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HYDRAULIC MODEL STUDIES
OF VEGA DAM OUTLET WORKS
COLLBRAN PROJECT, COLORADO

Hydraulic Laboratory Report No. Hyd-418

DIVISION OF ENGINEERING LABORATORIES



COMMISSIONER'S OFFICE
DENVER, COLORADO

September 17, 1956

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Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and Equipment Section
Denver, Colorado
September 17, 1956

Laboratory Report No. Hyd-418
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Subject: Hydraulic model studies of Vega Dam Outlet Works--Collbran
Project, Colorado

SUMMARY

Hydraulic model studies of the Vega Dam Outlet Works were made to develop an adequate stilling basin and to make certain that the flow entered the Southside Canal uniformly and with a minimum of waves. To accomplish this it was necessary to check the spread of the incoming flow and to determine the size and spacing of the chute blocks and baffle piers in the stilling basin.

In the preliminary design, Figure 4, the high pressure gates were tilted downward so that the jet impinged on the 2:1 slope at an angle of 5°00'. The tilt of the gates was found to be satisfactory. The incoming flow spread adequately on the 2:1 slope and entered the basin uniformly, Figure 6A. It was found that training walls having the same divergence as the downstream gate frame should extend at least 7 feet downstream from the gate frames to prevent flow disturbances where the jet joins the backwater from the jump. Pressures measured on the diverging walls were satisfactory, Figure 7.

The preliminary stilling basin was found adequate to handle the maximum discharge of 571 second-feet. However, the tests indicated that both baffle piers and chute blocks are required to satisfactorily reduce the turbulence and height of waves in the Southside Canal. Chute blocks ranging from 1 to 3 feet in height and baffle piers, 3 to 5 feet high, were tested, Table 1, page 8. The studies showed that a combination of chute blocks, 3 feet high, and baffle piers, 4 feet high, gave the best stilling basin performance. The waves in the canal for maximum discharge were reduced from a maximum of 0.87 foot in the preliminary design to approximately 0.3 foot in the recommended design. The waves will be further dampened in traveling to the measuring flume located several hundred feet downstream from the stilling basin; therefore, no wave suppressor is deemed necessary.

Two designs for the wing walls at the downstream end of the stilling basin were tested in the model. The studies indicated that a diverging wall extending from the stilling basin to the canal section, Figure 2, gave a smoother transition and eliminated side eddies at the downstream end of the stilling basin.

The recommended design is shown in Figures 2 and 10. The operation of the recommended design for discharges from 300 to 571 second-feet through 1 and 2 gates is shown in Figures 11 and 12.

Erosion in the canal downstream from the stilling basin was negligible.

INTRODUCTION

Vega Dam, Collbran Project, is located on Plateau Creek approximately 8 miles east of Collbran, Colorado, Figure 1. The dam is of the earthfill type and rises approximately 130 feet above the riverbed. The outlet works is located near the left dam abutment and includes an intake structure; 200 feet of circular conduit, 5 feet in diameter; a gate chamber; 370 feet of steel pipe, 51 inches inside diameter; a control house; and stilling basin, Figure 2. Immediately above the control house the circular steel pipe branches into two square conduits, 2 feet 3 inches on a side, which are the approaches to the slide gates. The maximum discharge of 571 second-feet is controlled by two 2 feet 3 inches by 2 feet 3 inches high pressure slide gates tilted downward at an angle of 5°00' with the 2:1 slope, Figures 3 and 4. The stilling basin discharges directly into the Southside Canal.

Hydraulic model studies of the outlet works were made to determine if a 5°00' downward tilt of the gate gave satisfactory flow conditions, to check the spread of the incoming flow, to determine the adequacy of the stilling basin, and to make certain that the flow entered the canal uniformly and with a minimum of waves. It is essential that the flow in the canal be comparatively uniform and without surface waves so that a measuring flume, located several hundred feet downstream from the stilling basin, will operate properly.

THE MODEL

The outlet works model was built to a geometrical scale of 1:11.25 and included the slide gates, stilling basin, and a short section of the Southside Canal, Figure 3. The conduit, Y-branch, and transitions upstream from the gates where no unusual hydraulic problems are anticipated were not reproduced in the model. This portion of the structure was represented by a manifold with circular pipes leading to

the two slide gates. The stilling basin was constructed of 3/4-inch plywood in an existing tail box with a glass window on one side to permit visual observation of the stilling action. The bottom of the transition downstream from the stilling basin and the bottom and side slopes of the Southside Canal were formed to wooden templates with erodible sand.

A manifold of 2 piezometers was placed 2 feet 3 inches upstream from the gates to measure the pressure head at the gates. Flow in the model was measured with a venturi meter.

THE INVESTIGATION

Because of fund limitations and the urgency to complete the model studies before the issuance of specifications for the outlet works, sufficient tests were made only to study the effect of the gate tilt on the flow leaving the gate and to check the adequacy of the stilling basin so that the flow entered the canal with a minimum of waves. The tilt of the gate was checked by observing the spreading of the flow downstream from the gates, analysis of the pressures measured along the warped wall, and the general appearance of the flow entering the stilling basin. The adequacy of the stilling basin was evaluated by observing the stilling action and by measuring the amount of erosion and the height of waves in the Southside Canal. In this study, the height of waves is the difference in feet between the maximum crest and minimum trough occurring over a prototype time span of 2-1/2 minutes measured in the center of the canal 20 feet downstream from the outlet structure.

To evaluate the various designs the model was operated at four possible operating conditions: (1) the maximum discharge of 571 second-feet through two gates 100 percent open, (2) the normal canal capacity of 300 second-feet through two gates 100 percent open at reservoir elevation 7925, (3) 300 second-feet through two gates 55 percent open at maximum reservoir elevation 7990.9, and (4) the maximum discharge of 317 second-feet through one gate 100 percent open. In general, the two critical operating conditions were the maximum discharges through two gates and one gate [conditions (1) and (4), respectively].

Preliminary Design

The preliminary basin design, shown in Figure 4, was initially constructed and tested in the model. This design included a basin 45 feet in length, 12-inch-high chute blocks, and a baffled end sill 3 feet in height. Figure 5 shows the operation of the preliminary design at the maximum discharges of 317 and 571 second-feet through one and two gates. The main portion of the flow remained near the floor of the stilling basin with very little vertical flow distribution. The surface

of the stilling basin was comparatively rough with numerous surges and waves being formed in the stilling basin. Wave heights of 0.87 foot were measured in the Southside Canal for both discharges, Table 1.

Gate Setting

In the preliminary design the gates were tilted downward so that the jets impinged on the 2:1 slope at an angle of 5°00', Figure 4. The spreading of the jet on the 2:1 slope was very good. The flow was well distributed, and the jets followed the outer diverging training walls along the 2:1 slope. However, water backed up into the corners formed by the center dividing wall and the 90° walls immediately downstream from the gates, Figure 4. The water in the corners tended to break up the inner edges of the jets and caused considerable splash and surging flow along the center dividing wall.

To eliminate the adverse flow conditions along the dividing wall, short diverging walls extending about 7 feet downstream from the gate frames were placed in the model. The diverging walls prevented the backwater from interfering with the jets and resulted in a smooth jet between the gate and the backwater from the jump, Figure 6A.

A row of 8 piezometers was placed along the warped surface of the diverging wall 6 inches above the 2:1 slope and spaced at 6-inch intervals downstream from the gate frame, Figure 7. Pressures were observed for discharges of 571 and 300 second-feet through two gates and 317 second-feet through one gate. The lowest pressures were observed for a discharge of 300 second-feet through two gates 55 percent open at reservoir elevation 7991. For this flow condition pressures approximately 1 foot below atmospheric were observed at Piezometers 1 through 3. Downstream from Piezometer 3 the observed pressures increased to a maximum of 1 foot above atmospheric at Piezometer 7. Since the observed pressures are well above the cavitation range, the divergence of the walls was considered satisfactory.

Wing Walls

During the initial tests on the outlet works structure, two wing wall designs downstream from the stilling basin were installed and tested at the same time, Figure 4. The right wing wall diverged from the basin width of 15 feet to the canal width of 18 feet and extended about 34 feet downstream from the basin. The left wing wall was a conventional 90° wall at the downstream end of the basin.

The preliminary tests indicated that the diverging wall provided a smoother transition from the stilling basin to the canal than the 90° wing wall. Eddies of water--sufficiently strong to move some

of the sand on the 1-1/2:1 side slopes--formed along the 90° wall while only a slight, unobjectionable flow disturbance occurred at the downstream end of the diverging wall.

From these preliminary tests it was decided to accept the basic design of the diverging walls and the structure was made symmetrical by replacing the 90° wing wall with a diverging wall.

Chute Block and Baffle Pier Studies

Comprehensive tests were made using combinations of chute blocks and baffle piers of varying heights, Table 1. The height of the chute blocks varied from 1 to 3 feet while the baffles ranged from 3 to 5 feet in height. The various combinations of chute blocks and baffle piers were evaluated by observing the distribution of flow in the stilling basin and by measuring the height of waves in the Southside Canal.

Figures 6B and 8 show the typical stilling basin performance for chute blocks, 1 to 3 feet high, with and without baffle piers installed in the basin for the maximum discharge of 317 second-feet through the right gate. In general, the higher the chute block, the farther the jump moved upstream on the 2:1 slope, giving a more nearly horizontal water surface in the stilling basin. Also, the vertical distribution of flow and the stilling action were improved with the higher chute blocks as evidenced by the reduced wave heights measured in the Southside Canal, Table 1. Wave heights of 0.87 foot were measured using the 12-inch chute blocks while the wave heights were reduced to 0.75 and 0.56 foot with chute blocks, 2 feet and 3 feet high, respectively.

Still greater improvement in the stilling basin performance was obtained when baffle piers, combined with the chute blocks, were installed on the stilling basin floor, Figures 6B, 8B, and 8D. The water surface in the stilling basin was practically horizontal downstream from a point above the baffle piers. The wave heights in the Southside Canal were further reduced to approximately 0.30 foot, Table 1. Observations were made using baffle piers 3, 4, and 5 feet high. Again the chute blocks, 3 feet high, in combination with baffle piers gave the best performance, both in height of waves and in stilling action. Although the maximum wave heights were approximately the same for the different heights of baffle piers, the average waves were lower and the general appearance of the stilling action was best when baffle piers 4 feet high were installed. Therefore, the combination of chute blocks, 3 feet in height, and baffle piers, 4 feet high, is recommended for prototype construction.

Erosion Downstream from Stilling Basin

Several erosion tests were made to determine the amount of erosion to be expected in the transition downstream from the stilling basin. Figure 9A shows the erosion after a discharge of 571 second-feet. The amount of erosion was negligible both in the transition and in the Southside Canal. There was minor sloughing of material from the canal banks at the end of the training walls, but since the canal will be rip-rapped for about 75 feet downstream from the structure, Figure 2, no movement of material should occur in the prototype.

Because the width of the structure is relatively narrow (15 feet), the designers decided to pave the floor of the transition. Thus, the dentated sill at the downstream end of the stilling basin was no longer required and was not included in the recommended design, Figure 10.

Basin Floor Raised 2 Feet

With the improved stilling basin performance using chute blocks and baffle piers it appeared that the floor of the stilling basin could be raised and thus reduce the total cost of the structure. Therefore, tests were made with the basin floor raised 2 feet to elevation 7870. Figure 9B shows the stilling basin operating at a discharge of 317 second-feet with chute blocks 3 feet high and no baffle piers installed. Raising the basin floor caused more splash and a rougher stilling basin operation as can be seen by comparing Figure 9B with Figure 8C. Therefore, it is recommended that the basin floor be placed at elevation 7868 as in the preliminary design.

Consideration was also given to shortening the stilling basin length, but since turbulence in the stilling basin extends nearly to the downstream end of the stilling basin and waves in the canal must be kept to a minimum, no change in the length of the stilling basin is recommended.

The Recommended Design

Late in the model studies the cross section of the Southside Canal was changed by the designers from a bottom width of 18 feet to 14 feet and the bottom of the canal was lowered from elevation 7876.6 feet to elevation 7875.0 feet. This change eliminated the need for diverging training walls along the transition. The recommended design, therefore, includes parallel training walls with a short transition in the canal from the basin width of 15 feet to a bottom width of 14 feet in the canal.

Figure 10 shows the recommended design, which includes chute blocks 3 feet high, baffle piers 4 feet high, basin floor at elevation 7868, no end sill, and parallel training walls to the downstream end of the 4:1 slope, Figure 2.

Figures 11 and 12 show the operation of the stilling basin at discharges of 300 to 571 second-feet through 1 and 2 gates.

Jump Sweep Out

Curves indicating the amount the water level in the canal, or tail water, can be lowered without the jump sweeping from the basin are shown in Figure 13. In this study, the jump was considered swept out when the jump moved downstream to the extent that no portion of the jump covered the chute blocks.

For the maximum discharge of 571 second-feet the canal water surface may drop 4 feet below normal tail water before the jump sweeps out. For flows of approximately 200 second-feet the sweep out curve is about 2 feet below the normal tail water curve. Thus, the tail water is adequate to maintain a satisfactory jump at all expected discharges.

Also shown in Figure 13 is the jump sweep out curve when the basin floor was raised 2 feet to elevation 7870 feet. This curve is 0.5 to 1.5 feet higher than that obtained with the recommended basin.

It should be noted that the jump sweep out curves were obtained with no baffle piers installed in the basin. Thus, with baffle piers installed, the water level in the canal could drop appreciably lower than that shown in Figure 13 before the jump sweeps out.

Wave Suppressor

The need for a wave suppressor in conjunction with the stilling basin was considered unnecessary. The observed waves in the Southside Canal varied from 0.1 to 0.3 foot. Since the wasteway and turnout are located about 400 feet downstream from the stilling basin and the measuring flume is another several hundred feet downstream from the turnout, the waves should be further dampened by the time they reach the measuring flume. Therefore, no wave suppressor is recommended for the structure.

Table 1

SUMMARY OF WAVE HEIGHTS* IN FEET OBTAINED WITH VARIOUS
CHUTE BLOCK AND BAFFLE PIER COMBINATIONS

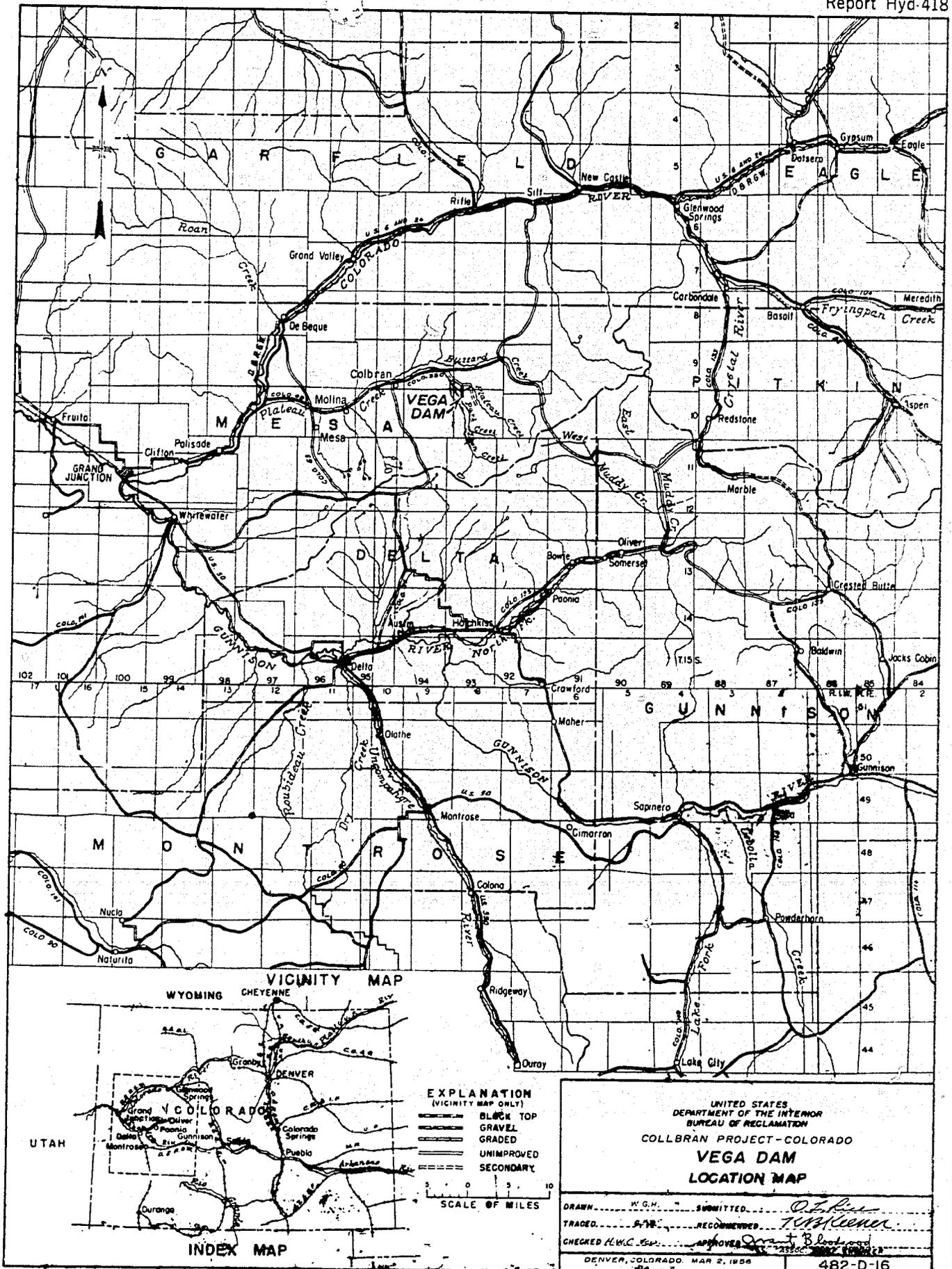
Discharge	Height of baffle piers, ft:	12" chute blocks				2' chute blocks				3' chute blocks				***
		None	3	4	5	None	3	4	5	None	3	4	5	Recom basin & canal section
571 cfs through 2 gates 100% open	**	0.87	0.43	0.43	0.48	0.68	0.45	0.38	0.34	0.57	0.29	0.29	0.48	0.30
300 cfs through 2 gates 55% open	**	0.53	0.29	0.30	0.27	0.45	0.28	0.30	0.26	0.27	0.12	0.16	0.17	0.17
300 cfs through 2 gates 100% open	**	0.28	0.18	0.16	0.15	0.33	0.14	0.10	0.09	0.12	0.10	0.10	0.08	0.12
317 cfs through 1 gate 100% open	**	0.87	0.29	0.34	0.41	0.75	0.27	0.25	0.30	0.56	0.24	0.20	0.27	0.20

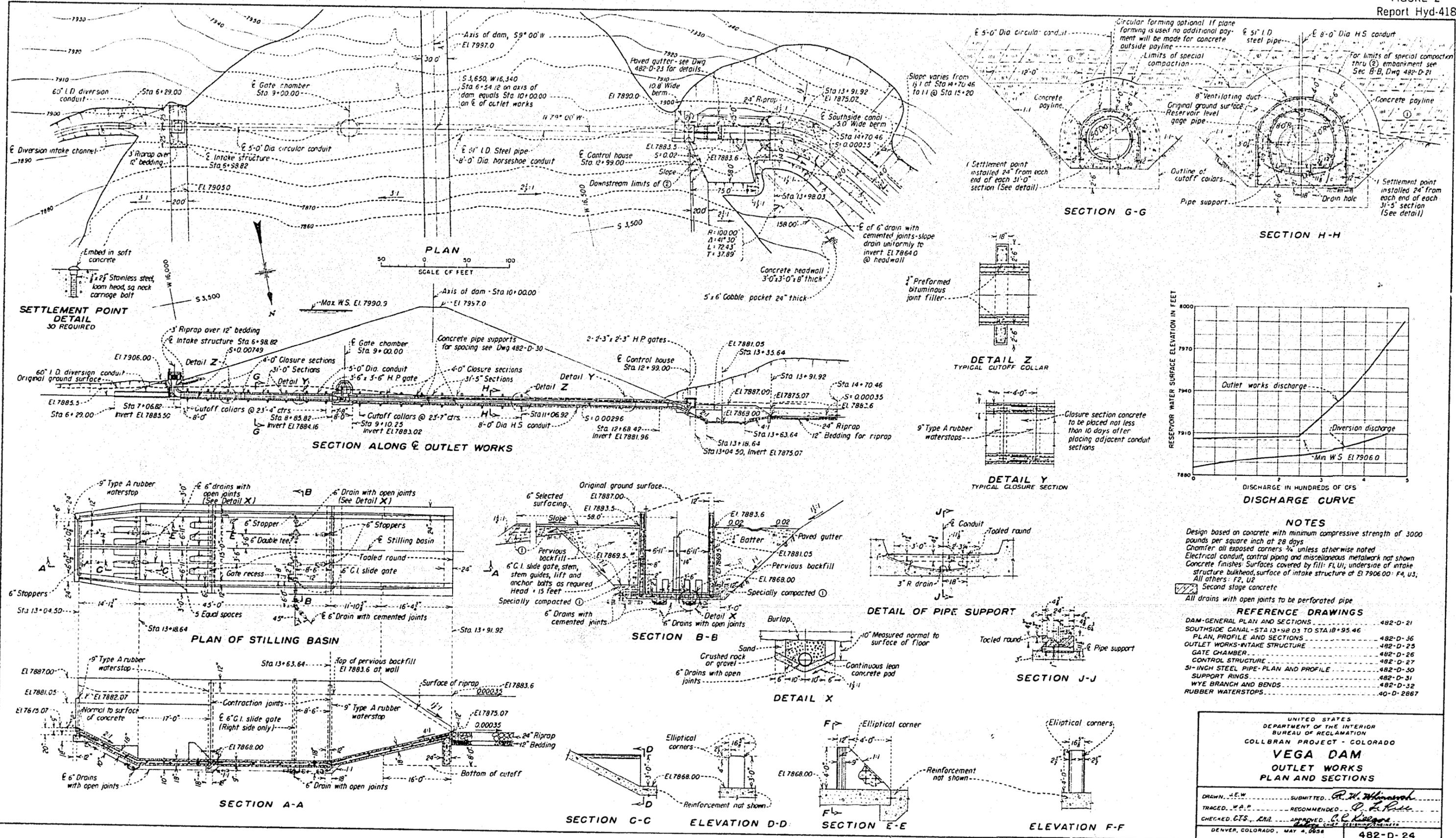
*Difference in feet between maximum crest and minimum trough measured in center of canal 20 feet downstream from outlet structure.

**Preliminary design.

***3-foot chute blocks and 4-foot baffle piers, no end sill, paved 4:1 slope, parallel training walls extending along 4:1 slope, and canal section with bottom width of 14 feet.

FIGURE 1
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NOTES

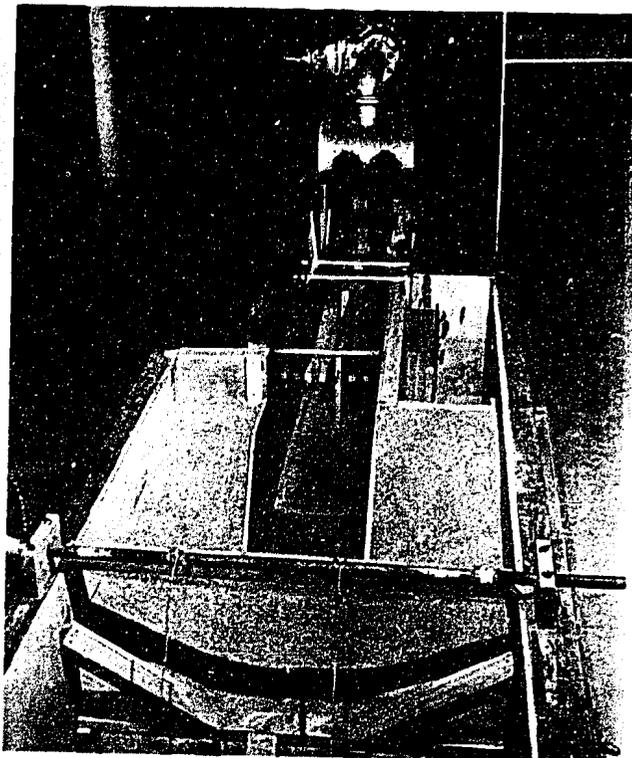
Design based on concrete with minimum compressive strength of 3000 pounds per square inch at 28 days
 Chamfer all exposed corners 1/4" unless otherwise noted
 Electrical conduit, control piping and miscellaneous metalwork not shown
 Concrete finishes: Surfaces covered by fill: F1, U1; underside of intake structure bulkhead, surface of intake structure at El 7906.00: F4, U3; All others: F2, U2
 Second stage concrete
 All drains with open joints to be perforated pipe

REFERENCE DRAWINGS

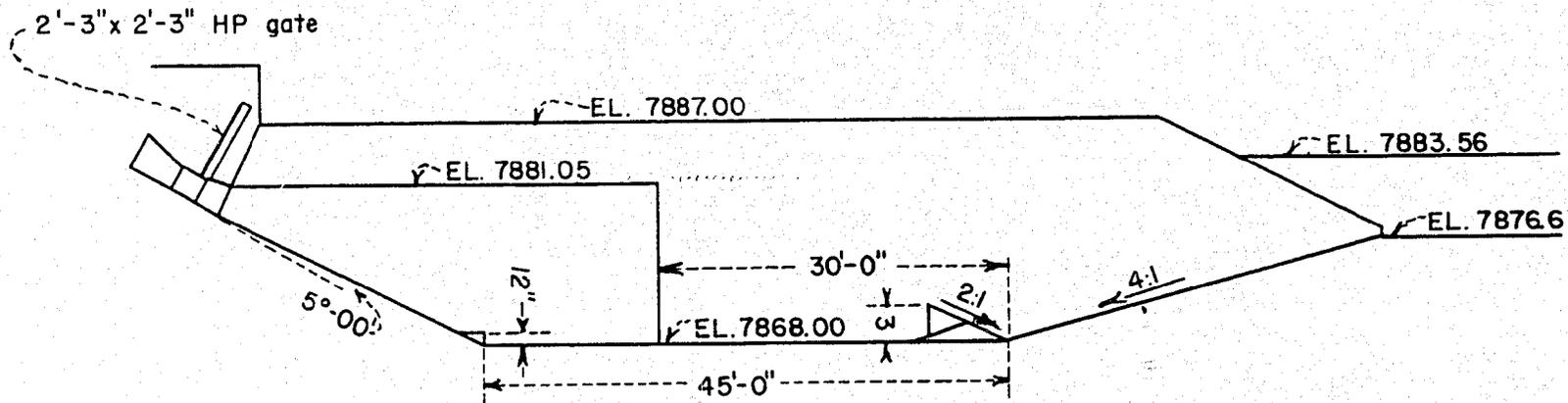
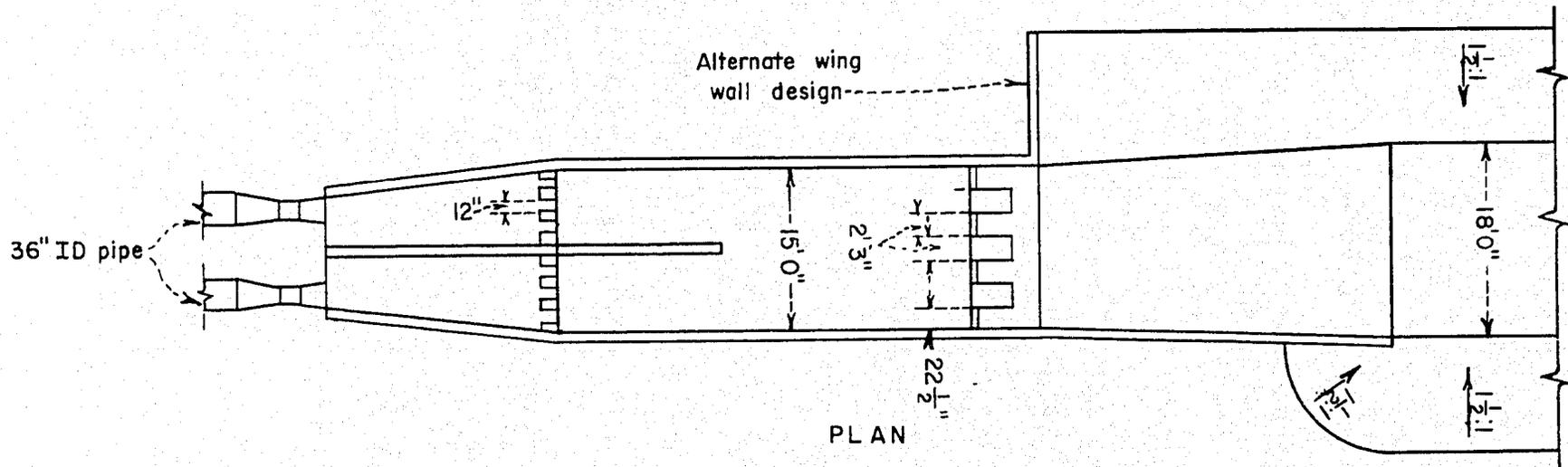
DAM-GENERAL PLAN AND SECTIONS 482-D-21
 SOUTHSIDE CANAL-STA 13+98.03 TO STA 18+95.46 482-D-36
 PLAN, PROFILE AND SECTIONS 482-D-25
 OUTLET WORKS-INTAKE STRUCTURE 482-D-26
 GATE CHAMBER 482-D-27
 CONTROL STRUCTURE 482-D-30
 51-INCH STEEL PIPE-PLAN AND PROFILE 482-D-31
 SUPPORT RINGS 482-D-32
 WYE BRANCH AND BENDS 482-D-32
 RUBBER WATERSTOPS 40-D-2867

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION COLLBRAN PROJECT - COLORADO	
VEGA DAM OUTLET WORKS PLAN AND SECTIONS	
DRAWN: J.E.W.	SUBMITTED: R.H. Whinnery
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CHECKED: G.T.S., L.M.R.	APPROVED: R.E. Keane
DENVER, COLORADO, MAY 4, 1938	
482-D-24	

FIGURE 3
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VEGA DAM OUTLET WORKS
The 1:11.25 Scale Model

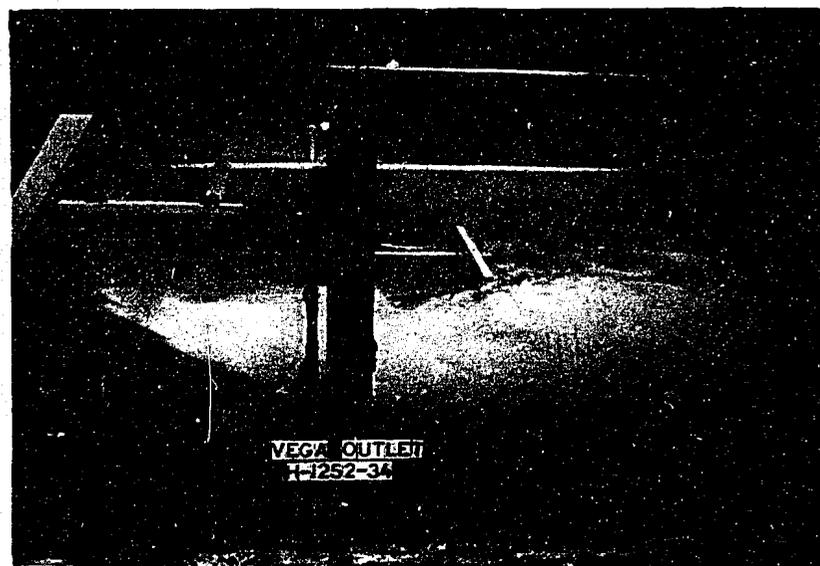


VEGA DAM OUTLET WORKS
PRELIMINARY BASIN DESIGN

1:11.25 SCALE MODEL

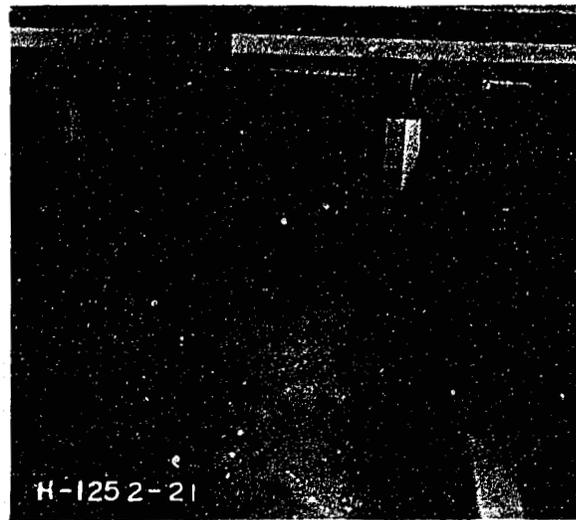


A. Discharge = 571 second feet
Both gates 100% open.



B. Discharge = 317 second feet
Right gate 100% open.

VEGA DAM OUTLET WORKS
Operation of Preliminary Basin
1:11.25 Scale Model



A. Spread of jet leaving H. P. gate.



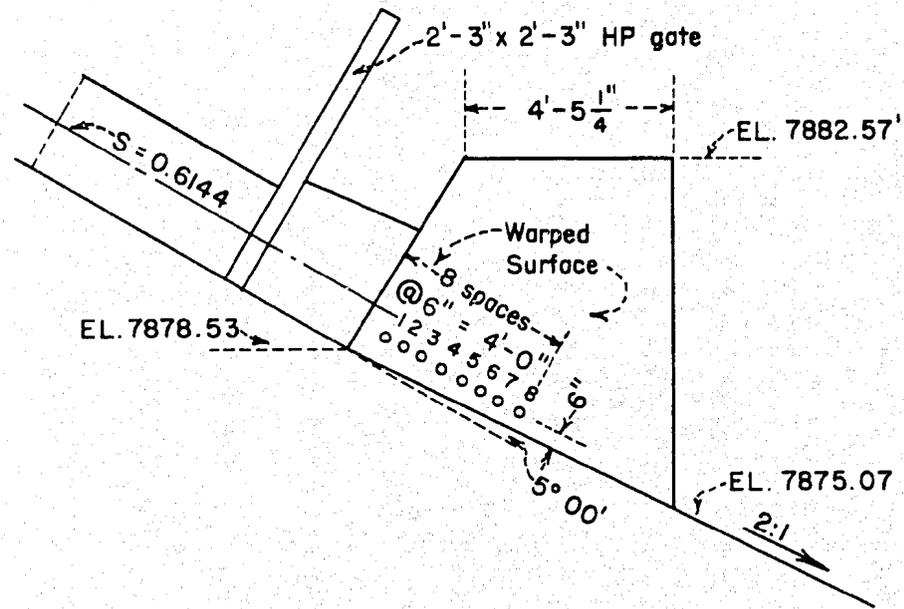
12-in. chute blocks and no baffle piers.



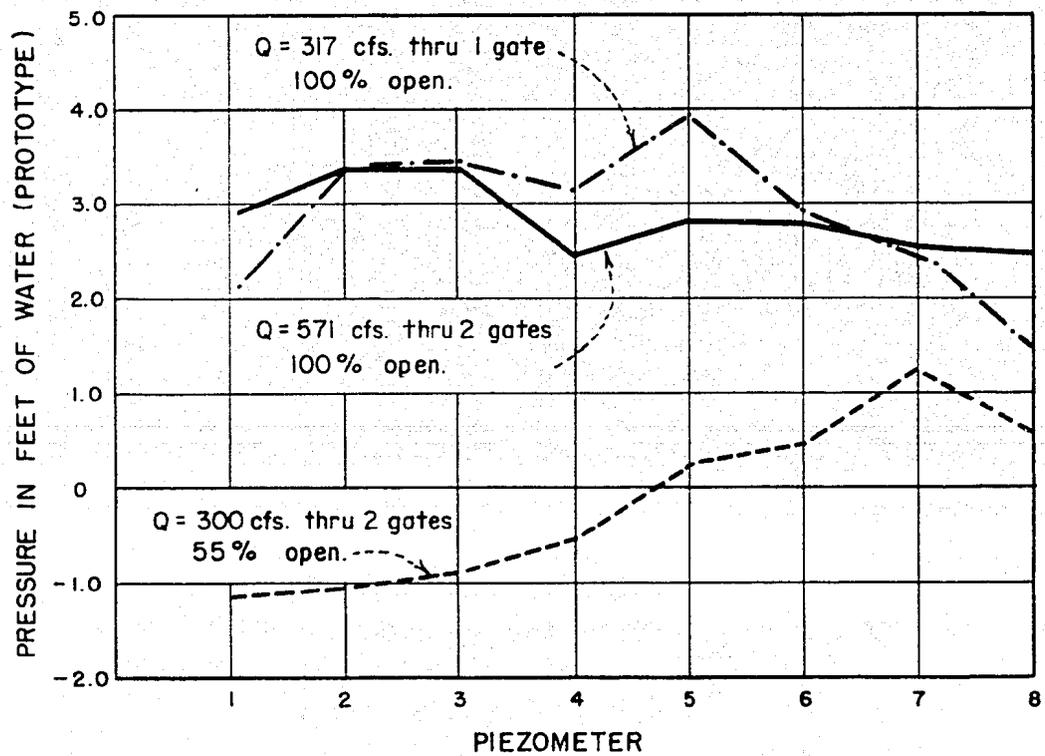
12-in. chute blocks and 4-ft. baffle piers.

Effectiveness of 12-in. chute blocks and 4-ft.
baffle piers.

VEGA DAM OUTLET WORKS
Spread of jet and effectiveness of baffle piers
Discharge = 317 second feet through right gate 100% open
1:11.25 Scale Model

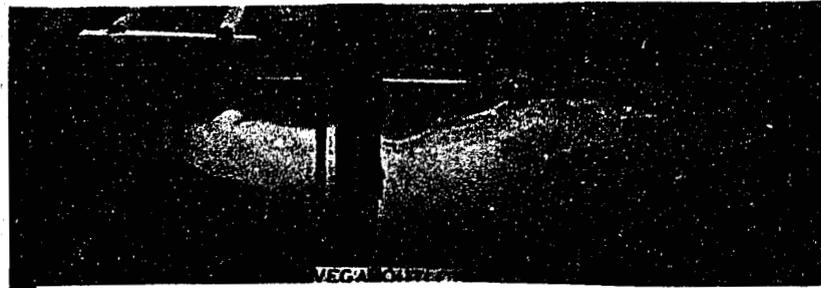


LOCATION OF PIEZOMETERS

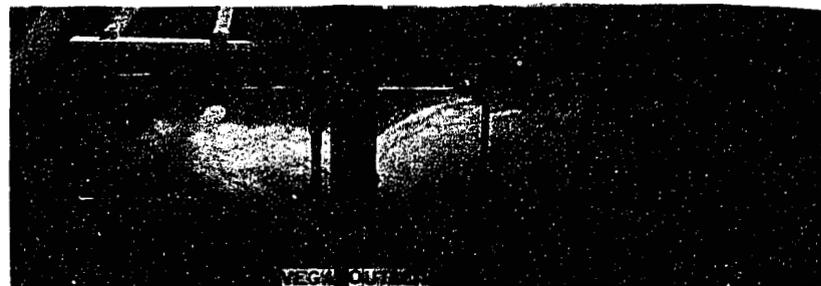


VEGA DAM OUTLET WORKS
PIEZOMETRIC PRESSURE ON WARPED WALLS
IMMEDIATELY DOWNSTREAM FROM GATE FRAME

1:11.25 SCALE MODEL



A. 2-ft chute blocks and no baffle piers



B. 2-ft. chute blocks and 4-ft. baffle piers.

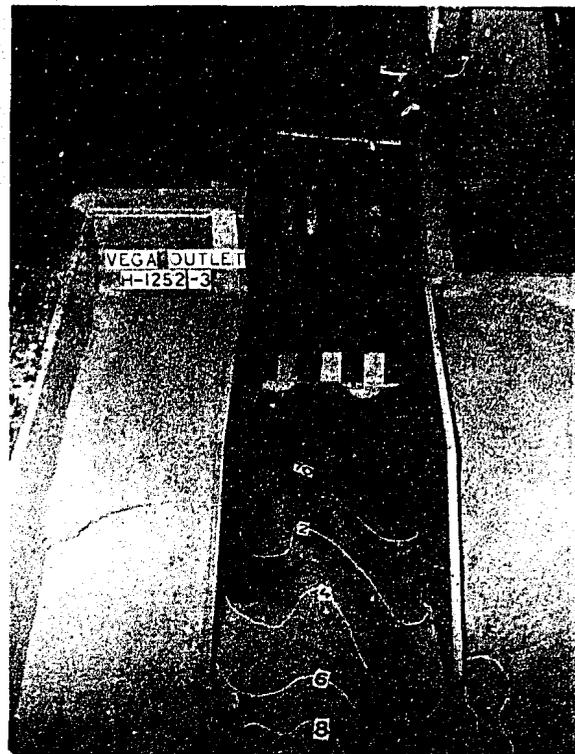


C. 3-ft. chute blocks and no baffle piers



D. 3-ft. chute blocks and 4-ft. baffle piers

VEGA DAM OUTLET WORKS
Effectiveness of Chute Blocks and Baffle Piers
Discharge = 317 second-feet through right gate
1:11.25 Scale Model



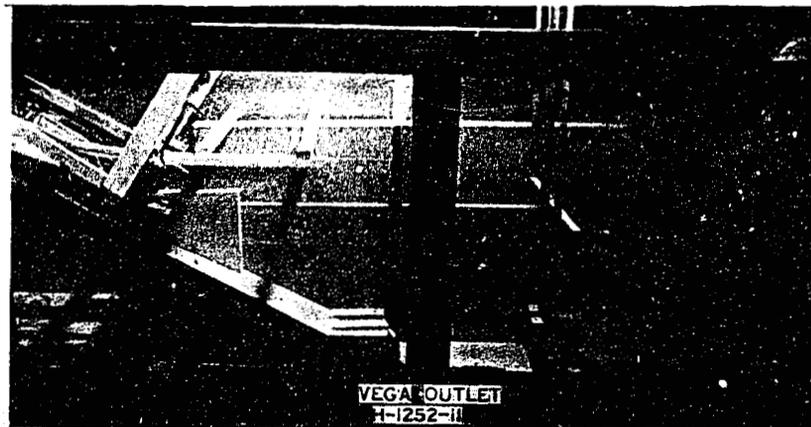
A. Erosion in outlet channel after
 $Q = 571$ cfs through both gates.



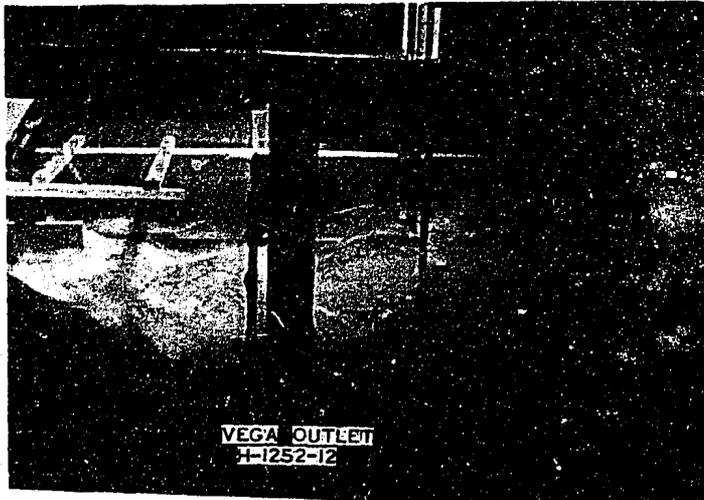
B. Basin floor raised two feet to El. 7870.
 $Q = 317$ cfs through right gate.

VEGA DAM OUTLET WORKS
Operation of Intermediate Basin Designs
1:11.25 Scale Model.

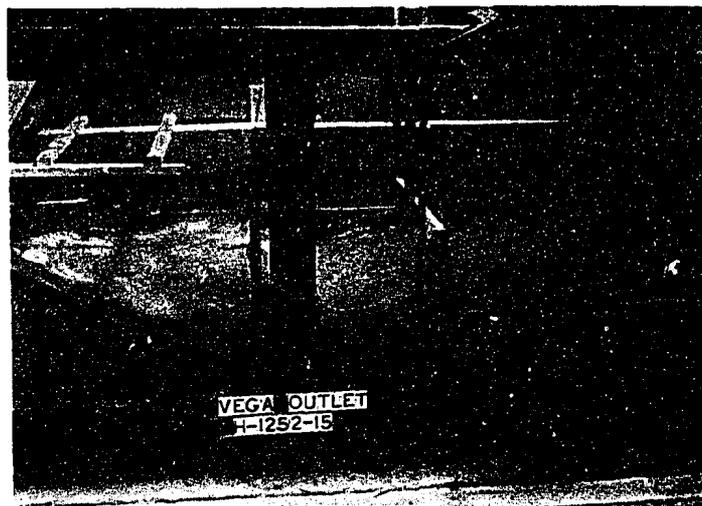
FIGURE 10
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VEGA DAM OUTLET WORKS
The Recommended Design
1:11.25 Scale Model

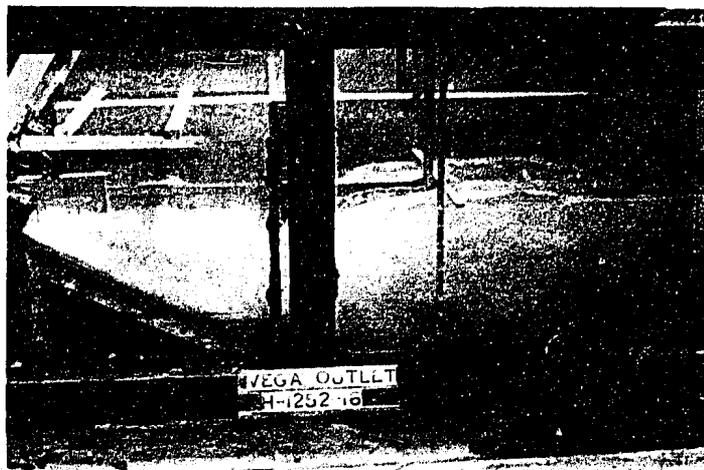


A. Discharge = 571 second feet.



B. Discharge = 300 second feet.

VEGA DAM OUTLET WORKS
Operation of the Recommended Design
Both gates 100% open
1:11.25 Scale Model

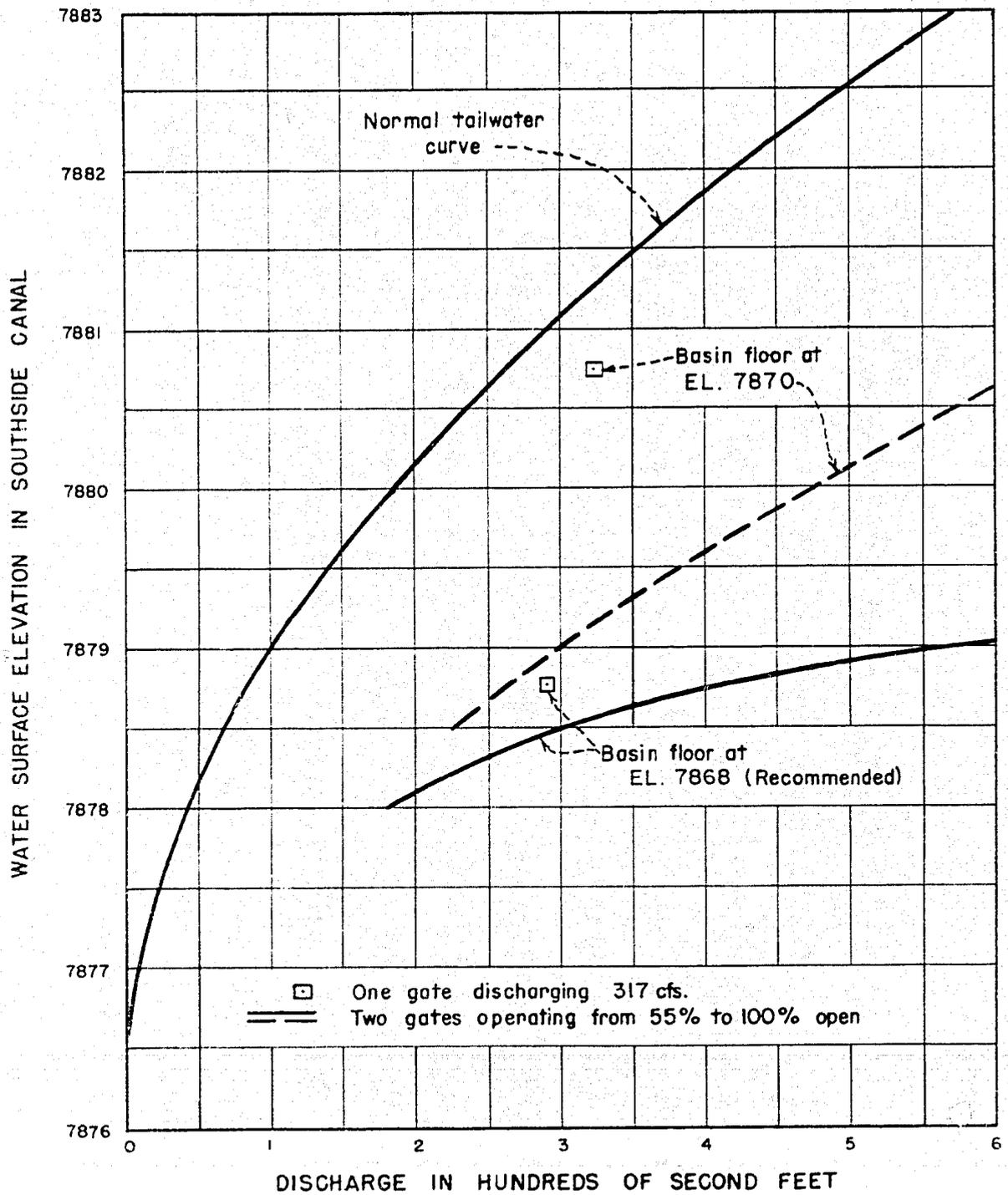


A. Discharge = 300 second feet through both gates 55% open.



B. Discharge = 317 second feet through right gate 100% open.

VEGA DAM OUTLET WORKS
Operation of the Recommended Design
1:11.25 Scale Model



Note: Basin equipped with chute blocks, 3 feet high, and preliminary end sill. No baffle piers.

VEGA DAM OUTLET WORKS
TAILWATER AND JUMP-SWEEPOUT CURVES

1:11.25 SCALE MODEL