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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF HOWARD PRAIRIE DAM OUTLET WORKS - TALENT DIVISION ROGUE RIVER BASIN PROJECT - OREGON

Hydraulic Laboratory Report No. Hyd-436

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
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Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and Equipment Section
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April 25, 1957

Laboratory Report No. Hyd-436
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Submitted by: H. M. Martin

Subject: Hydraulic model studies of Howard Prairie Dam Outlet Works--Talent Division--Rogue River Basin Project, Oregon

Hydraulic model studies of the Howard Prairie Dam Outlet Works were undertaken to develop an adequate stilling basin and to make certain that the flow entered the concrete-lined delivery canal with a minimum of waves and surges.

INTRODUCTION

Howard Prairie Dam is an earthfill structure located on Beaver Creek, Rogue River Basin, about 15 miles east of Ashland, Oregon (Figure 1). The dam embankment will be approximately 900 feet long at the crest and will rise about 88 feet above the creek bed.

The principal hydraulic features are the spillway and outlet works. The spillway, located at the left dam abutment and designed for a maximum discharge of 1,600 second-feet, will have a low overfall crest with a chute about 525 feet in length and a stilling basin (Figure 2).

The outlet works, designed for a maximum discharge of 100 second-feet, is located near the right abutment. The outlet works includes an intake structure, a 3-foot-diameter concrete conduit from the intake to the gate chamber, a 2-foot 3-inch by 2-foot 3-inch emergency gate, a 30-inch-diameter steel pipe from the gate chamber to the control house, a 2-foot 3-inch by 2-foot 3-inch high pressure regulating gate, and the stilling basin (Figure 3). Flow from the outlet works stilling basin enters a concrete-lined canal that conveys irrigation water to nearby farmland.

The model studies discussed herein were concerned with the portion of the outlet works downstream from the regulating gate. Specifically, the studies were made to investigate the distribution of flow from the gate, to test and develop an adequate stilling basin, and to determine if a wave suppressor was needed to minimize the waves and surges in the delivery canal.

Many of the results obtained from the model studies of Vega Dam Outlet Works 1/ were used in designing Howard Prairie Outlet Works because of the similarity between the two structures. However, the Froude number for Howard Prairie Outlet Works was higher than that for Vega Outlet Works and also above the range of Froude numbers used in developing the stilling basin design criteria contained in Hydraulic Laboratory Report No. Hyd-399.2/ Therefore, the model studies also served to check and extend the criteria of Hyd-399 so that it can be used in designing small outlet structures having Froude numbers between 20 and 25.

THE MODEL

The model, constructed to a geometrical scale of 1:11.25, included the control gate, chute, stilling basin, and about 40 feet of the lined delivery canal (Figure 4). The elbow and conduit upstream from the control gate, where no adverse flow problems were anticipated, were represented in the model by a 3-inch-diameter flexible hose leading from a pressure tank, a circular-to-square transition, and a section of square conduit to which the control gate was attached. The chute, stilling basin, and delivery canal were constructed of 3/4-inch plywood in an existing tail box with glass on one side to permit observation of the stilling action.

Water to the model was measured with an orifice meter, and the pressure head at the gate was measured by piezometers located the equivalent of 2 feet 3 inches upstream from the gate. Proper tail water elevations were set in the model by means of an adjustable gate.

THE INVESTIGATION

General

Because the downward tilt of the slide gate, the slope of the chute floor, and the divergence of the training walls of Howard Prairie and Vega Outlet Works were identical, no detailed testing of the flow from the gate was made, and visual observations were used to assure no adverse flow distribution existed in the chute. The adequacy of the

1/Report No. Hyd-418, Hydraulic Model Studies of Vega Dam Outlet Works, Bureau of Reclamation, September 1956.

2/Report No. Hyd-399, "Progress Report II, Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances," Bureau of Reclamation, June 1955.

stilling basin was evaluated by observing the stilling action and by measuring the height of the waves in the center of the delivery canal 20 feet downstream from the structure. In this study, the height of waves was the difference in feet between the maximum crest and the minimum trough measured over a prototype time period of 2-1/2 minutes.

To cover the complete range of operating conditions, the model was operated at four discharges: 60 second-feet at normal reservoir elevation of 4495.06 and 100, 60, and 32.5 second-feet at the maximum reservoir elevation of 4533.1. Gate openings for these discharges ranged from 17 percent for 32.5 second-feet to 52 percent for 100 second-feet. The most critical operating condition for the stilling basin was 100 second-feet at maximum reservoir elevation 4533.1.

Preliminary Design

The model was initially constructed to represent the preliminary design (Figures 4A and 5). In general, the operation of the stilling basin was fair for all discharges. The chute blocks were well covered and the jump was fairly stable (Figure 4B). However, surface waves and flow surges were prevalent in the downstream canal. Waves in the canal measured 0.34 foot for the maximum discharge of 100 second-feet. For discharges of 32.5 and 60 second-feet at normal reservoir elevation, the beginning of the jump submerged the downstream gate frame. Also, at the higher discharges, 60 to 100 second-feet, the gate frame was intermittently submerged, causing a surging action in the jump (Figure 4B).

Studies to Prevent Gate Submergence

It was desirable that the gate operate unsubmerged to eliminate possibilities of low pressures in the downstream gate frame and to reduce the amount of surging in the stilling basin. The obvious means of preventing submergence was to either raise the gate or lower the canal water level sufficiently to permit the gate to operate freely at all discharges. However, the elevations of the outlet conduit and the canal were fixed. The gate could be raised slightly by changing the radius of the bend upstream from the gate, but computations showed that a still higher elevation was needed to prevent submergence for all flows.

The decision was made, therefore, to develop a curtain wall which would permit the gate flow to pass under the wall and which would prevent the tail water from returning to the gate frame. Several tests were made using curtain walls of various heights. Results of these tests showed that a curtain wall placed at Station 4+92.50 (Figure 3) with a bottom elevation of 4465.75 prevented backflow from the stilling basin and provided an opening large enough to pass all gate flows without striking the wall. The top of the curtain wall was placed at elevation 4470.50 to provide a 2-foot-high passage for air between the curtain wall and the floor of the control house.

Baffle Pier Studies

The operation of the preliminary basin (Figure 4B) indicated that the baffle piers offered insufficient resistance to the incoming flow. The boil above the piers was negligible and the bulk of the turbulent flow remained near the basin floor throughout the basin length. It appeared that a more stable jump and better energy dissipation of the incoming flow would be obtained if larger baffle piers were installed in the basin.

Because the piers were relatively high in terms of d_1, the 2-foot 9-inch height in the preliminary design was maintained, and changes were made in the width and number of piers to increase the resistance to the flow. Initial tests were made with round- and square-faced piers, 11 and 15 inches wide, placed 10 feet downstream from the chute blocks.

It is interesting to note that the shape of the pier face greatly influenced the effectiveness of the baffle piers in resisting the high velocity flow (Figure 6). The 11-inch-wide square-faced piers offered more resistance to the flow than the round-faced piers, as evidenced by the flatter slope of the jump surface and the lack of turbulence near the basin floor at the downstream end of the stilling basin (Figure 6A). The difference in operation between round- and square-faced piers was even more pronounced when piers 15 inches wide were placed in the model (Figure 6B). Wave heights measured at a discharge of 100 second-feet with the 11-inch-wide piers installed were 0.34 foot for the round-faced piers and 0.28 foot for the square-faced piers. Wave heights for the 15-inch-wide round- and square-faced piers were 0.15 and 0.11 foot, respectively.

Because the maximum incoming flow velocity would be about 60 feet per second, it was desirable to use piers with a rounded upstream face to minimize the possibilities of cavitation pressures along the pier boundaries. Therefore, subsequent studies were made using round-faced piers, 2 feet 9 inches in height.

The stilling basin performance with the 15-inch-wide piers installed was satisfactory and acceptable (Figure 6B). A good stable jump formed in the basin, and waves 0.15 foot high were measured in the downstream canal. It was found necessary to install two rows of baffle piers 11 inches wide to form a satisfactory jump. Tests made with 3 piers placed 7 feet 6 inches and 2 piers placed 12 feet downstream from the chute blocks showed that the upstream row offered too much resistance to the flow and caused a large boil to form above the baffle piers. Waves measured in the canal with this arrangement were 0.10 to 0.14 foot high, or slightly lower than those observed with 1 row of 15-inch-wide piers.

Tests were also made with the 2 rows of 11-inch-wide baffle piers interchanged, that is, with 2 piers in the upstream row and 3 piers in the downstream row (Figure 7A). The stilling basin performance was very good with this arrangement (Figure 7B). The jump was stable, and the turbulence was well distributed in the stilling basin. Waves measured in the canal varied from 0.10 to 0.14 foot in height for discharges from 32.5 to 100 second-feet.

From the above tests, it appeared that the stilling basin performance was very similar when either two 15-inch-wide baffles or five 11-inch-wide baffles were installed in the basin. However, the wave heights were slightly lower, and slightly better distribution of the turbulence was obtained with the five piers. Therefore, it is recommended that 5 piers, 11 inches wide, be placed in 2 rows in the basin (Figure 7A).

<u>Wave Suppressor Studies</u>

To further reduce the wave heights in the canal, tests were made with a wave suppressor installed at the downstream end of the basin (Figure 5). Small boils and bubbles of air appeared downstream from the suppressor at the higher flows, indicating that the suppressor should not be placed in a turbulent part of the jump. Even so, the height of the waves in the canal was reduced to 0.07 foot for a discharge of 100 second-feet.

The wave suppressor was moved downstream into the basin exit transition with the bottom surface of the suppressor parallel to and 5.46 feet above the sloping floor of the transition (Figure 3). The wave heights were reduced to 0.05 foot for the maximum discharge of 100 second-feet and to 0.03 and 0.02 foot for discharges of 60 and 32.5 second-feet. The jump turbulence was confined to the stilling basin and only at maximum flow did air bubbles pass under the suppressor.

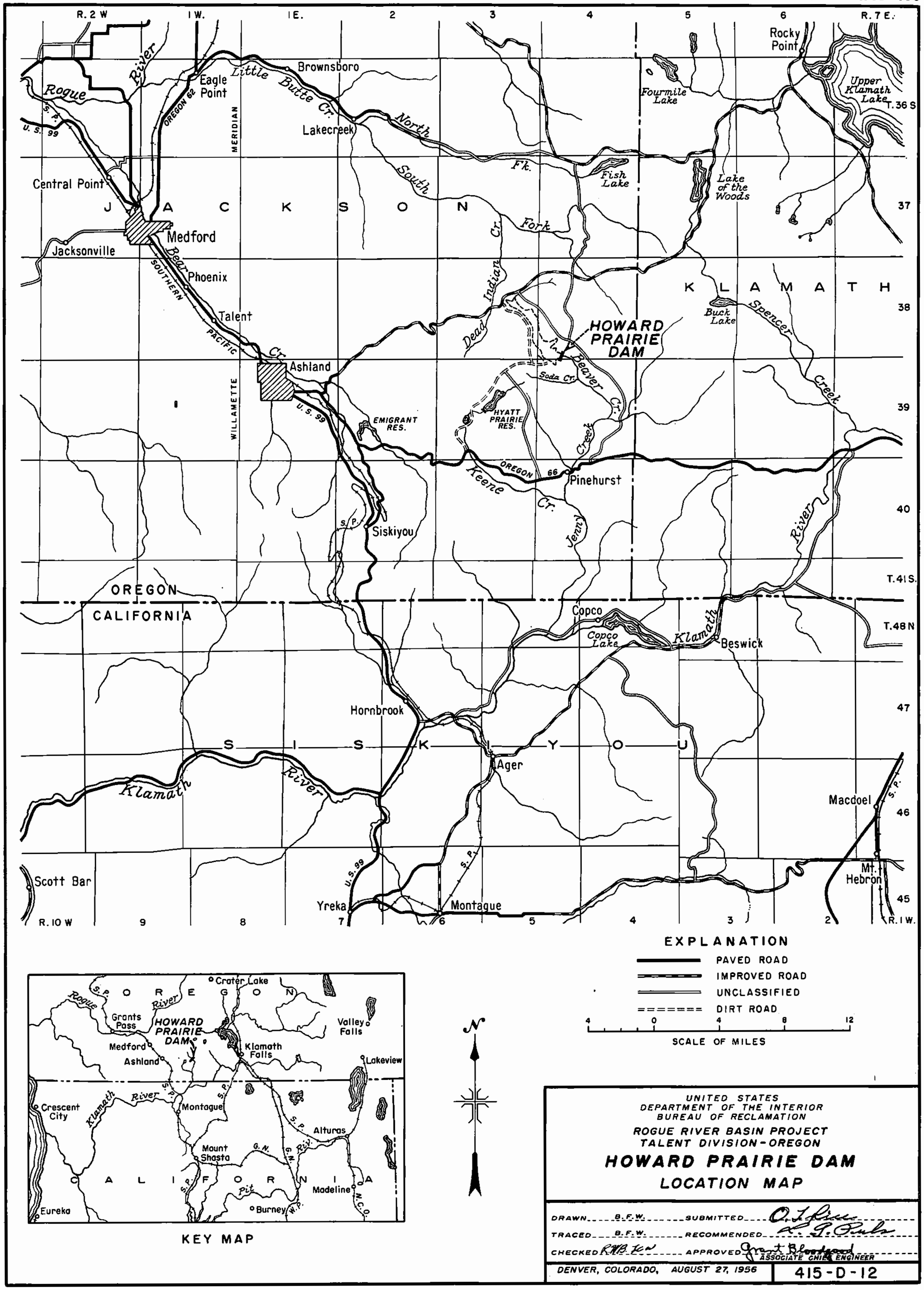
Without the wave suppressor, the waves in the canal were comparatively small (maximum of 0.14 foot in height). The concrete-lined canal was designed with 6 inches of freeboard, which appeared ample to confine the waves in the lined portion of the canal. The need for a wave suppressor was therefore questionable. However, a bridge across the stilling basin was needed to provide access to a parking area at the left of the structure. Because the wave suppressor could be combined with the bridge at very little additional cost, the wave suppressor was included.

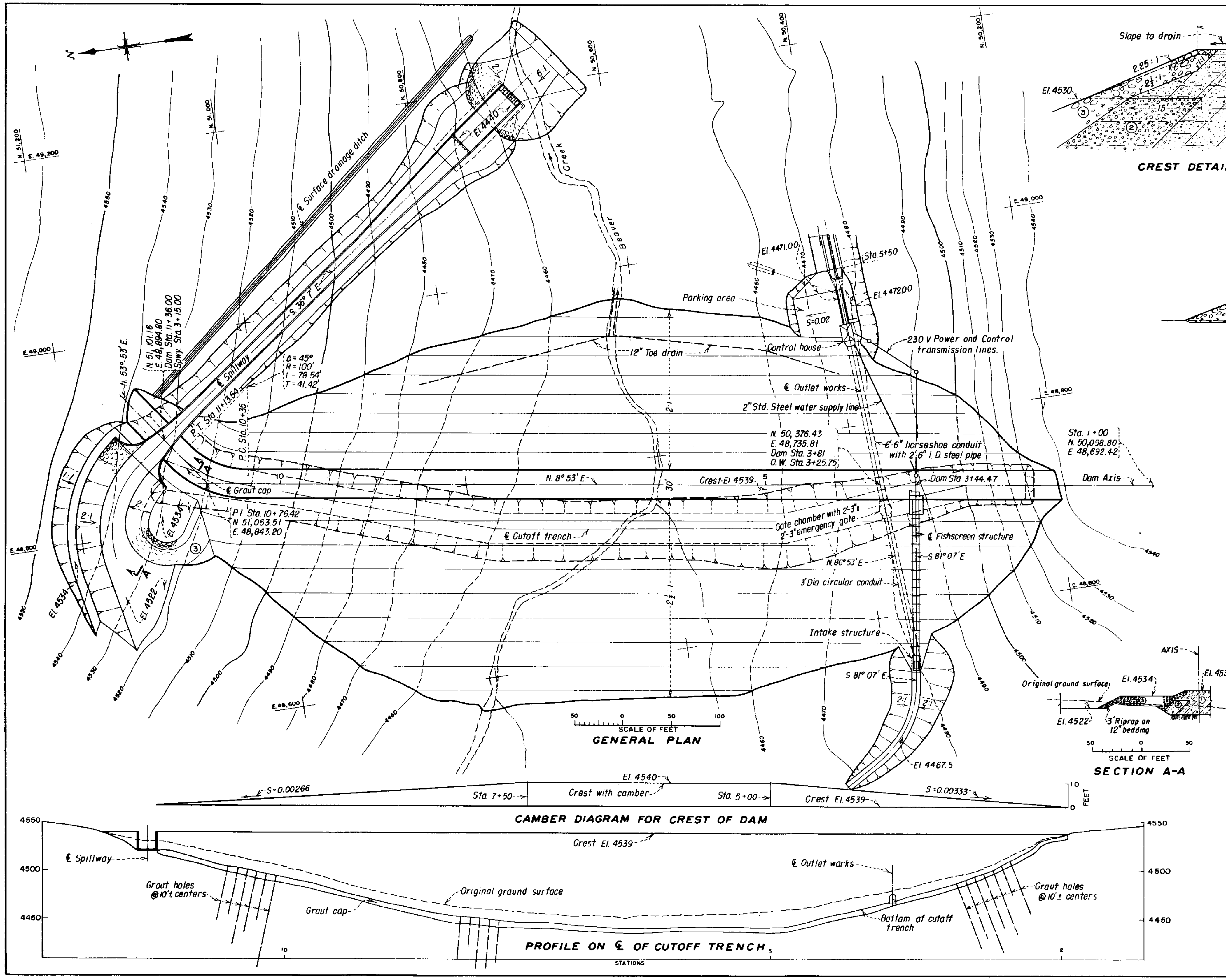
The operation of the recommended design for discharges of 100, 60, and 32.5 second-feet is shown in Figures 8 and 9. A recapitulation of the wave heights measured with the various baffle pier arrangements and wave suppressors is shown in the following table.

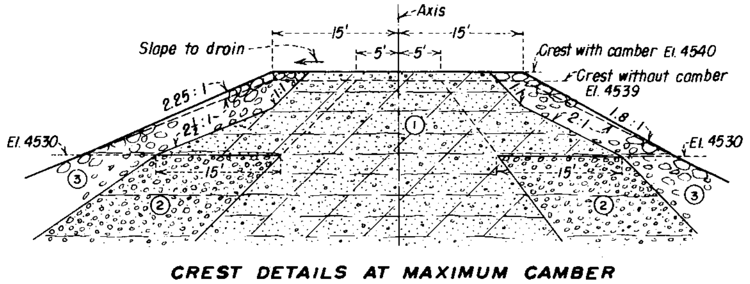
RECAPITULATION OF WAVE HEIGHTS

Baffle pier arrangement \ Discharge and res el	Height of waves			
	60 4495.1	60 4533.1	32.5 4533.1	100 4533.1
Preliminary				
2 rd-faced, 11" piers 10' from chute				0.34
2 sq-faced, 11" piers 10' from chute				.28
2 rd-faced, 15" piers 10' from chute				.15
2 sq-faced, 15" piers 10' from chute				.11
3 rd-faced, 11" piers at 7' 6" and two 11" piers at 12'		0.10		.14
2 rd-faced, 11" piers at 7' 6" and three 11" piers at 12'	0.10	.14	0.10	.14
Same as above but with wave suppressor in basin				.07
Same as above but with wave suppressor in transition	.03	.03	.02	.05

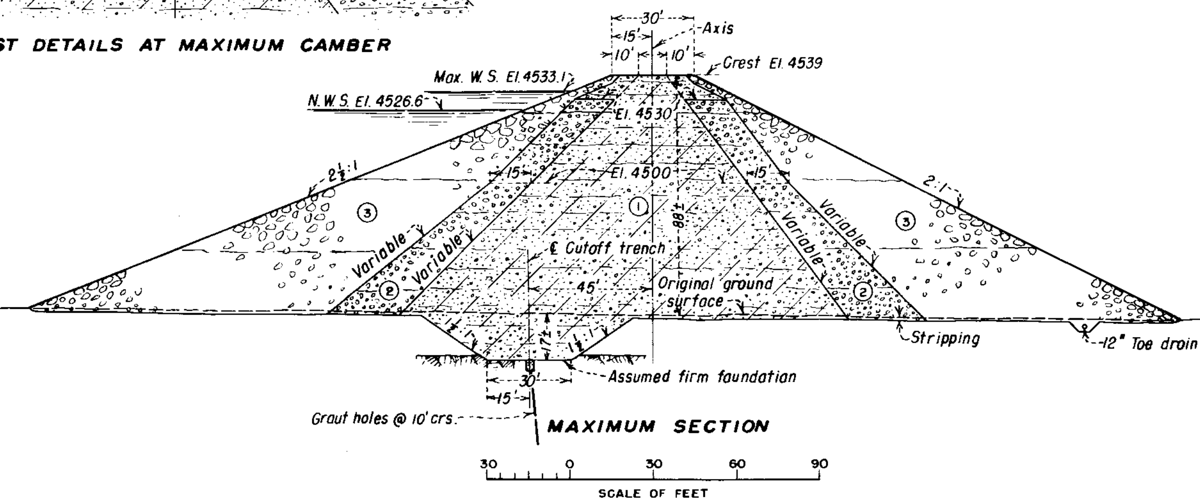
FIGURE 1
REPORT HYD 436

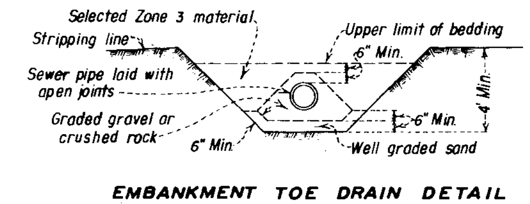


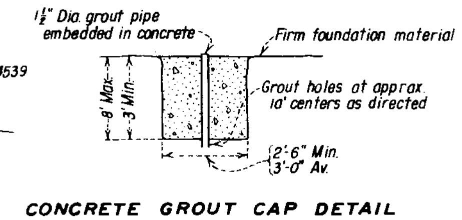


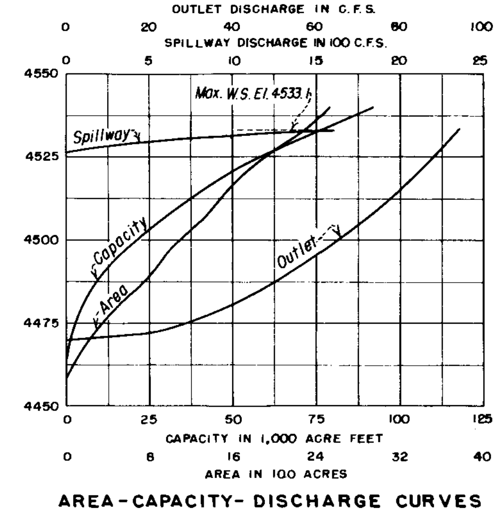


EMBANKMENT EXPLANATION
1. Selected clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers
2. Selected rock fines compacted by crowler-type tractor to 12-inch layers
3. Rock fill placed in 3-foot layers









RESERVOIR ALLOCATION

PURPOSE	ELEVATION	STORAGE ACRE FEET
Irrigation & Power	4471.0 to 4526.6	60,500
Dead storage	Streambed to 4471.0	1,500
Total storage capacity		62,000

A surcharge of 14,000 A.F. (Max. W.S. El. 4533.1) in combination with spillway capacity of 1600 c.f.s. and outlet capacity of 95 c.f.s. is provided to protect against the inflow design flood having a peak of 7000 c.f.s. and a 5 day volume of 19,800 acre feet

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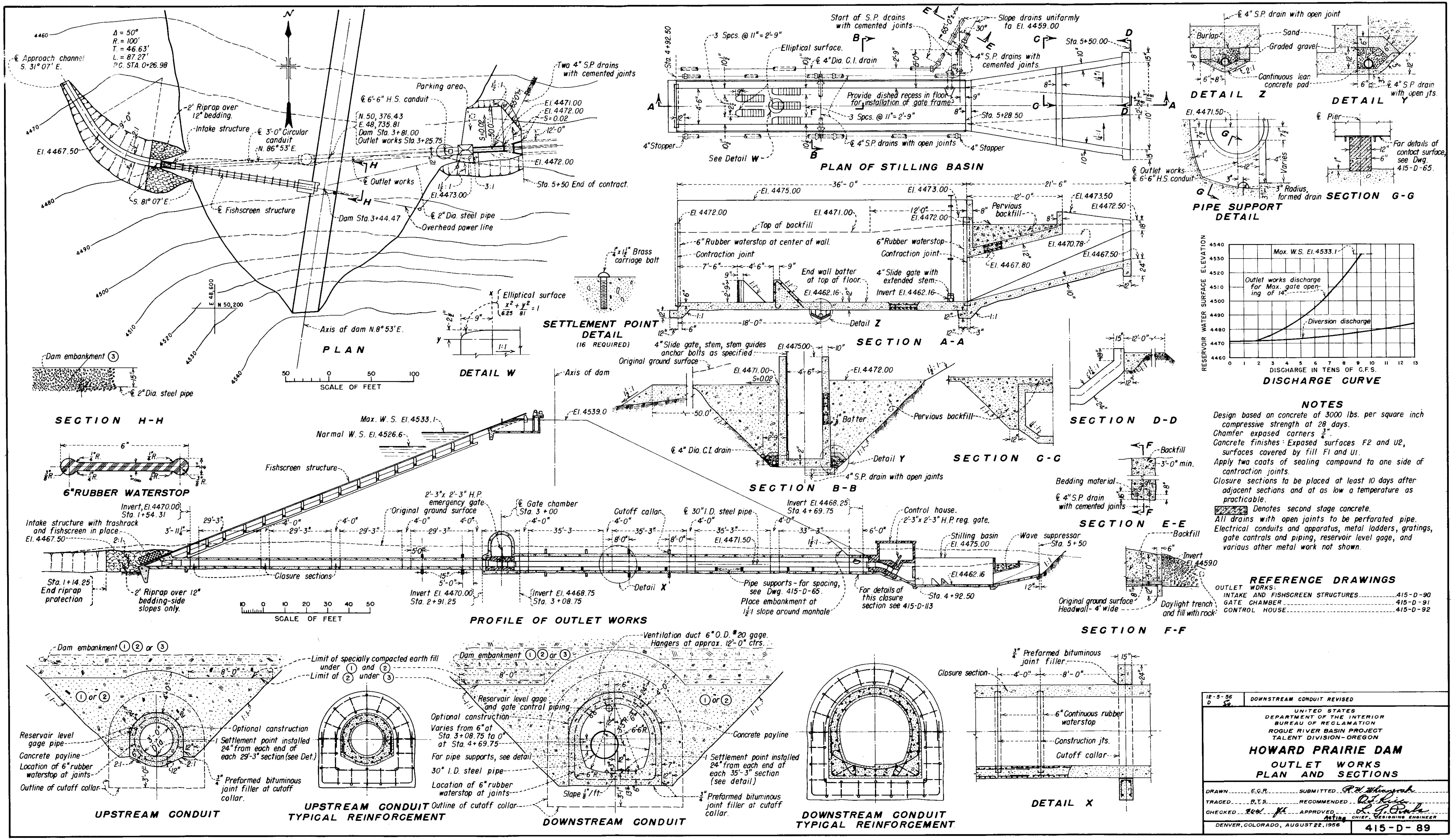
ROGUE RIVER BASIN PROJECT
TALENT DIVISION-OREGON

HOWARD PRAIRIE DAM

GENERAL PLAN AND SECTIONS

DRAWN TE SUBMITTED
TRACED N.R.W. RECOMMENDED
CHECKED APPROVED
ASSOCIATE CHIEF ENGINEER
DENVER, COLORADO AUG. 27, 1956

415-D-13


PLAN
SCALE OF FEET
DETAIL W
SETTLEMENT POINT DETAIL
(16 REQUIRED)
SECTION H-H
6" RUBBER WATERSTOP
PLAN OF STILLING BASIN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
DETAIL Z
DETAIL Y
PIPE SUPPORT DETAIL
SECTION G-G
DISCHARGE CURVE
RESERVOIR WATER SURFACE ELEVATION
DISCHARGE IN TENS OF C.F.S.
Max. W.S. El. 4533.1
Outlet works discharge for Max. gate opening of 14"
Diversion discharge
PROFILE OF OUTLET WORKS
DETAIL X
UPSTREAM CONDUIT
UPSTREAM CONDUIT TYPICAL REINFORCEMENT
DOWNSTREAM CONDUIT
DOWNSTREAM CONDUIT TYPICAL REINFORCEMENT
NOTES
Design based on concrete of 3000 lbs. per square inch compressive strength at 28 days.
Chamfer exposed corners 3/4".
Concrete finishes: Exposed surfaces F2 and U2, surfaces covered by fill F1 and U1.
Apply two coats of sealing compound to one side of contraction joints.
Closure sections to be placed at least 10 days after adjacent sections and at as low a temperature as practicable.
Denotes second stage concrete.
All drains with open joints to be perforated pipe.
Electrical conduits and apparatus, metal ladders, gratings, gate controls and piping, reservoir level gage, and various other metal work not shown.
REFERENCE DRAWINGS
OUTLET WORKS:
INTAKE AND FISHSCREEN STRUCTURES 415-D-90
GATE CHAMBER 415-D-91
CONTROL HOUSE 415-D-92
12-5-56 DOWNSTREAM CONDUIT REVISED
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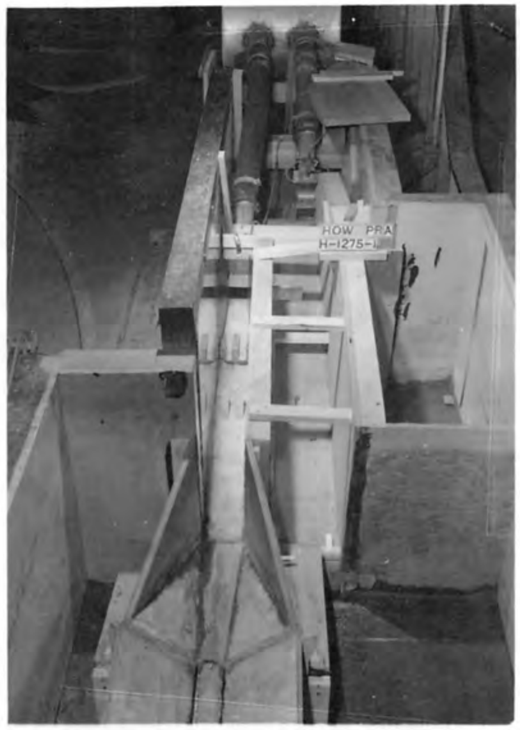
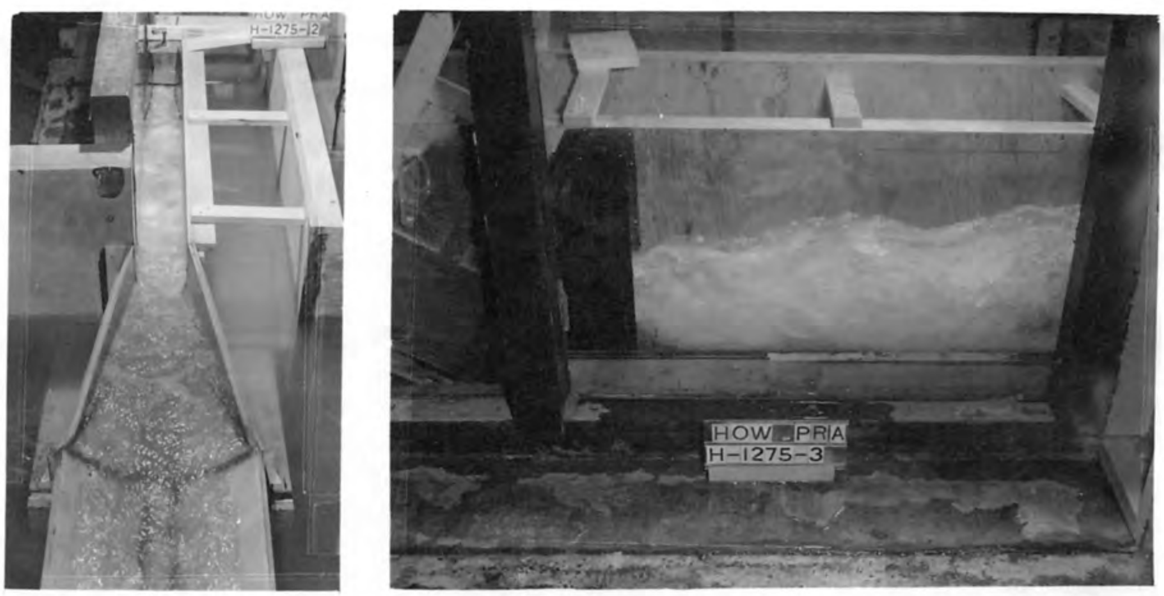
ROGUE RIVER BASIN PROJECT
TALENT DIVISION-OREGON
HOWARD PRAIRIE DAM
OUTLET WORKS
PLAN AND SECTIONS
DRAWN E.G.R. SUBMITTED
TRACED R.T.S. RECOMMENDED
CHECKED APPROVED
Acting CHIEF, DESIGNING ENGINEER
DENVER, COLORADO, AUGUST 22, 1956
415-D-89

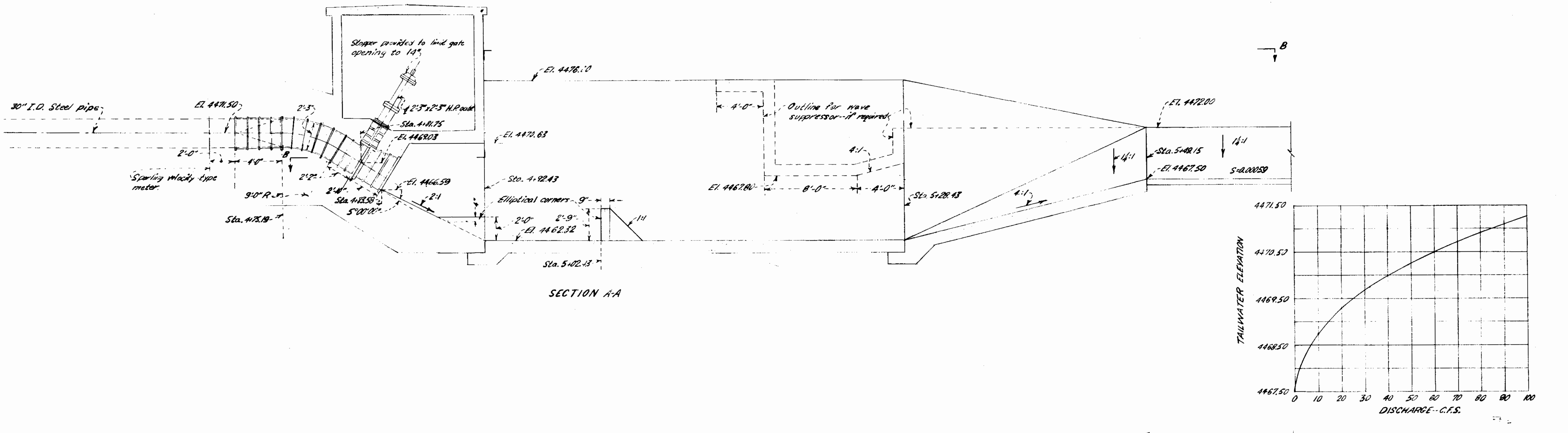


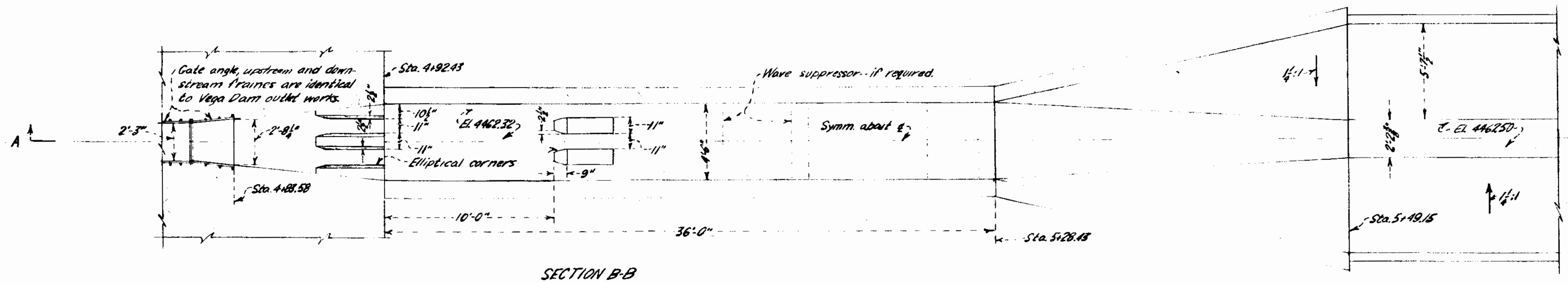
A. The Model



B. Discharge = 100 second-feet

HOWARD PRAIRIE DAM OUTLET WORKS
Preliminary Design
1:11.25 Scale Model





NOTES

Operating criteria for model study:

Discharge(c.f.s.)	Gate opening--% of total travel	Res. W.S. Elev.	Head at ℄ gate(ft)
60	~~69.4~~ 51.9	~~4491.9~~ 4495.6	20.0
100	51.9	4533.1	55.6
32.5	17.0	4533.1	61.3
60	31.0	4533.1	62.6

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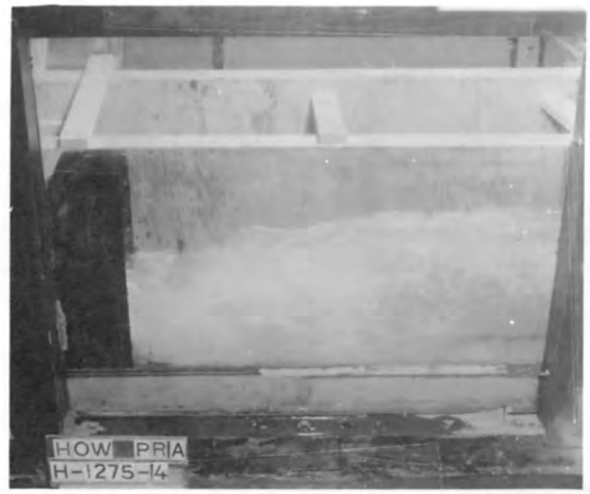
TALENT DIVISION
HOWARD PRAIRIE DAM
OUTLET WORKS
STILLING BASIN

DRAWN F.V.W. SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED

415-D0-7

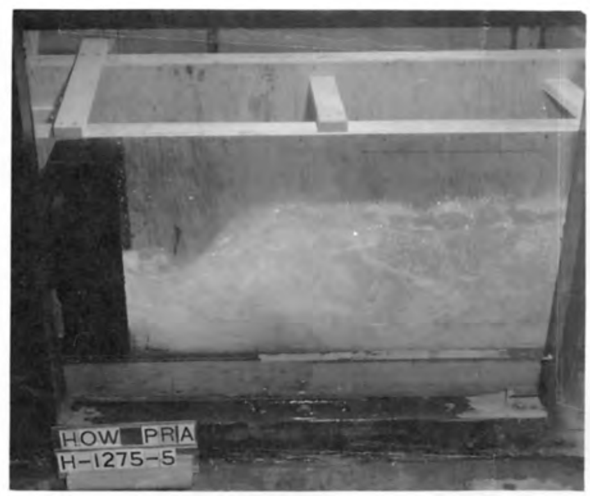
Round-faced piers



Square-faced piers

A. Two baffle piers, 11 inches wide, placed 10 feet downstream from chute blocks.

Round-faced piers



Square-faced piers

B. Two baffle piers, 15 inches wide, placed 10 feet downstream from chute blocks.

HOWARD PRAIRIE DAM OUTLET WORKS
Baffle Pier Studies
Discharge = 100 second-feet. Res. El. = 4533.1
1:11.25 Scale Model

A. Recommended Basin

B. Discharge = 100 cfs, Res. El. = 4533.1

HOWARD PRAIRIE DAM OUTLET WORKS
Recommended Basin
Without Wave Suppressor
1:11.25 Scale Model

Wave Suppressor Installation

Discharge = 100 cfs, Res. El. = 4533.1

HOWARD PRAIRIE DAM OUTLET WORKS
Recommended Basin With
Wave Suppressor in Outlet Transition
1:11.25 Scale Model

Discharge = 60 cfs, Res. El. = 4533.1

Discharge = 60 cfs, Res. El. = 4495.0

Discharge = 32.5 cfs, Res. El. = 4533.1

HOWARD PRAIRIE DAM OUTLET WORKS
Operation of Recommended Basin With
Wave Suppressor in Outlet Transition
1:11.25 Scale Model