868.

GRADUATION THESIS.

THE ROCKY FORD WATER POWER.

By

M.W. Sanderson.

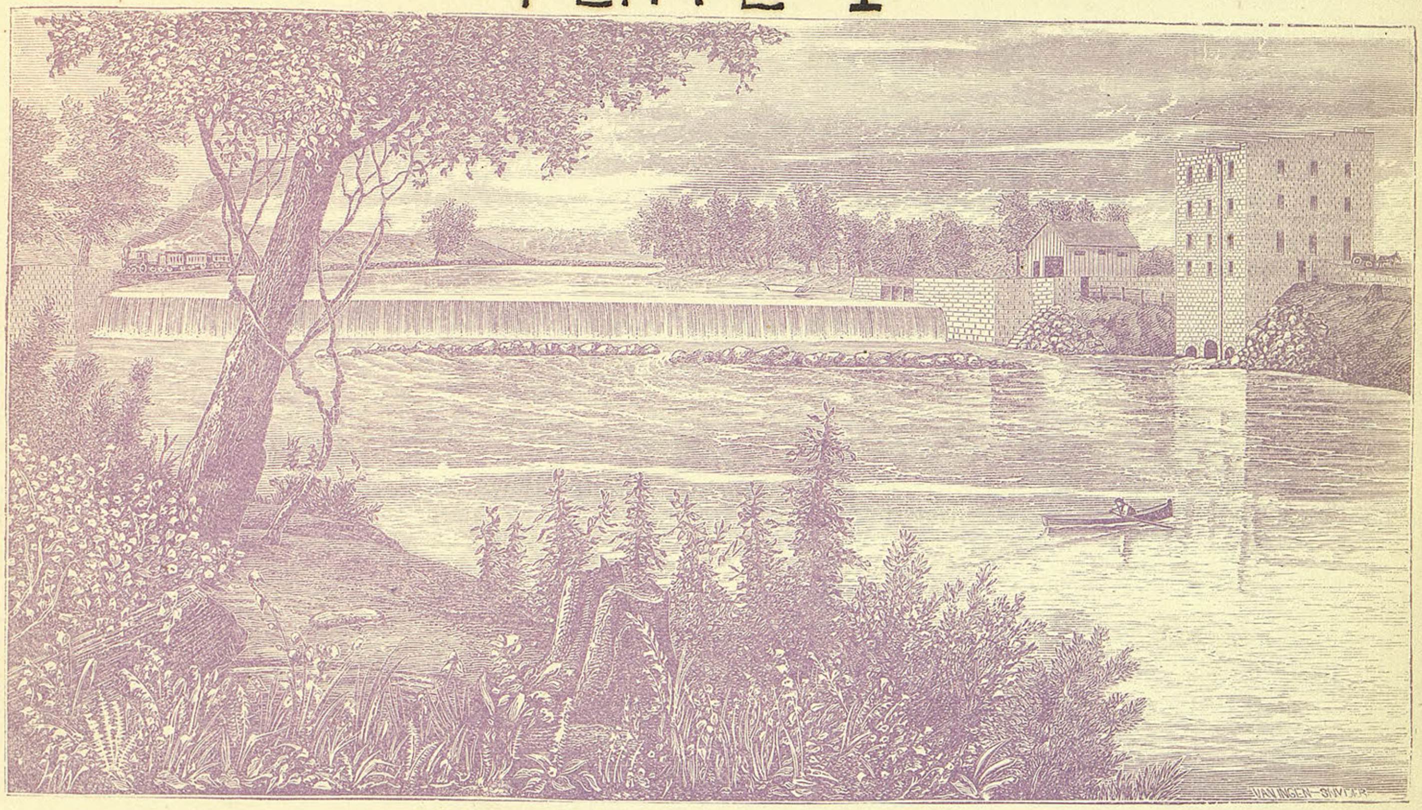
The questions have often been asked, Can the Blue River be used for irrigation purposes? and, Can this river be profitably used for power purposes? These questions have been investigated and the result of the investigation will be found in the following pages.

Rocky Ford is situated on the Blue River, about four miles North of the city of Manhattan, Kansas, in, approximately, latitude 39° 12' North, and longitude 96° 35' West. It derives its name from the fact that at this place there is a smooth rock bottom running entirely across the river; which affords a first class foundation for a dam, mills, and other buildings. The river bank on the West side rises forty-five feet to the Blue Valley Railroad track, from which the ground gradually slopes back a quarter of a mile, where it terminates in a bluff, containing an immense amount of the best structural limestone. The East side of the river is a level plain from twenty to twenty-five feet above the rock bottom of the river.

The water power of Rocky Ford was formerly used for power purposes. In 1868, Mr. E. B. Purcell of Manhattan dammed the river at this point and constructed a large grist mill. The dam was a framed structure 342 ft. long and 10 ft. high, terminating at each end in heavy stone abutments. It is reported to have cost $20000.00. The pond set back for seven miles. The mill was a massive stone structure, 40' × 60' and four stories high, located on the East side of the river, a short distance down stream from the dam; its foundations rest on the solid rock, and its walls are four feet thick up to the second story. For further description of the old Rocky Ford mill and dam see pages 28 and 51 "Sketch Book of Riley Co." published 1881 by the "Nationalist", Manhattan; and page 346, Vol. 17, Tenth census of U.S.. This milling plant was used for many years, but its operation was finally discontinued, and since then the timber dam has fallen into decay, and been broken up and carried away by high water; until now only a trace of it remains, altho the masonry abutments and mill are as good as ever.

The accompanying sketch, Plate I, was kindly furnished by Mr. Purcell, and gives an idea of the appearance of the plant while in operation.

PLATE I



ROCKY FORD MILLS, Near Manhattan, Kansas.

E. B. PURCELL, President.

The river at this point represents a drainage area of 9490 square miles located in the Northern part of Kansas and Southern Nebraska. With such a large drainage area and lying in the Permian and at the outcrop of the Dakota formations geologically, (the Dakota is a very porous shale and consequently acts as an underground feeder), the river at this point gives a large and fairly constant discharge, subject of course to heavy rises, often lasting for several days or weeks, caused by heavy successive rains during the months of April, May, June, July, August, and September while the minimum discharge usually occurs in September, October, and November the remaining months give a nearly constant discharge.

In order to obtain accurate data in regard to the discharge of the Blue River at this point the U. S. Geological survey April 14, 1895, established a stream measurement station at the Rocky Ford bridge, one half mile down stream from Rocky Ford proper, under the charge of Prof. O. P. Hood. The result of this investigation has been published in the "U. S. Geological survey, Report of stream measurements for 1896." From which has been compiled the following table. The discharge is found in a table of meter observations for a given guage reading.

Estimated Monthly Discharge of the Blue River.

Month	Maximum.		Minimum.		Month.	Maximum.		Minimum.	
	guage rdg.	discharge in cu. ft. per sec.	guage	discharge sec. ft.		guage	discharge sec. ft.	guage	discharge sec. ft.
1895 Apr. 14-30	3.8	605	3.4	502	October	3.6	552	2.9	385
May	5.2	1086	3.1	431	November	3.8	605	2.8	385
June	12.7	7500	3.6	552	December	3.8	605	3.3	490
July	7.6	2301	3.3	490	1896 January	3.9	619	3.4	502
August	14.9	9900	3.2	478	February	3.9	619	3.3	490
September	14.3	8550	3.5	552	March	No observations taken.			

Estimated Monthly Discharge of the Blue River.

Month	Maximum		Minimum		Month	Maximum		Minimum	
	guage	discharge sec. ft.	guage	discharge sec. ft.		guage	discharge sec. ft.	guage	discharge sec. ft.
1896 Apr. 16-30	11.1	5283	5.0	1028	April	26.9	35000	5.4	1231
May	18.0	13725	5.1	1065	May	10.5	4724	5.7	1354
June	20.7	19425	4.0	677	June	22.0	20600	4.5	850
July	23.1	21975	4.5	850	July	14.5	8670	5.0	1028
August	17.7	12375	4.5	850	August	9.0	3433	4.7	907
September	13.0	7560	4.6	868	September	5.0	1028	2.3	275
October	13.5	7725	3.0	408	October	4.4	793	3.0	408
November	11.0	4724	3.5	527	November	4.5	850	3.7	578
December	5.0	1028	3.0	408	December	4.6	868	4.0	662
1897 January	5.6	1303	4.0	662	1898 January	4.6	868	4.1	692
February	7.2	2175	4.0	662	February	10.2	4447	4.0	662
March	7.3	2176	4.5	850	Mar. 1-19.	5.0	1028	4.0	662

From this table, it will be observed that the minimum discharge that may be expected is somewhere in the neighborhood of 400 sec. ft. with few possible exceptions, and also average of over 500 sec. ft. flow.

Could these 400 sec. ft. be diverted into an irrigation canal, it would irrigate 70000 acres or three townships, counting the water duty at 175 acres per sec. ft. of supply entering the canal head, which would be a fairly liberal supply for this part of the country, the world's record of water duty ranges, for surface irrigation, from 60 to 300 acres per sec. ft., (Page 49, Wilson's "Manual of Irrigation Engineering.") Could this irrigation feat be accomplished the bottom lands North and East of Manhattan would be practically certain of a full crop every year. At present the crops seldom yield more than one third to one half what they might on account of seasons of dry weather just at the critical stage of the crop growth.

With this thought in mind, a survey was undertaken to ascertain the practicability of irrigating the Blue bottom just North of town, and lying on the West side of the river. This bottom contains 3000 acres in round numbers, the surface is smooth and apparently nearly level soil, sandy, and well adapted for irrigation purposes. The survey was undertaken March 16, 1898, by Prof. O. P. Hood, assisted by the author. A line of levels was run on the Blue Valley Ry. track, from a point opposite the city water works pump house to the West abutment of the old Rocky Ford dam. The instruments used was a 20" Engineer's Wye level, and a Troy leveling rod belonging to the Agricultural College. Stations were taken approximately every 600 ft.; care was taken that the observations be comparatively accurate. From station 7 to station 28, the elevation of the railroad track was the same as that of the adjoining fields; which gives an idea of the lay of the land near the West side of this bottom.

The following is a copy of the field notes of the survey.

Station	Back Sight	Height of Instrument	Fore Sight	Height of Station	Station	Back Sight	Height of Instrument	Fore Sight	Height of Station
B.M.	0.396			50.	17	4.703	66.289	3.353	62.936
0	6.542	50.396	1.279	49.117	18	4.543	67.639	5.136	62.503
1	5.998	55.659	3.074	52.585	19	5.239	67.046	4.885	62.161
2	5.25	58.583	4.495	54.088	20	4.727	67.4	4.294	63.106
3	5.018	59.338	2.914	56.424	21	5.156	67.833	4.649	63.184
4	5.384	61.442	3.810	57.632	22	5.637	68.34	3.72	64.62
5	4.449	63.016	4.713	58.303	23	5.937	70.257	4.081	66.176
6	3.216	62.752	5.07	57.682	24	5.74	72.113	3.755	68.358
7	4.28	60.898	5.143	55.755	25	5.445	74.098	4.168	69.93
8	5.062	60.035	4.987	55.048	26	5.28	75.375	3.952	71.423
9	6.092	60.11	4.165	55.945	27	5.96	76.703	4.158	72.545
10	6.24	62.037	3.145	58.892	28	5.654	78.505	3.705	74.8
11	6.09	65.132	3.84	61.292	29	4.659	80.454	4.864	75.59
12	2.912	67.382	5.817	61.565	30	4.916	80.249	5.093	75.156
13	4.107	64.477	6.172	58.305	31	0.503	80.072	10.259	69.813
14	5.78	62.412	4.885	57.527	32	3.989	70.316	10.683	59.633
15	5.268	63.307	3.824	59.483	33	1.816	63.622	10.553	53.069
16	5.773	64.751	4.235	60.516	34	0.306	54.885	11.504	43.381

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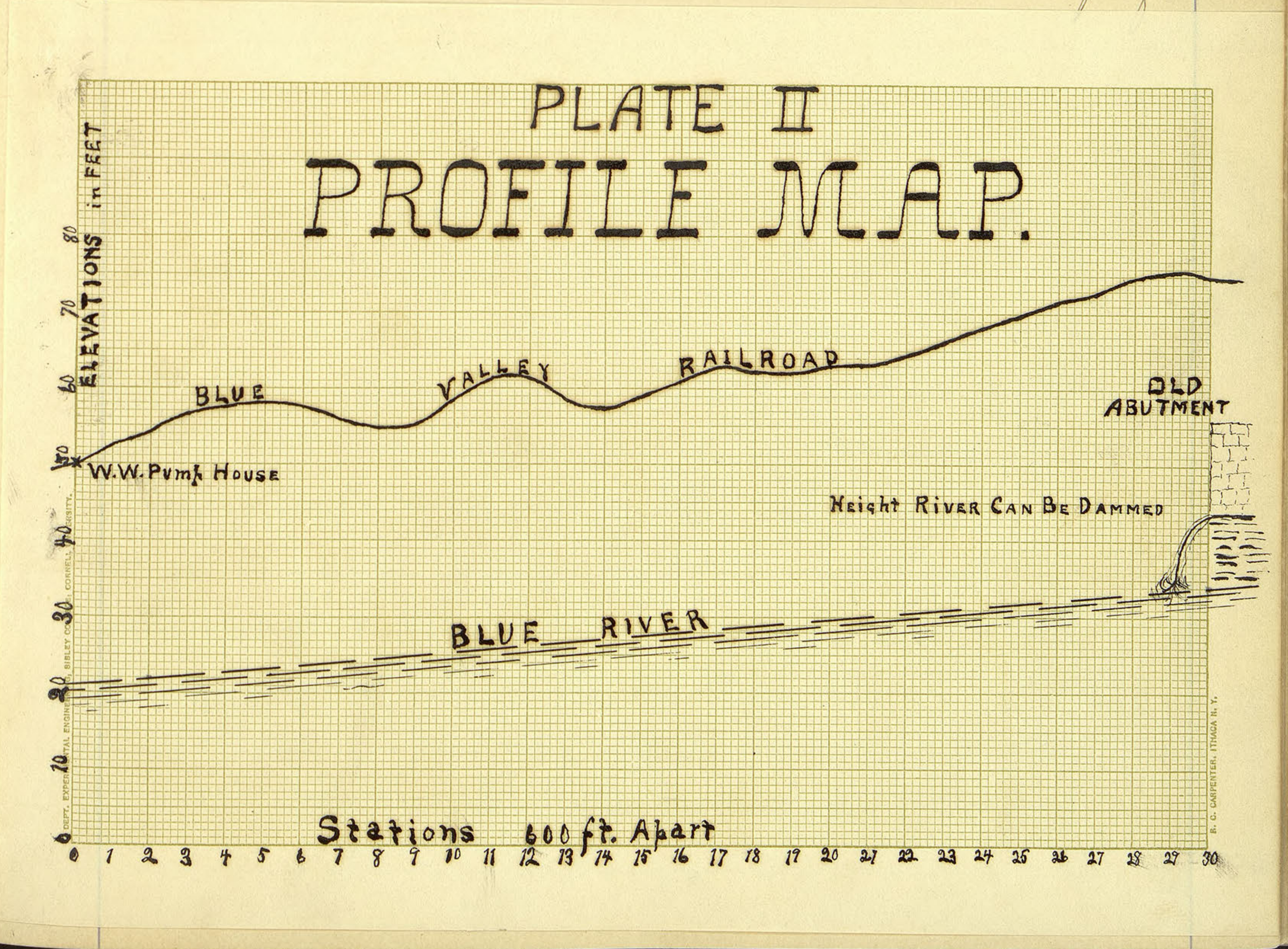
Station	Back Sight	Height of Instrument	Fore Sight	Height of Station	Station	Back Sight	Height of Instrument	Fore sight	Height of Station
35		43.687	9.728	33.959	0	0.977			49.117
32	4.769				a	0.922	50.094	12.2	37.894
36		64.402	8.094	56.308	b	3.335	38.816	11.469	27.347
					c		30.682	9.5	21.182

B.M. on lower edge of South door sill of water works pump house.
Stations 0 – 30 on Blue Valley Ry. track.
Station 35, surface of water in river.
" 36, top of old West abutment.
From 36 came back to "0" and ran a line to "c", surface of water.



From Plate II, it can be seen that the highest point to which the river can be dammed is several feet below the lowest point of the bottom lands which it was proposed to irrigate; consequently, the problem of irrigating the West bottom by a diversion weir or dam is impossible. The question as to the possibilities of raising sufficient water by pumps operated from the head of water secured by means of a dam, has not been investigated. The 3000 acres of bottom land would require 18 or 20 sec. ft. of water to properly irrigate it. This amount could no doubt be raised by pumps, but whether the advantages to be derived from irrigation would pay for the immense cost of a plant is doubtful at the present time.

While a survey of the land lying East of the Blue River and South of the Kansas River was not undertaken, it is possible that the irrigation engineering features are simpler on that side of the river. And as there is a large area that could be reached by a distributory canal it would no doubt be more profitable to attempt irrigation at that place. However, only a survey can determine the possibilities of the case.

The next feature of the Rocky Ford water power investigated was as to whether the river could be dammed at this place, and the head thus obtained be converted into electrical energy by means of turbines and electrical generators, and then be transported by means of electric wires to the city of Manhattan to be used for lighting purposes, for pumping the city's water supply, and for other power purposes.

Accordingly, a masonry dam has been designed to be placed on the site of the old dam. The masonry abutments now standing can thus be used to good advantage, also the old head race can be utilized by making slight repairs and the old mill, which is in good condition except the timber beams and floors, which would have to be replaced, could be used as a power house.

In designing this dam, the attempt has been to secure as great a head as possible without raising the river, in times of high water, high enough to overflow the low valley on the East side. Mr. Francis gives a formula for finding the depth of water on the crest of a weir, for a given discharge, $Q = 3.012\, l H^{1.53}$ or $H = \left(\frac{Q}{3.012\, l}\right)^{\frac{1}{1.53}}$ where Q = discharge in sec. ft., l = length of the weir, and H = depth on the crest; substituting the greatest discharge on our records, 35000 sec. ft. we find H = 10 ft.. Then with the old 10 ft. dam and this discharge, it raised the water above the dam to a depth of 20 ft.. In order to place a 12 ft. dam at this place, it was found that by lowering a section, four ft. in depth and 150 ft. long, in the central part of the dam, it would discharge nearly the same volume of water without raising the river any higher than the old dam. To place a dam in safe operation, it would probably be necessary to rip-rap the East bank of the river in places above the dam, and about three-fourths of a mile up stream, a levee would have to be constructed to prevent exceedingly high floods from changing the course of the river and leaving the dam dry.

The accompanying figures, Plate III, illustrate the form and special features of the dam designed. Since floods to the maximum depth of eight ft. are expected to pass safely over the highest part of this dam, it is built accordingly massive.

The two particulars in which a masonry dam is liable to fail are first by sliding on its base or on some horizontal joint, and second by overturning. The frictional stability F of any joint is found from the formula, $F = \frac{(W + w)f}{P}$ in which W = the weight of masonry above that joint, w = the weight of water on the crest,

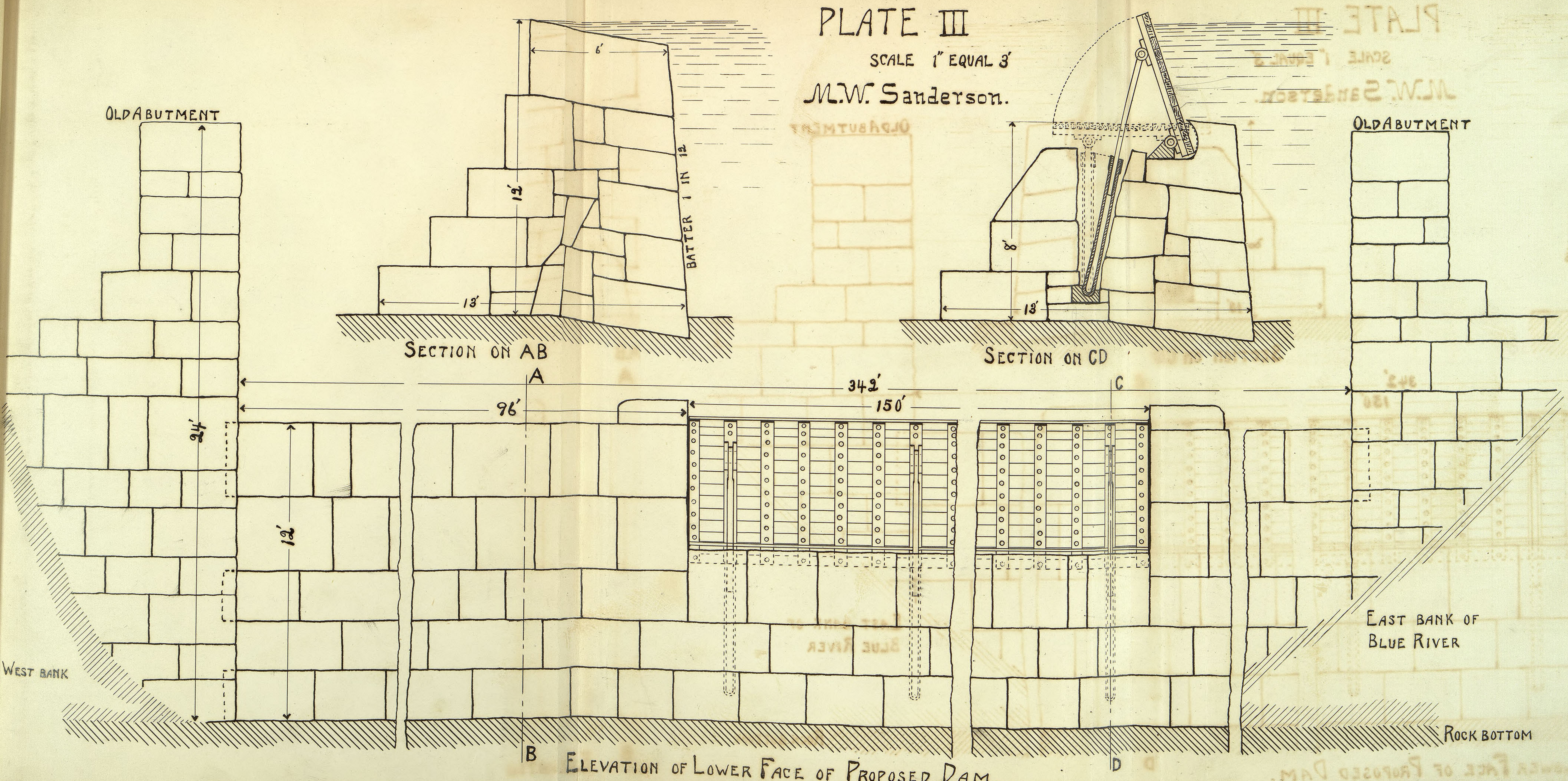


PLATE III
SCALE 1" EQUAL 3'
M.W. Sanderson.
OLD ABUTMENT
6'
12'
BATTER 1 IN 12
13'
SECTION ON AB
8'
13'
SECTION ON CD
OLD ABUTMENT
342'
96'
150'
A
C
24'
12'
WEST BANK
EAST BANK OF
BLUE RIVER
ROCK BOTTOM
B
D
ELEVATION OF LOWER FACE OF PROPOSED DAM.

f = the frictional coefficient of masonry 0.65 in this case, and P = the horizontal water pressure on the face of the dam above the joint in question. Allowing 150 lbs. to the cu. ft. for the weight of the masonry and 62.5 lbs. to the cu. ft. of water, P = 62.5 × area of the face × depth of the centre of gravity of that area. The dam designed gives a frictional stability of at least 1.5 for every horizontal joint, and is hence stable in this particular. The overturning moment is also fully satisfied; with a 12 ft. dam and a 20 ft. head, the horizontal water pressure for one ft. in length is 7500 lbs. acting with a lever arm of $6\frac{2}{3}$ ft., moment = 50000, while the opposing moment of the dam, the weight of a section one foot long acting with a lever arm of about 8 ft., 100 cu. ft. × 150 lbs. × 8 ft. = 120000, the overturning moment $= \frac{50000}{120000} = \frac{5}{12}$, which is stable.

Mr. Ed. Ulbrich kindly furnished figures as to the cost of masonry, \$5.00 per cu. yd. if laid in natural cement, \$0.75 to \$1.00 added if in Portland cement, and \$2.00 per cu. yd. to be added for cost of coffer damming and excavation, making a total of \$8.00 per cu. yd. if laid in Portland cement. The main portion of the dam has a cross section of 100 sq. ft., and a length of 192 ft., making 19200 cu. ft.

The lowered portion of the dam gives a cross-section of 81 sq. ft., and a length of 150 ft., making 12150 cu. ft., a total of 31350 cu. ft. or 1162 cu. yds. in the whole dam; and at $8.00 per cu. yd. would cost $9296.00 adding $1700 for cost of movable shutters and for hydraulic-jacks to operate them makes a total cost of $11000.00 for the dam.

In order to obtain a preliminary knowledge of the cost of turbine water wheels that would utilize the available power head, I corresponded with the following firms asking for prices on turbines: The Trump Mfg. Co., Springfield, Ohio; The Stilwell-Bierce and Smith-Vaile Co., Dayton, Ohio; and R. D. Wood and Co., Philadelphia; with the following result – Two 52 inch Trump Model turbines under a head of 12 ft. will use 488 sec. ft. and will deliver 511 H. P. with a speed of 89 R. P. M.. These wheels are rated at 80% efficiency. The two wheels will cost $1200.00 and with the necessary shafting, gearing, etc. and cost of placing them in position would range near $4000.00. Two 54 inch Victor turbines made by the Dayton firm will use 458 sec. ft. giving 497 H. P. at 89 R. P. M. The cost of these wheels, including shafting, gearing, pulleys, etc. is $4000.00. R. D. Wood & Co. asks $5100. for two wheels. From these figures, I concluded that two turbines could be obtained that would utilize about 5.00 sec. ft.; and deliver 500 H.P. costing when in place, probably $6000.00.

I next corresponded with the General Electric Co. of N.Y. in regard to prices on electrical generators, transmission apparatus, etc. and received the answer that a three phase generator with exciter and switch board would cost $5000.00, rating this at an efficiency of 80% it will deliver 400 H.P. or 300 kilowatts. The cost for copper and pole line to transmit this volume of power a distance of four miles, will be $2500.00, this line is designed to carry a line voltage of 3120 volts. Step down transformers would be required at the receiving end of the line, and these would cost about $15.00 per K.W. or about $4000.00, as the total cost of transforming. Allowing a 10% loss in transmission and transformation, we would have delivered in town 360 H.P. or 270 K.W..

The total cost of a plant would then be:

Dam	$11000.00
Turbines	6000.00
Electric generator	5000.00
Copper and pole line	2500.00
Transformers	4000.00
Interest on capital + general contingencies	6500.00
Total Cost	$35000.00

With the power now delivered in town, let us see how it can be disposed of. The engineer of the Manhattan Electric Light Co. informed us that at present they are carrying 26 arc and 630 incadescent lights on their line, and running at full capacity. Their fuel cost is $150.^{00} per month or $1,800.^{00} per year, the fuel would be the principal saving by using Rocky Ford electricity. One arc light requires 0.75 H.P. or 560 watts. An incadescent lamp requires 75 watts; hence, 26 arc lamps require 14560 watts; and 630 incadescent lamps require 47250 watts; making a total of 61810 watts, or nearly 62 K.W. which would leave us over 200 K.W. or 266 H.P. still unused. As the electric lights are only used in the evening and night, this same power could be used during the day for pumping the city water supply. The principal saving here again is the saving of fuel. From the "Report of the city Water Works Committee of April 18, 1898". The following data is taken:

Cost of fuel for	1889 ----	$675.77
" " " "	'90 ----	1010.46
" " " "	'91 ----	753.83
" " " "	'92 ----	930.31
" " " "	'93 ----	729.21

Cost of fuel for	1894	947.45
" " " "	'95	758.55
" " " "	'96	758.95
" " " "	'97	159.34
" " " to April 1,	'98	1080.66

This gives an average cost of about $800.00 per year, and we still have 260 H.P. to dispose of. The Trump Mfg. Co. volunteered the information that power delivered should sell from $25.00 to $30.00 per H.P. per year. Suppose that our 260 H.P. could be sold in Manhattan for $20.00 per H.P.; it would bring an annual income of $5200.00

The total income would then be:

Power rented,	$5200.00
Water works fuel saved,	800.00
Electric light plant fuel saved,	1800.00
Total annual income,	$7800.00

or over 20% on the capital invested.

If factories and mills requiring power can only be induced to locate at Manhattan, the future usefulness of the Rocky Ford water power is assured, and Manhattan will then take first place as the centre of the manufacturing industry of Kansas.