UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF A PROPOSED TEMPORARY INSTALLATION OF AN OUTLET WORKS VALVE AT ANDERSON RANCH DAM--BOISE PROJECT, IDAHO

Hydraulic Laboratory Report No. Hyd.-256

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
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Branch of Design and Construction
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Compiled by: W. P. Simmons, Jr.
Reviewed by: J. W. Ball

Subject: Hydraulic model studies of a proposed temporary installation of an outlet works valve at Anderson Ranch Dam--Boise Project, Idaho.

PURPOSE OF THE STUDY

Hydraulic model studies were conducted on a proposed temporary installation of a valve on the Anderson Ranch Dam power and outlet penstock to determine if the flow from this valve would cause excessive damage to the contractor's cofferdam or the toe of the main dam.

CONCLUSIONS

The conclusions of the model tests were:

1. The high-velocity flow from the 84-inch needle valve placed at any location in the diversion tunnel would produce severe scour in the river channel and particularly along the cofferdam.

2. The flow from a 72-inch hollow-jet valve for the same locations would produce equally severe scour.

3. Major structural modifications to the diversion channel would be required to control the high-velocity water in the event that either of the valves were installed.

4. The scour in the river channel, adjacent to the cofferdam and the toe of the main dam, will be reduced materially by regulating the flow with the bulkhead coaster gate and limiting the head on the gate to 100 feet.

5. If the coaster gate is used to regulate the amount of water released, the scour adjacent to the cofferdam and at the toe of the dam may be reduced further by placing deflectors on the floor and left sidewall near the end of the lined diversion channel.

RECOMMENDATIONS

The following recommendations are made:

1. The installation of either a needle or hollow-jet valve on the 15-foot diameter penstock is not recommended because of the severe scour adjacent to the cofferdam crib and the toe of the main dam.

2. Water should be released in the same manner as during 1948; i.e., regulating with the coaster gate at the tunnel inlet under heads not to exceed 100 feet and with open channel flow occurring through the conduit.

3. If it is desired to minimize the scour at the base of the cofferdam, the addition of a floor and sidewall deflector in the diversion channel is recommended.

INTRODUCTION

Anderson Ranch Dam is a compacted earth-fill structure approximately 330 feet high located on the south fork of the Boise River about 40 miles southeast of Boise, Idaho, Figure 1. The dam will form a reservoir 15 miles long with a storage capacity of 500,000 acre-feet. A spillway and an outlet works are provided at the left abutment of the dam to pass floodwaters and to release water for irrigation and power generation, Figure 2.

Construction has progressed sufficiently to permit storage of excess water in the reservoir at Anderson Ranch Dam during 1949. The storage must be limited, however, to about reservoir elevation 4170 to prevent flooding of the unfinished spillway and outlet works. Under the present construction schedule, the permanent outlet works will not be completed by summer and the release of water for downstream use or to prevent flooding the spillway must be made through the partially completed outlet facilities. If water is stored above elevation 4100.0 the bulkhead coaster gate at the inlet of the 20-foot diameter tunnel cannot be used for regulation as in 1948 since the head on the gate would be in excess of 100 feet and there would be danger of severe damage to the gate and the tunnel lining. It was proposed that either a needle or hollow-jet valve be installed by means of a transition section to the 15-foot diameter steel penstock near the outlet end of the 20-foot diameter concrete-lined tunnel, Figure 3. The valve would discharge its flow into the existing concrete-lined diversion channel. The 84-inch needle valve considered for this arrangement had a capacity of approximately 4,100 cfs. at a head of 300 feet, while the 72-inch hollow-jet valve had a capacity of 2,750 cfs. The project construction office felt that the smaller capacity of the hollow-jet valve could be permitted if improved flow conditions or savings in cost were realized.

The excavation for the powerhouse foundation to the left of the diversion channel is protected by the contractor's cofferdam, Figure 3. The cofferdam consists of a rock-filled sheet piling and timber crib extending 110 feet downstream from the left wall of the channel, and an earth-fill dike extending from the crib to the old river channel about 220 feet farther downstream. The toe of the main dam forms the right bank of the river channel below the diversion structure.

Hydraulic model studies were made to determine if the flow from the proposed temporary outlet facilities would cause excessive damage to the cofferdam or the toe of the main dam.

THE INVESTIGATION

The Model

A model was constructed on a 1:30 scale which included the lower 112 feet of the 15-foot diameter steel penstock, the lined diversion channel, and 300 feet of the excavated river channel downstream, Figure 4. The model penstock consisted of a 6-inch inside diameter steel pipe while the diversion channel was represented by a wooden chute lined with sheet metal. The riverbed was formed in compacted pea-gravel with coarse gravel placed at points where heavy rock exists in the prototype structure. The diversion channel and the riverbed were contained in a large sheet-metal lined, wooden box with a tail-gate placed at the downstream end for regulating the tailwater depth. Water was supplied to the model by the central laboratory system which contained venturi meters for measuring the flow. The accurately machined brass valve used to represent the 84-inch needle valve was connected to the penstock by a reducing section similar to the transition available at Grand Coulee Dam. A 2-inch hollow-jet valve was available for the model and although this valve was too small to represent the 72-inch prototype valve on the 1:30 scale, it was used to obtain an indication of the conditions which might be expected if the hollow-jet valve were used.

Scope of Tests

Tests were first conducted with the 84-inch needle valve placed near the outlet portal of the 20-foot diameter diversion tunnel and the flow discharging into the lined diversion channel. After severe scour was observed in the river bottom at the end of the diversion channel and along the toe of the cofferdam the study was expanded to investigate the effect of varying the location and elevation of the valve and of minor alterations to the diversion channel. A small hollow-jet valve was studied on the model to determine if improved flow conditions could be obtained by using one of the 72-inch hollow-jet valves of the permanent outlet works. The conditions obtained were substantially the same as for the needle valve. It thus became evident that major structural alterations to the diversion channel would be required to prevent excessive damage if a valve were installed. Such alterations were not considered feasible due to the temporary nature of the installation and because of insufficient time for construction. The only remaining means of controlling the flow of water through the unfinished outlet works was the bulkhead gate, the use of which would permit a maximum storage elevation of 4100. Studies were made of this method with the 15-foot diameter steel penstock terminated at Stations 18+46.00 and 17+50.00 to determine the effect of the location of the end of the steel conduit upon the flow conditions in the diversion channel. The effect of minor alterations to the diversion channel upon the flow conditions along the toe of the dam and cofferdam were also studied.

Eighty-four-inch Needle Valve at Station 18+46.00

The model was arranged to represent the 84-inch needle valve connected by means of a reducing section to the 15-foot diameter penstock at Station 18+46.00, Figure 4. All model tests were made with the valve in the wide-open position since that was the operation intended for the prototype structure. The valve was operated at heads representing up to 326 feet and discharges to 4,210 cfs.

At heads from 140 to 200 feet the obstruction presented by the powerhouse inset on the left wall of the diversion channel, Figure 3, produced a heavy fin that was thrown over the downstream portion of the right wall of the channel. Severe scour occurred in the riverbed and along the sheet-piling of the cofferdam.

At higher heads the velocities were so great that the sheet of water jumped free of the concrete slope at the end of the channel and plunged into the pool beyond the end of the diversion channel, Figure 5a. Severe scour resulted in the riverbed, particularly along the cofferdam and the toe of the main dam, Figure 5b. The sheet-piling and the crib were heavily buffeted by the high-velocity water. All attempts to obtain acceptable flow conditions by the use of deflectors on the walls and floor of the diversion channel and varying the elevation of the valve were unsuccessful. This was due in part to the fact that the high velocity water could not be deflected away from the dike without damaging the toe of the dam, and also to the fact that any structural arrangement found satisfactory for a certain range of heads was totally unsatisfactory for other heads. As the heads on the prototype structure will vary about 300 feet, such limited conditions would not be acceptable. It was concluded that the extensive damage to the cofferdam and toe of the main dam could not be eliminated without resorting to major structural changes.

Eighty-four-inch Needle Valve at Station 17+50.00

The needle valve was moved upstream to a point representing Station 17+50.00. The section of 20-foot diameter tunnel downstream from the valve was represented by an 8-inch transparent plastic pipe to facilitate observing flow conditions in the tunnel. At moderate heads the water formed fins which rose on the sides and impinged on one another at the top of the tunnel, making it likely that any control piping placed on the roof would be torn away. Lowering the valve in the tunnel improved this condition but had no effect on the damage wrought downstream. The flow in the diversion channel was more uniform and occurred with less spray. The scour in the river channel and buffeting on the piling for all valve elevations were as severe as with the valve installed further downstream and therefore, the arrangements were considered unsatisfactory.

Hollow-jet Valve at Station 18+46.00

The action using a 72-inch hollow-jet valve could not be studied in detail because the proper size valve was not available for the model. A smaller valve, equivalent to a 60-inch valve on the 1:30 scale, was installed at a point representing Station 18+46.00 on the penstock. The brief tests made with this valve showed that similar scour to that produced by the needle valve would be encountered. There would, therefore, be no advantage in using the hollow-jet valve in place of the needle valve.

Regulation by Bulkhead Coaster Gate

Because of the unfavorable results of the tests in which the valves were used for control, consideration was given to regulating the outflow with the bulkhead coaster gate and limiting the maximum head on the gate to 100 feet. The operation would be similar to that used during the 1948 season but the flow conditions might differ in that the 15-foot steel penstock has been extended much nearer the downstream end of the tunnel. With the model penstock terminated at a point representing Station 18+46.00 and with the equivalent of 4,210 cfs flowing at a velocity of 80 feet per second in the partially filled penstock, large fins formed at the walls of the channel where the jet from the penstock impinged on the channel floor, Figure 6b. Considerable scour occurred at the end of the concrete lining and along the cofferdam, Figure 6c, and a gravel bar was formed across the river channel at a point about 120 feet downstream. The erosion, though extensive, was much less than occurred with either valve installed.

The similarity of flow conditions between model and prototype is shown in Figure 6, a and b.

Deflectors were installed on the floor and left sidewall of the diversion channel at a point near the downstream end in an attempt to reduce the scour, Figure 7. The water was deflected away from the cofferdam, spread, and thrown a short distance downstream, Figure 8a. The amount of scour at all points in the river channel was materially reduced, Figure 8b.

Slight improvement in flow conditions, with smaller fins along the channel sidewalls, was obtained by terminating the model penstock at a point representing Station 17+50.00. However, there was no appreciable difference in the scour pattern or the flow action at the end of the diversion channel. Large fins formed in the tunnel where the jet from the penstock impinged on the tunnel invert. The only apparent benefit derived from the shorter penstock was a slight improvement in the flow conditions within the diversion channel. The effectiveness of the deflectors placed on the left wall and floor near the end of the diversion channel in the previous test was not altered by the change in penstock length. From these tests it was concluded that it was immaterial whether the penstock terminated at the tunnel portal or some distance upstream from it.

FIGURE I

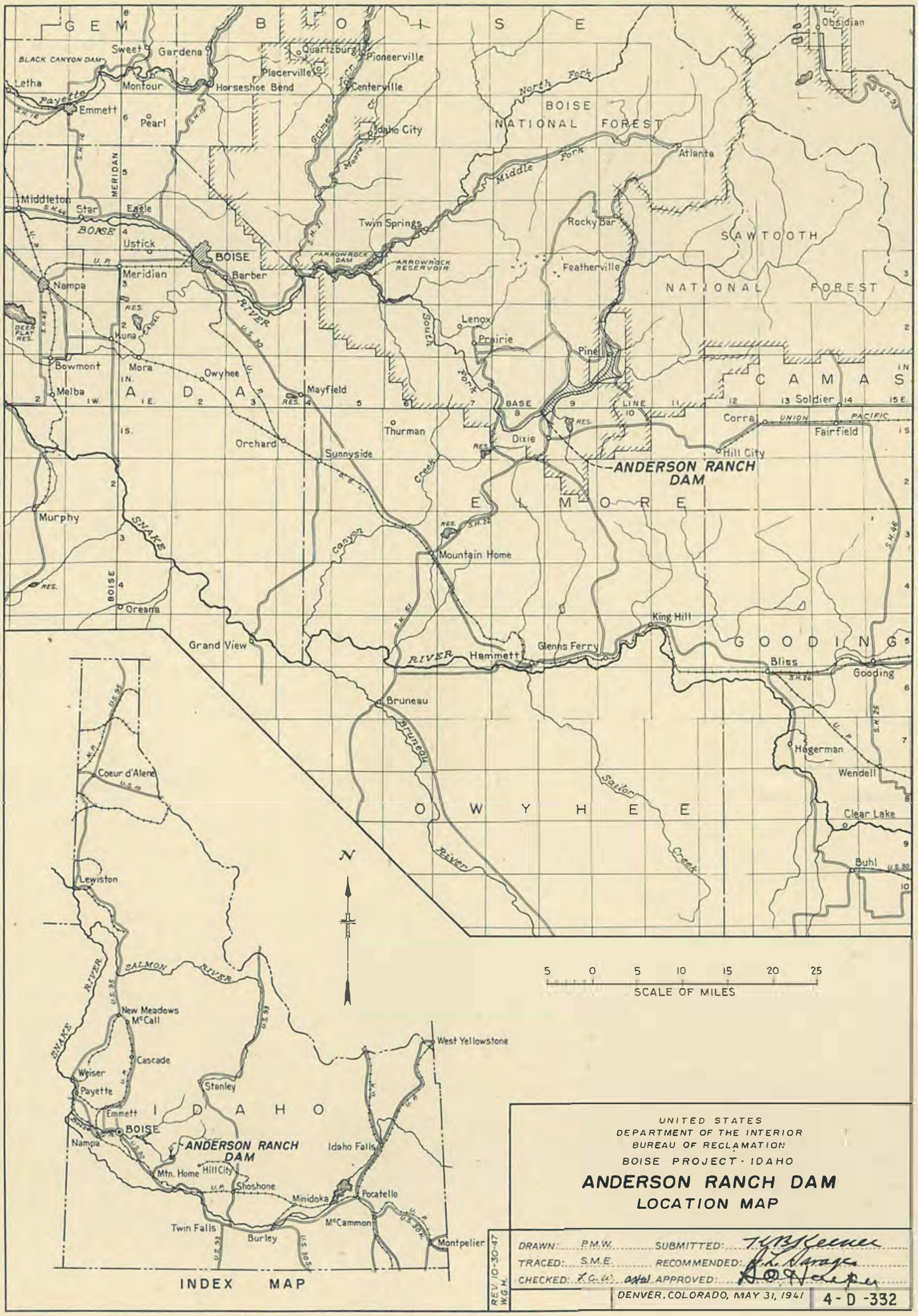
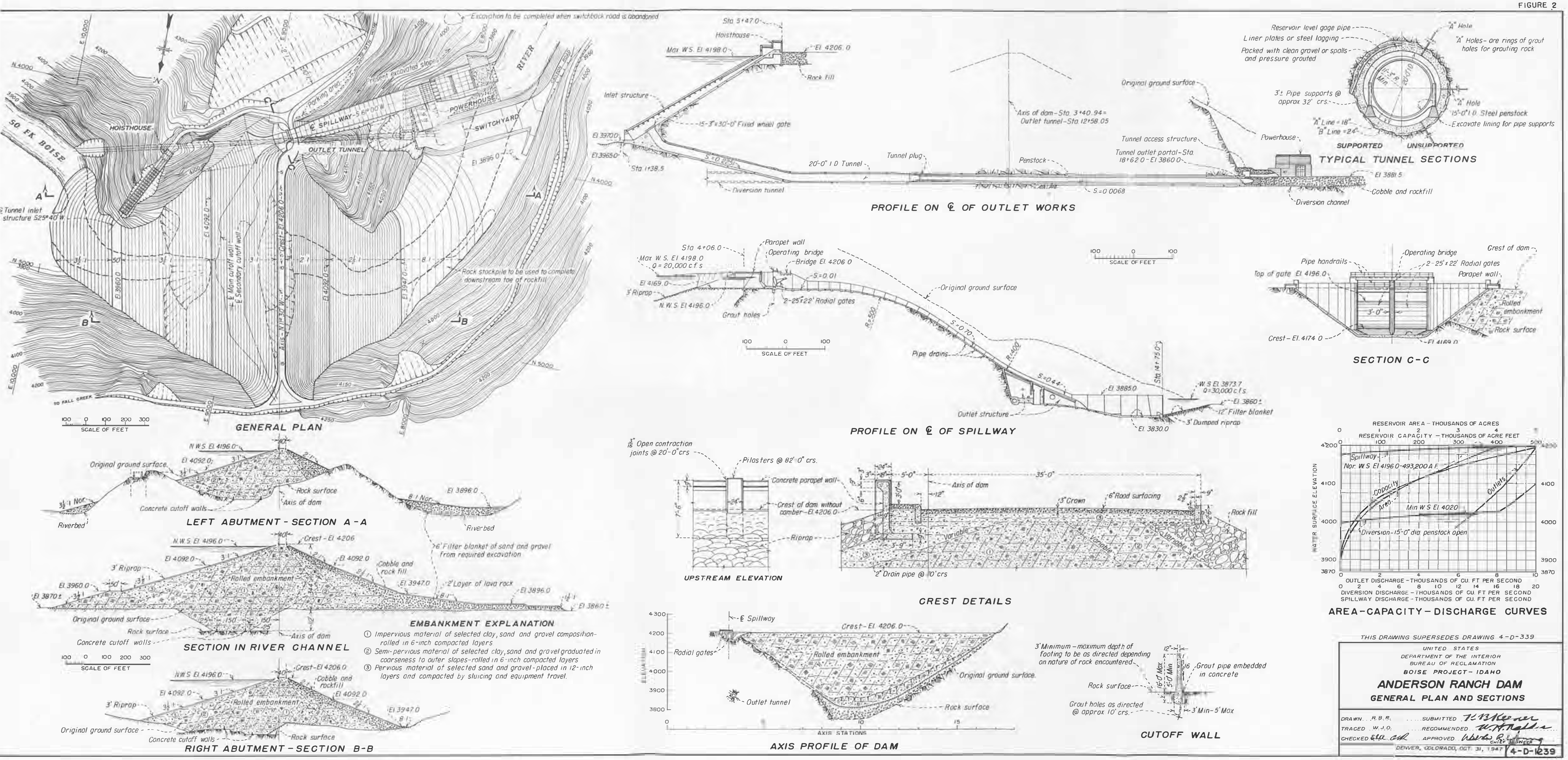

GEM
BOISE
ELMORE
ADA
CAMAS
GOODING
OWYHEE
BOISE NATIONAL FOREST
SAWTOOTH NATIONAL FOREST
ANDERSON RANCH DAM
Black Canyon Dam
Sweet
Gardena
Quartzburg
Pioneerville
Placerville
Centerville
Horseshoe Bend
Letha
Montour
Emmett
Pearl
Idaho City
Obsidian
Atlanta
Middleton
Star
Eagle
Ustick
Boise
Barber
Twin Springs
Arrowrock Dam
Arrowrock Reservoir
Rocky Bar
Featherville
Nampa
Meridian
Kuna
Deer Flat Res.
Bowmont
Melba
Mora
Owyhee
Mayfield
Lenox
Prairie
Pine
Dixie
Thurman
Orchard
Sunnyside
Corral
Soldier
Fairfield
Hill City
Murphy
Mountain Home
Oreana
Grand View
Hammett
Glenns Ferry
King Hill
Bliss
Gooding
Bruneau
Hagerman
Wendell
Clear Lake
Buhl
Snake River
Bruneau River
Sailor Creek
Canyon Creek
South Fork
Middle Fork
North Fork
Payette
Base Line
Meridian
5 0 5 10 15 20 25
SCALE OF MILES
N
INDEX MAP
IDAHO
Coeur d'Alene
Lewiston
Salmon River
Snake River
New Meadows
McCall
Cascade
Weiser
Payette
Emmett
Boise
Nampa
Stanley
Anderson Ranch Dam
Mtn. Home
Hill City
Shoshone
Idaho Falls
Minidoka
Pocatello
McCammon
Twin Falls
Burley
Montpelier
West Yellowstone
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO
ANDERSON RANCH DAM
LOCATION MAP
DRAWN: P.M.W.
TRACED: S.M.E.
CHECKED: F.C.W.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLORADO, MAY 31, 1941
4-D-332
REV. 10-30-47 W.G.H.

FIGURE 2


GENERAL PLAN
HOISTHOUSE
POWERHOUSE
SWITCHYARD
OUTLET TUNNEL
SO FK BOISE
RIVER
Excavation to be completed when switchback road is abandoned
Rock stockpile to be used to complete downstream toe of rockfill
Tunnel inlet structure S25°40'W
SCALE OF FEET
PROFILE ON ℄ OF OUTLET WORKS
Max W.S. El 4198.0
Hoisthouse
Sta 5+47.0
El 4206.0
Rock fill
Inlet structure
15-3'x30'-0" Fixed wheel gate
Axis of dam-Sta. 3+40.94= Outlet tunnel-Sta. 12+58.05
20'-0" I.D. Tunnel
Tunnel plug
Penstock
Diversion tunnel
S=0.0068
Original ground surface
Tunnel access structure
Tunnel outlet portal-Sta. 18+62.0-El 3860.0
Powerhouse
El 3881.5
Cobble and rockfill
Diversion channel
TYPICAL TUNNEL SECTIONS
Reservoir level gage pipe
Liner plates or steel lagging
Packed with clean gravel or spalls and pressure grouted
3'± Pipe supports @ approx 32' crs.
"A" Holes-are rings of grout holes for grouting rock
15'-0" I.D. Steel penstock
Excavate lining for pipe supports
SUPPORTED
UNSUPPORTED
PROFILE ON ℄ OF SPILLWAY
Sta 4+06.0
Max W.S. El 4198.0 Q=20,000 c.f.s.
Parapet wall
Operating bridge
Bridge El 4206.0
2-25'x22' Radial gates
Grout holes
Original ground surface
Pipe drains
Outlet structure
W.S. El 3873.7 Q=30,000 c.f.s.
12" Filter blanket
3' Dumped riprap
El 3830.0
SECTION C-C
Crest of dam
Top of gate El 4196.0
Crest-El 4174.0
Rolled embankment
Rock surface
LEFT ABUTMENT - SECTION A-A
SECTION IN RIVER CHANNEL
RIGHT ABUTMENT - SECTION B-B
EMBANKMENT EXPLANATION
① Impervious material of selected clay, sand and gravel composition-rolled in 6-inch compacted layers
② Semi-pervious material of selected clay, sand and gravel graduated in coarseness to outer slopes-rolled in 6-inch compacted layers
③ Pervious material of selected sand and gravel-placed in 12-inch layers and compacted by sluicing and equipment travel.
UPSTREAM ELEVATION
CREST DETAILS
AXIS PROFILE OF DAM
CUTOFF WALL
AREA-CAPACITY-DISCHARGE CURVES
THIS DRAWING SUPERSEDES DRAWING 4-D-339
UNITED STATES
DEPARTMENT OF THE INTERIOR
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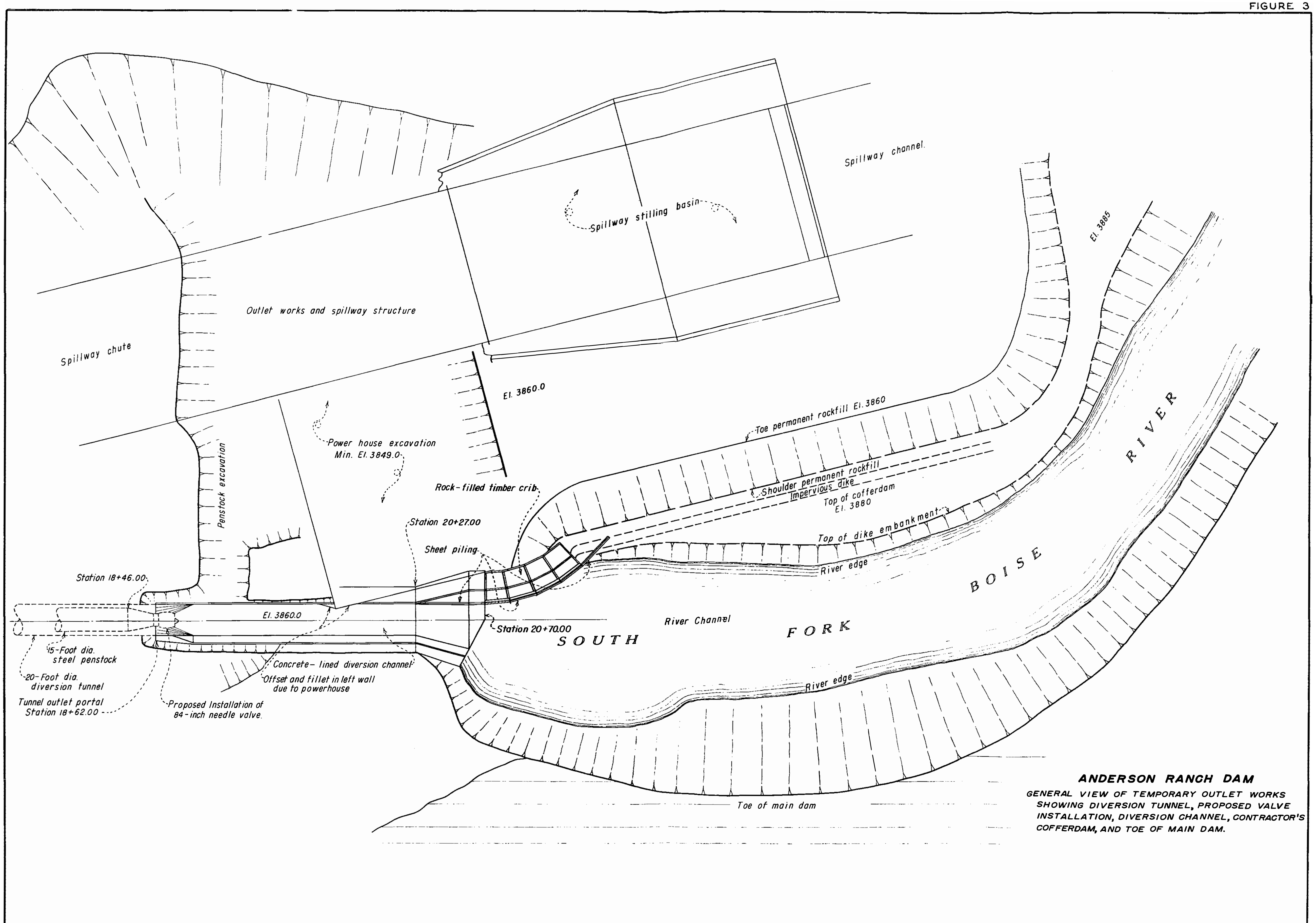
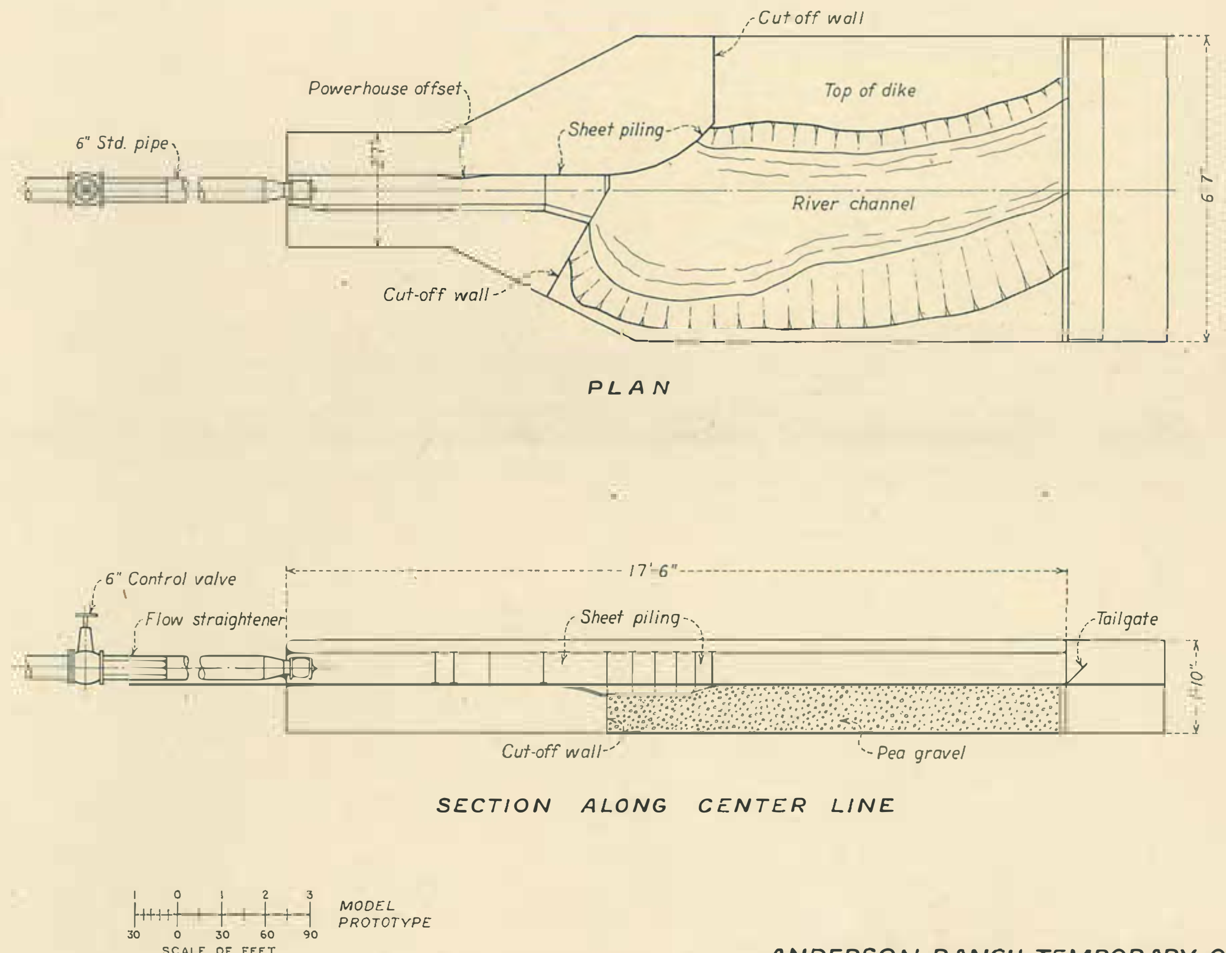
BOISE PROJECT - IDAHO
ANDERSON RANCH DAM
GENERAL PLAN AND SECTIONS
DENVER, COLORADO, OCT. 31, 1947
4-D-1239



ANDERSON RANCH DAM

GENERAL VIEW OF TEMPORARY OUTLET WORKS SHOWING DIVERSION TUNNEL, PROPOSED VALVE INSTALLATION, DIVERSION CHANNEL, CONTRACTOR'S COFFERDAM, AND TOE OF MAIN DAM.

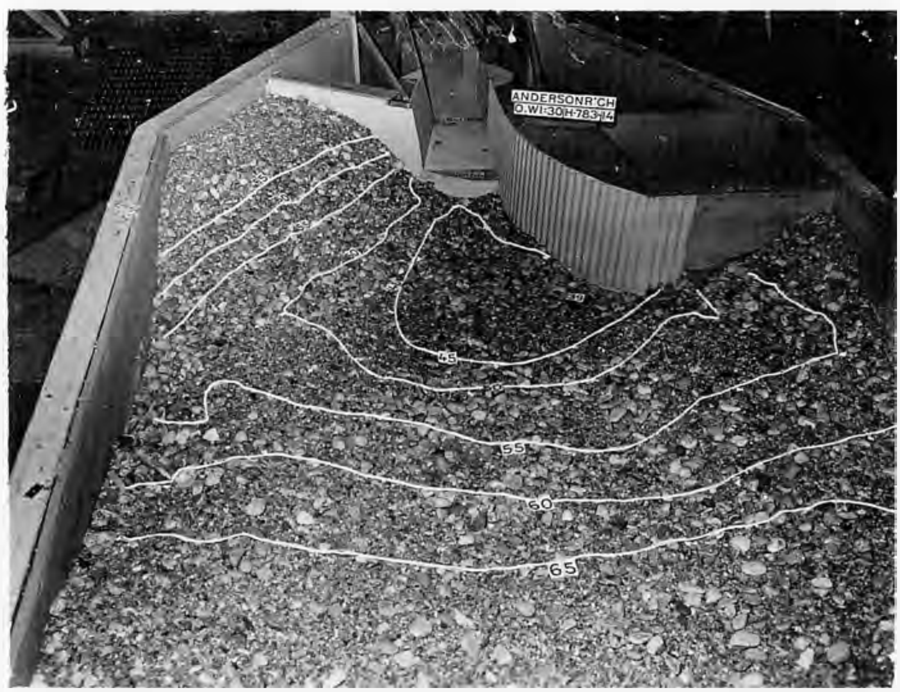


ANDERSON RANCH TEMPORARY OUTLET WORKS
1:30 MODEL

FIGURE 4

1-7-49

A. Flow conditions in diversion and river channels with valve discharge of 4210 cfs.



B. Scour after 15 minutes model operation at 4210 cfs.

FLOW CONDITIONS AND SCOUR WITH 84 - INCH NEEDLE VALVE
INSTALLED AT STATION 18 + 46.00.

1:30 MODEL - ANDERSON RANCH DAM TEMPORARY OUTLET WORKS

Figure 6

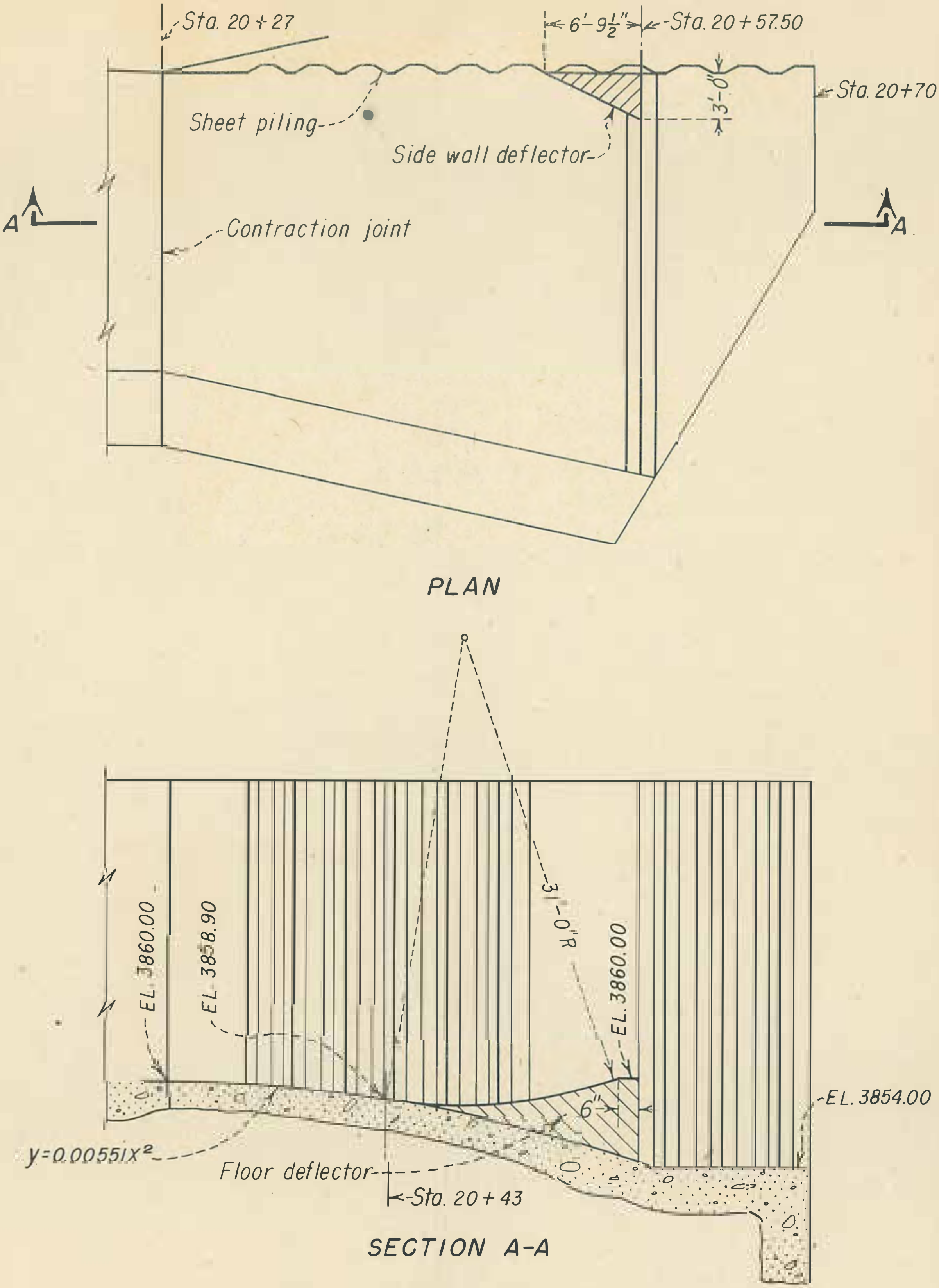
A. Flow in prototype river channel with flow of 4175 sec-ft.

B. Flow in diversion and river channels of model with a discharge of 4210 cfs at 80 f/s velocity.

C. Scour after 15 minutes model operation at 4210 cfs.

FLOW CONDITIONS AND SCOUR WITHOUT FLOOR AND SIDEWALL DEFLECTORS IN DIVERSION CHANNEL AND COASTER GATE USED FOR REGULATION.

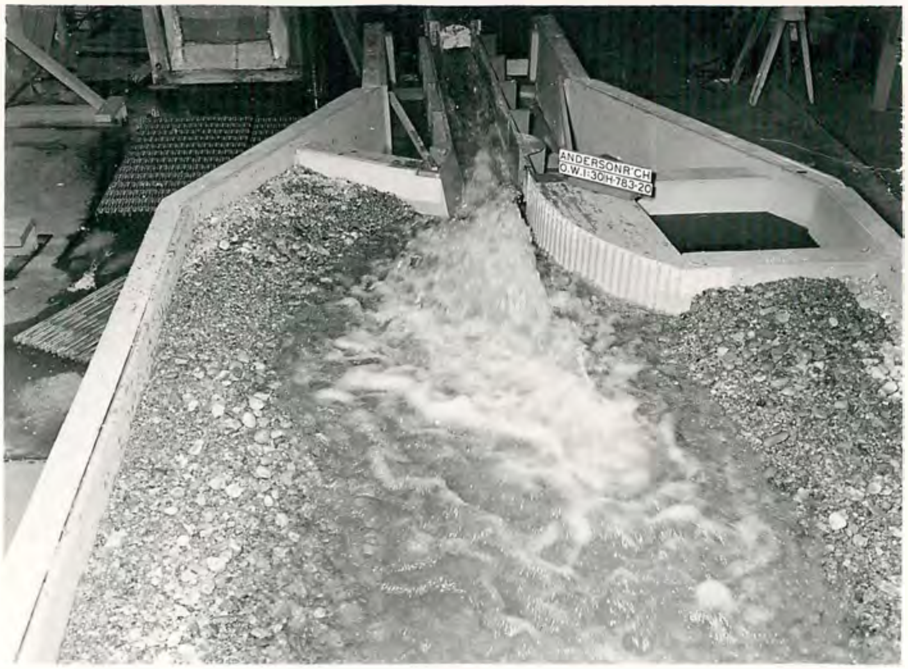
1:30 MODEL--ANDERSON RANCH DAM TEMPORARY OUTLET WORKS



ANDERSON RANCH TEMPORARY OUTLET WORKS

FLOOR AND SIDEWALL DEFLECTORS IN DIVERSION CHANNEL

1:30 MODEL



A. Flow conditions in diversion and river channels with a discharge of 4210 cfs at 80 f/s velocity.

B. Scour after 15 minutes model operation at 4210 cfs.

FLOW CONDITIONS AND SCOUR WITH FLOOR AND SIDEWALL DEFLECTORS IN DIVERSION CHANNEL AND COASTER GATE USED FOR REGULATION.

1:30 MODEL - ANDERSON RANCH DAM TEMPORARY OUTLET WORKS