ESTIMATING DESIGN-FLOOD DISCHARGES FOR STREAMS IN IOWA USING DRAINAGE-BASIN AND CHANNEL-GEOMETRY CHARACTERISTICS

By David A. Eash

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 93-4062

Prepared in cooperation with the
IOWA HIGHWAY RESEARCH BOARD
and the HIGHWAY DIVISION of the
IOWA DEPARTMENT OF TRANSPORTATION
(Iowa DOT Research Project HR-322)

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Iowa City, Iowa
1993

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	*By*	*To obtain*
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
mile per square mile (mi/mi^2)	0.621	kilometer per square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Drainage-basin and channel-geometry multiple-regression equations are presented for estimating design-flood discharges having recurrence intervals of 2, 5, 10, 25, 50, and 100 years at stream sites on rural, unregulated streams in Iowa. Design-flood discharge estimates determined by Pearson Type-III analyses using data collected through the 1990 water year are reported for the 188 streamflow-gaging stations used in either the drainage-basin or channel-geometry regression analyses. Ordinary least-squares multiple-regression techniques were used to identify selected drainage-basin and channel-geometry characteristics and to delineate two channel-geometry regions. Weighted least-squares multiple-regression techniques, which account for differences in the variance of flows at different gaging stations and for variable lengths in station records, were used to estimate the regression parameters.

Statewide drainage-basin equations were developed from analyses of 164 streamflow-gaging stations. Drainage-basin characteristics were quantified using a geographic-information-system procedure to process topographic maps and digital cartographic data. The significant characteristics identified for the drainage-basin equations included contributing drainage area, relative relief, drainage frequency, and 2-year, 24-hour precipitation intensity. The average standard errors of prediction for the drainage-basin equations ranged from 38.6 to 50.2 percent. The geographic-information-system procedure expanded the capability to quantitatively relate drainage-basin characteristics to the magnitude and frequency of floods for stream sites in Iowa and provides a flood-estimation method that is independent of hydrologic regionalization.

Statewide and regional channel-geometry regression equations were developed from analyses of 157 streamflow-gaging stations. Channel-geometry characteristics were measured onsite and on topographic maps. Statewide and regional channel-geometry regression equations that are dependent on whether a stream has been channelized were developed on the basis of bankfull and active-channel characteristics. The significant channel-geometry characteristics identified for the statewide and regional regression equations included bankfull width and bankfull depth for natural channels unaffected by channelization, and active-channel width for stabilized channels affected by channelization. The average standard errors of prediction ranged from 41.0 to 68.4 percent for the statewide channel-geometry equations and from 30.3 to 70.0 percent for the regional channel-geometry equations.

Procedures provided for applying the drainage-basin and channel-geometry regression equations depend on whether the design-flood discharge estimate is for a site on an ungaged stream, an ungaged site on a gaged stream, or a gaged site. When both a drainage-basin and a channel-geometry regression-equation estimate are available for a stream site, a procedure is presented for determining a weighted average of the two flood estimates. The drainage-basin regression equations are applicable to unregulated rural drainage areas less than 1,060 square miles, and the channel-geometry regression equations are applicable to unregulated rural streams in Iowa with stabilized channels.

INTRODUCTION

Knowledge of the magnitude and frequency of floods is essential for the effective management of flood plains and for the economical planning and safe design of bridges, culverts, levees, and other structures located along streams. Long-term flood data collected from a network of streamflow-gaging stations operated in Iowa are available for hydrologic analysis to compute design-flood discharge estimates for the gaged sites as well as for ungaged sites on the gaged streams. Techniques are needed to estimate design-flood discharges for sites on all ungaged streams in Iowa because most such stream sites in the State have no flood data available, particularly sites on smaller streams.

Flood runoff is a function of many interrelated factors that include, but are not limited to climate, soils, land use, and the physiography of drainage basins. Previous investigations for Iowa (Schwob, 1953, 1966; Lara, 1973, 1987) have been limited to the types of basin characteristics that can be investigated as potential explanatory variables for the development of multiple-regression flood-estimation equations because many of the flood-runoff factors are difficult to measure. Previous investigations defined hydrologic regions to account for factors affecting flood runoff that were difficult to measure directly. The hydrologic regions were delineated on the basis of physiographic differences of broad geographic landform regions. However, two major limitations are encountered when using the hydrologic-region method to estimate flood discharges for ungaged sites. First, it is difficult to weight flood estimates for drainage basins located in more than one hydrologic region or located near the boundaries of hydrologic regions because the boundaries are not well defined. Regional boundaries are transitional zones where the physiographic characteristics of one hydrologic region gradually merge into another. Second, because large hydrologic regions may contain drainage basins with physiographies that are anomalous to the region in which they are located, it is difficult to correlate their physiographic differences to another hydrologic region, or to weight their flood estimates. Quantitative measurements of basin morphology to determine appropriate regional equations for drainage basins are not applicable for resolving these regional limitations. As a result, flood estimates for some ungaged sites become very subjective.

To address the need to minimize the subjectivity encountered in applying regional flood-estimation methods, a study using two different flood-estimation methods was made by the U.S. Geological Survey in cooperation with the Iowa Highway Research Board and the Highway Division of the Iowa Department of Transportation. Two new flood-estimation methods for Iowa, which are presumed to be independent from each other, were used in this study. An advantage in developing flood-frequency equations using two independent flood-estimation methods is that each method can be used to verify the results of the other, and the estimates obtained from each method can be used to calculate a weighted average.

Methods are now available to more easily quantify selected morphologic and climatic characteristics for a large number of drainage basins. A geographic-information-system (GIS) procedure developed by the U.S. Geological Survey uses topographic maps and digital cartographic data to quantify several basin characteristics that typically were not quantified previously. This GIS procedure expands the capability to relate drainage-basin characteristics to the magnitude and frequency of floods for stream sites in Iowa and provides a flood-estimation method that is independent of hydrologic regionalization.

Measurements of channel-geometry characteristics have been used to estimate the magnitude and frequency of floods in investigations conducted by Fields (1975), Webber and Roberts (1981), Parrett and others (1987), Hedman and Kastner (1977), and Osterkamp and Hedman (1982). These investigations have shown that measurements of specific channel-geometry characteristics provide a reliable method for estimating flood discharges because channel cross-sectional characteristics are assumed to be a function of flow volume and sediment-load transport (Pickup and Rieger, 1979, p. 41; Osterkamp, 1979, p. 2).

Purpose and Scope

The purpose of this report is to: (1) define equations for Iowa that relate measurable drainage-basin characteristics to design-flood discharges having recurrence intervals of 2, 5, 10, 25, 50, and 100 years that are independent of hydrologic regionalization; (2) define corroborative equations for Iowa that relate channel-geometry characteristics to the same design-flood recurrence intervals; and (3) define application and reliability of drainage-basin and channel-geometry flood-estimation methods.

Both the drainage-basin and channel-geometry flood-estimation methods described in this report are applicable to unregulated rural streams located within the State. The drainage-basin flood-estimation method is limited to streams with drainage areas less than 1,060 mi^2. The channel-geometry flood-estimation method is applicable to stabilized stream channels in Iowa.

Acknowledgments

The U.S. Army Corps of Engineers, Omaha and Rock Island Districts, contributed to the funding of the sediment-sample analyses. James J. Majure, formerly with the U.S. Geological Survey, Iowa City, Iowa, and now with the Iowa State University, GIS Support and Research Facility, Ames, Iowa, developed the computer software used to quantify the drainage-basin characteristics and the software used to integrate the overall GIS procedure.

FLOOD-FREQUENCY ANALYSES OF STREAMFLOW-GAGING STATIONS IN IOWA

Flood-frequency curves were developed for 188 streamflow-gaging stations operated in Iowa by the U.S. Geological Survey. They were developed according to procedures outlined in Bulletin 17B of the Interagency Advisory Committee on Water Data (IACWD, 1982, p. 1-28). These flood-frequency curves include data collected through the 1990 water year for both active and discontinued continuous-record and crest-stage gaging stations having at least 10 years of gaged annual-peak discharges. A water year is the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends. The locations of the 164 gaging stations studied using the drainage-basin flood-estimation method are shown in figure 1, and the locations of the 157 gaging stations studied using the channel-geometry flood-estimation method are shown in figure 2. Map numbers for the gaging stations shown in figures 1 and 2 are referenced to gaging-station numbers and names in tables 8 and 9 (at end of this report). The observed annual-peak discharge record at each site includes water years during which the gaging station was operated, which is termed the systematic period of record. The observed annual-peak discharge record also may include historic-peak discharges that occurred during water years outside the systematic period of record.

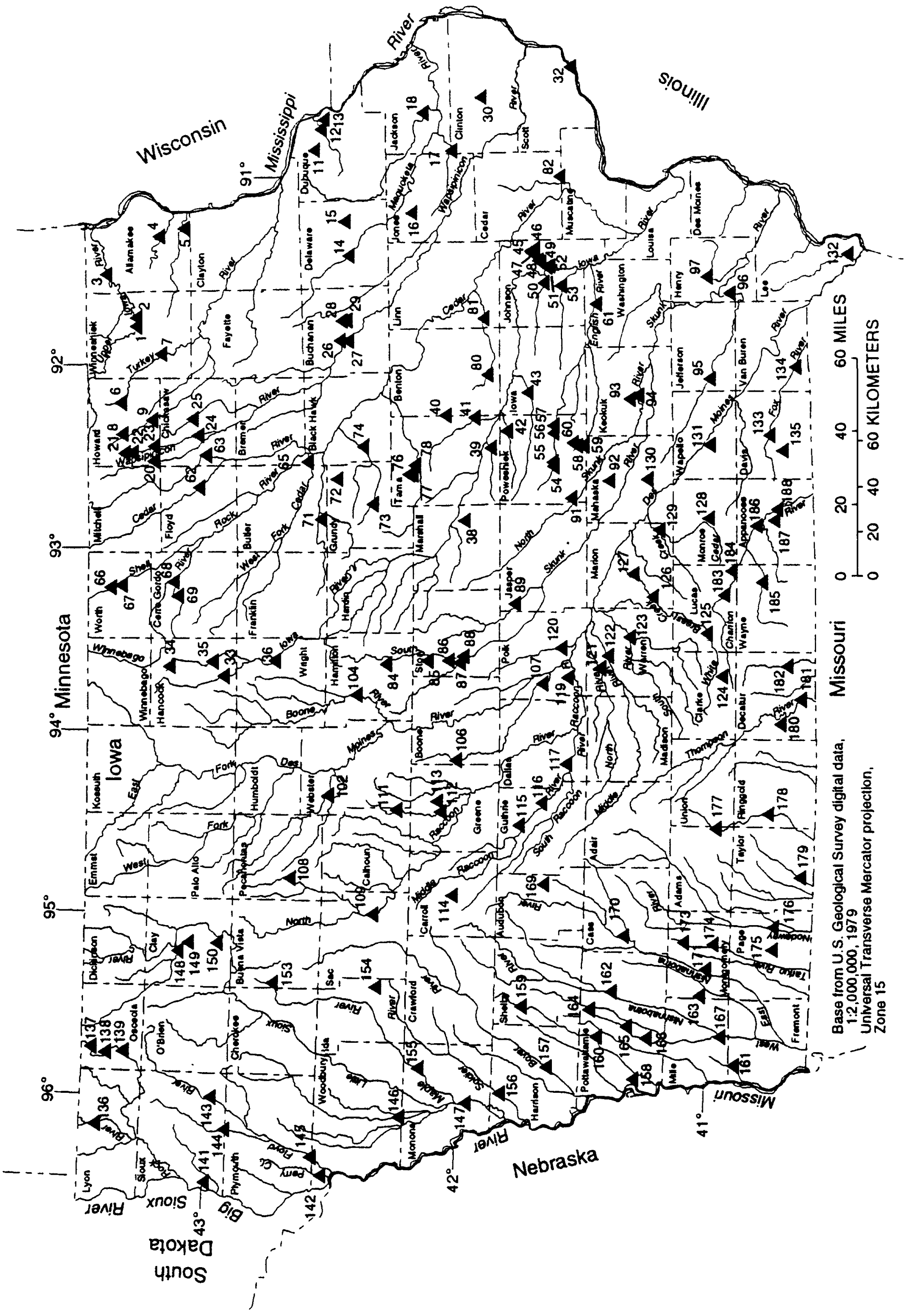
A flood-frequency curve relates observed annual-peak discharges to annual exceedance probability or recurrence interval. Annual exceedance probability is expressed as the chance that a given flood magnitude will be exceeded in any 1 year. Recurrence interval, which is the reciprocal of the annual exceedance probability, is the average number of years between exceedances of a given flood magnitude. For example, a flood with a magnitude that is expected to be exceeded once on the average during any 100-year period (recurrence interval) has a 1-percent chance (annual exceedance probability = 0.01) of being exceeded during any 1 year. This flood, commonly termed the 100-year flood, is generally used as a standard against which flood peaks are measured. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at shorter intervals or even within the same year.

Flood-frequency curves were developed by fitting the logarithms (base 10) of the observed annual-peak discharges to a Pearson Type-III distribution using U.S. Geological Survey WATSTORE flood-frequency analysis programs (Kirby, 1981, p. C1-C57). Extremely small discharge values (low outliers) were censored, adjustments were made for extremely large discharge values (high outliers), and the coefficient of skew was weighted for each gaging station with skew values obtained from a generalized skew-coefficient map (IACWD, 1982). Whenever possible, historically adjusted flood-frequency curves were developed to extend the flood record for gaging stations with historic peak-flood information.

The recommended equation (IACWD, 1982, p. 9) for fitting a Pearson Type-III distribution to the logarithms of observed annual-peak discharges of a gaging station is

$$\log(Q_{T(g)}) = \bar{x} + ks, \qquad (1)$$

where $Q_{T(g)}$ is the design-flood discharge for a gage, in cubic feet per second, for a selected T-year recurrence

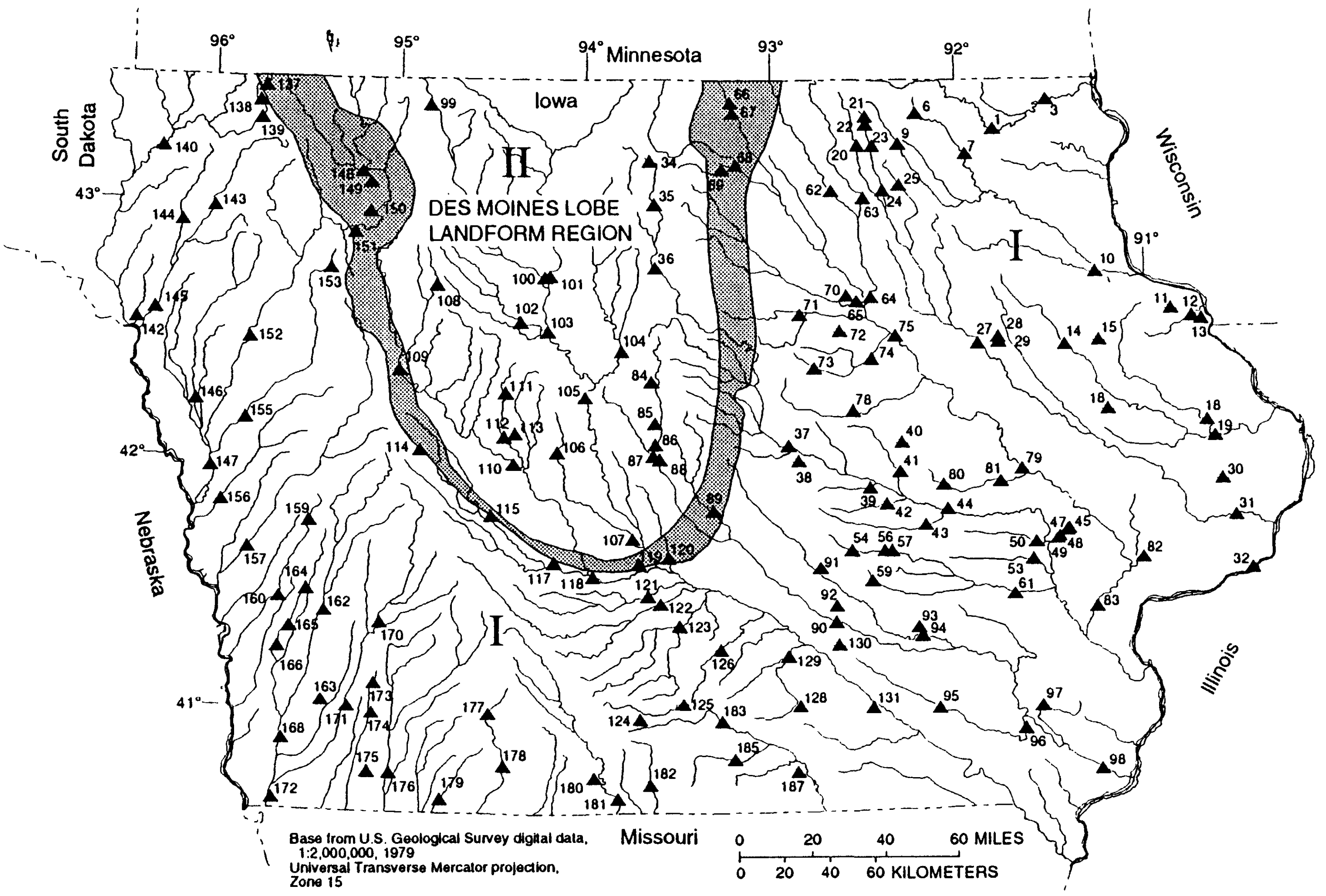


Base from U.S. Geological Survey digital data, 1:2,000,000, 1979
Universal Transverse Mercator projection, Zone 15

EXPLANATION

164▲ U.S. GEOLOGICAL SURVEY STREAMFLOW-GAGING STATION AND DOWNSTREAM-ORDER MAP NUMBER--map numbers are referenced in tables 8 and 9

Figure 1. Location of streamflow-gaging stations used to collect drainage-basin data.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1979
Universal Transverse Mercator projection, Zone 15

EXPLANATION

▨ REGIONAL TRANSITION ZONE

117▲ U.S. GEOLOGICAL SURVEY STREAMFLOW-GAGING STATION AND DOWNSTREAM-ORDER MAP NUMBER--Map numbers are referenced in tables 8 and 9

II CHANNEL-GEOMETRY, HYDROLOGIC-REGION NUMBER

Figure 2. Location of streamflow-gaging stations used to collect channel-geometry data and regional transition zone.

interval;

$\bar{x}$ is the mean of the logarithms (base 10) of the observed annual-peak discharges;

k is the standardized Pearson Type-III deviate for a selected T-year recurrence interval and weighted skew coefficient; and

s is the standard deviation of the logarithms (base 10) of the observed annual-peak discharges.

Results of the Pearson Type-III flood-frequency analyses are presented in table 8 (listed as method B17B, at end of this report) for the 188 streamflow-gaging stations analyzed using either the drainage-basin or channel-geometry flood-estimation techniques. Included in table 8 is information about the type of gage operated, the effective record length of the gage, whether a systematic or historical analysis was performed, the observed annual-peak discharge record (listed as flood period), and the maximum known flood-peak discharge and its recurrence interval. An example flood-frequency curve is shown in figure 3.

DEVELOPMENT OF MULTIPLE-REGRESSION EQUATIONS

Multiple linear-regression techniques were used to independently relate selected drainage-basin and channel-geometry characteristics to design-flood discharges having recurrence intervals of 2, 5, 10, 25, 50, and 100 years. A general overview of the ordinary least-squares and weighted least-squares multiple linear-regression techniques used to develop the equations is presented in the following two sections. Specific information on the multiple-regression analyses for either flood-estimation method is presented in later sections entitled "Drainage-Basin Characteristic Equations" and "Channel-Geometry Characteristic Equations."

Ordinary Least-Squares Regression

Ordinary least-squares (OLS) multiple linear-regression techniques were used to develop the initial multiple-regression equations, or models, for both the drainage-basin and channel-geometry flood-estimation methods. In OLS regression, a design-flood discharge (termed the response variable) is estimated on the basis of one or more significant drainage-basin or channel-geometry characteristics (termed the explanatory variables) in which each observation is given an equal weight. The response variable is assumed to be a linear function of one or more of the explanatory variables. Logarithmic transformations (base 10) were performed for both the response and explanatory variables used in all of the OLS regression analyses. Data transformations were used to obtain a more constant variance of the residuals about the regression line and to linearize the relation between the response variable and explanatory variables. The general form of the OLS regression equations developed in these analyses is

$$\log_{10}(Q_T) = \log_{10}(C) + b_1 \log_{10}(X_1) + b_2 \log_{10}(X_2) + \ldots + b_p \log_{10}(X_p)\,, \qquad (2)$$

where Q_T is the response variable, the estimated design-flood discharge, in cubic feet per second, for a selected T-year recurrence interval;

C is a constant;

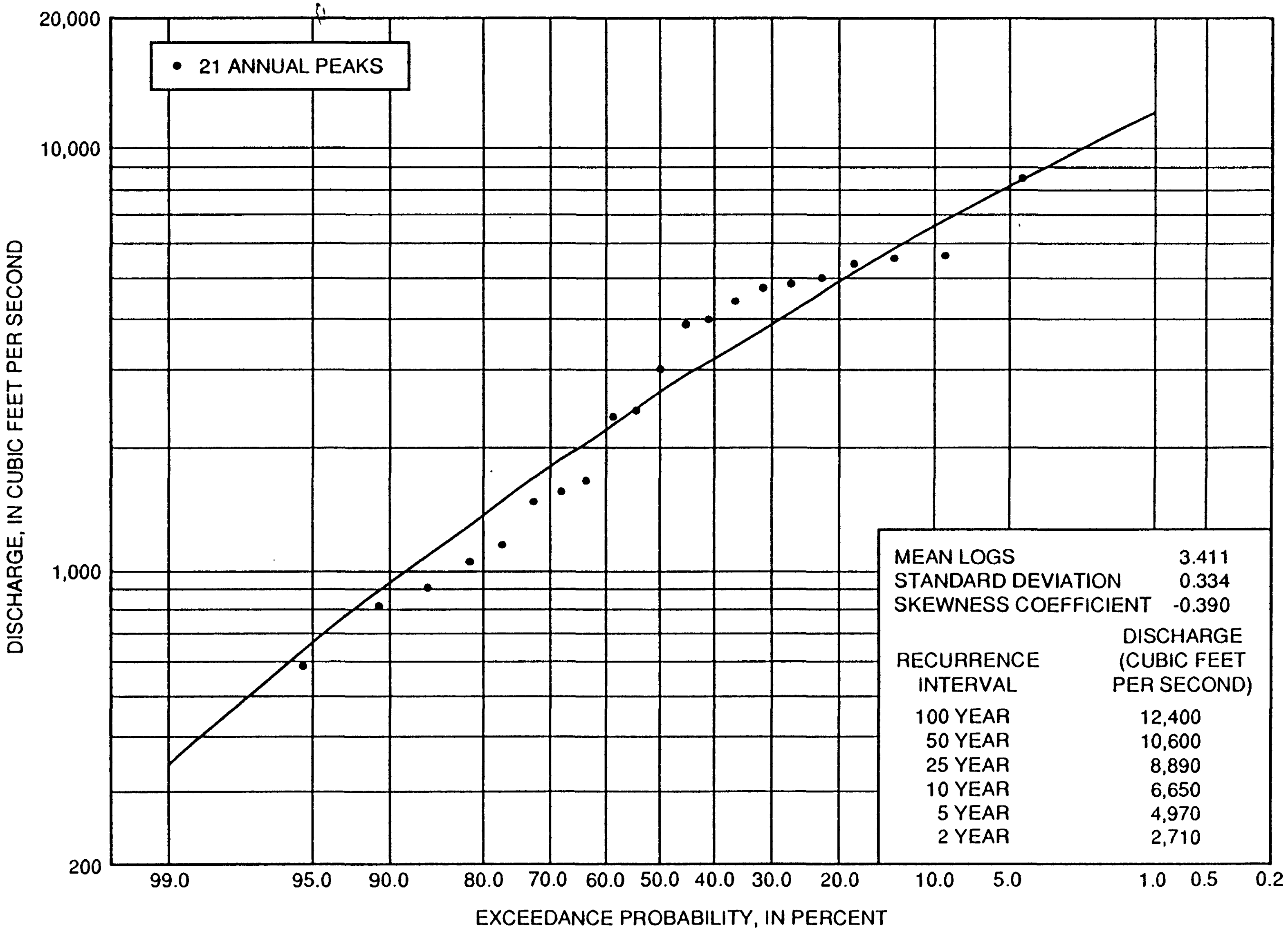
b_i is the regression coefficient for the ith explanatory variable (i = 1, ... ,p);

X_i is the value of the ith explanatory variable, a drainage-basin or channel-geometry characteristic (i = 1, ... ,p); and

p is the total number of explanatory variables in the equation.

Equation 2, when untransformed, is algebraically equivalent to

$$Q_T = C(X_1)^{b_1}(X_2)^{b_2}\ldots(X_p)^{b_p}. \qquad (3)$$



Pearson Type-III flood-frequency estimate for streamflow-gaging station 05494300 FOX RIVER AT BLOOMFIELD (map number 133, figure 1)

Figure 3. Example of a flood-frequency curve.

OLS regression analyses were performed using the Statit[1] statistical procedures ALLREG and SREGRES (Statware, Inc., 1990, p. 6-10 - 6-27). Initial selections of significant explanatory variables for the OLS regression models were performed by using the ALLREG procedure. The ALLREG procedure uses an all-possible subsets regression to identify the best-possible combinations of explanatory variables on the basis of the Mallows' C_p statistic (Mallows, 1973). The SREGRES procedure, based on stepwise-regression algorithms, then was used to perform an OLS regression analysis on each best-possible combination of explanatory variables. The final selection of explanatory variables was based on the following criteria as described by Koltun and Roberts (1990, p. 11):

1. The selection of explanatory variables, as well as the signs and magnitudes of their respective regression coefficients, need to be hydrologically valid in the context of flood runoff. This criterion takes precedence over all other criteria.

2. All explanatory variables should be statistically significant at the 95-percent confidence level.

3. The selection of explanatory variables, within the constraints of criteria 1 and 2, should minimize the prediction error sum of squares [the PRESS statistic, an index of the prediction error associated with the regression equation (Allen, 1971; Montgomery and Peck, 1982)], maximize the coefficient of determination (R^2, a measure of the proportion of the variation in the response variable accounted for by the regression equation), and minimize the standard error of estimate. Correlation between explanatory variables and the variance inflation factor (VIF) (Marquardt, 1970; Montgomery and Peck, 1982) was used to assess multicollinearity in the regression models.

Weighted Least-Squares Regression

A weighted least-squares (WLS) regression technique described by Tasker (1980 p. 1107-1109) was used to develop the final multiple-regression equations for both the drainage-basin and channel-geometry flood-estimation methods. WLS regression analyses improved R^2 values and standard errors of estimate obtained in the majority of the OLS regression analyses. Tasker (1980, p. 1107) reports that OLS regression assumes that the time-sampling variance in the response-variable estimates (design-flood discharges) are the same for each gaging station used in the analysis (assumption of homoscedasticity). In hydrologic regression, this assumption usually is violated because the reliability of response-variable estimates depends primarily on the length of the observed annual-peak discharge records. The error associated with response-variable estimates is inversely proportional to record length (Choquette, 1988, p. 16-17). WLS regression adjusts for the variation in the reliability of the response-variable estimates by using a weighting function to account for differences in the lengths of observed annual-peak discharge records at gaging stations. The weighting function (Tasker, 1980, p. 1107) is based on theory and on analysis of residuals from the initial OLS regression equation. The weighting function assumes that the response variable (the design-flood discharge) is determined by fitting the logarithms (base 10) of the observed annual-peak discharges to a Pearson Type-III distribution.

The variance of the response variable, Q_T, is estimated to determine the appropriate weight factors for the WLS regression analysis. To be effective, the weight factors should be inversely proportional to the variance of Q_T. The variance of Q_T, for a selected T-year recurrence interval, can be partitioned into two components--the variance due to OLS regression-model error, c_0, and the variance due to time-sampling error, t_i, which is related to the standard deviation and weighted skew coefficient of the logarithms of the observed annual-peak discharges and to the number of years of effective record length (Tasker, 1980, p, 1107-1109; Choquette, 1988, p. 16-17). The weight function has the form

$$w_i = \frac{1}{(c_0 + t_i)}, \qquad (4)$$

where w_i is the weight factor for the ith gaging station used in the

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[1] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

analysis.

The model error (c_0) is estimated by

$$c_0 = \text{maximum}\left[0;\,(SE)^2 - c_1\left(\frac{1}{\overline{ERL}}\right)\right], \tag{5}$$

where SE is the standard error of the estimate from the OLS equation;

c_1 is a constant; and

$\overline{ERL}$ is the mean effective record length, in years, for all gaging stations used in each respective regression-model data set.

The time-sampling error (t_i) is estimated by

$$t_i = c_1\left(\frac{1}{ERL_{(i)}}\right), \tag{6}$$

where $ERL_{(i)}$ is the effective record length, in years, for the ith gaging station used in each respective regression-model data set.

The constant, c_1, is related to the recurrence interval of the response variable and to the weighted skew coefficient (g) of the observed annual-peak discharges. It is determined by

$$c_1 = \text{maximum}\left[0;\,\bar{s}^2\left(1 + \frac{\bar{k}^2}{2}\left(1 + \frac{3}{4}\bar{g}^2\right) + \bar{k}\bar{g}\right)\right], \tag{7}$$

where $\bar{s}$ is the mean standard deviation of the logarithms (base 10) of the observed annual-peak discharges;

$\bar{k}$ is the mean standardized Pearson Type-III deviate for selected T-year recurrence interval and mean weighted skew coefficient $\bar{g}$ (IACWD, 1982, p. 3-1 - 3-27); and

$\bar{g}$ is the mean weighted skew coefficient of the logarithms (base 10) of the observed annual-peak discharges (IACWD, 1982, p. 12-15).

The values $\bar{s}$ and $\bar{g}$ are statewide estimates determined by the averages of the 188 streamflow-gaging stations analyzed using either the drainage-basin or channel-geometry flood-estimation techniques. These estimation methods are based on the assumption that $\bar{s}$ and $\bar{g}$ are approximately constant for all the gaging stations in the State.

The effective record length (ERL) of a gaging station is based on an empirical analysis made by Gary D. Tasker (U.S. Geological Survey, written commun., March 1992) of results reported in Tasker and Thomas (1978) and Stedinger and Cohn (1986). It is determined by

$$ERL = LS + (HST - LS)\,a, \tag{8}$$

where LS is the systematic record length of a gaging station, in years, the number of water years during which the gaging station was operated;

HST is the historic record length of a gaging station, in years, as used in a Pearson Type-III historical flood-frequency analysis; if a systematic flood-frequency analysis was performed, $HST = LS$; if $(HST-LS) > 200$, set $(HST-LS) = 200$; and

$$a = 0.55 - 0.1\left[\log_e\left(\frac{ph}{(1-ph)}\right)\right]. \tag{9}$$

In the last equation, $ph = 1.0 - (np\,/\,HST)$, and np is the number of historic and extremely large discharge (high-outlier) peaks.

The ERL used in the weighted least-squares regression analyses for each gaging station is listed in table 8 (at end of this report).

ESTIMATING DESIGN-FLOOD DISCHARGES USING DRAINAGE-BASIN CHARACTERISTICS

The drainage-basin flood-estimation method uses selected drainage-basin characteristics to estimate the magnitude and frequency of floods for stream sites in Iowa. Multiple-regression equations were developed by relating significant drainage-basin characteristics to Pearson Type-III, design-flood discharges for 164 streamflow-gaging stations in Iowa (fig. 1). Drainage-basin characteristics were quantified using a GIS procedure to process topographic maps and digital cartographic data. An overview of the GIS procedure is provided in the following section.

Geographic-Information-System Procedure

The GIS procedure developed by the U.S. Geological Survey (USGS) quantifies for each drainage basin the 26 basin characteristics listed in Appendix A (at end of this report). These characteristics were selected for the GIS procedure on the basis of their hypothesized applicability in flood-estimation analysis and their general acceptability as measurements of drainage-basin morphology and climate. Techniques for making manual measurements of selected drainage-basin characteristics from topographic maps are outlined in Appendix B (at end of this report). The GIS procedure uses ARC/INFO computer software and other software developed specifically to integrate with ARC/INFO (Majure and Soenksen, 1991; Eash, 1993).

The GIS procedure entails four main steps: (1) creation of four GIS digital maps (ARC/INFO coverages) from three cartographic data sources, (2) assignment of attribute information to three of the four GIS digital maps, (3) quantification of 24 morphologic basin characteristics from the four GIS digital maps, and (4) quantification of two climatic basin characteristics from two precipitation data sources.

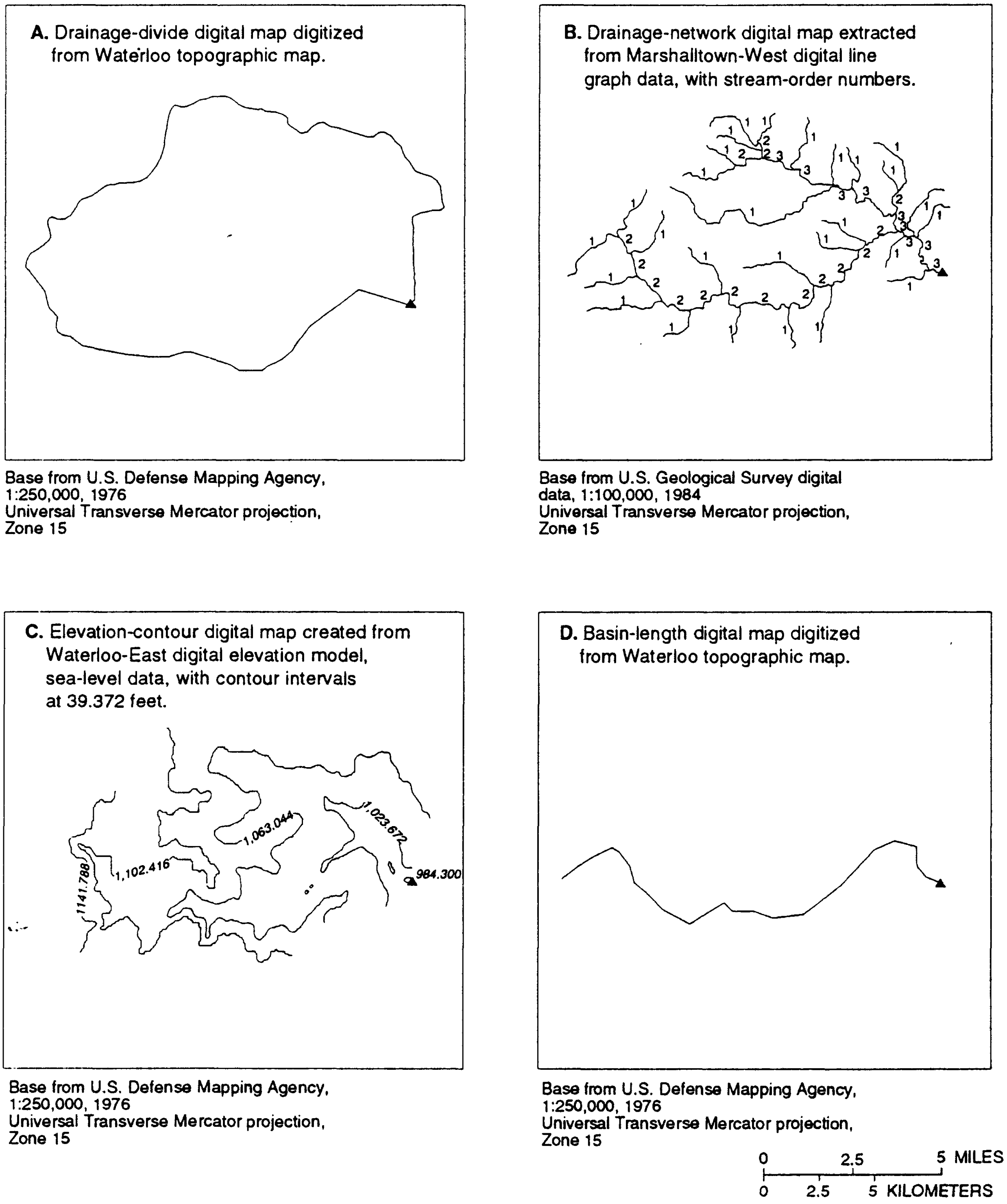
The first step creates four GIS digital maps representing selected aspects of a drainage basin. Examples of these maps are shown in figure 4. The drainage-divide digital map (fig. 4*A*) is created by delineating the surface-water drainage-divide boundary for a streamflow-gaging station on 1:250,000-scale U.S. Defense Mapping Agency (DMA) topographic maps. This drainage-divide delineation is manually digitized into a polygon digital map using GIS software. If noncontributing drainage areas are identified within the drainage-divide boundary, then each noncontributing drainage area also is delineated and digitized.

The drainage-network digital map (fig. 4*B*) is created by extracting the drainage network for the basin from 1:100,000-scale USGS digital line graph (DLG) data. The extraction process uses GIS software to select and append together the DLG data contained within the drainage-divide polygon.

The elevation-contour digital map (fig. 4*C*) is created from 1:250,000-scale DMA digital elevation model (DEM) data that are referenced to sea level (in meters). GIS software is used to convert the DEM data to a lattice file of point elevations for an area slightly larger than the drainage-divide polygon. This lattice file of point elevations is contoured with a 12-meter (39.372-ft) or smaller contour interval using ARC/INFO software. The contour interval is chosen to provide at least five contours for each drainage basin. GIS software selects the contours contained within the drainage-divide polygon to create the elevation-contour digital map. Elevation contours then are converted to units of feet.

The basin-length digital map (fig. 4*D*) is created by delineating and digitizing the basin length from 1:250,000-scale DMA topographic maps. The basin length characteristic is delineated by first identifying the main channel for the drainage basin on 1:100,000-scale topographic maps. The main channel is identified by starting at the basin outlet and proceeding upstream, repetitively selecting the channel that drains the greater area at each stream junction. The most upstream channel is extended to the drainage-divide boundary defined for the drainage-divide digital map. This main channel identified on 1:100,000-scale topographic maps is used to define the main channel on 1:250,000-scale topographic maps. The basin length is centered along the main-channel, flood-plain valley from basin outlet to basin divide and digitized with as straight a line as possible from the 1:250,000-scale maps. When comparing the basin length shown in figure 4*D* to those stream segments corresponding to the main channel in figure 4*B*, it can be seen that the basin length does not include all the sinuosity of the stream segments.

The second step assigns attributes to specific polygon, line-segment, and point



A. Drainage-divide digital map digitized from Waterloo topographic map.

Base from U.S. Defense Mapping Agency,
1:250,000, 1976
Universal Transverse Mercator projection,
Zone 15

B. Drainage-network digital map extracted from Marshalltown-West digital line graph data, with stream-order numbers.

Base from U.S. Geological Survey digital
data, 1:100,000, 1984
Universal Transverse Mercator projection,
Zone 15

C. Elevation-contour digital map created from Waterloo-East digital elevation model, sea-level data, with contour intervals at 39.372 feet.

Base from U.S. Defense Mapping Agency,
1:250,000, 1976
Universal Transverse Mercator projection,
Zone 15

D. Basin-length digital map digitized from Waterloo topographic map.

Base from U.S. Defense Mapping Agency,
1:250,000, 1976
Universal Transverse Mercator projection,
Zone 15

EXPLANATION

▲ STREAMFLOW-GAGING STATION

Figure 4. Four geographic-information-system maps that constitute a digital representation of selected aspects of a drainage basin.

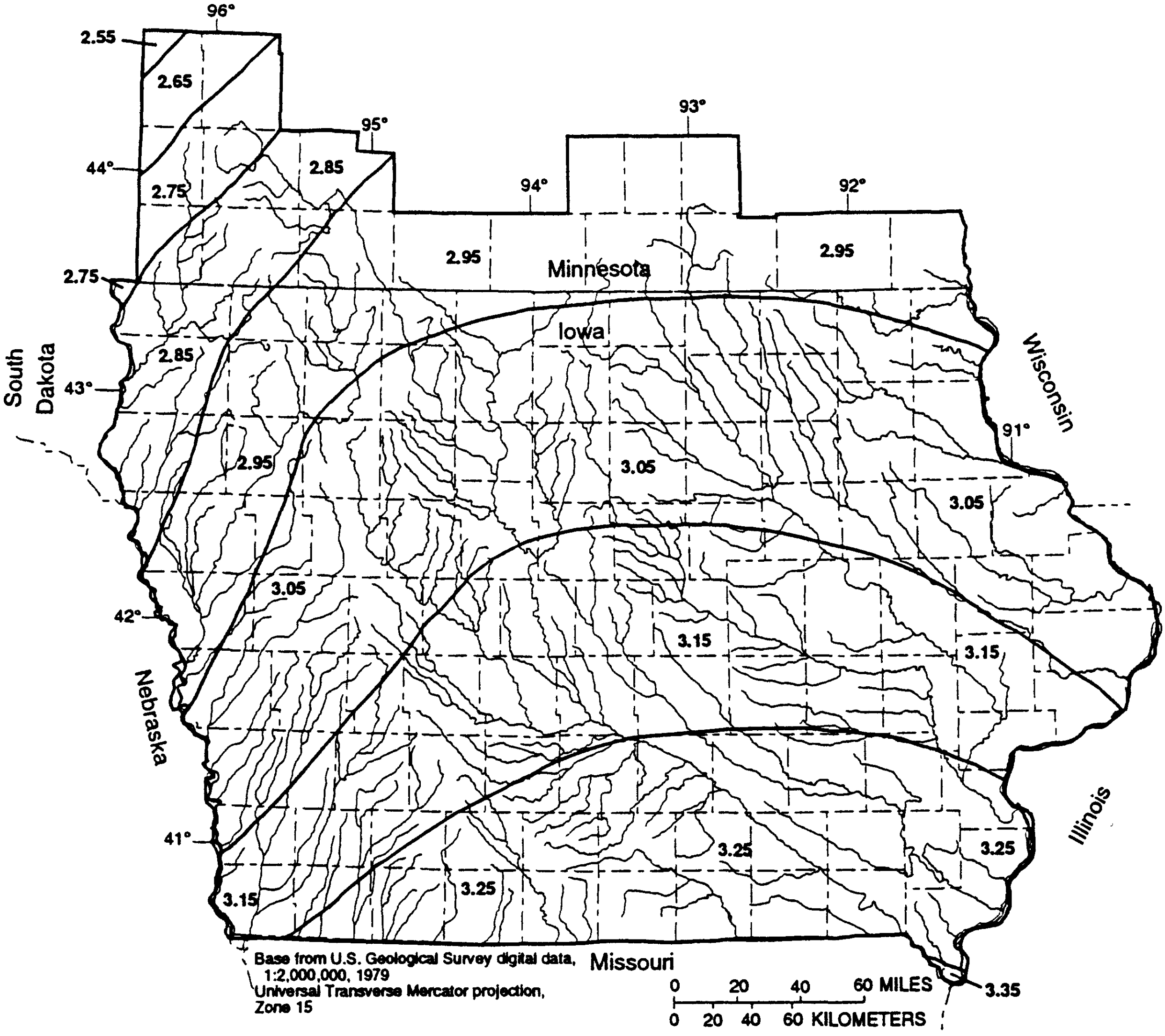
features in the first three of the four GIS digital maps shown in figure 4. As a prerequisite, the digital maps are edited to ensure that drainage-divide boundaries, stream segments, and the basin-length line segments are connected properly. If noncontributing drainage areas are identified, they are assigned attributes with separate polygon designations so that the basin-characteristic programs can distinguish between contributing and noncontributing areas. Each line segment in the drainage-network digital map is assigned a Strahler stream-order number (Strahler, 1952) and a code indicating whether the line segment represents part of the main channel or a secondary channel. Specific GIS programs have been developed to assign the proper stream-order number to each line segment and to code those line segments representing the main channel. Figure *4B* shows the Strahler stream-order numbers for streams in the Black Hawk Creek at Grundy Center (station number 05463090; map number 73, fig. 1) drainage basin. A description on how to order streams using Strahler's method is included in Appendix B (at end of this report).

The line segments in the elevation-contour digital map were assigned elevations from the processing of the DEM data. Line segments overlain by noncontributing drainage-area polygons are assigned attributes designating noncontributing contour segments. Two point attributes are added to the elevation-contour digital map to represent the maximum and minimum elevations of the drainage basin. The maximum basin elevation is defined from the highest DEM-generated contour elevation within the contributing drainage area. The minimum basin elevation is defined at the basin outlet as an interpolated value between the first elevation contour crossing the main channel upstream of the basin outlet and the first elevation contour crossing the main channel downstream of the basin outlet.

The third step uses the four GIS digital maps shown in figure 4 and a set of programs developed by the USGS (Majure and Soenksen, 1991) to quantify the 24 morphologic basin characteristics listed in Appendix A (at end of this report). These basin characteristics include selected measurements of area, length, shape, and topographic relief that define selected aspects of basin morphology, and several channel characteristics. The programs access the information automatically maintained by the GIS for each of the four digital maps, such as the length of line segments and the area of polygons, as well as the previously described attribute information assigned to the polygon, line-segment, and point features of three of the four GIS digital maps. The GIS programs then use this information to automatically quantify the 24 morphologic basin characteristics.

The fourth step uses a software program developed to quantify the remaining two basin characteristics listed in Appendix A (at end of this report). These two climatic characteristics are quantified using GIS digital maps representing the distributions of mean annual precipitation and 2-year, 24-hour precipitation intensity for the area contributing to all surface-water drainage in Iowa. This area includes a portion of southern Minnesota. The mean annual precipitation digital map was digitized from a contour map for Iowa, supplied by the Iowa Department of Agriculture and Land Stewardship, State Climatology Office (Des Moines), and from a contour map for Minnesota (Baker and Kuehnast, 1978). The 2-year, 24-hour precipitation intensity digital map was digitized from a contour map for Iowa (Waite, 1988, p. 31) and interpolated contours for southern Minnesota that were digitized from a United States contour map (Hershfield, 1961, p. 95). The digital map representing the distribution of 2-year, 24-hour precipitation intensity for Iowa and southern Minnesota is shown in figure 5. The weighted average for each climatic characteristic is computed for a drainage basin by calculating the mean of the area-weighted precipitation values that are within the drainage-divide polygon.

Of the 26 drainage-basin characteristics listed in Appendix A, 12 are referred to as primary drainage-basin characteristics because they constitute specific GIS procedure or manual topographic-map measurements. They are listed under headings containing the word "measurement." The remaining characteristics are calculated from the primary drainage-basin characteristics; they are listed in Appendix A under headings containing the word "computation." Each drainage-basin characteristic listed in Appendix A is footnoted with a



Base from U.S. Geological Survey digital data, 1:2,000,000, 1979
Universal Transverse Mercator projection, Zone 15

EXPLANATION

3.15 AREA OF EQUAL 2-YEAR, 24-HOUR PRECIPITATION INTENSITY--Number is precipitation intensity, in inches

Figure 5. Distribution of 2-year, 24-hour precipitation intensity for Iowa and southern Minnesota.

reference and the cartographic data source used for both GIS procedure and manual measurements.

Verification of Drainage-Basin Characteristics

To verify that the drainage-basin characteristics quantified using the GIS procedure are valid, manual topographic-map measurements of selected drainage-basin characteristics were made for 12 of the streamflow-gaging stations used in the drainage-basin flood-estimation method. These comparison measurements were made for those primary drainage-basin characteristics identified as being significantly related to flood runoff in the multiple-regression equations presented in the following section entitled "Drainage-Basin Characteristic Equations." Comparison measurements were made from topographic maps of the same scales as were used in the GIS procedure. The results of the comparisons are shown in table 1.

Table 1. *Comparisons of manual measurements and geographic-information-system-procedure measurements of selected drainage-basin characteristics at selected streamflow-gaging stations*

[*TDA*, total drainage area, in square miles; *BP*, basin perimeter, in miles; *BR*, basin relief, in feet; *FOS*, number of first-order streams; *TTF*, 2-year, 24-hour precipitation intensity, in inches; *MAN*, manual measurement; *GIS*, geographic-information-system procedure; *% DIFF*, percentage difference between *MAN* and *GIS*]

Station number	Measurement technique	Selected drainage-basin characteristics				
		TDA[1]	*BP*	*BR*	*FOS*	*TTF*
05411600	*MAN*	177	73.3	297	84	3.05
	GIS	178	73.9	274	84	3.05
	% DIFF	+0.6	+0.8	-7.7	0	0
05414450	*MAN*	21.6	21.9	444	10	3.05
	GIS	22.3	21.3	394	10	3.05
	% DIFF	+3.2	-2.7	-11.3	0	0
05414600	*MAN*	1.54	5.32	280	1	3.05
	GIS	1.53	5.97	291	1	3.05
	% DIFF	-0.6	+12.2	+3.9	0	0
05462750	*MAN*	11.6	15.0	160	6	3.05
	GIS	11.9	15.5	129	6	3.05
	% DIFF	+2.6	+3.3	-19.4	0	0
05463090	*MAN*	56.9	33.5	181	28	3.15
	GIS	57.0	33.1	160	28	3.15
	% DIFF	+0.2	-1.2	-11.6	0	0
05470500	*MAN*	204	69.8	318	60	3.15
	GIS	208	67.7	292	51	3.15
	% DIFF	+2.0	-3.0	-8.2	-15.0	0
05481000	*MAN*	844	139	303	152	3.05
	GIS	852	139	300	155	3.05
	% DIFF	+0.9	0	-1.0	+2.0	0
05489490	*MAN*	22.9	24.8	280	10	3.25
	GIS	22.2	26.2	263	10	3.25
	% DIFF	-3.1	+5.6	-6.1	0	0
06483430	*MAN*	29.9	28.8	198	12	2.85
	GIS	30.0	28.9	182	12	2.85
	% DIFF	+0.3	+0.3	-8.1	0	0
06609500	*MAN*	871	206	582	477	3.05
	GIS	869	210	550	475	3.05
	% DIFF	-0.2	+1.9	-5.5	-0.4	0

Table 1. *Comparisons of manual measurements and geographic-information-system-procedure measurements of selected drainage-basin characteristics at selected streamflow-gaging stations*--Continued

Station number	Measurement technique	Selected drainage-basin characteristics				
		TDA[1]	*BP*	*BR*	*FOS*	*TTF*
06807780	*MAN*	42.7	47.4	268	18	3.05
	GIS	42.8	48.8	280	19	3.05
	% DIFF	+0.2	+3.0	+4.5	+5.6	0
06903400	*MAN*	182	79.0	224	80	3.25
	GIS	184	79.6	256	80	3.25
	% DIFF	+1.1	+0.8	+14.3	0	0
WILCOXON SIGNED-RANKS						
TEST STATISTIC[2]		-1.726	-1.334	-1.843	-0.365	NO TEST[3]
p-VALUE STATISTIC		0.0844	0.1823	0.0653	0.7150	

[1] Manual *TDA* measurements are streamflow-gaging-station drainage areas published by the U.S. Geological Survey in annual streamflow reports. Noncontributing drainage areas (NCDA) are not listed because none were identified for these drainage basins.

[2] Using a 95-percent level of significance, the T-value statistic = 2.2010 (Iman and Conover, 1983, p. 438).

[3] All values for *% DIFF* = 0.

Comparison measurements for total drainage area (TDA) indicate that the GIS procedure was within about 1 percent of the drainage areas published by the USGS in annual streamflow reports for 8 of the 12 selected gaging stations. This comparison indicates that delineations of drainage areas used in the GIS procedure, made from 1:250,000-scale topographic maps, were generally valid. The Wilcoxon signed-ranks test was applied to four of the five drainage-basin characteristics listed in table 1 using STATIT procedure SGNRNK (Statware, Inc., 1990, p. 3-25 - 3-26). Results (table 1) indicate that GIS procedure measurements of total drainage area, basin perimeter (BP), basin relief (BR), and number of first-order streams (FOS) were not significantly different from manual topographic-map measurements at the 95-percent level of significance. The greater variation in measurement comparisons of basin relief are believed to be due to limitations in the 1:250,000-scale DEM data. Results of the comparison tests (table 1) indicate that GIS procedure measurements are generally valid for the primary drainage-basin characteristics used in the regression equations presented in the following section.

Basin slope (BS) is another drainage-basin characteristic that was quantified using DEM data. It is hypothesized that basin slope may have a significant effect on surface-water runoff. Basin slope was indicated as being a significant characteristic in a few of the initial multiple-regression analyses. Comparison measurements indicated that the GIS procedure greatly underestimated basin slope. Measurement differences for basin slope were between minus 9 and 66 percent, with an average underestimation of 40 percent for the 10 drainage basins tested (Eash, 1993, p. 180-181). For this reason, the basin-slope characteristic was deleted from the drainage-basin characteristics data set during the initial multiple-regression analyses. Basin-slope comparisons appear to indicate that the 1:250,000-scale DEM data used to create the elevation-contour digital maps are not capable of reproducing all the sinuosity of the elevation contours depicted on the 1:250,000-scale DMA topographic maps. The elevation contours generated using the GIS procedure are much more generalized than the topographic-map contours; thus, the total length of the elevation contours are undermeasured when using the "contour-band" method of calculating basin slope (BS) (Appendix A). A comparison of the elevation contours shown in figure 4*C* for the Black Hawk Creek at Grundy Center (station number 05463090; map number 73, fig. 1) drainage basin to those depicted on the DMA 1:250,000-scale Waterloo topographic map showed a significant difference in the sinuosity of the elevation contours depicted.

Drainage-Basin Characteristic Equations

The 26 drainage-basin characteristics listed in Appendix A were quantified for 164 streamflow-gaging stations (fig. 1) and investigated as potential explanatory variables in the development of multiple-regression equations for the estimation of design-flood discharges. Because of the previously described problems concerning measurement verification of basin slope and because of the difficulty associated with manual measurements of total stream length, six basin characteristics were deleted from the regression data set. The excluded characteristics were basin slope (*BS*), total stream length (*TSL*), stream density (*SD*), constant of channel maintenance (*CCM*), ruggedness number (*RN*), and slope ratio (*SR*).

Several other drainage-basin characteristics also were deleted from the data set because of multicollinearity. Multicollinearity is the condition where at least one explanatory variable is closely related to (that is, not independent of) one or more other explanatory variables. Regression models that include variables with multicollinearity may be unreliable because coefficients in the models may be unstable. Output from the ALLREG analysis and a correlation matrix of Pearson product-moment correlation coefficients were used as guides in identifying the variables with multicollinearity. The hydrologic validity of variables with multicollinearity in the context of flood runoff was the principal criterion used in determining which drainage-basin characteristics were deleted from the data set. Upon completion of the ALLREG analyses, any remaining multicollinearity problems were identified with the SREGRES procedure by checking each explanatory variable for variance inflation factors greater than 10.

Statewide flood-estimation equations were developed from analyses of the drainage-basin characteristics using the ordinary least-squares and weighted least-squares multiple-regression techniques previously described. The best equations developed in terms of PRESS statistics, coefficients of determination, and standard errors of estimate are listed in table 2. The characteristics identified as most significant in the drainage-basin equations are contributing drainage area (*CDA*), relative relief (*RR*), drainage frequency (*DF*), and 2-year, 24-hour precipitation intensity (*TTF*). Table 9 (at end of this report) lists these significant drainage-basin characteristics, as quantified by the GIS procedure, for 164 streamflow-gaging stations in Iowa.

Three of the four characteristics listed in the drainage-basin equations (table 2) are calculated from primary drainage-basin characteristics. The drainage-basin equations are comprised of six primary drainage-basin characteristics. Contributing drainage area (*CDA*) is a measure of the total area that contributes to surface-water runoff at the basin outlet. The primary drainage-basin characteristics used to calculate contributing drainage area are total drainage area (*TDA*) and noncontributing drainage area (*NCDA*). Relative relief (*RR*) is a ratio of two primary drainage-basin characteristics, basin relief (*BR*) and basin perimeter (*BP*). Drainage frequency (*DF*) is a measure of the average number of first-order streams per unit area and is an indication of the spacing of the drainage network. The primary drainage-basin characteristics used to calculate drainage

Table 2. *Statewide drainage-basin characteristic equations for estimating design-flood discharges in Iowa*

[*Q*, peak discharge, in cubic feet per second, for a given recurrence interval, in years; *CDA*, contributing drainage area, in square miles; *RR*, relative relief, in feet per mile; *DF*, drainage frequency, in number of first-order streams per square mile; *TTF*, 2-year, 24-hour precipitation intensity, in inches]

Estimation equation	Standard error of estimate		Average standard error of prediction (percent)	Average equivalent years of record
	Log_{10}	Percent		
Number of streamflow-gaging stations = 164				
$Q_2 = 53.1\, CDA^{0.799}\, RR^{0.643}\, DF^{0.381}\, (TTF - 2.5)^{1.36}$	0.171	41.0	42.2	3.9
$Q_5 = 98.8\, CDA^{0.755}\, RR^{0.652}\, DF^{0.380}\, (TTF - 2.5)^{0.985}$	.156	37.2	38.6	5.4
$Q_{10} = 136\, CDA^{0.733}\, RR^{0.654}\, DF^{0.384}\, (TTF - 2.5)^{0.801}$	.160	38.2	39.8	6.5
$Q_{25} = 188\, CDA^{0.709}\, RR^{0.655}\, DF^{0.393}\, (TTF - 2.5)^{0.610}$	.172	41.3	43.2	7.8
$Q_{50} = 231\, CDA^{0.694}\, RR^{0.656}\, DF^{0.401}\, (TTF - 2.5)^{0.491}$	.185	44.5	46.5	9.5
$Q_{100} = 277\, CDA^{0.681}\, RR^{0.656}\, DF^{0.409}\, (TTF - 2.5)^{0.389}$	.198	48.0	50.2	11.5

Note: Basin characteristics are map-scale dependent. See Appendix A and Appendix B for basin-characteristic descriptions, computations, and scales of maps to use for manual measurements.

frequency are the number of first-order streams (*FOS*) and contributing drainage area (*CDA*). The value of *FOS* is determined by using Strahler's method of ordering streams (Strahler, 1952). A description of Strahler's stream-ordering method is included in Appendix B. The 2-year, 24-hour precipitation intensity (*TTF*) is a primary drainage-basin-characteristic measurement of the maximum 24-hour precipitation expected to be exceeded on the average once every 2 years.

Additional information pertaining to the characteristics used in the drainage-basin equations (table 2) is included in Appendix A. Techniques on how to make manual measurements from topographic maps for the primary drainage-basin characteristics used in the equations are outlined in Appendix B. Several of the primary drainage-basin characteristics are map-scale dependent. Use of maps of scales other than the scales used to develop the equations may produce results that do not conform to the range of estimation accuracies listed for the equations in table 2. The scale of map to use for manual measurements of each primary drainage-basin characteristic is outlined in Appendix A and Appendix B.

Examination of residuals, the difference between the Pearson Type-III and multiple-regression estimates of peak discharge for the drainage-basin equations, indicated no evidence of geographic bias. The drainage-basin equations thus were determined to be independent of hydrologic regionalization within the State.

The drainage-basin flood-estimation method developed in this study is similar to the regional flood-estimation method developed by Lara (1987) because both methods estimate flood discharges on the basis of morphologic relations. While the standard errors of estimate appear to be higher for the drainage-basin equations than for Lara's equations (Lara, 1987, p. 28), a direct comparison cannot be made because of the different methodologies used to develop the equations. Lara's method is based on the physiography of broad geographic landform regions defined for the State, whereas the drainage-basin method presented in this report is based on specific measurements of basin morphology. The drainage-basin equations are independent of hydrologic regionalization. The application of regional equations often requires that subjective judgments be made concerning basin anomalies and the weighting of regional discharge estimates. This subjectivity may introduce additional unmeasured error to the estimation accuracy of the regional discharge estimates. The drainage-basin regression equations presented in this report provide a flood-estimation method that minimizes the subjectivity in its application to the ability of the user to measure the characteristics.

Example of Equation Use--Example 1

Example 1.--An application of the drainage-basin flood-estimation method can be illustrated by using the equation (listed in table 2) to estimate the 100-year peak discharge for the discontinued Black Hawk Creek at Grundy Center crest-stage gaging station (station number 05463090; map number 73, fig. 1), located in Grundy County, at a bridge crossing on State Highway 14, at the north edge of Grundy Center, in the NW1/4, sec. 7, T. 87 N., R. 16 W. Differences between manually computed values (table 1) and values computed using the GIS procedure (tables 1 and 9) are due to differences in applying the techniques.

Step 1. The characteristics used in the drainage-basin equation (table 2) are contributing drainage area (*CDA*), relative relief (*RR*), drainage frequency (*DF*), and 2-year, 24-hour precipitation intensity (*TTF*). The primary drainage-basin characteristics used in this equation are total drainage area (*TDA*), noncontributing drainage area (*NCDA*), basin relief (*BR*), basin perimeter (*BP*), number of first-order streams (*FOS*), and 2-year, 24-hour precipitation intensity (*TTF*). These primary drainage-basin characteristic measurements and the scale of maps to use for each manual measurement are described in Appendix A and Appendix B.

Step 2. The topographic maps used to delineate the drainage-divide boundary for this gaging station are the DMA 1:250,000-scale Waterloo topographic map and the USGS 1:100,000-scale Grundy County map. Figure 4*A* shows the drainage-divide boundary that was delineated for this gaging station on the 1:250,000-scale map. Contributing drainage area (*CDA*) is calculated from the primary drainage-basin characteristics total drainage area (*TDA*) and noncontributing drainage area (*NCDA*). The total drainage area published for this gaging station in the annual streamflow reports of the U.S. Geological Survey is 56.9 mi^2 (table 9). Inspection of the 1:100,000-scale map does not show any noncontributing drainage areas within the drainage-divide boundary of this basin. The contributing drainage area (*CDA*) is calculated as

$$\begin{aligned} CDA &= TDA - NCDA, \\ &= 56.9 - 0, \\ &= 56.9 \text{ mi}^2. \end{aligned} \tag{10}$$

Step 3. Relative relief (*RR*) is calculated from the primary drainage-basin characteristics basin relief (*BR*) and basin perimeter (*BP*). The difference between the highest elevation contour and the lowest interpolated elevation in the basin measured from the 1:250,000-scale topographic map gives a basin relief of 181 ft (table 1). Figure 4*C* shows an approximate representation of the topography for this drainage basin. The drainage-divide boundary delineated on the 1:250,000-scale topographic map (fig. 4*A*) is used to measure the basin perimeter, which is 33.5 mi (table 1). Relative relief (*RR*) is calculated as

$$RR = \frac{BR}{BP}, \qquad (11)$$

$$= \frac{181}{33.5},$$

$$= 5.40 \text{ ft/mi} .$$

Step 4. Drainage frequency (*DF*) is calculated from the primary drainage-basin characteristics number of first-order streams (*FOS*) and contributing drainage area (*CDA*). A total of 28 first-order streams are counted within the drainage-divide delineation for this gaging station on the 1:100,000-scale topographic map (table 1). These first-order streams are shown in figure 4*B*. Drainage frequency (*DF*) is calculated as

$$DF = \frac{FOS}{CDA}, \qquad (12)$$

$$= \frac{28}{56.9},$$

$$= 0.492 \text{ first-order streams/mi}^2 .$$

Step 5. The 2-year, 24-hour precipitation intensity (*TTF*) for the drainage basin is determined from figure 5. Because the drainage-divide boundary for this gaging station is completely within the polygon labeled as 3.15 in., the 2-year, 24-hour precipitation intensity is given a value of 3.15 in. (table 1).

Step 6. The 100-year flood estimate using the drainage-basin equation (table 2) is calculated as

$$Q_{100} = 277\,(CDA)^{0.681}\,(RR)^{0.656}\,(\mathrm{DF})^{0.409}\,(TTF - 2.5)^{0.389},$$

$$= 277\,(56.9)^{0.681}\,(5.40)^{0.656}\,(0.492)^{0.409}\,(3.15 - 2.5)^{0.389},$$

$$= 8{,}310 \text{ ft}^3\text{/s}.$$

Discharge estimates listed in this report are rounded to three significant figures. The difference between the above estimate of 8,310 ft^3/s and the estimate of 7,740 ft^3/s listed in table 8 (method GISDB) is due to measurement differences between manual measurement and GIS procedure techniques (table 1).

ESTIMATING DESIGN-FLOOD DISCHARGES USING CHANNEL-GEOMETRY CHARACTERISTICS

The channel-geometry flood-estimation method uses selected channel-geometry characteristics to estimate the magnitude and frequency of floods for stream sites in Iowa. The channel-geometry method is based on measurements of channel morphology, which are assumed to be a function of streamflow discharges and sediment-load transport. Multiple-regression equations were developed by relating significant channel-geometry characteristics to Pearson Type-III, design-flood discharges for 157 streamflow-gaging stations in Iowa (fig. 2).

Channel-Geometry Data Collection

The channel-geometry parameters that were measured for each of the gaging stations are as follows:

ACW - average width of the active channel, in feet;

ACD - average depth of the active channel, in feet;

BFW - average width of the bankfull channel, in feet;

BFD - average depth of the bankfull channel, in feet;

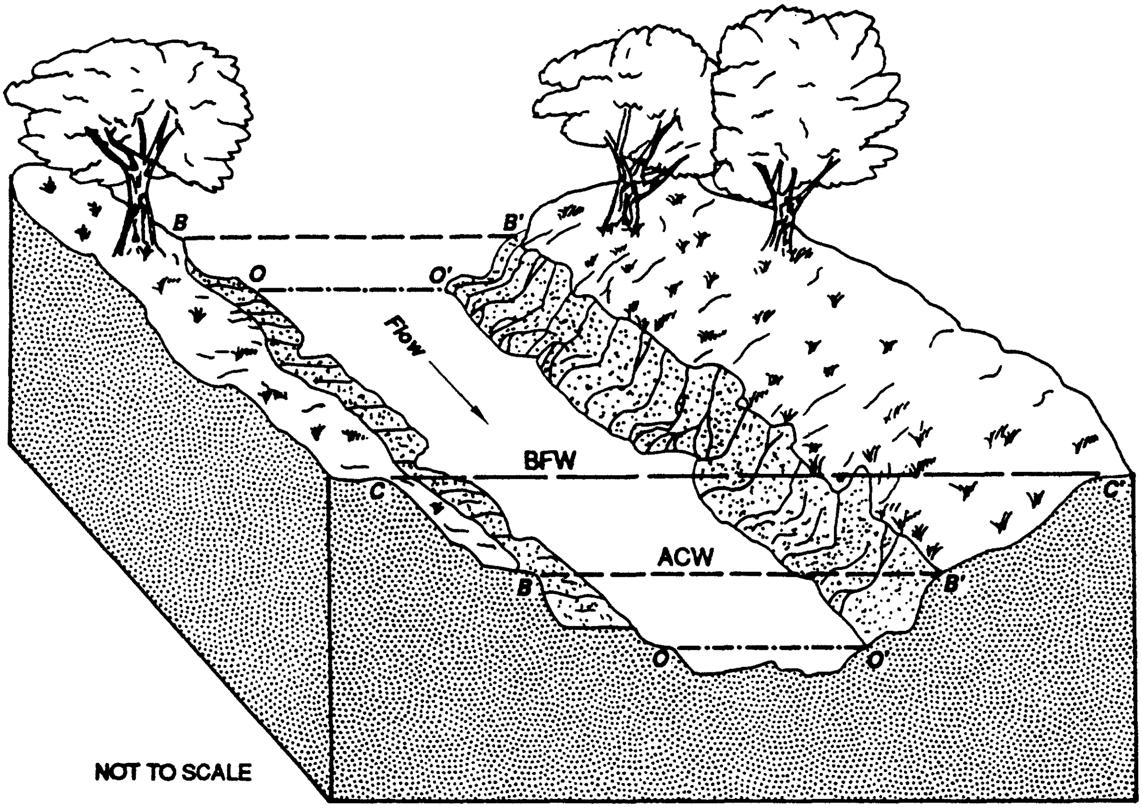
SC_{bd} - silt-clay content of channel-bed material, in percent;

SC_{lbk} - silt-clay content of left channel-bank material, in percent;

SC_{rbk} - silt-clay content of right channel-bank material, in percent;

D_{50} - diameter size of channel-bed particles for which the total weight of all particles with diameters greater than D_{50} is equal to the total weight of all particles with diameters less than or equal to D_{50}, in millimeters; and

GRA - local gradient of channel, in feet per mile.



EXPLANATION

B— — — — —B' ACTIVE-CHANNEL REFERENCE LEVEL
C——— ———C' BANKFULL REFERENCE LEVEL
O—·—·—·—·—O' LOW-FLOW WATER LEVEL
BFW BANKFULL WIDTH
ACW ACTIVE-CHANNEL WIDTH

Figure 6. Block diagram of a typical stream channel.

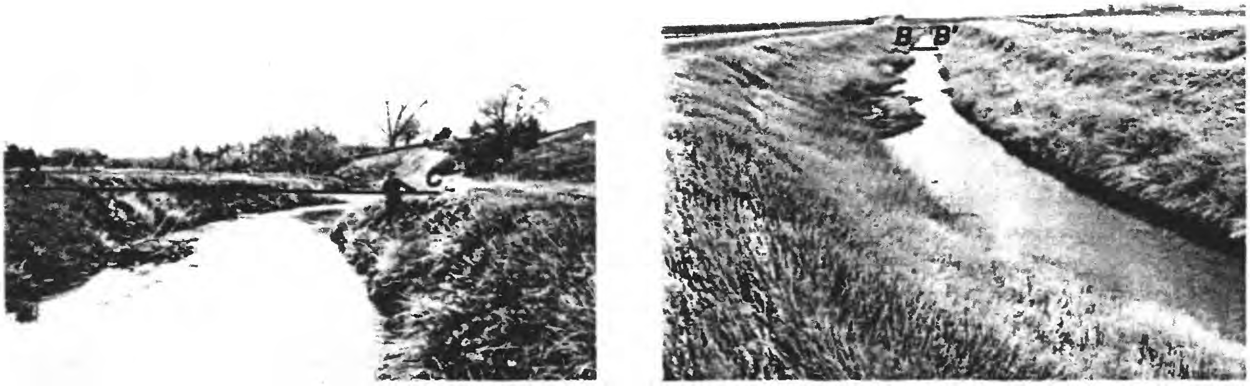
The active-channel and bankfull reference levels for a typical stream channel are illustrated in figure 6. Photographs of active-channel and bankfull reference levels at six gaging stations in Iowa are shown in figure 7.

A standard particle-size analysis (dry sieve, visual accumulation tube, and wet sieve) was performed for each of the composite sediment samples collected from the channel bed and the left and right channel banks (Guy, 1969). The local gradient (*GRA*) was measured from 1:24,000-scale topographic maps and was calculated as the slope of the channel between the nearest contour lines crossing the channel upstream and downstream of the gaging station.

Of the 157 gaging stations selected for study using the channel-geometry flood-estimation method, 46 were on stream channels that were or were suspected of being channelized. Bankfull width (*BFW*) and bankfull depth (*BFD*) measurements could not be made for these sites because channelization affects the long-term, stabilizing conditions of stream channels. Active-channel width (*ACW*) and active-channel depth (*ACD*) measurements were made at these 46 sites because channel conditions indicated that the active-channel portions of these

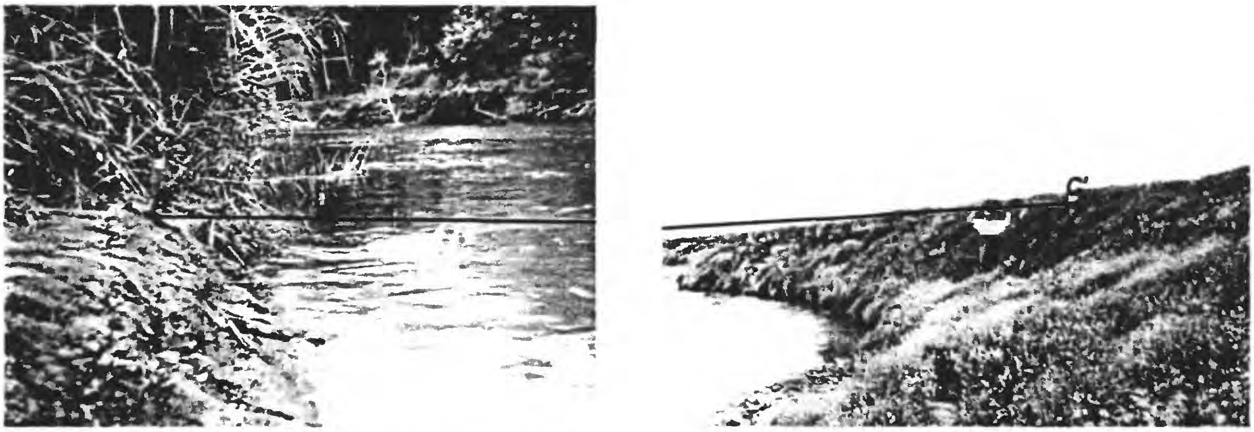
A. Willow Creek near Mason City
(station number 05460100;
map number 69, fig. 2)

B. Black Hawk Creek at Grundy Center
(station number 05463090;
map number 73, fig. 2)



C. Keigley Branch near Story City
(station number 05469990;
map number 85, fig. 2)

D. Big Cedar Creek near Varina
(station number 05482170;
map number 108, fig. 2)



E. Middle Raccoon River near Bayard
(station number 05483450;
map number 115, fig. 2)

F. West Branch Floyd River near Struble
(station number 06600300;
map number 144, fig. 2)

Figure 7. Active-channel (B-B') and bankful (C-C') reference levels at six streamflow-gaging stations in Iowa.

channels had stabilized. Commonly, the active-channel portion of the channel will adjust back to natural or stable conditions within approximately 5 to 10 years after channelization occurs (Waite Osterkamp, U.S. Geological Survey, oral commun., October 1992). Two data sets thus were compiled for the channel-geometry multiple-regression analyses: a 157-station data set that did not include bankfull measurements and a 111-station data set (a subset of the 157-station data set) that included both the active-channel and bankfull measurements.

Channel-Geometry Characteristic Equations

Analysis of Channel-Geometry Data on a Statewide Basis

Multiple-regression analyses initially were performed on both data sets. Statewide equations were developed for each data set using the ordinary least-squares (OLS) and weighted least-squares (WLS) multiple-regression techniques previously described. The best equations developed in terms of PRESS statistics, coefficients of determination, and standard errors of estimate for each data set are listed in table 3. The channel-geometry characteristics identified as most significant for the 111-station data set were bankfull width (*BFW*) and bankfull depth (*BFD*). The channel-geometry characteristic identified as most significant in the 157-station data set was active-channel width (*ACW*). Table 9 (at end of this report) lists the average values for *BFW*, *BFD*, and *ACW* for the streamflow-gaging stations analyzed in the 111- and 157-station data sets. Appendix C (at end of this report) outlines the procedure for conducting channel-geometry measurements of these characteristics.

Comparison of the average standard errors of prediction listed in table 3 indicate that the data set that included bankfull measurements provided better estimation accuracy for the design-flood discharges investigated in this study than did the active-channel measurements in the other data set. The size and shape of the channel cross section is assumed to be a function of streamflow discharge and sediment-load transport. The bankfull channel is a longer term geomorphic feature predominately sculptured by larger magnitude discharges, whereas the active channel is a shorter term geomorphic feature that is sculptured by continuous fluctuations in discharge. Because the design-flood discharge equations developed in this study estimate larger magnitude discharges, a multiple regression relation with better estimation accuracy was defined using bankfull characteristics.

In an attempt to further improve the estimation accuracy of the equations, each gaging station was classified into one of six channel types for which separate multiple-regression analyses were performed. Gaging stations were classified according to channel-type classifications described by Osterkamp and Hedman (1982, p. 8). This classification is based on the results of the sediment-sample analyses of percent silt-clay content (SC_{bd}) and diameter size (D_{50}) of the channel-bed particles, and the percent silt-clay content of the left (SC_{lbk})and right bank (SC_{rbk}) material. The channel-geometry flood-estimation equations developed using this procedure were inconclusive because the estimation accuracy of some channel-type equations improved while the estimation accuracy of other equations decreased. An analysis of covariance procedure described by W.O. Thomas, Jr., (U.S. Geological Survey, written commun., 1982), wherein each channel-type classification was identified as a qualitative variable, was used to test whether there was a statistical difference due to channel-type classifications. Based on the results of this analysis, there was no significant difference between the channel-type equations and the equations developed without channel-type classification. Because of the results of these two channel-type analyses, statewide channel-geometry equations classified according to sediment-sample analyses were determined to not significantly improve the estimates of design-flood discharges for streams in Iowa.

Analysis of Channel-Geometry Data by Selected Regions

Examination of residuals for both sets of statewide channel-geometry equations listed in table 3 indicated evidence of geographic bias with respect to the Des Moines Lobe landform

Table 3. *Statewide channel-geometry characteristic equations for estimating design-flood discharges in Iowa*

[Q, peak discharge, in cubic feet per second, for a given recurrence interval, in years; BFW, bankfull width, in feet; BFD, bankfull depth, in feet; ACW, active-channel width, in feet]

Estimation equation	Standard error of estimate		Average standard error of prediction (percent)	Average equivalent years of record
	Log10	Percent		
Bankfull equations Number of streamflow-gaging stations = 111				
$Q_2 = 4.56\, BFW^{0.982}\, BFD^{1.02}$	0.169	40.4	41.0	4.2
$Q_5 = 14.7\, BFW^{0.915}\, BFD^{0.899}$	.173	41.5	42.2	4.6
$Q_{10} = 26.7\, BFW^{0.874}\, BFD^{0.846}$	.186	44.9	45.8	5.1
$Q_{25} = 49.5\, BFW^{0.828}\, BFD^{0.797}$	.206	50.2	51.4	5.8
$Q_{50} = 73.2\, BFW^{0.796}\, BFD^{0.769}$	.221	54.4	55.8	7.0
$Q_{100} = 104\, BFW^{0.766}\, BFD^{0.747}$	.236	58.7	60.4	8.5
Active-channel equations Number of streamflow-gaging stations = 157				
$Q_2 = 38.5\, ACW^{1.06}$	0.267	67.8	68.3	1.6
$Q_5 = 98.2\, ACW^{0.980}$	.247	61.9	62.3	2.1
$Q_{10} = 157\, ACW^{0.937}$	.246	61.5	61.9	2.8
$Q_{25} = 256\, ACW^{0.891}$	.251	63.0	63.6	3.6
$Q_{50} = 349\, ACW^{0.861}$	.258	65.1	65.8	4.8
$Q_{100} = 458\, ACW^{0.833}$	.267	67.7	68.4	6.3

Note: Bankfull equations may provide improved accuracies over active-channel equations for channels unaffected by channelization. For channels affected by channelization, the active-channel equations only are applicable when the active channels have stabilized (approximately 5 to 10 years after channelization). See Appendix C for a discussion of stabilized channels.

region (fig. 2). Consequently, both data sets were split into regional data sets, and additional multiple-regression analyses were performed for two regions in Iowa.

The State was divided into two hydrologic regions using information on areal trends of the residuals for the statewide regression equations, the Des Moines Lobe landform region, and topography as guides. The delineation of channel-geometry Regions I and II is shown in figure 2. The topography of the Des Moines Lobe landform region (Region II) is characteristic of a young, postglacial landscape that is unique with respect to the topography of the rest of the State (Region I) (Prior, 1991, p. 30-47). The region generally comprises low-relief terrain, accentuated by natural lakes, potholes, and marshes, where surface-water drainage typically is poorly defined and sluggish. The shaded area between hydrologic Regions I and II (fig. 2) represents a transitional zone where the channel morphology of one region gradually merges into the other. This regionalization process served to compensate for the geographic bias observed in the statewide residual plots, which was not accounted for otherwise in the 111- and 157-station channel-geometry regression equations listed in table 3.

Using the OLS and WLS multiple-regression techniques previously described, two sets of flood-estimation equations were developed for each channel-geometry region. Of the 111-station data set, 78 stations were in Region I and 33 stations were in Region II. Of the 157-station data set, 120 stations were in Region I and 37 stations were in Region II. Gaging stations located within the regional transition zone (fig. 2) were compiled into either Region I or Region II data sets on the basis of residuals from the statewide regression equations and on the regional locations of their stream channels. The best equations developed in terms of PRESS statistics, coefficients of determination, and standard errors of estimate for the Region I data sets are listed in table 4 and the best equations developed for the Region II data sets are listed in table 5.

The channel-geometry characteristic that was identified as most significant in the Region I 78-station bankfull equations was bankfull width (*BFW*). The characteristic identified as most significant in the Region I 120-station active-channel equations was active-channel width (*ACW*). The channel-geometry characteristics that were identified as most significant in the Region II 33-station bankfull equations were bankfull width (*BFW*) and bankfull depth (*BFD*), and the most significant characteristic in the Region II 37-station active-channel equations was active-channel width (*ACW*). Appendix C (at end of this report) outlines the procedure for conducting channel-geometry measurements of these characteristics.

Comparison of Regional and Statewide Channel-Geometry Equations

Comparison of the Region I and II equations with the statewide equations shows an improvement in the average standard errors of prediction for all of the regional equations except the 25-, 50- and 100-year recurrence intervals of the Region II active-channel equations. The regional equations listed in tables 4 and 5 may provide improved accuracies for estimating design-flood discharges based on channel-geometry measurements. The statewide equations listed in table 3 also can be used to estimate design-flood discharges, although their accuracies may be less than for the regional equations. Comparison of the bankfull equations with the active-channel equations listed in tables 3-5 shows an improvement in the average standard errors of prediction for all of the bankfull equations. The bankfull equations may provide improved estimation accuracies in comparison to active-channel equations for estimating design-flood discharges for channels unaffected by channelization.

Bankfull depth (*BFD*) was identified as a significant channel-geometry characteristic in the statewide bankfull equations (table 3). It is also a significant channel-geometry characteristic in the estimation of design-flood discharges for stream sites located within the Des Moines Lobe landform region (fig. 2, Region II). While bankfull depth was not identified as significant in estimating flood discharges in Region I, it appears to be a significant morphologic feature distinguishing stream channels in Regions I and II.

Table 4. *Region I channel-geometry characteristic equations for estimating design-flood discharges in Iowa outside of the Des Moines Lobe landform region*[1]

[Q, peak discharge, in cubic feet per second, for a given recurrence interval, in years; BFW, bankfull width, in feet; ACW, active-channel width, in feet]

Estimation equation	Standard error of estimate Log$_{10}$	Standard error of estimate Percent	Average standard error of prediction (percent)	Average equivalent years of record
Bankfull equations Number of streamflow-gaging stations = 78				
$Q_2 = 4.55\ BFW^{1.45}$	0.160	38.1	38.9	4.8
$Q_5 = 15.6\ BFW^{1.32}$	.140	33.1	33.8	7.4
$Q_{10} = 29.2\ BFW^{1.25}$	.146	34.5	35.4	8.8
$Q_{25} = 55.7\ BFW^{1.18}$	.162	38.5	39.8	9.8
$Q_{50} = 84.2\ BFW^{1.13}$	.176	42.3	43.9	12.6
$Q_{100} = 122\ BFW^{1.09}$	.192	46.4	48.3	16.1
Active-channel equations Number of streamflow-gaging stations = 120				
$Q_2 = 45.6\ ACW^{1.07}$	0.213	52.1	53.0	2.4
$Q_5 = 118\ ACW^{0.982}$	.180	43.2	44.2	4.0
$Q_{10} = 190\ ACW^{0.937}$	.175	41.9	43.0	5.4
$Q_{25} = 312\ ACW^{0.889}$	.179	43.1	44.5	7.0
$Q_{50} = 427\ ACW^{0.858}$	.188	45.3	46.9	8.9
$Q_{100} = 566\ ACW^{0.828}$	.198	48.2	50.0	11.0

[1] The Des Moines Lobe landform region is delineated as Region II in figure 2.

Note: **Bankfull equations may provide improved accuracies over active-channel equations for channels unaffected by channelization. For channels affected by channelization, the active-channel equations only are applicable when the active channels have stabilized (approximately 5 to 10 years after channelization). See Appendix C for a discussion of stabilized channels.**

Table 5. *Region II channel-geometry characteristic equations for estimating design-flood discharges in Iowa within the Des Moines Lobe landform region*[1]

[*Q*, peak discharge, in cubic feet per second, for a given recurrence interval, in years; *BFW*, bankfull width, in feet; *BFD*, bankfull depth, in feet; *ACW*, active-channel width, in feet]

Estimation equation	Standard error of estimate		Average standard error of prediction (percent)	Average equivalent years of record
	Log_{10}	Percent		
Bankfull equations Number of streamflow-gaging stations = 33				
$Q_2 = 2.77\ \mathrm{BFW}^{0.844}\ BFD^{1.48}$	0.123	28.8	30.3	6.5
$Q_5 = 7.42\ \mathrm{BFW}^{0.783}\ BFD^{1.43}$	.131	30.8	33.6	6.1
$Q_{10} = 12.1\ \mathrm{BFW}^{0.748}\ BFD^{1.41}$	.143	33.9	37.7	6.3
$Q_{25} = 19.7\ \mathrm{BFW}^{0.715}\ BFD^{1.38}$	.162	38.6	43.4	6.6
$Q_{50} = 26.7\ \mathrm{BFW}^{0.694}\ BFD^{1.37}$	.176	42.3	47.8	7.9
$Q_{100} = 34.9\ \mathrm{BFW}^{0.675}\ BFD^{1.36}$	.190	45.9	52.1	9.3
Active-channel equations Number of streamflow-gaging stations = 37				
$Q_2 = 7.80\ ACW^{1.30}$	0.236	58.5	59.7	1.9
$Q_5 = 19.1\ ACW^{1.23}$	.235	58.4	60.1	2.1
$Q_{10} = 29.6\ ACW^{1.19}$	.240	59.7	61.8	2.6
$Q_{25} = 45.6\ ACW^{1.16}$	.248	62.0	64.8	3.3
$Q_{50} = 59.5\ ACW^{1.14}$	.255	64.2	67.4	4.4
$Q_{100} = 75.0\ ACW^{1.12}$	.262	66.4	70.0	5.7

[1] The Des Moines Lobe landform region is delineated as Region II in figure 2.

Note: Bankfull equations may provide improved accuracies over active-channel equations for channels unaffected by channelization. For channels affected by channelization, the active-channel equations only are applicable when the active channels have stabilized (approximately 5 to 10 years after channelization). See Appendix C for a discussion of stabilized channels.

The differences in peak-discharge estimation between regional and statewide active-channel width (*ACW*) equations are shown in figures 8*B* and 9*B* for the 2- and 100-year recurrence intervals, respectively. Figures 8*B* and 9*B* illustrate the higher estimated peak discharges obtained from the Region I equations relative to those obtained from the Region II equations for a specified active-channel width. The slopes of the Region I regression lines are parallel to those of the statewide regression lines at a higher estimated discharge. The Region II regression lines have steeper slopes relative to the Region I and statewide regression lines but at a lower estimated discharge. Figures 8*A* and 9*A* illustrate the relation of the Region I, bankfull regression equations for 2- and 100-year recurrence-interval discharges, respectively. Tests performed using STATIT procedure REGGRP (Statware, Inc., 1990, p. 6-32 - 6-36) indicated that there were statistically significant differences in the slopes and intercepts of the Region I and Region II regression lines for both the bankfull and active-channel equations.

The paired-t test was used to test whether design-flood discharge estimates obtained by both the bankfull and active-channel regression equations for the same gaging station were significantly different at the 95-percent level of significance. The paired-t test was applied using STATIT procedure HYPOTH (Statware, Inc., 1990, p. 3-21 - 3-23). For table 3, discharge estimates for 111 stations were not significantly different for all design-flood recurrence intervals. For table 4, discharge estimates for 78 stations were significantly different for the 2-year recurrence interval, but estimates were not significantly different for the 5-year to 100-year recurrence intervals. For table 5, discharge estimates for 33 stations were not significantly different for all design-flood recurrence intervals.

The application of the channel-geometry regression equations listed in tables 4 and 5 for a stream site are determined by two factors, and the application of the channel-geometry equations listed in table 3 are determined only by the second factor. First, the stream site is located in figure 2 to determine whether Region I or Region II equations apply. The user may be faced with a dilemma if design-flood discharges are to be estimated for a stream site located within the shaded transitional zone or for a stream that crosses regional boundaries. The discharges could be estimated using both the Region I and II equations and hydrologic judgment used to select the most reasonable design-flood estimate, or a weighted average based on the proportion of drainage area within each region could be applied. The most reasonable alternative to resolving this dilemma may be to use the statewide equations listed in table 3 because they preclude regional subjectivity and the majority of statewide design-flood estimates calculate between Region I and Region II estimates.

Second, the stream site is inspected to determine whether the stream was channelized. If evidence of channelization is not found, then the bankfull equations are applicable (the first set of equations listed in tables 3, 4, and 5); if evidence of channelization is found, then the active-channel equations may be applicable for stabilized channels (the second set of equations listed in tables 3, 4, and 5). Appendix C (at end of this report) outlines a procedure for identifying channelized streams and describes the stabilization conditions for which channel-geometry measurements of channelized streams are applicable.

Examples of Equation Use--Examples 2-4

Example 2.--Use a regional, channel-geometry equation to estimate the 100-year peak discharge for the discontinued Black Hawk Creek at Grundy Center crest-stage gaging station (station number 05463090; map number 73, fig. 2), located in Grundy County, at a bridge crossing on State Highway 14, at the north edge of Grundy Center, in the NW1/4 sec. 7, T. 87 N., R. 16 W.

Step 1. The appropriate regional equation is determined on the basis of which hydrologic region the stream site is located in and whether the stream has been channelized. This gaging station is located in Region I, and an inspection of the USGS 1:100,000-scale Grundy County map and a visit to the site show no evidence of channelization. Therefore the 100-year bankfull equation for Region I, listed in the first set of

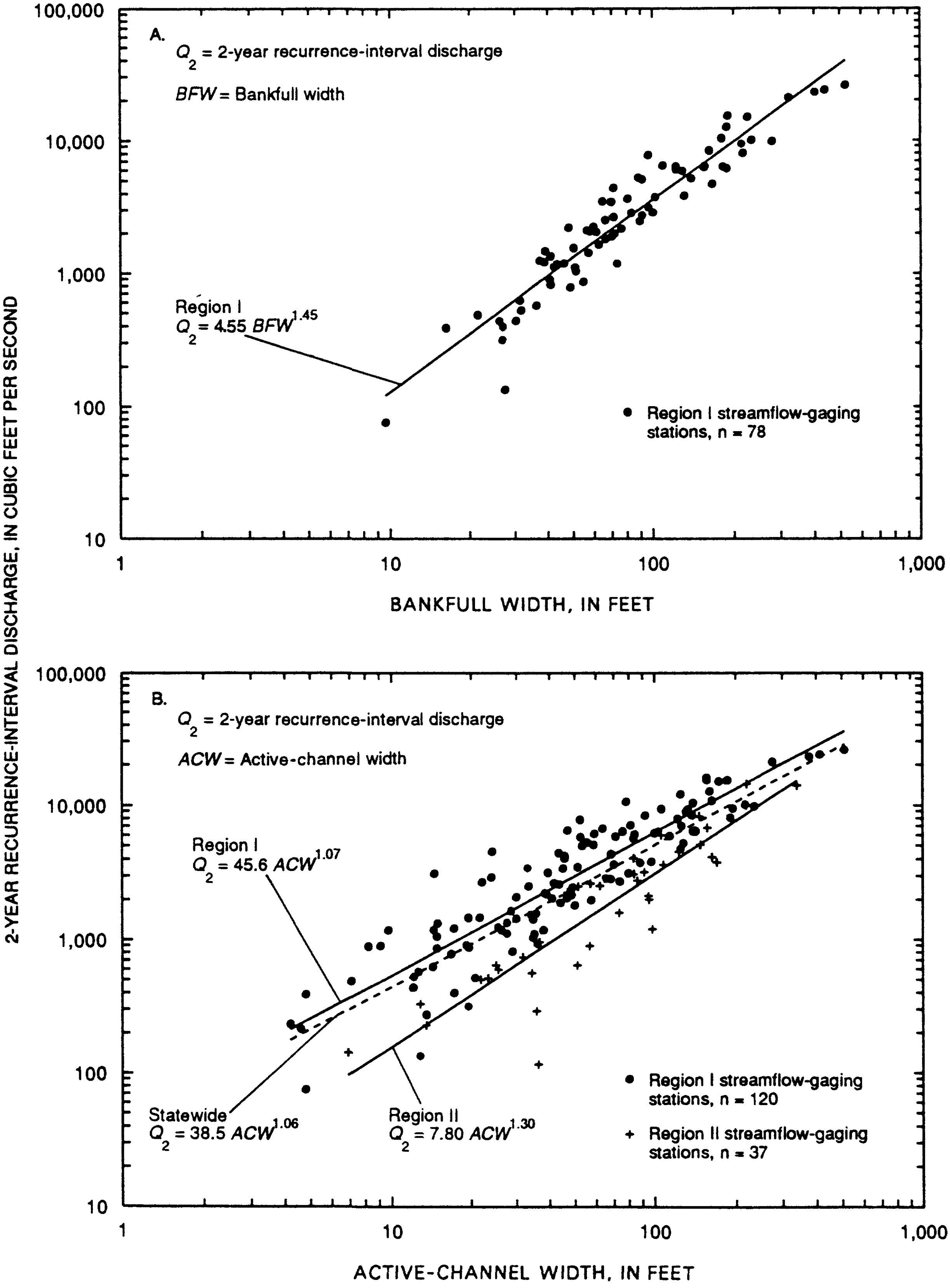


Figure 8. Relation between 2-year recurrence-interval discharge and channel width for (*A*) bankfull and (*B*) active-channel width regression equations.

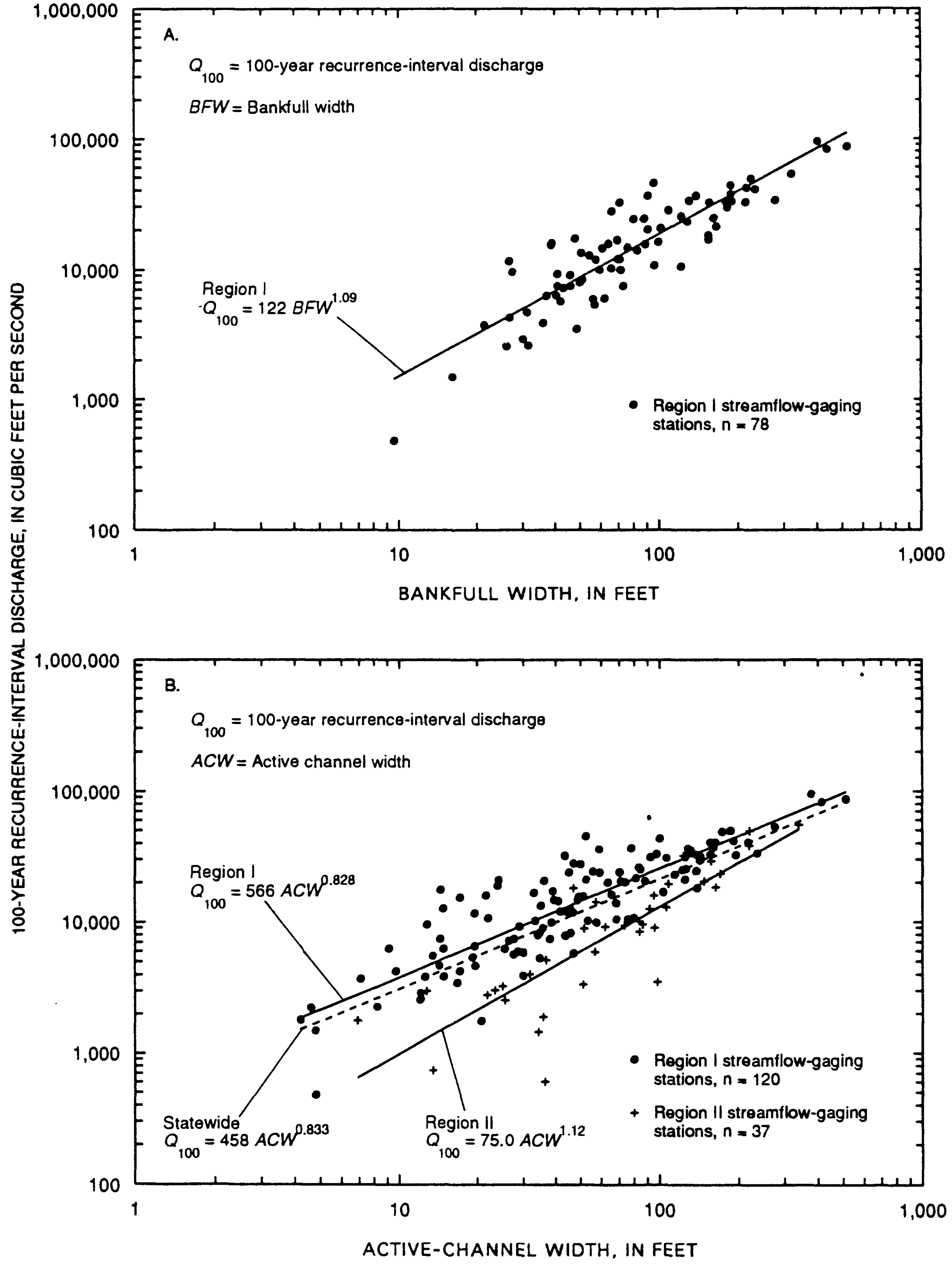


Figure 9. Relation between 100-year recurrence-interval discharge and channel width for (*A*) bankfull and (*B*) active-channel width regression equations.

equations in table 4, is determined to be the most applicable. The only channel-geometry characteristic used for the Region I bankfull equation is the bankfull width (*BFW*). Appendix C describes the procedure for conducting this channel-geometry measurement.

Step 2. Three bankfull widths measuring 52, 50, and 52 ft, measured along a straight channel reach about 0.75-1.0 mi downstream of the gaging station, were used to calculate an average bankfull width (*BFW*) of 51 ft. Figure 7*B* shows the bankfull reference level at one of these channel measurement sections.

Step 3. The 100-year flood estimate for the Region I bankfull equation (table 4) is calculated as

$$\begin{aligned} Q_{100} &= 122\,(BFW)^{1.09}, \\ &= 122\,(51)^{1.09}, \\ &= 8{,}860 \text{ ft}^3\text{/s}. \end{aligned}$$

Example 3.--Use a regional channel-geometry equation to estimate the 50-year peak discharge for the Big Cedar Creek near Varina continuous-record gaging station (station number 05482170; map number 108, fig. 2), located in Pocahontas County, at a bridge crossing on County Highway N33, 5.5 mi northeast of Varina, in the NE1/4 sec. 24, T. 91 N., R. 34 W.

Step 1. This gaging station is located in Region II, and an inspection of the USGS 1:100,000-scale Pocahontas County map and a visit to the site show evidence of channelization. Therefore, the 50-year active-channel equation for Region II, listed in the second set of equations in table 5, is determined to be the most applicable. Features that are characteristic of channelized streams are illustrated in figure 7*D*, which shows the straightened and leveed channel reach downstream of the gage. The only channel-geometry characteristic used for the Region II active-channel equation is the active-channel width (*ACW*). Appendix C describes the procedure for conducting this channel-geometry measurement.

Step 2. Three active-channel widths measuring 25.6, 25.3, and 24.2 ft, measured along a straight channel reach about 0.25-0.5 mi downstream of the gaging station, were used to calculate an average active-channel width (*ACW*) of 25.0 ft. Figure 7*D* shows the approximate active-channel reference level for the channel reach measured to calculate an average active-channel width.

Step 3. The 50-year flood estimate for the Region II active-channel equation (table 5) is calculated as

$$\begin{aligned} Q_{50} &= 59.5\,(ACW)^{1.14}, \\ &= 59.5\,(25.0)^{1.14}, \\ &= 2{,}330 \text{ ft}^3\text{/s}. \end{aligned}$$

Example 4.--Use a statewide channel-geometry equation in table 3 to estimate the 100-year peak discharge for the gaging station used in example 2.

Step 1. Because a statewide equation is to be used and no evidence of channelization is evident, as determined in example 2, the 100-year bankfull equation listed in the first set of equations in table 3 is applicable. Bankfull width (*BFW*) and bankfull depth (*BFD*) are the channel-geometry characteristics used for this equation. Appendix C describes the procedure for conducting these channel-geometry measurements.

Step 2. The average bankfull width (*BFW*) calculation of 51 ft for this stream channel is outlined in example 2.

Step 3. The average bankfull depth (*BFD*) for this stream channel was calculated to be 6.0 ft. The bankfull depth measurements used to determine this average are listed in the "Bankfull-Depth (*BFD*) Measurements" section of Appendix C, and they are illustrated in figure 10.

Step 4. The 100-year flood estimate for the statewide bankfull equation (table 3) is calculated as

$$\begin{aligned} Q_{100} &= 104\,(BFW)^{0.766}\,(BFD)^{0.747}, \\ &= 104\,(51)^{0.766}\,(6.0)^{0.747}, \\ &= 8{,}060 \text{ ft}^3\text{/s}. \end{aligned}$$

Examples 2 and 4 illustrate the use of bankfull measurements in computing 100-year flood estimates for this gaging station using regional and statewide multiple-regression equations. The regional estimate was determined to be 8,860 ft^3/s, and the statewide estimate was determined to be 8,060 ft^3/s.

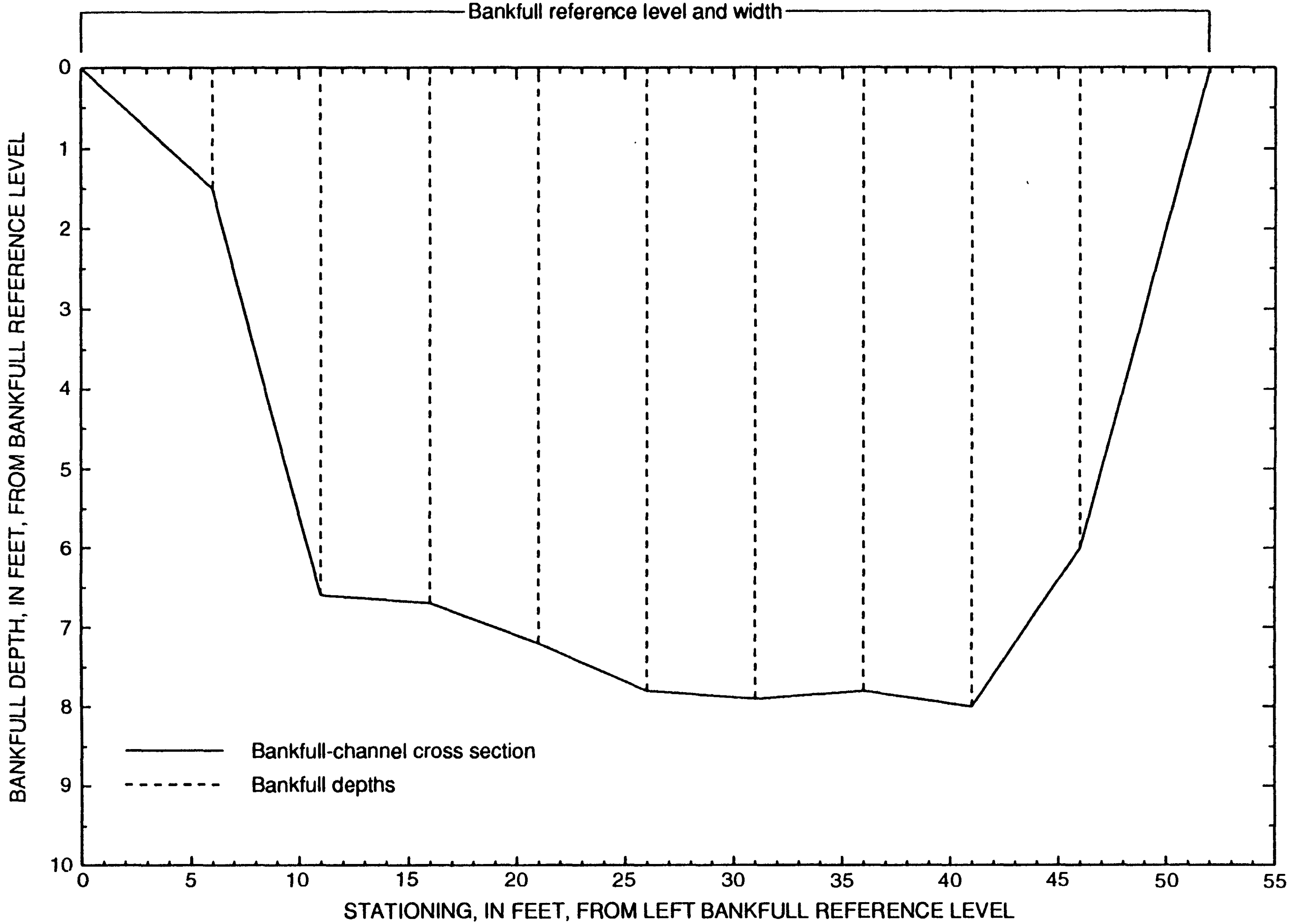


Figure 10. Bankfull cross section for Black Hawk Creek at Grundy Center (station number 05463090; map number 73, fig. 2).

APPLICATION AND RELIABILITY OF FLOOD-ESTIMATION METHODS

The regression equations developed in this study for both the drainage-basin and channel-geometry flood-estimation methods apply only to streams in Iowa where peak streamflow is not affected substantially by stream regulation, diversion, or other human activities. The drainage-basin method does not apply to basins in urban areas unless the effects of urbanization on surface-water runoff are negligible. The channel-geometry method does not apply to channels that have been altered substantially from their stabilized conditions by human activities, as outlined in Appendix C.

Limitations and Accuracy of Equations

The applicability and accuracy of the drainage-basin and channel-geometry flood-estimation methods depend on whether the drainage-basin or channel-geometry characteristics measured for a stream site are within the range of the characteristic values used to develop the regression equations. The acceptable range for each of the drainage-basin characteristics used to develop the statewide equations (table 2) are tabulated as maximum and minimum values in table 6. Likewise, the acceptable range for each of the channel-geometry characteristics used to develop the statewide and regional equations (tables 3-5) also are tabulated as maximum and minimum values in table 6. The applicability of the drainage-basin and channel-geometry equations is unknown when the characteristic values associated with a stream site are outside of the acceptable ranges.

The standard errors of estimate and average standard errors of prediction listed in tables 2-5 are indexes of the expected accuracy of the regression-equation estimates in that they provide measures of the difference between the regression estimate and the Pearson Type-III estimate for a design-flood recurrence interval. If all assumptions for applying regression techniques are met, the difference between the regression estimate and the Pearson Type-III estimate for a design-flood recurrence interval will be within one standard error approximately two-thirds of the time.

The standard error of estimate is a measure of the distribution of the observed annual-peak discharges about the regression surface (Jacques and Lorenz, 1988, p. 17). The average standard error of prediction includes the error of the regression equation as well as the scatter about the equation (Hardison, 1971, p. C228). Although the standard error of estimate of the regression gives an approximation of the standard error of peak discharges, the average standard error of prediction provides more precision in the expected accuracy with which estimates of peak discharges can be made. The average standard error of prediction is estimated by taking the square root of the PRESS statistic mean. Because the standard errors of estimate and average standard errors of prediction are expressed as logarithms (base 10), they are converted to percentages by methods described by Hardison (1971, p. C230).

The average standard errors of prediction for the regression models ranged as follows: statewide drainage-basin equations, 38.6 to 50.2 percent (table 2); statewide channel-geometry bankfull equations, 41.0 to 60.4 percent (table 3); statewide channel-geometry active-channel equations, 61.9 to 68.4 percent (table 3); Region I channel-geometry bankfull equations, 33.8 to 48.3 percent (table 4); Region I channel-geometry active-channel equations, 43.0 to 53.0 percent (table 4); Region II channel-geometry bankfull equations, 30.3 to 52.1 percent (table 5); and Region II channel-geometry active-channel equations, 59.7 to 70.0 percent (table 5).

The average equivalent years of record represents an estimate of the number of years of actual streamflow record required at a stream site to achieve an accuracy equivalent to each respective drainage-basin or channel-geometry design-flood discharge estimate. The average equivalent years of record as described by Hardison (1971, p.C231-C233) is a function of the standard deviation and skew of the observed annual-peak discharges at the gaging stations analyzed for each respective regression equation, the accuracy of the regression equation, and the recurrence interval of the design flood. The average equivalent years of record for a design flood with a recurrence

Table 6. *Statistical summary for selected statewide drainage-basin and channel-geometry characteristics, and for selected regional channel-geometry characteristics at streamflow-gaging stations in Iowa*

[*CDA*, contributing drainage area, in square miles; *RR*, relative relief, in feet per mile; *DF*, drainage frequency, in number of first-order streams per square mile; *TTF*, 2-year, 24-hour precipitation intensity, in inches; *BFW*, bankfull width, in feet; *BFD*, bankfull depth, in feet; *ACW*, active-channel width, in feet]

	Statewide drainage-basin characteristics			
Statistic	*CDA*	*RR*	*DF*	*TTF*
Maximum	1,060	48.7	2.95	3.26
Minimum	.338	1.57	.043	2.82
Mean	209	6.48	.520	3.11
Median	80.7	4.45	.510	3.14
No. of sites	164	164	164	164

	Statewide channel-geometry characteristics		
Statistic	*BFW*	*BFD*	*ACW*
Maximum	523	17.1	510
Minimum	9.6	1.7	4.2
Mean	110	7.0	77.0
Median	82.7	6.7	49.8
No. of sites	111	111	157

	Regional channel-geometry characteristics				
	Region I		Region II		
Statistic	*BFW*	*ACW*	*BFW*	*BFD*	*ACW*
Maximum	523	510	361	12.5	339
Minimum	9.6	4.2	19.3	2.0	6.9
Mean	106	73.7	120	6.6	87.4
Median	71.0	46.1	106	6.6	73.3
No. of sites	78	120	33	33	37

interval of T-years is calculated as (Hardison, 1971, p. C231)

$$E = r^2 \left(\frac{\bar{s}}{SE_p} \right)^2 , \tag{13}$$

where E is the average equivalent years of record, in years;

r is a factor that is a function of the mean weighted skew coefficient of the logarithms (base 10) of the observed annual-peak discharges at the gaging stations used in each respective regression-model data set and the recurrence interval relating the standard error of a T-year peak discharge to the index of variability ($\bar{s}$) and the number of observed annual-peak discharges;

$\bar{s}$ is an index of variability equal to the mean standard deviation of the logarithms (base 10) of the observed annual-peak discharges at the gaging stations used in each respective regression-model data set; and

SE_p is the average standard error of prediction, in log units (base 10), estimated using the Press statistic.

Several of the primary drainage-basin characteristics used in the regression equations listed in table 2 are map-scale dependent. Use of maps of scales other than the scales used to develop the equations may produce results that do not conform to the range of estimation accuracies listed for the equations in table 2. The scale of map to use for manual measurements of each primary drainage-basin characteristic is outlined in Appendix A and Appendix B.

An additional constraint in the application and reliability of the channel-geometry characteristic equations is the requirement to obtain onsite measurements of bankfull or active-channel width, and possibly bankfull depth. Training and experience are required to properly identify the bankfull and active-channel features in order to make these measurements. The variability in making these measurements can be large, even among experienced individuals. As reported by Wahl (1976), based on a test conducted in northern Wyoming, the standard error in estimated discharge due to variation in width measurements alone was about 30 percent (0.13 log unit). Variation in bankfull-depth measurements probably would increase this standard error in estimated discharge. Wahl (1976) also noted an average bias with respect to the mean channel width of about 14 percent (0.06 log unit). A truer total standard error, in log units, for a channel-geometry discharge estimate is calculated by Wahl (1984, p. 63) as the square root of the sums of the squares of the errors of the regression equation and of the variation and average bias in width measurements. Using the standard error of estimate for the Region I, 100-year flood bankfull equation (table 4) and assuming the standard errors for measuring channel width reported by Wahl (1976), the

$$\text{true standard error} = [(0.192)^2 + (0.13)^2 + (0.06)^2]^{0.5}, \\ = 0.240.$$

This yields an average standard error of 59.6 percent compared to 46.4 percent for the regression equation alone. Wahl (1984, p. 64) notes that the variability of the measurements collected in the Wyoming test probably is greater than normally would be encountered in applying channel-geometry measurements in a particular hydrologic area. Sites in the Wyoming test were chosen for their diversity, and they ranged from ephemeral streams in a nearly desert environment to perennial streams in a high mountain environment.

Despite the limitations associated with the channel-geometry method, the equations presented in this report are considered to be useful as a corroborative flood-estimation method with respect to the drainage-basin method. The channel-geometry equations are applicable to all unregulated, stabilized stream channels in the State, whereas the drainage-basin equations are applicable only to stream sites with drainage areas less than 1,060 mi^2. Although the error of measurement may be larger for channel-geometry characteristics than for drainage-basin characteristics, the variability of channel-geometry measurements made in Iowa are assumed to be not as great as reported by Wahl (1984) for the Wyoming test. An additional advantage in utilizing the channel-geometry method is that design-flood discharge estimates obtained from each flood-estimation method can be used to calculate a weighted average as described in the following section.

Weighting Design-Flood Discharge Estimates

Design-flood discharges determined using both the drainage-basin and channel-geometry flood-estimation methods are presumed to be independent from each other. Each flood-estimation method thus can be used to verify results from the other; when design-flood discharge estimates are independent, the independent estimates can be used to obtain a weighted average (IACWD, 1982, p. 8-1).

Calculation of Estimates

Design-flood discharge estimates calculated using both the drainage-basin and channel-geometry flood-estimation methods can be weighted inversely proportional to their variances to obtain a weighted average that has a smaller variance than either of their individual estimates. According to the Interagency Advisory Committee on Water Data (IACWD, 1982), the weighted average is calculated as

$$Q_{T(dbcg)} = \frac{Q_{T(db)}(SE_{(cg)})^2 + Q_{T(cg)}(SE_{(db)})^2}{(SE_{(db)})^2 + (SE_{(cg)})^2}, \quad (14)$$

where $Q_{T(dbcg)}$ is the weighted average design-flood discharge, in cubic feet per second, for a selected T-year recurrence interval;

$Q_{T(db)}$ is the drainage-basin regression-equation design-flood discharge, in cubic feet per second;

$SE_{(cg)}$ is the standard error of estimate, in log units (base 10), of the channel-geometry regression equation (tables 3-5);

$Q_{T(cg)}$ is the channel-geometry regression-equation design-flood discharge, in cubic feet per second; and

$SE_{(db)}$ is the standard error of estimate, in log units (base 10), of the drainage-basin regression equation (table 2).

The standard error of estimate ($SE_{(dbcg)}$), in log units (base 10), of the weighted average design-flood discharge estimate $Q_{T(dbcg)}$ can be calculated as

$$SE_{(dbcg)} = \left[\frac{(SE_{(db)})^2(SE_{(cg)})^2}{(SE_{(db)})^2 + (SE_{(cg)})^2}\right]^{0.5}. \quad (15)$$

Example of Weighting--Example 5

Example 5.--Use the 100-year drainage-basin and channel-geometry regression estimates (table 8) to obtain a weighted average, 100-year peak-discharge estimate for the discontinued Black Hawk Creek at Grundy Center crest-stage gaging station (station number 05463090; map number 73, figs. 1 and 2).

The 100-year flood estimate calculated for this gaging station using the drainage-basin equation is 7,740 ft^3/s (listed as method GISDB in table 8), and the standard error of estimate, in log units (base 10), for this equation is 0.198 (table 2). The 100-year flood estimate calculated for this gaging station using the Region I, bankfull channel-geometry equation is 8,860 ft^3/s (listed as method BFRI in table 8), and the standard error of estimate, in log units, for this equation is 0.192 (listed in the first set of equations in table 4). The weighted average, 100-year flood estimate is calculated using equation 14 as

$$Q_{100(dbcg)} = \frac{Q_{100(db)}(SE_{(cg)})^2 + Q_{100(cg)}(SE_{(db)})^2}{(SE_{(db)})^2 + (SE_{(cg)})^2},$$

$$= \frac{7,740(0.192)^2 + 8,860(0.198)^2}{(0.198)^2 + (0.192)^2},$$

$$= 8,320 \text{ ft}^3\text{/s}.$$

The standard error of estimate for this weighted average, 100-year peak-discharge estimate is calculated using equation 15 as

$$SE_{(dbcg)} = \left[\frac{(SE_{(db)})^2(SE_{(cg)})^2}{(SE_{(db)})^2 + (SE_{(cg)})^2}\right]^{0.5},$$

$$= \left[\frac{(0.198)^2(0.192)^2}{(0.198)^2 + (0.192)^2}\right]^{0.5},$$

$$= 0.138 \text{ log units or } 32.6 \text{ percent.}$$

Weighting Design-Flood Discharge Estimates for Gaged Sites

Weighted design-flood discharges are estimated for a gaged site based on either the Pearson Type-III estimate and regression-equation estimates from both the drainage-basin and channel-geometry flood-estimation methods or on the Pearson Type-III estimate and only one of the regression-equation estimates. The design-flood discharge estimate is a weighted average of these values in which the Pearson Type-III estimate for the gaged site is weighted by the effective record length (*ERL*) at the gaged site, and the regression-equation estimates are weighted by the average equivalent years of record associated with their respective regression equations.

Calculation of Estimates

The weighted design-flood discharge estimate for a gaged site as outlined by the Interagency Advisory Committee on Water Data (IACWD, 1982, p. 8-1 - 8-2) is calculated as

$$Q_{T(wg)} = \frac{(Q_{T(g)})\,(ERL) + (Q_{T(gdb)})\,(E_{(db)}) + (Q_{T(gcg)})\,(E_{(cg)})}{ERL + E_{(db)} + E_{(cg)}} \quad , (16)$$

where $Q_{T(wg)}$ is the weighted design-flood discharge for a gaging station, in cubic feet per second, for a selected T-year recurrence interval;

$Q_{T(g)}$ is the Pearson Type-III design-flood discharge for a gaging station, in cubic feet per second, as determined by the analysis of the observed annual-peak discharge record (listed as method B17B in table 8);

ERL is the effective record length for a gaging station, in years, representing the $Q_{T(g)}$ analysis (table 8);

$Q_{T(gdb)}$ is the drainage-basin regression-equation design-flood discharge for a gaging station, in cubic feet per second, (listed as method GISDB in table 8);

$E_{(db)}$ is the average equivalent years of record for the drainage-basin regression equation used to determine $Q_{T(gdb)}$ (table 2);

$Q_{T(gcg)}$ is the channel-geometry regression-equation design-flood discharge for a gaging station, in cubic feet per second, (listed as either method BFRI, ACRI, ACRII, or BFRII in table 8); and

$E_{(cg)}$ is the average equivalent years of record for the channel-geometry regression equation used to determine $Q_{T(gcg)}$ (table 4 or 5).

If both the drainage-basin regression-equation estimate $Q_{T(gdb)}$ and the channel-geometry regression-equation estimate $Q_{T(gcg)}$ are not available for a gaged site, then equation 16 used to calculate the weighted design-flood discharge estimate $Q_{T(wg)}$ is simplified to the weighting of two estimates based on $Q_{T(g)}$ and *ERL* and either $Q_{T(gdb)}$ and $E_{(db)}$ or $Q_{T(gcg)}$ and $E_{(cg)}$. An example of weighting a gaged site with only one regression-equation estimate is illustrated in "Example 7."

By including both the drainage-basin and channel-geometry regression-equation estimates, or only one of these estimates, with the computed Pearson Type-III estimate for a gaged site, design-flood histories for a relatively long period of time are incorporated into the weighted estimate for the gaged site and tend to decrease the time-sampling error (Choquette, 1988, p. 41). Climatic conditions during a short gaged period of record often are not indicative of the longer term climatic variability associated with a particular gaging station. Such time-sampling error may be particularly large when the observed gaged period of record represents an unusually wet or dry climatic cycle compared to the longer term average climatic conditions. Time-sampling error thus is minimized for a gaging station by weighting the design-flood discharge estimate $Q_{T(wg)}$.

Examples of Weighting--Examples 6-7

Example 6.--Calculate a weighted 100-year peak-discharge estimate for the discontinued Black Hawk Creek at Grundy Center crest-stage gaging station (station number

05463090; map number 73, figs. 1 and 2). An inspection of table 8 lists regression-equation estimates for both the drainage-basin and channel-geometry flood-estimation methods. The 100-year Pearson Type-III estimate is 8,320 ft^3/s, and the effective record length is 24 years (table 8). The 100-year drainage-basin regression estimate is 7,740 ft^3/s (table 8), and the average equivalent years of record for this regression equation is 11.5 (table 2). The 100-year Region I, bankfull channel-geometry regression estimate is 8,860 ft^3/s (table 8), and the average equivalent years of record for this regression equation is 16.1 (listed in the first set of equations in table 4). The weighted 100-year flood estimate for this gaging station is calculated using equation 16 as

$$Q_{100\,(wg)} = \frac{(Q_{100\,(g)})\,(ERL) + (Q_{100\,(gdb)})\,(E_{(db)}) + (Q_{100(gcb)})\,(E_{(cg)})}{ERL + E_{(db)} + E_{(cg)}},$$

$$= \frac{(8,320)\,(24) + (7,740)\,(11.5) + (8,860)\,(16.1)}{24 + 11.5 + 16.1},$$

$$= 8{,}360 \text{ ft}^3/\text{s}.$$

Example 7.--Calculate a weighted 50-year peak-discharge estimate for the discontinued Fox River at Bloomfield gaging station (station number 05494300; map number 133, fig. 1), located in Davis County, at a bridge crossing on a county highway, about 0.5 mi north of Bloomfield, in the SE1/4 sec. 13, T. 69 N., R. 14 W. Table 8 lists a regression-equation estimate for only the drainage-basin flood-estimation method. The 50-year Pearson Type-III estimate is 10,600 ft^3/s, and the effective record length is 21 years (table 8). The flood-frequency curve developed from the Pearson Type-III analysis for this gaging station is shown in figure 3. The 50-year drainage-basin regression estimate is 7,600 ft^3/s (table 8), and the average equivalent years of record for this regression equation is 9.5 (table 2). The weighted 50-year flood estimate for this gaging station is calculated using a simplified version of equation 16 as

$$Q_{50\,(wg)} = \frac{(Q_{50\,(g)})\,(ERL) + (Q_{50\,(gdb)})\,(E_{(db)})}{ERL + E_{(db)}},$$

$$= \frac{(10,600)\,(21) + (7,600)\,(9.5)}{21 + 9.5},$$

$$= 9{,}670 \text{ ft}^3/\text{s}.$$

Estimating Design-Flood Discharges for an Ungaged Site on a Gaged Stream

Design-flood discharges for an ungaged site on a gaged stream can be estimated if the total drainage area of the ungaged site is between 50 and 150 percent of the total drainage area of the gaged site by an adjustment procedure described by Choquette (1988, p. 42-45) and Koltun and Roberts (1990, p. 6-8). This procedure uses flood-frequency information from the Pearson Type-III and regression-equation estimates at the gaged site to adjust the regression-equation estimate at the ungaged site.

Calculation of Estimates

The regression-equation estimate for the ungaged site is determined as one of the following: (1) the weighted average $Q_{T(dbcg)}$ calculated from both the drainage-basin and channel-geometry regression-equation estimates using equation 14 or (2) the regression-equation estimate of $Q_{T(db)}$ or $Q_{T(cg)}$ calculated from either one of these flood-estimation methods. The calculation for this adjustment procedure is

$$Q_{T\,(au)} = Q_{T\,(ru)}\left[AF - \left(\frac{2\Delta TDA}{TDA_g}\right)(AF - 1)\right], \quad (17)$$

where $Q_{T(au)}$ is the adjusted design-flood discharge for the ungaged site, in cubic feet per second, for a selected T-year recurrence interval;

$Q_{T(ru)}$ is the regression design-flood discharge for the ungaged site, in cubic feet per second, determined as one of the following: (1) the weighted average of both the drainage-basin and channel-geometry regression-equation estimates $Q_{T(dbcg)}$ (equation 14); (2) only the drainage-basin regression-equation estimate $Q_{T(db)}$; or (3) only the channel-geometry regression-equation estimate $Q_{T(cg)}$;

AF is the adjustment factor for the gaged site and is calculated as

$$AF = \frac{Q_{T(wg)}}{Q_{T(rg)}}, \qquad (18)$$

where $Q_{T(wg)}$ is the weighted design-flood discharge for the gaged site, in cubic feet per second, as defined by equation 16;

$Q_{T(rg)}$ is the regression design-flood discharge for the gaged site, in cubic feet per second, determined as one of the following: (1) the weighted average of both the drainage-basin and channel-geometry regression-equation estimates $Q_{T(dbcg)}$, as defined by equation 14; (2) only the drainage-basin regression-equation estimate $Q_{T(db)}$; or (3) only the channel-geometry regression-equation estimate $Q_{T(cg)}$;

ΔTDA is the absolute value of the difference between the total drainage area of the gaged site (TDA_g) and the total drainage area of the ungaged site; and

TDA_g is the total drainage area of the gaged site, in square miles, listed as the published drainage area in table 9.

This procedure (1) adjusts the regression-equation estimate for the ungaged site $Q_{T(ru)}$ by the ratio AF when the total drainage area of the ungaged site equals the total drainage area of the gaged site TDA_g and (2) prorates the adjustment to 1.0 as the difference in total drainage area between the gaged site and the ungaged site approaches either 0.5 or 1.5 of the total drainage area of the gaged site. In other words, when the total drainage area of the ungaged site is 50 percent larger or 50 percent smaller than the total drainage area of the gaged site, no adjustment is applied to the regression-equation estimate for the ungaged site $Q_{T(ru)}$.

Example of Estimation Method--Example 8

Example 8.--Determine the 50-year peak-discharge estimate for an ungaged site on Otter Creek, located on the Osceola and Lyon County line, at a bridge crossing on County Highway L26, 4.75 mi southwest of Ashton, in the SW1/4 sec. 31, T. 98 N., R. 42 W. Because a crest-stage gaging station is located on this stream, Otter Creek near Ashton (station number 06483460; map number 139, fig. 1), the 50-year recurrence interval regression-equation estimate calculated for the ungaged site can be adjusted by the weighted 50-year flood-discharge estimate calculated for the gaged site. Estimating the adjusted 50-year peak discharge for the ungaged site $Q_{50(au)}$ (equation 17) involves four steps.

Step 1. A regression-equation estimate $Q_{50(ru)}$ (equation 17) is calculated for the ungaged site. Both drainage-basin and channel-geometry flood-estimation methods could be used to calculate a weighted average estimate $Q_{50(dbcg)}$ (equation 14) for the regression estimate ($Q_{50(ru)}$) or only one of these flood-estimation methods could be used to calculate the regression-equation estimate ($Q_{50(ru)}$). For this example, only the statewide drainage-basin estimate ($Q_{50(db)}$) (table 2) will be used for the 50-year recurrence interval regression-equation estimate ($Q_{50(ru)}$) at the ungaged site because channel-geometry measurements were not collected for calculating a channel-geometry estimate ($Q_{50(cg)}$).

(A). The characteristics used in the drainage-basin equation (table 2) are contributing drainage area (*CDA*), relative relief (*RR*), drainage frequency (*DF*), and 2-year, 24-hour precipitation intensity (*TTF*). The primary drainage-basin characteristics used in this equation are total drainage area (*TDA*), noncontributing drainage area (*NCDA*), basin relief (*BR*), basin perimeter (*BP*), number of first-order streams (*FOS*), and 2-year, 24-hour precipitation intensity (*TTF*). These primary drainage-basin characteristic measurements and the scale of maps to use for each manual measurement are described in Appendix A and Appendix B.

(B). The topographic maps used to delineate the drainage-divide boundary for this ungaged site are the DMA 1:250,000-scale Fairmont topographic map and the USGS 1:100,000-scale Osceola County map. Contributing drainage area (*CDA*) is calculated from the primary drainage-basin characteristics total drainage area (*TDA*) and noncontributing drainage area (*NCDA*). The drainage-divide boundary for this basin is delineated on the 1:250,000-scale map, and the total drainage area (*TDA*) for the ungaged site is listed in Larimer (1957, p. 313) as 120 mi^2. The total drainage area published for the gaged site, Otter Creek near Ashton (station number 06483460; map number 139, fig. 1), is 88.0 mi^2 (table 9). Because the total drainage area of the ungaged site is 136.4 percent of the total drainage area of the gaged site and within the 50- and 150-percent limits for application, the adjustment procedure is determined to be applicable to the ungaged site. Inspection of the 1:100,000-scale map does not show any noncontributing drainage areas within the drainage-divide boundary of this basin. The contributing drainage area (*CDA*) for the ungaged site is calculated using equation 10 as

$$
\begin{aligned}
CDA &= TDA - NCDA,\\
&= 120 - 0,\\
&= 120 \text{ mi}^2.
\end{aligned}
$$

(C). Relative relief (*RR*) for the ungaged site is calculated from the primary drainage-basin characteristics basin relief (*BR*) and basin perimeter (*BP*). The difference between the highest elevation contour and the lowest interpolated elevation in the basin measured from the 1:250,000-scale topographic map gives a basin relief of 286 ft. The drainage-divide boundary delineated on the 1:250,000-scale topographic map is used to measure the basin perimeter, which is 57.8 mi. Relative relief (*RR*) is calculated using equation 11 as

$$
\begin{aligned}
RR &= \frac{BR}{BP},\\
&= \frac{286}{57.8},\\
&= 4.95 \text{ ft/mi}.
\end{aligned}
$$

(D). Drainage frequency (*DF*) for the ungaged site is calculated from the primary drainage-basin characteristics number of first-order streams (*FOS*) and contributing drainage area (*CDA*). A total of 57 first-order streams are counted within the drainage-divide delineation for the ungaged site on the 1:100,000-scale topographic map. Drainage frequency (*DF*) is calculated using equation 12 as

$$
\begin{aligned}
DF &= \frac{FOS}{CDA},\\
&= \frac{57}{120},\\
&= 0.475 \text{ first-order streams/mi}^2.
\end{aligned}
$$

(F). The 2-year, 24-hour precipitation intensity (*TTF*) for the ungaged drainage basin is determined from figure 5. Because the drainage-divide boundary of this ungaged site overlies two of the 2-year, 24-hour precipitation intensity polygons shown in figure 5, a weighted average for the basin is computed using equation 19 as outlined in Appendix B. According to figure 5, approximately 60 percent of the total drainage area (*TDA*) for the ungaged site is located within the polygon labeled as 2.85 in., and approximately 40 percent of the total drainage area is located within the polygon labeled as 2.95 in. The weighted average for the 2-year, 24-hour precipitation intensity (*TTF*) is calculated using equation 19 (Appendix B) as

$$
\begin{aligned}
TTF &= (A_1)(TTF_1) + (A_2)(TTF_2),\\
&= (0.60)(2.85) + (0.40)(2.95),\\
&= 2.89 \text{ in.}
\end{aligned}
$$

(G). The 50-year flood estimate for the ungaged site using the drainage-basin equation (table 2) is calculated as

$$
\begin{aligned}
Q_{50} &= 231\,(CDA)^{0.694}\,(RR)^{0.656}\,(DF)^{0.401}\,(TTF - 2.5)^{0.491},\\
&= 231\,(120)^{0.694}\,(4.95)^{0.656}\,(0.475)^{0.401}\\
&\quad (2.89 - 2.5)^{0.491},\\
&= 8{,}550 \text{ ft}^3/\text{s}.
\end{aligned}
$$

Because $Q_{50} = Q_{50(\mathrm{db})}$, and $Q_{50(\mathrm{ru})}$ (equation 17) $= Q_{50(\mathrm{db})}$ in this example, then $Q_{50(\mathrm{ru})} =$ 8,550 ft^3/s.

Step 2. The weighted 50-year peak discharge for the gaged site $Q_{50(wg)}$ (equation 16) is estimated next. Because table 8 lists both the drainage-basin and channel-geometry regression-equation estimates for this gaged site, Otter Creek near Ashton (station number 06483460, map number 139, fig. 1), the weighted estimate will be based on the Pearson Type-III estimate and both of these regression-equation estimates.

The 50-year Pearson Type-III estimate is 11,100 ft^3/s, and the effective record length is 39 years (table 8). The 50-year drainage-basin regression estimate is 6,710 ft^3/s (listed as method GISDB in table 8), and the average equivalent years of record for this regression equation is 9.5 (table 2). The 50-year Region I, active-channel channel-geometry regression estimate is 9,260 ft^3/s (listed as method ACRI in table 8), and the average equivalent years of record for this regression equation is 8.9 (listed in the second set of equations in table 4). The weighted 50-year flood estimate for the gaged site is calculated using equation 16 as

$$Q_{50(wg)} = \frac{(Q_{50(g)})(ERL) + (Q_{50(gdb)})(E_{(db)}) + (Q_{50(gcg)})(E_{(cg)})}{ERL + E_{(db)} + E_{(cg)}},$$

$$= \frac{(11,100)(39) + (6,710)(9.5) + (9,260)(8.9)}{39 + 9.5 + 8.9}$$

$$= 10,100 \text{ ft}^3/\text{s}.$$

Step 3. The regression-equation estimate for the gaged site $Q_{50(rg)}$ (equation 18) is determined next. Because table 8 lists both the drainage-basin and channel-geometry regression estimates for this gaged site, Otter Creek near Ashton, the weighted average of these regression estimates $Q_{50(dbcg)}$ (equation 14) is calculated to determine the regression estimate $Q_{50(rg)}$.

The 50-year flood estimate calculated for this gaging station using the drainage-basin equation is 6,710 ft^3/s (listed as method GISDB in table 8), and the standard error of estimate, in log units (base 10), for this equation is 0.185 (table 2). The 50-year flood estimate calculated for this gaging station using the Region I, active-channel channel-geometry equation is 9,260 ft^3/s (listed as method ACRI in table 8), and the standard error of estimate, in log units, for this equation is 0.188 (listed in the second set of equations in table 4). The weighted average, 50-year flood estimate for the gaged site is calculated using equation 14 as

$$Q_{50(dbcg)} = \frac{Q_{50(db)}(SE_{(cg)})^2 + Q_{50(cg)}(SE_{(db)})^2}{(SE_{(db)})^2 + (SE_{(cg)})^2},$$

$$= \frac{6,710(0.188)^2 + 9,260(0.185)^2}{(0.185)^2 + (0.188)^2},$$

$$= 7,960 \text{ ft}^3/\text{s}.$$

Because $Q_{50(dbcg)} = Q_{50(rg)}$ in this example, then $Q_{50(rg)} = 7,960$ ft^3/s.

Step 4. The final step adjusts the 50-year recurrence interval regression-equation estimate of 8,550 ft^3/s ($Q_{50(ru)}$) calculated for the ungaged site by the 50-year recurrence interval information determined for the gaged site. The adjusted 50-year flood estimate for the ungaged site $Q_{50(au)}$ is calculated using equations 17 and 18 as

$$Q_{50(au)} = Q_{50(ru)}\left[AF - \left(\frac{2\Delta TDA}{TDA_g}\right)(AF - 1)\right].$$

ΔTDA is the absolute value of the difference between the total drainage area of the gaged site (88.0 mi^2) and the total drainage area of the ungaged site (120 mi^2),

$\Delta TDA = 32.0$ mi^2;

$TDA_g = 88.0$ mi^2;

$$AF = \frac{Q_{50(wg)}}{Q_{50(rg)}},$$

$$AF = \frac{10,100}{7,960},$$

$$AF = 1.27;$$

$$Q_{50(au)} = 8,550\left[1.27 - \left(\frac{(2)(32.0)}{88.0}\right)(1.27 - 1)\right],$$

$$= 9,180 \text{ ft}^3/\text{s}.$$

This adjustment procedure has increased the 50-year recurrence interval regression-equation estimate for the ungaged site $Q_{50(ru)}$ by

107.4 percent based on the 50-year recurrence interval information determined for the gaged site upstream of this ungaged site.

SUMMARY AND CONCLUSIONS

Drainage-basin and channel-geometry equations are presented in this report for estimating design-flood discharges having recurrence intervals of 2, 5, 10, 25, 50, and 100 years at stream sites on rural, unregulated streams in Iowa. The equations were developed using ordinary least-squares and weighted least-squares multiple-regression techniques. Statewide equations were developed for the drainage-basin flood-estimation method and statewide and regional equations were developed for the channel-geometry flood-estimation method. The drainage-basin equations are applicable to stream sites with drainage areas less than 1,060 mi^2, and the channel-geometry equations are applicable to stabilized stream channels in Iowa.

Flood-frequency curves were developed for 188 continuous-record and crest-stage gaging stations on unregulated rural streams in Iowa. Pearson Type-III estimates of design-flood discharges are reported for these gaging stations.

Regression analyses of Pearson Type-III design-flood discharges and selected drainage-basin characteristics, quantified using a geographic-information-system (GIS) procedure, were used to develop the statewide drainage-basin flood-estimation equations. The significant characteristics identified for the drainage-basin equations included contributing drainage area; relative relief; drainage frequency; and 2-year, 24-hour precipitation intensity. The regression coefficients for these equations indicated an increase in design-flood discharges with increasing magnitude in the values of each drainage-basin characteristic. The average standard errors of prediction for the drainage-basin equations ranged from 38.6 to 50.2 percent.

Techniques on how to make manual measurements from topographic maps for the primary drainage-basin characteristics used in the regression equations are presented along with examples. Several of the primary drainage-basin characteristics used in the regression equations are map-scale dependent. Use of maps of scales other than the scales used to develop the equations may produce results that do not conform to the range of estimation accuracies listed for the equations.

Regression analyses of Pearson Type-III design-flood discharges and selected channel-geometry characteristics were used to develop both statewide and regional channel-geometry equations. On the basis of a geographic bias identified from the statewide regression residuals, two channel-geometry hydrologic regions were defined for Iowa relative to the Des Moines Lobe landform region. The significant channel-geometry characteristics identified for the statewide and regional regression equations included bankfull width and bankfull depth for natural channels unaffected by channelization, and active-channel width for stabilized channels affected by channelization. The regression coefficients for the statewide and regional channel-geometry equations indicated an increase in design-flood discharges with increasing magnitude in the values of each channel-geometry characteristic. The average standard errors of prediction for the statewide regression equations ranged from 41.0 to 68.4 percent and for the regional regression equations from 30.3 to 70.0 percent. The regional channel-geometry regression equations provided an improved estimation accuracy compared to the statewide regression equations, with the exception of the Region II active-channel regression equations developed for design floods having recurrence intervals of 25, 50, and 100 years. Guidelines for measuring the channel-geometry characteristics used in the statewide and regional regression equations are presented along with examples.

Procedures for applying the drainage-basin and channel-geometry regression equations vary and depend on whether the design-flood discharge estimate is for a site on an ungaged stream, an ungaged site on a gaged stream, or a gaged site. When both a drainage-basin and a channel-geometry regression-equation estimate are available for a stream site, a procedure is presented for determining a weighted average of the two flood estimates. The procedure for estimating a design-flood discharge for an ungaged site on a gaged stream is based on information from the Pearson Type-III estimate for the gaged site, and on information from either both flood-estimation methods, or from only one of the methods. At a gaged site, a weighted design-flood discharge is estimated from the Pearson Type-III estimate, and from either both flood-estimation methods, or from only one of the methods. Examples are provided for each of these procedures.

The drainage-basin and channel-geometry flood-estimation methods presented in this report each measure characteristics that are presumed to be independent of each other. The drainage-basin flood-estimation method is based on measurements of morphologic and climatic characteristics that are related to how water flows off the land. The drainage-basin method measures the varying flood potential at stream sites as defined by differences in basin size, topographic relief, stream development, and precipitation. The channel-geometry flood-estimation method, in contrast, is based on measurements of channel morphology that are assumed to be a function of streamflow discharges and sediment-load transport. The channel-geometry method measures the variability of floods that have actually occurred as defined by differences in channel width and depth.

The drainage-basin flood-estimation method developed in this study is similar to the regional flood-estimation method developed in a previous study because both methods estimate flood discharges on the basis of morphologic relations. While the standard errors of estimate for the drainage-basin equations in this study appear to be higher, a direct comparison cannot be made because of the different methodologies used to develop the equations.

The statewide drainage-basin and statewide channel-geometry regression equations presented in this report provide flood-estimation methods that minimize the subjectivity in their application to the ability of the user to measure the characteristics. Although the user of the regional channel-geometry equations may still encounter a dilemma when a stream site is located within the transitional zone or when a stream crosses regional boundaries, application of the statewide channel-geometry equations may be utilized to preclude the regional subjectivity associated with estimating a design-flood discharge in this situation. Despite the greater variability in the error of measurement associated with the channel-geometry characteristics, the channel-geometry equations presented in this report are considered to be useful as a corroborative flood-estimation method with respect to the drainage-basin method.

The estimation accuracy of the drainage-basin regression equations possibly could be improved if drainage-basin characteristics were quantified from larger scale data. The drainage-basin characteristics quantified by the GIS procedure were limited to the 1:250,000- and 1:100,000-scale digital cartographic data currently available for Iowa.

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APPENDIX A

Selected Drainage-Basin Characteristics Quantified Using a Geographic-Information-System Procedure

[*, A primary drainage-basin characteristic used in the regression equations (table 2); superscripts $^{a\text{-}n}$, footnotes at end of the appendix reference the literary and data source for each drainage-basin characteristic and list topographic-map scales to use for manual measurements of primary drainage-basin characteristics used in the regression equations]

Basin-Area Measurements

*TDA** - Total drainage area[a], in square miles[b], includes noncontributing areas.

*NCDA** - Noncontributing drainage area[a], in square miles[b], total area that does not contribute to surface-water runoff at the basin outlet.

Basin-Length Measurements

BL - Basin length[c], in miles[b], measured along the main-channel, flood-plain valley from basin outlet to basin divide.

*BP** - Basin perimeter[a], in miles[b], measured along entire drainage-basin divide.

Basin-Relief Measurements

BS - Average basin slope[a], in feet per mile[b,d], measured by the "contour-band" method, within the contributing drainage area (*CDA*),

$$BS = \frac{(\text{total length of all selected elevation contours})\ (\text{contour interval})}{CDA}.$$

*BR** - Basin relief[e], in feet[d,f], measured as the sea-level elevation difference between the highest contour elevation and the lowest interpolated elevation at basin outlet within the *CDA*.

Basin Computations

CDA - Contributing drainage area[a], in square miles, defined as the total area that contributes to surface-water runoff at the basin outlet,

$$CDA = TDA - NCDA.$$

BW - Effective basin width[a], in miles,

$$BW = \frac{CDA}{BL}.$$

SF - Shape factor[a], dimensionless, ratio of basin length to effective basin width,

$$SF = \frac{BL}{BW}.$$

ER - Elongation ratio[a], dimensionless, ratio of (1) the diameter of a circle of area equal to that of the basin to (2) the length of the basin,

$$ER = \left[\frac{4CDA}{\pi (BL)^2}\right]^{0.5} = 1.13\left(\frac{1}{SF}\right)^{0.5}.$$

RB - Rotundity of basin[a], dimensionless,

$$RB = \frac{\pi (BL)^2}{4CDA} = 0.785\ SF.$$

CR - Compactness ratio[a], dimensionless, is the ratio of the perimeter of the basin to the circumference of a circle of equal area,

$$CR = \frac{BP}{2(\pi CDA)^{0.5}}.$$

RR - Relative relief[e], in feet per mile,

$$RR = \frac{BR}{BP}.$$

Channel- (Stream-) Length Measurements

MCL - Main-channel length[a], in miles[g], measured along the main channel from the basin outlet to the basin divide.

TSL - Total stream length[e], in miles[g], computed by summing the length of all stream segments within the *CDA*.

Channel-Relief Measurement

MCS - Main-channel slope[a], in feet per mile, an index of the slope of the main channel computed from the difference in streambed elevation[d] at points 10 percent and 85 percent of the distance[g] along the main channel from the basin outlet to the basin divide,

$$MCS = \frac{(E_{85} - E_{10})}{0.75\ MCL}.$$

Channel (Stream) Computations

MCSR - Main-channel sinuosity ratio[a], dimensionless,

$$MCSR = \frac{MCL}{BL}.$$

SD - Stream density[a], in miles per square mile, within the *CDA*,

$$SD = \frac{TSL}{CDA}.$$

CCM - Constant of channel maintenance[a], in square miles per mile, within the *CDA*,

$$CCM = \frac{CDA}{TSL} = \frac{1}{SD}.$$

MCSP - Main-channel slope proportion[h], dimensionless,

$$MCSP = \frac{MCL}{(MCS)^{0.5}}.$$

RN - Ruggedness number[i], in feet per mile,

$$RN = \frac{(TSL)\,(BR)}{CDA} = (SD)\,(BR).$$

SR - Slope ratio of main-channel slope to basin slope[e], dimensionless, within the *CDA*,

$$SR = \frac{MCS}{BS}.$$

First-Order Streams Measurement

*FOS** - Number of first-order streams within the *CDA*[j,g,k], using Strahler's method of ordering streams.

Drainage-Frequency Computation

DF - Drainage frequency[e], in number of first-order streams per square mile, within the *CDA*,

$$DF = \frac{FOS}{CDA}$$

Climatic Measurements

AP - Mean annual precipitation[c], in inches[l], computed as a weighted average within the *TDA*.

*TTF** - 2-year, 24-hour precipitation intensity[c], in inches[m,n], defined as the maximum 24-hour precipitation expected to be exceeded on the average once every 2 years, computed as a weighted average within the *TDA*.

---

[a] Modified from Office of Water Data Coordination (1978, p. 7-9 - 7-16).

[b] Measured from 1:250,000-scale U.S. Defense Mapping Agency topographic maps.

[c] Modified from National Water Data Storage and Retrieval System (Dempster, 1983, p. A-24--A-26).

[d] Measured from 1:250,000-scale U.S. Defense Mapping Agency digital elevation model sea-level data.

[e] Modified from Strahler (1958, p. 282-283).

[f] Use 1:250,000-scale U.S. Defense Mapping Agency topographic maps for manual measurements.

[g] Measured from 1:100,000-scale U.S. Geological Survey digital line graph data.

[h] Modified from Robbins (1986, p. 12).

[i] Modified from Melton (1957).

[j] Modified from Strahler (1952).

[k] Use 1:100,000-scale U.S. Geological Survey topographic maps (County Map Series) for manual measurements.

[l] Determined from Iowa Department of Agriculture and Land Stewardship, State Climatology Office (Des Moines), and from Baker and Kuehnast (1978); mean annual precipitation maps.

[m] Determined from Waite (1988, p. 31) and Hershfield (1961, p. 95); 2-year, 24-hour precipitation intensity maps.

[n] Use figure 5 for manual measurements.

APPENDIX B

Techniques for Manual, Topographic-Map Measurements of Primary Drainage-Basin Characteristics Used in the Regression Equations

The drainage-basin flood-estimation method is applicable to unregulated rural stream sites in Iowa with drainage areas less than 1,060 mi^2. Specific information concerning techniques for making manual measurements is outlined for the six primary drainage-basin characteristics that are used to calculate the four basin characteristics listed in the regression equations in table 2. Comparisons between manual measurements made from different scales of topographic maps are shown in table 7 for four of these six-primary drainage-basin characteristics. Table 7 demonstrates that several of these primary drainage-basin characteristics are map-scale dependent. Map-scale dependency refers to a condition whereby a drainage-basin characteristic value is affected substantially by the scale of topographic map used in the measurement. The comparisons in table 7 list the percentage differences between manual measurements made at the same scale used for geographic-information-system (GIS) measurements (the base scale) and manual measurements made at different scales. Use of maps of scales other than the scales used to develop the equations may produce results that do not conform to the range of estimation accuracies listed for the equations in table 2. The scale of map to use for manual measurements of each primary drainage-basin characteristic is outlined in this section and in the footnotes at the end of Appendix A.

Total Drainage Area (*TDA*)

The stream site is located and the drainage-divide boundary upstream of the site is delineated on 1:250,000-scale U.S. Defense Mapping Agency (DMA) topographic maps. The drainage-divide boundary is delineated along the topographic divide that directs surface-water runoff from precipitation to the basin outlet located at the stream site. The drainage-divide boundary is an irregular line that traces the perimeter of the drainage area and is perpendicular to each elevation contour that it crosses (Office of Water Data Coordination, 1978, p. 7-9 - 7-10). In some cases it may be difficult to delineate the drainage-divide boundary on 1:250,000-scale topographic maps, particularly for small drainage basins or for drainage basins located in areas of low relief. In such cases it may be necessary to use larger scale topographic maps, such as 1:100,000-scale or 1:24,000-scale maps, to facilitate the delineation. Figure 4*A* shows the drainage-divide boundary for the Black Hawk Creek at Grundy Center streamflow-gaging station (station number 05463090; map number 73, fig. 1).

Because GIS measurements of total drainage area were quantified from 1:250,000-scale topographic maps, the appropriate scale for manual measurements of total drainage area is 1:250,000. Total drainage areas for many Iowa stream sites are listed in "Drainage Areas of Iowa Streams" (Larimer, 1957). The total drainage areas listed in this publication can be used to calculate contributing drainage area (*CDA*) once any necessary adjustments for noncontributing drainage areas (*NCDA*) are accounted for. Manual measurements of total drainage area for stream sites typically are planimetered or digitized from topographic maps if drainage areas are not listed in Larimer's (1957) publication.

Noncontributing Drainage Area (*NCDA*)

Noncontributing drainage areas usually are identified as either an area of internal drainage or as an area draining into a disappearing stream. Internal drainage areas drain into depressions, which are represented by hachured contour lines on topographic maps. Internal drainage areas may include potholes or marshes, which are common within the Des Moines Lobe landform region in north-central Iowa (Region II, fig. 2). Disappearing streams do not connect with the drainage network that reaches the basin outlet. In the karst topography of northeast Iowa, sinkholes are a common cause of disappearing streams.

Table 7. *Comparisons of manual measurements made from different scales of topographic maps of primary drainage-basin characteristics used in the regression equations*[1]

[*TDA*, total drainage area, in square miles; *BP*, basin perimeter, in miles; *BR*, basin relief, in feet; *FOS*, number of first-order streams; 250K, manual measurements made from 1:250,000-scale U.S. Defense Mapping Agency topographic maps; *, base scale used for geographic-information-system measurements; 100K, manual measurements made from 1:100,000-scale U.S. Geological Survey County Map Series topographic maps; 24K, manual measurements made from 1:24,000-scale U.S. Geological Survey topographic maps; % DIFF, percentage difference between base-scale and comparison-scale manual measurements]

	Station numbers of three streamflow-gaging stations representing small, intermediate, and large drainage basins, respectively												
	05414450 (map number 11, fig. 1)					06903400 (map number 183, fig. 1)					06609500 (map number 157, fig. 1)		
Basin characteristics	250K*	100K	% DIFF	24K	% DIFF	250K*	100K	% DIFF	24K	% DIFF	250K*	100K	%DIFF
[2]*TDA*	22.7	21.8	-4.0	22.3	-1.8	189	184	-2.6	185	-2.1	906	870	-4.0
BP	21.9	22.1	+0.9	22.4	+2.3	79.0	84.0	+6.3	85.5	+8.2	206	228	+10.7
BR	444	490	+10.4	502	+13.1	224	234	+4.5	231	+3.1	582	520	-10.7
	250K	100K*	% DIFF	24K	% DIFF	250K	100K*	% DIFF	24K	% DIFF	250K	100K*	%DIFF
FOS	1	10	-90.0	41	+310.0	7	80	-91.2	272	+240.0	32	477	-93.3

[1] Regression equations are listed in table 2. Comparison measurements for 2-year, 24-hour precipitation intensities (*TTF*) were not applicable.

[2] A planimeter was used for manual measurements of *TDA*. Noncontributing drainage areas (*NCDA*) are not listed because no significant *NCDA* were identified for these drainage basins.

Noncontributing drainage areas are delineated on 1:250,000-scale topographic maps. When questionable noncontributing drainage areas are encountered, hydrologic judgment is required to determine whether to delineate these areas as noncontributing. Larger scale topographic maps facilitate the delineation of questionable noncontributing areas.

Basin Perimeter (*BP*)

The basin perimeter is measured along the drainage-divide boundary delineated on 1:250,000-scale topographic maps. Because GIS measurements of basin perimeter were quantified from 1:250,000-scale topographic maps, the appropriate scale for manual measurements is 1:250,000.

Basin Relief (*BR*)

Basin relief is the difference between the maximum elevation contour and the minimum interpolated elevation within the contributing drainage area delineated on 1:250,000-scale topographic maps. The minimum basin elevation is defined at the basin outlet as an interpolated elevation between the first elevation contour crossing the main channel upstream of the basin outlet and the first elevation contour crossing the main channel downstream of the basin outlet. Because GIS measurements of basin relief were quantified from 1:250,000-scale digital elevation model (DEM) data, the appropriate scale for manual measurements is 1:250,000. Figure 4*C* shows the elevation contours created from DEM data for the Black Hawk Creek at Grundy Center drainage basin.

Number of First-Order Streams (*FOS*)

The number of first-order streams is a count of all the stream segments defined as being a first-order drainage using Strahler's method of ordering streams (Strahler, 1952). First-order streams are defined for contributing drainage areas on 1:100,000-scale topographic maps. Figure 4*B* shows the stream ordering for the Black Hawk Creek at Grundy Center drainage basin. As shown in figure 4*B*, a stream segment with no tributaries is defined as a first-order stream. Where two first-order streams join, they form a second-order stream; where two second-order streams join, they form a third-order stream; and so forth. Because GIS measurements of the number of first-order streams were quantified from 1:100,000-scale digital line graph data, the appropriate scale for manual measurements is 1:100,000. Comparison measurements listed in table 7 indicate that the number of first-order streams is clearly map-scale dependent and use of map scales other than 1:100,000 may produce results that do not conform to the range of estimation accuracies listed for the equations in table 2.

2-Year, 24-Hour Precipitation Intensity (*TTF*)

The map shown in figure 5 is used to calculate 2-year, 24-hour precipitation intensities for drainage basins in Iowa and for basins that extend into southern Minnesota. This map shows polygon areas that represent averages for maximum 24-hour precipitation intensities, in inches, that are expected to be exceeded on the average once every 2 years. These polygons were created from the precipitation contours depicted on 2-year, 24-hour precipitation intensity maps for Iowa (Waite, 1988, p. 31) and the United States (Hershfield, 1961, p. 95). The polygon areas for southern Minnesota were interpolated from the precipitation contours depicted on the United States map. The polygons shown in figure 5 represent the average value, in inches, of rainfall between the precipitation contours and are not intended to represent interpolated values between the contours. Figure 5 was used to compute a weighted average of the 2-year, 24-hour precipitation intensity for each drainage basin processed by the GIS procedure. A manual measurement of 2-year, 24-hour precipitation intensity can be made by delineating the approximate location of the drainage-divide boundary for a stream site in figure 5. The approximate percentage of the total drainage area for the stream site that falls within each precipitation polygon shown in figure 5 is calculated, and a weighted average for the basin is computed as

$$TTF = (A_1)(TTF_1) + (A_2)(TTF_2) + \ldots + (A_p)(TTF_p), \qquad (19)$$

where TTF is the weighted average for 2-year, 24-hour precipitation intensity, in inches;

A_i is the approximate percentage of the total drainage area of a basin within the ith 2-year, 24-hour precipitation intensity polygon shown in figure 5 ($i = 1, \ldots, p$);

TTF_i is the 2-year, 24-hour precipitation intensity, in inches, for the ith polygon shown in figure 5 ($i = 1, \ldots, p$); and

p is the total number of 2-year, 24-hour precipitation intensity polygons shown in figure 5 overlain by the drainage-divide boundary of a basin.

For example, if approximately 70 percent of the total drainage area for a stream site overlies the polygon labeled as 3.15 in. and approximately 30 percent of the total drainage area overlies the polygon labeled 3.05 in., then the weighted average for the basin is calculated as

$$\begin{aligned} TTF &= (A_1)(TTF_1) + (A_2)(TTF_2), \\ &= (0.70)(3.15) + (0.30)(3.05), \\ &= 3.12 \text{ in.} \end{aligned}$$

APPENDIX C

Procedure for Conducting Channel-Geometry Measurements

The channel-geometry flood-estimation method is applicable to stream sites in Iowa with unregulated and stabilized stream channels. The following discussion outlines the procedure for conducting channel-geometry measurements.

Selection of Channel-Geometry Measurement Reaches

An inspection of 1:100,000- or 1:24,000-scale topographic maps is made to evaluate the channel reach both upstream and downstream of the stream site. Channel-geometry measurements are made along a straight channel reach, and an inspection of topographic maps is helpful in determining whether to start searching upstream or downstream of the site for a measurement reach. If the channel for some distance upstream and downstream of the stream site is very sinuous, unnaturally wide, or in an area that may be affected by development, topographic maps can be inspected to locate more suitable channel reaches at nearby bridges upstream or downstream of the stream site.

Channel-geometry measurements can be made at some distance away from the stream site, either upstream or downstream, as long as the drainage area upstream of the measurement reach does not change by more than about 5 percent from the drainage area of the stream site. The 5-percent change in drainage area is an approximate limitation to ensure that channel-geometry measurements are representative of the streamflow discharges that occur at the stream site.

Topographic maps are useful in identifying linear channels that are usually indicative of channelization. Channels that appear to be channelized are noted because application of the channel-geometry equations listed in tables 3-5 are dependent on whether a stream has been channelized. A visual inspection of the channel also is made upon visiting the stream site to check for evidence of channelization. Features that are characteristic of channelized streams are illustrated in figure 7*D*, which shows the straightened and leveed channel reach downstream of the Big Creek near Varina gaging station (station number 05482170; map number 108, fig. 2). If evidence of channelization is not found, then the bankfull equations (the first set of equations listed in tables 3-5) are applicable; if evidence of channelization is found, then the active-channel equations (the second set of equations listed in tables 3-5) may be applicable.

The channel-geometry method may not be applicable to poorly drained or pooled streams that have extremely low, local gradients (less than approximately 0.1 ft/mi.). A local gradient is measured from 1:24,000-scale topographic maps and is calculated as the slope of the channel between the nearest contour lines crossing the channel upstream and downstream of a stream site. This slope measurement is performed only for those stream sites that are suspected of having extremely low, local gradients and typically is not required for channel-geometry measurements.

Selection of Channel-Geometry Measurement Sections

Measurements of channel-geometry characteristics are made at channel cross sections that represent stable and self-formed channel-bank conditions. Self-formed channels are natural channels or channels that have been affected by channelization for which at least the active-channel portion of the channel has had time to adjust back to natural conditions. Commonly, the active-channel portion of the channel will adjust back to natural or self-formed conditions within approximately 5 to 10 years after channelization occurs.

Measurements are made far enough away from bridges or other structures crossing the stream channel to avoid any alterations to the channel caused by construction. More distance is allowed downstream of bridges to avoid the effects of the channel constriction and more distance is allowed upstream of culverts to avoid the effects of backwater. Ideally, measurements are made in a

As shown in figure 6, the active-channel reference level is identified at a lower channel-bank elevation. At least three active-channel width measurements are made that are within 10 percent of the average, and active-channel measurement sections are separated by at least twice the active-channel width. The tagline or tape is staked in a similar manner as previously described, and width measurements are read to at least two significant figures. As defined by Osterkamp and Hedman (1977, p. 256),

> "The active channel is a short-term geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level. The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge."

Figures 7*A* and 7*E* show photographs at two stream sites where a tape and a tagline, respectively, were staked at the active-channel reference level used to measure active-channel widths.

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*

[B, both continuous-record and high-flow, partial-record gage; C, continuous-record gage; P, high-flow, partial-record gage; ft³/s, cubic feet per second; Meth., method used to compute flood-peak discharge estimates; B17B, Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) Pearson Type-III analysis; GISDB, geographic information system quantified drainage-basin characteristics (table 2); BFRI, channel-geometry Region I (bankfull, table 4); ACRI, channel-geometry Region I (active channel, table 4); ACRII, channel-geometry Region II (active channel, table 5); BFRII, channel-geometry Region II (bankfull, table 5); ERL, effective record length, indicates systematic record length used in B17B analysis when no value is listed for HST; yrs, years; HST, historically adjusted record length used in B17B analysis; Disch., discharge; Recur. inter., approximate recurrence interval interpolated from B17B analysis, rounded to nearest 5 years for 20- to 50-year recurrence intervals and to nearest 10 years above the 50-year recurrence interval; *, ratio of maximum flood to 100-year B17B estimate; --, historically adjusted record length was not used in B17B analysis]

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft³/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft³/s)	Recur. inter. (yrs)
1	05387500	Upper Iowa River	B	5,930	10,200	13,200	17,200	20,100	23,000	B17B	43	77	1941, 1952-89	1941	28,500	1.2*
		at Decorah		5,620	10,500	14,400	19,600	23,800	28,100	GISDB						
				5,230	9,530	12,700	17,200	20,400	24,400	BFRI						
2	05388000	Upper Iowa River	C	8,070	11,700	14,100	17,000	19,000	21,000	B17B	35	77	1914, 1919-27,	1941	28,500	1.4*
		near Decorah		6,080	11,200	15,300	20,600	24,900	29,400	GISDB			1933-52			
3	05388250	Upper Iowa River	C	6,390	9,160	11,100	13,800	15,900	18,100	B17B	22	77	1941, 1976-90	1941	30,400	1.7*
		near Dorchester		8,190	15,000	20,200	27,100	32,600	38,200	GISDB						
				6,820	12,100	16,000	21,400	25,100	29,800	BFRI						
4	05388500	Paint Creek at	C	2,240	3,560	4,510	5,780	6,760	7,770	B17B	21	23	1951, 1953-73	1951	9,100	1.2*
		Waterville		1,890	3,820	5,420	7,650	9,520	11,500	GISDB						
5	05389000	Yellow River at	C	8,00	12,500	15,600	19,500	22,400	25,300	B17B	17	--	1935-51	1941	21,200	40
		Ion		4,930	9,250	12,700	17,200	20,900	24,700	GISDB						
6	05411530	North Branch	P	316	1,170	2,310	4,760	7,600	11,600	B17B	24	--	1966-90	1990	11,500	100
		Turkey River		650	1,350	1,940	2,800	3,530	4,310	GISDB						
		near Cresco		533	1,190	1,770	2,690	3,450	4,380	BFRI						
7	05411600	Turkey River at	C	2,850	5,460	7,400	9,980	11,900	13,900	B17B	33	44	1947, 1956-73,	1947	10,000	25
		Spillville		2,580	4,850	6,640	9,040	11,000	13,000	GISDB			1978-90			
				2,740	5,300	7,280	10,200	12,400	15,000	BFRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
8	05411650	Crane Creek tributary near Saratoga	P	632	1,180	1,580	2,120	2,520	2,930	B17B	23	--	1953-75	1962	1,830	16
				348	780	1,170	1,750	2,260	2,820	GISDB						
9	05411700	Crane Creek near Lourdes	P	2,040	4,580	6,670	9,610	12,000	14,400	B17B	38	--	1953-90	1962	11,900	50
				1,560	3,060	4,280	5,950	7,320	8,780	GISDB						
				1,760	3,550	4,980	7,120	8,760	10,800	BFRI						
10	05412500	Turkey River at Garber	C	15,400	20,800	24,000	27,800	30,400	32,800	B17B	75	101	1902, 1914-16, 1919-27, 1930, 1933-90	1922	32,300	90
				9,170	15,900	20,600	27,200	31,600	37,200	BFRI						
11	05414450	North Fork Little Maquoketa River near Rickardsville	P	1,240	2,200	2,990	4,150	5,150	6,250	B17B	37	--	1951-90	1972	7,180	1.1*
				1,350	2,820	4,060	5,820	7,300	8,880	GISDB						
				862	1,850	2,680	3,970	5,010	6,280	BFRI						
12	05414500	Little Maquoketa River near Durango	B	6,520	10,600	14,000	18,900	23,200	27,900	B17B	63	114	1925, 1935-83, 1986-90	1972	40,000	1.4*
				4,400	8,420	11,600	16,000	19,600	23,400	GISDB						
				4,100	7,630	10,300	14,100	16,900	20,300	BFRI						
13	05414600	Little Maquoketa River tributary at Dubuque	P	231	508	750	1,120	1,440	1,790	B17B	39	--	1951-65, 1967-90	1957	1,650	80
				342	811	1,240	1,900	2,500	3,160	GISDB						
				212	483	729	1,120	1,460	1,860	ACRI						
14	05417000	Maquoketa River near Manchester	C	4,740	8,310	11,000	14,800	17,900	21,100	B17B	53	59	1925, 1928-30, 1933-73, 1976-83	1925	25,400	1.2*
				4,710	8,640	11,700	15,800	19,000	22,400	GISDB						
				7,540	13,300	17,400	23,200	27,200	32,100	BFRI						
15	05417530	Plum Creek at Earlville	P	1,340	2,520	3,480	4,910	6,110	7,420	B17B	24	--	1966-90	1974	6,200	50
				1,330	2,670	3,790	5,360	6,680	8,080	GISDB						
				989	2,090	3,020	4,440	5,580	6,970	BFRI						
16	05417590	Kitty Creek near Langworthy	P	780	1,360	1,810	2,430	2,940	3,470	B17B	24	--	1966-90	1969	3,700	1.1*
				797	1,690	2,450	3,550	4,480	5,490	GISDB						
				1,270	2,630	3,750	5,450	6,780	8,410	BFRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
17	05417700	Bear Creek near Monmouth	C	1,710	2,960	3,870	5,050	5,940	6,840	B17B	19	--	1944, 1958-76	1965	7,340	1.1*
				1,730	3,430	4,830	6,780	8,410	10,100	GISDB						
18	05418450	North Fork Maquoketa River at Fulton	C	6,350	9,620	11,600	13,900	15,400	16,800	B17B	14	--	1974, 1977-90	1981	10,700	7
				6,730	12,100	16,200	21,500	25,800	30,200	GISDB						
				6,820	12,100	16,000	21,400	25,100	29,800	BFRI						
19	05418500	Maquoketa River near Maquoketa	C	15,000	23,800	29,800	37,500	43,200	49,000	B17B	79	88	1903, 1914-90	1944	48,000	90
				11,700	19,900	25,400	33,200	38,300	44,700	BFRI						
20	05420560	Wapsipinicon River near Elma	C	2,190	5,060	7,510	11,100	14,000	17,100	B17B	32	--	1959-90	1974	10,100	20
				1,720	3,410	4,790	6,690	8,260	9,920	GISDB						
				1,240	2,580	3,680	5,350	6,670	8,280	BFRI						
21	05420600	Little Wapsipinicon River tributary near Riceville	P	213	559	877	1,360	1,770	2,220	B17B	37	--	1953-90	1990	1,900	60
				158	381	590	921	1,220	1,560	GISDB						
				233	528	794	1,210	1,580	2,000	ACRI						
22	05420620	Little Wapsipinicon River near Acme	P	439	866	1,240	1,810	2,310	2,890	B17B	38	--	1953-90	1962	2,380	50
				419	911	1,340	1,970	2,510	3,100	GISDB						
				634	1,400	2,060	3,090	3,950	4,990	BFRI						
23	05420640	Little Wapsipinicon River at Elma	P	1,170	2,430	3,440	4,870	6,000	7,180	B17B	38	--	1953-90	1962	5,740	45
				989	2,000	2,830	4,000	4,970	6,010	GISDB						
				1,070	2,250	3,230	4,740	5,930	7,400	BFRI						
24	05420650	Little Wapsipinicon River near New Hampton	P	2,050	3,820	5,320	7,600	9,580	11,800	B17B	26	28	1966-90	1990	14,900	1.3*
				1,910	3,700	5,140	7,110	8,730	10,400	GISDB						
				1,620	3,280	4,620	6,640	8,200	10,100	BFRI						
25	05420690	East Fork Wapsipinicon River near New Hampton	P	1,460	3,800	5,980	9,430	12,400	15,800	B17B	24	--	1966-90	1969	11,000	35
				1,100	2,260	3,220	4,590	5,740	6,970	GISDB						
				923	1,960	2,850	4,200	5,290	6,620	BFRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years: 2	5	10	25	50	100	Meth.	Record: ERL (yrs)	HST (yrs)	Flood period	Maximum flood: Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
26	05420960	Harter Creek near Independence	P	371	960	1,520	2,420	3,220	4,120	B17B	12	--	1952-63	1962	2,280	20
				391	859	1,270	1,880	2,420	3,000	GISDB						
27	05421000	Wapsipinicon River at Independence	C	6,410	11,900	15,900	21,300	25,300	29,500	B17B	60	90	1934-90	1968	26,800	60
				8,550	14,800	19,500	25,400	30,000	34,700	GISDB						
				8,610	15,000	19,500	25,900	30,100	35,500	BFRI						
28	05421100	Pine Creek tributary near Winthrop	P	75	158	225	320	397	478	B17B	39	--	1952-90	1968	334	30
				148	373	594	957	1,300	1,690	GISDB						
				121	309	493	803	1,080	1,440	BFRI						
29	05421200	Pine Creek near Winthrop	P	1,100	2,620	4,180	6,960	9,750	13,300	B17B	41	--	1950-90	1968	24,200	1.8*
				1,010	2,070	2,960	4,220	5,270	6,390	GISDB						
				1,350	2,770	3,940	5,710	7,100	8,790	BFRI						
30	05421890	Silver Creek at Welton	P	1,180	2,500	3,560	5,040	6,220	7,440	B17B	25	--	1966-90	1974	4,820	20
				576	1,240	1,820	2,680	3,430	4,240	GISDB						
				1,170	2,440	3,500	5,100	6,370	7,920	BFRI						
31	05422000	Wapsipinicon River near De Witt	C	9,820	15,800	20,000	25,400	29,400	33,500	B17B	56	57	1935-90	1990	31,100	70
				16,000	26,400	33,300	42,800	48,800	56,500	BFRI						
32	05422470	Crow Creek at Bettendorf	C	816	2,000	3,160	5,120	6,970	9,190	B17B	13	--	1978-90	1990	7,700	60
				866	1,700	2,380	3,330	4,120	4,960	GISDB						
				989	2,090	3,020	4,440	5,580	6,970	BFRI						
33	05448500	West Branch Iowa River near Klemme	C	507	985	1,370	1,920	2,370	2,850	B17B	10	--	1949-58	1954	1,920	25
				1,110	2,120	2,920	3,990	4,840	5,730	GISDB						
34	05448700	East Branch Iowa River near Hayfield	P	116	219	301	416	508	606	B17B	36	--	1952-86, 1990	1954	457	35
				137	294	430	626	793	973	GISDB						
				832	1,580	2,130	2,940	3,570	4,190	ACRII						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft³/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft³/s)	Recur. inter. (yrs)
35	05449000	East Branch Iowa River near Klemme	C	898	1,830	2,620	3,810	4,820	5,930	B17B	41	--	1944, 1949-76, 1978-90	1954	5,960	100
				816	1,540	2,120	2,880	3,480	4,100	GISDB						
				1,170	2,190	2,950	3,950	4,790	5,650	BFRII						
36	05449500	Iowa River near Rowan	C	2,000	3,640	4,850	6,480	7,740	9,030	B17B	49	--	1941-76, 1978-90	1954	8,460	70
				2,280	4,090	5,470	7,220	8,580	9,960	GISDB						
				1,840	3,380	4,510	5,960	7,180	8,420	BFRII						
37	05451500	Iowa River at Marshalltown	C	8,240	14,000	18,000	23,100	26,800	30,500	B17B	77	109	1903, 1915-27, 1929-30, 1933-90	1918	42,000	1.4*
				5,590	9,810	12,800	16,500	19,600	22,700	BFRII						
38	05451700	Timber Creek near Marshalltown	C	2,650	4,850	6,490	8,670	10,300	12,000	B17B	42	44	1947, 1950-90	1977	12,000	100
				2,620	4,710	6,330	8,450	10,100	11,900	GISDB						
				2,200	4,330	6,020	8,520	10,400	12,700	BFRI						
39	05451900	Richland Creek near Haven	C	1,640	2,700	3,450	4,440	5,190	5,950	B17B	41	--	1918, 1950-90	1974	7,000	1.2*
				1,770	3,290	4,500	6,120	7,440	8,820	GISDB						
				1,820	3,650	5,120	7,310	8,990	11,000	BFRI						
40	05451955	Stein Creek near Clutier	P	1,180	2,350	3,340	4,810	6,060	7,430	B17B	22	43	1972-90	1982	11,400	1.5*
				926	1,790	2,500	3,470	4,270	5,120	GISDB						
				2,290	4,500	6,240	8,820	10,800	13,100	BFRI						
41	05452000	Salt Creek near Elberon	C	4,420	8,870	12,900	19,300	25,100	32,000	B17B	46	47	1944, 1946-90	1947	35,000	1.1*
				3,880	6,810	9,040	11,900	14,200	16,500	GISDB						
				2,200	4,320	6,010	8,500	10,400	12,700	BFRI						
42	05452200	Walnut Creek near Hartwick	C	2,510	4,440	5,800	7,560	8,870	10,200	B17B	42	43	1947, 1950-90	1983	7,100	20
				2,170	4,000	5,430	7,340	8,900	10,500	GISDB						
				1,980	3,930	5,490	7,810	9,580	11,700	BFRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
43	05453000	Big Bear Creek at Ladora	C	4,350	6,280	7,430	8,750	9,650	10,500	B17B	45	--	1946-90	1960	10,500	100
				3,850	6,760	8,980	11,900	14,200	16,500	GISDB						
				4,190	7,480	9,960	13,400	16,000	18,700	ACRI						
44	05453100	Iowa River at Marengo	C	12,700	19,800	24,300	29,700	33,500	37,100	B17B	34	36	1957-90	1960	30,800	30
				9,030	15,700	20,300	26,900	31,300	36,700	BFRI						
45	05453600	Rapid Creek below Morse	P	625	1,360	1,990	2,950	3,780	4,680	B17B	38	--	1951-90	1987	3,000	25
				573	1,170	1,670	2,380	2,970	3,600	GISDB						
				668	1,460	2,150	3,230	4,110	5,190	BFRI						
46	05453700	Rapid Creek tributary No. 4 near Oasis	P	178	404	600	893	1,140	1,410	B17B	24	--	1951-74	1953	956	30
				264	575	849	1,260	1,620	2,010	GISDB						
47	05453750	Rapid Creek southwest of Morse	P	1,110	2,110	2,880	3,950	4,790	5,660	B17B	38	--	1951-90	1972	4,300	35
				829	1,640	2,310	3,250	4,030	4,850	GISDB						
				1,030	2,170	3,130	4,600	5,760	7,190	BFRI						
48	05453950	Rapid Creek tributary near Iowa City	P	436	890	1,250	1,750	2,150	2,560	B17B	37	--	1951-90	1972	2,000	40
				252	535	776	1,120	1,410	1,720	GISDB						
				513	1,150	1,710	2,600	3,340	4,250	BFRI						
49	05454000	Rapid Creek near Iowa City	C	1,540	3,060	4,200	5,700	6,820	7,940	B17B	53	--	1938-90	1965	6,100	30
				1,240	2,400	3,340	4,620	5,680	6,790	GISDB						
				1,320	2,730	3,880	5,630	7,000	8,670	BFRI						
50	05454300	Clear Creek near Coralville	C	1,890	3,750	5,320	7,690	9,720	12,000	B17B	38	--	1953-90	1990	11,700	90
				2,300	4,170	5,620	7,510	9,020	10,600	GISDB						
				2,150	4,250	5,910	8,380	10,200	12,500	BFRI						
51	05455000	Ralston Creek at Iowa City	C	408	816	1,140	1,600	1,970	2,360	B17B	58	--	1925-82[1]	1971	2,200	80
				310	661	965	1,410	1,790	2,210	GISDB						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
52	05455010	South Branch Ralston Creek at Iowa City	C	418	732	954	1,240	1,450	1,660	B17B	17	--	1962, 1964-80[1]	1972	1,070	15
				244	522	761	1,110	1,400	1,710	GISDB						
53	05455100	Old Mans Creek near Iowa City	B	2,470	4,950	7,020	10,100	12,700	15,500	B17B	40	40	1951-87, 1989-90	1982	13,500	60
				3,090	5,410	7,160	9,420	11,200	13,000	GISDB						
				3,050	5,840	7,980	11,100	13,400	16,300	BFRI						
54	05455140	North English River near Montezuma	P	1,450	2,580	3,440	4,620	5,570	6,550	B17B	18	--	1973-90	1978	4,640	25
				1,050	2,010	2,780	3,830	4,700	5,620	GISDB						
				1,090	2,180	3,070	4,380	5,460	6,620	ACRI						
55	05455150	North English River near Montezuma	P	1,810	3,100	4,020	5,200	6,090	6,980	B17B	23	--	1953-77	1953	4,240	12
				1,150	2,180	3,010	4,150	5,090	6,080	GISDB						
56	05455200	North English River near Guernsey	P	2,600	4,040	4,990	6,170	7,020	7,850	B17B	30	--	1953-88	1953	7,000	50
				2020	3,730	5,070	6,870	8,340	9,870	GISDB						
				2,580	4,800	6,520	8,930	10,900	12,900	ACRI						
57	05455210	North English River at Guernsey	P	4,050	5,440	6,230	7,110	7,700	8,220	B17B	26	--	1960, 1966-90	1982	7,460	40
				2,220	4,050	5,490	7,410	8,960	10,600	GISDB						
				2,720	5,020	6,810	9,310	11,300	13,400	ACRI						
58	05455280	South English River tributary near Barnes City	P	380	676	886	1,160	1,360	1,560	B17B	23	--	1953-76	1970	900	11
				298	639	937	1,380	1,770	2,190	GISDB						
59	05455300	South English River near Barnes City	P	528	960	1,300	1,780	2,170	2,600	B17B	35	--	1953-88	1982	2,200	50
				978	1,940	2,740	3,850	4,790	5,780	GISDB						
				677	1,480	2,180	3,260	4,150	5,240	BFRI						
60	05455350	South English River tributary No. 2 near Montezuma	P	40	93	145	233	316	416	B17B	28	--	1953-80[1]	1961	344	60
				123	283	431	662	871	1,110	GISDB						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
61	05455500	English River at Kalona	C	6,080	10,500	13,800	18,200	21,600	25,200	B17B	54	61	1930, 1940-90	1965	20,000	35
				7,520	12,300	15,800	20,100	23,500	26,800	GISDB						
				4,820	8,850	11,800	16,100	19,200	22,900	BFRI						
62	05457700	Cedar River at Charles City	C	9,460	16,000	20,300	25,400	29,000	32,300	B17B	36	--	1946-53, 1961-62, 1965-90	1961	29,200	50
				5,610	10,100	13,600	18,000	21,500	25,100	GISDB						
				10,900	18,600	23,900	31,300	36,200	42,300	BFRI						
63	05458000	Little Cedar River near Ionia	C	2,870	5,840	8,140	11,300	13,700	16,100	B17B	37	--	1954-90	1961	10,800	20
				3,650	6,800	9,260	12,500	15,100	17,800	GISDB						
				3,610	6,810	9,230	12,800	15,300	18,500	BFRI						
64	05458500	Cedar River at Janesville	C	10,100	18,100	23,600	30,600	35,700	40,700	B17B	72	86	1905-06, 1915-21, 1923-27, 1933-42, 1945-90	1961	37,000	60
				12,300	20,800	26,600	34,600	39,800	46,400	BFRI						
65	05458900	West Fork Cedar River at Finchford	C	5,230	11,600	16,900	24,300	30,200	36,300	B17B	48	62	1929, 1946-90	1951	31,900	60
				6,400	11,200	14,800	19,300	22,900	26,500	GISDB						
				5,830	10,500	13,900	18,800	22,200	26,400	BFRI						
66	05459000	Shell Rock River near Northwood	C	1,200	1,880	2,310	2,830	3,190	3,540	B17B	41	--	1946-86	1965	3,400	80
				1,560	3,040	4,240	5,840	7,140	8,490	GISDB						
				1,460	2,700	3,590	4,750	5,720	6,710	BFRII						
67	05459010	Elk Creek at Kensett	P	293	626	895	1,280	1,580	1,900	B17B	24	24	1966-89	1986	1,450	40
				788	1,570	2,200	3,060	3,760	4,490	GISDB						
				280	568	797	1,110	1,380	1,670	BFRII						
68	05459500	Winnebago River at Mason City	C	3,190	5,450	7,080	9,220	10,900	12,500	B17B	59	61	1933-90	1933	10,800	50
				3,110	5,620	7,550	10,000	11,900	13,900	GISDB						
				4,220	7,480	9,800	12,700	15,100	17,600	BFRII						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft³/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft³/s)	Recur. inter. (yrs)
69	05460100	Willow Creek near	P	561	833	999	1,190	1,320	1,450	B17B	24	--	1966-90	1969	1,100	17
		Mason City		604	1,170	1,630	2,220	2,700	3,190	GISDB						
				590	1,160	1,590	2,180	2,680	3,200	BFRII						
70	05462000	Shell Rock River	C	8,080	15,700	21,500	29,300	35,400	41,600	B17B	43	135	1856, 1954-90	1856	45,000	1.1*
		at Shell Rock		11,000	18,800	24,200	31,700	36,600	42,700	BFRI						
71	05462750	Beaver Creek	P	905	1,900	2,680	3,750	4,540	5,440	B17B	25	--	1966-90	1983	3,000	14
		tributary near		512	1,090	1,590	2,310	2,930	3,600	GISDB						
		Aplington		1,080	2,150	3,030	4,320	5,390	6,540	ACRI						
72	05463000	Beaver Creek at	C	3,650	8,230	11,800	16,700	20,300	23,900	B17B	45	--	1946-90	1947	18,000	35
		New Hartford		4,650	8,430	11,300	15,100	18,100	21,200	GISDB						
				2,620	5,070	6,990	9,810	11,900	14,500	BFRI						
73	05463090	Black Hawk Creek	P	1,030	2,400	3,580	5,330	6,780	8,320	B17B	24	--	1966-89	1969	7,000	60
		at Grundy Center		1,570	2,920	3,980	5,400	6,550	7,740	GISDB						
				1,360	2,800	3,980	5,760	7,160	8,860	BFRI						
74	05463500	Black Hawk Creek	C	2,730	6,050	8,870	13,000	16,400	20,100	B17B	39	--	1952-90	1969	19,300	90
		at Hudson		4,320	7,530	9,950	13,000	15,400	17,900	GISDB						
				3,150	6,010	8,210	11,400	13,800	16,700	BFRI						
75	05464000	Cedar River at	C	23,000	41,900	55,000	71,600	83,600	95,200	B17B	59	88	1929, 1933,	1961	76,700	35
		Waterloo		27,300	42,900	52,700	66,100	74,000	84,400	BFRI			1941-90			
76	05464130	Fourmile Creek	C	437	771	1,000	1,290	1,500	1,700	B17B	14	--	1963-67,	1979	1,100	14
		near Lincoln		691	1,370	1,940	2,720	3,370	4,060	GISDB			1970-74,			
													1977-80			

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
77	05464133	Half Mile Creek near Gladbrook	C	147	250	329	439	527	622	B17B	14	--	1963-67, 1970-74, 1977-80	1979	611	90
				200	443	660	983	1,270	1,580	GISDB						
78	05464137	Fourmile Creek near Traer	C	516	829	1,050	1,330	1,540	1,760	B17B	17	--	1963-74, 1976-80	1979	1,450	40
				693	1,350	1,890	2,620	3,220	3,850	GISDB						
				1,170	2,310	3,250	4,610	5,750	6,960	ACRI						
79	05464500	Cedar River at Cedar Rapids	C	23,900	39,900	50,700	64,100	73,700	83,000	B17B	88	--	1851, 1903-90	1961	73,000	50
				30,900	48,000	58,700	73,100	81,500	92,600	BFRI						
80	05464560	Prairie Creek at Blairstown	P	2,170	3,160	3,800	4,610	5,190	5,770	B17B	21	--	1966-84, 1986-88	1982	4,750	30
				2,070	3,780	5,100	6,860	8,260	9,720	GISDB						
				2,800	5,160	6,990	9,550	11,600	13,700	ACRI						
81	05464640	Prairie Creek at Fairfax	C	3,140	5,110	6,460	8,180	9,440	10,700	B17B	16	--	1967-82	1979	8,140	25
				3,210	5,650	7,520	9,930	11,900	13,800	GISDB						
				3,420	6,470	8,800	12,200	14,700	17,700	BFRI						
82	05464880	Otter Creek at Wilton	P	894	1,940	2,810	4,090	5,150	6,280	B17B	24	--	1966-90	1990	5,940	80
				472	946	1,340	1,880	2,340	2,810	GISDB						
				978	2,070	2,990	4,400	5,530	6,910	BFRI						
83	05465000	Cedar River near Conesville	C	25,900	42,900	54,200	67,800	77,500	86,700	B17B	58	88	1929, 1940-90	1961	70,800	30
				39,800	60,500	73,000	89,900	99,400	112,000	BFRI						
84	05469860	Mud Lake drainage ditch 71 at Jewell	P	734	1,510	2,100	2,880	3,460	4,040	B17B	25	--	1966-90	1975	2,300	13
				1,020	1,900	2,580	3,460	4,150	4,860	GISDB						
				697	1,340	1,810	2,510	3,060	3,600	ACRII						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
85	05469990	Keigley Branch near Story City	P	516	997	1,400	1,980	2,480	3,030	B17B	25	--	1966-90	1975	2,250	35
				712	1,360	1,880	2,560	3,110	3,680	GISDB						
				531	1,060	1,480	2,040	2,520	3,030	BFRII						
86	05470000	South Skunk River near Ames	C	3,100	4,780	5,800	6,960	7,740	8,450	B17B	67	72	1921-27, 1930, 1933-90	1954	8,630	100
				3,620	6,260	8,210	10,600	12,400	14,300	GISDB						
				2,330	4,280	5,710	7,530	9,080	10,700	BFRII						
87	05470500	Squaw Creek at Ames	C	2,530	4,110	5,240	6,760	7,940	9,160	B17B	42	73	1918, 1920-27, 1965-90	1990	12,500	1.4*
				3,150	5,520	7,300	9,530	11,300	13,000	GISDB						
				2,230	4,130	5,540	7,330	8,870	10,400	BFRII						
88	05471000	South Skunk River below Squaw Creek near Ames	C	6,000	8,400	9,730	11,200	12,100	12,900	B17B	34	61	1944, 1953-79	1975	14,700	1.1*
				5,270	8,880	11,500	14,700	17,100	19,500	GISDB						
				4,670	8,310	10,900	14,200	16,900	19,700	BFRII						
89	05471200	Indian Creek near Mingo	C	4,050	5,980	7,120	8,420	9,280	10,100	B17B	23	--	1944, 1958-75, 1986-90	1966	7,380	12
				3,980	6,890	9,050	11,700	13,800	16,000	GISDB						
				3,430	6,200	8,230	10,800	13,000	15,200	BFRII						
90	05471500	South Skunk River near Oskaloosa	C	8,440	12,700	15,600	19,200	21,900	24,500	B17B	47	60	1944, 1946-90	1944	37,000	1.5*
				7,270	12,900	16,900	22,500	26,400	31,200	BFRI						
91	05472290	Sugar Creek near Searsboro	P	1,420	2,320	2,980	3,880	4,580	5,310	B17B	23	--	1966-88	1974	4,600	50
				1,820	3,380	4,630	6,300	7,670	9,090	GISDB						
				1,600	3,240	4,570	6,570	8,120	10,000	BFRI						
92	05472390	Middle Creek near Lacey	P	1,050	1,990	2,790	4,010	5,080	6,290	B17B	25	--	1966-90	1976	9,650	1.5*
				1,070	1,960	2,670	3,610	4,370	5,160	GISDB						
				815	1,660	2,370	3,420	4,310	5,270	ACRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
93	05472445	Rock Creek at Sigourney	P	870	1,650	2,270	3,150	3,870	4,650	B17B	22	--	1966-88	1970	4,100	60
				1,370	2,510	3,390	4,550	5,480	6,440	GISDB						
				1,100	2,190	3,090	4,400	5,490	6,650	ACRI						
94	05472500	North Skunk River near Sigourney	C	5,670	10,500	14,000	18,700	22,300	26,000	B17B	48	60	1944, 1946-90	1960	27,500	1.1*
				9,240	14,900	19,000	24,000	27,800	31,700	GISDB						
				5,160	9,050	11,900	15,900	18,900	22,000	ACRI						
95	05473300	Cedar Creek near Batavia	P	5,310	9,130	12,200	16,500	20,200	24,200	B17B	23	--	1965-89	1965	26,000	1.1*
				4,240	6,960	8,940	11,400	13,300	15,200	GISDB						
				3,000	5,750	7,870	11,000	13,300	16,100	BFRI						
96	05473400	Cedar Creek near Oakland Mills	C	6,400	7,870	8,640	9,470	9,990	10,500	B17B	12	--	1979-90	1983	8,560	9
				6,840	10,800	13,700	17,100	19,700	22,300	GISDB						
				4,820	8,850	11,800	16,100	19,200	22,900	BFRI						
97	05473500	Big Creek near Mount Pleasant	C	1,980	3,760	5,110	6,950	8,400	9,880	B17B	26	32	1948, 1956-79	1973	10,500	1.1*
				2,560	4,390	5,750	7,460	8,800	10,200	GISDB						
				2,230	4,380	6,080	8,600	10,500	12,800	BFRI						
98	05474000	Skunk River at Augusta	C	20,900	31,000	37,100	44,200	48,900	53,300	B17B	81	139	1903, 1915-90	1973	66,800	1.2*
				19,700	31,900	39,800	50,700	57,400	66,100	BFRI						
99	05476500	Des Moines River at Estherville	C	2,120	4,470	6,550	9,790	12,700	15,900	B17B	41	52	1952-90	1969	16,000	100
				2,370	4,340	5,790	7,630	9,200	10,800	BFRII						
100	05476750	Des Moines River at Humboldt	C	4,120	7,720	10,300	13,600	16,100	18,400	B17B	51	52	1940-90	1969	18,000	90
				3,640	6,480	8,490	11,000	13,100	15,300	BFRII						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
101	05479000	East Fork Des Moines River at Dakota City	C	3,780 3,570	7,600 6,340	10,700 8,300	15,300 10,700	19,100 12,800	23,200 14,900	B17B BFRII	54	72	1938, 1940-90	1938	22,000	80
102	05480000	Lizard Creek near Clare	C	1,590 1,920 2,080	3,350 3,540 3,830	4,710 4,780 5,120	6,560 6,370 6,770	7,990 7,620 8,180	9,420 8,880 9,610	B17B GISDB BFRII	42	--	1940-81	1947	10,000	1.1*
103	05480500	Des Moines River at Fort Dodge	C	9,930 7,760	16,700 13,300	21,500 17,100	28,000 21,800	33,000 25,700	38,200 29,600	B17B BFRII	65	87	1905-06, 1914-27, 1947-90	1965	35,600	70
104	05481000	Boone River near Webster City	C	5,090 4,430 4,750	8,840 7,730 8,380	11,500 10,200 10,900	15,100 13,200 14,100	17,800 15,600 16,800	20,500 17,900 19,600	B17B GISDB BFRII	55	95	1918, 1932, 1941-90	1918	21,500	100
105	05481300	Des Moines River near Stratford	C	14,000 16,800	23,800 27,600	30,900 34,900	40,400 43,300	47,700 50,600	55,200 57,700	B17B BFRII	85	88	1903, 1905-29, 1931, 1933-90	1954	57,400	100
106	05481680	Beaver Creek at Beaver	P	594 638 674	1,080 1,210 1,320	1,430 1,650 1,820	1,880 2,230 2,500	2,210 2,690 3,070	2,530 3,160 3,670	B17B GISDB BFRII	25	--	1966-90	1979	1,950	30
107	05481950	Beaver Creek near Grimes	C	2,770 3,940 2,120	4,570 6,720 3,910	5,800 8,770 5,240	7,340 11,300 6,940	8,460 13,300 8,380	9,550 15,300 9,860	B17B GISDB BFRII	31	--	1960-90	1986	7,980	40
108	05482170	Big Cedar Creek near Varina	C	640 691 512	1,260 1,350 1,000	1,720 1,860 1,360	2,330 2,540 1,910	2,780 3,080 2,330	3,240 3,630 2,760	B17B GISDB ACRII	31	--	1960-90	1962	2,080	18

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft³/s, for indicated recurrence interval, in years: 2	5	10	25	50	100	Meth.	Record: ERL (yrs)	HST (yrs)	Flood period	Maximum flood: Water year	Disch. (ft³/s)	Recur. inter. (yrs)
109	05482300	North Raccoon	C	3,620	7,370	10,200	13,900	16,700	19,500	B17B	34	37	1954, 1959-90	1979	13,100	20
		River near		4,010	7,080	9,360	12,200	14,400	16,600	GISDB						
		Sac City		4,200	7,470	9,810	12,700	15,200	17,700	BFRII						
110	05482500	North Raccoon	C	6,770	12,400	16,400	21,500	25,300	29,000	B17B	51	--	1940-90	1947	29,100	100
		River near		6,730	11,700	15,200	19,500	23,100	26,800	BFRII						
		Jefferson														
111	05482600	Hardin Creek at	P	503	992	1,380	1,910	2,340	2,780	B17B	39	--	1952-90	1954	2,000	30
		Farnhamville		298	592	832	1,160	1,420	1,700	GISDB						
				442	890	1,250	1,740	2,150	2,600	BFRII						
112	05482900	Hardin Creek near	P	648	1,230	1,690	2,330	2,840	3,370	B17B	40	--	1951-90	1990	2,470	30
		Farlin		1,050	2,000	2,760	3,770	4,580	5,420	GISDB						
				1,510	2,840	3,840	5,150	6,260	7,410	BFRII						
113	05483000	East Fork Hardin	C	227	362	455	572	658	744	B17B	39	--	1952-90	1990	754	100
		Creek near		213	415	575	783	947	1,110	GISDB						
		Churdan		323	656	922	1,290	1,600	1,930	BFRII						
114	05483349	Middle Raccoon	P	486	1,040	1,530	2,290	2,960	3,720	B17B	25	--	1966-90	1986	3,350	70
		River tributary		605	1,330	1,970	2,920	3,750	4,650	GISDB						
		at Carroll		386	890	1,340	2,070	2,680	3,440	BFRI						
115	05483450	Middle Raccoon	C	3,760	7,240	10,000	13,900	17,100	20,500	B17B	14	18	1973, 1979-90	1973	14,600	30
		River near Bayard		5,520	9,780	13,000	17,200	20,500	23,900	GISDB						
				3,720	6,990	9,470	13,100	15,700	18,900	BFRI						
116	05483600	Middle Raccoon	C	5,000	8,220	10,600	13,700	16,100	18,600	B17B	35	38	1953, 1958-90	1986	15,300	40
		River at Panora		5,690	10,000	13,300	17,500	20,800	24,200	GISDB						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
117	05484000	South Raccoon River at Redfield	C	10,400	16,400	20,400	25,400	29,000	32,500	B17B	51	--	1940-90	1958	35,000	1.1*
				12,000	20,000	25,800	33,000	38,500	44,100	GISDB						
				8,480	14,800	19,300	25,500	29,800	35,000	BFRI						
118	05484500	Raccoon River at Van Meter	C	14,400	23,400	29,700	37,700	43,700	49,700	B17B	76	--	1915-90	1947	41,200	40
				10,600	17,900	23,000	29,000	34,200	39,200	BFRII						
119	05484800	Walnut Creek at Des Moines	C	2,270	4,890	7,250	11,000	14,300	18,100	B17B	19	--	1972-90	1986	12,500	35
				1,950	3,580	4,850	6,510	7,850	9,220	GISDB						
				1,880	3,520	4,760	6,350	7,730	9,140	BFRII						
120	05485640	Fourmile Creek at Des Moines	C	2,510	4,190	5,330	6,770	7,830	8,860	B17B	18	--	1972-79, 1981-90	1977	5,380	10
				1,710	3,120	4,190	5,590	6700	7,840	GISDB						
				1,310	2,430	3,220	4,400	5,310	6,190	ACRII						
121	05486000	North River near Norwalk	C	3,420	6,990	10,100	14,900	19,200	23,900	B17B	51	--	1940-90	1947	32,000	1.3*
				7,140	12,200	16,100	20,900	24,700	28,500	GISDB						
				2,680	4,960	6,730	9,200	11,200	13,200	ACRI						
122	05486490	Middle River near Indianola	C	7,140	11,100	13,700	17,000	19,300	21,600	B17B	51	--	1940-90	1947	34,000	1.6*
				10,100	16,600	21,300	27,100	31,600	36,200	GISDB						
				5,020	8,830	11,700	15,500	18,500	21,500	ACRI						
123	05487470	South River near Ackworth	C	10,700	17,900	22,700	28,600	32,700	36,600	B17B	54	61	1930, 1940-90	1990	38,100	100
				9,520	15,300	19,400	24,300	28,100	31,900	GISDB						
				4,820	8,500	11,200	15,000	17,900	20,800	ACRI						
124	05487600	South White Breast Creek near Osceola	P	2,230	4,070	5,410	7,190	8,550	9,910	B17B	29	--	1953-81	1981	11,800	1.2*
				1,940	3,560	4,810	6,460	7,800	9,170	GISDB						
				1,700	3,430	4,830	6,910	8,520	10,500	BFRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
125	05487800	White Breast Creek at Lucas	P	3,450	6,320	8,530	11,600	14,000	16,600	B17B	37	--	1953-88, 1990	1981	15,500	80
				4,200	7,150	9,330	12,100	14,300	16,500	GISDB						
				2,140	4,220	5,870	8,320	10,200	12,400	BFRI						
126	05487980	White Breast Creek near Dallas	C	6,750	9,820	12,000	15,100	17,500	20,000	B17B	32	46	1962-90	1982	37,300	1.9*
				6,650	10,800	13,800	17,400	20,200	23,100	GISDB						
				3,870	6,950	9,290	12,500	15,000	17,600	ACRI						
127	05488000	White Breast Creek near Knoxville	C	6,150	9,320	11,400	13,900	15,700	17,400	B17B	21	36	1946-62	1947	14,000	25
				6,940	11,200	14,300	18,000	20,900	23,700	GISDB						
128	05488620	Coal Creek near Albia	P	1,210	3,170	5,150	8,490	11,600	15,300	B17B	24	--	1966-90	1982	12,700	60
				1,050	1,990	2,730	3,740	4,560	5,420	GISDB						
				912	1,940	2,820	4,160	5,240	6,560	BFRI						
129	05489000	Cedar Creek near Bussey	C	7,790	14,000	19,400	28,000	35,800	45,100	B17B	49	139	1946, 1948-90	1982	96,000	2.1*
				7,690	12,400	15,900	20,000	23,300	26,500	GISDB						
				3,410	6,450	8,770	12,200	14,600	17,700	BFRI						
130	05489150	Little Muchakinock Creek at Oskaloosa	P	397	937	1,470	2,370	3,220	4,250	B17B	23	--	1966-88	1970	4,500	1.1*
				500	963	1,330	1,830	2,230	2,640	GISDB						
				536	1,200	1,780	2,700	3,460	4,400	BFRI						
131	05489490	Bear Creek at Ottumwa	P	2,090	3,180	3,870	4,700	5,290	5,860	B17B	26	--	1965-90	1977	4,300	16
				1,390	2,560	3,480	4,690	5,670	6,680	GISDB						
				1,570	3,180	4,490	6,460	7,990	9,850	BFRI						
132	05491000	Sugar Creek near Keokuk	C	3,020	5,110	6,770	9,170	11,200	13,400	B17B	30	92	1905, 1923-28, 1930-31, 1959-73	1905	33,000	2.5*
				2,480	4,210	5,500	7,140	8,420	9,720	GISDB						
133	05494300	Fox River at Bloomfield	B	2,710	4,970	6,650	8,890	10,600	12,400	B17B	21	--	1953-73	1960	8,600	25
				2,160	3,730	4,910	6,410	7,600	8,810	GISDB						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
134	05494500	Fox River at Cantril	C	6,070	8,380	9,910	11,800	13,300	14,700	B17B	14	18	1920, 1941-51	1946	16,500	1.1*
				3,420	5,740	7,450	9,610	11,300	13,000	GISDB						
135	05495600	South Wyaconda River near West Grove	P	469	1,240	1,970	3,110	4,110	5,220	B17B	23	--	1953-75	1970	3,100	25
				453	899	1,260	1,770	2,190	2,640	GISDB						
136	06483270	Rock River at Rock Rapids	C	3,850	8,750	13,200	20,200	26,400	33,500	B17B	23	93	1960-74	1969	29,000	70
				4,280	9,220	13,500	19,700	25,000	30,700	GISDB						
137	06483410	Otter Creek north of Sibley	P	141	369	599	986	1,350	1,780	B17B	36	--	1952-88	1962	1,410	60
				203	513	810	1,280	1,710	2,190	GISDB						
				94	203	294	426	538	661	BFRII						
138	06483430	Otter Creek at Sibley	P	272	804	1,420	2,620	3,900	5,580	B17B	35	--	1952-88	1953	5,400	90
				445	1,070	1,670	2,580	3,390	4,300	GISDB						
				739	1,520	2,180	3,160	3,980	4,880	ACRI						
139	06483460	Otter Creek near Ashton	P	840	2,360	4,110	7,470	11,100	15,800	B17B	39	63	1952-72, 1974-88	1979	18,000	1.1*
				1,090	2,400	3,550	5,250	6,710	8,310	GISDB						
				2,120	3,990	5,470	7,560	9,260	11,000	ACRI						
140	06483500	Rock River near Rock Valley	C	6,220	13,700	19,900	28,800	35,900	43,500	B17B	49	93	1897, 1948-90	1969	40,400	80
				9,030	15,700	20,300	26,900	31,300	36,700	BFRI						
141	06484000	Dry Creek at Hawarden	C	735	1,930	3,100	5,060	6,860	8,960	B17B	27	43	1926, 1934, 1949-69	1953	10,900	1.2*
				685	1,620	2,490	3,820	5,000	6,320	GISDB						
142	06600000	Perry Creek at 38th Street, Sioux City	C	2,700	4,890	6,380	8,200	9,490	10,700	B17B	42	56	1939-69, 1981-90	1944	9,600	50
				998	2,340	3,560	5,430	7,080	8,900	GISDB						
				1,250	2,460	3,440	4,870	6,060	7,320	ACRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

				Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
143	06600100	Floyd River at Alton	C	1,810	5,100	8,560	14,600	20,400	27,500	B17B	41	115	1953, 1956-90	1953	45,500	1.6*
				2,530	5,080	7,180	10,100	12,500	15,100	GISDB						
				1,990	3,960	5,520	7,860	9,630	11,800	BFRI						
144	06600300	West Branch Floyd River near Struble	C	2,160	4,810	6,950	9,930	12,300	14,600	B17B	35	37	1956-90	1962	8,060	15
				1,320	2,940	4,380	6,490	8,310	10,300	GISDB						
				2,430	4,740	6,550	9,230	11,200	13,700	BFRI						
145	06600500	Floyd River at James	C	3,840	8,450	12,700	19,600	25,900	33,100	B17B	61	115	1935-90	1953	71,500	2.2*
				4,710	9,350	13,200	18,400	22,700	27,300	GISDB						
				5,350	9,730	12,900	17,500	20,800	24,800	BFRI						
146	06602020	West Fork ditch at Hornick	C	3,170	5,880	7,880	10,500	12,600	14,700	B17B	47	--	1939-69, 1975-90	1962	12,400	45
				3,680	7,180	10,000	13,900	17,100	20,500	GISDB						
				2,320	4,350	5,940	8,180	9,990	11,900	ACRI						
147	06602400	Monona-Harrison ditch near Turin	C	6,170	10,900	14,100	18,100	21,000	23,800	B17B	32		1959-90	1971	19,900	40
				5,240	9,920	13,700	18,600	22,600	26,800	GISDB						
				3,580	6,470	8,670	11,700	14,100	16,600	ACRI						
148	06605000	Ocheyedan River near Spencer	C	2,700	5,030	6,820	9,290	11,300	13,300	B17B	20	75	1953, 1969, 1978-90	1953	26,000	2.0*
				2,820	5,580	7,840	10,900	13,400	16,100	GISDB						
				2,020	3,680	4,870	6,410	7,690	8,980	BFRII						
149	06605340	Prairie Creek near Spencer	P	328	817	1,250	1,900	2,440	3,010	B17B	25	--	1966-90	1971	2,200	40
				316	702	1,040	1,540	1,960	2,420	GISDB						
				263	542	769	1,080	1,350	1,640	BFRII						
150	06605750	Willow Creek near Cornell	P	954	1,840	2,530	3,510	4,300	5,130	B17B	25	--	1966-90	1979	4,200	45
				916	1,890	2,710	3,850	4,810	5,820	GISDB						
				1,120	2,130	2,900	3,910	4,770	5,660	BFRII						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft³/s, for indicated recurrence interval, in years							Record				Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period		Water year	Disch. (ft³/s)	Recur. inter. (yrs)
151	06605850	Little Sioux River at Linn Grove	C	4,520	9,470	13,800	20,300	25,900	32,100	B17B	28	99	1953, 1961-62 1965, 1973-90		1953	22,500	35
				7,240	12,600	16,500	21,100	25,100	29,100	BFRII							
152	06606600	Little Sioux River at Correctionville	C	6,470	11,700	15,800	21,800	26,700	32,100	B17B	69	99	1891, 1919-25, 1929-32, 1937-90		1965	29,800	80
				6,890	12,200	16,100	21,600	25,300	30,000	BFRI							
153	06606790	Maple Creek near Alta	P	134	702	1,580	3,630	6,090	9,560	B17B	24	--	1966-89		1969	5,300	40
				828	1,740	2,530	3,660	4,620	5,660	GISDB							
				553	1,230	1,830	2,770	3,550	4,500	BFRI							
154	06607000	Odebolt Creek near Arthur	C	990	2,010	2,880	4,220	5,380	6,670	B17B	18	--	1951, 1958-75		1962	5,200	45
				1,880	3,800	5,410	7,690	9,610	11,700	GISDB							
155	06607200	Maple River at Mapleton	C	7,030	11,900	15,200	19,400	22,400	25,400	B17B	49	--	1942-90		1978	20,800	35
				6,720	12,100	16,300	21,800	26,200	30,700	GISDB							
				8,060	13,600	17,700	23,000	27,100	31,000	ACRI							
156	06608500	Soldier River at Pisgah	C	8,450	14,300	18,400	23,600	27,500	31,200	B17B	51	--	1940-90		1950	22,500	20
				5,920	10,900	14,800	19,900	24,000	28,400	GISDB							
				5,760	10,000	13,200	17,400	20,700	23,900	ACRI							
157	06609500	Boyer River at Logan	C	12,100	18,300	21,900	26,100	28,900	31,400	B17B	61	--	1881, 1918-25, 1938-90		1990	30,800	90
				7,750	13,500	17,900	23,500	27,900	32,300	GISDB							
				7,990	13,500	17,500	22,800	26,900	30,800	ACRI							
158	06610500	Indian Creek at Council Bluffs	C	561	1,520	2,480	4,110	5,640	7,440	B17B	25	35	1942, 1955-76		1942	9,200	1.2*
				583	1,280	1,880	2,760	3,520	4,340	GISDB							
159	06610520	Mosquito Creek near Earling	C	3,110	6,170	8,590	12,000	14,700	17,500	B17B	15	--	1965-79		1972	12,000	25
				946	1,930	2,740	3,880	4,820	5,830	GISDB							
				797	1,630	2,330	3,360	4,240	5,180	ACRI							

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
160	06610600	Mosquito Creek at Neola	P	4,540	7,900	10,500	14,300	17,400	20,800	B17B	39	--	1952-90	1958	17,300	50
				2,600	4,950	6,840	9,380	11,500	13,600	GISDB						
				1,370	2,690	3,750	5,280	6,550	7,890	ACRI						
161	06806000	Waubonsie Creek near Bartlett	C	2,870	5,780	8,170	11,700	14,600	17,700	B17B	24	--	1946-69	1950	14,500	50
				1,180	2,270	3,130	4,310	5,260	6,250	GISDB						
162	06807410	West Nishnabotna River at Hancock	C	9,410	15,500	19,500	24,300	27,700	31,000	B17B	31	--	1960-90	1972	26,400	40
				6,520	11,600	15,400	20,400	24,400	28,500	GISDB						
				6,700	11,500	15,000	19,700	23,300	26,900	ACRI						
163	06807470	Indian Creek near Emerson	P	858	2,240	3,720	6,420	9,170	12,700	B17B	25	--	1966-90	1982	15,800	1.2*
				1,310	2,490	3,420	4,670	5,680	6,730	GISDB						
				1,490	3,050	4,310	6,220	7,700	9,510	BFRI						
164	06807720	Middle Silver Creek near Avoca	P	387	679	879	1,130	1,310	1,480	B17B	32	--	1953-84, 1986-88	1976	1,200	35
				285	646	970	1,460	1,890	2,360	GISDB						
				258	616	949	1,490	1,960	2,540	BFRI						
165	06807760	Middle Silver Creek near Oakland	P	882	1,260	1,510	1,820	2,050	2,270	B17B	38	--	1953-90	1973	2,110	60
				849	1,740	2,500	3,570	4,470	5,430	GISDB						
				433	932	1,360	2,030	2,600	3,230	ACRI						
166	06807780	Middle Silver Creek at Treynor	P	1,320	1,960	2,410	2,980	3,420	3,870	B17B	37	--	1953-55, 1957-90	1973	3,700	80
				1,070	2,150	3,040	4,280	5,310	6,400	GISDB						
				821	1,670	2,390	3,440	4,340	5,300	ACRI						
167	06808000	Mule Creek near Malvern	C	762	1,840	2,730	3,980	4,950	5,930	B17B	16	--	1954-69	1954	2,070	6
				704	1,420	2,010	2,840	3,520	4,250	GISDB						
168	06808500	West Nishnabotna River at Randolph	C	15,300	25,700	32,200	39,800	44,900	49,600	B17B	42	43	1947, 1949-90	1987	40,800	30
				12,200	20,000	25,400	32,500	37,800	42,900	ACRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
169	06809000	Davids Creek near Hamlin	C	892	2,140	3,400	5,590	7,710	10,300	B17B	22	--	1952-73	1958	22,700	2.2*
				1,320	2,540	3,530	4,890	6,020	7,200	GISDB						
170	06809210	East Nishnabotna River near Atlantic	C	8,910	15,600	20,400	26,500	31,000	35,400	B17B	32	43	1958, 1961-90	1958	34,200	80
				6,570	11,200	14,800	19,200	22,800	26,400	GISDB						
				8,400	14,200	18,300	23,800	28,000	32,100	ACRI						
171	06809500	East Nishnabotna River at Red Oak	C	9,330	16,100	20,700	26,200	30,100	33,700	B17B	69	87	1917-25, 1936-90	1972	38,000	1.1*
				10,800	18,000	23,200	29,700	34,700	39,800	GISDB						
				8,540	14,400	18,600	24,100	28,400	32,500	ACRI						
172	06810000	Nishnabotna River above Hamburg	C	15,900	23,900	28,600	33,800	37,200	40,300	B17B	69	139	1917, 1922-23, 1929-90	1947	55,500	1.4*
				10,100	16,800	21,600	27,800	32,500	37,000	ACRI						
173	06811760	Tarkio River near Elliot	P	573	1,220	1,760	2,540	3,170	3,850	B17B	33	--	1952-90	1987	3,210	50
				629	1,270	1,800	2,540	3,170	3,830	GISDB						
				825	1,770	2,580	3,830	4,850	6,080	BFRI						
174	06811840	Tarkio River at Stanton	C	2,920	6,490	9,290	13,100	15,900	18,800	B17B	37	--	1952, 1954-56, 1958-90	1967	22,500	1.2*
				1,500	2,820	3,870	5,270	6,410	7,600	GISDB						
				1,360	2,660	3,720	5,240	6,500	7,840	ACRI						
175	06811875	Snake Creek near Yorktown	P	1,170	2,010	2,580	3,280	3,780	4,250	B17B	25	--	1966-90	1987	3,080	20
				837	1,630	2,270	3,140	3,850	4,600	GISDB						
				519	1,100	1,600	2,350	3,000	3,710	ACRI						
176	06817000	Nodaway River at Clarinda	C	10,800	19,300	24,900	31,600	36,200	40,400	B17B	66	87	1903, 1918-25, 1936-90	1947	31,100	25
				11,500	18,800	24,200	30,900	36,100	41,300	GISDB						
				10,600	17,500	22,500	28,900	33,800	38,400	ACRI						
177	06818598	Platte River near Stringtown	P	1,440	2,110	2,560	3,110	3,510	3,910	B17B	23	--	1966-88	1974	3,120	25
				1,550	2,740	3,650	4,830	5,770	6,740	GISDB						
				1,730	3,320	4,590	6,400	7,880	9,430	ACRI						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
178	06818750	Platte River near Diagonal	C	5,000	6,760	7,760	8,850	9,560	10,200	B17B	24	25	1967-90	1989	8,630	20
				3,880	6,420	8,280	10,600	12,400	14,200	GISDB						
				3,200	5,830	7,860	10,700	12,900	15,200	ACRI						
179	06819190	East Fork One Hundred and Two River near Bedford	C	4,210	6,460	7,960	9,820	11,200	12,500	B17B	24	--	1960-83	1974	9,980	25
				2,880	4,960	6,520	8,510	10,100	11,700	GISDB						
				2,720	5,020	6,810	9,310	11,300	13,400	ACRI						
180	06897950	Elk Creek near Decatur City	C	5,100	11,700	17,100	24,500	30,200	36,000	B17B	24	--	1959, 1967-90	1990	18,000	11
				3,080	5,460	7,280	9,660	11,600	13,500	GISDB						
				3,150	6,010	8,210	11,400	13,800	16,700	BFRI						
181	06898000	Thompson River at Davis City	C	7,940	12,300	15,300	19,200	22,100	25,000	B17B	68	106	1885, 1897, 1903, 1909, 1914-15, 1918-24, 1926, 1942-90	1885	30,000	1.2*
				11,400	17,900	22,600	28,200	32,500	36,800	GISDB						
				7,790	13,200	17,100	22,300	26,300	30,200	ACRI						
182	06898400	Weldon River near Leon	C	5,870	9,450	12,000	15,300	17,800	20,400	B17B	37	72	1959-90	1959	48,600	2.4*
				3,740	6,410	8,400	10,900	12,900	14,900	GISDB						
				4,370	7,770	10,300	13,800	16,600	19,300	ACRI						
183	06903400	Chariton River near Chariton	C	3,480	6,050	8,040	10,900	13,200	15,600	B17B	30	44	1947, 1960, 1966-90	1981	16,600	1.1*
				3,580	5,970	7,710	9,880	11,600	13,200	GISDB						
				1,910	3,810	5,330	7,590	9,320	11,400	BFRI						
184	06903500	Honey Creek near Russell	C	609	1,350	2,010	3,050	3,980	5,030	B17B	11	--	1952-62	1959	4,100	50
				847	1,590	2,190	2,990	3,650	4,340	GISDB						
185	06903700	South Fork Chariton River near Promise City	C	5,800	9,320	11,900	15,400	18,200	21,100	B17B	23	--	1968-90	1981	28,000	1.3*
				3,100	5,180	6,710	8,620	10,100	11,600	GISDB						
				3,150	5,760	7,760	10,500	12,800	15,000	ACRI						
186	06903900	Chariton River near Rathbun	C	5,570	12,000	17,600	25,800	32,700	40,300	B17B	13	--	1957-69[1]	1960	21,800	17
				7,040	11,100	14,000	17,500	20,200	22,800	GISDB						

Table 8. *Flood-frequency data for streamflow-gaging stations in Iowa*--Continued

Map no. (figs. 1 and 2)	Station number	Station name	Type of gage	Flood-peak discharge estimates, in ft^3/s, for indicated recurrence interval, in years							Record			Maximum flood		
				2	5	10	25	50	100	Meth.	ERL (yrs)	HST (yrs)	Flood period	Water year	Disch. (ft^3/s)	Recur. inter. (yrs)
187	06903990	Cooper Creek at Centerville	P	1,570	3,160	4,420	6,170	7,550	8,980	B17B	24	--	1966-89	1982	7,000	40
				1,660	2,940	3,930	5,210	6,230	7,280	GISDB						
				1,170	2,440	3,490	5,090	6,360	7,900	BFRI						
188	06904000	Chariton River near Centerville	C	5,420	10,600	14,900	21,000	26,100	31,600	B17B	25	31	1938-59	1946	21,700	30
				8,950	14,000	17,600	21,800	25,000	28,200	GISDB						

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[1] Streamflow regulated during part of gaged record. Only unregulated peak discharges at these stations were used in flood-frequency analysis.

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*

[mi^2, square miles; Drainage-basin characteristic measurements, values quantified using the geographic-information-system procedure; *CDA*, contributing drainage area, in square miles; *RR*, relative relief, in feet per mile; *DF*, drainage frequency, in number of first-order streams per square mile; *TTF*, 2-year, 24-hour precipitation intensity, in inches; Channel-geometry characteristic measurements, average values measured onsite; *BFW*, bankfull width, in feet; *BFD*, bankfull depth, in feet; *ACW*, active-channel width, in feet; --, not determined]

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
1	05387500	Upper Iowa River at Decorah	511	43°18'19"	91°47'48"	503	4.21	0.503	2.99	129	6.1	114
2	05388000	Upper Iowa River near Decorah	568	43°18'20"	91°45'00"	565	4.00	.490	3.00	--	--	--
3	05388250	Upper Iowa River near Dorchester	770	43°25'16"	91°30'31"	765	4.37	.490	3.00	155	7.2	139
4	05388500	Paint Creek at Waterville	42.8	43°12'37"	91°18'21"	41.9	12.9	.526	3.05	--	--	--
5	05389000	Yellow River at Ion	221	43°06'35"	91°15'55"	207	8.19	.493	3.05	--	--	--
6	05411530	North Branch Turkey River near Cresco	19.5	43°22'15"	92°12'49"	19.6	5.27	.713	3.05	26.7	3.7	19.5
7	05411600	Turkey River at Spillville	177	43°12'28"	91°56'56"	178	3.71	.472	3.05	82.7	5.1	68.2
8	05411650	Crane Creek tributary near Saratoga	4.06	43°22'00"	92°23'00"	4.13	13.7	.726	3.05	--	--	--
9	05411700	Crane Creek near Lourdes	75.8	43°14'57"	92°18'32"	74.7	4.87	.495	3.05	61.0	4.0	40.9
10	05412500	Turkey River at Garber	1,545	42°44'24"	91°15'42"	--	--	--	--	190	13.7	156

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
11	05414450	North Fork Little Maquoketa River near Rickardsville	21.6	42°35'09"	90°51'20"	22.3	18.5	0.448	3.05	37.2	3.4	25.4
12	05414500	Little Maquoketa River near Durango	130	42°33'18"	90°44'46"	136	9.69	.664	3.05	109	9.4	46.8
13	05414600	Little Maquoketa River tributary at Dubuque	1.54	42°32'33"	90°41'38"	1.53	48.7	.655	3.05	--	--	4.2
14	05417000	Maquoketa River near Manchester	305	42°27'22"	91°25'56"	306	4.34	.562	3.05	166	6.4	125
15	05417530	Plum Creek at Earlville	41.1	42°28'13"	91°14'53"	40.6	7.06	.616	3.05	40.9	3.9	27.5
16	05417590	Kitty Creek near Langworthy	14.4	42°12'04"	91°12'27"	14.8	12.1	.541	3.05	48.6	4.1	16.8
17	05417700	Bear Creek near Monmouth	61.3	42°02'18"	90°52'59"	58.4	6.39	.685	3.05	--	--	--
18	05418450	North Fork Maquoketa River at Fulton	516	42°08'48"	90°40'33"	511	3.62	.666	3.05	155	10.2	103
19	05418500	Maquoketa River near Maquoketa	1,553	42°05'05"	90°38'04"	--	--	--	--	225	13.8	173
20	05420560	Wapsipinicon River near Elma	95.2	43°14'34"	92°31'48"	94.5	4.87	.476	3.02	47.9	5.0	39.0

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
21	05420600	Little Wapsipinicon River tributary near Riceville	0.900	43°21'31"	92°29'08"	0.879	21.0	1.14	3.05	--	--	4.6
22	05420620	Little Wapsipinicon River near Acme	7.76	43°19'37"	92°29'07"	7.90	10.1	.507	3.05	30.1	2.8	12.1
23	05420640	Little Wapsipinicon River at Elma	37.3	43°14'30"	92°27'04"	38.0	5.87	.447	3.05	43.2	2.8	26.3
24	05420650	Little Wapsipinicon River near New Hampton	95.0	43°03'58"	92°23'38"	94.7	4.88	.507	3.05	57.5	4.0	46.6
25	05420690	East Fork Wapsipinicon River near New Hampton	30.3	43°05'11"	92°18'22"	30.2	7.83	.595	3.05	39.0	3.9	21.6
26	05420960	Harter Creek near Independence	6.17	42°29'52"	91°53'27"	6.11	10.7	.655	3.05	--	--	--
27	05421000	Wapsipinicon River at Independence	1,048	42°27'49"	91°53'42"	1,050	2.71	.449	3.05	182	7.7	142
28	05421100	Pine Creek tributary near Winthrop	0.334	42°29'17"	91°47'10"	.338	35.4	2.95	3.05	9.6	1.7	4.8
29	05421200	Pine Creek near Winthrop	28.3	42°28'11"	91°47'01"	27.6	9.15	.435	3.05	50.6	4.1	35.1
30	05421890	Silver Creek at Welton	9.03	41°54'54"	90°36'00"	9.30	9.21	.967	3.05	46.0	4.8	14.4
31	05422000	Wapsipinicon River near De Witt	2,330	41°46'01"	90°32'05"	--	--	--	--	279	7.2	235

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
32	05422470	Crow Creek at Bettendorf	17.8	41°33’03”	90°27’15”	17.5	7.18	0.629	3.15	40.9	4.4	28.9
33	05448500	West Branch Iowa River near Klemme	112	42°57’50”	93°42’20”	111	3.06	.190	3.05	--	--	--
34	05448700	East Branch Iowa River near Hayfield	7.94	43°10’50”	93°39’20”	8.00	2.65	.250	3.05	--	--	36.3
35	05449000	East Branch Iowa River near Klemme	133	43°00’31”	93°37’42”	130	1.68	.169	3.05	104	4.2	56.6
36	05449500	Iowa River near Rowan	429	42°45’36”	93°37’23”	429	1.86	.172	3.05	127	5.1	95.3
37	05451500	Iowa River at Marshalltown	1,564	42°03’57”	92°54’27”	--	--	--	--	165	9.3	147
38	05451700	Timber Creek near Marshalltown	118	42°00’25”	92°51’15”	117	3.98	.581	3.15	71.0	8.4	41.6
39	05451900	Richland Creek near Haven	56.1	41°53’58”	92°28’27”	55.1	5.13	.653	3.15	62.4	7.5	28.5
40	05451955	Stein Creek near Clutier	23.4	42°04’46”	92°18’00”	23.0	5.78	.610	3.15	73.1	4.1	38.0
41	05452000	Salt Creek near Elberon	201	41°57’51”	92°18’47”	199	3.74	.592	3.15	70.9	8.0	43.4
42	05452200	Walnut Creek near Hartwick	70.9	41°50’06”	92°23’10”	71.4	5.03	.672	3.15	66.0	8.4	33.3
43	05453000	Big Bear Creek at Ladora	189	41°44’58”	92°10’55”	189	3.56	.700	3.15	--	--	68.4

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
44	05453100	Iowa River at Marengo	2,794	41°48'48"	92°03'51"	--	--	--	--	188	11.8	160
45	05453600	Rapid Creek below Morse	8.12	41°43'45"	91°25'38"	7.94	11.5	0.504	3.15	31.2	3.8	14.3
46	05453700	Rapid Creek tributary No. 4 near Oasis	1.95	41°42'53"	91°24'52"	1.89	13.2	1.06	3.15	--	--	--
47	05453750	Rapid Creek southwest of Morse	15.2	41°43'23"	91°26'16"	14.7	8.46	.613	3.15	42.1	5.1	27.5
48	05453950	Rapid Creek tributary near Iowa City	3.43	41°41'56"	91°28'39"	3.48	12.5	.287	3.15	26	4.5	12
49	05454000	Rapid Creek near Iowa City	25.3	41°41'19"	91°29'15"	25.2	8.58	.555	3.15	50	6.8	34
50	05454300	Clear Creek near Coralville	98.1	41°40'36"	91°35'55"	97.4	4.85	.431	3.15	70	7.6	44
51	05455000	Ralston Creek at Iowa City	3.01	41°39'50"	91°30'48"	2.98	12.6	.671	3.15	--	--	--
52	05455010	South Branch Ralston Creek at Iowa City	2.94	41°39'05"	91°30'27"	2.92	13.3	.343	3.15	--	--	--
53	05455100	Old Mans Creek near Iowa City	201	41°36'23"	91°36'56"	200	2.88	.500	3.15	89	9.5	49.0
54	05455140	North English River near Montezuma	31.0	41°38'45"	92°34'20"	31.3	4.43	.703	3.15	--	--	19.5
55	05455150	North English River near Montezuma	34.0	41°39'00"	92°33'00"	33.8	4.47	.739	3.15	--	--	--

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
56	05455200	North English River near Guernsey	68.7	41°38'47"	92°23'47"	68.1	4.38	0.778	3.15	--	--	43.5
57	05455210	North English River at Guernsey	81.5	41°38'42"	92°21'28"	80.7	4.12	.768	3.15	--	--	45.6
58	05455280	South English River tributary near Barnes City	2.51	41°33'00"	92°28'00"	2.53	10.4	1.18	3.15	--	--	--
59	05455300	South English River near Barnes City	11.5	41°31'26"	92°27'56"	11.6	12.0	.773	3.17	31.5	4.9	12.1
60	05455350	South English River tributary No.2 near Montezuma	0.523	41°34'02"	92°27'01"	.537	13.8	1.86	3.15	--	--	--
61	05455500	English River at Kalona	573	41°27'59"	91°42'56"	584	2.59	.556	3.18	122	11.2	84
62	05457700	Cedar River at Charles City	1,054	43°03'45"	92°40'23"	1,060	2.27	.297	2.99	214	9.9	195
63	05458000	Little Cedar River near Ionia	306	43°02'05"	92°30'05"	305	3.95	.390	3.03	100	5.4	65.5
64	05458500	Cedar River at Janesville	1,661	42°38'54"	92°27'54"	--	--	--	--	233	8.6	217
65	05458900	West Fork Cedar River at Finchford	846	42°37'50"	92°32'24"	842	2.65	.346	3.05	139	5.3	128
66	05459000	Shell Rock River near Northwood	300	43°24'51"	93°13'14"	300	2.16	.197	2.96	148	4.0	97.8

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Lati-tude	Longi-tude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
67	05459010	Elk Creek at Kensett	58.1	43°22’18”	93°12’37”	58.7	4.18	0.187	3.04	41.5	2.7	35.7
68	05459500	Winnebago River at Mason City	526	43°09’54”	93°11’33”	520	2.17	.229	3.03	161	7.8	91.3
69	05460100	Willow Creek near Mason City	78.6	43°08’55”	93°16’07”	80.2	2.62	.100	3.05	57.9	3.7	34.3
70	05462000	Shell Rock River at Shell Rock	1,746	42°42’42“	92°34’58”	--	--	--	--	216	6.5	191
71	05462750	Beaver Creek tributary near Aplington	11.6	42°34’40”	92°50’49”	11.9	8.31	.505	3.05	--	--	19.2
72	05463000	Beaver Creek at New Hartford	347	42°34’22”	92°37’04”	352	4.05	.429	3.06	80	5.6	70.1
73	05463090	Black Hawk Creek at Grundy Center	56.9	42°22’10”	92°46’05”	57.0	4.84	.492	3.15	51	6.0	34.7
74	05463500	Black Hawk Creek at Hudson	303	42°24’28”	92°27’47”	299	3.45	.428	3.13	91	5.7	73.9
75	05464000	Cedar River at Waterloo	5,146	42°29’44”	92°20’03”	--	--	--	--	403	8.6	377
76	05464130	Fourmile Creek near Lincoln	13.78	42°13’32”	92°36’39”	13.5	7.83	.518	3.15	--	--	--
77	05464133	Half Mile Creek near Gladbrook	1.33	42°12’40”	92°36’39”	1.33	16.3	.750	3.15	--	--	--
78	05464137	Fourmile Creek near Traer	19.51	42°12’07”	92°33’44”	19.3	6.22	.363	3.15	--	--	20.7

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
79	05464500	Cedar River at Cedar Rapids	6,510	41°58'14"	91°40'01"	--	--	--	--	439	12.5	413
80	05464560	Prairie Creek at Blairstown	87.0	41°54'42"	92°05'03"	86.5	4.18	0.543	3.15	--	--	46.9
81	05464640	Prairie Creek at Fairfax	178	41°55'22"	91°47'02"	175	3.35	.566	3.15	96.2	7.0	79.6
82	05464880	Otter Creek at Wilton	10.7	41°36'17"	91°02'08"	10.9	6.91	.368	3.15	40.6	6.2	9.1
83	05465000	Cedar River near Conesville	7,785	41°24'36"	91°17'06"	--	--	--	--	523	10.6	510
84	05469860	Mud Lake drainage ditch 71 at Jewell	65.4	42°18'52"	93°38'23"	65.4	4.60	.138	3.14	--	--	31.7
85	05469990	Keigley Branch near Story City	31.0	42°09'01"	93°37'13"	30.5	5.28	.197	3.15	37.7	4.4	23.3
86	05470000	South Skunk River near Ames	315	42°04'05"	93°37'02"	322	4.12	.161	3.14	104	6.7	83.4
87	05470500	Squaw Creek at Ames	204	42°01'21"	93°37'45"	208	4.31	.245	3.15	87.2	7.2	62.1
88	05471000	South Skunk River below Squaw Creek near Ames	556	42°00'31"	93°35'37"	558	3.29	.199	3.14	131	9.4	106
89	05471200	Indian Creek near Mingo	276	41°48'17"	93°18'36"	278	4.00	.280	3.15	106	8.6	83.3
90	05471500	South Skunk River near Oskaloosa	1,635	41°21'19"	92°39'31"	--	--	--	--	162	10.9	138

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
91	05472290	Sugar Creek near Searsboro	52.7	41°34'26"	92°44'20"	54.0	5.24	0.703	3.15	57	7.7	34.7
92	05472390	Middle Creek near Lacey	23.0	42°43'55"	93°42'26"	22.5	5.21	.667	3.25	--	--	14.8
93	05472445	Rock Creek at Sigourney	26.3	41°20'12"	92°13'20"	26.1	8.84	.383	3.25	--	--	19.6
94	05472500	North Skunk River near Sigourney	730	41°18'03"	92°12'16"	728	2.44	.631	3.19	--	--	83.0
95	05473300	Cedar Creek near Batavia	252	41°00'34"	92°07'06"	247	2.52	.554	3.25	88	11.6	55.5
96	05473400	Cedar Creek near Oakland Mills	530	40°55'20"	91°40'10"	527	2.26	.476	3.25	122	12.7	75.7
97	05473500	Big Creek near Mount Pleasant	106	41°00'52"	91°34'49"	101	4.25	.397	3.25	71.6	9.3	57.4
98	05474000	Skunk River at Augusta	4,303	40°45'13"	91°16'40"	--	--	--	--	322	17.1	275
99	05476500	Des Moines River at Estherville	1,372	43°23'51"	94°50'38"	--	--	--	--	106	6.7	95
100	05476750	Des Moines River at Humboldt	2,256	42°43'12"	94°13'06"	--	--	--	--	172	6.8	163
101	05479000	East Fork Des Moines River at Dakota City	1,308	42°43'26"	94°11'30"	--	--	--	--	187	6.4	170

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
102	05480000	Lizard Creek near Clare	257	42°32'35"	94°20'45"	263	3.09	0.130	3.05	101	6.3	73.3
103	05480500	Des Moines River at Fort Dodge	4,190	42°30'22"	94°12'04"	--	--	--	--	239	9.4	219
104	05481000	Boone River near Webster City	844	42°26'01"	93°48'12"	852	2.16	.182	3.05	166	8.3	148
105	05481300	Des Moines River near Stratford	5,452	42°15'04"	93°59'52"	--	--	--	--	361	12.5	339
106	05481680	Beaver Creek at Beaver	38.5	42°02'04"	94°08'46"	38.8	4.24	.129	3.15	49.4	4.4	25.5
107	05481950	Beaver Creek near Grimes	358	41°41'18"	93°44'08"	358	2.66	.319	3.15	95.5	6.6	85.9
108	05482170	Big Cedar Creek near Varina	80.0	42°41'16"	94°47'52"	80.7	3.83	.074	3.05	--	--	25.0
109	05482300	North Raccoon River near Sac City	700	42°21'16"	94°59'26"	700	2.76	.140	3.05	150	8.1	108
110	05482500	North Raccoon River near Jefferson	1,619	41°59'17"	94°22'36"	--	--	--	--	178	10.1	157
111	05482600	Hardin Creek at Farnhamville	43.7	42°16'01"	94°25'10"	42.3	1.57	.142	3.05	32.9	4.2	21.8
112	05482900	Hardin Creek near Farlin	101	42°05'34"	94°25'39"	97.8	3.03	.205	3.06	71.0	6.2	51.0
113	05483000	East Fork Hardin Creek near Churdan	24.0	42°06'27"	94°22'12"	23.3	2.97	.043	3.13	36.6	3.2	13.5

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi²)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
114	05483349	Middle Raccoon River tributary at Carroll	6.58	42°02'30"	94°52'43"	6.53	17.7	0.766	3.05	21.4	3.2	7.1
115	05483450	Middle Raccoon River near Bayard	375	41°46'43"	94°29'33"	370	4.01	.511	3.09	102	7.4	88
116	05483600	Middle Raccoon River at Panora	440	41°41'14"	94°22'15"	423	3.63	.494	3.09	--	--	--
117	05484000	South Raccoon River at Redfield	994	41°35'22"	94°09'04"	1,000	3.41	.539	3.12	180	10.7	139
118	05484500	Raccoon River at Van Meter	3,441	41°32'02"	93°56'59"	--	--	--	--	250	11.3	220
119	05484800	Walnut Creek at Des Moines	78.4	41°35'14"	93°42'11"	77.2	5.35	.388	3.15	66.0	7.5	46.8
120	05485640	Fourmile Creek at Des Moines	92.7	41°36'50"	93°32'43"	92.2	4.14	.293	3.15	--	--	51.4
121	05486000	North River near Norwalk	349	41°27'25"	93°39'10"	349	4.82	.588	3.15	--	--	45.0
122	05486490	Middle River near Indianola	503	41°25'27"	93°35'09"	492	4.22	.686	3.20	--	--	81.0
123	05487470	South River near Ackworth	460	41°20'14"	93°29'10"	462	4.08	.552	3.25	--	--	77.9
124	05487600	South White Breast Creek near Osceola	28.0	40°57'36"	93°41'28"	27.5	12.0	.510	3.25	59.5	7.9	38.5
125	05487800	White Breast Creek at Lucas	128	41°01'24"	93°27'56"	128	5.35	.603	3.25	69.6	8.4	33.0

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
126	05487980	White Breast Creek near Dallas	342	41°14'41"	93°16'08"	341	3.32	0.577	3.25	--	--	63.5
127	05488000	White Breast Creek near Knoxville	380	41°19'25"	93°08'55"	379	3.09	.583	3.25	--	--	--
128	05488620	Coal Creek near Albia	13.5	41°01'02"	92°50'46"	13.4	10.3	.597	3.25	38.7	5.0	17.2
129	05489000	Cedar Creek near Bussey	374	41°13'09"	92°54'38"	370	3.49	.654	3.25	96	10.9	52.3
130	05489150	Little Muchakinock Creek at Oskaloosa	9.12	41°15'58"	92°38'33"	8.69	9.78	.230	3.25	26.8	3.7	17.2
131	05489490	Bear Creek at Ottumwa	22.9	41°00'43"	92°27'54"	22.2	10.0	.450	3.25	56.2	6.3	29.9
132	05491000	Sugar Creek near Keokuk	105	40°26'33"	91°28'24"	106	3.07	.547	3.26	--	--	--
133	05494300	Fox River at Bloomfield	87.7	40°46'10"	92°25'05"	85.1	3.37	.541	3.25	--	--	--
134	05494500	Fox River at Cantril	161	40°39'20"	92°03'30"	158	2.96	.615	3.25	--	--	--
135	05495600	South Wyaconda River near West Grove	4.69	40°43'00"	92°30'00"	4.58	12.7	.437	3.25	--	--	--
136	06483270	Rock River at Rock Rapids	788	43°26'13"	96°09'58"	790	3.76	.528	2.82	--	--	--
137	06483410	Otter Creek north of Sibley	11.9	43°27'41"	95°44'29"	11.8	6.59	.338	2.85	19.3	2.0	6.9
138	06483430	Otter Creek at Sibley	29.9	43°24'14"	95°46'10"	30.0	6.30	.401	2.85	--	--	13.5

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
139	06483460	Otter Creek near Ashton	88.0	43°20'07"	95°45'43"	89.2	4.78	0.460	2.89	--	--	36.1
140	06483500	Rock River near Rock Valley	1,592	43°12'52"	96°17'39"	--	--	--	--	188	5.9	100
141	06484000	Dry Creek at Hawarden	48.4	42°59'48"	96°28'10"	48.2	5.28	.622	2.85	--	--	--
142	06600000	Perry Creek at 38th Street, Sioux City	65.1	42°32'08"	96°24'39"	64.3	7.30	.528	2.85	--	--	22.0
143	06600100	Floyd River at Alton	268	42°58'55"	96°00'03"	267	3.56	.456	2.94	66.3	7.9	49.8
144	06600300	West Branch Floyd River near Struble	180	42°55'25"	96°10'34"	180	3.69	.405	2.85	76.0	8.1	48.5
145	06600500	Floyd River at James	886	42°34'36"	96°18'43"	886	2.74	.450	2.89	131	7.6	97.2
146	06602020	West Fork ditch at Hornick	403	42°13'37"	96°04'40"	404	3.41	.507	2.95	--	--	39.4
147	06602400	Monona-Harrison ditch near Turin	900	41°57'52"	95°59'30"	902	2.59	.409	2.94	--	--	59
148	06605000	Ocheyedan River near Spencer	426	43°07'44"	95°12'37"	424	3.03	.327	2.93	158	4.8	57.1
149	06605340	Prairie Creek near Spencer	22.3	43°05'16"	95°09'40"	22.4	4.43	.223	2.95	27.1	3.3	12.8
150	06605750	Willow Creek near Cornell	78.6	42°58'21"	95°09'40"	80.9	3.62	.297	2.97	67.8	5.2	36.8

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Lati-tude	Longi-tude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
151	06605850	Little Sioux River at Linn Grove	1,548	42°53'24"	95°14'30"	--	--	--	--	150	11.7	123
152	06606600	Little Sioux River at Correctionville	2,500	42°28'20"	95°47'49"	--	--	--	--	156	12.9	142
153	06606790	Maple Creek near Alta	15.5	42°44'56"	95°22'16"	16.0	10.7	0.624	3.05	27.4	3.4	12.8
154	06607000	Odebolt Creek near Arthur	39.3	42°20'10"	95°22'52"	38.6	10.6	.856	3.05	--	--	--
155	06607200	Maple River at Mapleton	669	42°09'25"	95°48'35"	671	3.00	.628	3.02	--	--	126
156	06608500	Soldier River at Pisgah	407	41°49'50"	95°55'54"	406	4.27	.665	3.03	--	--	92.1
157	06609500	Boyer River at Logan	871	41°38'33"	95°46'57"	869	2.62	.546	3.05	--	--	125
158	06610500	Indian Creek at Council Bluffs	7.99	41°17'32"	95°49'59"	7.62	20.5	.394	3.05	--	--	--
159	06610520	Mosquito Creek near Earling	32.0	41°45'10"	95°27'50"	32.9	7.40	.364	3.05	--	--	14.5
160	06610600	Mosquito Creek at Neola	131	41°26'36"	95°36'42"	133	5.14	.510	3.05	--	--	24.1
161	06806000	Waubonsie Creek near Bartlett	30.4	40°53'04"	95°44'47"	29.4	8.75	.340	3.15	--	--	--
162	06807410	West Nishnabotna River at Hancock	609	41°23'24"	95°22'17"	613	3.01	.571	3.05	--	--	106

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
163	06807470	Indian Creek near Emerson	37.3	41°01'50"	95°22'51"	38.6	7.09	0.363	3.15	54.4	4.4	14.8
164	06807720	Middle Silver Creek near Avoca	3.21	41°28'33"	95°28'06"	3.28	14.8	.610	3.05	16.2	2.8	4.8
165	06807760	Middle Silver Creek near Oakland	25.7	41°19'28"	95°33'19"	25.8	6.67	.543	3.05	--	--	8.2
166	06807780	Middle Silver Creek at Treynor	42.7	41°14'37"	95°36'53"	42.8	5.74	.444	3.05	--	--	14.9
167	06808000	Mule Creek near Malvern	10.6	40°56'40"	95°35'40"	10.6	13.1	,378	3.15	--	--	--
168	06808500	West Nishnabotna River at Randolph	1,326	40°52'23"	95°34'48"	--	--	--	--	--	--	186
169	06809000	Davids Creek near Hamlin	26.0	41°40'25"	94°48'20"	26.5	8.14	.641	3.15	--	--	--
170	06809210	East Nishnabotna River near Atlantic	436	41°20'46"	95°04'36"	429	3.10	.721	3.13	--	--	131
171	06809500	East Nishnabotna River at Red Oak	894	41°00'31"	95°14'29"	886	2.84	.679	3.13	--	--	133
172	06810000	Nishnabotna River above Hamburg	2,806	40°37'57"	95°37'32"	--	--	--	--	--	--	156
173	06811760	Tarkio River near Elliot	10.7	41°06'06"	95°06'09"	10.2	9.93	.488	3.15	36.1	5.4	12.6
174	06811840	Tarkio River at Stanton	49.3	40°58'52"	95°06'32"	47.0	5.62	.510	3.15	--	--	23.9

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Latitude	Longitude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
175	06811875	Snake Creek near Yorktown	9.10	40°44'33"	95°07'46"	9.34	14.6	0.428	3.23	--	--	9.7
176	06817000	Nodaway River at Clarinda	762	40°44'19"	95°00'47"	758	3.08	.810	3.16	--	--	163
177	06818598	Platte River near Stringtown	51.7	40°58'44"	94°29'39"	51.5	3.68	.563	3.25	--	--	29.9
178	06818750	Platte River near Diagonal	217	40°46'02"	94°24'46"	210	2.79	.520	3.25	--	--	53.1
179	06819190	East Fork One Hundred and Two River near Bedford	92.1	40°38'01"	94°44'41"	92.6	4.69	.550	3.25	--	--	45.6
180	06897950	Elk Creek near Decatur City	52.5	40°43'18"	93°56'12"	54.1	8.93	.684	3.25	91.0	8.5	58.7
181	06898000	Thompson River at Davis City	701	40°38'25"	93°48'29"	702	2.88	.692	3.24	--	--	122
182	06898400	Weldon River near Leon	104	40°41'45"	93°38'07"	108	5.83	.547	3.25	--	--	71.1
183	06903400	Chariton River near Chariton	182	40°57'12"	93°15'37"	184	3.22	.436	3.25	64.4	9.3	51.1
184	06903500	Honey Creek near Russell	13.2	40°55'25"	93°07'55"	13.7	7.27	.582	3.25	--	--	--
185	06903700	South Fork Chariton River near Promise City	168	40°48'02"	93°11'32"	169	2.60	.514	3.25	--	--	52.4

Table 9. *Selected drainage-basin and channel-geometry characteristics for streamflow-gaging stations in Iowa*--Continued

Map number (figs. 1 and 2)	Station number	Station name	Published drainage area (mi^2)	Lati-tude	Longi-tude	Drainage-basin characteristic measurements				Channel-geometry characteristic measurments		
						CDA	*RR*	*DF*	*TTF*	*BFW*	*BFD*	*ACW*
186	06903900	Chariton River near Rathbun	549	40°49'22"	92°53'22"	553	2.20	0.486	3.25	--	--	--
187	06903990	Cooper Creek at Centerville	47.8	40°45'02"	92°51'36"	47.2	4.70	.530	3.25	45.9	7.9	35.6
188	06904000	Chariton River near Centerville	708	40°44'20"	92°48'05"	709	2.31	.499	3.25	--	--	--

*U.S. GOVERNMENT PRINTING OFFICE:1993-759-354/80097