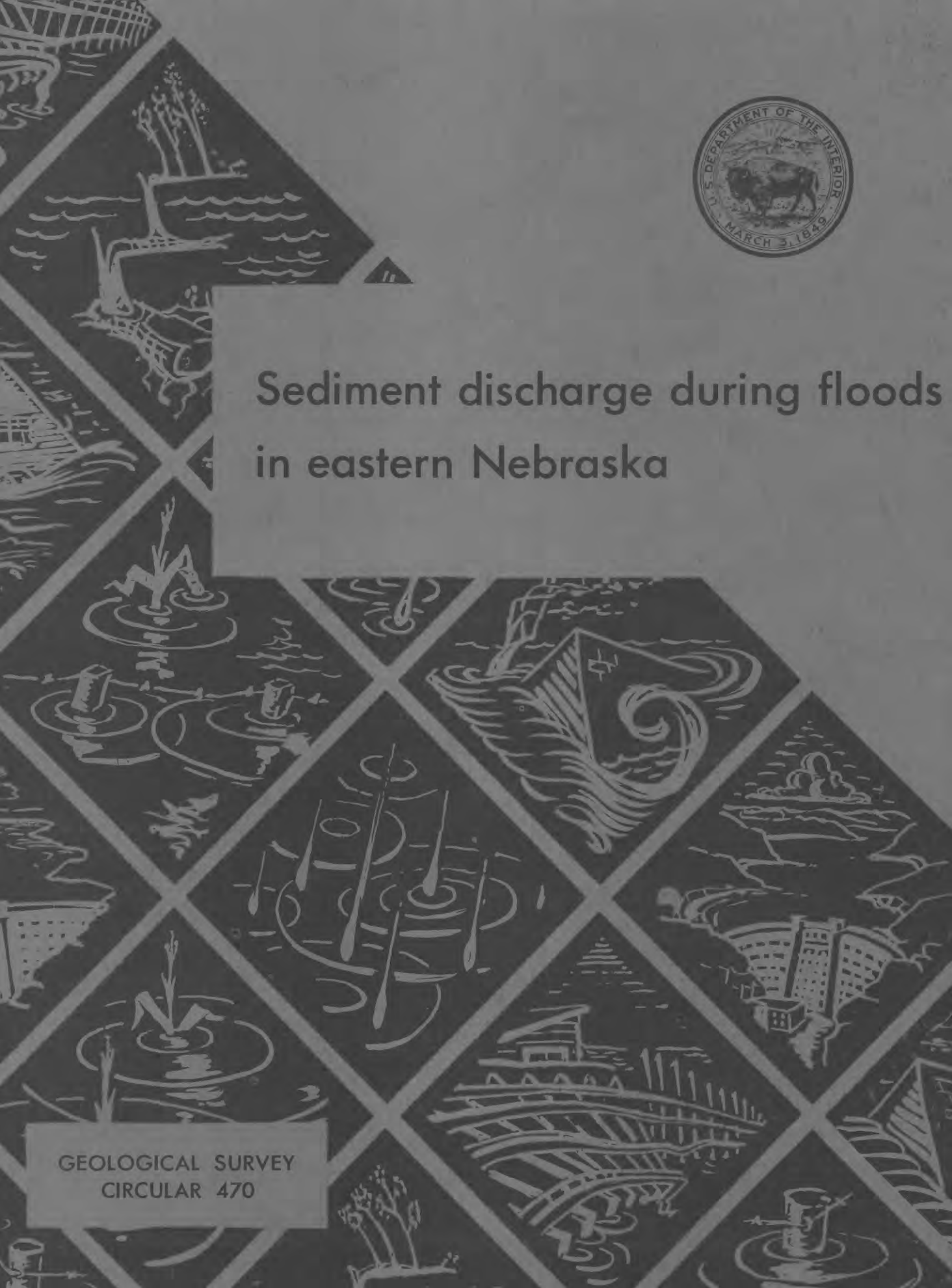
Sediment discharge during floods in eastern Nebraska



GEOLOGICAL SURVEY
CIRCULAR 470

Sediment discharge during floods in eastern Nebraska

By J. C. Mundorff

GEOLOGICAL SURVEY CIRCULAR 470

Washington 1962

United States Department of the Interior

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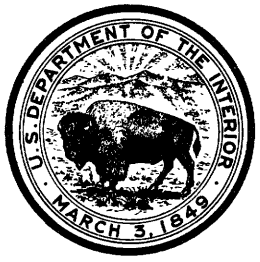

Geological Survey

THOMAS B. NOLAN, DIRECTOR

Free on application to the U.S. Geological Survey, Washington 25, D. C.

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Sediment discharge during floods in eastern Nebraska

By J. C. Mundorff

ABSTRACT

Runoff resulting from rapid melting of a deep snow cover over much of eastern Nebraska resulted in exceptionally high stream stages and in severe flooding on many streams in eastern Nebraska during the latter part of March and the early part of April in 1960. Suspended-sediment concentrations and discharges for most of the streams were somewhat lower than would be expected during similar water discharges that might resnlt from torrential rains rather than snowmelt. During the period March 28–April 8, 1960, when the total water discharge of Platte River at Louisville and of Elkhorn River at Waterloo was about one-fourth of the total for the year, the sediment discharge was an estimated 45 to 50 percent of the estimated total for the year at each station. Both the percentage of sand and the concentration of sand in the suspended sediment were much higher for the Platte and Elkhorn Rivers than for streams in the Big Blue River and Nemaha River basins. For Platte River at Louisville and for Elkhorn River at Waterloo, measured sediment discharges ranged from about 87 to 94 percent of the computed total sediment discharge.

INTRODUCTION

Between December 27, 1959, and March 26, 1960, depth of snowfall over most of eastern Nebraska was about twice as much as the annual average for the area, and snowmelt and resulting runoff were rather minor. By March 26, the average snow cover over much of eastern Nebraska ranged from 10 to 15 inches in depth, and had an exceptionally high moisture content. A few observations indicated that the accumulated and compacted snow had three to four times the average moisture content of newly fallen snow. A snow survey made by the U.S. Geological Survey on March 20 in a small drainage basin near Syracuse, Nebr., indicated an average snow depth of slightly more than 1 foot and a moisture content of about 3.5 inches per foot of snow. At Lincoln, Nebr., a few observations on March 22 indicated that the average moisture content was about 3.6 inches per foot of snow.

During the period March 27–29, air temperature increased markedly over eastern Nebraska. Figure 1 shows the daily minimum and maximum, temperatures at three places in eastern Nebraska for the period March 25–29. Snowmelt and runoff were relatively minor through March 26; nearly the entire snow cover that had accumulated during the preceding 3 months melted during the period March 27–29. The combination of very rapid melting and of soil frost over large areas resulted in high surface runoff. The large volume of runoff and the ice-choked condition of most streams resulted in exceptionally high stream stages and in severe flooding in some areas.

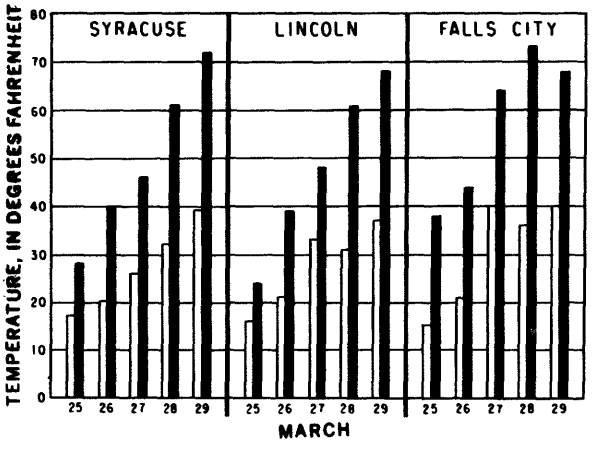

Figure 1.—Graph showing minimum and maximum temperatures at Syracuse, Lincoln, and Falls City, Nebr., during the period March 25–29, 1960.

Table 1.—*Water discharge and suspended-sediment concentration and discharge for some streams in eastern Nebraska*

Stream	Date (1960)	Time	Discharge (cfs)	Suspended sediment	
				Concentration (ppm)	Discharge (tons per day)
Cedar River:					
Near Spalding	Mar. 28	5:10 p.m.	346	1,120	1,050
	Apr. 5	9:35 a.m.	272	424	311
At Belgrade	Mar. 29	6:20 p.m.	1,730	7,450	34,800
	Apr. 5	1:30 p.m.	268	1,420	1,030
Near Fullerton	Mar. 28	1:20 p.m.	[1]3,300	2,690	24,000
	Mar. 29	12:00 m.	[1]2,000	1,980	10,700
	Mar. 30	5:00 p.m.	1,640	5,840	25,900
	Apr. 4	1:50 p.m.	551	1,250	1,860
Elkhorn River at Waterloo	Mar. 31	10:45 a.m.	21,800	6,540	385,000
	---do---	3:40 p.m.	21,400	5,180	299,000
	Apr. 1	10:20 a.m.	24,400	5,200	343,000
	---do---	2:50 p.m.	25,600	4,100	283,000
	Apr. 4	11:15 a.m.	31,800	2,910	250,000
	Apr. 6	11:45 a.m.	14,450	5,500	215,000
	Apr. 8	12:05 p.m.	10,000	5,540	150,000
Platte River at Louisville	Mar. 31	8:30 a.m.	90,000	4,600	1,120,000
	---do---	9:30 a.m.	88,400	5,350	1,280,000
	---do---	1:00 p.m.	85,800	6,100	1,410,000
	Apr. 1	11:35 a.m.	59,700	5,230	843,000
	Apr. 4	10:00 a.m.	59,300	5,460	874,000
	Apr. 8	10:10 a.m.	59,100	2,660	424,000
Missouri River at Nebraska City	Mar. 31	11:40 a.m.	132,000	2,860	1,020,000
	Apr. 4	3:10 p.m.	173,000	1,890	883,000
Brownell Creek near Syracuse:					
West Fork	Mar. 28	1:00 p.m.	[2]120	12,600	4,080
East Fork	Mar. 27	12:30 p.m.	[2]80	10,900	2,350
	Mar. 28	1:15 p.m.	[2]140	8,620	3,260
Little Nemaha River at Auburn	Mar. 31	12:50 p.m.	1,860	4,670	23,500
Big Blue River:					
Near Crete	---do---	5:20 p.m.	19,900	1,550	83,300
	Apr. 1	9:20 a.m.	14,600	1,640	64,600
	---do---	5:50 p.m.	12,700	1,280	43,900
	Apr. 2	1:10 p.m.	9,800	1,240	32,800
At Beatrice	Mar. 31	3:00 p.m.	24,000	1,700	110,000
	Apr. 1	11:00 a.m.	24,200	1,440	94,100
	---do---	11:50 a.m.	24,200	1,690	110,000
	---do---	4:25 p.m.	24,000	1,360	88,100
	Apr. 2	5:30 p.m.	20,000	1,240	67,000
At Barneston	Apr. 1	2:00 p.m.	25,800	1,550	108,000
Little Blue River:					
Near Deweese	Mar. 28	2:00 p.m.	7,030	2,400	45,600
	Apr. 2	3:00 p.m.	2,200	5,040	29,900
Near Fairbury	Mar. 31	4:10 p.m.	4,130	3,520	39,300
	Apr. 2	4:30 p.m.	5,230	5,820	82,200

[1]Daily mean discharge; flow affected by backwater from ice.
[2]Estimated.

SEDIMENT DISCHARGE AND CONCENTRATION

During the flood period (about March 27 to April 8), 41 sediment-discharge measurements were made with standard equipment and methods on streams in eastern Nebraska. The results of these measurements are shown in table 1. The suspended-sediment concentrations and discharges for most of the streams were somewhat lower than would be expected during similar water discharges that might result from torrential rains rather than from snowmelt. However, concentrations were high and suspended-sediment discharges were extremely high as compared with those of normal stream discharges.

The highest concentrations observed were on two branches of Brownell Creek near Syracuse. The contributing drainage area of each branch is only a few square miles, and the sediment discharge measurements were made during the peak-discharge period. Extensive conservation practices and numerous detention reservoirs in much of the watershed resulted in appreciably lower suspended-sediment concentrations than might be expected for such a watershed without conservation measures.

The lowest observed suspended-sediment concentrations were for Cedar River near Spalding; the drainage area is mainly in the Sandhills. Some relatively high concentrations were observed, however, at Belgrade and near Fullerton, which are in the downstream reaches of the Cedar River. The sharp increase in concentration at the downstream sites can be attributed mainly to the loessial areas, which predominate downstream from Spalding.

During the period March 31 to April 2 concentrations for the Big Blue River were rather uniform and relatively low at Crete, Beatrice, and Barneston, and concentrations for the Little Blue River were appreciably higher.

Concentrations and suspended-sediment discharges were high for Elkhorn River at Waterloo and for Platte River at Louisville during the flood period. The data indicate that the measured suspended-sediment discharge at Louisville at water discharges of about 60,000 to 90,000 cfs equaled or exceeded the measured suspended-sediment discharge of Missouri River at Nebraska City at much higher water discharges.

Although observed suspended-sediment concentrations during the flood period were high as compared with concentrations during periods of normal flow, they were not high as compared with maximum observed concentrations for the same streams during the spring and summer months of other years. Observed concentrations of 10,000 to 15,000 ppm were not uncommon for Little Blue River near Endicott and near Fairbury during 1956–59. Concentrations of more than 40,000 ppm have been measured on the Little Nemaha River.

The total water discharge for the 12-day period March 28 to April 8, 1960, for Platte River at Louisville was about 702,000 cfs-days (1,390,000 acre-feet), or nearly one-fourth of the total discharge for the entire 1960 water year. The discharge for 1960 was about 160 percent of the average annual discharge for the period of record 1954–60; both the maximum instantaneous discharge (124,000 cfs) and the maximum daily mean discharge (112,000 cfs) for the period 1954–60 occurred on March 30, 1960.

For most streams in Nebraska, except in the Sandhills, a large part of the total annual suspended-sediment discharge commonly occurs during a few days of high water discharges each year. During the period March 28–April 8, 1960, when the total water discharge of Platte River at Louisville was nearly one-fourth of the total for the year, the sediment discharge was an estimated 45 to 50 percent of the estimated total for the year. For Elkhorn River at Waterloo during the period March 30 to April 8, 1960, when the total water discharge was slightly more than one-fourth of the annual total, the sediment discharge was an estimated 45 percent of the estimated annual total.

PARTICLE-SIZE DISTRIBUTION

Particle-size analyses (table 2) show that for the Big Blue, Little Blue, and Little Nemaha Rivers, the suspended sediment was mostly silt (0.004 to 0.062 mm) and clay (< 0.004 mm). (See fig. 2.) Concentrations of

Table 2.—*Particle-size analyses of suspended sediment for some streams in eastern Nebraska*

[Methods of analysis: P, pipet; N, in native waters; W, in distilled water; C, chemically dispersed; M, mechanically dispersed; V, visual accumulation tube]

Date (1960)	Time	Discharge (cfs)	Water temperature (°F)	Suspended sediment												Methods of analysis
				Concentration (ppm)	Concentration of suspension analyzed (ppm)	Discharge (tons per day)	Percent finer than indicated size, in millimeters									
							0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	
Cedar River near Spalding																
Mar. 28	5:10 p.m.	346	44	1,120	----------	1,050	-----	[1]10	-----	-----	-----	27	53	90	100	-----	V
Apr. 5	9:35 a.m.	272	43	424	----------	311	-----	[1]10	-----	-----	-----	26	44	97	100	-----	V
Cedar River at Belgrade																
Mar. 29	6:20 p.m.	1,730	-----	7,450	6,610	34,800	13	15	18	21	34	69	85	97	100	-----	VPWCM
Do	6:20 p.m.	1,730	-----	7,450	6,840	34,800	5	8	11	16	29	69	85	97	100	-----	VPN
Apr. 5	1:30 p.m.	268	51	1,420	7,860	1,030	10	12	-----	19	-----	60	79	98	100	-----	VPWCM
Cedar River near Fullerton																
Mar. 28	1:20 p.m.	[2]3,300	34	2,690	5,090	24,000	29	32	36	41	55	86	95	99	100	-----	VPWCM
Mar. 29	12:00 m.	[2]2,000	39	1,980	4,230	10,700	39	44	50	58	74	94	97	100	-----	-----	VPWCM
Mar. 30	5:00 p.m.	1,640	43	5,840	13,300	25,900	13	15	17	21	32	69	82	98	100	-----	VPWCM
Apr. 4	1:50 p.m.	551	48	1,250	4,480	1,860	19	22	-----	31	-----	76	86	99	100	-----	VPWCM
Elkhorn River at Waterloo																
Mar. 31	10:45 a.m.	21,800	36	6,540	7,600	385,000	33	38	42	51	61	90	96	100	-----	-----	VPWCM
Do	3:40 p.m.	21,400	36	5,180	9,900	299,000	32	37	42	48	59	78	90	99	100	-----	VPWCM
Apr. 1	10:20 a.m.	24,400	-----	5,200	7,380	343,000	27	30	34	41	54	69	77	97	100	-----	VPWCM
Do	2:50 p.m.	25,600	-----	4,100	9,270	283,000	34	39	44	51	61	76	86	98	100	-----	VPWCM
Apr. 4	11:15 a.m.	31,800	40	2,910	8,030	250,000	42	48	54	59	65	69	76	96	100	-----	VPWCM
Apr. 6	11:45 a.m.	14,450	-----	5,500	7,450	215,000	29	33	38	45	59	77	88	96	98	100	VPWCM
Do	11:45 a.m.	14,450	-----	5,500	8,220	215,000	10	18	27	39	57	77	88	96	98	100	VPN
Apr. 8	12:05 p.m.	10,000	-----	5,540	6,970	150,000	29	33	37	44	59	79	89	98	100	-----	VPWCM

Platte River at Louisville

Mar. 31	9:30 a.m.	88,400	-----	5,350	3,790	1,280,000	17	19	21	24	31	42	54	91	99	100	VPWCM
Apr. 1	11:35 a.m.	59,700	-----	5,230	3,930	843,000	22	24	27	33	43	60	71	93	99	100	VPWCM
Apr. 4	10:00 a.m.	59,300	-----	5,460	4,650	874,000	23	26	28	32	39	49	59	85	96	100	VPWCM
Apr. 8	10:10 a.m.	59,100	-----	2,660	2,960	424,000	34	34	39	46	63	79	85	95	100	-----	VPWCM

Little Nemaha River at Auburn

Mar. 31	12:50 p.m.	1,860	-----	4,670	7,500	23,500	36	40	47	61	86	98	99	100	-----	-----	VPWCM

Big Blue River near Crete

Mar. 31	5:20 p.m.	19,900	-----	1,550	1,970	83,300	66	70	81	87	-----	100	-----	-----	-----	-----	VPWCM
Apr. 1	5:50 p.m.	12,700	41	1,280	2,000	43,900	62	69	75	83	91	99	99	100	-----	-----	VPWCM
Apr. 2	1:10 p.m.	9,800	42	1,240	1,610	32,800	30	50	65	77	89	99	100	-----	-----	-----	VPWCM

Big Blue River at Beatrice

Mar. 31	3:00 p.m.	24,000	-----	1,700	2,600	110,000	65	75	83	88	92	96	97	98	100	-----	VPWCM
Apr. 1	11:50 a.m.	24,200	-----	1,690	2,420	110,000	64	71	78	78	88	90	90	91	93	100	VPWCM

Big Blue River at Barneston

Apr. 1	2:00 p.m.	25,800	43	1,550	4,220	108,000	-----	63	70	80	89	98	99	100	-----	-----	VPWCM

Little Blue River near Deweese

Mar. 28	2:00 p.m.	7,030	-----	2,400	3,430	45,600	25	44	58	70	81	89	90	93	100	-----	VPN
Do	2:00 p.m.	7,030	-----	2,400	3,160	45,600	52	58	66	71	82	89	90	93	100	-----	VPWCM
Apr. 2	3:00 p.m.	2,200	42	5,040	3,140	29,900	61	66	70	76	86	95	98	99	100	-----	VPWCM

Little Blue River near Fairbury

Mar. 31	4:10 p.m.	4,130	-----	3,520	2,380	39,300	21	31	42	55	77	94	97	100	-----	-----	VPWCM
Apr. 2	4:30 p.m.	5,230	41	5,820	5,140	82,200	53	57	66	76	89	98	99	100	-----	-----	VPWCM

[1]Estimated.
[2]Daily mean discharge.

sand (0.062 to 2.000 mm) for these streams ranged from 0 to 264 ppm, while the total measured suspended-sediment concentrations ranged from 1,240 to 5,820 ppm. For Platte River at Louisville, sand concentrations ranged from 559 to 3,100 ppm at total concentrations that ranged from 2,660 to 5,460 ppm. For Elkhorn River at Waterloo, sand concentrations ranged from 654 to 1,610 ppm. The differences in sand concentration for the different streams are reflections of differences in hydraulic characteristics of the streams and in characteristics of the material available for suspension in the stream. Mean velocity at Elkhorn River at Waterloo was about double the mean velocity for the

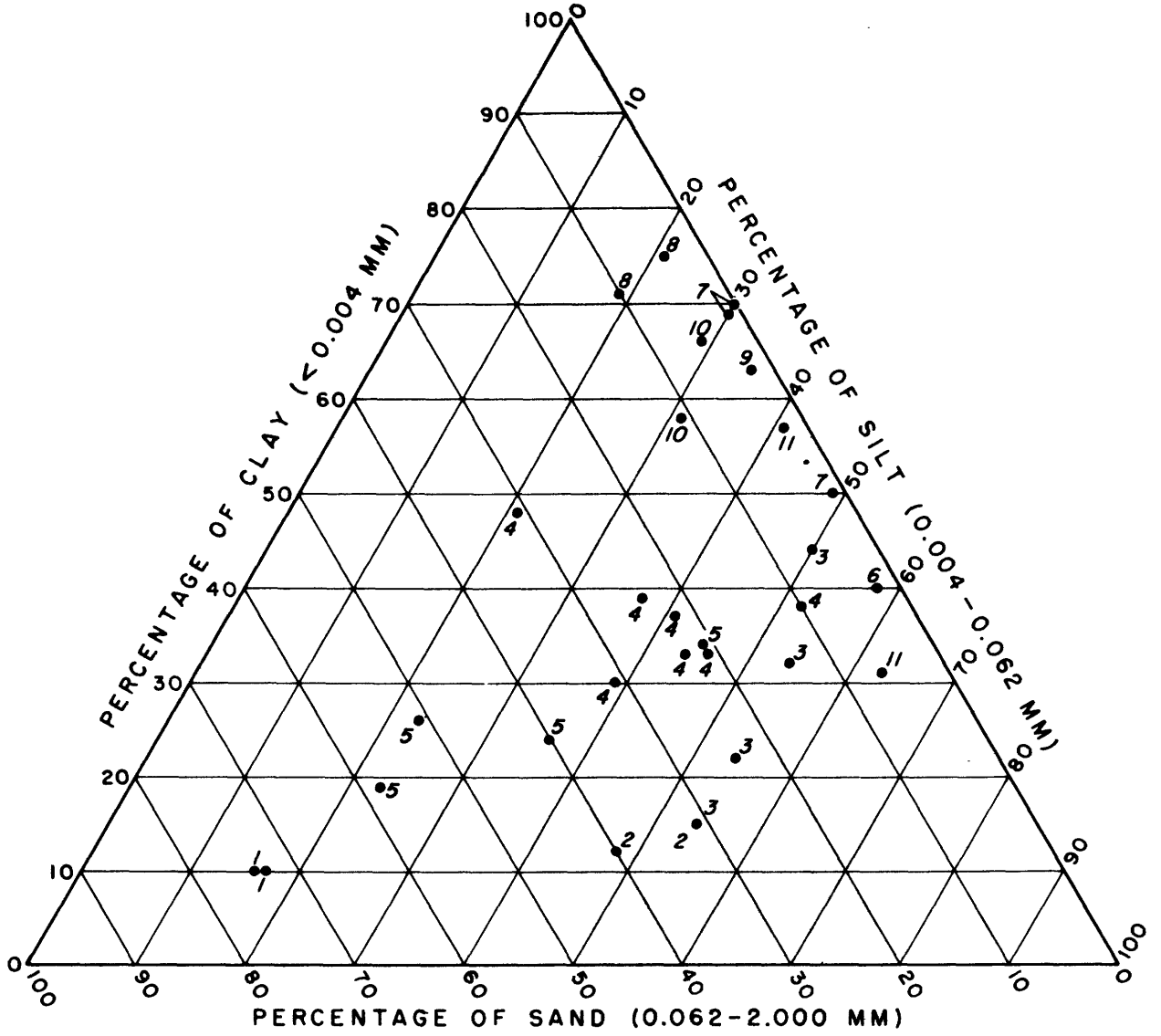

Figure 2.—Triangle diagram showing percentage of sand, silt and clay in suspended-sediment samples from streams in eastern Nebraska, March 28 to April 8, 1960. (1) Cedar River near Spalding; (2) Cedar River at Belgrade; (3) Cedar River near Fullerton; (4) Elkhorn River at Waterloo; (5) Platte River at Louisville; (6) Little Nemaha River at Auburn; (7) Big Blue River near Crete; (8) Big Blue River at Beatrice; (9) Big Blue River at Barneston; (10) Little Blue River near Deweese; and (11) Little Blue River near Fairbury.

Big Blue River and Little Blue River sites, and the streambed material was considerably coarser in the Blue Rivers than in Elkhorn River at Waterloo.

The particle-size analyses were made by sedimentation methods and were mainly for samples that had been chemically and mechanically dispersed by standard laboratory methods. The particle-size distributions that are shown for dispersed samples, especially for the silt and clay, are representative of the sizes that would exist in the stream if the water had certain chemical characteristics and if certain hydraulic conditions existed in the stream. For a few samples, one-half of each was analyzed under dispersed conditions, and the other half was analyzed with natural stream water as the settling medium. A comparison of the particle-size distributions of samples analyzed by both methods indicates that the chemical quality of the native (natural) water apparently is conducive to flocculation of sediment during the quiescent settling conditions in the laboratory. A part of the clay, however, is probably transported by the stream as original soil floccules or aggregates of silt size. Preparation of the sample for analysis under dispersed conditions destroys these floccules or aggregates; therefore, the differences between particle-size distributions for dispersed and native-water settling mediums may be caused as much by destruction of original soil aggregates as by the flocculating ability of the native water.

A few data obtained on particle-size distribution of bed material at Louisville, Waterloo, and Beatrice indicate that the material is finest at Waterloo, somewhat coarser at Louisville, and much coarser at Beatrice. (See following table.)

Bed material for the 3 percentages (by weight) shown is finer than the particles sizes listed

Stream	Particle size (millimeters)		
	15 percent	50 percent	85 percent
Elkhorn River at Waterloo	0.16	0.27	0.70
Platte River at Louisville	.22	.37	.87
Blue River at Beatrice	.50	.80	2.2

CONCLUSION

The suspended-sediment discharge of some streams, as computed by standard methods, does not include all the suspended sediment in an unsampled zone about 0.4 foot deep immediately above the streambed. Also, the suspended-sediment discharge obviously does not include sediment that may be transported as bedload. Estimates of the total sediment discharge are shown in table 3. For Big Blue River at Beatrice, the measured suspended-sediment discharge, as indicated by a single computation, was 96 percent of the total discharge. For Platte River at Louisville and for Elkhorn River at Waterloo, measured sediment discharges ranged from about 87 to 94 percent of the total discharge.

The available data are not sufficiently comprehensive for precise determination of total sediment discharge for each stream during the entire flood period. However, estimates of total sediment discharge based on the available data on streamflow and sediment discharge for three streams are as follows:

Elkhorn River at Waterloo, March 30 to April 8, 1960, 3.25 million tons; Platte River at Louisville, March 28 to April 8, 1960, 11

Table 3.—*Measured and total sediment discharge for selected streams in eastern Nebraska*

Date (1960)	Time	Discharge (cfs)	Sediment discharge (thousands of tons per day)	
			Measured	Total
Elkhorn River at Waterloo				
Mar. 31	3:40 p.m.	21,400	299	327
Apr. 4	11:15 a.m.	31,800	250	279
Apr. 6	11:45 a.m.	14,450	215	228
Platte River at Louisville				
Mar. 31	9:30 a.m.	88,400	1,280	1,410
Apr. 1	11:35 a.m.	59,700	843	913
Apr. 4	10:00 a.m.	59,300	874	1,010
Big Blue River at Beatrice				
Apr. 1	11:50 a.m.	24,200	110	115

million tons; Big Blue River at Beatrice, March 29 to April 3, 1960, 650,000 tons.

The quantity of sediment transported by Platte River at Louisville during the period March 28 to April 8 would be sufficient to form a deposit about 10 feet thick over 1 square mile.

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