UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MODEL STUDIES FOR THE DEVELOPMENT OF A DISCHARGE-MEASURING SYSTEM AT THE WEST PORTAL OF ALVA B. ADAMS TUNNEL COLORADO-BIG THOMPSON PROJECT, COLORADO

Laboratory Report No. Hyd-364

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

November 12, 1952

FOREWORD

The model studies to determine and calibrate a satisfactory measuring device for the Alva B. Adams Tunnel were performed in the United States Bureau of Reclamation Hydraulic Laboratory during the first half of 1950, following the disclosure that the original measuring device did not perform as expected.

Engineers of the Hydraulic Laboratory working in cooperation with the Canals Branch developed a relatively simple measuring device, which could be added to the existing structure. Plans for construction and field measurements were performed by the South Platte River District while actual construction of the field device was done by the project office.

CONTENTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Design and Construction Division
Engineering Laboratories Branch
Denver, Colorado
November 12, 1952

Laboratory Report No. Hyd.--364
Hydraulic Laboratory Section
Written by: E. J. Rusho
Reviewed and checked by:
A. J. Peterka and J. N. Bradley

Subject: Model studies for the development of a discharge-measuring system at the West Portal of Alva B. Adams Tunnel--Colorado-Big Thompson Project, Colorado

SUMMARY

The model studies discussed in this report were made on a 1:10 scale model of the West Portal portion of Alva B. Adams Tunnel, Figure 2. The studies were necessary because with the operation of the prototype tunnel it was not possible to obtain satisfactory measurements of the discharge. The studies were therefore concerned with (1) why the original measuring system was unsatisfactory and (2) the development of a satisfactory measuring device that would require a minimum of changes and additions to the existing structure, and would be simple to operate.

In the tests on the original structure it was apparent why the depth at Station 7+00 could not be used to obtain the discharge. Flow passed through the converging transition section downstream from the gates at supercritical velocities causing standing waves in a diamond pattern to occur in the depth measuring region. This made the depth difficult to measure and the relationship between the depth and discharge was unsatisfactory.

The control gates were calibrated in the hope that the discharge could be determined from the gate opening and the reservoir elevation. The curves obtained, Figure 8, showed that accurate gate settings would be required to determine the discharge. Since this method was also complex in its operation the idea was discarded. Before the calibration four baffle piers had been installed downstream from the gates. They caused a hydraulic jump to form for all discharges which increased the depth of flow and eliminated the standing waves, but the flow was not sufficiently smooth to use the depth measuring piezometer at Station 7+00 for a discharge indicator.

Studies were then made with seven different weirs installed 20 feet downstream from the depth-measuring section. The weirs increased the depth and smoothed out the flow which resulted in discharge-rating curves, Figure 9, that were not affected by the tunnel depth downstream except for the higher discharges. A piezometer was provided at Station 8+17.5 to determine this downstream depth. The curved Weir B, 20 inches high, was recommended for installation in the prototype. Studies on the piezometer opening at Station 7+00 showed that the surge in the stilling-well was decreased by reducing the 8-inch pipe opening to a 2-inch opening. Calibration of the 20-inch weir, considering the depths of flow upstream and downstream, resulted in the discharge-capacity curves on Figure 17.

The baffle piers and 20-inch curved weir were installed in the prototype during May of 1950 and field measurements were made to check the model rating. The agreement was not as close as expected, so in March of 1951 personnel of the Hydraulic Laboratory inspected the installation and the 20-inch weir was replaced with a weir that conformed to the model weir. Field measurements were then found to be in good agreement with the model rating, Figure 20.

INTRODUCTION

The Alva B. Adams Tunnel is an outstanding feature of the Colorado-Big Thompson Project, Colorado, Figure 1. Water from the Colorado River drainage area on the Western Slope is diverted by the tunnel to the Big Thompson River on the Eastern Slope. The 9-foot 9-inch-diameter bore extends 13.1 miles under the Continental Divide from the entrance, or West Portal, Figure 2, at Grand Lake to the East Portal at Marys Lake. Water enters the tunnel from Grand Lake which is connected to Shadow Mountain Reservoir. The water surface in the two lakes is maintained between elevations 8365.0 and 8367.0 by either spilling water over the spillway at Shadow Mountain Dam or by pumping from Granby Reservoir. The designed capacity of the tunnel is 550 cfs and the depth of flow cannot exceed 8.45 feet because of the clearance necessary for power cables enclosed in a conduit suspended from the roof of the tunnel. The discharge is regulated by two 9- by 10-foot radial gates, Figure 3, located at the West Portal just downstream from the curved entrance structure.

The Colorado State Engineers' office requires an accurate record of the total amount of water diverted through the tunnel. For this purpose provision was made to record the depth of flow 100 feet downstream from the gate structure at Station 7+00. With the first operation of the tunnel, difficulty was experienced with this measuring system as a large surge occurred in the stilling-well making it difficult to determine the depth of flow. The relationship between the depth of flow and the discharge was irregular because of the movement of the standing waves with a change in discharge. It was decided to develop a measuring device with the aid of a hydraulic model, and the results of these studies are described in this report.

THE 1:10 SCALE MODEL

The hydraulic model of the West Portal of the Alva B. Adams Tunnel was built to a scale of 1:10, resulting in a model tunnel diameter of 11.70 inches. The model represented 860 feet of prototype tunnel including the gate structure with 60 feet of double conduit upstream from the gates, Figure 4. The upstream end of the model was connected by a bellmouth entrance to a 6- by 4-foot head box built of wood and lined with sheet metal. A rock baffle in the head box smoothed out the flow entering the model. The inlet pipe was connected to the main laboratory supply line which contained Venturi meters for measuring the discharge. The maximum tunnel capacity of 550 cfs was represented by 1.74 cfs in the model. The gate structure was built of wood and was lined with sheet metal except that the right-side wall was made of transparent plastic. The gates were constructed of sheet metal and the center pier was built of wood. Thirteen feet of the model downstream from the gate structure was built of transparent plastic which represented 50 feet of transition and 80 feet of tunnel. The remaining 64.5 feet of the model was of metal pipe. A plastic stilling-well containing a hook gage was connected to Station 7+00 to determine the depth of flow. A similar arrangement was used to obtain the depth of flow at Station 8+17.5. A point gage was used for measuring the water-surface elevation in the head box. The upstream section of the model is shown in Figure 5.

With the scale ratio of 1:10 the smooth surfaces of the model tunnel represented very nearly the roughness of the concrete surfaces of the prototype tunnel. Calculations showed that with the prototype tunnel discharging freely the flow would be below normal depth for a distance of 3,000 feet upstream from the exit. This would require a model length of 300 feet to obtain normal depth of flow, so it was necessary to install a slide gate at the tunnel exit to adjust the depth of flow to that which would occur in the prototype.

THE INVESTIGATION

The Original Structure

Operation. The original West Portal structure, Figure 3, was investigated with the model. The extent of the structure contained in the model is shown in Figure 4. Operation was at various discharges up to the maximum of 550 cfs prototype At each discharge the depth of water was set to correspond to the normal depth of flow in the tunnel, considering steady uniform flow in which the slope of the water surface was parallel to the slope of the bottom. The normal depth was computed using a roughness value of Manning's n= 0.014. The elevation of the water surface upstream from the gates was also set to that which would occur with the water surface of the lake maintained between elevations 8365.0 and 8367.0. At low discharges the gate openings were small and a high-velocity jet issued from under the gates as shown for a discharge of 100 and 200 cfs, Figures 6A and 6B. The depth of flow was less than critical. Standing waves were formed in the transition section and extended downstream in the tunnel beyond the depth-measuring section. This rough water surface caused a large surge in the stilling-well connected to a piezometer at Station 7+00. With a change in discharge the position of the standing waves shifted so that an irregular relationship occurred between the elevation of the water surface in the stilling-well and the discharge. With higher discharges the waves were less pronounced and the depth at Station 7+00 gave a better indication of the discharge. When operating with one gate open, the waves were larger than with two gates open. The maximum discharge that could be passed with one gate open was about 300 cfs.

These tests on the original structure showed why the prototype measuring system was unsatisfactory. The remaining model studies were made with minor modifications to the structure to develop a reliable flow-measuring system.

Changes in the Structure

Baffle piers. The first modification to the structure was the addition of four baffle piers located 11.3 feet downstream from the gatehouse, as shown in Figure 7A. Each baffle was an 18-inch cube placed in the path of the high-velocity flow issuing from under the radial gates. When the model was operated a hydraulic jump formed, Figure 7B, resulting in an increase in the depth of flow and a smoother water surface in the tunnel. The improvement in flow due to the baffles can be seen by comparing Figure 6A with Figure 7B. This smoother and lower velocity flow was a better condition for determination of the discharge by the depth method. The maximum discharge of 550 cfs could be passed through the structure with the baffle piers in place so they were retained in the model for all subsequent tests.

Gate calibration. With the baffle piers installed the gates were calibrated since this was one possible method that could be used to determine the flow through the tunnel. For each discharge the two gates were opened equally and the corresponding computed normal depth of flow was set in the tunnel. The elevation of the water upstream from the gates was read after allowing time for the flow to stabilize. Discharge-capacity curves obtained from these tests are shown in Figure 8. The wide spacing of the curves at the lower discharges indicates that accurate setting of the gates is necessary to determine the discharge satisfactorily in this manner. These curves are only for the special case of normal depth flow in the tunnel. In the general case, for all conditions of flow, it is necessary to know the elevation of the water surface downstream from the gates, especially for the larger discharges. Since the gate openings and the two water-surface elevations must be continually recorded, the gate calibration method for determining the discharge through the tunnel was not considered practical. Tests were continued, therefore, using the depth at Station 7+00 as a means of obtaining the discharge.

Curved weirs. With the baffle blocks in place the discharge-rating curve at Station 7+00 corresponds to the computed normal depth which is shown by the dotted line in Figure 9. The normal depth curve is subject to change with a change in the roughness of the tunnel walls due to growth of moss or other conditions. It was decided to use a weir at Station 7+20 which would act as a control and increase the depth of flow at Station 7+00. The depth of flow in the tunnel would then have less effect on the depth upstream from the weir. Four curved weirs, A, B, C, and D, Figure 10A, varying in height from 12 to 24 inches, were tested in the model.

With Curved Weir A, 24 inches high installed, the depth was increased at Station 7+00 and the water surface was more uniform than occurred without the weir. Discharge-rating curves were obtained for the four heights of curved weirs and these are shown in Figure 9. In all tests the depth downstream from the weir at Station 8+17.5 was maintained at the normal depth shown by the dotted line in Figure 9. The submergence point or discharge at which a change in the depth downstream from the weir affected the depth at Station 7+00 was as follows: Weir A 450 cfs, B 400 cfs, C 350 cfs, and D 300 cfs. Appearance of the flow in the tunnel for a discharge of 300 cfs with Weirs B, C, and D installed is shown in Figure 11. Water-surface profiles for Weirs B, C, and D are shown in Figure 12 for discharges of 100, 500, and 550 cfs. The clearance between the water surface and the crown of the tunnel was sufficient for the power conduits with the 20-inch Weir B. The 24-inch Weir A was too high since the water came in contact with the power conduits at a discharge of 550 cfs. These tests with the curved weirs indicated that the performance was most satisfactory with the 20-inch weir. The weir submerged at a discharge of 400 cfs, and permitted the passage of 550 cfs without interference with the power conduit.

Sharp weirs. Tests were made with three weirs with plane surfaces since they would be easier to construct. Two weirs, E and F, had a flat crest, Figure 10B, and Weir G had a vee crest, Figure 10C. Flow conditions with these weirs were similar to that obtained with the curved weirs except that the flow was not as smooth. Energy-loss tests were made on the sharp weirs with a discharge of 550 cfs and compared with similar tests made on the curved weirs, Figure 13. The loss was less using the curved weirs and also less with lower weirs. After considering the losses and the conditions of flow, the Curved Weir B 20-inch height, was recommended for installation in the prototype.

Piezometer at Station 7+00. With the baffle blocks and 20-inch Weir B in place the surge in the stilling-well was measured for various flow conditions with an equivalent 8-inch piezometer opening at Station 7+00, Figure 14A. The maximum surge of over 0.18 foot, as shown in the figure, was considered excessive, so tests were made with the opening reduced to 2 inches by the two arrangements shown in Figures 14B and 14C. In both cases the surge was reduced to about one-fourth of that occurring with the 8-inch opening. The 2-inch opening in the 5/16-inch plate, Figure 14C, was recommended since this arrangement gave the least surge as shown in the figure.

The Recommended Structure

Operation. The recommended structure, Figure 15, had four 18-inch cubic baffle piers 11.3 feet downstream from the gate structure and a curved weir 20 inches high at Station 7+20. Piezometer openings at Stations 7+00 and 8+17.5 were connected to two separate stilling-wells to record the depth of flow at these two sections. As discussed under the curved-weir studies, smooth flow occurred throughout the structure at all discharges. The appearance of the flow from the gates to the downstream side of the weir is shown in Figure 16 for a discharge of 400 cfs.

Calibration. Discharge-rating curves were obtained with the recommended baffle piers and 20-inch curved weir installed as shown in Figure 15. For various discharges through the structure the water surface upstream from the gates was not allowed to exceed the maximum lake elevation 8367.00. After allowing time for the flow to stabilize, the depth at Station 7+00 was read using a hook gage in a stilling-well. The depth downstream from the weir at Station 8+17.5 was also obtained by this method. The tunnel discharge is related to the depth readings in the manner shown by the curves on Figure 17. In the figure the depths are expressed as the head above the crest of the curved weir. For discharges under 300 cfs, only the head H_1 upstream from the weir is needed to obtain the discharge. For greater flows the head H_2 downstream from the crest can become large enough to influence the head H_1. In this case the discharge is read by entering the curves with the given value of H_1 and the appropriate H_1 - H_2 curve. A calibration of the prototype tunnel could be made without recording H_2, but if the tunnel roughness should change due to growth of moss or wear to the surface, the value of H_2 would change, resulting in a change in H_1. Thus, H_2 is included to provide a more general calibration that will not require as frequent check measurements in the field. For convenience in obtaining the discharge, the curves are given in tabular form in Figures 18 and 19. The discharge rating as obtained with the 1:10 scale model was considered reliable, but the Colorado State Engineers' office wished to check the accuracy of the curves with field measurements.

THE PROTOTYPE STRUCTURE

Recommended Measuring System

First installation and calibration. The four baffle piers and curved 20-inch weir recommended from the model studies were installed in the prototype tunnel before the operating season of 1950. An additional piezometer was also installed at Station 8+17.5, so that records were made of the depth of flow both upstream and downstream of the 20-inch weir. In compliance with the desire of Colorado State Engineers' office, a temporary Parshall flume was placed at the East Portal Reservoir to check the accuracy of the 20-inch curved weir as a measuring device. Current meter measurements were used to calibrate the Parshall flume. The discharges indicated by the flume were greater than the discharges shown by the West Portal measuring system which was calibrated from the model studies. Since the discrepancy was too large to be accounted for by experimental error, it was decided to check the prototype installation to determine if the dimensions were in agreement with those used in the model.

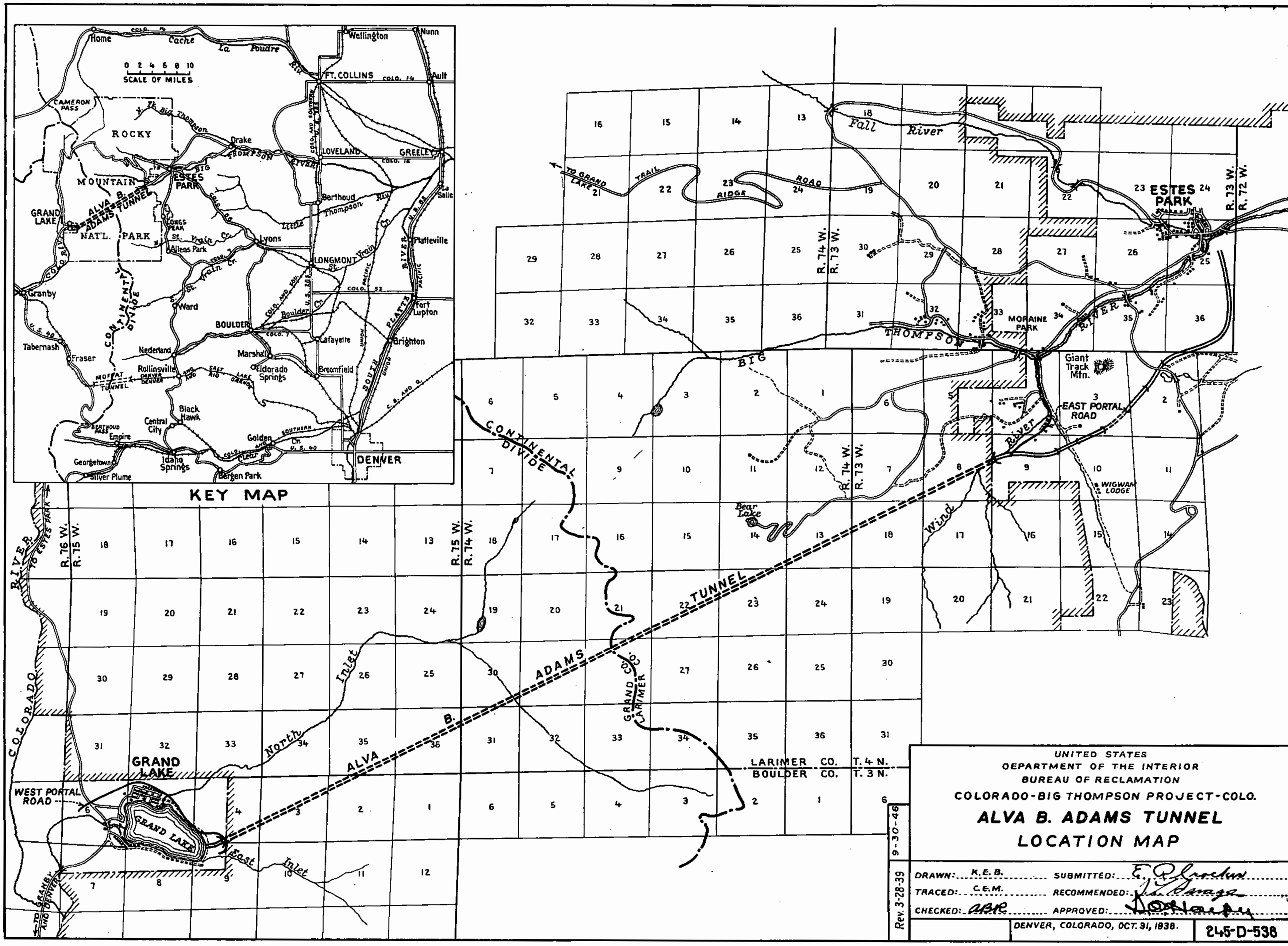
Second installation and calibration. In March of 1951 representatives of the Hydraulic Laboratory and the South Platte River District inspected the prototype installation 1/. The installation and condition of the four baffle piers downstream from the radial gates were found to be satisfactory. The shape of the 20-inch curved weir, in the direction of flow, did not agree with the one calibrated in the model. The upstream and downstream parts of the weir were flat instead of curved surfaces and the radius of the crest was too short. It was also found that the piezometer openings were not smooth and flush with the walls of the tunnel which could cause an error in determining the depth of flow.

1/ Field Trip Report No. Hyd-1099.

Prior to the operating season of 1951, the 20-inch curved weir was replaced with a weir having the shape and dimensions corresponding to the one used in the model studies. The piezometer openings were also repaired to give a smooth surface to the tunnel wall.

The West Portal measuring system was calibrated in the field by making discharge measurements with a current meter in the double conduit section upstream from the radial gates. The results obtained from these measurements are plotted on Figure 20 together with the model envelope curve from Figure 17. The agreement between the field measurements and the model calibration is considered satisfactory.

Interior - Reclamation - Denver, Colo.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT-COLO.

ALVA B. ADAMS TUNNEL

LOCATION MAP

DRAWN: K.E.B. SUBMITTED: [signature]
TRACED: C.E.M. RECOMMENDED: [signature]
CHECKED: [initials] APPROVED: [signature]

Rev. 3-28-39
9-30-46

DENVER, COLORADO, OCT. 31, 1938.

245-D-538

FIGURE 1

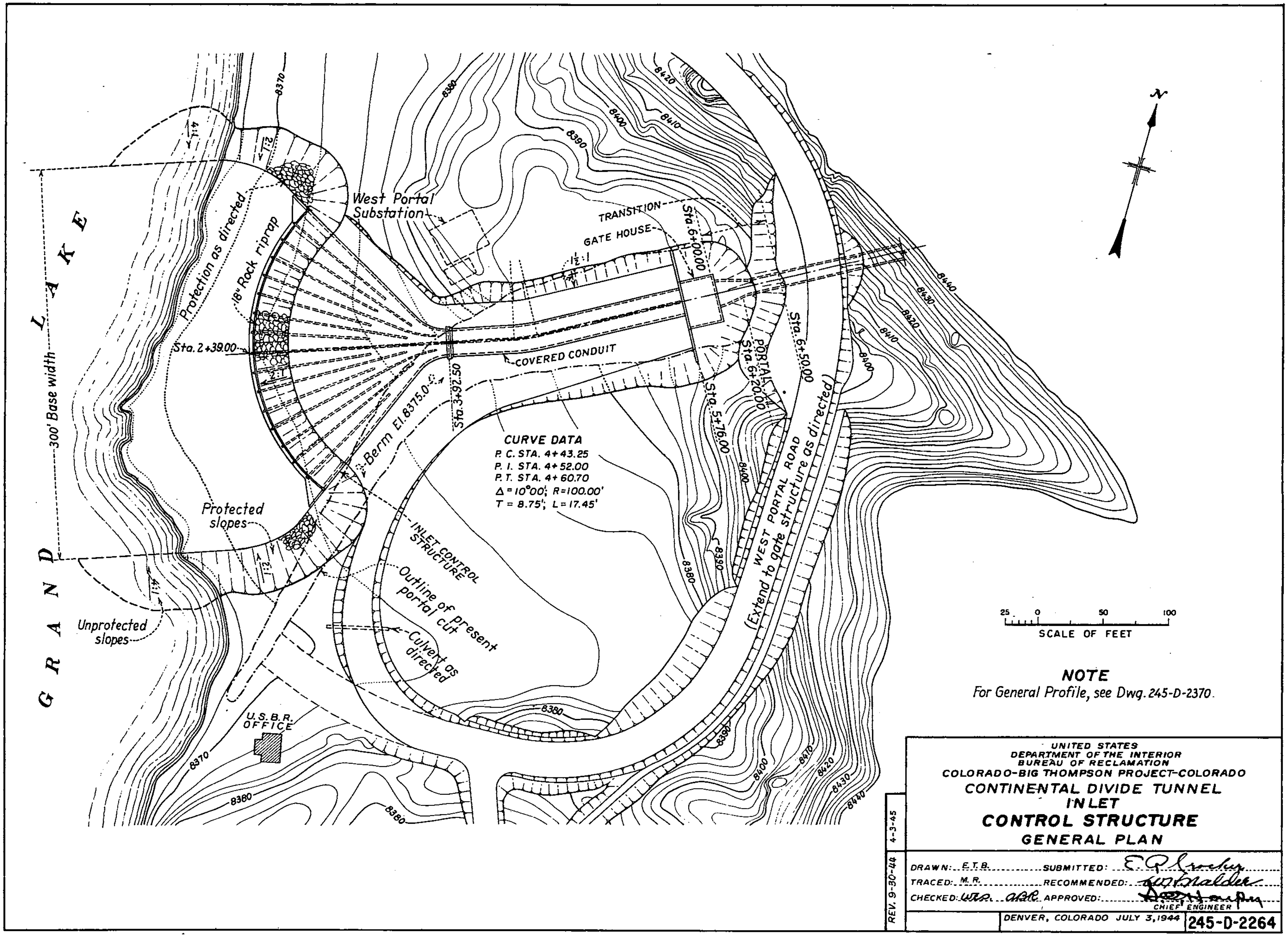
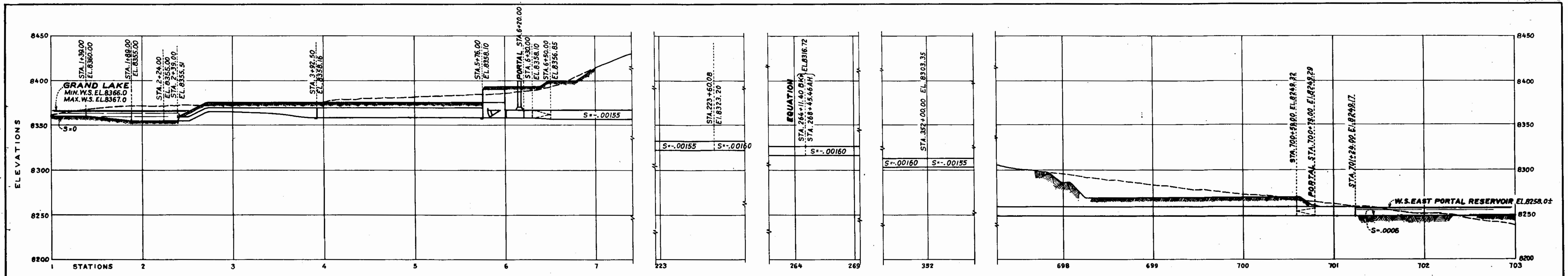
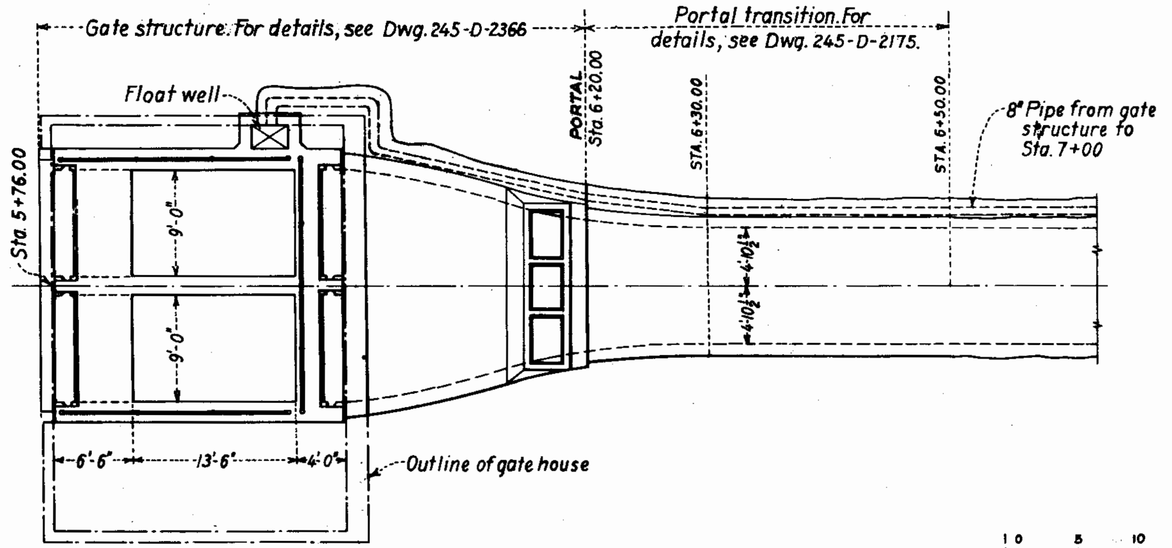

GRAND LAKE
300' Base width
Protection as directed
18" Rock riprap
Sta. 2+39.00
West Portal Substation
TRANSITION
GATE HOUSE
Sta. 6+00.00
COVERED CONDUIT
Sta. 3+92.50
Berm El. 8375.0
PORTAL Sta. 6+20.00
Sta. 6+50.00
Sta. 5+76.00
CURVE DATA
P. C. STA. 4+43.25
P. I. STA. 4+52.00
P. T. STA. 4+60.70
Δ = 10°00'; R=100.00'
T = 8.75'; L = 17.45'
Protected slopes
Unprotected slopes
INLET CONTROL STRUCTURE
Outline of present portal cut
Culvert as directed
WEST PORTAL ROAD
(Extend to gate structure as directed)
U.S.B.R. OFFICE
N
25 0 50 100
SCALE OF FEET
NOTE
For General Profile, see Dwg. 245-D-2370.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT-COLORADO
CONTINENTAL DIVIDE TUNNEL
INLET
CONTROL STRUCTURE
GENERAL PLAN
DRAWN: E.T.B. SUBMITTED:
TRACED: M.R. RECOMMENDED:
CHECKED: APPROVED:
CHIEF ENGINEER
DENVER, COLORADO JULY 3, 1944
245-D-2264
REV. 9-30-44
4-3-45

FIGURE 2

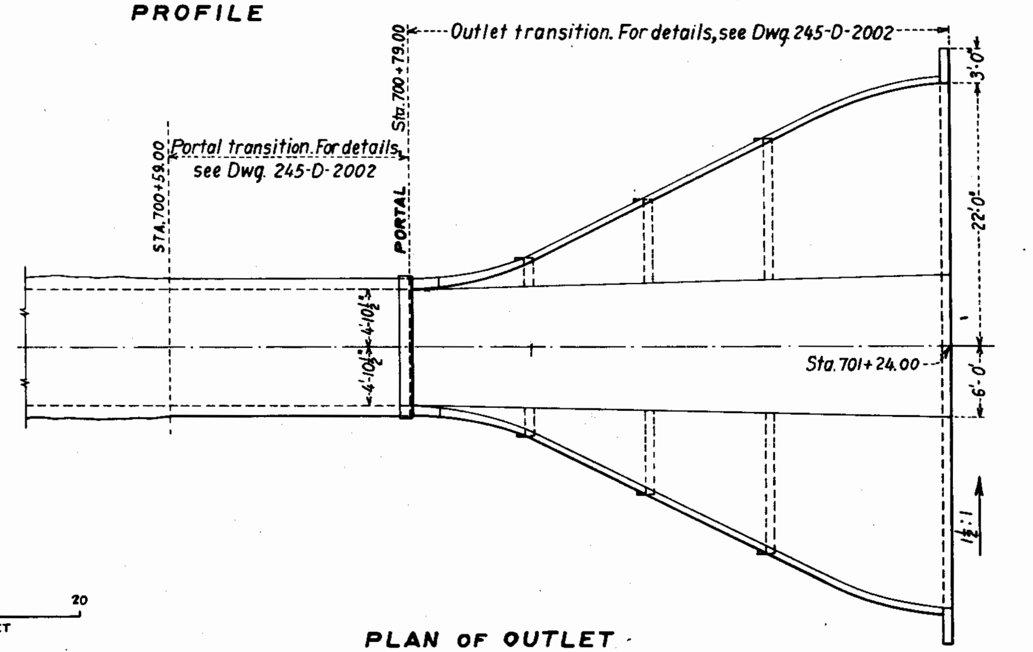


PROFILE

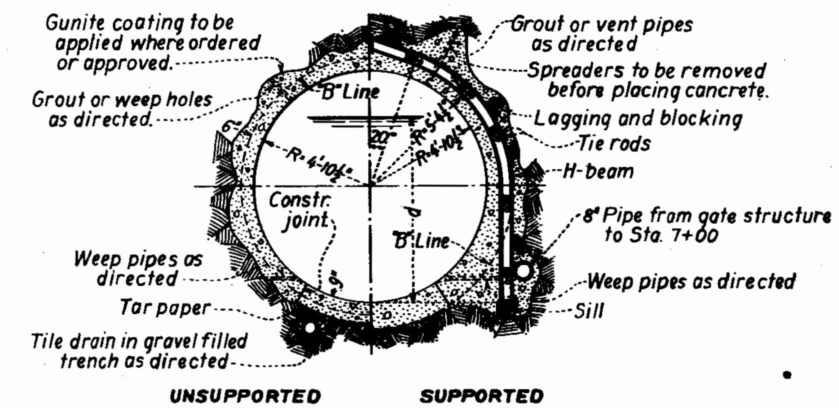


PLAN OF INLET

SCALE OF FEET



PLAN OF OUTLET



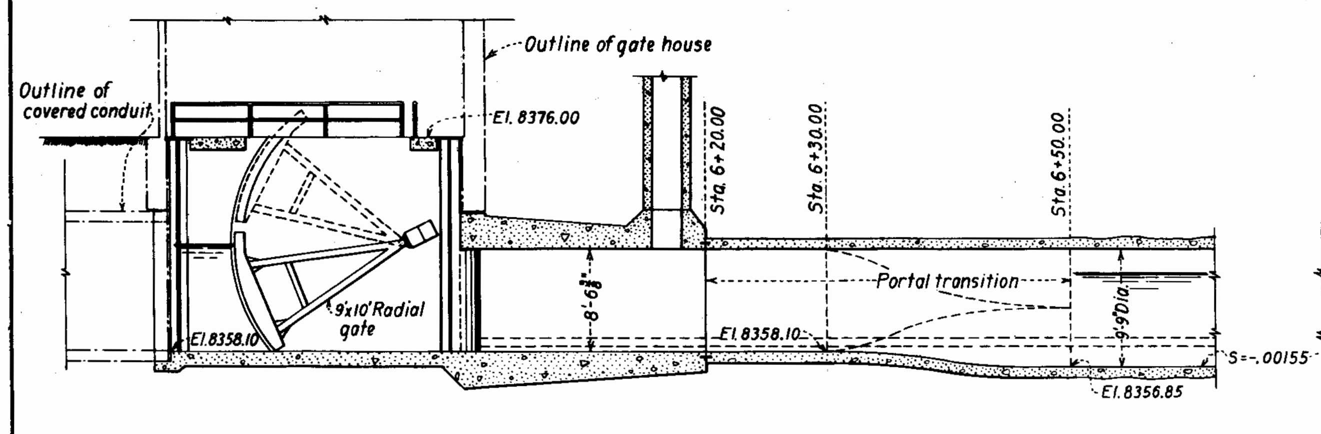
TUNNEL SECTION

HYDRAULIC PROPERTIES

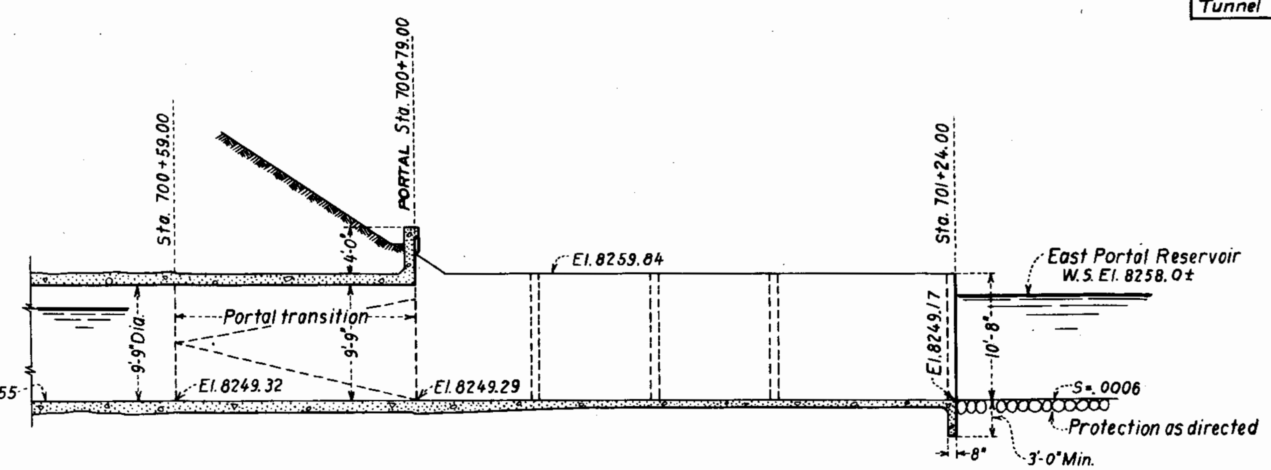
SECTION	A	V	Q	r	n	s	d
Tunnel	63.56	8.66	550	2.97	.014	.00155	7.74
Tunnel	62.67	8.78	550	2.96	.014	.00160	7.63

ESTIMATED QUANTITIES

Concrete lining..........Cu. Yds.



LONGITUDINAL SECTION OF INLET



LONGITUDINAL SECTION OF OUTLET

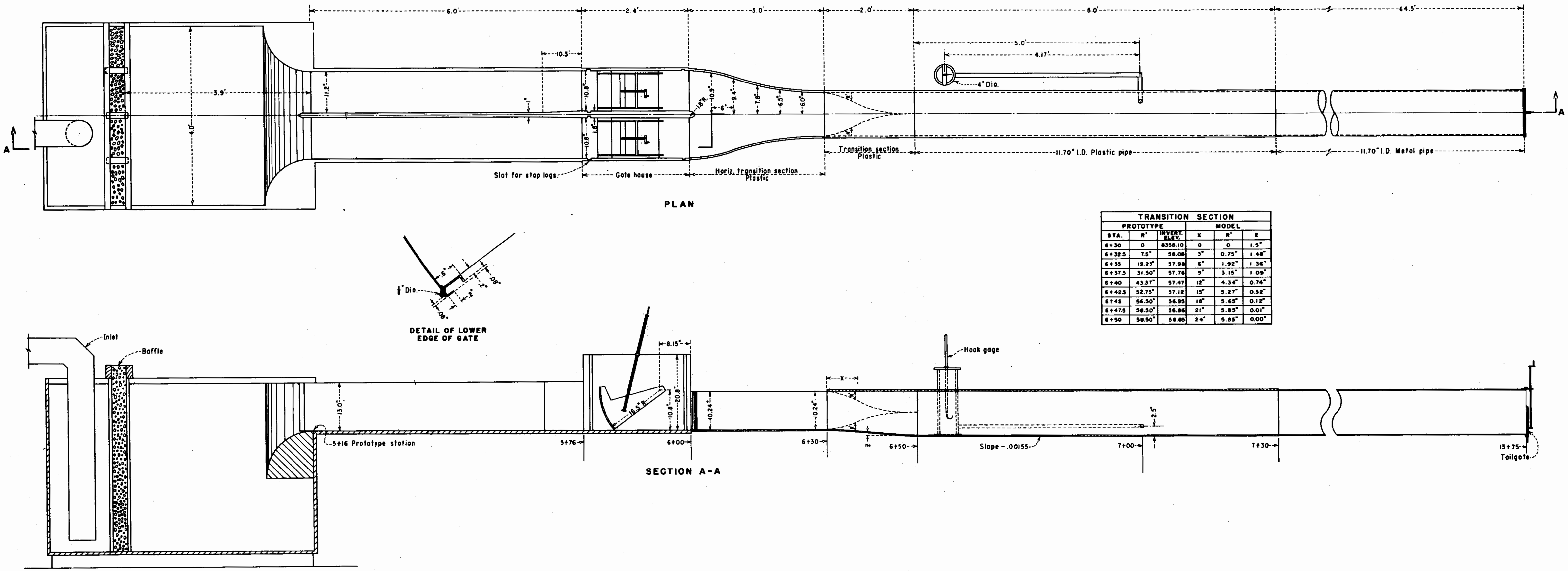
NOTES

Stations and Elevations shown on Profile refer to invert.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT-COLO.

CONTINENTAL DIVIDE TUNNEL
PROFILE-TRANSITIONS-SECTION

DRAWN W.E.S. SUBMITTED [signature]
TRACED W.C.W. RECOMMENDED [signature]
CHECKED C.T.K. APPROVED [signature]
REV. 10-24-44 3-27-45 11-8-45
DENVER, COLORADO OCT. 6, 1944 245-D-2308

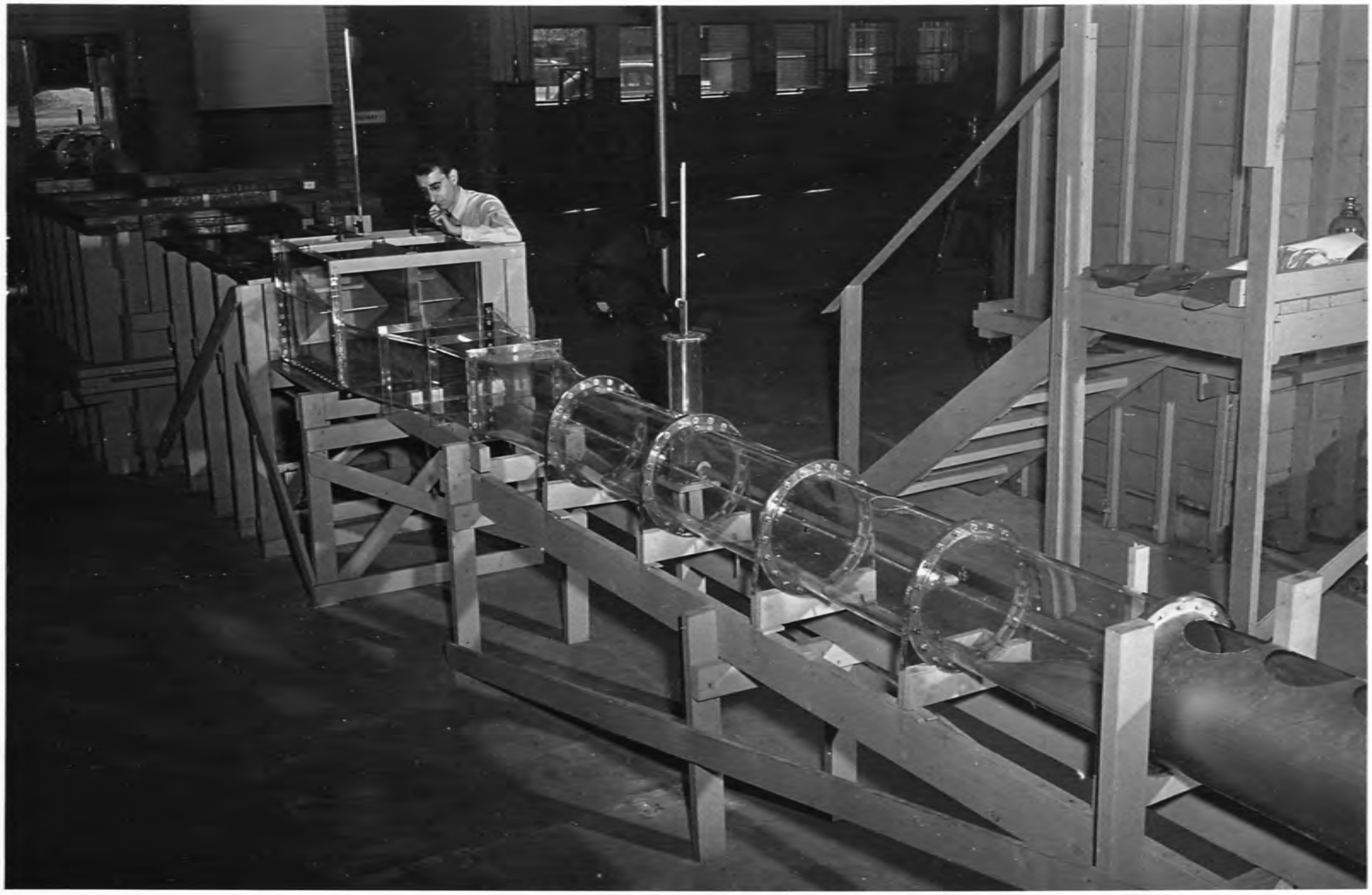


TRANSITION SECTION					
PROTOTYPE			MODEL		
STA.	R'	INVERT. ELEV.	X	R'	Z
6+30	0	8358.10	0	0	1.5"
6+32.5	7.5"	58.08	3"	0.75"	1.48"
6+35	19.23"	57.98	6"	1.92"	1.36"
6+37.5	31.50"	57.76	9"	3.15"	1.09"
6+40	43.37"	57.47	12"	4.34"	0.74"
6+42.5	52.75"	57.12	15"	5.27"	0.32"
6+45	56.50"	56.95	18"	5.65"	0.12"
6+47.5	58.50"	56.86	21"	5.85"	0.01"
6+50	58.50"	56.85	24"	5.85"	0.00"

WEST PORTAL

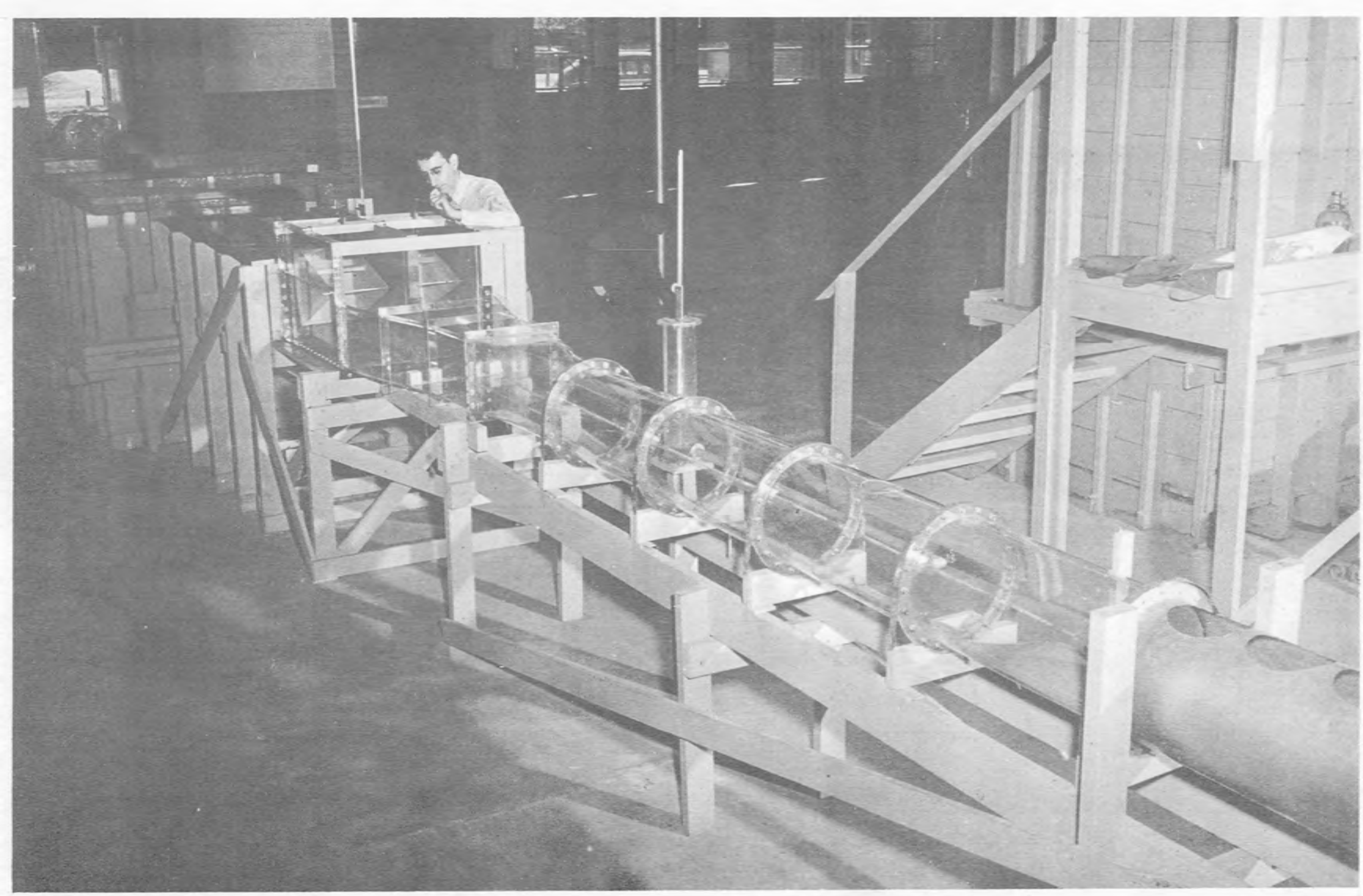
ALVA B. ADAMS TUNNEL

GENERAL LAYOUT OF 1:10 SCALE MODEL



VIEW OF 1:10 SCALE MODEL
WEST PORTAL - ALVA B. ADAMS TUNNEL

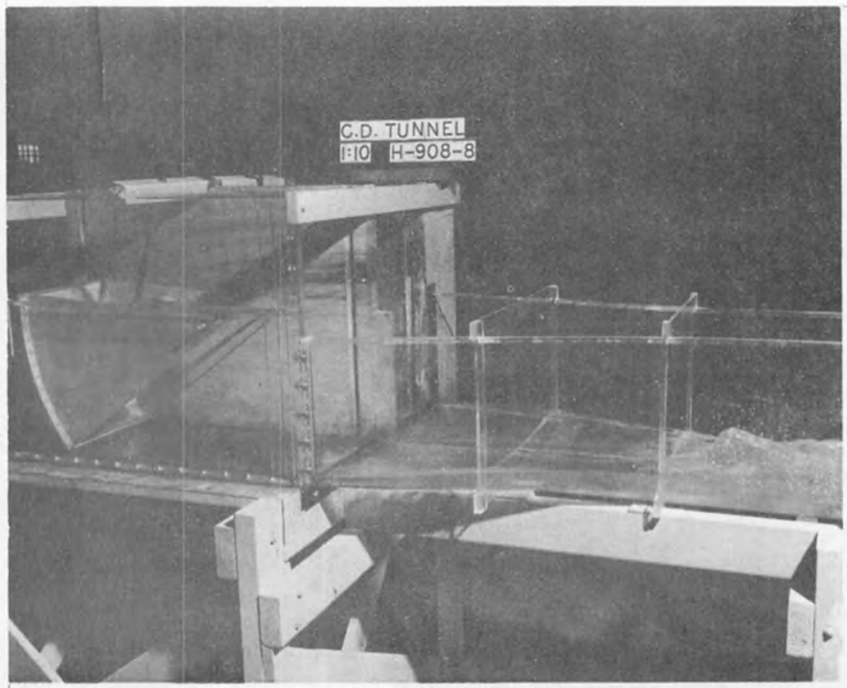
FIGURE 5



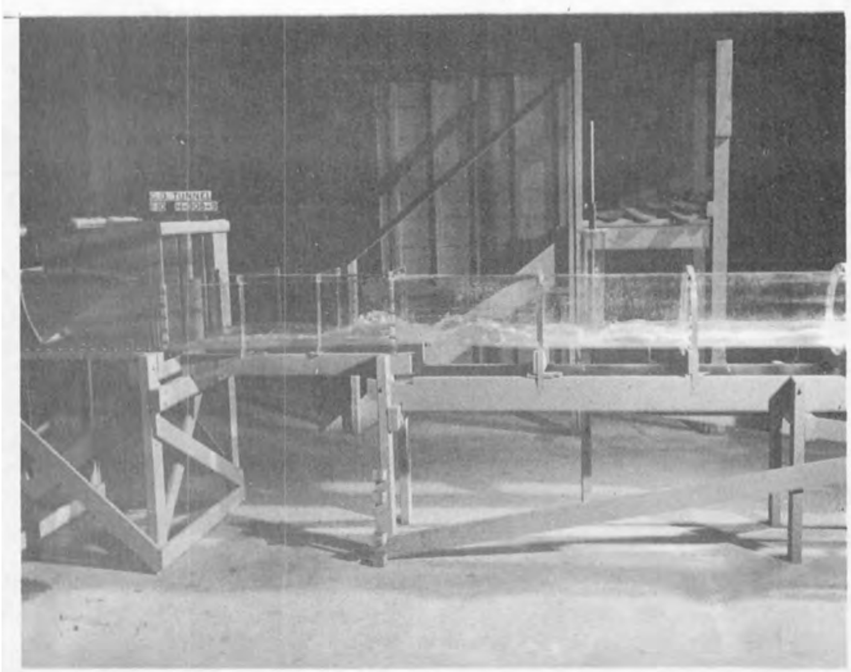
VIEW OF 1:10 SCALE MODEL
WEST PORTAL - ALVA B. ADAMS TUNNEL

FIGURE 5

FIGURE 6



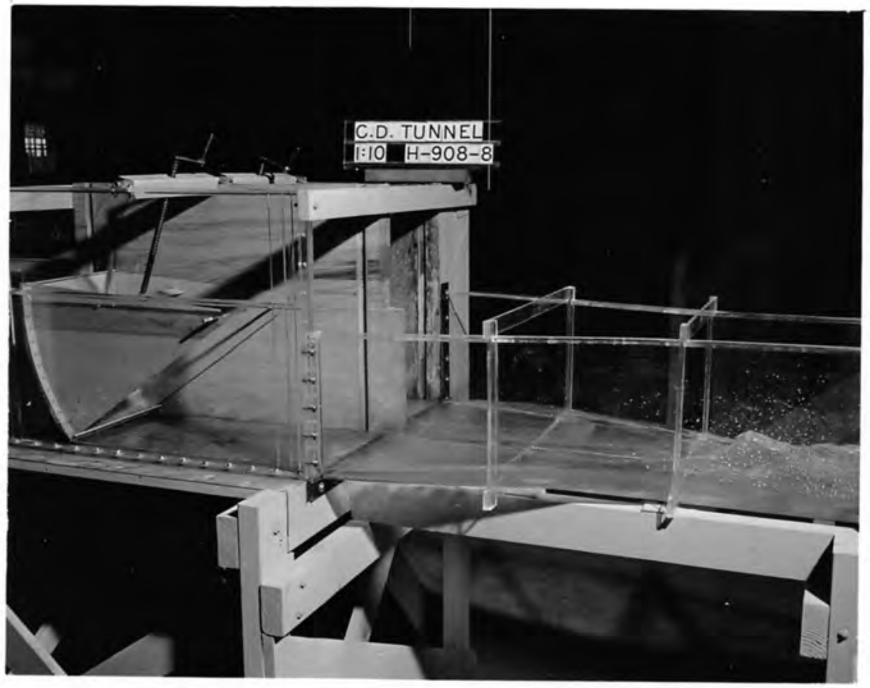
A. DISCHARGE 100 CFS



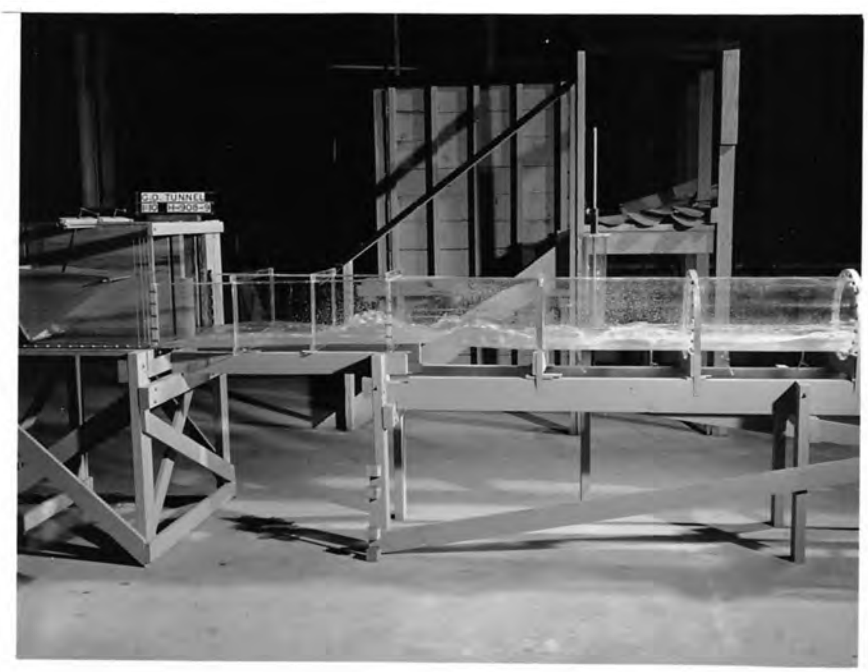
B. DISCHARGE 200 CFS

FLOW IN ORIGINAL STRUCTURE
WEST PORTAL - ALVA B. ADAMS TUNNEL

FIGURE 6

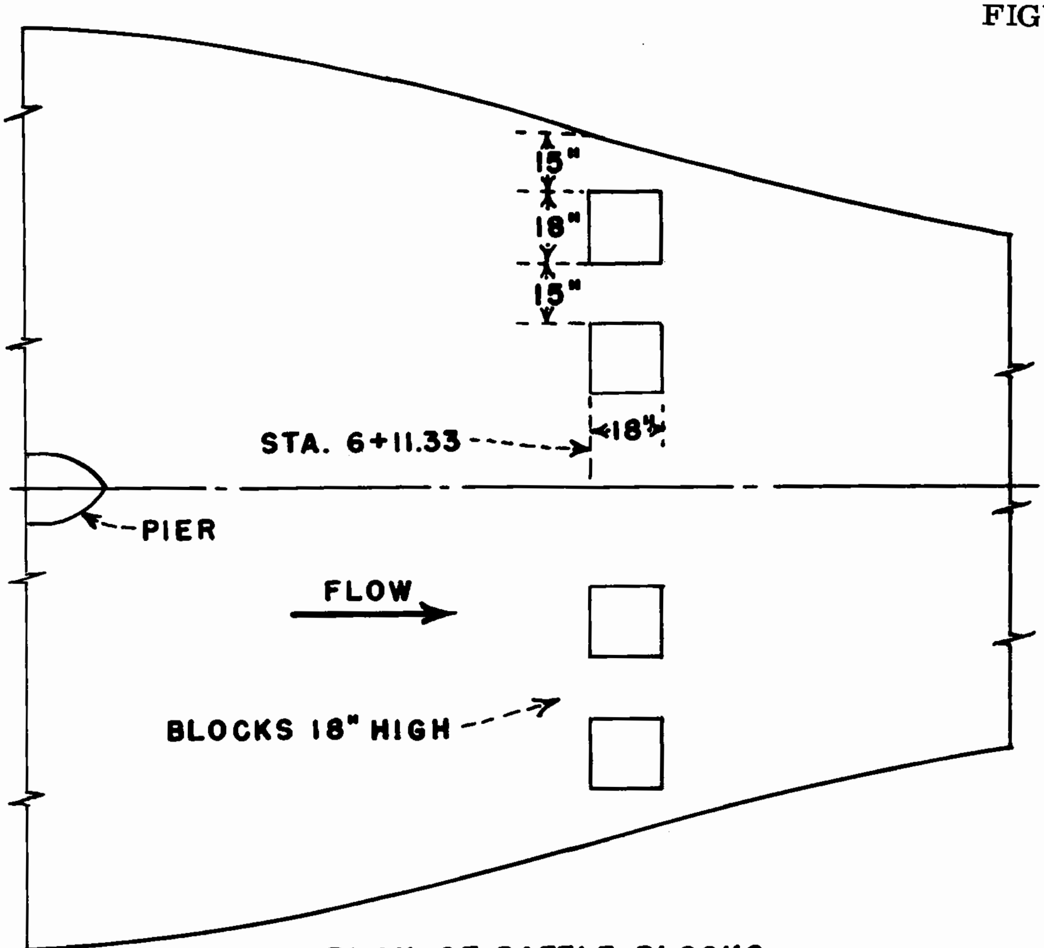


A. DISCHARGE 100 CFS



B. DISCHARGE 200 CFS

FLOW IN ORIGINAL STRUCTURE
WEST PORTAL - ALVA B. ADAMS TUNNEL

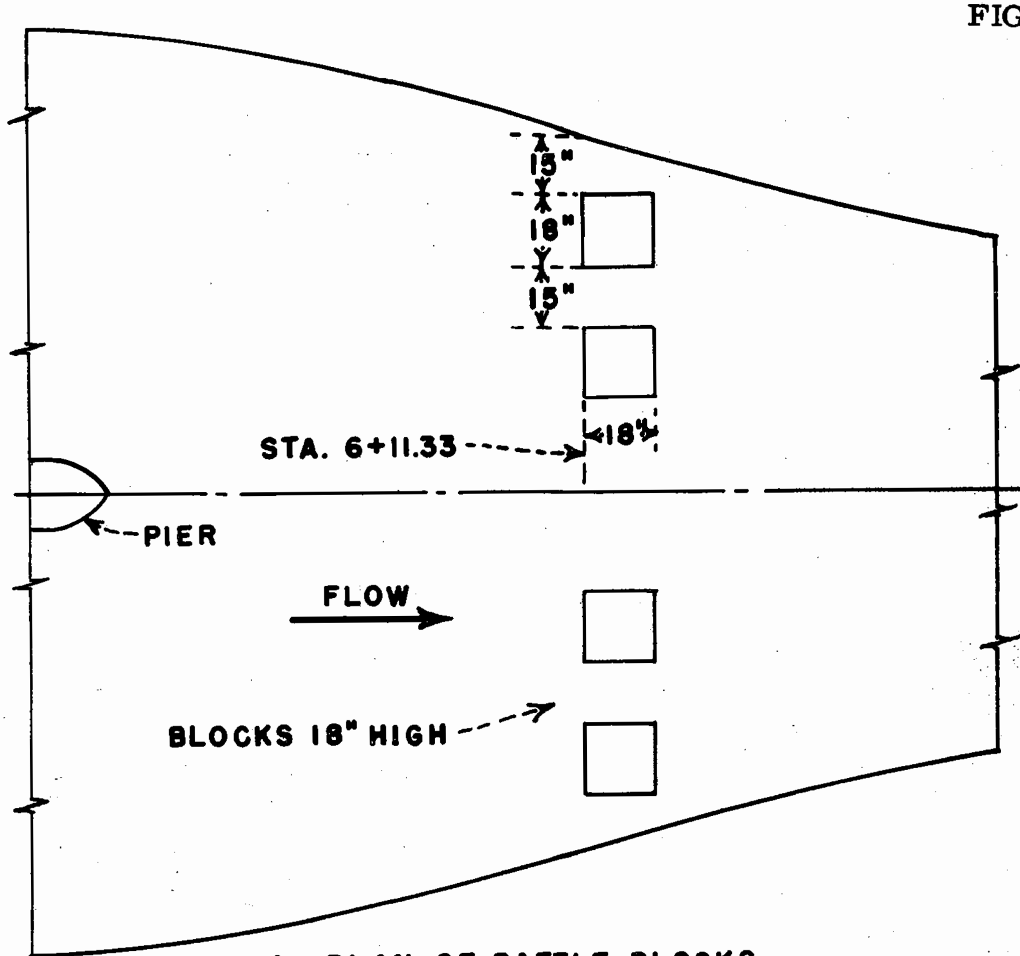


A. PLAN OF BAFFLE BLOCKS

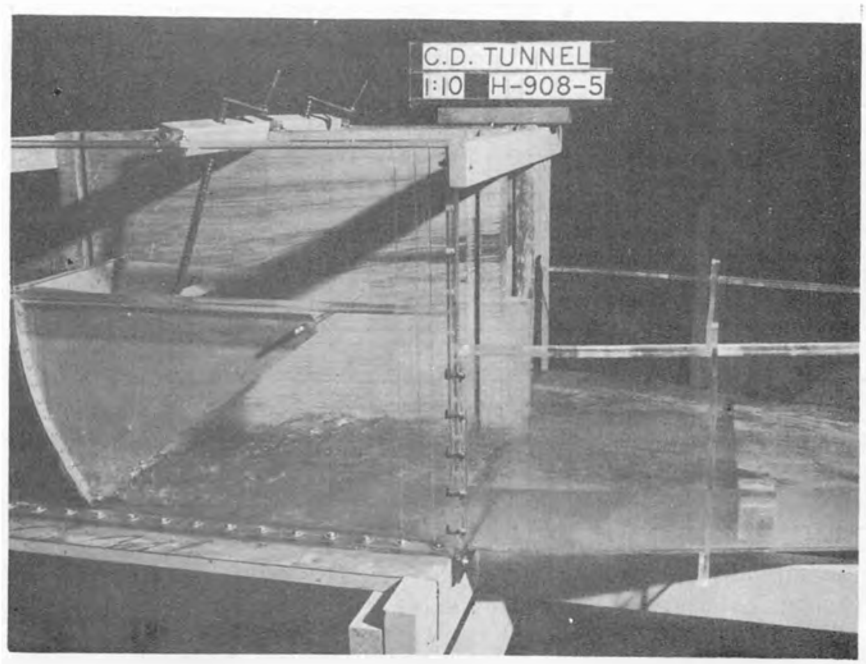
B. DISCHARGE 100 CFS

BAFFLE PIERS INSTALLED
WEST PORTAL - ALVA B. ADAMS TUNNEL

FIGURE 7

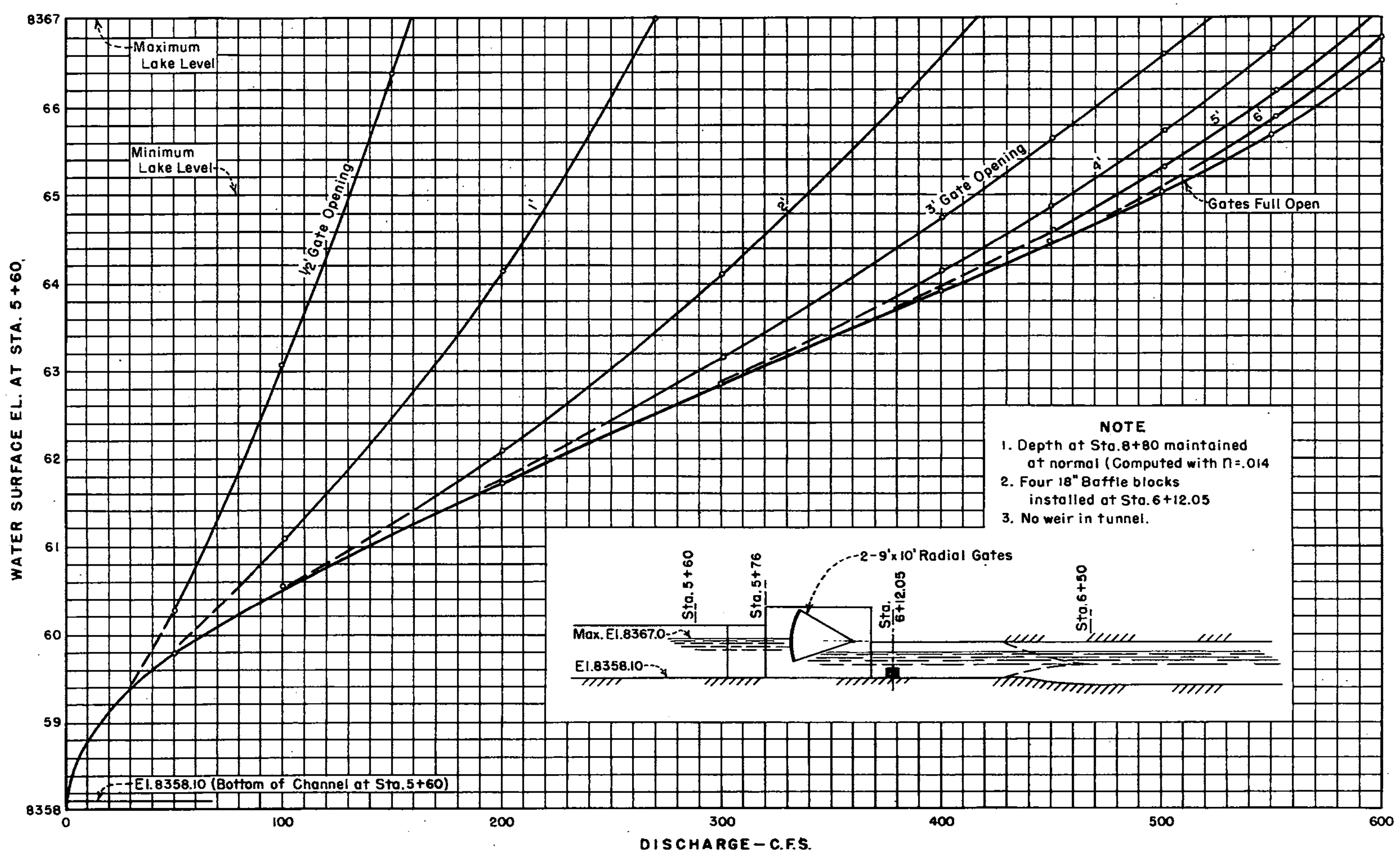


A. PLAN OF BAFFLE BLOCKS



B. DISCHARGE 100 CFS

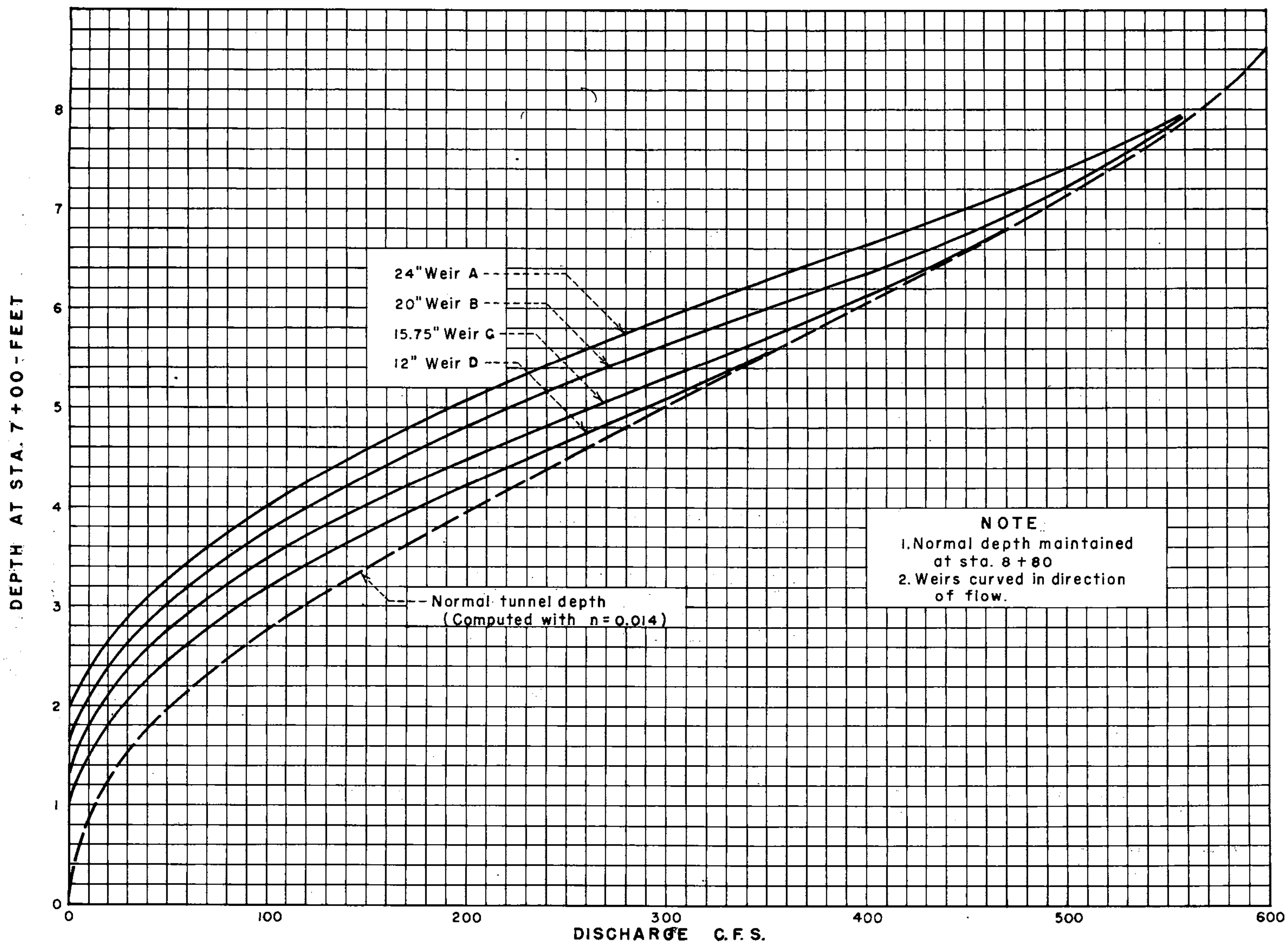
BAFFLE PIERS INSTALLED
WEST PORTAL - ALVA B. ADAMS TUNNEL



WEST PORTAL - ALVA B. ADAMS TUNNEL

GATES DISCHARGE CAPACITY WITH NORMAL TAILWATER

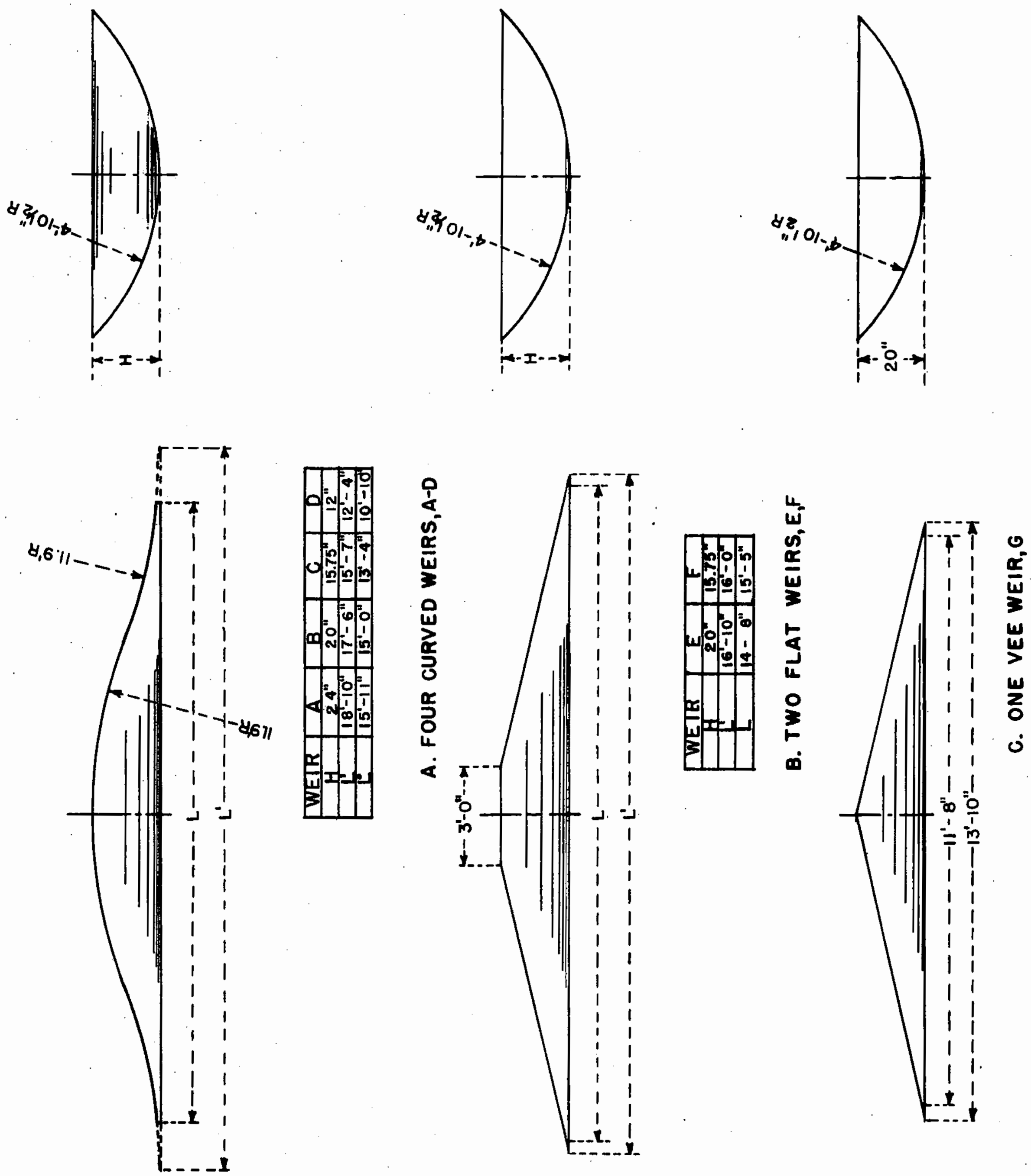
1:10 SCALE MODEL STUDY



WEST PORTAL - ALVA B. ADAMS TUNNEL
DISCHARGE RATING CURVES FOR FOUR HEIGHTS OF WEIR
1:10 SCALE MODEL STUDY

FIGURE 9

FIGURE 10



WEIR	A	B	C	D
H	24"	20"	15.75"	12"
L'	18'-10"	17'-6"	15'-7"	12'-4"
L	15'-11"	15'-0"	13'-4"	10'-10"

A. FOUR CURVED WEIRS, A-D

WEIR	E	F
H	20"	15.75"
L'	16'-10"	16'-0"
L	14'- 8"	15'-5"

B. TWO FLAT WEIRS, E,F

C. ONE VEE WEIR, G

WEST PORTAL - ALVA B. ADAMS TUNNEL

WEIR ARRANGEMENTS TESTED

1:10 SCALE MODEL STUDY

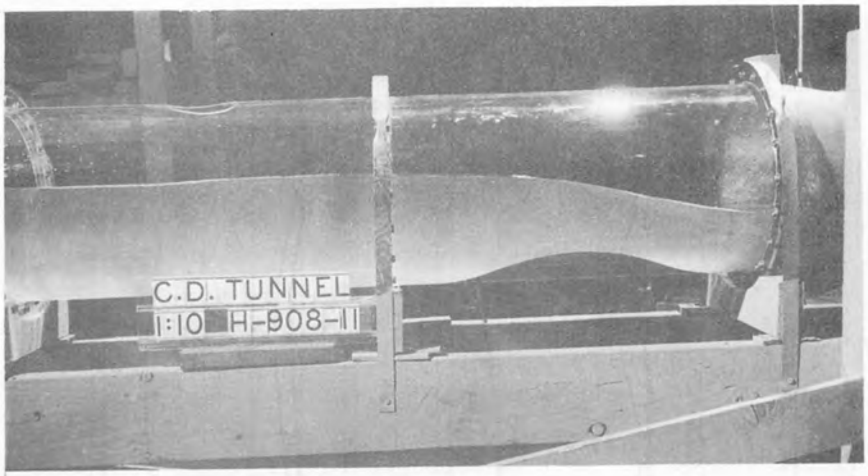
A. 20" WEIR B

B. 15-3/4" WEIR C

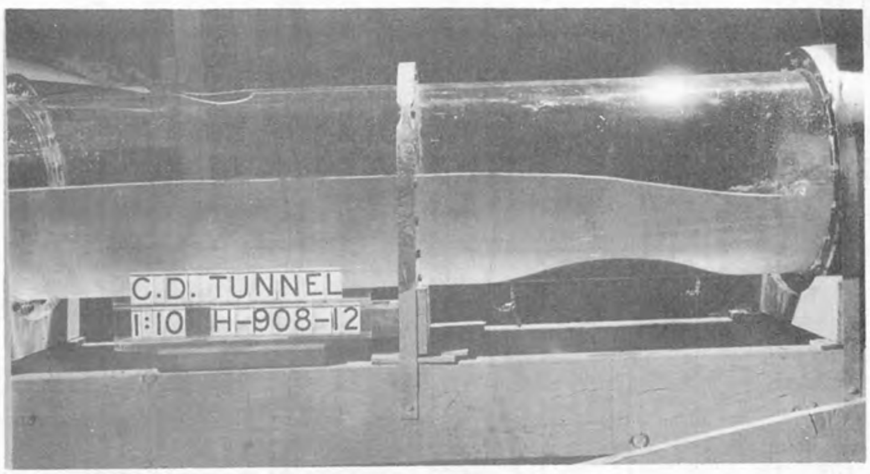
C. 12" WEIR D

FLOW IN TUNNEL - DISCHARGE 300 CFS
CURVED WEIRS INSTALLED
WEST PORTAL - ALVA B. ADAMS TUNNEL

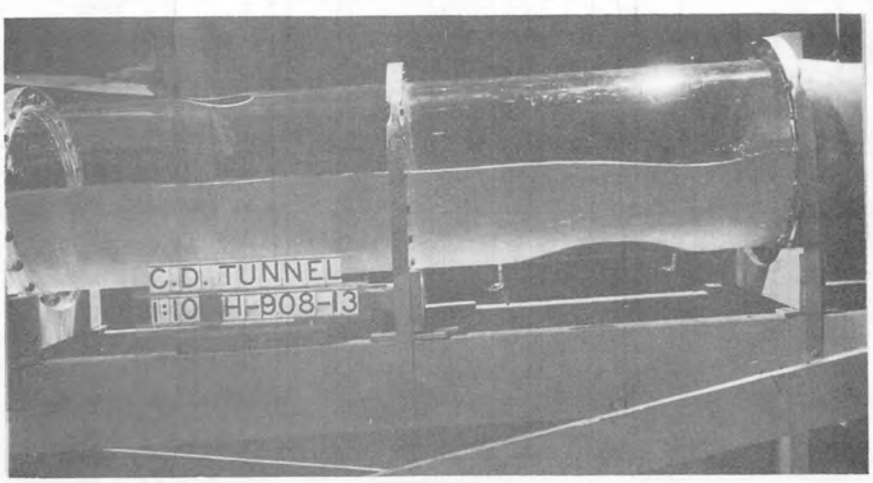
FIGURE 11



A. 20" WEIR B



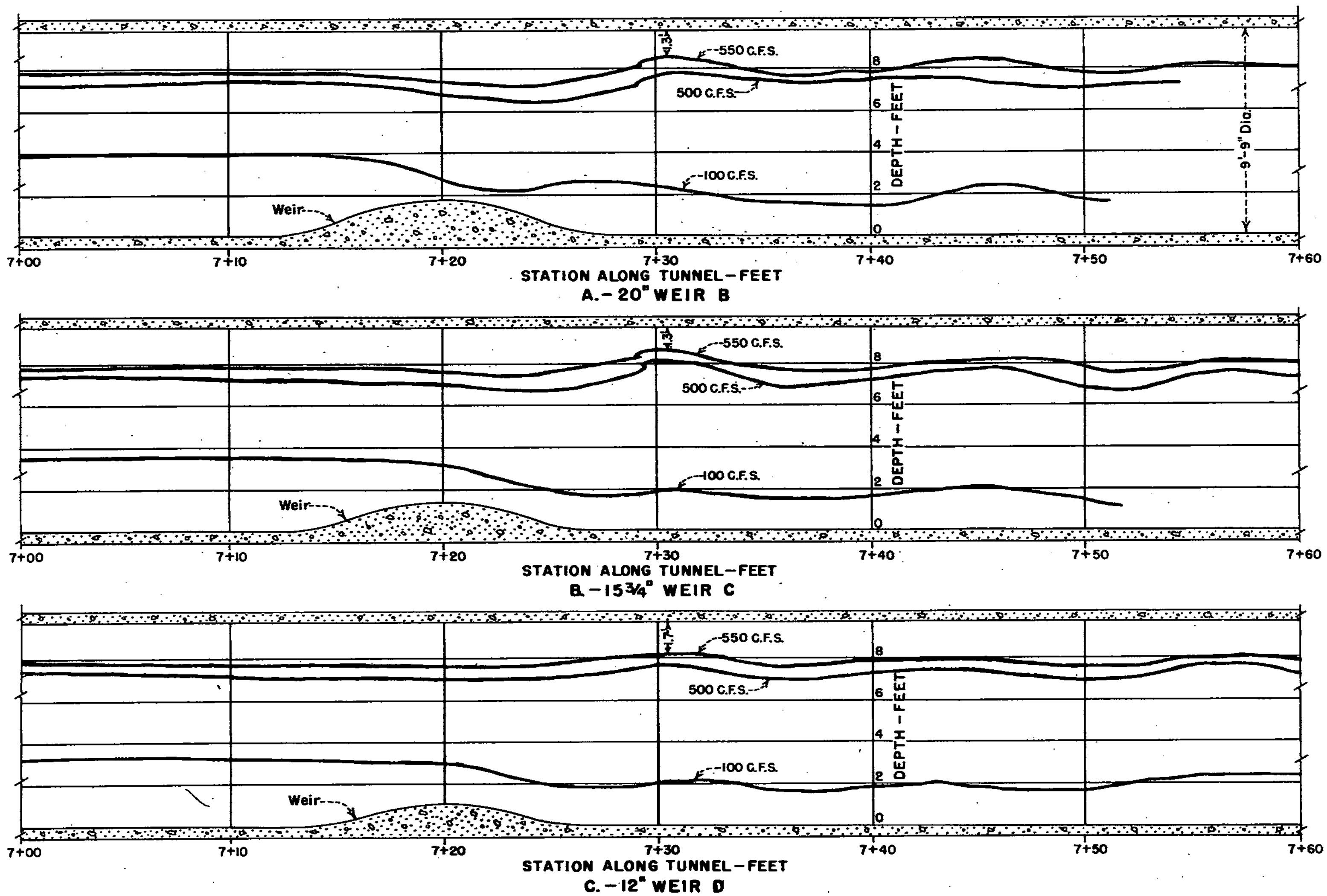
B. 15-3/4" WEIR C



C. 12" WEIR D

FLOW IN TUNNEL - DISCHARGE 300 CFS
CURVED WEIRS INSTALLED
WEST PORTAL - ALVA B. ADAMS TUNNEL

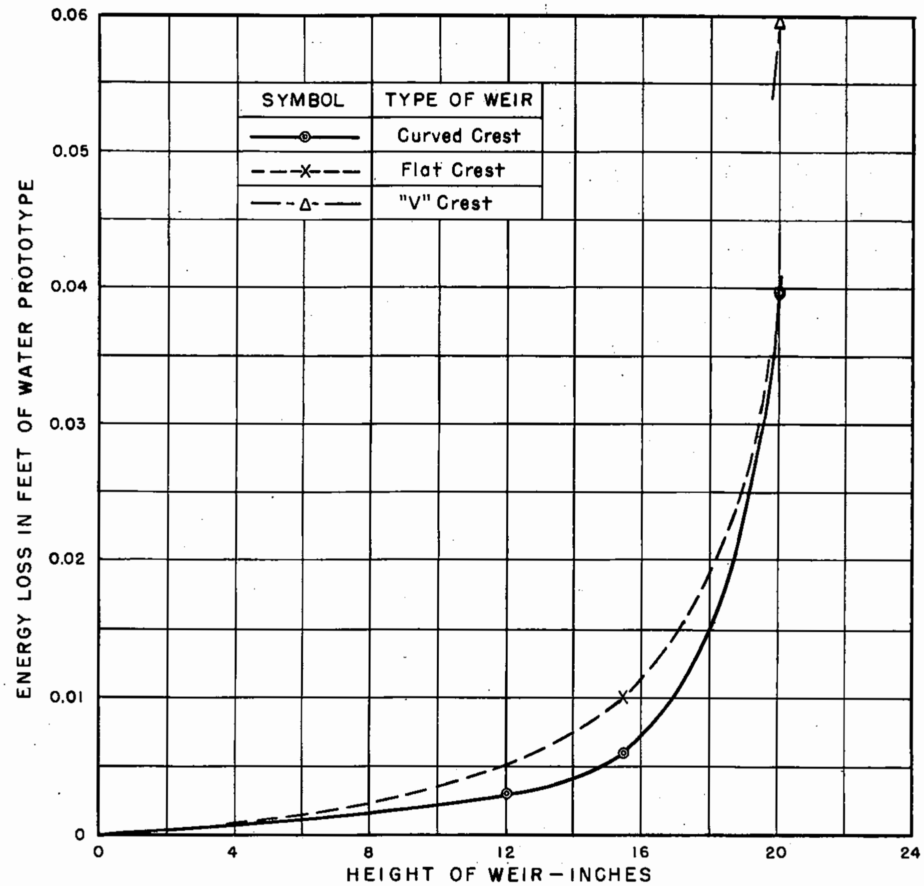
FIGURE 12

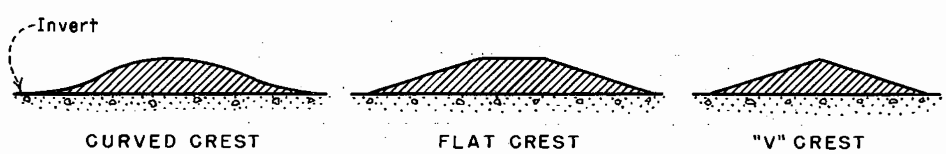


WEST PORTAL - ALVA B. ADAMS TUNNEL

WATER SURFACE PROFILES

1:10 SCALE MODEL STUDY





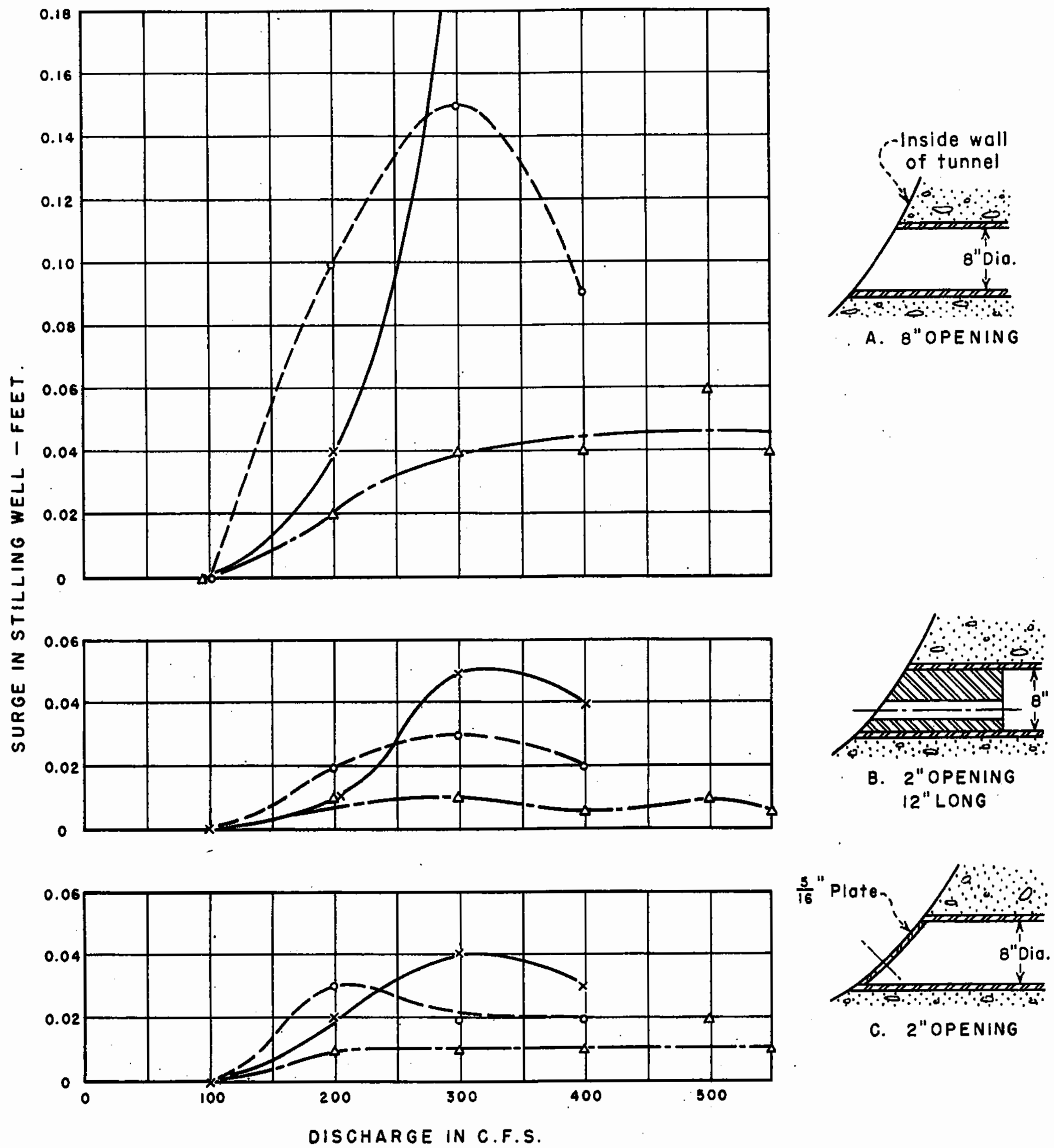
SECTIONS THROUGH WEIRS ON TUNNEL ℄

WEST PORTAL - ALVA B. ADAMS TUNNEL

ENERGY LOSS DUE TO WEIRS WITH DISCHARGE OF 550 C.F.S.

1:10 SCALE MODEL STUDY

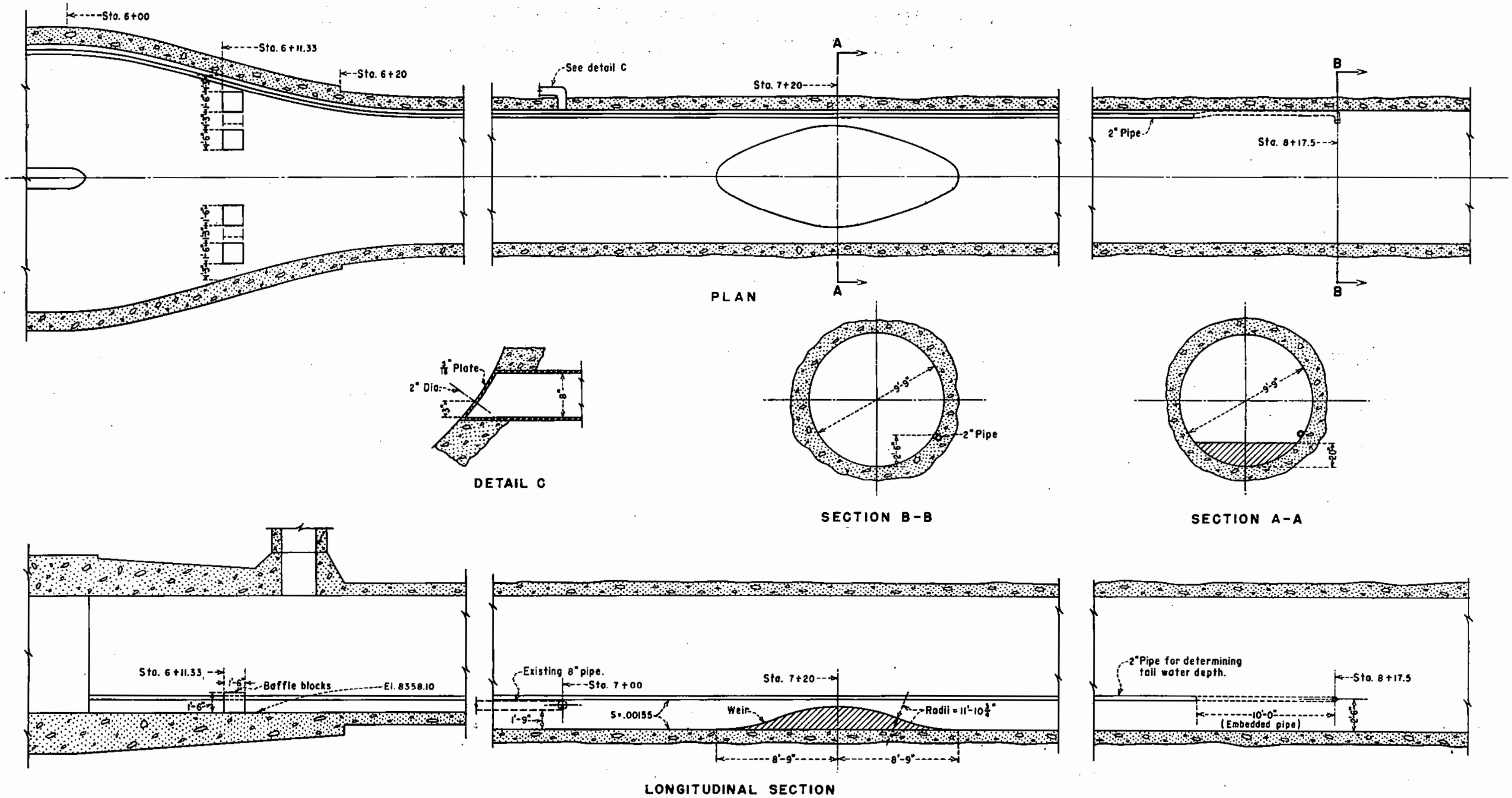
FIGURE 14



EXPLANATION

———·—Δ—·——— Both gates open equally.
– – – – –o– – – – – Left gate open.
————X———— Right gate open.

WEST PORTAL - ALVA B. ADAMS TUNNEL
STILLING WELL SURGE
FOR THREE TYPES PIEZOMETERS AT STA. 7+00
1:10 SCALE MODEL STUDY



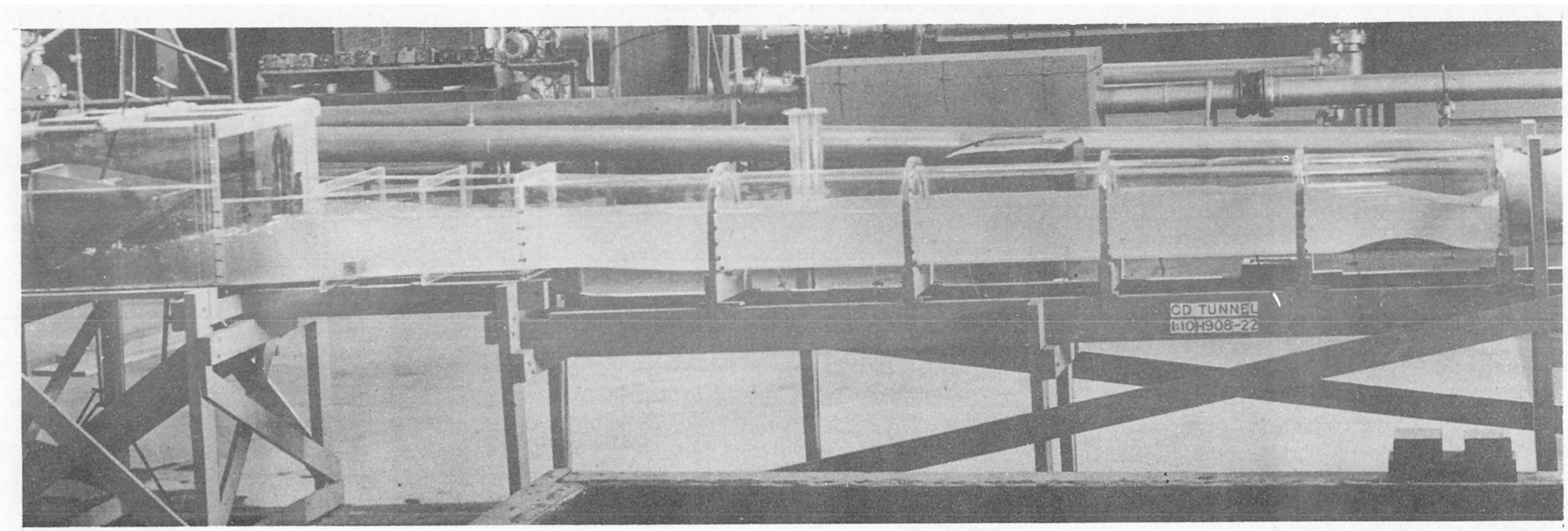
WEST PORTAL - ALVA B. ADAMS TUNNEL

BAFFLE BLOCKS, WEIR, AND PIPING ARRANGEMENT
RECOMMENDED FLOW MEASURING DEVICE

1:10 SCALE MODEL STUDY

FIGURE 15

FIGURE 16



FLOW IN TUNNEL - DISCHARGE 400 CFS
BAFFLE BLOCKS AND 20" CURVED WEIR INSTALLED -
RECOMMENDED
WEST PORTAL - ALVA B. ADAMS TUNNEL

FIGURE 16

FLOW IN TUNNEL - DISCHARGE 400 CFS
BAFFLE BLOCKS AND 20" CURVED WEIR INSTALLED - RECOMMENDED
WEST PORTAL - ALVA B. ADAMS TUNNEL

FIGURE 17

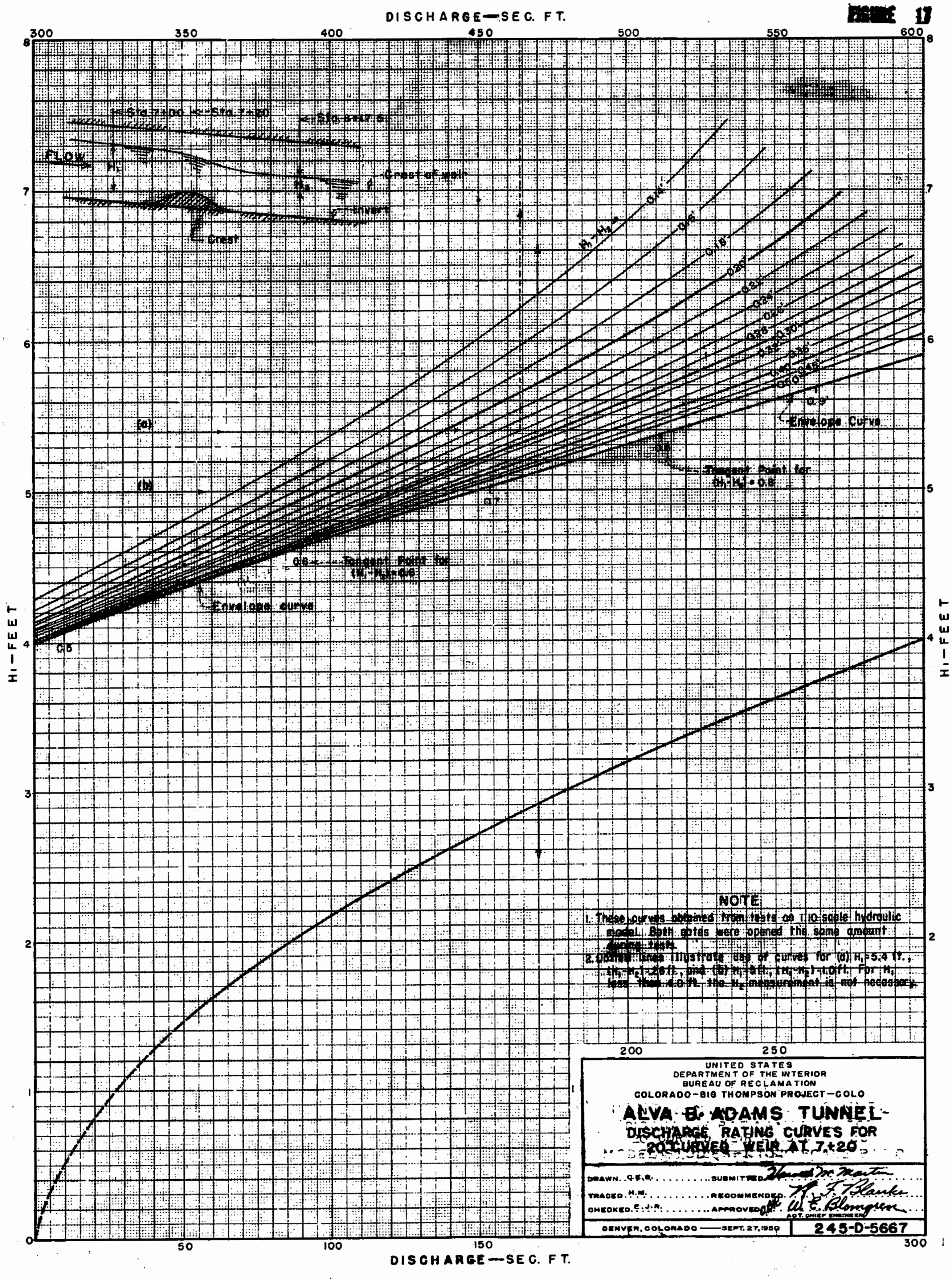

DISCHARGE—SEC. FT.
300
350
400
450
500
550
600
HI—FEET
FLOW
Crest of weir
Crest
Envelope Curve
Tangent Point for
Envelope curve
(a)
(b)
0.5
0.7
0.8
50
100
150
200
250
300
NOTE
1. These curves obtained from tests on 1:10 scale hydraulic model. Both gates were opened the same amount
2.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO-BIG THOMPSON PROJECT—COLO
ALVA B. ADAMS TUNNEL
DISCHARGE RATING CURVES FOR
20' CURVED WEIR AT 7+20
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO — SEPT. 27, 1950
245-D-5667
DISCHARGE—SEC. FT.

FIGURE 18

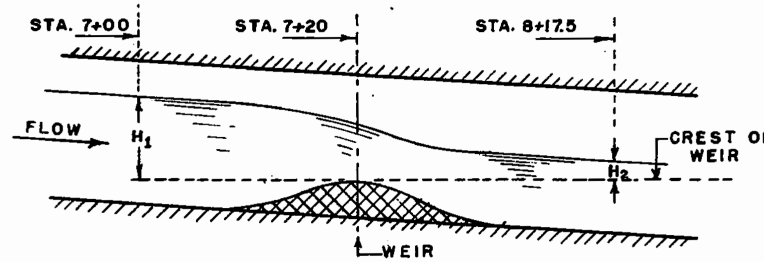
COLORADO-BIG THOMPSON PROJECT--COLORADO
ALVA B. ADAMS TUNNEL

Discharge Rating Tables for 20-Inch Curved Weir at Station 7+20
(Both control gates open the same amount)

Table 1

Discharge in second feet for values of H_1 from 1.0 to 4.0

H_1 feet	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	27.0	31.5	36.2	41.3	46.7	52.5	58.6	65.0	71.6	78.6
2	86.0	94	102	111	120	129	139	149	159	169
3	180	191	202	213	225	237	249	262	275	288
4	301									



SECTION ON ℄ OF TUNNEL

Table 2

Discharge in second feet for values of H_1 from 4.0 to 7.0

Sheet 1 of 2

	(H_1-H_2) feet																	
H_1 feet	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.45	0.50	0.60	1.00
4.00	272	277	281	284	287	289	291	293	294	295	296	297	297	298	299	301	301	301
.05	277	282	287	290	293	296	298	299	300	301	302	303	304	304	305	307	307	307
.10	282	287	292	296	299	302	304	305	306	307	308	309	310	310	311	312	313	313
.15	287	293	298	302	305	308	310	311	312	314	315	316	317	317	318	319	320	320
.20	292	298	303	307	310	313	315	317	319	320	321	322	323	323	324	326	327	327
.25	297	303	308	313	317	320	322	324	326	327	328	329	329	330	331	332	335	335
.30	301	308	314	319	323	326	329	331	332	333	334	335	335	336	338	339	342	342
.35	306	314	320	325	329	333	336	338	339	340	341	342	342	343	345	346	349	349
.40	311	319	325	330	334	338	341	344	346	347	348	349	350	350	351	352	355	355
.45	316	325	331	337	341	345	348	350	352	354	356	357	358	358	359	360	363	363
4.50	321	330	337	343	348	352	355	357	359	361	363	364	364	365	366	368	371	371
.55	326	335	342	348	353	358	362	364	366	368	370	371	372	373	374	375	378	378
.60	330	339	346	353	358	363	367	370	372	374	376	377	378	379	381	382	386	386
.65	335	345	353	359	364	369	373	376	379	381	383	384	385	386	389	390	393	393
.70	340	350	358	364	370	374	378	382	385	387	389	391	392	394	396	397	400	401
.75	345	355	363	370	376	380	384	388	391	394	396	398	400	401	403	404	407	409
.80	349	359	367	375	381	386	390	394	397	400	402	404	406	407	409	411	414	417
.85	354	364	373	381	388	393	397	401	404	407	409	411	413	415	417	419	422	425
.90	358	369	378	386	393	399	404	408	411	414	416	418	420	422	425	427	430	433
.95	363	374	383	392	399	405	410	415	418	421	423	425	427	429	432	434	438	442
5.00	367	378	388	397	405	411	416	420	424	427	430	432	434	436	438	441	446	450
.05	371	383	394	403	411	417	422	427	431	435	438	440	442	444	447	450	454	458
.10	376	388	399	408	416	423	429	434	438	442	445	447	449	451	455	458	463	467
.15	381	394	405	414	422	429	435	440	444	448	451	454	456	459	463	467	471	475
.20	385	398	409	419	428	435	441	446	450	454	458	461	463	466	471	475	479	483

For values of (H_1-H_2) in excess of 1.00 use the discharge listed for 1.00

Table 2--continued

Discharge in second feet for values of H_1 from 4.0 to 7.0

Sheet 2 of 2

H_1 feet	(H_1-H_2) feet: 0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.45	0.50	0.60	1.00
5.25	390	403	414	424	433	440	446	452	457	461	465	468	471	473	479	483	488	492
.30	394	407	419	429	438	445	451	457	462	467	471	475	478	480	486	491	496	500
.35	399	412	424	434	443	451	458	464	469	474	478	482	485	488	494	499	504	508
.40	403	416	428	439	448	456	464	471	476	481	485	489	492	495	501	506	512	516
.45	407	421	433	444	454	462	470	477	483	488	492	496	499	502	509	514	520	525
5.50	411	425	438	449	459	468	476	483	489	494	498	502	506	509	516	521	528	533
.55	415	429	442	454	464	473	481	489	495	500	505	509	513	516	523	529	536	542
.60	419	433	446	458	469	478	486	494	500	506	511	515	519	523	530	536	543	549
.65	423	438	451	463	475	484	492	500	507	513	518	523	527	531	538	544	551	558
.70	427	442	456	469	480	490	498	506	513	519	525	530	534	538	545	551	559	566
.75	431	447	461	474	486	496	504	512	519	526	532	537	541	545	553	560	568	576
.80	435	451	465	478	489	499	509	518	525	532	538	543	548	552	560	567	575	584
.85	439	455	469	482	493	503	513	523	531	538	543	549	554	558	567	573	580	
.90	442	459	474	487	499	510	519	528	536	543	549	555	560	564	573	579	585	
.95	446	463	478	492	505	516	525	534	543	550	555	561	566	571	580	586	593	
6.00	449	466	482	497	510	521	531	540	549	556	562	567	572	577	586	593		
.05	453	470	486	501	514	525	535	544	553	561	568	573	578	583	594			
.10	456	474	490	505	518	530	540	549	558	566	573	579	584	588				
.15	460	478	495	510	524	536	546	556	565	573	580	586	591	595				
.20	464	482	499	515	529	541	552	562	571	579	586	592	597					
.25	467	485	502	518	533	546	557	567	577	585	592	599						
.30	470	488	506	522	537	550	561	572	582	591	598							
.35	474	492	509	526	541	554	566	577	587	596								
.40	477	496	514	530	545	558	570	581	591									
.45	480	499	517	534	550	563	575	587	597									
6.50	483	502	521	538	554	568	581	592										
.55	486	506	525	542	558	572	585	597										
.60	489	509	528	545	561	576	590											
.65	491	511	530	558	565	581	595											
.70	494	515	534	554	569	585												
.75	497	518	538	557	574	589												
.80	500	521	541	561	577													
.85	503	524	544	564	583													
.90	506	527	548	568														
.95	508	530	551	571														
7.00	511	533	554	574														

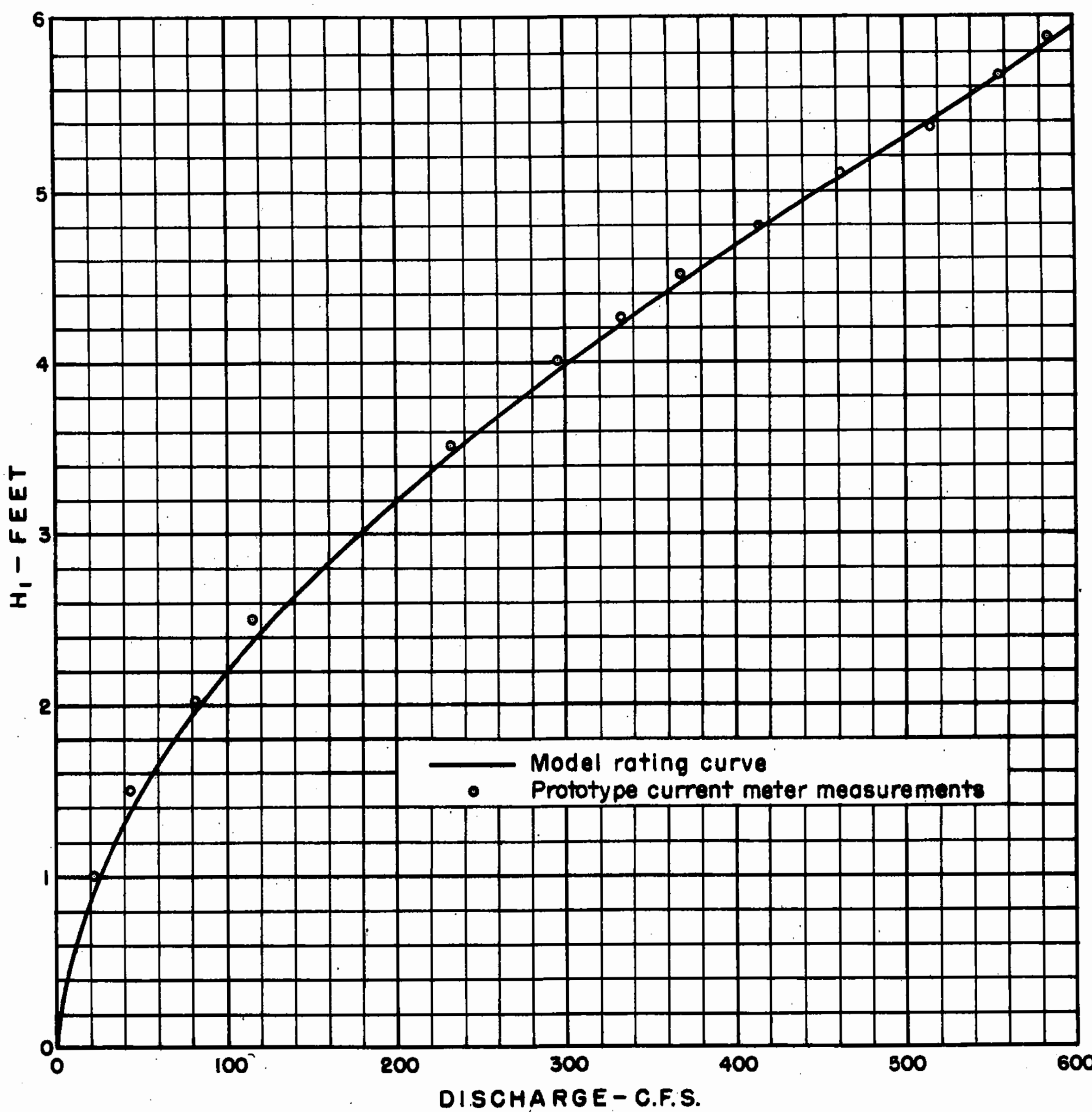
For values of (H_1-H_2) in excess of 1.00 use the discharge listed for 1.00

The above data are based on studies of a 1:10 scale hydraulic model. Drawing No. 245-D-5667 is a graph of the same data.

For values of H_1 less than 4.0 feet the H_2 measurement is not necessary (Table 1).

FIGURE 19

FIGURE 20



WEST PORTAL - ALVA B. ADAMS TUNNEL

DISCHARGE RATING CURVE, 20" CURVED WEIR

MODEL PROTOTYPE COMPARISON

1:10 SCALE MODEL STUDY