AN INVESTIGATION OF THE POSSIBILITIES OF A POWER SITE ON THE RIFLE RIVER

Thesis for the Degree of B. S.

H. F. Layer J. M. Beardslee

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THESIS

Civil engineering

An Investigation of the Possibilities of a Power Site on the Rifle River

A Thesis Submitted to

The Faculty of

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of

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By

H. F. Layer   J. M. Beardslee

Candidates for Degree of

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Showing the Rifle River

at

Proposed Dam Site

April 13, 1928

Lower pictures taken from river

Purpose and Scope of Report

In 1924, Prof. C.D.Wisler, of the University of Michigan, submitted to the Director of the Land Economic Survey of the State a report upon the water resources of Ogeman county, dealing particularly with the Rifle River. In this report he estimated the total power available in the river as a whole and suggested one of the many possible arrangements of dam locations and heights to utilize the entire fall. No attempt was made, however, to estimate the cost of developing any one site or to inquire into the financial desirability of taking up the project, either in part or as a whole.

Our purpose, then, was to take one of his proposed dam sites and the corresponding heights, investigate the cost of building, equiping, and maintaining such a dam at that point, and balance this cost against the return which might reasonably be expected. Inasmuch as the time which we were able to spend upon the actual survey of the dam site and flooded area was limited, there are still some unknown elements which should be investigated. However, unless they should prove radically different from our estimates and approximations they will not affect the validity of our conclusions.

Physical Features

The Rifle River has its source in the extreme northern portion of Ogeman County, flowing in a general southerly direction through Ogeman and thence in a southeasterly direction through Arenac County, emptying into Saginaw Bay a few miles below Omer. The proposed dam site about which our investigation centers lies at the south line of Sec.9.T.21N., R.3 E.

The nearest railroad point at which there is a regular station is the village of Prescott, on a branch of the Detroit and Mackinac, lying about six miles East and two miles South of the site in question, but, should it be desired to run a spur track to the dam site, the nearest connection would be about five miles southwest to the line of the Michigan Central between Standish and West Branch. We believe, however, that the best method of transporting materials and equipment to the site would be by truck from Prescott. This would involve a haul of about five miles on gravel road and the remainder (three miles) on fair plains road. The experience of the Consumers Power Company in hauling heavy machinery considerable distances through the plains surrounding the Au Sable River justifies our attitude as to the feasibility of this method.

The Rifle River basin comprises an area of about three hundred and ninety square miles, of which two hundred and seventy one square miles lies within Ogeman County, the remaining one hundred and nineteen being in Arenac County.

The portion of the country about our dam site and that territory which would be affected by the backwater from such a dam as that under consideration is rolling and hilly and through this portion the river flows between high clay bluffs overlaid by sand and gravel deposits. At the proposed site,

MAP OF RIFLE RIVER BASIN SHOWING POWER SITES BOTH DEVELOPED AND UNDEVELOPED

H.F.L - 1928

there is an extensive outcrop, in the stream bed, of a sandstone of such a quality as would afford an excellent foundation for dam and power house construction.

Since our investigations of soil conditions were limited to a few borings by hand with a four foot soil augur, they are too unreliable to be depended upon, but our results are as follows. The location of the test borings is shown on the large map of the site.

Boring No.	Results
1	1' Muck, 3' Clay
2	2' Muck, 2' Clay
3	All Sand
4	" "
5	" "
6	1' Muck, 3' Clay
7	" "
8	" "

The climatic conditions, of course, do not differ from those of the rest of central Michigan as regards temperature. It would probably involve an excessive expense to try to carry on construction during the winter months. The yearly precipitation averages about 28 inches and is fairly well distributed throughout the year, being slightly greater during the spring and summer than during other seasons. The snowfall is moderately heavy and the ground remains covered during most of the winter.

This project is unique in that, so far as we are able to estimate, the pond created by the proposed forty-eight foot head of our dam will afford ample storage to enable us to utilize the entire flow of the river. The mass curve submitted herewith shows that a storage capacity of 1,950,000,000 cubic feet is required to hold the entire stream flow, the continuous demand possible with this storage being 308 c.f.s. Now, assuming that the average horizontal section of the reservoir will be 10 sq. miles in area, a mean depth of slightly under 7 feet will afford the required capacity. Again, assuming that the reservoir is regular and of the form of an inverted pyramid with the highest point at the dam, the mean depth will be 2/3 x 2/3 x 48 = 21.4 feet or a value affording a safety factor of 3.1 over that required for complete storage. Although this estimate of a mean flooded area of ten square miles sounds rather large, PRofessor Wisler states that the valley of the West Branch of the Rifle will be flooded for a distance up the river of over two miles and that the valley is somewhat wide and flat here.

Should it ever be desired to develop the whole river for water power, the only possibility for obtaining regulated storage of any importance is in Devoe, Spring, and North Lakes. Professor Wisler states that it would be possible to construct a regulating works at low cost at the site of the old logging dam just below Devoe Lake and above the highway bridge near the center of Section 11, T. 23 N., R.3 E., raising the water level in Devoe Lake ten feet and creating a reservoir having an area of approximately one and one-half square miles. The cost of this project would be low as the land that would be overflowed has little value, and none of these lakes are or could well be used for resort purposes. It is believed that, after making proper allowance for evaporation, sufficient storage could be provided by this reservoir to increase the low water flow of the river at all lower points by an average of thirty cubic feet per second for the hundred days of minimum flow each year.

The subject of water supply is one upon which there is considerable doubt. No continuous daily records of discharge of the Rifle River have ever been obtained. A gaging station was established near Omer on September 1, 1902 and daily records of gage height were kept until December 31, 1903. The gage readings were then discontinued because of the shifting nature of the stream bed which destroyed the relation between gage height and discharge. Twenty-four discharge measurements had been made on this stream at various places however, the results of which are published in Water Supply Papers Nos. 83 97,129,170,206, and 244, these being annual reports of the United States Geological Survey for the years 1902-1908 inclusive. In addition, Professor Wisler made four discharge measurements at various points during the month of September 1923.

We procured the gage height records for the Omer gaging station referred to above, plotted the rating curve which accompanies this report, and from it obtained the values of the flow at ten day periods at Omer. Profesor Wisler's report contains estimates of normal flow of the river at various points, two of which are Omer, and our proposed dam site and the ratio between these quantities is as 1 to 0.75. Furthermore, the records of the U.S.Weather Bureau stations at Omer, at East Tawas, and at West Branch show that the total rainfall for the year of 1903 was about 1.05 times the total for the minimum year during the period of record (thirty-two years). Consequently, we took the discharge figured for the Omer gaging station and multiplied them throughout by the factor $\frac{0.75}{.105} = 0.71$ to obtain figures for the minimum discharge to be expected at our dam site. These resulting values are shown in the accompanying table.

Discharge Measurements 1903.

Month	Day	Discharge in c.f.s.
Jan.	1	391
	10	305
	20	315
	30	584
Feb.	10	433
	20	370
	30	494
Mar.	10	1328
	20	647
	30	341
Apr.	10	312
	20	426
	30	272
May	10	238
	20	190
	30	252
June	10	206
	20	206
	30	206
July	10	142
	20	154
	30	142

Aug.	10	185
	20	121
	30	185
Sep.	10	315
	20	229
	30	178
Oct.	10	257
	20	236
	30	190
Nov.	10	192
	20	215
	30	206
Dec.	10	232
	20	250
	30	327

As Professor Wisler states in his report; "These values should be considered as tentative estimates made for computing the approximate amount of power available from the stream. Although they are believed to be conservative, no design should be contemplated without first acquiring more data on the flow of the Rifle River than is at present available."

The present flow characteristics of the river (as indicated by the discharge records described above) are shown by the accompanying duration curve. The installation and operation of the proposed power plant would, as previously stated, render the flow continuous at a rate of slightly more than three hundred cubic feet per second and it is probable that this change would necessitate the purchase of flowage rights on the stream. Most of the flowage rights on the Rifle River were, until the spring of 1923, owned by McFarlan and Wilson of Flint, but at this time, these rights were sold through a third party to a purchaser whose identity is unknown even to the former owners.

General Description of Plant and Controlling Elevations.

It appears, from a study of the existing conditions, that the most economical type of dam in this case would be one of the earth fill type. It seems unnecessary to have any masonry section whatsoever, since according to the available data, there will never be any overflow. However, emergency spillways will be provided of sufficient capacity to care for the entire maximum rate of flow minus the three hundred cubic feet per second which may be removed through one turbine. Siphon spillways two feet in height and thirty feet wide will afford this capacity and will be set to keep the high water elevation at or below an elevation of 794.00.

Stephenson's formula for wave height, $H = 1.5\sqrt{D} + 2.5 - \sqrt[4]{D}$, where H is the height of the maximum wave in feet and D the fetch in miles, when solved using D as four gives H 4.1 ft. Hence, taking 5.0 ft. for additional safety, the elevation of the top of the dam becomes 799.00.

Since the bulk of the fill will of necessity be of sand, relatively flat slopes will have to be used. Say 1 on 4 upstream and 1 on 3 downstream, the downstream slope being protected by berms every fifteen feet vertically and the upstream by rip-rap. Imperviousness will be secured by the use of a clay puddle core wall. A twenty foot wide top will be allowed for a roadway. The toe limits of this dam and five foot contours across its surface are shown in the accompanying topographic map of the dam and site and, by measuring the areas of successive contour planes, the yardage of fill was computed and found to be 160,370 yds. The overall dimensions of the dam, measuring between extreme limits of the fill are about 800 x 400 feet.

The head of water will vary between forty-eight and forty one feet (assuming a draw down of seven feet during the period of minimum flow) the elevations of the headwater at these times being 794.00 and 787.00 respectively. The tail-water will be subject to less noticeable fluctuations and will have a mean elevation of 746.00. Below the dam site the channel is comparatively wide and clear and it is improbable that ice gorges will ever form of sufficient size to materially affect the elevation of the tail-water.

All these elevations are referred to the U.S.G.S. datum, the nearest bench being one set by Prof. Wisler in 1923 and described as follows. B.M.#4 Highest point on S.E. corner of west abutment of old iron bridge (now destroyed) over Rifle River at south line, Sec.9, T.21 N., R. 3 E., Elev.754.37.

The power house, to be located as shown on the map of the plant, should be about 30 x 60 x 50 feet with a substructure of reinforced concrete and the superstructure of brick.

Two reinforced concrete penstocks seven feet in diameter will be provided leading from an intake tower to the power house and a reinforced concrete blow-off pipe ten feet in diameter will be laid in order that the pond may be emptied should an emergency so require. These items are shown in plan on the accompanying topographic map and it will be noticed that the intake tower is located towards one side of the dam, thus calling for longer penstocks. This arrangement is necessary in order that the tower may be located upon firm ground rather than upon fill.

The game laws of the state will also require the installation of a fish ladder, specifications for which may be obtained from the Department of Conservation.

Machinery and Equipment

Although only one turbine will ever be required at any one time, the additional investment required to provide a reserve unit is small compared with the total involved and seems well worth while when it is considered that one unit may be out of operation for repair for a period of several months while much power goes to waste. Hence it seems advisable to install two 1500 H.P. turbines.

The alternators will each be 1100 K.V.A., 2300 volt, 3 phase, 60 cycle machines such as are commonly installed in plants of this size.

For reasons to be explained later under the heading of "Market", two sets of transformers will be required, one set to be installed at the power house and another at a substation some sixteen miles distant. The first set will consist of three single phase transformers, each of 400 K.V.A. capacity, with the windings so balanced as to step up the voltage from the generated value of 2300 to the transmitting voltage of 22,000. The other set of transformers will be of the same capacity but will be designed to raise the voltage from

22,000 to 140,000. Both sets will be of the oil insulated, air cooled type.

The transmission line, due to the fact that the power is transmitted at only 22,000 volts, need not be of the tower type equipped with expensive suspension insulators, but may be of ordinary poles with pin insulators.

Total Power, Market, & Year's Income

From a study of the accompanying mass curve and flow data and assuming a maximum draw-down of seven feet, we estimated the average head for each month of the year and, using a continuous discharge of three hundred cubic feet per second, computed the total annual power available at the turbines. Various handbooks give the following as reasonable values of the losses to be expected.

Unit	Loss (% of total)
Turbine	8
Generator	7
Transformers	2
Transmission lines	5
Minor losses	3
Total losses	25 %

By applying this percentage of loss to the primary power of the water the total output for the minimum year was found to be 7,404,000 K. W. H. delivered at destination. See accompanying table.

Mo.	Days	Hrs.	Head	K.W.H.	H.P.	Delivered output(KW)
Jan.	31	744	45	647,000	1530	857 K.W.
Feb.	28	672	46	588,000	1560	874 "
Mar.	31	744	47	666,000	1600	896 "
Apr.	30	720	48	658,000	1630	914 "
May	31	744	46	650,000	1560	874 "
June	30	720	44	602,000	1495	837 "
July	31	744	42	595,000	1430	800 "
Aug.	31	744	41	578,000	1390	778 "
Sep.	30	720	41	560,000	1390	778 "
Oct.	31	744	42	650,000	1430	800 "
Nov.	30	720	43	588,000	1460	817 "
Dec.	31	744	44	622,000	1495	837 "
				7,404,000		

The present market for power in Ogeman County is very small. At present the city of West Branch uses approximately 150,000 K.W.H. per year and Rose City and Prescott combined use slightly less. West Branch is already supplied with power from a small dam on the West Branch of the Rifle (see small map) and Rose City and Prescott are supplied by the Consumers Power Company. The total power demand in the county is about 250,000 K.W.H. per year. The proximity of Bay City and Saginaw however, provides an excellent market for any power that may be developed at this site.

It seems then, that the best method of disposing of the generated power would be to run a transmission line direct to the main lines of the Consumers Power Company joining them near Twining. This will necessitate the construction of about sixteen miles of transmission line and for this reason, we considered it advisable to install two separate sets of transformers, one at the power house and one at the Consumers Power 140,000 volt lines so that the voltage may be raised in two steps, allowing us to transmit at a low enough voltage to avoid the use of steel towers. There being no disturbing factor in this circuit except the almost negligible self inductance of the transmission line, the entire power delivery will be at a power factor very nearly equal to unity.

Since the rates at which power may be sold are supervised by the Public Utilities Commission it is hard to estimate the rate which one might expect to obtain under our circumstances. This rate is selected after a consideration of many factors, chief among which is the amount of the investment. We were able to find, however, in the incorporation papers of the Wolverine Power Company, figures showing that they originally sold their power to the Consumers Power Company at a figure of $0.00563 per kilowatt hour and the director of the Tariff Board states that this figure has since been raised to $0.008 per kilowatt hour. Since the total cost of the plant for which this rate is current was very nearly the same as ours, we feel justifies in counting upon selling our output at eight mills per kilowatt hour. This figure gives a total yearly income, upon a sale of 7,404,000 kilowatt hours, of $59,230.

Costs

The authorities upon which we base the following estimates of costs are:

"Handbook of Cost Data" - Gillette

"Hydro-electric Handbook" - Creager & Justin

"Hydro-electric Power Stations" - Rushlow & Lof

"Electrical Equipment" - Brown

"Engineering of Power Plants" - Fernald & Orrok

All costs are totals and refer to the units in place, proper allowance being made for engineering, inspection, etc. Prices on land were obtained from the original survey notes of Mr. DeVries of the Land Economic Survey Dep't. and were corrected to the present date by Mr. DeVries himself.

Total Cost of Entire Installation

Earthwork 160,372 - 1000=159372 yds.@.75/yd.=	$119,400.
Power House 60 x 30 x 50 @ .65/cu.ft.=	$ 58,500
Turbines 2, 1100 K.W. @ $14.00=	$ 30,800
Alternators, switchboards, exciters, and cables, 2, 100 K.W. Gen. @ $20.00/K.W.=	$ 44,000
Transmission line (16 mi. @ $1200)=	$ 19,200
Land (4920 Acres @ $7.00= $34,400) (3400 " @$10.00= $34,000)	$ 68,400
Penstocks 175 yds. @ $12.00 =	$ 2,100
Siphon spillway 550 yds. @ $12.00 =	$ 6,600
Blowoff pipe 217 yds. @ $12.00 =	$ 2,600
3 Transformers (400 Kva 22000 V) =	$ 4,500
3 Transformers (400 Kva 140,000 V) =	$ 7,500
Fish Ladder 82 yds. @ $12.00 =	$ 1,000
	$364,600.

The dam once constructed, it becomes necessary to estimate the fixed charges and costs of operation. A summary of our conclusions on these amounts and a calculation of the net return on the investment follow. Most of these figures were taken from Creager & Justin's "Hydro-electric Handbook".

Financial Statement Showing Return on Investment and Cost per K.W. hour.

Total Income			
7,404,000 Kw-hr. @ 8 mills =			$59,230
Operating Charges			
Depreciation 5% =		$18,230	
Sinking Fund 3% =		$10,900	
Operating Cost		$13,800	
Taxes	$7,000		
Operators salaries	$4,000		
Minor repairs	$1,000		
Insurance	$1,000		
Miscelaneous	$ 800		
Total Operating Charges			$42,930
Net Profit			$16,300

Interest on capital = $\frac{16,300}{364,600}$ = 4.48%

Total energy delivered = 7404,000 Kw-hr.

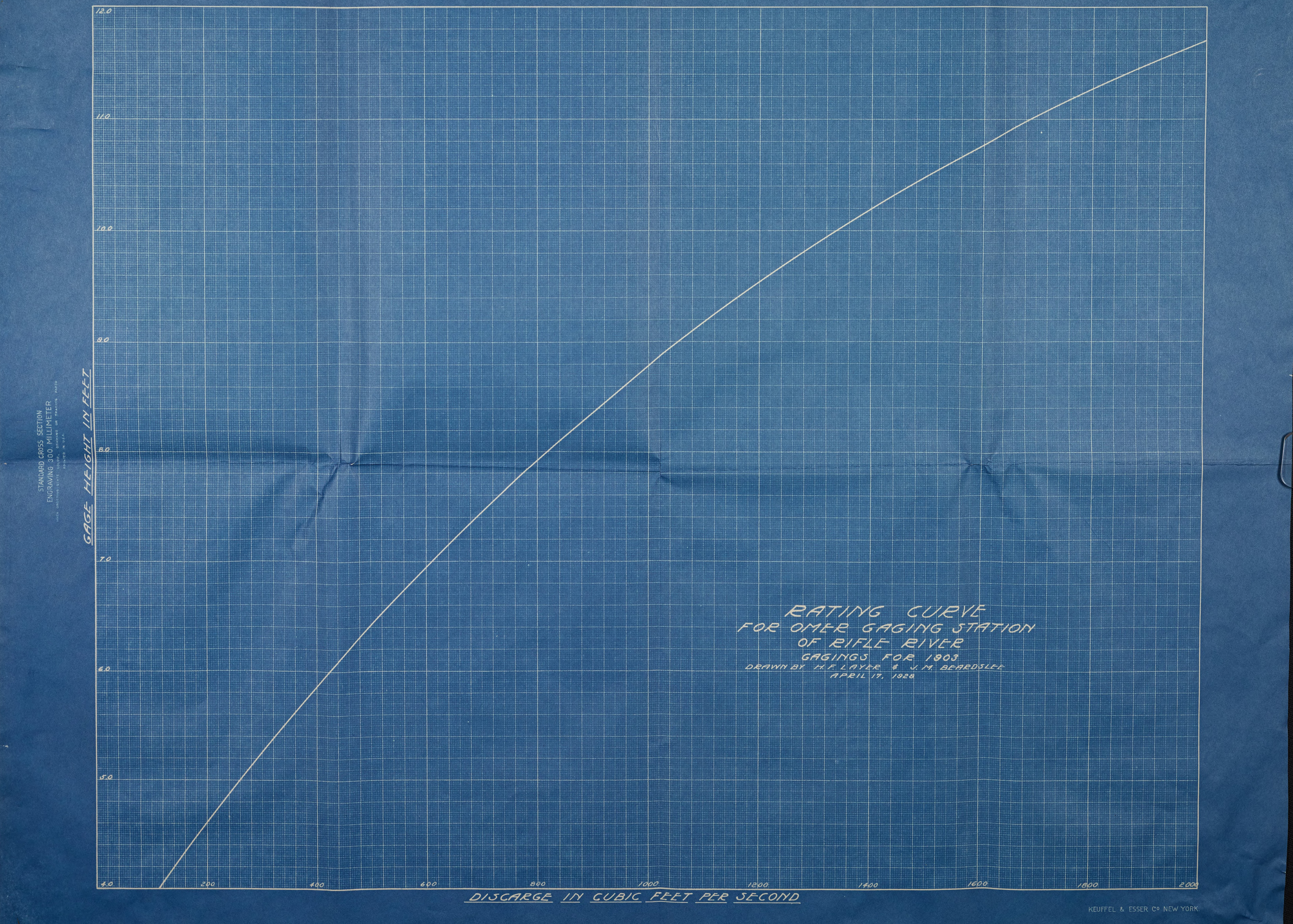
Cost per Kw-hr. $\frac{42930 \times 100}{7404000}$ = 5.8 mills

Construction cost per Kw = $\frac{364,600}{2200}$ = $165

Conclusions

From the above figures it will be seen that the net return on the investment which may be expected is less than four and one half percent. This return, of course, is too small to justify the execution of the project, inasmuch as larger returns are easily obtainable at less risk by simple investment. A more extensive and complete survey of the flooded area and stream gagings over a longer period might bring forth new elements not here considered or change assumptions here made, but it seems improbable that the change would be of such magnitude as to bring the possible return up to a satisfying figure.

One possibility still remains. While the development of this one project does not seem practicable it is possible that it's development in conjunction with the rest of the unit might prove desirable. There is some 250 feet of available fall in the river and the discharge increases considerably towards the lower part of the stream. Furthermore, certain savings would be possible were the whole stream developed as a unit. Among other things, one transmission line and one set of high voltage transformers would serve all the dams, automatic control might be practicable, and good control of the stream flow would be possible. It seems, then, that these considerations would at least justify a complete topographic survey of the river and the adjacent area and the establishment of gaging stations at several points. It should be understood, however, that unless funds are available for <u>complete</u> development, the particular project which is the subject of this thesis is unworthy of further investigation.


RATING CURVE
FOR OMER GAGING STATION
OF RIFLE RIVER
GAGINGS FOR 1903
DRAWN BY H.F. LAYER & J.M. BEARDSLEE
APRIL 17, 1928
GAGE HEIGHT IN FEET
DISCARGE IN CUBIC FEET PER SECOND
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
200
400
600
800
1000
1200
1400
1600
1800
2000
STANDARD CROSS SECTION
ENGRAVING 300. MILLIMETER
WHEN ORDERING STATE COLOR, DRAWING OR TRACING PAPER
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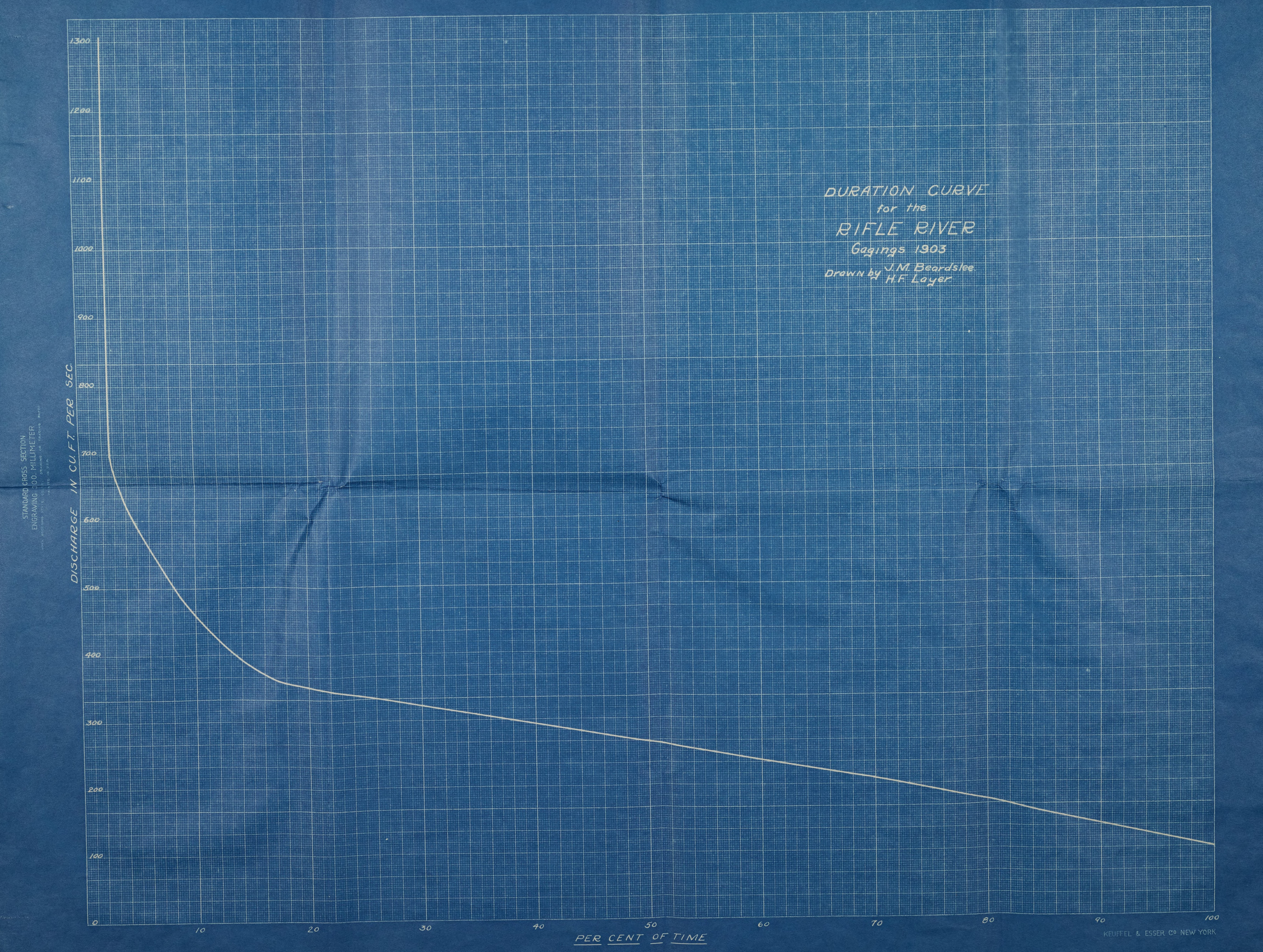
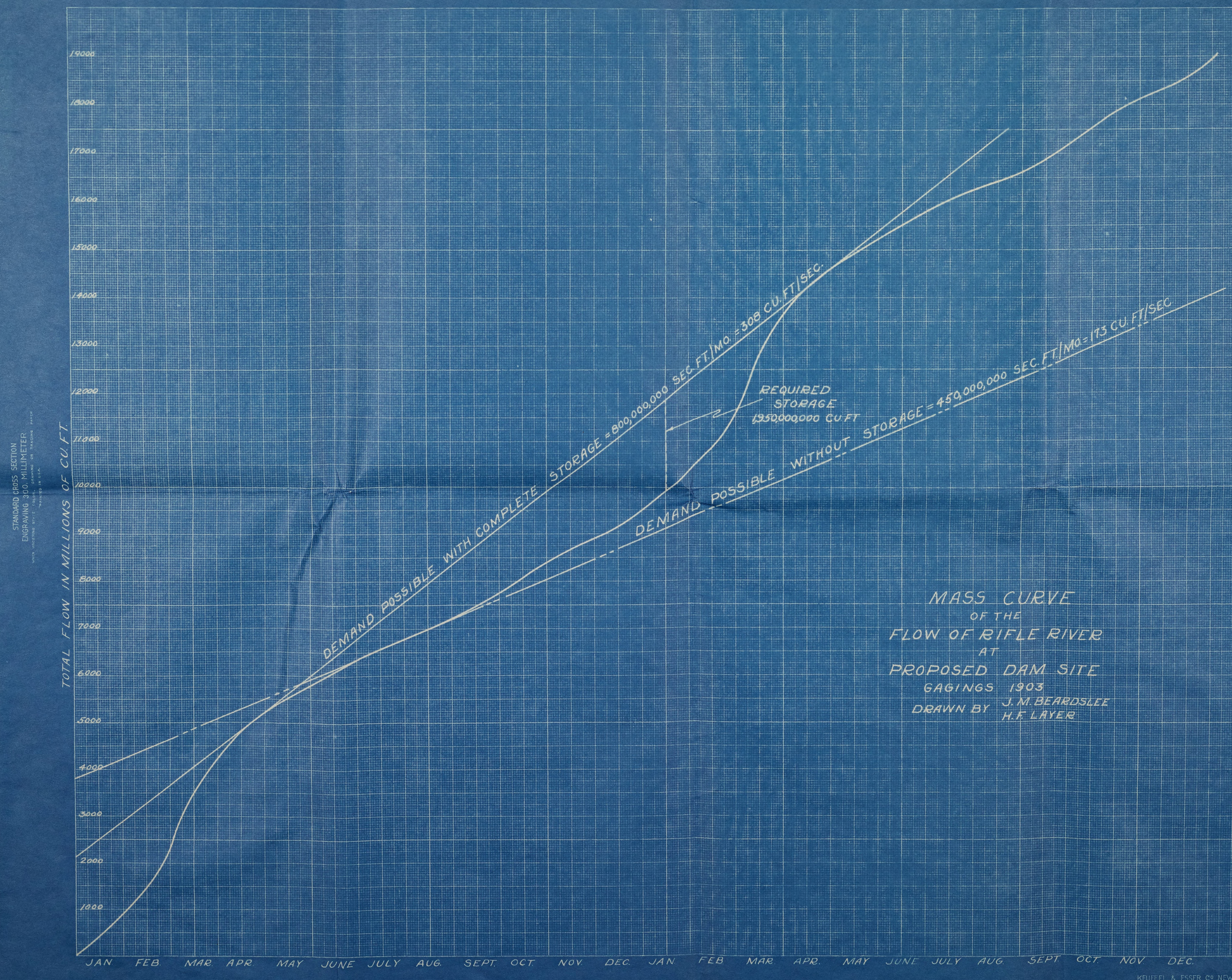


DURATION CURVE
for the
RIFLE RIVER
Gagings 1903
Drawn by J.M. Beardslee
H.F. Layer
DISCHARGE IN CU. F.T. PER SEC.
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
PER CENT OF TIME
STANDARD CROSS SECTION
ENGRAVING 300. MILLIMETER
WHEN ORDERING STATE COLOR, DRAWING OR TRACING PAPER
PRINTED IN U.S.A.
KEUFFEL & ESSER Co NEW YORK


MASS CURVE
OF THE
FLOW OF RIFLE RIVER
AT
PROPOSED DAM SITE
GAGINGS 1903
DRAWN BY J. M. BEARDSLEE
H. F. LAYER
TOTAL FLOW IN MILLIONS OF CU. FT.
DEMAND POSSIBLE WITH COMPLETE STORAGE = 800,000,000 SEC. FT./MO. = 308 CU. FT./SEC.
DEMAND POSSIBLE WITHOUT STORAGE = 450,000,000 SEC. FT./MO. = 173 CU. FT./SEC.
REQUIRED
STORAGE
1,350,000,000 CU. FT.
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
JAN
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN
FEB
MAR.
APR.
MAY
JUNE
JULY
AUG.
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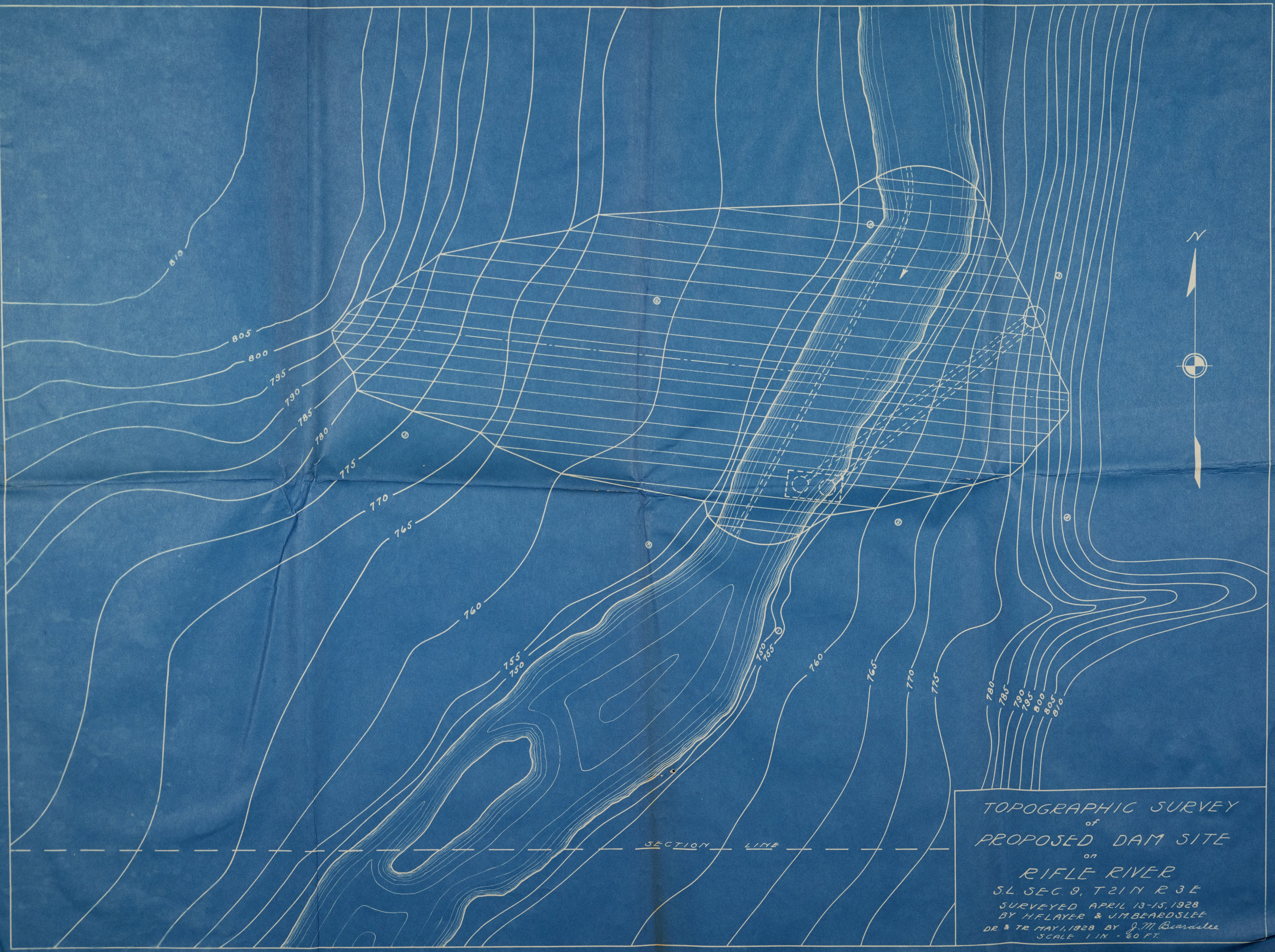
OCT.
NOV.
DEC.
STANDARD CROSS SECTION
ENGRAVING 300. MILLIMETER
KEUFFEL & ESSER Co. NEW YORK


N
810
805
800
795
790
785
780
775
770
765
760
755
750
SECTION LINE
TOPOGRAPHIC SURVEY
of
PROPOSED DAM SITE
on
RIFLE RIVER
S.L. SEC. 9, T 21 N R 3 E
SURVEYED APRIL 13-15, 1928
BY H.F. LAYER & J.M. BEARDSLEE
DR. & TR. MAY 1, 1928 BY J.M. Beardslee
SCALE 1 IN. = 60 FT.

Pocket has:
3 Graphs &
1 map