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THE SPRING FLOODS OF 1922

BY

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FOREWORD.

It is the purpose of this report to preserve in permanent form some history of the floods of the spring of 1922 in the Great Basin of the Mississippi River.

The report will be limited strictly to the original purpose of presenting in convenient and compact form data bearing upon the causes of the floods, their character, extent, duration, and effects, together with such other matters of scientific and general interest as may pertain to the subject. After the facts have been set forth it may be possible to formulate some general conclusions that will be of value in connection with future studies of Mississippi River flood problems.

Acknowledgment is made of the efficient services of Mr. Earl W. Graeff of the River and Flood Division, who assisted greatly in the compilation and computation of the masses of data that were used.

Chart I. Drainage Basin of the Mississippi River.

THE SPRING FLOODS OF 1922 IN THE MISSISSIPPI DRAINAGE BASIN.

OUTSTANDING FEATURES.

The floods of the year 1922 in the Mississippi Drainage Basin established a new epoch in the history of that region in at least two particulars.

First, in the extremely general distribution of the floods, the main stream and all of its principal tributaries, except the Tennessee and the Cumberland, having been in flood at the same time. In the two excepted streams very high stages had also prevailed during the early days of the flood. So far as history and tradition show the main stream and all its tributaries have never been in flood at the same time, the usual case being that one or more of the western tributaries failed to attain full flood stages, but during the present year the latter were high, although the Red was only moderately so, while at the same time the Kentucky, Green, White, Wabash, Illinois, lower Ohio, lower Osage, lower Missouri, and the Mississippi from Alton to Cairo, Ill., were also high, with the highest stages of record in the Illinois. As stated before, the only exceptions were the Tennessee and the Cumberland, where there was but a single, although a great rise, which occurred early in the flood period.

The distribution of the rainfall was, of course, responsible for the failure of these two important streams, but had another heavy rain occurred at an opportune time, opportune only so far as flood causation is concerned, the stages from Paducah, Ky., to the Passes, crevasses not considered, would have been still higher than those actually recorded. This point is emphasized on account of its essential bearing upon the problem of still more effective future control of flood waters.

Second, the 1922 flood was exceptional in the unprecedently high stages reached in the lower Mississippi River from the mouth of the Arkansas to the Passes, due to the enormous volumes of water from the western tributaries, especially the Arkansas and the White, which, although not as high as in some previous years (1892, 1912, and 1916), remained at high stage much longer than usual. Had all levees remained intact, the average stages of the 1922 flood over those of previous years would probably have been about 1 foot higher over the district indicated. The excess at Arkansas City, Ark., over the previous high stage of February 10, 1916, was 1.6 feet, but the United States Engineer Corps estimated that about 1 foot of this excess was due to the closure during 1921 of Cypress Creek, a short distance above Arkansas City—that is, the closure of this creek threw about 1 additional foot of water on the Arkansas City gage. Below Vicksburg, Miss., the excess over previous stages was greater, except at New Orleans, where it was only 0.3 foot. The flow from Red River also accounted for some of the excess below its mouth, and the excess at New Orleans would certainly have been greater than 0.3 foot had not the crevasse at Poydras, La., 14 miles below New Orleans, checked the rise at a stage of 22.3 feet with a steadily rising river above.

DRAINAGE BASIN OF THE MISSISSIPPI RIVER.

A diagram of this basin will be found on Chart I. A comprehensive description of the same will be found in Bulletin E, Weather Bureau, 1897. The grand divisions are as shown in the following table and are slightly different from those given in Bulletin E.

TABLE 1.—*Grand divisions of the Mississippi Basin.*

Designations.	Area in square miles.	Ratio to whole basin.
Ohio Basin	203,900	0.16
Upper Mississippi Basin	172,000	0.14
Lower Mississippi Basin	70,150	0.06
Missouri Basin	528,850	0.43
Arkansas Basin	175,700	0.14
Red Basin	90,000	0.07
Total	1,240,600	1.00

RIVER FLUCTUATIONS AND FLOOD FREQUENCY.

Available data.—Beginning with the year 1871, daily river data are quite complete for many places in the drainage basin of the Mississippi River. At a number of stations the daily data are available for 10 or more years previous to 1871. The oldest records in the possession of the Weather Bureau are those for Wheeling, W. Va., which extend back to March, 1838, with, however, only partial records from 1850 to 1868, inclusive. The record at Pittsburgh is continuous from August, 1854, and at Cincinnati from June, 1858. At Cairo the daily record covers the period from November, 1871, to date, with almost complete data from November, 1864, to August, 1868, inclusive, and fragmentary data from January, 1858, to July, 1864, inclusive. At St. Louis the data are complete from January, 1861, to date, except that those for Sundays are missing previous to August, 1872. So far as is known there are no earlier records at any places except those of some very great floods.

In the table following are given the crest stages and dates of occurrence of many floods in the Ohio River and in the Mississippi River below the mouth of the Missouri. This table was compiled with a principal object of recording comparative data in such form as to show the progressive downstream movements of flood crests. All great floods are shown, but some of the minor ones were omitted for the reason that they were more or less local in character—that is, flood stages did not prevail over either the entire river or even a considerable portion thereof.

With one exception the stations were selected so as to include the effects of the great tributaries at the nearest points below their junctions with the main streams. Below the mouth of Red River, New Orleans was selected as indicative of the combined effects of both main streams and tributaries.

TABLE 2.—*Crest stages and progressive flood movements during Ohio and Mississippi River floods.*

Year.	Pittsburgh, Pa.	Wheeling, W. Va.[1]	Cincinnati, Ohio.	St. Louis, Mo.	Cairo, Ill.	Memphis, Tenn.	Vicksburg, Miss.	New Orleans, La.
1762	36.0							
	Jan. 9							
1763	37.9							
	Mar. 9							
1826				33.7				
1832	35.0		64.2					
	Feb. 10		Feb. 19					
1840		38.0						
		Feb. 11						
1844				41.4				
				June 28				
1847		38.5						
		Dec. 15						
1858	24.0							
	May 27							
1859	22.0		51.2		46.5			
	Apr. 27		May 1		May 7			
1860	29.0		49.1		32.2			
	Apr. 12		Apr. 17		Apr. 24			
1861	31.0		41.8					
	Sept. 29		Oct. 2					
1862	30.0	40.5	57.3	31.4				
	Jan. 21	Jan. 21	Jan. 24	Apr. 26				
1865	24.0	33.0	56.2		47.9			
	Mar. 5	Mar. 4	Mar. 8		Mar. 18			
1867	26.5	32.0	55.7	20.4	51.0			
	Mar. 13	Mar. 14	Mar. 15	Mar. 15	Mar. 20			
1870	18.0	30.0	55.2					
	Jan. 19	Jan. 18	Jan. 19					
1873	16.8	25.8	41.5		42.6	32.5	39.7	
	Feb. 17	Feb. 18	Feb. 21		Feb. 26	Mar. 3	Mar. 11	
1875	21.0	29.2	55.4	29.9	45.2	33.0	40.8	11.4
	Aug. 3	Aug. 4	Aug. 6	Aug. 3	Aug. 7	Aug. 15	Aug. 16	Aug. 30
1876	14.5	24.1	51.8		45.2			
	Jan. 30	Jan. 30	Jan. 29		Feb. 4			
			40.5	24.2	46.4	34.0	43.8	
			Mar. 31	Apr. 6	Apr. 6	Apr. 7	Apr. 15	
				32.5	42.2	32.7	44.9	13.4
				May 10	May 14	May 18	May 10	May 8
1877	24.5	30.0	53.8		37.0	28.7	36.3	9.0
	Jan. 17	Jan. 18	Jan. 20		Jan. 27	Jan. 30	Feb. 6	Feb. 8
1880	21.6	32.0	53.2	11.6	43.4	32.3		
	Feb. 14	Feb. 15	Feb. 17	Feb. 20	Feb. 24	Feb. 29		
1881	23.2	38.8	50.8		42.5	31.6	41.8	14.0
	Feb. 11	Feb. 12	Feb. 16		Feb. 24	Mar. 1	Mar. 9	Mar. 16
	18.5	27.5	41.7		45.8	33.2		
	Apr. 14	Apr. 15	Apr. 17		Apr. 19	Apr. 26		
				33.6	42.7			
				May 5	May 9			
	27.1	39.5	35.0	24.7	30.9	22.8	31.5	11.8
	June 9	June 11	June 15	June 21	June 22	June 24	July 1	July 1
1882	21.1	31.1	58.6	28.2	51.9	35.2	48.8	15.8
	Feb. 22	Feb. 23	Feb. 21	Feb. 22	Feb. 26	Mar. 6	Mar. 20	Mar. 27
				32.2	38.8	30.0		
				July 5	July 8	July 12		
1883	28.0	35.5	66.3	26.2	52.2	34.8	43.1	16.2
	Feb. 8	Feb. 8	Feb. 15	Feb. 26	Feb. 26	Mar. 5	Mar. 14	Apr. 7
				34.8	39.7	30.2	39.6	13.6
				June 25	July 1	July 1	July 10	July 9
1884	33.3	52.1	71.1	15.8	52.0	34.1	49.0	16.3
	Feb. 6	Feb. 7	Feb. 14	Feb. 19	Feb. 23	Feb. 29	Mar. 25	Mar. 18
1886	22.2	33.0	55.8	23.7	51.0	34.7	44.2	14.3
	Apr. 7	Apr. 7	Apr. 9	Apr. 21	Apr. 19	Apr. 26	May 7	May 15
1887	21.9	33.9	50.3		47.2			
	Feb. 12	Feb. 13	Feb. 18		Feb. 28			
			54.6		48.6	35.4	44.7	15.1
			Mar. 1		Mar. 9	Mar. 10	Mar. 26	Apr. 9
1888				25.6	45.3	34.2	44.2	14.9
				Mar. 28	Apr. 3	Apr. 10	Apr. 26	Apr. 26
1890	18.8	24.9	56.5		48.8	35.6	48.0	16.7
	Feb. 21	Feb. 22	Feb. 28		Mar. 12	Mar. 15	Mar. 15	Mar. 21
	24.3	33.0	59.2		48.7	35.6	49.0	14.7
	Mar. 23	Mar. 24	Mar. 25		Apr. 3	Apr. 4	Apr. 23	May 1
1891	31.3	44.6	57.3		46.2	34.9	48.1	16.6
	Feb. 18	Feb. 19	Feb. 25		Mar. 4	Mar. 10	Apr. 2	Mar. 17
1892				36.0	46.0	34.4	48.4	17.6
				May 19	May 25	June 2	June 2	June 11
1893	23.1	32.1	54.9	11.2	44.9	33.1	42.4	13.9
	Feb. 8	Feb. 12	Feb. 20	Feb. 28	Feb. 28	Mar. 3	Mar. 13	Mar. 18
			51.0	31.5	49.3	35.2	48.3	
			May 7	May 3	May 9	May 15	May 22	
				28.0	43.3	33.5		17.9
				June 4	June 6	June 11		June 24
1897	29.5	38.7	61.2		48.6	37.1		
	Feb. 24	Feb. 24	Feb. 26		Mar. 11	Mar. 19		
1897			50.1		51.6	36.4	52.5	19.3
			Mar. 12		Mar. 25	Apr. 1	Apr. 16	Apr. 29
				31.0	37.6			
				May 2	May 4			
1898	19.7	27.5	52.2		44.4	33.6	43.0	15.0
	Jan. 24	Jan. 25	Jan. 26		Jan. 31	Feb. 3	Feb. 12	Feb. 17
	28.5	44.6	61.4	25.2	49.8	37.3	49.4	17.0
	Mar. 24	Mar. 24	Mar. 29	Mar. 24	Apr. 6	Apr. 11	Apr. 23	May 1
1899	22.0	28.2	57.4	19.8	46.0	35.3	47.3	17.2
	Mar. 6	Mar. 7	Mar. 8	Mar. 22	Mar. 24	Mar. 30	Apr. 16	Apr. 22
1901	27.4	41.8	59.7		43.2	32.1	41.5	14.2
	Apr. 21	Apr. 21	Apr. 26		May 2	May 6	May 15	May 14
1902	32.4	43.3	50.9	13.4	42.2	30.8	40.8	14.9
	Mar. 1	Mar. 2	Mar. 5	Mar. 17	Mar. 17	Mar. 20	Mar. 30	Apr. 19
1903	24.0	34.6	49.4		43.6			
	Feb. 5	Feb. 6	Feb. 7		Feb. 17			
	28.9	40.2	53.2	25.8	50.6	40.1	51.8	20.4
	Mar. 1	Mar. 2	Mar. 5	Mar. 11	Mar. 15	Mar. 20	Mar. 27	Apr. 6
				38.0	43.4	33.0	43.1	15.4
				June 10	June 13	June 18	June 24	July 3
1904				25.2	49.1	39.0	46.9	17.6
				Mar. 30	Apr. 5	Apr. 10	Apr. 24	May 2
				33.6	42.0	32.2		
				Apr. 29	May 6	May 8		
1906	18.8	27.5	50.2	25.7	46.9	37.1	47.2	17.3
	Apr. 1	Apr. 1	Apr. 2	Mar. 31	Apr. 9	Apr. 16	Apr. 26	May 3
1907	23.2	36.9	65.2		50.4	39.0	49.7	14.5
	Jan. 20	Jan. 20	Jan. 21		Jan. 27	Jan. 31	Feb. 11	Feb. 9
	35.5	50.1	62.1		46.2	35.5	45.3	17.3
	Mar. 15	Mar. 15	Mar. 18		Mar. 24	Mar. 30	Apr. 9	Apr. 13
				21.3	38.5	31.0	45.5	18.0
				May 18	May 18	May 20	May 27	May 31
1908	30.7	42.8	51.3	17.4	44.9	35.1		
	Feb. 16	Feb. 17	Feb. 20	Feb. 28	Feb. 26	Mar. 3		
	20.5	31.6	53.4	21.0	45.6	35.6	46.9	18.1
	Mar. 8	Mar. 8	Mar. 11	Mar. 10	Mar. 18	Mar. 23	Mar. 31	Apr. 9
			55.9	20.1	45.3	35.2	47.5	19.1
			Apr. 4	Apr. 13	Apr. 13	Apr. 20	Apr. 27	May 6
				34.9	35.5			
				June 20	June 21			
1909	22.3	33.9	54.6		46.8	38.1	40.6	17.9
	Feb. 25	Feb. 25	Feb. 28		Mar. 6	Mar. 14	Mar. 26	Apr. 3
				22.6	47.3	38.6	48.1	17.7
				Mar. 13	Mar. 17	Mar. 22	Apr. 2	Apr. 9
				35.2	43.4	33.7	40.7	14.6
				July 15	July 18	July 23	Aug. 1	Aug. 7
1910				31.9	32.4			
				Jan. 13	Jan. 16			
	22.0	37.4	51.8		45.4	33.1	40.6	14.4
	Mar. 1	Mar. 3	Mar. 7		Mar. 15	Mar. 18	Mar. 26	Mar. 26
1911			41.6		45.4	36.5	44.8	16.0
			Apr. 14		Apr. 20	Apr. 26	May 5	May 16
1912	28.1	38.6	53.4	29.8	52.5			
	Mar. 22	Mar. 22	Mar. 27	Mar. 31	Mar. 31			
	20.0	30.9	51.7	30.8	54.0	45.3	52.1	20.4
	Apr. 3	Apr. 4	Apr. 5	Apr. 5	Apr. 6	Apr. 6	Apr. 12	Apr. 17
				30.2	49.3	38.9	48.4	22.0
				May 1	May 4	May 10	May 6	May 11
1913	31.3	44.6	62.2		48.9	40.5	49.0	18.4
	Jan. 9	Jan. 10	Jan. 14		Jan. 26	Feb. 3	Feb. 16	Feb. 23
	30.4	51.1	69.9	25.8	54.8	46.5	52.3	20.5
	Mar. 28	Mar. 28	Apr. 1	Mar. 27	Apr. 4	Apr. 10	Apr. 27	May 8
1915	28.4	42.2	55.9		45.6	36.0	43.9	16.9
	Feb. 3	Feb. 3	Feb. 7		Feb. 11	Feb. 17	Mar. 1	Mar. 5
1916	20.7	33.5	53.2	31.5	53.4	43.5	53.9	21.9
	Jan. 3	Jan. 4	Jan. 14	Jan. 31	Feb. 4	Feb. 9	Feb. 14	Feb. 28
1917	23.1	37.0	56.1	17.0	49.2	40.1	49.8	18.2
	Mar. 13	Mar. 14	Mar. 17	Mar. 31	Mar. 25	Apr. 9	Apr. 21	May 1
1918	7.6	23.5	60.0		38.8	29.0		
	Jan. 30	Jan. 31	Jan. 31		Feb. 14	Feb. 16		
	27.1	39.8	61.8		39.8	30.2	37.6	12.9
	Feb. 21	Feb. 22	Feb. 12		Feb. 25	Feb. 28	Mar. 7	Mar. 13
	25.8	39.1	51.5		34.0	25.3	30.6	10.9
	Mar. 15	Mar. 16	Mar. 17		Mar. 25	Mar. 28	Apr. 1	Apr. 6
1919	22.8	34.6	52.0		41.3	31.3	40.0	14.7
	Jan. 3	Jan. 3	Jan. 6		Jan. 13	Jan. 17	Jan. 23	Jan. 26
1920	25.2	39.4	54.6	27.8	51.4	40.3	50.8	19.5
	Mar. 13	Mar. 14	Mar. 22	Mar. 30	Mar. 31	Apr. 5	Apr. 19	Apr. 28
	14.4	25.9	52.6	28.0	49.5	38.7	50.4	20.3
	Apr. 22	Apr. 23	Apr. 23	Apr. 23	May 1	May 7	May 14	May 17
1921-1922	21.2	31.3	56.1		39.0	29.3	34.8	12.1
	Dec. 25	Dec. 26	Dec. 27		Jan. 3	Jan. 6	Jan. 13	Jan. 17
1922	18.4	27.1	52.2	25.2	53.6	42.6		
	Mar. 16	Mar. 17	Mar. 18	Mar. 31	Mar. 25	Mar. 31		
	20.3	32.0	48.2	34.0	53.5	42.3	[2] 55.0	[2] 22.3
	Apr. 15	Apr. 16	Apr. 19	Apr. 19	Apr. 25	Apr. 29	Apr. 28	Apr. 24

[1] Data from Dam No. 13, near Wheeling, used from 1916 to 1922, inclusive.

[2] Crevasses prevented further rise.

Early floods.—For the Ohio River at Pittsburgh, where the flood stage is at 22 feet, there are authentic records of a stage of 36 feet on January 9, 1762, one of 37.9 feet (greatest) on March 9, 1763, and one of 35 feet on February 10, 1832. During the latter flood the river at Cincinnati reached a stage of 64.2 feet on February 19, flood stage being at 52 feet. No other early records for Cincinnati are available.

A review by Bowie of early severe floods in the St. Louis section of the Mississippi River will be found in Bulletin M, Weather Bureau, pages 42 et seq. This and other records show that that there were severe floods in

1724, between 1740 and 1750 (tradition only), 1785 (probably the greatest except 1844), 1811, 1823, 1826, 1844 (greatest), 1851, 1855, and 1858.

In the lower Mississippi River there were great floods in 1828, 1844, 1849, 1850, 1858, 1859, 1862, 1865, and 1867. (Bulletin E, Weather Bureau, p. 34.)

The daily records made at many places have been carefully studied with the view of determining the existence or nonexistence of any regularity or periodicity of flood occurrence. The stations selected for study were Pittsburgh, Pa., Cincinnati, Ohio, and Cairo, Ill., on the Ohio River; Nashville, Tenn., on the Cumberland River; Johnsville, Tenn., on the Tennessee River; Kansas City, Mo., on the Missouri River; St. Louis, Mo., Memphis, Tenn., Vicksburg, Miss., and New Orleans, La., on the Mississippi River; Little Rock, Ark., on the Arkansas River; and Alexandria, La., on the Red River. The daily records for Johnsonville begin with the year 1880 and those for Alexandria with the year 1885.

The results have been summarized in the following table:

TABLE 3.—*Summary of flood frequency, 1871–1922, inclusive.*

Station.	River.	Decade.					Total.	Average interval between floods.
		1871–1880	1881–1890	1891–1900	1901–1910	1911–1922[1]		
								Years.
Pittsburgh, Pa.	Ohio	5	11	10	15	14	55	0.95
Cincinnati, Ohio	do	4	7	7	9	12	39	1.33
Nashville, Tenn.	Tennessee	4	7	6	3	12	32	1.62
Johnsonville, Tenn.	do	.....	[2] 7	6	3	10	26	[3] 1.65
Kansas City, Mo.	Missouri	1	2	5	7	8	23	2.26
St. Louis, Mo.	Mississippi	1	3	3	6	6	19	2.74
Cairo, Ill.	Ohio	7	9	6	6	11	39	1.33
Memphis, Tenn.	Mississippi	5	8	6	9	10	38	1.37
Little Rock, Ark.	Arkansas	12	9	6	6	4	37	1.41
Vicksburg, Miss.	Mississippi	7	10	7	7	9	40	1.30
Alexandria, La.	Red	.....	.....	2	3	5	10	[4] 3.80
New Orleans, La.	Mississippi	7	10	9	6	7	39	1.33

[1] 12 years. [2] Includes 1880. [3] 43 years only. [4] 38 years only.

Flood stages at Cairo, Memphis, Vicksburg, and New Orleans were changed at different times after 1896, and the data in the tables are based upon the flood stages in use at the times of the floods, except at Johnsonville, Tenn., where the present flood stage of 31 feet was used, the old stage having been in error.

Whenever two or more floods occurred in any one year, they were considered as distinct floods provided they were separated by intervals of at least one month during which the river did not reach the flood stage.

It appears from Table 3 that in the extreme upper Ohio River a flood stage may be expected about once each year and over the middle and lower reaches of the river about once in a little less than one and one-half years. In the larger tributaries of the Ohio the flood stage may be expected to occur about once in every two years, while in the Mississippi River above Cairo and in the lower Missouri River the average period is about two and one-half years. In the lower Mississippi River and in the Arkansas River the average period is about one and one-third years and in the Red River rather more than three and one-half and less than four years.

The decade increases at Pittsburgh, years being considered, since 1900 were probably due in part to artificial channel restriction, while the low value for the decade, 1871–1880, in the lower Mississippi reflected the comparatively open-channel conditions that prevailed at the time. It will be noted that the progressive advance in levee construction since 1880 apparently affected the flood frequency but little.

When severe floods alone are considered, a more fortuitous arrangement is disclosed. In accordance with a previous procedure data for floods with crests 5 feet or more above the flood stage were assembled (only 4 feet at New Orleans on account of relatively low flood stage), and the results are set forth in Table 4.

TABLE 4.—*Summary of severe flood frequency, 1871–1922, inclusive.*

Station.	River.	Decade.					Total.	Average interval between floods.
		1871–1880	1881–1890	1891–1900	1901–1910	1911–1922[1]		
								Years.
Pittsburgh, Pa.	Ohio	0	3	4	8	5	20	2.60
Cincinnati, Ohio	do	1	6	5	5	7	24	2.17
Nashville, Tenn.	Cumberland	1	5	2	1	7	16	3.25
Johnsonville, Tenn.	Tennessee	.....	[2] 5	4	1	6	16	[3] 2.69
Kansas City, Mo.	Missouri	0	0	0	3	2	5	10.40
St. Louis, Mo.	Mississippi	0	1	1	3	0	5	10.40
Cairo, Ill.	Ohio	4	8	5	2	6	25	2.08
Memphis, Tenn.	Mississippi	0	0	0	4	6	10	5.20
Little Rock, Ark.	Arkansas	4	2	2	1	0	9	5.78
Vicksburg, Miss.	Mississippi	1	3	5	2	6	17	3.06
Alexandria, La.	Red	0	0	0	1	0	1	[4] 38.00
New Orleans, La.	Mississippi	1	1	3	3	5	13	4.00

[1] 12 years. [2] 43 years only. [3] 38 years only. [4] Includes 1880.

The data for the extreme upper Ohio River, as represented by Pittsburgh, indicate that while ordinary floods are of annual occurrence severe floods occur not oftener than about once in two and one-half years, while farther down the river the average interval between them is slightly more than two years. In the larger tributaries the average interval between severe floods is in the neighborhood of three years, a little less for the Tennessee and a little more for the Cumberland River. In the lower Mississippi River at Memphis severe floods have occurred once in a little more than five years and at Vicksburg about once in three years. Severe floods in the Arkansas River occur once in about five and three-quarter years, while those in the lower Red River are very infrequent, only one having been recorded in 38 years.

Closer inspection of Table 4 shows that there has been a marked increase in severe floods during the last 12 years from Cairo southward, indicating clearly the effects of extensive levee construction that were not apparent in ordinary floods, although, of course, it must not be assumed that the levee system alone was responsible for the increase. However, it is entirely safe to say that, while the levees have not materially affected flood frequency, they have increased the stage of water.

Flood periodicity.—It is not surprising that evidences of flood recurrence at reasonably constant intervals are wanting. Floods are caused not by excess of precipitation extending over long periods of time, such as a year or more, but normally by heavy general rains during comparatively short periods, the distribution of the precipitation being of equal importance with the amount. Generally speaking, marked excess of precipitation cov-

ering long periods of time is reflected in an increase in the average stage of water in a river but does not necessarily cause a flood, while more marked excess over a much shorter period will result in a flood. This short period of heavy rain may vary from a single day over basins drained by swift and turbulent streams to as much as two or three months for the lower Mississippi River, which is more leisurely in its progress and is constantly receiving increments from its tributaries. There is, however, no evidence of regular sequence of occurrence of floods for the reason that there is likewise no evidence of regular seasonal sequence of heavy precipitation.

For climatic reasons the floods of the upper Mississippi River are less frequent and later than those of the lower river. Severe floods between Alton, Ill., and Cairo can occur only when the Missouri River from Kansas City eastward, with either the Kansas or Osage Rivers, or both, are in marked flood. These floods usually occur sometime between May and July, and the only floods of any consequence that occurred earlier, according to a record for 62 years at St. Louis, were those of 1904 and 1922, both of which occurred in April. In the flood of 1904 the crest stage of 33.6 feet occurred on April 29, and the river at St. Louis remained above the flood stage until May 5. Above the mouth of the Missouri River severe floods are still less frequent.

Crest stages and dates at a number of important points for eleven great flood years are shown in Table 5.

TABLE 5.—*Crest stages and dates during lower Mississippi River floods from 1882 to 1922, inclusive.*

[Highest stages of record in bold-face type.]

Station.	River.	Flood stage.	1882		1883		1893		1897		1903		1907	
			Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.
Cincinnati, Ohio	Ohio	52	58.6	Feb. 21	66.3	Feb. 15	50.6	May 2	50.1	Mar. 12	53.2	Mar. 5	65.2	Jan. 21
Mount Carmel, Ill	Wabash	15					24.5	May 8[1]	26.4	Mar. 13	22.3	Mar. 12	24.5	Jan. 28
Nashville, Tenn	Cumberland	40	38.3	Feb. 22	41.6	Feb. 14	19.9	May 9	48.7	Mar. 21	40.7	Mar. 9	28.2	Jan. 24
Johnsonville, Tenn	Tennessee	31	43.8	Jan. 31	29.0	Feb. 2[1]	27.0	May 13	**48.0**	Mar. 24	33.7	Mar. 11	14.5	Jan. 27
				Feb. 2										
St. Louis, Mo	Mississippi	30	28.2	Feb. 22	26.2	Feb. 26	31.5	May 3	23.2	Mar. 28[1]	25.8	Mar. 11	26.3	Jan. 23
Cairo, Ill	Ohio	45	51.9	Feb. 26	52.2	Feb. 27	49.3	May 9[1]	51.6	Mar. 25[1]	50.6	Mar. 15[1]	50.4	Jan. 27
New Madrid, Mo	Mississippi	34					38.1	May 9[1]	40.2	Mar. 26[1]	39.5	Mar. 16[1]	39.3	Jan. 28[1]
Cottonwood Point, Mo	do	35	37.5	Feb. 28	37.8	Feb. 28	36.6	May 12[1]	39.4	Mar. 22[1]	40.0	Mar. 20	38.4	Jan. 30[1]
Memphis, Tenn	do	35	35.2	Mar. 6[1]	34.8	Mar. 5[1]	35.2	May 15[1]	37.1	Mar. 19[1]	40.1	Mar. 20	40.3	Feb' 3
Helena, Ark	do	44	47.2	Mar. 9	46.9	Mar. 8[1]	48.0	May 25	51.8	Apr. 4	51.0	Mar. 25[1]	50.4	Feb. 5[1]
Pine Bluff, Ark	Arkansas	25	26.6	Feb. 25	25.4	Feb. 20	28.5	May 5	[2] 21.4	Mar. 21	[2] 23.3	Mar. 13	21.0	Jan. 26
Clarendon, Ark	White	30					33.9	May 11	31.9	Mar. 30	32.6	Mar. 20	32.5	Jan. 9[1]
Arkansas City, Ark	Mississippi	48	47.0	Feb. 28	46.3	Mar. 11[1]	50.3	May 29	51.9	Mar. 29	53.0	Mar. 27[1]	52.1	Feb. 8
Greenville, Miss	do	42	41.7	Feb. 27[1]	40.4	Mar. 10[1]	44.3	May 29	46.8	Mar. 29	49.1	Mar. 27	47.3	Feb. 8[1]
Lake Providence, La	do		38.2	Feb. 28[1]	36.5	Mar. 11[1]	41.8	May 15[1]	44.5	Mar. 30	46.5	Mar. 27	46.3	Feb. 9[1]
			38.3	Mar. 20										
Vicksburg, Miss	do	45	44.8	Mar. 1[1]	43.1	Mar. 14[1]	48.3	May 22[1]	52.5	Apr. 16	51.8	Mar. 27[1]	49.7	Feb. 11
			48.8	Mar. 20[1]										
Natchez, Miss	do	46	47.8	Mar. 28[1]	44.0	Apr. 7[1]	46.8	May 22[1]	49.8	Apr. 29[1]	50.4	Mar. 28[1]	48.9	Feb. 13[1]
Alexandria, La	Red	36					25.6	June 8	26.3	Apr. 15[1]	36.2	Mar. 27[1]	22.8	Jan. 13[1]
Baton Rouge, La	Mississippi	35	36.0	Mar. 26	35.1	Apr. 9	38.4	June 23	40.6	May 12[1]	40.0	Apr. 7[1]	37.3	Feb. 14[1]
Donaldsonville, La	do	28					30.6	June 23	32.8	May 13	32.2	Apr. 4[1]	30.1	Feb. 16[1]
New Orleans, La	do	18	16.2	Mar. 27	16.6	Apr. 7[1]	17.9	June 24	19.6	May 8[1]	20.3	Mar. 27[1]	19.8	Feb. 13[1]
Melville, La	Atchafalaya	37					34.5	June 25[1]	36.1	May 15	38.7	Apr. 4[1]	37.7	Feb. 19[1]
Monroe, La	Ouachita	40	**49.7**				38.6	June 21[1]	37.9	Apr. 9[1]	44.5	Mar. 26[1]	38.5	Jan. 23[1]

Station.	River.	Flood stage.	1912		1913		1916		1920		1922	
			Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.	Stage.	Date.
Cincinnati, Ohio	Ohio	52	51.7	Apr. 5[1]	69.9	Apr. 1	43.9	Feb. 4	54.6	Mar. 22	52.2	Mar. 18
Mount Carmel, Ill	Wabash	15	23.2	Apr. 7[1]	**31.0**	Mar. 30	26.7	Feb. 6	52.6	Apr. 23	48.2	Apr. 19
Nashville, Tenn	Cumberland	40	46.6	Apr. 7[1]	44.9	Apr. 2	20.9	Feb. 3	20.0	Mar. 22	24.1	Mar. 23
Johnsonville, Tenn	Tennessee	31	35.4	Apr. 6	33.3	Mar. 29	25.0	Jan. 27	23.6	Apr. 28[1]	26.0	Apr. 23
St. Louis, Mo	Mississippi	30	30.8	Apr. 5	25.8	Mar. 27	31.5	Jan. 31	35.8	Mar. 16	45.1	Mar. 16
Cairo, Ill	Ohio	45	54.0	Apr. 6[1]	**54.8**	Apr. 4[3]	53.4	Feb. 4	24.0	Apr. 27	21.7	Apr. 21
New Madrid, Mo	Mississippi	34	44.0	Apr. 5[1]	**44.5**	Apr. 9[1]	41.9	Feb. 5[1]	29.1	Mar. 17	36.4	Mar. 15
Cottonwood Point, Mo	do	35	42.0	Apr. 11[1]	**42.3**	Apr. 11[1]	39.5	Feb. 7	24.9	Apr. 28	20.7	Apr. 23
Memphis, Tenn	do	35	45.3	Apr. 6	**46.5**	Apr. 10	43.5	Feb. 9	27.8	Mar. 30	23.9	Mar. 17[1]
Helena, Ark	do	44	54.4	Apr. 21	**55.2**	Apr. 22	53.4	Feb. 11	28.0	Apr. 24	34.0	Apr. 19
Pine Bluff, Ark	Arkansas	25	26.2	Apr. 4	20.4	Apr. 14	**29.6**	Feb. 3	51.4	Mar. 31	53.6	Mar. 25[1]
Clarendon, Ark	White	30	32.6	Apr. 14	30.4	Apr. 15[1]	**38.5**	Feb. 8	49.5	May 1[1]	53.5	Apr. 25
Arkansas City, Ark	Mississippi	48	55.4	Apr. 12	55.1	Apr. 21[1]	56.4	Feb. 10[1]	40.2	Apr. 1	41.6	Mar. 27[1]
Greenville, Miss	do	42	50.6	Apr. 12	50.4	Apr. 21	50.8	Feb. 11[1]	38.6	May 3	41.7	Apr. 26[1]
Lake Providence, La	do		48.2	Apr. 12	48.0	Apr. 21	48.8	Feb. 15	37.6	Apr. 3[1]	38.5	Mar. 28[1]
Vicksburg, Miss	do	45	52.1	Apr. 12	52.3	Apr. 27[1]	53.9	Feb. 15	36.5	May 4[1]	38.4	Apr. 28
Natchez, Miss	do	46	51.4	Apr. 14[1]	52.4	Apr. 26[1]	53.6	Feb. 15	40.3	Apr. 5	42.6	Mar. 31[1]
Alexandria, La	Red	36	33.6	Apr. 22	24.2	Apr. 6	36.8	Feb. 16[1]	38.7	May 7	42.3	Apr. 29[1]
Baton Rouge, La	Mississippi	35	43.8	May 11[1]	41.3	May 9	42.6	Mar. 1[1]	50.1	Apr. 8[1]	52.3	Apr. 3[1]
Donaldsonville, La	do	28	34.8	May 11	32.7	May 8[1]	34.0	Mar. 1	48.3	May 9[1]	53.1	May 3
New Orleans, La	do	18	22.0	May 11	20.5	May 8	21.0	Feb. 28[1]	23.5	Mar. 31	17.7	Mar. 22
Melville, La	Atchafalaya	37	41.7	May 6[1]	41.5	Apr. 24	43.0	Feb. 14	19.1	May 21	26.0	Apr. 16
Monroe, La	Ouachita	40	46.2	Apr. 22	36.9	Apr. 29[1]	40.6	Feb. 19[1]	29.6	Apr. 8[1]	27.8	Mar. 23[1]
									29.2	May 19[1]	30.7	Apr. 11[1]
									54.0	Apr. 11[1]	**58.0**	Apr. 22[1]
									52.4	May 13[1]	57.7	May 3[1]
									47.0	Apr. 16	**52.1**	Apr. 25[1]
									45.4	May 13	52.0	May 3[1]
									45.4	Apr. 15[1]	**49.5**	Apr. 27[1]
									44.3	May 13[1]	49.3	May 6[1]
									50.8	Apr. 19[1]	**55.0**	Apr. 28[1]
									50.4	May 14[1]	54.7	May 7[1]
									51.5	Apr. 28	[4] **55.2**	Apr. 26
									51.2	May 18[1]	[4] 52.8	May 9[1]
									27.6	Apr. 5	37.1	Apr. 18[1]
									37.1	June 2[1]	37.4	May 10
									40.2	Apr. 30	[4] 44.6	Apr. 27
									41.5	May 22[1]	**45.7**	May 16
									31.6	May 1[1]	[4] 35.8	Apr. 27[1]
									32.6	May 18[1]	**35.9**	May 16
									19.5	Apr. 28[1]	[4] **22.3**	Apr. 24
									20.3	May 17[1]		
									42.5	May 20[1]	**45.9**	May 14[1]
									41.0	June 5	42.3	May 9[1]

[1] And subsequently. [2] Little Rock stage. [3] Absolute crest probably on 7th; nearly stationary from 4th. [4] Crevasse prevented further rise.

CAUSES OF THE FLOODS.

The annual floods in the lower Mississippi almost invariably precede those in the upper river. The usual procedure has been described in Bulletins M, Y, and Z, Weather Bureau, and, briefly, is as follows: The most prolific type of rain-producing storms is what is known in Weather Bureau terms as the "Southwest type," that is, a storm, generally from the Pacific Ocean, which passes over the State of Texas and then moves in a northeasterly direction with high pressure to the northward. These storms are most frequent from January to April, and during their northeastward movement heavy rains generally occur over the drainage basins of the lower Mississippi and the Ohio Rivers. Normal rains are ordinarily sufficient to bring the lower Mississippi River to flood stage by midwinter, so that abnormal rains may create flood conditions over this area before the Ohio flood gets under way. The Ohio River and its tributaries, at least those on its southern side, are turbulent and fast-running streams and come quickly into flood. Consequently a flood volume from the Ohio poured into an already burdened Mississippi must necessarily cause a severe flood in the latter. The Ohio and lower Mississippi alone can produce a great flood without assistance from the upper Mississippi River or the western tributaries, and as a matter of fact the latter are usually in moderate flow when the two greater rivers are in flood, for, as stated by Henry,[1] "as the area of a watershed increases, the probability of rain falling simultaneously over all portions of it diminishes."

Fortunate it is that this is true. Should floods from the Missouri, upper Mississippi, and Ohio reach Cairo simultaneously, with the occurrence of floods below in the St. Francis, White, Arkansas, and Red, as well as in the main stream, the effect below Cairo can hardly be conceived. Fortunately such a combination of flood conditions has never occurred, at least within human knowledge. However, it is not absolutely impossible. In fact, the flood of 1922 apparently approached nearer than ever before to the maximum condition. The Missouri east of Kansas City, the upper Mississippi, the Illinois, Meramec, Kaskaskia, extreme lower Ohio, the St. Francis, White, Arkansas, Yazoo, and Red Rivers were in flood almost simultaneously, and had the first rise of the middle and upper Ohio, the Cumberland, and Tennessee been sustained a flood whose vast proportions it is impossible to conjecture might have been recorded.

While the upper Mississippi floods are, of course, due primarily to heavy rains, they are sometimes augmented by the melting snows accompanying decided thaws and at other times by ice gorges, which tend to make them more or less local in character.

[1] Bulletin Z, Floods of 1913, p. 12.

THE FLOODS OF 1922.

CONTRIBUTING CAUSES.

(*a*) *Snow cover.*—On February 15 there was no snow over the drainage basin of the Mississippi River south of Wisconsin, central Iowa, and South Dakota. At the end of the month there was a moderate cover of from 1 to 4 inches over eastern Colorado, western Oklahoma, Kansas, Nebraska, Iowa, northwestern Missouri, northern Illinois, northern Indiana, and northwestern Ohio, but much more to the northward. After March 6 there were no further increases and there was a steady recession of the snow line to the northward.

It is apparent, therefore, that the snow influence on the floods of 1922 was negligible.

(*b*) *Rainfall, character, amount, and distribution.*—Rain had been quite abundant over the Ohio Drainage Basin during November and December, 1921, and over the lower Mississippi and upper Tennessee Basins during January, 1922. Over the Ohio Basin the excess above the normal amount in November, 1921, was 2.7 inches, with a maximum departure of 5.1 to 5.4 inches over southern Indiana. Over the lower Mississippi Valley the rainfall was deficient. In December, 1921, the excess over the normal amount over the Ohio Valley was only 0.4 inch, while over the lower Mississippi Valley the deficiency persisted. During January, 1922, there was a deficiency of 1.4 inches over the Ohio Basin, but a moderate excess over the lower Mississippi section. Over the upper Mississippi Basin the usual condition of light winter precipitation prevailed. So it appears, further, that the precipitation preceding the floods had not been abnormal in any way, and the floods of 1922, with the exception of that in the Illinois River, may be said to have begun on February 16, when the Ohio River at Cairo was at a stage of 18.4 feet after a fall from 29.4 feet on February 2.

The stage at St. Louis was 2.7 feet after a fall from 5.0 feet on March 4 and that at Cincinnati 15.4 feet on February 13, with a rise about to begin. Not much rain had fallen during the first half of the month, and the rise had begun three days earlier in the main stream and tributaries above Cincinnati as a result of light rains, coupled with quite high temperatures for the season, the high temperatures causing a moderate thaw. The rise was important only in that it brought the river to such a stage that continued rains, even though only moderate in amount, would result in a sustained slow rise that would exercise a marked effect upon rising waters in the lower river. At this time the rivers below the mouth of the Ohio and the tributaries were at moderate stages and falling slowly. The Missouri and upper Mississippi Rivers were at their usual winter stages, but the Illinois was moderately full and had been vir-

tually so since November, 1921. Occasional moderate rains followed after February 13, and they were sufficient to cause a rise in the Ohio River and its West Virginia tributaries, especially between February 20 and 23. On the morning of February 23 a storm of the "southwestern type" was central over southern Michigan, and good general rains had fallen over the great river valleys except the upper Ohio. The stage of the river at Cincinnati was 35 feet, 17 feet below the flood stage, and the river below was rising.

The Green River of Kentucky was well above flood stage, the Cumberland and Tennessee were rising rapidly, and the flood below the mouth of the Green River had set in. The White River of Arkansas was at moderate stage, while the Arkansas and Red were low.

Appended charts XII to XV, inclusive, show the amount and general distribution of the rainfall for the months of January, February, March, and April, 1922, and Table 6 the amounts at selected stations during each week from February 22 to May 2, inclusive. An inspection of the charts will show that the rainfall of January and February over the lower Mississippi Basin was fairly large, although less than usual during January and February for seasons of severe flood, while over the Ohio Basin the deficiency in this respect during the same months was more marked. The upper Mississippi and the western tributary basins maintained their established traditions of nonactivity during the early months of the year.

General and heavier rains began during the last week of February over the Ohio and lower Mississippi Basins, and as they increased in frequency and intensity during March they were joined by heavy rains over the lower Missouri, the Arkansas, and the Red Basins. The rains for the two weeks ended April 11 were especially heavy over the lower Missouri drainage, with a marked excess during the second week, from April 5 to 11, inclusive.

Heavy rains were also frequent during the same period over the Arkansas Valley and over the Red River Valley during the two weeks ended April 4. Over the upper Mississippi Valley the heavy rain period covered the two weeks from April 5 to 18, inclusive, with the heavier fall during the first week. Moderate to heavy rains were of almost daily occurrence throughout the two weeks, and heavy rains also continued over the lower Missouri and the Arkansas Basins. Over the Red Basin, however, there were no general periods of heavy rain after April 4 until April 26 to 27. This lag over the Red River Basin was reflected in the May flood below Shreveport, Alexandria, La., reporting a stage of 37.4 feet on May 10, which was 0.3 foot higher than the crest of the April flood.

TABLE 6.—*Precipitation, by weeks, from February 22 to May 2, 1922 (measured at 8 a. m., 75th meridian time).*

Ohio Drainage Basin.

Station.	River.	Feb. 22 to 28.	Mar. 1 to 7.	Mar. 8 to 14.	Mar. 15 to 21.	Mar. 22 to 28.	Mar. 29 to Apr. 4.	Apr. 5 to 11.	Apr. 12 to 18.	Apr. 19 to 25.	Apr. 26 to May 2.	Total.
Warren, Pa	Allegheny	0.16	1.00	0.68	0.12	0.68	1.19	1.32	1.38	0.21	0.00	6.74
Martin, Pa	Monongahela	0.40	1.93	0.60	1.38	0.54	0.66	0.17	2.18	0.06	0.12	8.04
Pittsburgh, Pa	Ohio	0.31	1.44	0.78	0.54	0.83	2.17	0.37	2.70	0.33	0.04	9.51
Parkersburg, W. Va	do	0.18	1.06	0.84	2.42	0.87	0.87	0.14	3.27	0.18	0.22	10.05
Zanesville, Ohio	Muskingum	0.18	1.17	0.72	1.35	0.70	1.32	0.98	2.70	0.06	0.19	9.37
Hinton, W. Va	Kanawha—New	0.58	1.76	1.64	1.28	0.68	0.56	Trace.	0.88	0.62	0.90	8.90
Charleston, W. Va	do	0.40	1.75	0.73	0.82	0.56	1.72	Trace.	2.55	0.63	0.48	9.64
Point Pleasant, W. Va	Ohio	0.28	2.07	1.06	2.18	1.34	0.90	0.10	1.96	0.00	0.26	10.15
Columbus, Ohio	Scioto	0.24	0.97	0.17	0.66	0.00	0.41	0.88	1.83	0.06	0.28	5.50
Chillicothe, Ohio	do	0.18	1.33	1.08	2.27	0.45	1.60	0.78	3.64	0.15	0.55	12.03
Portsmouth, Ohio	Ohio	0.34	1.50	0.89	2.15	1.35	1.34	1.01	1.91	0.05	0.44	10.98
Cincinnati, Ohio	do	0.31	0.70	0.89	0.68	0.70	1.59	1.02	2.66	0.07	0.57	9.19
Dayton, Ohio	Miami	0.31	0.73	1.42	1.59	0.63	1.44	1.53	3.49	0.02	0.34	11.50
Madison, Ind	Ohio	0.63	0.91	0.98	2.68	1.42	1.28	1.78	2.16	0.17	0.78	12.79
Frankfort, Ky	Kentucky	0.42	1.53	2.02	1.96	0.52	1.13	1.19	2.56	0.05	0.40	11.78
Louisville, Ky	Ohio	0.34	0.74	1.13	2.10	1.55	0.94	1.82	3.46	0.01	0.77	12.86
Bowling Green, Ky	Barren	1.00	2.68	2.03	2.75	1.55	1.72	1.73	0.60	0.00	2.22	16.28
Woodbury, Ky	Green	0.71	1.40	1.34	2.28	1.93	1.03	1.47	0.40	Trace.	1.29	11.85
Evansville, Ind	Ohio	0.47	0.44	1.28	2.57	1.56	2.42	0.92	1.70	0.29	1.16	12.81
Indianapolis, Ind	White (W. Fork)	0.41	0.52	1.79	2.29	0.76	1.80	4.31	3.86	0.06	0.32	16.12
Elliston, Ind	do	0.59	0.54	1.12	3.32	0.83	2.63	2.82	3.13	0.13	0.55	15.66
Terre Haute, Ind	Wabash	0.41	0.56	2.22	2.41	0.81	2.45	3.78	6.25	0.35	0.19	19.43
Mount Carmel, Ill	do	0.20	0.40	1.05	3.43	1.40	4.19	1.62	2.25	0.75	0.60	15.89
Burnside, Ky	Cumberland	1.15	2.89	2.84	2.45	0.90	0.78	1.78	0.80	Trace.	2.05	15.64
Nashville, Tenn	do	1.08	2.90	2.86	1.33	1.02	1.68	1.12	1.11	0.05	2.25	15.40
Chattanooga, Tenn	Tennessee	1.25	5.06	3.10	0.75	0.70	0.48	1.47	2.05	4.18	0.65	19.69
Decatur, Ala	do	1.20	3.80	2.90	1.15	0.38	2.63	1.66	2.23	0.12	0.61	16.68
Johnsonville, Tenn	do	1.01	2.08	2.68	1.72	0.73	1.19	1.51	0.67	Trace.	3.75	15.34
Cairo, Ill	Ohio	0.47	0.38	1.17	3.21	0.81	3.13	1.22	0.99	0.23	0.91	12.52

Upper Mississippi Drainage Basin.

St. Paul, Minn	Mississippi	1.03	0.08	0.02	0.66	0.59	0.20	1.01	0.03	0.35	Trace.	3.97
Wisconsin Rapids, Wis	Wisconsin	.....	0.00	0.09	1.71	0.30	0.28	4.13	0.73	0.13	0.00	7.37
Portage, Wis	do	2.99	0.36	0.00	1.74	0.41	0.93	2.74	1.78	0.29	0.05	11.29
Davenport, Iowa	Mississippi	1.19	0.09	0.71	0.78	1.03	0.84	2.05	0.71	0.05	Trace.	7.45
Des Moines, Iowa	Des Moines	0.46	0.13	Trace.	1.69	0.26	0.26	2.01	0.40	0.34	0.28	5.83
Hannibal, Mo	Mississippi	0.44	0.34	2.99	0.20	1.58	1.42	2.62	2.04	0.65	0.01	12.29
Peoria, Ill	Illinois	0.68	0.11	1.60	0.77	1.04	1.81	1.49	1.09	0.75	0.05	9.39
Beardstown, Ill	do	0.40	0.24	2.25	0.65	1.42	1.35	1.90	1.85	0.65	0.00	10.71
St. Louis, Mo	Mississippi	0.63	0.56	2.09	0.86	0.59	1.24	2.57	3.93	0.66	0.24	13.37
Cape Girardeau, Mo	do	0.46	0.27	1.57	2.01	1.01	3.07	1.91	0.63	0.20	1.00	12 13

TABLE 6.—*Precipitation, by weeks, from February 22 to May 2, 1922 (measured at 8 a. m., 75th meridian time)*—Continued.

Station.	River.	Feb. 22 to 28.	Mar. 1 to 7.	Mar. 8 to 14.	Mar. 15 to 21.	Mar. 22 to 28.	Mar. 29 to Apr. 4.	Apr. 5 to 11.	Apr. 12 to 18.	Apr. 19 to 25.	Apr. 26 to May 2.	Total.
Missouri Drainage Basin.												
Topeka, Kans.	Kansas	2.41	0.10	2.92	0.81	0.46	0.78	2.94	0.04	0.56	1.35	12.37
Kansas City, Mo	Missouri	1.32	0.20	3.28	0.98	1.11	1.60	1.55	0.75	0.28	0.35	11.42
Boonville, Mo.	do	0.98	0.10	3.68	0.39	1.89	2.19	3.67	1.79	0.81	0.37	15.87
Ottawa, Kans.	Osage	0.53	0.54	3.13	0.48	2.99	1.98	4.33	0.66	0.95	1.20	16.79
Osceola, Mo.	do	0.98	0.61	2.34	0.98	1.41	3.18	5.48	1.90	1.25	1.36	19.49
Warsaw Mo	do	1.15	0.10	2.20	0.85	2.40	2.45	6.81	2.53	1.33	1.75	21.57
Hermann, Mo.	Missouri	0.63	0.32	2.46	0.79	1.24	2.65	6.89	2.92	0.91	0.56	19.37
Arkansas Drainage Basin.												
Oswego, Kans.	Neosho	0.88	0.30	4.10	1.25	1.31	2.39	5.37	3.00	2.34	0.37	21.31
Okay, Okla.	Verdigris	1.21	0.33	1.28	0.78	1.21	3.59	1.73	0.00	0.95	1.95	13.03
Woodward, Okla.	North Canadian	1.00	0.24	5.45	0.15	0.75	1.15	1.32	0.00	1.05	1.37	12.48
Oklahoma City, Okla.	do	0.42	0.22	2.33	0.03	1.67	1.80	3.27	Trace.	1.76	1.22	12.72
Calvin, Oka.	Canadian	1.74	0.50	1.43	0.08	1.20	3.85	1.95	0.02	1.02	1.39	13.18
Dodge City, Kans.	Arkansas	1.56	0.01	3.64	0.08	0.03	0.39	0.09	0.19	2.56	1.02	9.57
Wichita, Kans.	do	1.12	0.26	2.97	0.13	0.23	1.13	2.91	0.48	1.40	0.84	11.47
Fort Smith, Ark.	do	1.37	0.62	0.63	0.36	1.85	1.42	1.51	0.82	0.81	1.16	10.55
Little Rock, Ark.	do	1.45	1.45	2.49	0.75	2.76	2.82	0.62	0.19	0.47	1.75	14.75
Pine Bluff, Ark.	do	1.30	2.27	3.34	3.11	2.17	2.64	1.87	0.19	0.06	2.95	19.90
Black Rock, Ark.	Black	1.28	0.86	2.82	1.25	1.29	2.68	1.23	1.55	0.02	2.19	15.17
Batesville, Ark.	White	1.56	0.25	2.76	0.74	1.56	1.93	2.13	0.75	0.00	1.87	13.55
Newport, Ark.	do	1.45	0.47	2.66	1.27	2.20	2.65	1.66	0.36	0.02	2.82	15.56
Clarendon, Ark.	do	1.69	1.65	3.77	2.83	1.73	3.02	1.79	0.10	Trace.	1.58	18.16
Red Drainage Basin.												
Arthur City, Tex.	Red	2.60	0.00	0.40	0.00	1.30	3.60	0.50	1.20	2.80	0.80	13.20
Shreveport, La.	do	2.36	1.24	1.37	0.24	3.23	4.38	2.66	0.83	0.32	3.80	20.43
Alexandria, La.	do	1.66	3.31	4.06	3.35	3.08	1.72	1.70	1.64	0.15	3.33	24.00
Camden, Ark.	Ouachita	2.68	1.11	2.48	1.09	2.09	3.42	2.26	0.36	0.40	4.87	20.76
Monroe, La.	do	3.36	2.46	2.76	0.00	2.62	4.40	0.96	0.40	1.29	4.86	23.11
Melville, La.	Atchafalaya	1.85	0.20	0.25	0.05	3.95	4.60	0.00	0.80	0.00	4.05	15.75
Lower Mississippi Drainage Basin.												
New Madrid, Mo.	Mississippi	0.90	0.90	1.60	2.92	1.54	4.70	1.80	0.73	0.19	1.60	16.88
Memphis, Tenn.	do	1.25	1.36	3.52	2.30	0.60	0.51	2.43	0.06	Trace.	0.75	12.78
Marked Tree, Ark.	St. Francis	0.82	1.74	3.95	2.48	1.07	5.35	1.64	0.40	Trace.	1.91	19.36
Helena, Ark.	Mississippi	1.36	2.12	3.62	0.96	0.74	2.10	2.02	0.50	Trace.	2.58	16.00
Arkansas City, Ark.	do	1.90	3.33	3.02	0.10	0.91	2.78	2.15	0.22	0.49	2.47	17.37
Greenville, Miss.	do	2.66	4.61	2.30	0.40	1.03	4.65	1.65	0.33	0.76	2.96	21.35
Yazoo City, Miss.	Yazoo	4.74	3.53	2.90	0.31	0.97	2.93	2.16	1.14	0.47	1.93	21.08
Vicksburg, Miss.	Mississippi	6.14	3.45	2.24	0.40	1.62	2.19	1.08	1.20	0.60	2.14	21.06
Natchez, Miss.	do	1.98	3.34	2.18	0.60	2.31	2.26	2.09	2.38	0.27	0.43	17.84
Baton Rouge, La.	do	2.30	1.90	2.40	0.30	3.90	1.43	1.33	0.08	0.15	0.32	14.11
Donaldsonville, La.	do	2.28	1.05	1.40	0.52	2.10	2.50	1.61	Trace.	0.25	2.56	14.27
New Orleans, La.	do	1.10	2.07	0.78	0.95	2.47	2.18	0.67	0.00	0.57	2.62	13.41

It appears, then, that the usual precedents of flood causation were satisfied so far as the precipitation is concerned. An exception is noted in the case of the midwinter flood of 1916. The rains that caused this flood occurred between January 21 and 31 and were heavy over the entire drainage area except the northwest. As would have been expected, they were heaviest over the Ohio and Lower Mississippi Basins, but they were almost equally so over Arkansas, and the rivers of that State poured such a volume of water into the Mississippi flood as to exceed all previous records between the mouth of the Arkansas River and Natchez, Miss.

(*c*) *Run-off.*—Discharge measurements for the flood of 1922 are not yet available, and the figures given are based upon the average ratio of discharge to precipitation as given by Morrill in Bulletin E, Table XIV, page 27. The values were those assumed by Humphreys and Abbott and by Greenleaf and are as follows:

TABLE 7.—*Ratio of discharge to precipitation.*

Basin.	Ratio.	Basin.	Ratio.
Ohio	0.30	Red	0.22
Upper Mississippi	0.28	Lower Mississippi	0.52
Missouri	0.15		
Arkansas	0.16	Total	0.25

Using the values given above, a table of rainfall and run-off has been prepared for seven great floods, namely, those of 1882, 1903, 1912, 1913, 1916, 1920, and 1922. (See Table 8.)

TABLE 8.—*Precipitation in inches over drainage basins and discharge in millions of cubic yards for seven floods.*

Drainage basin.	1882							
	January.		February.		March.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	1.78	38,919	1.75	38,422	1.39	30,527	4.92	107,868
Upper Mississippi	0.27	5,711	0.64	13,563	0.54	11,419	1.45	30,693
Lower Mississippi	0.71	26,726	0.59	22,227	0.50	19,052	1.80	68,005
Missouri	0.10	1,062	0.79	8,763	0.46	5,046	1.35	14,871
Arkansas	0.41	5,805	0.88	12,522	0.53	7,499	1.82	25,826
Red	0.67	10,392	0.56	8,689	0.37	5,793	1.60	24,874
Total	3.94	88,615	5.21	104,186	3.79	79,336	12.94	272,137
Ratio		0.30		0.26		0.28		0.28

Drainage basin.	1903							
	January.		February.		March.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	0.62	13,474	1.63	35,949	1.13	24,580	3.38	74,003
Upper Mississippi	0.15	3,177	0.38	7,817	0.39	8,245	0.92	19,239
Lower Mississippi	0.32	12,119	0.62	23,180	0.47	18,046	1.41	53,345
Missouri	0.14	1,540	0.48	5,231	0.34	3,797	0.96	10,568
Arkansas	0.20	2,856	0.73	10,353	0.51	7,305	1.44	20,514
Red	0.24	3,678	0.77	11,841	0.50	7,598	1.51	23,117
Total	1.67	36,844	4.61	94,371	3.34	69,571	9.62	200,786
Ratio		0.29		0.27		0.28		0.28

TABLE 8.—*Precipitation in inches over drainage basins and discharge in millions of cubic yards for seven floods*—Continued.

Drainage basin.	1912							
	February.		March.		April.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	0.70	16,487	1.58	34,738	1.58	34,738	3.86	85,963
Upper Mississippi	0.27	5,711	0.49	6,203	0.68	13,997	1.44	25,911
Lower Mississippi	0.22	8,468	0.65	24,609	0.64	24,080	1.51	57,157
Missouri	0.38	4,355	0.82	8,946	0.86	9,454	2.06	22,755
Arkansas	0.42	6,047	0.71	10,159	0.82	8,783	1.95	24,989
Red	0.25	3,918	0.67	10,392	0.56	8,689	1.48	22,999
Total	2.24	44,986	4.92	95,047	5.14	99,741	12.30	239,774
Ratio	.....	0.25	.....	0.27	.....	0.27	.....	0.27

Drainage basin.	1913							
	January.		February.		March.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	1.87	41,054	0.70	15,264	1.10	37,370	4.27	93,688
Upper Mississippi	0.42	8,923	0.26	5,354	0.71	14,991	1.39	29,268
Lower Mississippi	0.64	24,344	0.39	14,553	0.42	15,877	1.45	54,774
Missouri	0.31	3,452	0.43	4,780	0.63	6,904	1.37	15,136
Arkansas	0.58	8,224	0.37	5,322	0.43	6,047	1.38	19,593
Red	0.41	6,304	0.38	5,963	0.29	4,033	1.08	16,300
Total	4.23	92,301	2.53	51,236	4.18	85,222	10.94	228,759
Ratio	.....	0.29	.....	0.27	.....	0.27	.....	0.28

Drainage basin.	1915-1916					
	December.		January.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	1.37	30,000	1.41	31,054	2.78	61,054
Upper Mississippi	0.32	6,782	0.78	16,419	1.10	23,201
Lower Mississippi	0.42	15,877	0.57	21,432	0.99	37,309
Missouri	0.31	3,452	1.06	11,684	1.37	15,136
Arkansas	0.36	5,080	0.97	13,788	1.33	18,868
Red	0.30	4,600	0.63	9,881	0.93	14,481
Total	3.08	65,791	5.42	104,258	8.50	170,049
Ratio	.....	0.28	.....	0.25	.....	0.26

Drainage basin.	1920							
	January.		February.		March.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	0.96	21,053	0.53	11,579	1.03	22,633	2.52	55,265
Upper Mississippi	0.19	3,926	0.10	2,142	0.75	12,905	1.04	18,973
Lower Mississippi	0.53	20,110	0.16	5,086	0.35	13,230	1.04	38,426
Missouri	0.36	3,983	0.14	1,593	0.87	9,560	1.37	15,136
Arkansas	0.44	6,289	0.10	1,451	0.56	7,982	1.10	15,722
Red	0.52	8,007	0.14	2,215	0.35	5,452	1.01	15,674
Total	3.00	63,368	1.17	24,066	3.91	71,762	8.08	159,196
Ratio	.....	0.28	.....	0.27	.....	0.25	.....	0.27

Drainage basin.	1922							
	February.		March.		April.		Total.	
	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.	Precipitation.	Discharge.
Ohio	0.77	15,264	1.75	38,482	1.25	27,369	3.70	81,115
Upper Mississippi	0.27	5,711	0.51	10,708	0.72	14,991	1.50	31,410
Lower Mississippi	0.40	15,083	0.69	26,197	0.30	11,378	1.39	52,658
Missouri	0.34	5,156	1.25	13,809	1.34	20,624	2.93	39,589
Arkansas	0.34	4,837	1.02	14,513	0.92	13,062	2.28	32,412
Red	0.42	6,474	0.76	10,755	0.69	10,733	1.87	27,962
Total	2.47	52,525	5.98	114,464	5.22	98,157	13.67	265,146
Ratio	.....	0.27	.....	0.25	.....	0.23	.....	0.25

The discharges are given in millions of cubic yards and were obtained from the ratios given in Table 7. It is admitted that these discharge values are based on estimates of high authorities rather than actual measurements of a reliable kind, but they at least represent an actual condition that does not change materially except during short periods, and they serve as a basis of comparison with other floods.

On account of the omissions of portions of the Missouri and Mississippi basins, for reasons given below, the actual drainage areas and the ratios of the different basins to the whole given in the following table were used in the computations for Tables 8 and 10.

TABLE 9.—*Drainage areas used in computations and ratios to entire basin.*

Basin.	Area in square miles.	Ratio to whole.
Ohio	203,900	24
Upper Mississippi	148,150	17
Lower Mississippi	60,300	7
Missouri	205,750	24
Arkansas	145,000	17
Red	90,000	11
Total	853,100	100

The rainfall for each drainage basin was computed according to a method suggested by Marvin and is as follows: Monthly data for a large number of stations were charted and isohyetal lines carefully drawn. These lines were then traced upon sheets of cross-section paper together with the outlines of the six drainage areas.

The isohyets divide the drainage basins into various irregular small subareas, over which the precipitation may be assumed to be uniform and of an amount represented by the mean between the two adjacent isohyetals. Therefore the number of squares in each subarea was counted. This number was then multiplied by the average precipitation for the subarea in question and the product divided by the sum of the counts for all the subareas, which latter, of course, is the number of squares in the whole drainage basin being studied. Finally, the sum of the quotients found in the above manner gives the depth of precipitation, which, spread uniformly over the whole basin, would represent the same amount of water as fell in the irregularly distributed precipitation. This procedure, while laborious, was well worth the time consumed, and it is thought to have accomplished a more accurate presentation of data than was possible otherwise.

The amount of squares in the subarea was limited always by the boundary lines of the watershed, except in the extreme upper Arkansas, Missouri, and Mississippi valleys. In these territories the winter and spring precipitation is invariably small, mostly in the form of light snow, contributing practically nothing to flood conditions. The drainage basins were therefore cut off for these regions by an arbitrary straight line running through Omaha, as shown by the heavy dash line on the left side of Chart I and of the sample chart which is reproduced below.

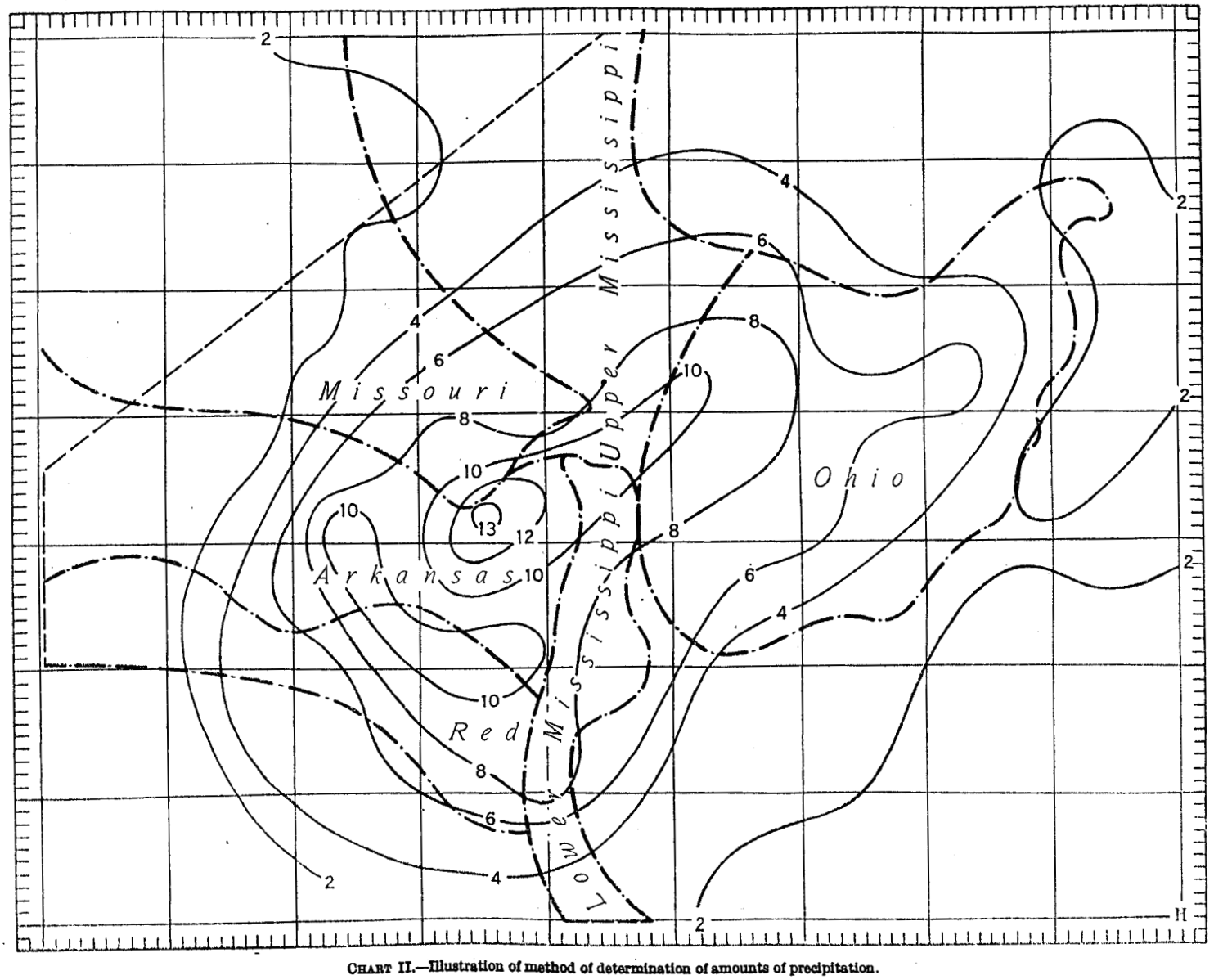


CHART II.—Illustration of method of determination of amounts of precipitation.

COMPARISON WITH PREVIOUS FLOODS.

(*a*) *Precipitation.*—Casual inspection of the data would appear to indicate that, measured by precipitation alone, the flood of 1882 should be awarded first place among the great floods of the last 40 years in the lower Mississippi River. However, if the precipitation data for the different drainage basins in Table 8 are disposed of in accordance with the ratios which they bear to the entire drainage area used, it will be seen that the flood of 1922 should take the lead, and the order of precedence would be 1922, 1882, 1912, 1913, 1903, 1916, and 1920. (See Table 10 immediately following.)

TABLE 10.—*Actual amount of precipitation during seven floods, based upon the relative areas of the drainage basins.*

[Total area used, 853,100 square miles.]

Drainage basin.	Percentage of whole.	Precipitation (inches).						
		1882	1903	1912	1913	1916	1920	1922
Ohio	24	4.9	3.4	3.9	4.3	2.8	2.5	3.7
Upper Mississippi	17	1.5	0.9	1.4	1.4	1.1	1.0	1.5
Lower Mississippi	7	1.8	1.4	1.5	1.4	1.0	1.0	1.4
Missouri	24	1.3	1.0	2.1	1.4	1.4	1.4	2.9
Arkansas	17	1.9	1.4	2.0	1.4	1.3	1.1	2.3
Red	11	1.6	1.5	1.4	1.1	0.9	1.0	1.9
Total	100	13.0	9.6	12.3	11.0	8.5	8.0	13.7

As shown in this table, the equivalent of 13.7 inches of rain fell over the combined drainage areas during the flood of 1922 and 13.0 inches during that of 1882, the flood of 1920 showing the smallest amount, 8.0 inches. It should be noted that in 1922 the Ohio and lower Mississippi Basins show a deficiency as compared with 1882 and that the excess occurred entirely in the western tributaries, an unusual occurrence. The significance of these figures is perhaps not of great importance, as the distribution and amount of precipitation in point of time must be the governing factor in flood causation, yet the data again clearly confirm the opinion previously expressed that with a little different distribution as to time, the crest stages during the flood of 1922, would have been still higher from Cairo to the Passes. All that were needed were earlier rains to the same amount over the western basins or additional rains over the Ohio and the upper Mississippi Basins at the time of the second rise in the Ohio. Had either of these occurred all the main streams and tributaries would have been in flood at the same time, and the maximum flood so often mentioned as a possibility, although a remote one, would have been recorded.

(*b*) *Stages.*—Table 5 gives the crest stages and dates of the greater floods from 1882 to 1922, inclusive. The table is self-explanatory, and attention is invited to two points only. One, that from the mouth of the Arkansas River to the Passes the stages in 1922 were the highest of record, mainly on account of the enormous increment from the Arkansas and White Rivers, and the other, that the levee failures at Ferriday and Poydras prevented still higher stages as far north as Lake Providence, La., if not as far as Greenville, Miss. It may be added that the stages below Cairo from 1916 to 1922, inclusive, indicate the conditions that will normally prevail with the levee system intact throughout its entire present extent, virtually a closed river.

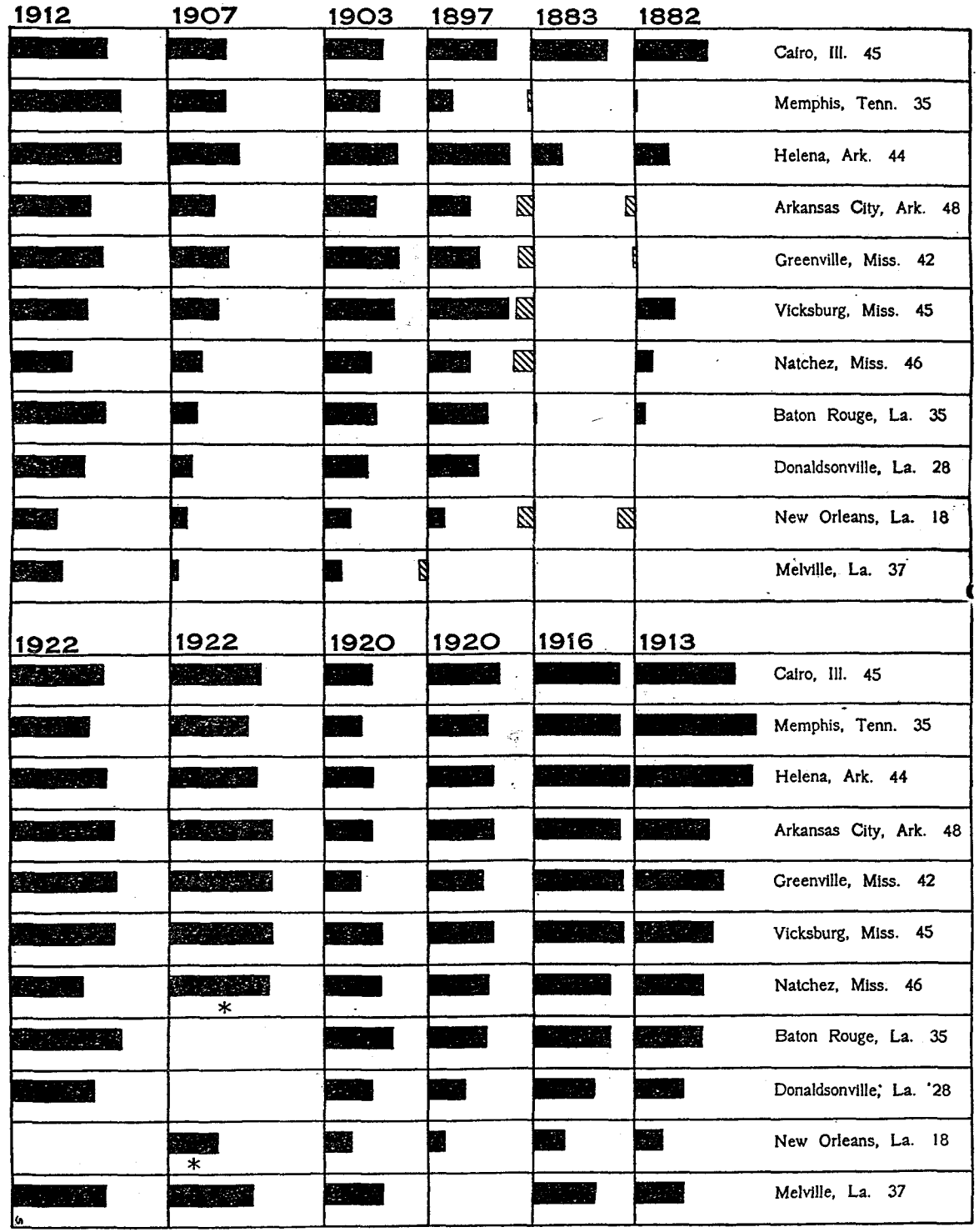
Chart III shows graphs of crest stages above flood stages and Chart IV hydrographs at selected places during the flood of 1922. It will be noted that the hydrograph data are given for every fifth day only.

It is rather difficult to determine as a general proposition which flood was the greatest measured by stages of water. The flood of 1922 was the greatest below and that of 1913 the greatest above the mouth of the Arkansas River, while the flood of 1912 might possibly be considered the greatest flood for the entire river from Cairo to the Passes, as above the mouth of the Arkansas River the stages were not much below those of 1913 and higher than in 1922; from the mouth of the Arkansas River to the mouth of Red River they were nearly the same as in 1913, while below the mouth of Red River they were the highest of record previous to 1922.

The February flood of 1916 also has claims to distinction, for the stages from Arkansas City to the mouth of Red River were the highest of record until the present year.

Owing to progressive changes in the levee system, comparison with floods previous to 1912 does not lead to any significant conclusions.

(*c*) *Duration.*—The duration of the floods and the number of days the river was at or above the flood stage at selected stations are shown in Table 11.



* Crevasse prevented further rise

CHART III.—Graphs showing heights of crest stages above flood stages for 12 floods.

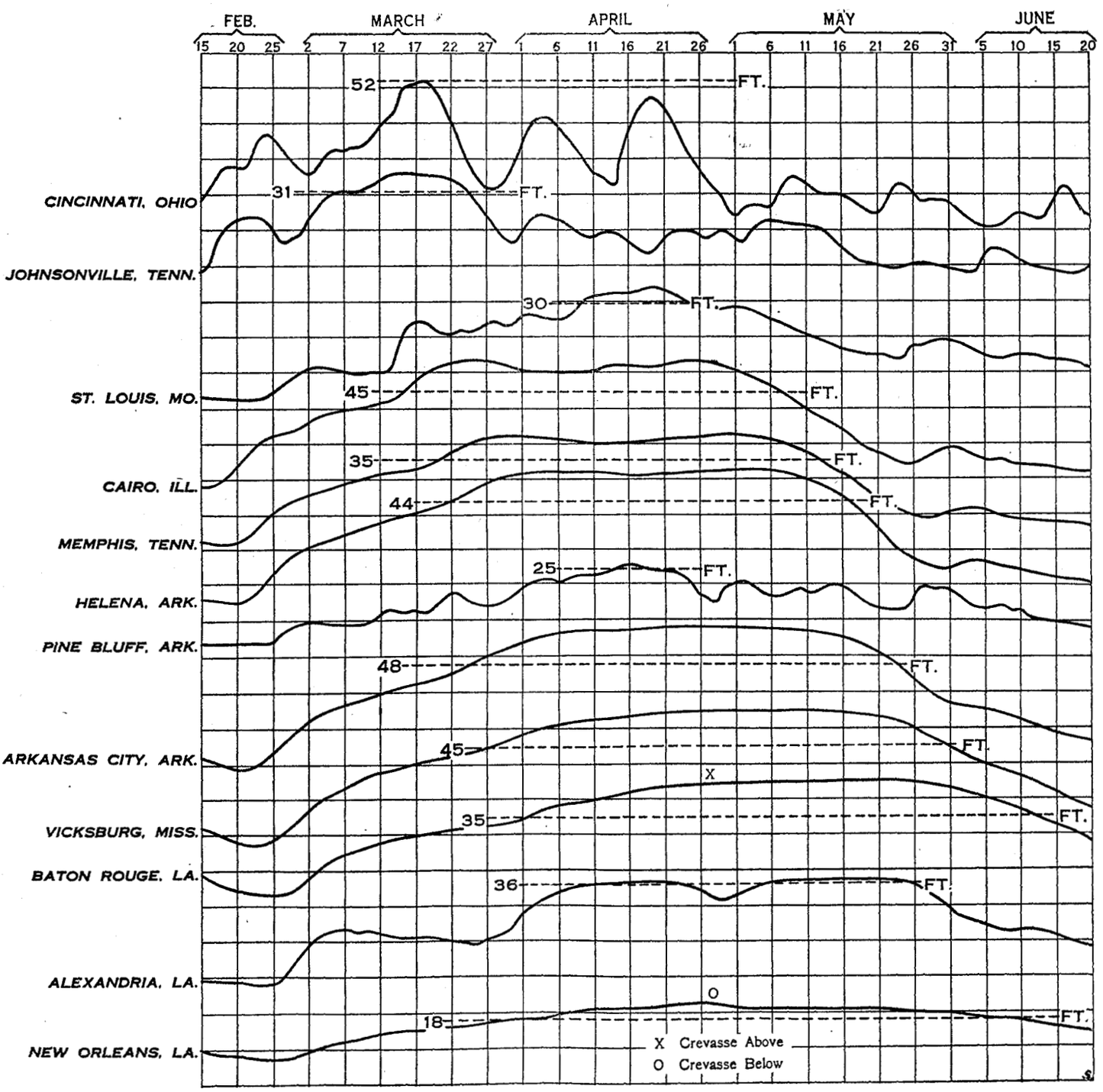


CHART IV.—Hydrographs for selected stations lower Mississippi River, flood of 1922.

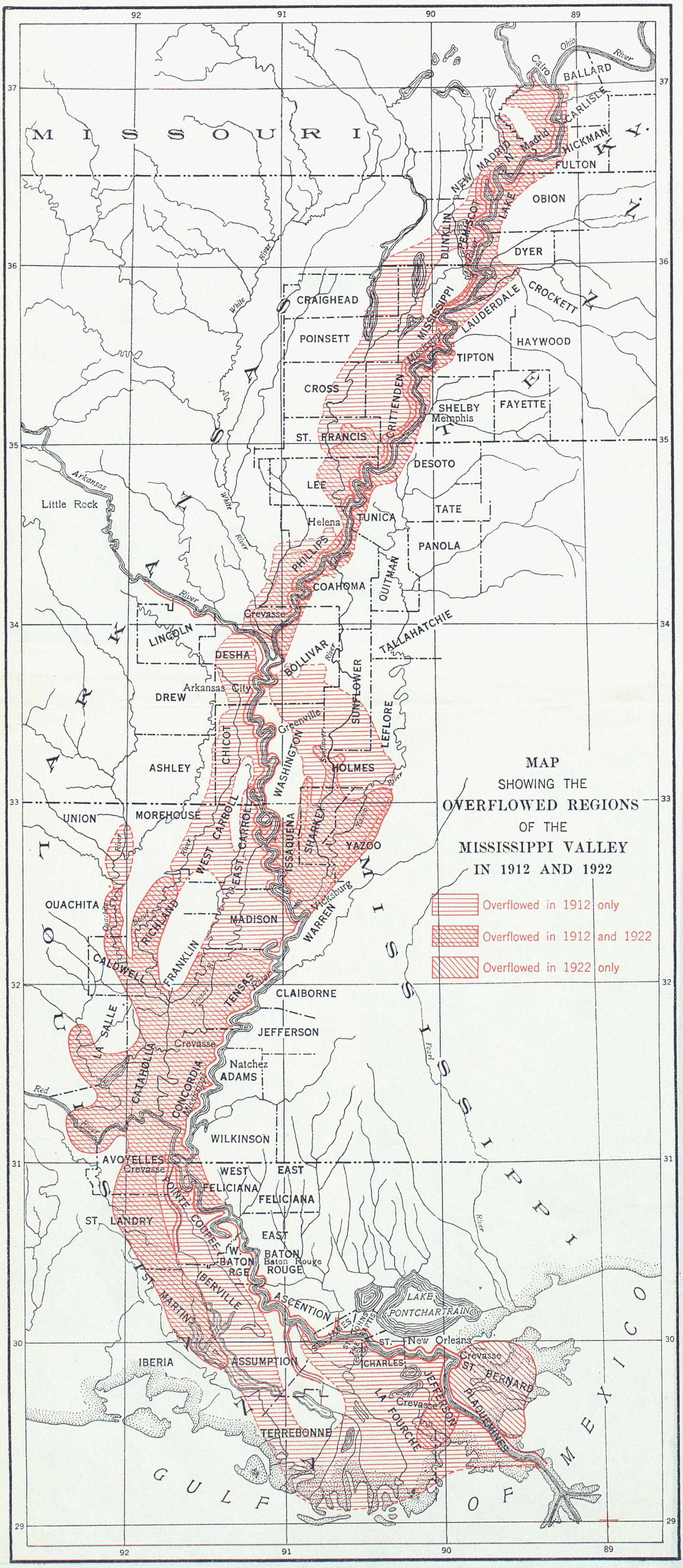

MAP
SHOWING THE
OVERFLOWED REGIONS
OF THE
MISSISSIPPI VALLEY
IN 1912 AND 1922
Overflowed in 1912 only
Overflowed in 1912 and 1922
Overflowed in 1922 only
MISSOURI
KENTUCKY
TENNESSEE
ARKANSAS
LOUISIANA
MISSISSIPPI
GULF OF MEXICO
BALLARD
CARLISLE
HICKMAN
FULTON
OBION
DYER
CROCKETT
HAYWOOD
TIPTON
FAYETTE
SHELBY
Memphis
DESOTO
TATE
PANOLA
TALLAHATCHIE
QUITMAN
TUNICA
Helena
LEE
ST. FRANCIS
CROSS
POINSETT
CRAIGHEAD
NEW MADRID
DUNKLIN
PEMISCOT
LAKE
LAUDERDALE
CRITTENDEN
PHILLIPS
COAHOMA
Crevasse
LINCOLN
DESHA
BOLLIVAR
SUNFLOWER
LEFLORE
Arkansas City
DREW
Greenville
CHICOT
ASHLEY
WASHINGTON
HOLMES
UNION
MOREHOUSE
WEST CARROLL
EAST CARROLL
ISSAQUENA
SHARKEY
YAZOO
Vicksburg
WARREN
OUACHITA
RICHLAND
MADISON
FRANKLIN
CALDWELL
TENSAS
CLAIBORNE
LA SALLE
JEFFERSON
Natchez
ADAMS
CATAHOULA
CONCORDIA
WILKINSON
AVOYELLES
WEST FELICIANA
EAST FELICIANA
ST. LANDRY
POINTE COUPEE
EAST BATON ROUGE
W. BATON RGE
IBERVILLE
ST. MARTIN
ASCENTION
LAKE PONTCHARTRAIN
ST. JAMES
ST. JOHNS BAPTIST
ST. CHARLES
New Orleans
Crevasse
ST. BERNARD
PLAQUEMINES
IBERIA
ASSUMPTION
JEFFERSON
LA FOURCHE
TERREBONNE
Little Rock
Cairo
Ohio River
White River
Arkansas River
Red River
Ouachita River
Bayou Bartholomew
Tensas River
Sunflower River
Yazoo River
Pearl River
Mississippi River
N. Madrid
92
91
90
89
37
36
35
34
33
32
31
30
29

TABLE 11.—*Number of days rivers were at or above present flood stages during great floods in the Lower Mississippi River (all dates inclusive).*

Station.	Flood stage (feet).	Dates and duration.					
		1882	1883	1893	1897	1903	1907
St. Louis, Mo	30	July 2-July 10 (9)	June 17-July 3 (17)	May 1-May 5 (5)	May 1-May 5 (5)	June 3-June 18 (16)	
Cairo, Ill	45	Jan. 20-Feb. 12 (24)	Feb. 16-Mar. 8 (21)	May 2-May 19 (18)	Mar. 6-Apr. 22 (48)	Mar. 8-Mar. 27 (20)	Jan. 22-Feb. 5 (15). Mar 22-Mar. 29 (8).
Memphis, Tenn	35	Mar. 6-Mar. 11 (6)		May 12-May 21 (10)	Mar. 13-Apr. 25 (44)	Mar. 11-Apr. 2 (23)	Jan. 27-Feb. 11 (16). Mar. 29-Apr. 4 (7).
Helena, Ark	44	Feb. 3-Apr. 2 (59).	Mar. 2-Mar. 19 (18)	May 14-June 17 (35)	Mar. 14-May 4 (52)	Mar. 2-Apr. 10 (40)	Jan. 25-Feb. 14 (21). Mar. 29-Apr. 7 (10).
Arkansas City, Ark	48			May 8-June 18 (42)	Mar. 21-May 3 (44)	Mar. 8-Apr. 13 (37)	Jan. 22-Feb. 18 (28).
Greenville, Miss	42			May 8-June 18 (42)	Mar. 22-May 5 (45)	Mar. 7-Apr. 14 (39)	Jan. 20-Feb. 19 (31). May 24-May 27 (4).
Vicksburg, Miss	45	Mar. 9-Apr. 16 (39)		May 8-June 21 (45)	Mar. 21-May 29 (70)	Mar. 4-May 1 (59)	Jan. 23-Feb. 23 (32). Apr. 7-Apr. 13 (7). May 25-May 31 (7).
Natchez, Miss	46	Mar. 13-Apr. 10 (29)		May 15-June 8 (25)	Mar. 30-May 30 (62)	Mar 9-May 1 (54)	Feb. 2-Feb. 25 (24).
Baton Rouge, La	35	Mar. 11-Apr. 7 (28)	Apr. 9 (1)	May 29-July 7 (40)	Apr. 5-June 7 (64)	Mar. 11-May 14 (65)	Feb. 6-Feb. 27 (22). May 31-June 3 (4).
Donaldsonville, La	28			June 6-July 5 (30)	Apr. 2-June 7 (67)	Mar. 10-May 14 (66)	Feb. 5-Feb. 27 (23). May 31 (1).
New Orleans, La	18				Apr. 11-June 1 (52)	Mar. 9-May 9 (62)	Jan. 29-Mar. 1 (32). May 31 (1).
Melville, La	37					Mar. 15-Apr. 28 (45)	Feb. 12-Feb. 25 (14).
Nashville, Tenn	40	Jan. 11-Feb. 2 (23)	Feb. 12-Feb. 17 (6)	Feb. 21-Feb. 23 (3)	Mar. 15-Mar. 25 (11)	Mar. 9 (1)	
Johnsonville, Tenn	31	Jan. 17-Feb. 17 (32)		Feb. 20-Mar. 1 (10)	Mar. 14-Apr. 10 (28)	Mar. 9-Mar. 17 (9)	
Mount Carmel, Ill	15			Feb. 11-Mar. 2 (20)	Feb. 23-Mar. 29 (35)	Mar. 2-Mar. 23 (22)	Jan. 4-Feb. 4 (32). Mar. 14-Mar. 27 (14).
Pine Bluff, Ark	25	Feb. 18-Mar. 3 (14)	Feb. 17-Mar. 4 (16)	May 1-May 15 (15)			
Clarendon, Ark	30			Feb. 18-Feb. 24 (7)	Mar. 23-Apr. 29 (38)	Mar. 13-Apr. 4 (23)	Jan. 5-Jan. 26 (22). May 13-May 27 (15).
Alexandria, La	36					Mar. 25-Mar. 31 (7)	

Station.	Flood stage (feet).	Dates and duration.				
		1912	1913	1916	1920	1922
St. Louis, Mo	30	Apr. 4-Apr. 10 (7). Apr. 30-May 1 (2).		Jan. 31-Feb. 2 (3)		Apr. 10-Apr. 23 (14).
Cairo, Ill	45	Mar. 22-Apr. 22 (32). Apr. 30-May 13 (14).	Jan. 19-Feb. 7 (20). Mar. 27-Apr. 22 (27).	Jan. 6-Feb. 16 (42)	Mar. 20-Apr. 18 (30). Apr. 25-May 8 (14).	Mar. 16-May 7 (53).
Memphis, Tenn	35	Mar. 26-May 20 (56)	Jan. 21-Feb. 14 (25). Mar. 30-Apr. 28 (30).	Jan. 6-Feb. 23 (49)	Mar. 27-May 13 (48)	Mar. 19-May 13 (56).
Helena, Ark	44	Mar. 28-May 24 (58)	Jan. 26-Feb. 15 (21). Apr. 3-May 3 (31).	Jan. 11-Feb. 27 (48)	Mar. 29-May 16 (49)	Mar. 22-May 16 (56).
Arkansas City, Ark	48	Mar. 31-May 26 (57)	Feb. 1-Feb. 17 (17). Apr. 6-May 8 (33).	Jan. 15-Mar. 5 (51)	Apr. 2-June 3 (63)	Mar. 26-May 23 (59).
Greenville, Miss	42	Mar. 31-May 24 (55)	Feb. 3-Feb. 17 (15). Apr. 8-May 8 (31).	Jan. 18-Mar. 5 (48)	Apr. 4-May 24 (51)	Mar. 28-May 22 (56).
Vicksburg, Miss	45	Apr. 1-May 31 (61)	Feb. 2-Feb. 26 (25). Apr. 8-May 15 (38).	Jan. 17-Mar. 16 (60)	Apr. 4-June 13 (71)	Mar. 28-May 30 (64).
Natchez, Miss	46	Apr. 5-June 6 (63)	Feb. 8-Feb. 28 (21). Apr. 11-May 18 (38).	Jan. 24-Mar. 21 (58)	Apr. 9-June 16 (69)	Mar. 31-June 3 (65).
Baton Rouge, La	35	Apr. 8-June 15 (69)	Feb. 12-Mar. 2 (19). Apr. 14-May 25 (42).	Jan. 28-Mar. 29 (62)	Apr. 12-June 25 (75)	Apr. 2-June 12 (72).
Donaldsonville, La	28	Apr. 8-June 12 (66)	Feb. 13-Mar. 1 (17). Apr. 15-May 25 (41).	Jan. 30-Mar. 27 (58)	Apr. 13-June 23 (72)	Apr. 1-June 10 (71).
New Orleans, La	18	Apr. 10-June 8 (60)	Feb. 18-Feb. 27 (10). Apr. 17-May 24 (38).	Feb. 1-Mar. 23 (52)	Apr. 15-June 22 (69)	Apr. 3-June 4 (63).
Melville, La	37	Mar. 31-June 19 (81)	Feb. 6-Mar. 8 (31). Apr. 9-May 26 (48).	Jan. 26-Mar. 31 (66)	Apr. 8-June 27 (81)	Apr. 1-June 14 (75).
Nashville, Tenn	40	Apr. 2-Apr. 11 (10). Apr. 30-May 5 (6).	Jan. 8-Jan. 19 (12). Mar. 28-Apr. 5 (9).	Jan. 2-Jan. 8 (7)	Jan. 25-Feb. 1 (8). Apr. 3-Apr. 8 (6).	Apr. 3-Apr. 20 (18).
Johnsonville, Tenn	31	Apr. 2-Apr. 13 (12). May 1-May 4 (4).	Mar. 27-Apr. 7 (9) [1]	Jan. 4-Jan. 10 (7)	Apr. 4-Apr. 17 (14)	Mar. 10-Mar. 24 (15).
Mount Carmel, Ill	15	Mar. 16-Apr. 14 (30). Apr. 28-May 23 (22).[2]	Jan. 12-Feb. 6 (26). Mar. 25-Apr. 22 (29).	Jan. 1-Feb. 17 (48)	Mar. 15-Mar. 28 (14). Apr. 22-May 4 (13).	Mar. 16-May 2 (48).
Pine Bluff, Ark	25	Apr. 3-Apr. 7 (5). May 3-May 7 (5).		Jan. 29-Feb. 6 (9)		Apr. 14-Apr. 17 (4).
Clarendon, Ark	30	Apr. 6-Apr. 30 (25). May 6-May 15 (10).	Jan. 23-Jan. 29 (7). Apr. 13-Apr. 21 (9).	Jan. 30-Feb. 23 (25)		Apr. 7-Apr. 27 (21).
Alexandria, La	36			Feb. 13-Feb. 20 (8)	May 29-June 6 (9)	Apr. 12-Apr. 23 (12).

[1] Below flood stage Apr. 2-4.

[2] Below flood stage May 11-14.

At Cairo in 1922 the river was above the flood stage of 45 feet from March 16 to May 7, inclusive, a total of 53 days, against the previous high record of 48 days in 1897, but below Cairo the 1922 records for duration fell slightly below those of some previous years, generally 1912 above the mouth of the Arkansas River and 1920 below (Greenville, Miss., 1912).

In both 1912 and 1920 the Atchafalaya River was in flood slightly longer than in 1922. The Red River at Alexandria, La., was at or above the flood stage of 36 feet for 12 days, only the fourth time in 40 years.

(*d*) *Extent of overflowed lands.*—Previous to the era of levee construction the total area of lands below Cairo subject to overflow during lower Mississippi River floods was 29,790 square miles.[2] In 1897 the overflowed area was 13,580 square miles; in 1903, 6,820 square miles; in 1912, 17,605 square miles; and in 1922, about 13,200 square miles, about 4,400 square miles less than in 1912, almost all of the deficiency occurring in the Vicksburg district, which extends from the mouth of the White River to Vicksburg. The extent of overflowed area below Vicksburg was only a little less than that of 1912, although distributed a little differently over the extreme northern and southern portions. Chart V shows the

[2] J. A. Ockerson, Proceedings American Society of Civil Engineers, May, 1922, p. 1171.

overflowed areas in the lower Mississippi Basin during the floods of 1912 and 1922.

(*e*) *Comparative gage relations.*—The relations between gages at different points on the lower river, as they exist at the present time, can be best obtained by comparison of the stages of the floods of 1882, 1916, 1920, and 1922. The flood of 1882 occurred when the levee system was in its infancy, figuratively speaking, while those of 1916, 1920, and 1922 occurred after its completion to such an extent that the Mississippi River virtually became a closed or canalized river from Cairo to its mouth. As the closing process progressed more and more water was confined to the river channel. The differences in the stages of water between Cairo, the key station at the head of the levee system, and other stations farther down the river gradually lessened until a relation has been reached with the completion of the levee system which will probably remain constant, although, of course, there is nearly always some variation within narrow limits. Tributary effects below Cairo must be considered at all times, but these can usually be computed with a reasonable degree of accuracy.

In 1882, with no crevasses between Cairo and Memphis, the Memphis crest stage differed from that at Cairo by −16.7 feet. In 1892, after the St. Francis levee had been constructed between Point Pleasant, Mo., and Pecan Point, Ark., the difference was −13.7 feet, a seeming rise of 3 feet at Memphis due to levee effect. In 1897 several crevasses occurred between the two places, and on account of the loss of overflow water into the State of Arkansas the difference was −15.2 feet. Mr. S. C. Emery[3] estimated that the crevasses at this time lowered the Memphis crest by at least 1 foot. If we are justified in increasing Mr. Emery's estimate to 1.5 feet, the gage relation of 1892 would then be sustained.

By 1903 the St. Francis levee system had been extended from Pecan Point to the head of Cat Island, a short distance below Memphis, and the Memphis gage for the flood of that year read 10.5 feet below Cairo, a relation about such as would have been expected, because the losses through Hollybush and Random Shot crevasses were probably offset by the excess caused by the Missouri Pacific Railroad embankment opposite Memphis, that had been constructed after 1897.

Originally the approach to the Missouri Pacific Railroad bridge consisted of several miles of trestle, but during the three or four years immediately preceding 1903 the trestlework had been filled with earth, making a solid embankment many feet in height from Bridge Junction, Ark., to the steel viaduct of the west approach to the bridge. Immediately under the steel viaduct a lower embankment was erected, running to the water's edge, the whole forming a complete barrier, or cross levee, against the water, which was forced to find an outlet through the opening between the St. Francis Levee and the western end of the railroad embankment or return to the river and pass under the bridge proper. It was this water that was forced back to the river that caused the increased stage of probably as much as 1.5 feet on the Memphis gage during the flood of 1903.

In 1912 and 1913 with several crevasses the differences were only −8.7 and −8.3 feet, respectively, the effect of the Missouri Pacific Railroad embankment apparently overshadowing the losses through the crevasse water. These figures are, roughly, about 2 feet above those for 1903, and the differences can readily be accounted for by noting the increased stages at Cairo. In 1903 the maximum stage at Cairo was 50.6 feet, whereas in 1912 it was 54.0 feet and in 1913, 54.8 feet, increases of 3.4 and 4.2 feet, respectively. The result was a greatly augmented volume of water against the railroad embankment opposite Memphis, with an increased ponding effect that was reflected in an equally increased stage on the Memphis gage almost directly opposite.

In 1916, with one crevasse above Memphis, the difference was −9.9 feet with a Cairo crest stage of 53.4 feet, the railroad embankment apparently causing an addition of about 2 feet on the Memphis gage, while the crevasse caused a loss of about 1 foot.

In 1920 and 1922, with no crevasses and with the *Missouri Pacific embankment replaced by an open trestle*, the differences between Cairo and Memphis were −11.1, −11.0, and −11.2 feet, respectively. (Two crests in 1922.)

In the table below is given for each of the great floods the amount the Memphis crest stages were lower than those at Cairo; also certain arbitrarily assigned effects due to crevasses, the Missouri Pacific Railroad embankment, etc.

TABLE 12.—*Comparison of crest stages (in feet) at Cairo, Ill., and Memphis, Tenn.*

Year.	Cairo.	Memphis.	Difference.	Disturbing factors.			Probable true difference.	Change since 1882.
				Crevasse effect.	Railroad embankment effect.	Total.		
1882	51.9	35.2	−16.7	0.0	0.0	0.0	−16.7	.....
1892	48.3	34.6	−13.7	0.0	0.0	0.0	−13.7	−3.0
1897	51.6	36.4	−15.2	−1.5	0.0	−1.5	−13.7	−3.0
1903	50.6	40.1	−10.5	−1.5	+1.5	0.0	−10.5	−6.2
1907	50.4	39.0	−11.4	0.0	+1.5	+1.5	−9.9	−6.8
1912	54.0	45.3	−8.7	−1.0	+3.0	+2.0	−10.7	−6.0
1913	54.8	46.5	−8.3	−1.0	+3.0	+2.0	−10.3	−6.4
1916	53.4	43.5	−9.9	−1.0	+2.5	+1.5	−11.4	−5.3
1920	51.4	40.3	−11.1	0.0	0.0	0.0	−11.1	−5.6
1922	53.6	42.6	−11.0	0.0	0.0	0.0	−11.0	−5.7
1922	53.5	42.3	−11.2	0.0	0.0	0.0	−11.2	−5.5

These figures indicate that the normal effect at Memphis, based upon a crest stage at Cairo of 50 feet or more with a canalized river, now makes the difference between stages about 11 feet, as against between 16 and 17 feet in 1882 when the levee system was incomplete, and the change may be considered as almost entirely due to the extension of the levee system.

[3] Bulletin E, Floods of the Mississippi River, 1897, p. 72

Relations between Cairo and Helena, Ark., changed materially between 1882 and 1897, but not much after 1897, although a slight positive difference between 1897 and 1916 has since changed into a more pronounced negative one. In 1882 the Helena difference was −4.7 feet, in 1892, −2.4 feet, and in 1897, +0.2 foot. Forecasts of precise relations between Cairo and Helena in high floods can be arrived at only by elimination during individual floods, as the stages of the St. Francis River and the Mississippi River at Arkansas City must be taken into consideration. However, it appears that during the last six years, under present levee conditions and with Cairo about 50 feet or more, the crest stages at Helena will average approximately 1 foot below those at Cairo.

In 1882 the crest stage at Arkansas City, Ark., was 4.9 feet below Cairo, almost the same as at Helena, and, following the gradual completion of the levee system, it had become 3 feet higher by 1916. This relation of about +3.0 feet for high stages continued until 1922, when it increased to +4.4 feet. Of the additional 1.4 feet, about 1 foot was caused by the closing in 1921 of Cypress Creek, Ark., and the remainder to the increased volume of water from the Arkansas River, due to prolonged stages above the usual height. It seems reasonable to assume, therefore, that for future Cairo crest stages of 50 feet or over the difference at Arkansas City, under normal Arkansas and White River conditions, will be about +4.0 feet.

It has been estimated that an artificial increase of 1 foot in the gage height at a given place in the lower Mississippi River should disappear entirely in about 600 or 700 miles of water travel. Arkansas City is 637 miles from the Gulf of Mexico, and therefore the increase of 1 foot in the positive difference between Cairo and Arkansas City, due to the closure of Cypress Creek, should disappear by the time the Gulf of Mexico is reached. It should be remembered, however, that from Vicksburg southward the relations will not be direct, as the Yazoo and Red River influence must be considered.

SUMMARY OF THE FLOODS OF 1922.

Drainage basins above the mouth of the Ohio River—Ohio River.—Only moderately high water occurred above the mouth of the Scioto River. The first rise began on March 12 during a period of high temperatures and light rains, followed by heavy rains on March 15. The crest stage at Pittsburgh, Pa., was 3.6 feet below the flood stage at 22 feet and at Parkersburg, W. Va., 6 feet below the flood stage of 36 feet, both on March 16. At Point Pleasant, W. Va., the crest on March 17 was 0.4 foot below the flood stage of 40 feet, while at Portsmouth, Ohio, it was 0.1 foot above the flood stage of 50 feet on the same date. The tributaries in the State of Ohio contributed but little. Between Portsmouth and the mouth of the Green River the stages were not much in excess of the flood stages, but over the Green River Drainage Basin the rains were heavier, with severe resultant floods that were soon reflected in the main stream which was already in flood from the rise above. At Lock No. 4, Woodbury, Ky., on the Green River, the crest stage of 40.4 feet on March 17 was 7.4 feet above the flood stage, and the river was continuously in flood from March 3 to 20, inclusive. Both forks of the White and the main stream and the Wabash were also in severe flood with further resultant effect upon the Ohio River gages at Mount Vernon, Ind., and points below.

The Cumberland and Tennessee River floods were also severe over their lower portions, the water having been high since the early days of the month. The crests occurred about the same time as in the other southern tributaries. The Paducah, Ky., crest of 48.85 feet occurred on March 24, and that of 53.6 feet at Cairo two days later. The succeeding rises were not so marked, except in the White and Wabash Rivers, where the crests were still higher than in March and served only to prolong the high stages in the lower main stream.

The lateness of the season made the floods in Indiana and extreme southeastern Illinois the most destructive in many years. The damage to prospective crops alone was estimated at $2,135,000 and that to other property $1,093,000. The reported value of property saved by the Weather Bureau warnings was $350,000. Over other portions of the Ohio watershed, except in the Cairo district, the damage reported was small.

Table 13 following gives the crest stages and dates of the three rises at selected places along the Ohio River and certain of its tributaries.

TABLE 13.—*Crest stages in Ohio River and tributaries during three rises in 1922.*

Station.	River.	Flood stage.	First rise.		Second rise.		Third rise.	
			Crest.	Date.	Crest.	Date.	Crest.	Date.
		Feet.	*Feet.*		*Feet.*		*Feet.*	
Warren, Pa.	Allegheny	12	6.4	Mar. 12	6.8	Apr. 1[1]	6.0	Apr. 16
Lock No. 7, Pa.	Monongahela.	30	30.0	Mar. 15	16.8	Apr. 2	25.2	Apr. 15
Pittsburgh, Pa.	Ohio	22	18.4	Mar. 16	16.0	do	20.3	do
Zanesville, Ohio.	Muskingum.	25	18.3	Mar. 15	18.8	Apr. 1	25.7	do
Parkersburg, W. Va.	Ohio	36	30.0	Mar. 16	27.2	Apr. 2	33.9	Apr. 17
Athens, Ohio	Hocking	17	19.8	do	14.6	Apr. 1	21.9	Apr. 16
Point Pleasant, W. Va.	Ohio	40	39.6	Mar. 17	32.0	Apr. 3	37.9	Apr. 18
Chillicothe, Ohio	Scioto	14	16.5	Mar. 16	14.9	Apr. 2	20.5	Apr. 16
Portsmouth, Ohio.	Ohio	50	50.1	Mar. 17	39.3	Apr. 3	45.8	Apr. 18
Falmouth, Ky.	Licking	28	26.8	Mar. 15	17.3	Apr. 1	20.9	Apr. 15
Cincinnati, Ohio	Ohio	52	52.2	Mar. 18	41.7	Apr. 4	48.2	Apr. 19
Madison, Ind.	do	46	46.1	Mar. 19	35.7	do	40.2	Apr. 20
Frankfort, Ky.	Kentucky	31	23.5	Mar. 18	17.4	Apr. 1	9.9	Apr. 15
Louisville, Ky.	Ohio	28	30.2	Mar. 19	17.3	Apr. 6	22.0	Apr. 20
Bowling Green, Ky.	Barren	20	20.0	Mar. 16				
Lock No. 4, Ky.	Green	33	40.4	Mar. 17	33.0	Apr. 3	18.6	Apr. 12
Evansville, Ind.	Ohio	35	42.9	Mar. 21	36.6	Apr. 7	37.6	Apr. 23
Shoals, Ind.	White (East Fork).	20	26.3	Mar. 20	22.5	Apr. 5	28.0	Apr. 19
Elliston, Ind.	White (West Fork).	19	26.3	Mar. 17	24.5	Apr. 3	27.0	Apr. 20
Decker, Ind.	White	18	24.6	Mar. 22	22.5	Apr. 6[1]	25.7	Apr. 22
Terre Haute, Ind.	Wabash	16	19.5	Mar. 16[1]	21.5	Apr. 4	24.4	Apr. 19
Mount Carmel, Ill.	do	15	24.1	Mar. 23	23.8	Apr. 8	26.0	Apr. 23
Mount Vernon, Ind.	Ohio	35	43.5	do	37.5	Apr. 9	39.5	Apr. 24
Shawneetown, Ill.	do	35	47.6	Mar. 25	41.3	Apr. 10	44.2	Apr. 25
Nashville, Tenn.	Cumberland.	40	45.1	Mar. 16	27.5	Apr. 3	23.0	Apr. 12
Clarksville, Tenn.	do	46	50.9	Mar. 11	32.7	Apr. 2	26.9	do
Chattanooga, Tenn.	Tennessee	33	32.8	Mar. 13	20.1	do	16.8	Apr. 8
Riverton, Ala.	do	32	42.8	Mar. 11	29.1	do	24.0	Apr. 11
Johnsonville, Tenn.	do	31	36.4	Mar. 15	24.5	Apr. 4	20.3	Apr. 13
Paducah, Ky.	Ohio	43	48.85	Mar. 24	41.9	Apr. 13	44.0	Apr. 25[1]
Cairo, Ill.	do	45	53.6	Mar. 25[1]	52.0	Apr. 15	53.5	do

[1] And subsequent dates.

The detailed discussion of the floods in the Cairo district includes also a portion of the Mississippi Basin and follows the report for the St. Louis district, beginning on page 20.

Mississippi River.—The rise in the extreme upper Mississippi River began during the first week of April, but without flood stages until La Crosse, Wis., was reached. Here the crest stage of 13.7 feet was reached on April 17, following high temperatures and frequent, although not very heavy, rains. The snow cover was less than usual. The river was at the flood stage of 12 feet from April 12 to 21, inclusive. The damage over the La Crosse district was only nominal.

Neither the Chippewa nor the upper Wisconsin Rivers were in flood, but in the lower Wisconsin there was a quick flood which ran out in about 10 days with a crest stage at Portage, Wis., of 15.8 feet, 1.8 feet above the flood stage on April 14. The stages generally reached were slightly below those of the flood of October, 1911, although at Boscobel, Wis., 30 miles from its mouth, the Wisconsin River was reported to have been higher than since 1898.

Losses were about $60,000, while property to an estimated value of $75,000 was saved through the flood warnings.

MISSISSIPPI RIVER FLOOD FROM BELOW LA CROSSE, WIS., TO DUBUQUE, IOWA.

By Thomas A. Blair, Meteorologist.

(Weather Bureau, Dubuque, Iowa.)

Warm weather during the latter half of March over the drainage area of the Mississippi River above Dubuque, particularly in Minnesota and Wisconsin, had resulted in considerable run-off, raising the Mississippi and its tributaries above Dubuque to rather high levels. There followed during the first 10 days of April frequent and moderately heavy rains, attended by unusually warm weather. Although the snow cover was thought to be less than average, the result was a flood beginning at La Crosse on April 12 and reaching a maximum stage at Dubuque on the 21st, which has been equalled but three times in the past 50 years.

In its maximum stages this flood was very nearly the counterpart of that of March and April, 1920, but in the manner of rise there was considerable difference. In 1920 a rather rapid rise began immediately after the breaking up of the ice, becoming very rapid as the crest of the flood was approached. In 1922 the river opened about the middle of March and from that time to the end of March moderately high stages, sufficient to overflow the lower islands and bottoms, were maintained with little change. Then began a continuous and approximately uniform rise until about five days before the peak was reached, when the rate increased considerably but did not attain the rate reached in 1920. In the latter half of its rise it resembled very closely the floods of 1880 and 1888, but these latter were more rapid in the early stages.

Maximum stages reached from La Crosse to Dubuque in the six floods of the past 50 years are shown in the accompanying table.

Table 14.

Station.	Flood stage.	1880	1881	1888	1916	1920	1922
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
La Crosse, Wis	12	16.0	13.2	14.5	13.6	14.2	13.7
Lansing, Iowa	18	.....	.....	.....	16.4	17.3	17.3
Prairie du Chien, Wis	18	21.5	19.0	20.0	18.3	19.6	19.4
Dubuque, Iowa	18	21.7	20.2	21.4	19.8	21.0	21.0

It is evident that a large part of the flood waters came from above La Crosse, for the maximum stage there was 1.7 feet above flood stage, and the highest at Lansing was the same as that of two years ago, but a flood exceeding that of 1920 was in progress on the Wisconsin River at the same time and added considerably to the stages reached at Prairie du Chien and Dubuque. The peak of the Wisconsin flood wave reached Prairie du Chien, however, about three days earlier than that from the Mississippi, and hence the crests occurred at Prairie du Chien and Dubuque a little earlier and were a little lower than would have been the case if the Wisconsin flood had been a few days later.

From below La Crosse to below Lansing the damage was comparatively slight, as is usually the case with spring floods. The largest item aside from the injury to and the cost of protection of railroad roadbeds was the collapse of a warehouse filled with ice at Lansing. At Prairie du Chien about one-fourth of the town was under water, and people were traveling on the streets by boat. As a result of the warnings all live stock and much movable property were moved to higher portions of the city, while many families either moved from their residences altogether or moved to the second floors. Railroad traffic east into the Wisconsin Valley and north into the Kickapoo Valley was suspended. Opposite Prairie du Chien, at Marquette and McGregor, Iowa, buildings along the river front were inundated, causing interruption of business. Much land was overflowed in the vicinity of Cassville, Wis., and Waupeton, Iowa, causing a loss estimated at about $50,000.

At Dubuque the overflow was a duplicate of that of 1920. Many plants and establishments along the river front and on the lower ground back from the river were surrounded or partially surrounded by water, and several were forced to suspend operations. Practically all of the factories and wholesale houses in the southern end of the town suffered flooded basements. Considerable lengths of track of the Illinois Central, the Chicago, Burlington and Quincy, and the Chicago, Milwaukee and St. Paul Railroads were under water, and traffic was diverted and partially suspended. Much labor and material were used in protecting tracks and embankments from undermining. A high northwest wind on the 19th, when the river was within 5 inches of its maximum stage, added to the difficulties of the railroads and others in preventing the wearing away of dikes.

Many families living in the lowlands on both sides of the river were temporarily driven from their homes, and a much larger number had flooded basements. At least 14 cottages, situated on the islands in the vicinity of Dubuque and used as summer residences, were carried away by the flood waters in conjunction with the high wind on the 19th.

On April 12, nine days before the crest of the flood reached Dubuque, flood warnings were issued for the entire district from below La Crosse to Dubuque. On April 17 definite forecasts of maximum stages were made as follows: Lansing, 17.0 feet; Prairie du Chien, 19.5 feet; Dubuque, 21.0 feet. Warnings were distributed by mail to all towns in the district, and those having property subject to overflow in general did whatever could be done to remove or protect it, so that the preventable loss was slight.

MISSISSIPPI RIVER FROM BELOW DUBUQUE TO MUSCATINE, IOWA.

By Andrew M. Hamrick, Meteorologist.

(Weather Bureau, Davenport, Iowa.)

During the first 21 days of April, 1922, rain fell on some part of the watershed of the Mississippi River from Muscatine northward on every day but three. The frequent rains, while not very heavy except on the 10th and 16th, fell on a well-saturated soil and the run-off was above normal.

As an index of the general situation, note the conditions at Davenport: The precipitation during the month of March was 3.40 inches, 1.19 inches above normal. There were 21 cloudy days during the month, and consequently little evaporation. The percentage of possible sunshine was 42, 16 per cent below the normal for March.

The rivers were rising steadily in the vicinity of Prairie du Chien, Wis., and Dubuque, Iowa, by the end of March, and the continued

rainy weather during the first 10 days of April made it apparent that a flood would be experienced in the Davenport district during the last decade of the month. Forecasts were issued daily for a steady rise, and on April 14 interests were advised that the crest stage would reach Davenport during the week of April 23–29. On April 17 a general flood warning was issued to the effect that the crest stages would equal those of the 1920 flood in this district. On April 19 the following definite stages were forecast: Clinton, Iowa, 19.0 feet; Le Claire, Iowa, 13.0 feet; Davenport, 17.0 feet; and Muscatine, Iowa, 19.0 feet by April 22. Those stages were reached within one-tenth of a foot at all stations.

At Davenport the crest stage was 17.1 feet on April 23, exactly the same as the crest in the flood of 1920; at Clinton the crest stage was 19.0 feet during the night of April 21–22, exactly the same as the crest in 1920; at Le Claire the crest was 12.9 feet during the night of April 22–23, 0.5 foot less than the crest in 1920, but the difference was due to the gage readings being affected by a dam which had been built near Le Claire since 1920, as the overflowed area was practically the same; at Muscatine the water rose above the permanent river gage, and a temporary gage showed a stage of 19.1 feet on the morning of the 23d. As afterward determined by actual survey, the highest stage was 19.5 feet on April 24, 1.5 feet above the previous high-water record of April 8, 1920. Levees in the vicinity of Muscatine have been strengthened considerably since the flood of 1920 and therefore a much higher gage reading resulted; the highest reached in 1920 was 18.0 feet, but the levees gave way and prevented what would have been at least another foot rise. On April 26 the levee broke at a point 10 miles north of Burlington, Iowa, relieving the situation at Muscatine even though the crest had already been reached at the latter place.

Forecasts and warnings were given wide distribution by mail, newspapers, telephone, and radio, and all interests had ample time to protect their property. No losses were sustained as a result of being unprepared to meet the emergency. In the vicinity of Muscatine and New Boston hundreds of men worked day and night patrolling and strengthening the leveess. High northwest winds on April 19 made conditions critical for the Illinois side of the river, but fortunately the levees held, and favorable weather prevailed during the remainder of the week.

The record of loss and damage is incomplete, but the total amount reported was $91,000, including losses occasioned by suspension of business. The reported value of property saved through the Weather Bureau warnings was $415,000.

Nothing of special interest occurred in the Hannibal, Mo., district, which extends from below Muscatine, Iowa, to Louisiana, Mo. Warnings were issued well in advance of the flood and were verified to within one-tenth of a foot.

Statistical data are given in the table following:

TABLE 15.

Station.	Flood stage.	Above flood stage.		Crest.	
		From—	To—	Stage.	Date.
	Feet.			*Feet.*	
Keithsburg, Ill	12	Apr. 17	May 2	15.3	Apr. 24.
Keokuk, Iowa	14	Apr. 15	May 3	17.6	Apr. 23.
Warsaw, Ill	17	...do....	May 2	20.2	Apr. 24.
Quincy, Ill	14	Apr. 14	May 5	18.7	Apr. 25.
Hannibal, Mo	13	Apr. 12	May 8	18.9	Do.
Louisiana, Mo	12	Apr. 10	...do....	17.0	Apr. 26–27.

The flood waters broke through the shore protection a few miles below Gregory, Mo. The crevasse was from 60 to 75 feet in width, and the overflow water ran into the Gregory levee district, and there was also a break in the levee 7 or 8 miles above Burlington, Iowa.

There were no preventable losses, but those reported totaled $357,500, of which $240,000 was in prospective crops, 34,000 acres having been overflowed. The reported value of property saved by the flood warnings was $190,000.

MISSISSIPPI RIVER AND TRIBUTARIES FROM BELOW LOUISIANA, MO., TO BUT NOT INCLUDING CAPE GIRARDEAU. (INCLUDES MISSOURI RIVER EAST OF LEXINGTON, MO., AND THE OSAGE RIVER IN MISSOURI.)

By M. W. HAYES, Meteorologist.

(Weather Bureau, St. Louis, Mo.)

A period of wet weather began on March 25 over Illinois and Missouri, and until the end of the month almost daily rains occurred. During the first 17 days of April rains also fell frequently and were heavy. The greatest amounts were in the drainage areas of the Osage River, the Missouri below Boonville, Mo., the Mississippi, and the Illinois below Morris. All the rivers of Missouri and Illinois rose under the influence of the excessive precipitation, and unusual floods occurred in the Osage, the exteme lower Missouri, the Mississippi below St. Louis, and in the Illinois.

THE OSAGE RIVER FLOOD.

Stage readings have not been made on this stream for a long period of years. The present system of gages was installed in 1916, but several high-water marks are available and have been referred to the gages. The flood of June, 1844, was by far the highest that has been known in the Osage. We have no knowledge of the length of time this flood prevailed. However, as it is historical and was phenomenally high in much of the central part of the country, it must have been caused by a long period of rains and undoubtedly was of long duration.

In 1895 and 1905 there were winter floods in the Osage that were slightly higher than the one of 1922, but those living along the river are unanimous in saying that the river was never known to stay out of its banks as long as it did in 1922.

The following is a tabulation of the 1922 crest stages and the time the stream was above flood stage:

Station.	Number days above flood stage.		Crest stage.	Date.
	March.	April.		
Osceola, Mo	5	16	28.8	Apr. 10
Warsaw, Mo	9	24	34.9	Apr. 12
Tuscumbia, Mo	6	25	37.7	Apr. 17

The crest stage at Ottawa, Kans., on the upper Osage, was 30 feet, or 6 feet above flood stage, on April 10.

WARNINGS ISSUED.

The first warning of a flood stage was issued at 11.05 a. m. March 14. At this time the stages were 15.9 feet at Osceola, 19.3 at Warsaw, and 15.3 at Tuscumbia. The flood stage at Osceola is 20 feet and was passed on the 19th. At Warsaw it is 22 feet and was passed on the 15th. At Tuscumbia it is 25 feet and was passed on the 17th. Other telegraphic warnings and advices were sent to places along the river on March 15, 16, 19, 20, 21, 30, 31, and April 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 17, 28, and 29.

At Osceola and Warsaw the river dropped within its banks on April 21–22, but local rains caused another but slight overflow at Warsaw on April 28, 29, and 30. The Tuscumbia stage was also below bankful on April 24 to 28, inclusive, but rose a little above flood stage on April 29 and 30 and May 1.

There are very few points along the Osage River that can be reached by telegraph. There are some telephone lines, but as a rule they are poorly constructed, and during the wet weather of March and April communication over most of them was almost impossible. This lack of wire communication reduced the value of the warnings materially. There was a daily river forecast disseminated by wireless telephone. but so far as can be learned there are no receiving stations on the Osage,

The reports concerning the damage along the river are meager or rather, of so general a nature they are of very little statistical value. Although persistent efforts to obtain accurate information have been made, about all that can be said is the following: Thousands of acres of growing wheat were a complete loss; however, this loss can not be charged to lack of communication, and the consequent nonreceipt of the warnings, for it would have occurred under any circumstances. The wheat land was planted to corn after the water subsided. There was considerable hay in stack and some corn still in the land overflowed. Upon receipt of the warnings, which were disseminated as widely as possible, the owners began to move these crops, but in some cases the ground was so soft it was impossible to get a wagon into the bottoms.

THE GRAND RIVER FLOOD.

In the Grand River drainage area the rainfall was quite uniformly distributed as to time, and there was no congested run-off. There was a rise that almost reached a bankful stage the middle of March, and on April 10 a somewhat higher rise began. At Chillicothe, where the flood stage is 18 feet, there were readings of 19.1 and 19.0 feet on the 10th and 11th. At Brunswick the flood stage of 10 feet was exceeded on the 10th to 14th, inclusive, the crest being 12.6 feet on the 11th and 12th.

A forecast of this rise was issued, but it was in more of an advisory than a warning nature. No damage was caused.

THE GASCONADE RIVER.

The Gasconade, like the Grand, was able to discharge the heavy rains that fell in its drainage area without any congestion, as there was sufficient time for run-off between rains. In fact, the river at Arlington did not reach flood stage.

THE MERAMEC RIVER.

The Meramec and its tributaries passed bankful stage several times in March and April, but the highest level reached gave an overflow only in low places. The various rises were forecast from one to three days in advance. There was no damage.

THE ILLINOIS RIVER.

The Illinois River throughout its alluvial reach was nearly bankful at the beginning of the winter. March 10 and 11 marked the beginning of a series of rainstorms, many of which were heavy, that occurred every few days until April 12.

At Morris, 35 miles above the head of the alluvial stream, the rise from the March rains reached a crest of 17.3 feet on April 2. Between April 2 and 10 the rains continued at intervals, but were not heavy enough to maintain the stage at Morris, and the water level dropped steadily but very slowly. On April 10 and 11 rains that ranged in amount from 0.75 to 1.75 inches fell over the entire drainage area, and the Morris stage rose from 13.0 feet on the 10th to 20.1 on the 12th, when a pronounced fall began.

The alluvial river discharges slowly, and the water that was poured into its upper reach, together with that received from the tributaries, caused a steady rise. The oscillations that occurred at Morris, almost coincident with the rains, were entirely lacking in the alluvial reach, and the rise was quite steady. However, as far south as Peoria the stages were almost stationary between April 6 and 10, but the rains of the 10th–11th brought about another gradual rise. This rain was the last that had any material effect on the river.

In any description or discussion of an Illinois River flood some mention of the slopes that prevail in this stream is necessary. The watercourses that form the Illinois have their sources on both sides of Lake Michigan, in Michigan and Illinois, quite close to the lake. As is well known, the Chicago Sanitary Canal is also a tributary now. The slope as far south as Utica, which is on the main stream, is ordinary, but at Utica the alluvial river begins and the slope becomes phenomenally small. From Grafton, on the Mississippi, at the mouth of the Illinois, to Peru, which is the highest Weather Bureau gage station on the alluvial reach, is 222.4 miles. On April 20, the day the flood was highest at Grafton, the surface of the water at Grafton was 429.5 feet above mean sea level. On the same day the surface of the water at Peru was 454.7 feet above mean sea level, giving a fall of 25.2 feet in the 222.4 miles, or very little more than 0.1 foot per mile.

A consideration of the small average slope for the entire alluvial reach makes it clear that with a high and rising Mississippi, a condition that prevailed during this flood, water poured into the Illinois at Utica by the upper river, together with the tributary increment from the rolling country on each side of the flood plane of the main stream, produces a rise in the Illinois that is in a manner similar to the rise that would occur in a small lake receiving a considerable volume of flood water. It also becomes clear that the entire alluvial reach, but more especially the lower half of it, can fall very little until a fall begins in the Mississippi. Incidentally, it may be mentioned that, for the same reason, the Illinois can not cause any material increase in a Mississippi flood height, but acts to maintain the stage at Grafton after all other influences are tending to produce a fall.

The flood of 1922 can not be compared with other high floods in a definite and conclusive manner. The topography of the flood plane has been undergoing a constant artificial change, especially in recent years, and complete discharge observations, upon which comparisons might be based, are not available. Therefore the best that can be done in this paper is to make a comparison of the water heights in the various floods that stand out as prominent. This is done in the table following:

TABLE 16.—*Illinois River—Comparative flood heights.*

Station.	Miles above mouth.	Zero above mean sea level.	Crest of flood (feet) in—												
			1844	1849	1858	1883	1892	1902	1904	1908	1913	1916	1919	1920	1922
Morris, Ill	263.3	478.65	.....	22.2	24.3	23.4	21.6	.....	20.2	.....	.....	.....	20.3	17.8	20.1
Peru, Ill	222.4	432.71	.....	25.7	.....	23.7	24.2	.....	.....	.....	.....	27.0	23.1	22.0	23.8
Henry, Ill	196.1	436.49	.....	.....	.....	14.8	16.7	15.4	17.2	16.8	16.6	17.1	16.7	16.2	18.0
Peoria, Ill	162.3	428.52	26.9	24.8	22.7	.....	21.9	21.0	23.0	22.2	22.3	23.1	23.2	22.9	24.8
Havana, Ill	119.9	424.37	22.0	22.0	21.8	20.6	17.8	19.2	19.9	18.7	19.9	19.5	18.6	19.7	22.6
Beardstown, Ill	88.6	419.95	22.5	.....	.....	21.8	18.4	18.0	20.0	20.6	21.8	20.7	19.5	21.3	25.1
Pearl, Ill	43.2	412.40	26.5	.....	.....	20.4	20.4	17.3	19.3	.....	.....	.....	16.6	19.1	23.0
Grafton, Ill	0.0	403.68	32.1	.....	30.7	23.3	25.7	20.4	18.6	14.8	19.7	23.4	18.5	22.4	25.8

The table shows that the 1922 flood was the highest of record at Havana and Beardstown, but below this reach and for some distance above it the 1844 flood exceeded the one just passed. A discussion of the conditions causing these differences can not be undertaken without a more thorough study of the subject being made than has been practicable thus far, but one of the causes that was evident was the high

Mississippi. The apparent dropping of the flood plane below Beardstown was due to levee breaks, which gave some relief, and in the meantime a fall began in the Mississippi at Grafton.

On March 15 telegraphic warning was sent along the river from Peru to the mouth that a gradual rise would continue several days.

On March 20, on account of rains that had fallen since the 15th, another warning was telegraphed, in which it was stated that the highest stages that would be reached could not be forecast then, on account of the continuing rains, but that the following stages would be reached:

	Feet.
Peru	17.5
Henry	10.5
Havana	15.5
Beardstown	16.5
Pearl	16.5

The stages forecast on the 20th took into account only the rainfall to that date. Rain was still falling, but it was impracticable to estimate the amount that would occur, and it seemed better not to attempt to make a forecast based on future rains but to raise the river stage estimates after the occurrence of the rain. This was done, and the stage estimates were raised on March 21 and 22 and again on the 27th. In fact, the continuing rains required an almost daily raise in the estimates, but every effort was made to keep before the public the fact that these estimates necessarily would be raised as additional precipitation occurred, and that they should not be understood to be crest forecasts. On April 10 a forecast of a 22.5-foot stage was made for Beardstown. The highest flood then known, that of 1844, was equal to a gage reading of 22.5 feet, and the forecast caused consternation in Beardstown. Inquiries concerning the authenticity of the estimate were still reaching the office on April 12, on which date changed conditions (more rain) necessitated the raising of the estimate to 23 feet.

The final forecasts were as follows:

Station.	Stage forecast.	Date forecast made.	Highest stage.	Date of occurrence of highest.
	Feet.		*Feet.*	
Morris	20.0	Apr. 11	20.1	Apr. 12
Peru	24.5	Apr. 12	23.8	Apr. 13
Henry	18.1	Apr. 14	18.0	Apr. 15
Peoria	24.8	Apr. 14	24.8	Apr. 15
Havana	22.4	Apr. 15	22.6	Apr. 20
Beardstown	25.1	Apr. 16	25.1	Apr. 20
Pearl	23.5	Apr. 17	23.0	Apr. 19

There is no way of estimating the monetary value of the forecasts made and issued to the Illinois Valley. Letters regarding the matter are still coming in, but everything bearing on the subject is, of course, a matter of personal opinion, in which there is a wide divergence. In fact, no estimates on the loss sustained by the valley have been compiled. Some very general ones have been published, but they were, in a very frank manner, given out as guesses. The estimates of the land covered by the flood ran as high as 200,000 acres, much of which was in wheat. In all the confusion there is one outstanding feature, on which all agree. That is the fact that the flood forecasts were timely, were broadly disseminated, and were as near to accuracy as could be expected; also, that they were invaluable as a source of information to those whose lives were in jeopardy and to those who had property to move or protect.

A letter from Peoria states:

"It is estimated to have been worth $100,000 to have the information in advance. The forecasts were very accurate for several days in advance, and I do not believe any community could expect better river forecast service than was given in this instance."

The recipient of the forecasts sent to Havana, a public-spirited gentleman who gave much of his time to broadcasting the information, writes as follows:

"During the crisis in the recent high water my office was besieged day and night. When a message was received it was instantly telephoned to managers and workers on levees, and where telephones were out runners were used to carry copies of the messages."

A Beardstown merchant writes:

"The popular clamor for the stage forecasts testifies to the value of them and the esteem in which they are held."

A banker in Carrollton, Ill. (not on the river), sends the following:

"Per request of radio station WEW, we are glad to drop you a few lines stating we are receiving your daily forecasts at 10.05 each morning, being broadcast by the above station. They come in plain and clear and are posted on our bulletin board and given to the other bank in this city to post on their board. During the high flood in the Illinois River the people having interests there were very glad indeed to get your full flood stage forecasts by wireless."

The work done in strengthening levees and in making preparations to save property was all guided by the forecasts.

In Beardstown, where the loss was greatest, a levee broke on April 11, flooding about 60 city blocks and 200 homes. The river stage at this time was 22.4 feet; the rise continued until a maximum of 25.1 feet was reached, inundating about 1,200 homes and business houses, which comprised more than three-fourths of the town. The Weather Bureau river gage was overtopped on April 12, and on the 13th a temporary gage was set on a reference bench mark in a step of the main entrance to the Odd Fellows' Building, Main and Washington Streets, 23.0 feet above the zero of the submerged gage.

Of all the losses sustained (except the loss of stored grain and feed), it may be said that few could have been avoided had the public known several weeks in advance that the flood was coming. No loss of life was reported, all live stock were driven out upon the receipt of the warnings, and most movable property was protected. The losses were confined largely to levees, growing crops, roads, bridges, railroads, telegraph and telephone lines, and to the homes and business houses in Beardstown, Frederick, and several very small places.

LOWER MISSOURI RIVER.

The Missouri was not in flood above the mouth of the Osage. At and below St. Charles the water was about 0.5 foot above flood stage on March 27 and was about 1.5 feet above it on April 1 and 2. However, beginning with April 8 there was a flood of more serious proportions; it lasted until the 20th at Hermann and until the 22d at St. Charles. The maximum stage at Hermann was 24.7 feet; it was the highest since June 12, 1917, when there was a stage of 24.8 feet. At St. Charles the highest was 30.8 feet. No observations were made at St. Charles in 1917, but from all information available the 1917 and 1922 crests were about the same.

These flood stages in the extreme lower Missouri were due to flood waters from the Osage, heavy rains below Jefferson City, and to the checking of the discharge by a high Mississippi.

A forecast for a slow rise at Hermann, reaching a crest of 25.5 feet, was issued on April 11. On April 17 this was changed to 24.5 feet. The crest was 24.7 feet on the 18th.

For St. Charles a warning of 26.5 feet was issued on March 31. There was a crest of 26.5 feet on April 1, when the river began to fall. On April 10 an estimate of a 31-foot stage was made. The crest was 30.8 feet on April 13 and 19.

The damage along the lower Missouri was sustained altogether by the farming interests. It is estimated that 75,000 acres of wheat were inundated and lost. Some of the hay stacked in the bottoms was also lost. Upon receipt of the warnings an effort was made to get all of this hay out, but in places the ground was too soft from the long-continued rains to admit of the use of teams. The wheat land was largely planted in corn after the river subsided. There are no levees of consequence along the lower Missouri, except near the mouth, where the land is subject to overflow by both the Missouri and the Mississippi. Some of these levees were overtopped.

MISSISSIPPI RIVER BETWEEN LOUISIANA AND CAPE GIRARDEAU, MO.

The Mississippi above St. Louis was almost bankful by the middle of March. There were minor fluctuations from slightly below to slightly above flood stage until April 7, when the reach between

Louisiana and Grafton went into flood and remained above bankful until May 9. The highest at Grafton was 25.8 feet on April 20. This was higher than the river has been at that station at any time since June 11, 1903, when a stage of 28.7 feet occurred. The latter is the highest of record since 1879, when gage readings were begun, but there are three high-water marks in Grafton, marking floods previous to 1880, that are equal to more than 30 feet. The highest is the mark of the 1844 flood and is equal to 32.1 feet on the present gage.

In that portion of the stream at and below the mouth of the Missouri the bed capacity has, of course, about doubled, and its stages are much more responsive to flood waters from the steep-sloped Missouri than to those from the flatter Mississippi. Hence the flood-stage period at St. Louis was almost identical with the one at Hermann after due allowance is made for the time that was required in movement of the water. The St. Louis crest was 34.0 feet on April 19.

For a long time it has been evident that a high Ohio River, which usually means a full Mississippi below Cairo, has an effect upon the Mississippi for a long distance above Cairo. No expression for this influence has been evolved, and it has been impracticable to determine the distance upstream the effect is felt. It has been apparent that the Chester stages show the Ohio River influence at times, and it has been thought upon several occasions that a slight influence upon the St. Louis stages could be detected. The latter, however, has never been clearly established, but the 1922 flood offers an opportunity to demonstrate beyond any question that the influence extends at least half-way up to St. Louis from Chester.

The St. Louis crest of 34.0 feet on April 19 was the highest since the 35.25-foot flood of July, 1909, but it was 4.0 feet lower than the June, 1903, crest. At Chester the 1922 crest was 34.0 feet, while the 1903 crest was only 33.3 feet—that is, the St. Louis maximum stage in 1922 was 4.0 feet lower than in 1903, while the Chester maximum in 1922 was 0.7 foot higher than in 1903. The tributary increment between St. Louis and Chester was unimportant in 1922, but the lower Ohio was phenomenally high and had been for a long period. In 1903 just the reverse was true of the lower Ohio; it was well within its banks throughout the period of the St. Louis-Chester flood. There is a table submitted (Table 17) herewith that shows some flood heights in a comparative way for the Mississippi between St. Louis and Cairo; the Paducah stages included in the table will enable the Ohio River influence to be seen with ease.

TABLE 17.—*Mississippi River. Comparative flood heights, in feet.*

Station.	Elevation zero.	Distance above Cairo.	1892		1903		1908		1909		1922	
			Crest on gage.	Crest above mean sea level.	Crest on gage.	Crest above mean sea level.	Crest on gage.	Crest above mean sea level.	Crest on gage.	Crest above mean sea level.	Crest on gage.	Crest above mean sea level.
St. Louis, Mo	379.8	190.8	36.0	415.8	38.0	417.8	34.95	414.75	35.25	415.05	34.0	413.8
Chester, Ill	340.8	115.5	31.2	372.0	33.3	374.1	30.7	371.5	31.0	371.8	34.0	374.8
Grand Tower, Ill	321.7	85.0	30.0	351.7	33.8	355.5	31.9	353.6	32.1	353.8	36.0	357.7
Cape Girardeau, Mo	304.5	54.5	36.4	340.9	36.5	341.0	34.1	338.6	35.0	339.5	38.0	342.5
Cairo, Ill	270.4	0.0	46.0	316.4	43.4	313.8	35.5	305.9	43.4	313.8	52.7	323.1
Paducah, Ky	286.3	43.0	33.0	319.3	29.4	316.7	20.5	307.8	30.2	317.5	42.0	328.3

The levees on the Missouri side of the river held well with few exceptions. There was considerable overflow around the mouth of the Missouri River, and a levee broke across the river from Chester. The total area inundated was not large, and probably 25,000 acres would represent the amount of total loss in wheat and alfalfa.

On the Illinois side there was no trouble of consequence, except in Jackson and Union Counties, where levees were crevassed or overtopped in numerous places. The total loss to growing crops amounts to about 75,000 acres of wheat and alfalfa.

There was no loss of consequence in live stock on either side of the river, as the warnings had been heeded and the stock driven out.

The warnings along the Mississippi were disseminated by telephone, telegraph, and mail. The St. Louis office was in constant communication with all points along that portion of the stream embraced in the district. The crest stages forecast and the actual crests were as follows:

Station.	Stage forecast.	Date forecast made.	Highest stage.	Date of occurrence of highest.
	Feet.		*Feet.*	
Grafton	25.5	Apr. 17	25.8	Apr. 20.
Alton	31.5	Apr. 17	31.5	Apr. 19, 20.
St. Louis	34.1	Apr. 18	34.0	Apr. 19.
Chester	34.5	Apr. 18	34.0	Apr. 20, 21.

The daily forecasts of the rises, but not refined to a tenth of a foot, were for an average of four to five days in advance.

The warnings made possible the saving of corn and hay in stack, movable property of various kinds along the river banks, $50,000 worth of flour in warehouses in Alton, $100,000 worth of goods along the river front in St. Louis, and live stock in the bottoms and on islands. They also enabled levees above Chester, on the Illinois side, to be held. The levee officials, upon receipt of the first warning, put large forces of men to work and ordered large supplies of levee bags from St. Louis. Commissioners of two levee districts attribute their success in holding their levees to the fact that they were enabled by heeding the warnings to get bags and put strengthening forces to work before the flood arrived. They credit a total saving of $4,250,000 to the warnings.

The reports to the St. Louis office on money value of property saved along the Mississippi by the warnings represent a total of $4,575,000. There is no way of determining how near the truth this enormous total is. Most requests for information were returned with the statement that "there is no way to estimate the amount," while other people took the ground that without the warnings they would have lost their levees and everything behind them. The latter position was taken more especially by the people between St. Louis and Cape Girardeau, where they did not expect a stage as high as, much less higher than, the flood of 1903. There was no condition upstream to indicate to the layman that water higher than in 1903 could be expected, and to the Weather Bureau alone belongs the credit of warning the people that the 1922 flood would be higher.

MISSISSIPPI RIVER FROM CAPE GIRARDEAU TO NEW MADRID, MO.; OHIO RIVER BELOW MOUTH OF WABASH RIVER; TENNESSEE RIVER FROM BELOW DECATUR, ALA., TO MOUTH.

By WILLIAM E. BARRON, Meteorologist.

(Weather Bureau, Cairo, Ill.)

A gradual rise began in the lower Ohio River on February 17, due to a rise from the upper Ohio and to rains over the Tennessee and Cumberland River Valleys on February 14–15, which produced rather sharp rises along those rivers, but with flood stage at Riverton, Ala., only.

The rise was continuous at Paducah, Ky., and Cairo, Ill., from February 17 to March 24 and 26, respectively. More heavy rains fell over the Tennessee and Cumberland Valleys on February 27 and still heavier rains on March 1 and 2, and the resulting floods from these rivers were the largest contributing factors to the lower Ohio during the early part of March. Rains on March 9 and 10 were excessive over the Tennessee and Cumberland and considerably augmented the flood waters from those streams, Riverton, Ala., reaching 42.8 feet on March 11, and Johnsonville, Tenn., 36.4 feet on the 15th, while Nashville, Tenn., reached 45.1 feet on the 16th. At the same time a rise set in at Cincinnati, Ohio, and this rise was in turn increased by general rains over the system on March 14–15. Flood stage was passed at Shawneetown, Ill., on the 15th.

At this time came a decided rise in the Mississippi between the mouth of the Missouri and Cairo, and also a rise in the Wabash. The Ohio passed flood stage at Cairo on the 16th and at Paducah on the 17th. Crests of 52.1 feet were reached at Cincinnati on March 18, of 30.2 feet

at Louisville on the 19th, of 42.9 feet at Evansville on the 21st, 43.6 feet at Mount Vernon on the 23d, 47.6 feet at Shawneetown on the 25th, and 48.85 feet at Paducah on the 25th. Following a stage of 24.0 feet (6.0 feet below flood stage) at St. Louis, Mo., on March 17, the Mississippi reached a stage of 29.6 feet (within 0.4 foot of flood stage) at Cape Girardeau, Mo., March 19, and then fell for a few days before beginning another rise which was still in progress when the crests of 53.6 feet at Cairo on March 26–27, and of 41.6 feet at New Madrid, Mo., on March 27–28 were reached. This rise at Cape Girardeau continued till April 3, when a stage of 32.4 feet was reached, one day after a stage of 26.4 feet at St. Louis.

Meanwhile, another rise was in progress in the upper Ohio and in the Tennessee and Cumberland. The fall at Shawneetown and Paducah was stopped on April 3. Shawneetown arose to 41.3 feet on April 10, and Paducah to 41.8 feet on April 6 and 7 (total rise 0.5 foot). At Cairo the river was practically stationary at 50.4 feet from April 2 to 6, when the fall was resumed for a few days.

The rains of April 8–9 were exceptionally heavy over northern Missouri and central Illinois. They were followed by more rains on April 11 and others from April 15 to 17. The Mississippi began rising again at St. Louis on April 7 and reached crests of 33.9 feet at St. Louis April 20, 34.0 feet at Chester, Ill., April 20–21, and 38.0 feet at Cape Girardeau, Mo., on April 22. A temporary fall of 0.1 foot at Cape Girardeau on the 21st was due to the loss of water through crevasses on the Illinois side.

The river at Cairo had fallen to 49.9 feet on April 9, when the second rise in the Mississippi began to affect the stage here, and there was a slow rise till April 15, when the stage reached 52.0 feet. For the next four days the fall in the Ohio and Tennessee Rivers was sufficient to produce a slight fall at Cairo, but the heavy rains of the 15th had extended up the Ohio, and following a rise that culminated with 48.1 feet at Cincinnati on the 19th the river was rising at Shawneetown (where it had not receded below flood stage) from the 17th to 25th, when a second crest of 44.2 feet was reached. Paducah began rising again on April 20 and reached a stage of 44.0 feet on the 26th. At Cairo the Ohio rose from 51.6 feet on April 19 to 53.5 feet on the 25th, three days after the crest of the Mississippi rise at Cape Girardeau, Mo., but on the same day as the last crest at Shawneetown. New Madrid followed with a second crest stage of 41.7 feet April 26–27.

The falls were continuous from the time of these last crests until the rivers passed below flood stages at Paducah on April 29, at Shawneetown on May 1, at Cape Girardeau on May 6, at Cairo on May 7, and at New Madrid on May 9, in spite of heavy rains on April 28 and May 3 in the vicinity of these stations and along the lower Tennessee.

Table 18, which follows, gives the duration of the flood and the highest stages reached at the stations in this district.

TABLE 18.

River.	Station.	Flood stage (feet).	Above flood stage.		Crest.	
			From—	To—	Stage.	Date.
Ohio	Shawneetown, Ill.	35	Mar. 15	May 1	47.6	Mar. 25.
					41.3	Apr. 10.
					44.2	Apr. 25.
	Paducah, Ky.	43	Mar. 17	Mar. 31	48.85	Mar. 25.
			Apr. 23	Apr. 29	44.0	Apr. 25–26.
	Cairo, Ill.	45	Mar. 16	May 7	53.6	Mar. 26 27.
					53.5	Apr. 25.
Mississippi	Cape Girardeau, Mo.	30	Mar. 27	May 6	38.0	Apr. 21–22.
	New Madrid, Mo.	34	Mar. 16	May 9	41.6	Mar. 27–28.
					41.7	Apr. 26–27.

Table 19 gives a comparison of crest stages and durations for all floods at Cairo in which a stage of 50 feet has beenrecor ded:

TABLE 19.—*Cairo, Ill., crest stages above 50 feet.*

Year.	Crest.	Date.	Days above flood stage.	Last date above flood stage.	Days 50 feet or more.	Last day above 50.
	Feet.					
1882	51.9	Feb. 25, 26	[1] 57	Mar. 21	10	Mar. 3
1883	52.2	Feb. 26, 27	21	Mar. 8	15	Mar. 4
1884	51.8	Feb. 21–24	[1] 43	Apr. 6	14	Feb. 29
1886	51.0	Apr. 18, 19	22	Apr. 25	9	Apr. 22
1897	51.6	Mar. 25–28	48	Apr. 22	19	Apr. 5
1903	50.6	Mar. 15–17	[1] 27	Apr. 25	9	Mar. 20
1907	50.4	Jan. 27	[1] 25	Mar. 29	4	Jan. 29
1912	54.0	Apr. 6, 7	[1] 47	May 13	23	Apr. 18
1913	54.8	Apr. 4, 7	[1] 48	Apr. 22	21	Apr. 18
1916	53.4	Feb. 4	42	Feb. 16	13	Feb. 10
1917	50.1	Apr. 4, 5	[1] 32	Apr. 16	4	Apr. 6
1920	51.4	Mar. 31	[1] 44	May 8	9	Apr. 4
1922	53.6	Mar. 26, 27	[1] 53	May 7	[1] 45	May 2

[1] In two or more periods; others continuous.

From the above table it is seen that the crest of the 1922 flood at Cairo exceeded all others, except those of 1912 and 1913, that the period above flood stage (45 feet) exceeded all others except that of 1882, and that the period above 50 feet was unprecedented. The crest lacked 1.2 feet of the highest crest of April 4 and 7, 1913. At New Madrid, Mo., the crest of March 27–28 lacked 2.4 feet of the crest of April 5–6, 1912, and 3.0 feet of the crest of April 9, 1913. The crest at Cairo was 0.2 foot higher than the crest of February, 1916, while the crest at New Madrid was 0.3 less than the crest of 1916. At Hickman, Ky., located 50 miles below Cairo and 20 miles above New Madrid, there was 0.3 foot more water in March, 1922, than in April, 1913. These discrepancies were due to the extension of the levees of the St. John levee and drainage district of Missouri. About 12 miles of these levees have been built since 1913 and 10 miles since 1916, thereby reducing the unleveed gap at the mouth of the St. John Bayou from 20 miles in 1913 to about 8 miles in 1922 and causing a narrowing of the channel or a funnel-like effect in the river in the vicinity of Hickman.

Has this change in the outlet below Cairo produced an effect on the gage readings at Cairo; and, if so, how much? The stages at key stations that preceded the Cairo crests during several floods are shown in parallel columns in Table 20.

Table 20 shows a lower flood crest at Cincinnati in 1922 than in any of the flood years under consideration, and almost the same flood crest at Evansville as in 1903, 1912, 1917, and 1920, but lower than in the other years. The Cumberland River factor of 1922 is about the same as that of 1913 and less than that of 1912. The Tennessee factor as shown by Johnsonville is slightly more than in 1912 or 1913, but less than in 1917 and much less than in 1897. Considering that the full effects of the Ohio and tributaries are assembled at Paducah, there can be no doubt that the 1922 water was much less than 1884, 1897, 1912, or 1913 so far as the effects of the Ohio are concerned. In 1884 the amount of water received from the upper Mississippi was small, as St. Louis only reached a stage of 15.7 feet. In 1897 there was a stage of 23.2 feet at St. Louis, the crest being reached on the day before the water began to recede at Cairo. Thus 50.9 feet at Paducah and 23.2 feet at St. Louis accompanied a stage of 51.7 at Cairo in 1897, whereas 48.85 at Paducah and 24.0 feet at St. Louis produced 53.6 feet at Cairo in March, 1922.

TABLE 20.—*Crest stages during several floods preceding crests of more than 50 feet at Cairo, Ill.*

Stations.	1882	1883	1884	1886	1897	1903	1907	1912	1913	1916	1917	1920	1922
Cincinnati	58.6 Feb. 21	66.3 Feb. 15	[1] 71.1 Feb. 14	55.8 Apr. 9	61.2 Feb. 26	53.2 Mar. 5	65.2 Jan. 21	53.4 Mar. 27	69.9 Apr. 1	53.2 Jan. 14	56.1 Mar. 17	54.6 Mar. 22	52.2 Mar. 18
Evansville	44.9 Feb. 24	47.8 Feb. 19	[1] 48.0 Feb. 19	43.4 Apr. 14	43.6 Mar. 2 and 3	42.4 Mar. 11	46.2 Jan. 24 and 25	42.6 Mar. 31	48.4 Apr. 5	43.6 Jan. 18	42.9 Mar. 22	42.8 Mar. 25	42.9 Mar. 21
Nashville	[1] 55.3 Jan. 22	41.6 Feb. 14	46.9 Feb. 15	49.3 Apr. 10 and 11	48.7 Mar. 21	40.7 Mar. 9	35.5 Jan. 4	46.6 Apr. 7	44.9 Apr. 2	42.4 Jan. 5	45.7 Mar. 10	35.8 Mar. 16	45.1 Mar. 16
Chattanooga	40.2 Jan. 19	38.2 Jan. 23	36.8 Feb. 11	52.1 Apr. 3	38.2 Mar. 14	31.1 Mar. 2	20.8 Jan. 1	31.3 Mar. 31	33.3 Mar. 30	32.9 Jan. 1	47.7 Mar. 7	26.6 Mar. 22	32.8 Mar. 13
Johnsonville	.....	.....	.....	.....	[1] 48.0 Mar. 24	33.7 Mar. 11	24.1 Jan. 6	35.4 Apr. 6	33.3 Mar. 29	32.5 Jan. 8	38.9 Mar. 18	29.1 Mar. 17	36.4 Mar. 15
St. Louis	28.2 Feb. 22	26.3 Feb. 26	15.9 Feb. 19	[2] 23.7 Apr. 21	[2] 23.2 Mar. 28 and 29	25.8 Mar. 11	26.3 Jan. 23	30.8 Apr. 5	27.2 Apr. 16 and 17	31.5 Jan. 31	20.3 Apr. 3	27.8 Mar. 30	24.0 Mar. 17
Cairo	51.9 Feb. 26	52.2 Feb. 27	51.8 Feb. 21 to 24	51.0 Apr. 19	51.6 Mar. 25 to 28	50.6 Mar. 15 to 17	50.4 Jan. 27	54.0 Apr. 6 and 7	[1] 54.8 Apr. 4 and 7	53.4 Feb. 4	50.1 Apr. 4 and 5	51.4 Mar. 31	53.6 Mar. 26 and 27

[1] Highest on record.

[2] Crest followed that at Cairo.

In 1912 the stage at St. Louis that preceded Cairo's crest of 54.0 feet was 6.8 feet more than that of March 17, 1922, while Paducah's crest was 1.1 feet less. In 1913 the St. Louis stage was 3.2 feet greater, while the Paducah stage was 5.5 feet greater, yet the stage at Cairo was only 1.2 greater than in 1922. From these figures and the comparatively lower stages reached during the recent flood at points from New Madrid, Mo., to Memphis, Tenn., there can be no other conclusion than that the maximum stage at Cairo in March, 1922, was 2.5 to 3 feet higher than it would have been with the bank conditions of 10 years previous, and that the long continuance of high stages was in part due to the same cause.

The second crest at Cairo, 53.5 feet on April 25, was due largely to upper Mississippi water coming down upon the lower basin already filled. The highest stage reached at Paducah on the April rise was 44.0 feet on the 27th, 4.8 feet less than on March 25. On the other hand, St. Louis reached 33.9 feet on April 20, 9.9 feet higher than the highest stage preceding the March crest af Cairo. At Cape Girardeau, Mo., the highest stage was 38.0 feet on April 21–22, 8.4 feet higher than the stage that preceded the March crest at Cairo.

The crest of 38 feet is the highest known at Cape Girardeau since that of 42.53 feet on July 4, 1844. High stages in the Mississippi above Cairo usually occur later in the season than the Ohio River floods. The highest previous record since gage readings have been kept was 36.53 feet on June 14, 1903. This stage was preceded by a stage of 38.0 feet at St. Louis on June 10. Prior to 1912 the stage reached at Cape Girardeau was usually slightly less than that reached at St. Louis, while from 1912 to 1922 it has averaged 4.0 feet in excess of St. Louis. From 1908 to 1918 several levees have been built between Chester and Gale, Ill., the one opposite Cape Girardeau having been completed in 1910. These levees have restricted the river within banks and raised the high-water stage at Cape Girardeau approximately 4.0 feet and greatly increased the period above flood stage. The fact that the main rise in the upper Mississippi was timed several weeks after the principal Ohio rise is the only feature that prevented the highest stages of record throughout the entire river from Cairo to the Gulf of Mexico.

Owing to the changed gage relations along both the Ohio and Mississippi Rivers, the preparation of flood forecasts during the recent flood was somewhat difficult. With the frequent rises, now in one stream or tributary and now in another, many revisions of the estimates were necessary.

Warnings of flood stages for the Ohio River at Shawneetown and Cairo, Ill., and New Madrid, Mo., were first issued on March 13 for Paducah, Ky., on March 15 and for the Mississippi River at Cape Girardeau on March 16. Flood forecasts were issued daily thereafter, but changes were made only as necessitated by changing conditions. On April 15 announcement was made of the coming of a prolonged period of very high water in the Ohio and Mississippi Rivers.

Table 21 contains estimates of the areas of land overflowed, both cultivated and uncultivated, and the period of overflow.

TABLE 21.—*Overflowed areas, Cairo, Ill., district.*

County.	Number of acres cultivated.	Overflowed undeveloped.	Total.	Number of days overflowed.
ILLINOIS.				
Gallatin	21,600	2,400	24,000	60
Hardin	[1] 200	.....	200	15
Pope	2,000	3,000	5,000	40
Massac	3,840	1,920	5,760	20
Pulaski	7,000	2,640	9,640	40
Alexander	39,920	17,360	57,280	15–60
KENTUCKY.				
Livingston	1,000	.....	1,000	35
McCracken	[1] 17,000	3,000	20,000	35–40
Ballard	10,000	25,000	35,000	40
Carlisle	5,000	15,000	20,000	30–55
Fulton	4,000	9,600	13,600	60
MISSOURI.				
Cape Girardeau	1,200	400	1,600	25
Scott	500	200	700	25
Mississippi	10,000	10,000	20,000	60
New Madrid	78,000	60,000	138,000	40–60
Total	201,260	150,520	351,780	15–60

[1] Crop not planted at time of overflow.

The losses and damage reported amounted to $1,121,940, of which nearly one-half was in prospective crops. The reported value of property saved through the Weather Bureau warnings was $407,000. There was also a great amount of railroad damage, the figures for which were not available.

Along the Ohio River the only levees are those protecting the cities of Shawneetown, Mound City, and Cairo, and the local levee protecting the Cairo drainage district lying between the city of Cairo and Cache River. Along the Mississippi in Kentucky there are small local levees at Columbus and Hickman. The Reelfoot Lake levees, which begin a short distance south of Hickman, are mostly within the Memphis river district. In the northwestern part of Alexander County, Ill., there are two drainage districts, the Clear Creek and East Cape Girardeau district, and the North Alexander district, which together embrace all of the lowlands north of Gale, where a range of hills comes close to the river. On the Missouri side, below Cape Girardeau, there is a short levee protecting the Little River drainage district, or head of the St. Francis basin, then come the Commerce hills, south of which are the Scott County, Mississippi County, and the St. John districts. The levees of the latter terminate about 8 miles above New Madrid, while New Madrid is protected by a local levee.

No crevasses occurred in this district. The leveed districts in the northwestern part of Alexander County, Ill., embracing 17,600 acres, were overflowed as a result of crevasses which occurred in the Clear Creek drainage district of Union County on April 18. This district filled slowly and the water passed down into the North Alexander district located between the railroads and the hills, after which the water poured over the St. Louis, Iron Mountain & Southern and the

FIG. 2.—Fisherman's house at foot of Fourth Street, Dubuque, Iowa. Stage of water, 21 feet.

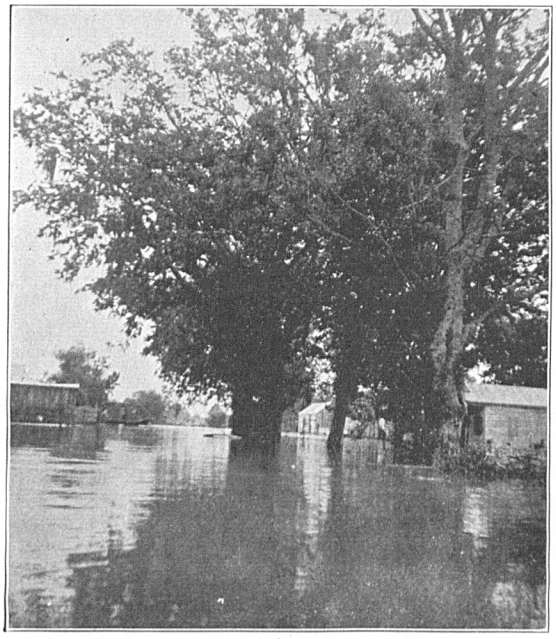


FIG. 3.—Overflow of water from Poydras crevasse, La.

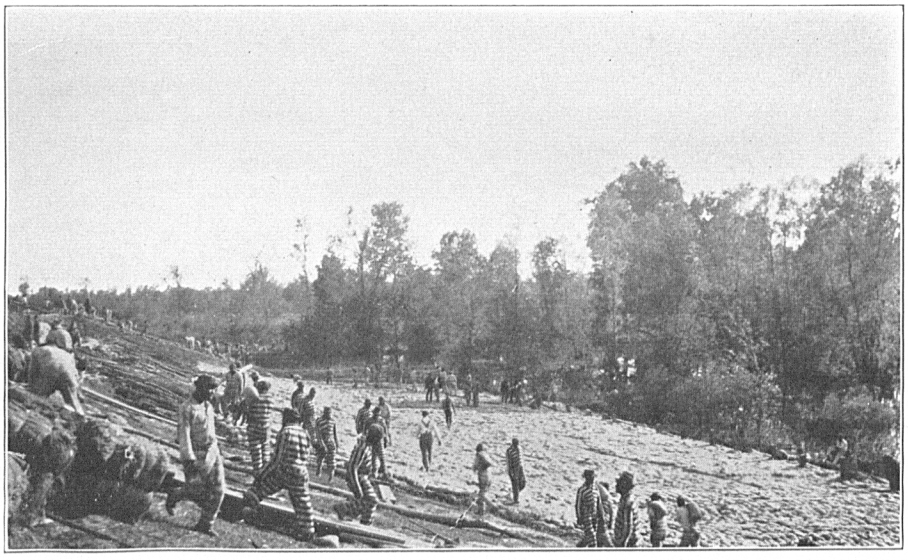


FIG. 4.—Repairing levee in vicinity of Arkansas City, Ark.

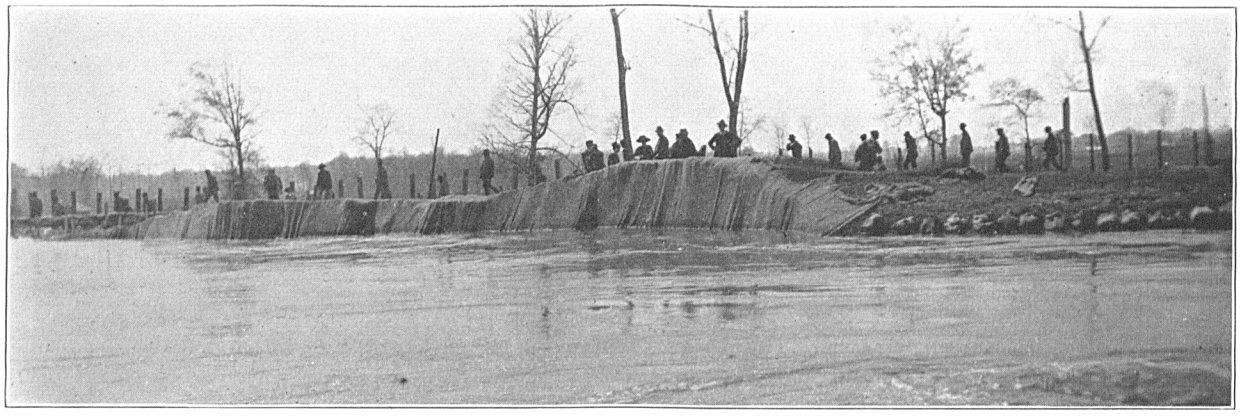


FIG. 5.—Damaged Old Town levee, Ark. View from river, showing cotton bagging used to protect levee from further encroachment of river.

Illinois Central Railroad embankments into the Clear Creek and East Cape Girardeau district, which was filled by the 23d. Damage and inconvenience to 2,560 acres in the Cairo drainage district was due entirely to seep water and rain water for about 60 days and to faulty or depreciated pumping equipment. All other overflow was over unprotected areas and through backwater, the latter especially in New Madrid County, Mo. The area flooded in Alexander County, Ill., was the largest ever known, embracing 40 per cent of the county and including much of its most productive lands.

Large sections of arable land in this county and in Mississippi County, Mo., were covered with deposits of mud 6 to 10 inches deep. Seed for replanting, mostly with corn, has been furnished needy farmers by the American Red Cross, and corn has been planted on some of the fields that were submerged as many as three times, and each successive stand destroyed by cutworms. There has also been considerable spread of cholera among hogs in the flooded district.

It is estimated by the American Red Cross that 670 families, or about 3,350 persons, had their homes flooded in Alexander County; 250 of these families lived in the Cairo drainage district in the settlement known as Future City. Most of these left by April 15 and were established by the Red Cross in a camp within the Cairo levees, where they continued until May 27. Several large woodworking plants were forced to suspend operations in the district for the same reason, the longest suspension being from April 14 to May 24.

The Interurban Railroad was able to operate intermittently through the drainage district but was forced to suspend service to Mound City and Mounds from March 19 to April 1 and from April 12 to 18 and to Mounds from April 23 to April 30. Full service was restored May 17, when all the water had drained off the concrete road in the drainage district.

The ferry boat *Three States*, running between Cairo and Wickliffe, Ky., and Birds Point, Mo., was forced to suspend regular trips from March 18 to May 5 on account of landing conditions.

MISSISSIPPI RIVER FROM BELOW NEW MADRID, MO., TO THE MOUTH OF WHITE RIVER.

By J. H. Scott, Meteorologist.

(Weather Bureau, Memphis, Tenn.)

The Mississippi River flood of the spring of 1922 did not attain record breaking height in the Memphis district, nor was it the longest flood of record, but in point of duration at high flood it is without precedent or approach thereto in the records.

Following moderate rises in the preceding December and January the river had fallen to a stage of 11.6 feet at Memphis on February 18, when the initial rise that culminated in the protracted flood set in. Flood stage was reached at Helena in the early morning of March 19 and at Memphis before noon of the same date. Crest stages on this rise were as follows:

Cottonwood Point, 38.5 feet, March 28–30; Memphis, 42.6 feet, March 31–April 1; Helena, 52.3 feet, April 3–6.

Following a gradual recession to 36.9 feet at Cottonwood Point, 40.2 feet at Memphis, and 51.3 feet at Helena, another rise set in about the middle of April, continuing about a week, and resulting in stages of 37.7 feet at Cottonwood Point, 41.2 feet at Memphis, and 52.0 feet at Helena. The river remained stationary for two or three days following this crest, but there was no recession, and a third rise resulted in crest stages as follows:

Cottonwood Point, 38.4 feet, April 27–28; Memphis, 42.3 feet, April 29–30; Helena, 53.1 feet, May 3.

From this time on the river subsided, very slowly at first and then more rapidly, passing below flood stage at Memphis May 14 and at Helena five days later. It was above flood stage at Memphis and Helena 56 days, practically duplicating in length the flood of 1912.

The three distinct rises at Cairo merged into one below Helena, and, while the flood in the Memphis district failed to reach the height attained in 1912, 1913, and 1916, from Arkansas City to the Gulf it was the highest flood of record.

At Memphis the river was above the 40-foot stage for 45 days, March 25 to May 8, inclusive. The longest preceding period with the water continuously above 40 feet was in 1912 with 23 days, though in 1913 there was a total of 28 days divided into two periods. Years in which the stage of 40 feet has been reached at Memphis are given in Table 22 below, with the number of days at or above that elevation in each instance. Days above 50 feet at Helena for corresponding years are given.

Table 22.—*Statistical data, Memphis, Tenn., and Helena, Ark.*

Year.	Days above 40 feet at Memphis.	Days above 50 feet at Helena.
1903	2	10
1907	3	5
1912	23	29
1913	(8+20) 28	24
1916	16	18
1920	4	3
1922	45	44

As the rise in the river progressed early in March, stages expected by definite dates were announced well in advance. The first flood warning proper was issued on March 15 at 9 a. m., as follows:

"The additional rains of the last 24 hours will cause a pronounced flood in this district. Flood stage is indicated at Memphis and Helena by the 19th, and the rise will continue at least 10 days with ultimate stages considerably above flood stage. All unprotected lands will be overflowed."

Following the original warning, advices were issued from time to time as conditions warranted. Crests on each rise were accurately forecast a week or more in advance, with later modifications where necessary on account of additional rainfall. The approximate dates at which the river would pass below flood stage were accurately announced 10 days in advance.

The warnings were distributed by telegraph, telephone, and mail, including the daily press, which gave much space to the river news. Levee engineers and contractors, planters, lumber companies, and others in the threatened regions called daily by long-distance telephone for the forecasts and river stages at principal points. Many additional copies of the river bulletin were distributed by boats at way landings, so that there was no occasion for any in the threatened regions to be unprepared for the overflow.

THE ST. FRANCIS FLOOD.

On March 21 flood stage was forecast for the St. Francis River at Marked Tree, Ark., by the last of the month, and the river reached flood on the 28th. Excessive rains over that basin on the closing days of March, and subsequent lighter rains, caused a further rise to 19.3 feet, or 2.3 feet above flood stage, April 15–17. Advices concerning the rise were issued from time to time. This is the highest flood of record in that portion of the St. Francis without the addition of water from breaks in the Mississippi levees, though it is understood that in the hill country in Missouri the flood was more moderate in proportions. Thousands of acres of land were inundated and, while much of it is swamp and subject to inundation annually, much valuable farming land was overflowed. An even greater area was overflowed from Mississippi backwater in the lower St. Francis basin. The river was above flood stage at Marked Tree until May 3, a total of 37 days.

STORM CAUSING THE MISSISSIPPI FLOOD.

The first definite intimation that the river would become full enough to cause anxiety concerning future rainfall was contained in a storm that moved across the Gulf States about the first of March, causing heavy rains northward over Tennessee that resulted in moderate floods in the Cumberland and the Tennessee. Additional rains resulted from a storm that crossed the central valleys on the 6th–7th. Another storm out of the Southwest, that moved northward to Missouri and

thence across the Ohio Valley on the 9th-10th, caused widespread rains that were particularly heavy in the Cumberland and Tennessee Valleys, augmenting the flood prevailing in the former river and causing another flood in the Tennessee. By the 14th-15th this was followed by a storm of similar character that caused excessive rains over the lower Missouri, middle Mississippi, and Ohio Valleys, thus assuring a flood of considerable proportions in the lower Mississippi Valley. Another storm that was central over the Mississippi Valley on the 19th caused general rains throughout the central valleys. By this time the lower Ohio was in high flood, the Mississippi also had come to flood below Cairo as far south as Helena, and there could be no doubt that a flood of the first magnitude was in prospect. A week later there was another series of general rains followed by still another at the end of the month. However, by this time the floods in the Tennessee and Cumberland had subsided and that in the lower Ohio was rapidly subsiding, and, although another marked rise occurred in the Ohio with flood stages in its lower course, it was not sufficient to stop the fall in the Mississippi below Cairo.

During the first week in April there were light to heavy showers at intervals and from the 8th to the 11th more general rains, particularly in the Missouri and upper Mississippi Valleys. These were followed on the 14th and 15th by excessive rains throughout the Ohio Valley; excessive rains occurred in the middle Mississippi Valley on the 17th and throughout the Tennessee Valley on the 18th. These rains were sufficient to complete the setting for the most protracted high flood in history. Showers occurred subsequently and were heavy in some localities, but no further generally heavy rains occurred over the territory affecting stages in this district.

The rains of April 8 to 18 were so synchronized that the maximum flood-producing effect from all main streams and principal tributaries above Cairo occurred at that point within a period of about two days, 24th–26th, and the crest at Cairo occurred on the 25th. Fortunately for the lower valleys, the Missouri and the Ohio did not reach flood stage at Kansas City and Cincinnati, respectively, and the Cumberland and Tennessee were much below flood at Nashville and Chattanooga.

Comparison with the great floods of 1912, 1913, and 1916 indicates a decided change in the gage relationship between Cairo and Memphis. In 1912 the difference was 8.7 feet and in 1913, 8.3 feet. While losses from crevasse water occurred in both years it was assumed that the effect of such losses was nearly the same at both places and that the difference between Cairo and Memphis would continue close to 8 feet. However, in 1916 without the loss of crevasse water the difference was 9.9 feet, and in 1922 it was 11.0 feet, 10.8 feet, and 11.2 feet on the three rises, respectively, thus apparently establishing a difference of 11.0 feet. The reason for the changed relationship between 1913 and 1916 is doubtless found in the removal in 1913 after the flood of that year of a solid railway embankment about 2,400 feet in length opposite Memphis, adjacent to the river and normal to its course, and its replacement by open trestle work. At the same time additional openings were made in other embankments between the river and the levee opposite Memphis. This allowed the escape of the surplus flood water instead of ponding it as in 1912 and 1913, and resulted in lowering the Memphis stage by perhaps 2 feet.

A further change has occurred since 1916 in the gage relationship between Cairo and all points in the Memphis district, which is probably due to the extension of the levee in the St. John levee and drainage district of Missouri. This levee has been extended about 10 miles since the 1916 flood, and comparison of Cairo stages with those in the Memphis district seems to indicate that its effect has been to raise the Cairo stage about 1 foot relative to points below New Madrid, Mo. It is understood that additional extension of about 6 miles, leaving only a one-half mile gap as an outlet to St. Johns Bayou, is contemplated. The effect of this should be still further to elevate the flood plane at Cairo in comparison with points in the Memphis district. The effect of the additional levee has been much more pronounced at Hickman, Ky., than at Cairo. The changed relationship will readily appear from the following table:

TABLE 23.—*Crest stages with differences from Cairo.*

Year.	Cairo stage.	Cottonwood Point.		Fulton.		Memphis.		Helena.	
		Stage.	Difference.	Stage.	Difference.	Stage.	Difference.	Stage.	Difference.
1916, February	53.4	39.5	−13.9	40.2	−13.2	43.5	−9.9	53.4	0.0
1922, first rise	53.6	38.5	−15.1	39.1	−14.5	42.6	−11.0	52.3	−1.3
1922, third rise	53.5	38.4	−15.1	39.2	−14.3	42.3	−11.2	53.1	−0.4

It is apparent that stages at Cottonwood Point, Fulton, and Memphis are at least 1 foot lower relative to Cairo. The change is not so easily perceived at Helena. The stages in the lower Mississippi when Cairo crested on the first rise in 1922, would fully account for the difference between Cairo and Helena. However, had not an unprecedented flood been coming out of the St. Francis, Helena would have shown one-half foot to 1 foot lower on both the first and the last rises of 1922.

There were no breaks in the main Mississippi levees in the Memphis district, though constant vigilance on the part of levee engineers was necessary, and serious trouble developed at some points, notably at Oldtown, Ark., and near Tunica, Miss. The Laconia Circle levee, protecting about 13,000 acres of land from backwater through the mouth of White River, broke near Snow Lake, Ark., on April 11 and flooded this area to a depth of several feet. The break was expected, however, and precautionary measures reduced the damage to a minimum. About 8,500 acres were flooded by a break in the levee on the left bank of the St. Francis 3 miles north of Kennett, Mo. The levees on the right bank of the St. Francis are inadequate and more or less broken, and the flooded area on the west side of the river can hardly be credited to breaks during this flood. With the exception of the areas mentioned above, the overflow was confined to unprotected lands, consisting of islands, lands between the levees, lands between the river and the high ground in Tennessee, and the backwater area in the lower St. Francis and White River Valleys. As near as can be ascertained the overflowed area was as follows:

	Acres.
West side of river:	
Below New Madrid, Mo., to Island 40, outside levee	94,000
Island 40 to mouth of St. Francis, outside levee	73,000
Below Helena, Ark., to Laconia Circle, outside levee	31,000
Lower St. Francis backwater area	360,000
Lower White backwater area, north of White River	285,000
Laconia Circle levee break	13,000
East side of river:	
Below New Madrid to Memphis (no levee protection)	309,000
Below Memphis to mouth of White River, outside levee	143,000
Total from Mississippi	1,308,000
St. Francis overflow below Missouri line and above Mississippi backwater area	180,000
Total in Memphis district	1,488,000

The land was submerged from six to eight weeks and slightly longer in some places. Planting operations were delayed until late in May or early in June. It is difficult to estimate the effect this will have on crop production. In some instances cotton was planted after the subsidence of the flood, and this will require a late frost in autumn for maturity. It will be subject to greater hazard from the boll weevil, which, owing to the mild winter, emerged from hibernation in unusual numbers. On the other hand, the corn planted after the flood will have time to mature and the soil, enriched by sediment, may return larger yields.

The flood caused a suspension of all levee work except that necessary for patrol duty and for strengthening threatened sections, which was considerable. Some revetment and additional levee construction will be necessary where the levee is endangered by caving banks. Suspension of lumbering operations was a costly item incident to the flood, though compensated in some measure by the opportunity to float logs

to desired locations. Stormy winds during the first two weeks in April, and particularly on the 11th, caused considerable damage to buildings and fences in the deeply inundated sections and additional damage to levees through wave wash. Owing to a general heeding of the flood warnings and preparation for the flood, the loss of live stock was negligible and the loss of other movable property was not large. In some instances people were forced to move out to higher ground, entailing some suffering, but there was little real distress in the Memphis district, although much inconvenience was suffered.

Railroad traffic was wholly or partially suspended in the backwater area of the lower St. Francis and White Rivers from April 1 to May 16, inclusive, and travel in part of that section was largely by means of boats and rafts. Switching lines in the industrial district in South Memphis were prevented by the flood from reaching some of the factories, causing a suspension of operations, though the factories as a rule were protected by private levees.

Attempt has been made to secure information direct from the railroads as to damage to roadbed and track, dates and points of traffic suspenson with the resulting losses, etc., and while in some cases promises have been received little definite information is available.

Statistics of losses collected from various sources are largely conflicting, and the estimates given are only a rough approximation. The acreage estimate under loss of prospective crops is confined to that sown to winter grains and that on which losses are reasonably certain because of delayed planting of other crops; it does not represent the area overflowed. The total losses reported aggregated $2,793,940, of which $825,000 was in prospective crops, 165,000 acres of crop lands having been overflowed. Railroad losses, including those occasioned by suspension of business, but not completely reported, were $698,940. Other losses occasioned by suspension of business amounted to $800,000, while the reported value of property saved by the Weather Bureau warnings, also very incomplete, was $1,155,000.

MISSISSIPPI RIVER FROM BELOW THE MOUTH OF WHITE RIVER TO VICKSBURG, MISS.

By R. T. Lindley, Meteorologist.

(Weather Bureau, Vicksburg, Miss.)

Detailed data regarding the stages of the river, etc., will be found in the tables preceding, except for the Tallahatchie-Yazoo River. This river was first in flood on March 5 at Swan Lake, Miss., following a period of heavy rains that began on February 26 and culminated in an excessive downpour on March 1. The flood stage of 36 feet at Greenwood, Miss., was not quite reached at any time, and at Yazoo City, Miss., the flood stage of 25 feet was reached on March 21. Details are given in Table 24 below.

Table 24.—*Crest stages, etc., Tallahatchie- Yazoo River.*

Station.	Flood stage.	Crest.		Flood stage.	
		Stage.	Date.	Days above.	Date.
	Feet.	*Feet.*			
Swan Lake, Miss.	25	29.2	Mar. 19[1]	86	Mar. 5-May 29.
Greenwood, Miss.	36	35.6	Mar. 22	0	
Yazoo City, Miss.	25	31.9	Apr. 29[1]	86	Mar. 21-June 14.

[1] And subsequent dates.

Although the Tallahatchie River at Swan Lake fell 0.5 foot on May 1 and 2, it was rising again on May 3, and the days above flood stage are considered as consecutive. The second crest of 27.7 feet occurred on May 13-17. There was also a second crest of 32.3 feet on May 13 and 14 at Greenwood. The rise at Yazoo City was continuous until a stage of 31.8 feet was reached on April 19. From this date until May 9 the river remained practically stationary at 31.7 to 31.9 feet, reaching 31.9 feet on six days. It will be noted that the return of the Mississippi backwater to the main stream was quite slow, as the river at Vicksburg fell below the flood stage on May 30, and on June 14 when the Yazoo at Yazoo City fell below flood stage the stage at Vicksburg was 32.3 feet.

No crevasses occurred within this river district, and few, if any, buildings were washed away. Owing to the unprecedented height attained by the Mississippi, backwater covered the lower Yazoo basin to a greater depth than ever before, so that there was considerable loss from damage to bridges, buildings, and fencing. It is unlikely that any considerable loss of tangible property occurred, as there was little current. It is estimated that about 885,000 acres of land were inundated, mostly by backwater from the Mississippi entering the lower Yazoo channel, levees protecting the upper left bank and the entire right bank of the Mississippi from overflowing lands adjoining its course.

Of the lower Yazoo-Mississippi Delta under water about 215,000 acres was cultivable land, much of which would have been planted in cotton at as early a date as the weather permitted. As a matter of fact, much of it has been planted in cotton since the water subsided, and it is a matter of speculation as to the amount of loss that will result from the delayed planting, the boll weevil being especially prevalent.

Such losses are impossible of close approximation at this time, but expenditures due to retaining the Mississippi within the levees, losses from suspension of business, and those due to the suspension or maintenance of lines of communication on the part of transportation companies, and the struggle to supply service can be closely estimated.

The expenditures on the part of the Mississippi River Commission and the individual levee boards involved in maintaining the effectiveness of the levees amount to about $1,000,000 for the flood period. The losses of the Yazoo & Mississippi Valley and other railroad companies, both direct and intangible, were considerable, but not unusual, considering the conditions.

The losses through suspension of ordinary business affairs on the part of planters, called with their help to work in maintaining the levees, are largely intangible and will depend, to a considerable degree, upon the character of the present crop season. The losses to business enterprises, to the shifting of stock, and to many minor outlays and subsequent losses numerous throughout this district, may reach a total of $150,000.

About 24,000 persons were rationed and otherwise assisted on account of flood conditions within this river district, some for as long a period as 75 days. It is understood that the total value of food and supplies so given amounted to about $200,000.

MISSISSIPPI RIVER BELOW VICKSBURG, MISS., ATCHAFALAYA AND OUACHITA RIVERS, AND ALSO THE RED RIVER BELOW SHREVEPORT, LA.

By Issac M. Cline, Meteorologist.

(Weather Bureau, New Orleans, La.)

The floods in the Mississippi River below Vicksburg and in the Atchafalaya, which commenced March 31, 1922, and continued until well toward the middle of June, 1922, were of unusually long duration and gave stages considerably in excess of those in any previous flood.

The first warnings for this flood were issued on March 21 and read as follows:

"The Mississippi River below Vicksburg and the Atchafalaya will rise and water now in sight indicates at least the following stages, April 15 to 20: Natchez, 50 to 51; Baton Rouge, 38.3 to 39.3; Plaquemine, 34.5 to 35.5; Donaldsonville, 30.3 to 31.3; New Orleans, 19 to 20; Simmesport, 43 to 44; and Melville, 41.0 to 42.0 feet. Flood stages will be passed at Natchez April 1 and at other stations the first week of April. (Signed) Dyke."

On March 29 the following bulletinwas issued:

"Water now in sight indicates at least the following stages, April 16 to 24: Natchez, 51.0 to 52.0; Baton Rouge, 39.3 to 39.8; Plaquemine, 35.5 to 36.0; Donaldsonville, 31.0 to 31.5; New Orleans, 20.0; Simmesport, 44.0 to 45.0; and Melville, 41.0 to 42.0 feet. Revised forecasts may be issued from time to time to meet changing conditions. (Signed) Dyke."

The flood stages were passed at Natchez, Miss., and New Orleans, La., April 3, Baton Rouge, Donaldsonville, and Melville, La., April 2, and Simmesport, La., April 6.

April 1, 1922: "Recent rains in the lower Mississippi Valley have augmented flood conditions and, with uninterrupted flow, water now in sight indicates stages as follows: Natchez, 52.0 to 52.8, April 16 to 22; Baton Rouge, 41.0 to 42.0; Plaquemine, 36.7 to 37.7; Donaldsonville, 32.5 to 33.5; and New Orleans, 20.5 to 21.0 feet, depending on the winds, by April 20 to 25. Stages on the Atchafalaya, Simmesport 46.0 to 47.0 and Melville 42.0 to 43.0 feet by April 25. (Signed) Cline."

Again, on April 10, 1922: "Continued easterly to southerly winds have retarded discharge of lower Mississippi River, and recent rains over drainage area of western tributaries have intensified flood conditions and water now in sight indicates stages as follows: Natchez, 53.2 to 53.8, April 16 to 22; Baton Rouge, 41.5 to 42.5; Plaquemine, 37.2 to 38.2; Donaldsonville, 32.9 to 34.0; and New Orleans, 21.5 to 22.0 feet, depending on the winds, April 20 to 25. Stages on the Atchafalaya, Simmesport 46.8 to 47.8, and Melville 42.8 to 43.5 feet by April 25. (Signed) Cline."

On April 18, 1922: "Recent rains have intensified the flood situation. The Mississippi River below Vicksburg and the Atchafalaya will rise and, with levees holding, water now in sight indicates stages as follows: Natchez, 54.8 to 55.4 by May 1; Baton Rouge, 43.2 to 44.0; Plaquemine, 38.8 to 39.8; Donaldsonville, 34.8 to 35.2; and New Orleans, 22.5 to 23.0 feet, depending on the winds, May 1 to 10. Stages on the Atchafalaya: Simmesport, 49.5 to 50.1, and Melville, 44.0 to 44.5 feet, May 1 to 10. (Signed) Cline."

And on April 24, 1922: "The flood crest now in the vicinity of Cairo will augment and intensify flood conditions in this district during May. The Mississippi River below Vicksburg and the Atchafalaya will continue to rise slowly and, if levees hold, water now in sight indicates stages as follows: Natchez, 56.0 to 56.5, May 7 to 15; Baton Rouge, 45.0; Plaquemine, 40.5 to 41.0; Donaldsonville, 35.8 to 36.4; and New Orleans, 22.8 to 23.4, depending on the winds, May 15 to 20. Stages on the Atchafalaya: Simmesport, 50.1 to 50.6; and Melville, 45.0 to 45.4 feet, May 15 to 20. (Signed) Cline."

Crevasses complicated the situation after April 26. The first one, on April 22 in the levee on the right bank at Myrtle Grove, La., 25 miles below New Orleans, did not materially influence the flood situation, but the great crevasse, known as the Weecama crevasse, that occurred on April 26 on the right bank of the Mississippi River near Ferriday, La., and another important one between 2 and 3 o'clock a. m. on April 27 at Poydras, La., on the left bank 14 miles below New Orleans, created a decided change in the flood conditions. Accordingly the following bulletin was issued on April 27:

FLOOD BULLETIN, NEW ORLEANS, LA., APRIL 27, 1922.

"The water from the crevasse in the right bank of the Mississippi River, which occurred Wednesday, April 26, at 5:30 p. m., 5 miles above Ferriday, La., will return to the Mississippi and Atchafalaya Rivers through the Black, lower Ouachita, and Red Rivers and will intensify and prolong the flood situation in this section.

"The water now in the Mississippi River below Old River is one-half foot to 1 foot higher than in 1912, when the previous highest stages of record occurred. The Atchafalaya at Simmesport is seven-tenths of a foot below and Melville 1.7 feet above the 1912 record of that river. With these conditions, if levees hold below Old River, the crevasse water above Old River will reach a stage of 1 foot or more above that of 1912.

"The water from the Ferriday crevasse will overflow Concordia, lower Tensas, southern Franklin, eastern and southern Catahoula, and part of Avoyelles Parishes. Heavy rains during the last 24 hours in the drainage of the Red and Ouachita Rivers have further intensified the flood situation.

"A crevasse occurred Thursday, April 27, between 2 and 3 a. m., in the levee on the left bank of the Mississippi River, 14 miles below New Orleans. At 10 a. m. the crevasse was 400 feet wide, the batture and levee having caved into the river. The ends on the crevasse will be tied to prevent further spread. Water from this crevasse will overflow sugar and trucking lands in St. Bernard and Plaquemines Parishes on the left side of the river and pass into Breton Sound. (Signed) Cline."

The crevasse near Ferriday spread to a width of 2,600 feet. The rise in the river at Natchez ceased with the break in the levee and stood at 55.2 feet on April 26, 52.8 feet on April 30, and 52.7 feet from May 1 to 10, after which there was a slow fall.

The Poydras crevasse below New Orleans was 800 feet on May 8 and spread to 1,260 feet before the flood ceased. The depth of the crevasse increased to about 60 feet at the levee, and this outlet, serving as a spillway, materially influenced stages at New Orleans and no doubt prevented the occurrence of a higher stage at Baton Rouge than was recorded. At New Orleans the water began falling immediately after the occurrence of the crevasse and continued to fall very slowly, whereas without the crevasse it would probably have risen to a stage in the neighborhood of 24 feet.

The stage at Baton Rouge, which was 44.6 feet when the Weecama and Poydras crevasses occurred on April 26–27, decreased to 44.1 feet on April 30, remained stationary until May 4, when the return of the Weecama crevasse water caused another rise to begin. This rise continued until May 16, when a stage of 45.7 feet was recorded.

The effect of the Poydras crevasse was most evident in the vicinity of the crevasse and diminished up the river. At New Orleans after an initial fall any further rise was prevented even though an increasing volume of water was coming down. Farther up the river, as far as Old River, while a further rise was not prevented, the rise was smaller than it would have been without the Poydras crevasse and the amount of the rise increased in a regular manner from College Point to Red River Landing.

The return of the water from the Weecama crevasse necessitated additional warnings on May 3, 8, 9, 11, and 15. The warning of May 15 stated that—

"velocity of flow through Old River toward Mississippi increased; stages indicated as follows: Baton Rouge, 46.2 to 46.8; Plaquemine, 41.4 to 41.7 feet, May 18 to 24. (Signed) Dyke."

An important crevasse occurred at 6 a. m., May 16, 1922, in the right bank of the Atchafalaya levee system on Bayou des Glaises, about one-half mile below Hamburg in Avoyelles Parish. The opening reached a width of 200 feet in a few hours. The ends of the crevasse were tied May 21, at which time it was 1,221 feet wide. This crevasse served as a spillway, and no further rise occurred in the Mississippi and Atchafalaya Rivers.

The levee around the State farm at Angola gave way May 17 and overflowed the farm.

Bulletin May 27, 1922: "Barring exceptional rains, the water is likely to pass below 46 feet at Natchez during the first week in June. (Signed) Cline."

The river showed a stage of 45.5 at Natchez June 3.

Bulletin June 5, 1922: "Water will go below flood stage at Donaldsonville by June 10, Baton Rouge June 12, and at Melville June 15. (Signed) Dyke."

The water fell below flood stage at the stations named as follows: Donaldsonville 28.0 on June 10, Baton Rouge 34.4 on June 13, and Melville 36.4 on June 15.

All flood warnings were mailed to postmasters in the bottoms below Vicksburg for distribution to the public. In this manner every person living in regions which might be subject to overflow from crevasses was kept fully posted as to the flood situation. Other means of distribution were utilized fully.

Crest stages have already been given in the tables preceding, and it appears that the warnings therefor were fully verified, both as to stage and time of occurrence, except as affected by crevasses.

During the period covered by the flood in the lower Mississippi River there were moderate floods in the Ouachita River as follows:

Camden, Ark.—March 30 to April 13, 15 days, with a crest stage of 36.2 feet on April 4.

April 30 to May 4, five days, with a crest stage of 32.4 feet on May 2.

Monroe, La.—Flood stage was reached April 11, and the river remained above the flood stage until May 29, 49 days in all, with a crest stage of 42.3 feet on May 9.

There was a moderate flood in the Red River below Shreveport, which commenced at Alexandria May 5 and continued to May 25, 21 days, with a crest stage of 37.4 feet on May 10. The great volume of water which the Red River contributed to the Mississippi backwater overflooded areas is indicated by the unusual duration of this flood in the Red River, which was preceded by another flood which crested at 37.1 feet at Alexandria April 18–19, with water above flood stage for 12 days.

Timely warnings were issued for the flood stages which occurred in the Ouachita and Red Rivers. These floods were moderate and no material damage has been reported.

Damage resulting from the flood in the Mississippi River below Vicksburg and in the Atchafalaya has been summed up as follows:

Total acreage of agricultural land overflowed	286,154
Acreage already planted which was overflowed	174,151
Loss to highways, buildings, etc	$150,000
Loss to crops which may or may not have been housed	$80,000
Loss to prospective crops	$2,488,500
Loss to live stock and movable property	$150,000
Loss due to suspension of business, including wages of employees	$102,500
Money value of property actually saved by the warnings (live stock and movable property)	$710,000

It is hardly possible to estimate the value of the warnings. The warnings for unprecedented stages in the Mississippi and Atchafalaya Rivers caused decisive action to be taken to strengthen the levees to meet the stages forecast. This was successfully accomplished below Old River. In this way the warnings certainly resulted in the saving of property and crops worth more than $10,000,000.

Many farmers in the overflowed areas had deferred planting their crops on account of the flood situation, waiting for the flood to subside. This accounts for the fact that about one-third of the agricultural lands had not been planted.

ARKANSAS RIVER.

There were no floods west of Wichita, Kans. In the vicinity of Wichita, including the basin of the Arkansas River and its tributaries, there were moderate floods on March 15, April 9, and again from April 23 to 29, inclusive. The first April flood was caused by the heavy rains of April 8, and about 3,200 acres of land were overflowed. Warnings were issued, and the damage was comparatively small, largely on account of the early season. The total losses reported were $5,000, exclusive of about 10 per cent damage to planted crops.

The flood during the latter part of April was caused by heavy rains on the 23d of the month, and bankful stages resulted in the main stream from Great Bend to below Wichita, with slight flooding from Kinsley to below Larned, Kans. Along the small tributaries, however, especially Coon Creek and the Pawnee River, there was considerable flooding. The flood waters from Coon Creek damaged the town of Kinsley to the extent of $31,000, while the water from Pawnee River cut through the eastern portion of the town of Larned, doing much damage to gardens and cellars. All lowlands were flooded.

Neither the March nor the late April floods were in evidence south of the State of Kansas to any noticeable extent, but the earlier April flood, augmented by contributions from its tributaries, large and small, pursued its course to the mouth of the river, where it delivered to the already overburdened Mississippi River another enormous increment of surplus water. The flood in the Cottonwood-Neosho River was most severe over the middle and lower reaches, having been only moderate above.

At Iola, Kans., the river was out of its banks from April 8 to 13, inclusive, with a crest stage of 19.2 feet, 4.2 feet above flood stage on April 10. Roads and fields were covered, but the total damage did not exceed $2,000. At Fort Gibson, Okla., the crest stage was 30 feet on April 11, 8 feet above flood stage. In the Verdigris River the flood was only moderate; neither were the rises in the Canadian Forks important.

Below the mouths of the Neosho and Canadian Rivers the flood assumed greater proportions, and at Fort Smith, Ark., the Arkansas River was above the flood stage of 22 feet from April 10 to 17, inclusive, with a crest of 27.8 feet at 2 p. m., April 12. Warnings for this district were issued on April 8. Warnings for the Little Rock district below Fort Smith, including the White River, were issued on March 31, and again for the lower Arkansas River on April 6, 7, and 11. These warnings were well verified.

Crest stages, etc., from Fort Smith to the mouth of the river are given in Table 25.

TABLE 25.—*Crest stages, etc., lower Arkansas Basin, flood of 1922.*

Station.	River.	Flood stage.	Crest.		Above flood stage.		
			Stage.	Date.	Number of days.	From—	To—
		Feet.	*Feet.*				
Fort Smith, Ark	Arkansas	22	27.8	Apr. 12	8	Apr. 10	Apr. 17
Danville, Ark	Petit Jean	20	22.7	Apr. 2	8	Mar. 31	Apr. 3
						Apr. 6	Apr. 9
Dardanelle, Ark	Arkansas	20	25.2	Apr. 13	8	Apr. 11	Apr. 18
Little Rock, Ark	do	23	23.3	Apr. 14	2	Apr. 14	Apr. 15
Pine Bluff, Ark	do	25	26.0	Apr. 16	4	do	Apr. 17
Black Rock, Ark	Black	14	23.4	Apr. 9	61	Mar. 10	May 9
Batesville, Ark	White	23	22.8	Mar. 31	0		
Newport, Ark	do	26	26.2	Apr. 13–14	2	Apr. 13	Apr. 14
Georgetown, Ark	do	22	23.9	Apr. 6 [1]	25	Mar. 31	Apr. 24
Clarendon, Ark	do	30	30.7	Apr. 11 [1]	21	Apr. 7	Apr. 27

[1] And subsequent dates.

About 320,000 acres of lowlands along the lower White River were inundated, but only 92,000 of these were under cultivation. The loss was conservatively estimated at $10 an acre, or $920,000, to which should be added another $100,000 for miscellaneous losses covering property that could not be moved.

Losses reported along the lower Arkansas totaled $58,000. Property to the value of $164,000 was reported saved through the warnings.

RED RIVER.

Heavy rains over northeast Texas on March 25 and 26 caused a general rise to set in over the Red River and its tributaries, and the flood stage of 20 feet at Ringo Crossing, Tex., on the Sulphur River was exceeded by 2.5 feet on March 27. The rains were soon followed by others, and during the early days of April two moderate flood waves were passing down the rivers, the second

one passing Shreveport, La., on April 12, with a crest of 30.6 feet, 8.4 feet below the flood stage, and reaching Alexandria, La., on April 18, with a crest of 37.1 feet, 1.1 feet above the flood stage. The Red River floods did not extend west of Arthur City, Tex.

Additional heavy rains between April 25 and 27 started another sharp rise as far west as Arthur City, with resulting stages higher than during the two previous rises, and on May 9 still more heavy rains created a fourth rise before the third one had passed out. This last rain brought the maximum crest for the period, 24.4 feet, in the Sulphur River at Ringo Crossing, Tex., in the Red River at Arthur City, Tex., 26.2 feet, at Shreveport 31.3 feet, and at Alexandria, La., 37.4 feet.

The crest stages, dates, etc., are given in Table 26.

TABLE 26.—*Crest stages, etc., Red River Basin, flood of 1922.*

Station.	River.	Flood stage.	Crest.		Above flood stage.		
			Stage.	Date.	Number of days.	From—	To—
		Feet.	*Feet.*				
Denison, Tex	Red	25	20.0	May 11	0		
Arthur City, Tex	do	27	26.2	May 12	0		
Whitecliffs, Ark	Little	28	26.1	Apr. 30	0		
Fulton, Ark	Red	28	28.5	Apr. 9	4	Apr. 8 May 2 May 16	Apr. 9 May 2 May 16
Ringo Crossing, Tex.	Sulphur	20	24.4	May 11	18	Mar. 27 Apr. 6 Apr. 26 May 10	Mar. 28 Apr. 10 May 2 May 13
Finley, Tex	do	24	28.2	Apr. 30	24	Mar. 31 Apr. 12 Apr. 28 May 15	Apr. 7 Apr. 14 May 6 May 18
Springbank, Ark	Red	37	32.7	May 4	0		
Jefferson, Tex	Cypress	18	21.6	Apr. 4	16	Apr. 2 Apr. 27	Apr. 8 May 5
Shreveport, La	Red	39	31.3	May 5-6	0		
Alexandria, La	do	36	37.4	May 10	33	Apr. 12 May 5	Apr. 23 May 25

Frequent warnings were necessary for these floods, and they were timely, accurate, and highly appreciated.

The losses and damage amounted to $29,500, the major portion of which was in prospective crops. The reported value of property saved through the warnings was $16,500.

LOSS AND DAMAGE.

Data of this character are always more or less unsatisfactory when related to floods. It is not a difficult matter to obtain reliable data from business interests other than public utilities not owned by State or municipality, but the very nature of the losses by agricultural interests precludes the possibility of obtaining exact data. The figures given in Table 27, so far as agriculture is concerned, are estimates only, but they were obtained from reliable sources and should be considered as approximately correct. In any event the values given are not in excess. The data for business, other than agricultural are trustworthy so far as they go, but they are far from complete, and they are particularly wanting in information from privately owned public utilities, in most of which there appears to dwell an inherent reluctance to supply information of this character.

The statements of the value of property saved through the Warnings of the Weather Bureau represent only the totals given by those who replied to requests for the data. Many of the requests remain unanswered. None of the estimates was made by a Weather Bureau official.

TABLE 27.—*Loss and damage by floods of spring of 1922, and value of property saved by warnings.*

District.	General losses.	Crops.		Suspension of business.	Saved by warnings.
		Actual.	Prospective.		
La Crosse, Wis	None.	None.	None.	None.	None.
Dubuque, Iowa	$162,200	$10,150	$3,500	$25,000	$179,000
Davenport, Iowa	66,000	13,000		12,000	415,000
Hannibal, Mo	52,500	15,000	240,000	50,000	190,000
Topeka, Kans	10,000				
St. Louis, Mo	[1] 4,000,000				4,575,000
Columbus, Ohio	8,000	20,000	15,000	15,000	5,000
Indianapolis, Ind	1,000,000		1,870,000		200,000
Terre Haute, Ind	55,000		250,000	15,000	150,000
Cairo, Ill	337,900	72,100	543,140	168,800	407,000
Memphis, Tenn	523,000	65,000	825,000	1,130,000	1,155,000
Wichita, Kans	35,200	1,000		800	
Little Rock, Ark	158,000		920,000		164,000
Vicksburg, Miss	1,400,000				
Shreveport, La	14,000		15,500		16,500
New Orleans, La	300,000	80,000	2,488,500	102,500	710,000
Total	8,121,800	276,250	7,170,640	1,519,100	8,166,500
All losses	17,087,790				

[1] Losses of every description. Estimated from extent of overflowed areas.

The work of the Weather Bureau during the floods.—Some brief mention will be made of the work of the Weather Bureau in connection with the floods.

It is one of the numerous functions of the Bureau to issue flood warnings for the rivers of the United States, giving timely notice of the approach, extent, and duration of floods. During the last 30 years, at least, its work has been almost uniformly successful, with a steady increase in precision as to stage and in definiteness as to time and place. As early as 1897 forecasts of crest stages for the lower Mississippi River were made from one to three weeks in advance, and at the time the Bureau was charged with unduly alarming the people of the threatened districts. The absolute verification of the forecasts brought about an immediate and wholesome change of attitude, and since that time similar forecasts have been accepted and acted upon without question. The year 1922 was no exception and forecasts were made with precision for from one to nearly four weeks in advance from Cairo to the Passes, subject only to such modifications as might become necessary by reason of changing conditions caused by unusually frequent or abnormal rainfall, or both, or by crevasses.

A sample bulletin follows:

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

Washington, D. C., Saturday, April 15, 1922.—8 P. M.

RIVER BULLETIN.

The frequent rains over the drainage area of the Mississippi River proper and its larger tributaries have so accentuated the flood conditions in the Mississippi River from Cape Girardeau, Mo., southward that stages higher than any previous record have already been reached at Cape Girardeau, Mo., Arkansas City, Ark., and Greenville, Miss., and present indications point toward the occurrence of similar conditions at most other places along the river, except between Cairo and the mouth of the Saint Francis River where previous high records will not be equaled unless more heavy rains fall in the near future. However, the present rise will continue over this latter section, as the upper Mississippi and the upper Ohio Rivers are again rising, and more rains are indicated by Monday.

The effect of these later rises and the coming rains will probably be apparent not so much in any great increase in stages over those previously forecast as in a prolongation of the flood period by as much as several weeks, and it is strongly urged that all necessary preparations be made against stages somewhat higher than those previously forecast and the continuation of abnormally high water for weeks to come.

Above Cairo the forecasts were made with equal precision for the larger rivers and with reasonable accuracy for the smaller ones. In no instance did a flood come unheralded, except probably in the small, rapidly flowing and turbulent streams and in branches and creeks where torrential local rains caused rapid and equally local overflows. Many expressions of appreciation of the valuable service rendered by the Weather Bureau were received, and a few of these are appended.

From the Dubuque (Iowa) Telegraph-Herald of April 23, 1922:

Damage in the recent flood was greatly minimized through the service rendered by the local Government bureau in keeping the people informed with absolute accuracy concerning the rise from day to day. This information was disseminated well in advance. Then, too, the rise this year was gradual, never much greater than half a foot in a single 24 hours. It was not as if the flood had come up unexpected overnight.

From the Davenport (Iowa) Times of April 26, 1922:

The Weather Bureau employees stationed in the territory from which data come on which to base forecasts of the extent of floods along the Mississippi River are to be congratulated upon the precision with which they foretold the extent of the rise of the river in the last 10 days.

While almost anyone may be able to say that the river is going up or falling, it is quite another matter to state in advance the exact stage the river will reach at a certain time. This the Weather Bureau did with almost uncanny precision.

It was on April 17 that the Dubuque weather office issued a flood warning to the effect that the water of the river would reach the same stage between Lansing and Dubuque as in 1920. The crests at Lansing and Dubuque were exactly the same as in 1920.

The Davenport weather office issued a statement April 17 that the flood from Dubuque to Muscatine would be the same as in 1920, considering the water then in sight. At Clinton the 1920 stage was reached. At Le Claire the stage was 0.5 foot less than 1920, the readings being affected since 1920 by the new wing dam. However, the flooded area at Le Claire was practically the same as two years ago. At Davenport the crest stage was 17.1 feet, exactly the same as in 1920. Because in 1920 the levee broke at Muscatine, thus reducing the water level there somewhat, a higher stage was forecast for this year—19 feet—and at 7 o'clock Sunday morning the level was 19.1 feet.

Considering the large volume of water that sweeps southward in the channel of the mighty Mississippi, the precision of these forecasts is worthy of commendation as evidence of efficiency and cooperation on the part of all employees of the Weather Bureau.

From the New York Herald of April 29, 1922:

What is to be done with the Mississippi is one of the enduring problems of the South. The work of the Federal Weather Bureau in forecasting the water stage at various points between Cairo and New Orleans is helpful, as it gives warning when the peak may be expected. The degree of accuracy attained by the bureau is remarkable. For example, between 42.5 and 43 feet was forecast for Memphis by the end of March. On March 31 and April 1 the stage was 42.6 feet.

With these forecasts to guide them engineers of the levee board are enabled to make more effective preparations on the levees than was once the case. Opportunity is given to do whatever man can do to avert disaster to human habitation and human beings.

In conclusion let it be said that presumptions as to future flood conditions in the lower Mississippi Valley would doubtless be largely academic and might possibly be nullified by those very conditions, yet it may not be unwise to venture the suggestions that the floods of the present year have confirmed the statements of earlier years that the possible limits of maximum flood heights have not yet been reached and that all plans and preparations for continued future protection from floods must be so projected and carried out as to afford safety for the dweller behind the levee against still higher stages of the river than were experienced during the year 1922.

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Chart VI. Precipitation for January, 1882.

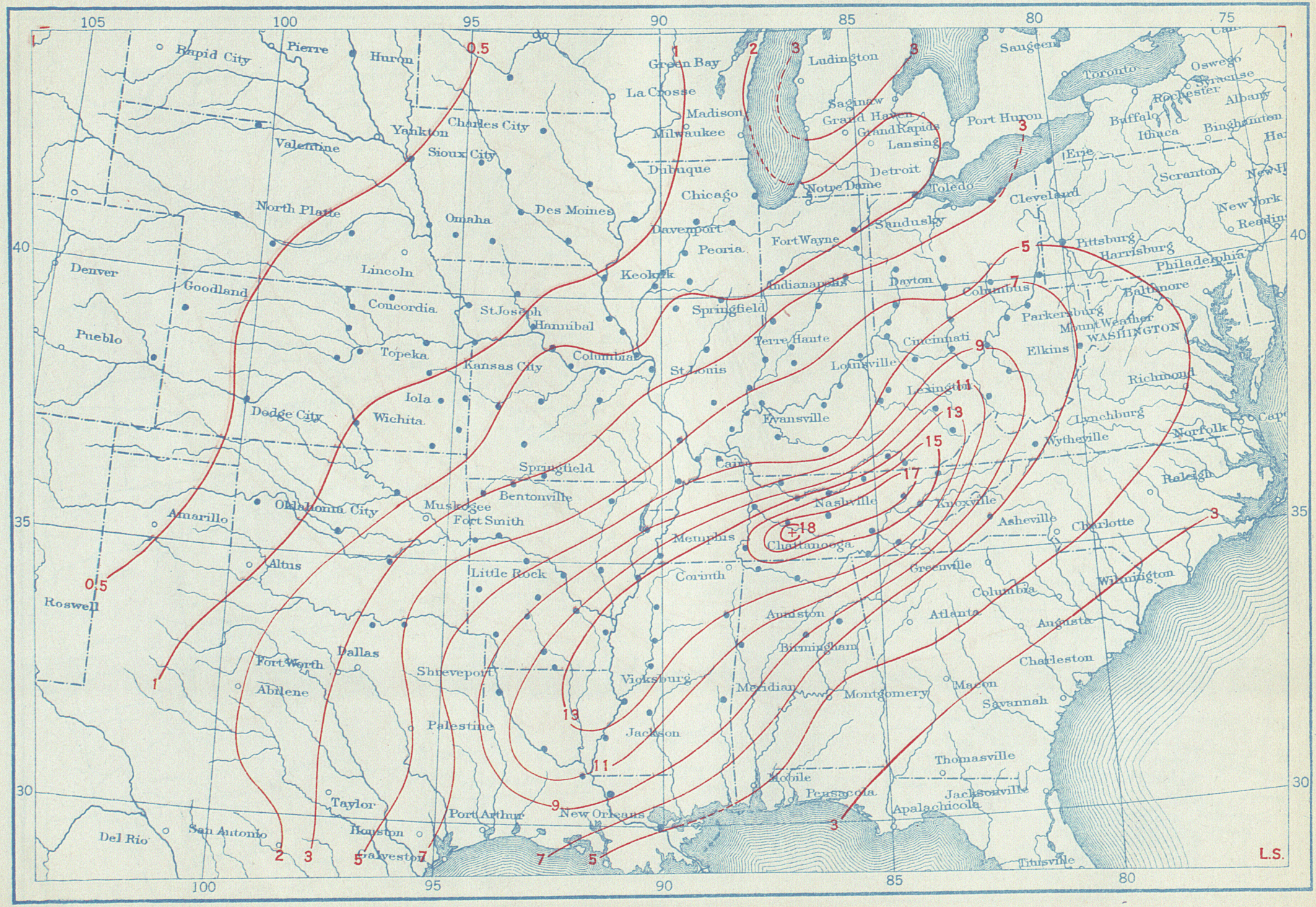

Chart VII. Precipitation for February, 1882.

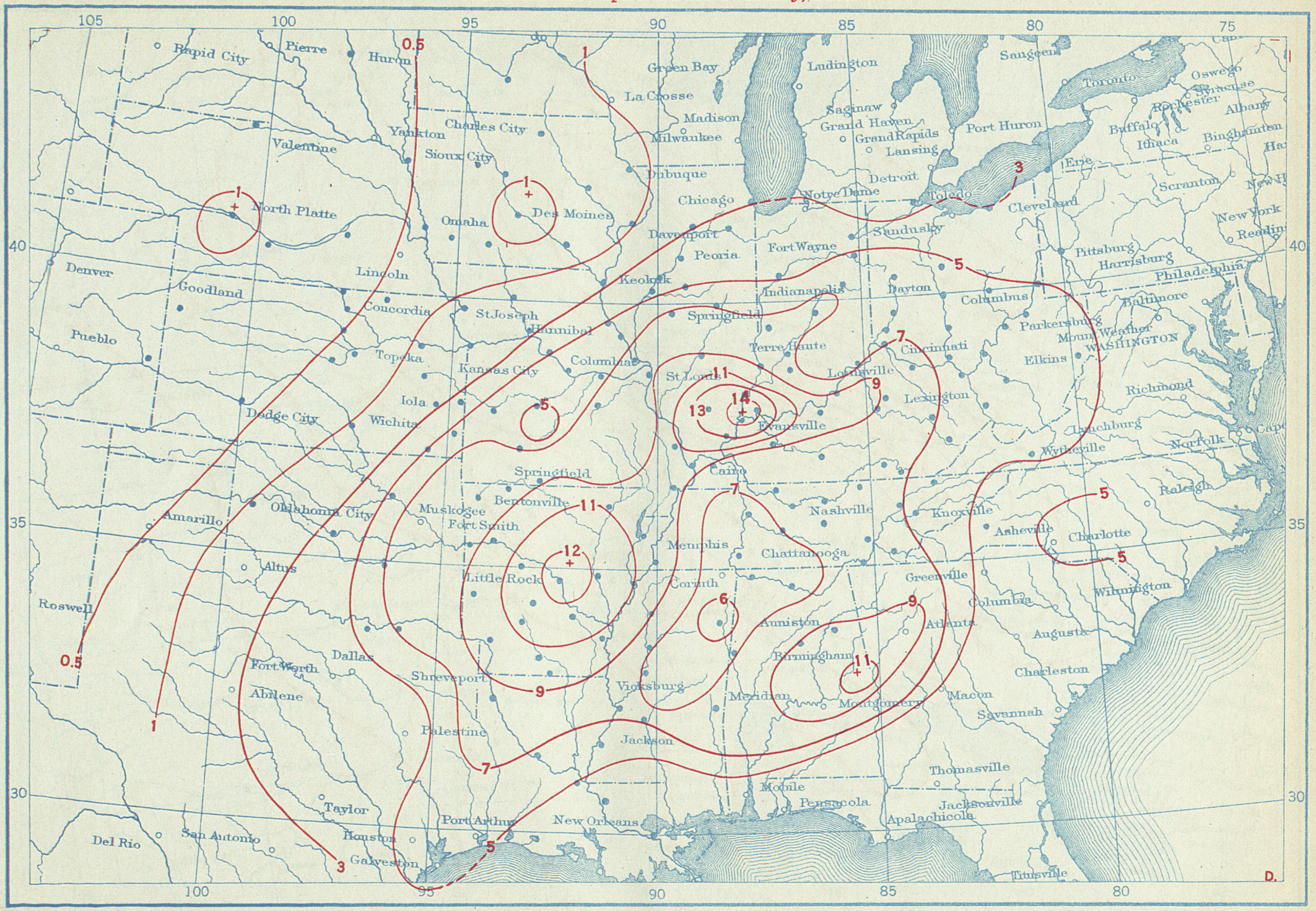

Chart VIII. Precipitation for March, 1882.

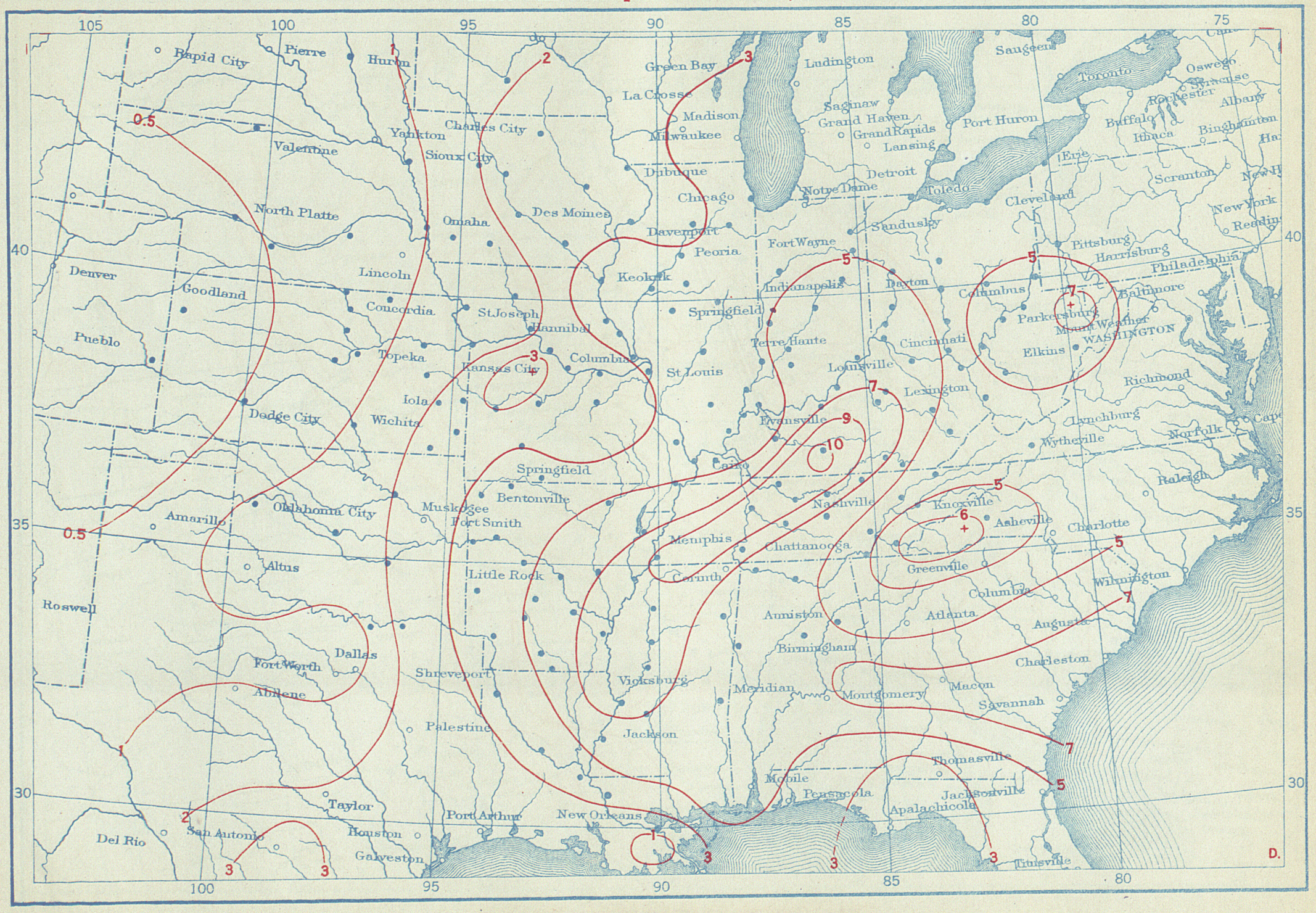

Chart IX. Precipitation for January, 1913.

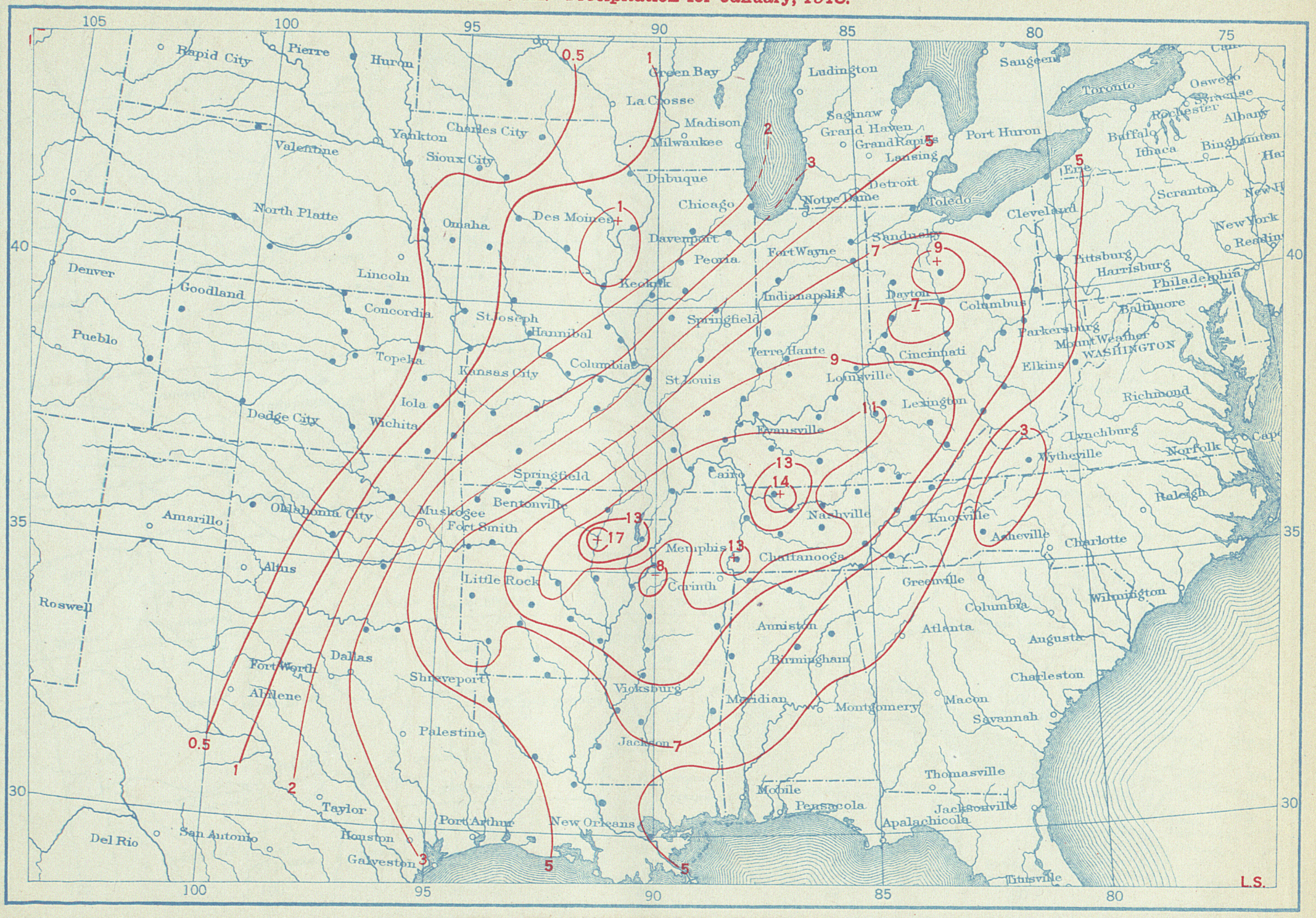

Chart X. Precipitation for February, 1913.

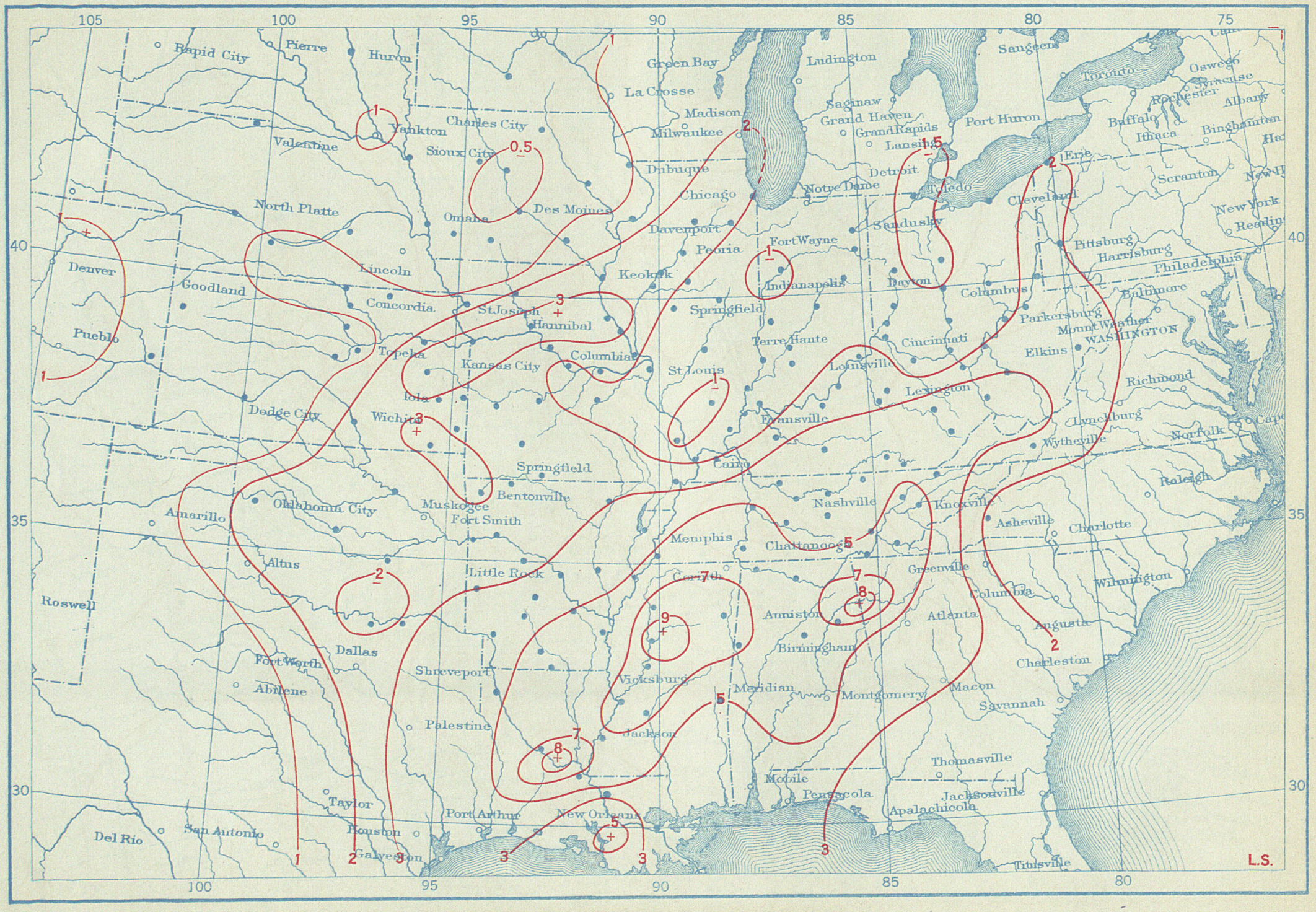

Chart XI. Precipitation for March, 1913.

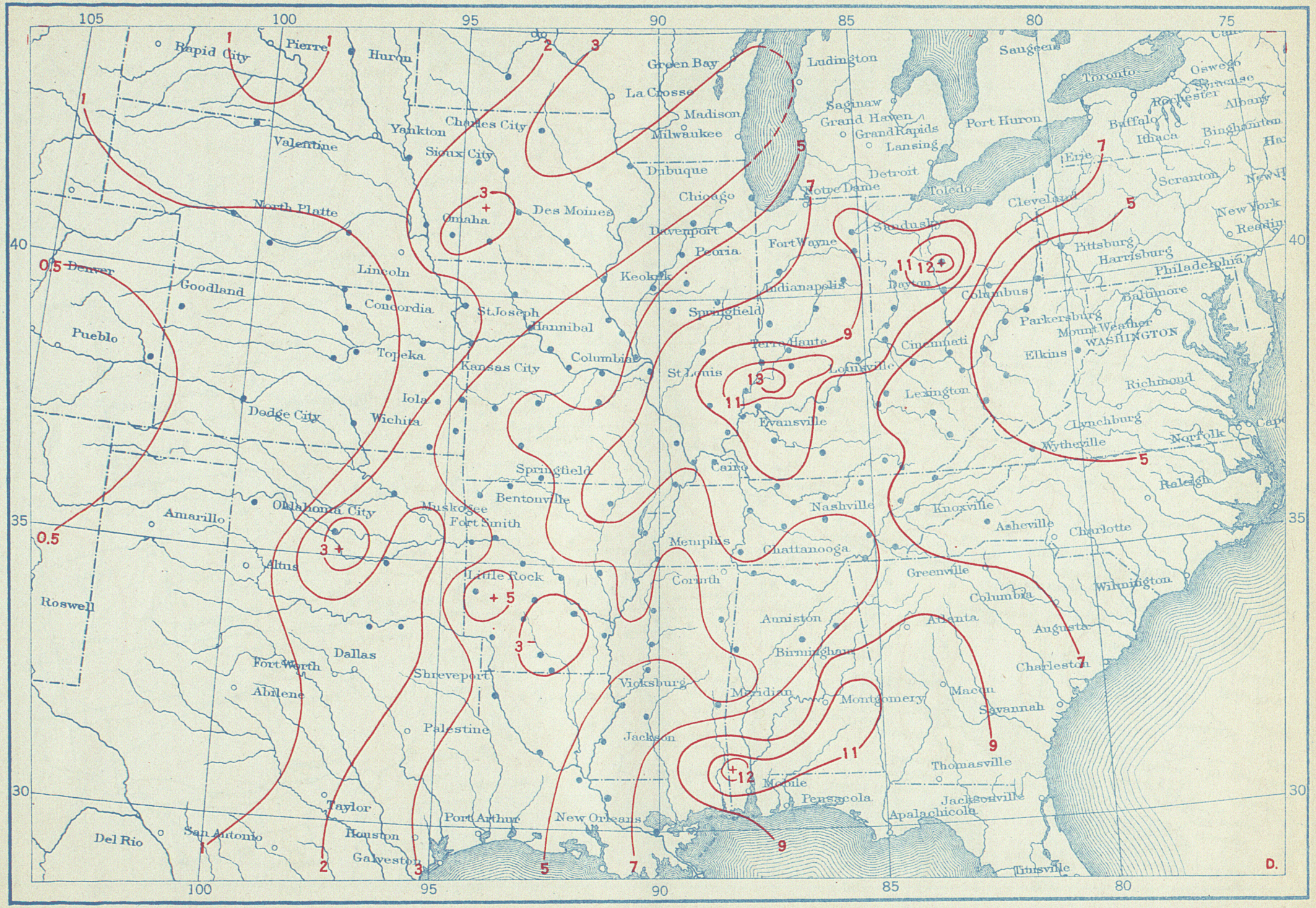

Chart XII. Precipitation for January, 1922.

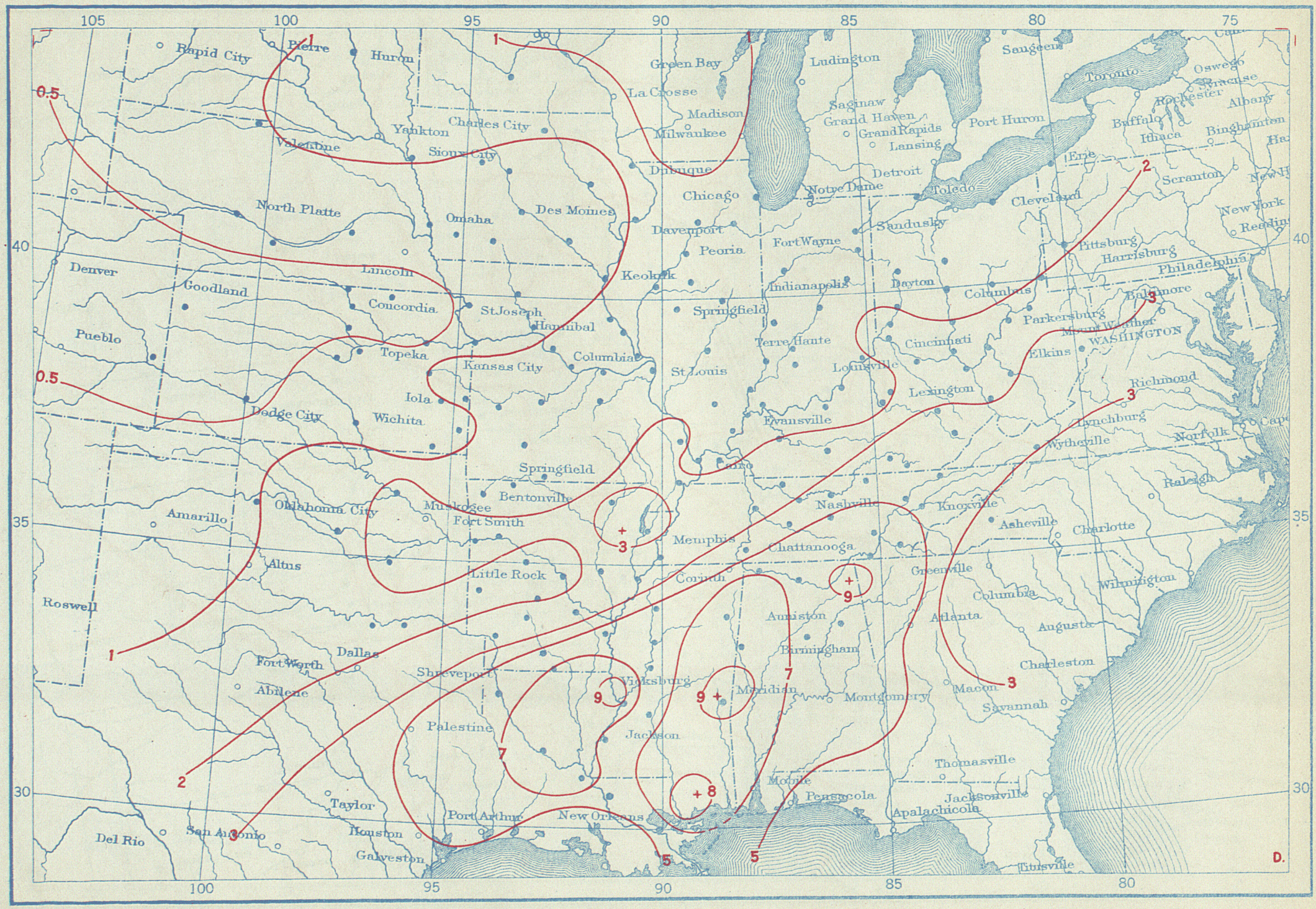

Chart XIII. Precipitation for February, 1922.

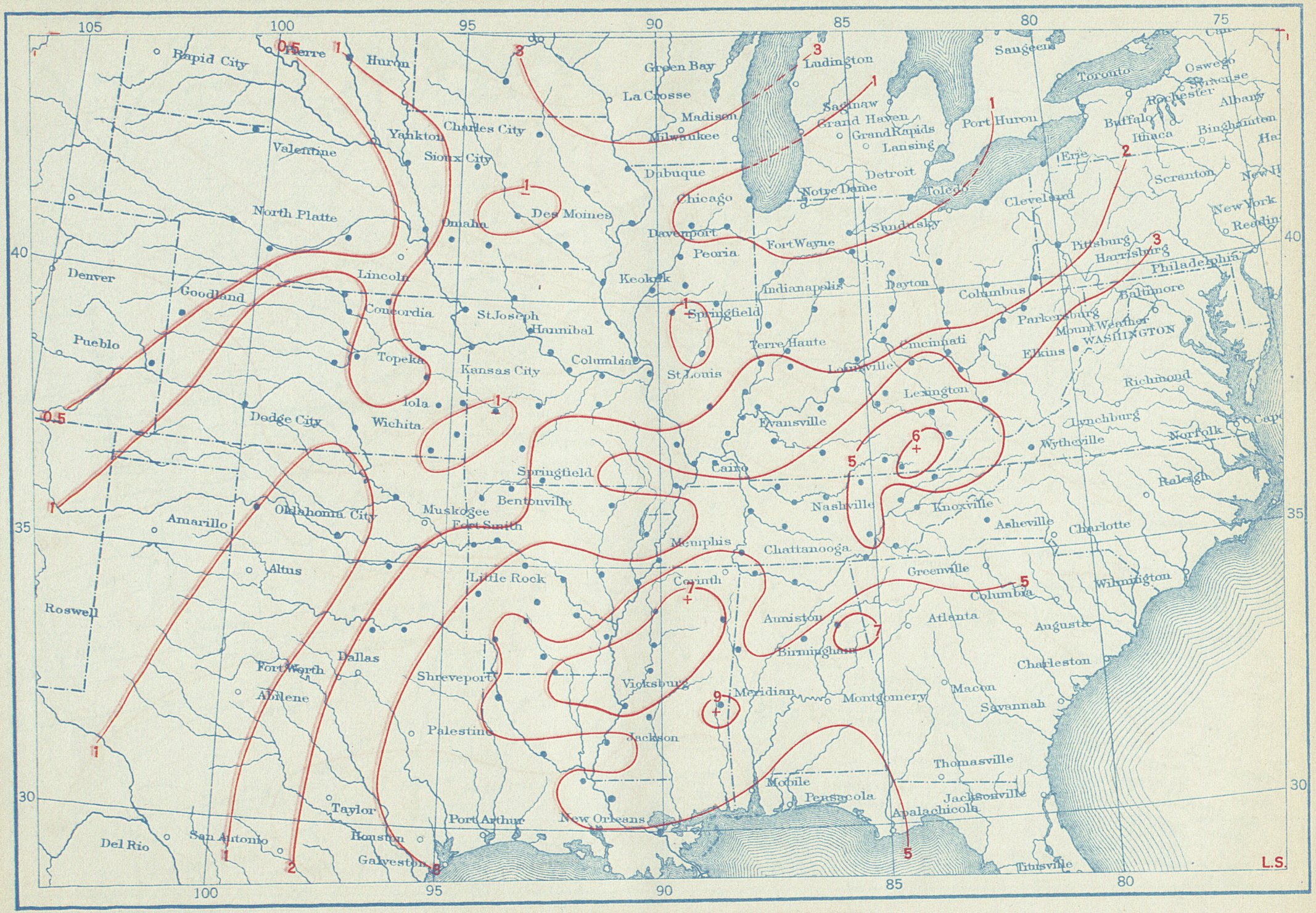

Chart XIV – Precipitation for March, 1922.

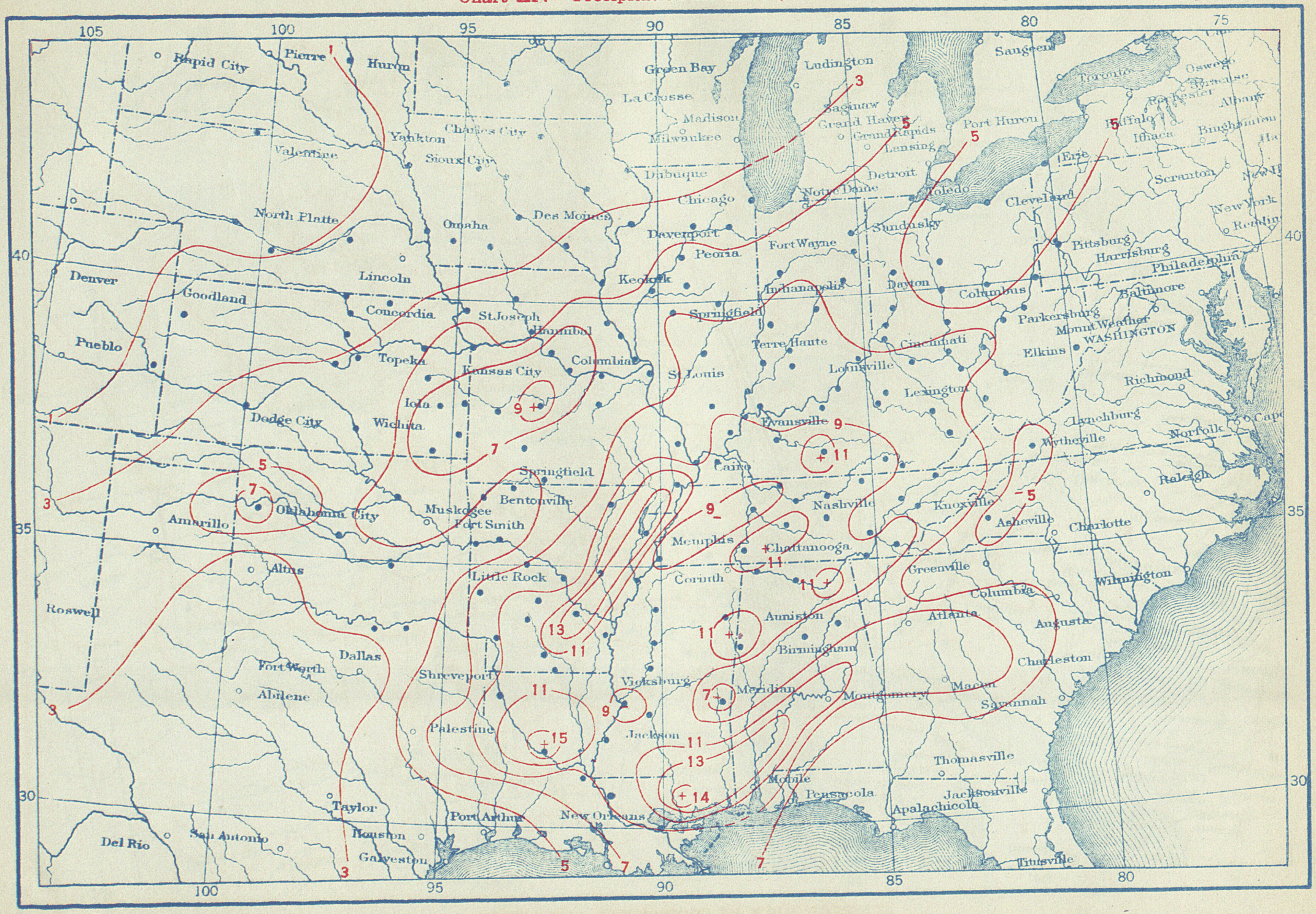
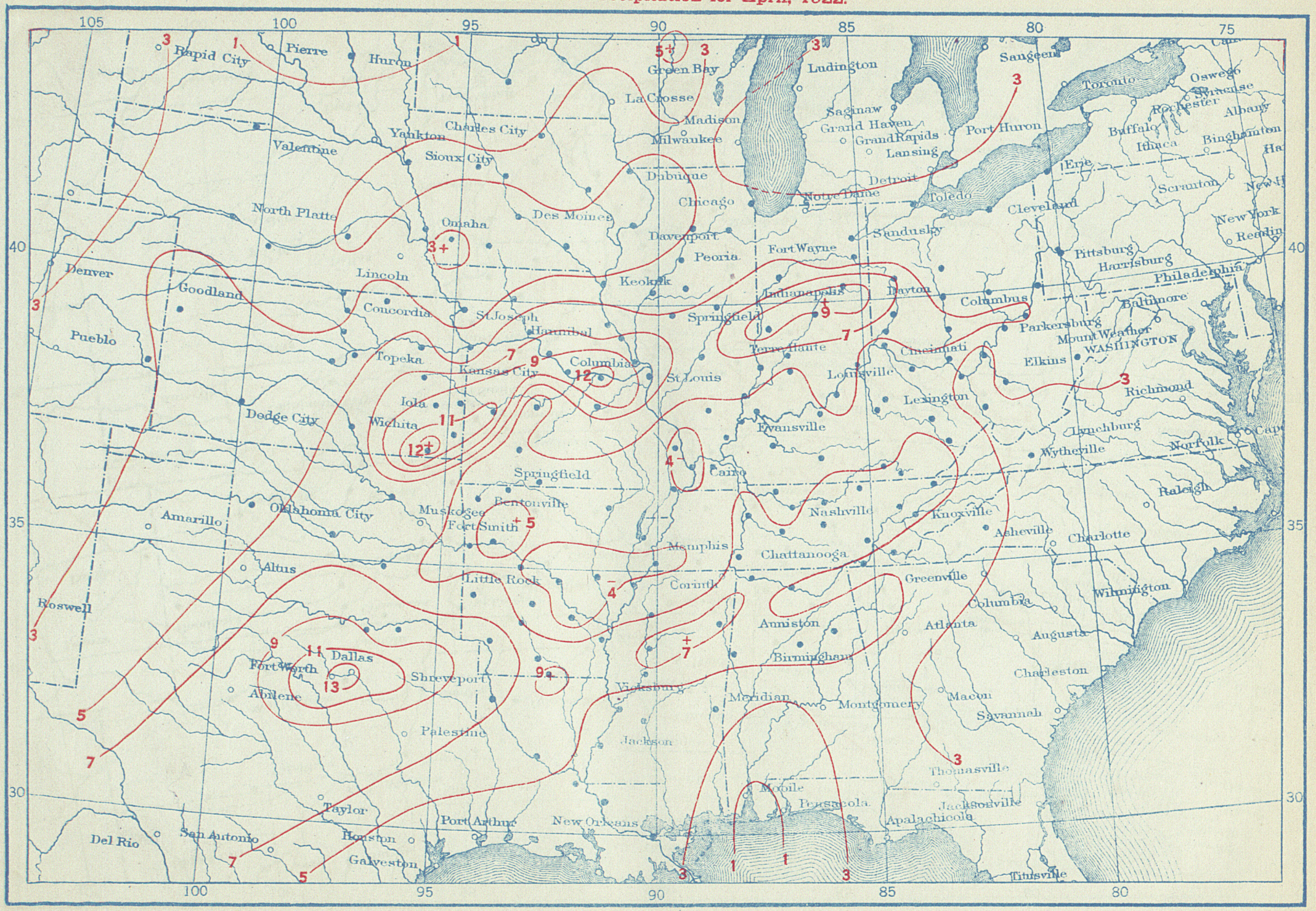
Chart XV.—Precipitation for April, 1922.