HYDRAULICS BRANCH
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WHEN BORROWED RETURN PROMPTLY

AIR DEMAND
ANDERSON RANCH OUTLETS

HYD-120

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HYD 120

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

- - -

HYDRAULIC MODEL STUDIES RELATING TO THE QUANTITY OF AIR REQUIRED AT THE OUTLET WORKS OF ANDERSON RANCH DAM

- - -

By

J. A. LIENOSKY, ASSISTANT ENGINEER

- - -

Denver, Colorado,
Jan. 28, 1948

J. W. Bradley

UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDRAULIC MODEL STUDIES RELATING TO

THE QUANTITY OF AIR REQUIRED

AT THE OUTLET WORKS OF ANDERSON RANCH DAM

By J. A. LINDSEY, ASSISTANT ENGINEER

Under Direction of

J. E. WARNOCK, ENGINEER
and
R. F. BLANKS, SENIOR ENGINEER

Denver, Colorado,
Jan. 20, 1965

Denver, Colorado, January 26, 1943.

MEMORANDUM TO CHIEF DESIGNING ENGINEER
(J. A. Lindsey through J. E. Warnock)

Subject: Hydraulic model studies relating to the quantity of air required at the outlet works of Anderson Ranch Dam.

INTRODUCTION

1. The prototype

The Anderson Ranch Dam is to be located on the South Fork of the Boise River, approximately 42 miles southeast of Boise, Idaho (figure 1). The project will consist of an earth dam across the river, an outlet works through the left abutment of the dam, and an open-channel spillway at the left abutment of the dam. The earth dam will be approximately 1,350 feet long and 530 feet above the river bed. The spillway discharge will be regulated by two 25- by 22-foot radial gates (figure 2). The outlet works will consist of a trashrack and inlet structure; a concrete-lined diversion tunnel 20 feet in diameter and approximately 1,500 feet long; and a plate-steel penstock and outlet pipe 15 feet in diameter, extending from a concrete plug in the tunnel to the powerhouse and outlet structure under the spillway channel and terminating in 96-inch ring-seal gates at the ends of the branch penstocks and in emergency gates and five 72-inch hollow jet valves at the ends of the branch outlet pipes (figures 3 and 4).

2. Purpose of model studies

Each of the five 72-inch valves will discharge into a chamber underneath the spillway. It was anticipated that when the outlet jet impinged against the spillway jet, air would be partially exhausted from the outlet chamber, thus reducing the air pressure inside the chambers to considerably less than atmospheric. If this pressure were sufficiently low, there would be the danger of the walls of the chamber collapsing due to the atmospheric force on the outside; consequently, 12-foot diameter vent holes were provided in the walls of each chamber to admit air to relieve this low-pressure con-

dition. A model of one chamber was constructed for the purpose of obtaining the quantity of air required and the pressure differential under the worst possible conditions.

3. Summary of the investigation

The investigation of the quantity of air required to relieve the subatmospheric pressures inside the outlet chambers proved that the air demand is much smaller than anticipated. It was established that the air demand at a spillway discharge of 20,000 second-feet and outlet discharge of 10,000 second-feet was equal to 5,625 second-feet of air, or 56 percent of the outlet discharge. The pressure differential between the chamber and the atmosphere would not be over 30 pounds per square foot even if the size of the vents in each chamber were reduced from 12 feet to 6 feet in diameter. With 6-foot diameter vents the air velocity would be 188 feet per second, which is less than the allowable maximum.

4. The model

The model was built to a scale ratio of 1 to 12 and represented the center outlet chamber, or one-fifth of the prototype. The model was made of wood with a galvanized-iron-lined chamber (figure 5). The hollow-jet valve was a 6-inch valve used in previous investigations of the valve itself. The water was supplied to the model by the laboratory piping system and regulated by differential gages calibrated to give accurate discharge measurements. The tailwater elevation was adjusted by wood pickets placed at the end of the stilling pool channel. The air admitted was measured by placing an anemometer in a 4-inch pipe.

DISCUSSION

5. Preliminary tests

The model was tested to obtain the difference in pressure between the atmosphere and the inside of the outlet chamber. This differential was found to be equal to 0.02 foot of water on the model. From this it was computed that the ratio of air discharge to outlet discharge was approximately 1/2 to 1. It was also found that the air demand increased slightly when

the tailwater was lowered. To provide an added safety factor in the tests, the tailwater was partially controlled to correspond to the condition which would be present if the river bed should retrogress enough to prevent the formation of the hydraulic jump in the stilling pool.

These preliminary tests demonstrated that the 12-foot diameter vent holes, provided on the prototype, would be more than sufficient to relieve the subatmospheric pressures inside the outlet chambers.

6. Tests leading to recommended design

In the next tests the left vent was plugged and a 4-inch pipe connected to the right vent. Tests were then made with a constant outlet discharge and a varying spillway discharge for the purpose of determining the effect of the spillway discharge on the air demand (table 1 and figure 6). The spillway discharge was then held constant and the outlet discharge varied to determine the effect of the outlet discharge on the air demand (figure 6). The spillway discharge-air demand curve is nearly vertical. It would be more nearly vertical on the prototype as spillway velocity would vary due to the change in hydraulic radius, whereas, on the model the velocity changed due to the difference in pressure in the diffuser with an increase in the discharge. The outlet discharge-air demand curve is assumed to be a straight line which does not pass through the origin, as some air is required when the flow is passing over the spillway only.

The maximum air demand was obtained by extrapolation, as the maximum outlet discharge obtainable with the laboratory system when the higher discharges were required for the spillway was limited to 3.83 second-feet. By a special arrangement at a low spillway discharge, the outlet discharge was increased to 4.09 second-feet. When the outlet discharge-air demand curve was drawn, it was observed that the air demand increased 0.07 second-foot when the outlet discharge was increased from 3.83 to 4.01 second-feet. It was then assumed that any curve of spillway discharge-air demand at a constant outlet discharge would be parallel to the straight-line curve previously obtained when the outlet discharge was approximately 3.83 second-feet. Thus, the air demand at 4.01 second-feet outlet discharge and 8.02

TABLE 1

ANDERSON RANCH DAM

BOISE PROJECT - IDAHO

HYDRAULIC MODEL STUDIES - 1:12 SCALE
Summary of Model Data

Run number	Spillway discharge Q_s	Outlet discharge Q_o	Air demand Q_a	Pressure differential p	Vent opening
A - 1	8.75	3.63	2.10	0.019	4-inch pipe
A - 2	6.29	3.82	2.09	0.021	4-inch pipe
A - 3	8.10	3.82	2.18	0.022	4-inch pipe
A - 4	1.50	3.83	1.96	0.015	4-inch pipe
A - 5	1.50	3.25	1.75	0.010	4-inch pipe
A - 6	1.50	2.50	1.20	0.003	4-inch pipe
A - 7 - a	1.50	3.83	1.98	0.012	4-inch pipe
A - 7 - b	1.50	3.83	1.37	0.014	3-inch orifice
A - 7 - c	1.50	3.83	0.32	0.018	1-1/2-inch orifice
A - 7 - d	1.50	3.83	0.06	0.018	1/2-inch orifice
A - 7 - e	1.50	3.83	0	0.020	No opening
A - 8	1.50	2.81	1.56	0.008	4-inch pipe
A - 9	1.50	3.61	1.93	0.012	4-inch pipe
A - 10	1.50	4.09	2.04	0.017	4-inch pipe

second-foot spillway discharge would be 0.07 second-foot greater than at 3.83 second-foot outlet discharge and 8.02 second-foot spillway discharge or equal to a total of 2.25 second-feet of air. This air demand, equal to 56 percent of the outlet discharge, was far less than the anticipated 200 to 400 percent; consequently, the size of the vents could be reduced considerably.

The difference in pressure between the inside of the chamber and the atmosphere was measured on each test. This pressure differential was very small, and, as the data was not obtained with sufficiently precise instruments, it will not be used in computing the prototype pressures.

CONCLUSIONS

7. Results of the investigation

The tests demonstrated that hydraulic model studies of the air demand on structures to be built should be made when analogous data is unobtainable. With the limited knowledge now available on the subject it is generally impossible to ascertain beforehand any reliable estimate of the air demand when two jets of water impinge on one another.

Using the formula for flow through an orifice, $Q = CA\sqrt{2gh}$, one obtains $h = \frac{\left(\frac{Q}{CA}\right)^2}{2g}$. Then by substituting p for the head h and dividing by 1,000 feet, the height of an air column equivalent in weight to a 1-foot column of water, one obtains the relationship $p = \frac{\left(\frac{Q_a}{CA}\right)^2}{2{,}000\ g}$, where p equals the pressure differential in feet of water, Q_a equals the air demand in cubic feet per second, C equals a coefficient of discharge assumed to equal 0.60, and A equals the area of the orifice opening in square feet, which will give a satisfactory estimate of the pressure differential. If 4-foot vents are provided through each chamber the air demand through the right chamber wall in the prototype would be equal to $\frac{10{,}000 \times 0.56}{2} = 2{,}800$ second-feet of air. Therefore, $p = \frac{\left(\frac{2{,}800}{0.6 \times 12.57}\right)^2}{2{,}000 \times 32.2} = 2.14$ feet of water or 134 pounds per square foot. From the relationship $v = \frac{Q}{CA}$

the velocity of the air may be obtained. For the 4-foot vent, therefore, $v = \frac{2,000}{0.4 \times 12.57} = 371$ feet per second. Air traveling at this velocity is extremely noisy; therefore the vents should be made approximately 6 feet in diameter. The velocity would then be reduced to $v = \frac{2,000}{0.6 \times 28.27} = 165$ feet per second and the pressure differential to $p = \frac{\left(\frac{2,000}{0.6 \times 28.27}\right)^2}{2,000 \times 32.2} = 0.42$ foot of water or 26 pounds per square foot. These values appear reasonable and justify the recommendation that the size of the vents be reduced from 12-foot to 6-foot diameter holes in each chamber.

An attempt was made to resolve the data into nondimensional form, but the results were unsatisfactory, and the undertaking was abandoned after it was seen that no pertinent data was obtainable. The apparatus used in the study was not sufficiently precise to give results which would agree when analyzed nondimensionally.

A very worthy project for future study would be to determine nondimensional data on the effect to the air demand of varying the angle of impingement, and the relative velocities of the two jets of water. Such data would enable the designer to predict, with some degree of certainty, the air demand for structures similar to this one. The model data is summarized for use in future investigations (table 1).

5. Recommendations

On the basis of the model studies, it is recommended that

(a) The size of the vents be reduced from 12-foot to 6-foot diameter.

(b) The location of the vents is relatively immaterial as the drop in pressure between the chamber and the atmosphere is quite small.

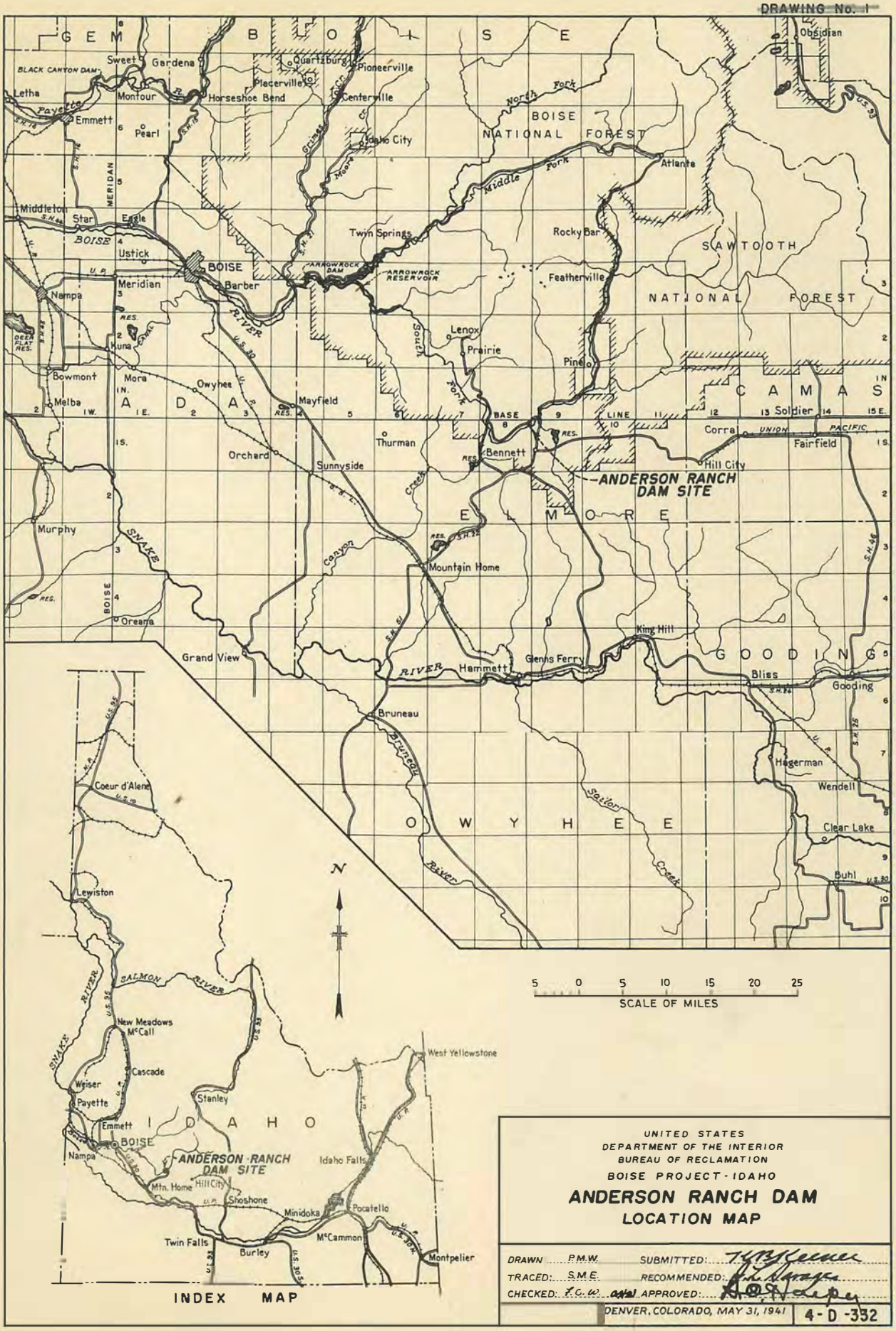
(c) The thickness of the walls remain the same as originally provided, inasmuch as the pressure differential is not sufficient to collapse them.

- - -

J. A. Lindsay

Figure 1

DRAWING No. 1



UNITED STATES
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BOISE PROJECT - IDAHO

ANDERSON RANCH DAM
LOCATION MAP

DRAWN	P.M.W.	SUBMITTED:	T.W. Lewis
TRACED:	S.M.E.	RECOMMENDED:	[illegible]
CHECKED:	F.C.W.	APPROVED:	[illegible]

DENVER, COLORADO, MAY 31, 1941 | 4-D-332

FIGURE 6

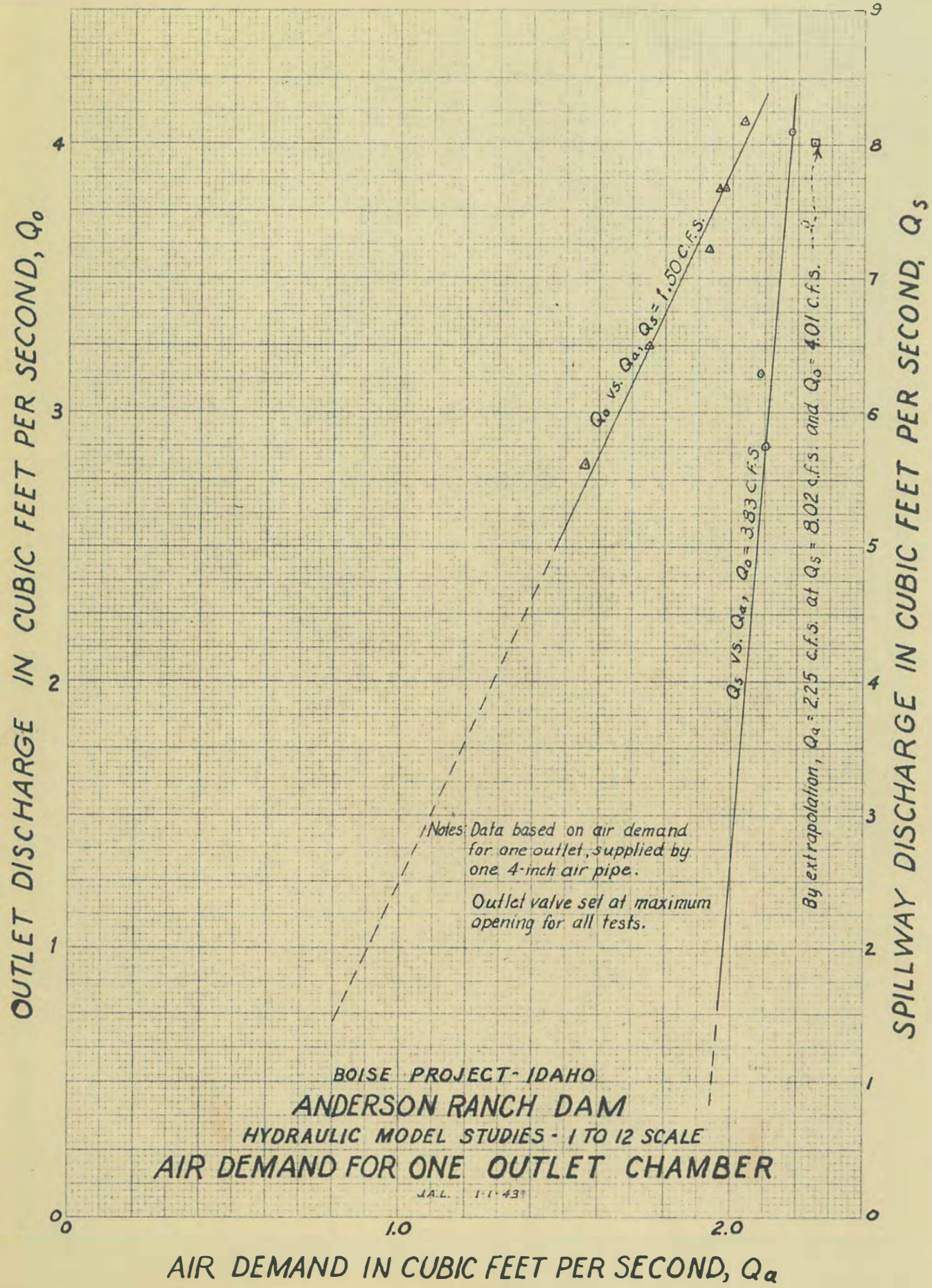
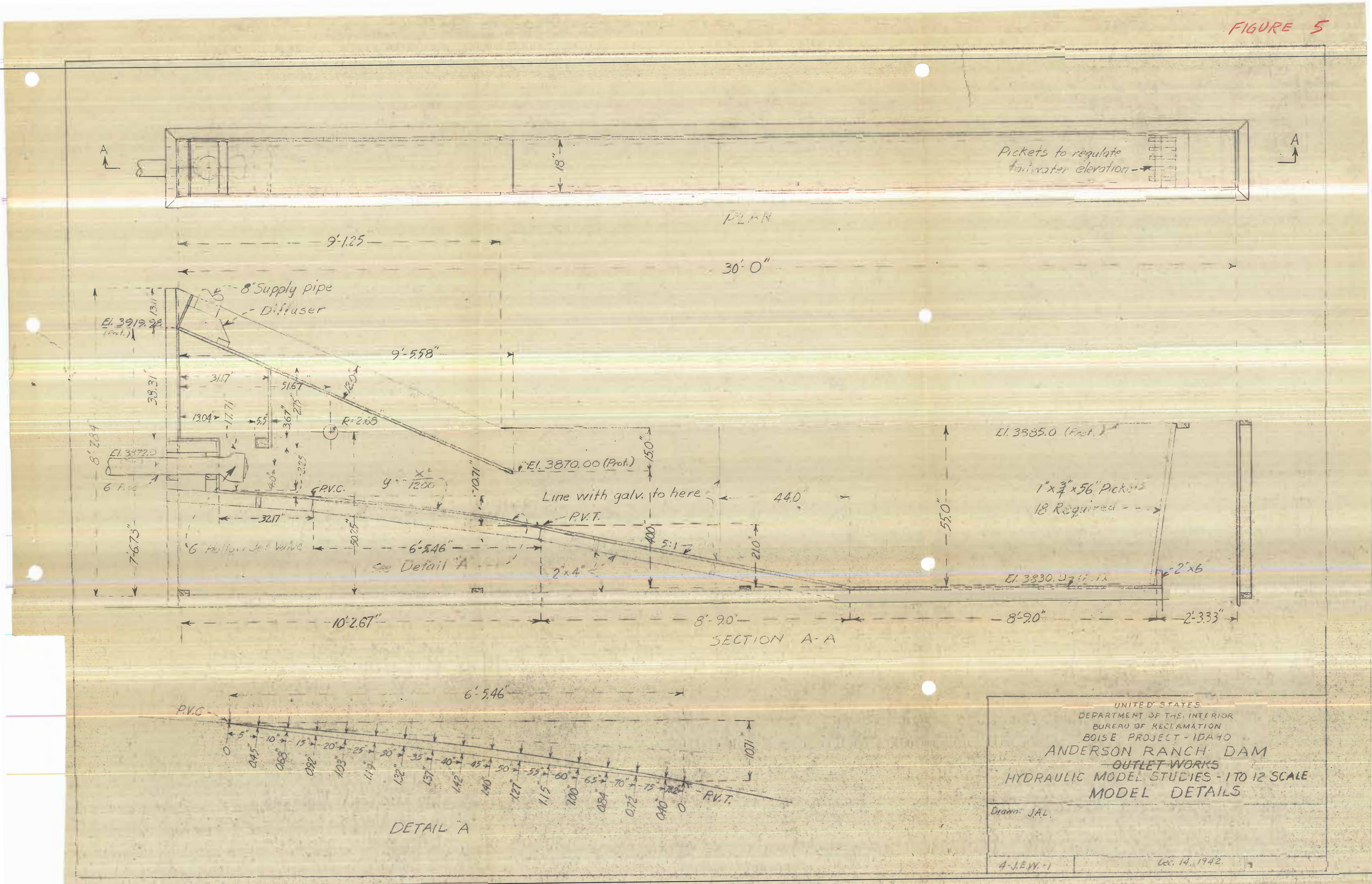

OUTLET DISCHARGE IN CUBIC FEET PER SECOND, Q_o
SPILLWAY DISCHARGE IN CUBIC FEET PER SECOND, Q_s
AIR DEMAND IN CUBIC FEET PER SECOND, Q_a
0
1.0
2.0
1
2
3
4
5
6
7
8
9
Q_o vs. Q_a, Q_s = 1.50 C.F.S.
Q_s vs. Q_a, Q_o = 3.83 C.F.S.
By extrapolation, Q_a = 2.25 c.f.s. at Q_s = 8.02 c.f.s. and Q_s = 4.01 c.f.s.
Notes: Data based on air demand for one outlet, supplied by one 4-inch air pipe.
Outlet valve set at maximum opening for all tests.
BOISE PROJECT - IDAHO
ANDERSON RANCH DAM
HYDRAULIC MODEL STUDIES - 1 TO 12 SCALE
AIR DEMAND FOR ONE OUTLET CHAMBER
J.A.L. 1-1-43

FIGURE 5



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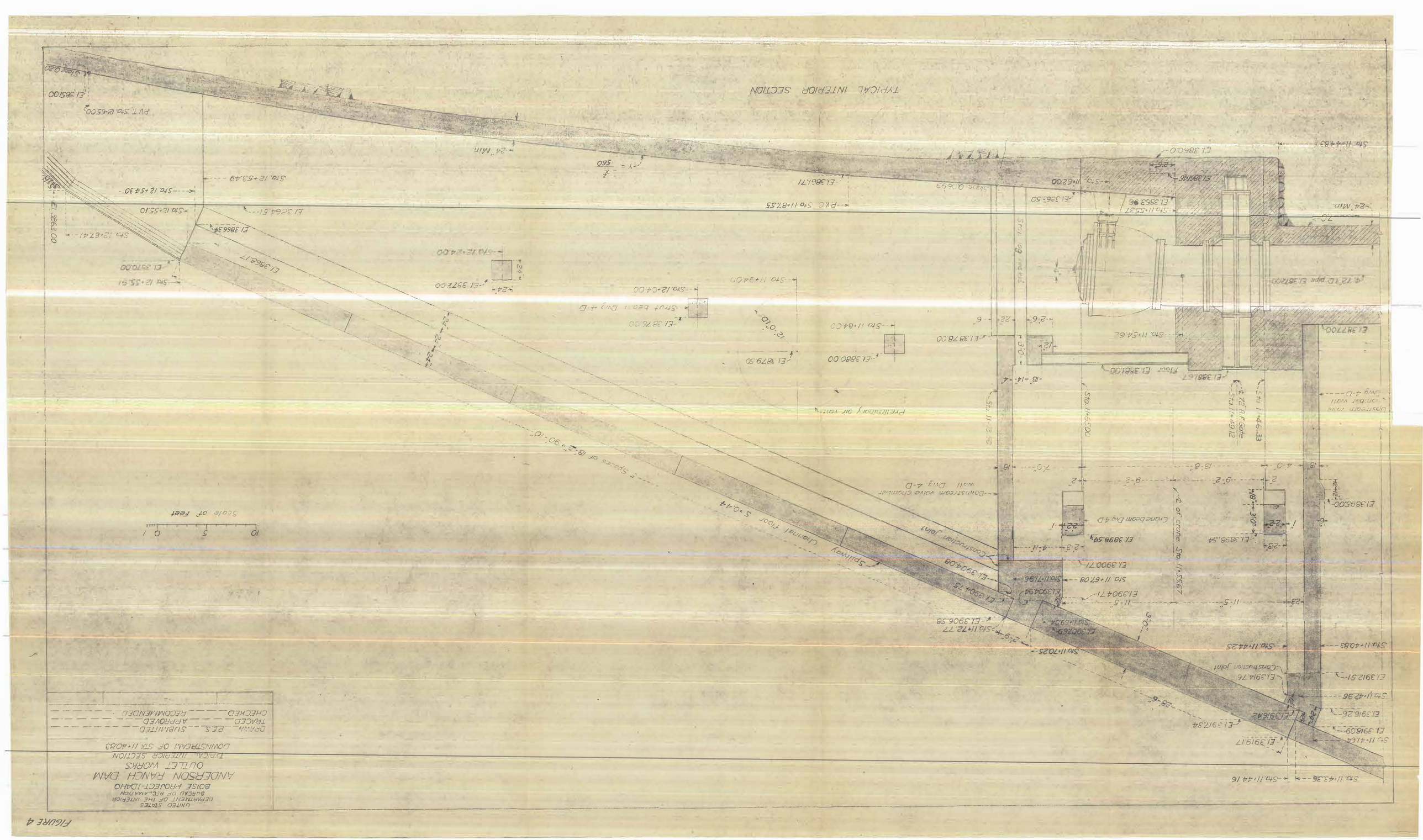
BOISE PROJECT - IDAHO

ANDERSON RANCH DAM
~~OUTLET WORKS~~
HYDRAULIC MODEL STUDIES - 1 TO 12 SCALE
MODEL DETAILS

Drawn: J.A.L.

4-J.E.W.-1 | Dec. 14, 1942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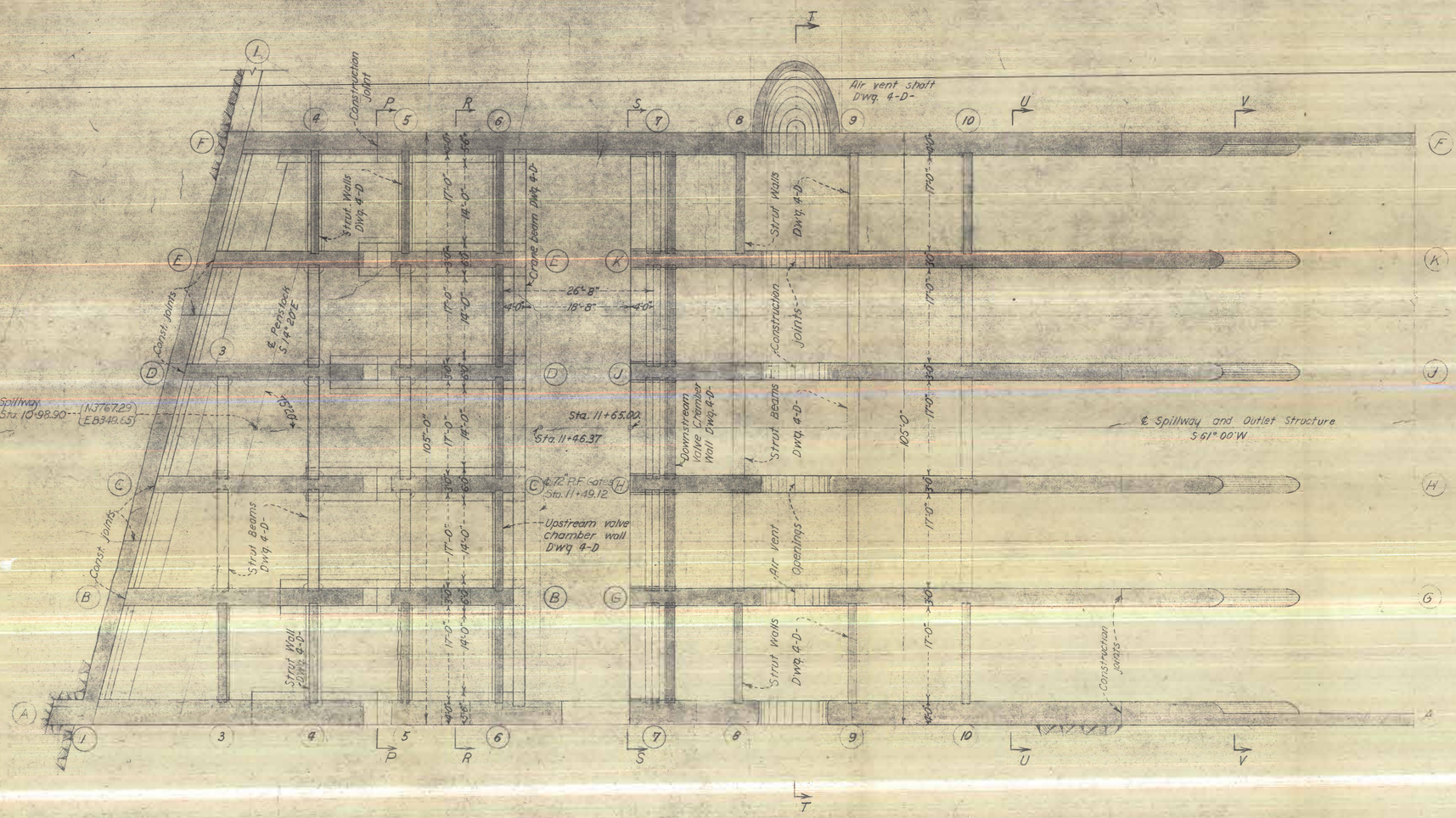
BUREAU OF RECLAMATION
BOISE PROJECT-IDAHO
ANDERSON RANCH DAM
OUTLET WORKS
TYPICAL INTERIOR SECTION
DOWNSTREAM OF STA. 11+40.83
DRAWN PES SUBMITTED
TRACED APPROVED
CHECKED RECOMMENDED
Scale of Feet
0 5 10
TYPICAL INTERIOR SECTION
Spillway Channel Floor S=0.44
Preliminary air vent
Downstream wall Dwg 4-D
Downstream wall Dwg 4-D
Construction Joint
Crane boom Dwg 4-D
Crane Sta. 11+35.67
Floor El. 3881.00
Sta. 11+46.33
Sta. 11+49.12
Sta. 11+43.36
Sta. 11+44.16
Sta. 11+41.64
Sta. 11+42.96
Sta. 11+40.83
Sta. 11+44.25
Sta. 11+70.25
Sta. 11+72.77
Sta. 11+62.00
Sta. 11+55.37
Sta. 11+54.61
Sta. 11+64.00
Sta. 11+67.08
Sta. 11+71.96
Sta. 12+24.00
Sta. 12+04.00
Sta. 11+94.00
Sta. 12+53.49
Sta. 12+54.30
Sta. 12+55.10
Sta. 12+67.41
Sta. 12+35.51
PVT Sta. 12+65.00
PVC Sta. 11+87.55
Slope 0.0693
Slope 0.20
Slope 0.0638
Slope 0.0560
Slope 0.0560
Slope 0.0560

FIGURE 3



SECTIONAL PLAN

SCALE OF FEET

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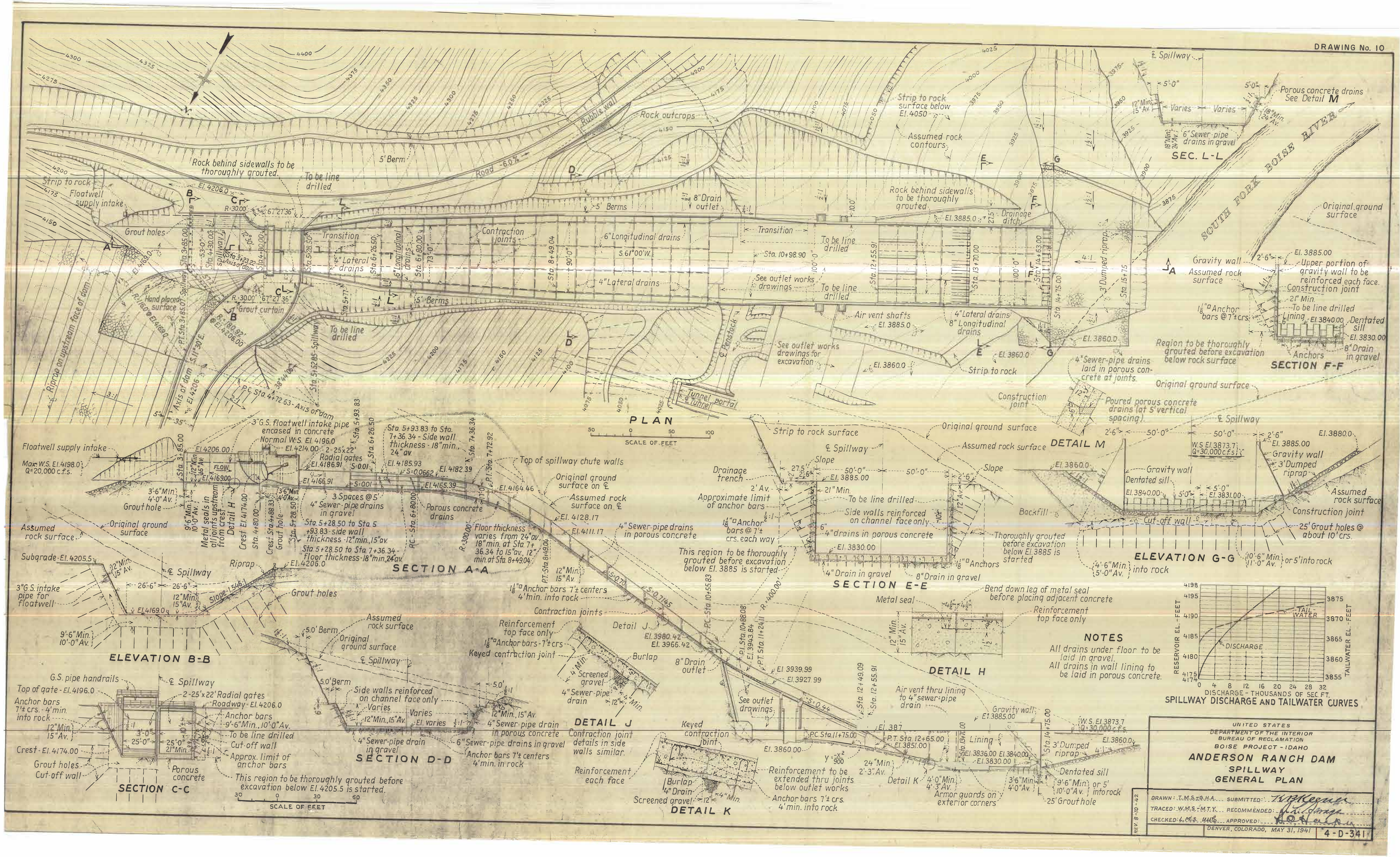
BOISE PROJECT - IDAHO
ANDERSON RANCH-DAM
OUTLET WORKS
OUTLET STRUCTURE - CONC. OUTLINE
SECTIONAL PLAN A-A

DRAWN P.E.S. SUBMITTED
TRACED APPROVED
CHECKED RECOMMENDED

4-ER-194


PLAN
SCALE OF FEET
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SEC. L-L
DETAIL H
DETAIL J
DETAIL K
DETAIL M
ELEVATION G-G
SPILLWAY DISCHARGE AND TAILWATER CURVES
NOTES
All drains under floor to be laid in gravel.
All drains in wall lining to be laid in porous concrete.
SOUTH FORK BOISE RIVER
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO
ANDERSON RANCH DAM
SPILLWAY
GENERAL PLAN
DRAWN: T.M.S. & H.A. SUBMITTED:
TRACED: W.M.S.-M.T.Y. RECOMMENDED:
CHECKED: L.M.S. APPROVED:
DENVER, COLORADO, MAY 31, 1941
4-D-341