Click here to return to USGS publications

FLOOD VOLUMES

IN THE UPPER MISSISSIPPI RIVER BASIN

APRIL 1 THROUGH SEPTEMBER 30

1 · 9 · 9 · 3

U.S. GEOLOGICAL SURVEY CIRCULAR 1120-H

Front cover—View of Highway 67, West Alton, Missouri (Srenco Photography, St. Louis, Mo.)
Back cover—View of Spirit of St. Louis Airport, Chesterfield, Mo. (Srenco Photography, St. Louis, Mo.)
Field Hydrologist making streamflow measurements (U.S. Geological Survey)

FLOOD VOLUMES IN THE UPPER MISSISSIPPI RIVER BASIN, APRIL 1 THROUGH SEPTEMBER 30, 1993

By Rodney Southard

Floods in the Upper Mississippi River Basin, 1993

U.S. GEOLOGICAL SURVEY CIRCULAR 1120–H

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
GORDON P. EATON, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1995

Free on application to the
U.S. Geological Survey
Information Services
Box 25286, Federal Center
Denver, CO 80225

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.

Gordon P. Eaton

Director

Contents

FIGURES

TABLES

CONVERSION FACTORS 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
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
acre-foot (acre-ft)	0.001233	cubic hectometer

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

Flood Volumes in the Upper Mississippi River Basin, April 1 Through September 30, 1993

By Rodney Southard

Abstract

Previous maximum flows on many streams and rivers were exceeded during the flood of 1993 in the upper Mississippi River Basin. Not only were peak discharges exceeded at many streamflow-gaging stations, but flood volumes were significantly higher than previous maximums. Rainfall amounts that were greater than 50 inches were recorded in parts of Kansas, Missouri, and Iowa from April 1 through September 30, 1993. As a result of the excess rainfall, 53 of the 60 stations discussed in this report had flow volumes that were greater than twice the mean flow volume for April through September. The Mississippi River at St. Louis, Missouri, remained above flood stage for 144 days from April 1 to September 30, 1993, compared with 81 days during the 1973 flood. Of the 60 stations, 24 recorded new maximum 3-day flood volumes, and 47 recorded new maximum 120-day flood volumes. This indicates that the flooding of 1993 is significant with respect to its long duration and magnitude of flow. The same aspect is indicated in the frequency analysis of the 1993 flood. During the 1993 flood, the 100-year 3-day flows were exceeded at 22 stations, and the 120-day flows were exceeded at 43 stations.

INTRODUCTION

A common definition of the word "flood" is the temporary overflow from a river onto adjacent lands not normally covered by water. In 1993, millions of acres of land in the upper Mississippi River Basin were flooded for weeks and months as persistent heavy rain fell over the Missouri and the Mississippi River Basins. Record or near-record flood discharges were recorded at streamflow-gaging stations in North Dakota, South Dakota, Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Kansas, and Missouri (fig. 1). At some streamflow-gaging stations, record peak discharges were measured early in the flood period only to have that record broken days or months later. The intense rainfall caused not only peak flood discharges, but sustained large flood volumes that resulted in more than 420 counties in the nine-State area being declared a Federal disaster area.

The sustained high flows transported enormous amounts of sediment and agricultural chemicals to the Gulf of Mexico, caused severe river bank erosion and instability, and resulted in scour of river channels at bridge crossings from April 1 through September 30, 1993. The Missouri and the Mississippi Rivers upstream from St. Louis, Missouri, were closed to all barge traffic. Numerous interstates and State highways also were closed for weeks until the flood waters finally receded.

Flow volume is an important aspect to be considered in the analysis and description of flooding in the upper Mississippi River Basin. At streamflow-gaging stations throughout the upper Mississippi River Basin, record or near-record flow peaks and volumes were observed during the April 1 through September 30, 1993, flood; record flow peaks at 154 selected streamflow-gaging stations were described by Parrett and others (1993). Because flow volumes may be defined by several different characteristics, the flow volume data require more extensive computations that do flow peak data. Only data for the 60 selected streamflow-gaging stations are presented in this report.

Reservoirs on the Missouri River main stem and tributaries to the Missouri and the Mississippi

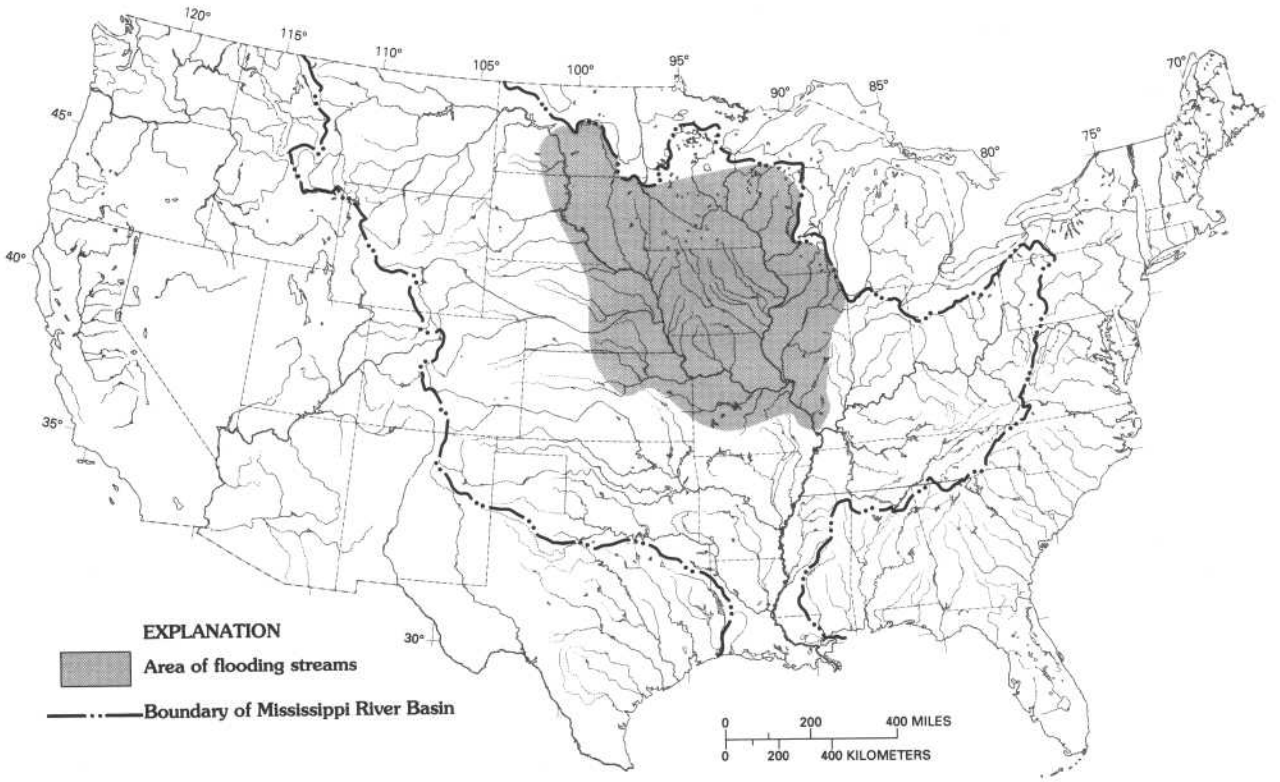

Figure 1. The Mississippi River Basin and general area of flooding, April 1 through September 30, 1993. (Map from Parrett and others, 1993.)

Rivers stored millions of acre-feet of water to minimize flood damages downstream of the reservoirs. An increase in storage of 3,152,000 acre-feet of water in the Harry S. Truman Reservoir at Warsaw, Missouri, from April 1 to August 2, 1993, decreased flooding on the main stem of the Missouri River downstream.

Purpose and Scope

The purpose of this report is to describe quantitatively, for selected locations in the upper Mississippi River Basin, the magnitude and frequency of the flood with respect to flow volume from April 1 through September 30, 1993. A brief summary of the excessive rainfall for the 6-month period is presented as background information. Flow volumes at selected streamflow-gaging stations were computed for the entire period of interest and compared with mean flow volume for the period; a comparison also is made to the period of record mean annual runoff at each station. To further document the magnitude of the flooding, selected *n*-day consecutive periods were summarized for 1993 and compared with the previous maximum *n*-day flood volume. The 1993 *n*-day flow volume recurrence intervals also were computed on the basis of the period of record at each station. The 1993 flow volumes are compared with the various 100-year flow volumes for *n*-day consecutive periods. The discharge hydrographs for main stem stations on the Mississippi and the Missouri Rivers are presented for April through September. Data from selected reservoirs are shown graphically to describe the magnitude of storage and to present the inflow and outflow discharges at these sites.

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 State and local agencies. Appreciation is expressed to the personnel in these offices who put forth an extensive effort to provide the data in a timely fashion. Also, sincere thanks is extended to all who were involved in the field collection of the data during often adverse conditions.

PRECIPITATION, APRIL 1 THROUGH SEPTEMBER 30, 1993

From April 1 through September 30, 1993, record or near-record precipitation was measured in the upper Mississippi River Basin. More than 50 inches of rain fell in parts of Iowa, Missouri, and Kansas (fig. 2) from April to September. The heaviest rain fell in eastern Kansas, from southwestern to northeastern Missouri, and in the eastern two-thirds of Iowa. Rainfall totals of 30 or more inches were measured in most places; a maximum of 52.2 inches of rain fell in east-central Missouri. Rainfall during this period followed above-normal precipitation that had fallen during the winter and early spring.

An unusual characteristic of the chronological distribution of the extreme rainfall is that the heaviest rain at any particular location could have fallen in any month from April 1 through September 30, 1993. To illustrate the distribution of precipitation in the general area of flooding, the 1993 and normal (1961–90) monthly precipitation totals of seven selected National Weather Service precipitation stations are shown in figure 3. At Sioux Falls, South Dakota, the largest monthly recorded rainfall was 8.26 inches in May. However, near the mouth of the Missouri River at St. Louis, Missouri, the largest monthly rainfall total (9.16 inches) was in September. The magnitude of the monthly rainfall totals also are shown in figure 3. The rainfall total for July at Lincoln, Nebraska, was 12.50 inches, or 3.9 times the normal rainfall. This distribution and magnitude of rainfall in the flood area sustained the high stages and discharge volumes of runoff on many streams and rivers, especially on the Missouri and the Mississippi River main stems. A general overview of the excessive precipitation during spring and summer 1993 is provided in Wahl and others (1993).

FLOOD VOLUMES, APRIL 1 THROUGH SEPTEMBER 30, 1993

One of the most significant aspects of the 1993 floods in the upper Mississippi River Basin is the volume of runoff in area streams and rivers. These flood volumes are directly related to total loads of sediment and agricultural chemicals that were transported to the Gulf of Mexico by the Mississippi River (Goolsby and others, 1993). Thus, the analysis of the displacement of these constituents is dependent on quantifying the volume of water in a given time period. A summary of the flood volumes at selected streamflow-gaging stations from April 1 through September 30 is presented in this report. The magnitude, frequency, and duration of the volume of runoff are discussed.

Magnitude and Duration of Volume of Runoff

The magnitude and duration of the 1993 flood volumes for April through September can be appreciated by comparing them with the mean runoff for the same period and to the previous maximum runoff for the period of record at each streamflow-gaging station listed in table 1.[1] The location of these stations in the general flood area is shown in figure 4. For informational purposes, the 1993 flows also may be compared with the mean annual flows for the period at each station.

To ensure a meaningful comparison or analysis of discharge at a streamflow-gaging station, the channel and drainage-basin characteristics for the station must be consistent during the period of record used in the analyses. For most streamflow-gaging stations in the upper Mississippi River Basin, significant effects on the river basin, such as reservoir operation and irrigation, do not exist, and the entire streamflow record can be used for comparison purposes and statistical analyses. However, at a few of the streamflow-gaging stations, such as those on the Kansas and the Missouri River main stems, the flow is affected by reservoir operation. In these instances, the period of record that was used to determine mean flow volumes and recurrence intervals began when the last major reservoir was put into operation.

The runoff volumes from April through September 1993 were in excess of the mean for the same period at the 60 stations (table 1; fig. 4). In fact, of the 60 stations, 53 had flow volumes that were greater than twice the mean. The ratio of the 1993 runoff volume to the mean flow volume at each station ranged from 1.18 for the Flambeau River near Bruce, Wisconsin (site number 7), to 8.75 for the Rock River at Rock Valley, Iowa (site number 35).

The runoff volume from April through September also was compared with the period of record mean annual runoff or the volume of runoff that

[1]Tables 1 through 3 appear on pages15 through 32.

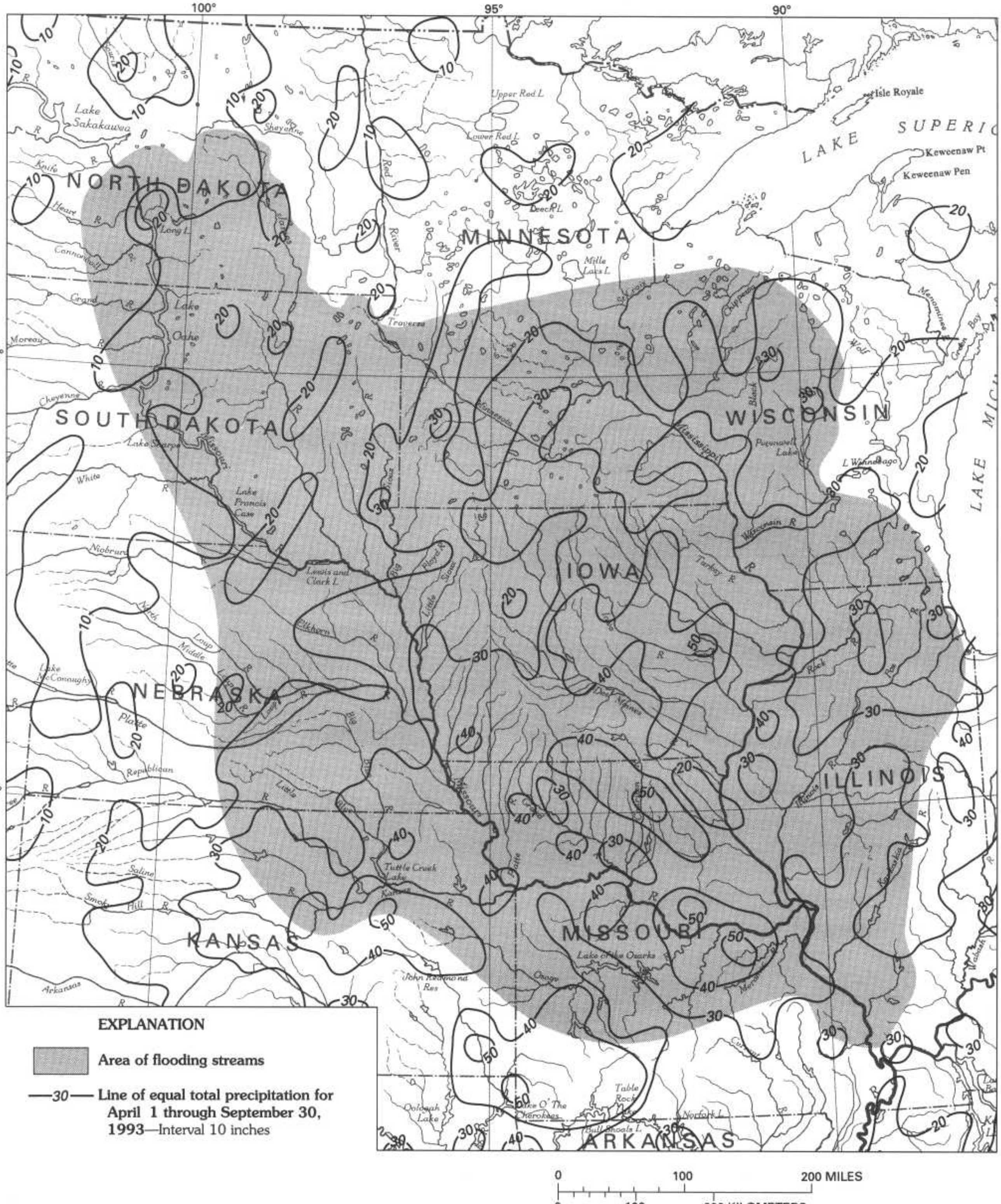

Figure 2. Areal distribution of total precipitation in the area of flooding in the upper Mississippi River Basin, April 1 through September 30, 1993. (Precipitation data from David Miscus, National Weather Service, written commun., 1993.)

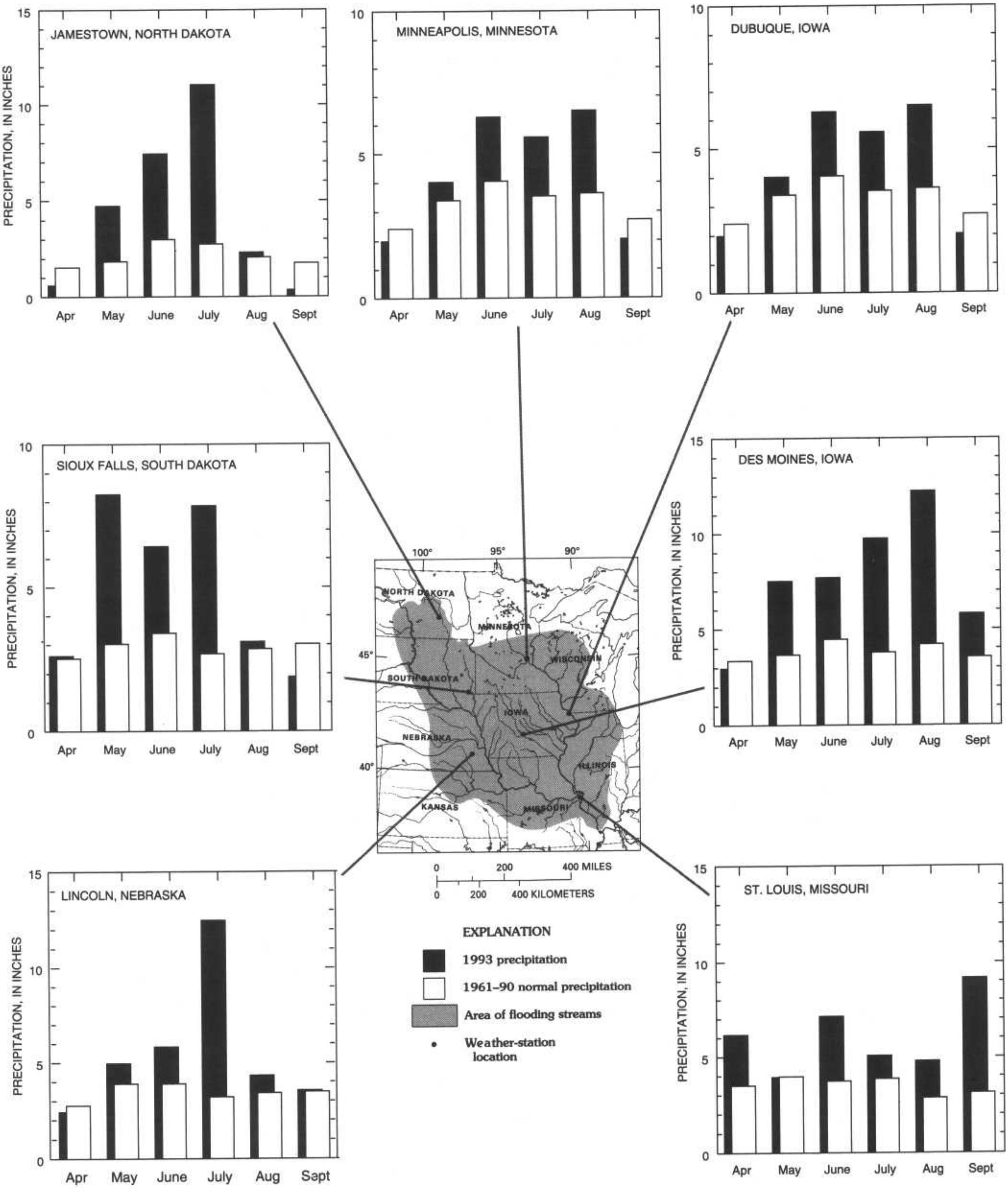

Figure 3. Monthly precipitation for April 1 through September 30, 1993, and 30-year monthly normals (April through September 1961–90) at seven weather stations in the upper Mississippi River Basin. (Map modified from Parrett and others, 1993.)

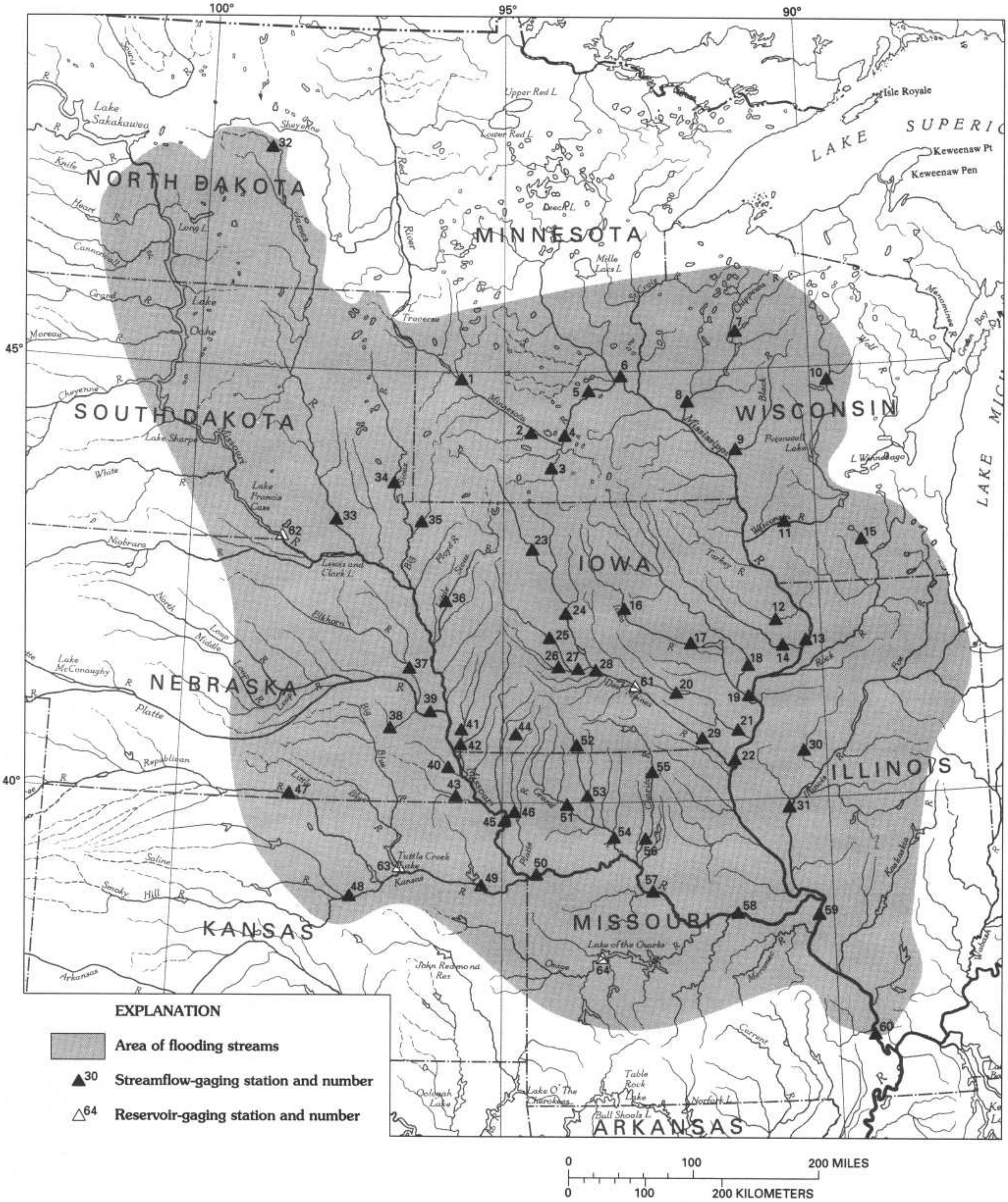

Figure 4. Location of selected streamflow-gaging stations and reservoirs in the upper Mississippi River Basin.

would normally be expected in a year. Of the 60 stations, only 4 had runoff volumes that were less than the mean runoff volume for an entire year, and 9 had volumes of flow that were greater than four times the mean annual runoff. Graphs of the monthly mean runoff from April through September 1993 and the mean monthly runoff for the period of record for seven streamflow-gaging stations are shown in figure 5. During August, the flows on the James River near Scotland, South Dakota (site number 33), were 18 times the August mean flow.

Excessive flow volumes also are reflected in the number of days the river remained above flood stage or the flow at flood stage. Of a possible 183 days from April 1 through September 30, 1993, 17 stations were above flood stage for longer than 90 days, or 3 months. In addition to the flood of 1993, the flood of 1973 was a significant event on the main stem of the Mississippi River at St. Louis. In a comparison of the floods of 1973 and 1993, the 1973 event had flows above flood stage for 81 days, and the 1993 event had flows above flood stage for 144 days. A plot of discharge hydrographs for stations on the Mississippi River main stem and stations on the Missouri River main stem are shown in figures 6 and 7. These hydrographs depict the long duration of flooding with respect to time and multiple peaks during the event. The time sequence as the flood peaks travel downstream also is shown on both figures.

The significance of the 1993 flow volumes also may be indicated by determining the period of *n* consecutive days in 1993, which had the highest accumulated flow, and comparing this flow (the 1993 annual *n*-day flow) with the previous maximum *n*-day flow for the period of record. This comparison for the 1993 flow volume and the previous maximum for the period of record for 3-, 7-, and 30-day periods is listed in table 2. Comparisons of the 60-, 90-, and 120-day periods for 1993 flow volumes and previous maximums are listed in table 3. In general, the longer the *n*-day period, the more significant the 1993 flow was when compared with previous maximums. For example, the streamflow-gaging station on the Blue Earth River near Rapidan, Minnesota (site number 3), had a 3-day flow of slightly less than one-half the previous 3-day maximum, but for the 120-day period, the 1993 flow was 1.69 times the previous maximum. Of the 60 stations analyzed in this report, 24 had new maximum 3-day flows (table 2) and 47 had new maximum 120-day flows (table 3).

Frequency of Volume of Runoff

Recurrence interval or probability of exceedance also can be used to quantify the magnitude of a specific flood event (tables 2, 3). The statistical procedure used here to compute recurrence intervals for peak discharges also is applicable to flow analysis for any specific highest daily mean discharge for *n*-day consecutive periods. A comprehensive description of the procedures used can be found in Bulletin 17B of the Interagency Advisory Committee on Water Data (1982). Recurrence interval is the number of years, on the average, between exceedances of the annual *n*-day flow of a specified discharge; for example, the 100-year flow volume is exceeded, on the average, once every 100 years. The probability of exceedance is the reciprocal of recurrence interval; for example, the 100-year flow volume has a 1 in 100 chance, or 0.01 probability, of being exceeded in any given year. The 100-year recurrence interval was exceeded at 22 stations for a 3-day duration (table 2) and at 43 stations for a 120-day duration (table 3). Comparison of the 1993 *n*-day flow with respect to the computed 100-year value for each *n*-day period is shown in figure 8 for selected stations. In the majority of cases, the 1993 flows exceeded the 100-year flows. The Missouri River at Kansas City, Missouri (site number 50), 3-day duration flow and the Iowa River at Wapello (site number 19), 120-day duration flow were 1.8 times the 100-year flow.

EFFECTS OF RESERVOIRS ON FLOODS

The effect of the main-stem reservoirs on the Missouri River in reducing flows is apparent when comparing the recurrence intervals for the 120-day duration at the Nebraska City, Nebraska (site number 40), streamflow-gaging station with a station farther downstream, such as that at St. Joseph, Missouri (site number 45). The 120-day flow at Nebraska City had a recurrence interval of 16 years in comparison to a recurrence interval of 80 years at St. Joseph; this indicates that the less severe flood at Nebraska City was the result of storage of flood waters in upstream reservoirs. However, because of the tremendous amount of inflow below the main-stem reservoirs, the shorter duration 3-day flow has a 60-year recurrence interval, which is significantly higher than the 16-year recurrence interval for the 120-day value at Nebraska City. The main-stem reservoirs on the Missouri River

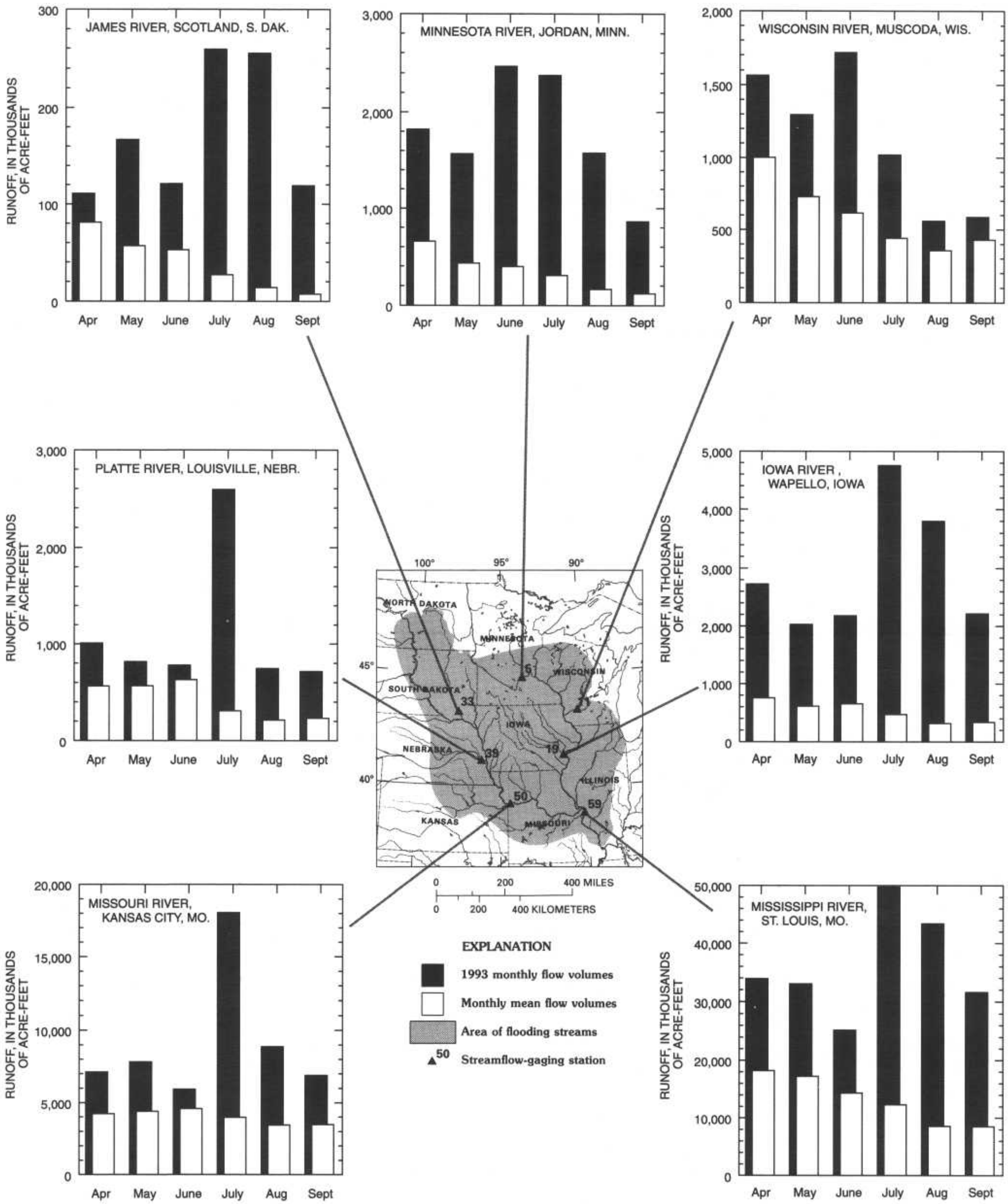

Figure 5. Monthly flow runoff, April 1 through September 30, 1993, and mean monthly runoff volumes at selected streamflow-gaging stations in the upper Mississippi River Basin.

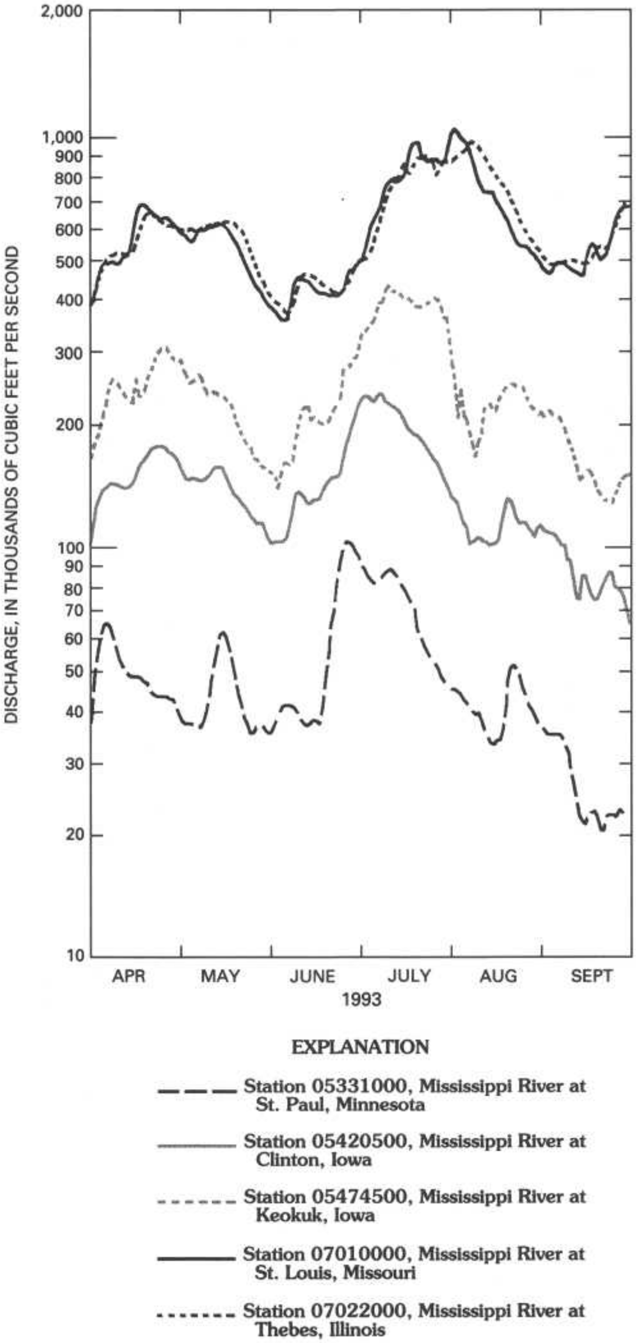

Figure 6. Discharge hydrographs at selected streamflow-gaging stations on the Mississippi River, April 1 through September 30, 1993.

stored a significant amount of flow from April through September, thus reducing the long duration of flooding downstream from the reservoirs. However, as a result of the magnitude and intensity of storms downstream of the reservoirs, shorter duration flow events were still very pronounced and had high recurrence intervals.

An important aspect of the flood of 1993 is the role of flood-control reservoirs in the upper Mississippi River Basin. Most of reservoirs are on the main stem of the Missouri River and in the Kansas River Basin, which is a major tributary to the Missouri River. Because of storage in the reservoirs in the Kansas River Basin, peak flows from below Tuttle Creek Lake downstream to the mouth of the Kansas River were reduced by 30 percent or more (Perry, 1994).

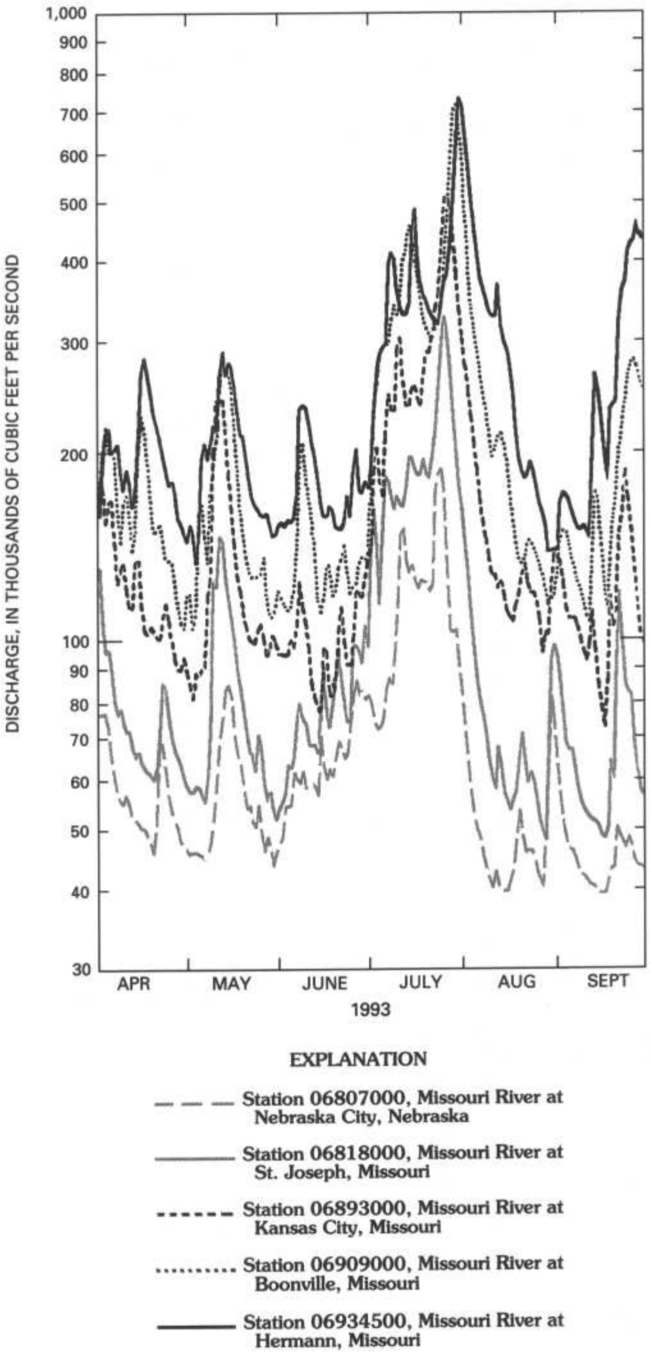

Figure 7. Discharge hydrographs at selected streamflow-gaging stations on the Missouri River, April 1 through September 30, 1993.

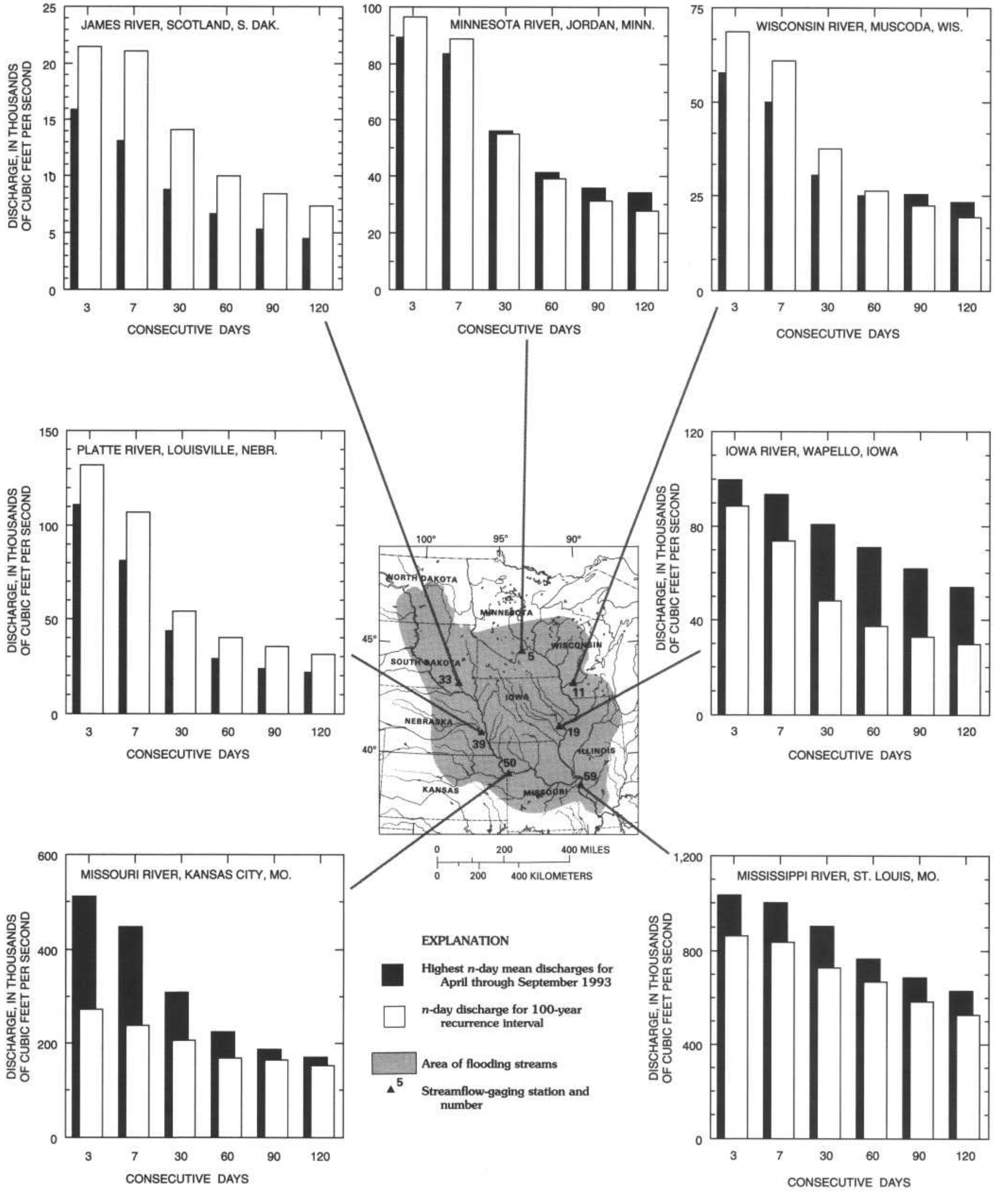

Figure 8. Highest *n*-day mean discharges for indicated number of consecutive days, April 1 through September 30, 1993, and 100-year recurrence-interval *n*-day annual discharges at selected streamflow-gaging stations in the upper Mississippi River Basin.

ELEVATION AND CONTENTS OF SELECTED RESERVOIRS

Record or near-record volumes of flood water were stored in many reservoirs to reduce outflows and to minimize flood damages downstream of reservoirs. The Tuttle Creek Lake on the Kansas River near Manhattan, Kansas (site number 63; table 4), had a maximum pool elevation of 1,137.76 feet above sea level, which was nearly 10 feet higher than the 1986 maximum, and storage of 2,420,000 acre-feet, which was 24 percent more flood volume than the 1986 maximum. The maximum pool elevation and contents data for four of the largest reservoirs in the general flood area are listed in table 4. Although not all these reservoirs established new maximum elevations or contents in 1993, the combined storage of the reservoirs and the dates of maximum releases substantially minimized flood damages downstream from the reservoirs. On the Des Moines River, Lake Red Rock (site number 61; table 4) near Pella, Iowa, stored 1,784,000 acre-feet of flood waters from April through September to minimize damages downstream. About 7,661,000 acre-feet was stored in the reservoirs listed in table 4. A graphical representation of the reservoir elevation and contents from April through September 1993 is shown in figure 9. The result of the storage of flood waters with plots of the inflow into the reservoirs and outflows from the reservoirs is shown in figure 10. In all cases, it is important to note that the maximum outflows were less than the maximum inflows during extensive flooding downstream.

SUMMARY

Record high flood flows were observed in nine States in the upper Mississippi River Basin from April 1 through September 30, 1993. In the upper Midwest, sustained high flows caused the halting of barge traffic, closing of highways, and flooding of farmland, which resulted in billions of dollars in damages. The high flows were sustained by storms that produced more than 30 inches of rain in Kansas, Missouri, and Iowa; some places received more than 50 inches from April through September. In July, Lincoln, Nebraska, recorded 12.50 inches of rain, or 3.9 times its normal rainfall for the month.

The flood runoff or volume that resulted from the excessive rainfall can be quantified by comparing

Table 4. Elevation and contents of selected reservoirs in the upper Mississippi River Basin

[mi^2, square mile; ft, foot; acre-ft, acre-feet]

Site number (fig. 4)	Station number (fig. 4)	Station name	Drainage area (mi^2)	Maximum in 1993			Previous maximum			Period of record
				Elevation (feet above sea level)	Contents (acre-ft)	Date	Elevation (feet above sea level)	Contents (acre-ft)	Date	
61	05488100	Lake Red Rock near Pella, Iowa. . . .	12,323	782.67	1,933,000	7/13	779.61	1,765,000	6/25/84	1969
62	06452500	Lake Francis Case at Pickstown, S. Dak.	263,500	1,361.0	4,129,000	7/31	1,364.20	5,087,000	6/20/62	1952
63	06886900	Tuttle Creek Lake near Manhattan, Kans.	9,628	1,137.76	2,420,000	7/22	1,127.90	1,958,000	10/18/86	1962
64	06922440	Harry S. Truman Reservoir at Warsaw, Mo.	11,500	735.20	4,352,000	8/2	738.69	5,020,000	10/11/86	1977

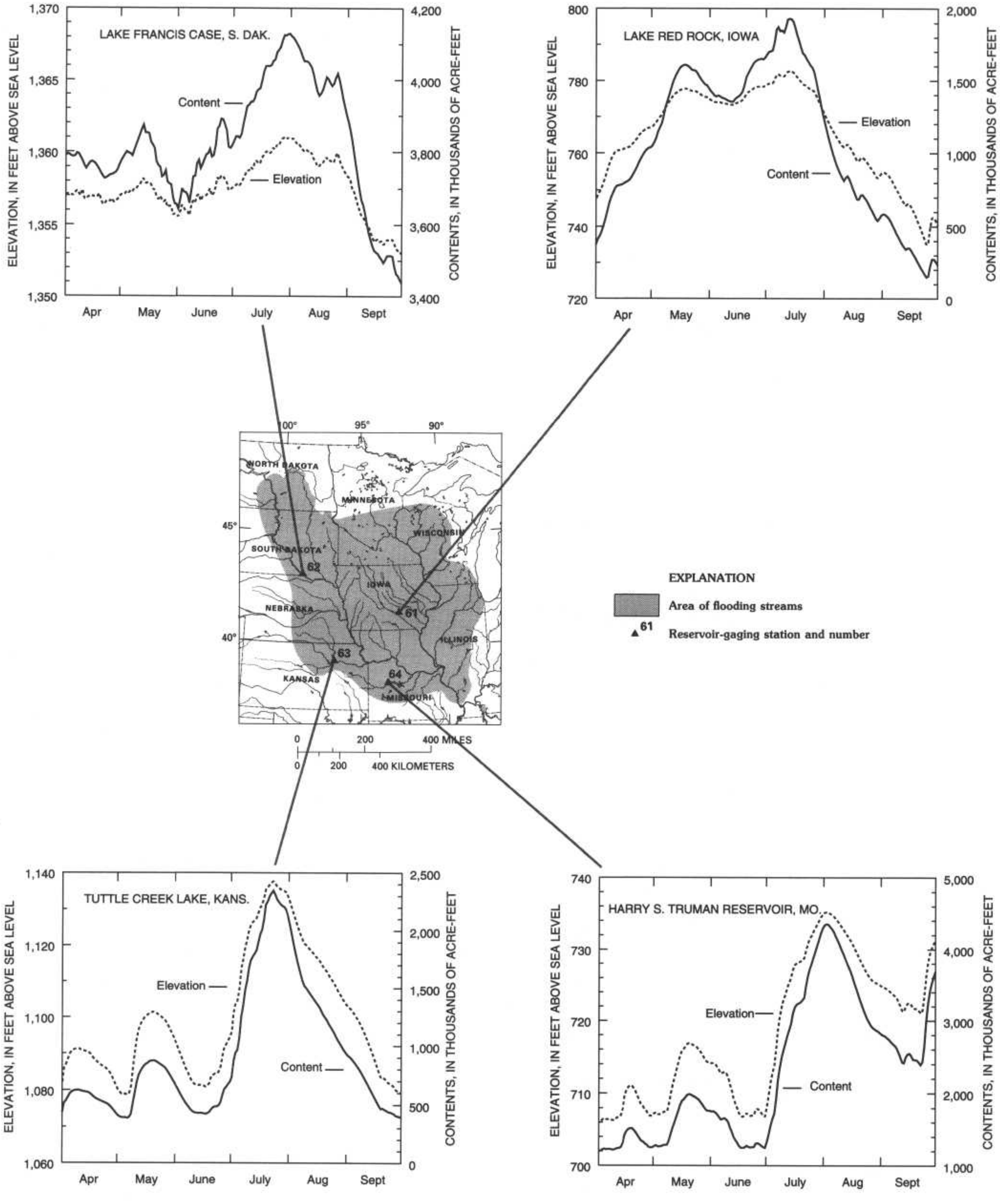

Figure 9. Elevation and contents at selected reservoirs in the upper Mississippi River Basin, April 1 through September 30, 1993.

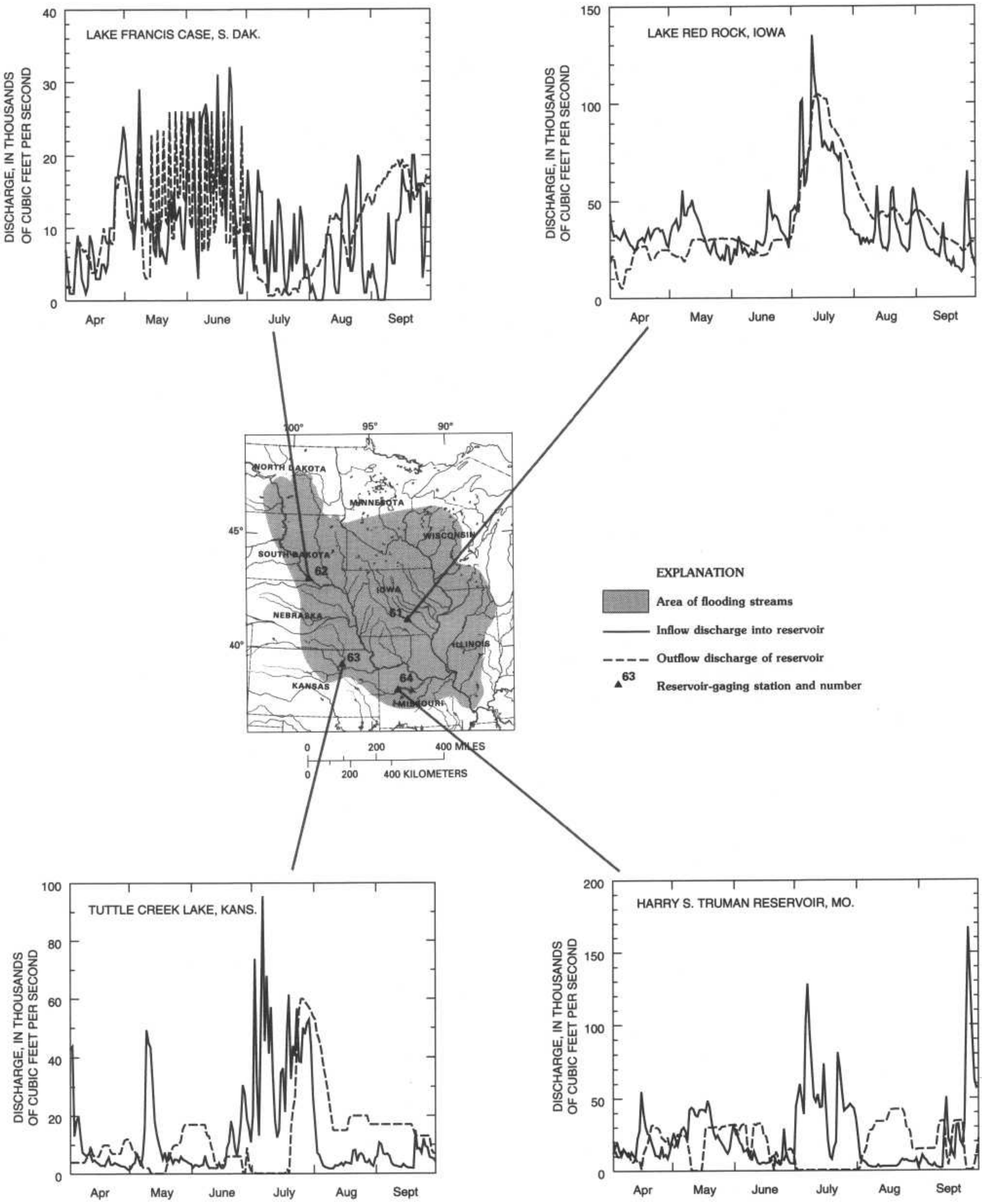

Figure 10. Inflow and outflow discharge at selected reservoirs in the upper Mississippi River Basin, April 1 through September 30, 1993.

the 1993 flood volumes at selected streamflow-gaging stations with the mean runoff for the period of record of each station. Comparisons also may be made by determining the highest mean discharges or accumulated flows for periods of *n* consecutive days (*n*-day values) and by comparing these values to previous maximums or determining recurrence intervals for the 1993 *n*-day values from station records. For the 60 stations included in this report, 53 recorded flow volumes that were greater than twice the mean for the April to September period. In fact, 9 of the 60 stations had flow volumes that were four times the mean annual flow. At 47 of the 60 stations, the magnitude of the 1993 flood volumes was significantly greater than the previously recorded maximums for 120-day volumes. Frequency analysis of the historic or period of record flows also indicated that the 100-year flood volume for the 120-day period was exceeded at 43 of the 60 stations in 1993. At the Iowa River streamflow-gaging station at Wapello, Iowa, the 1993 flood volume was 1.8 times the 100-year flood volume.

The storage of large volumes of water in reservoirs significantly decreased the peak flow and flood damages downstream from the dams. Lake Red Rock near Pella, Iowa, stored 1,784,000 acre-feet to minimize flooding downstream from April through September 1993. The storage of millions of additional acre-feet of water in reservoirs on the main stem of the Missouri River and in the Kansas River Basin eased the flooding on the Missouri and the Mississippi Rivers.

SELECTED REFERENCES

Anderson, D.B., and Burmeister, I.L., 1970, Floods of March–May 1965 in the upper Mississippi River basin: U.S. Geological Survey Water-Supply Paper 1850–A, 448 p.

Chin, E.H., Skelton, John, and Guy, H.P., 1975, The 1973 Mississippi River basin flood-compilation and analyses of meteorologic, streamflow, and sediment data: U.S. Geological Survey Professional Paper 937, 137 p.

Goolsby, D.A., Battaglin, W.A., and Thurman, E.M., 1993, Occurrence and transport of agricultural chemicals in the Mississippi River Basin, July through August 1993: U.S. Geological Survey Circular 1120–C, 22 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey Hydrology Subcommittee Bulletin 17B, 183 p.

Parrett, Charles, Melcher, N.B., and James, R.W., Jr., 1993, Flood discharges in the upper Mississippi River Basin: U.S. Geological Survey Circular 1120–A, 14 p.

Perry, Charles A., 1994, Effects of reservoirs on flood discharges in the Kansas and Missouri River Basins: U.S. Geological Survey Circular 1120–E, 20 p.

Wahl, K.L., Vining, K.C., and Wiche, G.J., 1993, Precipitation in the upper Mississippi River Basin, January 1 through July 31, 1993: U.S. Geological Survey Circular 1120–B, 13 p.