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All mat'l prepared in March 1959 for St. Louis Project in regard to raising design stage from 47 to 52'

STABILITY

STAGE-DISCHARGE CURVE

ST. LOUIS, MO.

1. There are many factors which affect the stage-discharge relationship at St. Louis. The factors which are believed to have had some effect on the St. Louis rating curve are:

A. Discharge measurements.

B. Man-made obstructions.

a. Levees

b. Pile dikes

c. Bridge embankments and others

C. Hydrology and hydraulic.

a. Origin and time of occurrence of storm-producing rainfall

b. Rate of rise and volume of the flood wave

c. Distribution of the flood waters between Missouri or Mississippi

d. Bed load

2. Prior to 1933, discharge measurements were obtained at St. Louis, Missouri, at ranges in the vicinity of the Engineer Service Base by use of boat and large size price current meters. Since 1933, discharge measurements have been made from the downstream side of MacArthur Bridge at St. Louis, Missouri, by the U. S. Geological Survey under the Cooperative Stream Gaging Program for the St. Louis District, Corps of Engineers. Measurements are usually made once a week, but in times of flood, daily measurements are obtained. There were some errors in the measurements by the Corps of Engineers as the side sway of the boat

caused over-registration of the meters, also the soundings recorded were too deep due to use of lead weight and clothes line. These two procedures tended to make the results as much as ten percent too large. However, when considering that instantaneous peak discharge values were not used by the Corps of Engineers and that the U. S. Geological Survey now obtains these values and the fact that they are always larger than the mean daily value, a compensating factor is thus introduced, tending to make the instantaneous peak discharge more comparable to the earlier Corps of Engineer discharges.

3. The construction of levees has a marked effect on stage. The restrictions of overbank flood flows to channel confinement by levees raises flood heights. It is believed, however, that the effect of confinement by levees is ~~already~~ primarily accounted for in the rating curves of recent years and the variation in these curves is due to factors other ~~than this~~ in addition to confinement.

4. Studies by this office indicate that the below bank full cross-sectional area of the river has not been reduced by the contraction works built in connection with the navigable channel. A study of three reaches, each 20 miles in length, reveals that the average below bank full cross-sectional area has been reduced less than one-half of one percent from 1908 to 1944, inclusive.

5. Because of the economic growth of the country and the successful nine-foot channel project, there has been in recent years a gradual encroachment on the confined channel in the harbor of St. Louis in the form of wharves, bridge approaches, etc. Although the individual effect of each is small, the cumulative effect of all may be large and would be reflected in the rating curves.

6. The factors under "Hydrology and Hydraulics" are all closely interrelated, and it is almost impossible to discuss any one individually without reference to some of the other factors. Besides the Missouri main stem proper,

a number of the major tributaries are conducive to producing large amounts of sediment during major floods. An example is the Kansas basin. This tributary during high intense storm rainfalls, such as occurred in 1844, 1903, and 1951, carried into the Missouri large amounts of sediment. For this reason it is felt that the origin and time of occurrence of major flood producing rainfall has a marked influence on the stage-discharge curve at St. Louis, Missouri.

7. Studies to date indicate that the rate of rise of the flood wave may have some effect on the stage-discharge relationship. The 1943 and 1944 floods took seven and eight days, respectively, to rise from bank full to crest, whereas the 1947 and 1951 flood both took 24 days to accomplish the same task. In conformance with the above features, the volumes of the floods are also comparable as shown below:

Volume above 540,000 c.f.s. (bank full flow)

Year	Volume c.f.s.
1943	2,673,000
1944	2,666,000
1947	5,168,000
1951	3,732,000

From this, it is possible that there could be direct relationship between rate of rise and flood volume and the carrying capacity.

8. Of the investigations conducted so far, the distribution of flood, Missouri or Mississippi, seems to play a most important part as to whether the rating curve is favorable or unfavorable. These studies reveal that, if the upper Mississippi basin flow drops below 50 percent of the water at St. Louis, the rating curve is

likely to be unfavorable. Conversely, if the upper Mississippi basin contributes 50 percent or more to the flow at St. Louis, the rating curve is likely to be favorable.

9. An analysis of hydrographic surveys over reaches established for studying the behavior of the river bottom, especially during flood periods, reveals that sand waves as much as 15 feet in maximum height move through the St. Louis harbor. The data collected and analyzed on ranges downstream of the discharge measuring station indicate that, during the 1951 flood, the river bottom rose to crest with the flood and thereafter fell with the falling stages. Much the same conditions prevailed in 1947; however, in 1943 and 1944, from other available data, the river bottom scoured. Thus, it is believed that the bed load has great effect on the stability of the rating curve.

10. In the determination of confined design height for a design flood, utilization is made of experienced flood data. The characteristics of a flood are analyzed and data collected therefrom are extrapolated to confined design height by use of "Mannings" formula, slope-elevation-discharge diagrams or any other acceptable methods. The characteristics of the flood play an important part in the determination of the confined design height selected. During the 1935 grade determination, considerable difficulty was experienced in reconciling confined design heights, through use of physical data collected on the 1922, 1927, and 1929 floods. The use of 1929 flood data gave greater design heights than either the 1922 or 1927 flood data. This same condition is applicable to the 1943-1944 and 1947-1951 floods. By use of the characteristics of the 1943-1944 floods, a design stage of 47 is computed, whereas, by use of the characteristics of the 1947-1951 floods, a design stage of 52 feet is computed.

11. No two floods of record have occurred in exactly the same manner, and it is not likely that any flood of the future will occur in precisely the same manner as any in the past. The maximum modern stage of confinement is about 40 feet on the gage, with a discharge of about 800,000 c.f.s. With 1,300,000 c.f.s. taken as the design flood, it then requires extrapolation for 500,000 c.f.s., an increase of about 60 percent above maximum observed, to determine the stage of the design discharge.

12. In conclusion, it is believed that the stage-discharge relationship at St. Louis, since 1943, is governed mainly by (1) the amount of bed material carried by the Missouri River, (2) the amount of flow contribution by the upper Mississippi River, and (3) the rapidity of rise of the flood wave. It is further believed that future floods confined by the levees, Alton to Gale, and reaching greater heights than those experienced in the recent past, will be erratic in their stage-discharge relationships because of the above-cited factors. It is unknown at this time what the behavior of the rating curve will be for flows of 1,300,000 c.f.s. On past experience, if 50 percent more of the flood flows originate on the Mississippi basin, the rating curves similar to 1943-1944 conditions should prevail, but based upon past records which show that when the Missouri ~~to be~~ is the greatest contributor during major floods, it is likely that the rating curve similar to 1947-1951 conditions would be more likely to occur ~~should prevail.~~

Not born out by 1973 flood [illegible] 4/74

DISCHARGE MEASUREMENTS

1. In general, the St. Louis rating curve has the characteristic loop; that is, the measured discharges for rising stages are greater than the measured discharges for falling stages with the transition taking place at crest. Stage-discharge relations for periods since beginning of levee construction are shown on plate 1. The end point of each curve represents the upper limit of discharge observations. Although the curves of the various periods are closely grouped around the 15-to-20-foot stage, there is considerable spread in discharge for equivalent stage at or about 35 and 40-foot stage; in addition, considering two curves grouped in chronological order, there is a crossing of the curves at 34-foot stage. From 1903 to 1951, inclusive, there is a marked decrease in discharge for stages approaching 40 feet.

2. A more detailed analysis of the discharge measurements for the floods from 1943 to date has been made and a plotting of the individual discharge measurements is shown on plate 2. The plotted points for the May-June 1943 and April-May 1944 floods are in general agreement at the upper extremities. Although at variance with the 1943-1944 points, the June-July 1947 and June-July 1951 floods are also in general agreement at the upper extremities. In contrast to the summer season floods of 1947 and 1951, the spring floods of both periods, though not attaining notable heights, produced greater discharges for comparable gage heights. This same phenomenum existed in the spring (April-May) of 1952 when, at the crest of this flood, greater discharges were experienced for comparable gage heights than for all other floods. In 1945, five distinct moderate flood crests were experienced, the first beginning in March and the last ending in June, with the carrying capacity of each flood becoming less than the previous flood.

3. It will be noted that the spread in discharge at about bank full is about 150,000 c.f.s., while at stage 34-35, the crossing point, it is only about half that amount and again at maximum stage the spread being about the same as bank full, however, due to deviation, extrapolated values would have a greater spread. For example, the flood of June 1945 was measured at about stage 35.2 at 584,000 c.f.s. while the flood of April-May 1952 was measured at about stage 33.6 at 681,000 c.f.s., a difference in stage of 1.6 feet and discharge of about 100,000 c.f.s.

Effect of levees

1. Prior to 1935, there existed many local levees in the vicinity of and downstream of St. Louis, the majority of which were of deficient height and section, the only levees constructed to an MRC standard were the East Side levee and sanitary district, Perry County levee districts Nos. 1 and 2, Preston and the East Cape Girardeau and Clear Creek drainage districts. Between 1935 and 1943, the following levees were enlarged or brought up to 1935 grade; portions of the riverfront of the Prairie du Pont and Columbia, Kaskaskia Island, (entire levee), Perry County (back levee), and East Cape Girardeau (entire levee). Although the local levee districts were of deficient height and section, they all withstood the 1942 flood, except the Ste. Genevieve district, which flood reached a height of 34.2 feet (666,000 cfs) at St. Louis, Missouri, on 30 June.

2. During the 1943 flood, all levees between Alton and Gale were overtopped or crevassed except the Chouteau, Nameoki and Venice, East Side, Prairie du Pont (upper flank and river front), Columbia and Kaskaskia Island. During the 1944 flood, all levees between Alton and Gale were overtopped or crevassed except the Chouteau, Nameoki and Venice, East Side, Prairie du Pont (upper flank and river front), Columbia, Kaskaskia Island and Perry County. During the 1947 flood, all levees between Alton and Gale were overtopped or crevassed except the Chouteau, Nameoki and Venice, East Side, Prairie du Pont (river front) Columbia, Kaskaskia Island, Perry County, Preston, Miller Pond, Clear Creek, North Alexander and East Cape Girardeau. During the 1951 flood all the levees between Alton and Gale remained intact and withstood the flood except the Grand Tower. During all above floods, the East Side district opposite St. Louis and the Columbia district just downstream of St. Louis remained intact and were not crevassed or flooded.

3. Table No. 1 shows the dates and stages at St. Louis when levee failure occurred for the floods of 1943, 1944, 1947 and 1951. It will be noted that there was very little difference between failure stages in 1944 and 1947 whereas there is some four to five feet difference in stage for failure in 1943, and no failure in 1951. If the levee failure effect were to be of material proportions, then why are the 1944 and 1947 stage-discharge curves not in better agreement at their upper extremities?

DATA ON LEVEE BREAKS

	1943		1944		1947		1951	
	MAY		APRIL		JUNE			
LEVEE DISTRICT	DATE	ST.L. GAGE	DATE	ST. L. GAGE	DATE	ST. L. GAGE	DATE	ST.L. GAGE
Prairie du Pont *	10 A.M. - 20th	35.5'	10 A.M.-28th	37.4'	9:30 P.M. 30th	39.5'	NO FAILURE	
Harrisonville	9 P.M. - 20th	36.2'	3:30PM-30th	39.0'	12N 27th	38.3'	ALL WITHSTOOD	
Fort Chartres	9 P.M. - 20th	36.2'	4 A.M.-20th	36.3'	Night 26th	37.2'	40.2 FEET.	
Stringtown	10 P.M. - 20th	36.3'	4 A.M.-27th	36.3'	Night 30th	39.5		

* During the 1943 and 1944 floods the upper flank and upper three miles of the river-front levee withstood the flood waters without crevassing or overtopping. During the 1947 flood all the district levee remained intact except for the extreme upper portion of the upper flank levee.

EFFECT OF PILE DIKES

Recent studies reveal that contraction by permeable dikes has had a negligible effect on the increase in flood heights, being only one-half of one percent since the work was first initiated. Three reaches of the Mississippi River, each 20 miles in length, in which typical channel regulating works and levees were built during the periods 1908, 1927, and 1944, were investigated. The reaches in upstream order are: (1) that portion of the river between Commerce, Missouri, (mile 40) and Poe Landing (mile 60); (2) from near the foot of Crains Island (mile 105) to Little Rock Landing (mile 125); and (3) from Chesley Island (mile 160) to St. Louis Eads Bridge (mile 180). Areas of the main channel up to lowest high bank elevation common to all three years are shown in the following table:

	40-60 Reach No. 1 Area Sq.Ft.	105-125 Reach No. 2 Area Sq.Ft.	160-180 Reach No. 3 Area Sq.Ft.
1908	96,000	74,000	80,000
1927	78,000	78,000	80,000
1944	79,000	76,000	78,000

The following is quoted from the results of surveys made under the direction of Colonel J. H. Simpson in 1879: "The area of cross-section in front of St. Louis at Pine Street was 41,000 square feet; stage, nine feet; the area added by a 30-foot stage would be 38,000 square feet; total, 79,000 square feet." The present area at Pine Street in St. Louis is 79,000 square feet at the 30-foot stage, hence, the cross-section has remained unchanged, although the St. Louis harbor is the most constricted reach of the open river section of the Mississippi River under consideration.

DERIVATION, FREQUENCY CURVE, ST. LOUIS, MISSOURI

1. The method used by the St. Louis District in computing the frequency curve of discharge at St. Louis, Missouri, is the Hazen method. Only the highest daily flow on a calendar year basis for each year of the period 1843 to date was used in the derivation of the frequency curve. The formula $P = \frac{2m - 1}{2n}$ was used in which P = the plotting position, m = magnitude of flood and n = number of years of record. From the annual crest discharges, the mean flood, coefficient of variation, and coefficient of skew were determined and from these the frequency curve was derived.

2. Discharge observations have been obtained at St. Louis for the following periods: 1866, 1872, 1874, 1880-1881, 1892, 1896-1905, 1909-1910, 1912-1915, 1919, 1922-1923, and 1927 to date. Gage readings at St. Louis are intermittent from 1826 to 1860; however, the crest of floods worthy of note were determined by levelling from the city directrix. The records are continuous from 1861 to date. The height of the historic flood of 1785 is also fairly well established, however, some doubt still exists as to correctness of height and flow.

3. Actual discharge measurements in excess of one million c.f.s. were obtained at St. Louis in 1892 when, on 20 and 21 May, flows of 1,043,000 c.f.s. by meters and 1,146,000 c.f.s. by floats were obtained; however, former engineers of the district discarded these measurements because they were considered unreliable, as flow estimated at 43,000 c.f.s. along the left bank railroad was not measured. Because of levee breaks at East St. Louis and downstream thereof, the 1903 flood was measured at Thebes, Illinois, 136 miles below St. Louis, the maximum measured discharge being 1,014,000 c.f.s. by meters on 14 June. Discharges in excess of 1,000,000 c.f.s. were also measured at this station on 15 June. At Chester, Illinois, 64 miles downstream of St. Louis, a flow of 1,060,000 c.f.s. was measured by rod floats on 27 April 1927. The above constitute all measurements of discharge in excess of 1,000,000 c.f.s.

4. The discharge observations were grouped by years and mean stage-discharge relationships for the selected periods were established. The stage-discharge relationship periods as established were: 1872-1881, 1896-1915, 1919-1928, and 1929-1934. The highest yearly discharge for use in determining the frequency curves was determined by applying the highest yearly stages to the stage-discharge relation curve of the appropriate period, except for the period from 1935 to date, where regular discharge measurements have clearly defined the flood discharge value.

5. The highest flood at St. Louis for which there are authentic records other than discharge is that of 1844. The accepted value of discharge for this flood is 1,300,000 c.f.s. A determination of the 1844 discharge value is printed in House Document 722, 59th Congress, 1st session. Subsequent to this determination, the peak discharge value for this flood was checked about 1935 by Upper Mississippi Valley Division hydraulic personnel and in 1951 by hydraulic personnel of the St. Louis District, each using a different method.

6. Floods in excess of 1,000,000 c.f.s. for which values were computed or determined from stage-discharge curves and used in the frequency curve determination are as follows:

Year	Stage (ft.)	Discharge (c.f.s.)
1785	41.5(±)	1,340,000(±)
1844	41.3	1,300,000
1851	36.6	1,022,000
1855	37.1	1,050,000
1858	37.2	1,054,000
1903	38.0	1,019,000 (1)

(1) Due to levee breaks, crest discharge estimated to be 1,040,000.

7. It may be interesting to note several comparisons of maximum measured discharge versus maximum stage-discharge curve discharge. In 1881 the mean of two crest rod measurements was 833,000 c.f.s. as compared to 822,000 c.f.s. determined from the stage-discharge curve and used in the frequency curve determination. In 1892, a maximum of 1,146,000 c.f.s. was measured by floats, but because of reasons previously stated, only 926,000 c.f.s. was used in the frequency curve determination. In 1909, a maximum of 851,000 c.f.s. was measured by meters as compared to 861,000 c.f.s. which was used in the frequency curve determination. Inasmuch as discharges at St. Louis were measured by various methods prior to 1935, it is believed that the adopted discharge for any flood used in the frequency curve determination is well within the accuracy of the methods of measurements. A study was previously made of the relationship of discharges measured by the Corps of Engineers using various types of equipment and measuring devices, floats (surface, subsurface, and rod) and meters (large old type and present small type). In general, it was found that the old methods and equipment gave results about ten percent larger than results obtained by present day methods and equipment. This error would be compensated for somewhat though not fully and would tend to make the older maximum discharge values comparable to present day maximum values as the instantaneous maximum peak discharge is always slightly larger than the mean daily maximum discharge.

NOTES - PHYSICAL CHANGES IN THE ST. LOUIS STAGE-DISCHARGE RELATIONSHIP

1. A number of selected stage-discharge curves, pertinent to the St. Louis gage, Mississippi River, are shown on chart No. . The 1872-1881 curve is shown to illustrate the discharge capacity prior to material regulating works or levee construction. The other curves represent discharge conditions during the flood years indicated as determined from records of discharge measurements.

2. The 1903 curve at stages above 34 feet lies about 1 foot above the 1872-81 curve for equal discharge.

3. The metered discharges for 1909 plot reasonably along the 1903 rating curve in the range 33-36 ft.

4. Discharge measurements for 1927 are available for only the flood crest. A curve based on these few measurements lies reasonably parallel to that of 1903 in the range 33-36 ft., but indicates discharge values in 1927 about 40,000 c.f.s. less than in 1903 for equal stages.

5. The discharge curve for 1929 at St. Louis starts deflecting to the left of that for 1903 at 30.6 stage. At 34 ft. the 1903 curve indicates a discharge of 776,000 c.f.s., while 1929 curve shows 666,000 c.f.s. The stage in 1929 did not rise high enough to indicate what might have happened above 34 ft.

6. Plottings of discharge data for the 1927, 1947, and 1951 floods disclosed a vertical shift in the stage-discharge relationship in the 31-35-ft. range.

7. The 1943-44 curves indicate a less efficient channel for practically all stages than previously experienced. In the 32- to 39-ft. range, the increase in stages for 1943-44 conditions over those experienced in 1927 and 1929 amounts to ±3 ft. The 1943-44 floods followed a drought of flood years subsequent to 1929 other than a stage of 33.45 in 1935 and 34.22 in 1942.

8. A study of available data indicates that stages for May-June-July (summer) floods are upwards of 3 ft. higher than for equal discharges in March-April-May periods for stages 26 ft. or above.

9. The 1947-51 summer curve lies reasonably close to the curve for 1943-44 up to 34 ft. It then deflects to the left until at 39 ft. the former indicates a discharge of but 740,000 c.f.s. compared to 830,000 c.f.s. for the 1943-44 curve.

10. The spring discharge in 1929, 1947, and 1951 plots closely to a January-April 1952 rating curve; i.e., up to the 34-ft. stage.

Excerpt from letter dated 11 March 1954

SLD & UMVD

11. Plotting of discharge measurements, giving due consideration to their time sequence, indicates with reasonable clearness that the stage-discharge relationship at the St. Louis gaging station is more favorable for March-April-May floods than for May-June-July floods, at least up to possibly the 35-ft. stage. Several theories, based on their studies, have been advanced by individuals as possible reasons for the above phenomenon. These involve, among possibly others, the elusive question of bed-load movements, the carrying capacity of the water at varying temperatures, the relative proportion of Missouri and Upper Mississippi water in floods at St. Louis, the effect of plant growth, and the effect of a series of flood peaks evolving into the major peak, which theories to date are inconclusive.

12. The relationship between levee and regulation works, Mississippi River, Alton to Gale (river miles 203 to 46), and stages at St. Louis for various discharges is shown on chart No. .

13. Notes pertaining to regulation works, channel maintenance, levee construction, and levee-district flooding are attached. They need to be correlated in time and action with the discharge curves to derive relationships.

14. Notes relative to changes in the stage-discharge relationship at Chester, Ill., attached, and the curves depicted on chart No. appear to have a bearing on the problem.

15. It would appear from available data that it is reasonably good judgment to consider the 1947-1951 physical conditions as a criterion for flood-protection works in the St. Louis region.

NOTES ON REGULATING WORKS
ST. LOUIS DISTRICT

Prior to 1908 the amount of regulating works in the Mississippi River, Alton to Cairo, was small except in the mile 160-180 reach.

Between 1908 and 1927 additional regulating works were built.

Between 1927 and 1944 the major portion of the regulating works was constructed.

The project depth was increased in 1927 from 6 feet to 9 feet.

Study of 3 reaches (mile 160-180), (105-125), (40-60), recorded in a report of St. Louis District dated 27 June 1945, for periods 1, 2, and 3 above, shows that channel cross sectional areas were practically the same for the 3 periods.

Both the position of more recent rating curves in relation to those of 1903 from low stages up to +24', and the recorded fact of the lowering of the low-water plane in the Mississippi at and below St. Louis, as well as the above x-section data, support the finding that the pile-dike construction has not weakened the carrying capacity of the stream.

NOTES ON FLOODING OF LEVEE DISTRICTS
ST. LOUIS DISTRICT

Levees were constructed by local interests during the period 1850-1892, between miles 195-110, to grades equivalent to a St. Louis stage of ±36 feet. Levees, in general, withstood the 1892 flood (36.0'), but were flooded in 1903 (38.0').

At the time of the 1892 (21 May) flood (St. Louis stage 36.0 ft.) levees and railroad embankments protected approximately the area encompassed by the Chouteau, Nameoki & Venice D. & L. District, the East Side L. & D. District, the [illegible]-Prairie du Pont D. & L. District, the Columbia D. & L. District and the Harrisonville & Ivy Landing D. & L. District. Mr. Wm. G. Mitchell's report of 2 December 1905 (contained in H. D. 772-59-1) records that these levees withstood the 1892 flood and he estimated the St. Louis stage to have been 1.9 ft. higher than the natural stage, due to the levee restrictions.

During the 1903 (June) flood (St. Louis stage 38.0 ft.) the aforesaid areas were flooded, yet Mr. Mitchell records that the levees, with but few exceptions, remained intact. He also records that the 1903 flood was abnormally high, rising about 2.7 ft. above the natural height, as evidenced by comparison with stages experienced at points downstream of St. Louis; i.e., Chester and Thebes, Illinois, where the river had been changed but little since the flood of 1844.

Mr. H. C. Frankenfield, Weather Bureau Forecaster at St. Louis, in his report on the 1903 flood, states:

> "The floods of 1903 descended upon broad, fertile, and highly cultivated fields, and upon rich valleys filled to overflowing with vast industries devoted with never-ceasing energy to the fulfillment of the insatiable demands of commerce.
>
> "Very little of the cities of St. Louis and East St. Louis were covered, but large portions of the manufacturing towns of Venice and Madison, through the breaking of their levees, were flooded to a considerable depth.
>
> "The greatest overflowed district, however, was that known as the American Bottom, which extends from Alton to near Chester on the Illinois side, a distance of about 95 miles, and comprises approximately 320,000 acres of the most productive land in Illinois. With the exception of minor areas this entire region was under from 1 to 15 feet of water."

During the 1909 (July 16) flood (St. Louis stage 35.25), the levee situation was similar to that in 1892 and 1903, the levees holding for the lesser stage. I find that the discharge measurements of record for the 1909 flood plot very close to a 1903 rating curve derived from 1903 measurements, particularly in the range 33-35 ft. St. Louis gage. I also find that the slope between peak stages at St. Louis and Chester was about 3 ft. greater during the 1892, 1903, and 1909 floods than during the 1944, 1951, and 1953 floods, indicating the same general effect of constriction by the then existing levees around the American Bottoms.

Wood River levees (miles 203-195) constructed during the period 1910-1915 to 38 ft. stage were overflowed in 1915 (31.6').

Local levees were in existence between miles 203 and 46 by 1927, many of them by 1922, as we have a record of Columbia, Perry County, Degognia and Fountain Bluff, [illegible], and North Alexander districts being overflowed in 1922 (stage 33.5'). Increase in height of levees was progressive; for example, Columbia D. & L. District was overflowed in 1926 (stage 31.6'), overflowed in 1927 (36.1'), but it held in 1943 (38.2'), in 1944 (39.05'), in 1947 (40.2'), and again in 1951 (40.15').

Study of 3 reaches (mile 160-140), (145-125), (40-[illegible]), recorded in a report of the St. Louis District dated 27 June 1945, shows that areas of floodway sections were reduced by 1/3 between 1908 and 1927 (mostly levees) and [illegible] ¼ of it between 1927 and 1944.

In 1943 sixteen out of nineteen levee districts were flooded at St. Louis stage varying from 35.3 to 38.9.

In 1944, 15 out of 19 levee districts were flooded at stages varying from 36.4 to 38.8.

In 1947, while 10 out of 19 levee districts were flooded at stages varying from 37.2 to 40.0, it is noted that, in general, they held out to a 2-foot higher stage than in 1943-44.

In 1951, only 3 out of 19 levee districts were flooded at St. Louis stage of 40.0'.

NOTES - CHESTER DISCHARGE CURVE
(RIVER MILE 110)

The 1927 rating curve is reasonably close to that of 1903 to 30-ft. stage or 700,000 c.f.s.

At 900,000 c.f.s. discharge, 1927 curve is ≈ 1.2 above 1903 curve.

The 1929 rating curve lies between 1926 and 1927 curves up to 28 feet. Thence diverges to left, indicating stages 1.2 ft. higher than the 1927 curve at 740,000 c.f.s. discharge (≈ 32-ft. stage).

The 1943, 44, 47, 51, and 52 curves are 20,- 30,000 c.f.s. to left of 1926-27 curves at 10-ft. stage. At 26-ft. stage the first group are some 100,000 c.f.s. to left of 26-29 curves (a difference of ≈ 3 ft. in stage for 500,000 c.f.s. discharge; i.e., 25.5 ft. to 28.5 ft.). At 800,000 the spread is ≈ 4 ft.

The 1943, 44, 47, 51, & 52 curves are reasonably grouped up to ≈ 640,000 c.f.s. or the 34-ft. stage.

The 1943, 44, & 47 curves are well grouped up to the 37-38-ft. stage (≈ 850,000 c.f.s.), while it will be noted that the 1951 curve diverges from the 1943 curve at the 34-ft. stage, resulting in a 2 - 2½-ft. higher stage at ≈ 38 ft.

Attention is invited to the fact that at Chester the 1947 curve follows the 1943-44 trend above the 34-ft. stage, showing effect of levee breaks, particularly Degognia & Fountain Bluff; Stringtown, Ft. Chartres & Ivy Landing; Ft. Chartres & Ivy Landing; Harrisonville; and Wilson, Henkel & Prairie du Pont Districts, while in 1951 the Chester curve shows the same trend as at St. Louis, as these levees held.

Examination of the gage relationship at St. Louis and Chester indicates the slope between gages to be the same in 1851 and 1858 as in 1844.

In 1892, 1903, and 1909 the slope is ≈ 3 ft. steeper, showing the effect of levees around the American Bottoms and possibly the regulating works in mile 160-180 reach;

while in 1927, 1943, 1944, 1947, and 1951 the slopes are again about the same as in 1844, as the effect of the extensive levee building downstream of St. Louis shows up at Chester as well as at St. Louis.

Mississippi River at St. Louis, Mo.

Study of Shifting

The request for the history of shifts at the gaging station on the Mississippi River at St. Louis, Mo. creates a problem that cannot be answered with a brief study if reasons for the shifts are to be given. The amount of the shifts in general through the years can be shown.

To study the shifts at St. Louis the period 1934 to 1961 was used. The study shows a general degradation of the low water channel, a loop effect for each flood, a shifting of the loop during any year which has several floods and the occurrence of the widest part of the loop between 20 and 35 feet gage heights.

For the period 1934-61 an average gage height was determined for various discharges at intervals from 50,000 to 800,000 cfs. These results were plotted on sheet No. 1. The small circles indicate the range in stage in any one year for discharge shown. Dotted lines indicate that the gage height for that particular year was not reached by the range for that year. This plotting indicates a general degradation below gage height of 25 feet with it being more evident at low stages. Above 25 feet not enough years of high flow have occurred to be specific about a trend, but there is a scour effect shown after a period of high flow with a filling in during a following period of years of low flow. During a period of low-flow years the rate of scour at low stages is greater, which is probably influenced by dredging of the channel and by less silty water entering the area. Plotting on sheet No. 2 shows degradation of more than 8 feet for stages representing 50,000 cfs for the period 1844 to 1961.

On all floods there is a loop effect showing a greater discharge on the rising than on the falling stage for a given gage height. This loop is widest between 20 and 35 feet gage heights. Gage height of 30 feet is considered flood stage, but above 20 feet the flow may leave the main channel at places downstream and effect of encroachment may influence the stage-discharge relation. For the few high years of record studied, the loop is always narrow above 35 foot stage. It appears the bank overflow has a decided effect on the loop effect. On the recession the water slope and velocities are always lower than on the rising stage. A composite plotting of several high years is shown on sheet No. 3. This demonstrates that the width of the loop is greatest between 20 and 35 feet. More information is needed to explain the variation shown above 35 feet.

To show the seasonal change in a particular year two prints of gage height vs discharge are shown for 1951 and 1961 on sheets 4 and 5. The shifting of the peaks from right to left is clearly demonstrated in these prints. The pattern is closely the same each year. From February to July the peaks progress from the right to the left. Then any rise in September and October move back toward the right. The sediment load possibly has an effect on this transition. During those years when the flow recedes to a low stage the recession curve will remain to the left until the late months in the calendar year. Then during the low period discharge measurements will begin to show a trend toward the right. Any later rise will show a stage-discharge relation to the right of the previous recession curve. This is the yearly pattern in general. In effect it might be stated that the loop extends down to a low stage.

Many factors are undoubtedly causing these changes. A detailed study of the cause and effect is beyond the scope of this brief study. From early days of record to the present time man's confinement of the channel and construction of reservoirs has no doubt caused degradation shown at low flows. Seasonal shifting must be caused by changes in the sediment load of the Mississippi and Missouri rivers. The slope, sediment load, overbank flow, dredging and encroachment are factors to be considered.

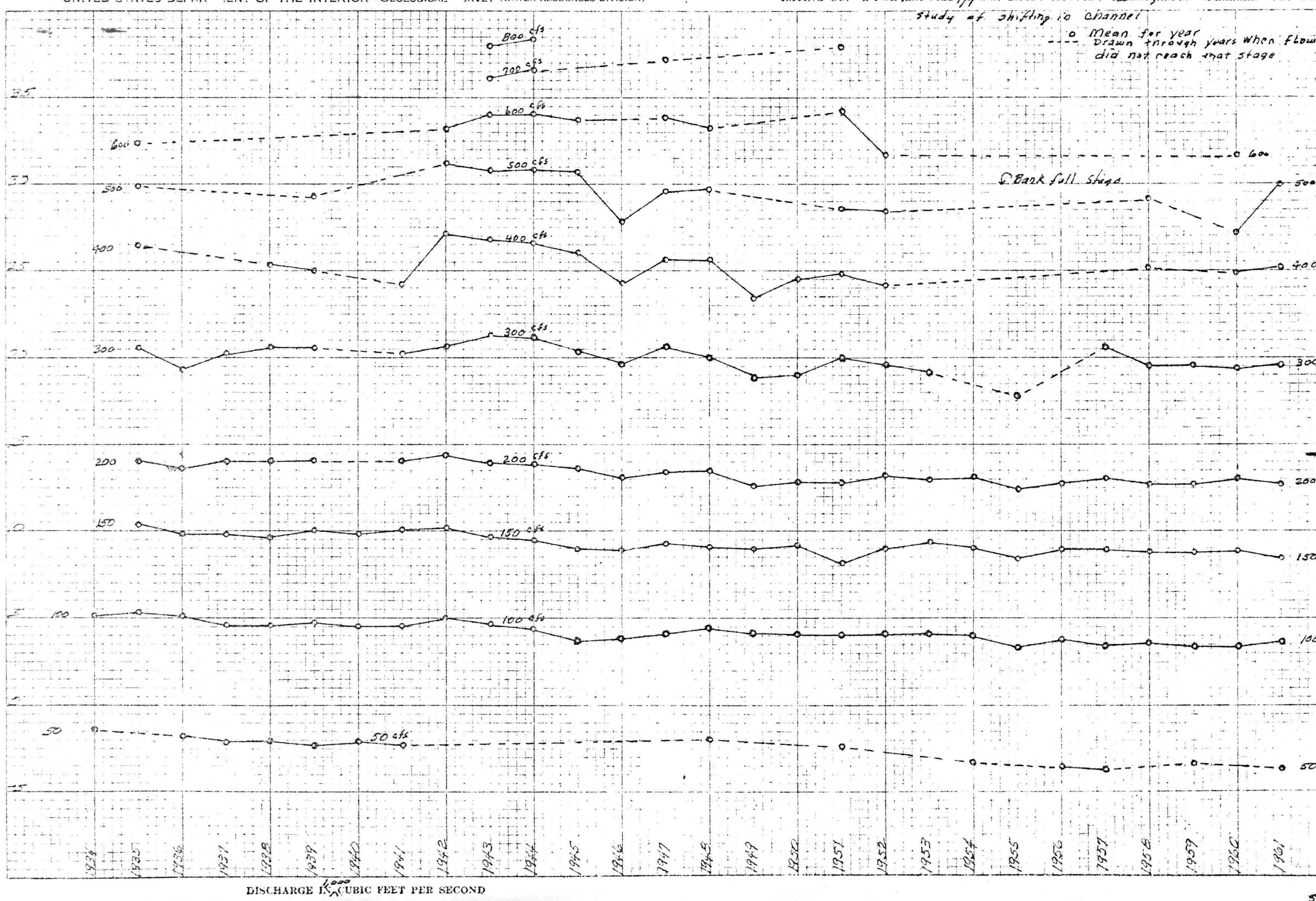
Roy H. Monroe
Engineer-in-Charge
1-30-62

USGS
ST LOUIS DIST OFFICE

UNITED STATES DEPAR[illegible]ENT OF THE INTERIOR—GEOLOGICAL [illegible]RVEY (WATER RESOURCES DIVISION)

RATING CU[illegible]E FOR Mississippi River at St. Louis, Mo. File No. { Washington .... Field ....

Study of shifting in channel



Year,		
Meas. Nos.,		
Max. G. H.,		
Min. G. H.,		
Plotted by		
Checked by		

Curve approved by: ....

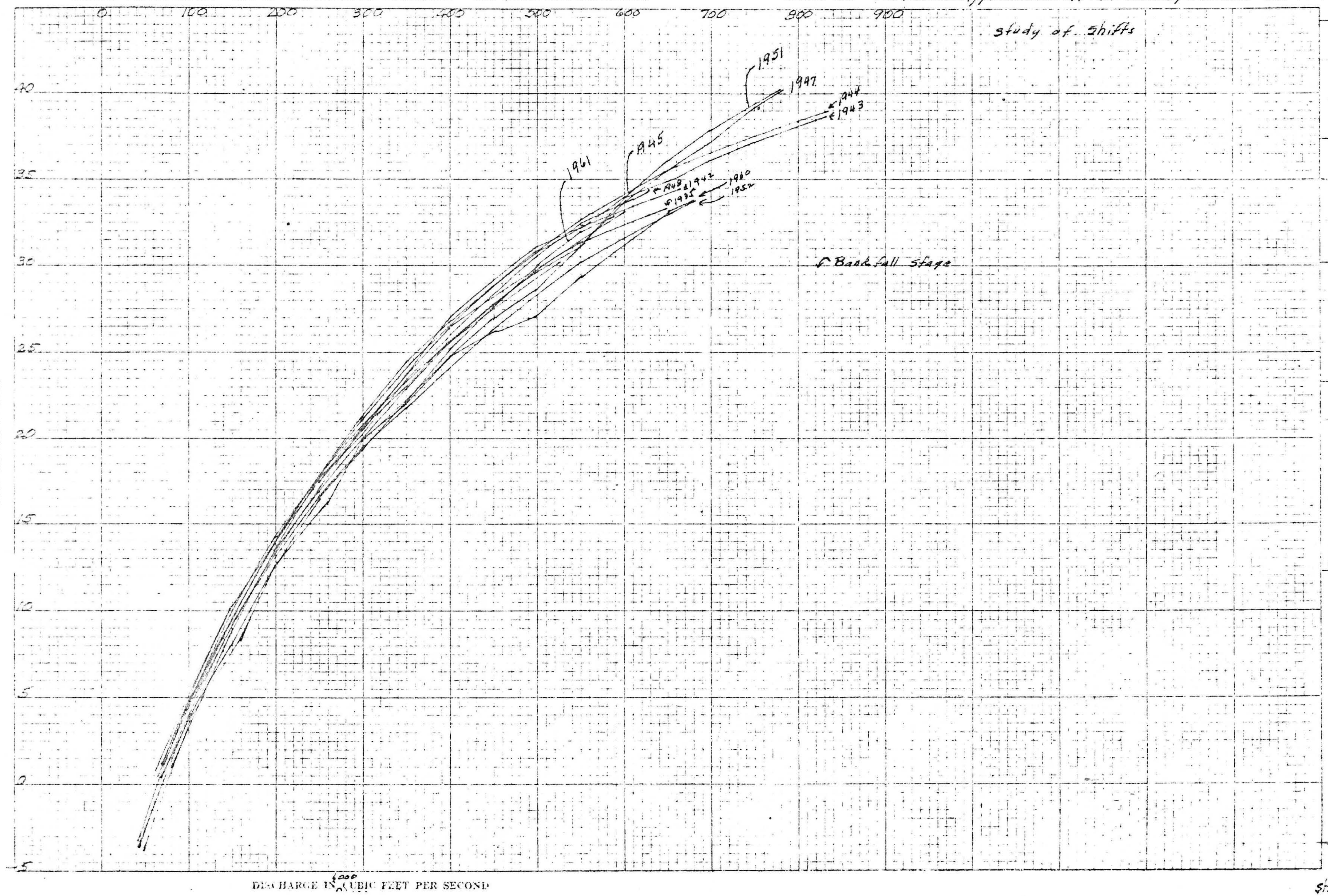
.... Office Engineer.

.... District Engineer.

Date .... A.Ross 1-26-62

Sheet No. 1

UNITED STATES DEPAR ENT OF THE INTERIOR--GEOLOGICAL RVEY (WATER RESOURCES DIVISION) RATING CUR FOR Mississippi River at St. Louis, Mo. File No. { Washington ____ Field ____



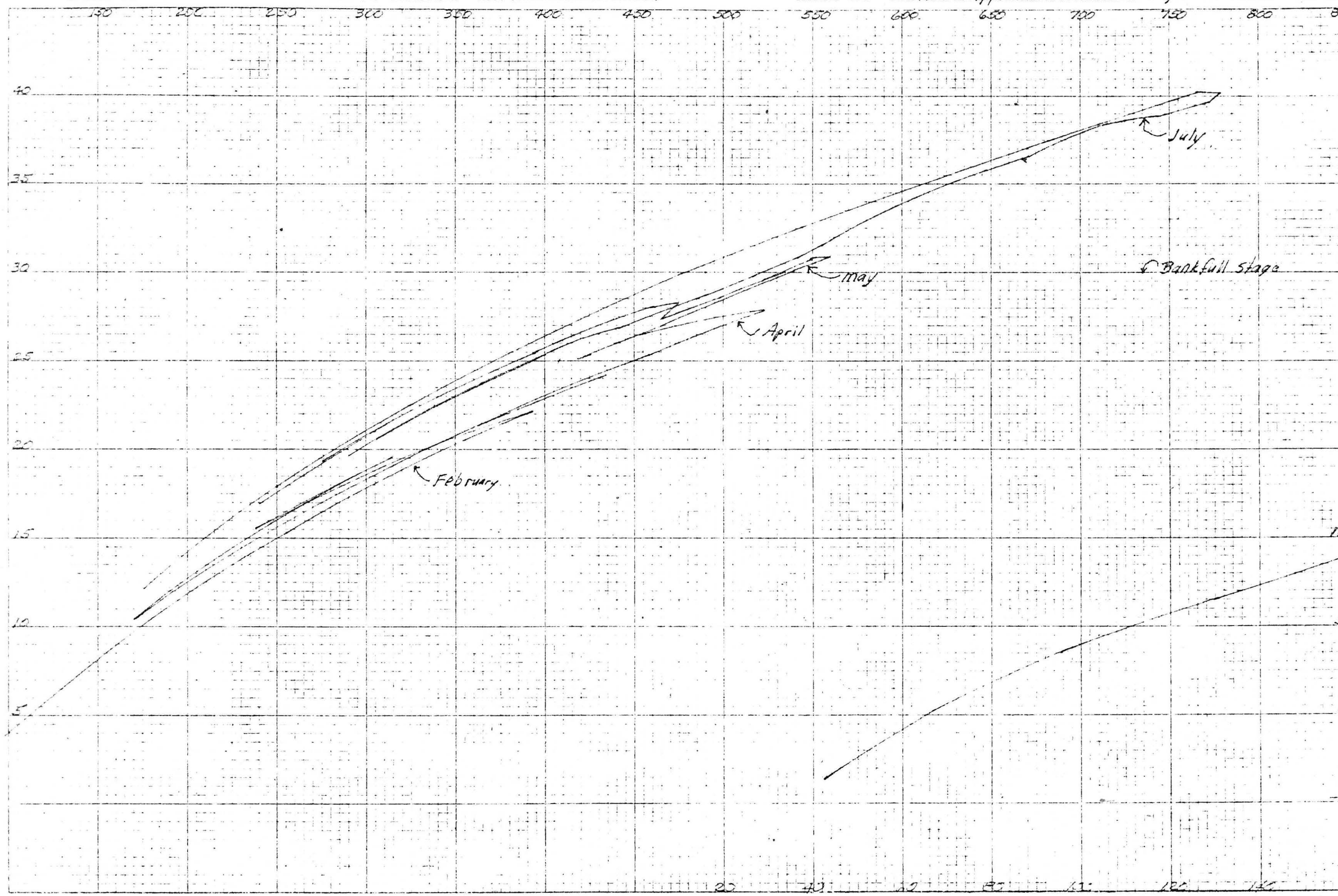
Year	Meas. Nos.	Max. G. H.	Min. G. H.	Plotted by	Checked by

Curve approved by: ____ Office Engineer, ____ District Engineer, RMM
Date ____ 1-26-62

Sheet No 3

UNITED STATES DEPAR ENT OF THE INTERIOR—GEOLOGICAL RVEY (WATER RESOURCES DIVISION)

RATING CURVE FOR *Mississippi River at St. Louis, Mo.* 19__ File No. { Washington...... Field......



DISCHARGE IN CUBIC FEET PER SECOND

Year. | Meas. Nos. | Max. G. H. | Min. G. H. | Plotted by | Checked by

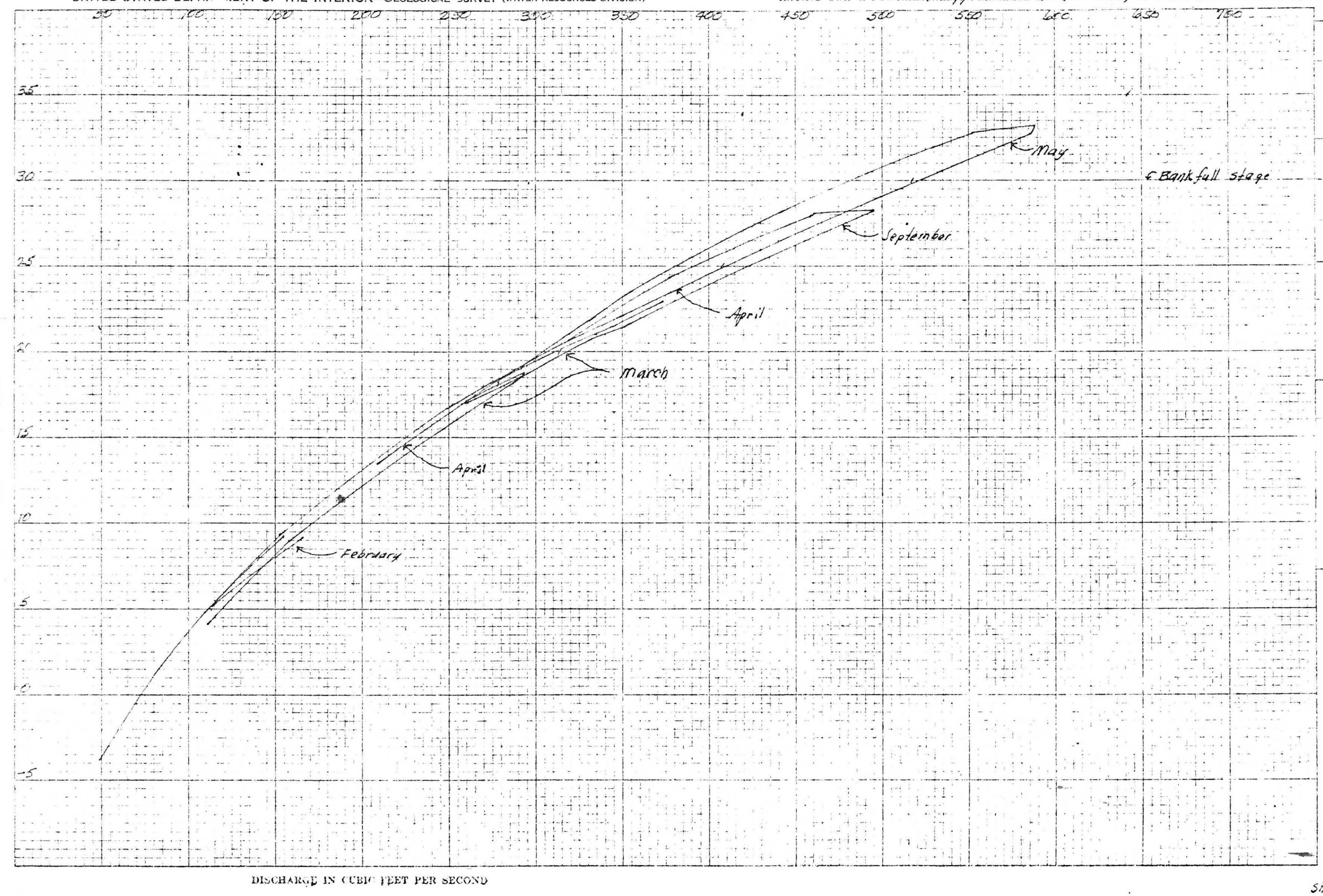
Curve approved by: Office Engineer. District Engineer. *RPH 1-29-62*

Date

Sheet No. 4

UNITED STATES DEPARTMENT OF THE INTERIOR—GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

RATING CURVE FOR Mississippi River at St. Louis, Mo. 1961 File No. Washington Field



Year. Meas. Nos. Max. G. H. Min. G. H. Plotted by Checked by

Curve approved by: Office Engineer. District Engineer. Date

Sheet No. 5