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EFFECTS OF THE 1993 FLOOD ON THE DETERMINATION OF FLOOD MAGNITUDE AND FREQUENCY IN IOWA

FLOODS IN THE UPPER MISSISSIPPI RIVER BASIN 1 · 9 · 9 · 3

U.S. GEOLOGICAL SURVEY CIRCULAR 1120-K

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Front Cover—View looking west along Interstate 80 crossing the Des Moines River north of Des Moines, Iowa, July 12, 1993 (U.S. Geological Survey).

Back Cover—View looking west along U.S. Highway 30 south of Ames, Iowa, July 9, 1993, of hydrologist making a road-overflow streamflow measurement for the South Skunk River (U.S. Geological Survey).

View of the Iowa River in Iowa County, Iowa, July 12, 1993 (U.S. Geological Survey).

EFFECTS OF THE 1993 FLOOD ON THE DETERMINATION OF FLOOD MAGNITUDE AND FREQUENCY IN IOWA

By David A. Eash

Floods in the Upper Mississippi River Basin, 1993

U.S. GEOLOGICAL SURVEY CIRCULAR 1120–K

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FOREWORD

During spring and summer 1993, record flooding inundated much of the upper Mississippi River Basin. The magnitude of the damages—in terms of property, disrupted business, and personal trauma—was unmatched by any other flood disaster in United States history. Property damage alone is expected to exceed $10 billion. Damaged highways and submerged roads disrupted overland transportation throughout the flooded region. The Mississippi and the Missouri Rivers were closed to navigation before, during, and after the flooding. Millions of acres of productive farmland remained under water for weeks during the growing season. Rills and gullies in many tilled fields are the result of the severe erosion that occurred throughout the Midwestern United States farmbelt. The hydrologic effects of extended rainfall throughout the upper Midwestern United States were severe and widespread. The banks and channels of many rivers were severely eroded, and sediment was deposited over large areas of the basin's flood plain. Record flows submerged many areas that had not been affected by previous floods. Industrial and agricultural areas were inundated, which caused concern about the transport and fate of industrial chemicals, sewage effluent, and agricultural chemicals in the floodwaters. The extent and duration of the flooding caused numerous levees to fail. One failed levee on the Raccoon River in Des Moines, Iowa, led to flooding of the city's water treatment plant. As a result, the city was without drinking water for 19 days.

As the Nation's principal water-science agency, the U.S. Geological Survey (USGS) is in a unique position to provide an immediate assessment of some of the hydrological effects of the 1993 flood. The USGS maintains a hydrologic data network and conducts extensive water-resources investigations nationwide. Long-term data from this network and information on local and regional hydrology provide the basis for identifying and documenting the effects of the flooding. During the flood, the USGS provided continuous streamflow and related information to the National Weather Service (NWS), the U.S. Army Corps of Engineers, the Federal Emergency Management Agency (FEMA), and many State and local agencies as part of its role to provide basic information on the Nation's surface- and ground-water resources at thousands of locations across the United States. The NWS has used the data in forecasting floods and issuing flood warnings. The data have been used by the Corps of Engineers to operate water diversions, dams, locks, and levees. The FEMA and many State and local emergency management agencies have used USGS hydrologic data and NWS forecasts as part of the basis of their local flood-response activities. In addition, USGS hydrologists are conducting a series of investigations to document the effects of the flooding and to improve understanding of the related processes. The major initial findings from these studies will be reported in this Circular series as results become available.

U.S. Geological Survey Circular 1120, *Floods in the Upper Mississippi River Basin, 1993*, consists of individually published chapters that will document the effects of the 1993 flooding. The series includes data and findings on the magnitude and frequency of peak discharges; precipitation; water-quality characteristics, including nutrients and man-made contaminants; transport of sediment; assessment of sediment deposited on flood plains; effects of inundation on ground-water quality; flood-discharge volume; effects of reservoir storage on flood peaks; stream-channel scour at selected bridges; extent of flood-plain inundation; and documentation of geomorphologic changes.

Mark Schaefer
Acting Director

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CONVERSION FACTORS

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer

Effects of the 1993 Flood on the Determination of Flood Magnitude and Frequency in Iowa

By David A. Eash

Abstract

To evaluate the effects of the 1993 flood in the upper Mississippi River Basin on the determination of flood magnitude and frequency, discharges that had recurrence intervals of 10, 25, 50, and 100 years computed from data through the 1992 water year were compared with those computed from data through the 1993 water year for 62 selected streamflow-gaging stations in Iowa. On the basis of the flood-frequency analysis computed from data through the 1993 water year, a flood that was greater than or equal to a 10-year recurrence-interval discharge occurred during 1993 at all 62 gaging stations, and a flood greater than or equal to a 100-year recurrence-interval discharge occurred at 11 of the gaging stations.

Results of the comparison indicated that inclusion of the 1993 flood in the data base resulted in an increase in the magnitude of discharges for all selected recurrence intervals at the 62 streamflow-gaging stations in Iowa. A larger percentage increase in the magnitude of discharge was computed for the larger recurrence intervals than for the smaller recurrence intervals for most of the selected gaging stations. As a result of including the 1993 peak discharge in the flood-frequency analysis, three gaging stations had an increase in the 100-year recurrence-interval discharge that was greater than 30 percent.

Several factors, which included recurrence intervals for the 1993 peak discharges and the effective record lengths for 1993, were investigated for the 62 selected streamflow-gaging stations to evaluate their possible effect on the computed flood-frequency discharges. The combined effect of these two factors on the computed 100-year recurrence-interval discharges was significant. Gaging stations were grouped into four discrete categories on the basis of recurrence intervals for the 1993 peak discharges and the effective record lengths for 1993. Of the 28 gaging stations that had small flood magnitudes in 1993 and long record lengths, the difference between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges at 22 gaging stations was less than 5 percent. Of the 10 gaging stations that had large flood magnitudes in 1993 and short record lengths, the increase in 100-year recurrence-interval discharges at 9 gaging stations was greater than 15 percent.

INTRODUCTION

A nine-State area of the upper Mississippi River Basin was flooded from late March through September 1993 (fig. 1). From mid-June through early August 1993, the flooding was severe as a result of the wide areal extent, large peak discharges, long duration, and overall destructiveness. Record or near-record peak discharges were recorded in 1993 at streamflow-gaging stations in Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin after intense and persistent rainfall on soils saturated from excessive precipitation (Parrett and others, 1993). Spring 1993 was wetter than average, and weather patterns that persisted from early June through July caused an unusually large amount of precipitation to fall in the upper Midwest (Wahl and others, 1993). From April through September, more than 50 inches of rain fell in parts of Iowa, Kansas, and Missouri (fig. 2).

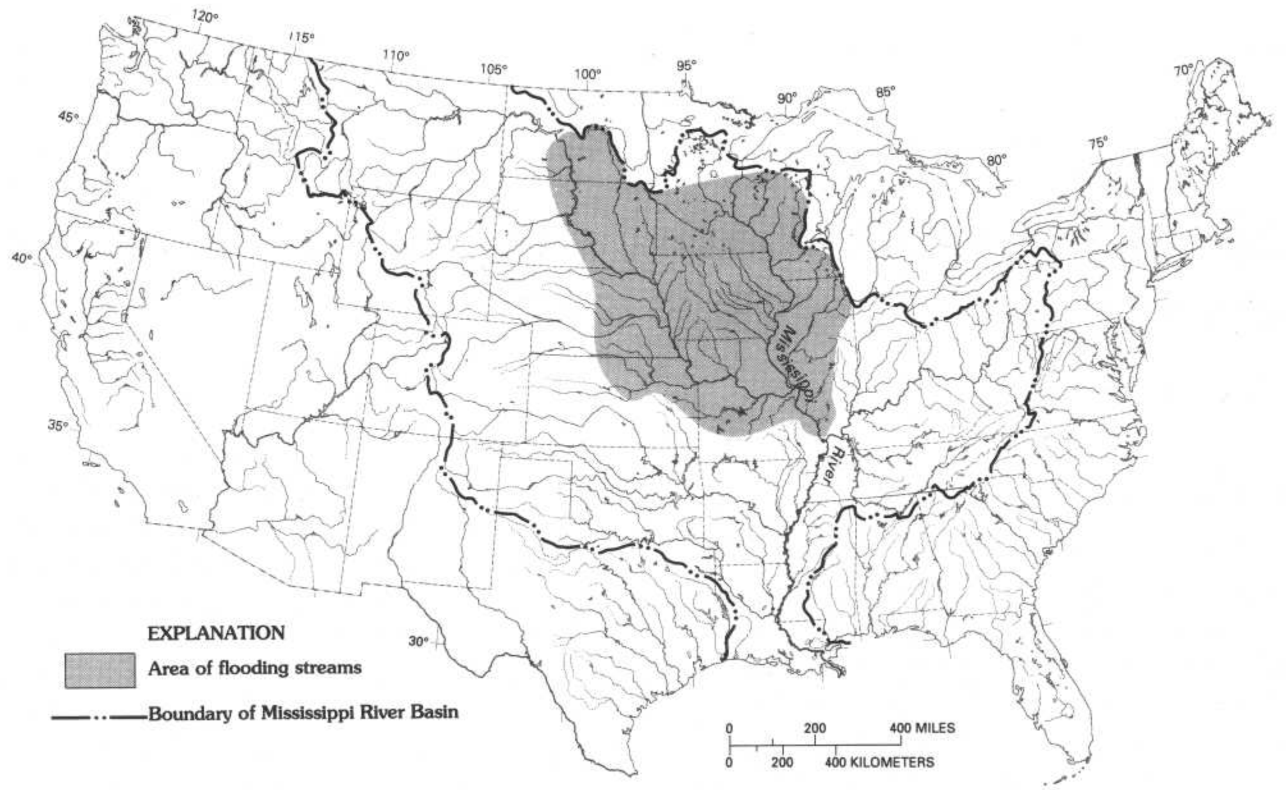


Figure 1. The Mississippi River Basin and general area of flooding streams, March through September 1993.

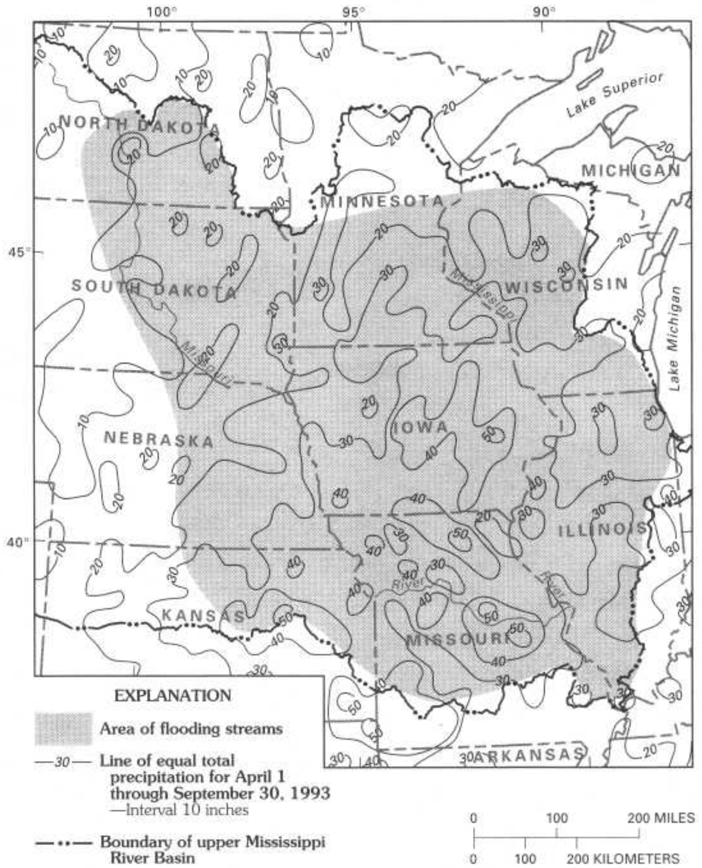


Figure 2. Areal distribution of total precipitation in the area of flooding streams in the upper Mississippi River Basin, April 1 through September 30, 1993. (Precipitation data from David Miscus, National Weather Service, written commun., 1993.)

The intense rain from the storm systems that tracked across the general area of flooding from April through September resulted in sustained high-flood volumes. Flood volumes at many gaging stations in the flooded area were significantly larger than previous maximums and more than twice the mean flow-volumes for April through September (Southard, 1995).

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, dams, levees, and other structures located in flood plains. Flood-frequency analyses are computed for streamflow-gaging stations by using annual peak discharges. As each additional annual peak discharge is added to the record of a gaging station, an updated flood-frequency analysis can be computed, and revised discharges for various frequencies of exceedance or recurrence intervals can be determined. Thus, flood-frequency statistics can be recalculated each year, and as additional annual peak discharges are collected and used in the analyses, these statistics become more reliable. One important aspect of the analysis and description of the 1993 flooding in the upper Mississippi River Basin must be considered—the effect the addition of 1993 peak discharges to the records of gaging stations will have on the determination of flood magnitude and frequency and, subsequently, on estimates of recurrence intervals of the 1993 flood.

Purpose and Scope

The purpose of this report is to compare quantitatively discharges that had recurrence intervals of 10, 25, 50, and 100 years computed from data through the 1992 water year to those computed from data through the 1993 water year and to evaluate the effects of the 1993 flooding on the computed flood-frequency statistics in Iowa. Iowa was selected for this study because a large number of streamflow-gaging stations recorded significant flooding in 1993, and a large data set could, therefore, be compiled for comparative flood-frequency analyses.

Acknowledgments

The information contained herein is based on data collected by the National Weather Service, the U.S. Army Corps of Engineers, the U.S. Geological Survey, and several State and local agencies. Appreciation is expressed to the personnel in these agencies who were involved in the collection of data. The flood data used in this study often were collected during adverse conditions, and the efforts of these individuals made this analysis possible.

FLOOD-FREQUENCY ANALYSES FOR IOWA

Engineers and planners often design structures or regulate development on flood plains for which damage may be incurred by occasional floods of varying magnitude (Dalrymple, 1960). By using flood-frequency analyses to design structures or to regulate development on flood plains to either a specific probability or a specific calculated risk, such as a 1- or a 2-percent chance that a given flood magnitude will be exceeded in any one year, engineers and planners are able to standardize the risk factors involved with estimating flood-frequency discharges.

Selection of Streamflow Data

In Iowa, 83 unregulated streamflow-gaging stations that had at least 11 years of systematic, continuous-record data through the 1993 water year were initially considered for use in this study. Peak discharges in 1993 at these gaging stations were initially compared with previously published flood-frequency discharges computed from data through the 1990 water year (Eash, 1993); on the basis of this comparison, 62 of these gaging stations that had a greater than or equal to 10-year recurrence-interval flood in 1993 were selected for this study.

Data Analyses

In this study, the method described in the Interagency Advisory Committee on Water Data (1982) was used to compute the magnitude and frequency of floods at each of the 62 selected streamflow-gaging stations in Iowa. Two separate flood-frequency curves were developed for each gaging station by fitting a Pearson Type–III distribution to the logarithms (base 10) of the annual peak discharges by means of the U.S. Geological Survey's WATSTORE flood-frequency-analysis program (Kirby, 1981). The flood-frequency analysis, which was based on data through the 1992 water year, is hereafter termed the "1992 analysis," and the flood-frequency analysis, which was based on data through the 1993 water year, is hereafter termed the "1993 analysis."

Table 1 (at end of report) lists the computed discharges that had recurrence intervals of 10, 25, 50, and 100 years for the 1992 and the 1993 analyses; the locations of these streamflow-gaging stations and ranges in recurrence intervals for their 1993 peak discharges, which were based on the 1993 analysis, are shown in figure 3. Table 1 also lists information on the drainage area; the discharge, date, and unit runoff of the 1993 peak discharge (Southard and others, 1994); the differences between discharges from the 1992 and the 1993 analyses; the recurrence interval for the 1993 peak discharge, which was interpolated from the 1992 and the 1993 analyses; the annual peak discharge period of record (listed as the WATSTORE peak flow record); the previous annual maximum discharge and date; use of historical data; and the effective record length of the gaging station for the 1993 analysis. The effective record length is an estimate of the record length when historical flood data are weighted with the systematic record length.

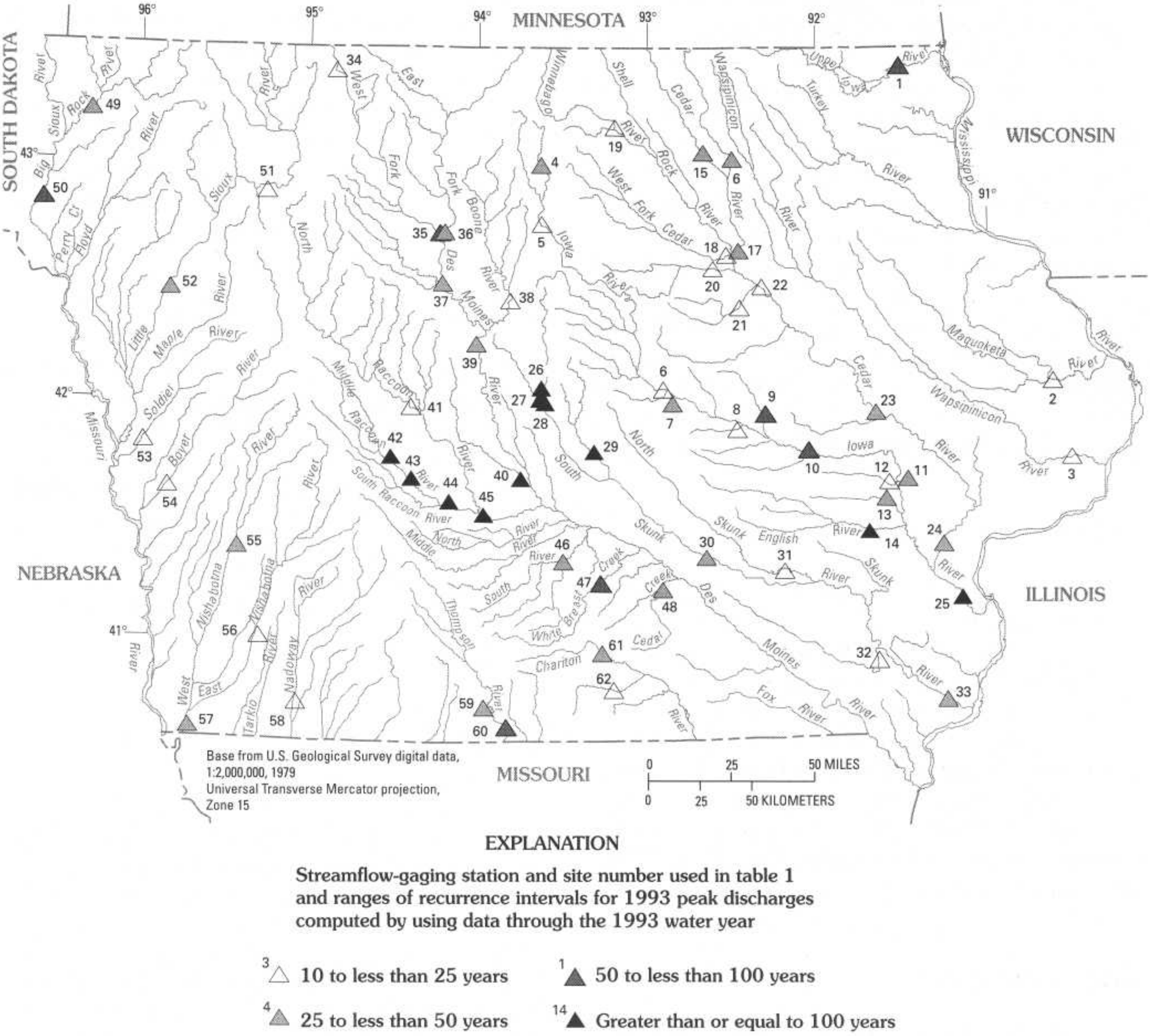


Figure 3. Location of selected streamflow-gaging stations in Iowa and ranges in recurrence intervals for the 1993 peak discharges.

The record of annual peak discharges for a streamflow-gaging station includes the water years during which it was operated, which is termed the "period of systematic record." This record also may include historical peak discharges during water years outside the period of systematic record. Annual peak discharges, which are maintained in the WATSTORE Peak Flow File data base (Lepkin and others, 1979), were used to perform the flood-frequency analyses described in this report.

For the 1992 and the 1993 analyses, extremely small discharge values (low outliers) were censored and adjusted for, historical data were used to make adjustments for extremely large discharge values (high outliers), and the coefficient of skew was weighted for each streamflow-gaging station with skew values obtained from a statewide skew analysis. Whenever possible, historical flood data were used to extend the flood record for gaging stations. Flood-frequency analyses for 41 of the 62 selected gaging stations were adjusted for historical data, whereas flood-frequency analyses for the other 21 were based only on their period of systematic record.

Assumptions of Data Analyses

The accuracy and reliability of flood-frequency analyses are dependent on several assumptions about the data (Interagency Advisory Committee on Water Data, 1982). The fundamental assumption is that the record of past flood discharges is an accurate and reliable indicator of the range of flood discharges that could occur in the future. This assumption implies the following assumptions:

- The flood-generating mechanism is time-stationary; this is, the meteorologic and hydrologic processes that generate future floods will be the same as they were during the period of the past flood record. This implies that the climatic and meteorologic conditions, hydrologic conditions created by land use and land cover in the watershed, and hydraulic conditions of the stream channel and flood plain remain constant through time.
- The flood record is an accurate and representative depiction of the floods that occurred during the period of record. This implies that measurements of flood discharges included in the record are accurate and that any special flood-risk conditions associated with a site were properly identified and considered in the flood-frequency analysis.
- The hydrologic process of flood occurrence can be represented mathematically as a sequence of independent annual peak discharges that are randomly sampled from a population of all possible flood discharges.

Flood-Recurrence Interval

The magnitude and frequency of floods are computed for a streamflow-gaging station by relating annual peak discharges to either annual exceedance probability or recurrence interval. Annual exceedance probability is expressed as the chance that a selected flood magnitude will be exceeded in any one year. Recurrence interval, which is the reciprocal of the annual exceedance probability, is the average number of years between exceedances of a selected flood magnitude. For example, if a theoretical flood magnitude is exceeded once on the average during any 100-year period (recurrence interval), then it has a 1-percent chance (annual exceedance probability equals 0.01) of being exceeded during any one year. This flood, which is commonly termed the "100-year flood," is the theoretical peak discharge against which actual flood peak discharges generally are compared to measure their severity. 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. For example, the South Skunk River near Ames streamflow-gaging station (fig. 3, site 26) has a theoretical 100-year recurrence-interval discharge of 9,090 cubic feet per second as computed from the 1993 analysis (table 1). During 1993, however, a flood peak discharge of 11,100 cubic feet per second occurred on July 9, and another flood peak discharge of 11,200 cubic feet per second occurred on August 16. Thus, two floods that, theoretically, each had less than a 1-percent chance of occurring during any one year occurred at this site in the same year.

COMPARISON OF 1992 AND 1993 FLOOD-FREQUENCY DISCHARGES FOR IOWA

Differences between discharges that had recurrence intervals of 10, 25, 50, and 100 years for the 1992 and the 1993 analyses were evaluated to determine the effects of the 1993 flood on the computed flood magnitude and frequency (table 1). Differences were calculated as follows: the difference between the 1993 recurrence-interval discharge and that of 1992 was divided by the 1992 recurrence-interval discharge, and this value was multiplied by 100. The ranges in differences between the discharges are shown in figure 4, and the summary statistics of the ranges are listed in table 2. The overall trend indicated by the differences in discharges for selected recurrence intervals (fig. 4; table 2) is that smaller differences were computed for discharges that had smaller recurrence intervals, and larger differences were computed for discharges that had larger recurrence intervals.

The mean and median statistics for differences listed in table 2 for each recurrence interval show this trend of larger differences for larger recurrence intervals. The mean differences range from 5.9 percent for the 10-year recurrence interval to 9.6 percent for the 100-year recurrence interval. The median differences range from 4.6 percent for the 10-year recurrence interval to 6.2 percent for the 100-year recurrence interval.

Figure 4 shows the number of streamflow-gaging stations that had differences of greater than or equal to 15 percent for the selected recurrence intervals—3, 10 year (fig. 4*A*); 6, 25 year (fig. 4*B*); 10, 50 year (fig. 4*C*); and 13, 100 year (fig. 4*D*). The spatial distribution of ranges in differences between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges is shown in figure 5.

Table 2. Summary statistics for differences between the 1992 and the 1993 flood-frequency analyses for selected recurrence-interval discharges at selected streamflow-gaging stations in Iowa

Summary statistic	Difference in discharge (percent) for indicated recurrence interval (years)			
	10	25	50	100
Maximum......	19.6	25.6	29.9	34.9
Minimum.......	1.7	1.5	1.9	1.6
Mean..............	5.9	7.3	8.4	9.6
Median...........	4.6	5.2	5.6	6.2

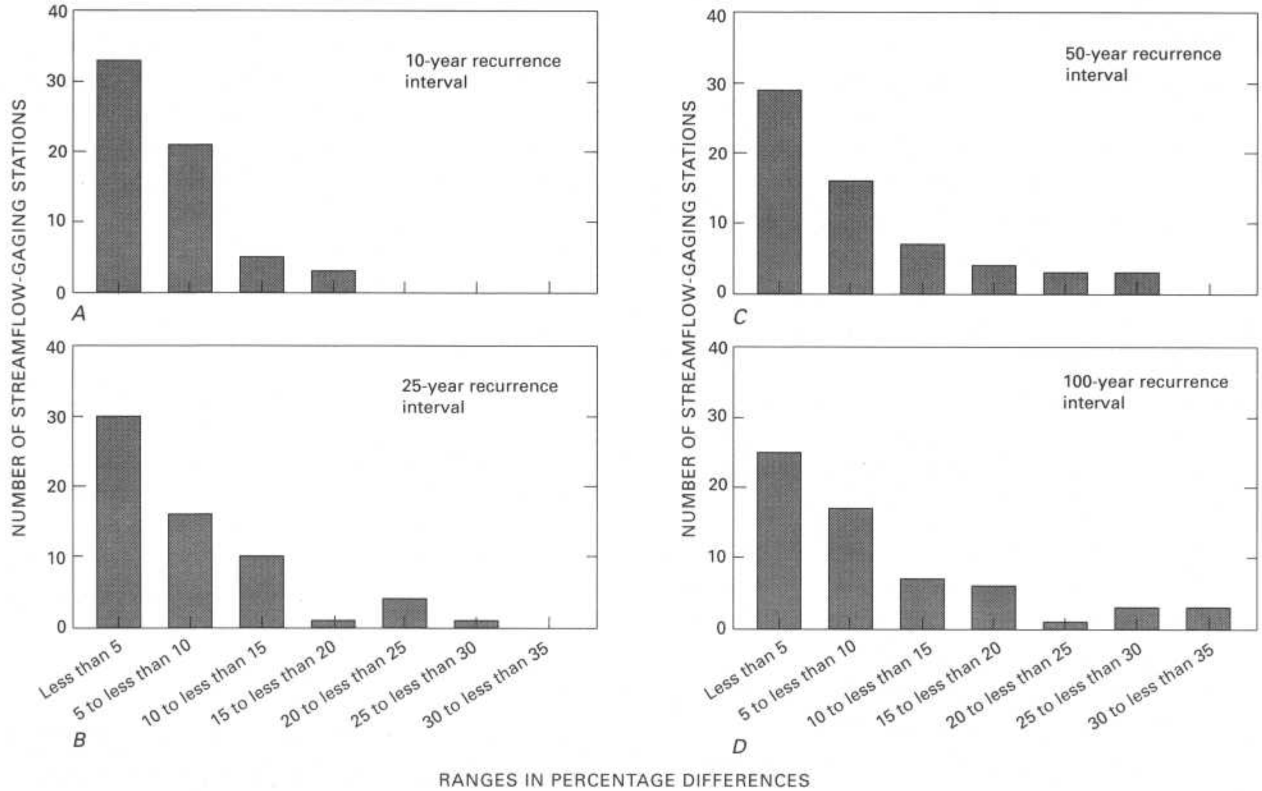
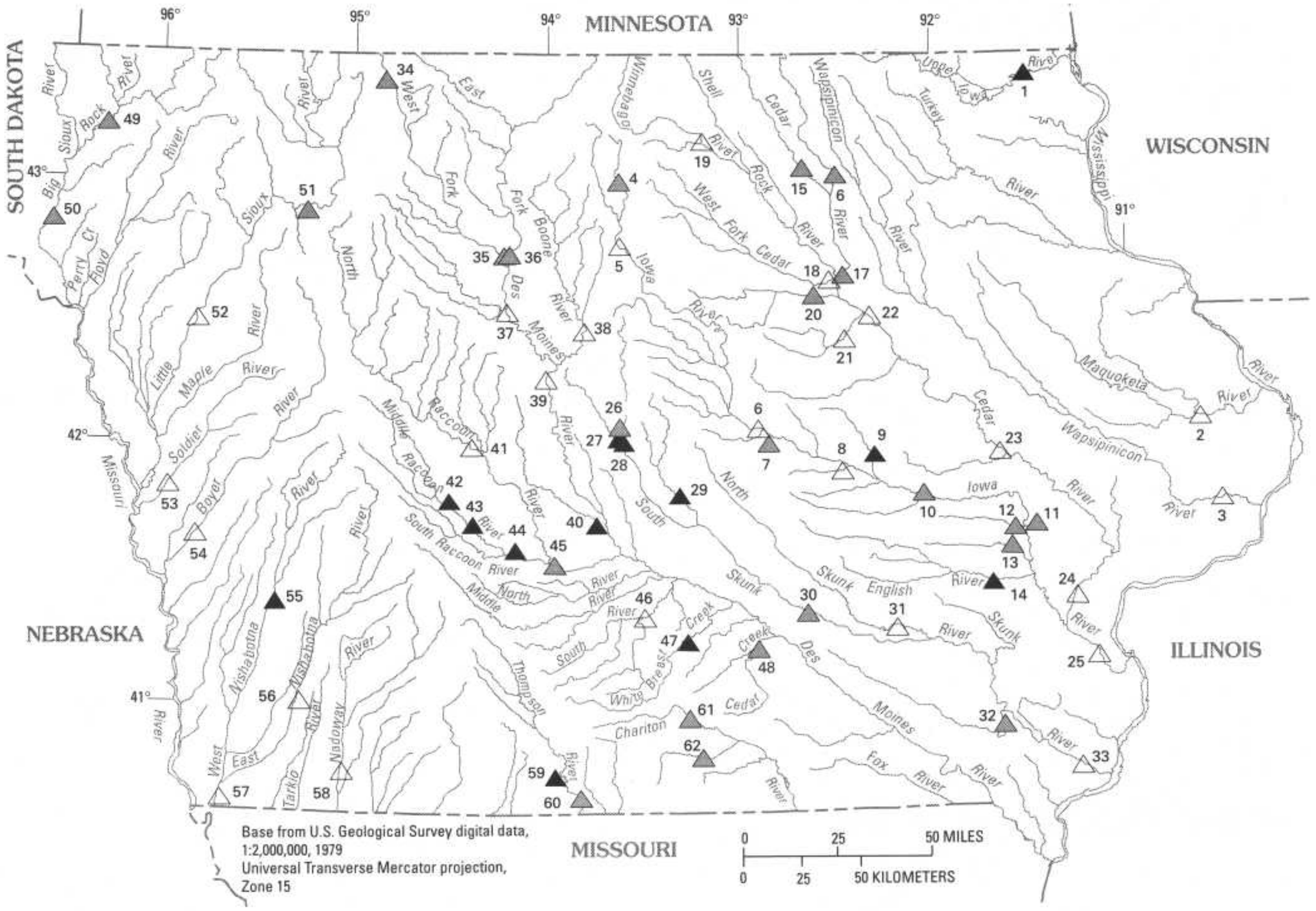


Figure 4. Ranges in differences between the 1992 and the 1993 flood-frequency analyses for selected recurrence-interval discharges at selected streamflow-gaging stations in Iowa. *A*, 10-year recurrence intervals; *B*, 25-year recurrence intervals; *C*, 50-year recurrence intervals; *D*, 100-year recurrence intervals.

A comparison of the computed discharges for the 1992 and the 1993 analyses listed in table 1 indicates that inclusion of the 1993 flood resulted in larger discharges for all selected recurrence intervals at the 62 selected streamflow-gaging stations. Including the 1993 flood in the flood-frequency analysis had a greater effect on the larger recurrence-interval discharges for the majority of these gaging stations. Differences between the 1992 and the 1993 analyses were slightly larger at the 10-year recurrence interval than at the 100-year recurrence interval at five of the gaging stations listed in table 1 (sites 18, 19, 38, 51, 56). On the basis of the 1993 analysis, recurrence intervals for 1993 peak discharges at these five gaging stations ranged from 10 to 14 years.

At three streamflow-gaging stations (sites 1, 29, 59) listed in table 1, the increase in the 100-year recurrence-interval discharge was greater than 30 percent as a result of including the 1993 flood in the flood-frequency analysis. The maximum difference between the 1992 and the 1993 analyses (tables 1, 2) was 34.9 percent for the 100-year recurrence-interval discharge for the Upper Iowa River near Dorchester (site 1). This site had a large flood magnitude in 1993 (recurrence interval of 70 years based on the 1993 analysis) and a fairly short record length (computed effective record length of 25 years).



EXPLANATION

Streamflow-gaging station and site number used in table 1 and ranges of differences between 1992 and 1993 flood-frequency analyses for 100-year recurrence-interval discharges

2 △ Less than 5 percent

4 ▲ 5 to less than 15 percent

1 ▲ Greater than or equal to 15 percent

Figure 5. Location of selected streamflow-gaging stations in Iowa and ranges in differences between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges.

FACTORS THAT AFFECT THE COMPUTED FLOOD-FREQUENCY DISCHARGES

The following factors were investigated to evaluate their possible effect on the differences between discharges computed from the 1992 and the 1993 analyses (table 1): drainage area, 1993 peak discharge, 1993 peak unit runoff (the 1993 peak discharge divided by the drainage area), recurrence interval of the 1993 peak discharge based on the 1993 analysis, and effective record length based on the 1993 analysis. Summary statistics for these factors are listed in table 3.

Table 3. Summary statistics for five selected factors for selected streamflow-gaging stations in Iowa

[mi^2, square miles; ft^3/s, cubic feet per second]

Summary statistic	Drainage area (mi^2)	1993 peak discharge (ft^3/s)	1993 peak unit runoff [(ft^3/s)/mi^2]	Recurrence interval of the 1993 peak discharge (years)	1993 effective record length (years)
Maximum	12,499	111,000	624.8	[1]1.8	91
Minimum	25.3	4,380	6.8	10	15
Mean	1,640	27,438	51.0	[2]77	53
Median	746	22,500	26.8	32	52

[1]Recurrence intervals for 1993 peak discharges that are greater than 100 years are herein reported as a ratio of the 1993 peak discharge to the 100-year recurrence-interval discharge for the 1993 flood-frequency analysis.

[2]For computation of the mean values, recurrence intervals of greater than 100 years were interpolated and rounded to the nearest 10 years for intervals between 100 and 200 years and to the nearest 25 years for intervals between 200 and 500 years. Recurrence intervals of greater than 500 years were rounded to 500 years.

Differences between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges were correlated with the factors. The 100-year recurrence interval was selected because the differences between the 1992 and the 1993 analyses were largest (fig. 4; table 2). Results of the correlations are listed in table 4 as Pearson's product-moment correlation coefficients and Spearman's rank correlation coefficients. The Pearson's product-moment correlation coefficient is computed by using a parametric correlation analysis on the data, and the Spearman's rank correlation coefficient is computed by using a nonparametric correlation analysis on the ranks of the data.

Table 4. Correlations of percentage differences between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges and five selected factors for selected streamflow-gaging stations in Iowa

Factor	Pearson product-moment correlation coefficient	Spearman rank correlation coefficient
Drainage area	−0.275	−0.438
1993 peak discharge	− .060	− .006
1993 peak unit runoff	.437	.513
Recurrence interval of 1993 peak discharge.	.507	.721
1993 effective record length	− .583	− .651

Correlation coefficients are statistics that provide a measure of the strength of the linear relation between two variables. The correlation coefficient ranges between -1.0 and +1.0, and the closer the value is to ±1.0, the stronger is the linear relation. A positive value for the correlation coefficient indicates that as one variable increases, the other variable also increases. A negative value for the correlation coefficient indicates that as one variable increases, the other variable decreases.

The two factors with the strongest correlations with differences between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges were selected for further investigation. Results of the correlation analyses listed in table 4 indicate that the two factors with the strongest correlations are recurrence interval of the 1993 peak discharge and 1993 effective record length. These two factors were investigated further to evaluate their possible effect on the computed flood-frequency discharges.

Effect of 1993 Flood Magnitude

Of the five factors investigated in the correlation analyses, 1993 peak discharge, 1993 peak unit runoff, and recurrence interval of the 1993 peak discharge are related to the magnitude of the 1993 flood. Of these three, the recurrence interval of the 1993 peak discharge most strongly correlated with the difference between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges (table 4). Thus, on the basis of the 1993 analysis (table 1), recurrence intervals of the 1993 flood peaks were used to evaluate the effect of 1993 flood magnitude on the computed flood-frequency discharges in Iowa.

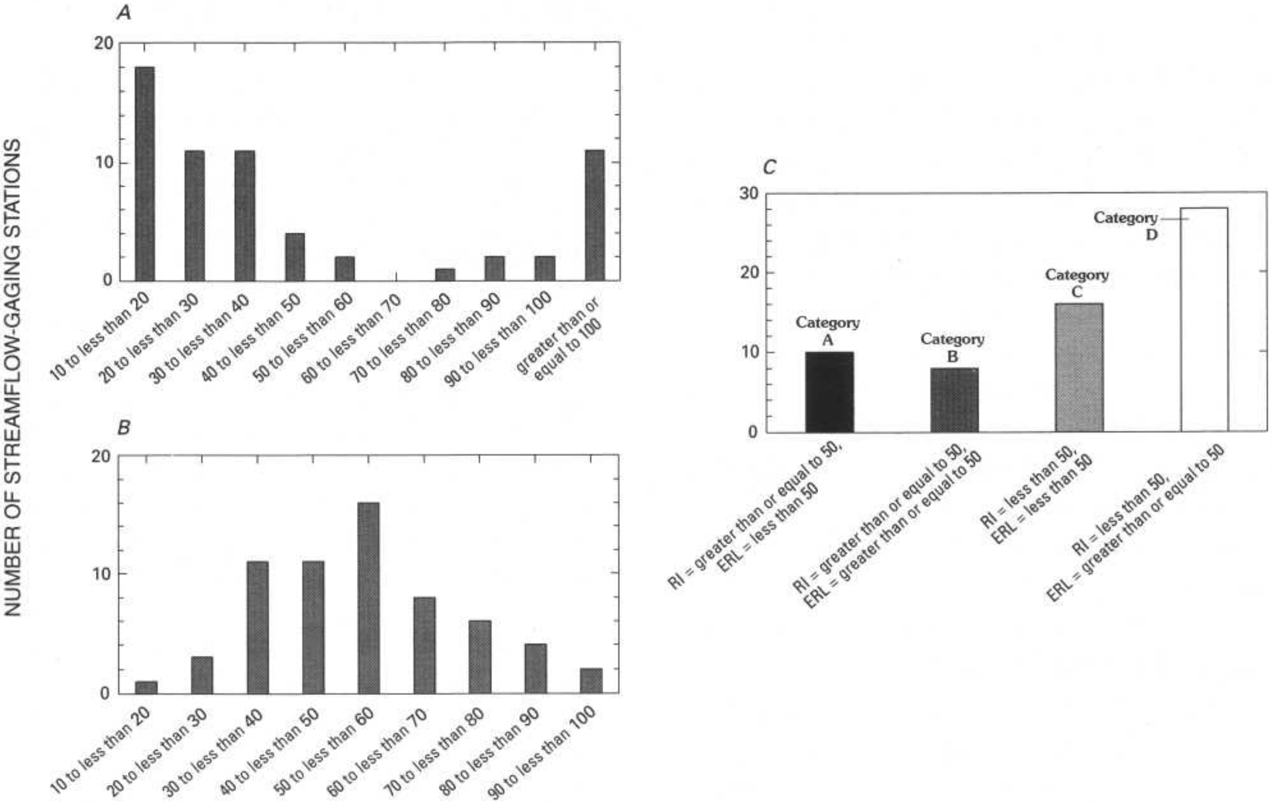


Figure 6. Frequency distributions of recurrence interval, effective record length, and selected categories of recurrence interval and effective record length for selected streamflow-gaging stations in Iowa. *A*, Ranges in recurrence intervals for the 1993 peak discharges, in years; *B*, Ranges in effective record lengths for 1993, in years; *C*, Selected categories of recurrence interval (RI) and effective record length (ERL), in years.

Figure 3 shows the spatial distribution and figure 6*A* shows the frequency distribution of ranges in recurrence intervals for the 1993 peak discharges for the selected streamflow-gaging stations. In table 5, summary statistics for each of the selected recurrence intervals for the 62 selected gaging stations are grouped on the basis of recurrence intervals for the 1993 flood of greater than or equal to 50 years and recurrence intervals of less than 50 years. The mean and median statistics for the two groups indicate that gaging stations that had large flood magnitudes (recurrence intervals of greater than 50 years) in 1993 generally had larger differences between the 1992 and the 1993 flood-frequency analyses for discharges of all selected recurrence intervals.

Table 5. Summary statistics for differences between the 1992 and the 1993 flood-frequency analyses for selected recurrence-interval discharges at selected streamflow-gaging stations in Iowa grouped on the basis of recurrence intervals for the 1993 peak discharges

Summary statistic	Difference in discharge (percent) for indicated recurrence interval (years)			
	10	25	50	100
1993 recurrence interval of greater than or equal to 50 years[1]				
Maximum	19.6	25.6	29.9	34.9
Minimum	2.7	3.6	4.0	4.9
Mean	9.1	12.5	15.1	17.8
Median	8.0	11.3	14.4	16.4
1993 recurrence interval of less than 50 years[2]				
Maximum	19.2	24.6	27.7	30.8
Minimum	1.7	1.5	1.9	1.6
Mean	4.5	5.2	5.7	6.2
Median	3.5	4.2	4.6	4.8

[1]Number of sites is 18.
[2]Number of sites is 44.

Effect of 1993 Record Length

Effective record lengths that were based on the 1993 analysis were used to evaluate the effect of record lengths on the computed flood-frequency discharges in Iowa. The effective record length is an estimate of the record length for a streamflow-gaging station when historical flood data are weighted with the systematic record length. The increase in the effective record length over the systematic record length provides an estimate of the value of the historical data. If a gaging station record only contains systematic data, then the effective record length is the same as the systematic record length. Effective record lengths calculated for gaging stations that have historical flood data can, therefore, be compared with the record lengths of those that have systematic data.

The effective record length of a streamflow-gaging station is based on an empirical analysis made by Gary D. Tasker (U.S. Geological Survey, written commun., 1992) of results reported in Tasker and Thomas (1978) and Stedinger and Cohn (1986). Table 1 lists the effective record lengths that were calculated for each gaging station.

Figure 6*B* shows the frequency distribution of the effective record lengths for the selected streamflow-gaging stations. As indicated in table 4, the correlation is negative between effective record length and the difference between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges. This correlation is negative because as the effective record length of a gaging station increases, the influence of any given annual peak discharge decreases even though an annual peak discharge may be very large. In table 6, summary statistics for each of the selected recurrence intervals for the 62 selected gaging stations are grouped on the basis of effective record lengths for 1993 of greater than or equal to 50 years and effective record lengths for 1993 of less than 50 years. The mean and median statistics for the two groups indicate that gaging stations that had short record lengths (effective record lengths of less than 50 years) through 1993 generally had larger differences between the 1992 and the 1993 flood-frequency analyses for discharges of all selected recurrence intervals.

Combined Effect of the 1993 Flood Magnitude and Record Length

To evaluate the combined effect of the 1993 flood magnitude and the record length on the computed flood-frequency discharges in Iowa, the 62 selected streamflow-gaging stations were grouped into four discrete categories on the basis of recurrence intervals of the 1993 flood and effective record lengths through 1993 as follows: A, the recurrence interval of the 1993 flood was greater than or equal to 50 years and the effective record length was less than 50 years; B, the recurrence interval of the 1993 flood was greater than or equal to 50 years and the effective record length was greater than or equal to 50 years; C, the recurrence interval of the 1993 flood was less than 50 years and the effective record length was less than 50 years; and D, the recurrence interval for the 1993 flood was less than 50 years and the effective record length was greater than or equal to 50 years. The frequency distributions of recurrence intervals for the 1993 flood, effective record lengths for 1993, and the above four categories are shown in figure 6. Table 7 lists summary statistics for differences between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges for each of these four categories.

Table 6. Summary statistics for differences between the 1992 and the 1993 flood-frequency analyses for selected recurrence-interval discharges at selected streamflow-gaging stations in Iowa grouped on the basis of effective record lengths for 1993

Summary statistic	Difference in discharge (percent) for indicated recurrence interval (years)			
	10	25	50	100
1993 effective record length of greater than or equal to 50 years[1]				
Maximum	8.1	11.7	15.1	17.8
Minimum	1.7	1.5	1.9	1.6
Mean	3.6	4.4	5.0	5.5
Median	3.1	3.8	4.0	4.4
1993 effective record length of less than 50 years[2]				
Maximum	19.6	25.6	29.9	34.9
Minimum	3.8	3.8	3.6	4.0
Mean	9.0	11.5	13.2	15.2
Median	8.2	10.2	11.5	13.0

[1]Number of sites is 36.
[2]Number of sites is 26.

Table 7. Summary statistics for differences between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges at selected streamflow-gaging stations in Iowa grouped on the basis of selected categories of recurrence intervals for the 1993 peak discharges and effective record lengths

Summary statistic	Difference in 100-year recurrence-interval discharges (percent) for selected categories of recurrence interval and effective record length			
	A[1]	B[2]	C[3]	D[4]
Number of sites	10	8	16	28
Maximum	34.9	17.8	30.8	10.7
Minimum	9.0	4.9	4.0	1.6
Mean	23.5	10.7	10.0	4.0
Median	24.2	10.6	8.0	3.4

[1]Recurrence interval of greater than or equal to 50 years and effective record length of less than 50 years.

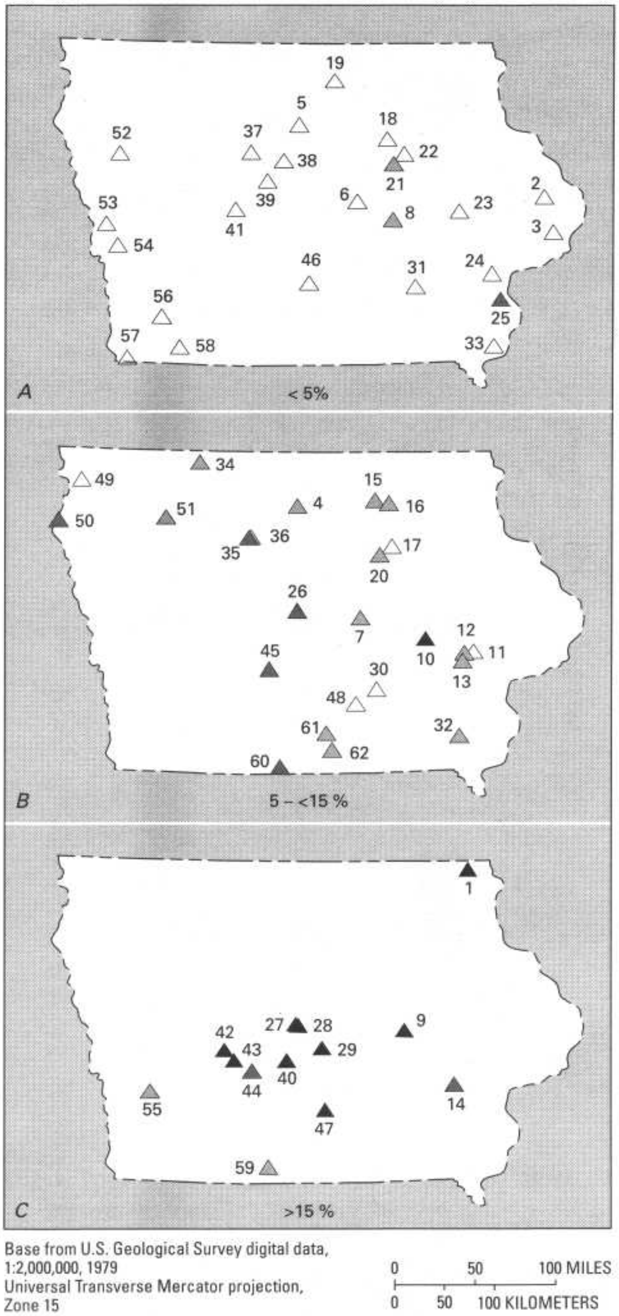
[2]Recurrence interval of greater than or equal to 50 years and effective record length of greater than or equal to 50 years.

[3]Recurrence interval of less than 50 years and effective record length of less than 50 years.

[4]Recurrence interval of less than 50 years and effective record length of greater than or equal to 50 years.

As indicated by the differences in the mean and median statistics listed in tables 5 to 7 for the 100-year recurrence-interval discharge, the combined effect of the 1993 flood magnitude and record length is greater than the effect of either individual factor on the computed flood-frequency discharges in Iowa. Categories A and D best indicate the combined effect of these two factors on the computed 100-year recurrence-interval discharges. Large flood magnitudes coupled with short record lengths (category A) have mean and median statistics of 23.5 and 24.2 percent, respectively (table 7). Conversely, small flood magnitudes coupled with long record lengths (category D) have mean and median statistics of 4.0 and 3.4 percent, respectively (table 7). The contrast between the mean and median statistics of these two categories of streamflow-gaging stations indicates that the 1993 flood magnitudes and record lengths that were used in the 1993 analysis had a significant combined effect on the computed 100-year recurrence-interval discharges.

The spatial and frequency distributions of the 62 streamflow-gaging stations were grouped on the basis of those that had a less than 5-percent difference, a 5- to less than 15-percent difference, and a greater than or equal to 15-percent difference between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges, as shown in figures 7 and 8, respectively. The spatial and frequency distributions shown in these two figures are identified according to the previously defined categories in figure 6C and table 7.



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

EXPLANATION

Streamflow-gaging station and site number used in table 1 and 1993 recurrence-interval and effective-record-length categories used in figure 6 and table 7

1 Category A 14 Category B 4 Category C 2 Category D

Figure 7. Location of selected streamflow-gaging stations in Iowa grouped on the basis of ranges in differences between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges and by selected categories of recurrence interval and effective record length. *A*, Streamflow-gaging stations that have a less than 5-percent difference; *B*, Streamflow-gaging stations that have a 5 – to less than 15–percent difference; *C*, Streamflow-gaging stations that have a greater than or equal to 15–percent difference.

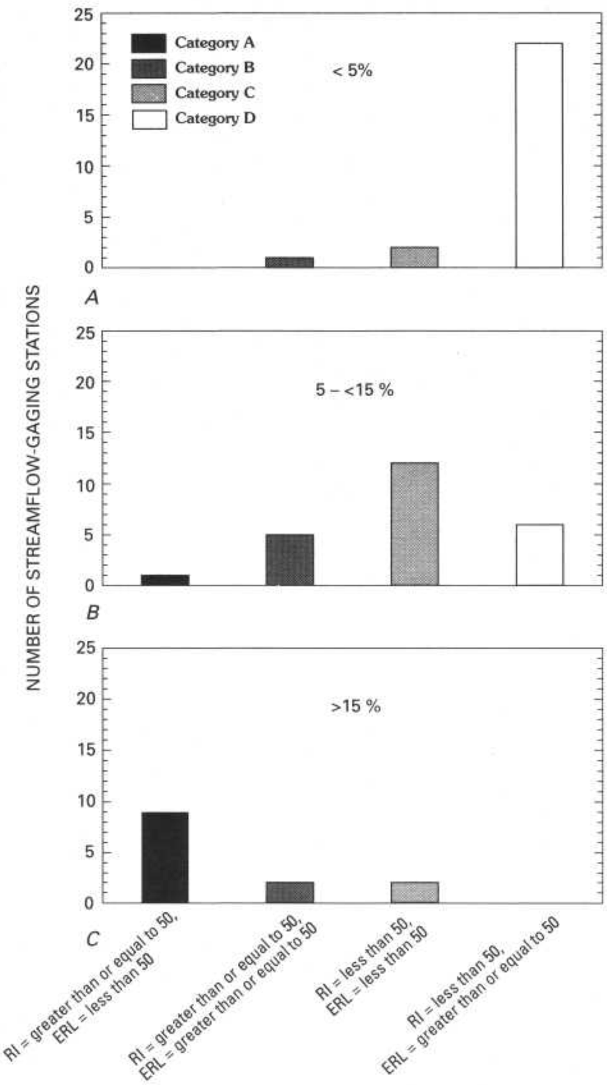


Figure 8. Ranges in differences between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges and selected categories of recurrence interval (RI) and effective record length (ERL), in years, for selected streamflow-gaging stations in Iowa. *A*, Streamflow-gaging stations that have a less than 5–percent difference; *B*, Streamflow-gaging stations that have a 5– to less than 15–percent difference; *C*, Streamflow-gaging stations that have a greater than or equal to 15-percent difference.

Of the 28 streamflow-gaging stations in category D (fig. 6*C*), 22 had a less than 5-percent difference between 100-year recurrence-interval discharges for 1992 and 1993 (fig. 8*A*), and of the 25 gaging stations that had a less than 5-percent difference between 100-year recurrence-interval discharges for 1992 and 1993, 22 were in category D (figs. 7*A* and 8*A*). Conversely, of the 10 gaging stations in category A (fig. 6*C*), 9 had a greater than or equal to15-percent difference between 100-year recurrence-interval discharges for 1992 and 1993 (fig. 8*C*), and of the 13 gaging stations that had a greater than or equal to 15-percent difference between 100-year recurrence-interval discharges for 1992 and 1993, 9 were in category A (figs.7*C* and 8*C*).

EFFECT OF FLOOD-FREQUENCY DISCHARGES ON WATER-SURFACE ELEVATIONS

Associated with a specified flood-frequency discharge is a water-surface elevation that can be determined by using hydraulic principles of open-channel flow or from a stage-discharge rating curve. Water-surface elevations determined for flood-frequency discharges are used for the effective management of flood plains and for the safe design of bridges, dams, levees, and other structures located in flood plains.

To evaluate the effect that changes in flood-frequency discharges may have on water-surface elevations, two of the streamflow-gaging stations in Iowa that had large differences between the 1992 and the 1993 flood-frequency discharges were selected for investigation. The Upper Iowa River near Dorchester (fig. 3, site 1) and the Squaw Creek at Ames (fig. 3, site 27) had differences between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges of 34.9 and 26.2 percent, respectively (table 1).

The records of annual peak discharges for these two streamflow-gaging stations are shown in figures 9*A* and 10*A*. The 1992 and the 1993 flood-frequency curves that were computed by fitting a Pearson Type–III distribution to the logarithms of the annual peak discharges for each of these gaging stations (table 1) are shown in figures 9*B* and 10*B*. These figures show a larger difference in estimated discharges between the 1992 and the 1993 flood-frequency curves at the smaller annual exceedance probabilities or larger recurrence intervals.

The computation of discharge records at a streamflow-gaging station is dependent upon the development of a stage-discharge relation, or rating curve, between water-surface elevations, or stages, and the corresponding flow rates, or discharges. A rating curve is developed by measuring the discharge at a variety of stages, graphing the stage versus discharge points, and drawing a best-fit curvilinear line through the points.

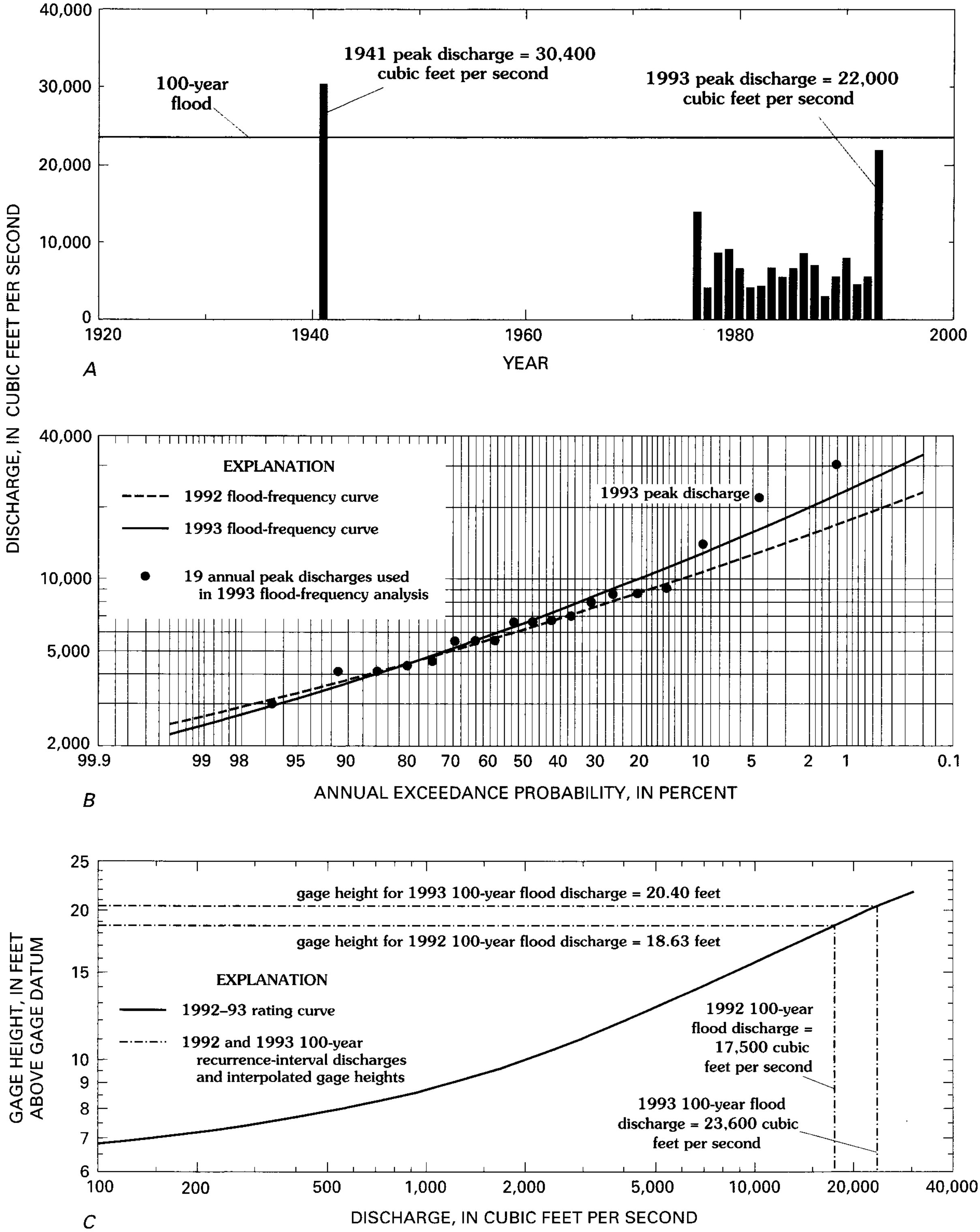


Figure 9. Effects of the 1993 flood on the determination of flood magnitude and frequency and 100-year flood elevation for the Upper Iowa River near Dorchester streamflow-gaging station (site1, fig. 3). *A*, Annual peak discharges; *B*. Flood-frequency curves; *C*, Stage-discharge rating curve and interpolated gage heights for 100-year recurrence-interval discharges.

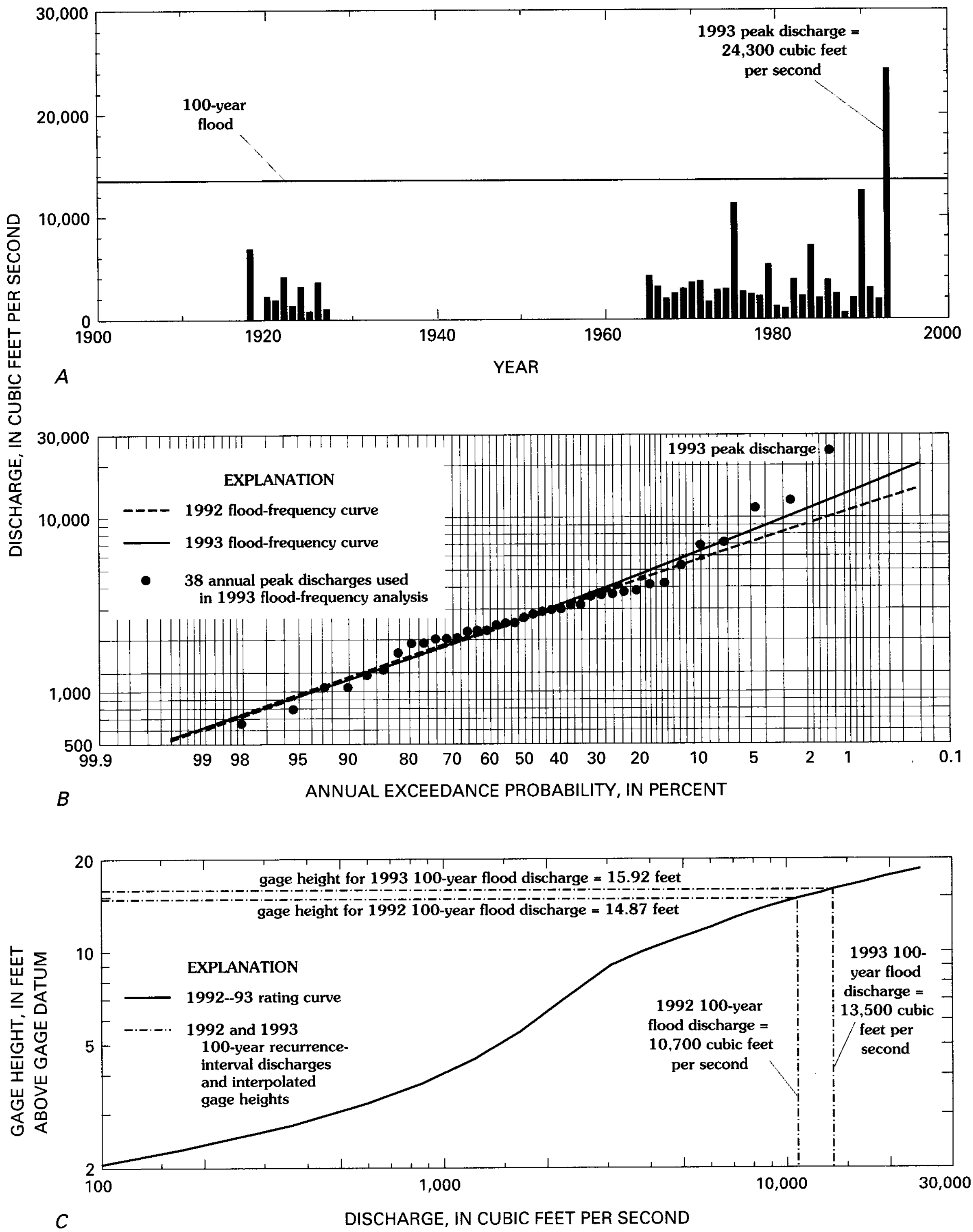


Figure 10. Effects of the 1993 flood on the determination of flood magnitude and frequency and 100-year flood elevation for the Squaw Creek at Ames streamflow-gaging station (site 27, fig. 3). *A*, Annual peak discharges; *B*, Flood-frequency curves; *C*, Stage-discharge rating curve and interpolated gage heights for 100-year recurrence-interval discharges.

The rating curves that were in use during the 1992 and the 1993 water years at the two selected streamflow-gaging stations are shown in figures 9*C* and 10*C*. Discharges that were computed for the 100-year recurrence interval for 1992 and 1993 (table 1) were used to interpolate gage heights (stages) from the respective rating curve for each gaging station. Differences in gage heights between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges were interpolated to have increased 1.77 feet for the Upper Iowa River near Dorchester gaging station (fig. 9*C*) and 1.05 feet for the Squaw Creek at Ames gaging station (fig. 10*C*).

The gage heights shown in figures 9*C* and 10*C* for 100-year recurrence-interval discharges are considered to be only approximate because they do not take into consideration adjustments that may have been made to the rating curves during the flood; consequently, they are presented only for illustrative purposes. The differences in gage heights between the 1992 and the 1993 analyses for 100-year recurrence-interval discharges for these two streamflow-gaging stations illustrate how changes in flood-frequency discharges, which result from the inclusion of the 1993 peak discharges, can affect water-surface elevations. It should be noted that the differences in gage heights that are illustrated for these two gaging stations are larger than anticipated for most gaging stations given their large differences in 100-year recurrence-interval discharges.

SUMMARY

To evaluate the effects of the 1993 flood on the determination of flood magnitude and frequency in Iowa, discharges that had recurrence intervals of 10, 25, 50, and 100 years computed from data through the 1992 water year were compared with discharges that had the same recurrence intervals computed from data through the 1993 water year for 62 selected streamflow-gaging stations in Iowa. On the basis of the 1993 flood-frequency analysis, a flood that was greater than or equal to a 10-year recurrence-interval discharge occurred during 1993 at all 62 gaging stations, and a flood that was greater than or equal to a 100-year recurrence-interval discharge occurred at 11 of the gaging stations.

Results of the comparison indicated that inclusion of the 1993 peak discharges in the flood-frequency analysis caused an increase in the magnitude of discharges for all selected recurrence intervals at the 62 selected streamflow-gaging stations in Iowa. A larger percentage increase in the magnitude of discharge was computed for the larger recurrence intervals than for the smaller recurrence intervals for most of the selected gaging stations. As a result of including the 1993 flood in the flood-frequency analysis, three gaging stations had an increase in the 100-year recurrence-interval discharge that was greater than 30 percent.

Several factors, which included recurrence intervals for 1993 peak discharges and effective record lengths for 1993, were investigated for the 62 selected streamflow-gaging stations to evaluate their possible effect on differences between 1992 and 1993 flood-frequency discharges. This investigation indicated that the 1993 flood magnitudes and record lengths that were used in the 1993 flood-frequency analysis had a significant combined effect on the computed 100-year recurrence-interval discharges. Gaging stations were grouped into four discrete categories on the basis of recurrence intervals for 1993 peak discharges and effective record lengths for 1993. Of the 28 gaging stations that had small flood magnitudes in 1993 and long record lengths, the difference between the 1992 and the 1993 flood-frequency analyses for 100-year recurrence-interval discharges at 22 gaging stations was less than 5 percent. Of the 10 gaging stations that had large flood magnitudes in 1993 and short record lengths, the increase in 100-year recurrence-interval discharges at 9 gaging stations was greater than or equal to 15 percent.

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Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa

[mi², square mile; ft³/s, cubic feet per second; (ft³/s)/mi², cubic feet per second per square mile; FF, flood-frequency analyses computed through the 1992 and the 1993 water years; RI, approximate recurrence interval interpolated from the 1992 and the 1993 flood-frequency analyses, rounded to nearest 5 years for 20- to 50-year recurrence intervals and to nearest 10 years above the 50-year recurrence interval; WATSTORE, National Water Data Storage and Retrieval System data base used to perform flood-frequency analyses; ERL, 1993 effective record length, indicates systematic record length used in the 1993 flood-frequency analysis when no value is listed for HST; HST, historically adjusted record length used in the 1993 flood-frequency analysis; *, ratio of 1993 peak discharge to 100-year recurrence-interval discharge for the 1992 and the 1993 flood-frequency analyses; % DIFF, percentage difference between recurrence-interval discharges for 1992 and 1993; --, historically adjusted record length was not used in flood-frequency analysis]

Site number (fig.3)	Station number	Station name	Drainage area (mi²)	1993 peak: Discharge (ft³/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft³/s)/mi²]	FF	Flood-peak discharge estimates (ft³/s) for indicated recurrence interval (years): 10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft³/s)	Previous maximum discharge: Date (month/year)
1	05388250	Upper Iowa River near Dorchester.	770	22,000	08/17	28.6	1992	10,700	13,300	15,400	17,500	*1.3	1941, 1976–93	25	80	30,400	05/1941
							1993	12,800	16,700	20,000	23,600	70					
							% DIFF	+ 19.6	+ 25.6	+29.9	+ 34.9						
2	05418500	Maquoketa River near Maquoketa.	1,553	35,300	07/06	22.7	1992	29,500	37,300	43,200	49,000	20	1903, 1914–93	82	91	48,000	06/1944
							1993	30,100	38,000	44,000	50,100	19					
							% DIFF	+ 2.0	+1.9	+1.9	+2.2						
3	05422000	Wapsipinicon River near De Witt.	2,330	22,300	07/08	9.6	1992	19,800	25,000	29,000	32,900	16	1935–93	59	60	31,100	06/1990
							1993	20,200	25,600	29,600	33,700	15					
							% DIFF	+ 2.0	+ 2.4	+ 2.1	+ 2.4						
4	05449000	East Branch Iowa River near Klemme.	133	4,380	03/31	32.9	1992	2,560	3,680	4,640	5,700	40	1944, 1949–76, 1978–93	44	--	5,960	06/1954
							1993	2,740	4,000	5,080	6,280	35					
							% DIFF	+ 7.0	+8.7	+ 9.5	+ 10.2						
5	05449500	Iowa River near Rowan.	429	6,140	04/01	14.3	1992	4,970	6,640	7,930	9,250	20	1941–76, 1978–93	52	--	8,460	06/1954
							1993	5,140	6,890	8,240	9,630	17					
							% DIFF	+ 3.4	+ 3.8	+ 3.9	+ 4.1						
6	05451500	Iowa River at Marshalltown.	1,564	20,400	08/17	13.0	1992	18,000	23,100	26,800	30,400	16	1903, 1915–27, 1929–30, 1933–93	80	112	42,000	06/1918
							1993	18,300	23,500	27,300	31,100	15					
							% DIFF	+ 1.7	+ 1.7	+ 1.9	+ 2.3						
7	05451700	Timber Creek near Marshalltown.	118	8,870	07/09	75.2	1992	6,380	8,540	10,200	11,900	30	1947, 1950–93	45	47	12,000	08/1977
							1993	6,690	9,030	10,800	12,700	25					
							% DIFF	+ 4.9	+ 5.7	+ 5.9	+ 6.7						
8	05451900	Richland Creek near Haven.	56.1	4,900	07/17	87.3	1992	3,970	5,460	6,710	8,070	18	1950–93	44	--	12,200	04/1991
							1993	4,130	5,690	7,000	8,430	16					
							% DIFF	+ 4.0	+ 4.2	+ 4.3	+ 4.5						

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi^2)	1993 peak: Discharge (ft^3/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft^3/s)/mi^2]	Flood-peak discharge estimates (ft^3/s) for indicated recurrence interval (years): FF	10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft^3/s)	Previous maximum discharge: Date (month/year)
9	05452000	Salt Creek near Elberon.	201	36,600	07/09	182.1	1992	13,400	20,000	25,900	32,800	*1.1	1944,	49	50	35,000	06/1947
							1993	14,800	22,600	29,900	38,500	90	1946–93				
							% DIFF	+ 10.4	+ 13.0	+ 15.4	+ 17.4						
10	05453100	Iowa River at Marengo.	2,794	38,000	07/19	13.6	1992	23,900	28,800	32,300	35,400	*1.1	1957–93	39	46	30,800	03/1960
							1993	25,200	30,800	34,800	38,600	90					
							% DIFF	+ 5.4	+ 6.9	+ 7.7	+ 9.0						
11	05454000	Rapid Creek near Iowa City.	25.3	6,700	08/10	264.8	1992	4,110	5,630	6,790	7,960	50	1938–93	56	- -	6,100	05/1965
							1993	4,320	5,990	7,280	8,580	35					
							% DIFF	+ 5.1	+ 6.4	+ 7.2	+ 7.8						
12	05454300	Clear Creek near Coralville.	98.1	6,760	07/06	68.9	1992	4,760	6,680	8,270	10,000	25	1953–93	41	- -	[1]10,200	06/1990
							1993	5,030	7,110	8,840	10,700	20					
							% DIFF	+ 5.7	+ 6.4	+ 6.9	+ 7.0						
13	05455100	Old Mans Creek near Iowa City.	201	13,000	07/06	64.7	1992	6,800	9,720	12,200	14,900	60	1951–87,	41	43	13,500	06/1982
							1993	7,360	10,700	13,600	16,800	45	1989–93				
							% DIFF	+ 8.2	+ 10.1	+ 11.5	+12.8						
14	05455500	English River at Kalona.	573	36,100	07/06	63.0	1992	13,600	17,900	21,200	24,700	*1.5	1930,	57	64	20,000	09/1965
							1993	14,700	20,000	24,400	29,100	*1.2	1940–93				
							% DIFF	+ 8.1	+ 11.7	+ 15.1	+ 17.8						
15	05457700	Cedar River at Charles City.	1,054	26,400	08/16	25.0	1992	19,900	24,700	28,100	31,200	35	1946–53,	39	- -	29,200	03/1961
							1993	20,800	26,000	29,700	33,100	25	1961–62,				
							% DIFF	+ 4.5	+ 5.3	+ 5.7	+ 6.1		1965–93				
16	05458000	Little Cedar River near Ionia.	306	14,000	08/16	45.8	1992	7,880	10,800	13,000	15,300	70	1954–93	40	- -	10,800	03/1961
							1993	8,530	11,900	14,500	17,300	45					
							% DIFF	+ 8.2	+ 10.2	+ 11.5	+ 13.1						
17	05458500	Cedar River at Janesville.	1,661	35,000	08/18	21.1	1992	23,400	30,200	35,100	39,900	50	1905–06,	75	89	37,000	03/1961
							1993	24,200	31,500	36,800	41,900	40	1915–21,				
							% DIFF	+ 3.4	+ 4.3	+ 4.8	+ 5.0		1923–27,				
													1933–42,				
													1945–93				

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi^2)	1993 peak			Flood-peak discharge estimates (ft^3/s) for indicated recurrence interval (years)						Record			Previous maximum discharge	
				Discharge (ft^3/s)	Date (month/day)	Unit runoff [(ft^3/s)/mi^2]	FF	10	25	50	100	RI	WATSTORE peak flow record (years)	ERL (years)	HST (years)	Maximum discharge (ft^3/s)	Date (month/year)
18	05458900	West Fork Cedar River at Finchford.	846	17,600	04/01	20.8	1992	16,800	24,100	29,800	35,600	11	1929, 1946–93	50	65	31,900	06/1951
							1993	17,400	24,900	30,800	36,800	10					
							% DIFF	+ 3.6	+ 3.3	+ 3.4	+ 3.4						
19	05459500	Winnebago River at Mason City.	526	7,190	04/01	13.7	1992	7,070	9,160	10,700	12,300	11	1933–93	62	64	10,800	03/1933
							1993	7,190	9,310	10,900	12,500	10					
							% DIFF	+ 1.7	+ 1.6	+1.9	+ 1.6						
20	05463000	Beaver Creek at New Hartford.	347	14,700	03/31	42.4	1992	12,100	17,000	20,800	24,500	17	1946–93	48	- -	18,000	06/1947
							1993	12,600	17,800	21,800	25,800	15					
							% DIFF	+ 4.1	+ 4.7	+ 4.8	+ 5.3						
21	05463500	Black Hawk Creek at Hudson.	303	9,670	07/09	31.9	1992	9,050	13,200	16,600	20,200	12	1952–93	42	- -	19,300	07/1969
							1993	9,400	13,700	17,200	21,000	11					
							% DIFF	+ 3.9	+ 3.8	+ 3.6	+ 4.0						
22	05464000	Cedar River at Waterloo.	5,146	68,100	04/02	13.2	1992	55,400	71,700	83,400	94,600	20	1929, 1933, 1941–93	63	91	76,700	03/1961
							1993	56,400	73,200	85,300	96,900	19					
							% DIFF	+ 1.8	+ 2.1	+ 2.3	+ 2.4						
23	05464500	Cedar River at Cedar Rapids.	6,510	71,000	04/04	10.9	1992	51,100	64,300	73,800	82,800	40	1851, 1903–93	91	- -	73,000	03/1961
							1993	52,200	66,100	76,000	85,600	35					
							% DIFF	+ 2.2	+ 2.8	+ 3.0	+ 3.4						
24	05465000	Cedar River near Conesville.	7,785	74,000	04/06	9.5	1992	54,300	67,700	77,100	85,900	40	1940–93	62	91	70,800	04/1961
							1993	55,500	69,400	79,300	88,600	35					
							% DIFF	+ 2.2	+ 2.5	+ 2.9	+ 3.1						
25	05465500	Iowa River at Wapello.	12,499	111,000	07/08	8.9	1992	69,900	84,300	94,100	103,000	*1.1	1903–93	91	- -	94,000	06/1947
							1993	71,800	87,300	97,900	108,000	100					
							% DIFF	+ 2.7	+ 3.6	+ 4.0	+ 4.9						
26	05470000	South Skunk River near Ames.	315	11,200	08/16	35.6	1992	5,780	6,930	7,690	8,380	*1.3	1921–27, 1930 1933–93	70	75	8,630	06/1954
							1993	6,050	7,360	8,260	9,090	*1.2					
							% DIFF	+ 4.7	+ 6.2	+ 7.4	+ 8.5						
27	05470500	Squaw Creek at Ames.	204	24,300	07/09	119.1	1992	5,740	7,590	9,080	10,700	*2.3	1918, 1920–27, 1965–93	46	76	12,500	06/1990
							1993	6,360	8,870	11,000	13,500	*1.8					
							% DIFF	+ 10.8	+ 16.9	+ 21.1	+ 26.2						

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi²)	1993 peak: Discharge (ft³/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft³/s)/mi²]	FF	Flood-peak discharge estimates (ft³/s) for indicated recurrence interval (years): 10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft³/s)	Previous maximum discharge: Date (month/year)
28	05471000	South Skunk River below Squaw Creek near Ames.	556	26,500	07/09	47.7	1992	10,200	11,900	13,000	14,000	*1.9	1944, 1953–79, 1990, 1992–93	39	75	14,700	06/1975
							1993	10,800	13,200	15,100	17,100	*1.5					
							% DIFF	+ 5.9	+ 10.9	+ 16.2	+ 22.1						
29	05471200	Indian Creek near Mingo.	276	18,600	07/09	67.4	1992	8,180	10,200	11,600	13,000	*1.4	1958–75, 1986–93	30	49	23,500	06/1991
							1993	9,600	12,600	15,000	17,400	*1.1					
							% DIFF	+17.4	+ 23.5	+ 29.3	+33.8						
30	05471500	South Skunk River near Oskaloosa.	1,635	20,700	07/15	12.7	1992	15,500	19,000	21,500	24,000	40	1944, 1946–93	50	63	37,000	05/1944
							1993	16,000	19,800	22,600	25,300	30					
							% DIFF	+ 3.2	+ 4.2	+ 5.1	+ 5.4						
31	05472500	North Skunk River near Sigourney.	730	17,500	07/06	24.0	1992	13,900	18,400	21,800	25,200	20	1944, 1946–93	50	63	27,500	03/1960
							1993	14,500	19,200	22,800	26,400	18					
							% DIFF	+ 4.3	+ 4.3	+ 4.6	+ 4.8						
32	05473400	Cedar Creek near Oakland Mills.	530	8,920	07/09	16.8	1992	8,350	9,140	9,650	10,100	20	1979–93	15	- -	8,560	04/1983
							1993	8,670	9,530	10,100	10,600	13					
							% DIFF	+ 3.8	+ 4.3	+ 4.7	+ 5.0						
33	05474000	Skunk River at Augusta.	4,303	46,600	07/10	10.8	1992	36,700	43,700	48,400	52,800	40	1903, 1915–93	82	142	66,800	04/1973
							1993	37,400	44,700	49,600	54,200	35					
							% DIFF	+ 1.9	+ 2.3	+ 2.5	+ 2.7						
34	05476500	Des Moines River at Estherville.	1,372	9,330	06/30	6.8	1992	6,560	9,670	12,400	15,400	25	1952–93	44	55	16,000	04/1969
							1993	6,950	10,300	13,300	16,600	20					
							% DIFF	+ 5.9	+ 6.5	+ 7.3	+ 7.8						
35	05476750	Des Moines River at Humboldt.	2,256	19,000	07/13	8.4	1992	10,300	13,600	15,900	18,100	100	1940–93	54	55	18,000	04/1969
							1993	11,000	14,600	17,300	19,900	80					
							% DIFF	+ 6.8	+ 7.4	+ 8.8	+9.9						
36	05479000	East Fork Des Moines River at Dakota City.	1,308	16,200	04/01	12.4	1992	11,000	15,700	19,500	23,600	30	1938, 1940–93	57	75	22,000	09/1938
							1993	11,600	16,500	20,600	25,100	25					
							% DIFF	+ 5.5	+5.1	+ 5.6	+ 6.4						

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi²)	1993 peak: Discharge (ft³/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft³/s)/mi²]	FF	Flood-peak discharge estimates (ft³/s) for indicated recurrence interval (years): 10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft³/s)	Previous maximum discharge: Date (month/year)
37	05480500	Des Moines River at Fort Dodge.	4,190	31,200	04/01	7.4	1992	21,900	28,400	33,400	38,500	35	1905–06, 1914–27, 1947–93	68	90	35,600	04/1965
							1993	22,600	29,600	34,900	40,400	30					
							% DIFF	+ 3.2	+ 4.2	+ 4.5	+ 4.9						
38	05481000	Boone River near Webster City.	844	13,100	04/01	15.5	1992	11,800	15,400	18,200	21,000	14	1918, 1932, 1941–93	57	97	21,500	06/1918
							1993	12,100	15,800	18,600	21,500	13					
							% DIFF	+ 2.5	+ 2.6	+ 2.2	+ 2.4						
39	05481300	Des Moines River near Stratford.	5,452	42,300	04/02	7.8	1992	31,200	40,700	48,000	55,500	30	1903, 1905–29, 1931, 1933–93	88	91	57,400	06/1954
							1993	31,900	41,800	49,400	57,200	25					
							% DIF	+ 2.2	+ 2.7	+ 2.9	+ 3.1						
40	05481950	Beaver Creek near Grimes.	358	14,300	07/10	39.9	1992	5,670	7,140	8,210	9,250	*1.5	1960–93	34	- -	7,980	06/1986
							1993	6,490	8,600	10,200	12,000	*1.2					
							% DIFF	+ 14.5	+ 20.4	+ 24.2	+ 29.7						
41	05482500	North Raccoon River near Jefferson.	1,619	16,900	07/10	10.4	1992	16,500	21,500	25,100	28,600	11	1940–93	54	- -	29,100	06/1947
							1993	16,800	21,900	25,700	29,300	10					
							% DIFF	+ 1.8	+1.9	+ 2.4	+ 2.4						
42	05483450	Middle Raccoon River near Bayard.	375	27,500	07/09	73.3	1992	8,590	11,800	14,500	17,300	*1.6	1973, 1979–93	22	41	14,600	07/1973
							1993	9,870	14,300	18,100	22,400	*1.2					
							% DIFF	+ 14.9	+21.2	+ 24.8	+ 29.5						
43	05483600	Middle Raccoon River at Panora.	440	22,400	07/09	50.9	1992	10,300	13,400	15,900	18,500	*1.2	1953, 1958–93	38	41	15,300	06/1986
							1993	11,300	15,200	18,300	21,700	100					
							% DIFF	+ 9.7	+ 13.4	+ 15.1	+ 17.3						
44	05484000	South Raccoon River at Redfield.	994	44,000	07/10	44.3	1992	20,300	25,100	28,500	31,800	*1.4	1940–93	54	- -	35,000	07/1958
							1993	21,900	27,800	32,300	36,700	*1.2					
							% DIFF	+ 7.9	+ 10.8	+ 13.3	+ 15.4						
45	05484500	Raccoon River at Van Meter.	3,441	70,100	07/10	20.4	1992	29,500	37,400	43,300	49,100	*1.4	1915–93	79	- -	41,200	06/1947
							1993	31,300	40,700	48,000	55,400	*1.3					
							% DIFF	+ 6.1	+ 8.8	+ 10.9	+ 12.8						

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi^2)	1993 peak: Discharge (ft^3/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft^3/s)/mi^2]	Flood-peak discharge estimates (ft^3/s) for indicated recurrence interval (years): FF	10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft^3/s)	Previous maximum discharge: Date (month/year)
46	05487470	South River near Ackworth.	460	32,200	07/06	70.0	1992	23,200	29,000	33,100	37,000	45	1930, 1940–93	57	64	38,100	06/1990
							1993	23,900	30,100	34,500	38,700	35					
							% DIFF	+ 3.0	+ 3.8	+ 4.2	+ 4.6						
47	05487980	White Breast Creek near Dallas.	342	25,500	07/06	74.6	1992	14,200	18,500	22,000	25,800	100	1962–93	34	49	37,300	07/1982
							1993	15,600	20,700	25,000	29,800	50					
							% DIFF	+ 9.9	+ 11.9	+ 13.6	+ 15.5						
48	05489000	Cedar Creek near Bussey.	374	36,100	07/05	96.5	1992	20,000	28,800	36,700	45,900	50	1946, 1948–93	51	142	96,000	07/1982
							1993	21,500	31,300	40,200	50,800	35					
							% DIFF	+ 7.5	+ 8.7	+ 9.5	+ 10.7						
49	06483500	Rock River near Rock Valley.	1,592	29,300	05/09	18.4	1992	19,400	28,200	35,600	43,300	30	1948–93	51	96	40,400	04/1969
							1993	20,600	30,300	38,400	47,000	25					
							% DIFF	+ 6.2	+ 7.4	+ 7.9	+ 8.5						
50	06485500	Big Sioux River at Akron.	8,424	66,700	05/10	7.9	1992	31,800	47,600	61,100	76,000	70	1929–93	65	- -	80,800	04/1969
							1993	33,900	51,600	67,100	84,500	50					
							% DIFF	+ 6.6	+ 8.4	+ 9.8	+ 11.2						
51	06605850	Little Sioux River at Linn Grove.	1,548	16,100	07/02	10.4	1992	13,100	19,000	24,000	29,500	17	1953, 1961–62, 1965, 1973–93	31	102	22,500	06/1953
							1993	14,200	20,600	26,000	31,900	14					
							% DIFF	+ 8.4	+ 8.4	+ 8.3	+ 8.1						
52	06606600	Little Sioux River at Correctionville.	2,500	22,600	07/18	9.0	1992	15,700	21,500	26,200	31,300	30	1919–25, 1929–32, 1937–93	71	102	29,800	04/1965
							1993	16,200	22,300	27,400	32,800	25					
							% DIFF	+ 3.2	+ 3.7	+ 4.6	+ 4.8						
53	06608500	Soldier River at Pisgah.	407	23,400	07/09	57.5	1992	18,700	24,000	28,000	31,900	25	1940–93	54	- -	22,500	06/1950
							1993	19,300	24,900	29,100	33,200	20					
							% DIFF	+ 3.2	+ 3.8	+ 3.9	+ 4.1						
54	06609500	Boyer River at Logan.	871	26,200	07/09	30.1	1992	22,400	26,900	29,900	32,600	20	1918–25, 1938–93	64	- -	30,800	06/1990
							1993	22,900	27,500	30,600	33,400	20					
							% DIFF	+ 2.2	+2.2	+ 2.3	+ 2.5						

Table 1. Flood-frequency data for selected streamflow-gaging stations in Iowa—Continued

Site number (fig.3)	Station number	Station name	Drainage area (mi²)	1993 peak: Discharge (ft³/s)	1993 peak: Date (month/day)	1993 peak: Unit runoff [(ft³/s)/mi²]	Flood-peak discharge estimates (ft³/s) for indicated recurrence interval (years): FF	10	25	50	100	RI	Record: WATSTORE peak flow record (years)	Record: ERL (years)	Record: HST (years)	Previous maximum discharge: Maximum discharge (ft³/s)	Previous maximum discharge: Date (month/year)
55	06807410	West Nishnabotna River at Hancock.	609	30,100	07/10	49.4	1992	19,500	24,600	28,300	31,700	70	1960–93	34	- -	26,400	09/1972
							1993	21,500	27,800	32,300	36,700	35					
							% DIFF	+ 10.3	+ 13.0	+ 14.1	+ 15.8						
56	06809500	East Nishnabotna River at Red Oak.	894	21,600	08/31	24.2	1992	21,000	26,600	30,400	34,100	11	1917–25, 1936–93	71	90	38,000	09/1972
							1993	21,400	27,000	31,000	34,700	10					
							% DIFF	+ 1.9	+ 1.5	+ 2.0	+ 1.8						
57	06810000	Nishnabotna River above Hamburg.	2,806	37,700	07/25	13.4	1992	28,700	33,900	37,300	40,300	60	1922–23, 1929–93	71	142	55,500	06/1947
							1993	29,400	34,900	38,500	41,800	45					
							% DIFF	+ 2.4	+ 2.9	+ 3.2	+ 3.7						
58	06817000	Nodaway River at Clarinda.	762	28,000	07/22	36.7	1992	25,800	32,700	37,400	41,800	14	1918–25, 1936–93	68	90	31,100	06/1947
							1993	26,300	33,400	38,200	42,700	13					
							% DIFF	+ 1.9	+ 2.1	+ 2.1	+ 2.2						
59	06897950	Elk Creek near Decatur City.	52.5	32,800	07/05	624.8	1992	16,700	23,200	28,200	33,100	100	1967–93	27	- -	18,000	07/1990
							1993	19,900	28,900	36,000	43,300	35					
							% DIFF	+ 19.2	+ 24.6	+ 27.7	+ 30.8						
60	06898000	Thompson River at Davis City.	701	30,300	07/05	43.2	1992	16,500	21,600	25,700	30,000	100	1885, 1919–24, 1926, 1942–93	69	109	57,000	09/1992
							1993	17,000	22,500	26,900	31,600	80					
							% DIFF	+ 3.0	+ 4.2	+ 4.7	+ 5.3						
61	06903400	Chariton River near Chariton.	182	14,900	07/05	81.9	1992	9,680	14,000	17,800	22,100	30	1947, 1960, 1966–93	33	47	37,700	09/1992
							1993	10,600	15,500	19,900	25,000	25					
							% DIFF	+ 9.5	+ 10.7	+ 11.8	+ 13.1						
62	06903700	South Fork Chariton River near Promise City.	168	16,900	07/05	100.6	1992	14,400	20,300	25,400	31,200	15	1968–93	30	47	70,600	09/1992
							1993	15,400	21,900	27,600	34,200	13					
							% DIFF	+ 6.9	+ 7.9	+ 8.7	+ 9.6						

[1]Discharge revised from a previously published value.

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