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A STUDY OF THE AVAILABLE WATER POWER
ON THIRD CREEK
KNOXVILLE, TENNESSEE.

BY
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A THESIS SUBMITTED FOR
THE DEGREE OF BACHELOR OF SCIENCE
MECHANICAL ENGINEERING COURSE.

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TOPOGRAPHY.

Third Creek rises at the foot of Black Oak Ridge and empties into the Tennessee River at Knoxville. All of it being in Knox County. The topography of the land is not unusually rough nor are there any notable falls. Plate XII, Appendix, is a map of the drainage area and the characteristics of the topography. The drainage area covers approximately 15.7 square miles. Most of it is under cultivation and therefore the run-off is rapid immediately after a rain. There are two important branches of the creek, known respectively as East and West Third Creeks. The fork is about one and a quarter miles from the mouth of the creek and therefore to utilize the entire flow the only place for a dam is below the fork. Probably a quarter of a mile below the fork there is a noticeable fall in the creek and therefore the only site possible for a dam to utilize the entire fall in the creek bed and also the largest quantity of water flowing is between the falls and the fork of the creek.

Plate I, A & B, is a map of the creek and the immediate topography between the mouth and a point on the stream which is probably the limiting distance for backing the water with a dam. By a survey contours of the area were located and a possible height for a dam determined. As can be seen by referring to the map Southerland Avenue and a settlement of several homes and small farms is located about on the 855 foot contour and above. Also the land spreads out into a broad level valley and adding a few feet to the height of the dam, supposing it to reach the 850 foot contour, would submerge several acres of land, the value of which would more than off-set the gain in head. It was therefore concluded that a dam with the elevation of the crest at the 850 foot contour would be the probable maximum economic height to which the dam could be built.

Contours for the 845 and the 840 foot elevations were drawn in. With a planimeter the plane area cut by the three contours, 850, 845 and 840, were secured. With these areas as abscissae and the elevations as ordinates a curve was plotted showing the acres of land submerged for each elevation. With the volume between the contours, in acre feet, as abscissae and the elev. as ordinates the draw down curves were plotted for a 20 foot dam and also for a 15 foot dam. These curves are shown on Plate X.

STREAM FLOW.

A gauging station was established at a suitable place near the dam site about November 15, 1922 and daily readings were taken until May 7, 1923. At various gauge readings between the minimum and the maximum the flow of the stream was measured with a Price current meter. Plate II Shows a cross section of the stream bed at the gauging station. With the gauge as ordinates and the flow as metered a curve was plotted which is the rating curve for the stream. (Plate IX). With the daily gauge readings, changed to cubic feet per second by the rating curve, as the ordinates and time as the abscissae the hydrograph of the stream was plotted, for the six months in which gaugings were taken.

Since there is no other data on record of the flow of this stream, a comparative hydrograph was constructed based on the flow of the Tennessee River at Knoxville over the same period of time. These two hydrographs are constructed on Plate III. The comparative hydrograph does not agree sufficiently with the actual hydrograph to warrant the construction of a comparative hydrograph covering a longer period of years. The six months record made by the author is the only indication of the flow of Third Creek available to use as a basis for calculating the power of the stream. This hydrograph may or may not represent the lowest flow of the stream. To ascertain this with some degree of accuracy, a comparative hydrograph was constructed for November based on the driest year on record of the flow of the Tennessee River at Knoxville. This was November, 1904. This hydrograph was compared with that constructed for November, 1922, and it was found that the flow of the Tennessee River for November, 1922, was lower than that for November, 1904. Hence, it is concluded that the flow of the stream as represented by the actual hydrograph is the lowest and may be safely used as a basis for the power development. The minimum flow as shown by the hydrograph is 12 second-feet, which represents the quantity of water available for power for 100% load factor continuously throughout the year, without pondage.

HEAD

With the height of the dam established and the minimum flow of the stream determined, the head available comes next. Plate VII is a profile of the creek below the dam to the mouth.

From the data on record of the Tennessee River flow and from observations a mean elevation of 805 feet was established as the level of the tail race at power house site. The flood stage of the Tennessee is probably up to an elevation of 820 or 825 feet. And the power house must be built so that water will not damage the generating machinery at flood stages. Considering 805 feet elevation the mean of tail water level and height of dam at the 850 foot elevation there is a maximum head of 45 feet. The minimum head is a matter of choice. It is taken as about 25% ^{of less} ~~of~~ ^{than} the maximum or say 35 feet.

Of course the head is variable at all times and ^affects the power to some degree. In the present study the head has been taken as an average and the power calculated based on this constant average head of 37 feet for the 20 foot dam and 32 feet for the 15 foot dam, 3 feet in each case being allowed for friction in the penstock.

STORAGE

From the drawdown curves on Plate X it is seen that with a reduction in head of 10 feet the lake level is lowered to an

elevation of 840 feet with a dam 20 feet high and to an elevation of 835 feet with a 15 foot dam. The draw-down curves show, for the 20 foot dam, a storage capacity of 525 acre feet and for the 15 foot dam a storage capacity of 310 acre feet.

DAM

Plate IV gives a cross-section of the dam site. From observations it is seen that the rock level is probably about 4 feet under the soil. The length of the dam is found to be 300 feet long and with a height of 20 feet the cross-section was calculated as shown in Plate VI. Since the crest of the dam is very near to the maximum level it is desirable to have a spillway long enough to take care of flood stages without an appreciable increase in head on the crest of the dam. From the best observation of gauge height and the rating curve the quantity of water flowing is known. It was decided to limit the flood stage head on the crest of the dam to 1 foot and to do so requires a spillway 170 feet long. The quantity of concrete to construct the dam is figured to be 2,000 cubic yards.

Since a spur track of the Southern Railway would be inundated by back water, it has been found necessary to construct a retaining wall. It is estimated that the retaining wall or dam would have to be 10 feet high and about 400 feet long. Requiring about 1400 cubic yards of concrete.

PENSTOCKS

To take advantage of the maximum head available, a pipe line would be required about 5200 feet long, approximately one mile. To carry the discharge of 67 cubic feet per second and to limit the head lost to a desirable figure, of say 3 feet, requires a 54 inch pipe. Wood stave pipe is the best suitable for this size both in handling and in construction. Plate V shows a profile of the pipe line. The pipe or penstock being of wood staves gives better satisfaction under pressure, hence the pipe is dropped from intake to level of ground below dam at once. The pipe is then carried along on the creek bank to the power house. Plate I map gives a plan of the pipe line. There needs to be no excavation for the pipe and no trestle work excepting at 3 places. It crosses the creek at two places and would need support and brackets would be necessary to suspend it in going thru the arch of the Kingston Pike bridge. The right of way for the pipe line would not be very expensive. The land below the dam has been laid out into a park by the owner. Since at present it is frequently swept by floods and with the regulation provided by a 20 foot dam, the park would not be inundated so often. Below the park the land is not under cultivation except about 1000 feet of pipe passes thru a pasture.

POWER

To determine the rate at which water can be used with a

storage capacity of 525 acre feet requires that the mass curve for the stream be drawn. Plate VIII shows this mass curve starting in the dry period of November, 1922, and continuing thru the 6 months of records. From the curve it is seen that a rate of 67 acre feet per day may be used and still have the reservoir refill after a maximum draw-down. Assuming a 50% load factor this is equal to 67 cubic feet per second flow that can be used for power with an average head of about 37 feet and plant efficiency of 80% gives 224 H.P. 3 feet is allowed for loss of head between dam and power house. This represents the continuous or primary power. The stream might furnish secondary power but the wide fluctuations of the stream above the primary power range is such that in my opinion would not be dependable for secondary power. With secondary power or with a higher primary power an auxiliary steam plant would be required. This is not economic because a steam plant for the development of power would cost less per K.W.H. than it does to develop the stream.

MARKET

Since the power development is inside Knoxville City limits there is no doubt about a market.

The Transmission line is not considered since it would be short - connecting right in at the plant to the distribution system of the City.

COSTS

The water rights would, on a small stream, be invested in the owners of the adjacent land. Estimating 85 acres for the reservoir and dam - possibly strip 20 feet wide and 5,000 feet long or about $2\frac{1}{2}$ acres for the pipe line and power site, making a total of approximately 87.5 acres of land. Due to the situation of the land being admirable factory site, etc., a price of \$1,000.00 per acre is not considered too high. On this price I talked to a real estate man handling such land at \$1,000.00. 87.5 acres would cost \$87,500.00

The dam contains 2,000 cubic yards of concrete. From records of other concrete work \$7.50 per cubic yards has been taken as a fair price to cover costs of materials, labor, etc., making the dam cost \$15,000.00

The retaining wall for the Southern Railway spur track contains about 1,400 cubic yards and at \$7.50 would cost about \$10,500.00

5,200 feet of wood stave pipe at \$4.00 per foot cost \$20,800.00. Estimating the cost of Turbines, Generator and switch-board and transformers from costs of other developments of

similar size and character to be \$8,350.00. The power house, foundations, etc., are estimated to cost about \$2,800.00, allowing 2% for engineering, extras and contingencies, amounts to \$2,900.00.

Some of these estimates are not exact perhaps. But due to a lack of time to get prices from the manufacturers, the estimates in most cases are based upon a careful study of the costs per K.W. H. of installed capacity of other small plants. To be safe liberal allowances have been made where the estimate seems low or conditions call for an extra allowance.

TABULATED COSTS BASED ON A 20-FOOT DAM.

Land	\$ 87,500.00
Dam	15,000.00
Retaining Wall	10,500.00
Wood Stave Pipe Line	20,800.00
Turbine, Generator, Switch board, Transformer, etc.	8,350.00
Power Plant Building, Foundation, etc.	<u>2,800.00</u>
Total Cost.....	\$144,950.00
Add for Engineering (2%)	<u>2,900.00</u>
Total Cost of Development.....	\$147,850.00
Cost per H.P. of Capacity	657.00

ANNUAL EXPENSE

Operating:

Salary Supt. & Office Expense	\$2,000.00
Wages Operators at Station	2,000.00
Supplies & Extra Expense	<u>900.00</u>
Total Operating.....	\$4,900.00

Overhead:

Interest @ 6%	\$8,871.00
Depreciation	
Dam @ 1%	\$255.00
Power House & Bldgs. 2%	\$56.00
Turbines & Equipt. 4%	<u>\$334.00</u>
	645.00
Insurances & Taxes @ 2%	<u>\$2,957.00</u>
Total Overhead.....	\$12,473.00

Total Annual Expense.....\$17,373.00

Cost to develop power 2.37¢ per K.W.H.

TABULATED COSTS - BASED ON A 15 FOOT DAM

Land 50 acres	\$50,000.00
Dam - 1,550 cubic yards @ 7.50	11,600.00
Concrete retaining wall	5,000.00
Pipe Line	20,800.00
Power House, & foundation	2,800.00
Turbines and Generating Equipment, including switch board and transformers	<u>8,350.00</u>
	\$98,550.00
For Engineering 2%	<u>1,971.00</u>
Total cost development.....	\$100,521.00
Cost to develop per H.P.	627.00

Annual Expense:

Operating (Same as before)	\$ 4,900.00
Overhead	
Interest @ 6%	\$6,031.26
Depreciation dam	146.00
Power House, etc.	56.00
Turbines and equipment	<u>334.00</u>
Total Depreciation	\$536.00
Insurance & Taxes 2%	<u>2,010.42</u>

Total Overhead..... \$8,577.68

Total Annual Expense.....\$13,477.68

Cost to develop power 2.57¢ per K.W.H.

SUMMARY

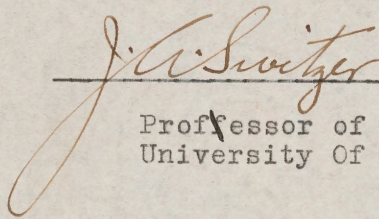
The cost per H.P of installed capacity for development is high. Usually \$250 per H.P. is a high cost, but is not excessive. But \$650 is above good economic practice. The cost of generating power - that of 2.5¢ per K.W.H. is very high also. On the whole, the proposition does not look promising as a power development.

Some of the disadvantages are excessive length of dam and penstocks for such a small development. The necessity of a retaining wall at Southern Railway spur line and the high cost of land per acre.

The development being in the City limits accounts for most of the inconvenient aspects of the situation.

APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject , carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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Professor of Hydraulic Engineering,
University Of Tennessee.

PLATE I-A
SEC. 2.

CONTINUED FROM SEC. 1.

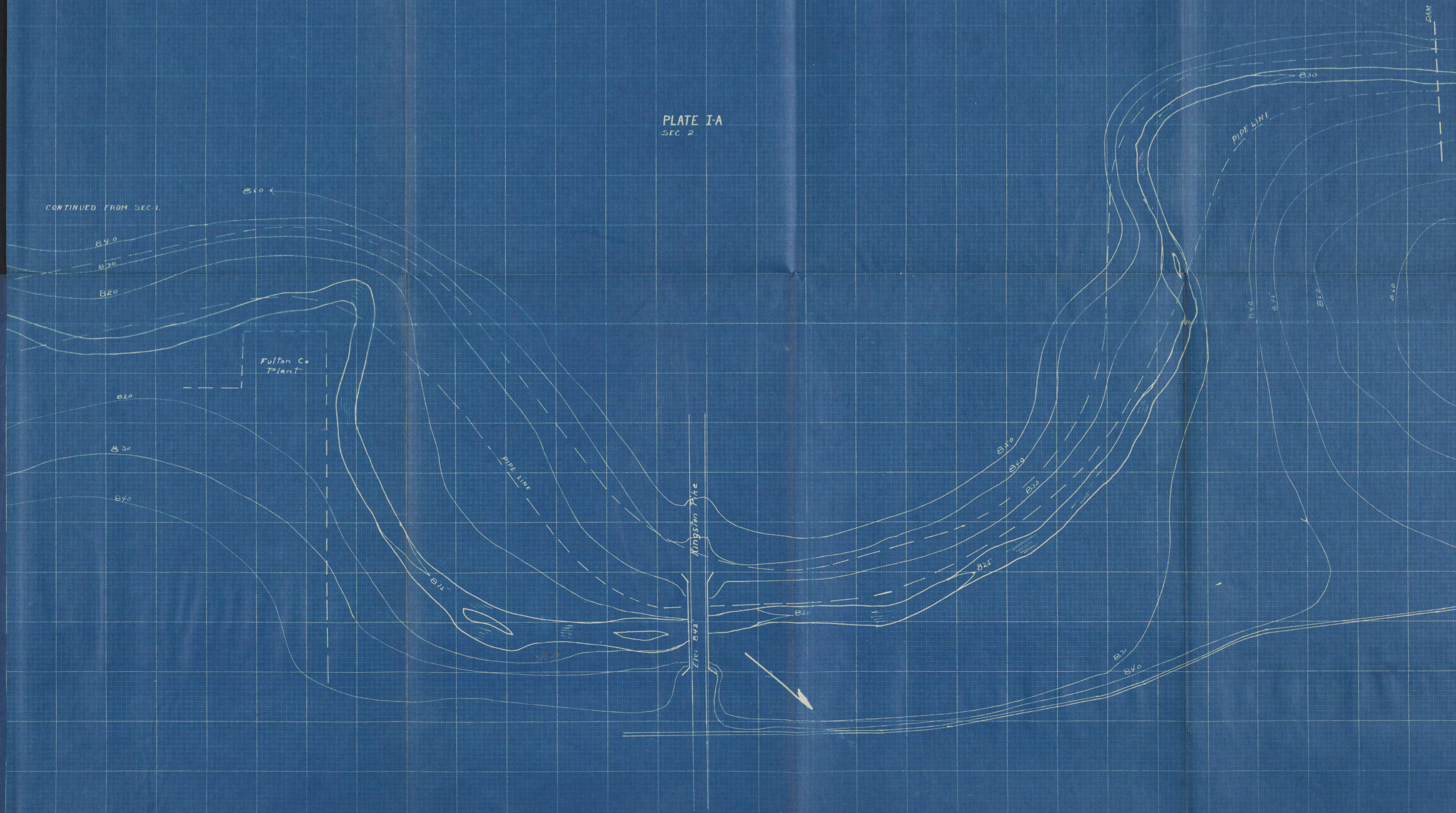


PLATE I-B
MAP OF THIRD CREEK FROM
SITE OF DAM TO HEAD OF
BACK WATER
IN THREE SECTIONS
SEC. 1

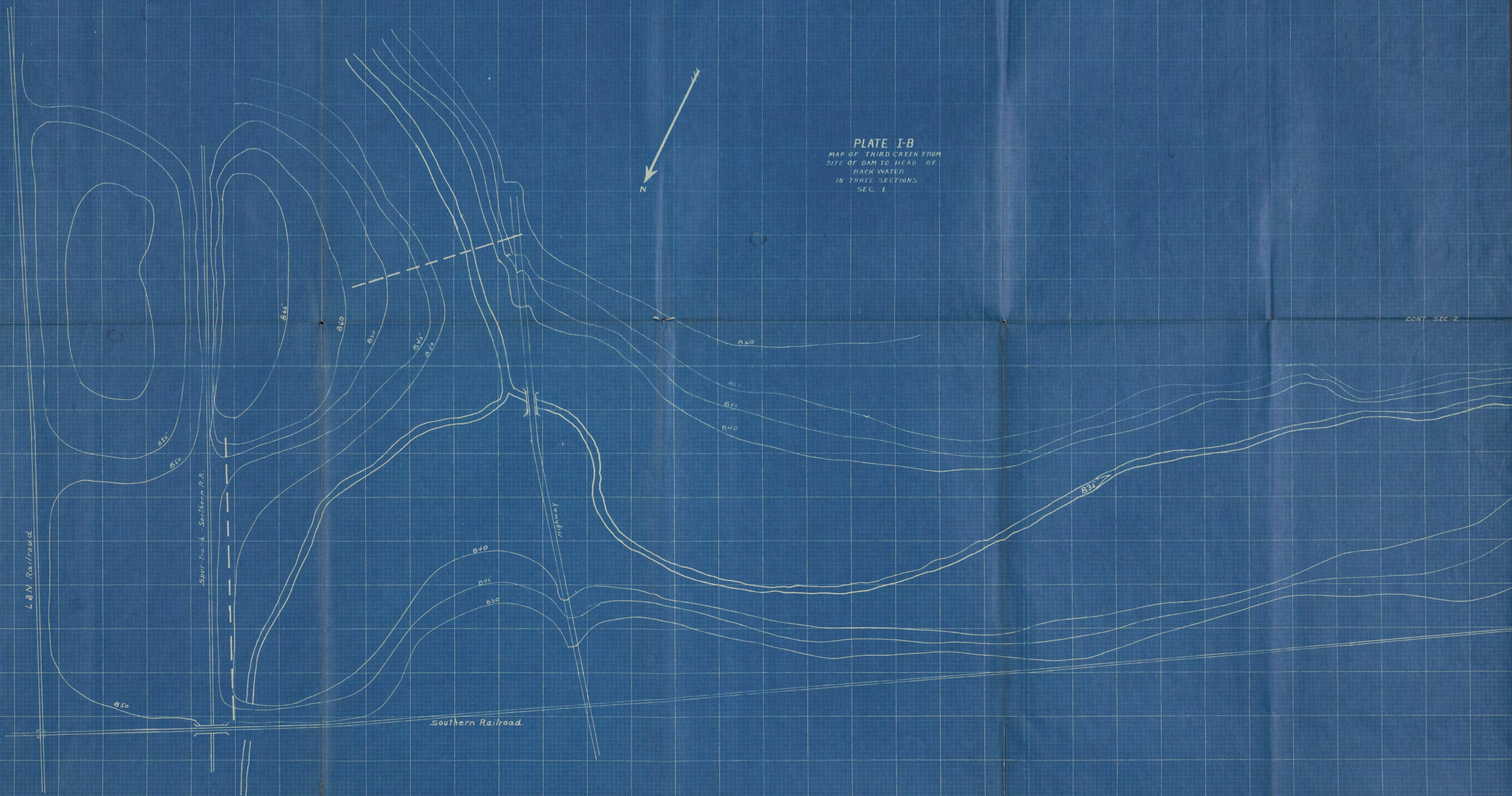
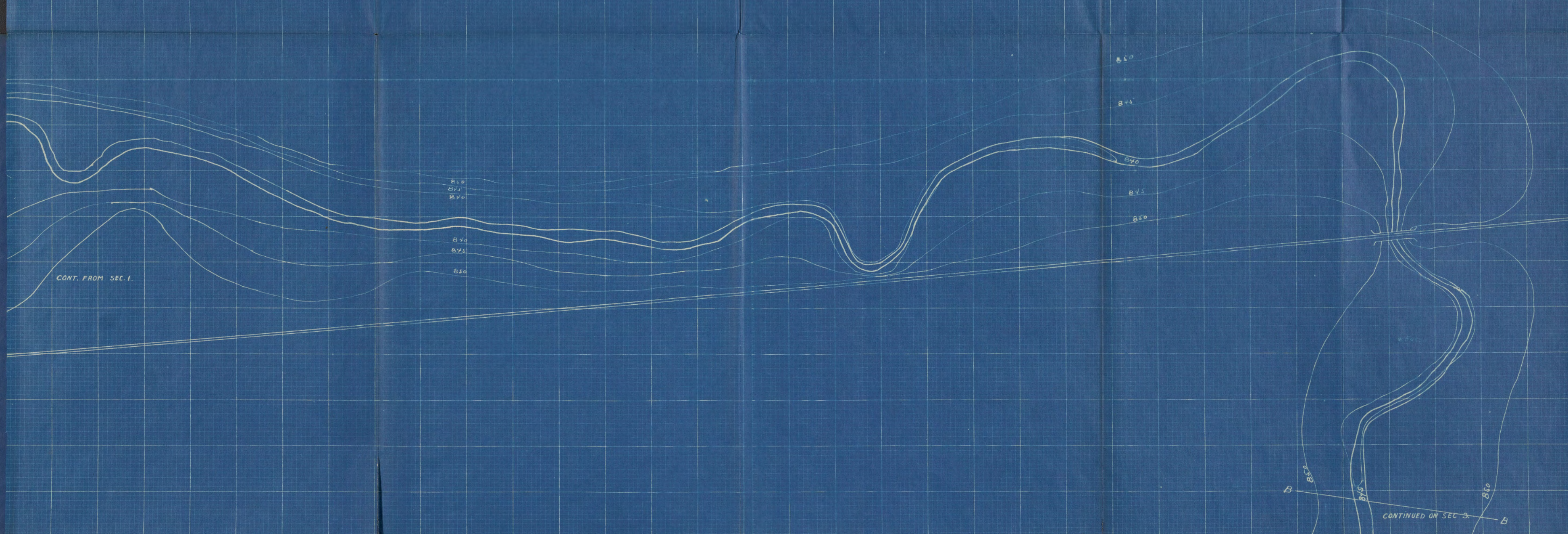


PLATE I-B
SECTION 2



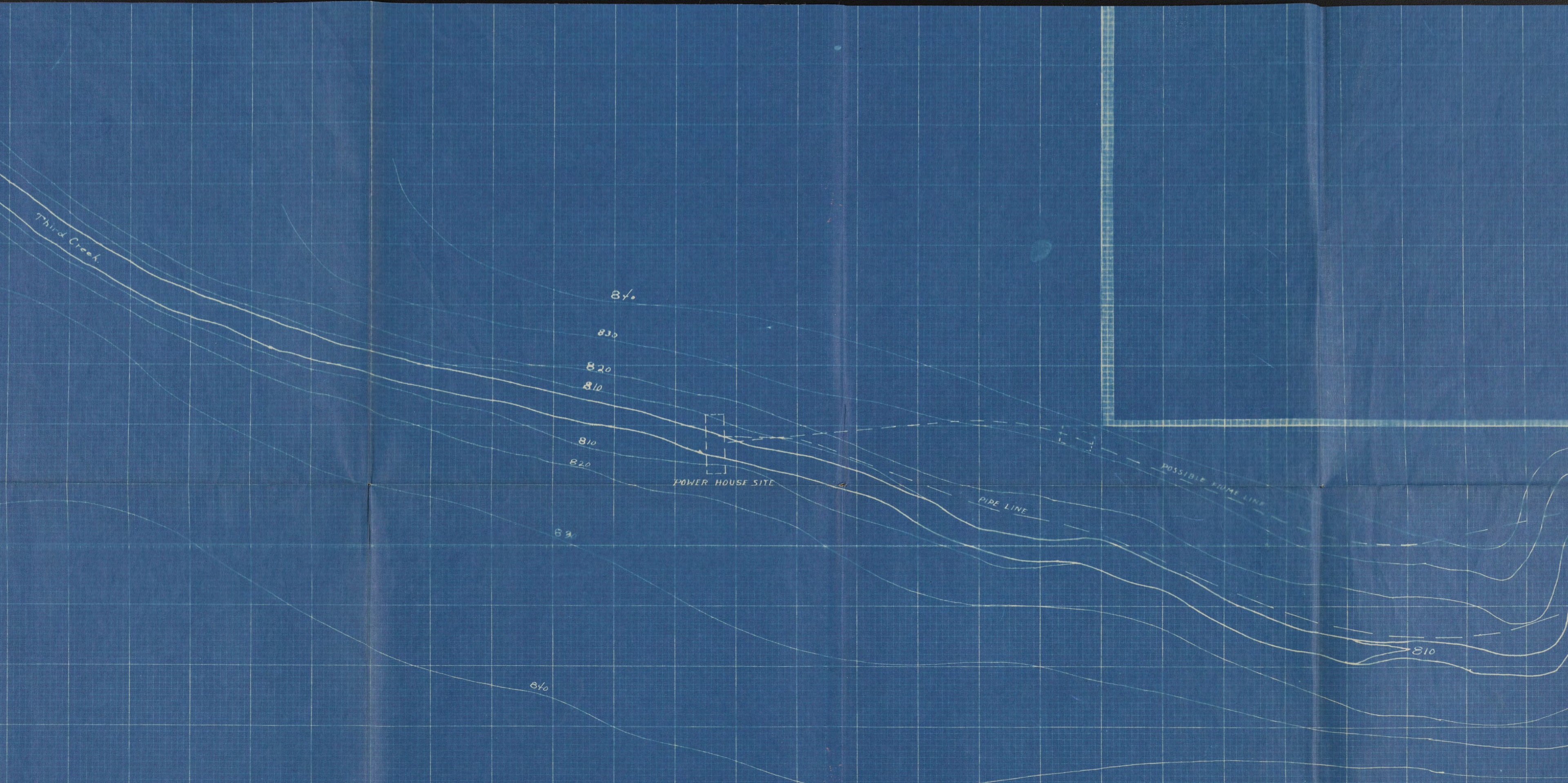


PLATE I-A
MAP OF THIRD CREEK FROM THE
TENNESSEE RIVER TO DAM SITE
IN TWO SECTIONS.
SEC. I.

PLATE I-B
SEC. -3

CONT. FROM SEC. 2

B

B

850

850

3rd Creek.

Southerland Ave.
Elevation 853.5'

850

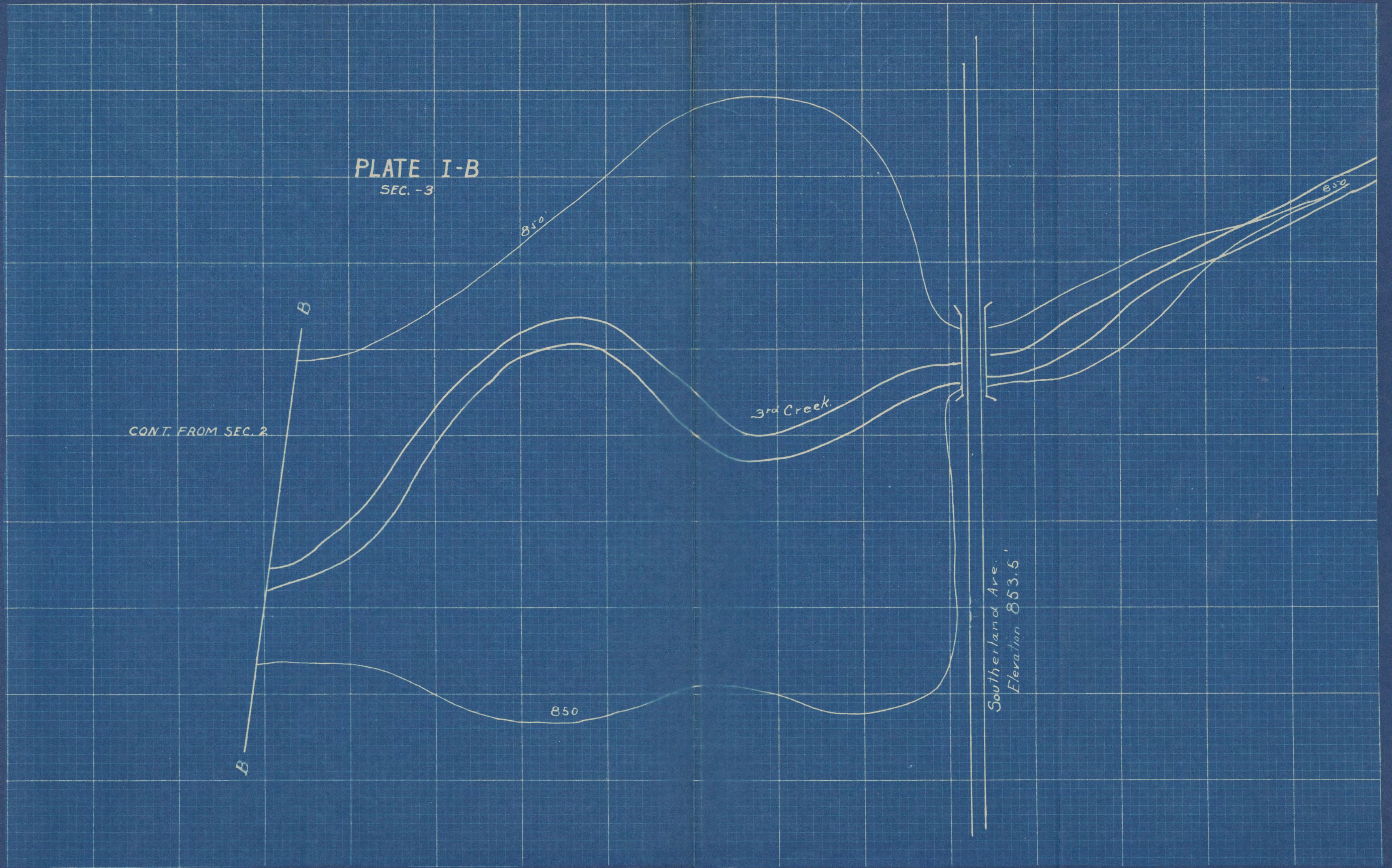


PLATE III

HYDROGRAPHS OF THIRD CREEK

ACTUAL HYDROGRAPH —————

COMPARATIVE HYDROGRPH - - - - -

COMPARATIVE HYDROGRAPH BASED ON
THE TENNESSEE RIVER FLOW.

180

160

140

120

100

80

60

40

20

DISCHARGE IN SECOND FEET.

NOVEMBER

DECEMBER

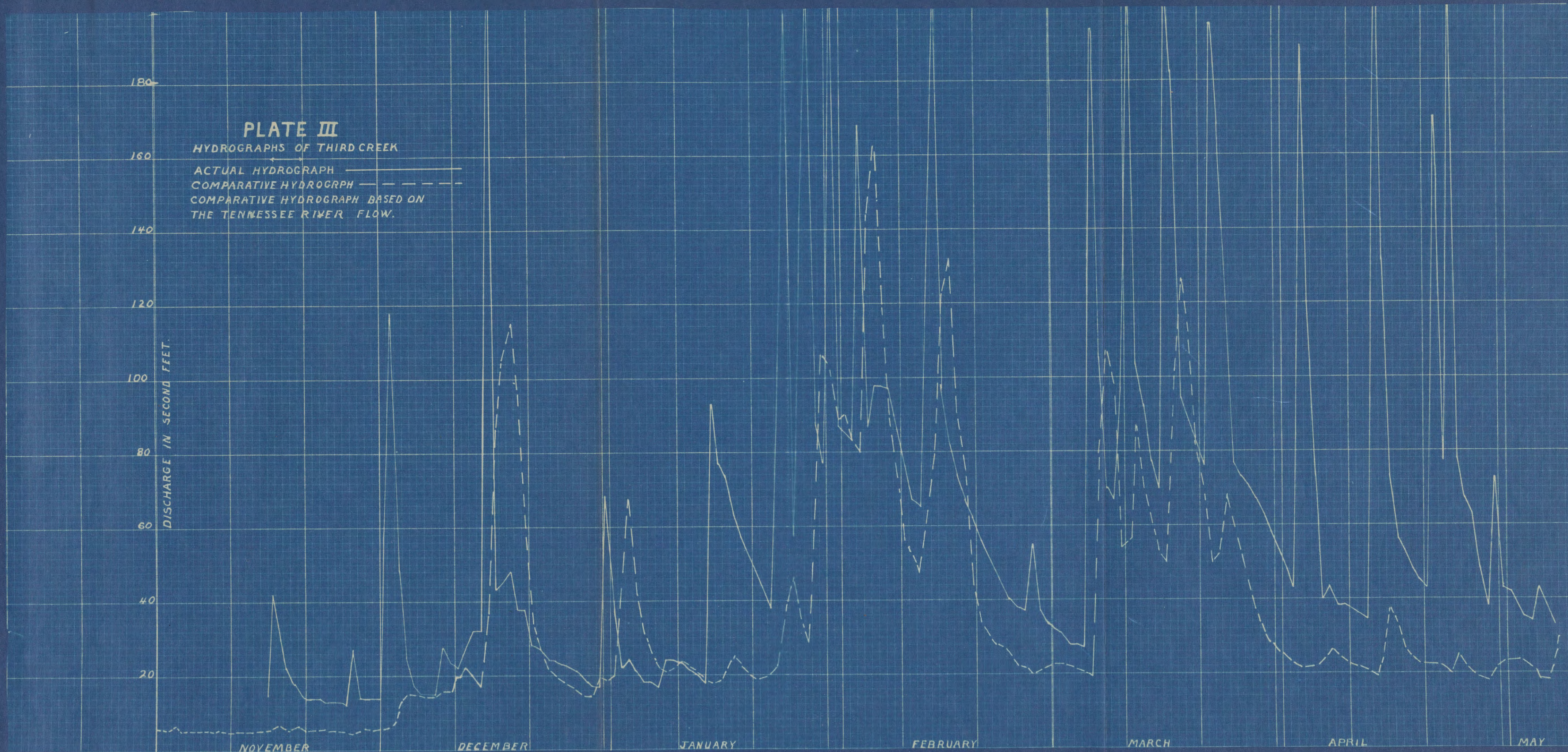
JANUARY

FEBRUARY

MARCH

APRIL

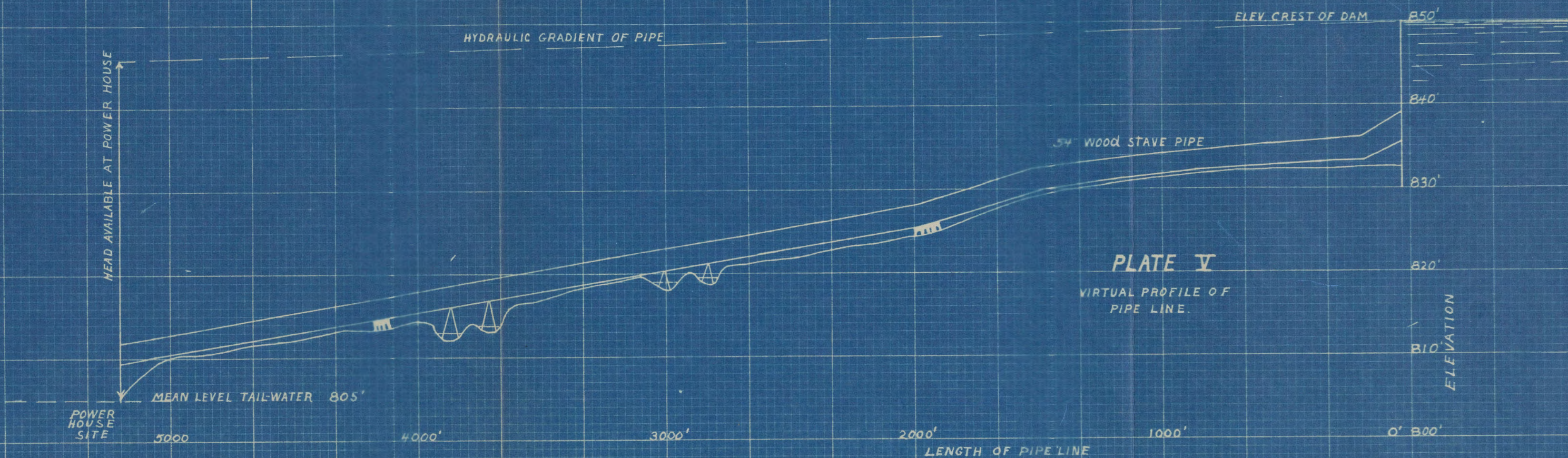
MAY



WEST BANK

EAST BANK

PLATE II
CROSS-SECTION OF THIRD CREEK
AT GAUGING STATION



ELEV. ABOVE MEAN SEA LEVEL.

PLATE IV

CROSS SECTION AT THE DAM SITE
ON THIRD CREEK.

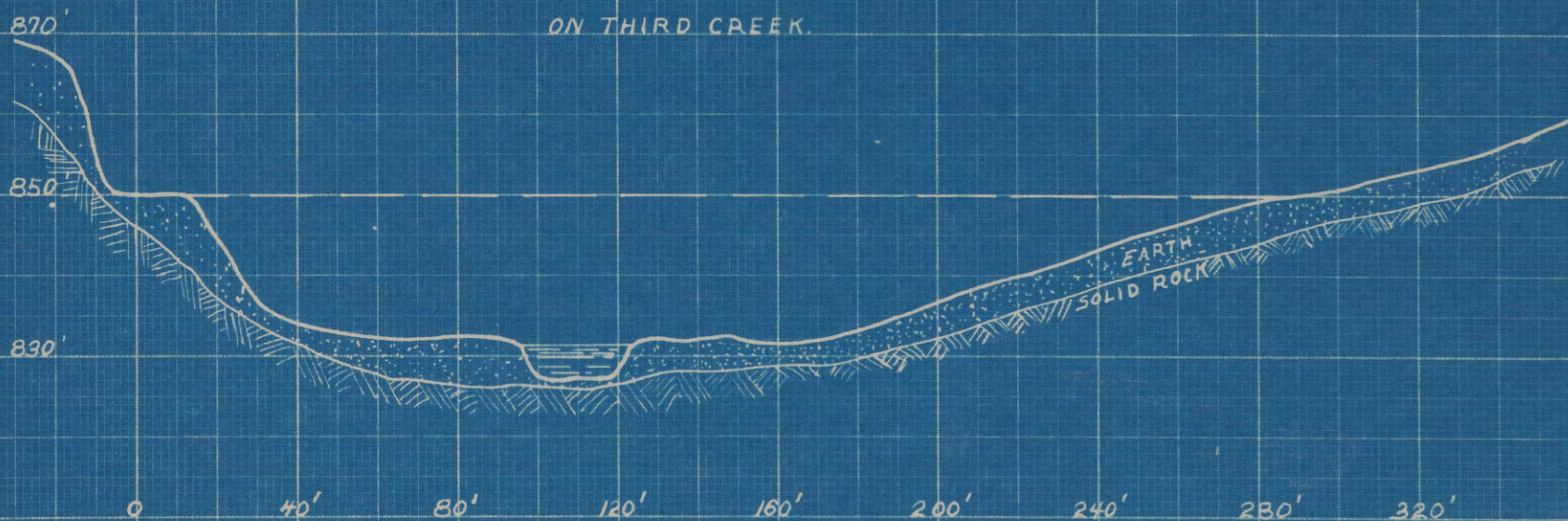


PLATE VI A
CROSS SECTION OF DAM
AT SPILLWAY

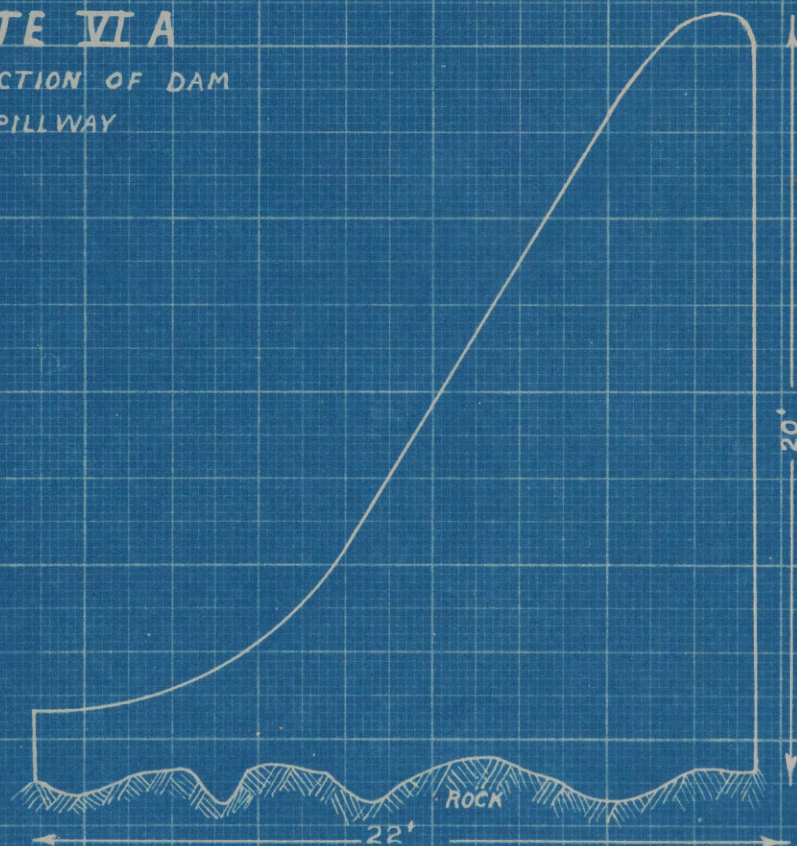
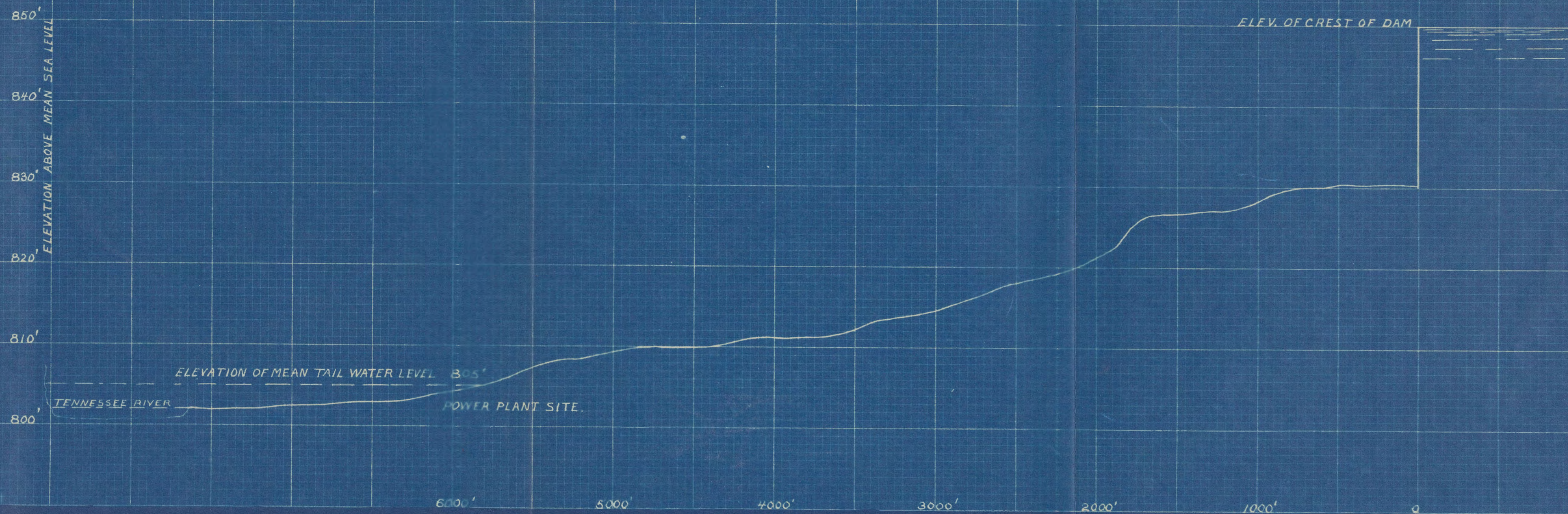


PLATE VII
VIRTUAL PROFILE OF THIRD CREEK
FROM DAM SITE TO TENNESSEE RIVER



18000

16000

14000

12000

10000

8000

6000

4000

2000

0

ACRE FEET

PLATE VIII

MASS CURVE OF THIRD CREEK FOR THE TIME SHOWN.
NOVEMBER 15, 1922 TO MAY 7, 1923.

RATE OF USE = $66\frac{2}{3}$ ACRE FEET PER DAY

STORAGE CAPACITY WITH A 20 FOOT DAM = 525 ACRE FEET.

RATE OF USE = 54 ACRE FEET PER DAY.

STORAGE CAPACITY WITH A 15 FOOT DAM = 315 ACRE FEET.

NOVEMBER

DECEMBER

1922

1923

JANUARY

FEBRUARY

MARCH

APRIL

MAY

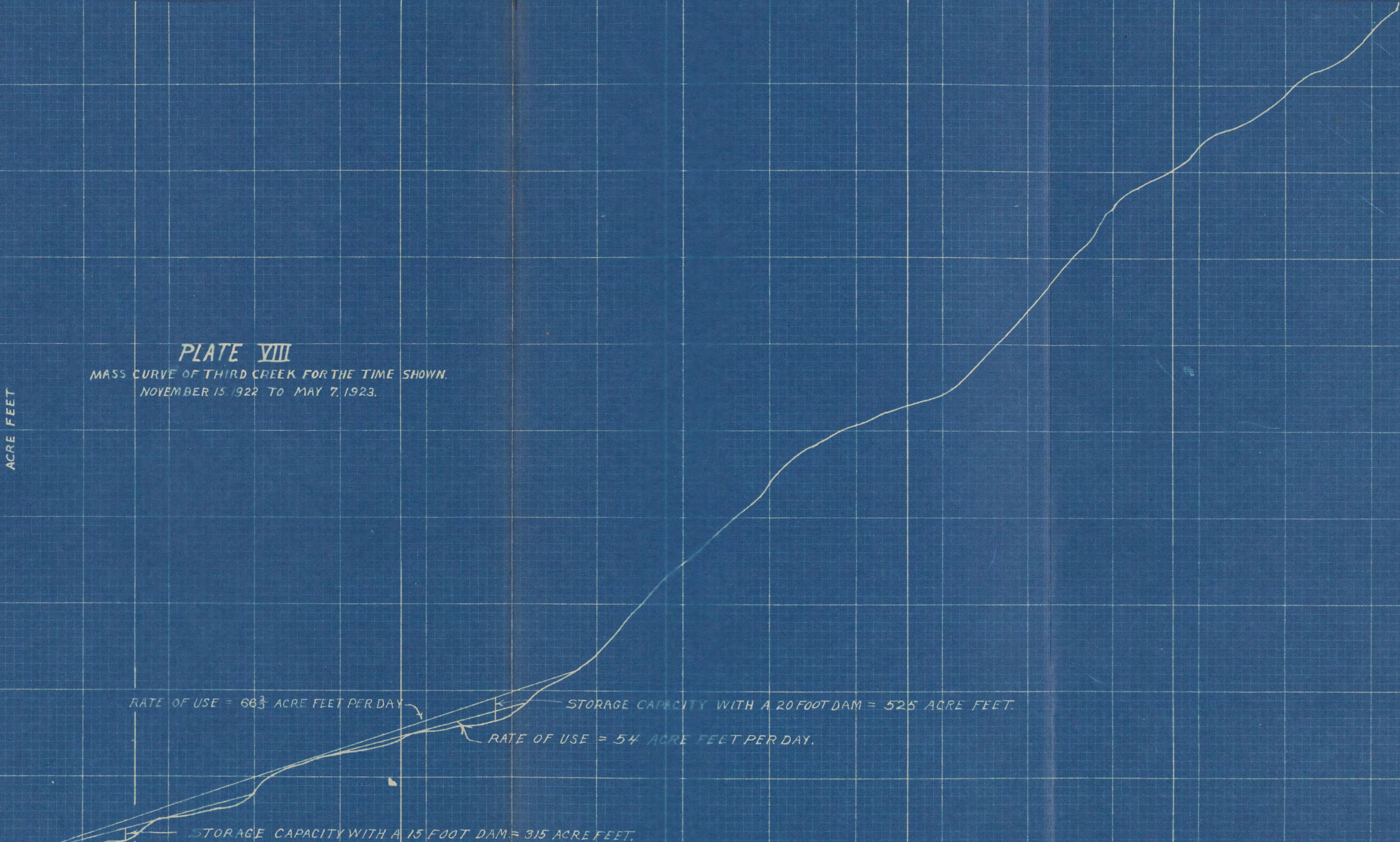
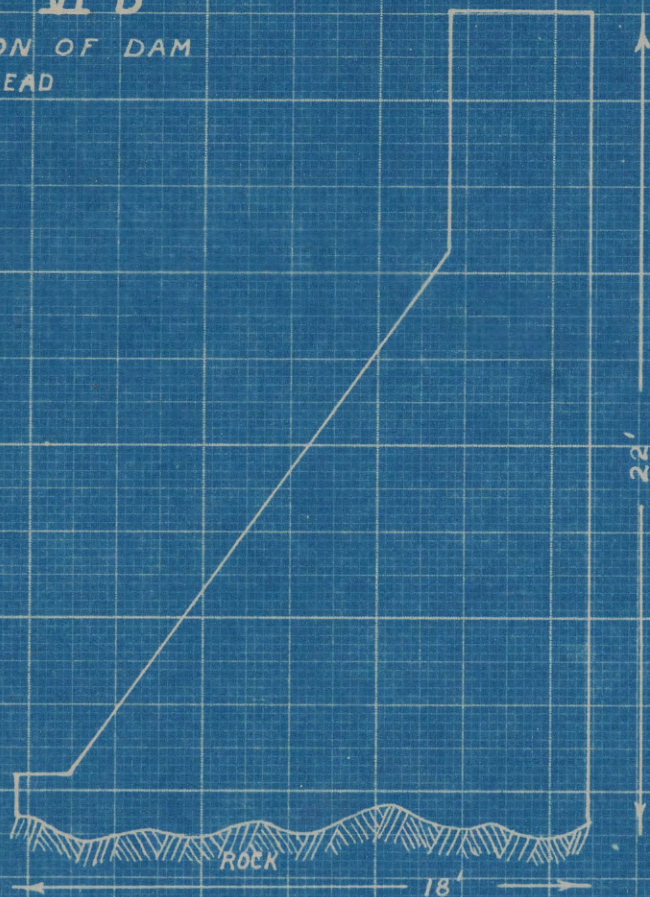


PLATE VI B

CROSS-SECTION OF DAM
BULKHEAD



GAUGE HEIGHT IN FEET

4

3

2

1

0

100

200

300

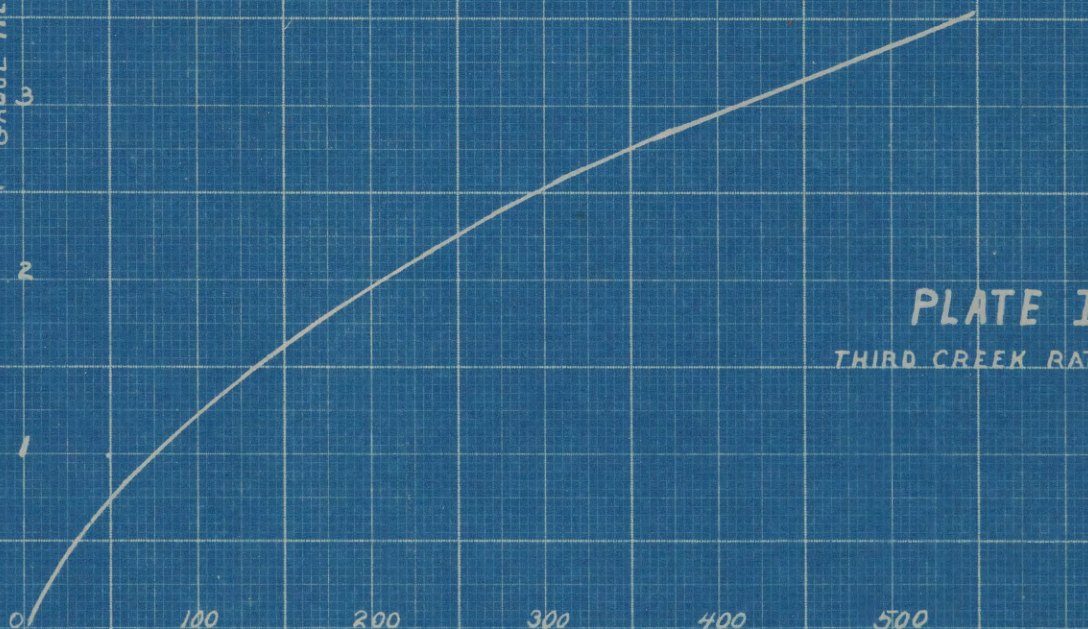
400

500

DISCHARGE IN SECOND-FEET

PLATE IX

THIRD CREEK RATING CURVE



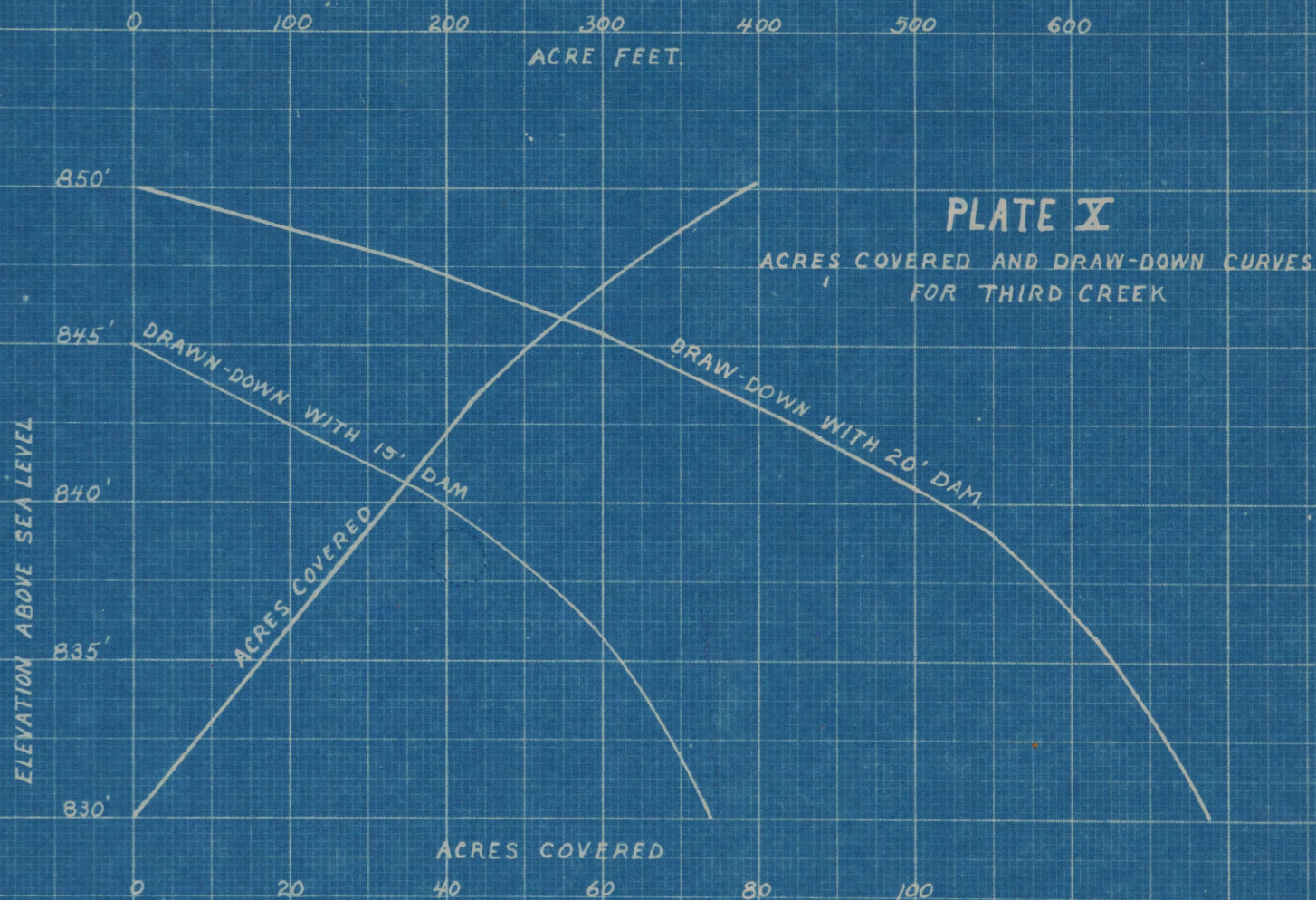




PLATE XII

MAP OF THIRD CREEK
KNOXVILLE, TENN.

DRAINAGE AREA = 15.7 SQ. MI.