DESIGN FOR RAPID VALLEY IRRIGATION PROJECT RAPID VALLEY, SOUTH DAKOTA

BY

CHARLES JAMES CRAIGMILE

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THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1913

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I recommend that the thesis prepared under my supervision by CHARLES JAMES CRAIGMILE entitled Design for Rapid Valley Irrigation Project, Rapid Valley, South Dakota, be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

A. B. McDaniel

Asst. Professor of Civil Eng'g.

Recommendation approved

Ira O. Baker

Head of Department of Civil Eng'g.

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INTRODUCTION.

The territory under consideration in this thesis is that part of Rapid Valley east of Rapid City, Pennington County, S.D., and extending to the south forks of the Cheyenne River. On the north it is bounded by the natural divide between Box Elder and Rapid Valley, and on the south by Rapid Creek. The location as determined by the public land surveys of the government is as follows:- Township 1 North of Range 7 E., Township 1 North of Range 8 East, Township 1 North of Range 9 East, Township 1 North of Range 10 East, Township 1 North of Range 11 East, Township 1 North of Range 12 East, Township 1 North of Range 13 East, Township 1 South of Range 9 East, Township 1 South of Range 10 East, Township 1 South of Range 11 East, Township 1 South of Range 12 East, Township 1 South of Range 13 East of Black Hills Meridian.

The lower valley through which Rapid Creek flows has an average width of about two miles, and an average elevation above sea level of 3000 feet. A reference to the map, which accompanies and forms a part of this thesis, shows that the valley extends from Rapid City in a general easterly direction, with an average fall of about 15 feet per mile. Leaving the north edge of the lower valley, the surface rises almost uniformly with an average slope of about 80 feet per mile to the ridge which separates the valley of Rapid Creek from that of Box Elder Creek. This great inclined terrace is traversed about every mile in its length by

large ravines or "dry draws" running in a general southerly direction down into the lower valley. These ravines become larger and more pronounced at the eastern section of the area.

WATER SUPPLY.

Rapid Creek rises in the Central portion of the Black hills uplift, where its upper branches as the forks of Castle Creek, gather their water from the limestone plateau. This creek is peculiarly fortunate in the formation of its bed, as stream measurements taken about the same time, 20 miles above, and about one mile below Rapid City, show a very slight loss through seepage and absorption. Many of the other creeks in the Black Hills, such as Box Elder and Elk Creeks disappear entirely when they reach the sandstone and limestone outcroppings of the lower sections of the eastern slope.

The following table gives the estimated monthly discharge of Rapid Creek, taken near Rapid City, for the years 1903 to 1906 inclusive. This table is taken from Professional Paper No. 65, U.S. Geological Survey:-

1903.

Date	Discharge in second feet.		
	Max.	Min.	Mean.
June	240	124	163
July	197	64	117
August	102	48	75
September	102	48	73
October	72	48	63
November	81	40	52
December	72	33	41

1904

Date	Discharge in second feet		
	Max.	Min.	Mean.
March	101	47	70.1
April	141	87	120.0
May	153	120	142.0
June	798	146	434.0
July	234	96	175.0
August	96	64	81.3
September	196	68	88.0
October	99	74	86.8
November	92	76	85.5
December	96	62	79.2

1905.

January -1-6	85	70	79.0
February 21-28	70	51	63.8
March	93	60	72.5
April	104	60	83.2
May	241	58	173.0
June	259	99	131.0
July	880	203	359.0
August	299	110	195.0
September	128	80	102.0
October	98	67	84.0
November	104	64	82.3

1906.

April	91	43	67.7
May	312	63	126.0
June	323	91	148.0
July	99	45	74.0
August	480	71	166.0
September	91	84	87.5
October	99	71	81.7
November	84	60	70.5

The flow of Rapid Creek reached a maximum flood flow of 908 second feet June 6, 1904.

A method for properly utilizing this water is the construction and maintenance of storage reservoirs for holding back the surplus water. While it is not thought that the entire flow of streams would be improved even a small percentage of the flow thus treated would be of immense benefit. In this manner, by the

construction of the immense Owl Creek reservoir for storing flood waters of the Belle Fourche river, the reclamation of 100,000 acres of land under the Belle Fourche project is made possible.

The plan most feasible is, that the six mile ditch shown on the map and known as the Iowa Irrigation ditch, be made the starting point of the Project. A suitable concrete diversion dam will replace the present wooden structure on Rapid Creek in Rapid City. The present ditch has a bottom width of ten feet, and an average depth of three feet and side slopes of 1:1. The grade can be reduced to 2.0 feet per mile for the extension of the ditch; and will give a ditch line as shown on the map accompanying this thesis. This ditch will be the high line canal, and will direct the flood waters of Rapid Creek and carry them along the south side of the divide, through a series of small reservoirs made by constructing dams across the "dry draws"; and finally reaching the great reservoir as shown on the map. This would require a canal having a length of about thirty-five miles and a capacity of 810 second feet. This will require a ditch having a bottom width of about thirty feet, nine and one half feet deep, and side slopes varying from 1:1 to 1½:1. The reservoir system will be composed of about twenty-two small reservoirs between the head-works and the large reservoir at the end of the high line canal. These smaller, intermediate reservoirs will be formed by the construction of small dams across the dry draws or ravines which traverse the territory in a general southerly direction at intervals of about one mile. The reservoirs could be used as feeders for the high line canal. These reservoirs will have a capacity of from 2500 acre feet each at the western side of the territory

to 4000 acre feet each at the eastern side. The large reservoir will have a capacity of about 60,000 acre-feet, by the construction of a large earth dam at its western end. Such a dam would have a length at top of about 3000 feet, and a height at center of about fifty feet. The reservoir thus formed would supply the land to the west and south with about 20,000 acre-feet of water, and the land to the east and south with about 40,000 acre-feet of water, Another high line canal would run east and along the south side of the divide and link together a series of about five reservoirs formed by damming up the ravines, through which it would pass. These smaller auxilliary reservoirs would add about 20,000 acre-feet of water to the available supply, and would be of great service for local sub-irrigation.

The Iowa ditch itself furnishes 15 second feet above normal flow which will be utilized during the irrigation season of about 110 days of the regular flow of Rapid Creek. The duty of water as given by the state water code is one cubic foot of water per second, or one second foot for every seventy acres of land to be irrigated. This is the maximum appropriation, but from inquiry among water users in the lower valley; the average duty was found to be one second foot for every one hundred acres of land irrigated. Hence, the main canal alone during the irrigation season under normal condition of flow will supply 1500 acres of land. During the remainder of the year, for a period of nine months, the canal will carry the flood waters of Rapid Creek to the reservoir, making a storage about as follows:-

17 auxilliary reservoirs west of central reservoir,	40,000 acre feet
Large central reservoir,	60,000 acre feet
5 auxilliary reservoirs east of central,	20,000 acre feet
Total	120,000 acre feet

A study of the discharge tables as given above for the years 1903-1906 inclusive, will show that during the flood season at least 100,000 acre feet can be supplied to the reservoir system by means of the high line canal. The remaining 20,000 can be obtained from the impounding of water due to precipitation over the adjacent water sheds or from Rapid Creek in years of unusual flood conditions.

In the 5th annual report of the Reclamation Service, it is stated in the account of the Belle Fourche Project, that the duty of water is two feet. Also in the second Biennial report of the State Engineer of South Dakota is found the following statement. "The duty of water for efficient irrigation is about two acre-feet per annum. That is, for every acre to be irrigated there should be storage capacity sufficient to provide water over it to a depth of two feet." There are about 60,000 acres of land included in this project, which are available for cultivation, and hence the storage supply of 120,000 acres feet is ample for the purpose of thorough and complete irrigation. No allowance is made for evaporation and seepage as the uniform rainfall will make up losses resulting from these causes.

The construction of the necessary dams, ditches and structures, on account of the unusually fortunate location of the various parts of the proposed irrigation system, requires only

simple direct work, and includes nothing in the way of special and difficult engineering and construction work. This accounts for the low average cost of construction.

HEAD WORKS.

The headworks will be constructed at the location of the present wooden dam and will consist as nearly as possible of monolithic concrete.

The entire structure will rest upon the gravel which under-lies the bed of Rapid Creek at a uniform depth of from 12 to 14 feet. Piles driven to the gravel will support the weir and broken stone carried up from the gravel will support the retaining wall.

The diversion weir will consist of 1:2½:4 rubble concrete with enough reinforcing to resist temperature stresses. It will be seventy-five feet long with a height of fourteen feet from the under side of the structure to the crest and thirty-six feet from the upstream toe of the weir to the downstream toe.

The crest is sloped sufficiently to divert the ice pressure tending to shear the top portion of the weir. The down stream face is of the ogee type or consisting of two curves of small radius connected by a tangent plane of a 1:5½ batter. The downstream apron is about three feet thick until four feet three inches from the toe where it is sloped until the toe has an additional thickness of six inches. The object being to form a pool which will keep the water with its relatively high content of grit,

from eroding the apron. Through the portion of the weir nearest the headgates are two sluice gates operated by hand or a motor. These gates are for the purpose of flushing out the silt which sooner or later collects in every set of headgates. With a head of eight feet the sluice gates will cause a velocity of twelve feet per second in the neighborhood of the headgates, which should clear the silt out easily.

The weir is continued a distance of about fifteen feet along the main ditch. This part of the structure will be of the form of the retaining walls on each side of the stream and is of the same dimensions as this retaining wall, and will be founded upon gravel.

HEADGATES.

The headgates are seven in number and each spans an opening of six feet.

The headgates themselves are of cast iron and their frames are set in concrete piers. This arrangment of gates when opened to their widest extent will with a head of eight feet produce a discharge of 950 cu. ft. per second. This is as great as any flood on record. The gates are raised by means of power supplied by a motor and the machinery is the common racket and spindle connected by a shaft and operated simultaneously or separately.

RETAINING WALLS.

The top of the retaining walls is to be at all points

INVESTIGATION OF RETAINING WALL.

Assuming a horizontal earth of 24# per square foot with an application point at 1/3 h.

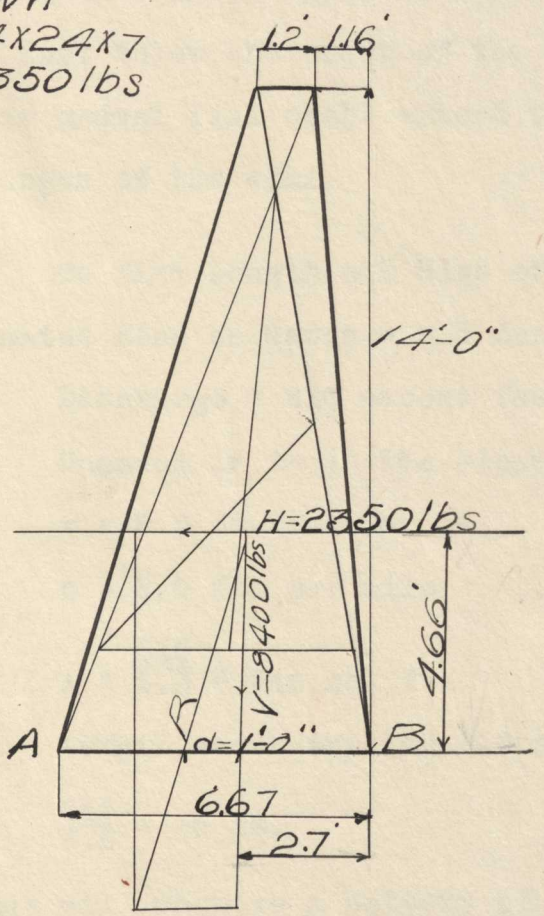
14' x 24 = 336.0 for a unit length of wall.

Weight of wall = 56 x 150 = 8400. lbs

$H = \frac{1}{2} W h^2$

$= 14 \times 24 \times 7$

$= 2350$ lbs



Factor of safety against overturning = 2 approximately

$$p = \frac{8400}{6.62} \pm \frac{6 \times 8400 \times 1.}{43.7}$$

$= 1270 \pm 1170$

$= 2440$ pounds sq. ft. at point A.

Pressure at B = 100 pounds square ft.

Both safe against crushing and safe on sandy soil.

two feet higher than the crest of the weir and to be of the same materials as the weir with the same specifications as regards the concrete and amount of stone or hardheads to be used. This wall is to extend as shown in drawing No.1. The foundation shall be of gravel and the earth shall be excavated until in the opinion of the engineer, fair gravel for a foundation is reached, when the resulting excavation shall again be filled up with gravel to a point twelve feet below the crest of the weir. The upper six inches of this gravel fill shall extend ten feet in width along the entire length of the wall.

To find Length and Size of Gates.

Average estimated Head on Gates = 6.5 feet.

Discharge = 810 second feet.

Channel is $1\frac{1}{2}$:1 side slope with n = .025

v = 3.3 ft. per sec.

s = 2.0 ft. per mile

$A = \frac{810}{3.3} = 246$ sq. ft.

Length necessary for 810 sec. ft.

$\frac{246}{6.5} = 38$ ft.

This will require a battery of seven gates each 6 x 6.

Wt. of Gates 7(2330 + 1410)

26,180 lbs.

THE PIERS.

The piers shall each be one foot in thickness. They shall be eight feet in height, seven feet in depth at the top, fourteen feet in depth at the bottom, with a uniform batter between and shall be composed of a 1;2½:4 mixture.

A sidewalk shall be built connecting the top of these piers and the span of each opening shall be a separate slab which shall be dovetailed to the next slab in a manner as shown on drawing No. 1. These slabs shall be reinforced by ½ in. square rods spaced six inches apart and to be placed not nearer than two inches to or farther than three inches from the bottom of the slab. The rods will continue in all cases to within two or three inches of the edge of the concrete.

The piers shall be built on a floor of concrete which shall be two feet in thickness and which shall be set upon piles. The piles to be driven to gravel at not less than fourteen feet in depth. A row of one half inch square rods shall project six inches into and six inches above on the site of the piers. The tops of the piles to be carefully cleared of brooming and to be set into the concrete not less than six inches nor more than eight inches. The piles to be spaced not more than six feet apart each way or less than three feet and to be set not less than one foot from the edge of the concrete. A tongue of concrete one foot wide to run two feet below the lowest part of the concrete on the upstream side of the piers.

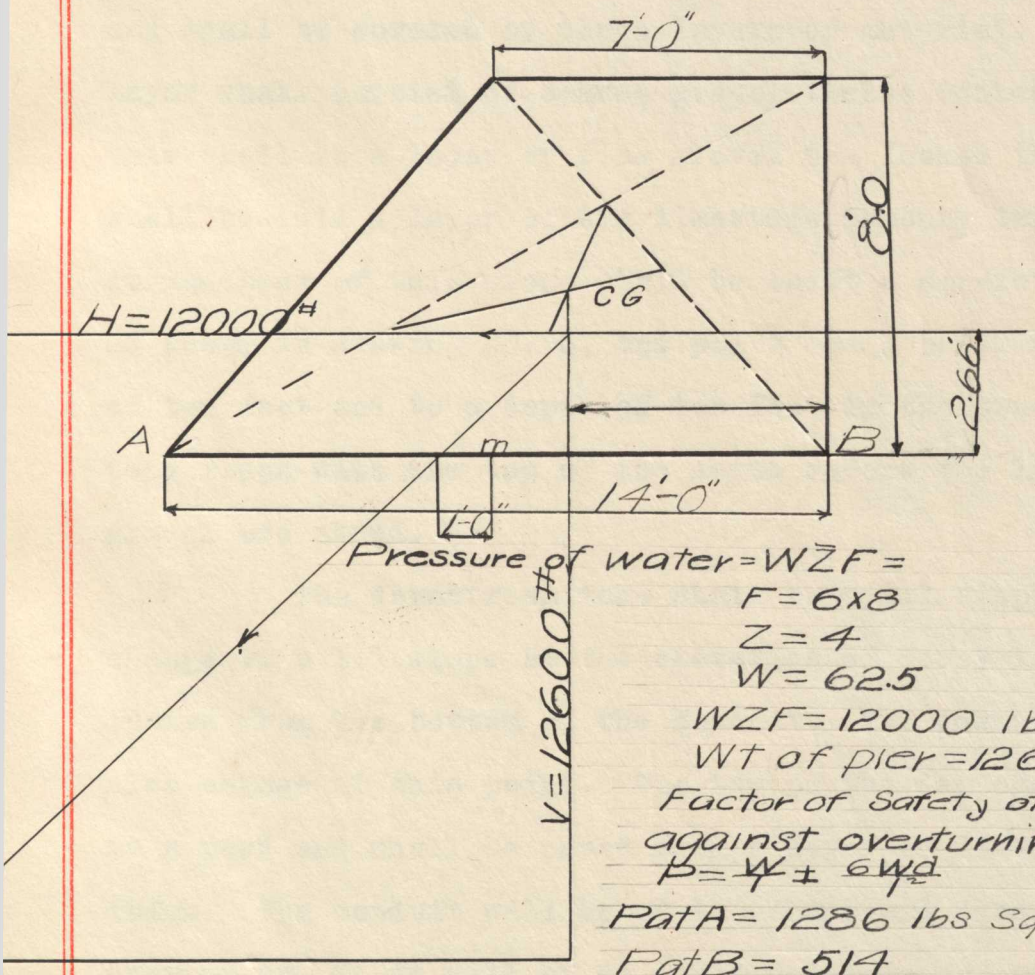
The piers to be shod on the upstream face with a steel angle, 8 x 8 x ¾ ins. The steel to extend from the sidewalk to

the pier foundation and to be fastened every foot by rods bent to secure a flush bearing upon the steel and embedded at least one foot in the pier. The concrete flooring shall be poured with no less than three expansion joints, the joints to be filled with asphalt. And a joint to be left between the sidewalks and the flooring.

The sidewalls are to be built with the same section as the retaining walls and are to be built under the same specifications.

DESIGN AND STABILITY INVESTIGATION OF PIERS.

Assuming a top width of pier of seven feet and a bottom width of fourteen feet, with a thickness of 1'-0" and height of eight feet.



Pressure of water = WZF =

$F = 6 \times 8$

$Z = 4$

$W = 62.5$

$WZF = 12000$ lbs

Wt of pier = 12600

Factor of Safety of 3 against overturning

$P = \frac{W}{A} \pm \frac{6Wd}{b^2}$

Pat A = 1286 lbs Sq ft

Pat B = 514

Pier is Safe

LARGE DAM.

The large dam shall be constructed with the same side slopes and same structures as shown in drawing No.3.

The upstream face of the dam shall be sloped at a $2\frac{1}{2}$:1 and shall be covered by three layers of material. The bottom layer shall consist of coarse gravel twelve inches thick; on top of this shall be a layer of fine gravel ten inches thick; over this shall be laid a layer of dry limestone masonry twelve inches thick. At the back of this slope shall be built a concrete retaining wall as shown in drawing No. 3, and piles shall be driven at intervals of ten feet and to a depth of ten feet in the true soil with their tops flush with the top of the earth before the layers of sand and gravel are added.

The downstream face shall be a 2:1 slope and shall change to a 1:1 slope at the elevation of forty-four feet six inches from the bottom of the conduit. The downstream slope shall also change at this point. The top of the dam shall be constructed as a road and shall be paved with a layer of limestone six inches thick. The conduit will be of the shape and dimensions shown in drawing No. 3; it will be of 1:2:4 concrete and will be reinforced on all four sides by one half inch square rods spaced six inches apart, the steel to be laid not closer than two inches or not farther than three inches from the conduit invert, the ends of the rods to be two inches from the outside edge of the conduit. The conduit shall be laid upon a layer of gravel two feet deep and as wide as the conduit. The gate-well shall be constructed of 1:$2\frac{1}{2}$:4

concrete with the dimensions as shown and the reinforcing shall be the same in all four walls as in the one shown. The rods shall be laid not closer than two inches or farther than three inches from the inside of the wall. The gate-pier as shown in the middle of the wall shall extend to the top of the wall and shall have $\frac{3}{4}$ in. square rods bent as shown in the plan spaced every six inches to the top, and at every point placed not more than two or more than three inches from the surface. The pier shall also be reinforced vertically; $\frac{1}{2}$ in. square rods shall be placed at a spacing of three inches around the pier, with the same requirement as before as regards edge distance. The gates will be as shown in the detail; spanning an opening of 5 x 5 ft. with adequate hoisting machinery at the top of the gate well. An emergency gate as shown in the detail shall be installed as shown in drawing No. 3.

The body of the dam shall be constructed of soil taken from the neighboring hillsides and the surface soil shall first be stripped off and under no consideration shall anything but colluvial soil be used. The soil shall be applied in six inch layers and shall be as thoroughly wetted as the engineer shall demand. In no case shall the soil be dumped where the earth has not been compacted by two passes of a steam roller weighing not less than eight tons. The earth shall in all cases be thoroughly wetted previous to being rolled; (thoroughly) being defined as that condition demanded by the engineer.

SPILLWAY.

The spillway shall be fully completed before the upper

ten feet of the dam is completed. It shall have a cross section equal in section and similar in form to the inflow ditch and running as shown by the map.

AUXILIARY DAMS.

The auxiliary dams are to be constructed in general like the one shown in drawing No. 5 and in the upstream slope shall in no case be sharper than 1:3. In all cases both toes of the dam shall be secured by piles driven into the natural soil not less than fourteen feet and with the heads not less than one foot below the filled earth. The piles to be spaced not less than ten feet C to C and to be driven at least 10 ft. from the foot of the slope as determined by the engineer. The piles shall not be used when the crest of the dam is less than ten feet higher than the toe of the slope. The earth used in the construction is to be taken from soil of a colluvial nature and in all cases the first six inches of surface soil must be removed before any such earth is incorporated in the dam. The earth to be applied in no more than six inch layers and when wetted to the consistency demanded by the engineer, shall be compacted with two passes of a roller weighing not less than eight tons and rolling a strip more than five feet in width.

All concrete work shall be of a 1:2½:4 mixture and shall be placed in the manner shown in drawing No. 5, and in all respects to coincide with the specifications. The gate-well shall be reinforced with one half inch square rods placed six inches apart and not more than three inches or less than two inches from the inside faces of the gate-well the rods to be not less than four

feet long or according to the engineer's judgment.

The gates are to be of cast iron and to be designed according to the specifications of the Reclamation Service of the United States. The gate-house to cover the gate-well as shown in drawing No. 5, and to be of such a character to admit of adequate hoisting apparatus for the gates.

DITCH.

Starting with the present site of the headgates, the present Iowa ditch will be enlarged as shown on Drawing No. 4.

The cut on both sides of the side slopes used will be 1:1 and the width of the bottom will be thirty-two feet. On side hill work, or where one side is partly or wholly fill the cut side shall be on a slope of 1:1 and on the fill side shall be $1\frac{1}{2}$:1.

Earth shall not be left closer than fifteen feet to the edge of the bank where the ditch is cut on both sides. No sods of surface soil shall be left in the earth on the spoil side of the ditch. Definition of surface soil to be soil less than six inches in depth. The ditch will run as shown on the map. The contractor shall install where directed by the engineer gates of the Powell type and shall encase the gate-frame carefully in 1:$2\frac{1}{2}$:4 concrete. Temporary bridges shall be erected so that traffic shall not be inconvenienced and all such structures shall be subject to the approval of the engineer and must be so approved before any such structure is used for traffic. The completed ditch shall be left entirely ready for operation at the completion of the contract.

LATERALS AND MISCELLANEOUS STRUCTURES.

The construction of the laterals and contingent structures will be carried on under the same general specifications as regards excellence of work as the work hitherto described.

All excavation will be done under three classifications, viz:

Earth - plowable material.

Gravel and loose rock- all rock that can be handled by hand without blasting.

Rock - all rock that must be drilled and blasted before handling.

All concrete work shall be done with Portland cement and with sand and gravel specified by the engineer.

All materials to be inspected by the engineer before incorporating in any structure.

SPECIFICATIONS.

General Conditions.

1. Form of proposal and signature.- The proposal must be made on the form provided for that purpose, inclosed in a sealed envelope, and marked and addressed as required in the advertisement, stating, in writing and in figures, the sum of money for which the bidder proposes to supply the materials and perform the work required by the drawings and the specifications, the unit prices, and the separate estimates called for in the proposal. It must be signed with the full name and address of the bidder; if a co-partnership, the co-partnership name by a member of the firm, with the name and address in full of each member; and if a corporation, by an officer in the corporate name, with the corporate seal attached to such signature. No telegraphic proposal or telegraphic modification of proposal will be considered.

2. Proposals.- All blank spaces in the proposal must be filled in, and no change shall be made in the phraseology of the proposal, or addition to the items mentioned therein. Any conditions, limitations, or provisos attached to a proposal will be liable to render it informal and may cause its rejection. Alterations by erasure or interlineation must be explained or noted in the proposal over the signature of the bidder. If a bidder wishes to withdraw his proposal he may do so before the time fixed for the opening, without prejudice to himself, by communicating his purpose in writing to the officer who holds it. No bids received after the time set for opening the proposals will be considered.

3, Certified check.- Each bidder must submit with his proposal a certified check for the sum stated in the advertisement, drawn to the order of the Rapid Creek Development Co. and if for any reason whatever, the bidder withdraws from the competition after the opening of the bids or refuses to execute the contract and bond as required, if his bid is accepted, the proceeds of said check shall be the property of Rapid Creek Development Co. Checks submitted by the unsuccessful bidders will be returned after the approval of the contract and bond executed by the successful bidder.

Contractor's bond.- The contractor will be required to give a bond in the sum of twenty per cent of the amount of the contract, unless a different amount is specified in the advertisement or proposal, conditioned upon the faithful performance by the contractor of all the covenants, stipulations, and agreements in the contract. If at any time during the continuance of the contract the sureties, or any of them, shall die, or become irresponsible in the opinion of the Engineer he shall have the right to acquire additional and sufficient sureties, which the contractor shall furnish to the satisfaction of that officer within ten days after notice, and in default thereof the contract may be annuled by the engineer and the work carried to completion in the manner provided in the contract.

Engineer.- Where the word "engineer" is used in the general conditions or detail specifications, or in the contract, it shall be and is mutually understood to refer to the chief engineer or any of his authorized assistants or inspectors, limited by the particular duties intrusted to them. The engineer will

give the locations and grades for the work, and no work depending on such locations and grades will be commenced until these have been established. It shall be his duty to point out to the contractor any neglect or disregard of the plans, specifications and general conditions of the contract. Upon all questions concerning the execution of the work and the classification of the material, in accordance with the specifications, the decision of the engimeer shall be binding on both parties. All materials furnished and all work done shall be subject to rigid inspection, and if not in accordance with the specifications, in the opinion of the engineer, shall be made to conform thereto. Unsatisfactory material will be rejected and shall be immediately removed from the premises, at the expense of the contractor, if so ordered by the engineer.

Contractor.- Whenever the word "contractor" is used, it shall be held to mean the party, firm, or corporation with whom the contract is made by the Rapid Creek Development Co. for the construction of the work, the agent of his party who may be appointed to represent him in the execution of the work, or the legal representatives of the contractor. The foreman in charge of the work will be held to represent the contractor during the absence of the latter or his designated agent.

Foreman and copy of the plans, etc.- The contractor shall at all times keep upon the work a copy of the plans and specifications, so that reference may be made thereto by the engineer, in case of misunderstanding or misconstruction. Instructions given to the contractor's foreman or agent on the work, by the engineer, shall be considered as having been given to the contractor himself.

Local conditions.- Bidders must satisfy themselves as to the nature of the material and as to all local conditions affecting the work, and no information derived from the maps, plans, specifications,profiles, or drawings, or from the engineer or his assistants, will in any way relieve the contractor from any risks or from fullfilling all the terms of his contract.

Damages.- The contractor will be held responsible for and, when possible, be required to make good, at his own expense, any and all damages, of whatsoever nature, to persons or property, caused by carelessness, neglect, or want of due precaution on the part of the contractor, his agents, employees, or workmen. He will not allow any of his agents, employees, or workmen to trespass upon the premises or lands of persons in the vicinity of the works, and will discharge, at the request of the engineer, anyone in his employ who may be guilty of committing such damage.

Drawings and specification requirements.- Any drawings or plans which may be listed in the detail specifications shall, together with such detail specifications, be regarded as forming part hereof and of the contract. The engineer will furnish from time to time such detail drawings, plans, profiles, and special specifications as may be necessary to enable the contractor to complete the work in a satisfactory manner. The general conditions and detail specifications shall apply to all work done or material furnished, and shall control the special specifications, where the latter are silent. In case of conflict in the general conditions, the detail specifications, and the general specifications, the last shall control in the particular work to which they apply.

Experience.- Bidders must, if required, present satis-

factory evidence that they have been regularily engaged in the business of constructing such work as they propose to execute, and that they are fully prepared with the necessary capital, machinery, and material to begin the work promptly and to conduct it to the satisfaction of the engineer.

Character of workmen.- The contractor shall discharge from his service, when required by the engineer, any disorderly, dangerous, insubordinate, or incompetent person employed on or in the vicinity of the works under construction by the Rapid Creek Development Co. None but skilled foremen or workmen shall be employed on work requiring special qualifications, as tunnels, concrete work, etc.

Methods and applicances.- The methods and appliances adopted by the contractor shall be such as will secure a satisfactory quality of work and will enable him to complete the work in the time agreed upon. If at any time such methods and appliances appear inadequate, the engineer may order the contractor to improve their character, or increase their efficiency, and the contractor must conform to such order; but the failure of the engineer to order such improvement of methods or increase of efficiency will not relieve the contractor from his obligations to perform good work or finish it in the time agreed upon.

Material and workmanship.- All materials must be of the specified quality and fully equal to approved samples, when samples are required. All work must be done in a thorough workmanlike manner by mechanics skilled in their various trades, notwithstanding any omission from the drawings or specifications; and anything mentioned in the specifications and not shown in the

drawings, or shown in the drawings and not mentioned in the specifications must be done as though shown or mentioned in both.

Samples.- The contractor shall submit samples of any or all of the materials proposed to be used in the work if required to do so by the engineer.

Delays.- The contractor shall not be entitled to any compensation for delays or hindrances to the work from any cause whatever. Extension of time will be allowed for unavoidable delays, such as may result from causes which, in the opinion of the engineer are undoubtedly beyond the control of the contractor, such as acts of Providence, fortuitous events, or the like. If any delay or hindrance is caused by specific instructions on the part of the Company or the engineer, or by their failure to provide material sufficient to carry on the work, or to give such instructions as may be necessary for the same, or to provide necessary right of way, then such delay will entitle the contractor to an extension of time equivalent to the time lost by such delay. The engineer must receive from the contractor a written notice of claim for such delay before any extension of time will be allowed. Any extension of time, however, shall not release the sureties from their obligations, which shall remain in full force and effect until the discharge of the contract. In case the contractor should fail to complete the work in the time agreed upon in the contract, or in such extra time as may have been allowed for delays as herein provided, the engineer shall compute and appraise the direct damages for the loss sustained by the Company on account of further employment of engineers, inspectors, and other employees, including all disbursements on the engineering account,

properly chargeable to the work as liquidated damages. The amount so appraised and computed shall be deducted from any money due the contractor under his contract. The decision of the chief engineer as to the appraisal of such damages shall be final and binding on both parties. Any provisions in the detail specifications concerning deductions for delay shall be held as modifying or revoking the provisions herein.

Suspension of contract.- Should the contractor fail to begin the work within the time required, or fail to begin the delivery of material as provided in the contract, or fail to prosecute the work or delivery in such manner as to insure a full compliance with the contract within the time limin, or should any question arise as to whether or not the contractor is properly carrying out the provisions of his contract in their true intent and meaning, at any time during the progress of the work, notice thereof in writing shall be served upon him, and upon his neglect or refusal to provide means for a more energetic and satisfactory compliance with the contract within the time specified in such notice, then and in either case the engineer shall have the power to suspend the operation of the contract, and he may take possession of all machinery, tools, appliances, and animals employed on any of the works to be constructed under the contract and of all materials belonging to the contractor delivered on the ground, and may use the same to complete the work, or he may employ other parties to carry the contract to completion, substitute other machinery or materials, purchase the material contracted for in such manner as he may deem proper, or hire such force and buy such machinery, tools, appliances, materials, and animals at the con-

tractor's expense as may be necessary for the proper conduct of the work and, for finishing it in the time agreed upon. Any excess of cost arising therefrom over and above the contract price will be charged against the contractor and his sureties, who shall be liable therefor. The failure to order improvement of methods or increase of force, plant, or efficiencies will not relieve the contractor from his obligation to perform good work or finish in the time agreed upon.

Climatic conditions.- The engineer may order the contractor to suspend any work that may be damaged by inclemency of the weather or other climatic conditions (as, for example, excessive heat or cold) and due allowance shall be made to the contractor for the time actually lost by him on account of such suspension.

Quantities.- The quantities given in the proposal are for the purpose of comparing bids, and are approximately only, and no claim shall be made against the Company on account of any excess or deficiency, absolute or relative, in the same.

Changes.- The engineer reserves the right to make such changes in the specifications of work or material at any time as may be deemed advisable, without notice to the surety or sureties on the bond given to secure compliance with the contract, by adding thereto or deducting therefrom, at the unit price of the contract, or at such allowances for changes of materials as shall be deemed just and reasonable by the engineer, whose decision shall be binding on both parties. The right to make material changes in the quantities listed in the proposal is an essential part of the contract, and bidders must make their estimates

accordingly. Should any change be made in a particular piece of work after it has been commenced, so that the contractor is put to extra expense, the engineer shall make reasonable allowance therefor; which action shall be binding on both parties. Claim of payment for extra work or for work not provided for in the specifications will not be allowed unless such work shall have been previously ordered in writing by the engineer. Demand for such extra payment must be accompanied by the certificate of the engineer that such work has been satisfactorily performed or the material furnished, and stating the amount to be allowed therefor, which amount, when no price for work of such kind is specified in the proposal, shall be the reasonable actual cost to the contractor, plus fifteen per cent. Such demand must be made before the time of the payment following the completion of said extra work, or the furnishing of the material.

Inspection of work.- The engineers and inspectors appointed by the company shall at all times have the right to inspect the work and materials. The contractor shall furnish such persons reasonable facilities for obtaining such information as they desire respecting the progress and manner of the work and the character of the material, including all information necessary to determine the cost of the work, such as the number of men employed, their pay, the time during which they worked on the various classes of construction, etc. He shall, when required, furnish the engineer and his assistants meals and camp accomodations at reasonable prices at any camp under his control. Whenever the contractor shall decide to inaugurate night work, or to otherwise vary the period during which work is carried on each day, he shall give due

notice to the engineer so that proper inspection may be provided for. Such work shall be done under regulations to be furnished in writing by the engineer, and no extra compensation shall be allowed therefor.

Removal of defective work.- The contractor shall remove and rebuild, at his own expense, any part of the work which has been improperly executed, even though such work should have been already allowed for in the monthly estimates. The engineer shall give to the contractor written notice of such defective work, when found. If the contractor refuses or neglects to replace such defective work, it may be replaced by the company at the contractor's expense.

Protection of finished work and cleaning up.- The contractor will be held responsible for any material furnished to him, and for the care of any finished work until final completion of the work, and will be required to make good, at his own cost, any damage or injury it may sustain from any cause. He shall take all risks from floods and causalties of every description and make no charge for detention from such causes. He may, however, be allowed a reasonable extension of time on account of such detention, as provided herein. The contractor shall remove all rubbish and unused material upon completion of the work, and place the premises in a condition satisfactory to the engineer.

Errors and omissions.- The contractor will not be allowed to take advantage of any error or omission in these specifications, as full instructions will always be given should such error or omission be discovered.

Roads and fences.- All roads crossing the work, and subject to interference therefrom, must be kept open until proper bridges or crossings are provided if necessary, and all fences crossing the work must be kept up by the contractor until the work is finished.

Bench marks, stakes, etc.- All bench-marks and slide-slope stakes must be carefully preserved by the contractor, and in case of their willful or careless destruction or removal by him or any of his employees such stakes shall be replaced by the engineer at the contractor's expense.

Use of liquor.- The use and sale of intoxicating liquor will be absolutely prohibited on the work except under the direction and supervision of the engineer or his agent, and then only for medical purposes.

Payments.- The payments due shall be made to the contractor upon the presentation of proper accounts, prepared by the engineer and approved by the chief engineer, in accordance with the provisions made therefor and pertaining to the contract. When the work has been completed or all the material has been delivered, to the satisfaction of the chief engineer, and when a release of all claims against the contract on account of the contract shall have been executed by the contractor, final payment of the balance due will be made.

COST DATA.

Estimate of Cost of Head Works

Wt. of gates 26,180 lbs.

Cost of gates at $.05 a pound - - - - - - - - $1309.00

Computations for weir volume and cost.

Cross section of weir, 176.64 sq. ft.

Length of weir, 75 ft.

Volume of weir, 13400.00 cu. ft.
500 cu. yd.

Cost of concrete same as on Belle Fourche Project @ $6.75 per cu. yd. It is specified that no less than 30% boulders be used. Boulders should be placed for $3.00 a yd. thus the cost of the masonry is: Concrete - - - - - $2250.00

Boulders - - - - - 500.00
$2750.00

Wt. of weir = 13,400 x 150 = 2,020,000 lbs.

Wt. supported by 1 sq.in. of pile 150 lbs.

Total cross-section required= 13,000 sq. ins.

Cross section of 14 in. pile = 154 sq. ins.

No. of piles required = 84.

Requiring a spacing of 7 ft. 6 ins. lengthwise of the dam.

Cost of 84 piles and driving.

Cost of piles @ 25¢ foot	84 piles @ 14 ft.,	295.40
Cost of driving at 25¢,		295.40
		590.80
Cost of excavation @ $0.30	100 cu. yds at 0.30	30.00

Estimate of ost of Head works. (Cont.)

Cost of weir (cont) 75 ft. of sheet steel piling 12 ft. deep, $700.00

Cost of gravel for foundation of weir,

25 yards of gravel @ $0.30, 7.50

Cost of 7 piers of concrete @ $6.50 a yard, 22.8 yds. @ $6.50, 148.50

Cost of 7 cast iron gates and fittings,

Cast iron @ $0.05 lb.

Wt. 1 gate 3220 lbs.

7 x 3220 = 22450 x$.05, 1122.50

Cost of concrete in canal sidewalls each 14 ft. long and of same general dimensions as retaining wall, 58.1 yds. @ $6.50 377.50

Cost of 21 piles to support floor of head gates,

Cost for driving and piles @ 50¢ ft. 294 ft. @ $0.50 147.00

One row of these piles to be placed under tongue under piers.

Cost of concrete in floor, 42.5 cu. yds, @ $6.50, 276.00

Cost of steel rods to bond piers to floor,

Space $\frac{1}{2}$ in. square rods 6 ins. apart making 28 rods in each pier.

No. rods 28 x 7 = 196

Wt. $\frac{(28 \times 7)\ (12 \times .25)}{1728} \times 486 = 166$ lbs.

Cost of steel @ $0.034 $0.034 x 166 = 5.60

Cost of retaining walls.

Section of wall $\frac{1.20 + 6.62 \times 14}{2}$ = 55 sq. ft.

Length of both walls to north end of apron =

98.75 + 36 + 45.25 = 180 ft.

Volume = 55 x 180 = 367 cu. yds.

367 yds. @ $6.50, = $2380.00

Cost of attendant excavation in Headworks construction,

with average depth of 6 ft. with 6.5 ft.

width. Average section 39.0 sq. ft.

Total length 250 ft.

362 cu. yds.

362 yds. @ $0.20, = 72.40

Gravel @ $.30 yd. for retaining wall base.

Volume $\frac{(6.5 \times 2)\ 180}{27}$ = 86.5 cu. yds.

86.5 cu. yds @ $.30, = 25.95

Total - - - - - - - $ 9942.75

Cost of ditch.

Enlarging old Iowa ditch.

Cross section of ditch as projected=400 sq. ft.

Cross section of old Iowa ditch = 56 sq. ft. leaving

344 sq. ft. to be excavated for 5 miles of ditch to be

enlarged the cost will be

$\frac{5 \times 5280 \times 343}{27}$ x $0.12 = $40,240.

$\frac{30 \times 5280 \times 400}{27}$ x $0.12 = 282,000.

$322,240.

Cost of large Dam.

Total cross-section of Max. section of dam, 5560 sq. ft.

Volume of middle portion of dam = 5,560,000 cu. ft.

Volume of two end parts.

$$2 \times \frac{1000}{6} (5560) + 4 (70.7 \times 22) + 265.0) =$$

342,000 cu. yds.

cost @ $0.30 = $102,600.00

Cost of concrete work

Concrete in cut off walls,	3.4 yds.	
" " base,	7.0 "	
" " retaining walls,	55.5 yds.	
" " conduit,	225.0 "	
" " Gate well,	174.0 "	
Total,	464.9 "	
Cost @ $6.50 =		3,020.00
Cost of steel @ $0.035 in conduit,		30.00
" " " $0.035 in well,		186.00
" " 143 piles @ 50¢ ft.,		700.00
" " Spillway ditch @ $0.30 yd. 2½ miles,		27,030.00
Pavement and gravel foundation for upstream side @ $3.00 per cu. yd.,		74,000.00
Total - - - - - - - - -		$ 207,566.00

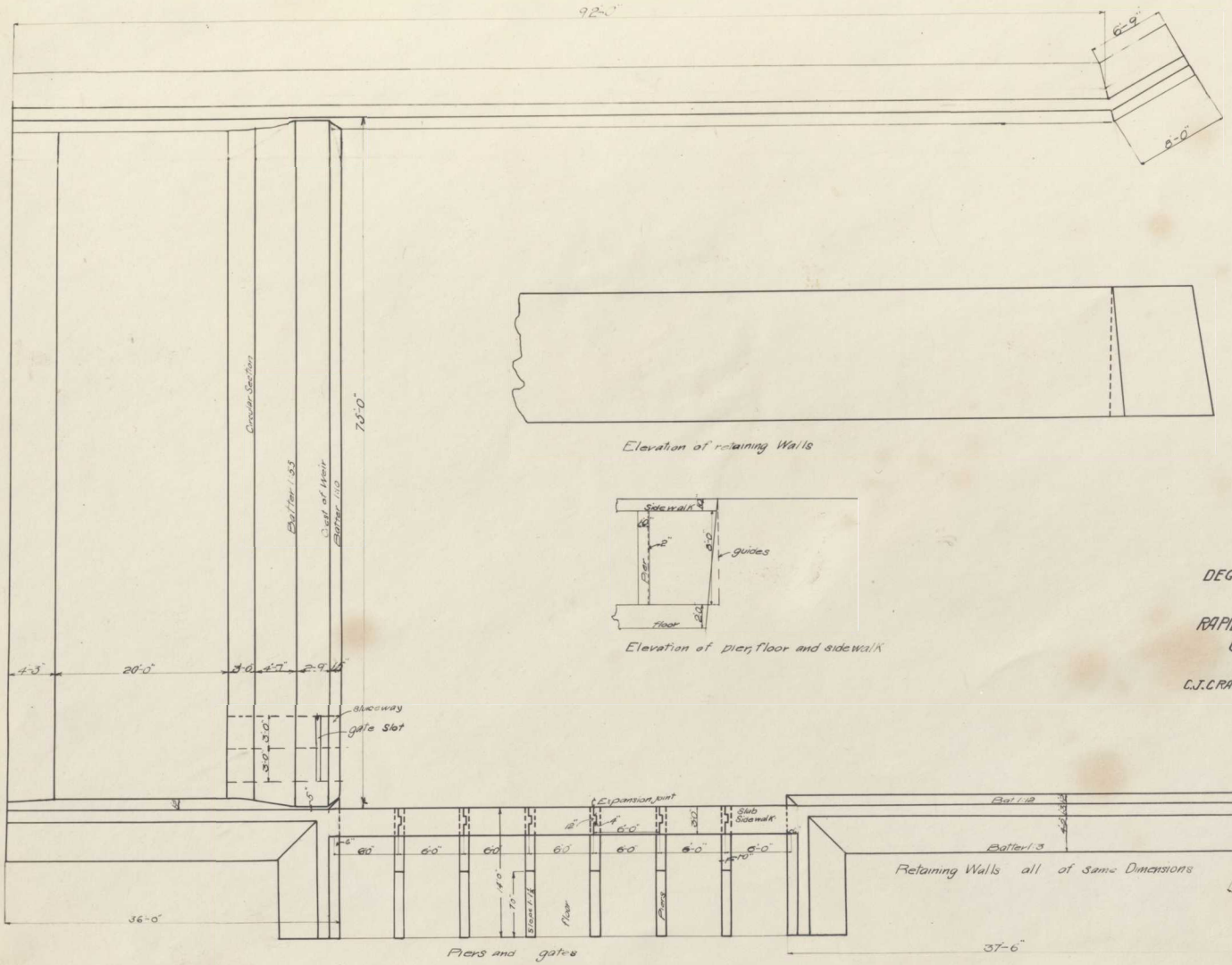
Total cost estimate

Head works	$ 9,942.75
High line canal	322,240.00
Large Dam	207,566.00
22 Auxiliary Dams	137,000.00
Laterals	125,000.00
Other structures	150,000.00
Engineering and other expenses	150,000.00
Total	$1,101,748.75

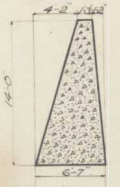
Conclusion.

The project contemplates the irrigation of about 60,000 acres of land in Rapid Valley, between Rapid City and the south forks of the Cheyenne River. By the construction of about twenty-two small and one large central reservoirs, 120,000 acre feet of storm water can be impounded. A high line canal of 810 second feet capacity will supply about 100,000 acre feet annually, from the flood flow of Rapid Creek. This supply canal in virtue of its location also acts as a main distributary. The construction of the necessary dams, ditches and structures, on account of the unusually fortunate location of the various parts of the proposed irrigation system requires only simply direct work; and includes nothing in the way of special and difficult engineering and construction works.

This accounts for the low average cost of construction of about $20,00 per acre. Compared with the Belle Fourche Project of the U. S. Reclamation Service for example, this project from an engineering point of view has many great advantages.



Elevation of retaining Walls



Vertical Section of retaining Walls

Elevation of pier, floor and sidewalk

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

RAPID VALLEY IRRIGATION PROJECT

OUTLAY OF HEADWORKS

DRAWING No 1

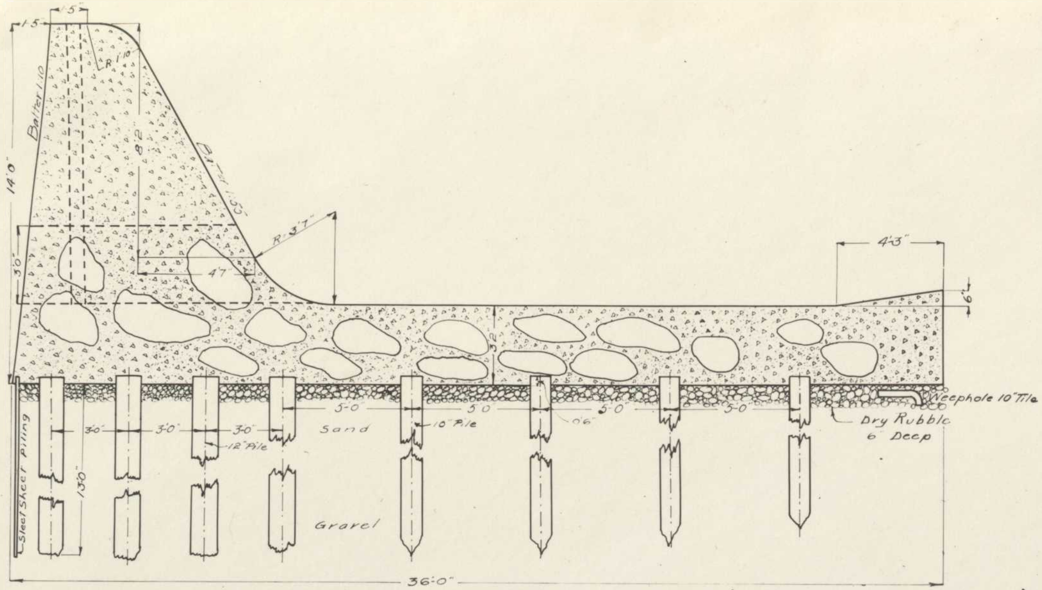
SCALE 1-4

C.J. CRAIGMILE

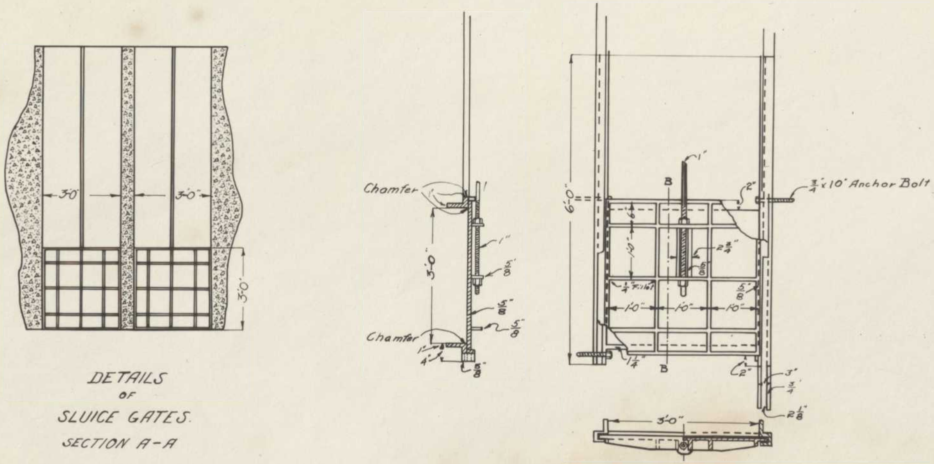
MAY 1913

Piers and gates

Retaining Walls all of same Dimensions

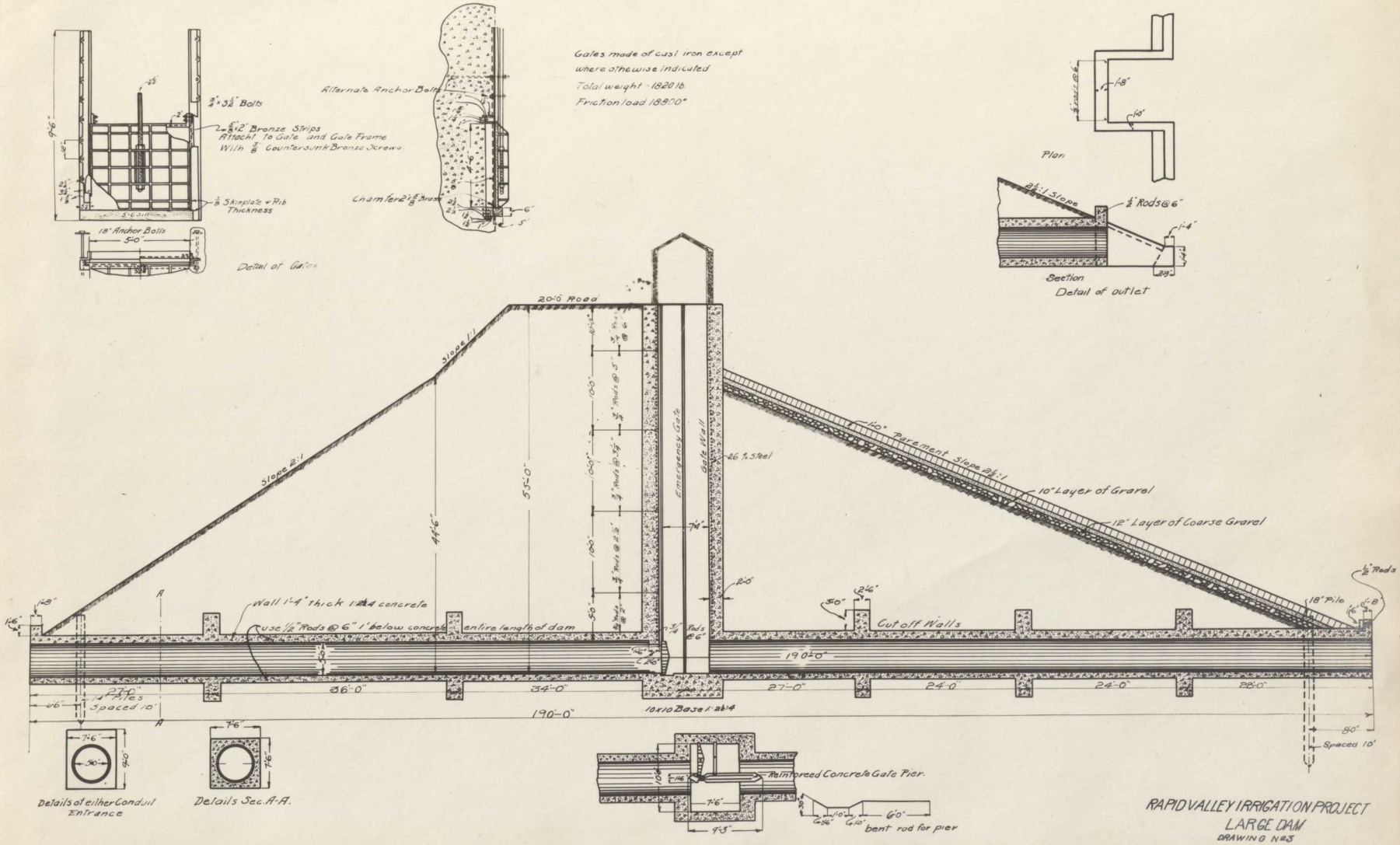


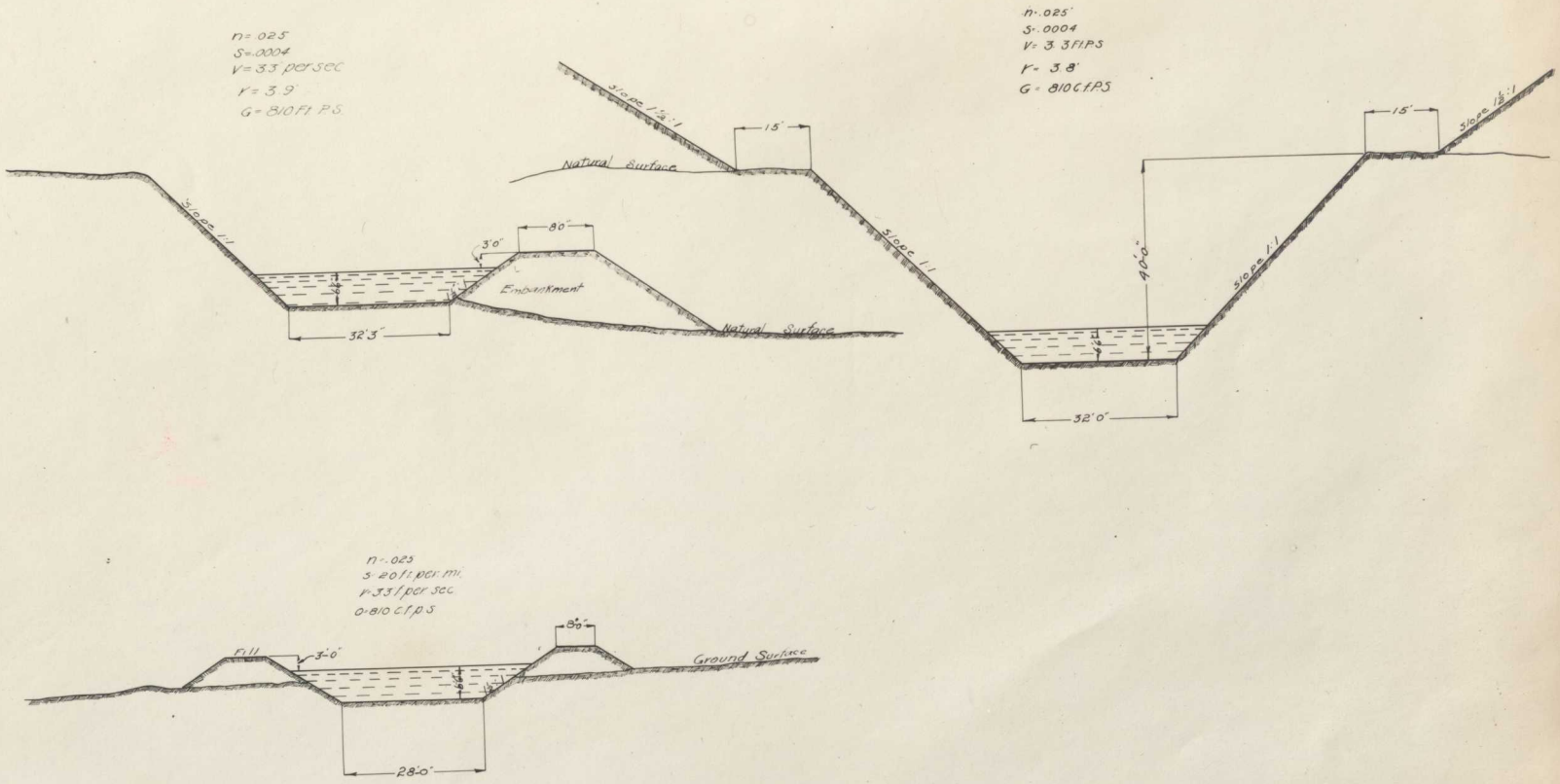
NOTE
not less than 30% boulders to be used in the weir + retaining walls.



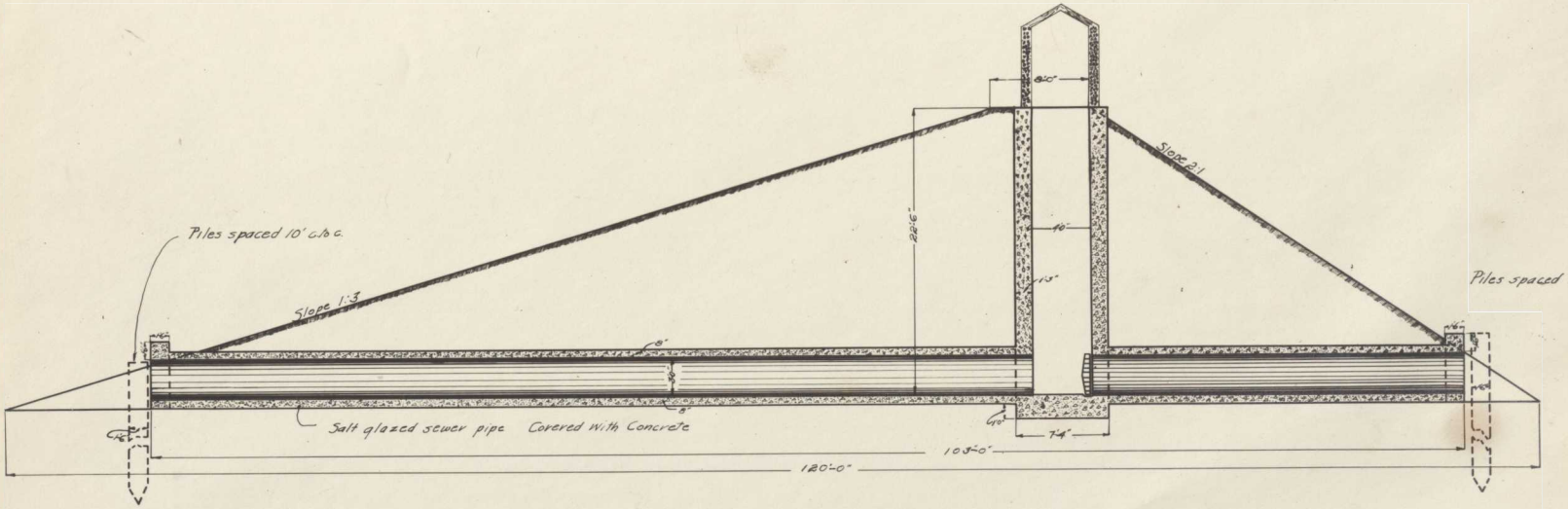
DETAILS
OF
SLUICE GATES.
SECTION A-A

RAPID VALLEY IRRIGATION PROJECT
CROSS-SECTION OF WEIR
DRAWING No 2
SCALE
C J CRAIGMILE
MAY 1913

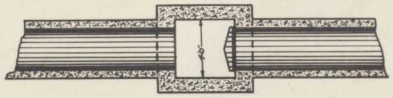

Gates made of cast iron except where otherwise indicated
Total weight 18201b
Friction load 18800#
Alternate Anchor Bolt
3"x3½" Bolts
⅝"x12" Bronze Strips Attach to Gate and Gate Frame With ⅝" Countersunk Bronze Screws.
⅛ Skinplate + Rib Thickness
Chamfer 2½"x⅝" Brass
18" Anchor Bolts
Detail of Gates
Plan
2½:1 Slope
½" Rods @ 6"
Section
Detail of outlet
20'-6" Road
Slope 2:1
55'-0"
44'-6"
Emergency Gate
Gate Well
26 ft. Steel
10" Layer of Gravel
12" Layer of Coarse Gravel
Wall 1'-4" thick 1:2:4 concrete
use ½" Rods @ 6" 1' below concrete entire length of dam
Cut off Walls
18" Pile
½" Rods
190'-0"
36'-0"
34'-0"
27'-0"
24'-0"
24'-0"
22'-0"
10x10 Base 1:2:4
Details of either Conduit Entrance
Details Sec. A-A.
Reinforced Concrete Gate Pier.
bent rod for pier
RAPID VALLEY IRRIGATION PROJECT
LARGE DAM
DRAWING No 3
C J CRAIGMILE
MAY 1913



RAPID VALLEY IRRIGATION PROJECT
CROSS-SECTIONS OF MAIN CANAL
DRAWING No. 4
C.J. CRAIGMILE MAY 1913

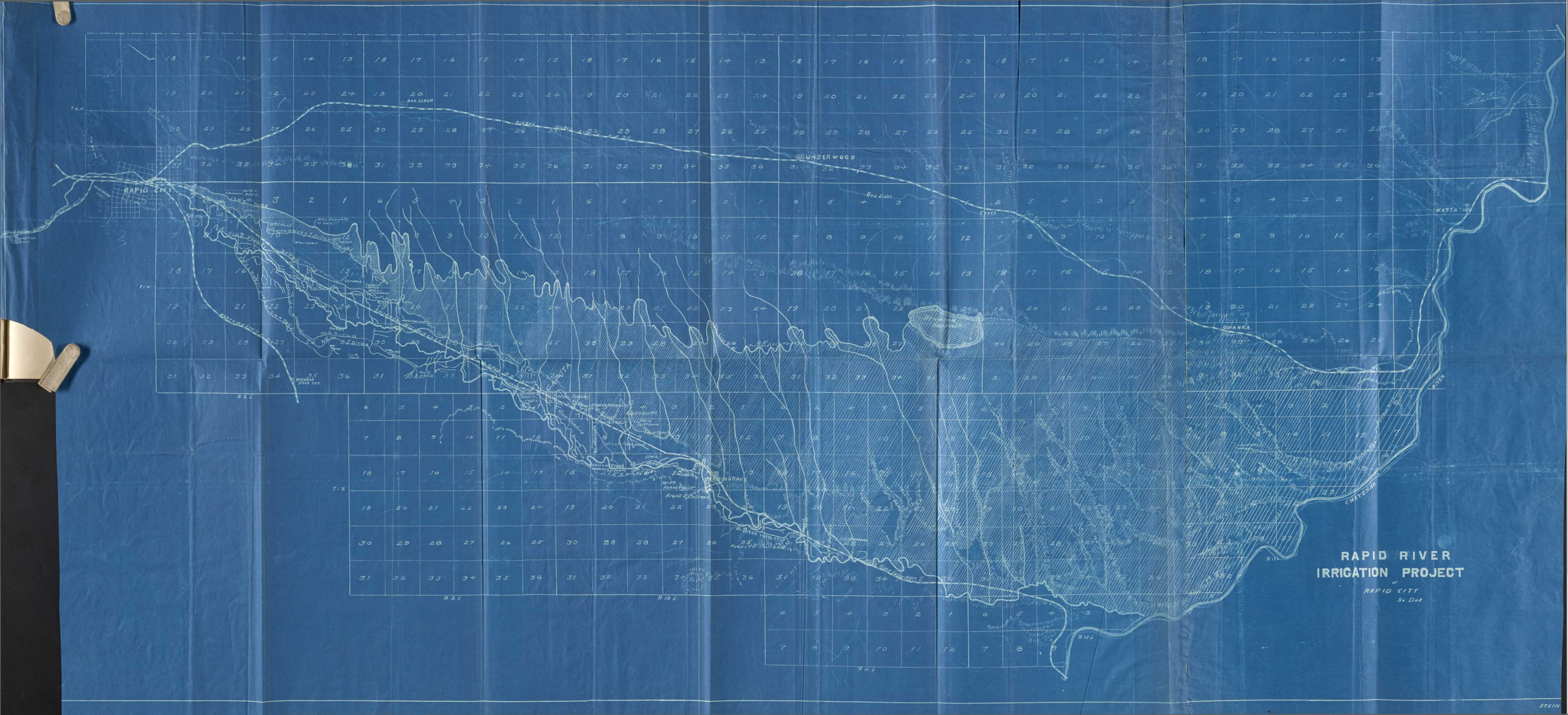


Detail of Conduit Entrance



Plan

RAPID VALLEY IRRIGATION PROJECT
SMALL DAM
DRAWING No 5
CJ CRAIGMILE
MAY 1913


RAPID CITY
BOX ELDER
UNDERWOOD
Box Elder Creek
WASTA
OWANKA
CHEYENNE RIVER
RAPID RIVER
IRRIGATION PROJECT
at
RAPID CITY
So. Dak
STEIN