UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE REGULATING GATE AND STILLING WELL-- TRENTON DAM CANAL OUTLET WORKS-- MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd.-300

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

April 11, 1951

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Laboratory Report No. Hyd-300
Hydraulic Laboratory
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Subject: Hydraulic model studies of the regulating gate and stilling well--Trenton Dam Canal Outlet Works--Missouri River Basin Project

PURPOSE

(a) To study the feasibility of using a modified, *high pressure slide gate for regulation under submerged conditions.

(b) To determine the effectiveness of a side-entry, vertical stilling well in dissipating the destructive energy of the released water.

*Note: The modification includes narrow gate slots, wedge-shaped gate slot flow deflectors, and either a flat or a concave gate leaf--see Report No. Hyd-245.

CONCLUSIONS

1. The regulation of the water flow is accomplished smoothly by the modified high pressure slide gate, shown schematically on Figure 5, at the submerged conditions applicable to this installation. The head difference between the gate centerline and the maximum reservoir water surface is 112.42 feet, while the minimum difference between the gate centerline and the tail-water elevation is 27.42 feet.

2. At all conditions where the 300-cfs canal capacity is not exceeded, subatmospheric pressures will not occur on the gate leaf bottom (Figure 7). Subatmospheric pressures as low as 6.2 feet of water will occur on the bottom of the leaf when the reservoir is full (elevation 2785.00) and the gate is 99 percent open. However, this operating condition would result in a discharge of 776 cfs which greatly exceeds the 300-cfs capacity of the canal. This condition should, therefore, never be encountered.

3. No seriously low pressures or vibration will occur in the conduit downstream from the gate, even without an air vent. All pressures recorded were positive at all gate settings and at an equivalent total head of 70 feet at the gate entrance (Figure 8). The lowest pressure, a positive 4.4 feet of water, occurred on the top of the conduit 1.5 feet downstream from the

centerline of the gate stem at a gate opening of 95 percent and with a discharge of 690 cfs. Therefore, there should be no need for an air vent.

4. The stilling well shown in Figure 2, using the recommended baffle, satisfactorily dissipates the destructive energy of the discharging water.

5. The vertical placement of the preliminary design stilling well baffle (Figure 10A) was critical and to be effective a higher elevation was required for small gate openings than for large openings. The recommended baffle design (Figure 10B) is not critical to gate opening and operates effectively in any position where the baffle top lies between elevations 2680.0 and 2690.0.

6. The walkway and two dividing piers at the exit of the preliminary stilling well design (Figure 12A) partially obstruct the flow into the canal at discharges greater than 700 cfs. Improved flow conditions into the canal at all flows and an economy in construction are obtained by removing these obstructions (Figure 12B).

7. The invert of the canal may be lowered 1 foot below the well exit sill to provide a step to restrict the upstream movement of debris into the well (Figure 12B).

8. Any debris, such as stones or large construction material, should be removed from the well as it will produce abrasive erosion on the floor and lower walls of the well during operation.

9. No objectionable scour occurs in the riprapped portion of the canal at the well or in the unlined canal immediately downstream (Figure 14). The 24-inch, dump-placed riprap in the final design extends 65 feet downstream from the well.

10. Discharge capacity curves for the canal outlet works with the modified gate are presented in Figure 9.

RECOMMENDATIONS

1. Use the modified design of the standard high pressure slide gate, shown schematically on Figure 5, for regulation in the Trenton Dam Canal Outlet Works.

2. Use the recommended stilling well baffle design in the prototype structure (Figure 10B).

3. Omit the walkway and the two dividing piers on the prototype structure to effect a flow improvement and an economy in construction.

4. Lower the canal invert 1 foot below the well sill to restrict the upstream movement of debris into the well (Figure 12B).

5. Remove all debris from the well before releasing any water to prevent abrasive erosion of the well floor and walls.

6. Install, during construction, sufficient piezometers in the conduit downstream from the gate to obtain prototype data for future design use.

ACKNOWLEDGMENT

The recommended design of the Trenton Dam Canal Outlet Works is the result of cooperative efforts of the Spillway and Outlets Section No. 1 of the Dams Division and the Hydraulic Laboratory of the Research and Geology Division.

INTRODUCTION

Trenton Dam is an earth-fill structure about 9,000 feet long which rises 103 feet above the Republican River. It is located 3 miles upstream from Trenton, Nebraska, and will be used for storing irrigation water and for flood control (Figure 1). A spillway controlled by three 42-foot wide radial gates is provided at the left abutment to pass flood waters while river outlets, located underneath the spillway crest to discharge upon the spillway face, are provided to release the required river flows. An additional outlet works is provided 6,300 feet to the right of the spillway to supply water into an irrigation canal. The final design of this outlet works, which incorporates the model test results, is shown in Figure 2.

The necessity of obtaining a discharge of 300 cfs (the canal capacity) at the minimum operating water surface elevation of 2720.00 fixed the size of the regulating slide gate at about 4'-0" x 4'-0". At higher heads it will be necessary to partially close the gate to avoid exceeding the 300 cfs canal capacity.

The design of the canal outlet works was complicated because bedrock was at elevation 2674.0, while the invert of the irrigation canal was at elevation 2699.0, or 25 feet higher. It was desirable to have the outlet conduit through the dam placed solidly on bedrock, so an unusual design was developed wherein the conduit dropped vertically from the intake at elevation 2710.0, then turned horizontal with the centerline at elevation 2673.75. The 66-inch round conduit then continued downstream past the emergency gate structure to the transitions leading to the 4-foot by 4-foot regulating slide gate. A short section of straight pipe and another transition completed the conduit and connected the gate to the vertical stilling well (Figure 2). The well carried the water upward to the elevation of the irrigation canal and dissipated the destructive energy of the flow. The well was octagonal in cross section, 16 feet across the flats, and the bottom was at elevation 2666.75. The top of the preliminary design well was at elevation 2708.00 giving a well depth of 41.25 feet. A deflector similar to a dentated sill was placed on the wall opposite the inlet to increase the energy dissipation within the well. The centerline of the 56-inch-diameter inlet pipe was 5.66 feet above the well floor and 27.59 feet below the sill. The water discharged from the well at elevation 2700.0 through openings in the three downstream walls to enter the irrigation canal (Figure 12A). The well sill-to-floor depth was 33.25 feet. Twenty-four-inch dumped riprap was provided in the first 20 feet of the unlined canal to prevent excessive scour.

There was considerable doubt about whether the regulating gate, modified as for the Cedar Bluff Outlet Works (Report No. Hyd-245), could be operated at partial openings without damage to itself or to the conduit downstream when used to discharge underwater against a back pressure of 27.5 or more feet. Information was also required of the effectiveness of the side entry, vertical stilling well in dissipating the destructive energy of the water and of any design changes necessary to the well to insure smooth delivery into the canal. Accordingly, hydraulic model studies were requested to determine the operating characteristics of the regulating gate, the pressures on the bottom of the gate leaf and in the conduit between the gate and the well, the effectiveness of the stilling well in dissipating the destructive energy in the water, the entrance conditions into the canal, and the nature of the scour at the canal entrance. This report concerns the method of conducting these studies and the results obtained from them.

INVESTIGATIONS

Description of 1:12 Model Outlet Works

A 1:12 scale model was constructed which included the 4-foot by 4-foot regulating gate, the conduit between the gate and the stilling well, the well, and 98 feet of the unlined canal (Figures 3 and 4). A 6-inch gate valve was installed 10.5 feet upstream from the regulating gate so that any applicable flow and pressure head could be obtained by manipulation of the two gates. Water was supplied to the model by the laboratory system which contained venturi meters for measuring the flow rate. The pressure head acting on the model regulating gate was measured with a water manometer connected to the reference piezometer located on the conduit horizontal centerline 2 inches (model) upstream from the gate stem centerline (Figure 5). Pressures were measured at 9 points on the bottom of the gate leaf (Figure 7). The sections of conduit between the regulating gate and the well were made of transparent plastic so the flow within the conduit could be more readily studied. A total of 22 piezometers were installed in this conduit and connected to water manometers to measure the pressure distribution (Figure 5). Three sides of the octagonal stilling well were made of transparent plastic while the remainder of the well was formed by a sheet-metal lining on a wooden base. The deflector was made of oil-treated wood and it was fastened to the downstream well wall in a manner permitting it to be moved vertically. The irrigation canal was constructed in a metal-lined wooden box that was provided with a tail gate for regulating the canal water surface elevation and a point gage for measuring this elevation. During the early stages of the model tests the full length of the model canal was formed in compacted sand. For the final tests pea gravel was placed downstream from the well for a distance equivalent to 20 feet to represent the 24-inch dumped riprap. A box trap was provided near the end of the model to retain any canal bed material washed downstream, and the water leaving the model flowed freely back to the main supply channel.

Regulating Gate and the Downstream Conduit Pressures

Model tests showed that the high pressure slide gate, modified to the design recommended for Cedar Bluff Outlet Works, can be operated safely under water for the design conditions of the Trenton Dam Canal Outlet Works. The model studies herein described were conducted using the modified gate design with the flat leaf (Figure 5), and the results of the tests are not to be applied to the standard gate design shown on Figure 6.

In the Trenton Dam Canal Outlet Works the difference in elevation of the upstream gate frame centerline and the maximum reservoir water surface (2785.00) is 112.42 feet. The minimum back pressure on the downstream gate frame centerline when the water in the stilling well is at the elevation of the discharge sill (2700.00) is 27.42 feet (Figure 2).

Regulation of flow in the model occurred smoothly and without vibration. Subatmospheric pressures were found on the bottom of the gate leaf at high heads with gate settings of 99 and 100 percent open. The pressure data shown on Figure 7, were obtained at an arbitrarily selected total head of 70 feet at the gate entrance for a series of gate openings that covered the operating range of the structure. This data may be converted for other total heads by the use of the pressure coefficient P_k, where the coefficient for a desired piezometer is given by the relation,

$$P_k = \frac{\text{reference piezometer pressure-desired piezometer pressure}}{\text{velocity head at the reference piezometer}}$$

An example of the use of the pressure coefficient would be to determine the minimum pressure which is likely to occur on the gate leaf at the maximum reservoir elevation with the gate 99 percent open. From the model data for a 70-foot head the pressure coefficient for the lowest reading piezometer, No. 3, equals 36.72 - (-2.40) ÷ 33.28 or 1.177 The discharge with a full reservoir and a 99 percent gate opening would be 776 cfs, (Figure 9). The velocity head at the location of the reference piezometer will be 36.6 feet and the piezometric head will be 36.9 feet. The pressure coefficient, 1.177, multiplied by the velocity head of 36.6 equals 43.1--this is the pressure drop from the reference piezometer to the point on the leaf. Subtracting this pressure drop from the available piezometric head of 36.9 feet results in a subatmospheric pressure of 6.2 feet of water at this particular point on the leaf.

The only time subatmospheric pressures occur is when the reservoir is at or near the maximum elevation and when the gate is near or at full opening, a situation which would flood out the irrigation canal with more than twice its capacity of 300 cfs. At smaller openings or in the lower head range there will be no subatmospheric pressures at any point on the bottom of the gate leaf.

Pressures were measured at the 22 stations in the conduit downstream from the gate (Figure 5) at representative operating conditions and all pressures were positive. The pressures for 17 piezometers are shown in Figure 8. The lowest pressure, +4.4 feet of water, occurred at the top of the conduit 1.5 feet downstream from the centerline of the gate stem at the total head of 70 feet, and with the gate 95 percent open, an operating condition which would produce a flow of 690 cfs. Opening or closing the gate from this position or decreasing the head on the structure caused the pressure to increase rapidly.

The absence of subatmospheric or highly fluctuating pressures on the bottom of the gate leaf or in the conduit downstream from the gate structure (within prototype operating limits), together with the smooth flow regulation obtained, makes the modified high pressure slide gate design acceptable for use in the outlet works. No air was admitted into the conduit in the model studies because none was found necessary.

Discharge Capacity Curves

The discharge capacity of the recommended outlet works was determined by model tests for gate openings varying from 10 to 100 percent open and for heads on the upstream gate frame centerline varying from 0 to 112 feet (Figure 9). No flow will occur through the outlet works until the head at the gate entrance exceeds the submergence of the gate. The actual head differential across the gate will thus vary with the elevations of both the reservoir and the canal water surfaces. Due to lack of information concerning backwater the canal water surface was maintained at 2705.00 for all discharges in the model tests.

The available total head on the horizontal centerline at the gate inlet is shown in dashed lines for the normal and maximum reservoir water-surface elevations, 2752.00 and 2785.00, respectively. The head difference between the no-flow conditions and the dashed lines at any discharge condition is the computed head loss incurred through the conduit to the gate entrance. The head loss computed by the Hydraulic Laboratory is less than that used in preparing the curve shown on Figure 2.

Stilling well and Deflector

Water enters the octagonal stilling well through a 56-inch-diameter opening in the center of the upstream wall at elevation 2672.41 (Figure 2.). The water flows across the well in a high-velocity stream to strike the downstream wall which directs part of the flow back upstream along the side walls and floor toward the well entrance. The high velocity eddies and currents which result in the lower portion of the well hurl debris within the well violently against the sidewalls and floor. A handful of 1/2-inch by 3/4-inch rocks (prototype size, 6 inches by 9 inches) were placed in the well of the model, and the resulting abrasive action of the rocks removed the paint from the floor near the well entrance in 20 hours of model operation. Care must be taken, therefore, to remove all foreign material from the well after construction and to prevent other material from entering.

The water turned upward at the downstream well wall was directed back toward the center of the well by the deflector (Figure 10A) to prevent it from rising directly to the surface to cause excessive turbulence. The control exerted on the water by the deflector was found in the model tests to be an important feature of the well design, and essential for good operation. The height the preliminary deflector design was placed above the well floor was critical. A greater height was required when the regulating gate was operated at small openings than when it was operated at large openings. This condition was corrected by revising the deflector design. The radius on the lower upstream portion of the deflector was changed from 8 feet to 16 feet and the distance between the upstream and the downstream faces was reduced from 5 feet 4 inches to 4 feet 9 inches (prototype), (Figure 10B). In tests which were first made with no dentates in the deflector the water was thrown violently upstream toward the top of the well. Dentates were cut into the top upstream edge of the baffle to produce the recommended design. This deflector produced good flow conditions, and it was much less sensitive to position than the preliminary design. It operated effectively at all positions where the top surface was between elevations 2680.0 and 2690.0, a range of 10 feet. Best results were obtained, however, at elevation 2682.75, and this is the position recommended for the prototype structure. The strength of the currents diminished greatly as the water rose toward the top of the well. Moderate boils occurred occasionally at the water surface. The waves created by these boils were dissipated within the riprapped portion of the canal, and, no objectionable erosion of the canal banks was indicated.

Pressure measurements were made at 25 stations on the lower parts of three walls and on the deflector to determine the pressures acting on these surfaces (Figure 11). All the pressures were positive, and the higher ones occurred on the downstream wall where the flow from the conduit impinges.

Stilling well Exit into the Canal

In the preliminary design the well exit consisted of openings 7 feet high by about 6 feet wide in the three downstream walls (Figure 12A). The bottoms of the openings were at elevation 2700.00 and were formed by sills 3 feet wide. The tops of the openings (elevation 2707.00) were formed by the underside of a walkway which passed around the downstream portion of the well and was supported by two 8-inch-thick piers at the intersections of the three downstream walls. The top of the well was at elevation 2708.00 while the invert of the canal was level with the bottom of the well exit. The canal invert was 20 feet wide at the well, and the sides rose on a 1-1/2:1 slope.

The normal maximum capacity of the canal is 300 cubic feet per second, and the canal rate of discharge will be restricted to this or smaller flows. However, discharges up to 784 cubic feet per second may inadvertently be released through the structure. Model tests were made to determine if these flows could be handled. The walkway over the stilling well exit was found to partially obstruct the flow and splashing overtopped the well at discharges exceeding 700 cfs. The walkway and two piers were removed and the top of the well was raised 1 foot to elevation 2709.00. The canal invert was lowered 1 foot below the well outlet to elevation 2699.00, thus providing a step to prevent riprap or other foreign material from being carried back into the well. The recommended design of the stilling well exit is shown on Figures 2 and 12B. Flow conditions within the well and through the exit into the canal are shown at gate settings of 25, 50, 75, and 100 percent open in Figures 13A, B, C, and D, respectively. The discharge with the gate 25 percent open represented 180 cubic feet per second at the maximum reservoir elevation, 2785.00 feet while the flow was limited to 300 cfs at the 50, 75, and 100 percent gate openings by adjusting the total head at the gate. The heads were 86.0, 51.0 and 39.6 feet, respectively.

Scour in the Irrigation Canal

The water leaving the stilling well flows across the exit sill and descends 1 foot to the invert of the irrigation canal at elevation 2699.00. This drop, together with the mild turbulence and the attendant surface waves of the occasional boils in the well, might cause erosion in the unlined canal near the well. To protect the canal the designers specified 24-inch dumped riprap for a distance of 20 feet downstream from the well, and gravel corresponding to the prototype riprap size was placed in the model for an equivalent distance. The remainder of the canal was formed in compacted sand to represent the earth material (Figure 14A).

Water was passed through the model at a gate setting of 25 percent open and at a head equivalent to the maximum reservoir elevation (110.3 feet at the valve) to produce an equivalent flow of 180 cfs. The model was also operated at 50, 75, and 100 percent gate openings and at reduced heads to represent a flow of 300 cfs (Figures 13A, B, C, and D). After each of the above flow conditions was established, it was maintained for 30 minutes; then the flow was stopped, and the model was drained. Contours were determined at 2-foot (prototype) intervals, laid out with white cotton string, and each contour line was marked with the contour elevation. Photographic records were taken and the canal was reshaped to the original contours in preparation for the next test (Figure 14A). The scour in the canal for a 25 percent gate opening and a discharge representing 180 cfs is shown in Figure 14B, while the scours at 50 percent and 100 percent gate openings at a flow of 300 cfs are shown in Figures 14C and D. Almost no movement of the canal bed occurred in the riprapped area and only a moderate amount occurred in the sand bed downstream. The maximum scour took place at the 50 percent gate opening, but even this was negligible. A final test was made at the maximum possible flow in the prototype of 784 cfs (2.6 times the design flow) without excessive scour. Therefore, it is expected that the prototype canal will operate without objectionable scour at any point near the stilling well. As a final precaution, the designers elected to extend the riprap 45 feet further downstream thereby providing a total riprap length of about 65 feet (Figure 2).

FIGURE 1
REPORT HYD 300

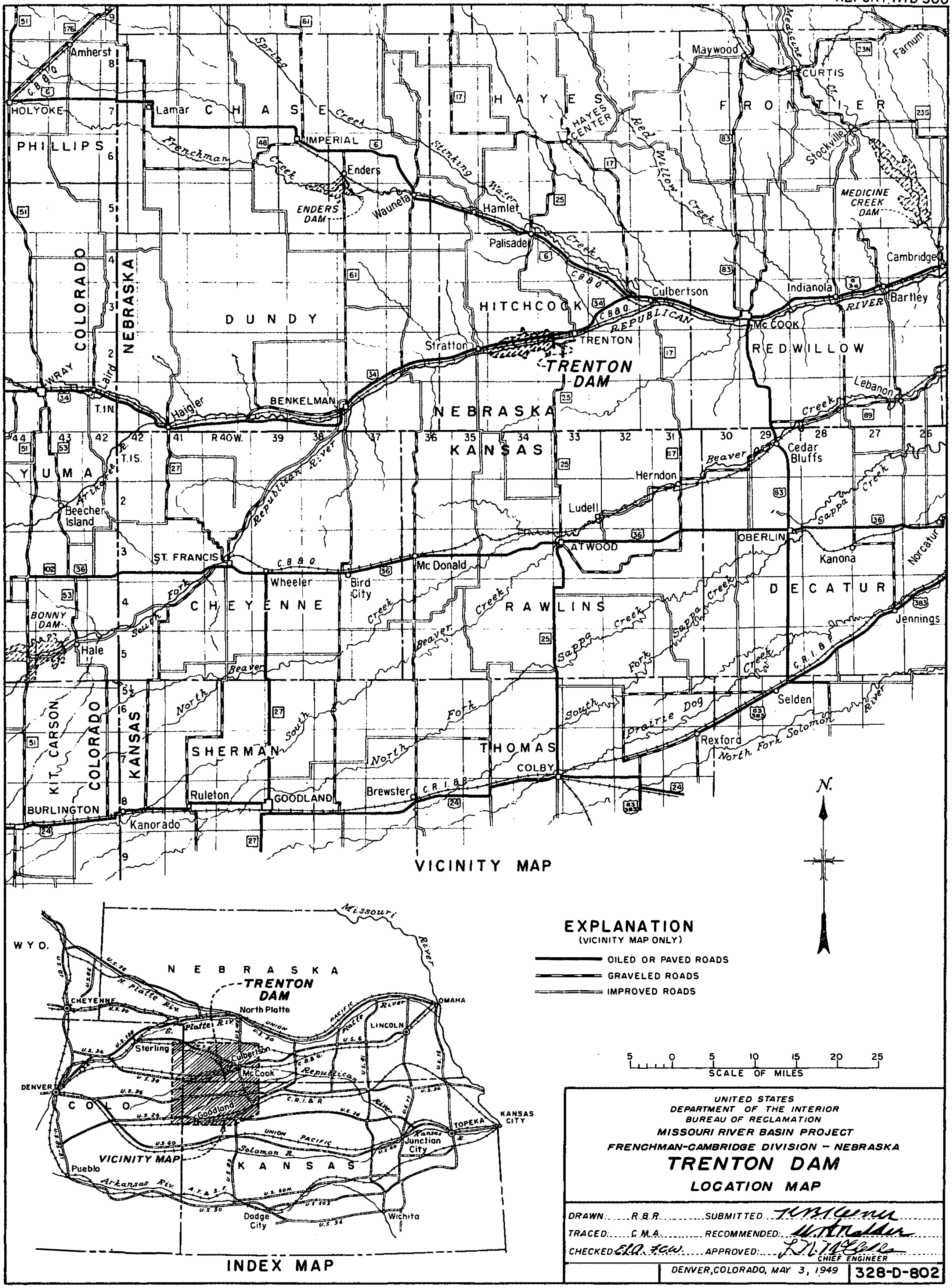
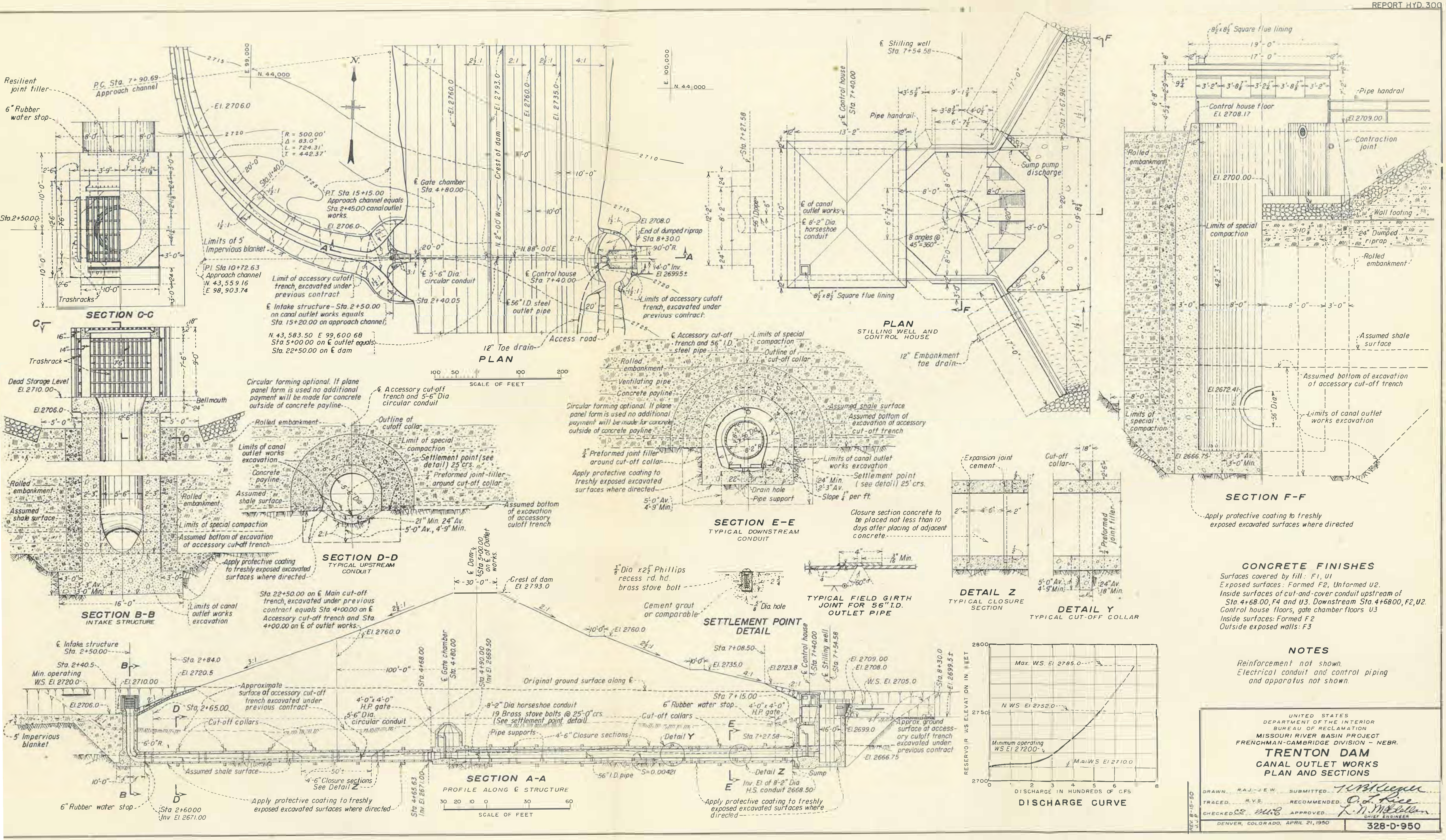
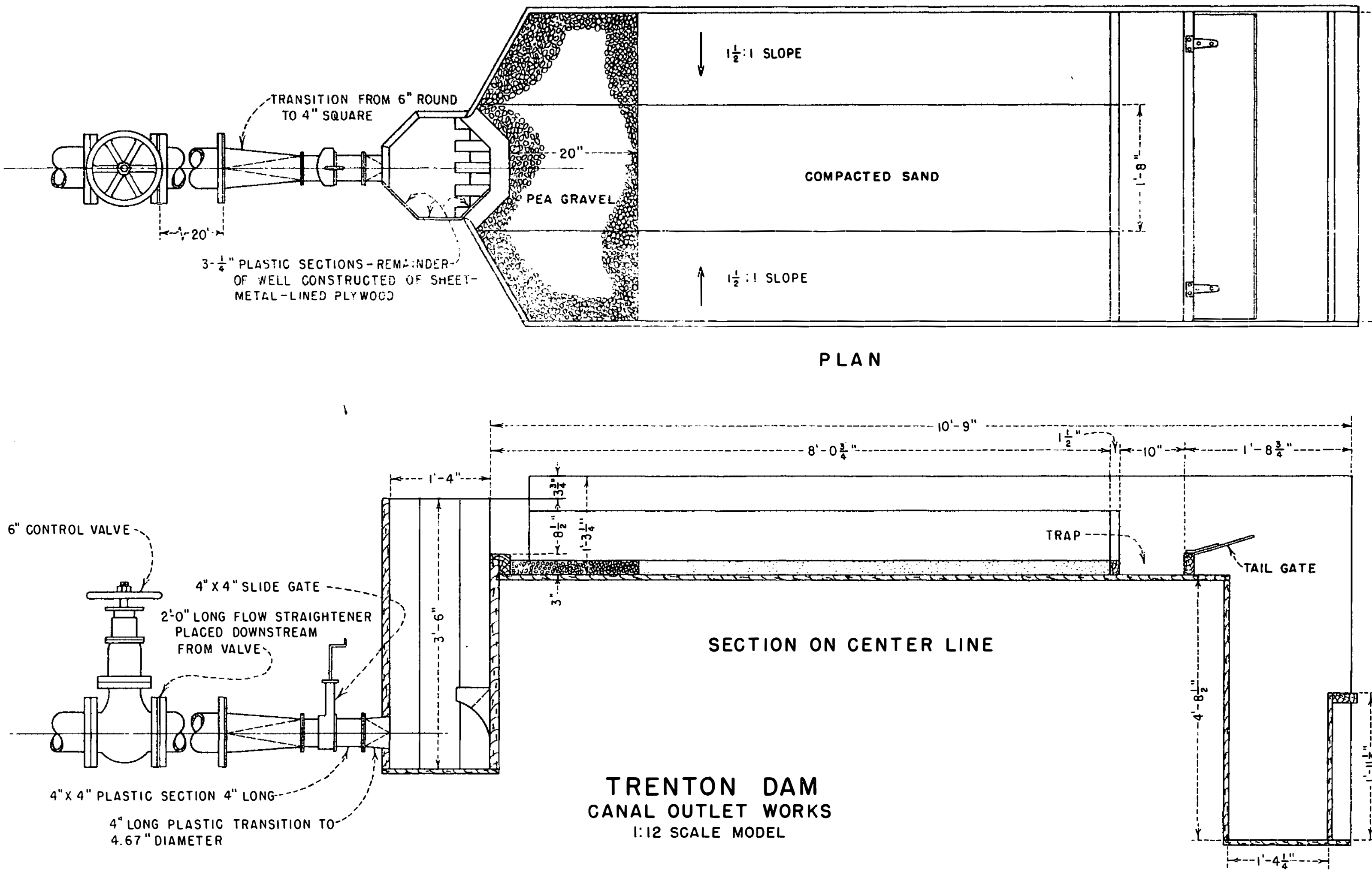


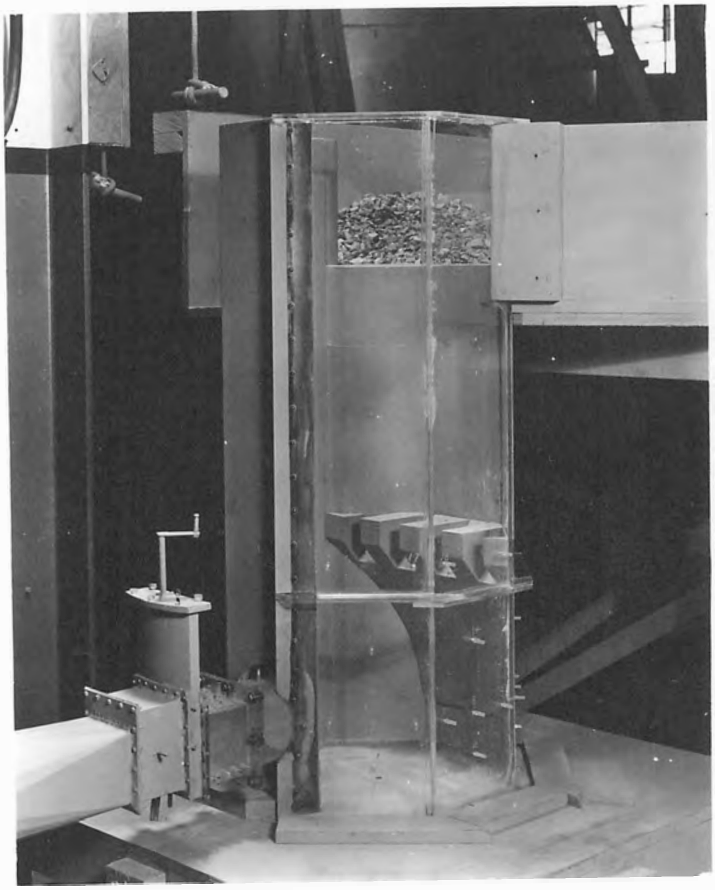
FIGURE 2
REPORT HYD. 300





TRENTON DAM
CANAL OUTLET WORKS
1:12 SCALE MODEL

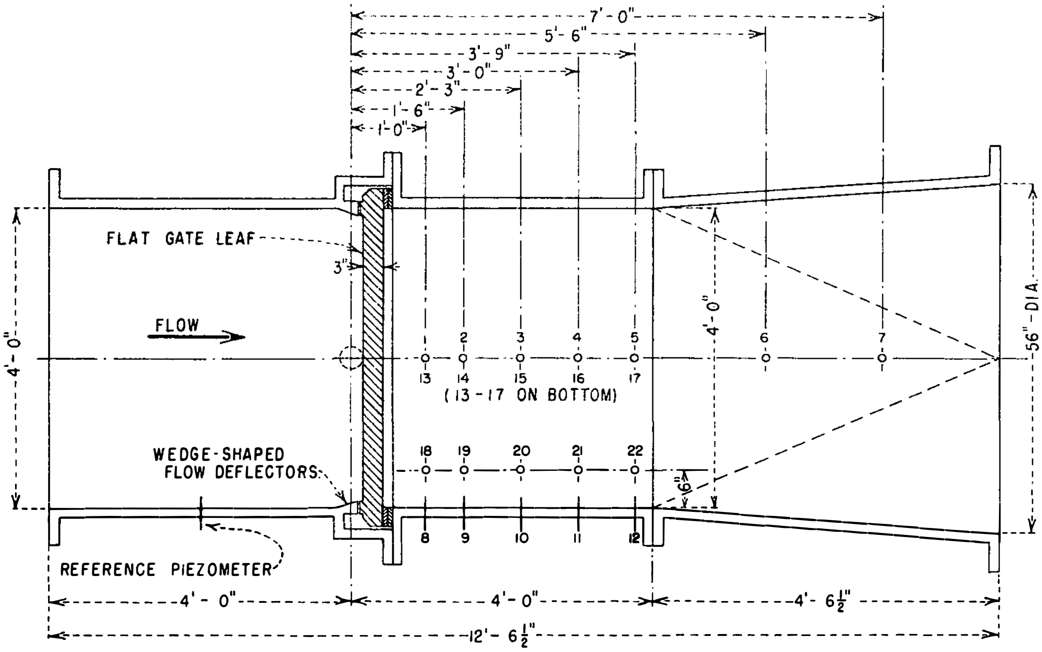
FIGURE 3
REPORT HYD. 300



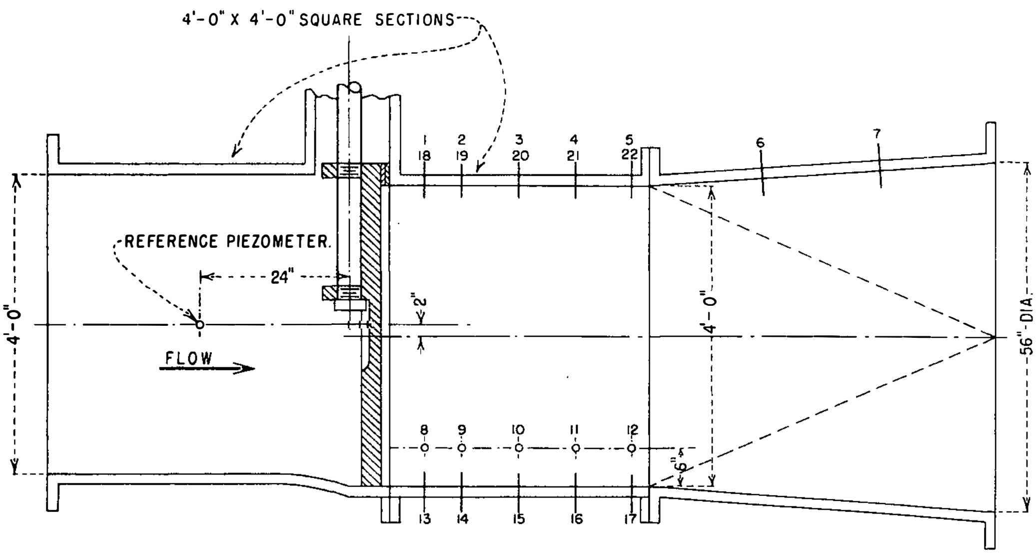
No discharge

Trenton Dam
Canal Outlet Works
Regulating Gate, Conduit, and Stilling Well

1:12 Scale Model.



PLAN

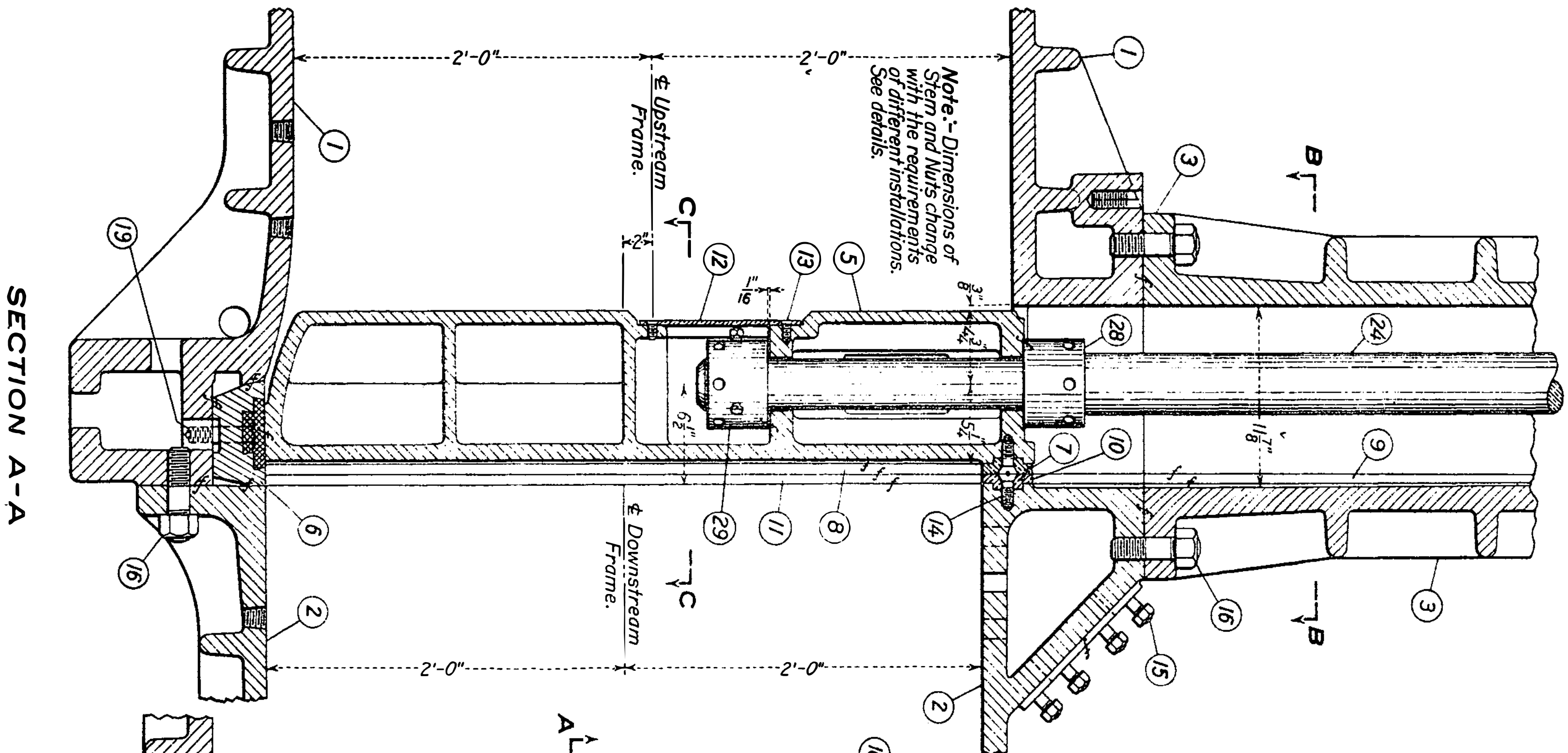


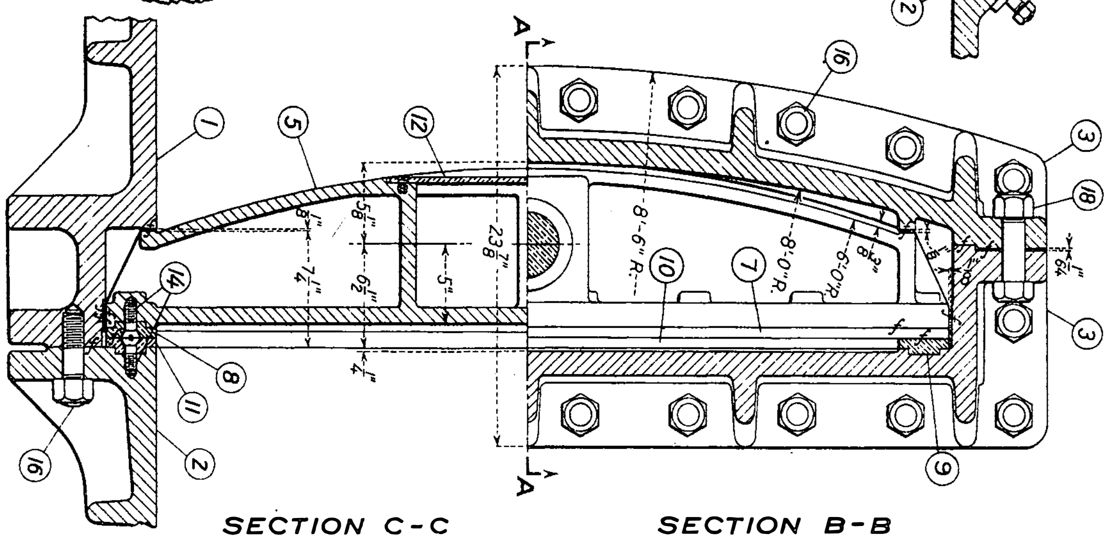
ELEVATION

TRENTON DAM

CANAL OUTLET WORKS

SCHEMATIC VIEWS OF THE 4'-0" X 4'-0" MODIFIED
SLIDE GATE AND THE PIEZOMETERS IN THE CONDUIT
1:12 SCALE MODEL





SHOP NOTE

With Screws 14 and Bronze Seats 7, 8, 9, 10 and 11 in place, lock Screws with 4 center punch scores in head.
After this Assembly make Final Machining on Sliding Faces of Bronze Seats, which must be in a True Plane.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE STANDARD DESIGN

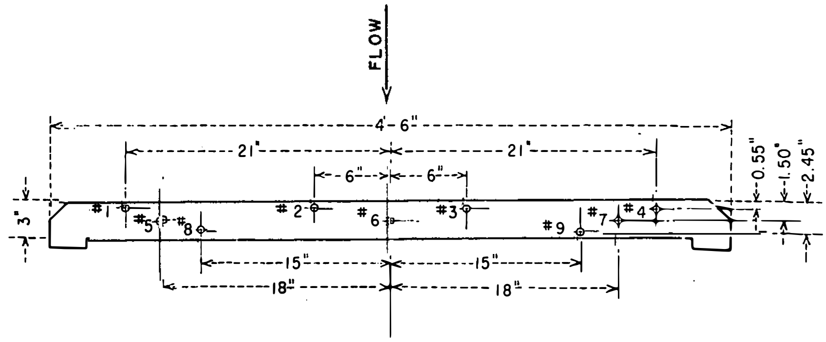
4'x4' HIGH PRESSURE GATE
ASSEMBLED SECTIONS
SHEET 2 OF 8
DECEMBER 1925

Edward Mead — COMMISSIONER
R. F. Walter — CHIEF ENGINEER

ACCESSION No. 22030 DRAWING No. 100-D-2030

REV. JAN. 1930 - DEC. 1936 E.B. NOV. 1942

FIGURE 6
REPORT HYD 300



A. LOCATION OF PIEZOMETERS ON THE BOTTOM OF THE LEAF

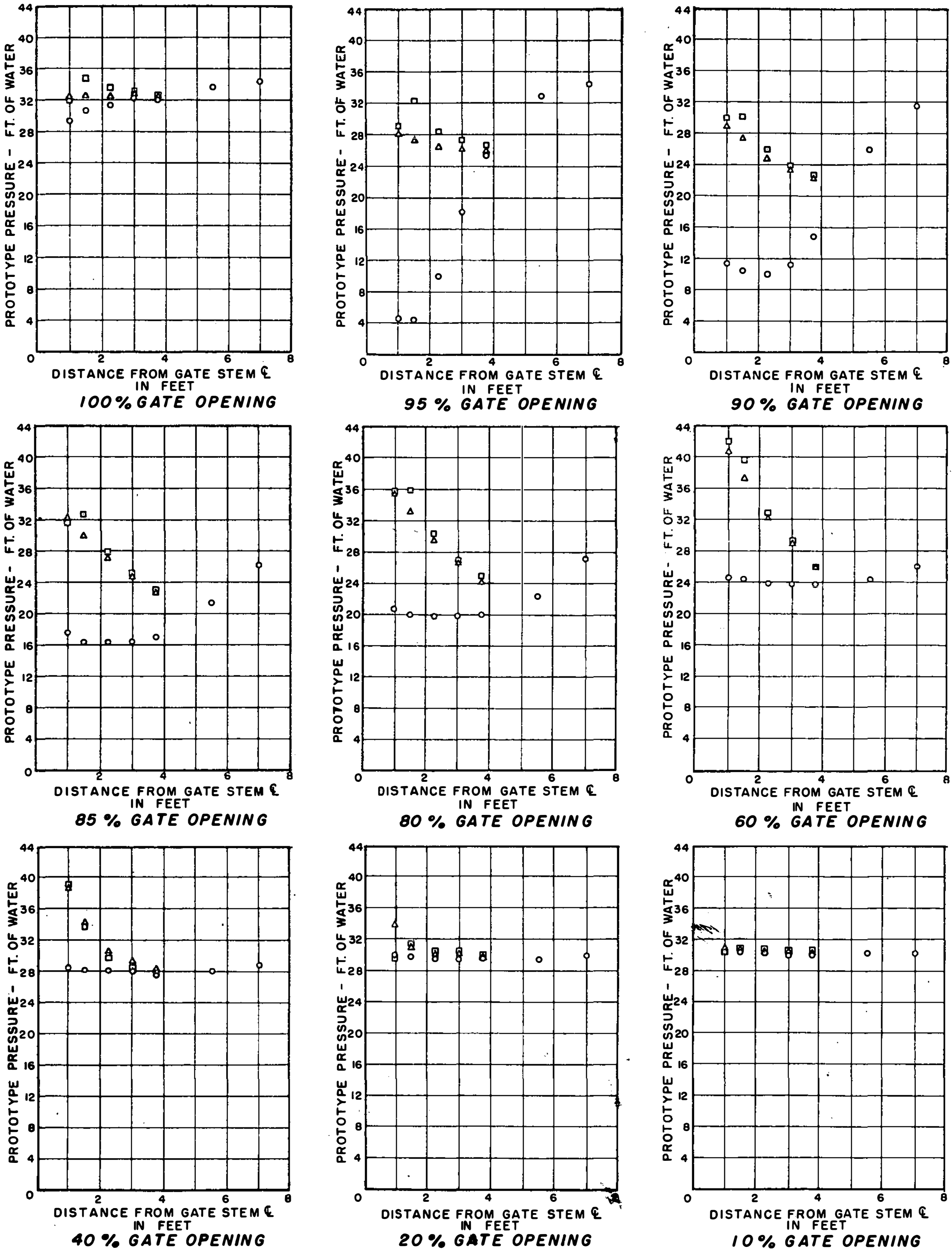
GATE OPENING	100%	99%	95%	90%	85%	80%	75%	60%	20%	10%
DISCHARGE c.f.s	754	740	685	626	554	490	436	313	106	64
REF. PIEZ.	35.40	36.72	41.40	46.20	51.00	55.32	58.44	63.96	69.12	69.72
PIEZ. 1	4.80	4.80	11.76	13.92	18.72	22.68	24.96	27.72	42.00	42.00
2	-0.60	-1.92	12.00	15.96	20.04	22.80	25.08	27.60	41.52	41.64
3	-0.96	-2.40	12.12	15.24	19.80	22.92	25.08	27.72	41.52	41.64
4	6.96	5.52	11.88	13.80	18.60	22.68	25.08	27.84	41.16	41.16
5	4.44	2.40	12.36	14.64	18.48	21.84	24.96	28.32	41.52	41.64
6	7.32	6.48	11.64	15.60	20.16	22.80	24.96	27.24	41.40	41.52
7	7.08	5.76	11.52	14.16	18.36	21.72	24.84	27.72	41.76	41.76
8	13.56	12.72	11.64	14 40	18.12	21.00	24.00	27.60	41.28	41.28
9	13.32	12.60	11.16	13.56	18.12	21.60	24.60	27.48	41.52	41.76

B. PRESSURES ON THE BOTTOM OF THE LEAF

NOTES

1. Discharge capacity is 300cfs.
2. Discharges and pressures given as prototype values.
3. All data were taken at an equivalent total head at the gate entrance of 70 feet.

TRENTON DAM
CANAL OUTLET WORKS
PRESSURES ON THE BOTTOM OF THE GATE LEAF
DATA FROM 1:12 SCALE MODEL



TRENTON DAM
CANAL OUTLET WORKS

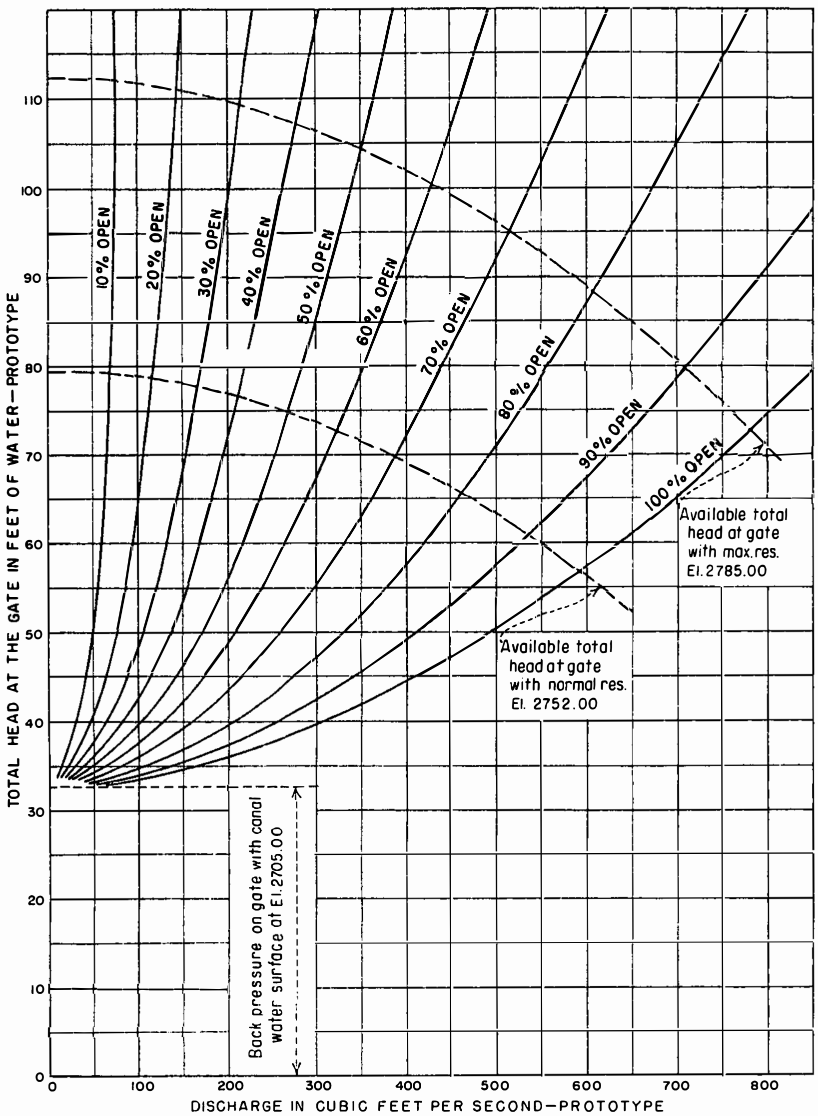
PRESSURES IN THE CONDUIT DOWNSTREAM FROM THE REGULATING GATE

All data were taken at an equivalent total head at the gate entrance of 70 feet.

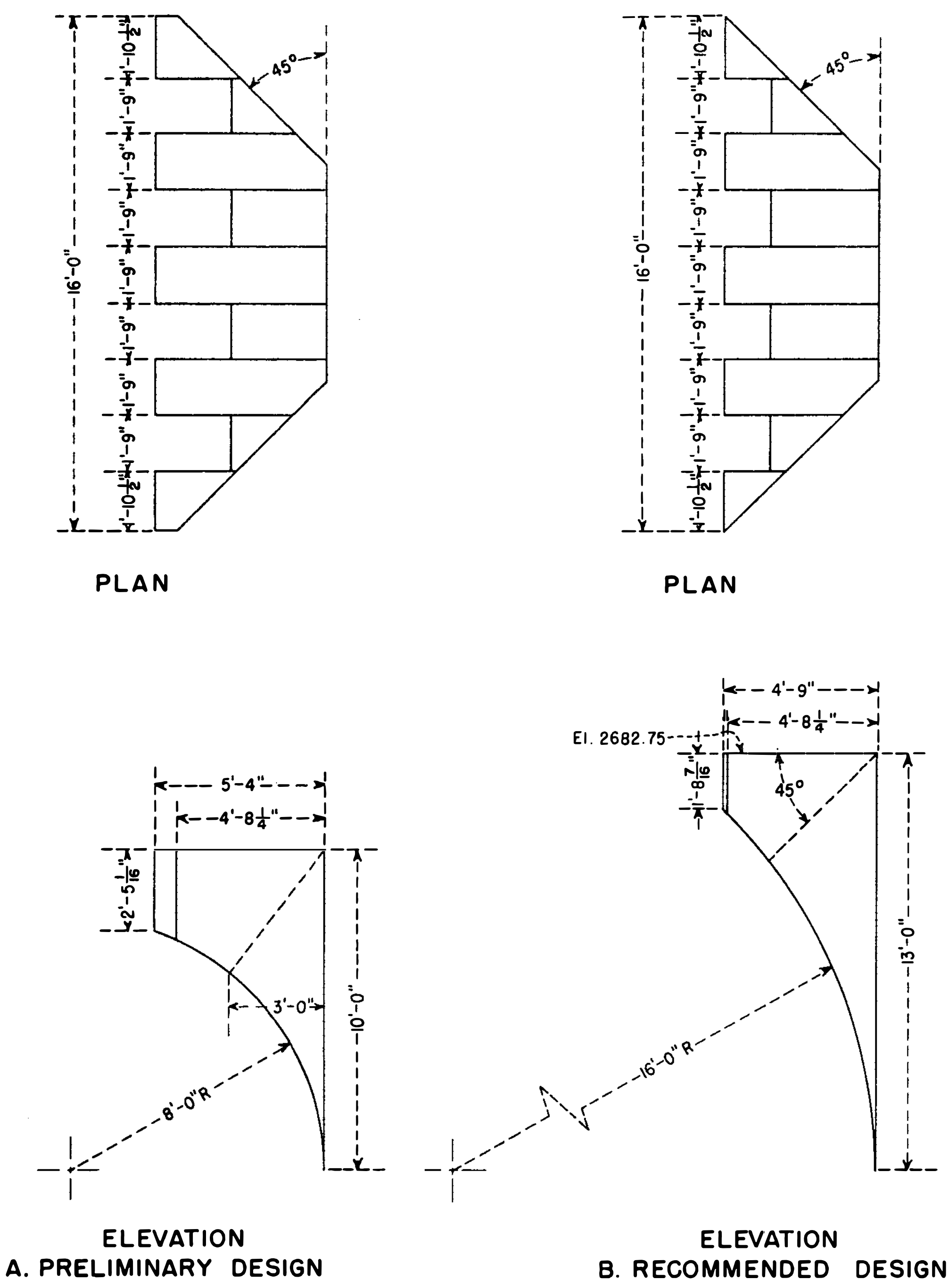
- o *Top of conduit on ℄, piezometers 1-7 inclusive.*
- □ *Side of conduit 6" above floor, piezometers 8-12 inclusive.*
- △ *Bottom of conduit on ℄, piezometers 13-17 inclusive.*

Data from 1:12 scale model.

F.E. 7-30-50



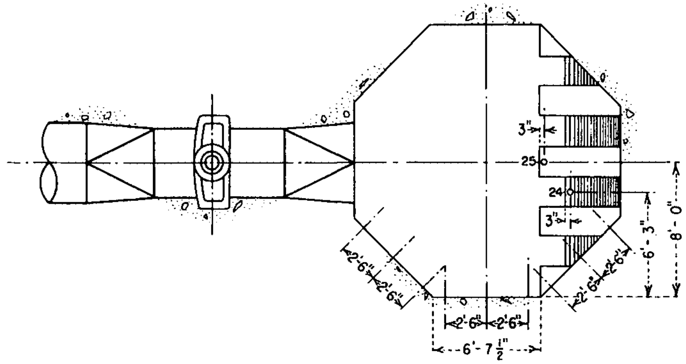
TRENTON DAM
CANAL OUTLET WORKS
DISCHARGE CURVES
DATA FROM 1:12 SCALE MODEL



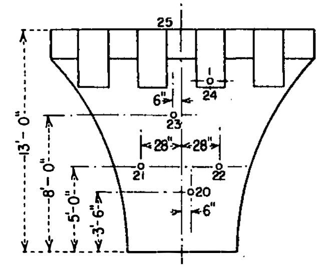
TRENTON DAM

CANAL OUTLET WORKS

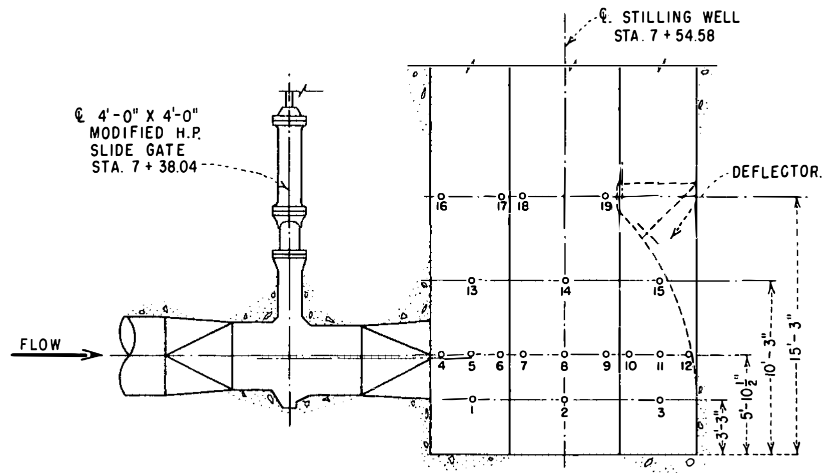
STILLING WELL BAFFLE DESIGNS



PLAN
CONTROL GATE AND STILLING WELL



FRONT VIEW
DEFLECTOR

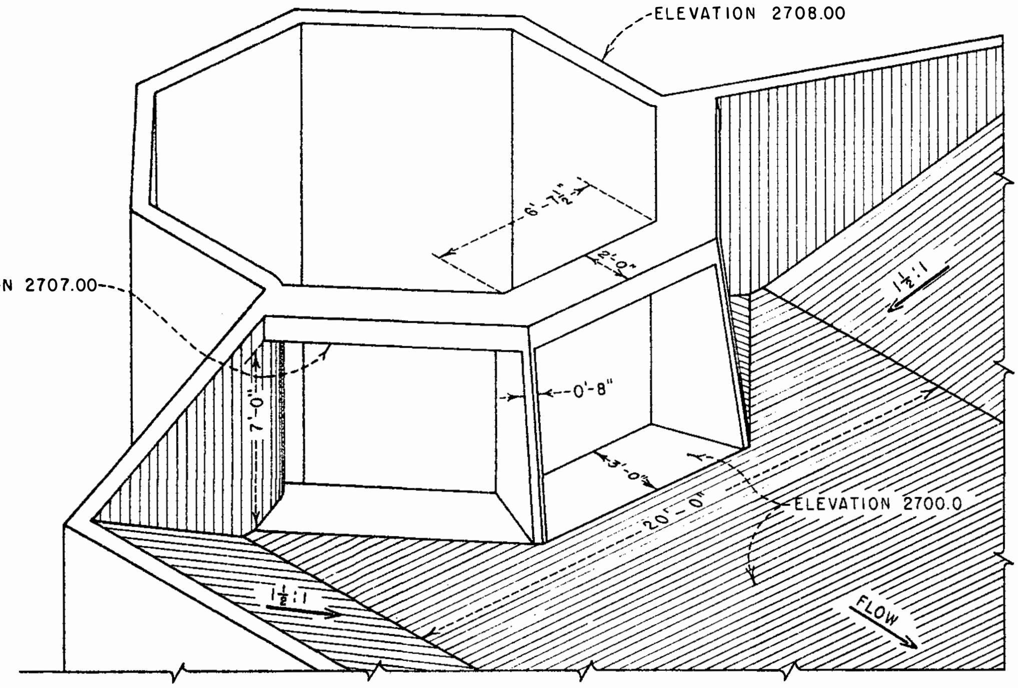


ELEVATION

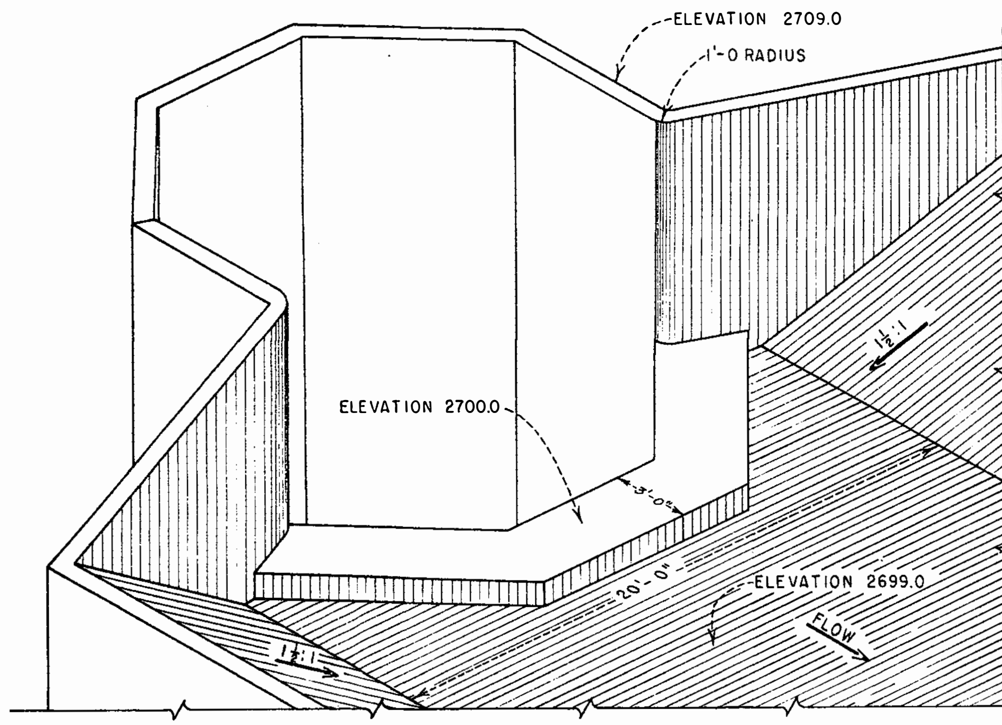
STILLING WELL WALL PRESSURES
GAGE ZERO AT ELEVATION OF WELL FLOOR
PRESSURE IN FEET OF WATER

PIEZOMETER NUMBERS	25% GATE OPENING Q= 170 c.f.s.	50% GATE OPENING Q = 300 c f s.	75% GATE OPENING Q = 300 c.f.s.	100% GATE OPENING Q = 300 c.f.s.	100% GATE OPENING Q = 700 c.f.s.
1.	38.64	39.84	39.60	38.40	38.40
2.	37.68	38.04	38.40	39.12	43.20
3.	37.20	37.20	38.40	40.08	49.44
4.	38.76	39.96	39.36	38.52	38.40
5.	38.28	39.12	39.00	38.76	38.88
6.	37.92	38.88	39.48	38.88	41.16
7	38.04	39.00	39.60	39.12	42.60
8.	37.56	38.04	38.52	39.36	43.80
9.	38.16	39.24	39.24	39.24	42.96
10	37.80	38.40	39.00	39.12	42.48
11.	37.56	37.08	39.00	39.24	44.64
12.	44.52	49.20	43.92	41.04	54.60
13.	37.80	38.28	38.64	38.88	40.80
14.	37.92	38.40	38.52	39.00	41.64
15.	40.92	43.56	41.64	39.48	44.28
16.	38.40	39.12	39.00	39.00	41.88
17.	38.40	38.88	38.76	38.76	41.28
18.	38.40	39.00	38.88	38.88	40.80
19.	38.52	39.00	38.88	38.64	38.88
20.	46.32	51.00	44.04	40.80	53.40
21.	41.40	44.04	41.40	38.76	42.60
22.	41.76	44.40	40.56	40.44	51.00
23.	42.60	48.00	42.84	39.60	33.60
24.	36.60	36.60	37.44	37.56	36.00
25.	37.80	38.40	38.64	38.40	38.40

TRENTON DAM
CANAL OUTLET WORKS
PRESSURES ON STILLING WELL WALLS
DATA FROM 1:12 SCALE MODEL



A. PRELIMINARY DESIGN



B. RECOMMENDED DESIGN

TRENTON DAM
CANAL OUTLET WORKS
STILLING WELL EXIT INTO CANAL

A. Gate 25% Open. Q = 180 cfs.
Head at gate = 110.3 feet (Max. reservoir elevation)

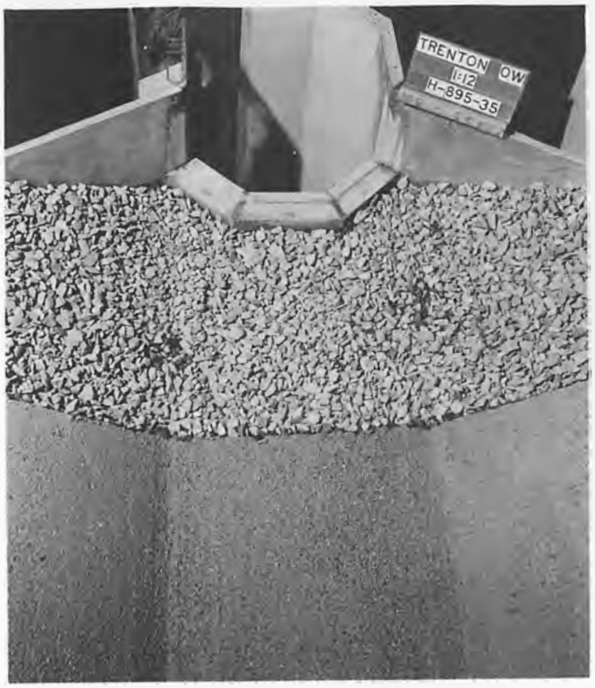
B. Gate 50% Open. Q = 300 cfs.
Head at gate = 86.0 feet

C. Gate 75% Open. Q = 300 cfs.
Head at gate = 51.0 feet

D. Gate 100% Open. Q = 300 cfs.
Head at gate = 39.6 feet.

Trenton Dam
Canal Outlet Works
Flow conditions in the well and through the well exit into the canal

1:12 Scale Model.



A. Canal previous to each scour test.

B. Scour after 30 minutes operation at 25% gate opening. Q = 180 cfs. Head at gate = 110.3 feet (Max. reservoir elevation)

C. Scour after 30 minutes operation at 50% gate opening. Q = 300 cfs. Head at gate, 86.0 feet

D. Scour after 30 minutes operation at 100% gate opening. Q = 300 cfs. Head at gate, 39.6 feet

Trenton Dam
Canal Outlet Works
Scour in the Canal Entrance

1:12 Scale Model.