UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES ON THE SPILLWAY FOR CASCADE DAM

BOISE PROJECT

Hydraulic Laboratory Report Hyd.-234

ENGINEERING AND GEOLOGICAL
CONTROL AND RESEARCH DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

NOVEMBER 7, 1947

HYD-234

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HYD 234

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
November 7, 1947

Laboratory Report No. Hyd-234
Hydraulic Laboratory
Compiled by: B. R. Blackwell
Reviewed by: A. J. Peterka

Subject: Hydraulic model studies on the spillway for Cascade Dam--Boise Project.

SUMMARY

Model studies of the Cascade Spillway were made to investigate flow conditions in the spillway approach, the gate section, the chute, and the stilling-pool, and to modify the structure where necessary to provide an economical and satisfactorily operating structure.

The hydraulic model studies indicated that the approach to the spillway gave satisfactory though somewhat unsymmetrical flow conditions. Both the high and the low crest designs will pass slightly more than the required discharges. Changes in the slope and width of the chute are recommended in order to improve flow conditions. A diffuser-type bucket energy dissipator was found to give the required protection to the Pacific Power Company's wood stave penstock.

DESCRIPTION OF THE PROJECT

The Cascade Dam, Boise Project, Idaho, is located on the North Fork of the Payette River near Cascade, Idaho, as shown on the location map, Figure 1. The earthfill dam will be approximately 800 feet long at the crest with a maximum height of 80 feet above the riverbed. The open channel spillway is to be located on the right abutment of the dam. The spillway flow, 12,500 second-feet maximum, will be controlled by two 21- by 20-foot radial gates. Flow through the low level outlets, 2,800 second-feet maximum, will be controlled by two 5-foot square high-pressure slide gates. The general plan of the project is shown in Figure 2.

DESCRIPTION OF THE MODEL

The Cascade Spillway model was constructed in the Hydraulic Laboratory at the Denver Federal Center to a scale of 1 to 30. The model layout, recommended design, is shown in Figure 3. The original model was designed and constructed according to the plan and sections of the spillway shown in Figure 4. Photographs of the model, recommended design, are shown in Figure 5. In the original design the crest was at elevation 4808 with normal reservoir at elevation 4828. A proposed future addition to the project is a high crest at elevation 4823 which will raise the normal reservoir to elevation 4843. The same radial gates will be used on both the high and the low crest.

THE INVESTIGATION

The Spillway Approach

The approach to the spillway is slightly unsymmetrical as indicated in Figure 4. This results in somewhat unsymmetrical flow conditions in the chute. This condition is minor in nature and no change in the approach is recommended. The approach in the model for the high and low crests, is shown in Figure 6. Flow in the approach section, high and low crests, is shown in Figure 7 for the maximum discharge of 12,500 second-feet.

The Gate Section

The coefficient of discharge used for the design of the low crest was 3.33. Model calibration showed the coefficient to be 3.40. The coefficient of discharge for the high crest with the reservoir at elevation 4843 was found by model calibration to be 3.67. Both crests will therefore pass somewhat more than the required discharges. Discharge curves for the low crest are given in Figure 8 and for the high crest in Figure 9.

The Chute

Two chute designs were tested in the model. In the original design, Figure 4, the principal slope of the chute floor was 0.373. The chute width decreased from 45 feet at Station 3+19.81 to 20 feet at Station 4+75.00 with the 20-foot width continuing to the end of the chute, Station 5+55.00. In the revised design, Figure 3, the principal slope of the chute floor was increased to 0.463, and the convergence of the chute walls was decreased from that in the original design. The chute width decreased from 45 feet at Station 3+19.81 to 20 feet at the end of the chute, Station 5+55.00. Both the increased slope and the increased width in the central portion of the chute contributed to the smoother flow conditions observed in model operation of the revised design. Water surface profiles in the final chute design for both the high and low crests with one and two gates open are shown in Figures 10, 11, 12, and 13. Figures 11 and 13 show the slightly unsymmetrical flow in the chute resulting from the unsymmetrical approach to the spillway.

The Stilling-Pool

General. The primary consideration for satisfactory operation of the stilling-pool is the protection of the 72-inch wood stave penstock of the Pacific Power Company located across the river from the spillway, Figures 2 and 5. Three types of chute outlets were tested in the model. Straight and curved chute outlets did not give adequate protection to the penstock. A diffuser bucket gave satisfactory results.

Straight chute outlet. Straight chute outlets at elevation 4745.0 and 4751.5 were tested in the model. Figure 4 shows the details of the outlet at elevation 4745.0. In both cases the jet from the spillway crossed the river and climbed the opposite riverbank with practically no dissipation of energy. Model operation is shown in Figures 14 and 15.

Curved chute outlets. In an attempt to keep the spillway jet away from the penstock, numerous curved chute outlets were tried. The curved outlets were successful in keeping the jet along the right bank but resulted in extremely rough surface conditions at the railroad bridge downstream, and a very damaging upstream eddy over the penstock. These unsatisfactory flow conditions are shown in Figure 16.

Attempts were made, using the curved chute outlet, to direct the flow down the center of the river, and thus avoid the damaging upstream eddies. The jet, directed to the center of the river, was unstable. It either swung across the river and climbed the bank over the penstock, or it followed the right bank causing an upstream eddy along the left bank and the penstock. Even for the brief periods that the jet stayed in the center of the river, flow conditions were very rough.

Diffuser bucket. A diffuser-type-bucket outlet gave satisfactory flow conditions. Disturbances in the vicinity of the penstock were at a minimum and flow downstream in the river was smooth. All diffuser buckets tests were made with the chute outlet at elevation 4745.0. The first diffuser bucket, Figure 17, extended 30 feet downstream to Station 5+81.5 and was 10 feet high. Model operation is shown in Figure 18. Observation of this operation indicated that the jet should have a greater spread with a shorter trajectory in order to give maximum protection to the penstock.

To accomplish this result, the following items were changed as indicated:

1. The base width of the chute at the outlet was increased.
2. The length of the lip of the diffuser bucket was increased.
3. The height and steepness of the lip of the bucket was increased.
4. The length of the bucket from the end of the chute was decreased.
5. The side slopes were adjusted.

From a series of tests incorporating the above changes, the recommended design of diffuser bucket was evolved, Figure 17. The recommended bucket extended 20 feet downstream to Station 5+71.5 and was 12.5 feet high. This bucket spread the jet and shortened the trajectory giving satisfactory protection to the penstock. The trajectory of the jet for various discharges is shown in Figure 19. For small discharges, the bucket acts as a stilling-pool. The flow washes out of the bucket at a discharge of about 2,700 second-feet, Figure 20. As the flow is decreased, the stilling-pool action again starts at a discharge of about 1,300 second-feet. Model operation of the diffuser bucket, recommended design, is shown in Figure 5B, and 21 through 25.

FIGURE I

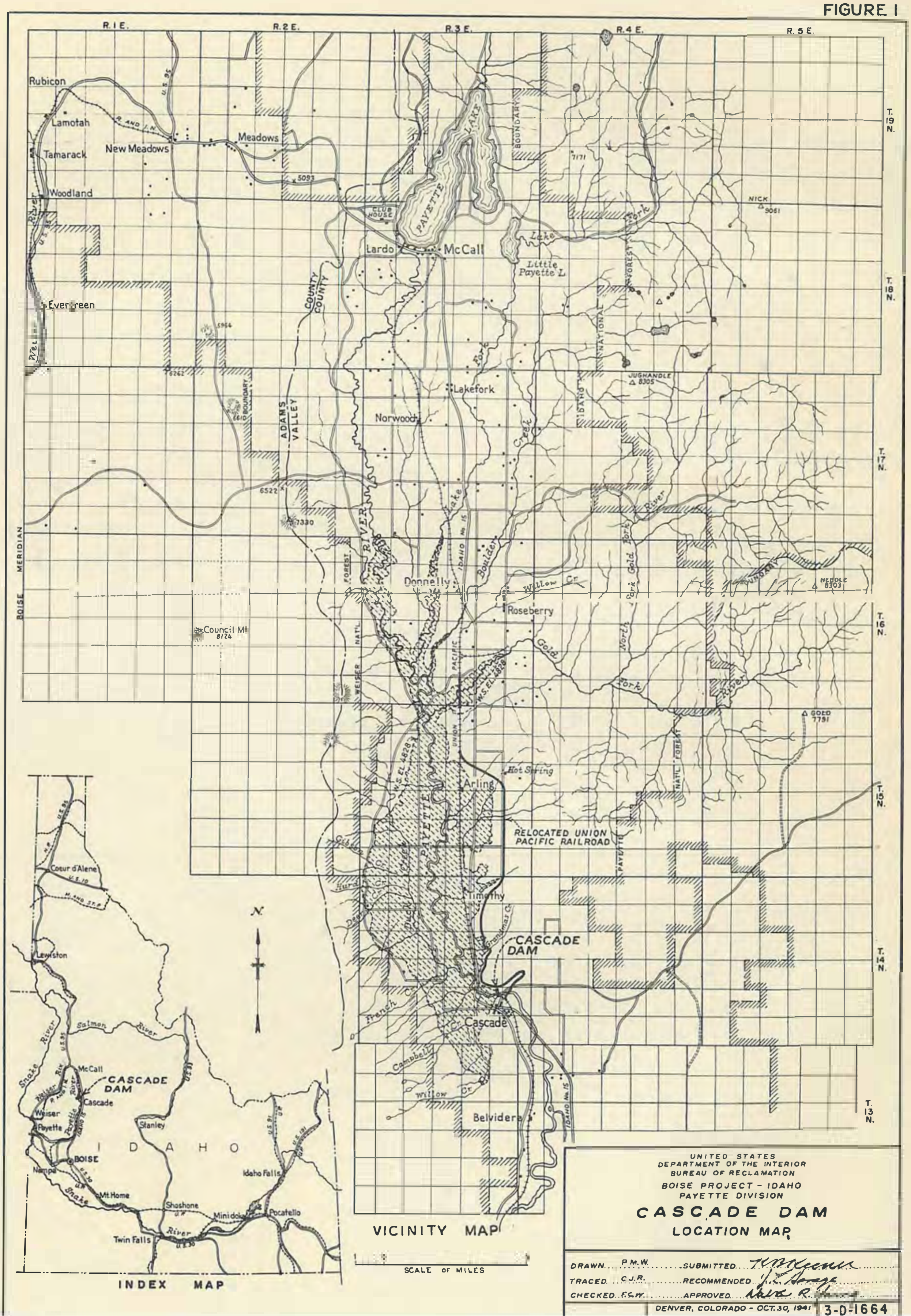
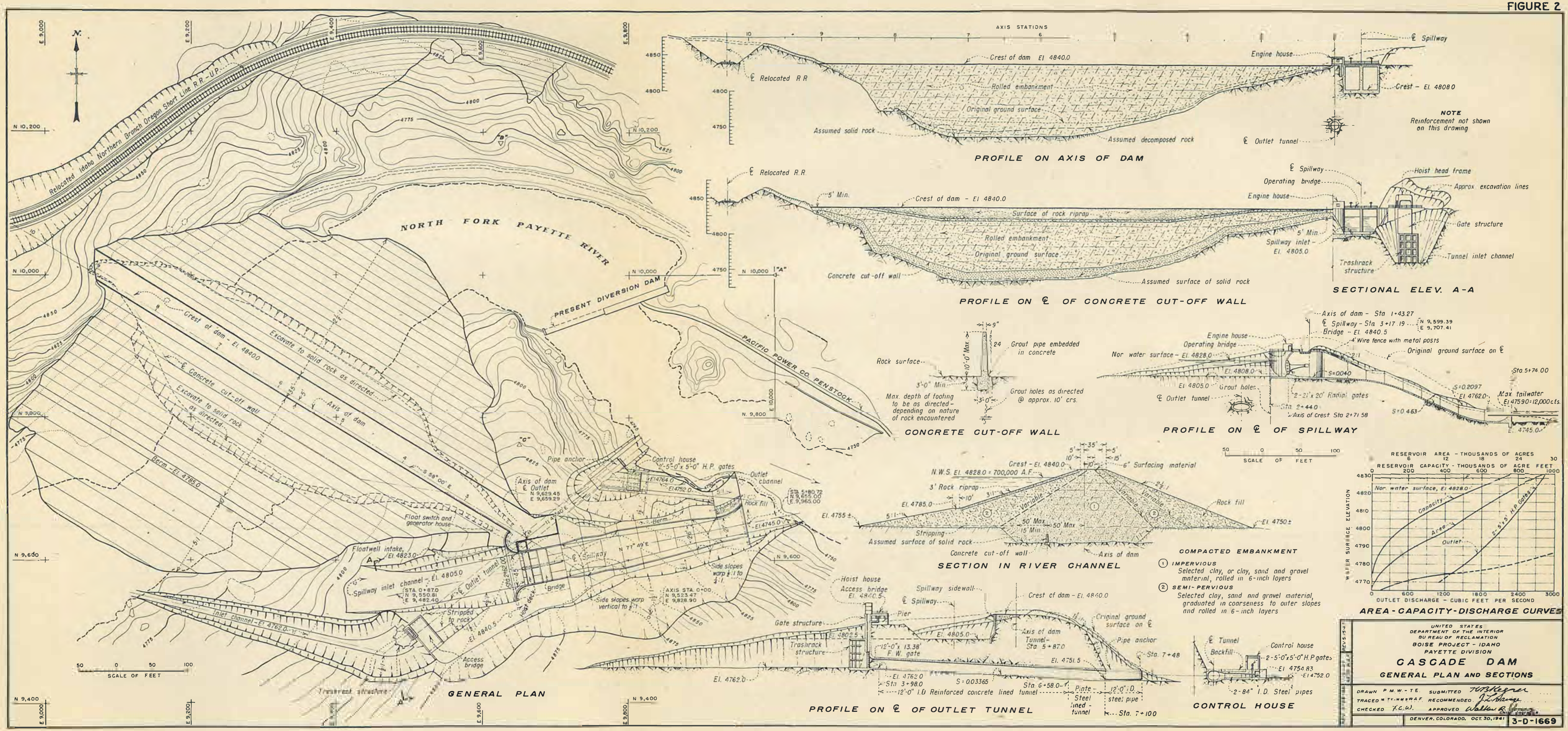
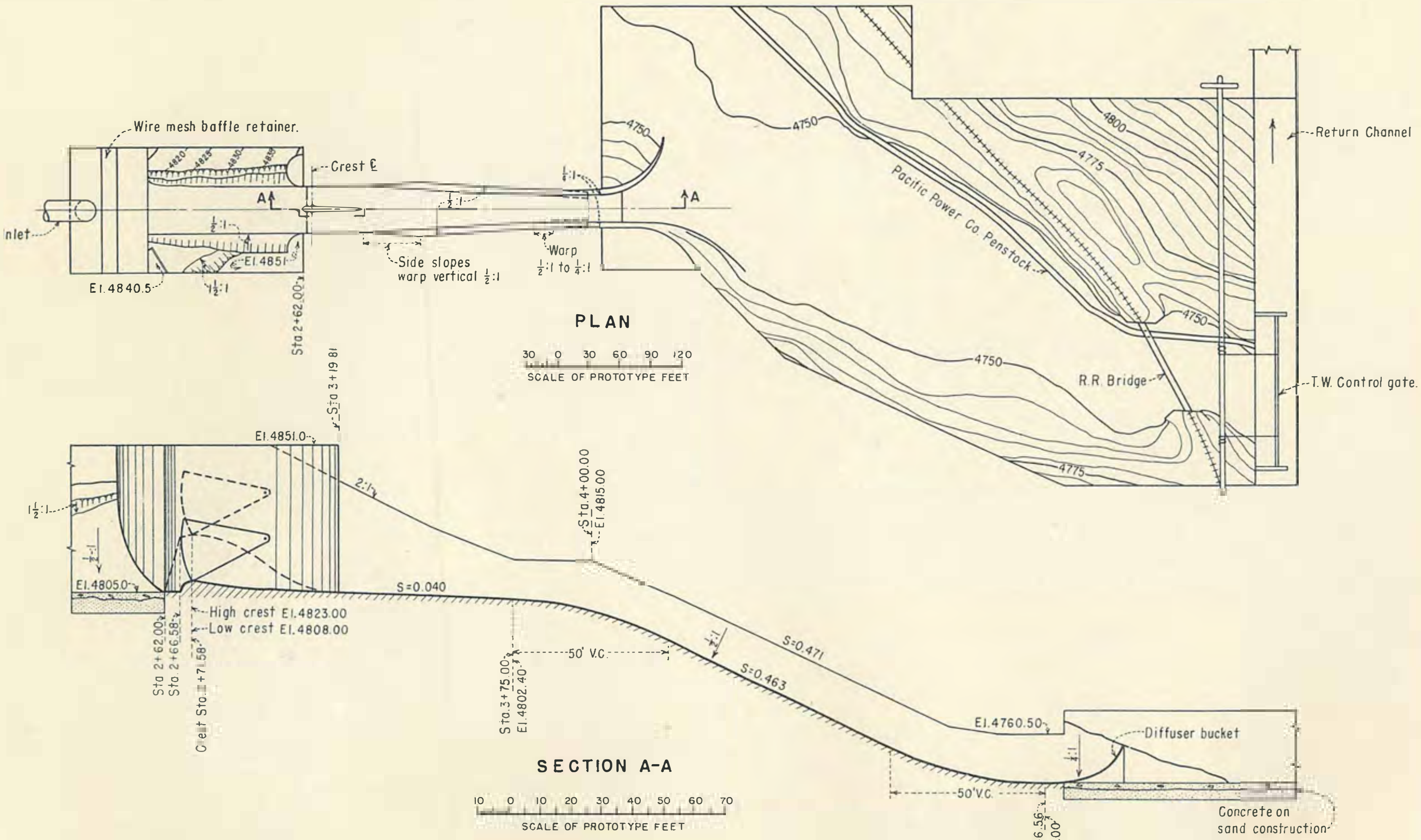

R.1 E.
R.2 E.
R.3 E.
R.4 E.
R.5 E.
T. 19 N.
T. 18 N.
T. 17 N.
T. 16 N.
T. 15 N.
T. 14 N.
T. 13 N.
Rubicon
Lamotah
Tamarack
New Meadows
Meadows
Woodland
Evergreen
Weiser River
BOISE MERIDIAN
PAYETTE LAKE
CLUB HOUSE
Lardo
McCall
Little Payette L.
Lake Fork
NICK 9061
JUGHANDLE 8305
NEEDLE 8303
GOED 7791
Lakefork
Norwood
ADAMS VALLEY
COUNTY BOUNDARY
IDAHO NATIONAL FOREST BOUNDARY
WEISER NAT'L FOREST
Council Mt. 8124
Donnelly
Roseberry
Willow Cr.
Boulder
Gold Fork
North Fork Gold Fork River
IDAHO No. 15
UNION PACIFIC
W.S. EL. 4828
Hot Spring
Arling
RELOCATED UNION PACIFIC RAILROAD
PAYETTE NAT'L FOREST
PAYETTE RIVER
Timothy
CASCADE DAM
Cascade
French Cr.
Campbell Cr.
Willow Cr.
Belvidere
VICINITY MAP
SCALE OF MILES
INDEX MAP
Coeur d'Alene
Lewiston
Salmon River
Snake River
McCall
CASCADE DAM
Cascade
Weiser
Payette
Stanley
I D A H O
BOISE
Nampa
Mt. Home
Idaho Falls
Shoshone
Minidoka
Pocatello
Twin Falls
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO
PAYETTE DIVISION
CASCADE DAM
LOCATION MAP
DRAWN P.M.W. SUBMITTED
TRACED C.J.R. RECOMMENDED
CHECKED F.S.W. APPROVED
DENVER, COLORADO - OCT. 30, 1941
3-D-1664

FIGURE 2



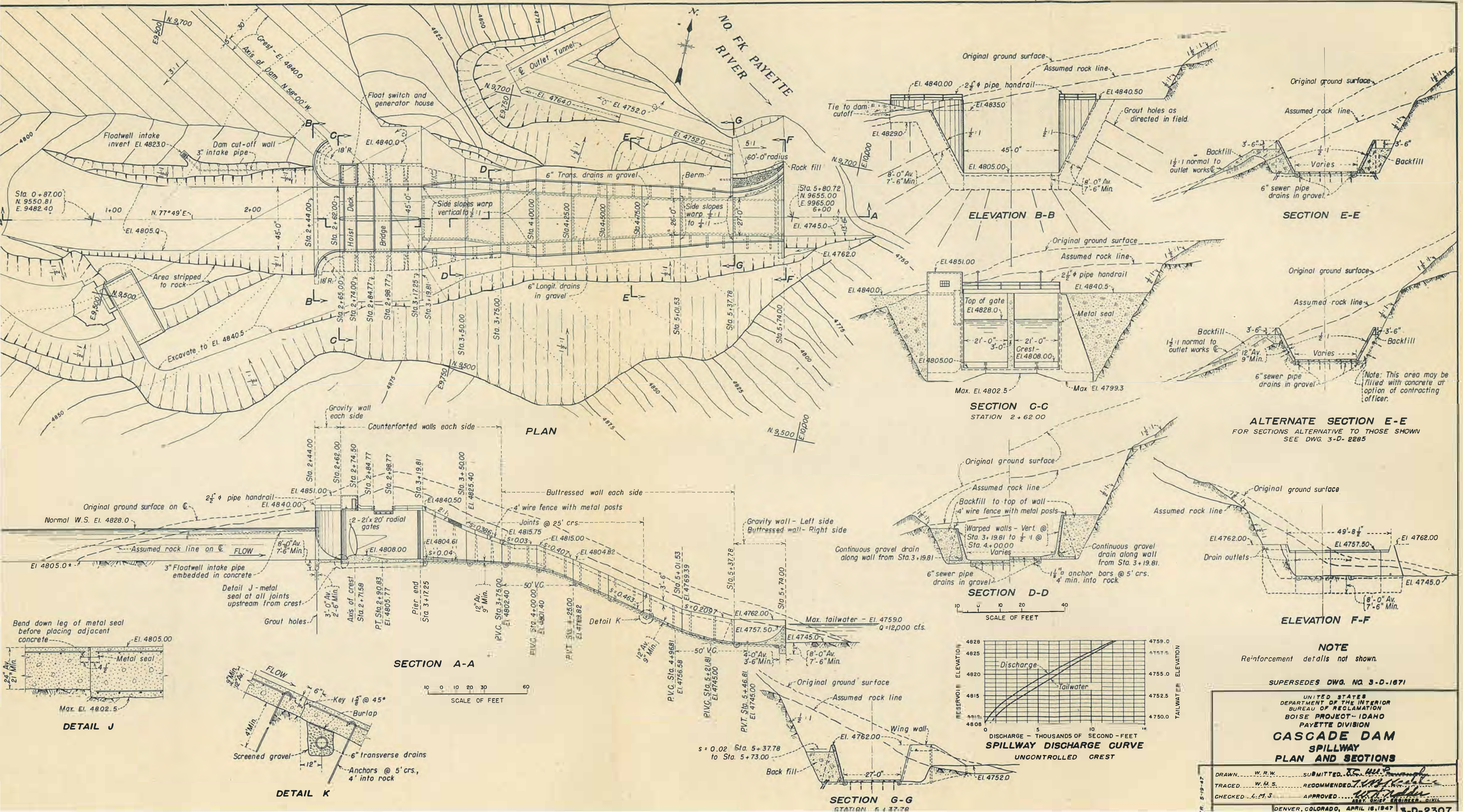
GENERAL PLAN
NORTH FORK PAYETTE RIVER
PRESENT DIVERSION DAM
PACIFIC POWER CO. PENSTOCK
Relocated Idaho Northern Branch Oregon Short Line R.R.-U.P.
Crest of dam - El. 4840.0
Excavate to solid rock as directed
Axis of dam
℄ Concrete cut-off wall
Excavate to solid rock as directed
Berm - El. 4785.0
Control house
2-5'-0" x 5'-0" H.P. gates
Outlet channel
Rock fill
Pipe anchor
Float switch and generator house
Floatwell intake, El. 4823.0
Spillway inlet channel - El. 4805.0
℄ Outlet tunnel
℄ Spillway
Bridge
Side slopes warp vertical to ½:1
Inlet channel - El. 4762.0
Stripped to rock
Access bridge
Trashrack structure
SCALE OF FEET
PROFILE ON AXIS OF DAM
AXIS STATIONS
Crest of dam El. 4840.0
Rolled embankment
Original ground surface
Assumed solid rock
Assumed decomposed rock
℄ Relocated R.R.
Engine house
℄ Spillway
Crest - El. 4808.0
℄ Outlet tunnel
NOTE
Reinforcement not shown on this drawing
PROFILE ON ℄ OF CONCRETE CUT-OFF WALL
Surface of rock riprap
Concrete cut-off wall
Assumed surface of solid rock
SECTIONAL ELEV. A-A
Hoist head frame
Operating bridge
Approx. excavation lines
Gate structure
Spillway inlet - El. 4805.0
Trashrack structure
Tunnel inlet channel
CONCRETE CUT-OFF WALL
Grout pipe embedded in concrete
Rock surface
Max. depth of footing to be as directed - depending on nature of rock encountered
Grout holes as directed @ approx. 10' crs.
PROFILE ON ℄ OF SPILLWAY
Axis of dam - Sta 1+43.27
℄ Spillway - Sta 3+17.19
Bridge - El. 4840.5
Nor. water surface - El. 4828.0
2-21'x 20' Radial gates
Original ground surface on ℄
Max. tailwater El. 4759.0 = 12,000 c.f.s.
SECTION IN RIVER CHANNEL
N.W.S. El. 4828.0 = 700,000 A.F.
3' Rock riprap
6" Surfacing material
Stripping
Assumed surface of solid rock
Concrete cut-off wall
COMPACTED EMBANKMENT
1 IMPERVIOUS
Selected clay, or clay, sand and gravel material, rolled in 6-inch layers
2 SEMI-PERVIOUS
Selected clay, sand and gravel material, graduated in coarseness to outer slopes and rolled in 6-inch layers
AREA-CAPACITY-DISCHARGE CURVES
RESERVOIR AREA - THOUSANDS OF ACRES
RESERVOIR CAPACITY - THOUSANDS OF ACRE FEET
OUTLET DISCHARGE - CUBIC FEET PER SECOND
WATER SURFACE ELEVATION
Capacity
Area
Outlet
2-5'x5' H.P. Gates
PROFILE ON ℄ OF OUTLET TUNNEL
Hoist house
Access bridge
Spillway sidewall
Crest of dam - El. 4840.0
Original ground surface on ℄
12'-0" x 13.38' F.W. gate
12'-0" I.D. Reinforced concrete lined tunnel
12'-0" I.D. steel pipe
Pipe anchor
CONTROL HOUSE
℄ Tunnel
Backfill
Control house
2-5'-0"x5'-0" H.P. gates
2-84" I.D. Steel pipes
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO
PAYETTE DIVISION
CASCADE DAM
GENERAL PLAN AND SECTIONS
DENVER, COLORADO, OCT. 30, 1941
3-D-1669

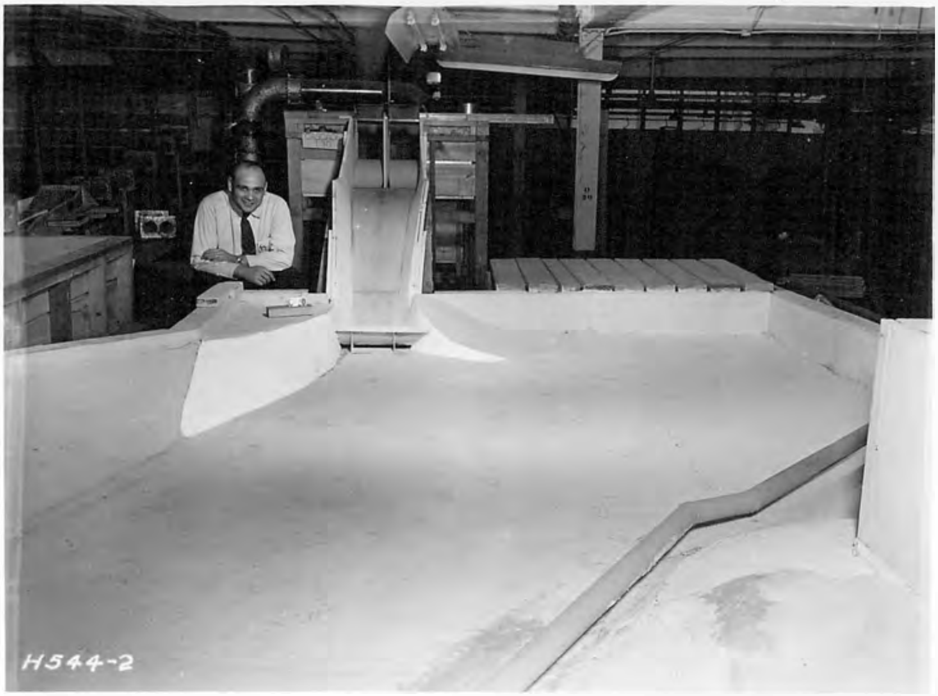


CASCADE DAM
1:30 SCALE HYDRAULIC MODEL
RECOMMENDED DESIGN

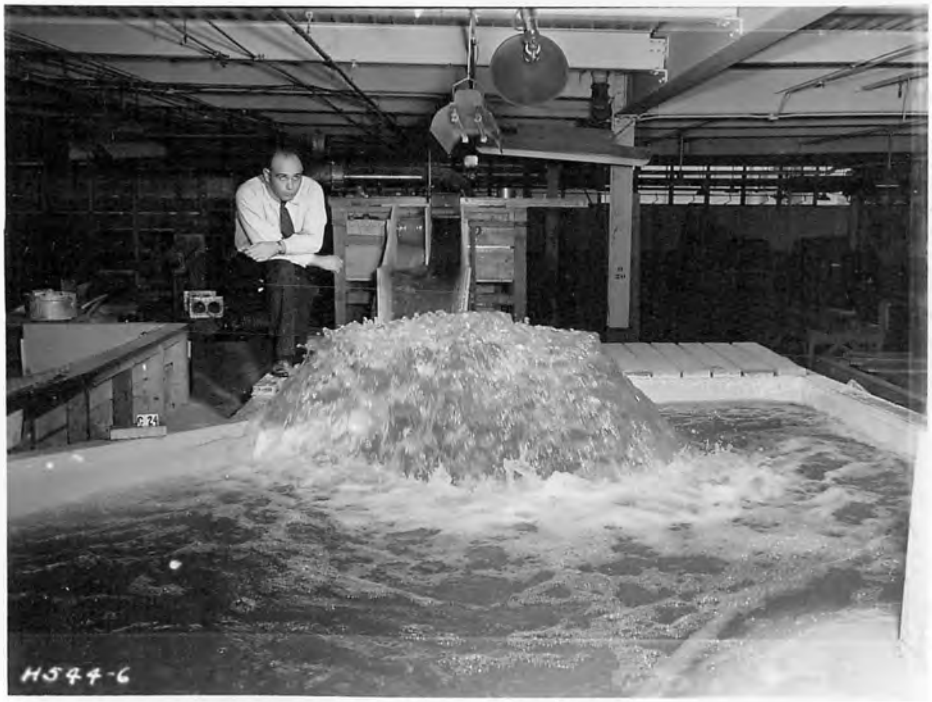
FIGURE 3

FIGURE 4


NO. FK. PAYETTE RIVER
N.
PLAN
Crest El. 4840.0
Axis of Dam N.58°00'W.
Outlet Tunnel
Float switch and generator house
Floatwell intake invert El. 4823.0
Dam cut-off wall
3" intake pipe
6" Trans. drains in gravel
Berm
60'-0" radius
Rock fill
Sta. 0+87.00 N. 9550.81 E. 9482.40
N.77°49'E.
El. 4805.0
Side slopes warp vertical to 1/2:1
Side slopes warp 1/2:1 to 1/4:1
Sta. 5+80.72 N. 9655.00 E. 9965.00
El. 4745.0
El. 4762.0
Area stripped to rock
6" Longit. drains in gravel
Excavate to El. 4840.5
Original ground surface
Assumed rock line
El. 4840.00
2½" ϕ pipe handrail
El. 4840.50
El. 4835.0
Grout holes as directed in field.
Tie to dam cutoff
El. 4829.0
45'-0"
El. 4805.00
8'-0" Av. 7'-6" Min.
ELEVATION B-B
Backfill
1½:1 normal to outlet works ℄
Varies
6" sewer pipe drains in gravel
SECTION E-E
El. 4851.00
El. 4840.0
El. 4840.5
Top of gate El. 4828.0
Metal seal
21'-0"
3'-0"
Crest- El. 4808.00
El. 4805.00
Max. El. 4802.5
Max El. 4799.3
SECTION C-C
STATION 2+62.00
Note: This area may be filled with concrete at option of contracting officer.
ALTERNATE SECTION E-E
FOR SECTIONS ALTERNATIVE TO THOSE SHOWN SEE DWG. 3-D-2285
Gravity wall each side
Counterforted walls each side
Buttressed wall each side
Original ground surface on ℄
Normal W.S. El. 4828.0
2-21'x20' radial gates
4' wire fence with metal posts
Joints @ 25' crs.
Assumed rock line on ℄
FLOW
3" Floatwell intake pipe embedded in concrete
Detail J - metal seal at all joints upstream from crest
Grout holes
Gravity wall - Left side
Buttressed wall - Right side
Detail K
Max. tailwater - El. 4759.0
Q = 12,000 cfs.
El. 4762.00
El. 4757.50
El. 4745.0
SECTION A-A
SCALE OF FEET
s = 0.02 Sta. 5+37.78 to Sta. 5+73.00
Bend down leg of metal seal before placing adjacent concrete
El. 4805.00
Metal seal
Max. El. 4802.5
DETAIL J
Key 1⅝" @ 45°
Burlap
Screened gravel
6" transverse drains
Anchors @ 5' crs., 4' into rock
DETAIL K
Wing wall
Back fill
27'-0"
El. 4752.0
SECTION G-G
STATION 5+37.78
Backfill to top of wall
Warped walls - Vert. @ Sta. 3+19.81 to 1/2:1 @ Sta. 4+00.00
Continuous gravel drain along wall from Sta. 3+19.81
Continuous gravel drain along wall from Sta. 3+19.81
1½" ϕ anchor bars @ 5' crs. 4' min. into rock
SECTION D-D
Drain outlets
El. 4762.00
El. 4757.50
El 4745.0
49'-8½"
ELEVATION F-F
Discharge
Tailwater
RESERVOIR ELEVATION
TAILWATER ELEVATION
DISCHARGE - THOUSANDS OF SECOND - FEET
SPILLWAY DISCHARGE CURVE
UNCONTROLLED CREST
NOTE
Reinforcement details not shown.
SUPERSEDES DWG. NO. 3-D-1671
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO
PAYETTE DIVISION
CASCADE DAM
SPILLWAY
PLAN AND SECTIONS
DRAWN W.R.W.
TRACED W.H.S.
CHECKED L.M.S.
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO, APRIL 18, 1947
3-D-2307

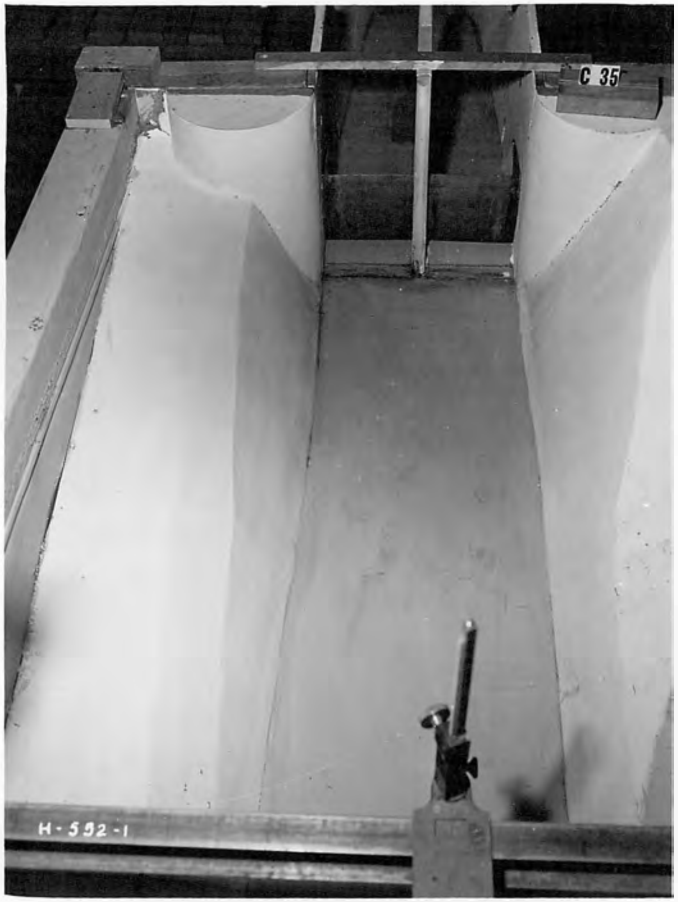


A. Model - Ready for operation

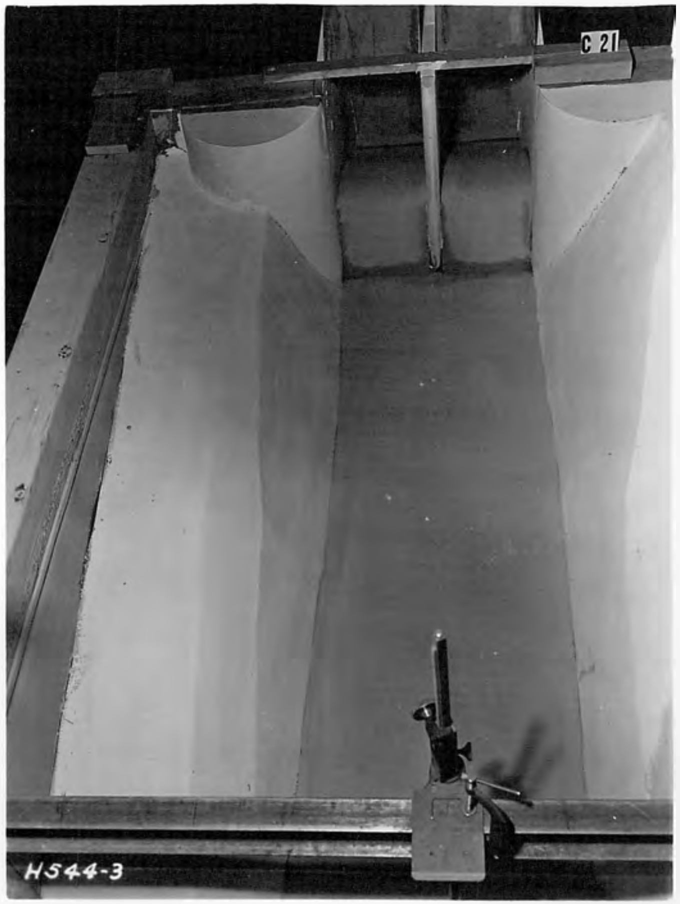


B. One gate discharging 6,250 second-feet

CASCADE DAM 1:30 MODEL
RECOMMENDED DESIGN



A. Low Crest - Elevation 4808
Gates in lowered position



B. High Crest - Elevation 4823
Gates in raised position

CASCADE DAM 1:30 MODEL
APPROACH TO THE SPILLWAY

FIGURE 6

A. Low Crest

B. High Crest

CASCADE DAM 1:30 MODEL
APPROACH TO THE SPILLWAY
12,500 SECOND-FEET THROUGH TWO GATES

FIGURE 7

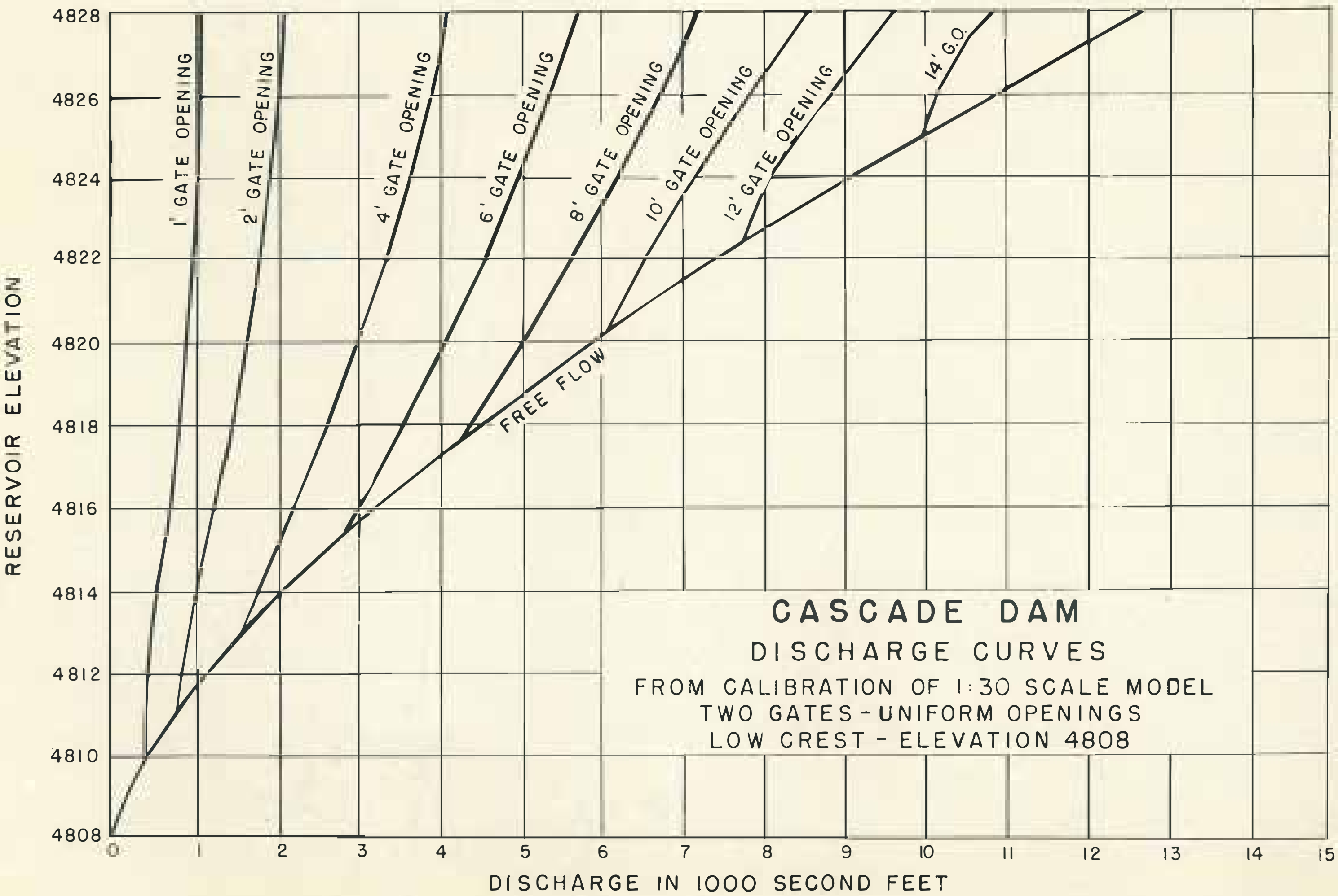

CASCADE DAM
DISCHARGE CURVES
FROM CALIBRATION OF 1:30 SCALE MODEL
TWO GATES - UNIFORM OPENINGS
LOW CREST - ELEVATION 4808
RESERVOIR ELEVATION
DISCHARGE IN 1000 SECOND FEET
1' GATE OPENING
2' GATE OPENING
4' GATE OPENING
6' GATE OPENING
8' GATE OPENING
10' GATE OPENING
12' GATE OPENING
14' G.O.
FREE FLOW
4808
4810
4812
4814
4816
4818
4820
4822
4824
4826
4828
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

FIGURE 8

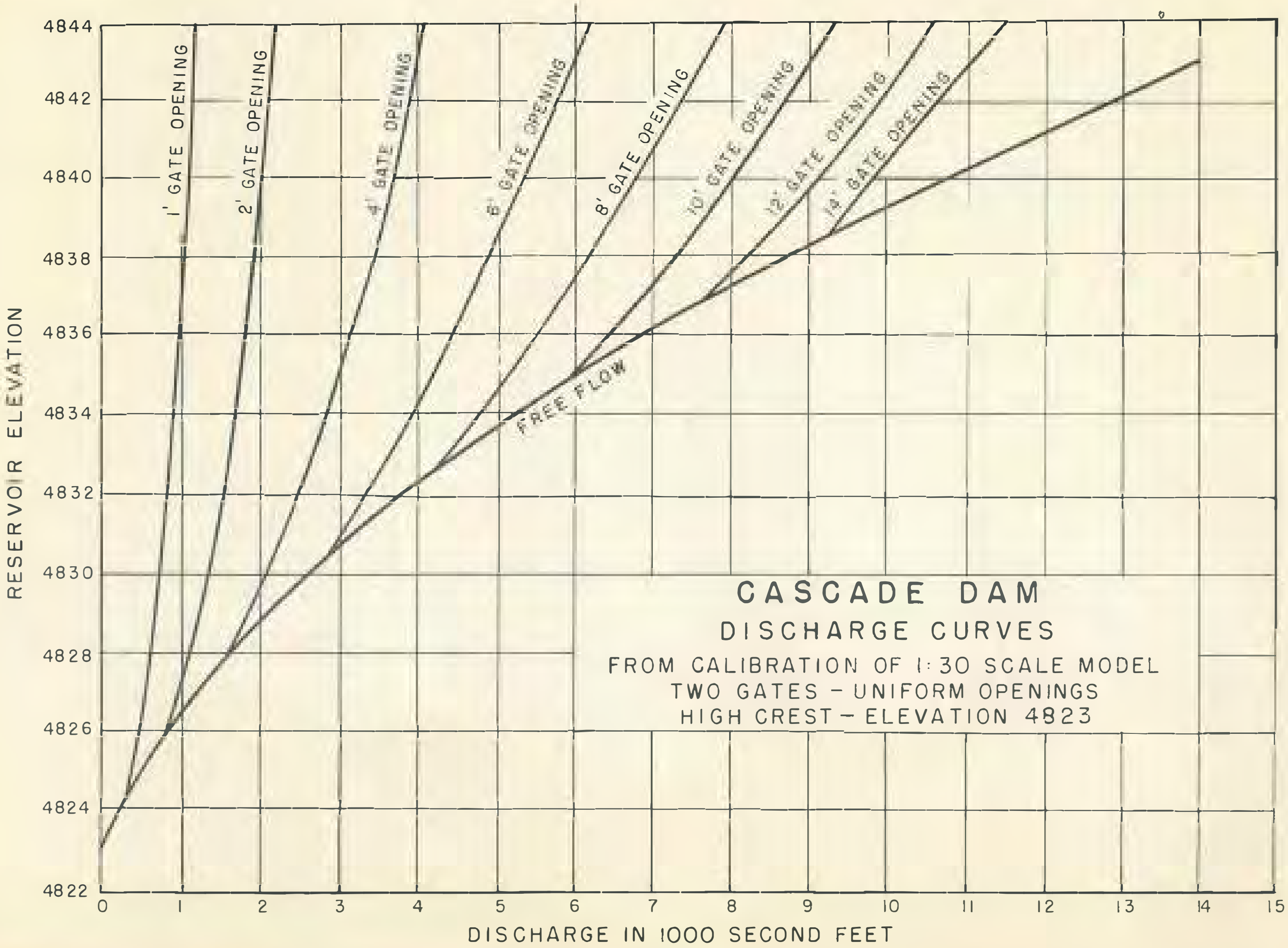
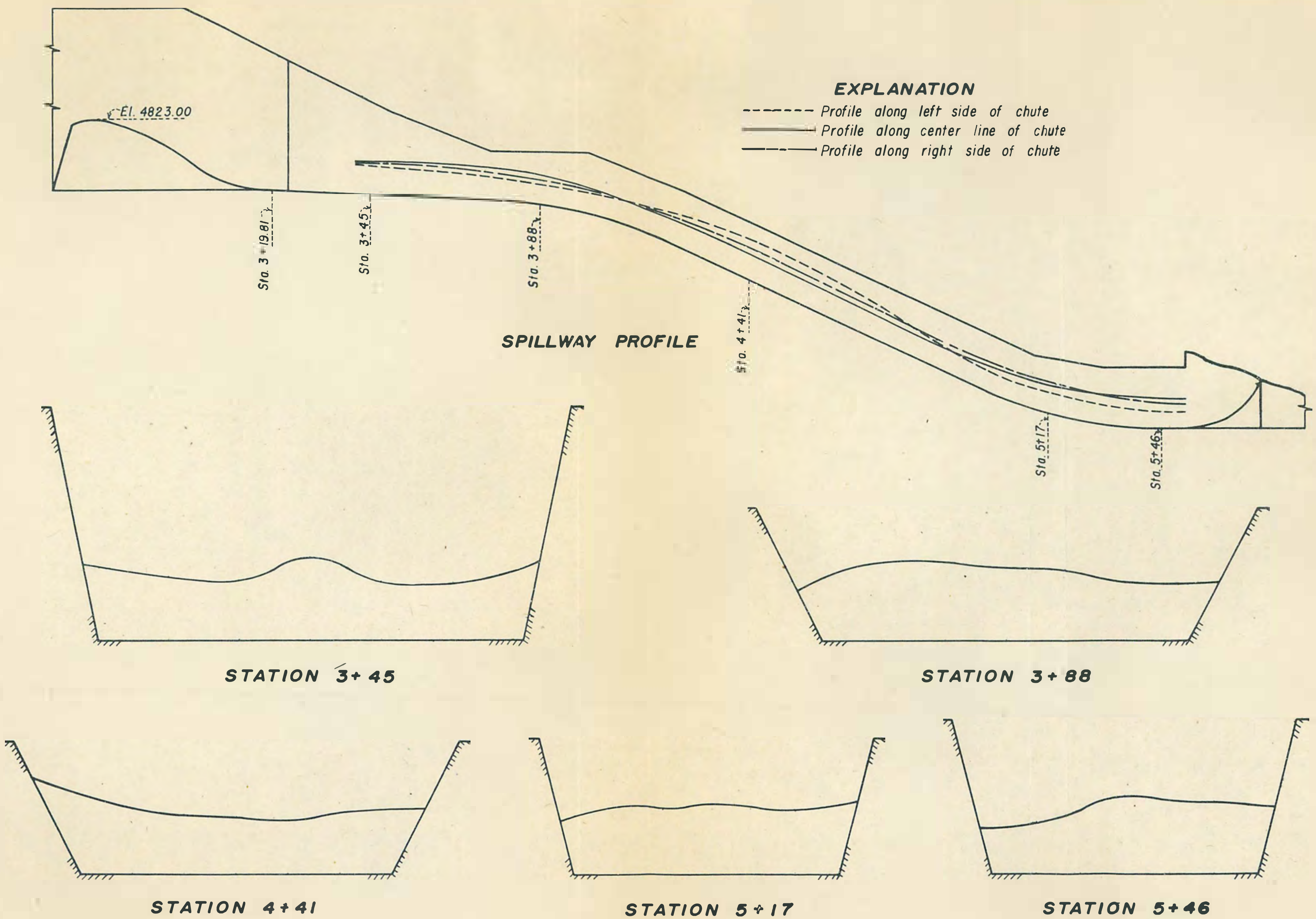
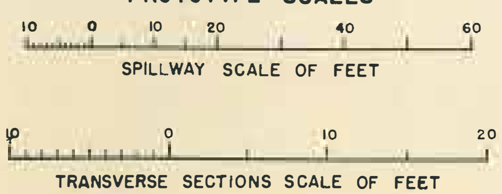

4844
4842
4840
4838
4836
4834
4832
4830
4828
4826
4824
4822
RESERVOIR ELEVATION
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DISCHARGE IN 1000 SECOND FEET
1' GATE OPENING
2' GATE OPENING
4' GATE OPENING
6' GATE OPENING
8' GATE OPENING
10' GATE OPENING
12' GATE OPENING
14' GATE OPENING
FREE FLOW
CASCADE DAM
DISCHARGE CURVES
FROM CALIBRATION OF 1:30 SCALE MODEL
TWO GATES – UNIFORM OPENINGS
HIGH CREST – ELEVATION 4823

FIGURE 9

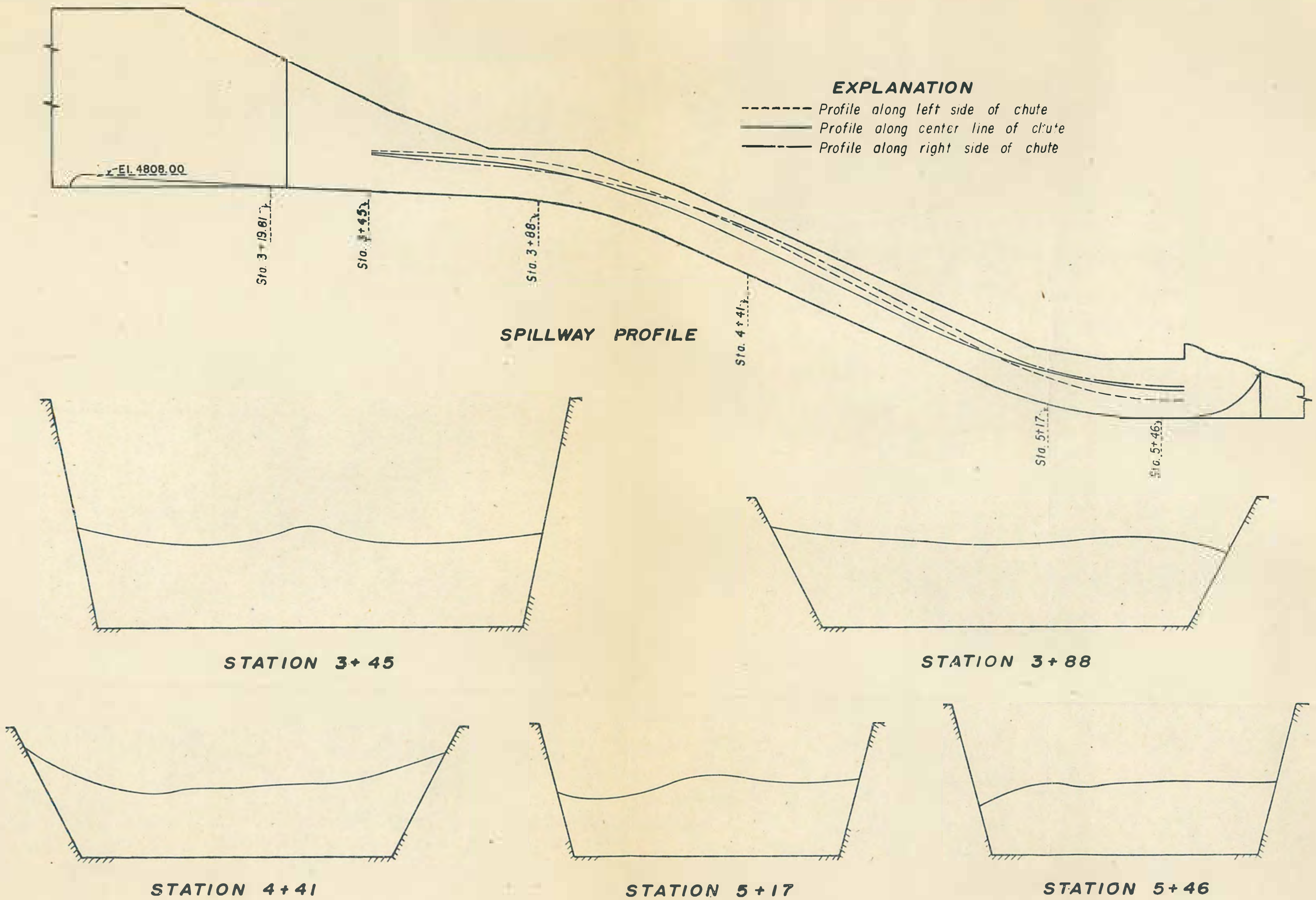


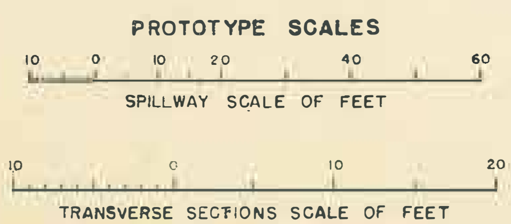


CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES IN RECOMMENDED CHUTE DESIGN
HIGH CREST-BOTH GATES OPEN
MODEL SCALE 1:30—DISCHARGE 12,500 S.F.

NOTE
Transverse section taken normal to chute floor looking downstream.

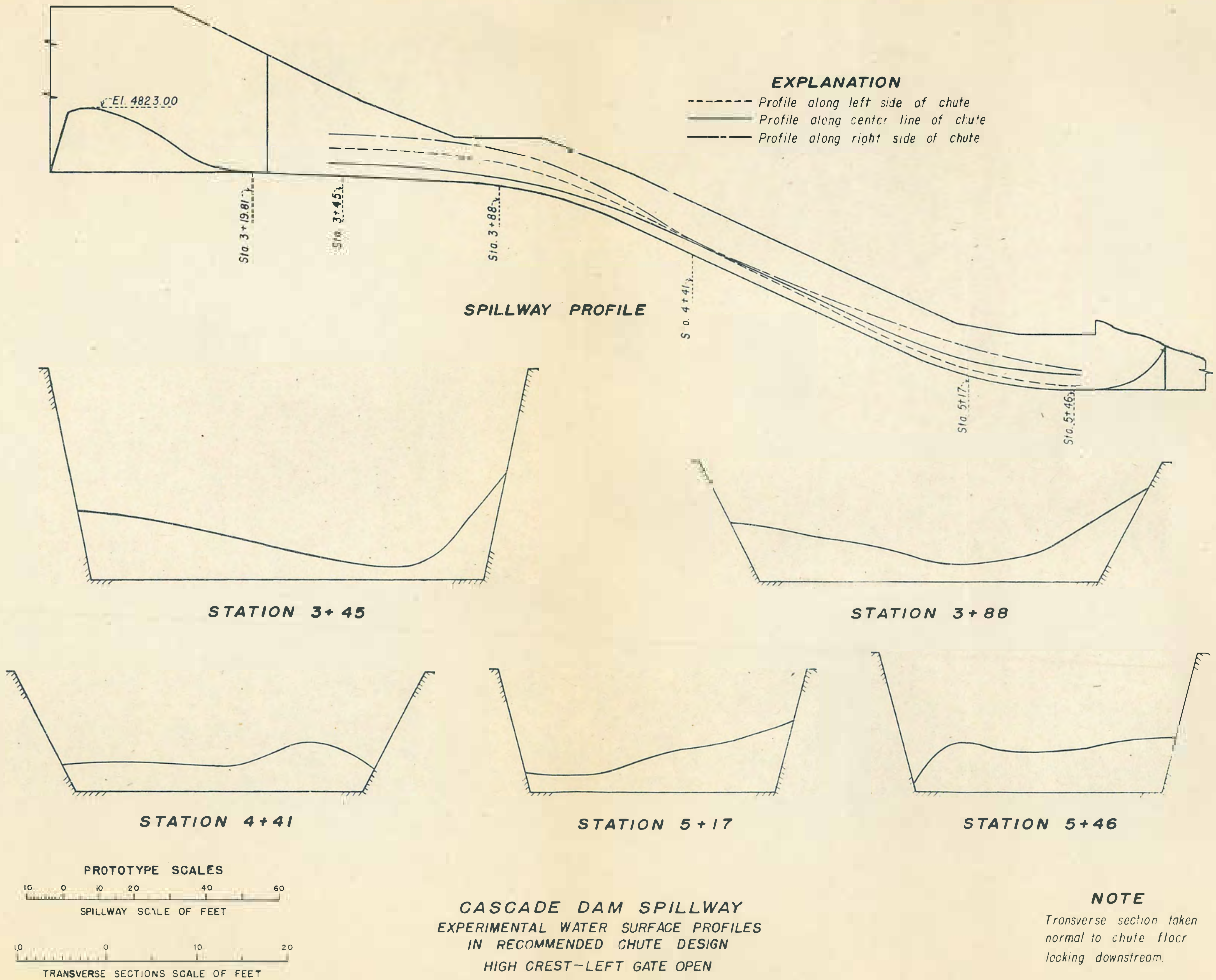
FIGURE 11





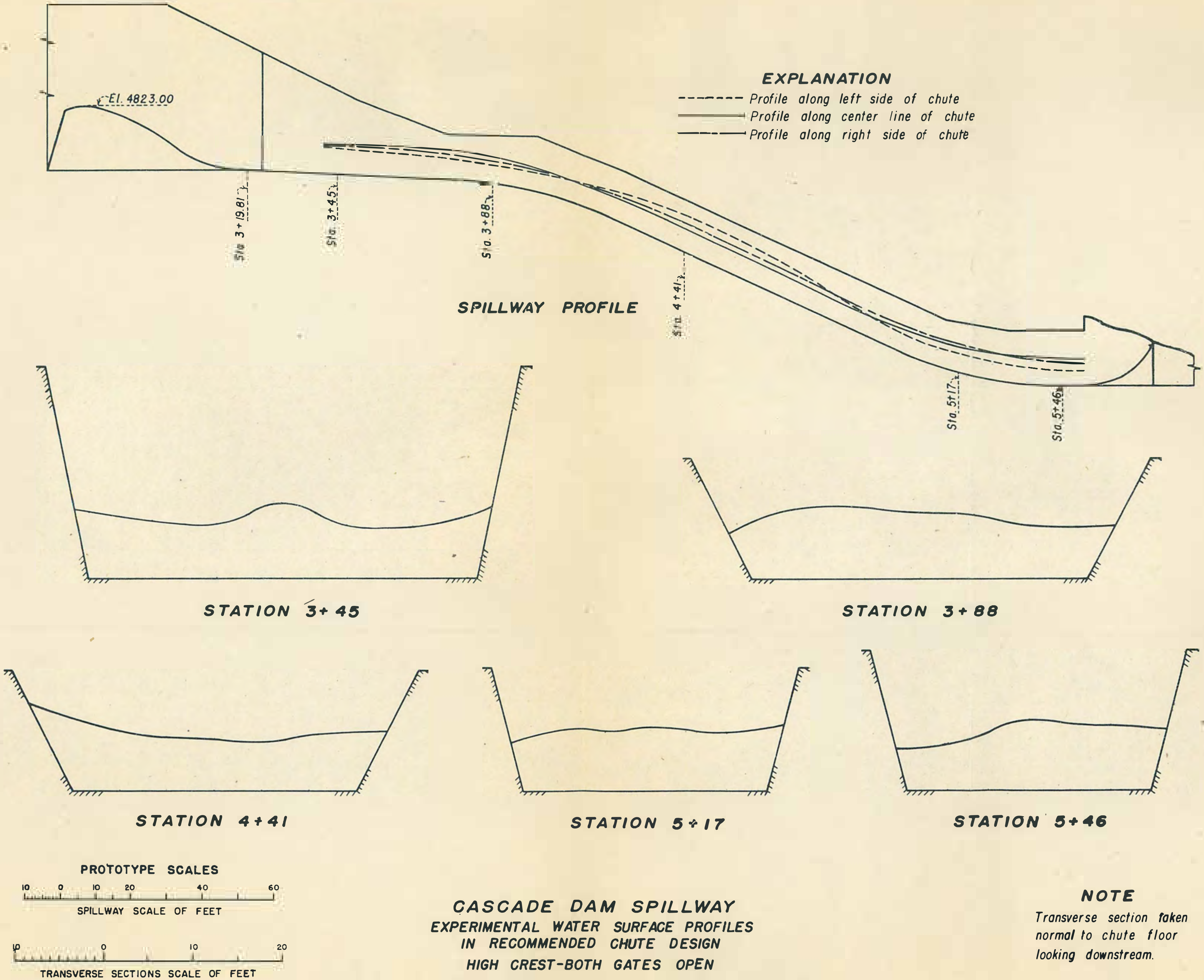
CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES IN RECOMMENDED CHUTE DESIGN
LOW CREST—BOTH GATES OPEN
MODEL SCALE 1:30—DISCHARGE 12,500 S.F.

NOTE
Transverse section taken normal to chute floor looking downstream.



CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES
IN RECOMMENDED CHUTE DESIGN
HIGH CREST—LEFT GATE OPEN
MODEL SCALE 1:30—DISCHARGE 6,250 S.F.

NOTE
Transverse section taken normal to chute floor looking downstream.



CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES IN RECOMMENDED CHUTE DESIGN
HIGH CREST-BOTH GATES OPEN
MODEL SCALE 1:30—DISCHARGE 12,500 S.F.

NOTE
Transverse section taken normal to chute floor looking downstream.

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A. Straight Chute Outlet - Elevation 4745.0

B. Straight Chute Outlet - Elevation 4751.5

CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET

A. Straight Chute Outlet in Operation

B. Resulting Flow Conditions at the R.R. Bridge

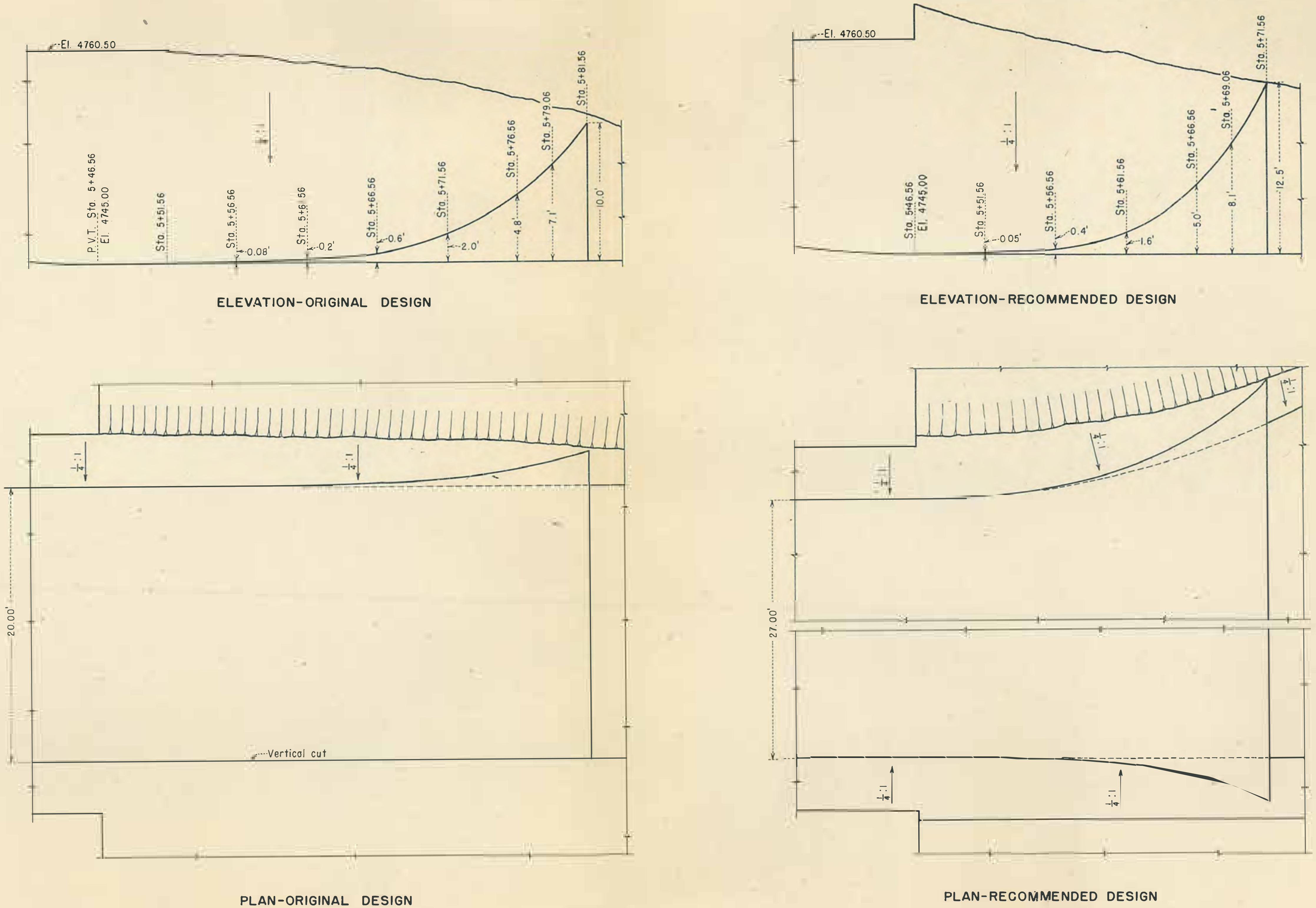
CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET

A. Curved Chute Outlet in Operation

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET

HYD 234



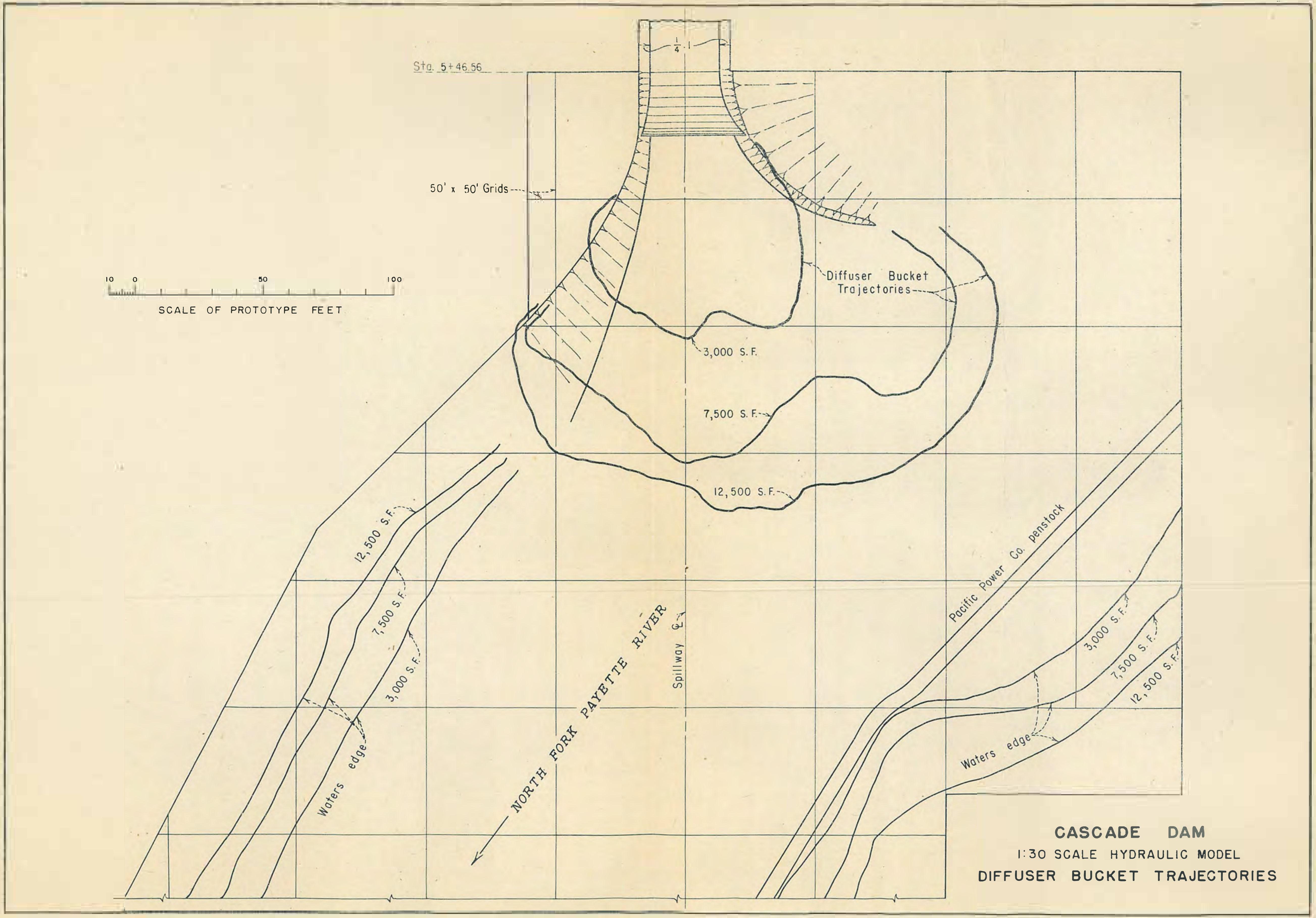
CASCADE DAM
1:30 SCALE HYDRAULIC MODEL
DIFFUSER BUCKET DETAILS

FIGURE 18

A. Discharge - 5,000 Second-feet

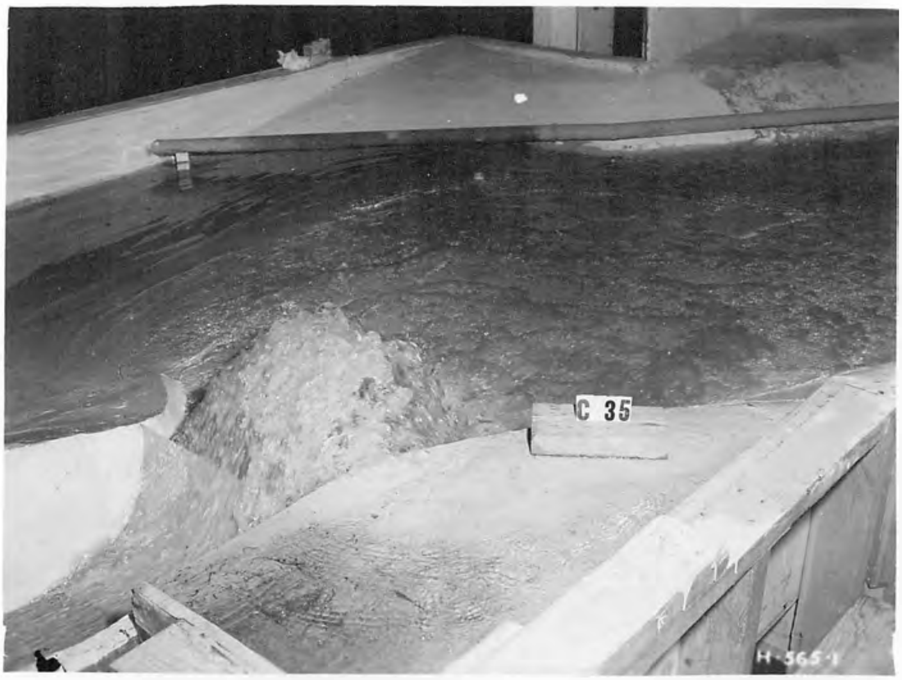
B. Discharge - 12,500 Second-feet

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - ORIGINAL DESIGN



CASCADE DAM
1:30 SCALE HYDRAULIC MODEL
DIFFUSER BUCKET TRAJECTORIES

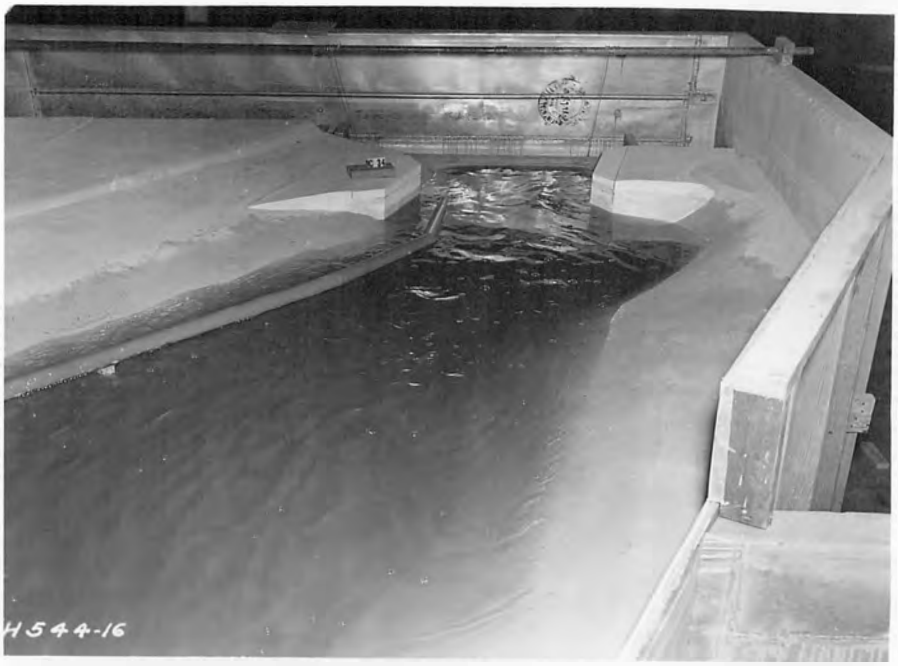
A. Diffuser Bucket Discharging Approx. 2,500 Second-feet. The Jet is approaching the washout stage.



B. Diffuser Bucket Discharging 2,700 Second-feet. The Jet has just washed out of the bucket.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN

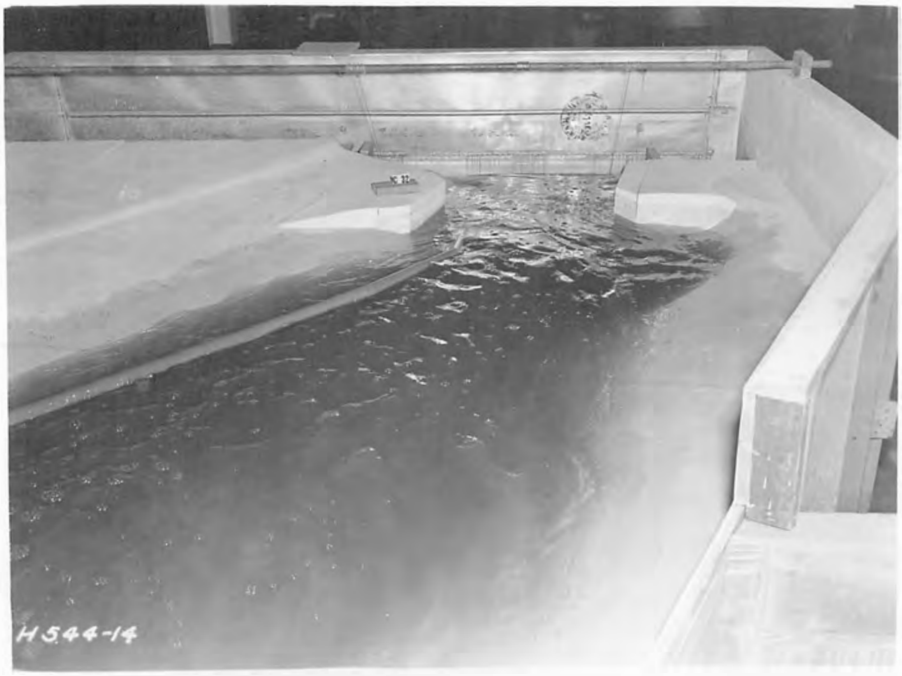
A. Diffuser Bucket Discharging 2,500 Second-feet.



B. Resulting Flow Conditions at the R.R. Bridge.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN

A. Diffuser Bucket Discharging 5,000 Second-feet.



B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN

A. Diffuser Bucket Discharging 7,500 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN

A. Diffuser Bucket Discharging 10,000 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN

Diffuser Bucket Discharging 12,500 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN