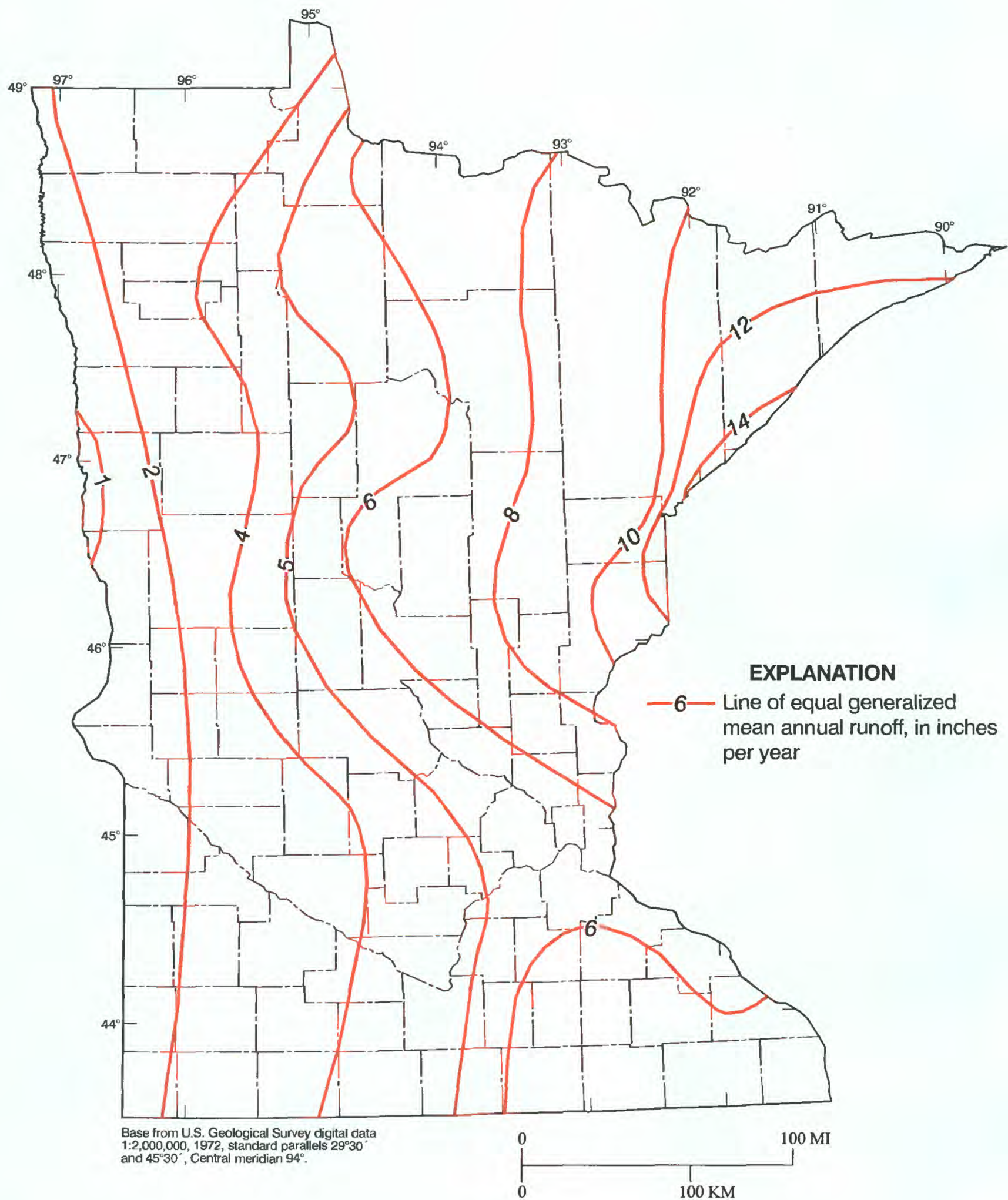


Figure 1. Locations of streamflow gaging stations and regions for estimating peak flow.





**Figure 2. Generalized mean annual runoff in Minnesota, 1951-85  
[modified from Gebert and others, 1985].**

because of the difference in record length. Cross correlation is the correlation between peak flow at two different streamflow gaging stations as a result of similar weather patterns affecting those stations. In ordinary least squares regression, cross-correlated peak-flow data decrease the effective amount of information in an analysis and can contribute to errors in predictive precision (model error) and errors in determination of the coefficients of the independent variables (Stedinger and Tasker, 1985).

The GLS technique requires a reasonable estimate of the cross correlation between flows at every pair of stations (Tasker and Stedinger, 1989). An estimate based on the measured flows is not reliable because of the short concurrent records usually encountered in peak-flow data. Therefore, sample cross correlations are estimated by relating the distance between each pair of stations to the correlation between peak flows. Stations with at least 25 years of record were selected for the analysis of cross correlation and distance. From these stations, there were 9,735 pairs of correlations where there were at least 25 years of concurrent record. These 9,735 data pairs were reduced to 152 using the following two steps. First, the data were sorted by distance. Second, the mean distance and mean correlation, both weighted by concurrent record length, were computed for each sequential group of 64 data points. These 152 pairs of reduced data were used in a nonlinear regression analysis to relate cross correlation to distance. These data are shown in figure 3. These data summarize the trend of the entire data set, but do not represent the true scatter of the original data. The nonlinear regression equation relating cross correlation to distance is as follows:

$$\rho(i,j) = 0.6314 - 0.4062 * \text{atan}(\text{dist}(i,j) / 92.27),$$

where

$\rho(i,j)$  = the estimated cross correlation between stations  $i$  and  $j$ ,

$\text{atan}(x)$  = the arctangent of  $x$ , and

$\text{dist}(i,j)$  = the distance, in miles, between stations  $i$  and  $j$ .

The equation is valid for  $i$  not equal to  $j$ ; for  $i$  equal to  $j$ , the cross correlation is 1.

Step-backward selection is used for selecting variables in the regression models. The selection process begins by calculating statistics for all

independent variables. Then variables are deleted from the model if the coefficient has the incorrect sign or if the T-score is less than 1.7. At each step, the variable having the lowest T-score is deleted.

## Regional analysis

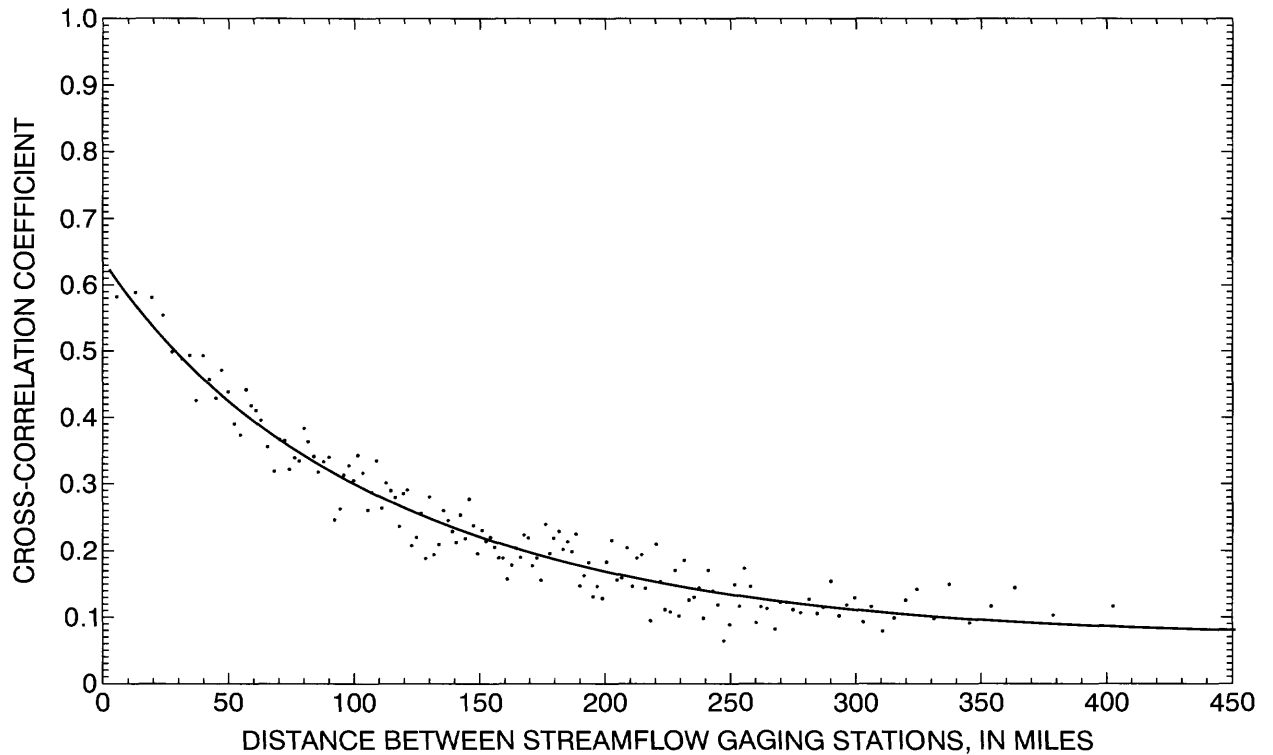
The regions for estimating peak flow shown on figure 1 were modified from those in Jacques and Lorenz (1987). The regions defined in that report formed the basis for formation of new regions described in this report. Regional regression equations were developed for the regions defined by Jacques and Lorenz (1987). The residuals of peak-flow values associated with the regressions were examined in a two-step process. In the first step, the residuals from each regional regression were examined for a subregional pattern. If a subregional pattern was evident, that subregion was removed from the original region. In the second step, the residuals were examined to verify a normal, homoscedastic distribution. If the residuals were approximately normally distributed and homoscedastic, the region was accepted; otherwise, the region was subdivided again and the second step was repeated from this two-step process, two new regions, E and F, were identified and regions B and C were slightly modified. The average standard error of the estimate (SEE), discussed in the Accuracy and Limitations of the Estimating Techniques section, decreased from 51 percent for old region D to an average 47 percent for new regions D, E, and F.

Regional boundaries are shown on figure 1. Table 3 includes the number of streamflow gaging stations in each region. The regional boundaries follow drainage divides so that the drainage basin of a small stream will not overlap two regions, making interpretation easier for all small streams.

## TECHNIQUES FOR ESTIMATING PEAK FLOW ON SMALL STREAMS IN MINNESOTA

This section presents two statistically-derived techniques for estimating peak flows on small, ungaged streams in Minnesota. Both of the techniques relate physical and climatic characteristics to peak flows for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals.





**Figure 3. Distance between streamflow gaging stations and peak-flow cross correlation in Minnesota.**

#### Regional regression equation technique

Regression equations were developed for each recurrence interval and for each region shown on figure 1. Table 3 presents those equations, the SEE and the equivalent years of record discussed in the Accuracy and Limitations of the Estimating Techniques section. The SEE is included for comparison to previous regional regression equations.

#### Region of influence regression technique

The fundamental premise of the region of influence regression (ROI) technique is that there is no need for distinct boundaries between regions (Burn, 1990). Each region is defined by selecting streamflow gaging stations with characteristics that are similar to the site of interest. Thus, the ROI technique allows use of a potentially unique set of streamflow gaging stations for each site of interest. Two methods are available for this technique. The similarity method selects streamflow gaging stations that have similar characteristics (variables). The proximity method selects streamflow gaging stations that are nearby.

The ROI technique requires the selection of a distance metric defining the similarity of each streamflow gaging station to the site of interest. Similarity is defined in terms of shortest distance. An appropriate metric is the weighted Euclidean distance in M-dimensional space (Burn, 1990). The distance metric is defined:

$$D(i) = \sqrt{\sum_{m=1}^M [W(m) \times (X(m, i) - X(m))^2]}$$

where

$D(i)$  = the distance from station  $i$  to the site of interest,

$W(m)$  = the weight applied to variable  $m$ ,

$X(m, i)$  = the value of attribute  $m$  for station  $i$ , and

$X(m)$  = the value of the attribute for the site of interest.

In most cases, the weight for each attribute is the reciprocal of the variance of the attribute, computed from the values at all streamflow gaging stations. This technique selects a certain number, 36 for this study, of streamflow gaging stations

Table 3.--Regression equations, standard errors of the estimate, and the equivalent years of record.  
[SEE, standard error of the estimate; EY, equivalent years of record; DA, drainage area, in square miles; ST, storage, in percent of drainage area; LK, area covered by lakes, in percent of drainage area; RO, generalized runoff, in inches; SL, slope, in feet per mile.  
Number in parentheses following region is number of streamflow gaging stations used to develop the equation.]

Regression equation	SEE (percent)	EY
REGION A (42)		
Q2 = 22.2 DA <sup>0.667</sup> (ST+1) <sup>-0.076</sup> (LK+1) <sup>-0.121</sup>	40	4.7
Q5 = 49.7 DA <sup>0.680</sup> (ST+1) <sup>-0.136</sup> (LK+1) <sup>-0.186</sup>	36	7.5
Q10 = 75.2 DA <sup>0.682</sup> (ST+1) <sup>-0.168</sup> (LK+1) <sup>-0.208</sup>	37	9.9
Q25 = 116. DA <sup>0.681</sup> (ST+1) <sup>-0.205</sup> (LK+1) <sup>-0.223</sup>	39	12.4
Q50 = 154. DA <sup>0.678</sup> (ST+1) <sup>-0.230</sup> (LK+1) <sup>-0.228</sup>	41	13.6
Q100 = 197. DA <sup>0.675</sup> (ST+1) <sup>-0.252</sup> (LK+1) <sup>-0.231</sup>	44	14.5
REGION B (59)		
Q2 = 5.16 DA <sup>0.820</sup> (ST+1) <sup>-0.136</sup> (LK+1) <sup>-0.400</sup> RO <sup>0.859</sup>	38	2.8
Q5 = 15.2 DA <sup>0.818</sup> (ST+1) <sup>-0.170</sup> (LK+1) <sup>-0.479</sup> RO <sup>0.667</sup>	41	3.4
Q10 = 26.0 DA <sup>0.818</sup> (ST+1) <sup>-0.195</sup> (LK+1) <sup>-0.515</sup> RO <sup>0.590</sup>	43	4.1
Q25 = 44.9 DA <sup>0.818</sup> (ST+1) <sup>-0.228</sup> (LK+1) <sup>-0.550</sup> RO <sup>0.523</sup>	45	5.2
Q50 = 63.2 DA <sup>0.818</sup> (ST+1) <sup>-0.252</sup> (LK+1) <sup>-0.570</sup> RO <sup>0.489</sup>	47	6.0
Q100 = 85.4 DA <sup>0.818</sup> (ST+1) <sup>-0.276</sup> (LK+1) <sup>-0.587</sup> RO <sup>0.464</sup>	49	6.7
REGION C (29)		
Q2 = 34.6 DA <sup>0.961</sup> SL <sup>0.359</sup> (ST+1) <sup>-0.532</sup> (LK+1) <sup>-0.280</sup>	33	3.2
Q5 = 64.5 DA <sup>0.928</sup> SL <sup>0.387</sup> (ST+1) <sup>-0.561</sup> (LK+1) <sup>-0.314</sup>	37	3.6
Q10 = 81.4 DA <sup>0.913</sup> SL <sup>0.425</sup> (ST+1) <sup>-0.567</sup> (LK+1) <sup>-0.328</sup>	39	4.4
Q25 = 97.6 DA <sup>0.898</sup> SL <sup>0.481</sup> (ST+1) <sup>-0.569</sup> (LK+1) <sup>-0.342</sup>	42	5.4
Q50 = 106. DA <sup>0.890</sup> SL <sup>0.527</sup> (ST+1) <sup>-0.569</sup> (LK+1) <sup>-0.350</sup>	44	6.0
Q100 = 112. DA <sup>0.883</sup> SL <sup>0.574</sup> (ST+1) <sup>-0.567</sup> (LK+1) <sup>-0.356</sup>	47	6.5
REGION D (126)		
Q2 = 7.15 DA <sup>0.796</sup> SL <sup>0.449</sup> (LK+1) <sup>-0.401</sup>	49	3.4
Q5 = 14.1 DA <sup>0.796</sup> SL <sup>0.475</sup> (LK+1) <sup>-0.411</sup>	44	5.7
Q10 = 19.8 DA <sup>0.794</sup> SL <sup>0.488</sup> (LK+1) <sup>-0.414</sup>	45	7.5
Q25 = 28.2 DA <sup>0.792</sup> SL <sup>0.503</sup> (LK+1) <sup>-0.416</sup>	47	9.3
Q50 = 35.1 DA <sup>0.791</sup> SL <sup>0.513</sup> (LK+1) <sup>-0.416</sup>	50	10.3
Q100 = 42.5 DA <sup>0.790</sup> SL <sup>0.522</sup> (LK+1) <sup>-0.416</sup>	54	10.9
REGION E (36)		
Q2 = 1.84 DA <sup>0.848</sup> SL <sup>0.758</sup> RO <sup>0.690</sup>	62	5.0
Q5 = 6.12 DA <sup>0.826</sup> SL <sup>0.721</sup> RO <sup>0.647</sup>	48	10.8
Q10 = 10.8 DA <sup>0.821</sup> SL <sup>0.706</sup> RO <sup>0.644</sup>	42	18.4
Q25 = 18.4 DA <sup>0.823</sup> SL <sup>0.698</sup> RO <sup>0.655</sup>	36	33.7
Q50 = 25.0 DA <sup>0.828</sup> SL <sup>0.697</sup> RO <sup>0.670</sup>	32	50.4
Q100 = 32.2 DA <sup>0.834</sup> SL <sup>0.699</sup> RO <sup>0.686</sup>	30	71.8
REGION F (36)		
Q2 = 37.6 DA <sup>0.712</sup> SL <sup>0.223</sup>	38	5.3
Q5 = 55.3 DA <sup>0.718</sup> SL <sup>0.317</sup>	32	10.1
Q10 = 66.7 DA <sup>0.721</sup> SL <sup>0.367</sup>	30	15.2
Q25 = 79.7 DA <sup>0.723</sup> SL <sup>0.425</sup>	30	21.4
Q50 = 87.9 DA <sup>0.724</sup> SL <sup>0.466</sup>	31	24.6
Q100 = 94.9 DA <sup>0.725</sup> SL <sup>0.505</sup>	33	26.3

closest to the site of interest to represent the region. For this study, slope, percent storage, percent lake area, and generalized runoff were used to define the region of influence for the similarity method. These variables vary regionally across Minnesota to a certain extent. Drainage area is not included in the selection variables because the correlation between drainage area, slope, percent storage and percent lakes does restrict the range of drainage basin areas when the other variables are included.

An alternative to the similarity method is the proximity method, in which the distance metric is defined as the actual distance, in miles for example, between the site of interest and streamflow gaging stations. In the proximity method, the weight of variables is not considered. This method assumes that the region of influence is determined from a gradient of climatic and physiographic factors that are best represented by location and that those factors are not necessarily limited to the independent variables selected for this analysis.

The trade-off between the similarity method and the proximity method is in the cross correlation between the streamflow gaging stations selected in the region of influence. Stations selected using the proximity method probably will have a higher cross correlation than stations selected using the similarity method. The higher cross correlation reduces the effective amount of information for the region and can make the regression equations appear more accurate than they are when comparing predicted and measured peak flows. The average cross-correlation coefficient was 0.09 for the similarity method and 0.13 for the proximity method in Minnesota. These average cross-correlation coefficient values for the two methods were not substantially different.

#### Comparison of regional regression equation and region of influence regression techniques

One method for comparing the regional regression equation technique and the region of influence regression technique is to use the PRESS/n statistic, which is the mean Prediction Error Sum of Squares. The PRESS/n statistic is determined by removing each site (of n sites) from the analysis, re-developing the prediction equations, and comparing the predicted peak-flow value to the measured value for that site in a region. The differences between the predicted and

measured values are squared and the mean for all sites is computed. That way, n analyses are made without the predicted site being included. It is a reasonably unbiased comparison if the sites are not highly cross correlated.

Table 4 is a listing of the PRESS/n statistics for each region and recurrence interval. The minimum mean PRESS/n statistic indicates the preferred technique for each region. However, for region C, because the difference between the PRESS/n for the regional regression equation and the proximity method of ROI is only 0.0001 and the individual PRESS/n statistics for each recurrence interval greater than 5 years is less for the regional regression equation; that technique is preferred for that region. For the other regions, the proximity method is preferred for region B, the similarity method for regions A and D, the regional regression equations for regions E and F.

Regional regression appears strongly preferable for region E because the mean PRESS/n statistics for the ROI methods are so much higher than those for the regional regression equation. For the other regions, all methods might be given some consideration in evaluating the peak flow for a given recurrence interval.

#### Software

A software packet is included with this report. It is a 3.5-inch floppy disk that contains the program and data files to run the regional regression equations and the region of influence regression techniques. The program is for use on an MSDOS operating system (version 3.0 or higher) and requires a math co-processor.

The software can be installed on any computer system using the MSDOS operating system. The steps for installing the software are as follows.

1. Open a MSDOS window if using any window system.
2. Insert the floppy disk into drive a:.
3. Type "a:install c:\peakflow", where c:\peakflow is the desired directory to install the software.
4. Two versions of the executable are included. The version called pf16.exe will run on any MSDOS computer. The version called pf32.exe will only run on a computer that supports a 32-bit operating system (Windows 95 or newer).



5. To run the program, change directory to c:\peakflow and type pf32 or pf16, whichever is appropriate for the system.

The program requires the user to enter an output file name; select a technique, either RRE for regional regression equations or ROI for region of influence regression; enter a site identifier; and enter the necessary basin characteristics. For the RRE technique, only those basin characteristics necessary for the equation are entered. For the ROI technique, drainage area, main-channel slope, area of storage, area of lakes, and generalized runoff must be entered. For the ROI technique, the user must specify a selection method, usually P for proximity or S for similarity. Multiple analyses for any number of stations or techniques can be performed during a single session.

An example of the dialogue from the program is shown in the Supplemental Information section, with informative messages in normal font, program prompts in italics, and user input in bold. The dialogue includes an example of both the RRE and ROI techniques, and the similarity and proximity method for the ROI technique. The method of selecting stations by list is not shown in the dialogue because it is a specialized method and should be used only when the user does not get a satisfactory result from the ROI technique (see discussion of output) and the user elects not to use the regional regression equation. The list method is used by selecting G as the option for selecting stations, then entering the number of stations to use and the eight-digit station number for each station, one to a line.

The example site is Judicial Ditch 11 in Sibley County, at the crossing of County Road 51, 3 miles south of Buffalo Lake. The relevant basin characteristics are:

Drainage area: 15.0 mi<sup>2</sup>,  
Main-channel slope: 2.6 ft/mi,  
Storage: 0.0 percent,  
Lake area: 0.0 percent,  
Generalized runoff: 4.0 in./yr,  
Latitude: 44° 41' 22", and  
Longitude: 94° 37' 10".

The example site is in region D, where the recommended technique is ROI using the similarity method. RRE and ROI using the proximity method are also shown as an example.

Table 4.--PRESS/n statistics for each region and recurrence interval.  
[ROI, region of influence regression]

Region identifier	Recurrence interval (years)	PRESS/n		
		Proximity method ROI	Similarity method ROI	Regional regression
A	2	0.0431	0.0425	0.0358
A	5	.0411	.0369	.0411
A	10	.0402	.0350	.0401
A	25	.0439	.0392	.0442
A	50	.0458	.0436	.0534
A	100	.0498	.0493	.0628
A (mean)		.0440	.0411	.0462
B	2	.0362	.0360	.0337
B	5	.0413	.0423	.0430
B	10	.0447	.0507	.0445
B	25	.0488	.0603	.0510
B	50	.0516	.0682	.0546
B	100	.0543	.0770	.0598
B (mean)		.0462	.0558	.0478
C	2	.0232	.0344	.0318
C	5	.0314	.0404	.0339
C	10	.0385	.0429	.0383
C	25	.0466	.0561	.0445
C	50	.0532	.0630	.0496
C	100	.0599	.0685	.0549
C (mean)		.0421	.0509	.0422
D	2	.0453	.0449	.0498
D	5	.0442	.0421	.0435
D	10	.0528	.0466	.0473
D	25	.0705	.0560	.0566
D	50	.0828	.0649	.0654
D	100	.0957	.0747	.0752
D (mean)		.0652	.0549	.0563
E	2	.0856	.0594	.0809
E	5	.0734	.0538	.0578
E	10	.0778	.0591	.0550
E	25	.0903	.0729	.0582
E	50	.1074	.0838	.0638
E	100	.1204	.1004	.0713
E (mean)		.0925	.0716	.0645
F	2	.0423	.0485	.0348
F	5	.0315	.0428	.0301
F	10	.0297	.0457	.0312
F	25	.0332	.0527	.0350
F	50	.0384	.0545	.0392
F	100	.0432	.0605	.0443
F	mean	.0364	.0508	.0358

The dialogue lists the peak flow, standard error of prediction (SEP) (discussed in the Accuracy and Limitations of Estimating Techniques section), equivalent years of record, and the lower and upper flow values of the 90-percent prediction interval. The SEP for the RRE will always be equal to or larger than the value of the SEE in table 3.

The output file from the regional regression equation technique reiterates the screen output and is not shown in this report. The output from the region of influence regression technique contains additional diagnostics about the regressions. A section of the output file is shown in the Supplemental Information section. The basic form of the output is repeated for each recurrence interval.

The output file presents information about the regression analysis. First, the results of the step-backward selection of independent variables are shown. Second, the residuals and influence statistics are listed. Third, the estimated peak flow and statistics are shown.

The output from the step-backward selection process shows the coefficients and their statistics, the variable to be deleted, and the reason for deletion for each of the steps. If the variable is forced out of the analysis, the coefficients and statistics are not shown.

The residuals and influence list includes the stations used in the analysis, the base-10 logarithm of the observed peak, the base-10 logarithm of the predicted peak, the studentized residual, the leverage, and Cook's D for each station. The studentized residual is the computed residual divided by the estimated standard deviation of that residual. Leverage is a measure of the distance from the observation to the mean of all observations. The leverage statistic can identify stations that are potentially influential because of their location in independent-variable space. Cook's D is a measure of influence that uses the studentized residual and leverage. Cook's D reveals which observations are influential in affecting the coefficients of the regression equation. Stations with values of the studentized residual, leverage, and Cook's D that are substantially larger than any other of the respective values could be considered for deletion. If basin characteristics of a particular station are substantially different from the remaining stations

and the site in question, it could be deleted from the analysis and the remaining stations used in the ROI technique, using the list method.

Two statistics are printed at the bottom of the list. They are the mean sampling error variance and the mean model error variance. The mean sampling error variance is the portion of the average prediction error that is caused by estimation errors in the regression coefficients as opposed to the model error. The mean model error variance is the error caused by an imperfect model (lack of fit). The sum of these numbers is the mean prediction error variance. Hodge and Tasker (1995) describe the development of these statistics.

The predicted peak flow and statistics reiterate the information shown on the screen. The statistics include the percent standard error of prediction, the equivalent years of record, and the upper and lower 90-percent prediction interval. These statistics are explained in the Accuracy and Limitations of the Estimating Techniques section. The output on the screen will include a caution statement if the predicted value for a peak is smaller than the predicted value for a shorter recurrence interval.

The program will make a second pass through all regressions to construct a set of equations for estimating peak-flow that are based on a consistent set of independent variables. Independent variables that are used in at least three of the peak-flow estimates are included in that consistent set. Predicted peak flows based on a consistent set of independent variables may be desirable in all cases and should eliminate the occurrence of smaller predicted values at longer recurrence intervals.

## **ACCURACY AND LIMITATIONS OF THE ESTIMATING TECHNIQUES**

The accuracy of a statistically derived equation is measured by the closeness of the estimated value to the true value. Regression analyses give an unbiased estimate of the true value and statistics to assess the accuracy of the estimate.

The standard error of the estimate (SEE) is a measure of the fit of the observed data about the regression surface. The SEE is expressed as a percentage of the estimated value. It has traditionally been used for comparing the relative accuracy of the equations, although it is less useful for GLS regressions.

The standard error of prediction (SEP) is an estimate of the accuracy of the result of applying a

regression equation to a set of independent variables. It accounts for the regression error and the uncertainty of the coefficients of the independent variables. It varies from site to site because it is a function of the basin characteristics at a site.

Hardison (1971) presented an equation that defines the equivalent years of record (EY) represented by the regression equation. The EY is the ratio of the mean variance of the logarithms of the annual peak to the mean square error of prediction, multiplied by a factor dependent on the recurrence interval. It is an estimate of the number of years of record that would be needed at a site to compute a peak flow at that recurrence interval with the same confidence interval.

The 90 percent confidence interval is another measure of the uncertainty of the predicted value. It is the estimated value multiplied or divided by a factor that is dependent on the mean SEP and the critical value of the t-distribution for a particular model. The information necessary to compute prediction intervals are in the file predict.dat on the disk included with this report.

The accuracy of the estimating equation is limited by the variance and bias of the input data. Variance is a measure of the random variation about the true value, and bias is the consistent deviation of the value from the true value.

The accuracy of the regression estimate is affected by errors in the independent variables. Errors in quantifying the drainage-basin characteristics result from an inability to completely describe the effect of those characteristics. For example, the effects of wetlands and lakes depend on their size and location in the basin and in the stream channels, but the independent variable storage is simply expressed as a percentage of total drainage area without regard to size or location.

Bias of an estimate can result from systematic errors in the computation of the dependent variable. Bias in the computation of the dependent variable is probably the result of collecting peak-flow data over a period of time that does not reflect the long-term population of peak flows. Most short-term records at streamflow gaging stations used in this analysis were from the 1960-85 and current (through 1995) periods. The derived peak-flow statistics reflect those periods, which may not be representative of the long-term conditions.

The accuracy of an estimate made using the techniques presented in this report can also be affected by the user. Each user will make certain decisions based on his or her best judgement about the actual outline of the drainage basin, the path of the main channel, interpolation of generalized runoff, and the source of lake and wetland data. These individual sources of error can be reduced by use of shared computer data sets that are updated as improved information becomes available and the use of geographic information systems that provide consistent results.

The accuracy of peak-flow estimates made at sites immediately downstream of a lake or ponding area where the storage capacity could substantially alter peak-flow characteristics can be improved by a routing adjustment. In such places, the frequency relations could be used as an aid in developing a hydrograph of the inflow and then a simulation of that flow can be routed through the lake to determine the peak of the outflow.

The values of the independent variables used in this analysis were all computed from consistent data sets using a GIS or spatial interpolation software. It is expected that careful analysis using 7 1/2-minute USGS topographic maps should provide accurate estimates of drainage area, main-channel slope, percent storage, and percent lake. Interpolation of generalized runoff from figure 2 can be improved by using runoff data from table 2 in conjunction with data for nearby streamflow gaging stations.

Multi-collinearity among the independent variables can have adverse effects on the accuracy of coefficients of those variables in the regression equation (Helsel and Hirsch, 1992). Freund and Minton (1979) indicated that predictions from regressions where the independent variables exhibit multi-collinearity are reliable where the correlation structure of the predicted site is similar to that of the data used to construct the regression equation. This condition likely is true for any site in Minnesota using any of the techniques for predicting peak flow described herein.

Collinearity can be intrinsic in the data, such as the relation between main-channel slope and drainage area, or introduced in the computation of variables, such as percent storage and percent lake. The correlation (a measure of collinearity) between slope and drainage area is about -.85 for regions in Minnesota. The correlation between percent storage and percent lake is less than 0.6 for regions in Minnesota. A measure of multi-collinearity is



the variance inflation factor (VIF). Helsel and Hirsch (1992) stated that VIFs of less than 10 were not a concern in multiple linear regression analyses. The VIF for each independent variable in each regional regression equation in this study was less than 8.

Peak-flow-frequency equations presented in this report can be used to estimate the peak flows of several recurrence intervals on most small streams in Minnesota. The applicability and accuracy of these relations depend partly on whether the basin characteristics of the site are within the range of the characteristics used to define the peak-flow equations. The range in sampled basin characteristics is large enough to allow the application of the equations at most sites where streamflow is not affected by regulation, diversion, or urbanization. The upper and lower value and geometric mean for each basin characteristic for each region are listed in table 5.

Table 5.--Upper and lower values and geometric mean of the independent variables used in the regional regression analysis for each region.  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile]

	Drainage area (mi <sup>2</sup> )	Main- channel slope (ft/mi)	Storage (percent)	Lake (percent)
REGION A				
Upper	1560	36.7	72	10
Mean	82	6.2	17	.7
Lower	1.2	1.3	0.1	.0
REGION B				
Upper	1680	251	95	26
Mean	66	5.9	26	2.2
Lower	.4	.4	1.7	.0
REGION C				
Upper	609	214	46	21
Mean	19	33	18	1.4
Lower	.5	4.5	0.8	.0
REGION D				
Upper	2640	219	44	23
Mean	26	9.6	4.8	.9
Lower	.1	.9	.0	.0
REGION E				
Upper	790	122	5.7	2.4
Mean	14	16	.8	.1
Lower	.2	4.0	.0	.0
REGION F				
Upper	1540	237	4.1	.7
Mean	25	20	1.1	.1
Lower	.1	3.1	.0	.0

The geometric mean is included because it best represents the mean of the data. Where runoff is included as an independent variable, the range of those data is sufficient to ensure that any value in that region is within the range. The program will issue a warning message if the predicted peak flow is an extrapolation beyond the data on which the prediction is based

## SUMMARY

This report (1) documents the analytical techniques used for annual series peak-flow-frequency computations, basin characterization, regionalization, and development of equations for estimating peak flows on small drainage basins; (2) presents peak-flow data and basin characteristics at streamflow gaging stations; and (3) discusses techniques for estimating peak flow at ungaged sites on small, unregulated streams in Minnesota.

Two statistically derived techniques, regional regression equation and region of influence regression, for estimating peak flow on small, ungaged streams in Minnesota were developed. Both of the techniques relate physical and climatic characteristics to peak flows for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. Regional regression equations were developed for each recurrence interval in each of the six regions in Minnesota. The region of influence regression technique dynamically selects stations with characteristics similar to site of interest. Two methods of selecting streamflow gaging stations, similarity and proximity, can be used in the region of influence regression technique. Thus, the region of influence regression technique allows use of a potentially unique set of stations for estimating peak flow at each site of interest.

The regional regression equation technique is preferable as a first estimate of peak flow in regions C, E, and F. The similarity method of the region of influence regression technique is preferable as a first estimate in regions A and D. The proximity method should be used as a first estimate in region B.

Tables showing the peak-flow-frequency data and basin characteristics for streamflow gaging stations, and regional peak-flow prediction equations are documented in the report and in the Supplemental Information section.

## SELECTED REFERENCES

- Akima, H., 1978, Bivariate interpolation and smooth surface fitting for irregularly distributed data points: Association for Computing Machinery, Transactions on Mathematical Software, v. 4, no. 2, p. 160-164.
- Burn, D.H., 1990, Evaluation of regional flood frequency analysis with a region of influence approach: Water Resources Research, v. 26, no. 10, p. 149-165.
- Freund, R.J. and Minton, P.D., 1979, Regression methods, a tool for data analysis: Marcel Dekker, Inc. New York, 261 p.
- Gebert, W.A., Graczyk, K.J., and Krug, W.R., 1985, Average annual runoff in the United States, 1951-80: U.S. Geological Survey Open-File Report 85-627, 1 sheet, scale 1:2,000,000.
- Guetzkow, L.C., 1977, Techniques for estimating magnitude and frequency of floods in Minnesota: U.S. Geological Survey Water-Resources Investigations 77-31, 33 p.
- Hardison, C.H., 1971, Prediction of error of regression estimates of streamflow characteristics at gaged sites: U.S. Geological Survey Professional Paper 750-C, p. C228-C236.
- Helsel, D.R. and Hirsch, R.M., 1992, Statistical methods in water resources: Elsevier, Amsterdam, The Netherlands, 522 p.
- Hodge, S.A. and Tasker, G.D., 1995, Magnitude and frequency of floods in Arkansas: U.S. Geological Survey Water-Resources Investigations Report 95-4224, 275 p.
- Jacques, J.E. and Lorenz, D.L., 1987, Techniques for estimating the magnitude and frequency of floods in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 87-4170, 48 p.
- Lorenz, D.L., 1997, Generalized skew coefficients for flood-frequency analysis in Minnesota: U.S. Geological Survey Open-File Report 97-4089, 15 p.
- Lorenz, D.L., and Payne, G.A., 1989, Selected data describing stream subbasins in the Redwood River Basin, southwestern Minnesota: U.S. Geological Survey Open-File Report 89-405, 5 p., 1 plate, scale 1:100,000.
- \_\_\_\_\_, 1991a, Selected data for stream subbasins in the Le Sueur River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report 91-62, 8 p., 1 plate, scale 1:100,000.
- \_\_\_\_\_, 1991b, Selected data for stream subbasins in the Watonwan River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report 91-61, 7 p., 1 plate, scale 1:100,000.
- \_\_\_\_\_, 1992, Physical characteristics of stream subbasins in the Blue Earth River Basin, south-central Minnesota and north-central Iowa: U.S. Geological Survey Open-File Report 91-512, 10 p., 1 plate, scale 1:100,000.
- \_\_\_\_\_, 1994, Physical characteristics of stream subbasins in the Pomme de Terre River Basin, west-central Minnesota: U.S. Geological Survey Open-File Report 93-47, 8 p., 1 plate, scale 1:100,000.
- Lorenz, D.L., Sanocki, C.A., and Winterstein, T.A., 1994, Physical characteristics of stream subbasins in the Lac qui Parle River Basin, southwestern Minnesota and eastern South Dakota: U.S. Geological Survey Open-File Report 93-46, 12 p., 1 plate, scale 1:100,000.
- Minnesota Department of Transportation, 1997, Basemap '97: Office of Land Management, Surveying and Mapping Section, 1 compact disk.
- Patterson, J.L., and Gambel, G.R., 1968, Magnitude and frequency of floods in the United States, Part 5: U.S. Geological Survey Water-Supply Paper 1678, 546 p.
- Prior, C.H., 1949, Magnitude and frequency of floods in Minnesota: Minnesota Department of Conservation, Division of Waters Bulletin 1, 128 p.
- Prior, C.H. and Hess, J.H., 1961, Floods in Minnesota--Magnitude and frequency: Minnesota Department of Conservation, Division of Waters Bulletin 12, 142 p.
- Sanocki, C.A., 1995a, Physical characteristics of stream subbasins in the Cottonwood River Basin, southwestern Minnesota: U.S. Geological Survey

- Open-File Report 95-333, 14 p., 1 plate, scale 1:100,000.
- Sanocki, C.A., 1995b, Physical characteristics of stream subbasins in the Upper Minnesota River Basin, west-central Minnesota, northeastern South Dakota, and southeastern North Dakota: U.S. Geological Survey Open-File Report 95-162, 16 p., 1 plate, scale 1:100,000.
- Sanocki, C.A., 1996a, Physical characteristics of stream subbasins in the Middle Minnesota-Little Cottonwood River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report 96-631, 13 p., 1 plate, scale 1:100,000.
- Sanocki, C.A., 1996b, Physical characteristics of stream subbasins in the Hawk Creek-Yellow Medicine River Basin, southwestern Minnesota and Eastern South Dakota: U.S. Geological Survey Open-File Report 96-632, 21 p., 1 plate, scale 1:100,000.
- Sanocki, C.A., 1997a, Physical characteristics of stream subbasins in the Lower Minnesota River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report 97-205, 16 p., 1 plate, scale 1:100,000.
- Sanocki, C.A., in press, Physical characteristics of stream subbasins in the North Fork Crow River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report.
- Sanocki, C.A., in press, Physical characteristics of stream subbasins in the South Fork Crow River Basin, south-central Minnesota: U.S. Geological Survey Open-File Report.
- Sanocki, C.A., and Krumrie, J.R., 1994, Physical characteristics of stream subbasins in the Chippewa River Basin, west-central Minnesota: U.S. Geological Survey Open-File Report 94-488, 16 p., 1 plate, scale 1:100,000.
- Stedinger, J.D., and Tasker, G.D., 1985, Regional hydrologic analysis 1--Ordinary, weighted, and generalized least squares compared: *Water Resources Research*, v. 21, no. 9, p. 1421-1432.
- Tasker, G.D., Eychaner, J.H., and Stedinger, J.R., 1986, Application of generalized least squares in hydrologic regression analysis, *in* *Selected Papers in the Hydrologic Sciences: U.S. Geological Survey Water-Supply Paper 2310*, p. 107-115.
- Tasker, G.D., and Stedinger, J.D., 1989, An operational GLS model for hydrologic regression: *Journal of Hydrology*, v. 111, no. xx, p. 361-375.
- U.S. Water Resources Council, 1982, Guidelines for determining flood flow frequency, revised September 1981, Editorial corrections March 1982: *Hydrology Committee Bulletin 17B*, Washington, D.C., 190 p., 1 plate.
- Wiitala, S.W., 1965, Magnitude and frequency of floods in the United States, Part 4: U.S. Geological Survey Water-Supply Paper 1677, 357 p.



## **Supplemental Information**



Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
1	C	04010500	Pigeon River at Middle Falls near Grand Portage, Minnesota	4360	6130	7390	9090	10400	11900	
2	C	04011370	Little Devil Track River near Grand Marais, Minnesota	146	246	327	447	549	664	
3	C	04011390	Little Devil Track River Tributary near Grand Marais, Minnesota	12.8	26.8	40.9	66.4	92.3	126	
4	C	04011990	Cascade River near Grand Marais, Minnesota	712	948	1110	1340	1510	1690	
5	C	04012500	Poplar River at Lutsen, Minnesota	865	1340	1710	2260	2740	3260	
6	C	04013100	Lake Superior Tributary near Taconite Harbor, Minnesota	74.9	167	267	461	672	959	
7	C	04013200	Caribou River near Little Marais, Minnesota	541	1000	1450	2220	2990	3960	
8	C	04014500	Baptism River near Beaver Bay, Minnesota	2380	3850	5080	6980	8670	10600	
9	C	04015150	Crow Creek near Silver Creek, Minnesota	40.1	75.0	109	169	228	304	
10	C	04015250	Silver Creek Tributary near Two Harbors, Minnesota	300	579	846	1300	1750	2310	
11	C	04015300	Little Stewart River near Two Harbors, Minnesota	169	256	326	430	520	621	
12	C	04015330	Knife River near Two Harbors, Minnesota	2850	4090	5020	6330	7390	8540	
13	C	04015360	Lake Superior Tributary #2 at French River, Minnesota	143	315	497	833	1190	1650	
14	C	04015370	Talmadge River at Duluth, Minnesota	247	432	598	864	1110	1410	
15	B	04015400	Miller Creek at Duluth, Minnesota	231	357	447	567	660	757	
16	B	04015500	Second Creek near Aurora, Minnesota	122	1659	196	237	270	305	
17	B	04016000	Partridge River near Aurora, Minnesota	939	1610	2110	2810	3370	3960	
18	B	04016500	St. Louis River near Aurora, Minnesota	1430	2160	2700	3470	4090	4760	
19	B	04017000	Embarrass River at Embarrass, Minnesota	570	994	1330	1820	2220	2660	
20	B	04017700	McKinley Lake Tributary at McKinley, Minnesota	12.5	24.4	34.1	48.2	59.9	72.5	
21	B	04018800	East Two River Tributary at Virginia, Minnesota	53.8	73.0	85.7	102	114	126	
22	B	04018900	East Two River near Iron Junction, Minnesota	334	502	617	763	873	984	
23	B	04019000	West Two River near Iron Junction, Minnesota	543	799	966	1170	1320	1470	
24	B	04019500	East Swan River near Toivola, Minnesota	1180	1530	1750	2010	2200	2380	
25	B	04020480	North Branch Whiteface River near Fairbanks, Minnesota	167	291	392	543	672	817	
26	B	04020700	Bug Creek at Shaw, Minnesota	287	397	469	560	628	695	
27	B	04021690	Cloquet River near Toimi, Minnesota	525	755	930	1180	1380	1600	
28	C	04024095	Nemadji River near Holyoke, Minnesota	1730	2500	3050	3790	4380	5000	
29	C	04024098	Deer Creek near Holyoke, Minnesota	360	764	1150	1800	2430	3190	
30	C	04024100	Rock Creek near Blackhoof, Minnesota	445	831	1150	1610	2010	2440	
31	C	04024110	Rock Creek Tributary near Blackhoof, Minnesota	18.4	35.9	51.0	74.4	95.1	119	
32	C	04024200	South Fork Nemadji River near Holyoke, Minnesota	740	1260	1650	2200	2630	3090	
33	B	05030000	Otter Tail River near Detroit Lakes, Minnesota	169	255	309	374	419	461	

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
34	B	05040000	Pelican River near Detroit Lakes, Minnesota	139	186	214	249	274	298	
35	B	05040500	Pelican River near Fergus Falls, Minnesota	299	475	607	789	936	1090	
36	B	05047700	West Branch Mustinka River Tributary near Graceville, Minnesota	31.6	75.4	119	192	261	344	
37	B	05049000	Mustinka River above Wheaton, Minnesota	841	2400	3980	6630	9060	11900	
38	B	05049200	Eighteen Mile Creek near Wheaton, Minnesota	179	644	1210	2300	3440	4880	
39	B	05050700	Rabbit River near Nashua, Minnesota	477	950	1310	1800	2190	2570	
40	A	05060800	Buffalo River near Callaway, Minnesota	235	445	604	820	989	1160	
41	A	05061000	Buffalo River near Hawley, Minnesota	660	1230	1650	2220	2660	3100	
42	A	05061200	Whisky Creek at Barnesville, Minnesota	145	271	374	527	657	799	
43	A	05061400	Spring Creek Above Downer, Minnesota	47.0	142	261	510	796	1200	
44	A	05061500	South Branch Buffalo River at Sabin, Minnesota	1070	2400	3580	5400	6980	8740	
45	A	05062000	Buffalo River near Dilworth, Minnesota	1370	3080	4660	7170	9430	12000	
46	A	05062280	Mosquito Creek near Bagley, Minnesota	31.8	59.8	80.2	107	127	146	
47	A	05062470	Marsh Creek Tributary near Mahnomen, Minnesota	118	244	344	481	589	700	
48	A	05062500	Wild Rice River at Twin Valley, Minnesota	1330	2700	3810	5380	6640	7980	
49	A	05062700	Wild Rice River Tributary near Twin Valley, Minnesota	90.5	175	237	318	379	440	
50	A	05062800	Coon Creek near Twin Valley, Minnesota	472	1240	1930	2960	3800	4690	
51	A	05063200	Spring Creek Tributary near Ogema, Minnesota	54.7	81.1	97.5	117	130	143	
52	A	05064000	Wild Rice River at Hendrum, Minnesota	2520	4460	5910	7900	9460	11100	
53	A	05067500	Marsh River near Shelly, Minnesota	953	2190	3190	4560	5610	6670	
54	A	05069000	Sand Hill River at Climax, Minnesota	1030	2070	2910	4090	5040	6040	
55	A	05073600	South Branch Battle River at Northome, Minnesota	53.3	80.7	99.4	123	141	158	
56	A	05073750	Spring Creek near Blackduck, Minnesota	80.9	171	256	395	525	679	
57	A	05073800	Perry Creek near Shooks, Minnesota	35.3	60.9	79.6	105	124	145	
58	A	05075700	Mud River near Grygla, Minnesota	753	1060	1250	1480	1650	1810	
59	A	05076000	Thief River near Thief River Falls, Minnesota	1420	2630	3420	4350	4970	5520	
60	A	05076600	Red Lake River Tributary near Thief River Falls, Minnesota	74.9	121	153	196	229	262	
61	A	05077700	Ruffy Brook near Gonvick, Minnesota	193	299	365	443	496	546	
62	A	05078000	Clearwater River at Plummer, Minnesota	1370	2260	2900	3750	4420	5100	
63	A	05078100	Lost River at Gonvick, Minnesota	150	244	304	376	426	474	
64	A	05078180	Silver Creek near Clearbrook, Minnesota	55.1	98.6	128	163	187	210	
65	A	05078200	Silver Creek Tributary at Clearbrook, Minnesota	54.5	93.6	121	158	185	212	
66	A	05078230	Lost River at Oklee, Minnesota	1110	2010	2640	3440	4030	4600	



Table 1.--Peak-flow frequency data for streamflow gaging stations.

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s					
				2-year	5-year	10-year	25-year	50-year	100-year
67	A	05078400	Clearwater River Tributary near Plummer, Minnesota	51.5	101	141	201	252	307
68	A	05078500	Clearwater River at Red Lake Falls, Minnesota	3020	5300	6980	9210	10900	12700
69	A	05079901	Burnham Creek near Crookston, Minnesota	421	1080	1700	2670	3510	4450
70	A	05086900	Middle River near Newfolden, Minnesota	222	470	673	961	1190	1440
71	A	05087500	Middle River at Argyle, Minnesota	783	1700	2400	3310	3990	4640
72	A	05094000	South Branch Two Rivers at Lake Bronson, Minnesota	1310	2350	3090	4070	4800	5530
73	A	05095500	Two Rivers Below Hallock, Minnesota	942	1850	2530	3450	4150	4860
74	A	05096000	North Branch Two Rivers near Lancaster, Minnesota	84.9	253	419	685	919	1180
75	A	05096500	State Ditch #85 near Lancaster, Minnesota	136	275	394	573	727	898
76	A	05104000	South Fork Roseau River near Malung, Minnesota	453	997	1420	1980	2410	2830
77	A	05104500	Roseau River Below South Fork near Malung, Minnesota	1590	3170	4310	5760	6810	7820
78	A	05106000	Sprague Creek near Sprague, Manitoba, Canada	549	1130	1550	2090	2490	2860
79	A	05107000	Pine Creek near Pine Creek, Minnesota	293	533	697	899	1040	1180
80	A	05107500	Roseau River at Ross, Minnesota	1620	2830	3680	4760	5560	6340
81	A	05112000	Roseau River Below State Ditch 51 near Caribou, Minnesota	1600	2280	2660	3090	3360	3610
82	B	05124480	Kawishiwi River near Ely, Minnesota	981	1330	1550	1820	2010	2200
83	B	05124500	Isabella River near Isabella, Minnesota	1880	2990	3820	4970	5910	6900
84	B	05125500	Stony River near Isabella, Minnesota	807	1310	1710	2280	2760	3280
85	B	05125550	Stony River near Babbitt, Minnesota	1020	1470	1780	2200	2530	2870
86	B	05126000	Dunka River near Babbitt, Minnesota	326	510	650	848	1010	1190
87	B	05126500	Bear Island River near Ely, Minnesota	235	332	395	475	533	591
88	B	05127205	Burnside River near Ely, Minnesota	244	322	373	438	486	535
89	B	05127210	Armstrong Creek near Ely, Minnesota	53.8	78.5	97.0	123	144	167
90	B	05127215	Longstorff Creek near Ely, Minnesota	98.4	141	172	214	249	286
91	B	05127220	Burgo Creek near Ely, Minnesota	82.5	181	281	462	645	880
92	B	05128300	Pike River near Gilbert, Minnesota	22.7	38.0	50.5	69.1	85.1	103
93	B	05128500	Pike River near Embarrass, Minnesota	724	1180	1540	2070	2520	3030
94	B	05128700	Pike River Tributary near Wahlsten, Minnesota	47.2	72.8	91.2	116	136	156
95	B	05129000	Vermilion River below Vermilion Lk near Tower, Minnesota	1080	1540	1840	2230	2510	2800
96	B	05129115	Vermilion River near Crane Lake, Minnesota	2340	3230	3800	4510	5030	5540
97	B	05129650	Little Fork River at Cook, Minnesota	527	858	1130	1530	1870	2260
98	B	05129710	Johnson Creek near Britt, Minnesota	25.8	31.7	35.1	39.2	42.0	44.7
99	B	05130300	Borin Creek near Chisholm, Minnesota	173	298	397	539	657	785

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s					
				2-year	5-year	10-year	25-year	50-year	100-year
100	B	05130500	Sturgeon River near Chisholm, Minnesota	1010	1530	1910	2440	2860	3310
101	B	05131000	Dark River near Chisholm, Minnesota	307	503	661	891	1090	1300
102	B	05131500	Little Fork River at Littlefork, Minnesota	9020	13700	16900	21100	24300	27500
103	B	05131750	Big Fork River near Bigfork, Minnesota	1270	1780	2100	2490	2770	3040
104	B	05131878	Bowerman Brook near Craigville, Minnesota	244	431	577	783	951	1130
105	B	05132000	Big Fork River at Big Falls, Minnesota	5340	8580	10800	13700	15900	18100
106	B	05134100	North Branch Rapid River near Baudette, Minnesota	417	700	895	1140	1320	1500
107	B	05134200	Rapid River near Baudette, Minnesota	2930	4800	6050	7580	8680	9750
108	B	05137000	Winter Road River near Baudette, Minnesota	439	863	1190	1630	1970	2320
109	B	05139500	Warroad River near Warroad, Minnesota	601	1180	1620	2210	2660	3110
110	B	05140000	Bulldog Run near Warroad, Minnesota	142	336	490	693	845	993
111	B	05140500	East Branch Warroad River near Warroad, Minnesota	336	662	908	1240	1490	1740
112	B	05200200	Hennepin Creek near Becida, Minnesota	79.2	135	179	243	297	356
113	B	05200445	Mississippi River at Bemidji, Minnesota	540	865	1110	1430	1690	1970
114	B	05205200	Boy River near Remer, Minnesota	350	539	670	842	972	1110
115	B	05210200	Smith Creek near Hill City, Minnesota	79.7	171	253	379	491	618
116	B	05212700	Prairie River near Taconite, Minnesota	1320	2230	2920	3870	4630	5440
117	B	05216700	O'Brien Creek near Nashwauk, Minnesota	76.7	97.2	109	124	133	142
118	B	05216980	Swan River Tributary at Warba, Minnesota	37.4	55.7	67.5	81.9	92.2	102
119	B	05217000	Swan River near Warba, Minnesota	753	1140	1430	1830	2160	2520
120	B	05217700	Bluff Creek near Jacobson, Minnesota	34.3	63.9	87.6	122	150	180
121	B	05221020	Willow River Below Palisade, Minnesota	1600	2450	3030	3770	4320	4880
122	B	05229450	Pine River near Pine River, Minnesota	598	857	1030	1260	1440	1610
123	B	05241500	Rabbit River near Crosby, Minnesota	22.0	39.8	53.7	73.3	89.3	106
124	B	05244000	Crow Wing River at Nimrod, Minnesota	1270	1940	2410	3030	3520	4010
125	B	05244100	Kitten Creek near Sebek, Minnesota	104	204	287	411	517	633
126	B	05244200	Cat River near Nimrod, Minnesota	176	304	403	541	654	774
127	B	05244440	Leaf River near Aldrich, Minnesota	1700	3020	4040	5470	6630	7850
128	B	05245100	Long Prairie River at Long Prairie, Minnesota	762	1250	1630	2170	2610	3100
129	B	05245800	Sevenmile Creek near Pillager, Minnesota	95.5	172	233	321	394	474
130	B	05261520	Nokasippi River Below Fort Ripley, Minnesota	405	684	886	1150	1360	1570

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
131	D	05267800	Big Mink Creek Tributary near Lastrup, Minnesota	11.8	27.9	43.0	67.4	89.4	115	
132	D	05267900	Hillman Creek near Pierz, Minnesota	438	998	1480	2200	2800	3450	
133	D	05268000	Platte River at Royalton, Minnesota	1250	2300	3040	3980	4670	5350	
134	D	05270150	Ashley Creek near Sauk Centre, Minnesota	289	471	597	758	878	997	
135	D	05270300	Sauk River Tributary at Spring Hill, Minnesota	175	353	525	818	1100	1460	
136	D	05270310	Sauk River Tributary #2 near St. Martin, Minnesota	25.0	68.0	118	219	330	483	
137	D	05270500	Sauk River near St. Cloud, Minnesota	1490	2640	3530	4780	5790	6870	
138	D	05271800	Johnson Creek Tributary at Luxemburg, Minnesota	33.2	62.6	88.0	127	162	201	
139	D	05272000	Johnson Creek Tributary #2 near St. Augusta, Minnesota	84.1	144	188	250	299	351	
140	D	05272300	Johnson Creek near St. Augusta, Minnesota	295	580	819	1180	1480	1820	
141	D	05272950	Clearwater River near South Haven, Minnesota	296	669	992	1480	1880	2330	
142	D	05273700	Otsego Creek near Otsego, Minnesota	91.3	164	219	295	355	418	
143	D	05274200	Stony Brook Tributary near Foley, Minnesota	44.5	96.6	142	210	269	334	
144	D	05275000	Elk River near Big Lake, Minnesota	1580	2980	3990	5310	6290	7260	
145	D	05276000	North Fork Crow River near Regal, Minnesota	816	1250	1560	1970	2290	2610	
146	D	05276100	North Fork Crow River Tributary near Paynesville, Minnesota	19.1	35.5	48.7	67.9	84.0	101	
147	D	05276200	North Fork Crow River at Paynesville, Minnesota	791	1390	1850	2490	3000	3550	
148	D	05278000	Middle Fork Crow River near Spicer, Minnesota	203	347	447	572	664	753	
149	D	05278120	North Fork Crow River near Kingston, Minnesota	1710	3570	5100	7300	9090	11000	
150	D	05278350	Fountain Creek near Montrose, Minnesota	50.7	78.5	99.9	131	156	184	
151	D	05278500	South Fork Crow River at Cosmos, Minnesota	339	682	986	1460	1890	2390	
152	D	05278700	Otter Creek near Lester Prairie, Minnesota	113	222	315	453	572	704	
153	D	05278750	Otter Creek Tributary near Lester Prairie, Minnesota	28.7	46.4	58.7	74.5	86.4	98.2	
154	D	05278850	Buffalo Creek Tributary near Brownton, Minnesota	34.2	63.2	86.0	118	145	173	
155	D	05278930	Buffalo Creek near Glencoe, Minnesota	1210	2210	3020	4170	5120	6160	
156	D	05279000	South Fork Crow River near Mayer, Minnesota	2140	4460	6400	9290	11700	14400	
157	D	05280000	Crow River at Rockford, Minnesota	3540	6990	9680	13400	16300	19400	
158	D	05280300	School Lake Creek Tributary near St. Michael, Minnesota	30.8	70	110	179	248	333	
159	D	05284100	Mille Lacs Lake Tributary near Wealthwood, Minnesota	13.8	29.7	43.5	64.4	82.3	102	
160	D	05284600	Robinson Brook near Onamia, Minnesota	88.8	176	241	327	393	458	
161	D	05284620	Rum River Tributary near Onamia, Minnesota	56.2	111	160	237	306	387	

Table 1.--Peak-flow frequency data for streamflow gaging stations.

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
162	D	05284920	Stanchfield Creek Tributary near Day, Minnesota	36.0	68.7	94.4	130	159	190	
163	D	05287890	Elm Creek near Champlin, Minnesota	281	480	615	784	906	1020	
164	D	05289500	Minnehaha Creek at Minnetonka Mills, Minnesota	65.7	174	279	450	604	780	
165	D	05290000	Little Minnesota River Near Peever, SD	770	1840	2880	4600	6200	8080	
166	D	05291000	Whetstone River Near Big Stone City, SD	1290	3470	5500	8640	11300	14200	
167	D	05293000	Yellow Bank River near Odessa, Minnesota	1270	2970	4410	6490	8170	9940	
168	D	05294000	Pomme De Terre River at Appleton, Minnesota	729	1530	2230	3280	4200	5220	
169	D	05299100	Lazarus Creek Tributary near Canby, Minnesota	111	301	478	748	975	1220	
170	D	05300000	Lac Qui Parle River near Lac Qui Parle, Minnesota	1620	3750	5720	8880	11700	15000	
171	D	05301200	Minnesota River Tributary near Montevideo, Minnesota	6.9	25.4	48.7	95.6	146	213	
172	D	05302500	Little Chippewa River near Starbuck, Minnesota	114	181	226	282	323	363	
173	D	05302970	Outlet Creek Tributary near Starbuck, Minnesota	10	20.7	29.8	43.1	54.3	66.3	
174	D	05303450	Hassel Creek near Clontarf, Minnesota	53.5	93.8	128	179	224	275	
175	D	05304000	Shakopee Creek near Benson, Minnesota	765	2120	3490	5810	7980	10500	
176	D	05304500	Chippewa River near Milan, Minnesota	1960	4090	5880	8560	10800	13300	
177	D	05305000	Chippewa River near Watson, Minnesota	512	2200	4620	10100	16500	25500	
178	D	05305200	Spring Creek near Montevideo, Minnesota	113	267	405	620	806	1010	
179	D	05311200	North Branch Yellow Medicine River near Ivanhoe, Minnesota	89.0	268	454	772	1070	1410	
180	D	05311250	North Branch Yellow Medicine River Tributary near Wilno, Minnesota	16.9	32.8	44.9	61.3	74.0	86.9	
181	D	05311300	North Branch Yellow Medicine Tributary #2 near Porter, Minnesota	93.0	137	168	210	242	276	
182	D	05311400	South Branch Yellow Medicine River at Minneota, Minnesota	637	1470	2210	3340	4310	5380	
183	D	05313500	Yellow Medicine River near Granite Falls, Minnesota	1430	3880	6250	10000	13400	17100	
184	D	05313800	Kandiyohi County Ditch #16 near Blomkest, Minnesota	32.2	61.6	83.9	114	138	162	
185	D	05314500	Hawk Creek near Maynard, Minnesota	1520	2500	3210	4150	4880	5620	
186	D	05314900	Redwood River at Ruthton, Minnesota	117	279	421	632	808	996	
187	D	05315000	Redwood River near Marshall, Minnesota	722	1720	2640	4080	5360	6790	
188	D	05315200	Prairie Ravine near Marshall, Minnesota	38.5	77.9	110	156	194	234	
189	D	05316500	Redwood River near Redwood Falls, Minnesota	1180	3350	5550	9230	12600	16500	
190	D	05316550	West Fork Beaver Creek near Olivia, Minnesota	73.7	149	211	303	380	464	
191	D	05316570	Beaver Creek near Beaver Falls, Minnesota	718	1120	1400	1770	2040	2320	



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[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
192	D	05316690	Spring Creek Tributary near Sleepy Eye, Minnesota	39.0	78.3	110	154	190	228	
193	D	05316700	Spring Creek near Sleepy Eye, Minnesota	206	423	606	879	1110	1360	
194	D	05316800	Cottonwood River Tributary near Balaton, Minnesota	36.8	117	204	359	508	687	
195	D	05316850	Meadow Creek Tributary near Marshall, Minnesota	17.2	54.1	95.1	169	241	329	
196	D	05316900	Dry Creek near Jeffers, Minnesota	133	298	448	683	892	1130	
197	D	05316920	Cottonwood River Tributary near Sanborn, Minnesota	28.1	65.4	99.6	153	201	255	
198	D	05316950	Cottonwood River near Springfield, Minnesota	2870	5730	8130	11700	14700	18000	
199	D	05317000	Cottonwood River near New Ulm, Minnesota	3230	6880	10200	15600	20500	26300	
200	D	05317200	Little Cottonwood River near Courtland, Minnesota	508	1000	1430	2090	2670	3340	
201	D	05317845	East Branch Blue Earth River near Walters, Minnesota	369	468	527	594	641	685	
202	D	05317850	Foster Creek near Alden, Minnesota	90.3	166	219	288	338	388	
203	D	05318000	East Branch Blue Earth River near Briceyn, Minnesota	373	761	1070	1510	1860	2220	
204	D	05318100	East Branch Blue Earth River Tributary near Blue Earth, Minnesota	151	288	398	555	685	824	
205	D	05318300	Watowan River near Delft, Minnesota	104	329	606	1170	1790	2630	
206	D	05318897	South Fork Watowan River near Ormsby, Minnesota	450	1020	1520	2270	2910	3620	
207	D	05319490	Watowan River Above Garden City, Minnesota	3280	5340	6820	8780	10300	11800	
208	D	05319500	Watowan River near Garden City, Minnesota	2750	5160	7230	10400	13200	16400	
209	D	05320000	Blue Earth River near Rapidan, Minnesota	6200	11800	16200	22300	27300	32500	
210	D	05320200	Le Sueur River Tributary near Mankato, Minnesota	19.3	47.3	77.8	135	196	276	
211	D	05320300	Cobb River Tributary near Mapleton, Minnesota	133	222	291	390	471	560	
212	D	05320400	Maple River Tributary near Mapleton, Minnesota	140	348	567	963	1360	1870	
213	D	05320440	Judicial Ditch #49 near Amboy, Minnesota	183	317	423	577	706	847	
214	D	05320480	Maple River near Rapidan, Minnesota	2080	3080	3710	4470	5000	5510	
215	D	05320500	Le Sueur River near Rapidan, Minnesota	4190	8010	11200	15800	19700	24100	
216	D	05325100	Minnesota River Tributary near North Mankato, Minnesota	67.0	195	347	646	972	1410	
217	D	05326100	Middle Branch Rush River near Gaylord, Minnesota	546	906	1150	1470	1700	1930	
218	D	05327000	High Island Creek near Henderson, Minnesota	936	1670	2200	2880	3390	3890	
219	D	05330150	Sand Creek Tributary near Montgomery, Minnesota	20.6	32.3	41.2	53.7	63.8	74.7	
220	D	05330200	Rice Lake Tributary near Montgomery, Minnesota	49.9	88.4	118	158	189	223	
221	D	05330300	Sand Creek near New Prague, Minnesota	259	474	646	896	1100	1330	
222	D	05330550	East Branch Raven Stream near New Prague, Minnesota	164	272	359	489	601	726	

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
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Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
223	D	05330600	Sand Creek Tributary #2 near Jordan, Minnesota	47.0	97.4	145	224	299	389	
224	D	05330800	Purgatory Creek at Eden Prairie, Minnesota	106	144	167	196	216	235	
225	D	05330900	Nine Mile Creek at Bloomington, Minnesota	198	314	395	501	582	664	
226	D	05335170	Crooked Creek near Hinckley, Minnesota	598	1160	1600	2220	2730	3260	
227	D	05336200	Glaitsby Brook near Kettle River, Minnesota	415	694	900	1180	1400	1630	
228	D	05336300	Moose River Tributary at Moose Lake, Minnesota	72.5	146	210	310	398	498	
229	D	05336550	Wolf Creek Tributary near Sandstone, Minnesota	53.6	124	186	278	356	441	
230	D	05336600	Kettle River Tributary at Sandstone, Minnesota	16.4	34.4	49.2	70.6	88.1	107	
231	D	05336700	Kettle River Below Sandstone, Minnesota	6520	10100	12600	15700	18000	20300	
232	D	05338200	Mission Creek near Hinckley, Minnesota	73.0	121	155	200	235	271	
233	D	05338500	Snake River near Pine City, Minnesota	4820	7670	9570	11900	13600	15300	
234	D	05339747	Goose Creek at Harris, Minnesota	157	288	383	506	598	689	
235	D	05340000	Sunearise River near Stacy, Minnesota	308	465	572	711	816	922	
236	D	05345000	Vermillion River near Empire, Minnesota	767	1700	2610	4160	5650	7470	
237	D	05345900	Vermillion River Tributary near Hastings, Minnesota	25.7	112	240	535	893	1410	
238	D	05348550	Cannon River Below Sabre Lake near Kilkenny, Minnesota	240	401	518	677	801	929	
239	D	05352700	Turtle Creek Tributary #2 near Pratt, Minnesota	56.8	120	174	251	316	385	
240	D	05352800	Turtle Creek Tributary near Steele Center, Minnesota	97.2	186	257	358	440	528	
241	D	05353800	Straight River near Faribault, Minnesota	2840	4370	5380	6630	7530	8410	
242	D	05355024	Cannon River at Northfield, Minnesota	4060	6430	7980	9870	11200	12500	
243	D	05355100	Little Cannon River Tributary near Kenyon, Minnesota	176	386	572	861	1110	1400	
244	D	05355150	Pine Creek near Cannon Falls, Minnesota	154	349	518	774	990	1230	
245	D	05355200	Cannon River at Welch, Minnesota	5920	10600	14500	20300	25300	30800	
246	D	05355230	Cannon River Tributary near Welch, Minnesota	20.3	43.2	62.3	90.2	113	138	
247	F	05372800	South Fork Zumbro River On Belt Line at Rochester, Minnesota	2140	4050	5680	8190	10400	12900	
248	F	05372930	Bear Creek at Rochester, Minnesota	1120	2360	3600	5750	7880	10500	
249	F	05372950	Silver Creek at Rochester, Minnesota	513	1200	1960	3460	5090	7320	
250	F	05372990	Cascade Creek at Rochester, Minnesota	578	1060	1440	1980	2430	2920	
251	F	05373080	Milliken Creek near Concord, Minnesota	323	480	583	710	803	894	
252	F	05373350	Zumbro River Tributary near South Troy, Minnesota	30.1	64.4	94.6	141	182	229	
253	F	05373700	Spring Creek near Wanamingo, Minnesota	431	951	1420	2140	2780	3510	

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[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
254	F	05373900	Trout Brook Tributary near Goodhue, Minnesota	90.4	184	270	413	547	708	
255	F	05374000	Zumbro River at Zumbro Falls, Minnesota	10400	17100	21700	27200	31200	35000	
256	F	05374400	Long Creek near Potsdam, Minnesota	196	370	513	724	902	1100	
257	F	05374500	Zumbro River at Theilman, Minnesota	12200	18000	21900	26600	30000	33400	
258	F	05376000	North Fork Whitewater River near Elba, Minnesota	1480	3640	5760	9340	12700	16700	
259	F	05376500	South Fork Whitewater River near Altura, Minnesota	1540	3100	4280	5830	7010	8180	
260	F	05376800	Whitewater River near Beaver, Minnesota	3260	6690	9510	13600	16900	20500	
261	F	05378300	Straight Valley Creek near Rollingstone, Minnesota	268	674	1050	1630	2140	2710	
262	F	05379000	Gilmore Creek at Winona, Minnesota	354	992	1680	2950	4210	5800	
263	F	05383600	North Branch Root River Tributary near Stewartville, Minnesota	68.2	153	232	358	472	604	
264	F	05383700	Mill Creek Tributary near Chatfield, Minnesota	405	595	723	885	1010	1130	
265	F	05383720	Mill Creek near Chatfield, Minnesota	1360	2650	3810	5700	7450	9520	
266	F	05383850	South Fork Bear Creek near Grand Meadow, Minnesota	683	1380	1980	2910	3730	4660	
267	F	05384000	Root River near Lanesboro, Minnesota	7800	13000	16700	21400	24900	28400	
268	F	05384100	Dushee Creek near Lanesboro, Minnesota	214	569	925	1530	2090	2750	
269	F	05384150	Root River Tributary near Whalan, Minnesota	27.6	67.4	107	173	236	311	
270	F	05384200	Gribben Creek near Whalen, Minnesota	610	1610	2680	4600	6530	8940	
271	F	05384300	Big Springs Creek near Arendahl, Minnesota	17.8	45.8	74.3	124	171	229	
272	F	05384350	Root River at Rushford, Minnesota	6270	10100	12900	16700	19700	22800	
273	F	05384400	Pine Creek near Arendahl, Minnesota	823	1890	2780	4060	5080	6160	
274	F	05384500	Rush Creek near Rushford, Minnesota	2060	4460	6550	9720	12400	15500	
275	F	05385000	Root River near Houston, Minnesota	9910	17000	22000	28600	33500	38500	
276	F	05385500	South Fork Root River near Houston, Minnesota	2420	5100	7470	11200	14400	18100	
277	F	05386000	Root River Below South Fork near Houston, Minnesota	13400	22200	28700	37700	44800	52200	
278	F	05387030	Crooked Creek at Freeburg, Minnesota	425	1050	1640	2590	3440	4410	
279	F	05457000	Cedar River near Austin, Minnesota	4030	6930	8860	11200	12800	14400	
280	F	05457080	Rose Creek Tributary near Dexter, Minnesota	99.8	196	280	411	527	660	
281	F	05457778	Little Cedar River near Johnsburg, Minnesota	1440	2420	3100	3980	4640	5300	
282	F	05458960	Bancroft Creek at Bancroft, Minnesota	237	395	513	674	802	936	
283	D	05474750	Beaver Creek Tributary #2 near Slayton, Minnesota	79.0	135	177	238	288	341	
284	D	05474760	Beaver Creek Tributary Above Slayton, Minnesota	52.9	94.2	125	166	197	230	

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
285	D	05475400	Warren Lake Tributary near Windom, Minnesota	42.5	103	166	280	396	543	
286	D	05475800	Des Moines River Tributary near Jackson, Minnesota	24.1	49.5	70.4	101	126	153	
287	D	05475900	Des Moines River Tributary #2 near Lakefield, Minnesota	73.7	120	153	194	226	258	
288	D	05476000	Des Moines River at Jackson, Minnesota	1710	3630	5290	7850	10100	12600	
289	D	05476010	Nelson Creek at Jackson, Minnesota	359	807	1240	1960	2640	3460	
290	D	05476100	Story Brook near Petersburg, Minnesota	646	1390	2040	3010	3840	4760	
291	D	05476900	Fourmile Creek near Dunnell, Minnesota	223	531	830	1330	1800	2350	
292	D	05476989	East Fork Des Moines River near Ceylon, Minnesota	517	960	1300	1770	2150	2540	
293	E	06479215	Big SIOUX RIVER near Florence, South Dakota	292	956	1650	2790	3820	4960	
294	E	06479240	Big Sioux River Tributary No 2 near Summit, South Dakota	8.9	24.5	40.4	67.5	93.1	123	
295	E	06479260	Big Sioux River Tributary No 3 near Summit, South Dakota	93.8	331	591	1040	1440	1910	
296	E	06479350	Soo Creek Tributary near South Shore, South Dakota	44.3	129	222	388	552	754	
297	E	06479515	Willow Creek near Watertown, South Dakota	698	1770	2830	4590	6240	8190	
298	E	06479529	Stray Horse Creek near Castlewood, South Dakota	832	2310	3910	6790	9660	13200	
299	E	06479640	Hidewood Creek near Estelline, South Dakota	905	2340	3830	6480	9100	12300	
300	E	06479750	Peg Munky Run near Estelline, South Dakota	259	793	1340	2240	3060	3980	
301	E	06479800	North Deer Creek near Estelline, South Dakota	171	711	1500	3330	5580	8870	
302	E	06479810	North Deer Creek Tributary near Brookings, South Dakota	24.3	79.4	144	268	396	559	
303	E	06479900	Sixmile Creek Tributary near Brookings, South Dakota	114	447	865	1680	2520	3590	
304	E	06479910	Sixmile Creek near Brookings, South Dakota	330	652	902	1250	1520	1800	
305	E	06479950	Deer Creek near Brookings, South Dakota	55.5	250	505	1010	1520	2160	
306	E	06479980	Medary Creek near Brookings, South Dakota	802	1790	2660	3990	5130	6390	
307	E	06480400	Spring Creek near Flandreau, South Dakota	598	1570	2520	4080	5500	7140	
308	E	06480650	Flandreau Creek above Flandreau, South Dakota	1020	1890	2510	3290	3850	4400	
309	E	06480720	Bachelor Creek Tributary near Wentworth, South Dakota	12.1	34.1	56.0	92.1	125	162	
310	E	06482600	West Pipestone Creek Tributary near Garretson, South Dakota	134	433	745	1260	1720	2230	
311	E	06482610	Split Rock Creek at Corson, South Dakota	2390	5660	8910	14500	19900	26400	
312	E	06482870	Little Beaver Creek Tributary near Canton, South Dakota	25.0	43.7	58.6	80.3	98.5	119	
313	E	06482933	Chanarambi Creek near Edgerton, Minnesota	233	538	796	1170	1480	1800	
314	E	06482950	Mound Creek near Hardwick, Minnesota	39.1	109	184	321	458	629	
315	E	06482960	Mound Creek Tributary at Hardwick, Minnesota	37.4	112	188	312	422	547	

Table 1.--Peak-flow frequency data for streamflow gaging stations.  
[ft<sup>3</sup>/s, cubic feet per second]

Site number (figure 1)	Region identifier	Station number	Station name	Peak flow at specified recurrence intervals, in ft <sup>3</sup> /s						
				2-year	5-year	10-year	25-year	50-year	100-year	
316	E	06483000	Rock River at Luverne, Minnesota	1960	4370	6700	10600	14400	19000	
317	E	06483050	Rock River Tributary near Luverne, Minnesota	34.4	104	179	312	443	601	
318	E	06483200	Kanaranzi Creek Tributary near Lismore, Minnesota	96.7	177	241	334	411	495	
319	E	06483210	Kanaranzi Creek Tributary #2 near Wilmont, Minnesota	128	328	510	787	1020	1280	
320	E	06483270	Rock River at Rock Rapids, Iowa	3850	8750	13200	20200	26400	33500	
321	E	06483460	Otter Creek near Ashton, Iowa	840	2360	4110	7470	11100	15800	
322	E	06600100	Floyd River at Alton, Iowa	1810	5100	8560	14600	20400	27500	
323	E	06600300	West Branch Floyd River near Struble, Iowa	2160	4810	6950	9930	12300	14600	
324	E	06603000	Little Sioux River near Lakefield, Minnesota	73.5	276	551	1150	1860	2860	
325	E	06603500	Jackson County Ditch #11 near Lakefield, Minnesota	43.7	203	444	1010	1710	2720	
326	E	06603520	Judicial Ditch #28 Tributary near Spafford, Minnesota	46.1	110	174	284	391	521	
327	E	06603530	Little Sioux River near Spafford, Minnesota	276	790	1370	2480	3630	5130	
328	E	06603540	Prairie Creek near Spencer, Iowa	328	817	1250	1900	2440	3010	



**Table 2.--Basin characteristics for streamflow gaging stations.**  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
1	609	11.2	19.3	11.6	11.7
2	6.97	55.2	21.8	3.0	12.2
3	0.47	127	17.0	.0	12.2
4	87.6	26.5	27.2	5.5	12.2
5	114	20.9	27.4	7.3	12.7
6	1.58	214	16.6	.0	13.2
7	22.6	56.4	15.1	.0	13.4
8	137	44.7	29.4	0.7	13.9
9	1.04	111	25.8	0.0	14.2
10	3.62	145	0.8	0.0	14.6
11	4.96	56.2	13.0	0.0	14.6
12	83.6	39.1	17.6	0.0	14.2
13	1.44	144	3.1	0.0	14.4
14	5.86	85.1	12.9	0.0	14.4
15	4.91	25.9	18.3	0.0	12.5
16	23.4	7.9	17.7	1.6	10.2
17	159	7.8	33.4	2.7	10.2
18	293	7.2	43.1	3.2	10.0
19	95.4	3.6	37.7	2.8	10.1
20	0.37	251	4.7	0.0	9.0
21	4.46	23.7	8.9	1.2	8.6
22	40.9	6.4	17.8	2.6	8.3
23	67.3	8.7	18.7	3.4	8.3
24	131	6.7	31.4	1.6	8.4
25	17.1	7.3	47.9	0.3	12.2
26	24.8	12.0	30.5	0.0	9.3
27	40.8	16.7	54.8	1.1	13.2
28	127	13.2	27.3	1.3	12.4
29	7.7	45.5	15.9	0.0	12.4
30	4.85	40.5	1.9	0.0	12.5
31	0.49	36.9	14.2	0.0	12.5
32	19.9	43.9	15.8	0.3	12.4
33	218	4.6	33.9	15.2	3.4
34	125	4.7	30.1	14.9	2.8
35	486	2.2	27.4	15.2	1.9
36	9.22	11.5	1.9	0.0	1.6
37	810	2.1	6.9	1.5	1.6
38	47.1	5.5	1.7	0.0	1.5
39	99.2	4.8	5.6	1.6	1.5
40	76.4	9.5	29.9	10.1	2.9
41	325	6.2	17.0	4.9	1.7
42	76.3	17.8	12.8	3.1	1.5
43	7.93	14.7	5.5	0.0	1.4
44	305	5.6	7.9	1.0	1.0
45	975	2.6	10.9	2.3	1.0

**Table 2.--Basin characteristics for streamflow gaging stations.**  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
46	4.0	11.2	5.6	0.0	4.2
47	13.0	4.1	5.7	0.0	2.9
48	934	4.2	18.8	4.2	2.3
49	4.75	17.7	7.7	0.0	2.1
50	50.1	12.7	7.4	0.0	2.1
51	4.99	3.0	21.7	0.0	2.9
52	1560	4.4	13.5	2.6	0.9
53	220	7.3	4.3	0.1	1.2
54	420	4.8	8.4	1.5	1.3
55	2.8	8.8	28.8	2.2	5.7
56	8.23	14.3	32.5	0.4	5.5
57	1.16	10.3	72.2	0.0	5.6
58	150	3.1	48.1	0.0	3.9
59	985	1.9	55.2	1.3	3.2
60	2.35	5.5	0.1	0.0	3.4
61	46.2	11.1	18.3	2.3	4.6
62	555	3.4	23.2	1.3	3.7
63	51.3	6.0	21.5	5.4	4.6
64	5.05	36.7	20.4	0.0	4.5
65	6.18	34.2	16.2	1.1	4.6
66	254	4.9	17.2	1.2	4.1
67	6.61	13.2	5.2	0.0	3.5
68	1380	5.3	18.9	2.0	3.1
69	134	11.1	13.3	0.1	1.7
70	88.8	9.3	14.6	0.0	2.9
71	255	4.3	11.3	0.0	1.9
72	422	4.0	13.4	0.2	2.4
73	637	4.3	12.7	0.1	2.0
74	38.3	3.9	17.9	0.0	2.4
75	92.8	1.7	43.7	0.0	2.4
76	219	3.3	36.8	0.0	3.4
77	424	3.3	48.6	0.2	3.3
78	176	5.1	15.8	0.0	3.2
79	83.0	13.2	7.2	0.0	3.1
80	1090	2.0	35.9	0.1	3.1
81	1420	1.3	36.7	0.2	2.6
82	254	7.3	27.0	11.4	11.3
83	339	7.3	29.9	4.7	11.6
84	214	7.8	46.4	3.5	11.8
85	215	9.8	46.3	3.5	11.6
86	55.1	13.0	36.7	0.3	11.3
87	65.6	4.5	37.9	9.0	10.9
88	68.9	13.3	31.9	21.4	10.5
89	5.99	45.1	29.4	0.0	10.5
90	8.6	28.2	30.3	9.0	10.6

**Table 2.--Basin characteristics for streamflow gaging stations.**  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
91	2.84	48.4	18.1	1.1	10.7
92	0.7	109	3.3	0.0	8.8
93	118	4.2	35.2	1.8	9.7
94	2.71	17.9	41.1	3.5	9.8
95	490	1.8	39.2	17.4	9.5
96	905	3.0	34.4	12.8	9.1
97	68.2	3.3	56.0	1.7	9.1
98	7.95	4.5	45.4	15.4	8.9
99	13.7	13.6	26.8	0.3	8.7
100	180	7.3	32.5	4.1	8.8
101	50.6	10.7	29.4	8.9	8.8
102	1680	1.7	40.0	2.0	7.7
103	606	0.4	45.0	9.0	6.7
104	25.7	11.0	38.7	0.0	6.9
105	1480	1.0	46.1	5.3	7.4
106	174	2.4	94.7	0.0	6.1
107	542	2.8	95.1	0.0	6.3
108	140	4.3	86.7	0.2	5.5
109	170	5.8	77.6	0.1	3.5
110	11.8	7.0	17.3	0.0	3.6
111	54.1	5.4	61.0	0.0	3.6
112	36.0	6.3	15.3	2.5	4.5
113	358	2.4	18.5	2.6	4.8
114	289	1.8	35.4	18.1	5.9
115	8.01	39.0	22.4	0.8	7.2
116	371	2.7	35.5	5.9	7.8
117	10.1	43.4	16.1	1.0	8.4
118	3.87	12.9	30.1	2.1	8.1
119	239	2.8	29.8	7.5	8.1
120	1.46	11.8	27.7	0.0	8.1
121	523	2.1	44.9	2.6	7.8
122	261	3.3	27.3	7.5	6.1
123	8.28	5.5	36.0	25.6	6.6
124	1030	2.9	21.1	6.1	5.7
125	18.9	14.1	20.2	0.5	5.2
126	57.1	6.3	29.4	0.2	5.6
127	870	1.5	23.3	1.1	5.9
128	434	1.2	25.4	10.7	5.4
129	20.1	14.8	15.0	0.1	6.0
130	193	2.1	28.2	4.6	6.2
131	1.31	23.2	19.1	0.0	6.6
132	45.0	8.2	29.7	0.0	6.5
133	432	4.0	27.4	2.0	5.8
134	119	4.0	14.1	1.9	4.9
135	7.11	16.1	4.8	0.0	4.7

**Table 2.--Basin characteristics for streamflow gaging stations.**  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
136	0.26	77.5	1.0	0.0	4.8
137	1030	2.5	16.9	4.2	5.4
138	3.89	7.4	24.3	0.0	5.2
139	14.5	16.1	23.0	1.4	5.2
140	45.6	13.0	21.9	0.6	5.3
141	78.8	10.4	17.3	2.5	4.9
142	3.09	23.4	10.1	0.0	5.5
143	2.63	9.6	20.7	0.0	6.0
144	559	3.1	20.7	1.3	5.5
145	213	4.2	16.8	0.9	4.4
146	0.49	44.4	8.4	0.0	4.4
147	243	4.5	16.9	0.8	4.5
148	163	3.6	30.7	10.6	4.1
149	779	3.4	20.5	4.7	4.6
150	8.83	4.8	28.6	7.7	5.0
151	240	2.4	14.2	6.2	4.0
152	31.3	3.2	14.4	1.7	4.7
153	1.09	17.5	2.4	0.0	4.7
154	9.24	3.5	16.2	8.8	4.2
155	373	2.1	7.7	1.5	4.5
156	1160	1.8	11.7	3.2	4.9
157	2640	2.7	17.4	4.6	5.2
158	8.83	11.0	24.8	12.8	5.3
159	0.54	36.3	21.0	0.0	7.8
160	4.73	9.8	33.1	0.0	7.6
161	2.33	13.1	29.4	0.0	7.6
162	1.34	34.5	14.9	0.0	7.2
163	86.0	8.2	22.9	1.9	5.3
164	128	0.9	36.6	22.8	5.5
165	438	5.0	3.8	1.0	1.3
166	398	7.3	2.4	1.4	1.1
167	459	15.0	3.3	1.7	1.2
168	864	2.1	12.0	7.6	1.9
169	2.95	55.2	2.7	0.0	1.3
170	960	4.9	3.7	1.1	2.1
171	0.4	7.9	5.8	0.0	2.4
172	96.2	6.5	17.7	11.1	3.3
173	0.57	53.5	0.5	0.0	3.3
174	7.24	38.1	3.6	0.3	3.1
175	308	4.0	9.9	4.1	2.8
176	1880	3.0	12.5	5.5	2.4
177	2050	2.9	11.6	5.1	2.4
178	15.8	5.7	1.7	0.0	2.6
179	14.7	8.5	2.4	0.8	1.3
180	0.33	84.6	0.0	0.0	1.4

Table 2.--Basin characteristics for streamflow gaging stations.  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
181	3.72	29.9	0.6	0.0	1.4
182	115	12.3	2.7	0.9	2.0
183	664	8.4	2.3	0.9	3.0
184	0.83	15.6	0.0	0.0	3.6
185	315	2.5	6.6	3.6	3.1
186	6.43	23.3	0.1	0.0	1.9
187	259	9.4	4.4	2.9	2.4
188	5.56	11.6	0.9	0.0	2.5
189	629	7.0	2.7	1.6	3.5
190	8.75	4.3	6.8	1.0	3.7
191	191	3.6	0.9	0.1	3.7
192	4.13	7.7	0.0	0.0	3.9
193	32.8	2.7	0.0	0.0	3.9
194	0.9	34.8	0.0	0.0	2.2
195	0.47	54.9	0.0	0.0	2.7
196	3.16	47.2	0.0	0.0	3.6
197	0.38	44.2	0.1	0.1	3.7
198	777	6.0	1.5	0.7	3.7
199	1300	4.8	1.6	0.6	4.2
200	170	6.9	2.7	0.5	4.2
201	30.2	12.9	0.2	0.0	5.8
202	2.34	26.3	0.0	0.0	6.1
203	120	5.8	4.6	2.6	5.6
204	9.66	9.1	0.0	0.0	4.9
205	13.5	14.6	2.0	0.6	3.7
206	107	6.3	2.5	1.9	4.2
207	843	5.1	2.5	1.4	4.4
208	851	4.9	2.5	1.4	4.4
209	2410	2.2	2.0	1.3	4.5
210	0.06	103	0.0	0.0	4.8
211	8.21	7.9	0.0	0.0	4.9
212	5.74	10.0	0.1	0.0	4.8
213	19.0	9.6	0.7	0.2	4.6
214	338	2.7	3.0	2.2	4.7
215	1110	4.1	4.2	2.3	4.6
216	0.23	219	0.0	0.0	4.6
217	67.3	3.5	0.3	0.0	4.3
218	238	3.5	3.9	2.3	4.6
219	0.35	75.3	0.0	0.0	5.6
220	3.18	13.8	17.4	0.1	5.5
221	62.2	2.3	12.5	4.7	5.4
222	22.2	10.5	5.7	1.0	5.3
223	2.76	17.1	0.7	0.0	5.2
224	27.2	8.3	13.2	5.0	5.5
225	45.4	7.7	9.9	5.3	5.7

Table 2.--Basin characteristics for streamflow gaging stations.  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
226	94.4	12.1	31.6	1.0	11.0
227	27.0	12.2	43.5	0.0	9.6
228	1.45	25.5	20.6	0.0	9.6
229	4.02	8.6	16.0	0.0	10.0
230	0.55	24.2	18.7	0.0	10.0
231	868	5.9	35.7	1.6	10.0
232	4.12	22.9	26.7	0.0	9.6
233	974	4.4	30.6	1.2	9.2
234	47.3	2.8	33.7	5.2	7.5
235	163	2.2	38.9	7.1	6.7
236	129	8.2	11.6	1.3	5.9
237	15.5	6.8	0.5	0.0	5.9
238	87.9	1.9	20.7	6.5	5.5
239	1.26	35.6	1.3	0.0	6.5
240	5.0	15.3	0.2	0.0	6.5
241	435	3.4	4.0	0.6	6.3
242	929	4.2	9.6	3.4	6.0
243	2.12	49.2	2.2	0.0	6.1
244	20.5	12.6	0.8	0.0	6.0
245	1340	4.9	8.1	2.6	5.9
246	0.07	193	0.0	0.0	5.9
247	155	7.4	4.1	0.1	6.6
248	78.8	17.6	2.9	0.0	6.6
249	17.7	26.1	2.6	0.0	6.5
250	38.2	14.3	1.7	0.1	6.6
251	22.1	5.2	0.7	0.0	6.5
252	0.11	152	0.0	0.0	6.2
253	10.0	18.9	1.5	0.0	6.2
254	0.37	88.3	1.3	0.0	6.0
255	1150	6.8	2.4	0.2	6.0
256	4.44	44.0	0.0	0.0	5.9
257	1340	5.7	2.2	0.2	5.5
258	101	11.3	1.2	0.0	5.8
259	77.4	15.9	1.2	0.0	5.7
260	271	12.1	1.8	0.0	5.5
261	5.02	91.7	0.4	0.0	5.5
262	9.04	84.7	0.3	0.0	6.1
263	0.74	50.1	2.3	0.0	7.1
264	2.39	71.3	0.3	0.0	6.9
265	22.6	49.8	0.8	0.0	7.0
266	14.1	13.1	2.9	0.0	7.0
267	615	5.8	1.5	0.0	7.4
268	3.86	18.6	0.3	0.0	7.6
269	0.09	237	0.0	0.0	7.5
270	7.78	73.7	0.2	0.0	7.6



Table 2.--Basin characteristics for streamflow gaging stations.  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
271	0.15	82.9	0.0	0.0	7.1
272	992	5.6	1.4	0.0	7.5
273	28.2	16.1	0.2	0.0	7.0
274	132	20.1	0.4	0.0	7.2
275	1250	6.2	1.3	0.0	8.4
276	275	10.6	0.4	0.0	8.5
277	1540	6.2	1.2	0.0	8.6
278	44.8	44.4	0.7	0.1	8.8
279	399	3.1	2.3	0.7	6.9
280	1.13	38.0	2.3	0.0	7.0
281	45.8	10.4	2.7	0.0	6.9
282	28.7	6.5	0.5	0.0	6.5
283	5.01	25.9	3.7	2.3	2.7
284	2.22	35.4	0.6	0.0	2.7
285	3.29	24.0	0.1	0.0	3.8
286	1.45	20.3	3.8	0.0	3.9
287	5.1	13.5	0.3	0.0	3.9
288	1250	2.6	5.3	2.3	4.0
289	6.15	42.6	0.5	0.0	4.0
290	25.8	9.2	0.7	0.0	4.0
291	15.4	14.0	0.1	0.0	4.2
292	128	4.7	1.7	0.8	4.2
293	65.8	6.8	1.9	0.2	1.0
294	0.26	53.2	0.0	0.0	1.0
295	6.61	26.6	0.3	0.0	1.0
296	1.56	55.6	0.1	0.0	1.0
297	110	5.6	5.7	2.4	1.0
298	74.5	27.7	1.2	0.0	1.0
299	164	4.8	5.0	1.2	1.0
300	25.2	24.8	1.1	0.0	1.0
301	48.3	18.1	0.8	0.0	1.0
302	0.33	54.2	0.0	0.0	1.1
303	9.78	23.4	0.4	0.0	1.1
304	54.0	14.6	1.0	0.0	1.1
305	4.04	47.4	0.5	0.0	1.1
306	200	6.3	1.8	0.0	1.1
307	63.2	15.9	0.8	0.0	1.3
308	100	6.1	2.0	0.0	1.4
309	1.03	31.6	0.0	0.0	1.0
310	2.16	49.5	0.9	0.0	1.2
311	475	5.5	1.3	0.0	1.3
312	0.31	122	0.0	0.0	1.2
313	57.3	6.5	2.6	0.0	2.1
314	2.52	24.1	1.0	0.0	1.7
315	0.2	105	0.0	0.0	1.7

**Table 2.--Basin characteristics for streamflow gaging stations.**  
[mi<sup>2</sup>, square miles; ft/mi, feet per mile; in., inches; in./yr, inches per year]

Site number (figure 1)	Drainage area	Main-channel slope	Storage (percentage of drainage area)	Lake (percentage of drainage area)	Mean annual runoff (in./yr)
316	419	4.1	1.7	0.0	1.8
317	0.22	94.3	0.0	0.0	1.8
318	0.15	65.2	0.0	0.0	2.5
319	2.13	30.8	1.5	0.0	2.7
320	790	4.0	1.5	0.0	2.0
321	89.2	6.9	0.7	0.1	3.3
322	267	4.8	0.4	0.0	2.8
323	180	4.4	0.4	0.0	2.3
324	15.6	6.5	2.6	0.0	3.7
325	7.63	5.4	0.1	0.0	3.8
326	2.67	13.9	0.8	0.0	3.7
327	40.5	5.8	1.3	0.0	3.8
328	22.4	8.2	0.0	0.0	4.0

This program computes estimates of 2-, 5-, 10-, 25-, 50-, and 100-year peak flows for ungaged sites in Minnesota based on either a Regional Regression Equation (RRE) method or a Region Of Influence (ROI) method. (see the report "Techniques for Estimating Peak Flow on Small Streams in Minnesota" by Loren Carlson, and Sanocki, USGS Water Resources Investigations Report 97-\_\_\_).

- \* No warranty, expressed or implied, is made by the
- \* USGS as to the accuracy and functioning of this
- \* program and related program material.

ENTER name of output file

#### output

Use regional regression equations (RRE)  
or region of influence method? (ROI)

#### rre

ENTER site id

#### Judicial Ditch 11

ENTER region where site is located:

A B C D E F

#### d

ENTER basin characteristics for site

Drainage area (sq. mi.)

15.0

Main-channel slope (ft./mi.)

2.6

Lakes percent area + 1

1.0

Flood frequency estimates for

Judicial Ditch 11

Region D

RECURR. INTERVAL	PEAK FLOW (cfs)	SEP(%)	EQ. YRS.	90% PRED. INTERVAL	
2	95.	52.	3.16	42.	212.
5	191.	46.	5.18	92.	397.
10	271.	47.	6.78	129.	570.
25	389.	50.	8.38	177.	855.
50	487.	54.	9.20	212.	1120.
100	593.	57.	9.75	245.	1430.

Do you want to perform another analysis (y or n)?

#### y

Use regional regression equations (RRE)  
or region of influence method? (ROI)

#### roi

ENTER identifier for ungaged site

#### Judicial Ditch 11

ENTER basin characteristics for site

Drainage area (sq. mi.)

15.0

Main-channel slope (ft./mi.)

2.6

Storage percent + 1

1.0

Lakes percent area + 1

1.0

Generalized runoff

**4.0**

Enter option for selecting stations  
 List of gaging stations (G)  
 Proximity criterion (P)  
 Similarity criterion (S)

**P**

Enter the latitude of the site (ddmmss)

**444122**

Enter the longitude of the site (dddmmss)

**0943710**

Flood frequency estimates for  
 Judicial Ditch 11

RECURR. INTERVAL	PEAK FLOW (cfs)	SEP(%)	EQ. YRS.	90% PRED. INTERVAL	
2-year	128.	46.	3.42	60.	270.
5-year	230.	43.	5.28	114.	464.
10-year	311.	44.	6.99	153.	630.
25-year	424.	45.	9.05	204.	884.
50-year	516.	47.	10.33	241.	1100.
100-year	612.	49.	11.35	277.	1350.

Do you want to perform another analysis (y or n)?

**y**

Use regional regression equations (RRE)  
 or region of influence method? (ROI)

**roi**

ENTER identifier for ungaged site

**Judicial Ditch 11**

ENTER basin characteristics for site  
 Drainage area (sq. mi.)

**15.0**

Main-channel slope (ft./mi.)

**2.6**

Storage percent + 1

**1.0**

Lakes percent area + 1

**1.0**

Generalized runoff

**1.0**

Enter option for selecting stations  
 List of gaging stations (G)  
 Proximity criterion (P)  
 Similarity criterion (S)

**S**

Flood frequency estimates for  
 Judicial Ditch 11

RECURR. INTERVAL	PEAK FLOW (cfs)	SEP(%)	EQ. YRS.	90% PRED. INTERVAL	
2-year	118.	68.	2.15	41.	335.
5-year	362.	46.	5.89	174.	756.
10-year	544.	43.	8.87	272.	1090.
25-year	824.	45.	11.29	399.	1700.
50-year	1070.	49.	11.81	487.	2350.

100-year	1340.	54.	11.70	567.	3180.
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The results above are based on an inconsistent set of independent variables. The estimates will be redone using the same independent variables for each regression.

Flood frequency estimates for

Judicial Ditch 11

RECURR. INTERVAL	PEAK FLOW (cfs)	SEP(%)	EQ. YRS.	90% PRED. INTERVAL	
2-year	161.	61.	2.58	62.	419.
5-year	362.	46.	5.89	174.	756.
10-year	544.	43.	8.87	272.	1090.
25-year	824.	45.	11.29	399.	1700.
50-year	1070.	49.	11.81	487.	2350.
100-year	1340.	54.	11.70	567.	3180.

*Do you want to perform another analysis (y or n)?*

**n**

# REGION OF INFLUENCE ANALYSIS OF PEAK FLOW DATA FOR SITE Judicial Ditch 11

## Basin characteristic data:

Drainage area (sq. mi.)	15.00000
Main channel slope (ft./mi.)	2.600000
Storage percent + 1	1.000000
Lakes percent area + 1	1.000000
Generalized runoff(in./yr)	4.000000

## STEP 1 regression coefficients:

Variable	Coefficient	Standard error	T for H0:beta=0	Prob> T
Constant	0.61422	0.38234	1.60648	
log(DA)	0.75374	0.04108	18.34867	0.0001
log(SL)	0.42451	0.11144	3.80943	0.0006
log(ST)	-0.26657	0.11679	-2.28255	0.0297
log(LK)	-0.04523	0.17081	-0.26482	0.7930
log(RO)	0.73404	0.56706	1.29446	0.2054
Deleting variable: log(LK) , T-score less than 1.7.				

## STEP 2 regression coefficients:

Variable	Coefficient	Standard error	T for H0:beta=0	Prob> T
Constant	0.59563	0.37027	1.60865	
log(DA)	0.75285	0.04045	18.61240	0.0001
log(SL)	0.42856	0.10836	3.95498	0.0004
log(ST)	-0.28958	0.07753	-3.73509	0.0008
log(RO)	0.76109	0.55065	1.38217	0.1768
Deleting variable: log(RO) , T-score less than 1.7.				

## Final regression statistics for Judicial Ditch 11 2-year peak

### Regression coefficients:

Variable	Coefficient	Standard error	T for H0:beta=0	Prob> T
Constant	1.04533	0.17730	5.89592	
log(DA)	0.74722	0.04074	18.33976	0.0001
log(SL)	0.43872	0.10960	4.00301	0.0003
log(ST)	-0.25140	0.07342	-3.42397	0.0017

## Residuals and influence statistics for the log10 transformed data:

Station ID	Observed peak	Predicted peak	Studentized residual	Leverage	Cook'sSD
05278850	1.53403	1.69661	-1.03862	0.15572	0.06969
05278500	2.52994	2.69222	-0.94780	0.08219	0.02545
05316700	2.31366	2.36756	-0.37244	0.25178	0.01454
05316690	1.59107	1.89450	-1.91156	0.14998	0.23161
05326100	2.73679	2.62171	0.68460	0.12760	0.02276
05316570	2.85588	2.92385	-0.40408	0.07536	0.00545
05316550	1.86747	1.80286	0.39272	0.10462	0.00676
05278930	3.08167	2.87110	1.17193	0.04970	0.03252



05317000	3.50949	3.56785	-0.37756	0.12369	0.00635
05313800	1.50786	1.50831	-0.00263	0.13656	0.00000
05316500	3.07159	3.36391	-1.86984	0.10661	0.13194
05278750	1.45788	1.48492	-0.16629	0.08584	0.00111
05278700	2.05231	2.08270	-0.18783	0.09886	0.00152
05317200	2.70552	2.93639	-1.33240	0.03139	0.03419
05327000	2.97123	2.88720	0.48727	0.03127	0.00464
05278120	3.23216	3.10417	0.69726	0.07755	0.01482
05279000	3.33116	3.17161	1.00557	0.09114	0.03377
05316950	3.45797	3.44627	0.07015	0.08889	0.00018
05278350	1.70501	1.68274	0.14215	0.17099	0.00141
05278000	2.30685	2.56704	-1.65283	0.12732	0.13179
05325100	1.82607	1.59528	1.22965	0.23058	0.13022
05316920	1.44871	1.44281	0.03694	0.14487	0.00008
05314500	3.18301	2.86495	1.84783	0.05440	0.07802
05313500	3.15616	3.42916	-1.76749	0.13407	0.14438
05272950	2.47129	2.59120	-0.66121	0.10833	0.01632
05320000	3.79260	3.59834	1.26334	0.13533	0.07568
05276200	2.89840	2.80096	0.57833	0.07145	0.01011
05276000	2.91180	2.74267	0.91056	0.07334	0.01983
05316900	2.12385	2.15309	-0.18230	0.13674	0.00182
05319500	3.43889	3.39870	0.24245	0.07650	0.00180
05276100	1.28103	1.29184	-0.07052	0.20479	0.00041
05320500	3.62262	3.40783	1.34446	0.08127	0.05638
05319490	3.51574	3.40371	0.43945	0.03766	0.00253
05330600	1.67210	1.85768	-1.11415	0.06887	0.04062
05320200	1.28556	1.01541	1.80840	0.23682	0.32477
05330550	2.21352	2.29238	-0.46507	0.03791	0.00456

Mean sampling error variance: 0.0048  
Mean model error variance: 0.0263

For Judicial Ditch 11  
2-year peak  
Predicted flow (cfs)      Std. Err. prediction (percent)      Equivalent years      90% Prediction interval (cfs)

128.      46.      3.42      60.      270.

\*\*\*\*\*