DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1903

BY

E. C. MURPHY

TRANSFER CASE

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WS 32. Water resources of Porto Rico, by H. M. Wilson. 1899. 48 pp., 17 pls. and maps.

WS 43. Conveyance of water in irrigation canals, flumes, and pipes, by Samuel Fortier. 1901. 86 pp., 15 pls.

WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.

WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.

WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.

WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.

WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. — pp.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Pt. II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Pt. III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.

WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.

WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.

WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.

WS 58. Storage of water on Kings River, California, by J. B. Lippincott. 1902. 100 pp., 32 pls.

WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.

WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.

WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.

WS 89. Water resources of Salinas Valley, California, by Homer Hamlin. 1904. 91 pp., 12 pls.

WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. — pp.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Pt. IV.

DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1903

BY

E. C. MURPHY

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., January 9, 1904.

SIR: I have the honor to transmit herewith a manuscript prepared by E. C. Murphy, entitled "Destructive Floods in the United States in 1903," and request that it be published as a water-supply paper.

This paper treats of three of the destructive floods that occurred in the United States in 1903.

Very respectfully,   F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
    Director United States Geological Survey.

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DESTRUCTIVE FLOODS IN THE UNITED STATES IN 1903.[a]

By E. C. MURPHY.

INTRODUCTION.

Experience has shown that in the area of the United States great variations from normal climatic conditions must be expected; the temperature, or the wind velocity, or the precipitation, or all three combined, may vary from the normal by a considerable amount at any place and in any season of the year.

The year 1903 will long be remembered for its extreme local variations from normal climatic conditions. A cloud-burst at Heppner, Oreg., on June 14, caused the loss of 200 lives and a quarter of a million dollars' worth of property; a tornado and an excessive rainfall at Gainesville, Ga., caused a loss of 100 lives and of property valued at half a million dollars; the excessive rainfall of June 6 in South Carolina devastated Pacolet, Clifton, and Glendale, causing the loss of many lives and of property valued at $3,000,000, and tornadoes and excessive rainfall of the upper-central Mississippi Valley and lower Missouri Valley from May 16 to 30 resulted in the destruction of much property.

Nearly coincident in time with these extremes was the other extreme of small precipitation, with cold, backward spring, retarded growth of vegetation, forest fires, and very small flow of streams in New York and the New England States.

THE HEPPNER, OREG., FLOOD.

The flood of Willow Creek, Morrow County, Oreg., commonly spoken of as the "Heppner disaster," occurred on Sunday evening, June 14. It was due to one of those very heavy storms of short duration covering a very small area, so peculiar to the arid region, and popularly called a "cloud-burst." Such a storm is almost like the tornado in its suddenness, destructibility, and limited extent. The duration of this storm was only half an hour, and the resulting flood lasted

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less than one hour, yet in that short time one-third of the town of
Heppner was entirely swept away, one-quarter of a million dollars'
worth of property destroyed, and over 200 persons, from a total popu-
lation of 1,400, were drowned.

Character of stream and country.—Willow Creek rises in the south-
eastern part of Morrow County in the west spur of the Blue Moun-
tains, and flows northwest into Columbia River. The distance in a
straight line from its source to its mouth is about 100 miles. Its
three principal tributaries are Balm Creek, which enters a short dis-
tance above Heppner; Hinton Creek, which enters a short distance
below Heppner; and Wilson Creek, the mouth of which is about 25
miles below Heppner. At its mouth Willow Creek has an elevation
of about 220 feet, and at Heppner, 45 miles by rail above its mouth,
it is 1,920 feet above sea level. The mean slope is, therefore, 37.8
feet per mile. The channel at Heppner has a width of 30 to 40 feet,
and the banks are from 10 to 15 feet in height. The valley is a fer-
tile strip of cultivated land, 500 to 1,500 feet in width. Back from
the valley the country on both sides has barren rocky soil, with steep
slopes, and the precipitation passes off very rapidly.

Sources of information.—Unfortunately there were no measure-
ments of rainfall and gage heights in the watershed of Willow Creek,
and the extent of the storm and the volume of run-off can not be
determined. All the data on which are based the estimates of run-off,
duration of storm, and height and duration of flood were obtained
from persons who saw the flood at various points along Willow Creek.

On the fourth day after the flood Mr. John T. Whistler, engineer
of the United States Geological Survey, visited Heppner and made a
thorough study of the situation. From his description, published in
Engineering News of July 16, and from additional facts obtained from
personal conversation with him, this report has been prepared.

The storm.—The storm came on suddenly between 4 and 5 p. m.,
and had entirely passed away in less than half an hour. Authentic
accounts agree that it started in the foothills of the Blue Mountains,
on Balm Creek, about 8 or 10 miles north of Heppner, and moved
north, down Balm Creek, to some distance beyond Willow Creek. It
is estimated that the storm area was from 2 to 4 miles in width and
from 8 to 10 miles in length and affected an area of perhaps 20 square
miles.

The storm was accompanied by a very heavy fall of hail, the depth
of which can not definitely be ascertained, but an idea of its amount
can be formed from the fact that five days after the storm some bodies
were found in drifts of hail in a nearly perfect state of preservation.
Some of the hailstones are said to have measured $1\frac{1}{4}$ inches in diam-
eter. Five days after the storm some that measured five-eighths of
an inch by seven-sixteenths of an inch were removed from a house
buried under silt and brush. Nearly all of this hail was of clear ice;

unlike the usual hailstones, which are more or less opaque and built up from a nucleus by successive layers.

The flood.—The height of the flood may easily be determined from the high-water marks, though these are often deceiving to the unpracticed eye, as marks are frequently found in places where the water did not reach. Bark is knocked off trees by floating bodies that project a considerable distance out of the water; small trees are often bent over and light drift deposited on them, and when the water pressure is removed and the tree straightens up this material is lifted high above the water level. But the rings of silt left on trees, all at approximately the same level, show the true water line. These watermarks show that the flood plane at Heppner was about 5 feet above the general road level and had a width of about 500 feet. The maximum depth of the flood at the center of the creek was from 15 to 20 feet.

The crest of the flood wave is said to have been almost simultaneous with the first water as far down the creek as Lexington; so that if a person had been standing on a structure 40 feet in height above the center of the creek bed at Heppner he would have seen flowing down the creek a bank of water 20 to 25 feet in height and having a face slope of about 30° with the horizontal. The force of a bank of water of this height moving down a slope of 38 feet to the mile, sweeping everything before it, can readily be imagined. At Ione, 8 miles below Lexington, the crest of flood was one-half hour behind first water, and at Cecils, 14 miles above the mouth, it was several hours behind.

At Heppner the creek is said to have returned to its normal flow in one and one-half hours after the passage of the crest of the flood. The crest is said to have reached the mouth of the creek about twenty hours after passing Heppner, the speed of crest thus averaging from 5 to 6 miles an hour.

The discharge on Balm Creek near its mouth was computed from the formula:

$$v = C\sqrt{s\,r}$$

s being the slope, r the hydraulic depth, C a coefficient, and v the mean velocity.

Two sections 2,200 feet apart gave a slope of 0.025; area, 1,700 square feet; wet perimeter, 260 feet. With these data and the value of 0.040 for the coefficient of roughness, the maximum discharge is found to be 36,000 second-feet. As the flood lasted less than one hour, the total flood volume was probably not more than the maximum flow for one-third of an hour. On this assumption the total volume of the flood at this point amounted to about 1,000 acre-feet.

The discharge of Willow Creek at Heppner and at Lexington has been computed. In these computations the mean velocity was assumed to be 6 miles per hour at Heppner and 4 miles per hour at Lexington. The total volume of flow was also assumed to be the maximum flow

for one-third of the time. The total flood volume at Heppner was found to be 1,100 acre-feet, and at Lexington 800 acre-feet.

The increased discharge at Heppner over that in Balm Creek was due principally to the water which enters Willow Creek below the mouth of Balm Creek, but partly to a small amount from shore. The flood volume near the mouth of Willow Creek was also computed and found to be 750 acre-feet.

It is very likely that the storm area was at least 20 square miles. Assuming that two-thirds of the rainfall reached Heppner, the total precipitation was approximately 1,600 acre-feet, which amounts to $1\frac{1}{2}$ inches in depth over this area, a rate of rainfall of about 3 inches per hour.

The flood water was very heavily laden with silt and in color is said to have resembled molasses.

Effect of the flood.—As a result of the flood one-third of the town of Heppner was entirely destroyed, and about 200 lives were lost. It seems almost incredible that a flood of a depth of only 5 feet above the general road level of the town should cause such a loss of life. The explanation lies in the peculiar construction of the houses. Nearly all of the houses simply rested on posts or open foundations of stone. The water freely passed underneath, but could not so rapidly get to the inside of the houses, so they were lifted off their foundations and floated away like boats. The rapid velocity soon drove them against trees or other objects and crushed them to pieces. In such a swift current and among such masses of timber it was almost impossible for a person to get ashore.

The duration of the flood was so short that the only considerable scouring effect observed was at the mouth of Balm Creek, where the flood crossed Willow Creek and struck the opposite shore. At this point a new channel was formed.

In 1888 a similar flood, possibly a larger one, came down Hinton Creek, but did little damage, as there were only a few houses there at that time. In 1883 there was a large flood in Willow Creek, but reliable records are not available for the comparison of these floods with the one of 1903.

Lessons taught by the flood.—Storms of great violence, short duration, and affecting comparatively small areas are to be expected occasionally in all parts of the arid and semiarid region, as the bare, steep, nonabsorbent surface causes the resulting floods to be large, sudden, and very destructive. All streams should have an ample waterway under bridges and through towns, and all buildings should be out of reach of the flood. No building that can be lifted from its foundation and swept away should be allowed in the area of a possible flood. Buildings in the line of a flood, such as mills, warehouses, pumping stations, etc., should be protected from drift during high water.

THE SOUTH CAROLINA FLOOD.[a]

A destructive flood occurred in Spartanburg County, S. C., on June 6, 1903. Considering the small area affected by the storm, the precipitation was very large and the loss of life and property great.

Character of country and streams.—In the twenty-four hours of the storm there was a rainfall of from 3½ to 5 inches in the counties of Cherokee, Spartanburg, Greenville, and the eastern half of Pickens, in South Carolina; and in the southern part of Rutherford, Polk, and Henderson counties, in North Carolina—a total area of 2,300 to 2,500 square miles. This region is situated on the southern slope of the Saluda Mountains. It does not extend up into the mountains, but includes the foothills and rolling country. About half of it is covered with timber; the remainder is cultivated and pasture land. The surface slopes are such that the water runs off rapidly and there is very little storage.

The streams that drain this area are Pacolet, North, South, and Middle Tiger, and Enoree rivers. These are tributaries of Broad River and enter it from the west. The upper tributaries of Saluda River, which flow to the west, rose to an unusual height, but little damage was done on them. Practically all the damage was confined to Spartanburg County, S. C.

The streams mentioned rise within a comparatively short distance of each other. North Fork of the Pacolet heads in Polk County, N. C.; all the others head in Greenville County, S. C. They are characterized by deep, narrow channels, with rapid fall. The Pacolet is said to have a fall of 500 feet from its head to Pacolet mills, a distance of 35 miles. There are no ponds or wide bottom lands to hold back the water in time of flood. The ground was soaked almost to saturation just previous to the flood, so that there was very little ground storage.

The storm.—During the week preceding this flood there was rain over this area almost daily; not hard rains, but gentle, penetrating showers, that nearly saturated the soil. On Friday, June 5, 1903, rains fell almost incessantly. In the evening the rain became more violent and continued until 4 a. m. without interruption.

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[a] Prepared from report of B. S. Drane, assistant hydrographer.

The precipitation for the first six days of June, as reported to the United States Weather Bureau, is given in the following table:

Daily rainfall reported from Weather Bureau stations in and surrounding area of South Carolina flood for the first six days in June, 1903.

Station.	June 1.	June 2.	June 3.	June 4.	June 5.	June 6.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Waynesville, N. C_____	0.30	_____	0.10	0.40	0.80	0.08
Asheville, N. C_____	.59	0.10	_____	.06	.99	.62
Morganton, N. C_____	.62	.86	.14	1.50	_____	1.13
Statesville, N. C_____	.35	.54	_____	_____	.70	1.25
Hendersonville, N. C_____	.61	.74	.40	_____	1.22	1.50
Brevard, N. C_____	1.60	.40	_____	.30	2.00	2.10
Highlands, N. C_____	1.10	1.57	_____	1.28	3.20	1.21
Henrietta, N. C_____	.19	1.44	_____	Trace.	1.51	4.85
Charlotte, N. C_____	Trace.	.51	.07	.10	.59	1.51
Liberty, S. C_____	1.20	Trace.	_____	.25	.55	2.03
Spartanburg, S. C_____	Trace.	.90	.07	_____	.35	5.05
Greenville, S. C_____	.27	.80	.08	_____	1.15	3.82
Gaffney, S. C_____	_____	.10	.82	.09	.94	3.64
Santuc, S. C_____	_____	1.15	_____	.73	.87	.90
Rock Hill, S. C_____	.04	1.17	.02	.33	1.15	1.99
Columbia, S. C_____	.82	2.30	.12	.41	.22	2.33
Heath Springs, S. C_____	.80	1.10	.01	1.50	.60	1.44
Barksdale, S. C_____	1.80	.60	_____	_____	2.75	1.23

Fig. 1 shows the location of some of these stations and the depth of rainfall reported at each on the morning of June 6, 1903. It is seen that the greatest precipitation in the twenty-four hours was at Spartanburg, diminishing in amount in every direction from that place, rapidly to the northwest and southeast and gradually to the northeast and southwest.

The precipitation northwest of Spartanburg was considerably greater than 5 inches. The washouts, landslides, and gullies cut by the flowing water indicate that the precipitation over the rain area was probably from 7 to 11 inches in the twenty-four hours preceding the morning of June 6, 1903. This region is included in an area that Prof. A. J. Henry, of the United States Weather Bureau, states is second in precipitation in the United States. The people who live in that region are accustomed to very heavy rains, and their estimates confirm the figures given above of the precipitation.

A. VIEW OF DAMAGED PORTION OF PACOLET MILL, NO. 3.

B. VIEW OF WRECKAGE OF PACOLET MILLS, NOS. 2 AND 3.

The flood.—There are no gaging stations on the streams on which the damage was done by this flood.   For about seven years the United States Geological Survey has maintained gaging stations on Broad
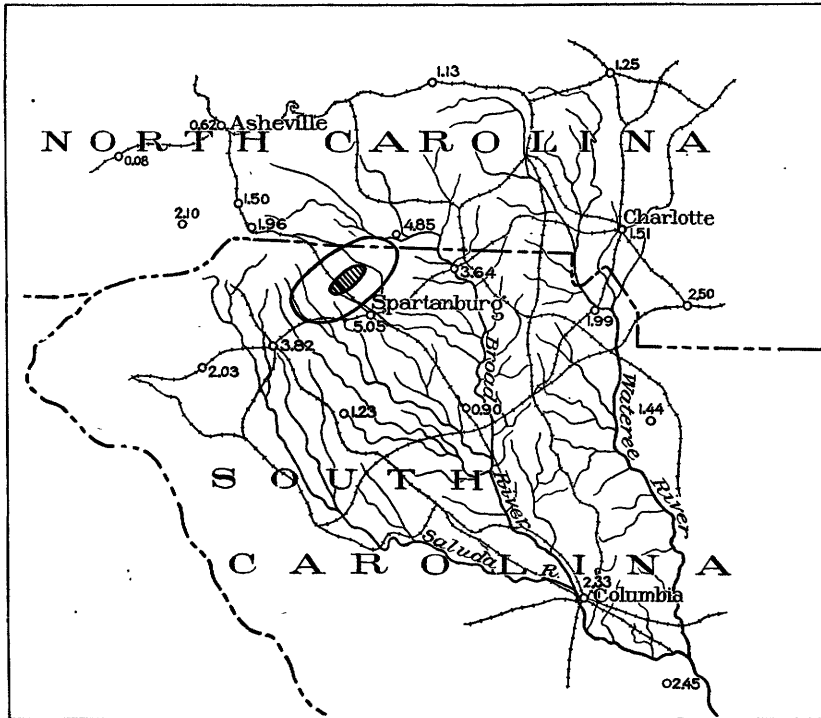
FIG. 1.—Map showing distribution of Weather Bureau stations, etc.

River at Alston, about 75 miles below Pacolet, and on the Saluda near Waterloo.   The mean daily gage heights at each of these places from June 1 to 10 are given in the following table:

Mean daily gage heights, in feet, June 1 to 10, 1903.

Place.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Broad River at Alston, S. C	5.60	7.55	8.70	6.65	7.30	13.60	27.20	26.70	17.30	9.90
Saluda River at Waterloo, S. C.	9.85	10.40	8.40	7.75	12.15	14	19.25	22.35	14.45	10.30

The highest water previous to this flood at these stations during these seven years was in 1901.   At Alston, S. C., the maximum on June 7, 1903, was 29 feet, which is $5\frac{1}{2}$ feet higher than in 1901.   At Waterloo the maximum was 23.15 feet, which is $2\frac{1}{4}$ feet higher than in 1901.

These figures, while they convey some idea of the magnitude of this flood, are not definite, because these stations are far below where the

storm occurred and where the damage was done. Had there been a gaging station on Pacolet River near its mouth it would have shown a much greater difference between the flood readings of 1901 and 1903 than do the figures at the Alston station.

A few flood marks of the flood of 1852 still remain at points on these streams. At Fingerville the new mark is 3.7 feet higher than the old one. At Whitneys mill, on Lawsons Fork near Spartanburg, the new mark is 9.9 feet higher than the old one. On the main Pacolet and Middle Tiger rivers the new marks are about 10 feet higher than the old ones. On Enoree River the new mark is $1\frac{1}{2}$ feet lower than the one of 1852.

For computing the discharge a section was taken above the dam at Pacolet. The pond at this point is shallow and the section rather narrow, and it is therefore believed that the current was fairly uniform. On the right bank the high-water mark was found in a garden, and is undoubtedly reliable. This gives a difference in elevation between high and low water of 24.4 feet and a flood section of 6,150 square feet. At gaging stations during floods, when the section was similar and the slope similar or not so great, the mean velocity has been observed to be as much as 5.78 feet per second. Assuming this velocity and using the area of section given above, the discharge at this place is 35,547 second-feet. The drainage area of the Pacolet at this place is about 400 square miles. The estimated discharge is equivalent to a run-off of 88.9 second-feet per square mile.

The flood of Catawba River of May, 1901, which caused great destruction of farming land, had an estimated run-off per square mile of 51.8 second-feet at the Catawba, N. C., station, and of 44.4 second-feet at the Rockhill, S. C., station. The estimated run-off at Pacolet during the 1903 flood is seen to exceed that of 1901 at the Catawba by 70 per cent and at Rockhill by 100 per cent. It is possible, however, that the estimated run-off at Pacolet is too great. The method of obtaining the mean velocity was not very reliable.

Destruction wrought by the flood.—There was some destruction of property on Tiger River, but the largest amount was on Pacolet River, at Clifton mills and Pacolet mills. The destruction of the Clifton mills is thus described in the report of Mr. B. S. Drane:

Clifton mill No. 3, known as " Converse mill," stood just above the bridge over which the main line of the Southern Railway crosses Pacolet River. It was built in 1890 and 1895, and as completed was a four-story mill 496 feet long and 100 feet wide. It was valued at $1,000,000 and contained 50,100 spindles.

The river was noticed to be about 8 feet above low water at midnight, but did not appear to be rising, and caused no anxiety. At 3.30 a. m. Mr. Kirby, master machinist of the mill, upon going down, saw that the water was beginning to rise into the wheelhouse. Getting assistance, he began to remove belts and ropes, but before any headway had been made the water forced him to leave. By 4.30 the rise was beginning to be rapid, and in a few minutes the water was flowing over the right end of the dam and breaking on the boiler houses and shops. These were wrecked before 5 o'clock. A little after 5 the brick stack, 137 feet high, was washed down with the part of the dam immediately behind it; it fell

A. PACOLET BEFORE THE FLOOD OF 1903.

B. PACOLET DURING THE FLOOD OF 1903.

on the corner of the mill. The mill began to wash down immediately, and the wreck was practically complete by 6 o'clock. The mill was washed entirely away, except for the three-story picker room. Shops, boiler houses, wheelhouse, and 16 cottages were also carried away.

The dam here had a section of 27 feet height, 27 feet base, and 11 feet crest. The construction was said to have been hasty and of materials much inferior to those usual on this river. The crest was broken off irregularly to a depth averaging 10 feet for 100 feet from the right bank, and to a depth of 7 feet for the next 40 feet. One footbridge and one county bridge, of wood, were carried away from just below the mill.

About 1½ miles below was the original Clifton mill, known as "No. 1." It was built in 1880, and had 27,500 spindles. At this point the rise was not alarming at 2 o'clock a. m. The rapid rise began at some time between half past 4 and 5. Just after 5 the water rose 2 feet in ten minutes, according to the assistant superintendent. The first thing to be carried away was a large hall. This floated off at about 5.45 and was hurled down into the upper corner of the mill, which stood out into the stream. The blow broke in part of the corner of the mill, but the destruction of the mill did not begin until the wreckage from above began to come down thickly, a little after 6 o'clock. Large timbers were then dashed into the projecting corner and the mill began to settle down gradually, little by little, beginning at this end. Altogether about 110 feet of the main building and the wheelhouse were totally wrecked. The machinery on the two lower floors was severely damaged throughout the length of the mill by the water, mud, and drift. The dam was uninjured, except for the tearing off of the wooden apron. Fifteen cottages were carried away from this mill village. About 8 o'clock the water began very slowly to fall.

Clifton mill No. 2, known as "Dexter mill," was a little over a mile from Clifton, was built in 1888, and had 30,500 spindles.

This mill stood on a point on the left bank. Just opposite the mill the right bank is steep and high, while on the left bank a ridge extends out on the point almost to the mill. Above the mill, on either side of the river, the hills open out, and there the greater part of the mill village stood. Also on the point on the left bank below the mill were many cottages.

The rise here began to alarm the watchman at 3 a. m., and at 3.30 it began to be rapid. One of the watchmen noticed that the rise was 1 foot in five minutes at about 4 o'clock. The alarm was sent out among the operatives at once. Most of them refused to realize that they were in any danger and would not make any effort to save themselves and their property until the water surrounded them. There were many narrow escapes, but at least 52 persons were lost here, most of them women and children. There was a deep deposit of sand and silt over the point below the mill where most of the lives were lost. Toward the end of the week following the disaster this began to crack as it dried. Searching parties kept watch of these cracks, and wherever flies were seen to crawl down them they dug. Several human bodies were found in this way.

At about twenty minutes past 4 the covered wooden highway bridge was washed down. The cotton warehouses and some of the cottages began to go about 6 o'clock, but the mill stood until 7. At that time the wreckage was coming down thickly from the upper mills. Exactly as at the Clifton mill above, the outer upstream corner was torn down. This mill was L-shaped, a wing extending shoreward from the lower end. When the mill was surrounded by the flood the heavy wreckage from above was hurled into this extension, tearing down the middle of it and practically filling the whole with driftwood. The machinery throughout the two lower floors of this mill was largely destroyed by the sand and drift thrown into it. All the cotton and cloth warehouses here were washed

away; 42 of the company's cottages and 6 belonging to outsiders were wrecked and carried away.

After bending to the left about the point on which the mill stands the river formerly bent to the right again around a low point on the right bank. During this flood the water overflowed this low point and cut a new channel over it, abandoning the old one. The crescent-shaped island left is about 400 yards long and 100 wide.

Several lines of the Southern Railway were tied up for about a week. The main line from Charlotte, N. C., to Atlanta, Ga., passing through Spartanburg, was broken by the washing away of a bridge over Lawsons Fork of Pacolet River. The Charleston and Western Carolina Railway, also entering Spartanburg, lost its bridge over Tiger River.

What purports to be a very conservative estimate of the financial loss due to the freshet is given as follows:

Estimate of losses caused by South Carolina flood.

Clifton mills, Nos. 1, 2, and 3	$1,750,000
Pacolet mills, Nos. 1, 2, and 3	1,250,000
Glendale mills	30,000
Mary Louise mills	18,000
Whitney mills	5,000
Fingerville mills	8,000
Tucapau mills	10,000
Tiger mills	8,000
Two other mills	20,000
Bridges	15,000
Spartanburg Electric Railway Company	30,000
Southern Railway Company	300,000
Not included above (lands and crops ruined, etc.), at least	6,000
Total	3,450,000

These figures do not include the loss due to the interruption of railway traffic, the stoppage of large industries throwing thousands of operatives out of employment, the loss to the various trades and commercial enterprises, and, worst of all, the loss of over 50 lives.

Lessons taught by the flood.—Very heavy storms, covering small or large areas, are to be expected on the southern and eastern slopes of the Appalachian Mountains. Floods much greater and more destructive than ordinary result from these storms.

Ample unobstructed waterway must be provided for streams through towns. Usually the greater part of the destruction wrought is due to the failure of a temporary dam formed by drift in front of a bridge. Drift of all kinds collecting in front of a bridge forms a dam, raises the water several feet higher than it would have been without the obstruction, finally the pressure on the obstruction becomes so great that it is swept away, and the resulting wave destroys other bridges and buildings that otherwise would not have been injured. The washing out of a dam by the water cutting a channel around one end of it

A. CLIFTON BEFORE THE FLOOD OF 1903.

B. CLIFTON AFTER THE FLOOD OF 1903.

is often the cause of a great wave that sweeps away bridges and buildings below that otherwise would not have been injured.

Buildings that can be lifted from their foundations and swept away should not be allowed in the path of a possible flood.

Mills, power stations, and other buildings on the banks of streams should be protected from the destructive action of drift during high water.

NOTES ON EARLY FLOODS IN MISSISSIPPI VALLEY.

Data on the floods of the Mississippi River basin prior to 1798 are very meager. Since that date a record of the fluctuation of the surface has been kept at one or more points along the river. At Natchez a record was kept by Governor Winthrop Sargeant from 1798 to 1819, by Samuel Davis from 1819 to 1841, and by Professor Forshey from 1841 to 1848. From 1848 to 1851 a record was kept at Carrollton by Professor Forshey. From 1851 to 1860 a very comprehensive study of the lower basin was made by Humphrey and Abbott. From 1851 to the present time several gaging stations have been maintained by the United States engineers, and for several years the United States Weather Bureau has also measured surface fluctuations at several places in this basin. From the available data the following tables have been prepared.

The following table,[a] from the records of Dr. George Englemann, shows the date of each flood on the Mississippi River at St. Louis from 1785 to 1865 and the height of the highest water above a datum plane:

Statistics of floods at St. Louis, Mo., 1785 to 1865.

Date.	High water.	Date.	High water.
	Feet.		*Feet.*
April, 1785	42.0	May 20, 1852	28.0
March, 1828	33.6	May 7, 1853	30.0
May 8, 1833	27.0	May 9, 1856	27.4
May 28, 1838	27.4	June 14, 1858	37.0
May 2, 1843	27.2	May 15, 1861	25.3
June 27, 1844	41.0	April 26, 1862	31.3
June 27, 1845	32.4	May 4, 1863	18.0
May 10, 1846	25.0	May 14, 1864	24.3
March 10, 1849	27.4	July 28, 1865	26.7
June 10, 1851	27.0		

According to these records the highest water at St. Louis, Mo., was in April, 1785, when the gage read 1 foot higher than in 1844 and 4 feet higher than in June, 1903. Very little is known of the flood of

a Russell, T. Stages of Mississippi River and its principal tributaries. U. S. Weather Bureau, Washington, D. C., 1891.

1785.   The 1844 flood is well remembered by persons still living in this
section of the country. In 1858 high water at St. Louis came within
4 feet of that of 1844, and the flood of 1845 was within about 9 feet of
that of 1844.   The following table gives the dates of highest water on
the Mississippi at St. Louis, Mo., and on the Missouri at Kansas City,
Mo., for each year from 1872 to 1903; also the gage reading:

Statistics of floods at St. Louis, Mo., and Kansas City, Mo.

| Year. | St. Louis, Mo. | | Kansas City, Mo. | |
	Date.	Gage height.	Date.	Gage height.
		Feet.		*Feet.*
1872	June 12-14	23.7		
1873	April 11	26.7	July 5	19.3
1874	June 19-20	19.1	June 17-19	16.2
1875	August 3	30.5	April 30	17.8
1876	May 10	32.7	June 16	18.0
1877	June 14	27.3	June 10	22.2
1878	June 15	26.5	July 3	19.8
1879	July 3	21.9	June 30	19.2
1880	July 2	26.2	July 10-12	16.7
1881	May 6	34.3	April 30	26.3
1882	July 5	33.1	July 3	19.2
1883[a]	June 26	35.5	June 26	23.8
1884	April 9-10	28.8		
1885	June 17	27.8	June 19	19.1
1886	May 13	27.7	April 17	15.8
1887	April 3	21.4	July 3	18.9
1888	June 4	30.1	do	20.4
1889	June 1	25.3	August 14	13.9
1890	do	21.3	June 11	17.2
1891	July 4	24.4	July 1	23.1
1892	May 19	36.7	May 21	24.9
1893	May 3	32.3	April 13	17.7
1894	May 11	24.1	June 21	20.1
1895	July 8	17.8	June 12	16.9
1896	May 26-28	28.4	May 22	19.2
1897	May 2	31.7	April 20	22.6
1898	May 23	27.2	June 12	21.5
1899	April 27	25.6	July 9	22.2
1900	March 16	23.4	June 20	17.8
1901	April 18-19	22.4	June 24-25	19.4
1902	July 26	26.9	July 15	23.2
1903	June 10	38.0	June 1	35.0

[a] Record May 1 to June 16 and July 1 to December 31 missing.

It is seen that at no time during the fifty-nine years from 1844 to 1903 has the highest water been within 3 feet of the stage it reached on June 27, 1844. Seven times, however, it approached within about 8 feet of it. The records of the Kansas City station on Missouri River cover a period of thirty years; the flood of 1903 exceeded in height by about 9 feet that of any year during this period; only nine times in the thirty years was the highest water at this place within 15 feet of its height in 1903.

The years of greatest flood at St. Louis are usually years of greatest flood in the lower basin of Mississippi River, but this is not always the case. Very frequently the lower Mississippi is very high while at St. Louis the stage is considerably below that of the great flood. This is due to a large part of the discharge of the lower basin coming from Ohio and Arkansas rivers, which enter the Mississippi below St. Louis. The frequency of floods and their magnitude increases with the distance down the river. Floods are the exception at Kansas City; they are the rule below Memphis.

KANSAS FLOODS AND HYDROGRAPHIC DATA.

THE FLOOD OF 1903.

The Kansas flood of 1903 is, with the exception of the flood of 1844, the largest one on record in the upper-central Mississippi and lower Missouri river valleys. In loss of property and life the flood of 1903 was vastly more destructive than that of 1844, on account of the country now being much more thickly settled and improved. Although the loss of property in the aggregate is large—estimated at $22,000,000 in Kansas and Kansas City, Mo., alone—it is not large when one considers the great value of the property in the path of the flood. The loss of life is surprisingly small considering the population driven from their homes and the rapid approach and vastness of the flood. The following table (p. 22) gives flood data of Kansas River taken at Lawrence and Lecompton.

Flood data, Kansas River, 1881 to 1903.

Year.	Place.	Date.	Gage reading.	Discharge.
			Feet.	*Sec. ft.*
1881	Lawrence, Kans_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	Mar. 7	4.2	_ _ _ _ _ _ _ _
1882	_ _ _ _ _do _	Apr. 10	4.3	_ _ _ _ _ _ _ _ _
1883	_ _ _ _ _do _	June 25	4.3	_ _ _ _ _ _ _ _
1884	_ _ _ _ _do _	May 5	3.8	_ _ _ _ _ _ _ _
1885	_ _ _ _ _do _	Apr. 27	3.7	_ _ _ _ _ _ _ _
1886	_ _ _ _ _do _	May 10	4.3	19,370
1887	_ _ _ _ _do _	May 23	2.5	8,840
1888	_ _ _ _ _do _	June 25	3.5	14,290
1889	_ _ _ _ _do _	{May 13 / July 22}	5.0	24,340
1890	_ _ _ _ _do _	Jan. 13	2.8	10,370
1891	_ _ _ _ _do _	June 1	6.0	[a]35,598
1892	_ _ _ _ _do _	May 16	8.8	[a]67,718
1893	_ _ _ _ _do _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ .	{June 5 / July 3}	4.3	19,370
1894	_ _ _ _ _do _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	June 25	5.3	26,620
1895	_ _ _ _ _do _	{June 10 / Aug. 19}	4.0	17,390
1896	_ _ _ _ _do _	July 20	7.7	[a]53,308
1897	_ _ _ _ _do _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ . _	Apr. 26	8.8	[a]67,718
1898	_ _ _ _ _do _	June 10	5.6	28,990
1899	Lecompton, Kans _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	July 8	11.0	30,250
1900	_ _ _ _ _do _	Mar. 10	10.2	24,898
·1901	_ _ _ _ _do _	Apr. 14	10.0	25,000
1902	_ _ _ _ _do _	July 15	17.6	81,400
1903	_ _ _ _ _do _	May 31	29.5	233,070

[a] Computed from rating table for period May 15 to Aug. 31, 1896.

From this table it is seen that Kansas River at Lecompton was 12 feet higher during this flood than at any time during the twenty-two years covered by the record. The gage reading at this place ordinarily varies from 4 to 12 feet, but on May 31 it read $29\frac{1}{2}$ feet, or $17\frac{1}{2}$ feet higher than ordinary high water. The volume of water flowing in Kansas River on May 31 was nearly three times greater than at any other time during these twenty-two years.

THE STORM.

Duration, extent, and depth of rainfall.—The period of excessive rainfall dates from May 16 to 31; the temperature during this time was abnormally high, the pressure was low, and a strong wind was

blowing from the south, which developed tornadoes in parts of Iowa, Nebraska, and Kansas, killing 50 persons, injuring about 60 others, and destroying many thousands of dollars' worth of property. The daily rainfall during this period is shown in the following table, which is condensed from a table taken from the Monthly Weather Review for May, 1903:

Daily rainfall at Weather Bureau stations, May 16–31, 1903.

Station.	16.	17.	18.	19.	20.	21.	22.	23.	24.
Williston, N. Dak	0.16	0.08	0.34	T.	T.	0.94	1.49	0.12	0.02
Bismarck, N. Dak	_____	T.	.86	T.	_____	.47	1.06	_____	_____
Pierre, S. Dak	_____	.26	_____	_____	_____	.14	.62	_____	.19
Rapid, S. Dak	.02	.14	.30	0.16	_____	.14	.18	_____	T.
Huron, S. Dak	_____	_____	_____	T.	_____	.16	.50	.34	.24
Yankton, S. Dak	_____	_____	_____	.03	T.	.39	.76	.63	1.00
St. Paul, Minn	_____	T.	_____	.10	_____	_____	.01	.64	T.
Moorhead, Minn	_____	.04	.30	.60	_____	.24	.42	1.50	_____
Valentine, Nebr	_____	_____	_____	_____	_____	.26	.24	T.	.10
North Platte. Nebr	T.	_____	_____	_____	_____	.18	.02	_____	.02
Lincoln, Nebr	_____	.07	T.	.24	_____	.56	.79	.28	_____
Omaha, Nebr	_____	.16	_____	.04	.10	.64	.80	.01	_____
Concordia, Kans	.30	.14	.78	.04	_____	.18	1.10	.94	_____
Topeka, Kans	T.	_____	_____	.05	_____	.50	.04	.64	.35
Wichita, Kans	.01	_____	.98	.10	_____	2.24	.04	1.29	T.
Dodge, Kans	.14	.10	_____	_____	.10	.58	.06	_____	_____
Denver, Colo	T.	T.	.01	_____	_____	T.	T.	T.	_____
Pueblo, Colo	_____	_____	_____	_____	_____	_____	_____	_____	_____
Cheyenne, Wyo	.10	.06	.10	_____	_____	T.	.01	_____	T.
Oklahoma, Okla	.58	T.	.01	T.	_____	.02	1.25	T.	4.06
Fort Worth, Tex	T.	.01	_____	_____	_____	T.	_____	T.	T.
Dubuque, Iowa	_____	.08	T.	T.	.01	.06	.50	.02	_____
Davenport, Iowa	_____	_____	T.	T.	_____	.48	.08	.20	.05
Des Moines, Iowa	_____	.30·	T.	·.04	.02	.06	1.38	.12	_____
Keokuk, Iowa	_____	T.	.06	T.	_____	.76	.04	.06	1.40
Sioux City, Iowa	_____	.02	.72	1.08	_____	_____	.88	.24	.02
Kansas City, Mo	_____	.02	_____	.06	T.	.70	.34	.74	.26
St. Louis, Mo	_____	_____	.16	.04	.40	.06	_____	_____	T.
Springfield, Mo	T.	.04	.02	.70	1.06	.35	_____	_____	.06
Hannibal, Mo	_____	T.	.17	.02	_____	.49	_____	.04	1.93
Fort Smith, Ark	T.	.03	T.	1.36	T.	_____	T.	_____	_____
Little Rock, Ark	T.	T.	T.	.54	T.	_____	_____	_____	_____

Daily rainfall at Weather Bureau stations, May 16–31, 1903.—Continued.

Station.	25.	26.	27.	28.	29.	30.	31.	Total.
Williston, N. Dak	_____	0.08	_____	0.60	0.04	_____	_____	3.87
Bismarck, N. Dak	_____	.20	_____	_____	_____	_____	0.50	3.09
Pierre, S. Dak	_____	.04	_____	_____	.46	T.	_____	1.71
Rapid, S. Dak	0.02	_____	_____	T.	.12	_____	.16	1.⸀4
Huron, S. Dak	.08	.24	0.01	_____	_____	_____	_____	1.57
Yankton, S. Dak	_____	.39	.39	.43	.40	0.10	.03	4.55
St. Paul, Minn	.62	1.04	.24	_____	_____	_____	_____	2.65
Moorhead, Minn	_____	_____	_____	_____	_____	_____	_____	3.10
Valentine, Nebr	.04	.50	_____	_____	.32	.02	_____	1.48
North Platte, Nebr	.08	.18	_____	.01	.43	.06	_____	.98
Linc ln, Nebr	1.37	1.03	.43	.15	1.94	1.13	.10	8.09
Omaha, Nebr	.95	.93	.56	T.	.52	.40	.10	5.21
Concordia, Kans	.16	.96	_____	1.64	3.68	.25	.42	10.59
Topeka, Kans	.22	.21	.28	.24	1.71·	.26	.91	5.41
Wichita, Kans	_____	.22	_____	.22	.82	.02	.26	6.17
Dodge, Kans	_____	.30	.26	.28	.03	.04	_____	1.89
Denver, Colo	.01	T.	_____	.01	.03	_____	.28	.34
Pueblo, Colo	_____	.06	_____	.22	T.	_____	_____	.28
Cheyenne, Wyo	_____	T.	_____	.12	T.	_____	_____	.39
Oklahoma, Okla	_____	T.	_____	.18	3.26	.02	T.	9.38
Fort Worth, Tex	_____	T.	_____	.68	.46	T.	_____	1.15
Dubuque, Iowa	.10	1.40	1.11	.02	T.	.34	.12	3.76
Davenport, Iowa	.08	.87	.42	.38	.32	2.02	.46	5.36
Des Moines, Iowa	.18	2.08	1.38	.06	.94	2.52	.30	9.38
Keokuk, Iowa	.52	_____	.06	_____	T.	T.	.38	3.28
Sioux City, Iowa	.01	.47	_____	_____	2.27	.42	.08	6.21
Kansas City, Mo	.22	T.	.76	.01	.23	.68	1.0 ﹔	5.10
St. Louis, Mo	.01	T.	.12	_____	.40	T.	.42	1.61
Springfield, Mo	_____	T.	T.	.20	.80	1.54	1.66	6.43
Hannibal, Mo	.06	T.	.04	_____	.28	.32	1.61	3.96
Fort Smith, Ark	_____	T.	.22	.02	1.96	.12	.44	4.15
Little Rock, Ark	_____	_____	T.	1.14	.68	.91	T.	3.27

In the northeast-central part of Kansas in the vicinity of Concordia, where the precipitation was greatest, it rained daily for fifteen days, a total of about 10 inches in depth.

Rainfall during storm and during May compared.—The rainfall for the first half of May was considered above the normal for this month; the streams were carrying more than their normal amount, as can be seen from the gage readings in the table on pages 35, 36, and the ground storage available was small. It was this lack of surface and
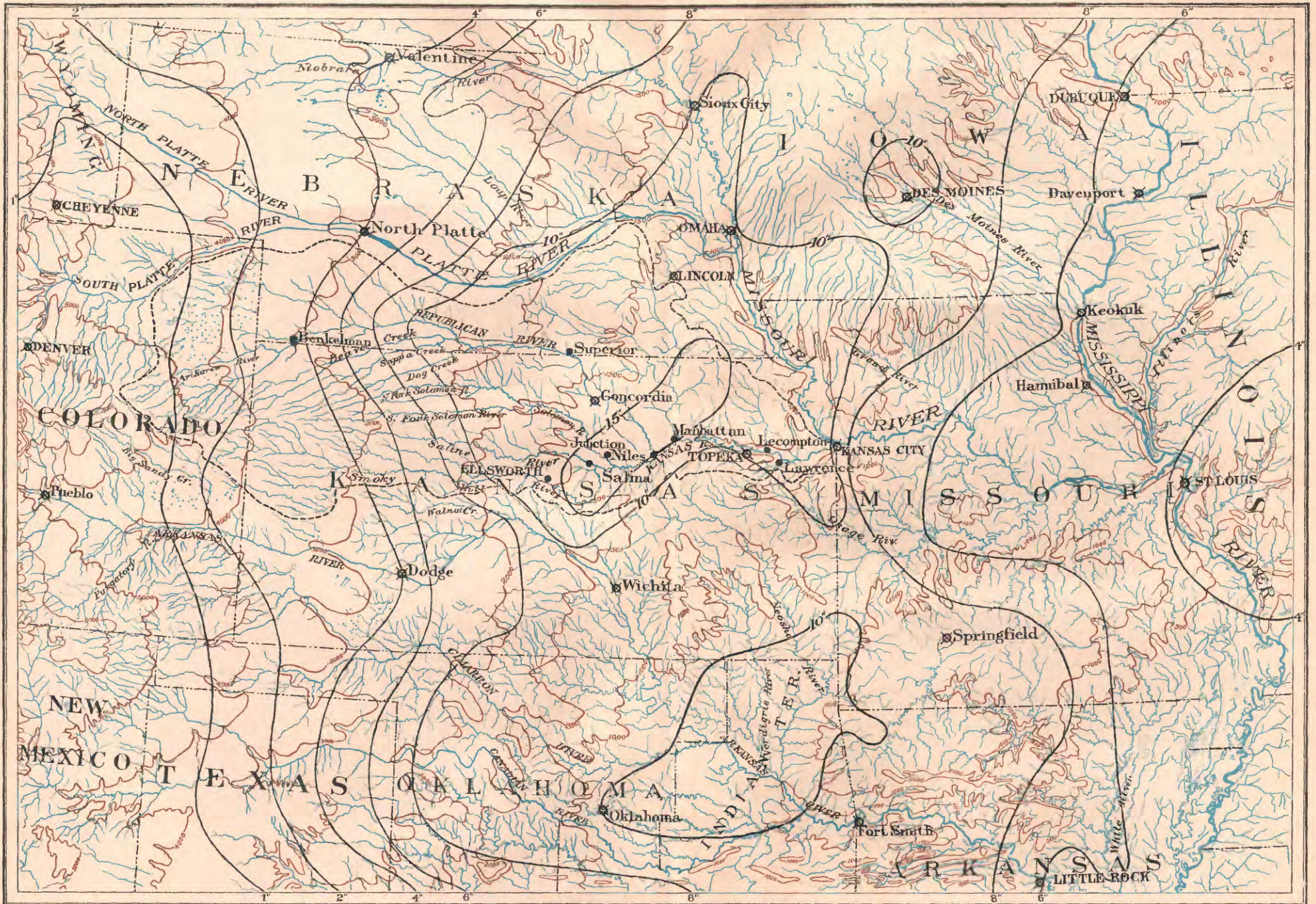
MAP OF KANSAS AND ADJOINING STATES
SHOWING THE WATERSHEDS OF THE KANSAS RIVER AND OTHER STREAMS AFFECTED BY THE KANSAS FLOOD OF 1903
ALSO LINES OF EQUAL RAINFALL FOR MAY, AND THE LOCATION OF U.S. GEOLOGICAL SURVEY GAGING STATIONS

GRAY LITH. CO. N.Y.

Scale

100   50   0   100   200 miles

Contour interval 500 feet.   Datum is mean sea level

ground storage at the beginning of the flood period that made the
flood of such exceptional magnitude.

The rainfall for May was over 17 inches at some stations. It was
17.34 inches at Salina, Kans.; 17.22 inches at Bradshaw, Nebr.; 15.45
inches at Thurman, Iowa; 17.29 inches at Blackburn, Okla. The
area having a depth of 8 to 17 inches of rainfall during May covers
the eastern two-thirds of Kansas, northern Indian Territory and
Oklahoma, western Arkansas and Missouri, eastern two-thirds of
Nebraska, western half of Iowa, and small parts of southern Wiscon-
sin and southeastern Minnesota. The storm was more nearly central
over Kansas River and tributary watersheds than over any other
watershed of this area, hence the Kansas River flood was greater than
that of any other stream. On the accompanying map (Pl. IV) are
shown the watersheds affected, the lines of equal rainfall for May,
and the location of the United States Geological Survey gaging sta-
tions.
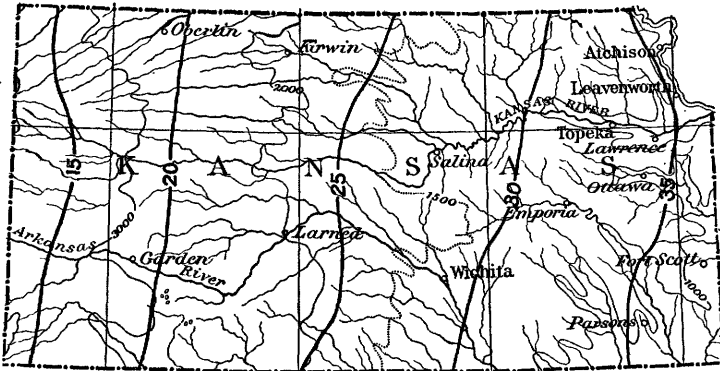
FIG. 2.—Mean annual rainfall lines over Kansas.

Curves of annual rainfall and rainfall during May compared.—
Fig. 2 shows the lines of mean annual rainfall over Kansas. This
mean annual rainfall is seen to decrease from about 35 inches in the
eastern part of the Kansas River watershed to about 12 inches in the
western part. More than half, therefore, of the ordinary mean annual
rainfall over the eastern half of the Kansas River watershed fell dur-
ing May, 1903, whereas, ordinarily, only about 14 per cent of this
falls during that month.

CHARACTER OF WATERSHED FLOODED.

Location, extent, and topography.—Kansas River and its tribu-
taries (Blue, Republican, Solomon, Saline, and Smoky Hill rivers),
along which the greatest amount of damage was done by this flood,
drain a long, comparatively narrow strip of country lying between
Platte River on the north and Arkansas River on the south, and
extending from Missouri River on the east to the foothills of the

Rocky Mountains in Colorado on the west.   The length from east to west is 485 miles, and the width varies from 140 to 190 miles; the total area drained is 61,440 square miles—9,459 square miles in Colorado, 17,455 square miles in Nebraska, and 34,526 square miles in Kansas. This country is rolling prairie, with little timber except narrow strips along the streams in the eastern half of the State; the soil is very productive, especially in the river bottoms, and is mostly under cultivation where the rainfall is sufficient to mature crops.   The eastern third of this area is covered with a tough buffalo-grass sod.   The altitude on Gannett's contour map of the United States varies from 750 feet at Kansas City to 5,000 feet in the western part in Colorado.   The 500-foot contour lines are shown in Pl. IV.   The surface is seen to rise at a gradually increasing rate from east to west; the valleys are wide and comparatively shallow, with very little opportunity for storage of water.

Description of Kansas River.—Kansas River differs greatly from both the Platte on the north and the Arkansas on the south, in that it is wholly within the plains area and has no mountain drainage; its entire water supply comes from rain falling on the plains within its drainage area.   The surface storage is very small, there being no lakes, ponds, or swamps to hold back the flow, and no mountains to hold back the winter precipitation.   The minimum flow is, therefore, very small and the flood flow very large.   The term "Kansas" is applied to this stream only after the Smoky Hill joins the Republican near Manhattan; the Solomon and the Saline are tributaries of the Smoky Hill.   The principal tributaries of the Kansas are the Blue and the Delaware on the north and the Wakarusa on the south.   The areas drained by these streams in the different States are given in the table below:

Drainage areas in Kansas River basin.

Basin.	Total area.	Area in Kansas.	Area in Nebraska.	Area in Colorado.
	Sq. miles.	*Sq. miles.*	*Sq. miles.*	*Sq. miles.*
Kansas River entire _____	61,440	34,526	17,455	9,459
Kansas River above Lawrence_____	59,841	33,927	17,455	9,459
Kansas River above Lecompton_____	58,550	31,636	17,455	9,459
Blue River above Manhattan _____	9,490	2,450	7,040	_____
Republican River entire _____	25,837	7,496	10,415	7,926
Republican River above Superior _____	22,347	_____	_____	_____
Smoky Hill River entire_____	20,428	18,895	_____	1,533
Smoky Hill River above Ellsworth_____	7,980	6,447	_____	_____
Saline River entire _____	3,311	3,311	_____	1,533
Solomon River entire_____	6,882	6,882	_____	_____
Solomon River above gaging station _____	6,815	_____	_____	_____
Kansas River (proper) above Lecompton_____	5,123	_____	_____	_____

Kansas River above Lawrence meanders through the bottom land, crossing and recrossing it, but as a rule being closer to the south border than to the north. This bottom land, which includes the land adjacent to the river and not more than 20 feet in elevation above it, is mainly alluvial matter and varies in width from 1 to 4 miles. The bed is mainly shifting, sandy, alluvial material, though in a few places it is rocky. The banks as a rule are not more than 10 feet in height except where the river runs near the bluffs, where they are from 30 to 40 feet high. They are easily eroded by the current, and frequently a new channel is formed and a considerable amount of land washed away.

THE FLOOD.

Reasons for magnitude of flood.—The unprecedented rainfall of 5 to 10 inches in sixteen days, falling on a watershed with practically no surface storage, and at a time when the flow of the streams was considerably above their normal and the ground well saturated with water, was sure to produce an enormous flood. The Kansas daily newspapers of the 24th to 27th report heavy rain and wind storms, with loss of life and property.

Flood in vicinity of Topeka.—On the 27th the Topeka Capital reports "200 homeless in Salina, Kans., from flood due to rain the previous night;" also several tornadoes in Kansas and Iowa, in which a number of persons were killed. The mean reading of the United States Geological Survey gage near Salina, on Saline River, for the 27th, was 32.6 feet, only about 1 foot less than the maximum during this flood. On the 28th the same paper reports the streams in Missouri, Iowa, Nebraska, and Oklahoma out of their banks. The mean daily gage reading at Lecompton for this date is 18 feet, about 1 foot higher than at any time during the previous twenty-two years. On May 29 the same paper reported "the worst flood situation that has ever confronted Kansas for many years; bridges and tracks under water; many families driven from their homes; thousands of acres of corn ruined, and greater floods expected on account of continued heavy rain." The mean daily gage reading at Lecompton for this date was 21.1 feet, which is $3\frac{1}{2}$ feet higher than the highest in the twenty-two years' record. On the 30th the same paper reports "practically all of North Topeka submerged; 4,000 North Topeka persons driven from their homes, and 1,500 houses partly submerged." The mean daily gage height at Lecompton for this date is 24 feet, which is 6.4 feet higher than the highest reading in the twenty-two years' record. On Sunday, May 31, the flood in Kansas River reached its maximum height. The mean reading of the Lecompton gage for this date was 28.75 feet and the maximum 29.50, which is about 12 feet higher than the highest gage reading at this place in twenty-two years. The Topeka Capital of this date states that over the highest part of North Topeka the river was flowing 5 feet deep. The water had reached the eaves of many houses supposed to be above high water.

Flood in the vicinity of Kansas City.—Missouri River at Kansas City reached danger line—21 feet gage height—on the 27th of May. On the morning of the 31st it reached 27½ feet, and on June 1 it reached its highest point—35 feet—which is 14 feet above danger line and only 2 feet below the highest point reached by the great flood of June 20, 1844.

The Kansas City Times of June 1 described the condition in Kansas City as follows:

Kansas City passed yesterday the most disastrous day in its history; and to-day an emergency confronts its people greater than they have ever known before; problems, too, that affect the welfare of all of the city are to be met, and they must be met promptly. All Saturday night and all yesterday the torrents swept down the Missouri and Kansas until the valleys of the Kansas and Missouri were a solid mass of raging water from bluff to bluff. On the Union Depot platform there were 6 feet in depth of water, and all over the west bottoms, the center of the heavy wholesale and manufacturing business of the city, there was an equal or greater depth. Several lives it is known have been lost, and many more it is feared have perished. Hundreds were rescued from impending death, but late last night people standing on the west bluff could hear the agonizing cries for help from men and women in houses out on the wide expanse of water, but what the loss of life has been can not be accurately known until the water recedes. Early yesterday frame and other unstable structures in Argentine and Armourdale, that had been partly submerged for several days, began to leave their foundations and float away, thus a great mass of wreckage collected; it swept down on the bridges that spanned the Kansas. First the Kansas City Belt Line bridge above the stock yards went out, later the bridges at the stock yards and the Union Pacific Railroad bridge. The mass of wreckage grew. Soon it was joined by the great oil tank that had floated down from the Armourdale oil plant, which surged against the double-deck Central Avenue bridge, which carried the electric railway across to Kansas City, and the bridge went down as if made of paper. Five more bridges between this point and the mouth of the Kansas were swept away, and worst of all the bridge which carried the flow line of the Kansas City waterworks went down, carrying with it the 36-inch pipe which furnishes 200,000 people with their water supply.

In the Kansas City Times of June 10 is the following statement of the Executive Relief Committee of Kansas City, Kans:

Two entire wards and parts of two others, comprising, by the official census of March, 1903, at least 23,000 out of the population of 60,000 in the whole city, are made homeless and destitute. Hundreds of their houses have been swept away, and those that remain have been under 10 to 20 feet of water, and left with a deposit of silt both inside and out from 1 to 3 feet in depth. In most instances persons were able to save only the clothing they wore. Their household goods and clothing have been swept away or destroyed by the water and mud.

Flood in vicinity of Lawrence.—Some idea of the magnitude of the flood and its effect in the vicinity of Lawrence, Kans., can be gathered from the following notes taken from the Lawrence Daily Journal:

At 3 a. m., May 29, the pumping plant which supplies the city with water was compelled to shut down on account of the very high water, and it could not resume pumping again until June 6. At 8 a. m. the electric-light plant was

compelled to shut down. At noon the water broke through the Union Pacific embankment, flooding North Lawrence. The Santa Fe trains could not pass Lake View, 4 miles west of Lawrence, on the main line.

At 9 a. m., May 30, Congressman Bowersock's flouring mill was swept off from its foundation, and in a few minutes not a vestige of it was left. The flume also was destroyed, but the dam was practically uninjured.

Six hundred feet of the Eudora highway bridge was swept away this morning. * * * The water is running over the Lecompton highway bridge, and the floor is being taken up to save the structure being swept away. * * * During the day 50 buildings were counted as they passed over the dam.

June 1: The scene in North Lawrence is one of destruction and desolation. There is probably not a building standing on its foundation west of Bridge street, save the few structures north of the Usher block, and there is hardly a habitation of any kind for man or beast in that part of the city. The part north of the Union Pacific depot has also been swept, and numerous houses there have been carried from their foundations down the streets. The Griffin ice houses and their contents, the transfer barns and their equipment, including several head of horses, the Union Pacific freight depot, and many of the larger frame stores were carried down by the stream, while the foundations of brick and stone structures softened, and the crumbling ruins are all that is left to tell the story of their existence.

There was very little furniture or personal property saved. No opportunity was afforded to get live stock on higher ground. * * * At 5.30 Sunday evening the north span of the Lawrence highway bridge was swept from its piers by the house of Mr. William Parsons striking it as it was being swept away by the raging torrent. This house had only been deserted by Mr. Parsons and his family on Friday, and contained all of its furniture. If it had not been for the forethought of the authorities in uncoupling this bridge span from the others in anticipation of such an accident, the damage to the bridge might have been much greater.

Flood in vicinity of St. Louis.—At St. Louis the highest stage of the river was 38 feet, or half a foot higher than the flood of 1858 and 3.4 feet below the flood stage of 1844.

The Journal of Agriculture for June contains the following:

The great flood of 1844, although it reached a higher point, did comparatively little damage, as the localities covered by it were almost uninhabited at that time. Kansas City, with its great railroad and packing industries, was not even dreamed of and was bare prairie land. East St. Louis, which is now a big city engulfed in the flood, had no existence, but was simply an entrance to St. Louis. * * * So the former floods, however high their waters, could inflict but small loss compared with that now deluging so many thousand miles of fertile country and cities teeming with large population. The money loss involved is simply enormous, but the most lamentable feature is the loss of life. * * * The damage inflicted by these periodic inundations seems to be irremediable. The ingenuity of man has not yet been able to suggest any plan by which the excessive rainfall which causes floods can be subjected to control. To anyone who saw the mighty Missouri at its highest flood near the junction with the Mississippi the bare idea of storage reservoirs and dams is absurd. Its volume is so vast that probably no valley in our country could contain it, even if it were at all possible to restrain it by dams and barriers. The Missouri River defies restraint, and all that can possibly be done to mitigate its ravages when on the rampage is to be prepared for it generally and by building railroads and dwellings in future higher than its recorded heights.

DESTRUCTION WROUGHT BY THE FLOOD.

The destruction wrought by the flood may be treated under three headings: First, drowning and wetting by the water; second, pressure and transportation by the water; third, scouring by the water.

By drowning and wetting.—It is seen from table on page 22 that for eleven successive days (May 28 to June 7) Kansas River was higher than it had been in the previous twenty-two years covered by the record. The height of the water above previous high-water mark was 6½ feet for six consecutive days, 8.7 feet for four consecutive days, and 9.6 feet for two days. When it is remembered that the slope of the country at right angles to the river is very gentle, it will readily be seen why a very large part of this river bottom was submerged for several days. Over a considerable part of the area the velocity was such as to cause much damage by its scour; over the remainder of it the damage was due mainly to the drowning or soaking action. Farmers report the loss of much stock, and at the packing houses in Kansas City a large number were lost. All crops covered by the water were a total loss; young orchards surrounded by water were ruined; many thousand barrels of corn stored in cribs, and household furniture and clothing were destroyed. Several business houses in North Topeka and Kansas City suffered heavily, as goods in basements and first stories of buildings were soaked with the muddy water for several days. The very high water flooded pumping plants, electric-light stations, gas plants, and small power plants, leaving cities without water for drinking purposes and without light, and depriving manufacturing industries of power.

By pressure and transportation.—Much property was destroyed by the transporting power of the water. Many wooden buildings in Lawrence, Topeka, and Kansas City were taken from their foundations and swept bodily down with the current or dashed to pieces against trees or other buildings. Some buildings not thus entirely lost were moved some distance from their foundations and badly damaged; several feet of sand was piled around some of them, while large holes were scoured around others. Some brick buildings were undermined and left uninhabitable. A large quantity of this floating material was swept down the river and collected against bridges, which were subjected to tremendous strain, as they acted as dams. Many of the railroad companies, anticipating the flood, had loaded their bridges with engines and flat cars. The water passed over the tops of these cars and the drift formed a dam against them. Of the 16 bridges spanning Kansas River from Armourdale to its mouth, all except one, the Missouri Pacific Railway bridge (shown in Pl. V, *B*), were in part or wholly destroyed. The location of this bridge is shown on the map (Pl. VI, p. 32). Within two hours 16 bridges, within a distance of only 4 miles, were swept away. The Missouri

A. VIEW OF "FLOW-LINE" BRIDGE, REPAIRED WITH SUSPENSION SPAN.

B. VIEW OF MISSOURI PACIFIC RAILROAD BRIDGE AT KANSAS CITY AFTER
THE FLOOD.

Pacific bridge, which withstood the flood, is a very heavy, double-track bridge, and was loaded from end to end with locomotives. Some idea can be formed of the débris which came down the river from the amount which was lodged against the piers and abutments of this bridge. (See Pl. V, *B*.) The damaged bridges were nearly all steel structures of about 200 feet span, resting on masonry or metal piers. Several of them were double-track structures. The cost of replacing them is estimated to be from one and a quarter to one and a half million dollars. One of the bridges destroyed carried a 36-inch water-supply pipe for supplying Kansas City, Mo., and a part of Kansas City, Kans., with water. As a result of its failure, the whole city was without water for twelve days, and the electric-light company, gas company, and street railways were compelled to shut down for lack of water.

The highway bridge at Eudora was partly washed away. The highway bridge at Lawrence had one span washed away. The river at this point made a new channel around the north end of the bridge, washing away the Union Pacific freight station and several other structures. In September the total flow of the river was passing through this new channel.

The highway bridge at Lecompton was uninjured, but a channel was scoured around the north end of it. All the bridges across the Kansas at Topeka were destroyed except the Melan arch bridge, and the approaches of that were so badly damaged that for several days the only means of access between the north and south parts of the city was by boat.

By scouring action.—The damage due to the scouring action of the flood was very great, the railroad companies being the heaviest losers in this respect. Many miles of railway track located near Kansas River were washed away or badly undermined.

It can be shown mathematically that the increase in the scouring action of water and its transporting power is proportional to the sixth power of the velocity. If, for example, the velocity along the bed of a stream at a given point is 2 feet per second at ordinary stage, and during the flood the velocity is found to be 4 feet per second, then the cutting or scouring action of the water for the 4 feet velocity during flood is sixty-four times that of the 2 feet velocity at ordinary stage, and bowlders will be carried along during the flood that are sixty-four times as heavy as those carried at ordinary stage.

However, the power of a stream in flood to cut river banks and make new channels, as compared with its action at ordinary flow, varies at a much larger rate than as the sixth power of its velocity, because the toughness of a bank of alluvial material and its ability to resist scour decreases very rapidly from the bottom toward the top. Take, for example, the case of a stream flowing in a channel with banks 10 feet high. When the water is 2 feet deep it comes in contact

with only the lower 2 feet of the bank, which is tough and firm. When the river rises 3 feet, the water flows more rapidly and comes in contact with a part of the bank which is 5 feet up from the bed, and which is less tough and more readily scoured.   When water rises to 8 feet or more, the velocity is several times greater than at the shallow depth and the water comes in contact with a part of the bank much more easily eroded than the portion near the bottom; hence the wear is very rapid during a flood, and in a few hours deep channels are cut and acres of land washed away.   This cutting action is greatest just below a bend in the stream.   Here water tends to continue moving in a straight course, and hence strikes the concave surface of the bank just below the bend.   When, as during the recent flood, the river rises high above its banks, it takes a straight course, regardless of its banks, and often does much damage where it was supposed the water could never reach.   The new channel through North Lawrence around the dam is 200 feet wide and so deep that the whole flow of the river passes through it.   The bed of the Kansas at Lecompton Bridge was scoured to a depth of from 3 to 6 feet during the flood; a depth of several feet was scoured also for several hundred feet in width north of the north abutment.   A large amount of material was scoured from the left bank of Republican River at the gaging station at Junction, and, in fact, in many places along the stream there is evidence of a very considerable amount of material having been carried away.   In many places material has been deposited as well. Some of this deposit is fine silt which will enrich the land, but often it is sand which will injure it to a considerable extent.

HYDROGRAPHIC DATA OF KANSAS RIVERS.

METHOD OF OBTAINING DATA.

The United States Geological Survey has at present eight gaging stations in the Kansas River basin.   Four of these are in the Republican River basin, two at Benkelman, Nebr., one at Superior, Nebr., near the State line, and one at the mouth of the river near Junction, Kans.   There is one on the Smoky Hill River at Ellsworth, one on the Saline near its mouth, one on the Solomon near its mouth, one on the Blue near its mouth, and one on the Kansas at Lecompton.   Six of these stations have been in operation about eight years. At each of these stations there is a gage for measuring the rise and fall of the water surface.   This gage is read twice a day by a person living near by, and a copy of the reading is sent at the end of each week to a resident hydrographer who has charge of all the stations in that State.   The resident hydrographer visits each station several times a year to measure the volume of water flowing and inspect the station.   He measures the depth at 5-foot intervals across the stream and computes the area of the prism of water flowing.

Mud and Sand Deposits:
Cutting and Wash:
Bridges Demolished:
Bluff Line:
Flood   "   :
Steam Railways:
Electric   "   :

0'   1000'   2000'   3000'   4000'
Scale.

N
W — E
S

KANSAS CITY,
KANSAS

KANSAS CITY, MO.

MISSOURI RIVER

HARLEM

Deposit of from one to two ft.

Two to three ft.

Deposit of from one to two ft.

Hole 20 ft. deep.
Hole 10 ft. deep.

8 ft. Hole   10 ft. Hole

El. St. Ry.

Tunnel

Shops and High way.

Tracks Completely destroyed.

Chi. G. W. R. R.

K.C.O.B.& E.R.R.

Freight Yds.

Proposed Bridge

Mo. Pac. Ry.

Mo. Pac. Yds.

U. P. Ry.

U. P. Ry.

Union Pacific Ry.
Chi., R. I. & Pac. R. R.

One ft. Deposits

Slight Deposits

ARMOURDALE

K. C. Belt Ry.

Union Terminal Ry.
Track Gutted

Two ft. Deposit

A. T. & S. F.
So. Kansas Ry.
Ry.

ARGENTINE Ry.

KANSAS

RIVER OR KAW

TURKEY

K.C. Belt Yds.

ENG. NEWS.

MAP OF KANSAS CITY, SHOWING FLOODED AREA.

He also measures the velocity at a sufficient number of points in the cross section to enable him to compute the mean velocity of the prism of flowing water. From the cross section and mean velocity he computes the volume passing down the stream for that particular gage height and stream stage. After he has obtained the volume of flow for all stages, he prepares a station rating table which gives the volume of flow for each gage reading. The mean volume flowing per day is then taken from this table, using as a gage reading the mean of the gage readings of the morning and evening. Having the mean daily flow, the monthly and yearly flow are easily computed. The tables (pp. 37–68) give the maximum and minimum monthly flow, as well as the mean, for purposes of comparison; they give the total flow in acre-feet, for purposes of storage; the run-off per square mile, to show the number of square miles necessary to yield a given flow per second, also the depth in inches of run-off, for the purpose of showing the proportion of rainfall that is flowing in the stream.

The table on pages 35, 36 gives the mean daily gage heights and corresponding estimated discharges for May and June, 1903, at seven of the gaging stations in the Kansas River basin. These flood discharges are very difficult to measure, or even to estimate. In fact, it was impossible to measure the velocity, or even to visit some of the stations during this flood. During floods there is always more or less backwater, and consequent retarding of velocity, so that usually the volume of water flowing is much less than the flooded land indicates; much of the overflow water has very little velocity, so that flood estimates made by eye are, as a rule, too large. In computing the discharges in the table the station-rating table has been extended to the greatest gage height, assuming that the banks were not overflowed, and a certain percentage of the discharge has been added, depending on the magnitude of the overflow and the velocity as shown by the scour. The difficulty of computing accurately the discharge during this flood is further complicated by the change in the bed of the stream during the flood. The station-rating curve for 1902 can not be used for computing the discharge for 1903, and the discharge measurements made in 1903 are too few to enable a good station-rating table to be prepared. At the Lecompton and Junction stations the river bed was scoured, so that the discharge after the flood was greater than before it for a given gage reading. At Salina, Niles, and Ellsworth the channel was filled in to such an extent at some point below the station that the discharge is less for a given gage reading since the flood than before it. The bed of the stream at the Manhattan station changed very little during this flood. The results given in the table are believed to be under- rather than over-estimates.

This table is arranged so as to show the increase in flow from the western part of the drainage basin to the eastern part. The run-off per square mile in May increases from 0.30 second-foot at Ellsworth

in the western part to 2.01 second-feet at Manhattan, and in June increases from 0.12 second-foot at Ellsworth to 1.73 second-feet at Manhattan.

Among the many interesting facts shown by the table the following may be noted: (1) The great volume of flood flow as compared with the ordinary flow.   (2) The sudden changes in stream stage—as, for example, the change from 3.30 feet gage height on May 27, at Ellsworth to 15.40 feet on the 28th.   (3) The large range of stage of stream—as, for example, the change from 5.90 to 36.50 feet at the station on Blue River.

It is seen from the Ellsworth record that this flood extended only a short distance west of Ellsworth, Kans., that is, it did not extend beyond the eastern two-thirds of the State of Kansas.
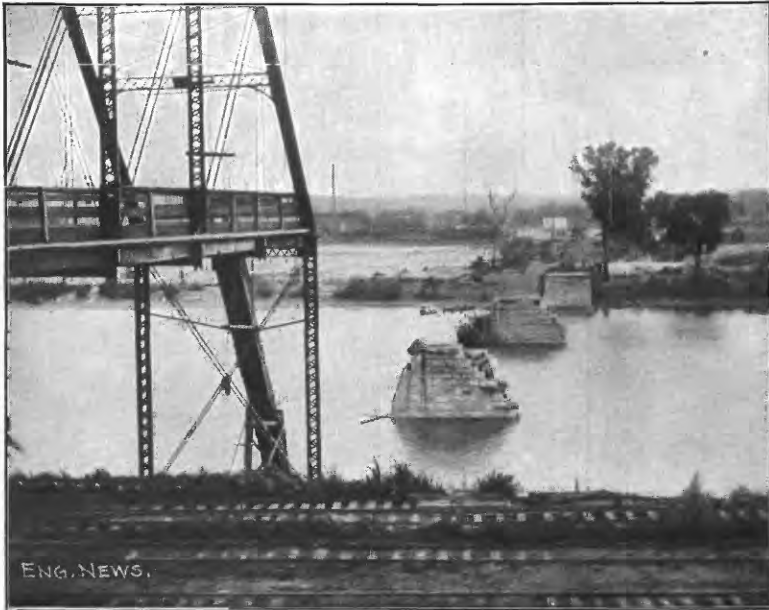
A TWELFTH STREET BRIDGE, ARGENTINE, KANS.. AFTER THE FLOOD.

B. KANSAS CITY SOUTHERN RAILROAD BRIDGE, KANSAS CITY, AFTER THE FLOOD.

Daily mean gage height and discharge in second-feet.

Day	Smoky Hill River at Ellsworth, Kans.				Saline River at Salina, Kans.				Solomon River at Niles, Kans.				Republican River at Junction, Kans.			
	May		June		May		June		May		June		May		June	
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
1	8.50	823	7.70	4,005	11.50	955	(a33.50)	7,895	15.40	2,429	32.90	10,208	7.17	6,450	17.90	44,280
2	8.00	557	7.00	3,410	15.90	1,712	(33.30)	7,805	15.60	2,491	33.30	10,388	5.90	3,400	16.22	40,520
3	8.00	557	5.40	2,129	13.90	1,353	(33.00)	7,670	12.80	1,645	33.80	10,602	4.87	1,780	13.85	31,880
4	8.90	510	4.80	1,690	13.90	1,251	32.70	7,535	10.50	997	33.00	10,514	4.32	1,155	11.83	22,680
5	9.00	1,835	4.40	1,410	11.20	910	32.00	7,220	10.20	915	32.80	10,165	4.12	945	10.60	20,180
6	5.00	2,054	4.30	1,342	11.30	1,200	31.30	6,868	9.90	853	32.00	9,815	3.95	787	9.35	13,050
7	5.90	2,829	8.90	1,075	11.00	925	30.60	6,580	10.40	970	30.00	8,941	3.92	735	8.22	9,600
8	6.90	2,512	3.60	883	13.30	1,251	28.50	5,645	10.70	1,052	25.60	7,018	3.90	735	7.85	7,150
9	5.90	2,204	3.50	823	13.80	1,694	24.70	3,995	16.80	2,877	20.80	4,296	3.90	682	6.80	5,400
10	5.50	1,835	3.40	765	15.50	1,856	20.20	2,488	20.80	4,590	18.80	3,568	3.85	1,290	6.47	4,525
11	5.00	1,762	3.30	710	16.70	1,820	17.80	1,645	21.80	4,000	18.10	3,380	4.40		6.20	4,000
12	4.40	1,410	3.20	657	15.40	1,622	17.20	1,555	23.10	5,153	18.50	3,460	4.42	21,000	5.97	3,500
13	4.50	2,204	3.10	657	13.90	1,553	15.80	1,450	23.20	5,191	16.60	3,285	10.85	26,100	5.72	3,020
14	5.60	2,280	3.00	606	16.10	1,748	15.80	1,345	25.10	6,800	15.90	2,807	12.27	18,180	5.45	2,600
15	4.50	1,479	2.90	557	17.30	1,964	14.90	1,270	28.20	8,155	15.50	2,583	10.05	10,650	5.40	2,520
16	4.00	1,141	2.90	510	17.50	2,000	14.50	1,210	29.50	8,723	15.10	2,460	8.55	10,650	5.25	2,287
17	8.80	1,010	2.70	465	18.00	2,090	14.10	1,150	32.10	9,859	14.70	2,336	7.62	7,800	5.15	2,148
18	8.60	883	2.60	422	17.20	1,946	13.80	1,090	31.00	9,378	14.40	2,215	7.20	6,000	5.02	1,960
19	8.40	765	2.80	381	18.60	1,302	13.50	1,045	25.00	6,756	14.20	2,124	7.87	8,550	4.92	1,840
20	8.20	657	2.80	465	12.30	1,081	14.00	1,000	18.20	3,855	14.00	2,005	6.52	4,650	4.75	1,660
21	8.00	557	2.60	465	13.30	1,251	14.10	1,075	17.50	3,115	18.70	1,915	6.37	4,300	4.67	1,660
22	8.10	606	2.80	381	20.10	2,469	13.50	1,090	21.50	4,557	18.40	1,825	6.72	5,150	4.60	1,540
23	8.50	823	2.80	465	23.10	3,215	13.60	1,000	20.20	4,074	13.20	1,765	8.90	11,700	4.52	1,480
24	8.30	657	2.70	465	20.20	2,488	13.60	1,015	17.70	3,183	13.50	1,855	8.17	9,450	4.60	1,370
25	8.00	557	3.40	422	18.00	2,090	13.20	1,000	18.00	3,585	13.80	1,945	7.35	7,050	5.48	1,480
26	5.00	1,835	3.90	765	28.70	5,735	13.70	955	20.30	4,111	13.70	1,945	9.20	12,600	6.07	2,680
27	3.40	710	3.00	1,075	32.60	7,490	12.40	880	25.00	6,756	15.70	2,522	11.50	23,400	5.47	3,700
28	15.40	10,868	2.80	657	30.70	6,635	12.70	885	23.80	5,229	15.60	2,491	13.10	23,160	5.20	2,600
29	16.00	11,392	2.50	465	(b31.40)	6,950	12.80	880	32.30	9,946	17.20	3,013	18.00	46,800	5.50	2,210
30	18.90	9,466		342	(23.10)	7,295		1,045	31.30	9,509			18.20	47,520		2,680
31	10.20	6,130			(32.80)	7,650			32.20	9,902			17.75	45,900		
Total		73,021		28,109		83,255		86,186		149,880		133,414		375,484		244,860
Mean		2,356		937		2,685		2,873		4,835		4,447		12,112		8,162
Run-off per square mile		0.30		0.12		0.81		0.87		0.71		0.65		0.47		0.31

a Maximum gage height, 33.90 feet.   b Gage heights marked thus ( ) are interpolated.

Daily mean gage height and discharge in second-feet—Continued.

Day	Republican River at Superior, Nebr.				Blue River at Manhattan, Kans.				Kansas River at Lecompton, Kans.			
	May		June		May		June		May		June	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	0.80	840	2.60	6,365	11.00	5,880	(35.00)	66,170	4.00	5,000	27.20	205,500
2	.88	940	2.10	4,240	11.50	6,490	(33.80)	63,050	4.00	5,000	26.25	196,500
3	.96	1,060	1.89	3,510	9.50	4,145	32.50	59,670	6.90	14,170	26.35	197,500
4	.80	840	1.78	3,015	7.20	2,060	30.00	53,170	6.70	13,490	24.35	177,500
5	.95	1,100	1.68	2,590	6.80	1,770	27.00	45,370	6.40	12,470	23.05	164,500
6	.99	1,150	1.45	2,290	6.60	1,630	25.50	41,470	6.40	12,470	20.50	188,500
7	1.09	1,470	1.38	2,055	6.40	1,630	21.50	23,900	6.30	12,190	18.30	115,500
8	2.02	3,805	1.44	2,310	6.30	1,490	17.50	15,900	6.15	11,620	16.50	98,500
9	2.08	4,490	1.41	2,205	6.00	1,350	14.60	10,880	5.90	10,770	14.80	81,500
10	2.59	6,480	1.20	1,610	5.90	1,220	13.30	8,960	5.95	10,940	13.85	72,500
11	3.20	6,415	1.19	1,595	6.90	1,155	12.40	7,700	6.80	12,190	13.70	60,500
12	2.75	7,985	1.21	1,640	11.90	1,420	11.90	7,015	7.50	16,250	11.55	49,500
13	2.60	6,300	1.13	1,560	18.90	1,015	11.30	6,290	9.25	22,375	10.45	38,900
14	2.08	4,950	1.08	1,350	18.00	17,500	10.40	5,500	10.80	29,000	9.85	33,725
15	2.08	4,155	1.07	1,265	12.30	18,100	10.10	5,150	13.10	42,475	9.85	29,000
16	1.99	3,795	1.04	1,260	10.40	7,560	9.80	4,800	12.45	38,312	9.30	28,100
17	1.68	2,910	1.00	1,070	9.70	5,150	9.50	4,470	10.25	28,250	8.90	23,400
18	1.42	2,325	.99	1,080	9.00	4,360	9.30	4,145	9.65	23,775	8.50	20,900
19	1.41	2,155	.96	1,005	8.60	3,690	11.10	3,985	9.40	22,900	8.05	19,150
20	1.38	2,040	.91	920	11.70	3,240	10.60	5,985	9.60	24,300	7.80	17,625
21	1.20	1,690	.98	975	22.00	6,750	10.00	5,380	9.95	23,600	7.45	15,050
22	1.54	2,545	.94	830	23.00	24,900	9.50	4,690	12.90	24,825	7.00	13,725
23	1.41	2,165	1.09	1,080	25.00	26,900	9.10	4,145	14.40	41,125	6.65	12,500
24	1.30	1,880	1.08	1,070	27.50	40,170	9.30	3,730	14.15	52,600	6.40	11,000
25	3.48	11,220	1.16	1,170	25.00	46,670	12.80	3,935	12.15	80,075	6.00	11,750
26	2.80	7,205	1.29	1,465	25.00	40,170	12.20	8,260	16.60	55,500	6.20	19,150
27	2.88	5,060	1.76	2,545	32.00	54,470	9.90	7,430	18.00	99,500	7.80	29,000
28	1.96	3,665	1.58	2,165	32.00	58,370	9.30	4,470	18.00	113,500	9.30	29,000
29	3.88	13,275	1.41	1,690	(38.50)	62,270	8.80	3,935	21.10	144,500	9.30	26,100
30	3.76	13,000	1.19	1,260	(34.80)	65,650	8.80	3,430	24.00	173,500	8.55	24,050
31	2.88	7,850			a(36.00)	68,770			b28.75	221,000		
Total		187,810		57,175		591,865		492,815		1,395,552		1,958,025
Mean		4,445		1,906		19,092		16,427		45,018		65,268
Run-off per square mile		0.20		0.09		2.01		1.73		0.77		1.11

a Maximum gage height, 36.50 feet.   b Maximum gage height, 29.50 feet.

A. BRIDGE AT LAWRENCE, KANS.

B. BRIDGE AND GAGE, LECOMPTON, KANS.

DESCRIPTION OF STATIONS AND DISCHARGE TABLES.

KANSAS RIVER AT LAWRENCE AND LECOMPTON, KANS.

The first gaging station on Kansas River was established in 1880 by Mr. J. D. Bowersock at the highway bridge at Lawrence, Kans. The gage consisted of a vertical timber marked to feet and inches and fastened to the lower side of the pier adjacent to the right bank. This gage was read daily, or oftener, and the readings recorded whenever there was any material change in them until August, 1895, when this place was selected as a United States Geological Survey gaging station. From this date to April 16, 1899, gage readings were taken twice daily, a station-rating curve prepared, and the run-off computed. On account of the sluggish flow at this place during low stages it was deemed advisable to move this station to the highway bridge at Lecompton. This bridge and the gage are shown in Pl. VII, *B*, p. 34. The channel at this place is about 800 feet wide, broken by four metal piers. The bridge is only a short distance from a bend and is somewhat oblique to the course of the stream. The bed is mainly sand and was scoured out a considerable amount during the recent flood. The gage is a 2 by 4 inch timber bolted to the metal pier adjacent to the right bank. The pier on the right bank is marked to half feet for high-water gage readings. The low-water flow is practically the same at Lecompton as at Lawrence, but during high stages Delaware River contributes a considerable amount between these places.

The following tables give run-off at Lawrence and Lecompton:

Estimated monthly discharge of Kansas River at Lawrence, Kans.

[Drainage area 59,841 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1891.a						
January	2,123	967	1,445	88,850	0.02	0.02
February	7,400	1,098	3,538	196,491	.06	.06
March	11,440	1,437	6,144	377,780	.10	.12
April	12,550	5,207	8,455	503,107	.14	.16
May	32,290	4,037	10,560	649,309	.18	.21
June	35,750	13,120	23,102	1,374,664	.39	.44
July	19,370	9,440	13,846	851,357	.23	.26
August	9,440	3,673	5,444	334,739	.09	.10
September	6,490	1,255	2,768	164,707	.05	.60
October	10,900	2,687	5,925	364,314	.10	.12

a Bull. U. S. Geol. Survey No. 140, 1896, pp. 151–152.

Estimated monthly discharge of Kansas River at Lawrence, Kans.—Continued.

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1891.						
November	2,998	1,872	2,382	141,739	0.04	0.04
December	4,803	1,870	3,129	192,395	.05	.06
The year	35,750	967	7,228	5,239,452	.12	2.19
1892. [a]						
January	2,395	1,255	1,669	102,623	.03	.03
February	8,350	2,395	5,292	304,399	.09	.09
March	23,600	6,940	12,581	773,576	.21	.24
April	17,390	7,870	12,712	756,417	.21	.23
May		14,890	37,005	2,275,348	.61	.70
June	14,890	2,687	8,134	484,007	.10	.11
July	2,687	1,437	2,059	126,603	.03	.03
August	3,673	1,255	2,010	123,590	.03	.03
September	2,998	787	1,448	86,262	.02	.02
October	1,643	787	1,042	64,070	.02	.02
November	1,872	1,098	1,487	88,483	.02	.02
December	1,643	787	1,225	75,322	.02	.02
The year		787	7,222	5,260,700	.12	1.54
1893. [a]						
January	1,437	1,098	1,278	78,581	.02	.02
February	6,490	1,255	3,650	202,711	.06	.06
March	2,123	1,098	1,339	82,332	.02	.02
April	2,998	1,255	2,011	119,663	.03	.03
May	5,207	1,643	3,209	197,314	.05	.06
June	21,440	3,327	9,284	553,031	.16	.18
July	21,440	3,327	8,474	521,046	.14	.16
August	15,500	1,643	5,980	368,311	.10	.12
September	6,940	787	2,072	123,293	.03	.03
October	10,900	1,098	3,663	225,844	.06	.07
November	1,872	1,098	1,426	84,853	.02	.02
December	1,872	787	1,021	62,779	.02	.02
The year	21,440	787	3,617	2,619,758	.06	.79
1894. [a]						
January	1,643	787	1,230	75,630	.02	.02
February	2,123	863	1,315	78,248	.02	.02

[a] Bull. U. S. Geol. Survey No. 140, 1896, pp. 151–152.

Estimated monthly discharge of Kansas River at Lawrence, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1894.						
March	4,035	1,255	2,134	131,215	0.04	0.04
April	7,400	1,437	2,903	172,741	.06	.05
May	2,123	787	1,208	74,277	.02	.02
June	28,990	1,255	9,044	538,155	.17	.15
July	11,990	1,437	4,740	291,451	.09	.08
August	2,687	787	1,478	90,879	.03	.03
September	2,123	967	1,445	85,984	.02	.02
October	3,327	787	1,189	73,109	.02	.02
November [a]			787	46,830	.01	.01
December [a]			550	33,818	.01	.01
The year			2,326	1,692,337	.51	.04
1895. [b]						
January [a]			500	33,818	.01	.01
February [a]	1,098	550	680	37,765	.01	.01
March	1,643	967	1,364	83,869	.02	.02
April	1,872	967	1,372	81,640	.02	.02
May	1,437	787	1,074	66,038	.02	.02
June	20,050	967	5,927	352,681	.10	.11
July	10,370	2,395	5,666	348,389	.10	.12
August	28,190	3,163	11,318	695,917	.19	.22
September	20,050	1,255	5,088	302,757	.09	.10
October	1,346	967	1,090	67,022	.02	.02
November	1,346	863	1,044	62,122	.02	.02
December	1,255	863	926	56,938	.02	.02
The year			3,008	2,188,956	.05	.69
1896. [c]						
January	1,540	698	973	59,827	.016	.018
February	1,540	1,255	1,400	80,529	.023	.025
March	1,437	825	1,230	75,630	.021	.024
April	12,550	1,176	4,447	264,615	.074	.082
May	34,158	4,223	13,944	857,389	.230	.260
June	38,583	5,546	14,809	882,980	.250	.280
July	53,308	5,546	23,408	1,439,311	.390	.450
August	22,688	3,956	8,935	549,395	.150	.170

[a] Approximate.
[b] Bull. U. S. Geol. Survey No. 140, 1896, pp. 151–152.
[c] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 222.

Estimated monthly discharge of Kansas River at Lawrence, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.						
September	12,550	2,123	4,436	263,960	0.074	0.082
October	7,170	1,437	1,960	120,516	.033	.038
November	11,440	2,123	3,724	221,593	.062	.069
December	3,327	2,123	2,477	152,306	.041	.047
The year	53,308	825	6,814	4,968,051	.114	1.545
1897.[a]						
January	2,687	967	2,137	131,399	.035	.040
February	11,440	1,643	4,720	262,136	.079	.082
March	5,837	2,687	3,515	216,130	.059	.068
April	58,000	4,035	13,782	820,085	.230	.256
May	14,890	3,327	5,907	363,200	.099	.114
June	32,290	2,395	7,321	435,630	.122	.136
July	39,000	2,998	10,420	640,700	.174	.201
August	5,623	897	2,904	178,560	.049	.056
September	1,255	715	969	57,660	.016	.018
October	1,872	787	1,156	71,080	.019	.022
November	2,687	662	1,927	114,664	.032	.036
December	1,255	562	775	47,652	.013	.015
The year	58,000	562	4,628	3,338,896	.077	1.044
1898.[b]						
January	1,255	863	1,125	69,174	.02	.02
February	6,490	692	2,700	149,950	.05	.05
March	6,490	1,643	2,412	148,309	.04	.04
April	6,490	1,643	3,497	208,085	.06	.07
May	26,235	5,207	14,555	894,958	.24	.28
June	28,990	4,803	13,684	814,253	.23	.26
July	4,803	1,255	2,570	158,024	.04	.05
August	2,395	692	1,008	61,980	.02	.02
September	2,687	692	1,397	83,127	.02	.03
October	1,177	592	825	50,728	.01	.02
November	1,032	517	746	44,390	.01	.01
December	4,035	507	1,448	89,035	.02	.02
The year	28,990	507	3,831	2,772,013	.06	.87

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 350.
[b] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 323.

A. VIEW OF THE KANSAS RIVER, DURING FLOOD. TAKEN FROM TOP OF THE
NATIONAL BANK, LECOMPTON, KANS.

B. "MAD WATERS," LAWRENCE, KANS., DURING FLOOD.

Estimated monthly discharge of Kansas River at Lecompton, Kans.

[Drainage area, 58,550 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1899.[a]						
April [b]	--------	--------	2,693	160,245	0.05	0.06
May	16,800	2,380	5,455	335,415	.09	. .10
June	24,800	3,600	10,609	631,279	.18	.20
July	30,250	3,865	9,771	600,795	.17	.20
August	8,335	2,720	4,855	298,522	.08	.09
September	2,580	1,850	2,154	128,172	.04	.05
October	3,150	1,750	1,938	119,163	.03	.03
November	3,000	1,950	2,236	133,051	.04	.05
December	3,150	1,850	2,379	146,279	.04	.05
1900.[c]						
January	3,481	2,960	3,421	210,349	.06	.07
February	3,613	2,830	3,234	179,607	.06	.06
March	24,898	3,220	7,807	480,034	.13	.15
April	9,520	4,150	5,896	350,836	.10	.11
May	12,220	6,045	7,965	489,749	.14	.16
June	9,200	3,880	6,303	375,055	.11	.12
July	18,722	3,613	7,340	451,319	.13	.15
August	5,095	3,481	4,455	273,927	.08	.09
September	15,635	3,880	6,947	413,375	.12	.13
October	7,810	3,746	4,913	302,089	.08	.09
November	8,110	3,613	4,622	275,028	.08	.09
December	3,613	3,350	3,418	210,165	.06	. .07
The year	24,898	2,830	5,527	4,011,533	.10	1.29
1901.[d]						
January	2,375	1,210	1,772	108,956	.03	.03
February	8,820	1,210	3,142	174,497	.05	.05
March	11,110	4,465	6,353	390,631	.11	.13
April	25,000	4,332	12,844	764,271	.22	.25
May	7,005	2,625	4,767	293,111	.08	.09
June	4,465	2,375	3,231	192,258	.06	.07
July	2,625	275	1,123	69,051	.02	.02
August	4,465	275	2,173	133,613	.04	.05

a Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 228.
b For entire month, based on gage heights of April 16 to 30.
c Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 338.
d Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 144.

Estimated monthly discharge of Kansas River at Lecompton, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.						
September	6,710	2,375	4,367	259,855	0.07	0.08
October	5,000	445	2,270	139,577	.04	.05
November	1,885	275	1,222	72,714	.02	.02
December	1,000	625	805	49,498	.01	.01
The year	25,000	275	3,672	2,648,032	.06	.85
1902.[a]						
January	1,000	445	767	47,161	.01	.01
February	625	275	492	27,324	.01	.01
March	3,675	100	2,460	151,259	.04	.05
April	3,415	2,250	2,653	157,864	.05	.06
May	23,075	2,125	8,435	518,648	.14	.16
June	28,500	11,110	17,131	1,019,365	.29	.32
July	81,400	11,450	38,291	2,354,422	.65	.75
August	40,812	6,415	11,941	734,223	.20	.23
September	53,050	5,270	14,990	891,977	.26	.29
October	42,112	9,130	17,734	1,090,421	.30	.35
November	13,320	9,450	10,830	614,430	.18	.20
December	15,900	9,130	11,785	724,631	.20	.23
The year	81,400	100	11,459	8,361,725	.20	2.66
1903.						
January	14,170	11,100	12,613	775,542	.22	.25
February	13,830	9,130	11,035	612,883	.19	.20
March	25,000	9,610	16,156	993,394	.28	.32
April	10,265	5,275	7,182	427,359	.12	.13
May	221,000	5,000	45,018	2,768,049	.77	.89
June	205,500	11,000	65,268	3,883,715	1.11	1.34
July	20,900	11,750	14,085	866,052	.24	.28
August	58,500	11,187	27,568	1,695,090	.47	.54
September	18,325	2,635	8,631	513,580	.15	.17
October	5,000	2,375	3,698	227,381	.063	.073
November	12,500	5,692	10,182	605,871	.17	.19
December	8,205	5,000	6,472	397,948	.11	.13
The year	221,000	2,375	18,992	13,766,834	.324	4.513

[a] Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 97.

The hydrographs of this river at this station (see Pl. XII, *A*, p. 52) show very clearly how the discharge varies throughout the year. The minimum flow occurs in December or January, during very cold weather, and has been less than 600 second-feet. The maximum flow occurs, as a rule, some time between May 1 and July 31, and hence is due to rain and not melting snow. The monthly run-off per square mile prior to May, 1903, varies from 0.01 to 0.60 second-foot and the yearly run-off per square mile from 0.04 to 0.20 second-foot. In June, 1903, during the flood, however, the run-off per square mile was 1.11 second-feet, and the run-off for the year was 0.324 second-foot. The maximum monthly run-off is 129 times the minimum monthly run-off.

BLUE RIVER NEAR MANHATTAN, KANS.

The station on Blue River is at a highway bridge 4 miles north of Manhattan. It was established April 12, 1895, and has been in operation since that date. The channel is straight for several hundred feet above and below the bridge and is 225 feet wide at ordinary stage, without piers. The bed is mainly clay and changes very little. The gage is a vertical timber, marked to feet and tenths of a foot. The left bank is subject to overflow. During the flood of May and June, 1903, the water was 3 feet deep on the bridge, and the drift and a considerable portion of the flood, estimated at 60 per cent of the flow, passed around the bridge.

The following table gives the run-off data obtained at this station:

Estimated monthly discharge of Blue River near Manhattan, Kans.

[Drainage area, 9,490 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.[a]						
April 14 to 30	605	502	548	18,479	0.06	0.04
May	986	431	552	33,941	.06	.07
June	7,500	552	1,604	95,444	.17	.19
July	2,301	527	756	46,485	.09	.10
August	9,900	478	2,036	125,190	.21	.24
September	8,550	552	1,207	71,822	.13	.15
October	552	385	495	30,436	.05	.06
November	605	385	531	31,597	.06	.07
December	605	502	577	35,478	.06	.07

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 218.

Estimated monthly discharge of Blue River near Manhattan, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.[a]						
January	605	515	568	34,925	0.06	0.07
February	619	502	567	32,614	.06	.06
March[b]						
April 16 to 30	5,283	1,115	2,196	65,340	.23	.13
May	13,725	1,328	4,800	295,142	.51	.59
June	19,425	677	4,594	273,362	.49	.55
July	21,975	888	5,494	337,815	.58	.67
August	12,375	1,007	2,659	163,497	.28	.31
September	4,724	868	1,621	96,456	.17	.19
October	7,725	363	1,179	72,494	.12	.13
November	4,724	527	1,189	70,751	.13	.14
December	1,028	408	786	48,329	.08	.09
1897.[c]						
January	1,300	610	965	59,335	.10	.12
February	2,200	610	1,228	68,200	.13	.14
March	2,165	870	1,434	88,174	.15	.17
April	32,256	1,200	7,935	472,166	.84	.93
May	4,815	1,375	2,232	137,240	.24	.28
June	20,694	810	2,966	176,490	.31	.35
July	8,158	1,010	2,555	157,100	.27	.31
August	3,392	890	1,698	104,405	.18	.21
September	970	210	578	34,395	.06	.07
October	770	320	561	34,494	.06	.07
November	810	505	681	40,523	.07	.08
December	850	610	730	44,886	.08	.09
The year	32,256	210	1,964	1,417,408	.21	2.82
1898.[d]						
January	830	555	732	45,009	.08	.08
February	5,319	500	2,078	115,406	.22	.23
March	1,050	527	765	47,028	.08	.09
April	3,335	610	1,485	88,363	.16	.18
May	8,548	1,522	3,491	214,653	.37	.43
June	10,774	1,081	4,496	267,530	.47	.53

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 218.
[b] No record.
[c] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 348.
[d] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 319.

A. UNDERMINED SECTION OF RAILROAD NEAR LAWRENCE, KANS.

B. RAILROAD TRACK ON TOP OF COAL CAR NEAR LAWRENCE, KANS.

Estimated monthly discharge of Blue River near Manhattan, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1898.						
July	1,333	500	740	45,501	0.08	0.09
August	610	230	454	27,916	.05	.06
September	665	230	377	22,433	.04	.04
October	637	207	360	22,136	.04	.04
November	555	342	443	26,361	.05	.06
December	775	432	615	37,815	.06	.07
The year	10,774	207	1,336	960,151	.14	1.90
1899. [a]						
January	910	680	721	44,333	.08	.09
February	1,080	770	876	48,651	.09	.09
March	7,240	792	1,845	113,445	.19	.22
April	1,325	702	944	56,172	.10	.11
May	29,693	635	4,081	250,931	.43	.49
June	30,030	1,325	4,767	283,656	.50	.56
July	10,371	885	2,699	165,955	.28	.32
August	6,367	305	1,532	94,199	.16	.18
September	635	400	498	29,633	.05	.06
October	2,212	287	597	36,708	.06	.07
November	612	460	536	31,894	.06	.07
December	747	380	524	32,220	.06	.07
The year	30,030	287	1,635	1,187,797	.17	2.33
1900. [b]						
January	960	270	619	38,061	.07	.08
February	815	460	585	32,489	.06	.06
March	5,705	657	1,388	85,345	.15	.17
April	4,457	522	1,392	82,830	.15	.17
May	8,240	1,160	2,736	168,230	.29	.33
June	1,690	590	967	57,540	.10	.11
July	23,280	400	2,580	158,638	.27	.31
August	2,927	500	973	59,827	.10	.12
September	4,410	522	1,812	107,821	.19	.21
October	1,110	545	731	44,947	.08	.09

[a] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 227.
[b] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 337.

Estimated monthly discharge of Blue River near Manhattan, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1900.						
November	1,500	590	727	43,259	0.08	0.09
December	635	460	589	36,216	.06	.07
The year	23,280	270	1,258	915,203	.13	1.81
1901.[a]						
January	815	522	682	41,935	.07	.08
February	4,082	635	1,471	81,695	.16	.17
March	3,013	· 770	1,129	69,420	.12	.14
April	13,155	1,010	2,146	127,696	.23	.26
May	2,325	725	1,152	70,834	.12	.14
June	1,500	460	828	49,269	.09	.10
July	770	305	473	29,084	.05	.06
August	2,800	380	775	47,653	.08	.09
September	1,010	305	511	30,407	.05	.06
October	590	380	470	28,899	.05	.06
November	1,325	460	590	35,107	.06	.07
December	680	380	498	30,621	.05	.06
The year	13,155	305	894	642,620	.09	1.29
1902.[b]						
January	560	408	461	28,346	.05	.06
February	910	408	619	34,378	.07	.07
March	910	480	618	37,983	.07	.08
April	560	408	483	28,740	.05	.06
May	17,510	408	2,157	132,629	.23	.27
June	17,510	910	6,298	374,757	˙.66	.74
July	43,430	4,540	16,866	1,037,050	1.78	2.05
August	27,686	1,790	4,329	266,180	.46	.53
September	29,990	1,460	5,011	298,175	.53	.59
October	20,006	1,790	5,071	311,804	.53	.61
November	4,740	1,526	1,945	115,735	.20	.22
December	3,136	1,066	1,897	116,642	.20	.23
The year	43,430	408	3,813	2,782,419	.40	5.51

[a] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 143.
[b] Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 99.

Estimated monthly discharge of Blue River near Manhattan, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1903.						
January	2,710	875	1,542	94,814	0.16	0.18
February	11,460	785	2,373	131,790	.25	.26
March	9,815	1,220	4,929	303,072	.52	.60
April	1,560	785	1,046	62,241	.11	.12
May	68,770	1,220	19,092	1,173,920	2.01	2.42
June	66,170	3,430	16,427	977,474	1.73	1.93
July	4,580	1,700	2,644	162,573	.28	.32
August	34,710	1,840	9,626	591,880	1.01	1.16
September	6,235	1,155	2,576	153,282	.27	.30
October	2,710	925	1,337	82,209	.14	.16
November	5,860	1,035	1,849	50,519	.19	.21
December	2,290	785	1,044	64,193	.11	.13
The year	68,770	785	5,374	3,847,967	.565	7.79

The hydrograph of this stream at the gaging station is shown on Pl. XII, *B*, p. 52. It resembles to some extent that for the station on Kansas River at Lawrence, the minimum discharge occurring in December or January, and the maximum some time between April 1 and August 31. The monthly run-off per square mile prior to 1903 varied from 0.04 to 1.78 second-feet, and the yearly run-off per square mile from 0.09 to 0.40 second-foot. In May, 1903, the run-off per square mile was 2.01 second-feet, and the run-off per square mile for the year 1903 was 0.565 second-foot. The maximum monthly discharge is 53 times the minimum monthly discharge.

This stream is seen to have a more steady flow than Kansas River. This is because the Blue has a larger rainfall over its whole drainage area than the Kansas. In the Blue River watershed the mean annual rainfall is about 30 inches, and in the Kansas River basin it varies from 35 inches in the eastern part to 12 inches in the western part.

REPUBLICAN RIVER AT JUNCTION, KANS.

There are four stations on Republican River. One is at Junction, Kans., one at Superior, and two at Benkelman, Nebr. The station at Junction, Kans., is at Washington street highway bridge. It was established April 26, 1895, and has been maintained continuously since that time. This bridge is at a large bend in the stream. At low stages the channel is straight for 200 feet above and below the

station.   The width is about 375 feet, broken by three piers.   The
bed is sandy and somewhat changeable.   The velocity is rapid.   The
gage is a vertical timber marked to feet and tenths of a foot.   During
the flood of May and June a portion of the flow, estimated at 50 per
cent of the total, passed around the left abutment and scoured out a
channel about 4 feet deep and 200 to 300 feet in width.

The run-off results obtained at this station are given in the fol-
lowing table:

Estimated monthly discharge of Republican River at Junction, Kans.

[Drainage area, 25,837 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.[a]						
July	6,000	439	1,800	110,678	0.070	0.081
August	[b]25,000	265	3,192	196,269	.124	.143
September	4,170	219	542	32,251	.021	.023
October	326	220	249	15,310	.010	.012
November	355	230	282	16,779	.011	.012
December	575	230	392	24,103	.015	.017
1896.[a]						
January	556	392	448	27,547	.017	.020
February	1,131	504	756	43,486	.029	.031
March	504	504	504	30,990	.019	.022
April	3,770	485	1,414	84,139	.055	.061
May	3,920	785	2,124	130,601	.082	.095
June	3,980	494	1,370	81,520	.053	.059
July	[b]37,500	594	3,678	226,153	.142	.164
August	2,340	459	893	54,909	.034	.039
September	2,425	326	667	39,690	.026	.029
October	2,180	356	475	29,207	.018	.021
November	1,480	459	655	38,976	.025	.028
December	1,121	594	810	49,805	.031	.036
The year	[b]37,500	326	1,150	837,023	.044	.601
1897.[c]						
January	1,160	560	740	45,507	.029	.033
February	3,055	625	1,343	74,563	.052	.054
March	1,160	750	898	55,228	.035	.040

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 205.
[b] Estimated.
[c] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 340.

A. BRIDGE STREET, NORTH LAWRENCE, KANS., DURING THE FLOOD.

B. PILE DRIVER CONSTRUCTING TEMPORARY BRIDGE OVER NEW NORTH
CHANNEL, LAWRENCE, KANS.

Estimated monthly discharge of Republican River at Junction, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.						
April	8,250	1,000	2,032	120,895	0.078	0.087
May	2,550	325	833	51,213	.032	.037
June	6,053	290	1,592	94,713	.062	.068
July	6,360	440	1,824	112,147	.071	.082
August	2,210	254	619	38,042	.024	.028
September	537	125	204	12,156	.008	.009
October	415	85	205	12,605	.008	.009
November	1,120	290	632	37,577	.024	.027
December	930	290	668	41,070	.026	.030
The year	6,360	85	966	695,716	.037	.504
1898.[a]						
January	900	475	732	45,009	.03	.03
February	1,895	645	1,034	57,425	.04	.04
March	825	475	656	40,336	.03	.03
April	1,310	590	804	47,841	.03	.03
May	7,175	862	2,126	130,723	.08	.09
June	6,165	700	2,125	126,446	.08	.09
July	645	210	429	26,378	.02	.02
August	252	69	142	8,732	.01	.01
September	325	69	155	9,223	.01	.01
October	252	124	190	11,683	.01	.01
November	475	210	310	18,446	.01	.01
December	645	325	403	24,780	.02	.02
The year	7,175	69	759	547,022	.03	.39
1899.[b]						
January	870	500	702	43,165	.027	.031
February	1,020	555	768	42,653	.030	.031
March	2,320	870	1,432	88,050	.055	.063
April	1,020	615	870	51,769	.034	.038
May	7,750	500	1,515	93,154	.059	.068
June	12,000	475	1,952	116,569	.076	.085
July	3,570	395	1,415	87,005	.055	.063
August	2,395	295	838	51,527	.032	.037

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 318.
[b] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 221.

Estimated monthly discharge of Republican River at Junction, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1899.						
September	345	100	187	11,127	0.007	0.008
October	1,140	35	302	18,569	.012	.014
November...............	395	63	175	10,413	.007	.008
December	800	205	488	30,006	.019	.022
The year	12,000	35	888	644,007	.034	.468
1900.[a]						
January	670	400	559	34,372	.02	.02
February	890	550	716	39,765	.03	.03
March	4,875	610	1,327	81,594	.05	.06
April	3,450	500	1,465	87,173	.06	.07
May	3,260	735	1,362	83,746	.05	.06
June...................	975	450	554	32,965	.02	.02
July	735	225	373	22,935	.01	.01
August	450	150	275	16,909	.01	.01
September	3,090	198	771	45,878	.03	.03
October	345	150	258	15,864	.01	.01
November.............	225	130	162	9,640	.01	.01
December	500	173	257	15,802	.01	.01
The year	4,875	130	673	486,643	.03	.34
1901.[b]						
January	570	405	510	31,359	.020	.023
February ...:..........	1,015	450	669	37,154	.026	.027
March	1,750	850	1,030	63,332	.040	.046
April	5,010	930	1,530	91,041	.059	.066
May	1,015	405	747	45,931	.029	.033
June..................	510	315	406	24,159	.016	.018
July	450	75	177	10,883	.007	.008
August	110	20	53	3,259	.002	.002
September	3,160	20	906	53,911	.036	.040
October	770	405	564	34,679	.022	.025
November.............	510	405	472	28,086	.018	.020
December	660	450	594	36,524	.023	.027
The year	5,010	20	638	460,318	.025	.335

[a] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 333.
[b] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 141.

Estimated monthly discharge of Republican River at Junction, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.[a]						
January	945	600	710	43,656	0.03	0.03
February	1,425	735	775	43,041	.03	.03
March	1,480	570	887	54,539	.03	.03
April	1,207	510	654	38,916	.03	.03
May	7,800	482	2,128	130,846	.08	.09
June	8,400	1,260	3,338	198,625	.13	.15
July	23,100	840	7,887	484,953	.30	.35
August	11,700	260	2,046	125,804	.08	.09
September	10,500	88	1,646	97,944	.06	.07
October	5,150	427	1,436	88,296	.06	.07
November	787	400	471	28,026	.02	.02
December	2,443	220	422	25,944	.02	.02
The year	23,100	88	1,867	1,360,590	.07	.98
1903.						
January	1,102	325	684	42,058	.026	.030
February	3,600	482	1,217	67,589	.047	.049
March	13,500	1,155	5,099	313,525	.200	.230
April	1,102	375	624	37,130	.024	.027
May	47,520	682	12,112	744,738	.470	.540
June	44,280	1,370	8,162	485,673	.310	.340
July	9,750	997	2,578	158,515	.100	.120
August	10,350	735	3,254	200,081	.120	.140
September	3,020	400	859	51,114	.033	.037
October	1,315	240	466	28,653	.018	.021
November	1,207	455	746	44,390	.029	.032
December	1,102	570	757	46,546	.029	.033
The year	47,520	240	3,046	2,220,012	.117	1.599

[a] Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 102.

The hydrograph for this stream at this station is shown on Pl. XII, *C.* It is seen to resemble to some extent that for Kansas River at Lawrence, Kans. The minimum flow, however, occurs in the fall instead of in the winter. The maximum flow usually occurs some time between April 1 and July 31.

The monthly run-off per square mile prior to 1903 varied from 0.002
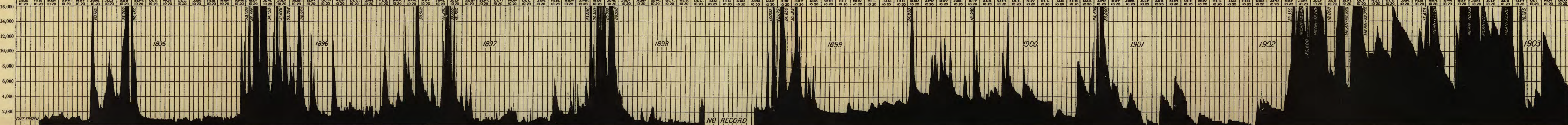
A. HYDROGRAPH OF KANSAS RIVER AT LAWRENCE AND LECOMPTON, KANS.
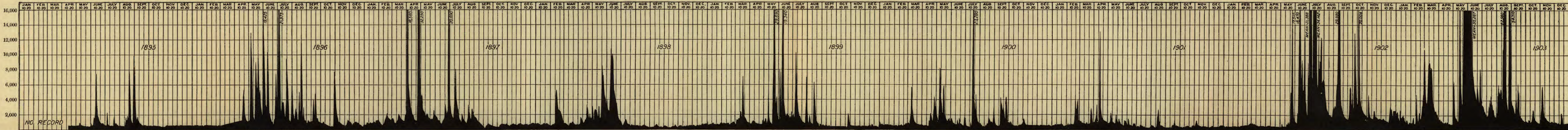
B. HYDROGRAPH OF BLUE RIVER NEAR MANHATTAN, KANS.
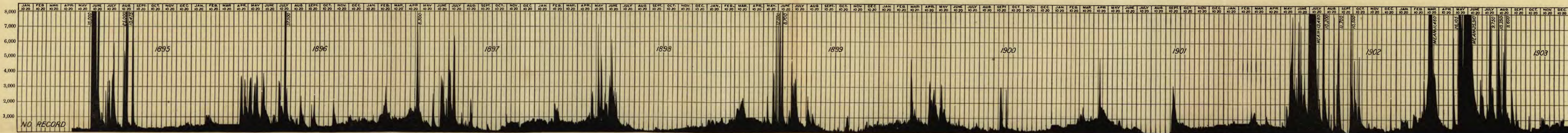
C. HYDROGRAPH OF REPUBLICAN RIVER AT JUNCTION, KANS.

to 0.30 second-feet and the yearly run-off per square mile from 0.03 to 0.07 second-feet. The run-off for May, 1903, was 0.47 second-feet and the yearly run-off for 1903 was 0.117. The maximum monthly discharge is 230 times the minimum monthly discharge.

REPUBLICAN RIVER NEAR SUPERIOR, NEBR.

The station on Republican River near Superior, Nebr., is at a highway bridge, 150 feet upstream from a dam which diverts water into a mill race. The channel at this point is about 500 feet wide, broken by three piers. The bed is sand and silt and somewhat changeable. The velocity is sluggish at low stages. The first gage used at this place was an inclined timber fastened to the left bank just above the bridge. In the spring of 1898 two other gages were established here, one in the river a few feet upstream from the crest of the dam, the other in the mill race at a bridge about 150 feet below its head. The discharge of this mill race was measured at this bridge, and the difference between it and the river at the bridge gave the amount flowing over the dam. It was found, however, that the discharge of the mill race was regulated more or less by the mill below, so that there was no relation between the gage heights and the discharge. The method of remedying this defect is described on page 103 of Water-Supply and Irrigation Paper No. 84.

The run-off data obtained at this station are given in the following table:

Estimated monthly discharge of Republican River near Superior, Nebr.

[Drainage area, 22,347 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.[a]						
June [b]			627	13,244	0.028	0.011
July [c]			1,179	70,155	.093	.059
August			659	40,520	.029	.033
September [d]			279	16,048	.012	.013
October			230	14,142	.010	.012
November [e]			449	25,827	.020	.022

[a] Based on daily discharges published in Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 202. Discharge at both dam and mill race are included.
[b] For 11 days.
[c] For 30 days.
[d] For 29 days.
[e] For 29 days.

Estimated monthly discharge of Republican River near Superior, Nebr.—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1897. [a]						
January [b]	900	555	710	43,656	0.032	0.037
February [b]	1,520	420	906	50,316	.041	.043
March [b]	650	385	510	31,359	.023	.026
April	2,870	620	1,244	74,023	.056	.062
May	1,130	180	420	25,825	.019	.022
June [b]	750	180	359	21,362	.016	.018
July	4,310	119	922	56,690	.041	.047
August	1,460	94	259	15,924	.012	.014
September	241	0	71	4,225	.003	.003
1898. [c]						
April [d]	2,130	490	755	44,926	.03	.03
May	1,870	500	1,053	64,747	.05	.06
June	2,300	560	1,235	73,487	.06	.07
July	1,345	220	479	29,453	.02	.02
August	380	100	195	11,990	.01	.01
September	470	185	289	17,197	.01	.01
October	365	145	264	16,233	.01	.01
November [e]	470	320	382	22,731	.02	.02
1899. [f]						
March [g]	956	601	706	43,411	.031	.036
April	842	375	578	34,393	.026	.029
May	1,800	292	511	31,420	.023	.026
June	4,036	141	531	31,597	.021	.023
July	1,384	209	458	28,162	.020	.023
August	868	136	303	18,631	.014	.016
September	102	6	50	2,975	.002	.002
October	101	24	53	3,259	.002	.002
1900. [h]						
April	1,671	565	909	54,089	.041	.046
May	2,945	320	735	45,193	.033	.038
June	674	250	392	23,326	.018	.020

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 339. Discharges represent amount going over dam only; the mill race carries on an average, 85 second-feet.
[b] Approximate.
[c] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 317.
[d] For entire month; based on gage heights of April 20 to 30.
[e] For entire month; based on gage heights of November 1 to 19.
[f] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 220.
[g] For entire month, based on gage heights of March 19 to 31.
[h] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 332.

Estimated monthly discharge of Republican River near Superior, Nebr.—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1900.						
July	349	67	159	9,777	0.006	0.007
August	1,278	24	149	9,162	.006	.007
September	2,010	8	156	9,283	.006	.007
October	148	26	69	4,243	.003	.003
November *a*	162	36	87	5,177	.004	.004
1901. *b*						
April	1,507	637	961	57,183	.043	.048
May	622	146	364	22,381	.016	.018
June	480	117	219	13,031	.010	.011
July	154	5	44	2,618	.002	.002
August	856	5	70	4,304	.003	.003
September	4,991	10	1,246	74,142	.056	.062
October	1,490	285	443	27,239	.020	.020
November	1,030	312	419	24,932	.019	.021
1902. *c*						
March 9 to 31			675	29,453	.03	.02
April	740	390	555	33,020	.02	.02
May	2,810	335	1,269	78,020	.06	.07
June	3,235	320	1,372	81,640	.06	.07
July *d*	12,490	970	3,080	189,360	.14	.16
August	1,920	330	674	41,440	.03	.03
September	10,875	155	1,175	69,910	.05	.06
October	1,995	520	937	57,610	.04	.05
November	970	460	622	37,010	.03	.03
1903.						
March 14–31	7,750	1,260	2,692	96,120	.120	.080
April	1,260	705	918	54,625	.041	.046
May	14,100	845	4,491	276,141	.201	.232
June	6,455	835	1,921	114,307	.086	.096
July	7,825	465	1,948	119,778	.087	.100
August	3,285	520	1,230	75,630	.055	.063
September	700	270	389	23,147	.017	.019
October	390	245	326	20,045	.015	.017
November	690	130	417	24,813	.019	.021

a For entire month, based on gage heights of November 1 to 24.
b Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 140.
c Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 105.
d Exclusive of four days flood discharge.

It is seen that the minimum monthly discharge occurs in September and is less than 50 second-feet. The smallest daily discharge is 0. The maximum monthly discharge is 4,491 second-feet, which is 102 times the minimum monthly discharge. The monthly run-off per square mile varies from 0.002 to 0.20 second-feet.

<div align="center">REPUBLICAN RIVER NEAR BENKELMAN, NEBR.</div>

A station was established on North Fork of Republican River about 2 miles west of Benkelman, Nebr., November 4, 1894. A station was also established on South Fork near Benkelman, at about the same time. The former station was maintained continuously until September 1, 1895. The other was maintained, with short breaks, to September 31, 1895. The stream bed at these stations is sandy and shifting, and each flood changes the channel by a considerable amount, so that a rating curve at either station was applicable for only a few months. Stations were again established at these places in May, 1903.

The monthly discharge was as follows:

Estimated monthly discharge of Republican River at Benkelman, Nebr.

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
NORTH FORK.				
1903.				
May 20-31	71	47	58	1,382
June	81	43	59	5,511
July	112	19	39	2,398
August	61	26	32	1,968
September	47	19	39	2,321
October	54	43	49	3,013
November 1-20 [a]	64	50	56	2,204
SOUTH FORK.				
1903.				
May 20-31	57	36	48	1,148
June	65	7	37	2,202
July	36	7	15	922
August	79	7	25	1,537
September [b]	22	7	11	655
October	50	22	39	2,398
November 1-20 [a]	65	50	57	2,269

[a] Frozen November 21 to December 31.
[b] Records from 6 to 13, *inclusive*, are missing.

A station was established on Solomon River at a highway bridge in Beloit, April 22, 1895, and was maintained continuously until June 30, 1897, when it was discontinued on account of poor section. The present gaging station on Solomon River is located 56 miles down the river from Beloit, at an iron bridge about 1½ miles from Niles. It was established May 5, 1897, and has been maintained continuously since that date. The channel at the present station is about 150 feet wide, nearly straight for 100 feet above and below, and broken by two piers. The bed is clay and silt. The velocity is sluggish at low stages. Surface fluctuations are measured with a wire gage.

The run-off data obtained at these two stations on Solomon River are given in the following table:

Estimated monthly discharge of Solomon River at Beloit, Kans.

[Drainage area, 5,539 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.[a]						
July	[b]21,000	159	2,202	135,396	0.399	0.460
August	[b]24,000	172	1,629	100,164	.294	.339
September	615	14	156	9,283	.028	.032
October	62	7	28	1,722	.005	.006
November	26	7	23	1,369	.004	.005
December	250	7	114	7,010	.021	.024
1896.[a]						
January	121	5	88	5,411	.016	.018
February	121	19	103	5,925	.018	.020
March	123	8	94	5,780	.017	.019
April	[b]18,500	8	1,658	98,658	.300	.334
May	4,700	72	429	26,378	.077	.089
June	8,740	104	852	50,698	.154	.172
July	[b]21,800	108	1,238	76,122	.226	.255
August	803	92	354	21,767	.065	.073
September	960	28	130	7,735	.023	.026
October	6,760	10	302	18,569	.055	.062
November	117	34	76	4,522	.013	.015
December	124	38	92	5,657	.017	.019
The year	[b]21,800	5	451	327,222	.083	11.02

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, pp. 209–210.
[b] Estimated. NOTE.—Recent measurements show that these estimates are too large.

Estimated monthly discharge of Solomon River at Beloit, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.[a]						
January	225	16	130	8,024	0.023	0.027
February	387	20	193	10,724	.035	.036
March	312	92	227	13,933	.041	.047
April	7,470	180	663	39,463	.120	.133
May	368	18	150	9,254	.027	.031
June	6,400	19	1,377	81,913	.249	.278

[a]Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 341.

Estimated monthly discharge of Solomon River near Niles, Kans.

[Drainage area, 6,815 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.[a]						
May [b]	669	161	267	16,411	0.039	0.045
June	4,500	103	1,083	64,433	.159	.177
July	5,380	215	838	51,551	.123	.142
August	320	108	193	11,892	.028	.033
September	200	65	106	6,319	.016	.017
October	142	62	97	5,976	.014	.016
November	154	86	114	6,784	.017	.019
December	161	60	100	6,124	.015	.017
1898. [c]						
January	172	126	155	9,531	.02	.02
February	260	109	164	9,108	.02	.02
March	190	98	131	8,055	.02	.02
April	353	109	146	8,688	.02	.02
May	677	160	243	14,942	.04	.04
June	1,175	196	534	31,775	.08	.09
July	335	79	156	9,592	.02	.02
August	103	35	56	3,443	.01	.01
September	190	42	79	4,701	.01	.01

[a]Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 343.
[b]Estimated from gage heights of May 6 to 31.
[c]Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 314.

Estimated monthly discharge of Solomon River near Niles, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1898.						
October	79	47	58	3,566	0.01	0.01
November	120	47	72	4,284	.01	.01
December	268	87	147	9,039	.02	.02
The year	1,175	35	162	116,724	.02	.29
1899.[a]						
January	303	131	178	10,944	.026	.030
February	202	147	178	9,886	.026	.027
March	315	125	177	10,883	.026	.030
April	159	90	128	7,617	.019	.021
May	2,364	85	304	18,692	.045	.052
June	6,240	131	1,789	106,453	.262	.29
July	3,895	147	580	35,663	.085	.098
August	1,283	105	272	16,725	.039	.045
September	131	53	88	5,236	.013	.014
October	1,152	37	126	7,747	.018	.021
November	120	53	81	4,820	.012	.013
December	131	62	99	6,087	.015	.017
The year	6,240	37	328	236,880	.048	.646
1900.[b]						
January	128	58	90	5,534	.01	.01
February	159	74	103	5,720	.02	.02
March	1,870	80	246	15,126	.04	.05
April	4,627	74	760	45,223	.11	.12
May	1,156	211	532	32,711	.08	.09
June	860	80	230	13,686	.03	.03
July	630	54	135	8,301	.02	.02
August	860	66	242	14,880	.04	.05
September	2,020	54	294	17,494	.04	.04
October	755	66	116	7,133	.02	.02
November	100	54	71	4,225	.01	.01
December	100	58	75	4,612	.01	.01
The year	4,627	54	241	174,645	.04	.47

[a] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 223.
[b] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 334.

Estimated monthly discharge of Solomon River near Niles, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.[a]						
January	114	46	91	5,595	0.013	0.015
February	193	54	90	4,998	.013	.014
March	341	100	152	9,346	.022	.025
April	2,020	114	452	26,896	.066	.074
May	303	89	142	8,731	.021	.024
June	989	46	157	9,342	.023	.026
July	54	7	27	1,660	.004	.005
August	62	7	18	1,107	.003	.003
September	1,604	70	243	14,460	.036	.040
October	89	38	67	4,120	.010	.012
November	176	38	99	5,891	.015	.017
December	100	54	79	4,858	.012	.014
The year	2,020	7	135	97,004	.020	.269
1902.[b]						
January	152	94	106	6,517	.02	.02
February	142	102	119	6,608	.02	.02
March	207	38	101	6,210	.02	.02
April	152	54	89	5,296	.01	.01
May	1,415	38	285	17,524	.04	.05
June	6,155	316	1,392	82,830	.20	.22
July	7,040	252	2,492	153,227	.37	.43
August	2,375	299	847	52,080	.12	.14
September	7,040	132	1,392	82,830	.20	.22
October	7,780	761	2,263	139,145	.33	.38
November	855	470	601	35,764	.09	.10
December	490	316	402	24,718	.06	.07
The year	7,780	38	841	612,749	.12	1.68
1903.						
January	410	282	341	20,967	.050	.058
February	830	237	356	19,882	.052	.054
March	5,002	587	1,866	114,736	.270	.310
April	564	120	345	20,529	.051	.057
May	9,946	635	4,835	297,292	.710	.820
June	10,602	1,765	4,447	264,615	.650	.720

[a] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 142.
[b] Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 107.

Estimated monthly discharge of Solomon River near Niles, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1903.						
July	4,074	835	1,658	101,946	0.240	0.280
August	7,091	1,190	3,625	222,893	.530	.610
September	2,460	472	970	57,719	.140	.160
October	495	363	427	26,255	.063	.073
November	760	343	456	27,134	.067	.075
The period	10,602	120	1,611	1,173,958	.235	3.217

The hydrographs for this stream at these stations are shown in Pl. XIII, *B*, p. 64. The minimum monthly flow was very small, and less than 20 second-feet in August, 1901. The flood flow is occasionally very large, and was 4,835 second-feet in May, 1903. The maximum monthly discharge is 269 times the minimum monthly discharge. The monthly run-off per square mile varies from 0.003 to 0.710.

SALINE RIVER AT BEVERLY AND NEAR SALINA, KANS.

A station was established on Saline River at Beverly, April 18, 1895, and was maintained continuously from that date to June 30, 1897, when it was discontinued on account of poor section. The present station on Saline River is located at a highway bridge, about $4\frac{1}{2}$ miles north of Salina and 24 miles down the river from Beverly. It was established May 4, 1897, to take the place of the station at Beverly, and has been maintained continuously from that time to the present. The channel is about 170 feet wide, nearly straight for a short distance above and below the bridge, and without piers. The bed is soft material; the velocity sluggish. Surface fluctuations are measured with a wire gage. Both banks are subject to overflow during floods.

The run-off results obtained at this station are given in the following tables:

Estimated monthly discharge of Saline River at Beverly, Kans.

[Drainage area, 2,730 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.[a]						
July	[b]10,000	73	574	35,294	0.201	0.232
August	339	58	101	6,210	.037	.043
September	92	9	38	2,261	.014	.016
October	58	6	27	1,660	.010	.012
November	62	9	33	1,964	.012	.013
December	57	13	33	2,029	.012	.014
1896.[a]						
January	76	26	52	3,197	.019	.022
February	96	33	51	2,934	.018	.020
March	65	33	49	3,013	.018	.020
April	693	37	151	8,986	.055	.062
May	3,000	45	313	19,245	.114	.132
June	[b]16,000	167	2,291	136,324	.839	.936
July	679	103	286	17,586	.104	.120
August	493	41	107	6,579	.037	.045
September	90	33	58	3,451	.021	.024
October	[b]6,130	31	260	15,987	.095	.109
November	188	41	75	4,463	.027	.031
December	98	31	62	3,505	.023	.027
The year	[b]16,000	26	313	225,270	.114	1.548
1897.[c]						
January	108	17	48	2,927	.017	.020
February	243	27	73	4,054	.026	.027
March	67	32	46	2,835	.017	.019
April	626	49	192	11,424	.070	.078
May	357	53	146	8,953	.053	.061
June	[b]11,000	38	452	26,920	.166	.185

a Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 212.
b Approximate.
c Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 344.

Estimated monthly discharge of Saline River near Salina, Kans.

[Drainage area, 3,311 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second feet per square mile.	Depth in inches.
1897. [a]						
May _____ __ _ _____	335	79	147	9,039	0.044	0.051
June ___ _____	[b] 4,400	51	256	15,203	.077	.085
July _____ _____	[a] 685	36	83	5,104	.025	.028
August _____	381	28	74	4,532	.022	.025
September _____	57	20	30	1,803	.009	.010
October _____ _____	70	16	32	1,955	.010	.011
November _____	48	26	38	2,279	.012	.013
December_____ __ ____	46	28	41	2,521	.012	.014
1898. [c]						
January _____	82	40	57	3,505	.02	.02
February _____	94	34	50	2,777	.02	.02
March _____	46	24	37	2,275	.01	.01
April _____	60	24	35	2,083	.01	.01
May _____	1,095	34	109	6,702	.03	.04
June_____ _	1,100	72	271	16,126	.08	.09
July _____	421	22	86	5,288	.03	.03
August _____	32	7	20	1,230	.01	.01
September ____ ___ __	970	6	121	7,440	.04	.04
October _____ __ ___	52	22	35	2,152	.01	.01
November _____	40	15	25	1,488	.01	.01
December _____	690	29	144	8,854	.04	.04
The year _____	1,100	6	83	59,920	.03	.33
1899. [d]						
January _____	110	60	67	4,120	.020	.023
February _____ __	102	50	63	3,499	.019	.020
March _____ _ _____	117	50	80	4,919	.024	.028
April _____ _____	72	30	53	3,154	.016	.018
May _____	1,010	18	155	9,531	.047	.054
June_____ _ _____	5,000	110	1,334	79,378	.403	.45
July _____ ____ _____	684	132	279	17,155	.084	.097
August ___ __ _ _____	152	62	100	6,149	.030	.035
September _ _____	102	55	68	4,046	.021	.023

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, p. 346
[b] Approximate.
[c] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 316.
[d] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 224.

Estimated monthly discharge of Saline River near Salina, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum-	Mean.		Second-feet per square mile.	Depth in inches.
1899.						
October	386	40	79	4,858	0.024	0.028
November	181	70	88	5,236	.027	.030
December	102	70	84	5,165	.025	.029
The year	5,000	18	204	147,210	.062	.835
1900. [a]						
January	55	42	49	3,013	.01	.01
February	55	42	47	2,610	.01	.01
March	700	44	114	7,010	.03	.03
April	2,930	50	471	28,026	.04	.06
May	1,100	166	347	21,336	.10	.12
June	1,427	70	245	14,578	.07	.08
July	3,370	46	382	23,488	.12	.14
August	370	36	76	4,673	.02	.02
September	1,160	40	120	7,141	.04	.04
October	133	40	56	3,443	.02	.02
November	76	46	51	3,035	.02	.02
December	60	46	53	3,259	.02	.02
The year	3,370	36	168	121,612	.05	.67
1901. [b]						
January	71	47	56	3,443	.017	.020
February	115	55	74	4,110	.022	.023
March	122	51	76	4,673	.023	.027
April	3,580	85	470	27,967	.142	.158
May	315	60	112	6,887	.034	.039
June	2,680	37	376	22,374	.114	.127
July	51	22	31	1,906	.009	.010
August	153	25	47	2,890	.014	.016
September	85	40	53	3,154	.016	.018
October	60	37	47	2,890	.014	.016
November	65	40	53	3,154	.016	.018
December	65	47	57	3,505	.017	.020
The year	3,580	22	121	86,953	.036	.492

[a] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 335.
[b] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 142.
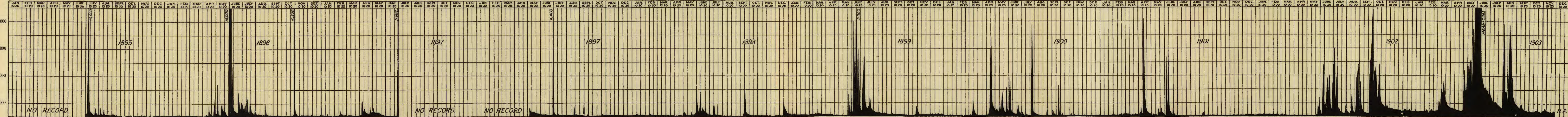
A. HYDROGRAPH OF SALINE RIVER NEAR SALINA, KANS.
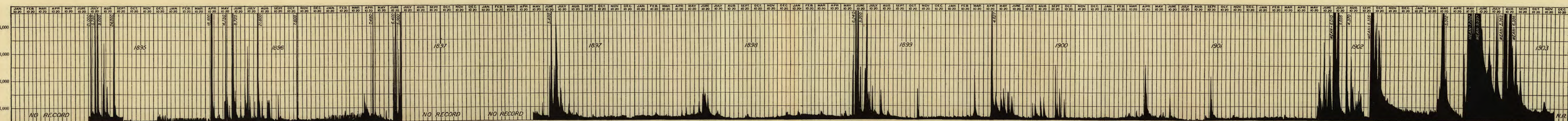
B. HYDROGRAPH OF SOLOMON RIVER AT NILES, KANS.
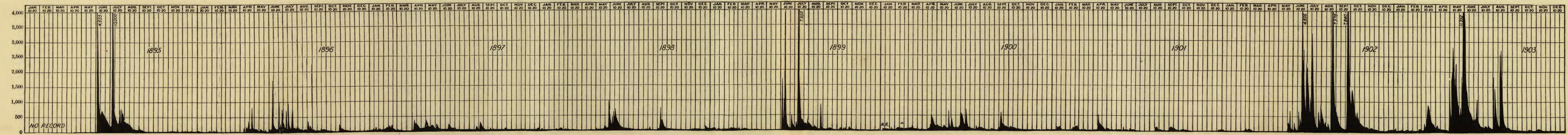
C. HYDROGRAPH OF SMOKY HILL RIVER AT ELLSWORTH, KANS.

Estimated monthly discharge of Saline River near Salina, Kans.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1902.*a*				·	￠	
January	90	45	64	3,935	0.019	0.022
February	70	41	60	3,332	.018	.019
March	75	34	45	2,767	.014	.016
April	41	25	35	2,083	.011	.012
May	698	25	112	6,886	.034	.039
June	1,892	70	792	47,127	.239	.267
July	2,507	110	621	38,184	.188	.217
August	1,910	100	512	31,482	.155	.179
September	3,920	110	874	52,007	.264	.295
October	3,920	364	1,089	66,960	.329	.379
November	424	250	305	18,159	.092	.103
December	275	190	234	14,388	.071	.082
The year	3,920	25	395	287,310	.120	1.630
1903.						
January	240	180	205	12,605	.062	.071
February	280	140	207	11,496	.062	.064
March	1,336	210	628	38,614	.190	.220
April	340	220	271	16,126	.082	.091
May	7,580	910	2,685	165,094	.810	.930
June	7,895	835	2,873	170,955	.870	.970
July	985	332	533	32,773	.160	.180
August	3,410	458	1,434	88,173	.430	.500
September	472	207	322	19,799	.097	.108
October	262	168	212	13,035	.064	074
November	304	168	223	13,270	.067	.075

a Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 110.

The hydrograph for this stream at this station is shown on Pl. XIII, *A.* The mean monthly flow is seen to be very small, being only 20 second-feet in August, 1898. The maximum is very large, and usually occurs between May 1 and July 31. The monthly run-off per square mile varies from less than 0.01 to 0.87 second-foot. The yearly run-off per square mile varies from 0.03 to 0.120 second-foot for the years with complete record. The maximum monthly discharge is 143 times the minimum monthly discharge.

The station on Smoky Hill River is at a highway bridge in Ellsworth.   It was established April 17, 1895, and has been maintained continuously from that time to the present.   The channel is about 180 feet wide at ordinary stage and nearly straight for 200 feet above and below the station.   The bed is mainly sandy material and somewhat changeable.   Velocity is moderate at ordinary stages.   The surface fluctuations are read from the vertical gage bolted to one of the bridge piers.

The run-off results obtained at this station are given in the following table:

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans.

[Drainage area, 7,980 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1895. [a]						
April 17–30	14	11	12	336	0.002	0.001
May	20	9	11	676	.001	.001
June	4,900	10	690	41,058	.086	.096
July	21,000	202	1,438	88,420	.180	.208
August	344	65	186	11,437	.023	.027
September	135	19	44	2,618	.006	.007
October	22	14	18	1,107	.002	.003
November	19	12	18	1,071	.002	.003
December	22	11	17	1,045	.002	.003
1896. [a]						
January	57	17	25	1,537	.003	.004
February	49	18	26	1,496	.003	.004
March	21	14	18	1,107	.002	.002
April	800	14	130	7,736	.016	.018
May	116	18	62	3,812	.008	.009
June	1,713	72	313	18,625	.039	.044
July	951	119	230	14,142	.029	.033
August	372	66	115	7,071	.014	.016
September	117	50	72	4,284	.009	.010
October	255	25	54	3,320	.007	.008
November	122	20	54	3,213	.007	.008
December	43	18	34	2,337	.004	.005
The year	1,713	14	95	68,680	.012	.161

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 214.

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans.—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.[a]						
January	153	22	68	4,198	0.008	0.010
February	213	35	122	6,798	.015	.016
March	77	22	35	2,164	.004	.005
April	385	35	158	9,401	.020	.022
May	385	87	173	10,624	.022	.025
June	240	35	87	5,153	.011	.012
July	97	19	38	2,336	.005	.006
August	295	15	95	5,854	.012	.014
September	130	15	40	2,386	.005	.006
October	97	10	32	1,949	.004	.005
November	77	15	38	2,285	.005	.005
December	107	19	38	2,337	.005	.006
The year	385	10	77	55,485	.010	.132
1898.[b]						
January	70	18	36	2,214	.005	.005
February	95	21	47	2,610	.006	.006
March	32	16	24	1,476	.003	.003
April	37	15	20	1,190	.003	.003
May	1,000	32	136	8,362	.017	.020
June	717	78	281	16,721	.035	.039
July	78	18	43	2,644	.005	.006
August	105	15	25	1,537	.003	.004
September	763	14	131	7,795	.016	.018
October	55	18	30	1,845	.004	.004
November	42	18	19	1,131	.002	.003
December	147	24	53	3,259	.006	.007
The year	1,000	14	70	50,784	.009	.118
1899.[c]						
January	75	14	44	2,705	.0055	.0063
February	84	42	63	3,499	.0079	.0082
March	75	19	40	2,460	.0050	.0058
April	35	10	20	1,190	.0025	.0028
May	23	10	11	676	.0014	.0016

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1897, p. 347.
[b] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 4, 1900, p. 315.
[c] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 225.

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans.—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1899.						
June	3,890	10	492	29,276	0.0617	0.0688
July	7,947	56	832	51,158	.1043	.1202
August	862	42	152	9,346	.0190	.0219
September	75	19	46	2,737	.0058	.0064
October	124	14	48	2,951	.0060	.0069
November	42	19	30	1,785	.0038	.0043
December	35	19	27	1,660	.0034	.0039
The year	7,947	10	150	109,443	.0189	.2571
1900. [a]						
January [b]	97	40	49	3,013	.006	.007
February [b]			60	3,332	.008	.008
March [b]	183	40	66	4,058	.008	.009
April	594	35	156	9,283	.020	.022
May	660	77	147	9,039	.018	.021
June	616	87	241	14,340	.030	.033
July	705	35	117	7,194	.015	.017
August	97	18	47	2,890	.006	.007
September	616	18	140	8,331	.018	.020
October	144	40	78	4,796	.010	.012
November	40	22	28	1,666	.004	.004
December	26	18	21	1,291	.003	.003
The year			96	69,233	.012	.163
1901. [c]						
January	120	18	50	3,074	.006	.007
February	165	20	72	3,999	.009	.009
March	50	20	33	2,029	.004	.005
April	662	23	124	7,378	.016	.018
May	81	23	47	2,890	.006	.007
June	142	23	48	2,856	.006	.007
July	18	5	9	553	.001	.0)1
August	143	5	46	2,828	.006	.007
September	142	12	62	3,689	.008	.009

[a] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, p. 336.
[b] Approximate.
[c] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey, 1903, p. 143.

Estimated monthly discharge of Smoky Hill River at Ellsworth, Kans.—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.						
October	73	14	36	2,214	0.005	0.006
November	14	8	11	655	.001	.001
December	50	12	22	1,353	.003	.003
The year	652	5	47	33,518	.006	.080
1902.[a]						
January	55	17	24	1,475	.003	.003
February	100	17	38	2,110	.005	.005
March	290	19	39	2,398	.005	.006
April	23	15	18	1,071	.002	.002
May	700	13	87	5,349	.011	.013
June	4,856	40	821	48,853	.103	.115
July	3,267	137	891	54,785	.112	.129
August	7,375	62	1,021	62,779	.128	.148
September	7,840	100	1,033	61,468	.130	.144
October	1,390	187	588	36,155	.074	.085
November	187	62	125	7,438	.016	.017
December	85	40	64	3,935	.008	.009
The year	7,840	13	396	287,816	.050	.676
1903.						
January	131	50	69	4,243	.0086	.0099
February	110	50	65	3,610	.0081	.0084
March	1,410	62	431	26,501	.0340	.0620
April	1,834	62	182	10,830	.0230	.0260
May	11,392	510	2,356	144,865	.3000	.3400
June	3,750	342	937	55,755	.1200	.1300
July	305	120	180	11,068	.2300	.2600
August	2,708	155	735	45,193	.0920	.1100
September	143	50	81	4,820	.0100	.0110
October	92	45	58	3,566	.0073	.0084
November	120	45	70	4,304	.0088	.0098
December	92	36	44	2,705	.0055	.0063
The year	11,392	36	434	317,460	.0723	.9818

[a] Water-Sup. and Irr. Paper No. 84, U. S. Geol. Survey, 1903, p. 112.

The hydrograph of this stream at this station is shown on Pl. XIII, *C*. The minimum monthly flow is seen to have been less than 10 second-feet during July, 1901. The maximum discharge was 1,438 second-feet in July, 1895, which is 160 times the minimum monthly discharge. The monthly run-off per square mile varies from less than 0.001 to 0.18, and the yearly run-off from 0.006 to 0.050 second-feet.

COMPARISON OF FLOOD AND ORDINARY DATA.

In the following table is given a comparison of the ordinary low flow with the flood flow of these streams. The flood flow is seen to be many times larger than the ordinary low-water flow.

Low-water and flood-flow data of streams in Kansas River basin.

Stream and place.	Low-water data.				
	Date.	Gage.		Discharge.	
	1902.				
Kansas, Lecompton, Kans	April	3.00 to 3.40		2,375 to 3,415	
Blue, Manhattan, Kans	do	3.80	4.20	480	560
Republican, Junction, Kans	do	3.60	4.30	510	1,155
Solomon, Niles, Kans	do	4.40	5.50	54	152
Saline, Salina, Kans	do	3.10	3.60	25	41
Smoky Hill, Ellsworth, Kans	do	.75	.95	15	23

Stream and place.	Flood-flow data.		
	Date.	Gage.	Discharge.
	1903.		
Kansas, Lecompton, Kans	May 31	29.5	233,070
Blue, Manhattan, Kans	do	36.5	86,640
Republican, Junction, Kans	May 30	18.2	59,400
Solomon, Niles, Kans	June 1	32.9	12,000
Saline, Salina, Kans	do	33.9	11,200
Smoky Hill, Ellsworth, Kans	May 29	16.0	11,610

The following table gives a comparison of the discharges at the six gaging stations and also the run-off for four months of 1903. The stations are arranged in order from the west to the east. The increase in run-off from the west to the east is clearly shown.

Comparisons of monthly discharge and run-off at gaging stations in Kansas River watershed.

MONTH OF APRIL, 1902.

Stream and place.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maxi-mum.	Mini-mum.	Mean.		Second-feet per square mile.	Depth in inches.
Smoky Hill, Ellsworth, Kans	23	15	18	1,071	0.002	0.002
Saline, Salina, Kans	41	25	35	2,083	.01	.01
Solomon, Niles, Kans	152	54	89	5,296	.01	.01
Republican, Junction, Kans	1,207	510	654	38,916	.03	.03
Republican, Superior, Nebr	740	390	555	33,020	.02	.02
Blue, Manhattan, Kans	560	408	483	28,740	.05	.06
Kansas, Lecompton, Kans	3,415	2,250	2,653	157,864	.05	.06

MONTH OF MAY, 1902.

Stream and place.	Maxi-mum.	Mini-mum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
Smoky Hill, Ellsworth, Kans	700	13	87	5,349	0.011	0.013
Saline, Salina, Kans	698	25	112	6,886	.034	.039
Solomon, Niles, Kans	1,415	38	285	17,524	.04	.05
Republican, Junction, Kans	7,800	482	2,128	130,846	.08	.09
Republican, Superior, Nebr	2,810	335	1,269	78,020	.06	.07
Blue, Manhattan, Kans	17,510	408	2,157	132,629	.23	.27
Kansas, Lecompton, Kans	23,075	2,125	8,435	518,648	.14	.16

MONTH OF JUNE, 1902.

Stream and place.	Maxi-mum.	Mini-mum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
Smoky Hill, Ellsworth, Kans	4,856	40	821	48,853	0.10	0.12
Saline, Salina, Kans	1,892	70	792	47,127	.24	.27
Solomon, Niles, Kans	6,155	316	1,392	82,830	.20	.22
Republican, Junction, Kans	8,400	1,260	3,338	198,625	.13	.15
Republican, Superior, Nebr	3,235	320	1,372	81,640	.06	.07
Blue, Manhattan, Kans	17,510	910	6,298	374,757	.66	.74
Kansas, Lecompton, Kans	28,500	11,110	17,131	1,019,365	.29	.320

MONTH OF JULY, 1902.

Stream and place.	Maxi-mum.	Mini-mum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.
Smoky Hill, Ellsworth, Kaus	3,267	137	891	54,785	0.112	0.129
Saline, Salina, Kans	2,507	110	621	38,184	.188	.217
Solomon, Niles, Kans	7,040	252	2,492	153,227	.37	.43
Republican, Junction, Kans	23,100	840	7,887	484,953	.30	.35
Republican, Superior, Nebr	12,490	970	a3,080	•a189,360	a.14	a.16
Blue, Manhattan, Kans	43,430	4,540	16,886	1,037,050	1.78	2.05
Kansas, Lecompton, Kans	81,400	11,450	38,291	2,354,422	.65	.75

METHODS FOR PREVENTING DAMAGE BY FUTURE FLOODS.

It must be remembered that the storm that caused the flood on Kansas River was not a local one of short duration, but extended over a considerable portion of six States and Territories and lasted nearly half a month. The storm was brought about by a rare combination of atmospheric pressure, temperature, moisture, and wind

velocity. Each of these was practically at or near its maximum influence at the time. There is no reason why this combination of rainfall factors may not occur again, and when it does occur a storm of approximately the same magnitude may be expected. Nothing whatever can be done to prevent its occurrence. It is sixty years since the last great flood, but there is no way of predicting when the next one will occur.

Although nothing can be done to prevent the occurrence of such a storm, much can be done to lessen the height of the resulting flood and the loss of property due to it. It is self-evident that to reduce the magnitude of a flood we must in some way either store the water that falls or hasten its flow from the drainage area, or both.

SURFACE AND GROUND STORAGE.

Nature has two ways of storing water, viz, on the surface of the ground and in the ground. In mountain regions water is stored for several months as snow and ice, and in the early summer passes down the streams. In regions of higher temperature surface water is stored in lakes, ponds, and swamps. Where streams are fed from mountain snow or lakes the distribution of flow throughout the year is very different from that of streams without surface storage. Surface storage in some sections of the country is vastly greater than that in others. In Maine, for example, there is 1 square mile of lake and pond area to every 14.3 square miles of land area. In other words, 7 per cent of the surface is natural water storage. On the prairies of the Kansas River watershed the natural surface storage is so small that it amounts practically to nothing.

EFFECT OF GROUND STORAGE ON FLOW OF STREAMS.

A rainfall of a depth of, say, 2 inches on a watershed disappears in three ways. A part flows over the surface and forms what is called surface run-off. A second part evaporates, thus passing off unseen from the surface of the ground and from pools of water. A third part sinks into the ground and is held for a greater or less time, but eventually is either absorbed by vegetation and passes off into the air through leaves or percolates through the ground into the streams. The total run-off—that which is left of the rainfall after the loss by evaporation and plant growth—varies from about 50 per cent in the eastern part of the country to almost nothing in the arid portions.

The amount of water that the soil will hold when saturated or full, depends on its porosity and depth. Let us suppose that the ground at a certain place is composed of a 6-foot layer of sand whose porosity is 33⅓ per cent. Each foot in depth of this material will contain, when fully saturated, 4 inches of water, and the 6-foot layer will contain 2 feet depth of water. It will rarely be possible to store, even in sand, this amount of water, because it is seldom empty. It always holds back or contains some water.

miles.   The ratio of 455,348 to 58,550 shows the average number of acre-feet of water flowing on May 31 from each square mile of the whole drainage of Kansas River.   In other words, if there had been a storage reservoir 1 acre in area and 7.8 feet deep on every square mile of the whole Kansas River drainage basin the water flowing down Kansas River on May 31 would have filled every one of them.   If on each half section of the whole of the Kansas River basin there had been a reservoir 1 acre in extent and 4 feet in depth the water flowing in Kansas River on May 31 would have been sufficient to nearly fill each one of them.

RAPID REMOVAL OF WATER.

Water that can not be held back for some days by storage should be passed out of the watershed as rapidly as possible if the danger of floods is to be reduced to a minimum.   Anything that retards the flow backs up the water and causes a rise in the river and consequent overflow of area.

Dams and river bends have a decided retarding effect.   The water has a longer distance to travel by reason of the bends and thus a longer time is necessary for it to pass out of the watershed, and the velocity of the water is reduced by striking the bank at each bend.

Bridges across a stream are sometimes a very fruitful cause of increasing high water.   They restrict both the width and depth of the waterway.   The partial or total destruction of nearly all the bridges across Kansas River is very positive evidence of this fact.   The Engineering News of September 17, 1903, contains the following in regard to the restriction in width of Kansas River at Kansas City:

The Kaw [Kansas] River near the mouth has been gradually encroached upon for years, the abutting property owners filling in and reclaiming the land for industrial purposes.   The normal width of the river from bank to bank is about 800 feet.   At the James street bridge, just above the mouth, this channel has been narrowed down to about 450 feet between abutments.   The effect of this construction is also shown by the fact that the high-water mark at the Turkey Creek pumping station, about 2 miles above the mouth of the river, was 10 feet above that at the mouth.   If the river had been given its natural width through the city, the water would not have risen so high by from 6 to 8 feet in the upper districts as it did under the existing conditions.   It is evident that the clear channel of the Kaw should be made from 800 to 1,000 feet wide from Argentine to the Missouri River.   .

A channel 200 feet wide was cut around the north end of the bridge at Lawrence by the flood.   This channel is being closed by an embankment.   The closing of this opening by a solid structure, thus reducing the waterway to its old dimensions, which the flood has shown to be too small, is ignoring one of the obvious lessons of the flood.   It would have been better to have built a structure here with gates for holding back the water for power purposes, which could have been opened in time of flood to give a larger waterway.

The masonry arch bridge across the Kansas at Topeka is a good example of the evil resulting from restricting too much the waterway. The flood passed several feet in depth over both abutments of this bridge, washing out one of them and badly damaging the bridge and the other abutment. The old bridge at this place had six spans of 150 feet each; the present masonry structure has reduced the waterway nearly one-half, and has had much to do with the overflow at Topeka. There are several new bridges across the Kansas that restrict its flow much more than the old ones. The small saving in the cost of a bridge by reducing its length 100 feet is paid many times over in the loss of property caused by the overflow due to restricting the waterway. A very obvious means of reducing the height of future floods is to widen the channel in the cities through which the river passes. The minimum width and the number and size of bridge piers should be prescribed by law.

This flood has shown that many of the bridges across Kansas River before the flood were too low. The new ones should be higher than the old ones or of a design such that the bridge can be raised or swung out of the way during very high water and leave a clear channel for drift to pass.

CUT-OFFS AND OVERFLOW CHANNELS.

The effect of a cut-off is to shorten the distance traveled by the water, to reduce the loss of head due to friction, to increase the velocity of flow, and thus to reduce the height of the flood. If the bed and banks are composed of firm material that will not be worn away by the current, this plan works well, but for rivers flowing through alluvial material, such as Mississippi, lower Missouri, and Kansas rivers, this remedy is only temporary. The increased velocity will cause additional scours and the formation of new bends. Thus this process will continue until the river is restored to its former length. The studies of Humphrey and Abbott, and other engineers, of the Mississippi prove conclusively that this plan is not a good one for rivers flowing through alluvial bottoms.

Overflow channels increase the high-water waterway of the river and thus reduce the height of flood. They are equivalent to widening the main channel. Increasing the area of the main channel for a given amount, say 1,000 square feet, is, as a rule, more effective than one or more overflow channels of the same total area.

LEVEES.

Levees are proposed as a remedy for floods. This method is used on the Mississippi for securing the land against inundation. It was begun in 1717 at New Orleans by riparian owners and carried on until 1850 by the States through which the river passes. Since this date levee building has been carried on by cooperation of the State and National governments. All of the engineers who have made a

study of methods of preventing floods in the Mississippi basin recommend this as the only feasible method of accomplishing the desired result. The levees or earth banks on each side of the river approximately parallel to the course of the stream, limit the width of the stream, increase somewhat the velocity and consequent scour, and the height of high water.

Three objections are raised to the use of levees: First. That they can not be made strong enough. Second. The cost is too great. Third. They raise the bed of the river by depositing in it the silt that otherwise would be deposited on the flooded land.

It is difficult to see how the third objection can be true. The increased velocity will cause a scour rather than a deposit of material on the bed. Furthermore, a careful study of the effect of the levees along Mississippi River fails to show any appreciable rise in the bed of that river.

The numerous and frequent breaks in the levees during the floods apparently show that there may be some truth in the first objection. This is only apparent, however, as earth embankments can be made so strong and durable that they will not fail and so high that the greatest floods can not pass over them. Many earth dams and embankments have been built much higher than any of the levees and have stood the test of many years. The strength and durability of such a structure is only a matter of cost.

Whether or not the levee method of preventing inundation of the Kansas River bottom is feasible can be definitely decided when the cost and benefits to be derived are known. Ordinary floods cause overflow of some of the bottom lands along the river. The flood of 1903 was 17 feet higher than ordinary floods, so that the levee will need to be 20 feet high in some places. The cost per mile in length of an embankment of this height, with a top width of 5 feet and side slopes of 2 horizontal and 1 vertical, will be as follows, assuming the cost to be 20 cents per cubic yard:

$$\frac{900 \times 5280}{27} \times .20 = \$35,200.$$

If the embankment is only 10 feet high, 3 feet top width, side slopes of 2 horizontal to 1 vertical and the cost per cubic yard 20 cents, the total cost per mile of the embankment will be \$8,993.

The benefits to be derived will scarcely justify either of these expenditures except at or near cities.

SUMMARY.

The highest recorded flood at St. Louis occurred in 1785. The flood of 1844 came within 1 foot of the height reached in 1785, and the flood of 1903 came within about 3 feet of the stage of 1785.

The highest flood on record at Kansas City was in 1844. The flood

of 1903, although it did not reach that height, was vastly more destructive on account of the country being more thickly settled and improved.

The Kansas River gage records at Lawrence and Lecompton cover a period of twenty-two years. The flood of May and June, 1903, was 17½ feet higher than at any other time within this period. The volume flowing in Kansas River on May 31 was nearly three and a half times larger than that at any time during these twenty-two years.

The period of excessive rainfall extended from May 16 to May 31. Water fell to a depth of 10 inches in some places during this time. The rainfall at some of the stations for the whole month of May was 17 inches, so that the precipitation for the first half was above the normal, the ground was well supplied with moisture, and the flow of the streams was above the normal. The mean annual rainfall of the Kansas River basin varies from about 35 inches in the eastern part to 12 inches in the western part. About 14 per cent of this mean annual rain falls in May, but in May, 1903, nearly 50 per cent of the mean annual rainfall occurred.

The drainage area of Kansas River is a long narrow strip between the Platte and the Arkansas River drainage areas. It is rolling prairie without mountains, with broad, shallow valleys, fertile soil, and very little forest. There is very little service storage, but the ground will absorb a large quantity of water. The flood flow of the stream is large and the minimum flow small, as compared with streams in the eastern half of the United States.

The Kansas River bottom is mainly sandy, alluvial material from 1 to 4 miles in width; the banks as a rule are not more than 10 feet in height and are easily eroded by the current.

For eleven days, May 28 to June 7, inclusive, the water was from 1 to 12 feet higher at Lecompton than it had been before in twenty-two years; and for twenty days, May 23 to June 11, it was from half a foot to 17½ feet higher than ordinary high water. The whole river bottom was flooded, crops were destroyed, stock drowned and swept away; railroads were under water, partly washed away and undermined; wooden buildings were lifted from their foundations and swept down the stream; brick and stone buildings crumbled and fell; bridges were swept away and cities left without drinking water, light, or power; traffic was almost entirely suspended for two weeks. The property loss in Kansas and Kansas City is estimated to have been $22,000,000.

Nothing can be done to prevent the recurrence of a storm like the one from May 16 to 31, 1903, which caused this enormous loss, and no person can predict the time of occurrence of the next one.

To reduce the magnitude of the resulting flood, the rainfall must quickly be passed out of the watershed or stored in it. The opportunities for surface storage in the Kansas River basin are small, for the

valleys and depressions are broad and shallow, the amount that can be stored small, and the cost of storage large. On the headwaters, where the possibility of storage is greatest, the rainfall is smallest. By a glance at the map it will be seen that nearly all of the rain that caused this flood fell on the lower half of the watershed, where the possibilities for surface storage are the least.

If there had been a reservoir 1 acre in extent and 4 feet in depth on each half section of land in the whole Kansas River basin, the volume of water flowing down Kansas River on May 31 was sufficient to have nearly filled all of them.

Ground storage in the Kansas River basin is large; it can be increased by cultivation of the soil and growth of forests. Not more than 7 per cent of the rainfall on this drainage area appears as run-off in ordinary years; the remaining 93 per cent disappears as evaporation directly from the surface and indirectly through plant growth.

Any obstruction in the form of a dam, bend in the channel, or reduction of the normal width retards the flow and increases the magnitude of a flood. The partial destruction of nearly all the bridges across Kansas River is positive evidence that they restricted the flow too much. The normal width of Kansas River at Kansas City has been reduced nearly one-half, and as a result the recent flood was about 10 feet lower at the mouth than about 2 miles up from the mouth.

Reducing the length of the channel by straightening it will reduce the magnitude of the flood, but in alluvial bottom land the increased velocity causes scour and the formation of new beds, so the remedy is only temporary.

Overflow channels give an additional waterway and reduce the height of floods, but are seldom practicable.

Levees have proved to be the best means of preventing inundation in the Mississippi River basin; they do not reduce the height of floods, but simply prevent overflow. The cost of levees sufficiently high and durable to prevent overflow of the Kansas River bottom during a flood of the magnitude of that of 1903 would be too expensive to build except in and near cities.

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Author.

Murphy, E[dward] C[harles]

. . . Destructive floods in the United States in 1903, by E. C. Murphy. Washington, Gov't print. off., 1904.

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