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A STUDY OF IOWA RIVER FLOODS

AT IOWA CITY

by

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AT IOWA CITY

INTRODUCTION

A knowledge of the floods to be expected on a river and the frequency with which they occur is very valuable at times, especially to those who live near the river and to those who have occasion to work with it. For instance, a man living on the bottom lands might be interested to know that he could expect to have his fields covered once in five or six years. He could then balance the loss of an occasional crop against the increased fertility of the soil.

A much more important application of flood frequencies, however, occurs in the work of the engineer. Suppose he is building a bridge across the river, to stand fifty years before being replaced. He wishes to build his approaches high enough so that the water will not overflow them and wash them away, and also far enough apart so that the water can flow between them without raising the water level upstream and with velocities which will not scour. In order then, to design his bridge intelligently, the engineer

must know how large a flood to expect in the average fifty-year period.

Another application of more immediate interest to people in Iowa City, is the case of buildings located near the river, such as the new Memorial Union building. The question arises, will the river ever rise high enough to flood the basement, or the first floor, and how often may this be expected to happen? A knowledge of the frequency of floods on the river will enable the engineer to answer these and similar questions.

Thus far, there has been considered the flood to be expected on the average, in a given interval of time. Suppose now, that there is a heavy rain, and the river begins to rise. People living along its banks want to know to what maximum height it may be expected to rise. A study of the floods that have already occurred on the river, related to the rainfall causing them will furnish data for the answer to this question.

It is the purpose of this paper to study the floods of the Iowa River, their occurrence at Iowa City, and the rainfall preceding them in order to answer such questions as those suggested above.

DEFINITION OF TERMS USED

In order to avoid confusion, it is necessary to define some terms used in the discussion.

The term flood has been applied only to flows of water in the Iowa River at Iowa City in which more than 7,000 cubic feet per second is being discharged.

Discharge, as used in this paper, unless otherwise specified, will mean the greatest average daily discharge for any flood, measured in cubic feet per second.

The unit of discharge will be the cubic foot per second and will hereafter be abbreviated to sec. ft.

Frequency (of a flood of given size) will be understood to mean the average probable interval of time between the occurrence of the flood in question and another flood as large or larger.

Time of concentration is the time elapsed from the time of maximum rainfall until the time of maximum discharge.

SOURCES OF DATA

In collecting the flood data presented, the most natural source was the flow records of the United States Geological Survey as reported in the

Water Supply Papers. These are available for the Iowa River at Iowa City for the period beginning June 1, 1903 and ending July 21, 1906, and also for the period beginning November 1, 1913 and continuing to date, August 1, 1926. The gap from July 1906 to November 1913 was filled, with the exception of sixteen months from July 1906 to November 1907, by computation from the records of the State University's hydroelectric plant at Iowa City. Crest heights for the floods occurring in 1907 were obtained from the records of Mr. Curtis Dey (given in full at another place). Thus a continuous record of floods of considerable accuracy is available for a period of twenty-three years.

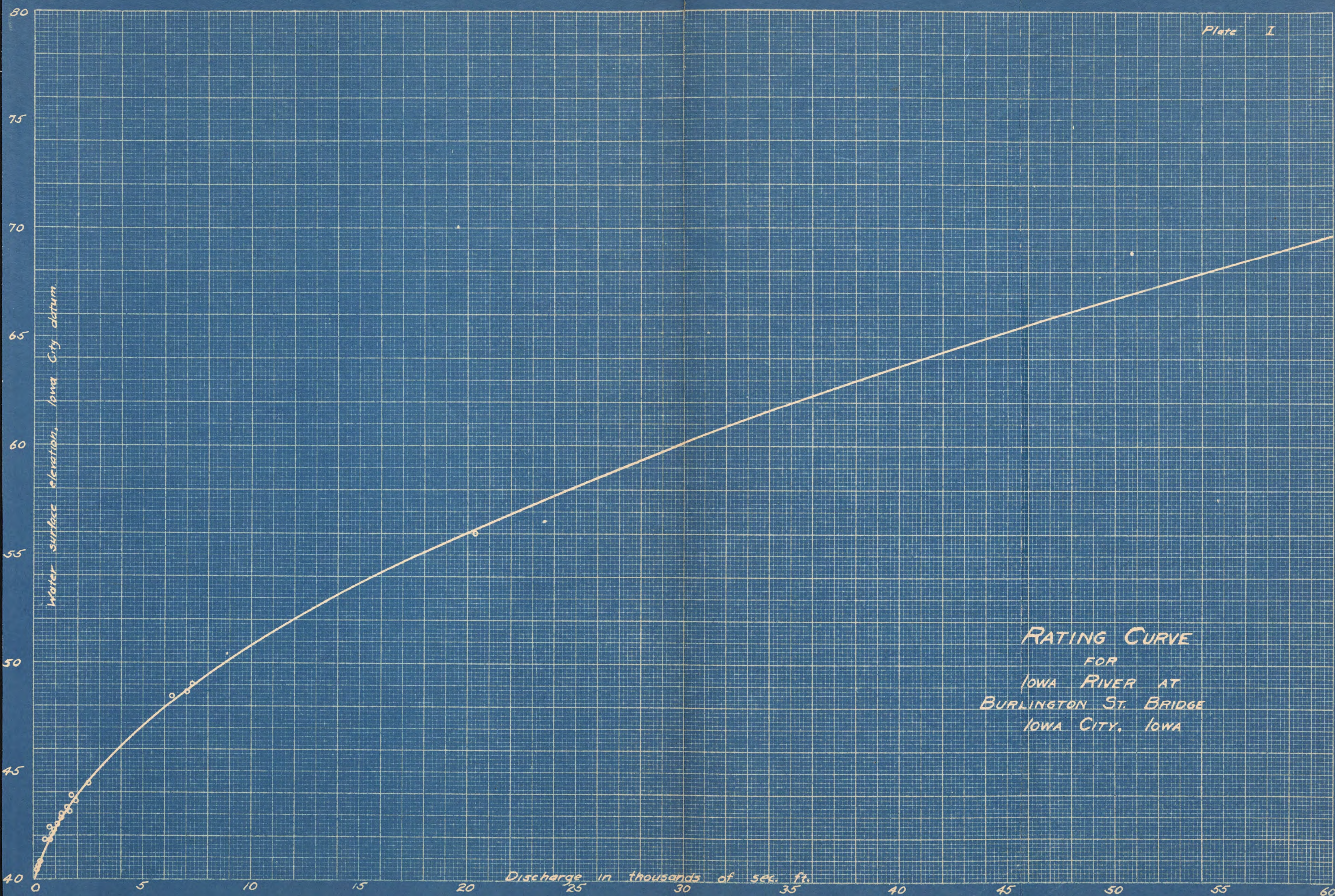
Old settlers have been interviewed and newspapers have been consulted but data obtained from these sources are very unsatisfactory. Too often the only record kept of floods was in the memory which is very apt to be faulty with respect to details. Where memory is confirmed by marks or notes made at the time of the flood, the record may be considered reliable. Nails in roots of trees, marks on buildings, and the records of a diary were accepted as fairly accurate. Great care was taken, however, to make sure that other conditions had not greatly changed before making such data the basis of extended estimates.

For example, at Coralville the 1913 flood rose seven inches higher than the 1881 flood while the 1881 flood was actually greater than the one of 1913. The reason is that at Coralville, in about 1910, the natural flood channel was partly closed by rock and earth fills.

Newspaper records proved unsatisfactory because they were written for their news value and often contain no record of value to those who did not witness the event. Newspaper records are of value in one respect however; they serve to determine accurately, dates of occurrence.

Rainfall records were obtained for the flood of 1881 from the Report of the Iowa Weather Service for that year, and for the period from July 1909 to December 1913 from the Monthly Weather Review. From January 1914 to date, rainfall records have been taken from the Report of the Weather Bureau, U. S. Dept. of Agriculture.

Other miscellaneous information was obtained from the Reports of the Iowa Weather Service and from a History of Johnson County published in 1883 and from another History of Johnson County, by Clarence Ray Aurner, published in 1912.



RATING CURVE
FOR
IOWA RIVER AT
BURLINGTON ST. BRIDGE
IOWA CITY, IOWA

RATING CURVE

In order to estimate the quantity of water flowing in the river for any given elevation of the water surface, it is necessary to know the relation between elevation and discharge. A rating curve showing this relation has been prepared for the Iowa River at the Burlington St. bridge at Iowa City, on the basis of gagings made by the U. S. G. S. during 1903-1906. This is the earliest available rating curve for the river and is used throughout this paper on the assumption that it applies, roughly at least, as far back as 1851. Gagings were available for discharges ranging between 200 sec. ft. and 20,400 sec. ft. The curve was extended by three methods, and the mean of the three used. The extensions agreed remarkably well with each other, the difference not exceeding one per cent. The curve is shown in Plate I with elevations referred to Iowa City datum. The curve does not conform exactly to the rating tables published in Water Supply Papers by the U. S. G. S. but is an independent curve obtained by consideration of all gagings made in the period 1903-1906. The largest discharge measured was published as 18,300 sec. ft. but was subsequently corrected to 20,400 sec. ft. The corrected value was used in constructing the curve of Plate I.

FLOODS SINCE 1903

Table I contains a list of the floods occurring since 1903. These data were all taken from U. S. G. S. records or from S. U. I. hydroelectric plant records with the exception of that for 1907 which was obtained from Mr. Dey. Hydrographs for all these floods with the exception of the one in 1907 will be found on Plates VIII to XXX inclusive.

TABLE I

LIST OF FLOODS SINCE 1903

Date of Flood	Maximum Discharge (sec. ft.)	Maximum Instantaneous Discharge (sec. ft.)
1903, June 3	21,800	
1904, March 25	8,400	
1905, May 24	8,700	
1905, June 10	8,100	
1906, March 2	11,900	
1906, April 3-6	8,100	
1907, July 15	13,000	
1909, July 7	12,400	
1910, March 9	9,500	12,600
1911, February 17	9,600	17,200
1912, April 3?	19,600	
1913, March 21	7,000	

TABLE I (CONTINUED)

Date of Flood	Maximum Discharge (sec. ft.)	Maximum Instantaneous Discharge (sec. ft.)
1914, September 15	9,300	
1915, February 18, 24-25	20,000	
1915, June 4-5	9,300	
1915, August 2	9,200	
1915, September 30	11,500	
1916, March 26	10,500	12,300
1917, June 16?	17,500	
1918, May 27	14,200	
1918, June 8	35,300	36,200
1919, March 20	9,000	
1919, April 27	7,500	
1919, May 7	12,800	
1920, March 17-18	8,100	
1921, September 23	14,300	
1923, April 7	8,400	8,700
1924, June 8	7,500	8,900
1924, July 1	19,100	20,100
1924, July 27	9,100	9,800
1926, Sept 23	17,400	17,500

FLOODS PRIOR TO 1903

In discussing these floods, the data obtained will be given in full.

DATA OBTAINED FROM OLD INHABITANTS

Mr. John Davis, Coralville. Age, 92.

In 1864 or 1865, the river was very high. At this time a Mississippi steamer ascended the Iowa River, crossed the Terrell dam at Iowa City, and loaded at the Coralville mill.

The flood of 1881 was 7 inches lower than the flood of 1918 which came just to the floor of Mr. Davis' house. Upstream near the Mahaffy bridge, the flood of 1881, according to reports he heard from people living near there at the time, was from 12 to 18 inches higher than the flood of 1918. He explains this as being due to the filling of a natural flood channel which discharged part of the 1881 high water into Clear creek by way of the low ground to the west of Coralville, to the building of the levee on the east side of the river, and to the raising of the dam proper.

During the flood of 1881, a steam launch which was kept near Butler's bridge, steamed down through the streets of Coralville and on down the river to Iowa City. The operator returned just in time to

get over the Coralville dam safely.

Mr. Curtis Dey, Iowa City. Age, about 50.

The greater part of Mr. Dey's notes refer to floods later than 1903 but are all included at this point.

High Water, 1881, marked by a nail in root of a tree about 30 feet south of Dey's boathouse.

Elevation, 63.28

High Water, 1918, marked by three nails on corner of boathouse. Elevation, 63.18

High Water, 1903, near site of Park bridge,
(from McGowan's notes) Elevation, 57.60

Mr. Dey also furnished the gage readings of Table II. The gage is located on the corner of the boathouse just back of the Dey residence on north Clinton St. The zero of the gage is set at elevation 49.00 . This is the elevation of the crest of the University dam, so the gage heights of the following table, after being corrected for fall between the boathouse and the dam, give elevations over the crest of the dam.

TABLE II

GAGE READINGS AT DEY'S BOATHOUSE

Date	G. H.	Date	G. H.	Date	G. H.
6-10-07	3.6	3-1-15	4.0	7-30-15	2.9
7-11-07	4.5	3-2-15	3.5	7-31-15	2.9
7-15-07	5.2	3-3-15	3.0	8-1-15	3.7
7-20-07	4.8	5-29-15	3.3	8-2-15	4.3
6-3-08	3.0	5-30-15	3.1	8-3-15	4.1
7-7-09	5.0	5-31-15	3.0	8-4-15	3.4
2-7-11	6.5	6-1-15	3.1	9-26-15	4.7
4-3-12	8.5	6-2-15	3.5	9-27-15	4.9
9-15-14	3.0	6-3-15	4.4	9-28-15	4.1
2-14-15	5.5	6-4-15	4.5	9-29-15	4.7
2-18-15	5.5	6-5-15	4.5	9-30-15	5.9
2-19-15	5.7	6-6-15	4.2	10-1-15	5.6
2-22-15	5.1	6-7-15	3.9	10-2-15	5.2
2-23-15	5.5	6-8-15	3.7	10-3-15	5.0
2-24-15	5.8	6-9-15	3.5	10-4-15	4.8
2-25-15	5.9	6-10-15	3.3	10-5-15	4.3
2-26-15	6.0	6-11-15	3.0	10-6-15	3.8
2-27-15	5.8	7-27-15	3.2	10-7-15	3.6
2-28-15	5.0	7-28-15	3.8	10-8-15	3.3
		7-29-15	4.1		

Mr. George Folsom, Iowa City. Age, about 70.

There was a high water in August, 1869. In 1881 was the highest flood on record, as far as he knew. In 1892 or 1893, in the spring, there was a high water, perhaps larger than the flood of July, 1924.

Mr. Chas. Ryerson, Iowa City. Age, about 65.

There have been three large floods that he knows of. One in 1851, one in 1881, and one in 1918. At the time of the flood of 1881, which occurred just thirty years after the flood of 1851, the old settlers remembered that the Indians told them there would be a flood of that size every thirty years. The next one was looked for in 1911, but it failed to arrive until 1918, seven years late. He had no record of the height of the flood of 1851 but marks in his kitchen indicate the high waters of 1881 and 1918. The crest of the 1881 flood was just 18 inches higher than the crest of the 1918 flood. Mr. Ryerson is of the opinion that the floods in earlier years were much more frequent than now, especially in the spring. He attributes this to the fact that the ice being held back by dams and bridges, cannot go out with the violence with which it used to and consequently cannot form a jam or gorge to hold the water back and flood the flats upstream. He is also of the opinion that the rains are less heavy than they were years ago, at

least, that we are now having a period of years in which the rainfall is less.

Mr. R. E. Jones, Iowa City. Age, about 75.

Mr. Jones remembers three large floods. There was one during the Civil war, (he cannot remember the date) one in 1881 and one in 1918. He did not live near the river and did not pay much attention to it.

DATA OBTAINED FROM OTHER SOURCES

Iowa City Republican for 1881

July 11. "The river is up again today. This morning it was only two or three inches lower than during the flood of three weeks ago. The bottoms below town were inundated and back yards were in danger."

July 13. "The north bridge was filled with people while the road leading to it was alive with people going and coming constantly. The gauge under this bridge marked 17 feet above low water at 9 o'clock in the morning. The road leading to the south bridge being lower than the one further north was covered with water to a depth of about two feet."

July 14. "On Dubuque street, from the corner

of Lafayette to Wyoming road, there is at least two feet of water in the middle of the street. The west end of Court street and the north end of Madison street are also flooded."

"The river at 1 o'clock had fallen about one inch and since then it has been steadily falling."

History of Johnson County. 1883.

"In the spring of 1844 while the Coralville dam was being built, a rapid rise of the river brought down a great amount of ice and part of the dam was lost."

Page 534. "January 10, 1876, in response to a request from the Iowa Weather Service, the county board ordered a water gauge to be constructed 'at or near the free bridge' at Iowa City, provided the cost should not exceed ten dollars. This is the bridge at the foot of Burlington street."¹

Page 535. "The greatest amount of rain in any one year of which we have any record was in 1851 when it amounted to a little over six feet (74.49 inches)."

Page 536. "In the year of 1851, there were 17 rainy days in May, 21 in June, and 15 in July. In 1853, May had 21, June 6, and July 16 rainy days

.....The noticeable difference in the seasons of 1851 and 1858, was that in the former, the rain came in showers and fell in torrents, with much sunshine between the showers, while in the latter, the rain fell more continuously with a great deal of cloudiness."

History of Johnson County, Vol. I. 1912

Page 198. "A freshet in the spring of 1849 took the Clear creek bridge away bodily."

Page 199. "There was a great freshet in June, 1851 which caused the commissioners to meet in extra session to consider means by which the destroyed bridges on the main roads could be repaired."

Report of the Iowa Weather Service for 1881

March. "At Iowa City, the Iowa river rose 13 feet above the ordinary level, surrounded one of the mills and submerged river roads, but none of the dams were injured, nor any of the great bridges seriously damaged."

June. 28th "The Iowa river rose 6 feet during the night."

July. "The flood resulting was highest at

Marshalltown and Des Moines on the 12th, at Iowa City on the 14th, at Ottumwa on the 15th. The rich bottom land skirting our rivers in central and southeastern Iowa was all under water, and nearly all crops on these lands were destroyed. Also immense damage was done to roads and bridges, and much village and city property was lost.

The flood was highest in the Iowa river. At Iowa City, it reached a level but about 3 feet below that attained by the flood of 1851, the highest on record for all southeastern Iowa. The flood reached almost up to the top of the piers of the new free bridge of 1876, across the Iowa. The mill property just above the city and at Coralville was much damaged by the river cutting a new channel."

"High water in the Iowa river. 11th: River roads under water, due to local rains. 12th: In P. M. great rise due to water coming down from Marshalltown. Continued to rise until noon of 17th, when highest mark reached, within less than 3 feet as high as in 1851, never been as high between 1851 and now. Water made a lake of territory near Terrell's mill, reaching into kitchen of Terrell's house at foot of hill."

TABLE III

Readings of River Gauge at Centennial Bridge in
Iowa River, at Iowa City, taken by Frank Fletcher,
Ice Merchant.¹

July, 1881

Day	G. H.	Day	G. H.	Day	G. H.
1	8'-0"	11	8'-6"	21	15'-0"
2	8'-0"	12	9'-0"	22	13'-0"
3	8'-0"	13	15'-0"	23	12'-0"
4	8'-6"	14	15'-0"	24	11'-0"
5	8'-6"	15	12'-6"	25	10'-0"
6	8'-6"	16	17'-6"	26	9'-0"
7	9'-0"	17	22'-6"	27	8'-6"
8	9'-0"	18	20'-0"	28	8'-6"
9	8'-6"	19	18'-6"	29	8'-6"
10	8'-0"	20	17'-0"	30	8'-0"
				31	8'-0"

October. "28th. River high; 29th, very
high; road near Terrell's mill again under water--
the third time this year."

ESTIMATE OF FLOOD DISCHARGES

Flood of July 1881: The records of Mr. Dey and Mr. Ryerson furnish a basis for estimating the discharge of the flood of 1881. Consider first Mr. Dey's records. The flood of 1903, with a known discharge of 21,800 sec. ft. reached elevation 57.6 at the site of the Park bridge. At the Burlington St. bridge, the elevation was 56.7 (gage height as given in Water Supply Paper). This is a fall of 0.9 ft. between the two bridges. Assume that there was a fall of 0.2 ft. between the Park bridge and Mr. Dey's boathouse. This would give an elevation of 57.4 for the flood of 1903 at Dey's boathouse. The flood of 1881, 22 years before, reached elevation 63.3 at this place. This is a difference of 5.9 ft. Assuming no great change in the river channel during this period, and applying the difference in gage heights to the rating curve for the Burlington St bridge, (this assumes that the curves for the river at the Burlington St bridge and at Dey's boathouse are parallel) it is found that the discharge in 1881 was approximately 40,200 sec. ft. The floods of 1881 and 1918 are not comparable at this point in the river, because of the backwater caused by construction of the State University's dam in 1906.

25

20

15

10

5

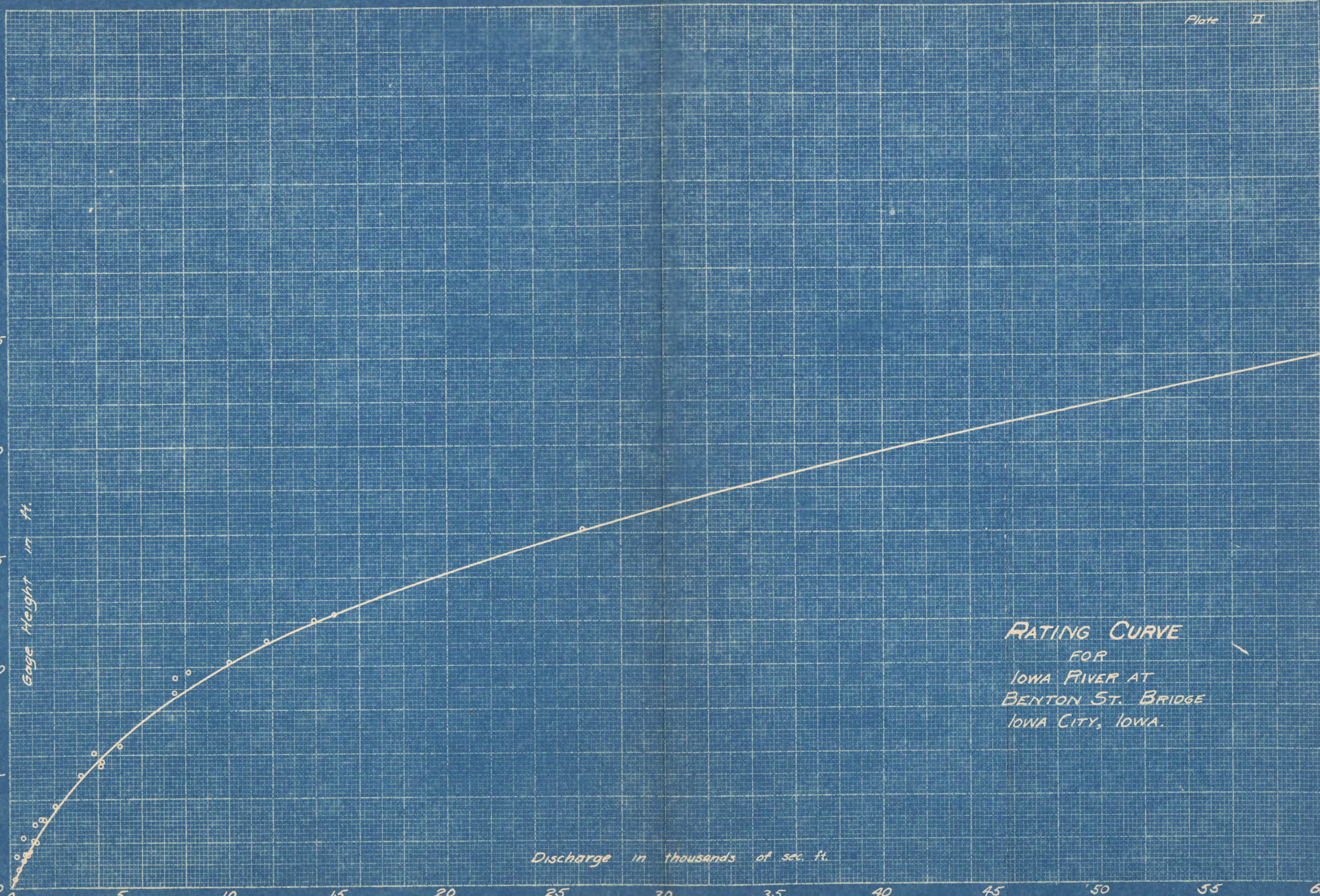
0

Gage Height in ft.

Discharge in thousands of sec. ft.

RATING CURVE
FOR
IOWA RIVER AT
BENTON ST. BRIDGE
IOWA CITY, IOWA.

0 5 10 15 20 25 30 35 40 45 50 55 60



Turning to Mr. Ryerson's records, two similar assumptions are necessary; that the river channel did not change much between 1881 and 1918, and that the rating curve for the river at the Burlington St. Bridge parallels the curve for the river at a point opposite Mr. Ryerson's house. Now applying the difference in elevation of the 1881 and 1918 floods, 1.5 ft., to the Burlington St. bridge rating curve, and taking 35,300 sec. ft. as the discharge in 1918, 39,800 sec. ft. is found to be the discharge in 1881. This is very nearly the same as obtained from Mr. Dey's data. In fact the difference is only one per cent, which is probably within the limits of accuracy of the rating curve.

Mr. Ryerson's data may also be applied to the rating curve for the river at the Benton St. bridge a short distance below the Ryerson home. Applying the difference in elevation between the 1881 and 1918 floods, 1.5 ft., to this curve, (Plate II) and assuming the discharge for the 1918 flood as 35,300 sec. ft. as before, the discharge for the 1881 flood is found to be 41,400 sec. ft. The discharge in 1881 may be assumed to be the average of these three values, 40,200, 39,800 and 41,400 sec. ft., or 40,500 sec. ft.

The gage readings purported to have been made at the Centennial (Burlington St.) bridge during

the flood of July, 1881, and published in the Report of the Iowa Weather Service for that date, do not agree with the newspaper as to the date of maximum high water. According to the newspaper report, high water occurred on the 14th, and according to the gage readings, on the 17th. However, a hydrograph has been constructed on the basis of the gage readings and the rating curve of Plate I, assuming a discharge of 40,000 sec. ft. for gage reading 22'-6". This hydrograph is on Plate VII.

Flood of June, 1851: The data for this flood is very meagre, consisting of two quotations from the Iowa Weather Service Report, both probably from the same source. This quotation remarks that the flood of 1851 was about three feet higher than that of 1881. Assuming that the rating curve applies to the river at that time, and assuming further that the estimate for the flood of July 1881 is correct, it is found that the discharge for 1851 was approximately 50,000 sec. ft. This discharge does not seem improbable when the precipitation for that year is known. The flood of 1918, (35,300 sec. ft.) was caused by a total precipitation of 12 inches in about thirty-five days. In 1851 the precipitation records for eastern Iowa were as follows:

TABLE IV

Precipitation in Eastern Iowa
in the Summer of 1851

	May	June	July	August
Dubuque	11.04	11.38	4.92	6.53
Muscatine	12.60	14.30	8.60	14.00
Ft. Madison	10.80	8.60	5.95	2.95

These figures are indicative of very heavy rainfall over all of eastern Iowa during the months of May and June and serve to justify the estimate of 50,000 sec. ft. for the flood of June 1851.

FREQUENCY OF FLOODS

Since a complete record of flood discharges dates back only to 1903, the study of the frequency of all floods smaller than the three great floods of 1851, 1881, and 1918 will be limited to this period of twenty-three years.

The thirty floods of this period were arranged in the order of their magnitude (Table V) and the total interval of time investigated (23 years) was divided by the serial number of each flood. The quotient (Column 3 of Table V) represents the average number

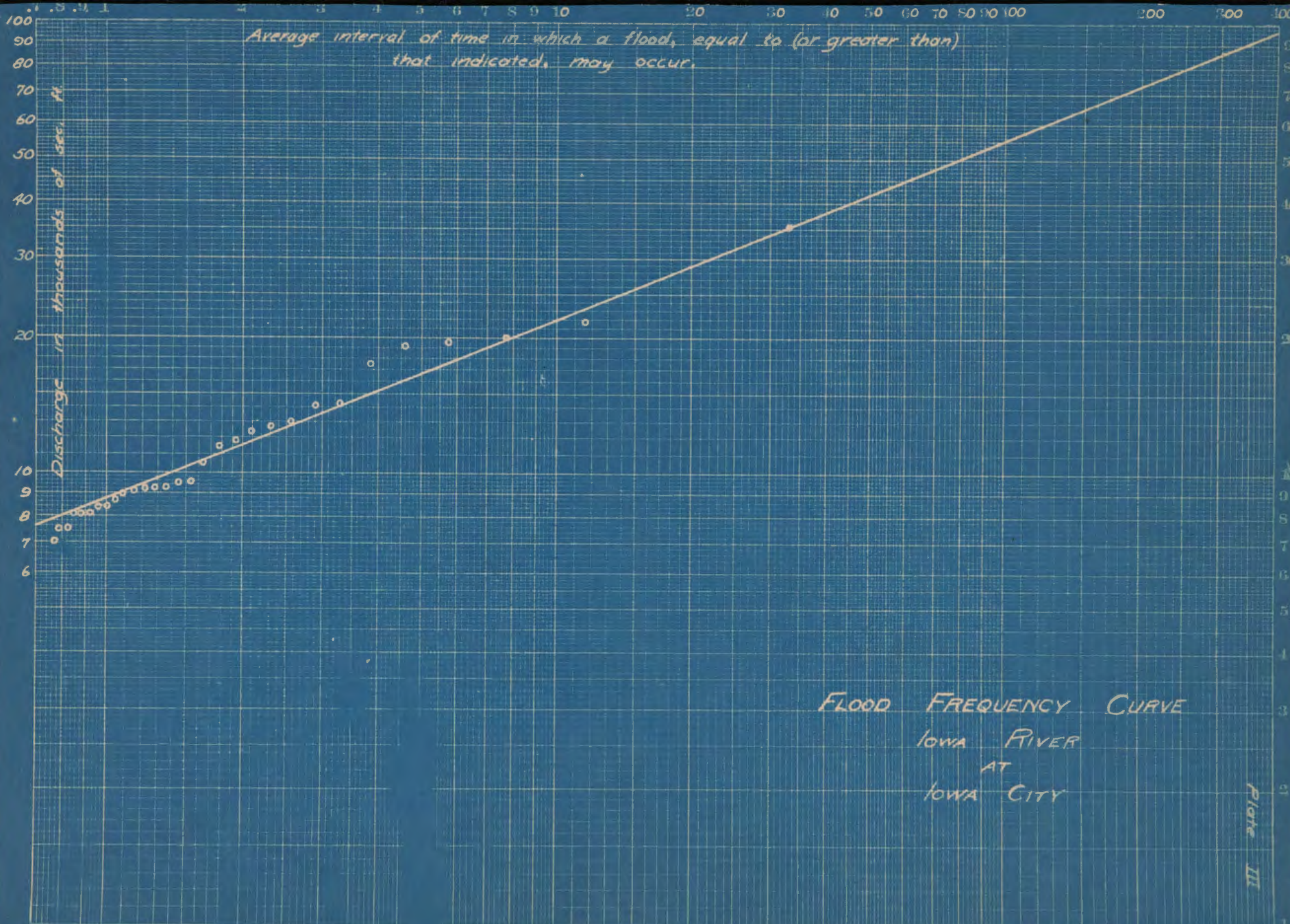
TABLE V

Frequency of Floods

No.	Discharge	Frequency	No.	Discharge	Frequency
1	35,300	23.0	16	9,500	1.44
2	21,800	11.5	17	9,300	1.35
3	20,000	7.66	18	9,300	1.28
4	19,600	5.75	19	9,200	1.21
5	19,100	4.60	20	9,100	1.15
6	17,500	3.83	21	9,000	1.09
7	14,300	3.29	22	8,700	1.05
8	14,200	2.88	23	8,400	1.00
9	13,000	2.55	24	8,400	0.96
10	12,800	2.30	25	8,100	0.92
11	12,400	2.09	26	8,100	0.88
12	11,900	1.92	27	8,100	0.85
13	11,500	1.77	28	7,500	0.82
14	10,500	1.64	29	7,500	0.79
15	9,600	1.53	30	7,000	0.77

Average of 30 floods, $\frac{370,700}{30} = 12,400$ sec. ft.

of years between the occurrence of a flood of given size and another flood as large or larger. This is probably more nearly true with respect to the smaller floods than the larger ones for the interval of occurrence of a flood that occurs but once or twice in the interval studied cannot, of course, be determined accurately. The figure for the largest flood then, must be discarded entirely. From other considerations, that is, the occurrence of similar floods in 1851 and in 1881, and the fact that these floods were both somewhat larger than the 1918 flood, the interval of occurrence of a flood of 35,300 sec. ft. was taken to be 33 years. With this one change, the values were plotted as calculated, on logarithmic paper, (Plate III). With the exception of four points above 15,000 sec. ft., they form nearly a straight line. These points deviate for the reason given above, namely, that the interval of time is not long enough to accurately determine the frequencies of the larger floods. The last point is well established however, and a straight line was therefore drawn through it and the average of the remaining points. Table VI is based on the curve of Plate III and gives the average interval in which a flood equal to (or greater than) that indicated may occur.



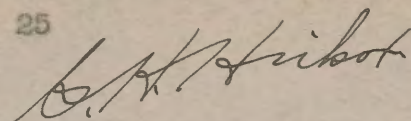
FLOOD FREQUENCY CURVE
IOWA RIVER
AT
IOWA CITY

TABLE VI

Average Interval of Occurrence for Flood
of Given Magnitude

Discharge (sec. ft.)	Average Interval (years)
10,000	1 1/3
15,000	3 3/4
20,000	8
25,000	14
30,000	22
35,000	33
50,000	78
60,000	120
75,000	215
100,000	400

These figures should not be taken too literally. For example, a flood of 10,000 sec. ft. will not occur every 15 months, but on the average, there will be three such floods (or larger) in four years. Further, it is always dangerous to extrapolate a set of experimental data, and not much reliance should be placed on values beyond 50,000 sec. ft. It is believed that conditions are well represented below that point.



RELATION OF FLOODS TO RAINFALL

In studying the floods with respect to rainfall, they divide themselves naturally into two groups; the spring floods, occurring in February, March and April, and the summer and fall floods occurring from May to October. The main difference between the groups is that the spring floods have no apparent relation to the immediate precipitation but are dependent largely on temperature, snow and ice conditions. The summer and fall floods, on the other hand, are largely the result of rainfall. The division of the two groups may be clearly seen on Plate IV. It will be noticed that the first floods of the year occur in February, March and April. These are largely caused by moderate rainfall on frozen ground and partly by melting ice and snow, and there are few large floods at this season. From the middle of April until the middle of May there are very few floods, and those that occur from this time on, are the result of rainfall. The heaviest rains of the year come in June and July, and it is then that the large floods may be expected. There are very few, if any floods on the Iowa river during the late fall and winter, including the months of October, November, December, and January.

SEASONAL DISTRIBUTION OF IOWA RIVER FLOODS IOWA CITY

50

40

30

20

10

Discharge in thousands of sec. ft.

0 Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

0.11
0.18

0.15

0.10

0.13

0.20

0.16

0.19

0.23

0.16

0.19

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0.12

0.03

0.24

0.17

0.18

0.19

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.17

0.26

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.29

Plate IV

Table VII shows the relation between rainfall and maximum discharge for the summer and fall floods for which complete rainfall records are available.

The rainfall of Table VII was obtained by taking the records for all the stations on and near the Iowa River drainage basin and averaging them for each day by Thiessen's method; that is, weighting each record in proportion to that part of the area of the basin that is nearer the station in question than any other station. Rainfall records from the following stations were used:

Forest City	Toledo	
Britt	Grinnell	<i>Silsman</i>
Belmond	Belle Plaine	<i>Dycoot</i>
Iowa Falls	Williamsburg	
Whitten	Amma	
Marshalltown	Cedar Rapids	
	Iowa City.	

Clear Lake
Dows
Hampton
White City
Ames
Grading

The rainfall in Column 4 of Table VII was taken for a period of four days in order to have a uniform rainfall period for each flood, and thus a basis of comparison. Four days is the average time of concentration for the basin.

It was found convenient to subdivide the summer and fall floods into two divisions on the basis of time of occurrence. This is necessary be-

TABLE VII

Relation of Floods to Rainfall

	Date	Discharge (sec. ft.)	Time of Concentration (days)	Max. 4-day rainfall (inches)	Rainfall for preceding 30 days (inches)	Total
<u>Division A</u>						
1.	Sept. '14	9,300	5	4.87	3.44	8.31
2.	June '15	9,300	7	1.61	4.70	6.31
3.	Sept. '15	11,500	4	3.32	4.95	8.27
4.	June '17	17,500	4	1.36	6.58	7.94
5.	May '18	14,200	3	2.75	5.6	8.35
6.	June '18	35,300	4	4.27	7.71	11.98
7.	May '19	12,800	4	1.77	5.71	7.48
8.	Sept. '21	14,300	5	3.13	5.25	8.38
9.	June '24	7,500	2	3.31	1.46	4.77
<u>Division B</u>						
1.	July '09	12,400	3	3.54	6.	9.54
2.	Aug. '15	8,700	5	1.38	5.81	7.19
3.	July '24	19,100	3	2.27	7.25	9.52
4.	July '24	9,100	3	1.80	5.17	6.97

cause much more water is absorbed during the growing season (June and July) than in the spring or fall. Division A of the table is composed of floods occurring in May, early June, late August, September, and October; and division B is composed of those occurring in late June, July, and early August. It can be shown that the maximum discharge of this group of floods depends not only on the rainfall that is the immediate cause of the flood but also on the amount of rainfall during the 30 days preceding. In other words, the degree of saturation of the soil determines the size of a flood as well as the amount of rainfall that occurs in the four or five days immediately preceding the maximum discharge. The amount of rainfall for the 30 days immediately preceding the final heavy rain, has been chosen as a figure which is proportional to the degree of saturation of the soil.

To illustrate, consider Plate V. The points on this plate are plotted using the quantities of Column 5, Table VII as abscissas and the quantities of Column 2, Table VII as ordinates. The maximum four-day rainfall for each flood is shown close to each point. The two curves are drawn to represent roughly the maximum discharge for various amounts of rain for 30 days, followed by a two-inch rain in four days. Now consider the floods of September 1914, and June 1915, both having a discharge of 9,300 sec. ft. The

40000

○ Division A Late Spring, Late Summer

Plate II

□ Division B Early Summer

35000

30000

25000

20000

15000

10000

5000

Discharge in sec. ft.

R-inch rain, Late Spring, Late Summer

R-inch rain, Early Summer

Inches of rainfall for 30 days
preceding 4 days maximum rainfall.

0 1 2 3 4 5 6 7 8 9 10

6.

4270

227

436

313 2.95

4.77

3.32

487

2.47

1.61

1.80

1.30

0.147

3.37

3.324

former had a 4.87-inch rain in four days and the latter only a 1.61-inch rain in the same time. It will be noticed that the amount of rain during the preceding 30 days is less for the September flood than for the June flood and consequently they take their places on either side of the two-inch line as shown. It may be argued that this illustration has no weight because one flood takes place in June and one in September, two widely different seasons. Consider then the floods of September 1914, September 1915, and September 1921. In that order, their maximum discharges are 9,300 sec. ft., 11,500 sec. ft., and 14,300 sec. ft. The four-day rainfall which is the immediate cause of these floods is respectively, 4.87 inches, 3.32 inches, and 3.13 inches. There is evidently no direct relation there. The rainfall for the preceding 30 days is in each case, however, 3.44 inches, 4.95 inches, and 5.25 inches, respectively. This is a very strong indication that the magnitude of a flood depends on something more than the rainfall which directly precedes it, and is good evidence that it depends also on the rainfall of the preceding 30 days. As a further illustration, consider the rainfall of May and June, 1926. On June 11-14, there was 2.54 inches of rain; enough if the ground were thoroughly saturated, to produce a sizable flood. The saturation as measured by the rainfall of the preceding 30 days was very low, as only

2.41 inches had fallen. Plate V shows that a very small flood, if any, could be expected under these conditions. The actual discharge was 1,500 sec. ft.

The 30-day period was chosen after much experimenting with shorter and longer intervals. Thirty days appears to be necessary for light rains evenly distributed to saturate the soil thoroughly. More than thirty days adds nothing. It might be mentioned here that the point on Plate V at 40,000 sec. ft. discharge represents the flood of 1881 when the immediate cause of the flood was about six inches of rain in two days instead of four days.

From this data, it is possible to predict within limits, what kind of a flood to expect with a given combination of rainfall conditions. With a rainfall of six inches in May followed by a two-inch rain four days, we should expect about 15,000 sec. ft. discharge. If the six-inch rainfall occurred during June, followed as before by a two-inch rain in four days, we should not expect more than about 12,000 sec. ft. If there should be a six-inch rainfall during May followed this time by a four-inch rain in four days, we might expect a flood with a maximum discharge between 20,000 and 25,000 sec. ft. On the other hand, if we should get the four-inch rain in four days preceded by only four inches during May, we should not be justified in expecting as much as 15,000 sec. ft. One

must be very cautious, however, in using such a curve for prediction of events outside the scope of the data which was used in constructing it, and it can only be used roughly in the field which it appears to cover. This particular curve is more qualitative than quantitative. Its ~~purpose~~ purpose is to show tendencies and not exact figures.

Table VIII is presented to show the runoff for each flood expressed as a percentage of total rainfall. It contains the floods of Table VII with the addition of the spring floods. The floods are grouped as in Table VII. The quantity in the column headed "Rainfall" is the amount of rainfall for each flood beginning with the four-day rainfall of Column 4, Table VII and continuing until five or six days before the stream returned to normal flow. The reason this additional rainfall was taken is that in almost every case, there are contributing rains occurring after the peak of the flood has been reached, which are the cause of the humps mentioned later under the subject of "Flood Hydrographs". They are usually small rains and their effect probably does not extend beyond the period selected for each flood. The column headed "Days" is the length of time in days from the beginning of the flood until the river has reached a normal or almost normal stage.

TABLE VIII
Runoff Expressed as a Percentage
of Total Rainfall

Date	Discharge (sec. ft.)	Rainfall (inches)	Runoff (inches)	Days	Per cent Runoff
Spring Floods					
4-3-12	19,600	1.21	2.69	23	222. 3" snow
3-22-13	7,000	0.44	0.45	12	102.
2-25-15	20,000	2.87	3.16	26	110. 4" snow
3-16-16	10,500	1.60	0.93	18	59.0
3-20-19	9,000	2.41	1.14	17	47.3
4-7-19	12,800	2.12	1.50	19	70.7
3-16-20	8,100	3.44	1.80	28	52.3
4-7-23	8,400	0.88	1.05	20	119. 3" snow
Late Spring and Late Summer Floods					
9-15-14	9,300	6.14	0.84	16	13.7
6-5-15	9,300	7.08	1.68	24	23.8
9-30-15	11,500	5.36	1.77	21	33.0
6-16-17	17,500	Data Incomplete			
5-27-18	14,200	3.84	1.17	10	30.5
6-8-18	35,300	4.97	2.22	17	44.6
9-23-21	14,300	5.84	1.47	16	25.2
6-8-24	7,500	4.77	0.48	14	10.0
Early Summer Floods					
7-6-09	12,400	4.40	1.34	17	30.5
8-2-15	9,200	4.81	1.47	25	30.6
7-1-24	19,100	6.90	1.75	20	25.4
7-27-24	9,100	3.65	0.77	15	21.1

The table shows that in the spring, a very large percentage of runoff, up to 100 percent, may be expected even with bare ground, and if there is snow which may melt and run off with the rain, the runoff factor may run beyond 200 percent. The late spring and summer floods show a general increase of runoff factor with increase of discharge. There seems to be no relation between the amount of rainfall and the runoff factor. This is interesting as tending to uphold the theory advanced that the immediate rainfall is not solely responsible for the size of a flood. The early summer floods show no characteristics worth mentioning, due perhaps to the scarcity of data.

MAXIMUM FLOOD TO BE EXPECTED

There seems to be no approach to this subject by means of anything thus far discussed in this paper. It is evident that the limit to the size of flood to be expected is set by the greatest rainfall that could occur over the Iowa river basin in four days. The engineers of the Miami Conservancy District made some very extended studies of rainfall and their data show that no more than twelve inches of rain in four days has ever been recorded on an area of 3, 140 square miles (This is the area drained by the Iowa river above Iowa City.) in any state north of Arkansas. The greatest

four-day rainfall ever recorded in Iowa on 3,140 square miles is ten inches.² In order to get this average over the basin, the storm would need to have its outlines in the same general shape as the Iowa river basin, namely, long and narrow, which is very unlikely to happen. Assuming the worst conditions, however, it is conceivable that there might at some time be a twelve-inch four-day rainfall over the Iowa river basin preceded by enough rain to thoroughly saturate the soil. Under these conditions, the greater part of the twelve-inch rainfall would appear in the streams as runoff. A portion would evaporate, and some would be lost by transpiration. The maximum rate of runoff would occur at the end of the four day period, that is, as soon as the rainfall on the basin could concentrate. Of course it could not all run off in this time. That which did not run off would either have evaporated or would remain on the ground in stream beds and depressions. Some would be held by grass, trees, and other plant life. If we assume this retention and evaporation to be six inches,³ the remaining six inches must have run off in the preceding four days. It may be assumed that the water rose uniformly. In that case, the rate of runoff at the end of four days would be twice the average runoff for that period, or three inches per day--about 275,000 sec. ft. from an area of 3,140 square

miles. It should be clearly understood that this is an estimate of a maximum condition that will probably never occur; and further, that it is based on conditions so far removed from experience as to make an accurate estimate impossible. It is worth noting here that although conditions on the drainage basin of the Miami river in Ohio are not comparable to conditions on the Iowa river basin, the flood discharge of 1913 from the Miami river, with a drainage area of 3,937 square miles was 384,000 sec. ft.⁴ *97.5 c.f.s./sq.mi.*

FLOOD HYDROGRAPHS

Plates VIII to XXX inclusive present hydrographs of the floods from 1903 to date. These hydrographs are plotted as a series of points, using for each day the average discharge for that day. The points are then connected by a series of straight lines. This method shows the approximate shape of the flood over a period of days, but does not show the peak or maximum instantaneous discharge. The curves are all similar in several ways. The sharp rise to a maximum, followed by a sharp drop is characteristic. Most of them show a hump or even a rise three or four days after the peak has passed. This might be due either to additional rainfall or to the belated discharge of some tributary stream far up the basin. Investigation

shows that in almost every instance, such a hump or rise is preceded by additional rainfall. The cases where they are not preceded by rainfall occur in the spring when additional flow may be accounted for by temperature changes.

NOTES

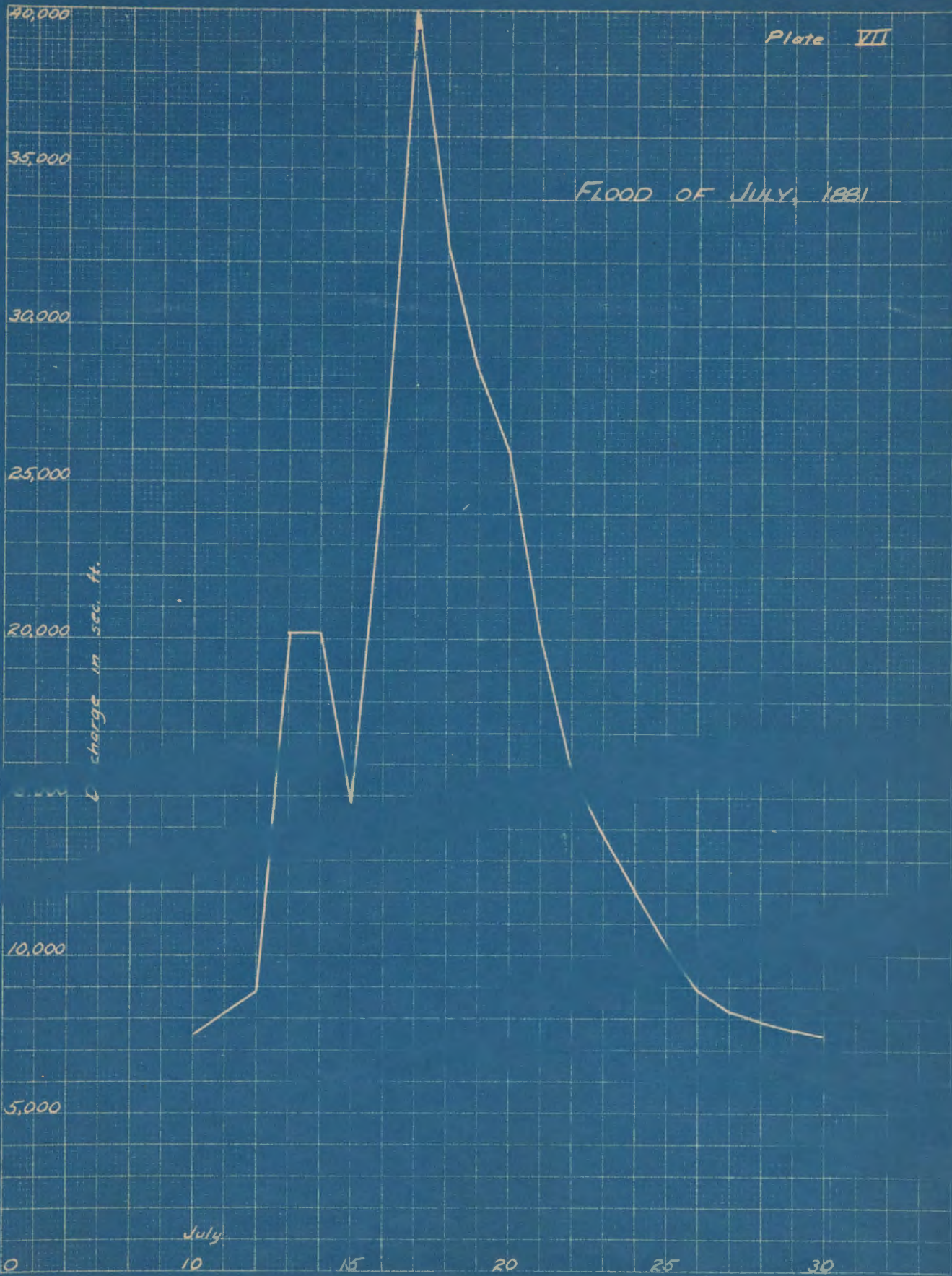
Note 1. An effort was made to find more records of the gage at the Centennial bridge. The county officials have no records of any kind, nor does the Weather Bureau, either at Des Moines or Washington. Frank Fletcher is now living in Oakland California.

Note 2. Technical Reports of the Miami Conservancy District. Part V, pp 188-189

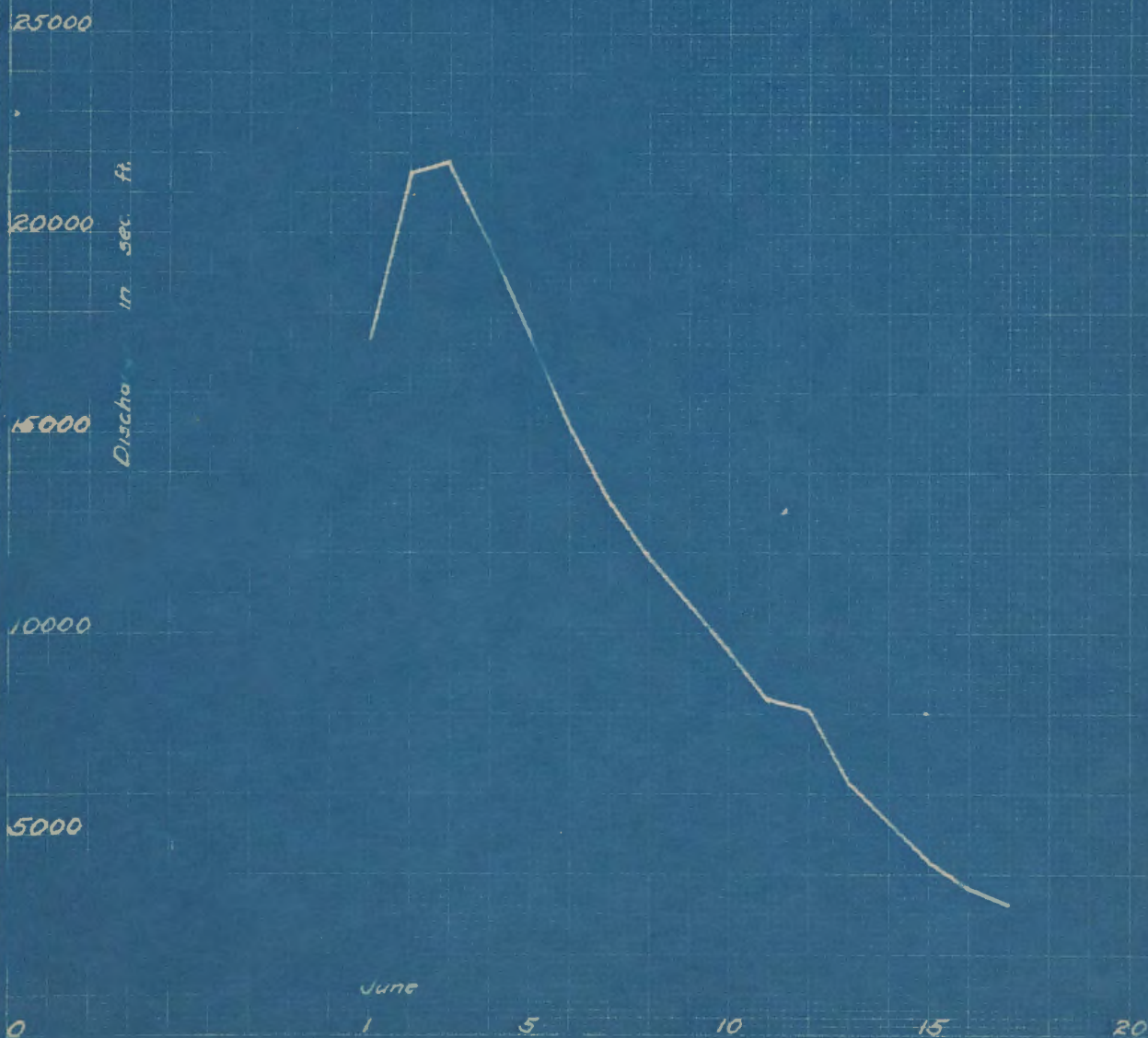
Note 3. Technical Reports of the Miami Conservancy District. Part VII, p32. Any other value might have been chosen for the retention. Six inches was chosen because it was convenient for calculation. Evaporation and retention probably would not exceed this amount.

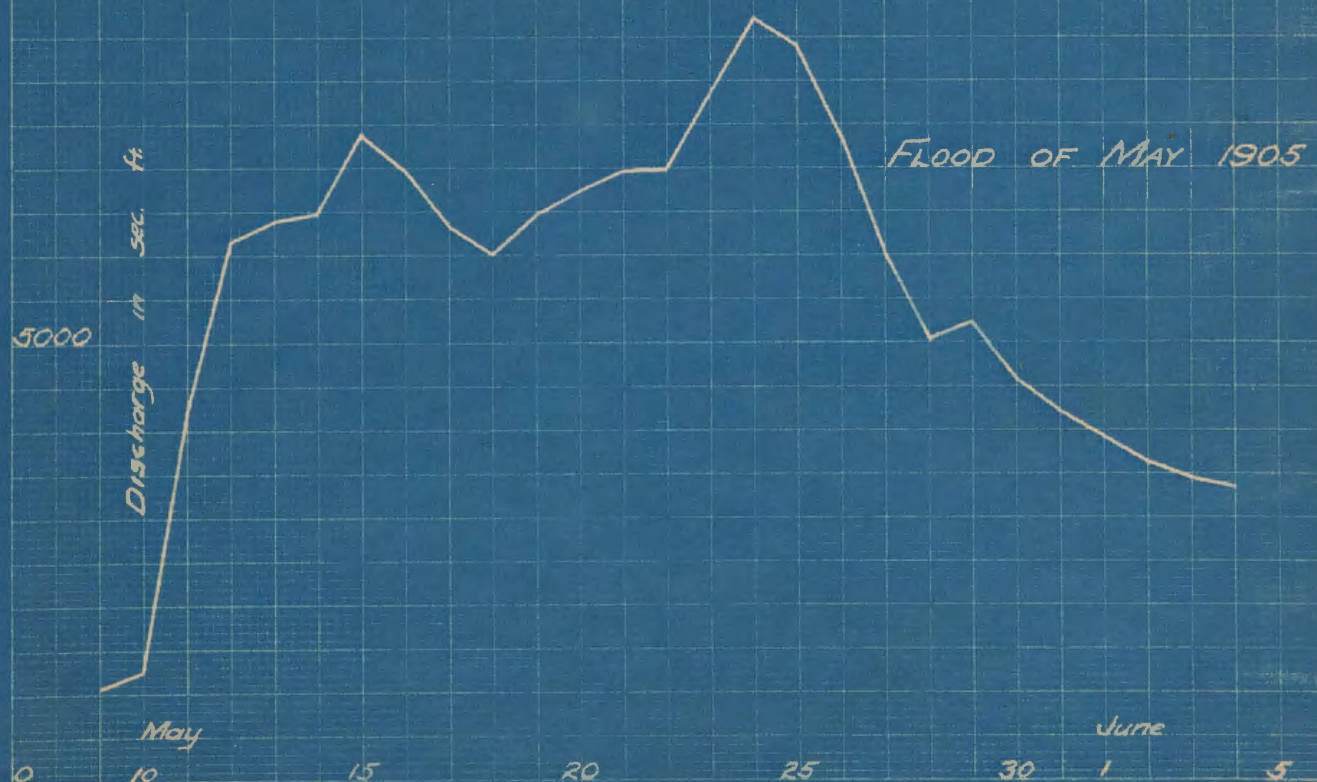
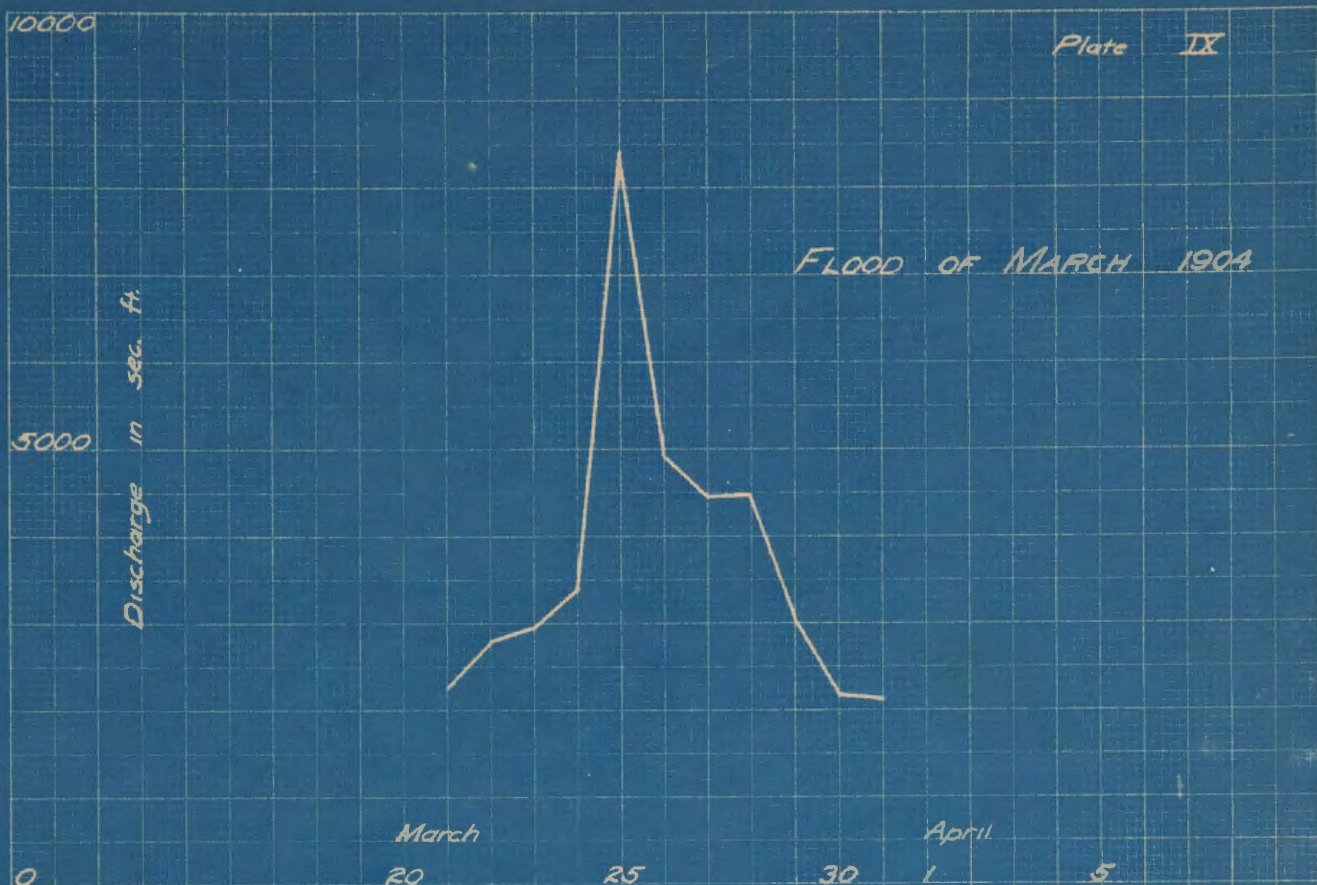
Note 4. Technical Reports of the Miami Conservancy District. Part VII, p 33.

FLOOD OF JULY, 1881



FLOOD OF JUNE 1903





FLOOD OF JUNE 1905

10000

Discharge in sec. ft.

5000

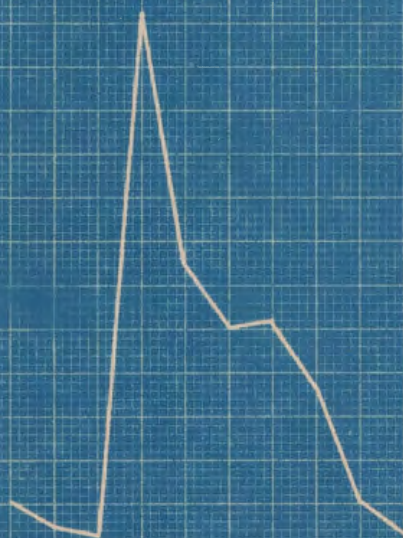
June

5

10

15

20



FLOOD OF
FEBRUARY - MARCH
1906

15000

10000

Discharge in sec. ft.

5000

February

March

0

22

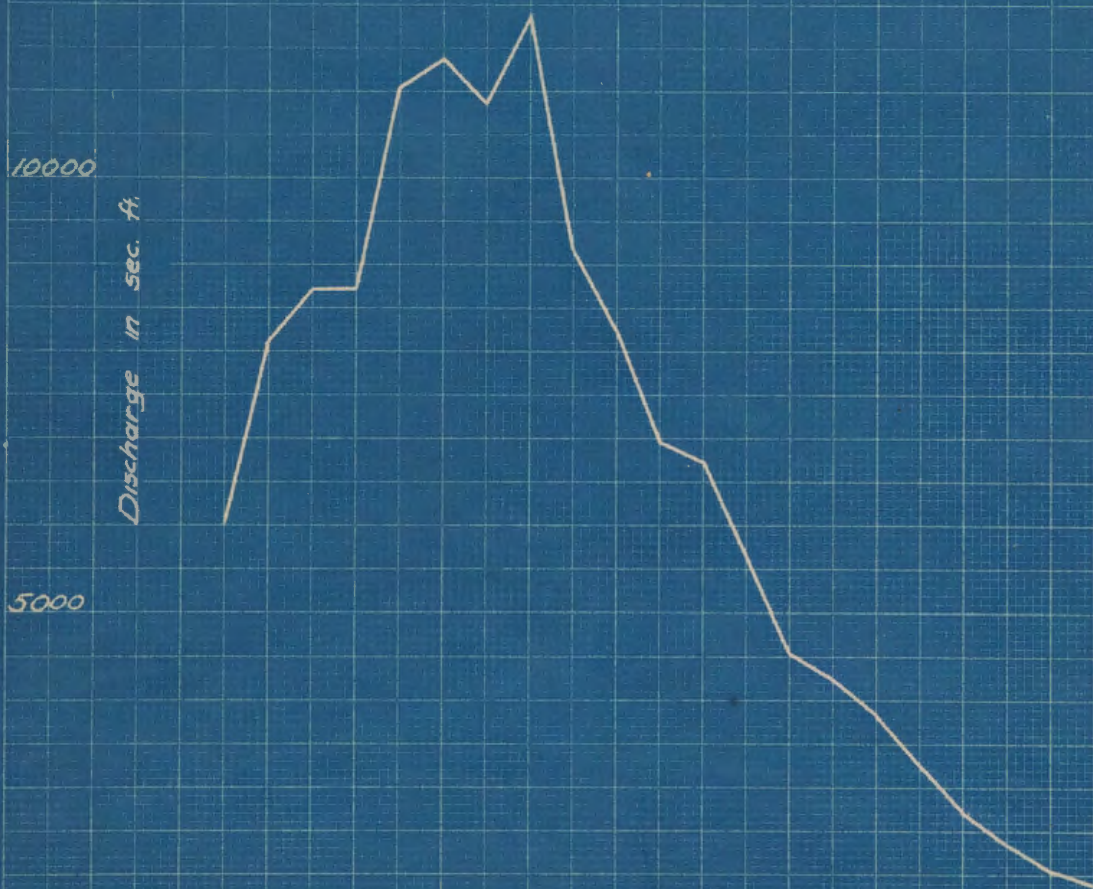
25

1

5

10

15



FLOOD OF
MARCH - APRIL
1906

15000

10000

5000

Discharge in sec. ft.

0

25

30

1

5

10

15

March

April



FLOOD OF JULY 1909

15000

10000

5000

Discharge in sec. ft.

Precipitation in inches

July

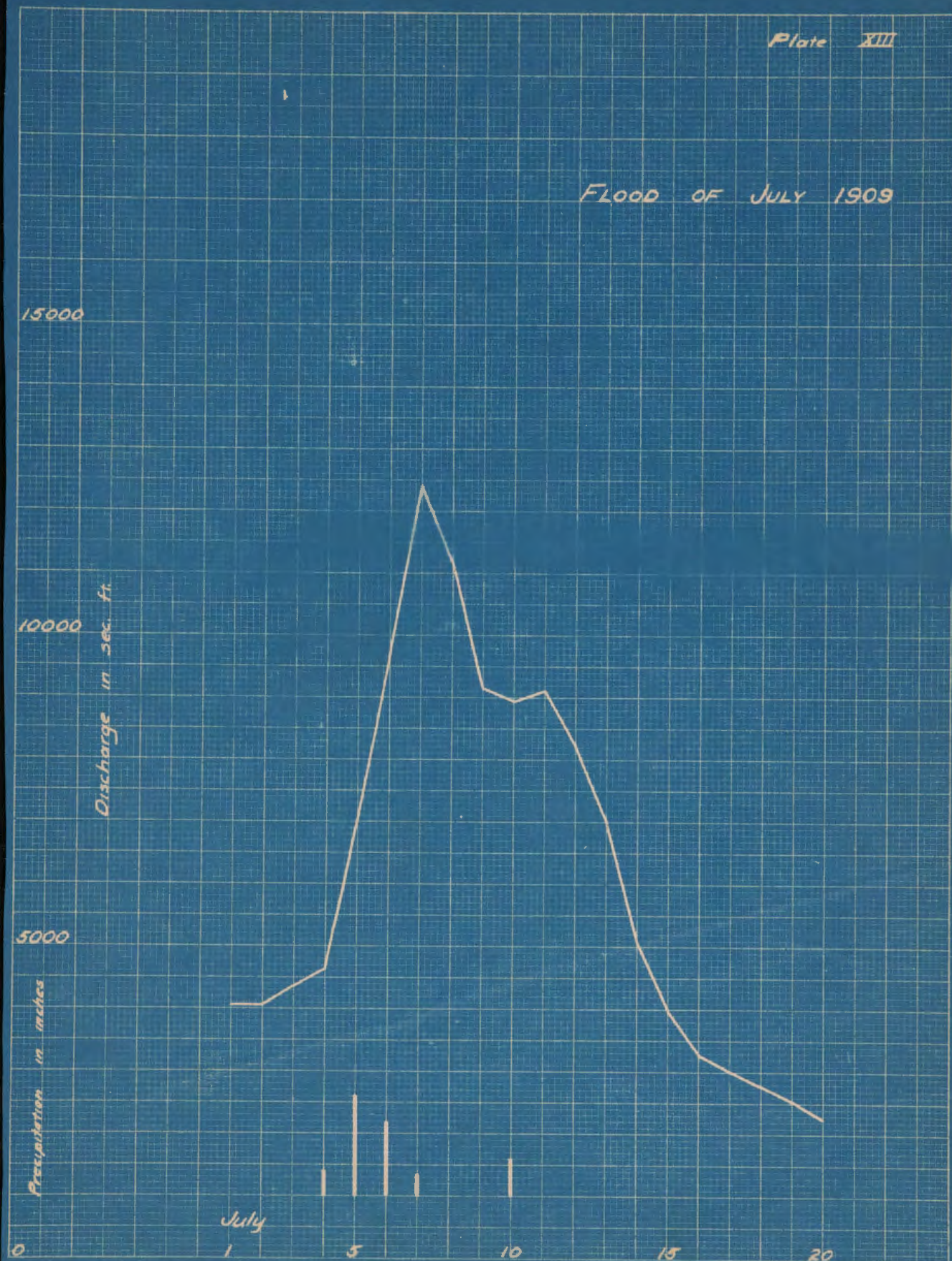
1

5

10

15

20



Discharge in sec. ft.

FLOOD OF MARCH 1910

March

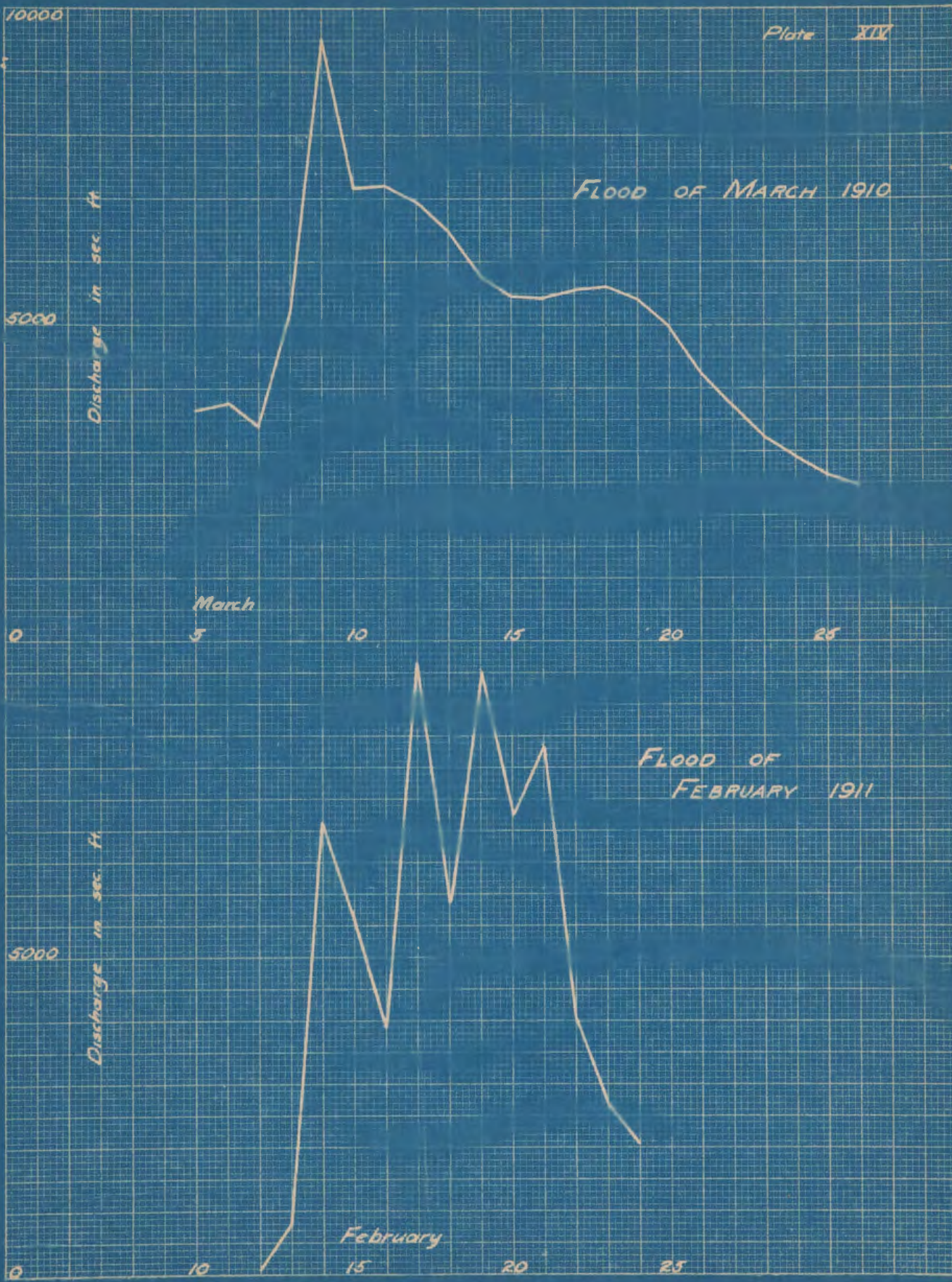
0 5 10 15 20 25

Discharge in sec. ft.

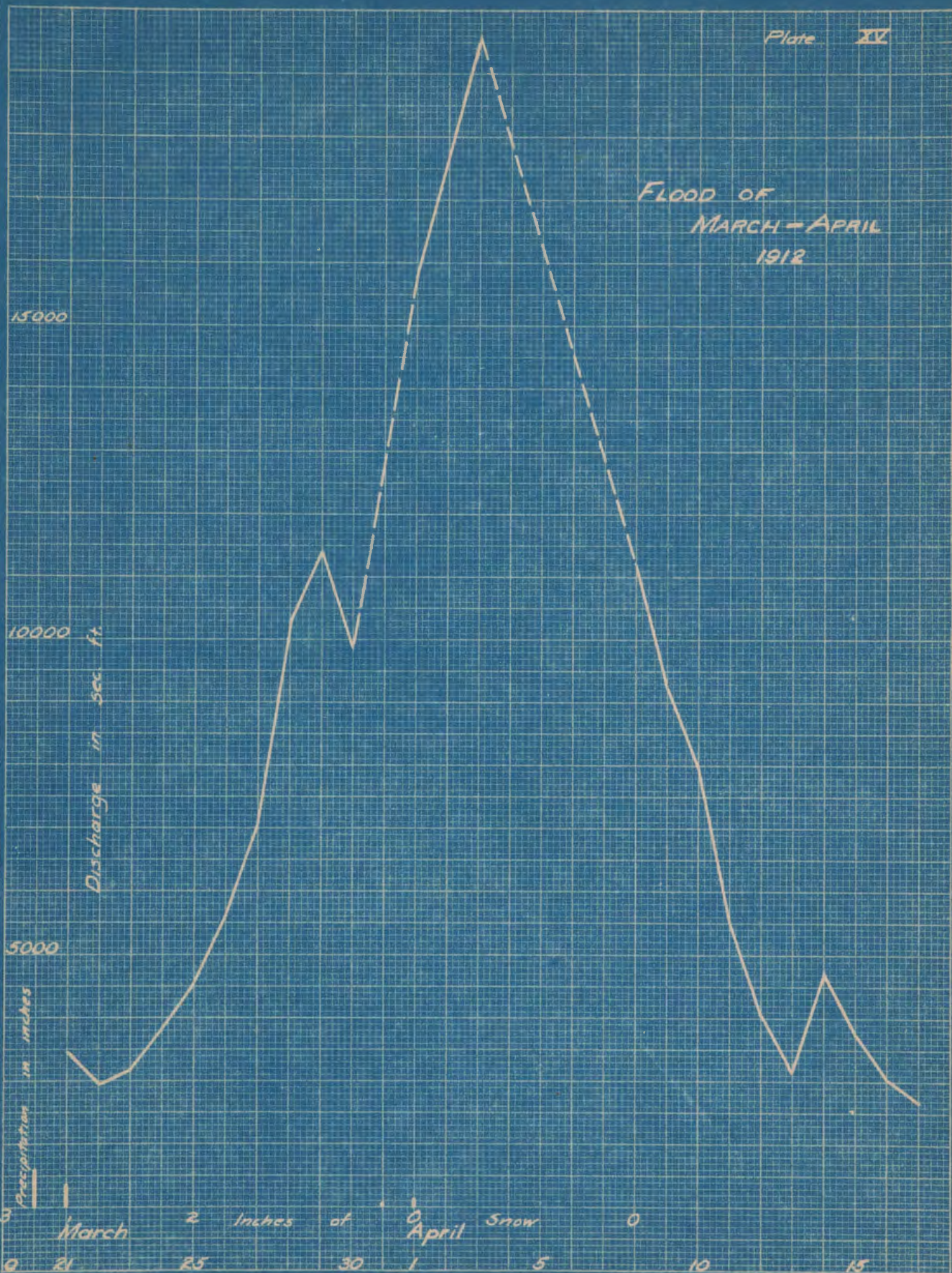
FLOOD OF
FEBRUARY 1911

February

0 10 15 20 25



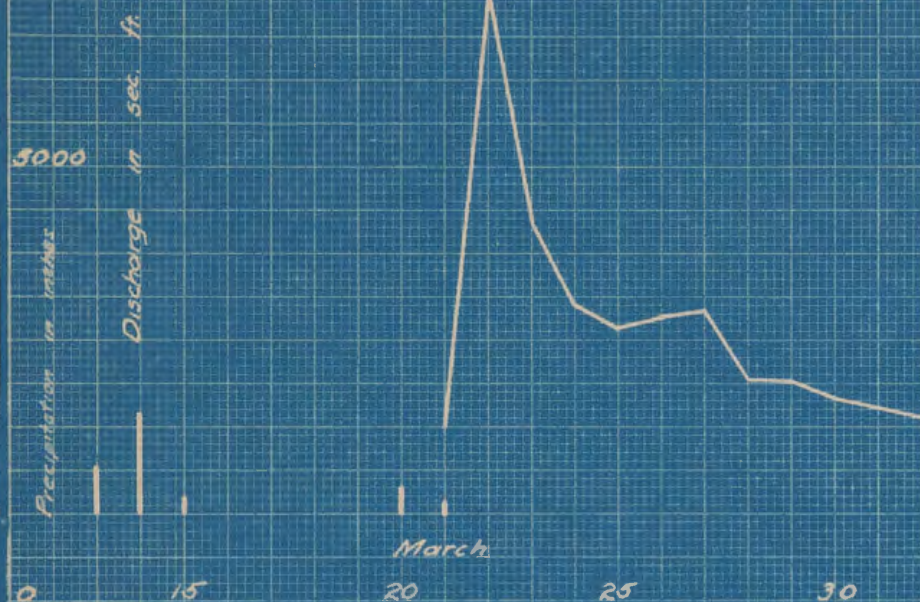
FLOOD OF
MARCH-APRIL
1912



10000

Plate XVI

FLOOD OF MARCH 1913



FLOOD OF SEPTEMBER 1914



20000

Plate XVII

FLOOD OF
FEBRUARY-MARCH
1915

15000

10000

Discharge in sec. ft.

5000

Precipitation in inches

3 February

Inches of

0

Snow

2 March

5

15

20

25

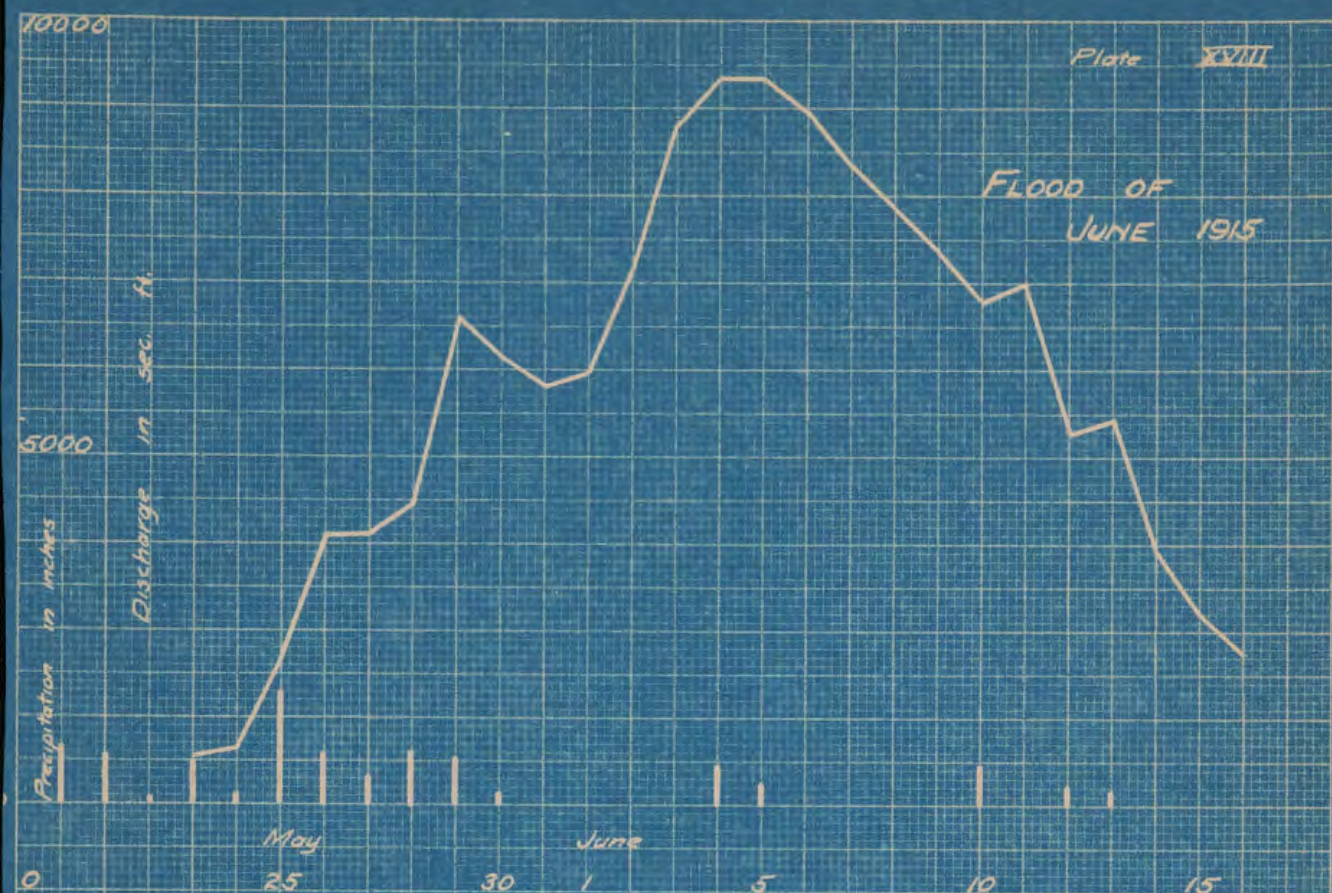
1

5

10

0

FLOOD OF JUNE 1915



FLOOD OF JULY - AUGUST 1915



FLOOD OF SEPTEMBER - OCTOBER 1915

15000

10000

5000

Discharge in sec. ft.

Precipitation in inches

September

October

0

20

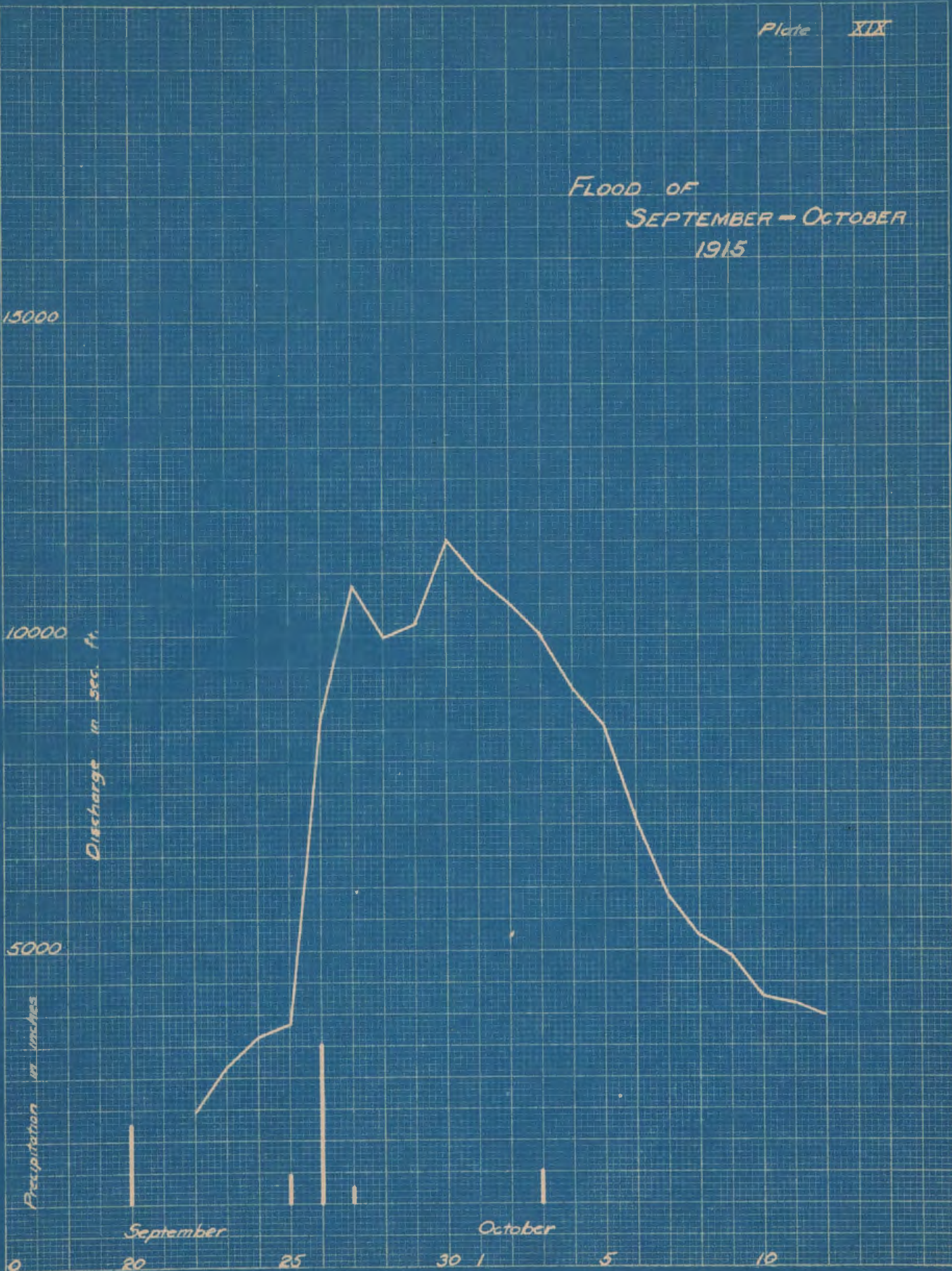
25

30

1

5

10



FLOOD OF MARCH-APRIL 1916

15000

Discharge in sec. ft.

10000

5000

Precipitation in inches

0

Inches of March

0

Snow

April 0

20

25

30

1

5

10

0

20000

Plate XXI

FLOOD OF JUNE 1917

15000

10000

5000

Discharge in sec. ft.

Precipitation in inches

June

5

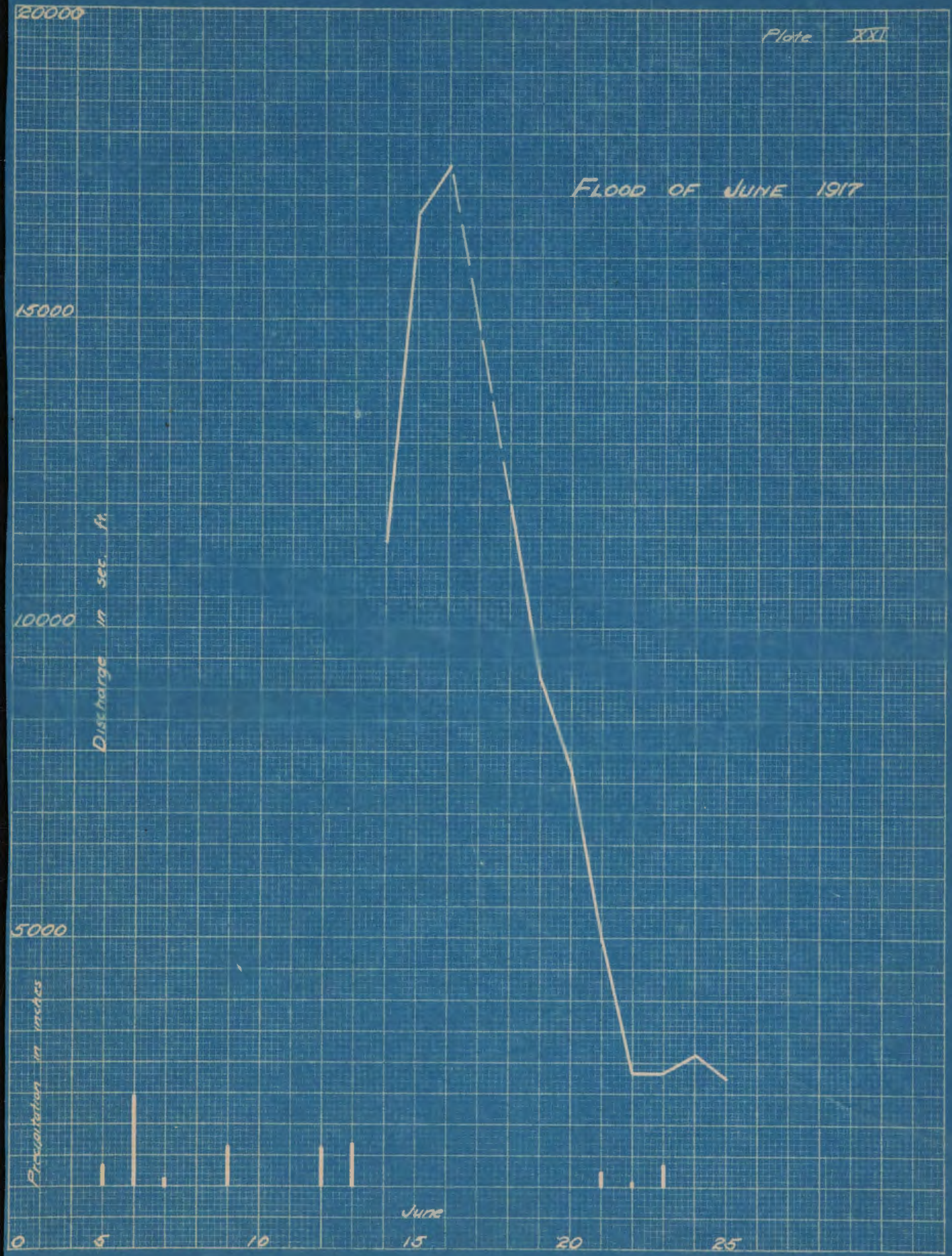
10

15

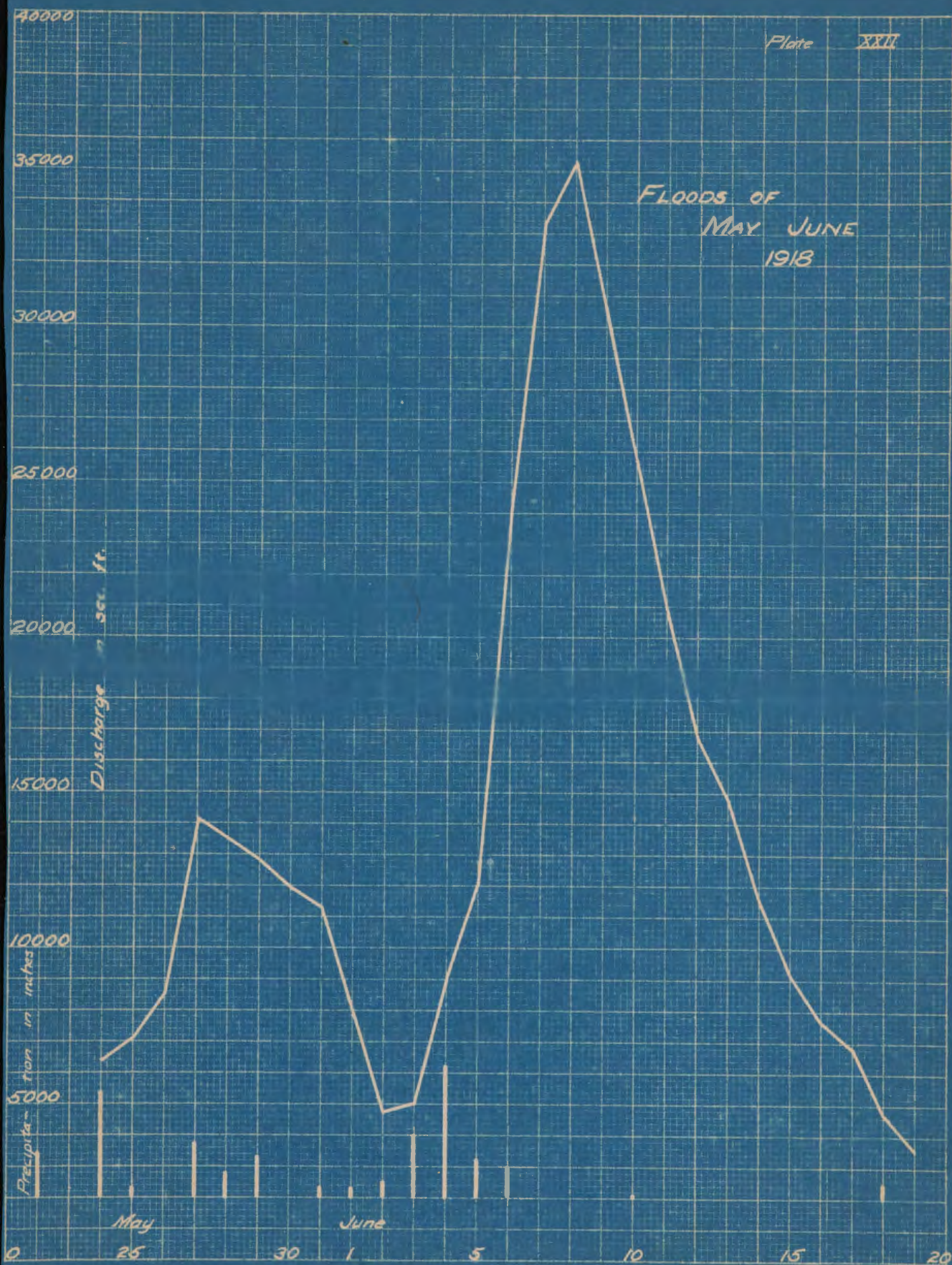
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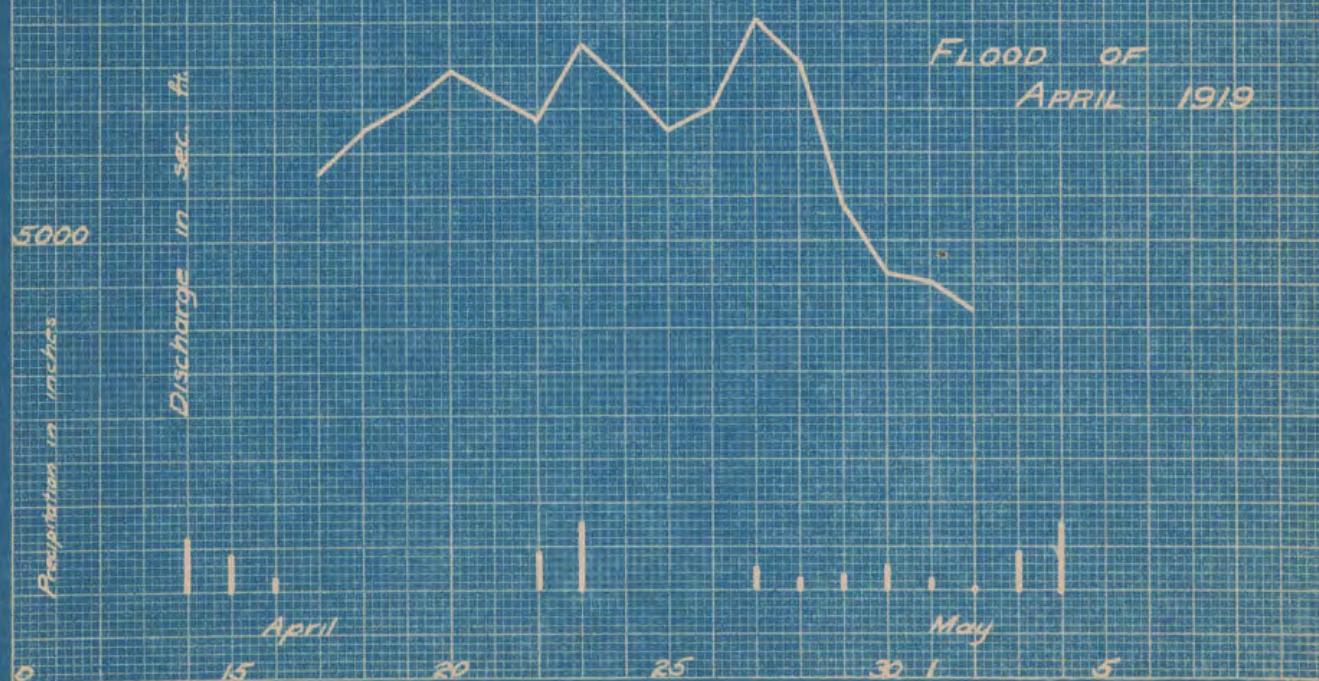
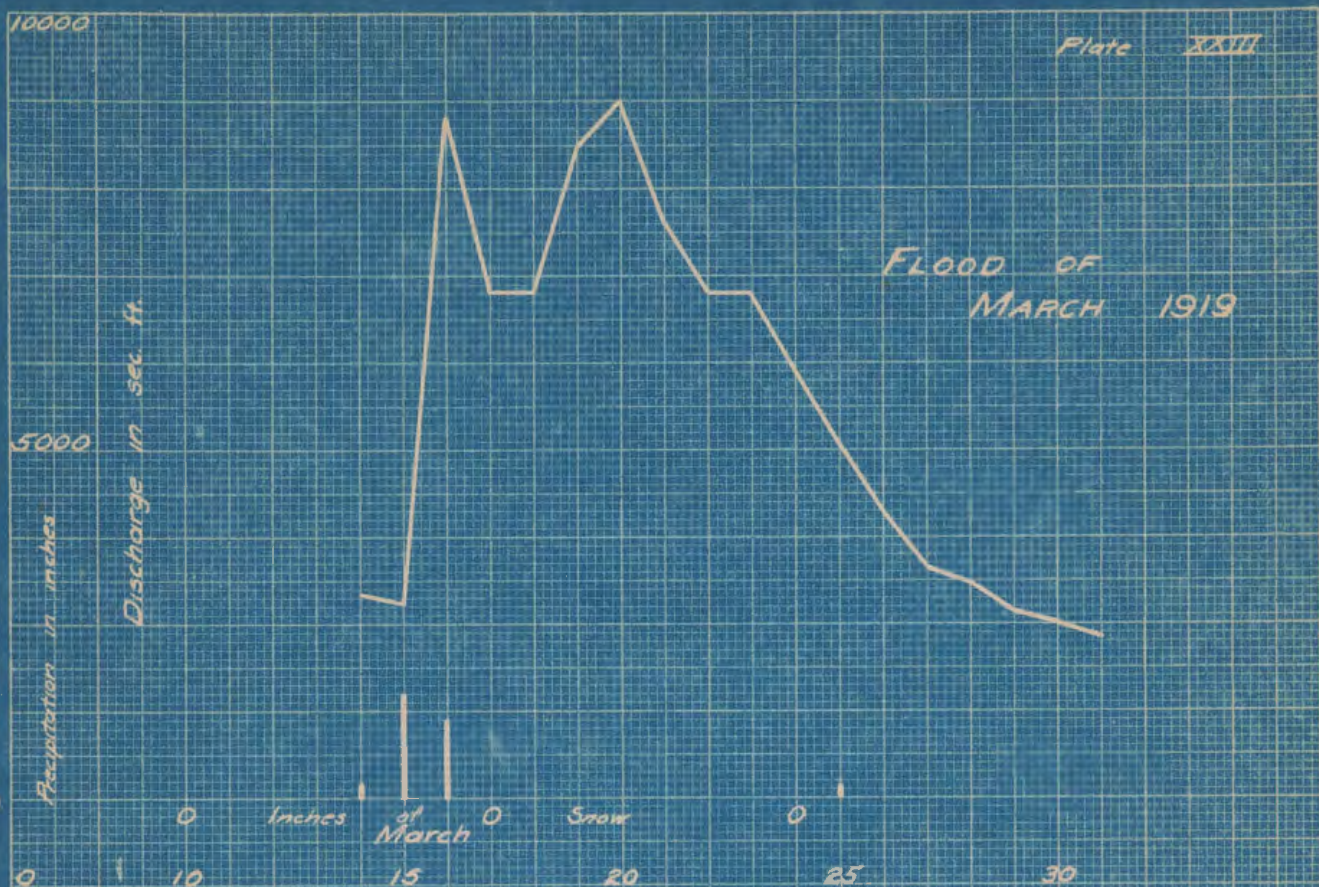
25

0



FLOODS OF
MAY JUNE
1918





FLOOD OF MAY 1919

15000

10000

5000

Discharge in Sec. Ft.

Precipitation in inches

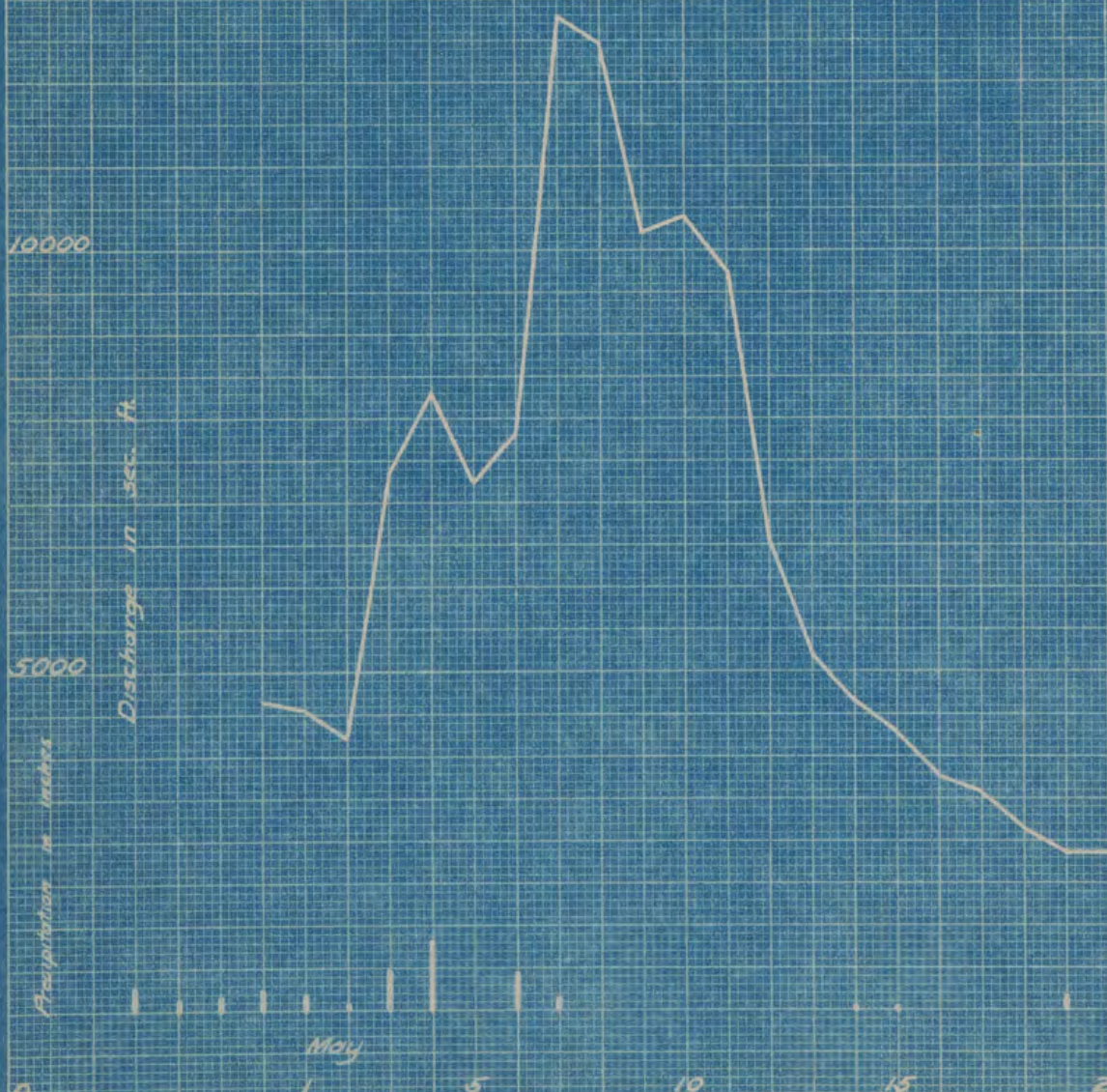
May

5

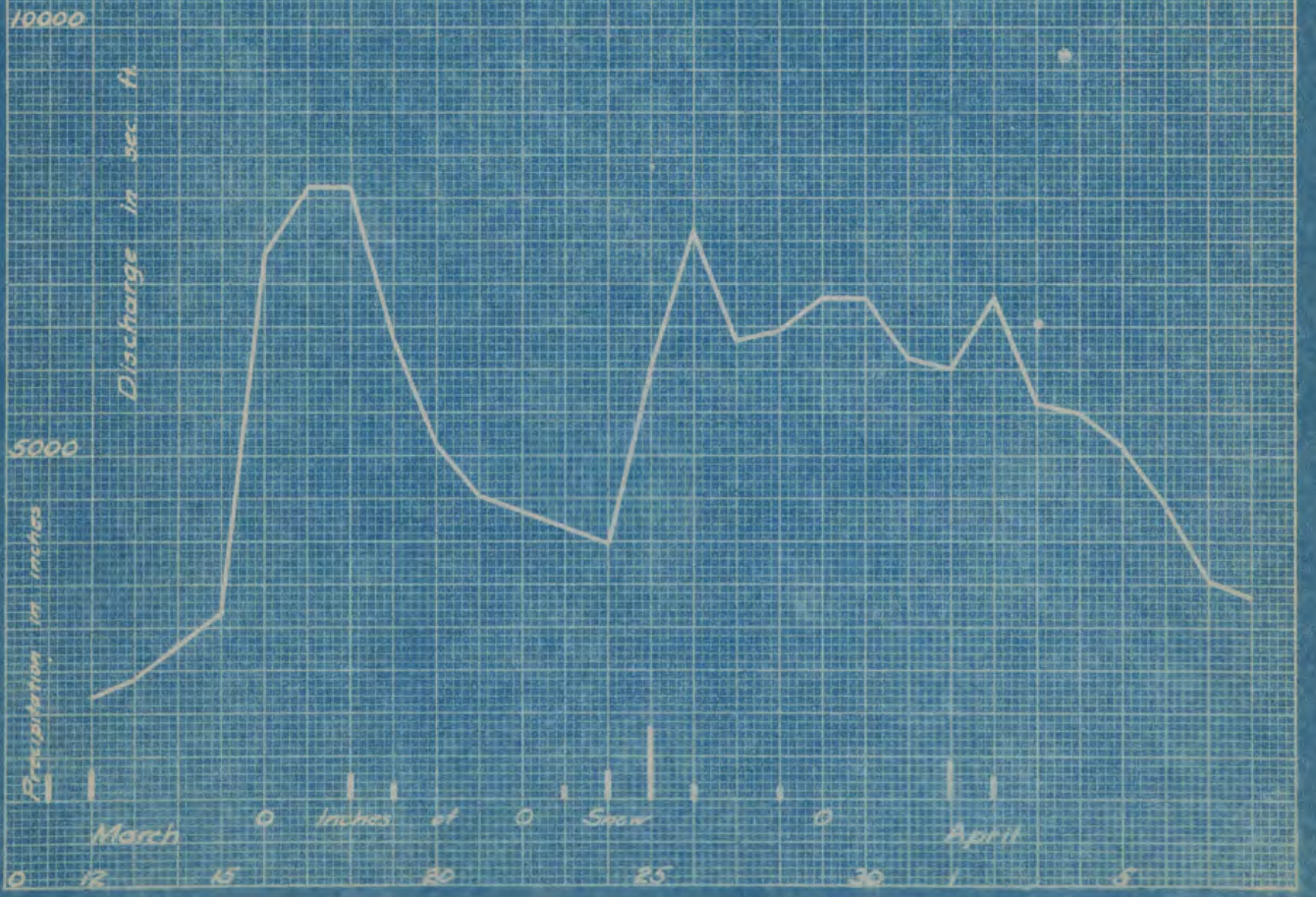
10

15

20



FLOOD OF MARCH 1920



FLOOD OF SEPTEMBER 1921

15000

10000

5000

Discharge in sec. ft.

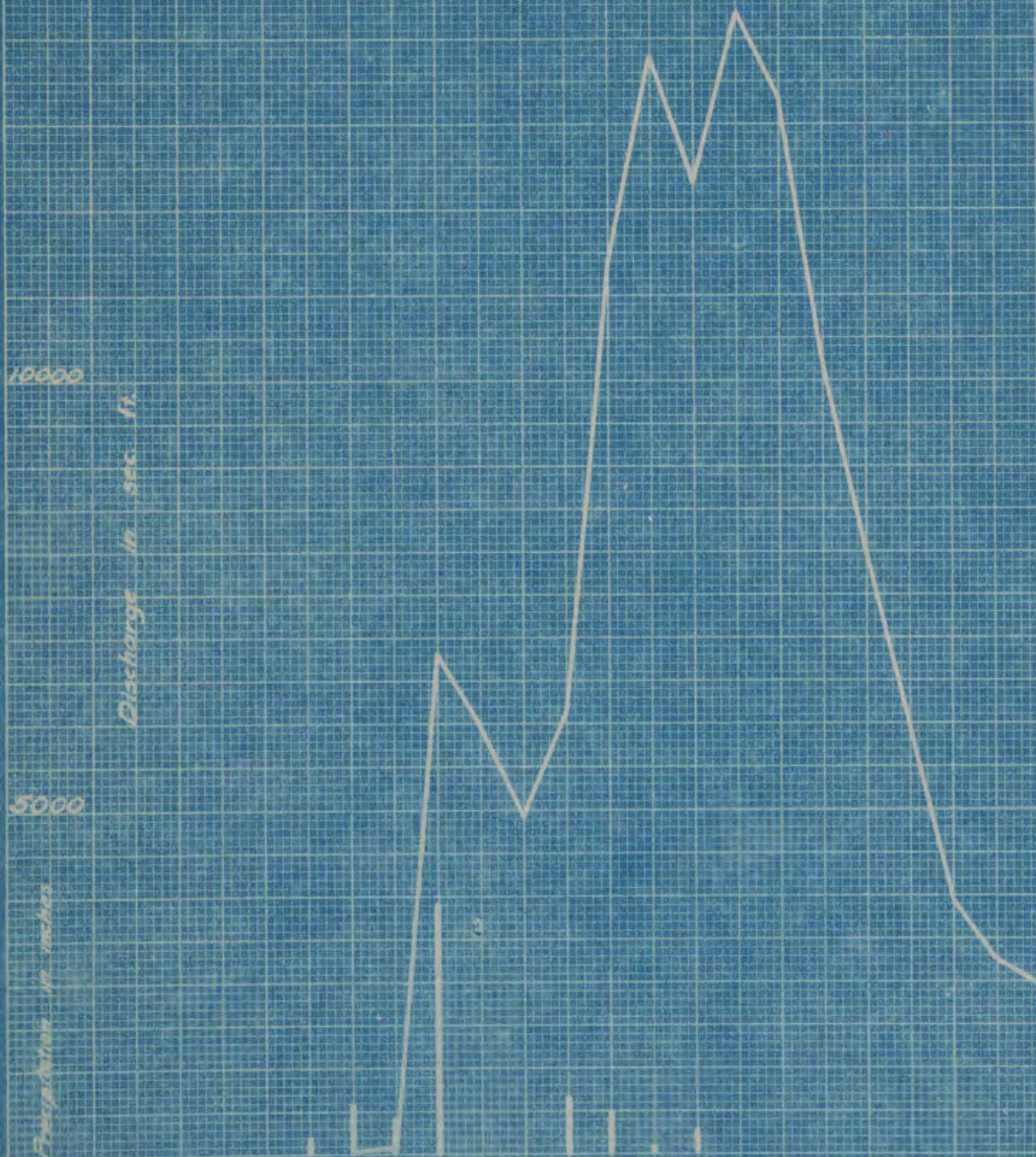
September 1921

September

20

25

30



FLOOD OF MARCH - APRIL 1923

Discharge in sec. ft.

10000

5000

Precipitation in inches

9

0

March

25

Inches

30

of April

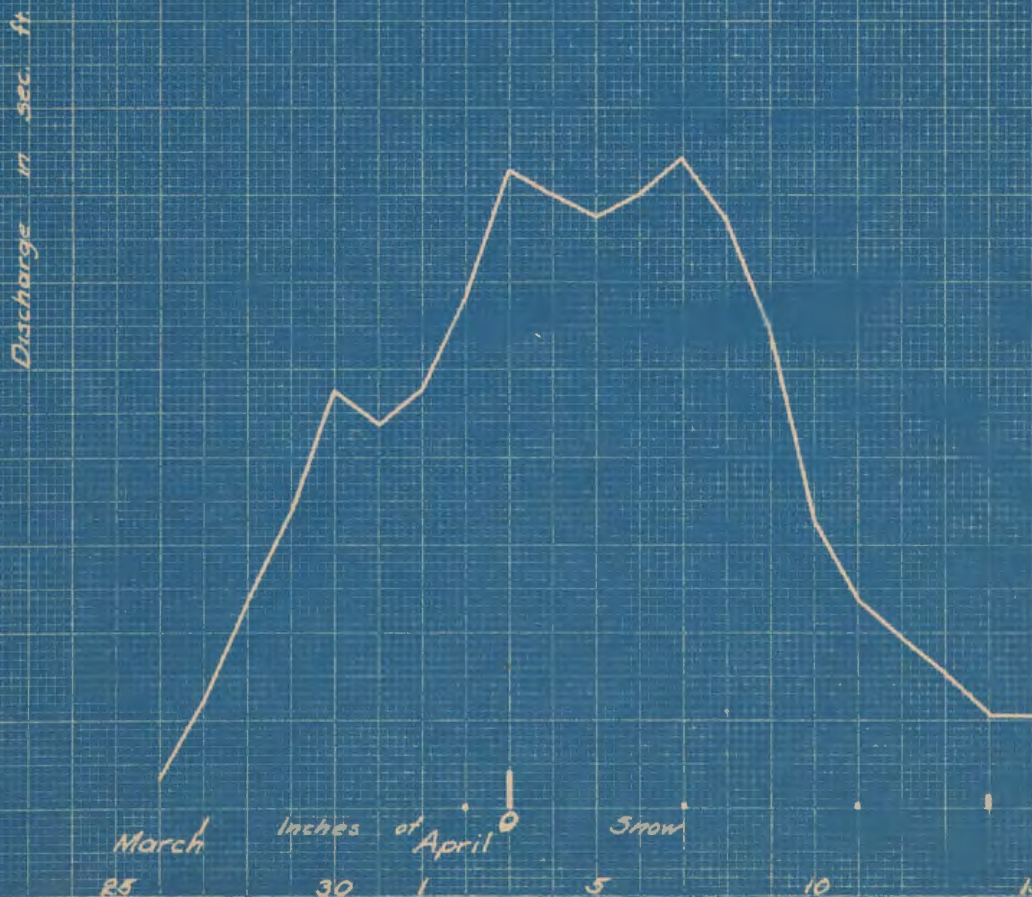
1

5

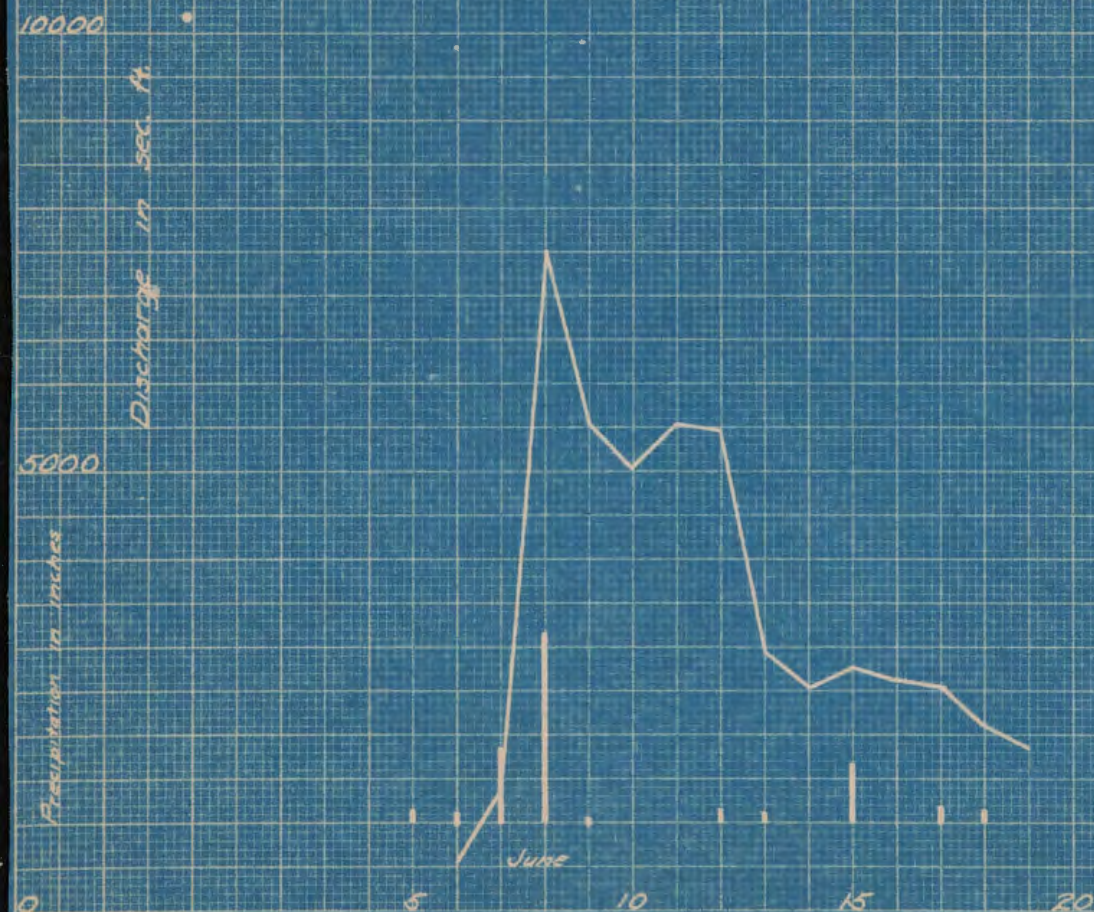
10

15

15



FLOOD OF JUNE 1924



20000

15000

FLOOD OF
JUNE - JULY
1924

10000

Discharge in sec. ft.

5000

Precipitation in inches

0

June

20

25

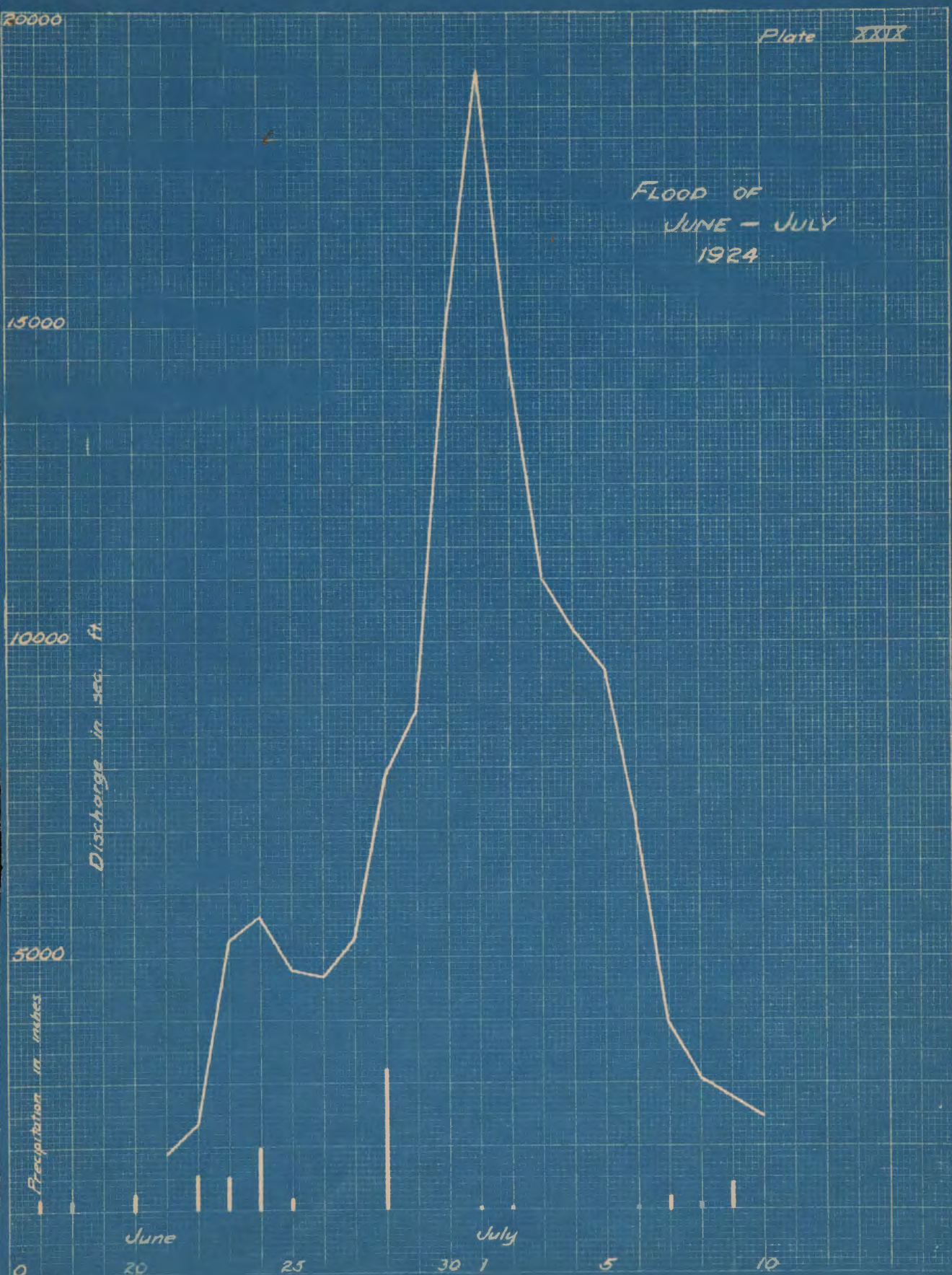
30

July

1

5

10



FLOOD OF JULY 1924

10000

Discharge in 500 ft.

5000

Precipitation in inches

0

July

20

25

30

August

1

5

