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Design of reinforced concrete settling basin for St. Joseph, Mo.

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UNIVERSITY OF MISSOURI

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DESIGN

of

REINFORCED CONCRETE SETTLING BASIN

for

ST. JOSEPH, MO.

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by

F. I. ROTH and A. F. PORZELIUS

A THESIS

for the

DEGREE OF BACHELOR OF SCIENCE

In Civil Engineering

UNIVERSITY OF MISSOURI

DEPARTMENT OF ENGINEERING

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Table of Contents.

	Page
Title	i
Table of Contents	ii
General Description	1
Design of Basin	5
Design of Wall	6
Design of Base	9
Design of Counterfort	10
Design of Cantilever	10
Design of Beam	11
Design of Gate House	14
Design of Gutters	16
Design of Inlet System	18
Design of Conduit	20
Design of Outlet	22
General Specifications	24
List of Rods	25
Estimate of Cost	26
Bibliography	28

92187

General Description.

The basin is designed for the City of St. Joseph, Missouri, to partly relieve the present basin, which has become inadequate for the present needs of the city. The capacity of the basin is 5, 000,000 gallons, which is one fourth more than the old basin.

Water from the Missouri River contains a very large percentage of suspended matter in the form of silt, mud etc, etc, which is removed, by allowing to settle, before passing through the filters.

The basin will be located 20'-0" south of the present settling basin with the west line of basin about 150 feet from east bank of river.

The soil upon which the basin is founded, is of a clayey loam structure, which, in the case of the old basin shows itself of sufficient supporting power and firmness, not to necessitate

any piling, in order to insure a good foundation.

The actual size of the basin will be 200' x 200' x 16', which gives a capacity of 5, 000,000 gallons.

The system or method used is known as the "Continuous Flow" type of settling basin. The water enters at the west side of basin from the low service pumps, through a series of vertical pipes, which act as an aerating system, and at same time distribute the water evenly along this side of the basin. The water flows toward the east side and is intercepted at the center of basin by a baffle wall which extends the entire length of basin, and about 8' from top. This wall quiets the water and directs it downward, causing any suspended matter to deposit at the bottom. The water beyond the baffle wall becomes very quiet and any suspended matter still remaining tends to settle giving a fairly clear water. Along the east side of the basin, are the outlet pipes, which consist of a series of vertical broad mouthed pipes, leading directly into a reinforced concrete conduit.

This conduit extends along the east wall of basin, and leads into the gate chamber, at the north-east corner of basin. From the gate chamber the water flows to the pump well, from which it is pumped into filters and thence to reservoirs.

For the removal of the mud deposit, which collects in bottom of basin, two gutters are constructed sloping from east toward west wall. The floor of basin slopes to these gutters from both sides allowing the sediment to flow into the gutters. This flow of sediment is brought about by a high pressure water pipe situated in center of basin, and extending the full length. By means of this pipe the deposit is loosened up, causing its flow in gutters and then through drain pipes from basin to the river. The pipe line carries the city pressure and has valves placed at intervals in order to secure as great a force as possible at any point along the line. To prevent any water, due to seepage, from flowing along drain pipes, a pier is built just outside of basin, which forms a collar around each pipe. In some instances such seep-

age has caused a weakening of the foundation and a destruction of the floor.

The basin itself will be built with reinforced concrete walls having counterforts at intervals. The floor and gutters are of plain concrete. The floor will be in two layers of 4 inches each; the top layer having expansion joints of asphaltic tar.

Design of Basin

In the design of the basin the following notation will be used,-

f_s = 14000# = Stress in steel per sq. in.

f_c = 600# = Stress in concrete per sq. in.

n = 15 = $\frac{\text{Modulus of elasticity of Steel}}{\text{Modulus of elasticity of concrete}}$

p = 0.0083 = Percentage of Steel.

A = = Area of Steel.

S = 30# = Shearing stress per sq. in.

B = 60# = Bond stress per sq. in.

p_1 = 24# = Equivalent Fluid pressure of earth per cu. ft.

W_1 = 150# = Weight of concrete per cu. ft.

W_2 = 100# = Weight of earth per cu. ft.

$\frac{l}{h}$ = $\frac{4}{10}$ = Ratio of length of base to height of wall.

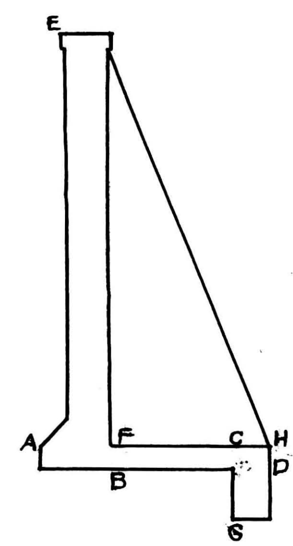
R = 102 = Moment of Resistance.

d = = Effective depth of section.

b = = Breadth of section.

d' = = Extreme depth of section.

The general form of wall will be as shown in sketch below,



Design of Wall E-F.

The wall has an embankment of earth on back side extending to top. The equivalent fluid pressure of earth = 24# per sq. ft. while water pressure on face of wall = 62.5 # per sq. ft. When the basin is full, both water and earth pressures act, and resultant pressure on face of wall =62.5# less 24#= 38.5 # per sq. ft. The wall acts as a

slab between counterforts, which are spaced 13.5 feet center to center. Assuming width of counterforts as 12", gives unsupported distance 13.5' -1' = 12.5'. In designing we will consider a beam 12.5 ft in length, and take breadth as 12" =1'-0".

The height "h" of wall is 16'-0", therefore the pressure at base =16 x 38.5# =616#; this, is weight on beam per linear foot.

B.M. due to water pressure= $1/8wl^2 = \frac{616 \times 12.5 \times 12.5 \times 12}{8}$

$= 144375$

$M= bd^2R, \quad bd^2 = \frac{M}{R} \quad d=\sqrt{\frac{M}{R \times b}}$

$d= \sqrt{\frac{144375}{102 \times 12}} = 11" \quad d'= 13"$

Area of steel = pbd = 0.0083 x (12 x11) = 1.09 sq in.

Rods used = $\frac{5"}{8}$ round spaced 3" c-c.

These rods will extend from base to a point 8' from base. At this latter point,-

B.M. due to water = $\frac{1}{2}$(144375) = 72187

$d = \sqrt{\frac{72187}{102 \times 12}} = 8"$

Area of steel = 0.0083 x (12x 8) = 0.7968 sq in.

Rods used = 1/2" round spaced 3" c-c.

These rods will extend from a point 8' from base to top of wall.

The wall will now be designed to take the earth pressure alone, a condition which arises when the basin is empty. Pressure on back of wall at base = 24 x 16 = 384#.

B. M. due to earth pressure=384 x12.5)12.5 x12

= 90000

$$d = \sqrt{\frac{90000}{102 \times 12}} = 9"$$

Area of steel = 0.0083 x (12 x 9) = 0.8764 sq in.

Rods used = 9/16" round spaced 3" c-c.

These rods extend to a point 8' from base.

At this point,-

B. M. due to earth = 1/2(90000)= 45000

$$d = \sqrt{\frac{45000}{102 \times 12}} = 6".$$

Area of steel = 0.0083 x (12 x6) = 0.5976 sq in.

Rods used = 7/16" round spaced 3" c-c.

For stresses due to temperature changes the percentage of reinforcement is taken as .2%. This is the vertical reinforcement used.

Area of steel = 0.002 x (12 x 12) = 0.29 sq in.

Rods used = 1/2" round spaced 12" c-c.

Referring to sketch on page 8 ;

Length AD = 4/10(16 + 0.67) = 6.67'

" AB = 1/3 (6.67) = 2'-3"

" BD = 6.67 -2'-3" = 4'-6"

" BC = 4'-6"-12"(CD) = 3'-6"

Design of Base BC.

This acts as a slab between back of wall and beam as shown in sketch. It sustains the weight of earth above. (16 ft) We will design a length of slab = 12" = breadth of beam of unit length.

Weight per linear foot = 16 x 100#

= 1600#

B. M. due to earth = $\frac{3.5 \times 3.5 \times 1600 \times 12}{8}$

= 29400

$d = \sqrt{\frac{29400}{102 \times 12}}$ = 6' d'= 8".

Area of steel = 0.0083 x (12 x 6) = 0.597 sq in.

Rods used = 5/8" round spaced 6" c-c.

These rods will be bent as shown in the drawings.

Design of Counterfort EH.

The counterfort is designed as a cantilever carrying the pressure against face of wall over a distance equal to 13'-6" or a length of panel. Here we find the breadth "b" having the depth "d" known, equal to Bd-4" = 4.5'-3.3'=4.17'

Total moment about F = $\frac{P_2 h^3}{6}$ x 13.5

B.M.= $\frac{24 \times 16 \times 16 \times 16 \times 13.5 \times 12}{6}$ =2556000

$M = Rbd^2$ $\qquad b=\sqrt{\frac{M}{Rd^2}}$,

$b=\sqrt{\frac{2556000}{50 \times 50 \times 102}}$ = 12", d= 4.17' = 50 inches.

Area of steel = 0.0083 x (12 x 4.17) = 5.00 sq in.

Rods used = 6 - 1 1/8"= round spaced in pairs as shown in drawings 4" c-c.

Design of Cantilever AB

This part of wall is designed to take upward pressure due to earth. This pressure varies from zero at extreme right to 2 $\left(\frac{W_1+W_2}{1}\right)$, a

maximum, at A. We will neglect downward pressure and apply one half of upward pressure at A mid-way between A and B. In formula W_1= weight of concrete, W_2= weight of earth, for length of all = 1'0".

Pressure = $2(\frac{3600+7200}{6.75})$ =3200#

B. M. = 3200 x 13.5 = 43200 lb inches.

$d=\sqrt{\frac{43200}{102x\ 12}}$ = 6" d'= 8".

Area of steel = 0.0083 x (12 x 6) = 0.597 sq in.

Rods used = 5/8" rods spaced 6" c-c.

For reinforcing in this part the rods in BC will extend into toe of wall and bend up at an angle of 45^{o} and extend into wall as shown in section drawing of wall.

Design of Beam GH.

The beam has a concentrated downward pressure due to pressure against wall transmitted through counterforts; there is also a downward uniform pressure to weight of earth

above beam and on slab between counterforts. We will find reaction or pressure of counterforts on beam by taking moments about B.

Taking moments about B,

$$\frac{13.5 \times 16 \times 16 \times 16 \times 24}{6 \times 4.5} = 49200 \text{ lb in.}$$

Next we find the downward pressure due to weight of earth.

Weight per linear foot = 2.75 x 16 x 100

= 4400#

Downward pressure = 12.5 x 4400= 55000#

The pressure of counterfort acts in an upward direction and earth acts in downward direction. The difference in pressures is 55000# - 49200# =5800#, which is the total resultant downward pressure on beam between counterforts.

$$\text{Uniform pressure downward} = \frac{5800}{12.5} = 4400\#$$

$$\text{B. M. due to this pressure} = \frac{4400 \times 12.5 \times 12.5 \times 12}{8}$$

= 1,031,000 lb in.

$$d = \sqrt{\frac{1031000}{12 \times 102}} = 29'' \qquad d' = 30''.$$

Area of steel = 0.0083 x (12 x 29) = 2.88 sq in.

Rods used = 4 -1" round rods spaced 3"c-c.

The two outside rods will be bent as shown to take care of negative bending moment.

We will investigate the beam for shear:

Shear at end = 1/2 (55000) - 27,500#

Area of cross section = 12 x 30 = 360 sq. in.

Shear per sq. in = $\frac{27500}{360}$ = 77#

Allowable shear = 30#, therefore the steel must take care of 77-30 = 47 # per sq in.

Area of steel = $\frac{360 \times 47}{14000}$ = 1.21 sq in.

This area is for a length equal to depth of beam, but spacing the rods 5" c-c, and using 4 rods at each point, we have the area ($\frac{30}{5}$ = 6 spaces) of one rod equal to $\frac{1.21}{6 \times 4}$ = 0.05 sq in.

Rod used is 1/4" round bent around the large rods as stirrups; shown in drawings. These rods or stirrups will extend to a point where the concrete alone is able to take the shear or where the shear is equal to 30 x 360 = 10,800#.

Shear at any point = $\frac{wl - wx^2}{2}$

$$10800 = 27500 - \frac{4400x^2}{2}$$

$$x \# 2.8' = 36''$$

Therefore the web reinforcement will extend 35" from end of counterfort.

Design of Gate House.

The gate house proper will extend from bottom of basin, and be of reinforced concrete to top of wall, above top it will be of brick to conform with existing one of other basin. It will be 8'-0" square and placed in north-east corner of basin. The walls will be securely bonded into main walls with rods to take negative bending moment. The walls of Gate chamber take only the pressure of water.

Pressure at base per lin ft. = 16 x 62.5

= 1000#

B. M. due to this pressure $= \frac{1000 \times 7 \times 7 \times 12}{8}$

= 73500

$$d = \sqrt{\frac{73500}{12 \times 102}} = 8'' \qquad d' = 10''$$

Area of steel = 0.0083 x (12 x 8) = 0.79 sq in.

Rods used = 5/8" round spaced 4" c-c.

At a point 8' -0" from base,

$$B.\ M. = 1/2\ (73500) = 36750$$

$$d = \sqrt{\frac{36750}{12 \times 102}} = 5.5"$$

Area of steel = 0.0083 x (12 x 5.5) = 55 sq in.

Rods used = 1/2" round spaced 4" c-c.

These rods extend from top a distance equal to 8'-0".

The floor of gate house will be of concrete, the top of which is on a level with top of wall of basin. The floor will be designed to take a weight of 200# per sq ft.

$$B.\ M. = \frac{200 \times 7 \times 7 \times 12}{8} = 13200$$

$$d = \sqrt{\frac{13200}{12 \times 102}} = 3.8" \qquad d' = 5"$$

Area of steel = 0.0083 x (12 x 3.8) = 0.38 sq in.

Rods used = 1/2" round spaced 6" c-c.

Shear at end = 3.5 x 200 = 750#

" per sq in $= \frac{750}{12 \times 5} =$ 13# per sq in.

Allowable shear = 30# per sq in, therefore, no reinforcement for shear is required.

Design of Gutters.

The two gutters will each be 150' feet long, starting at a point 50 feet from east wall of basin and sloping toward west wall. At the starting point the bottom of the gutters is 6 inches below the floor, whence it slopes with a 3% grade, making the bottom, 5 feet below the floor at the west wall.

The bottom and top widths will be made of sufficient size to allow repairing or cleaning when necessary. The bottom width will be 18" and the top width 36" at the west wall.

The walls of the gutter will be designed as a retaining wall. Assuming the thickness of wall equal to 9 inches at the top, gives a thickness of 18 inches at a depth of 4 feet 3 inches. The earth pressure against the wall is due to a triangle of earth tending to slide along the line of friction.

Weight of this earth triangle = 520#.

Perpendicular pressure on wall $= \frac{520 \times 2.5}{4.25} = 300\#$

(From Trautwine)

This pressure acts at a distance equal to one third the height, giving a moment abou the toe of wall,

$$\frac{300 \times 4.25 \times 12}{3} = 5100 \text{ lb /in.}$$

The weight of the wall is,

$$\left(\frac{9 + 18}{2 \times 12}\right) \times 4.25 \times 150 = 700\#.$$

Distance of center of gravity from toe of wall is10".
Taking moments about toe, we have 700 x 10 = 7000.
Therefore this will will resist any overturning effect. The stability of the wall is also increased since it is connected to the floor at the top and to the gutter at the bottom.

Design of Inlet System.

The water will be pumped from the river to the basin thru a 20" cast iron pipe. Since the water is distributed along the west wall four inlet pipes will be led from the 20" pipe into the basin.

Each of the inlet pipes will have two risers which deliver the water in a fountain, acting as an aerating system.

Since the basin is a continuous flow system there will be 12,000,000 gallons of water passing thru the basin in 24 hours. Therefore, the water passing thru the inlet pipe per second will be:

$$\frac{12,000,000}{60x60x24} = 139 \text{ gallons/sec}$$

$$= \frac{139}{7.48} = 18.6 \text{ cu ft/sec.}$$

Then velocity in 20" pipe =8.8 ft/sec.

The quantity of water passing thru the four pipes into the basin is:

$$\frac{18.6}{4} = 4.67 \text{ cu ft/sec}$$

Size of pipe required to deliver this quantity of water is 10".

The quantity of water passing thru one riser is:

$$\frac{4.65}{2} = 2.38 \text{ cu ft/sec.}$$

Size of pipe required to deliver this quantity of water is 8".

These pipes will be made of wrought iron, with flanges at bottom in order to make a rigid inlet system.

The pipes will be partially supported by a 3" pipe which acts as a support.

Design of Conduit.

As determined previously, the quantity of water flowing thru the basin is 18.6 cu ft/ sec.

The velocity of water in the conduit should be less than 5 ft/sec. Taking the velocity as 4 ft/ sec, the

Area of conduit required $= \frac{18.6}{4} = 4.7$ sq ft.

Diameter of conduit $= \sqrt{\frac{4.7 \times 4}{3.14}} = 2.5$ ft

$= 30''$

The slope required for a 4 ft. velocity thru a 30" pipe is .3 ft per 100 ft.

The maximum pressure on the conduit is due to external pressure of the water in basin. when the conduit is empty. Any internal pressure in the conduit will be balanced by the external pressure on the conduit.

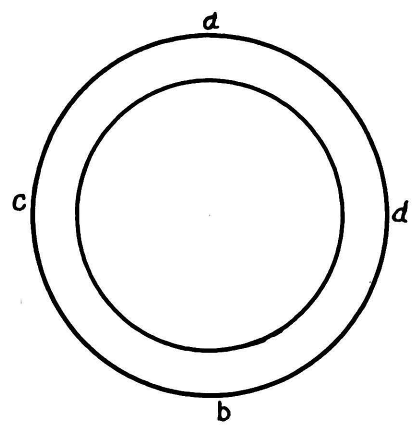
Maximum head is 14 ft.

Maximum water pressure

$= 14 \times 62.5 = 875^{\#}/\text{sq ft.}$

Assuming thickness of conduit as 4" gives a dead load of 50# / sq ft.

Total load = 875 + 50 = 925 # / sq ft.



Moments due to downward pressure

$M_a = M_b = 1/16\ pd^2$

$M_c = M_d = -1/16 pd^2$

d= diameter of pipe

p= pressure per sq ft.

$$M_a = M_b = \frac{925 \times 2.5 \times 2.5 \times 12}{16}$$

$= 4340\#$

$M_c = M_d = -4340\#$

Moments due to lateral pressure:

$M_a = M_b = -1/16\ pd^2$

$M_c = M_d = 1/16\ pd^2$

Maximum pressure = 62.5 x 16 = 1050#

$$\text{Then } M_a = M_b = -\frac{1050 \times 2.5 \times 2.5 \times 12}{16}$$

$$= -4920\#$$

$$M_c = M_d = 4920\#$$

The resultant moment is 4920-4340

= 580#,

which is plus at top and bottom and minus at the sides.

$$\text{Then } d^2 = \frac{580\#}{12 \times 102} = .5''$$

$$d = .71''$$

This however is too small for practical purposes, therefore the conduit will be 4" in thickness.

A= .0083 x .71 x 12 =.07.

This requires 1/4" rods spaced 6" c.c.

The longitudinal reinforcement will consist of 1/4" rods spaced 12" c.-c to take care of temperature stresses.

The area of the four risers or pipes which carry the surface water to the

conduit requires the same area as the conduit.

Area of conduit = 706.86 sq in.

Area required for one riser $= \frac{706.86}{4} = 176.46$

Size of pipe required = 12" in diameter.

For the easy flow of water into these risers the upper part of pipe will be made wider than the body of the pipes as shown in drawings.

The pipes will be made of 1/8" steel plate.

General Specifications.

The proportion for the reinforced concrete will be 1:2:4.

The proportions for plain concrete will be 1:3:6.

The floor and gutters will be of plain concrete. The gutters will be in the form of a monolith while the floor will be in two layers of 4" each; the top layer to have expansion joints of asphaltic tar.

The reinforced conduit is to be securely bonded to wall of gate house as shown in drawings. The walls of gate chamber will also be bonded to main wall by means of the horizontal rods of wall.

List of Rods.

Size of Rods	No. of Rods	Length of one Rod	Total Length	Weight per Lin. Ft.	Weight	Total Weight
1/4"	896	7'-9"	6262	0.167	1050	
1/4"	16	3'-0"	48	"	9	
1/4"	280	16'-0"	4500	"	755	
1/4"	112	12'-0"	1344	"	226	2040
1/2"	48	8'-6"	408	0.668	272	
1/2"	1632	16'-6"	27000	"	18000	
1/2"	360	23'-0"	8280	"	5500	
1/2"	309	10'-0"	3090	"	2060	
1/2"	128	8'-0"	1024	"	692	
1/2"	16	3'-0"	48	"	32	
1/2"	2040	15'-6"	31620	"	21600	48156
7/16"	2040	15'-6"	31620	0.511	16100	16100
9/16"	1800	15'-6"	31620	0.845	26600	26600
5/8"	2040	15'-6"	31620	1.04	31620	[illegible]
5/8"	1640	10'-0"	16400	"	16400	48020
1"	120	16'-9"	1920	2.67	5100	
1"	120	22'-0"	2640	"	7050	
1"	8	12'-0"	96	"	352	
1"	8	17'-0"	136	"	362	12764
1 1/8"	384	23'-6"	9024	3.38	30400	30400
					Total	184080

Estimate of Cost.

2	20" Gates (Drain)	@ $	450.00	900.00
2	30" " (Gate Chamber)	"	1000.00	2000.00
3	Manholes & Cover	"	8.00	24.00
720 ft	1/2" Steel Cable	"	.26	144.00
72 sq ft	Slate Roof	"	.05	3.60
2500	Brick	"	14.00	35.00
3600 ft	Lumber (Baffle Wall)	"	27.00	97.20
1015 cu yd	Concrete (Plain)	"	6.00	6090.00
815 "	" (Reinforced)	"	10.00	8150.00
12000 "	Excavation	"	.30	3600.00
8000 "	Embankment	"	.30	2400.00
184080 lb	Steel Reinforcement	"	.03	5522.40
3	Windows	"	5.00	15.00
1	Door	"		3.70
6 T	Asphaltic Tar	"	40.00	240.00
1	30" -30" C.I. Tee	"		75.00
4.	20" -10" C.I. Tee (Inlet)	"	40.00	160.00
4	10" - 8" W.I. Tee (Inlet)	"	50.00	200.00
8	8" - 8" W.I. Tee (Inlet)	"	17.00	136.00
200 ft	20" C.I. Pipe (Inlet)	"	1.87	375.00
200 "	6" C.I. " (Pressure Pipe)	"	.75	150.00
16	Valves (Pressure Pipe)	"	10.00	160.00
			Forward	30480.90

Amount Brought Forward				$ 30480.90
300 ft	20" C.I. Pipe	@ $	1.87	562.50
80 "	10"W.I. "	"	4.00	320.00
144 "	8" W.I. "	"	2.50	360.00
4	Risers(Outlet)		25.00	100.00
4 T	Special Castings		40.00	160.00
	Cost			31983.40
	Superintendence			1500.00
	TOTAL COST			33483.40

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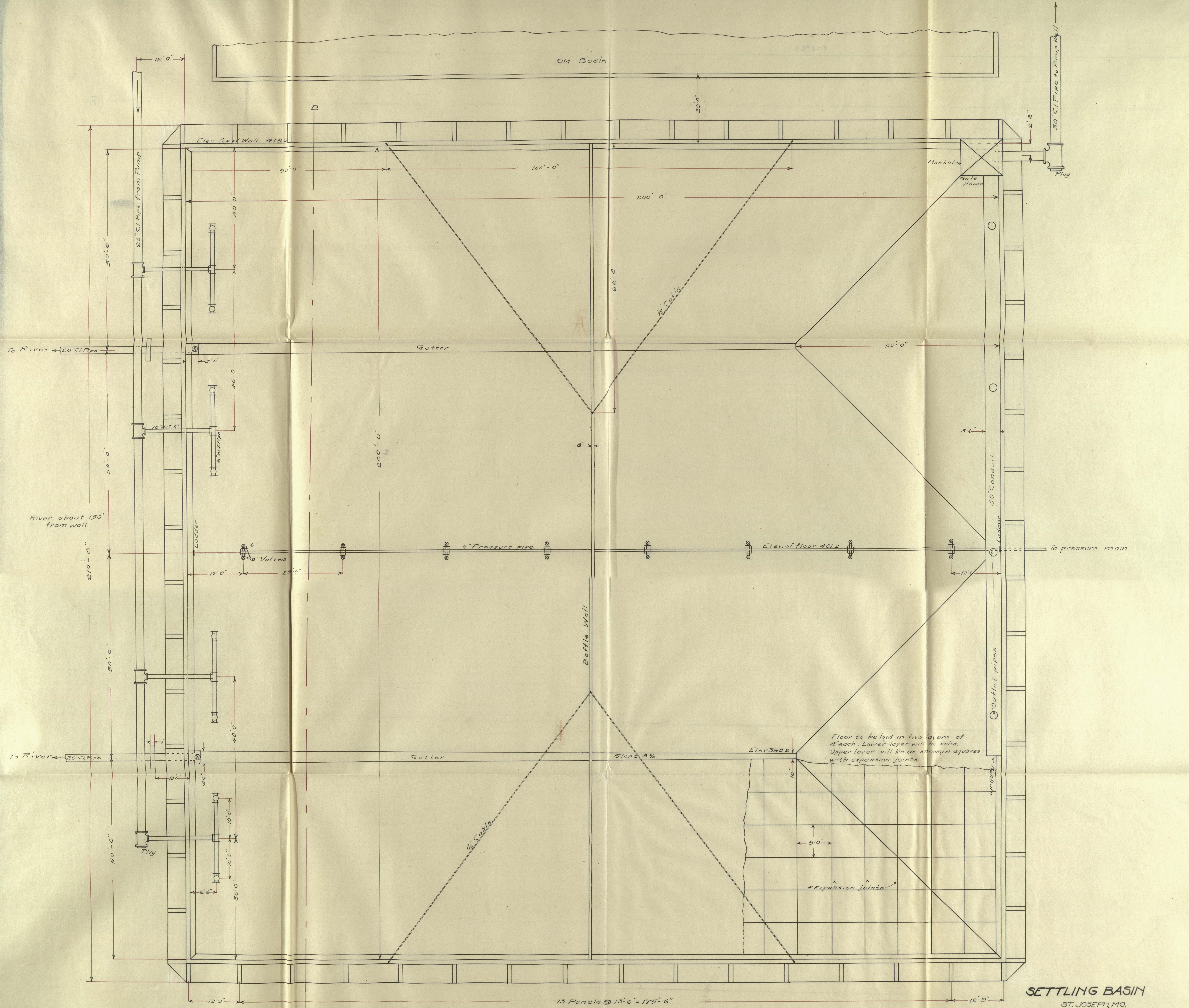


PLAN OF BASIN

SETTLING BASIN

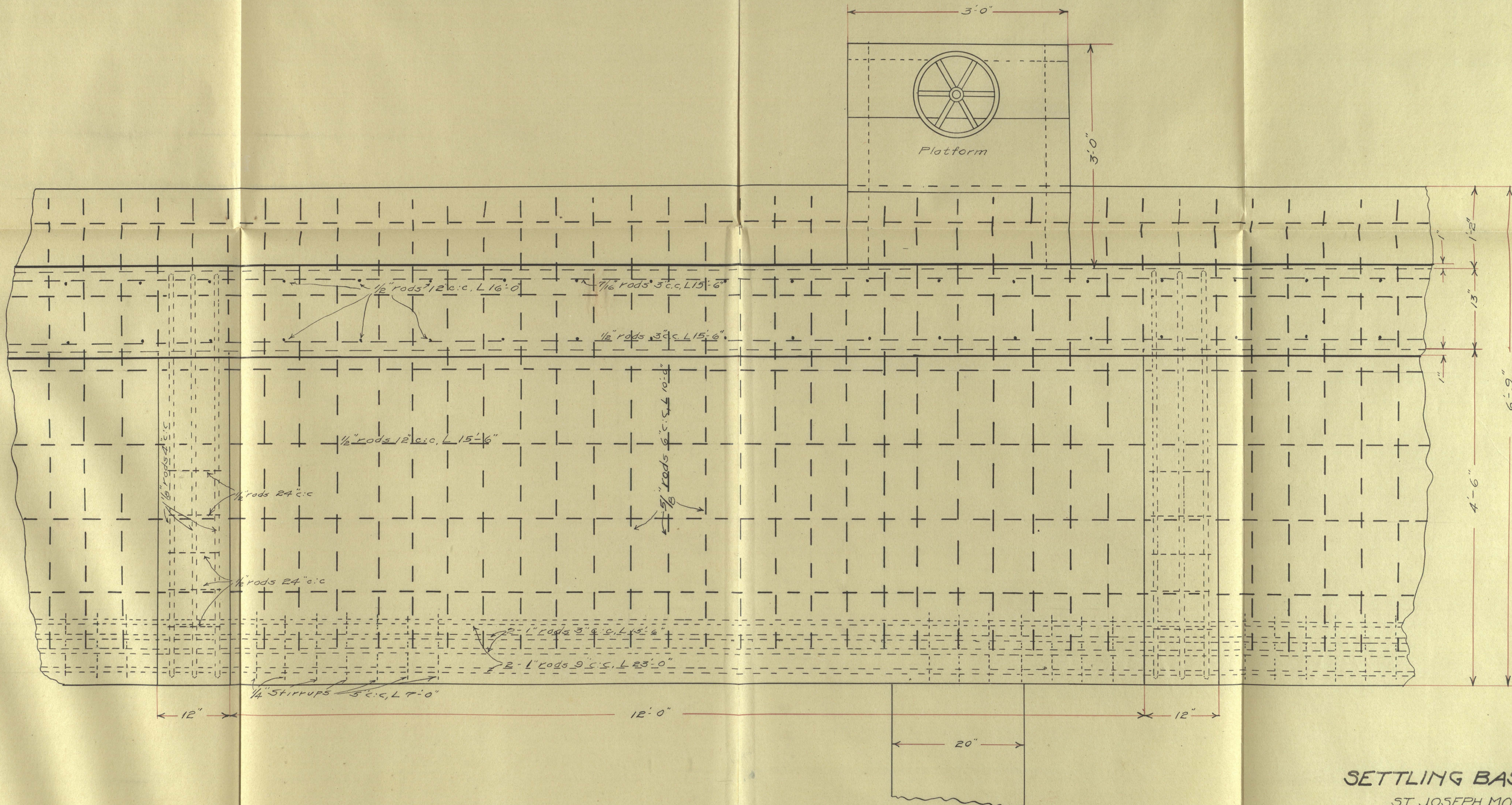
ST. JOSEPH, MO.

MAY, 1909

A.F. PORZELIUS
F. I. ROTH

Scale 1/32" = 1'

1



PLAN OF A PANEL
also showing gate platform

SETTLING BASIN

ST. JOSEPH, MO.

MAY, 1909

A.F. PORZELIUS
F.I. ROTH

Scale 1" = 1'

2

SECTION THRU GUTTER

SECTION AB
SEE PLAN
Scale $\frac{1}{8}$"=1'

SETTLING BASIN

ST. JOSEPH, MO.

MAY, 1909.

F. I. ROTH.
A.F. PORZELIUS

SCALE $\frac{1}{8}$"=1'

3

SETTLING BASIN

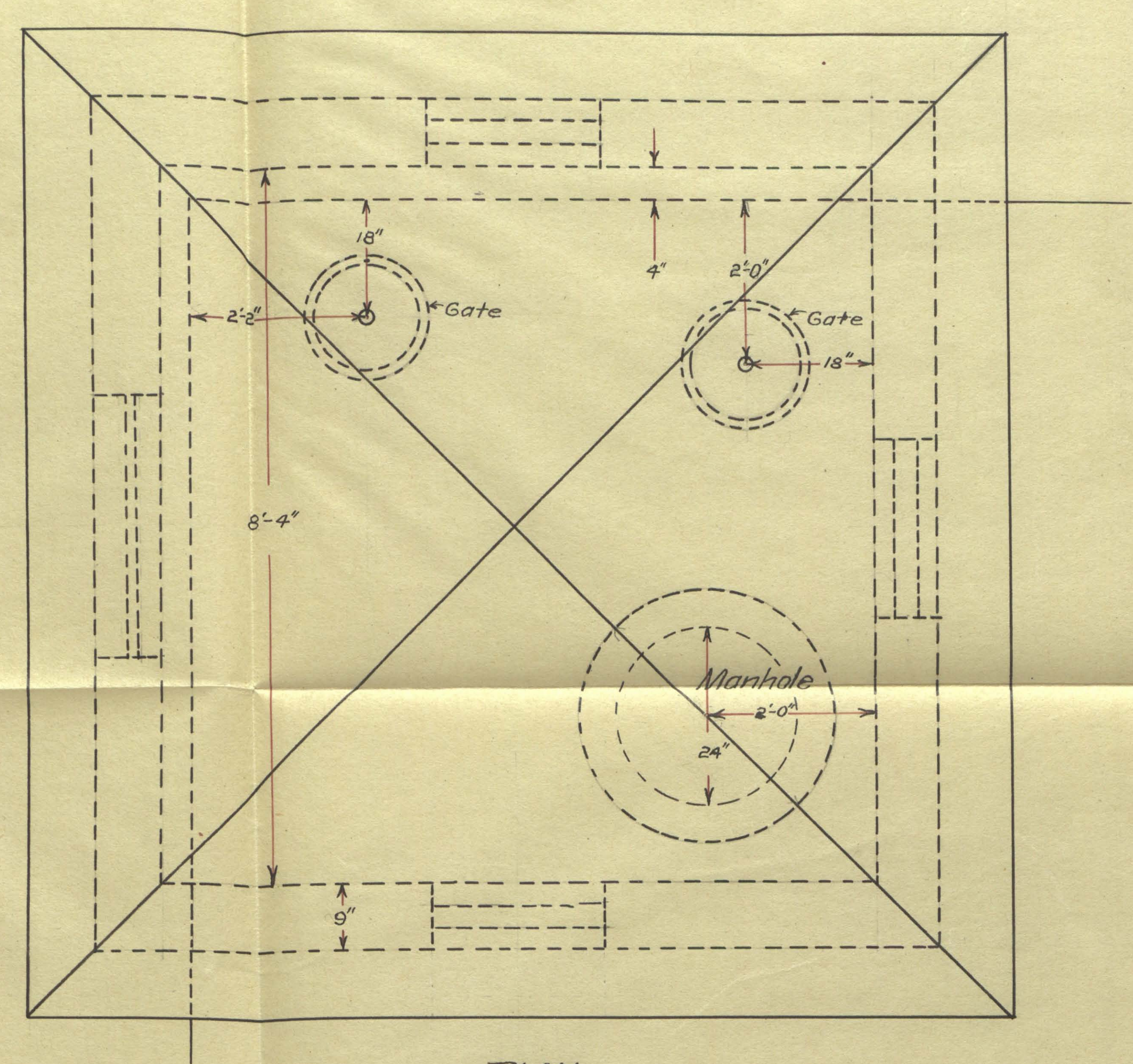
ST. JOSEPH MO

MAY, 1909.

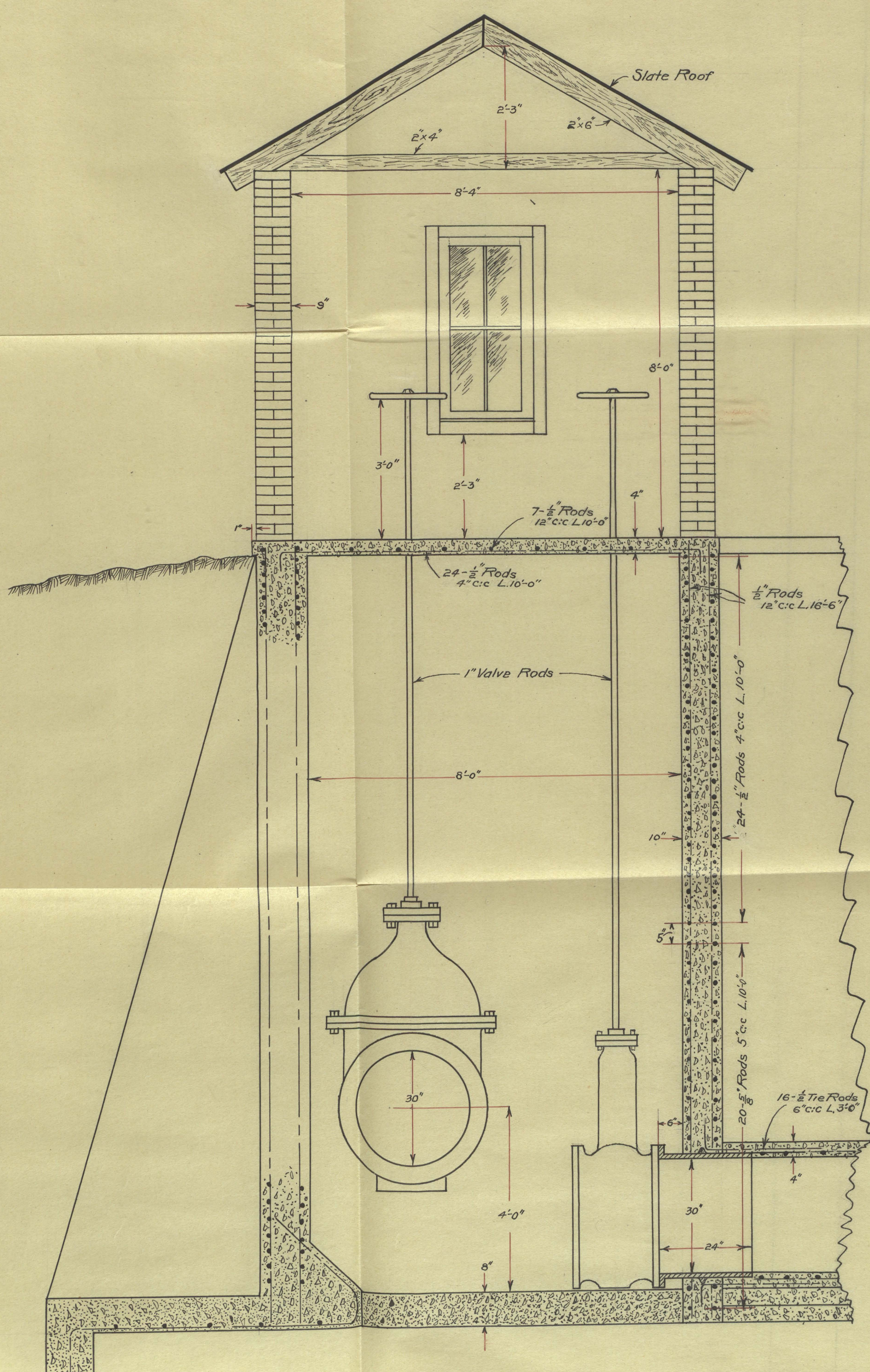
F.I. ROTH
A.F. PORZELIUS

SCALE 1/2" = 1'

4



PLAN



SECTION OF GATE HOUSE

SETTLING BASIN

ST. JOSEPH MO.

MAY, 1909.

A. P. PORZELIUS.
F. I. ROTH.

SCALE ½" = 1'

5


18"
10'0"
1/8" Steel Pipe
18"
12"
1¼" Drilled Hole for Tap Bolts
4"
1½"
¾"
2"
OUTLET RISER
¾"
24"
1" Drilled Hole
5"
2"
¾"
2"
15"
4"
MANHOLE
To be placed in concrete
3'0"
1"
12"
1"
30"
1¼ Drilled Hole
4½"
To be placed in concrete
1"
1½"
12"
2'0"
1"
SPECIAL CASTINGS
8"
2" Screw Flange
7'3"
8"
Wrought Iron Pipe
Blind Flange
8"
10"
8'4"
3½"
INLET RISER
SETTLING BASIN
ST. JOSEPH, MO.
MAY, 1909
A.F. PORZELIUS
F.I. ROTH
Scale 1"=1'
6

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