PRECIPITATION

IN THE UPPER MISSISSIPPI RIVER BASIN

JANUARY 1 THROUGH JULY 31

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U.S. GEOLOGICAL SURVEY CIRCULAR 1120-B

Front Cover—View of Highway 367, West Alton, Illinois, (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)

PRECIPITATION IN THE UPPER MISSISSIPPI RIVER BASIN, JANUARY 1 THROUGH JULY 31, 1993

By Kenneth L. Wahl, Kevin C. Vining, and Gregg J. Wiche

Floods in the Upper Mississippi River Basin, 1993

U.S. GEOLOGICAL SURVEY CIRCULAR 1120-B

U.S. DEPARTMENT OF THE INTERIOR
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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 shipping before 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.

Robert M. Hirsch

Acting Director
September 8, 1993

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By Kenneth L. Wahl, Kevin C. Vining, *and* Gregg J. Wiche

Abstract

Excessive precipitation produced severe flooding in a nine-State area in the upper Mississippi River Basin during spring and summer 1993. Following a spring that was wetter than average, weather patterns that persisted from early June through July caused the upper Midwest to be deluged with an unusually large amount of rainfall. Monthly precipitation data were examined at 10 weather-station locations in the flood-affected region to illustrate precipitation patterns and amounts in the flood-affected area. In 1993, all 10 of the selected locations received greater than the normal rainfall for January through June 1961–90, 8 of the 10 locations received more than 200 percent of the normal rainfall for July 1961–90, and 3 received more than 400 percent of the normal rainfall for July. (The average rainfall for any given 30-year period is termed the "normal" rainfall for the given period.) May through July 1993 was the wettest or nearly the wettest such period on record at many locations in the flooded area. Of the 10 locations, 6 received more rainfall in the first 7 months of 1993 than generally is received in a year.

INTRODUCTION

This report, one of a series that documents the effects of the 1993 flooding in the upper Mississippi River Basin, covers precipitation in the upper Mississippi River Basin from January 1 through July 31, 1993. As of August 1993, large storms continued to pass through the affected area; however, weather conditions indicate that the widespread flooding might be coming to an end. The floodwaters in the Mississippi River crested at St. Louis, Missouri, on August 1, while the river stages along the mainstem and on the principal tributary streams upstream from St. Louis were receding.

This report provides a general overview of the unusually excessive precipitation that produced severe flooding in a nine-State area in the upper Mississippi River Basin (fig. 1) during spring and summer 1993. A general overview of precipitation during the first 7 months of 1993 is presented and is followed by an analysis of monthly precipitation for 10 weather-station locations distributed throughout the flood-affected area. Weather patterns associated with two specific storm systems and the resulting rainfall totals are shown as examples of storms that occurred throughout the area.

Preparation of this report required cooperation among many persons in many organizations. The authors are particularly appreciative of the cooperation of State Climatologists and of persons in various State agencies and in the offices of the National Weather Service, National Oceanic and Atmospheric Administration, for making provisional data and maps available on a near real-time basis.

PRECIPITATION, JANUARY 1–JULY 31, 1993

General precipitation conditions throughout the nine-State area of the upper Midwest for the 7-month period ending in July are best summarized by the following news item from the Associated Press, July 17, 1993:

> The rain, of course, was the problem. Although much of the spring downpour fell on vast undammed tracts and could not be contained, the real culprit was the volume dumped by stalled weather systems. With the ground already saturated by spring rainfall, June was

the wettest month in the region since record keeping began. July has been just as soggy.

The Associated Press statement was accurate when written in mid-July but proved to be conservative. July ended up being much soggier than June.

Monthly Precipitation

Annual precipitation over the nine-State area affected by flooding (fig. 1) generally averages slightly more than 30 inches but ranges from about 16 inches in south-central North Dakota to about 40 inches in southern Missouri. Although precipitation is about evenly divided between the first and last halves of the year, the accumulation rates are not uniform throughout the year. Normally, 45 percent of the annual precipitation falls between April 1 and July 31; June precipitation represents about 15 percent (2–5 inches) of the average annual precipitation total.

Precipitation amounts recorded throughout the upper Mississippi River Basin during the first 7 months of 1993 generally were substantially greater than normal (January–July 1961–90). Although April-through-July precipitation was much greater than normal, little evidence early in the year indicated that precipitation amounts in 1993 would be above normal. January-through-March precipitation in the States of the upper Mississippi River Basin was near normal to slightly above normal. Because precipitation for those 3 months is often in the form of snow and generally totals less than 6 inches of moisture, potential flooding caused little concern. However, that situation began to change in April.

Precipitation in April and May over the area ranged from near normal to much greater than normal, but the areas of greatest precipitation differed for the 2 months. April rainfall was nearly twice the normal amounts in parts of Wisconsin and in Missouri but was only moderately above normal in much of the remainder of the flood-affected area. By contrast, May rainfall was more than twice the normal amounts for the month over an area that extended from southeastern South Dakota across Iowa to eastern Kansas. The largest storms, though, were still to come.

In early June, a weather pattern (fig. 2) developed that was characterized by a strong low-pressure system over the Western United States and a corre-

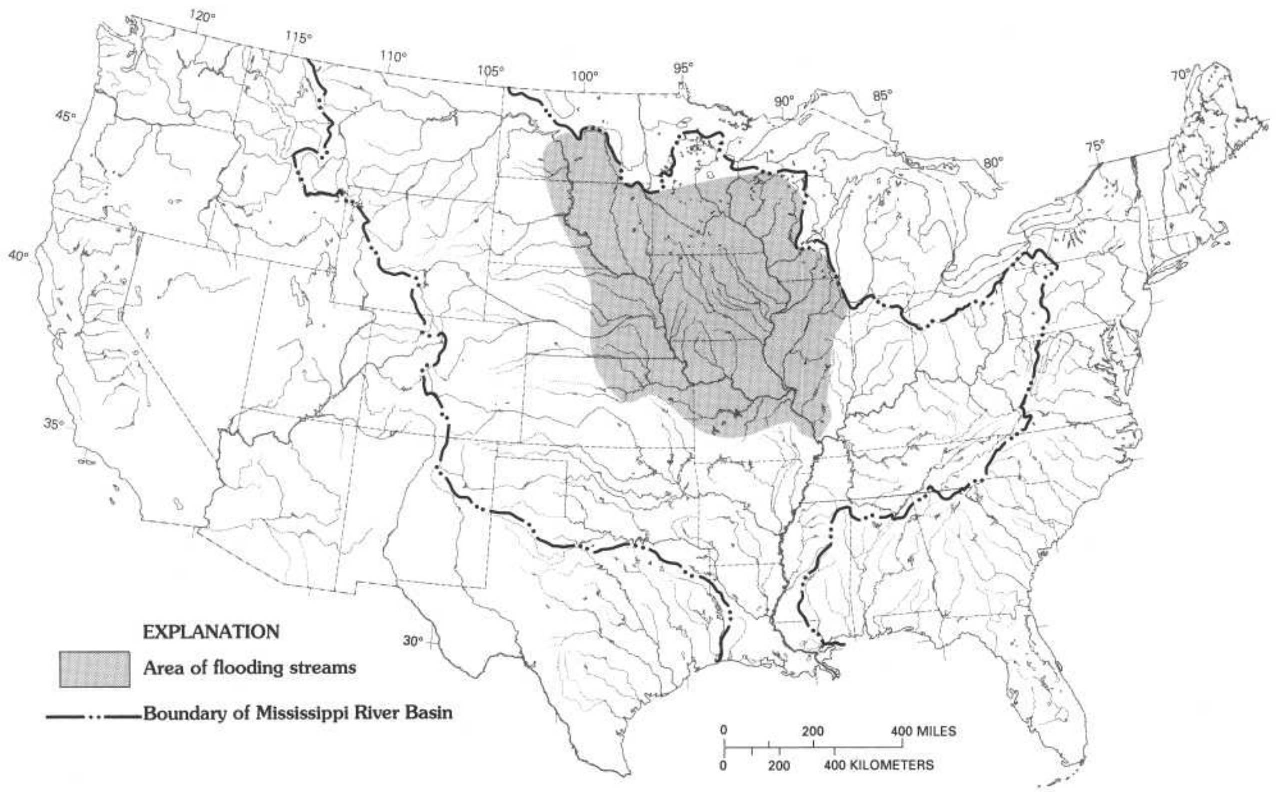


Figure 1. Mississippi River Basin and general area of flooding streams, June through August 1993 (from Parrett and others, 1993).

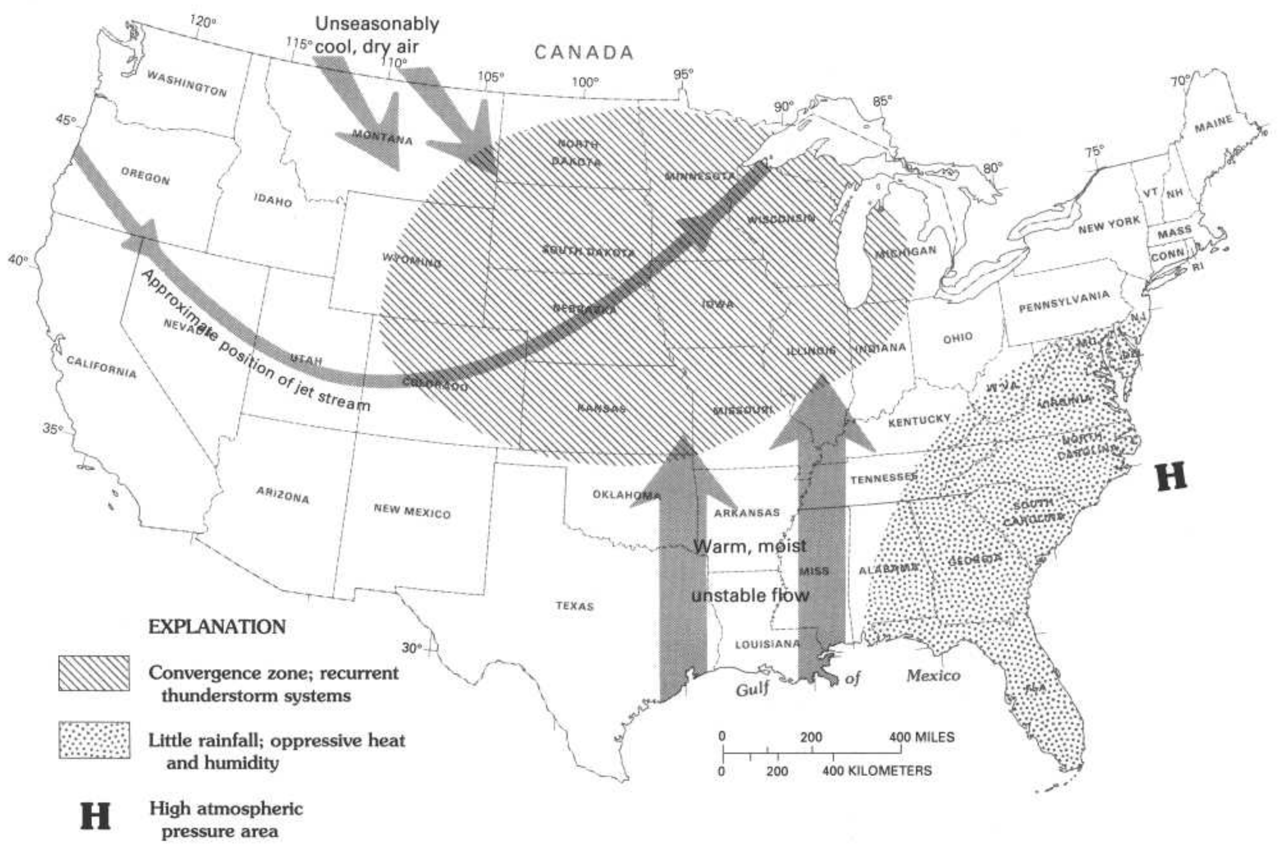


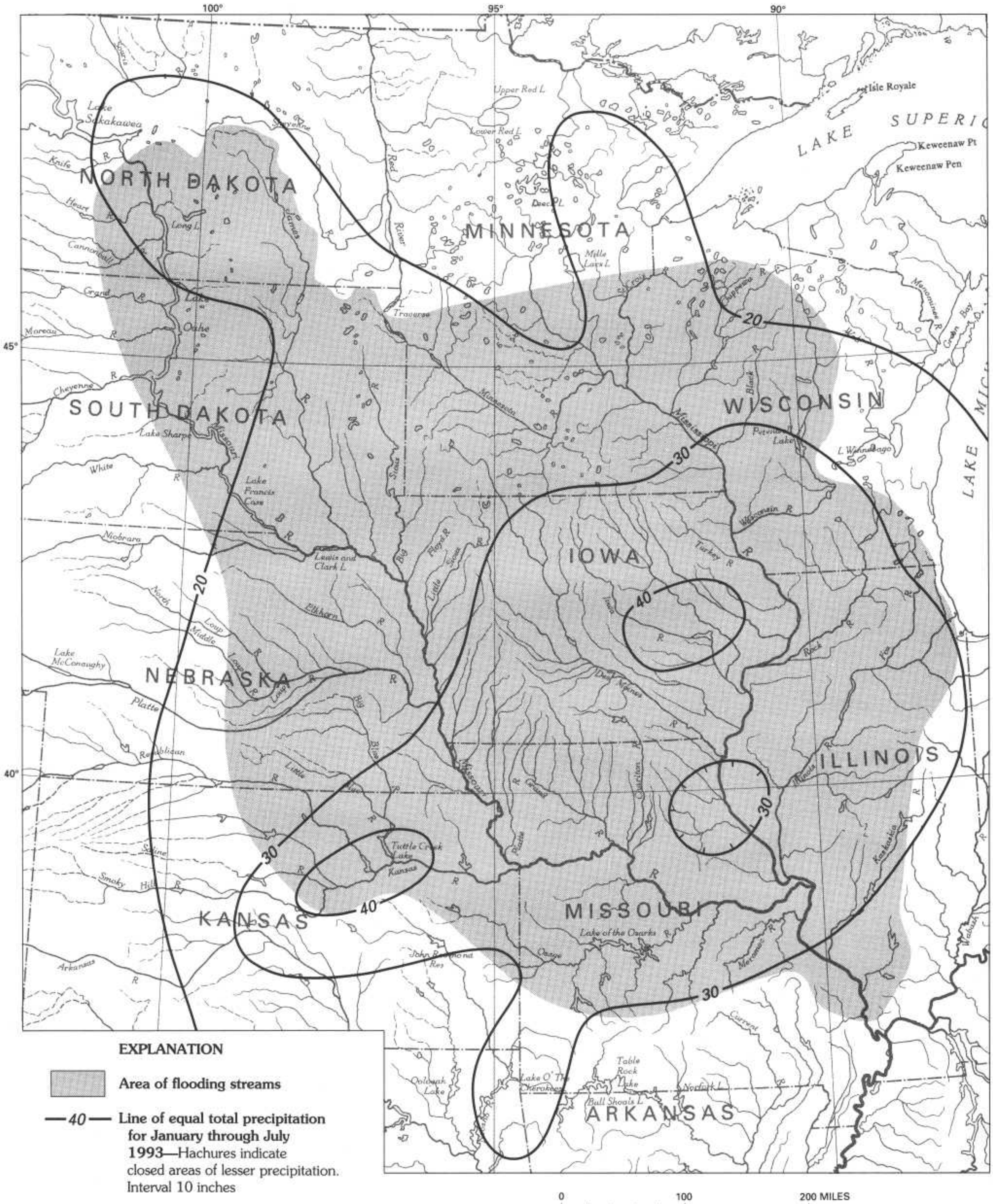
Figure 2. Dominant weather patterns over the United States for June through July 1993 (from National Weather Service, 1993).

sponding large high-pressure system positioned over the Southeastern United States. The jetstream dipped south over the Western United States and flowed northeasterly across the upper Midwest. A southeastern high blocked the eastward movement of storms, thus creating a convergence zone between the warm, moist flow from the Gulf of Mexico and the much cooler and drier air from Canada, which resulted in thunderstorms. This pattern persisted through most of June and July (National Weather Service, 1993). As a result, the upper Midwest within this convergence zone was deluged with rain while the Southeastern and the Eastern United States from Alabama to Vermont, under the influence of the high-pressure system, was very hot and dry. Slight movements in the atmospheric pattern determined the timing and location of the excessive rainfall throughout the upper Midwest.

The persistence of this weather pattern caused unusually large amounts of rain to fall over the upper Midwest. These large amounts and the wetter-than-normal spring produced flooding throughout the upper Mississippi River Basin, including the lower Missouri River Basin. The rains were extraordinary in the areal extent and in the amounts accumulated in the first 7 months of the year. Precipitation for the 7 months totaled more than 20 inches over most of the flood-affected area and was more than 40 inches in areas of northeast Kansas and east-central Iowa (fig. 3*A*). Most of the area received from 150 to 200 percent of the 1961–90 normal total amounts for January through July (fig. 3*B*; Parrett and others, 1993).

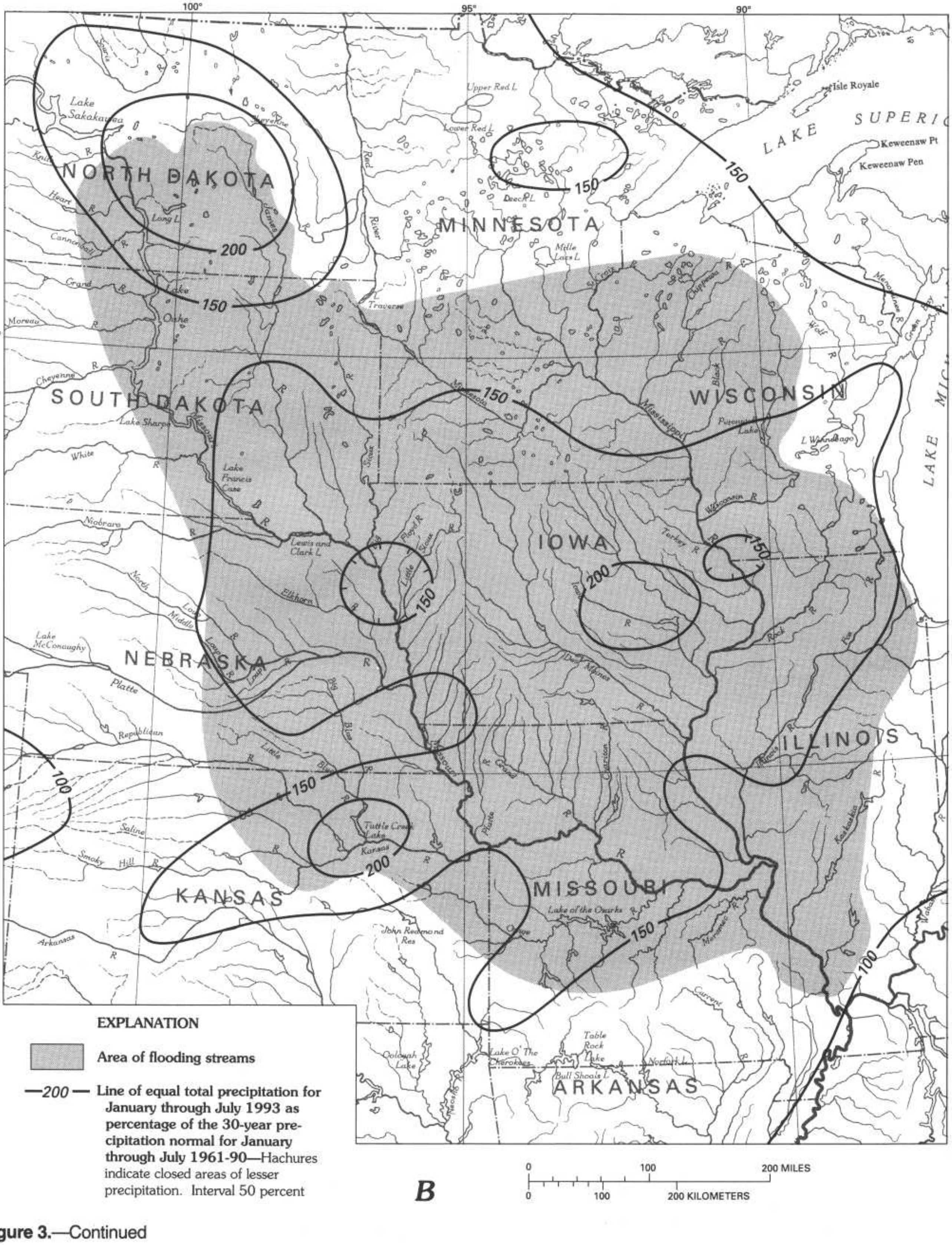
Monthly precipitation data for 1993 and the normal amounts for the period 1961 to 1990 are listed in table 1 (National Oceanic and Atmospheric Administration, 1992) and compared in figure 4 for 10 weather-station locations in the upper Mississippi River Basin. These locations—Bismarck, North Dakota, Sioux Falls, South Dakota, Minneapolis, Minnesota, Des Moines and Cedar Rapids, Iowa, Madison, Wisconsin, Peoria, Illinois, Manhattan, Kansas, and Kansas City and St. Louis, Missouri—are illustrative of precipitation patterns in the flood-affected area.

The significance of the July 1993 rainfall totals can best be understood by examining them in relation to the totals for the January-through-June period. All 10 of the selected locations received



A

Figure 3. Areal distribution of total precipitation in the area of flooding in the upper Mississippi River Basin, January through July 1993. *A*, In inches; *B*, In percentage of 30-year precipitation normal for January through July 1961–90 (from Parrett and others, 1993). Data were supplied by the National Weather Service (David Miscus, National Weather Service, written commun., 1993).



B

Figure 3.—Continued

Table 1. Summary of 1993 precipitation and 30-year averages (1961–90) at 10 weather-station locations in the upper Mississippi River Basin

[in., inches. National Oceanic and Atmospheric Administration (1992)]

	Bismarck, North Dakota	Sioux Falls, South Dakota	Minneapolis, Minnesota	Des Moines, Iowa	Cedar Rapids, Iowa	Madison, Wisconsin	Peoria, Illinois	Manhattan, Kansas	Kansas City, Missouri	St. Louis, Missouri
January:										
1993 (in.).............	0.29	0.70	1.25	1.59	1.18	1.60	3.55	0.98	1.96	3.54
Average (in.)........	.45	.51	.95	.96	1.01	1.07	1.51	.81	1.09	1.81
1993 (percent).......	64	137	132	166	117	150	235	121	180	196
February:										
1993 (in.).............	.33	.81	.39	1.52	1.11	1.18	1.68	1.12	1.28	2.75
Average (in.)........	.43	.64	.88	1.11	1.02	1.08	1.42	.93	1.10	2.12
1993 (percent).......	77	127	44	137	109	109	118	120	116	130
March:										
1993 (in.).............	.38	2.04	1.25	3.22	3.63	3.29	4.08	3.46	2.15	3.31
Average (in.)........	.77	1.64	1.94	2.33	2.32	2.17	2.91	2.36	2.51	3.58
1993 (percent).......	49	124	64	138	156	152	140	147	88	92
April:										
1993 (in.).............	1.26	2.61	1.99	2.96	3.86	5.33	4.89	1.88	5.59	6.16
Average (in.)........	1.67	2.52	2.42	3.36	3.19	2.86	3.77	2.95	3.12	3.50
1993 (percent).......	75	104	82	88	121	186	130	64	179	176
May:										
1993 (in.).............	2.36	8.26	4.02	7.51	5.43	3.81	3.25	10.99	7.30	3.94
Average (in.)........	2.18	3.03	3.39	3.66	3.71	3.14	3.70	4.56	5.04	3.97
1993 (percent).......	108	273	119	205	146	121	88	241	145	99
June:										
1993 (in.).............	4.57	6.43	6.28	7.68	8.79	6.67	5.70	6.83	5.67	7.12
Average (in.)........	2.72	3.40	4.05	4.46	4.55	3.66	3.99	5.54	4.72	3.72
1993 (percent).......	168	189	155	172	193	182	143	123	120	191
July:										
1993 (in.).............	13.75	7.86	5.58	9.75	17.03	9.34	10.15	17.56	10.90	5.06
Average (in.)........	2.14	2.68	3.53	3.78	4.11	3.39	4.20	3.28	4.38	3.85
1993 (percent).......	643	293	158	258	414	276	242	535	249	131
Seven months:										
1993 (in.).............	22.94	28.71	20.76	34.23	41.03	31.22	33.30	42.82	34.91	31.88
Average (in.)........	10.36	14.42	17.16	19.66	19.91	17.37	21.50	20.43	21.96	22.55
1993 (percent).......	221	199	121	174	206	180	155	210	159	141
Annual average........	15.47	23.86	28.32	33.12	33.72	30.88	36.25	33.82	37.62	37.51

more than 100 percent of the normal precipitation for January through June 1961–90 (fig. 5), and 8 locations received more than 130 percent of the normal precipitation for that period. By the end of June, the soil was saturated; then came the 1993 July deluge. Of the 10 locations, 8 received more than 200 percent of the normal rainfall for July (1961–90). Only Minneapolis (158 percent) and St. Louis (131 percent) did not receive 200 percent of the normal rainfall in July. Three locations, Bismarck, Cedar Rapids, and Manhattan, received from about 400 to about 650 percent of the normal rainfall amounts for July.

Total January-through-July rainfall for 1993 for each of the 10 locations was compared to the 1961–90 normals for the 7-month period and the annual total (fig. 6). Of the 10 locations, 6 received more rain in the first 7 months of 1993 than is generally received in a year, and 3 had nearly equaled their 1961–90 normal annual rainfall total. Only Minneapolis had some reprieve; only 121 percent of normal and 79 percent of the annual total was received during the first 7 months.

The National Weather Service (1993) computed statewide-average precipitation by month for 1895 to the present. They reported that the statewide averages for July 1993 were among the three wettest years since 1895 for eight of the nine States in the flood-affected area. May and June were among the wettest months for one-third of the years that have elapsed since 1895 for six and eight States, respec-

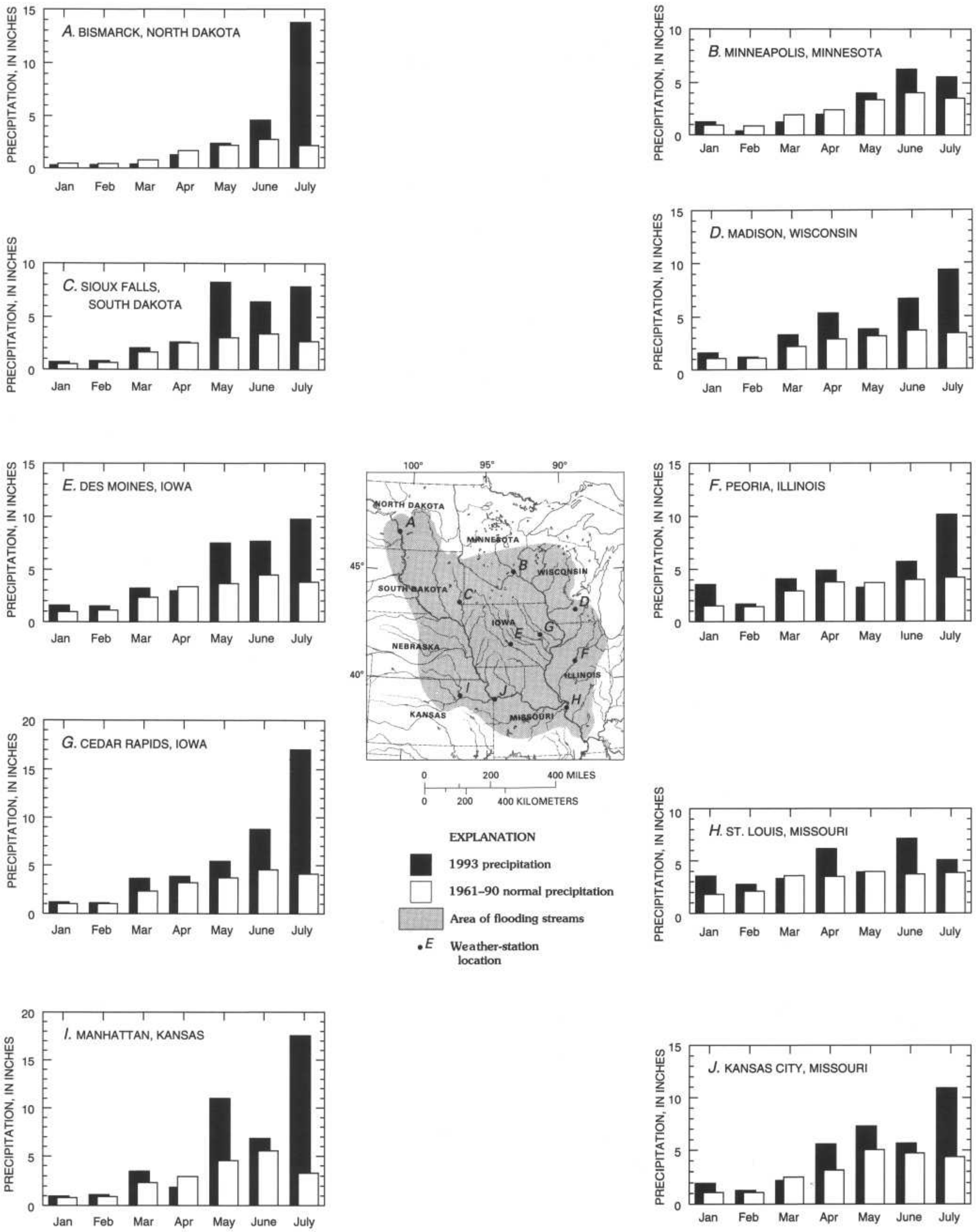


Figure 4. Monthly precipitation for January through July 1993 and 30-year monthly normals (January through July 1961–90) at 10 weather-station locations in the upper Mississippi River Basin. Data were supplied by the National Weather Service.

tively. Rainfall totals for the 3-month period (May through July) were computed for this report for Bismarck, Cedar Rapids, and Manhattan and were compared to period-of-record maximums for that 3-month period (table 2). At Bismarck and Cedar Rapids, May through July 1993 was the wettest such period in more than 100 years of recordkeeping. At Manhattan, May through July 1993 was the second wettest such period in 104 years of record; in 1951, the 3-month rainfall total was only 4 percent greater than that of 1993.

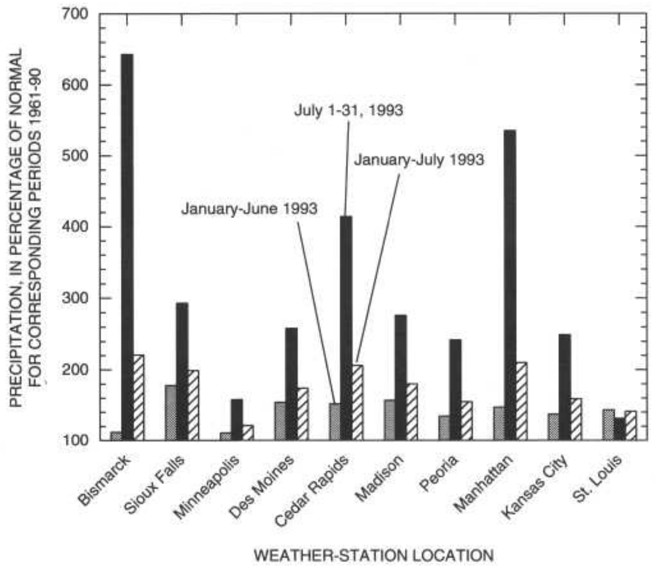


Figure 5. Seasonal precipitation for 1993 at 10 weather-station locations in the upper Mississippi River Basin. Data were supplied by the National Weather Service.

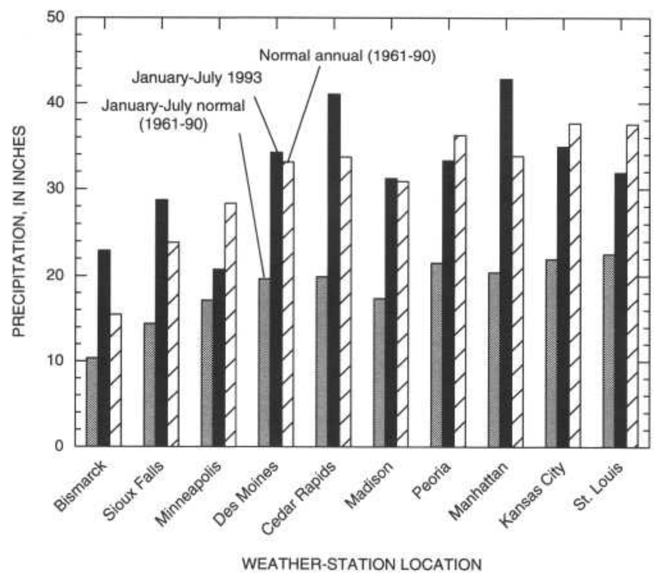


Figure 6. Precipitation for January through July 1993, normal precipitation for January through July 1961–90, and normal average precipitation for 1961–90 at 10 weather-station locations in the upper Mississippi River Basin. Data were supplied by the National Weather Service.

Table 2. Five greatest May-through-July precipitation totals at Bismarck, North Dakota, Cedar Rapids, Iowa, and Manhattan, Kansas

[Totals, in inches; record of lengths, in parentheses]

May-through-July precipitation totals					
Bismarck (119 years)		Cedar Rapids (112 years)		Manhattan (104 years)	
Year	Total	Year	Total	Year	Total
1993	**20.68**	**1993**	**31.25**	1951	36.73
1914	15.55	1969	25.44	**1993**	**35.38**
1915	14.15	1892	22.06	1915	28.15
1879	12.91	1990	21.89	1908	25.16
1927	12.02	1971	20.48	1977	22.71

Daily Accumulations

The rates of accumulation for 1993 daily precipitation are compared with historic values in figure 7. The historic values are the accumulated daily averages for the period 1961 to 1990 smoothed to pass through the month-end accumulated totals. The precipitation totals for January through July 1993 at all three locations were about 200 percent of normal for January through July 1961–90, but the rates at which the precipitation accumulated were different (fig. 7). Although the rate of accumulation at Bismarck was about normal through June, a dryer-than-normal January through March caused the amount of precipitation received to be slightly less than normal until the end of June. Three large storms, June 29 through July 1, July 15–16, and July 21–22, combined to produce the large seasonal totals. Precipitation at Manhattan followed a pattern similar to that of Bismarck, except that several large storms came earlier in the year. Manhattan's large seasonal total resulted primarily from precipitation during four distinct periods: March 29 through 31, May 7 through 11, July 1–2, and July 18 through 22.

The rate of accumulation of precipitation at Cedar Rapids was different from that at either Bismarck or Manhattan. Although large storms, such as that for July 4–5, contributed to the excessive moisture, the rate of accumulation was greater than normal after mid-March. Unlike Bismarck and Manhattan, the rate reflected the accumulation of many small-to-moderate precipitation amounts and shows the effects of widespread storms over the entire area.

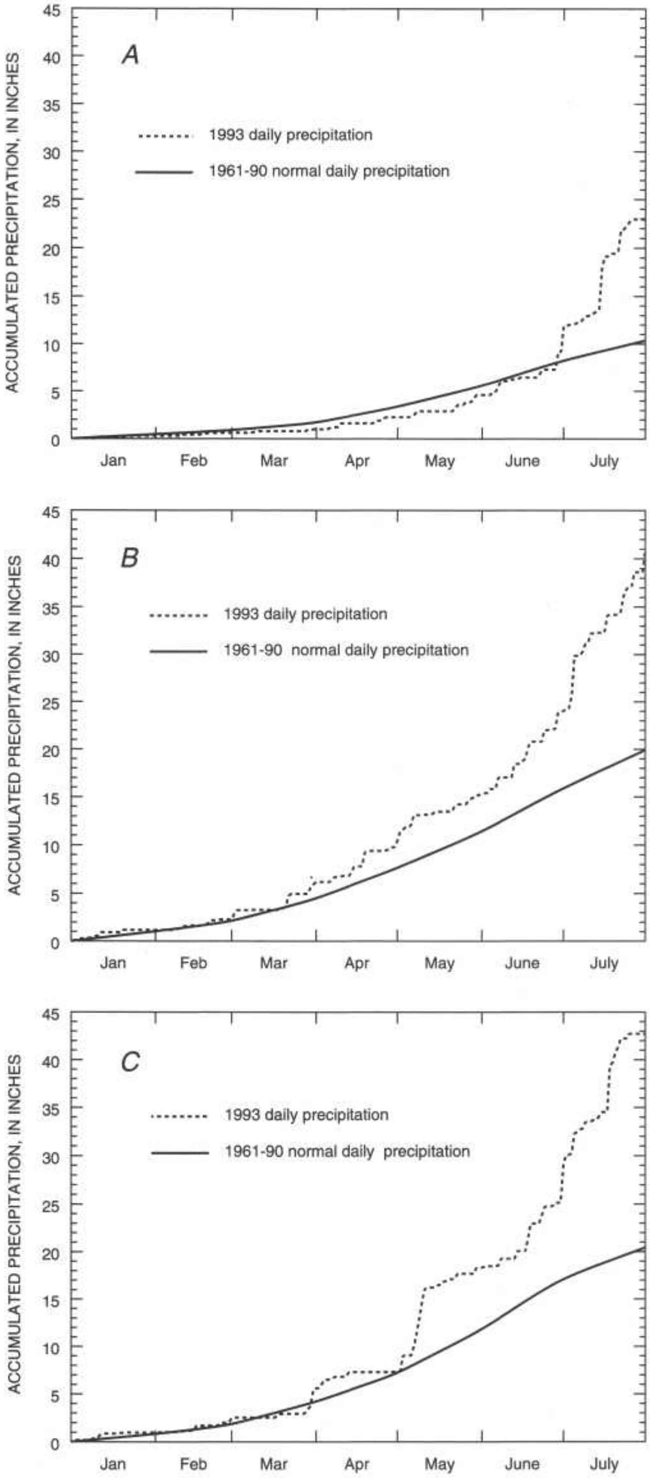


Figure 7. Accumulated daily precipitation for January through July 1993 and accumulated normal daily precipitation for January through July 1961–90. *A*, Bismarck, North Dakota; *B*, Cedar Rapids, Iowa; *C*, Manhattan, Kansas. Data were supplied by the National Weather Service.

Distribution of July Precipitation

Much of the severe flooding in the upper Mississippi River Basin in 1993 was the culmination of the wet spring and a series of storms in July. Daily rainfall totaled more than 4.00 inches at many locations in July. Thus, flooding was influenced not only by wet antecedent conditions and large rainfall totals, but also by the way July daily rainfall was distributed. Maximum 1- and 3-day rainfall totals for July at Bismarck, Cedar Rapids, and Manhattan are similar (table 3). Maximum 5-day rainfall totals are similar at Bismarck and Cedar Rapids, but the maximum 5-day rainfall total at Manhattan was about 1.6 inches greater than at Bismarck and Cedar Rapids (table 3). Based on the data in table 3, the maximum 1-day July rainfall totals were greater than the total normal July rainfall at many locations throughout the flooded area.

Table 3. Maximum 1-, 3-, and 5-day rainfall totals for July 1993 at Bismarck, North Dakota, Cedar Rapids, Iowa, and Manhattan, Kansas

[Totals, in inches]

	Rainfall		
	1-day	3-day	5-day
Bismarck................	4.32	5.74	6.18
Cedar Rapids...........	4.18	5.55	6.01
Manhattan...............	4.81	5.56	7.70

Analysis of Selected Storms

Several storms in July produced large amounts of rainfall in the area of flooding. Two of the larger storms are described in detail.

Southeastern Iowa, July 4–5

The storm of July 4–5 produced copious amounts of rainfall and added to the flooding over southeastern Iowa. This storm was only one in a series that passed over Iowa and other areas of the upper Mississippi River Basin during June and July.

Average weather conditions over the Central United States during the July 4–5 storm are depicted in figure 8. A large high-pressure system was positioned over the Southeastern United States while an area of warm, moist air flowed into the Midwestern United States as a result of the circulation around the southeastern high and the low-pressure system in southern Canada. Furthermore, a stationary front

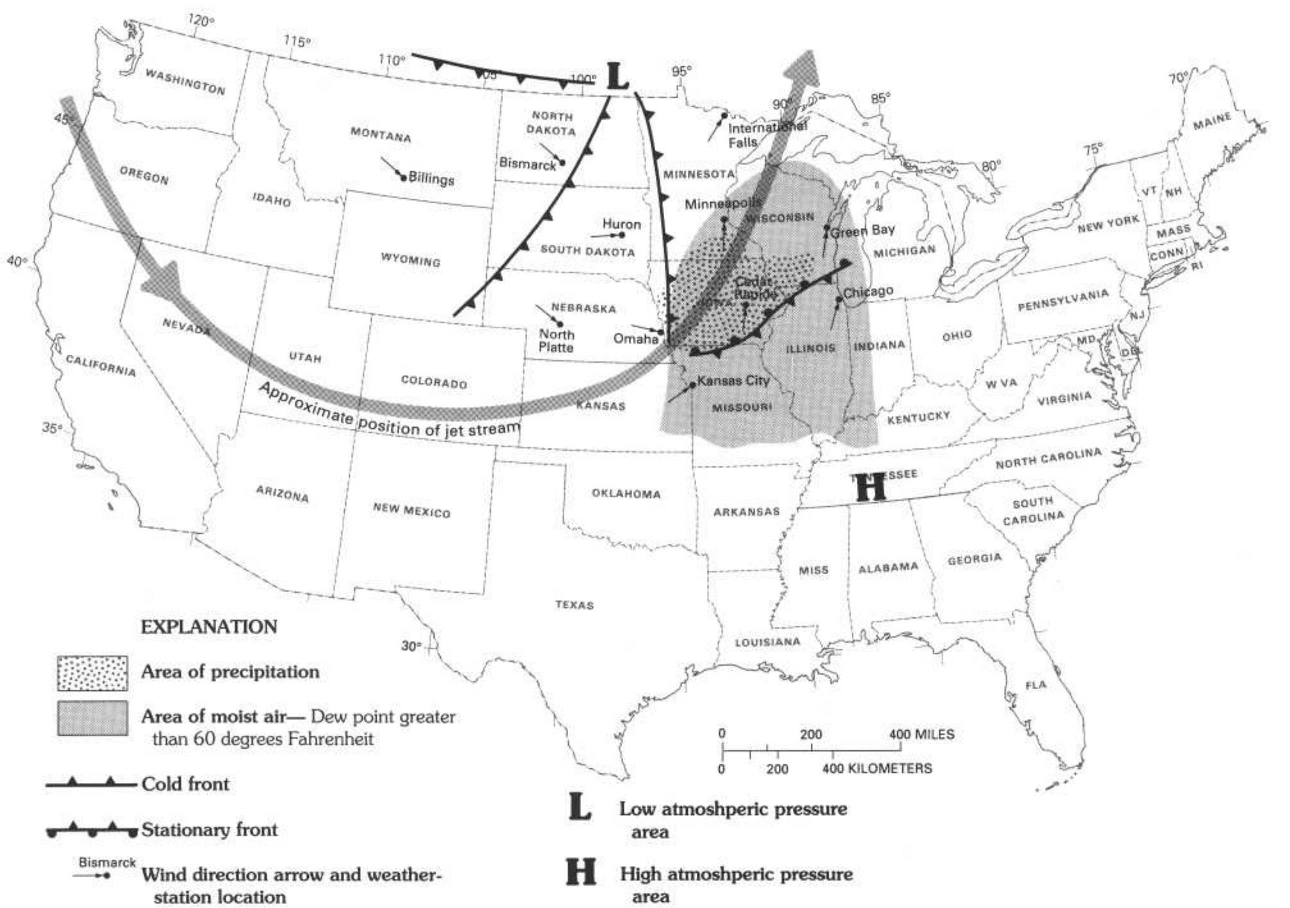


Figure 8. Average weather patterns over the United States for July 4–5, 1993. Data were supplied by the National Weather Service.

extended from northern Missouri across southeastern Iowa to southern Wisconsin, and a series of cold fronts rotated cyclonically around the low into western Iowa. The dense air behind each cold front lifted the lighter warm air ahead of it, and as each front collided into the warm air over Iowa, thunderstorms formed. Rain fell over much of Iowa, southern Minnesota, and southern Wisconsin. Aiding the production of rain was a strong area of vorticity in the middle atmosphere (about 18,000 feet above sea level), which created additional lift for thunderstorm development. (Vorticity is an incipient storm that contains enhanced cyclonic spin and associated upward motion.) This area of vorticity began over Kansas and Nebraska just to the west of the cold front in western Iowa and proceeded over Iowa from the southwest. The jetstream that passed directly over Iowa from southwest to northeast also aided the production of rain and created what is called the chimney effect in which strong winds in the upper atmosphere blow across the region of thunderstorm development. The effect of the winds was to evacuate air from the top of thunderstorms, which created an updraft. Thus, more warm, moist air was then drawn up into the thunderstorms, and copious amounts of rain were produced. As the storm moved northeastward at about 10 to 20 miles per hour, new thunderstorms formed to the southwest of the original thunderstorms and passed over the same areas, thus adding to the large rainfall totals.

Rain from the July 4–5 storm fell across Iowa; one-third of the State received more than 2 inches total (fig. 9). The greatest amounts of rain fell in the south- and east-central parts of the State. Rainfall totals from the storm exceeded 4 inches in a 50- to 100-mile-wide band from Lamoni to Cedar Rapids and Dubuque. The occurrence of many storms in the span of a few days led to the extensive and severe flooding throughout much of Iowa, most notably in Des Moines and Cedar Rapids and along the main-stem of the Mississippi River.

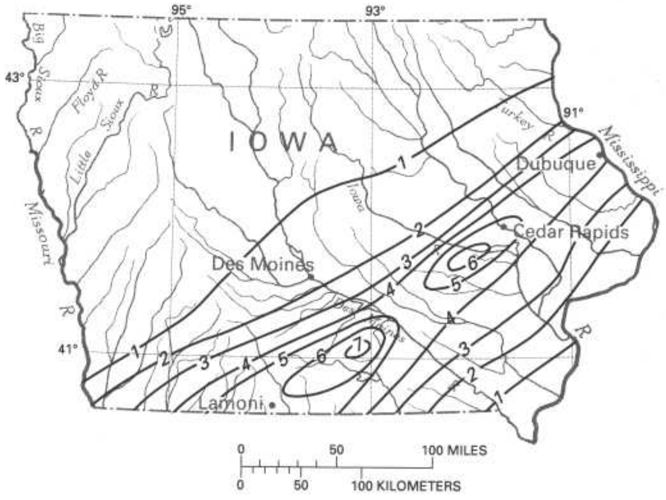


Figure 9. Areal distribution of rainfall for the July 4–5, 1993, storm in Iowa. Data were supplied by the National Weather Service.

North Dakota and Minnesota, July 15–16

During July 15–16, 1993, thunderstorms that produced large amounts of rain moved slowly from western North Dakota to west-central Minnesota. Urban and stream flooding were considerable along this path. Meteorological conditions that caused these rains were part of the overall pattern responsible for heavy rains in the upper Midwest throughout the summer.

Average weather patterns over the North-Central United States during the July 15–16 storm are depicted in figure 10. A warm front extended across northern South Dakota while an area of warm, moist air was drawn over the front on southerly winds of 5 to 15 miles per hour by a developing low-pressure system over Montana. Thunderstorms formed in south-central North Dakota by late evening of July 14 and produced moderate amounts of rain before the storms moved quickly towards the northeast. However, the weather patterns that produced heavy rainfall remained in place.

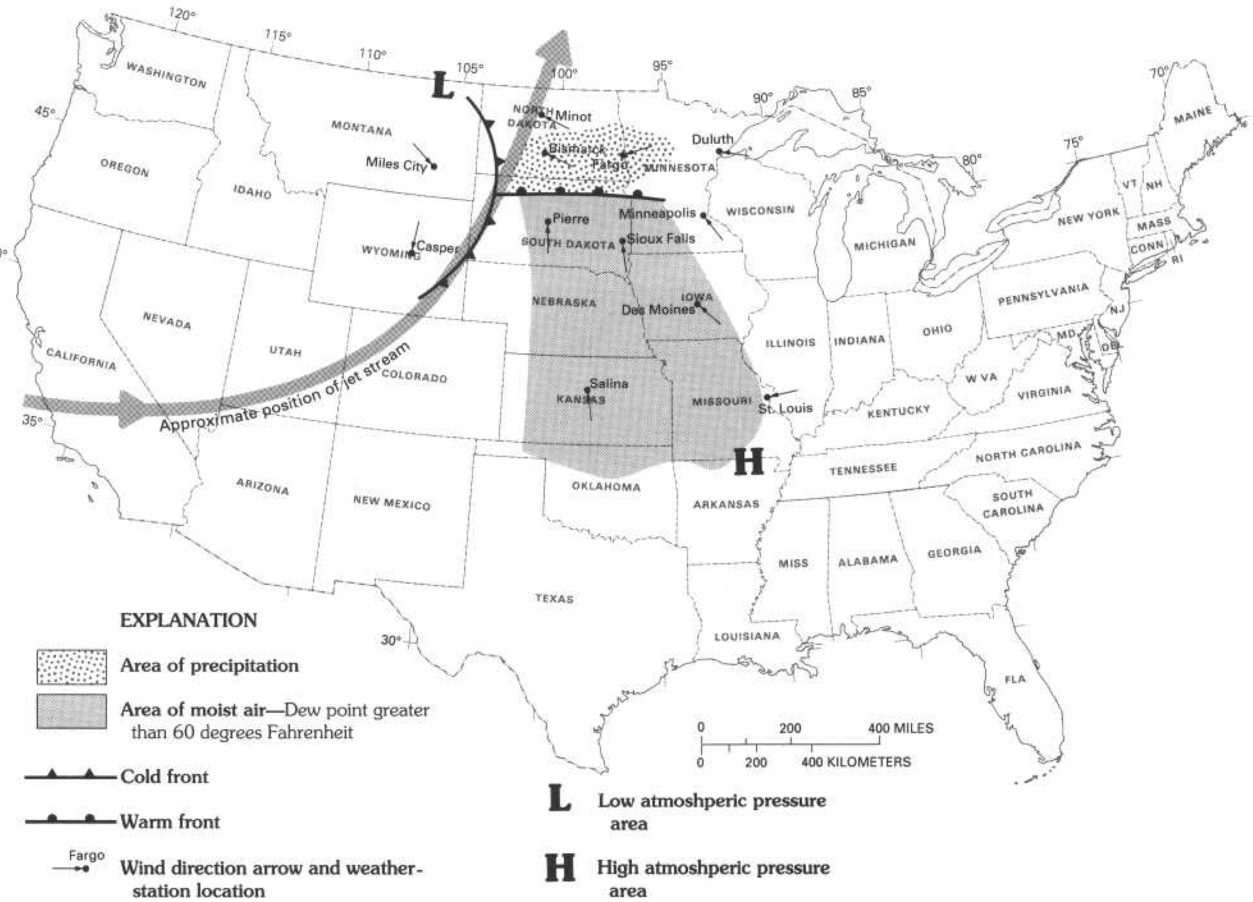


Figure 10. Average weather patterns over the United States for July 15–16, 1993. Data were supplied by the National Weather Service.

A cold front entered North Dakota from Montana during the morning of July 15 and increased atmospheric instability. A series of vorticity maxima (incipient storms) at 18,000 feet above sea level also approached North Dakota from the southwest and provided additional lift and cyclonic motion for the formation of thunderstorms. By midafternoon of July 15, all the above conditions—moist air, frontal boundaries, vorticity maxima—collided over Bismarck. Thunderstorms formed and produced large amounts of rain and considerable flooding. The storms moved slowly towards the east at only 10 to 15 miles per hour, which permitted large amounts of rain to fall. The continued flow of moisture from the south over the warm front and the lifting caused by the western cold front maintained the large rainfalls. Intense rain continued along a 50-mile-wide path from Bismarck to Fargo, North Dakota, and into west-central Minnesota during the early hours of July 16. Rainfall reports of 4 to 7 inches were common along this path (fig. 11). Bismarck had a record 24-hour rainfall total of 5.27 inches by the afternoon of July 16. Officially, the greatest rainfall total from North Dakota was 7.25 inches at Jamestown. The greatest rainfall observed in Minnesota was an unofficial total of 7.50 inches at Callaway.

SUMMARY

Excessive precipitation during April through July produced severe flooding in a nine-State area in the upper Mississippi River Basin during spring and summer 1993. Precipitation in May was more than twice the normal (1961–90) amount over an area that

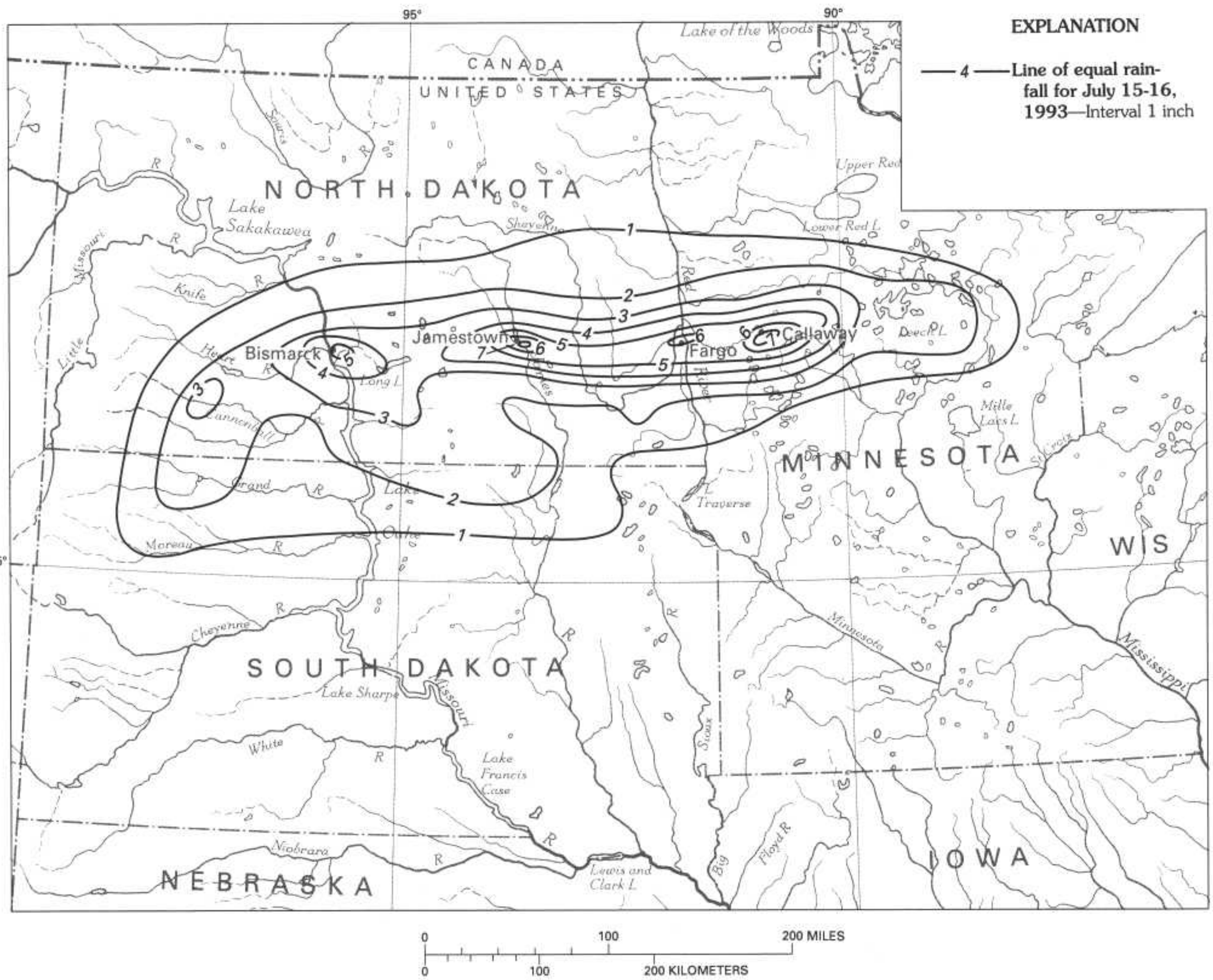


Figure 11. Areal distribution of rainfall for the July 15–16, 1993, storm in North Dakota, South Dakota, and Minnesota. Data were supplied by the National Weather Service.

extended from southeastern South Dakota across Iowa to eastern Kansas. In early June, weather patterns combined to produce a convergence zone over the upper Midwest between the warm, moist air from the Gulf of Mexico and the much cooler, drier air from Canada. These weather patterns persisted until the end of July. As a result, the upper Midwest was deluged with rain while the Southeastern and the Eastern United States, under the influence of a high-pressure system, was hot and dry. The persistence of this weather pattern caused unusually excessive rains that, together with the wetter-than-normal spring, produced severe flooding throughout the region.

Monthly precipitation data at 10 weather-station locations in the flood-affected area were used to illustrate precipitation patterns and amounts. In 1993, all 10 of the selected locations received greater than the normal (1961–90) precipitation for January through June, 8 received more than 200 percent of the normal July rainfall; and 3 received from about 400 to about 650 percent of the normal rainfall for July. May through July 1993 was the wettest or nearly the wettest such period on record at many locations in the flooded area. Of the 10 locations, 6 received more rain in the first 7 months of 1993 than is generally received in a year.

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