UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 72

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HYDRAULIC MODEL STUDIES FOR THE DESIGN OF THE OUTLET WORKS AND SPILLWAY CABALLO DAM

By

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and
H. W. BREWER

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Denver, Colorado
October 30, 1939

CONTENTS

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGMENT

The investigations discussed in this memorandum were made by the Hydraulic Research Section of the Bureau of Reclamation in the Arapahoe Street Laboratory at Denver, Colorado. The tests were initiated under the direction of E. W. Lane, research engineer, and completed under the direction of his successor, J. E. Warnock, research engineer. Construction and testing were directly supervised by the authors. H. G. Dewey, Jr., assistant engineer; R. K. Vierck and F. R. Cline, junior engineers, assisted in the preparation of this report.

This report was prepared under the general supervision of G. J. Hornsby, engineer.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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

October 30, 1939

Laboratory Report No. 72
Hydraulic Laboratory
Compiled by: H. M. Martin, F. L. Panuzio, and H. W. Brewer
Reviewed by: J. G. Hornsby

Subject: Hydraulic Model Studies for the Design of the Outlet Works and Spillway for the Caballo Dam.

I. SYNOPSIS

Hydraulic model tests were conducted to determine the answers to the following questions, relative to the design of the outlet works at Caballo Dam:

a. Is the outflow energy successfully dissipated in the stilling-basin for all outlet outflow conditions?

b. For outlet discharges less than three thousand cubic feet per second, is the flow approaching the Parshall flume sufficiently smooth and quiet to give an accurate head reading?

c. Is the tunnel flow downstream from the gates of a satisfactory character?

d. Is the riprap protection at the downstream end of the Parshall flume adequate?

The model tests showed that the preliminary design was unsatisfactory on four counts: The flow in the downstream section of the gate structure was rough, the shape of the tunnel was not suitable for various quantities of flow, the stilling-pool was not adequate for various combinations of gate openings and discharges, and the Parshall flume was too near the stilling-pool to be reliable.

The gate section and the tunnel were altered to produce satisfactory flow conditions in these structures but the flow in the stilling-pool and Parshall flume remained rough and of poor velocity distribution. The stilling-pool and the approach to the Parshall flume were then altered, producing satisfactory performance.

At this stage of the investigation it was decided to remove the Parshall flume and replace it with a venturi meter in the circular tunnel upstream from the gate structure. A hasty series of trials determined the most efficient stilling-pool design, causing the least erosion in the channel to the river and causing the least splash and disturbance in the pool.

Tests were made on models of spillways for each of the three alternative project plans: the low dam, the high dam as a subsequent development of the low dam, and the completely redesigned high dam. Pressure distributions and discharge coefficients over the crests and pressures along the pool floor were measured. The most significant tests were concerned with the improvement of the stilling-pool design. These indicated that satisfactory conditions could be obtained with the original pool walls shortened from 103.00 to 78.75 feet and with the pool floor shortened from 1?2.0 to 88.13 feet and raised 4 feet. A slope of 3 to 1 instead of 1-1/2 to 1 and a depth of 5 instead of 3 feet were found to be necessary for the riprap in the trapezoidal streambed.

II. INTRODUCTION

The Caballo Dam was constructed as a part of the Rio Grande Rectification Project under the authority of the International Boundary Commission but under the engineering supervision of the Bureau of Reclamation. It is located on the Rio Grande River about 11 miles south of Los Palomas, New Mexico, and 24 river miles downstream from the existing Elephant Butte Dam (Figure 1).

The reservoir will provide both flood control and irrigation storage, and in addition will make possible the continuous instead of the previous seasonal production of power at Elephant Butte Dam by conserving the water passed through the Elephant Butte turbines during the fall and winter months. For the present, the Elephant Butte Plant will be able to supply all the power for which there is a local market. No power development was therefore projected for the Caballo Dam.

Three separate plans for the storage and regulation of water at Caballo Dam were considered. Plan No. 1 provided for an earthfill dam with its crest at elevation 4162 and with a reservoir capacity of 100,000 acre-feet when the pond elevation was 4152. This plan provided for a spillway of 34,000 second-foot capacity. Plan No. 2 provided for an increase in the storage capacity of 350,000 acre-feet by raising the earthfill dam to elevation 4190 and the pond elevation to 4182, the change to be made at some future date as an addition to the structure of Plan No. 1. The irrigation outlet was to remain practically unchanged and a new concrete spillway crest of 34,000 second-foot capacity, about thirty feet higher than the first, was to be added. Plan No. 3 represented an entire redesign of the dam with the spillway at the opposite end. The height of the dam, the pond elevation, the reservoir capacity, and the irrigation outlet remained approximately as for Plan No. 2


ARROYO DIVERSION CANAL
HIGHWAY BRIDGE
ARROYO DIVERSION DAM
CREST EL. 4200.0
GOVERNMENT CAMP
CABALLO DAM
CREST EL. 4190.0
BORROW PIT AREA
OUTLET TUNNEL
SPILLWAY
BONITA LATERAL VALVE HOUSE
BASE LINE
STA. 0+00 BASE LINE = 5,000 NORTH 6,000 EAST
1½ MILES TO ROCK QUARRY IN SW¼ OF SW¼, SEC. 21
1½ MILES TO SAND AND GRAVEL DEPOSITS
BONITA LATERAL
RIO GRANDE
Percha Arroyo
TO ALBUQUERQUE
U.S. HIGHWAY No. 85
TO EL PASO
R.5W. T.16S.
R.4W. T.16S.
SCALE OF FEET
LAYOUT MAP
VICINITY MAP
ELEPHANT BUTTE RESERVOIR
HOT SPRINGS
DAM
Elephant Butte
Engle
Las Palomas
Cutter
Aleman
Caballo
STANDARD PARALLEL SOUTH
ARREY DIVERSION DAM
BONITA LATERAL
CABALLO DAM
PERCHA DIVERSION DAM
Arrey
ARREY CANAL
Upham
CABALLO MOUNTAINS
GARFIELD FLUME
Derry
SIERRA COUNTY LINE
DONA ANA
Garfield
Grama
Salem
HATCH SIPHON
HATCH
RINCON SIPHON
Rincon
Rodey
SIERRA CO.
LUNA CO.
Hackett
Detroit
Tonuco
INDEX MAP
COLORADO
OKLA.
SANTA FE
Gallup
Albuquerque
Belen
NEW MEXICO
ELEPHANT BUTTE RESERVOIR
CABALLO DAM
ARIZONA
TEXAS
Hatch
Rincon
Lordsburg
Deming
Las Cruces
El Paso
Carlsbad
MEXICO
TEXAS
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT–NEW MEXICO–TEXAS
CABALLO DAM
LOCATION MAP
DRAWN. P.M.W.
TRACED D.C.K.
CHECKED.
SUBMITTED
RECOMMENDED
APPROVED.
28106
DENVER, COLORADO, FEB. 18, 1936.
230-D-61

The tests on models of the irrigation outlet works were undertaken at the request of the design section as part of the design investigations necessary for determining the correct approach conditions and the proportions for the Parshall flume. The spillway experiments were made to determine whether the stilling-pools as designed would be satisfactory under the imposed head and tailwater conditions, and to determine hydrostatic pressure distributions over the crest and over the pool floor. As is frequently the case with investigations of this kind, the initial tests indicated that considerable improvement was possible both in flow conditions and in economy of construction. The experiments on the outlet works and spillway were therefore continued to determine the most satisfactory design.

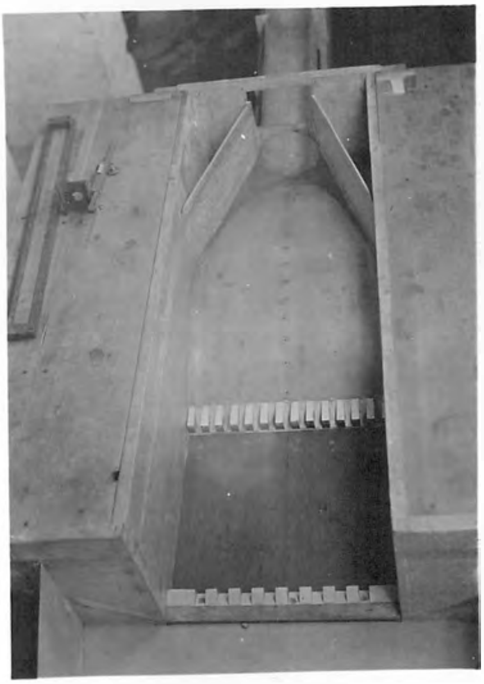
At the time this investigation was made the Hydraulic Laboratory of the Bureau of Reclamation occupied the greater part of the basement of the Old Custom House at Sixteenth and Arapahoe Streets. The Laboratory water supply system, which recirculated the same water, included a weir tank with a 90-degree, V-notch weir and a pump sump, set below the floor level, a 6-inch centrifugal pump with a discharge of up to 3-1/2 cubic feet per second, and a head tank for water supply to the models. The discharge returned from the models to the weir tank in a sheet-metal flume.

III. THE OUTLET WORKS

The model. The model of the outlet works was constructed to the scale of 1 to 30. The circular tunnel upstream from gate section, the gate section, horseshoe tunnel, stilling-pool, and Parshall flume were developed and constructed of sheet metal. The pier in the gate section was of redwood and the gates were of brass. The gates were actuated by screw stems and brass knurled nuts. The top of the horseshoe tunnel was constructed of sheet pyralin, permitting observation of the flow downstream from the gates. The stilling-pool and Parshall flume were placed in a sandbox in order to observe the erosion downstream from the flume and to facilitate alterations. The tailwater was regulated and controlled by a tailgate at the end of the sandbox and the tailwater elevation was read on a gage on the side of the sandbox. To compensate for the dissimilarity between the effects of friction losses in model and prototype, the slope of the model tunnel was increased in accordance with calculations relating to the actual model and prototype losses indicated by application of Kutter's "n."

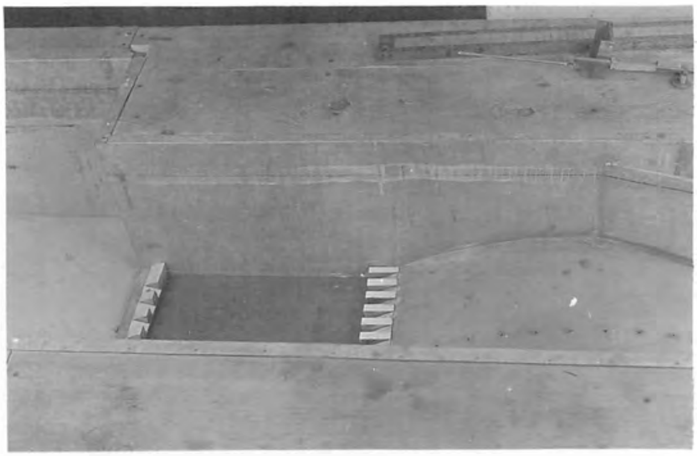
Plate I shows the model of the original design and Figure 1a shows the original prototype features.

Original design. As ordinarily designed, that portion of the outlet works downstream from the gate section performed unsatisfactorily. When operated at 3,000 cubic feet per second, a high fin arose down the center of the transition and tunnel. With either gate fully open at normal head, the flow in the tunnel was very rough and spiral in shape.



B. GATE SECTION

A. STILLING POOL

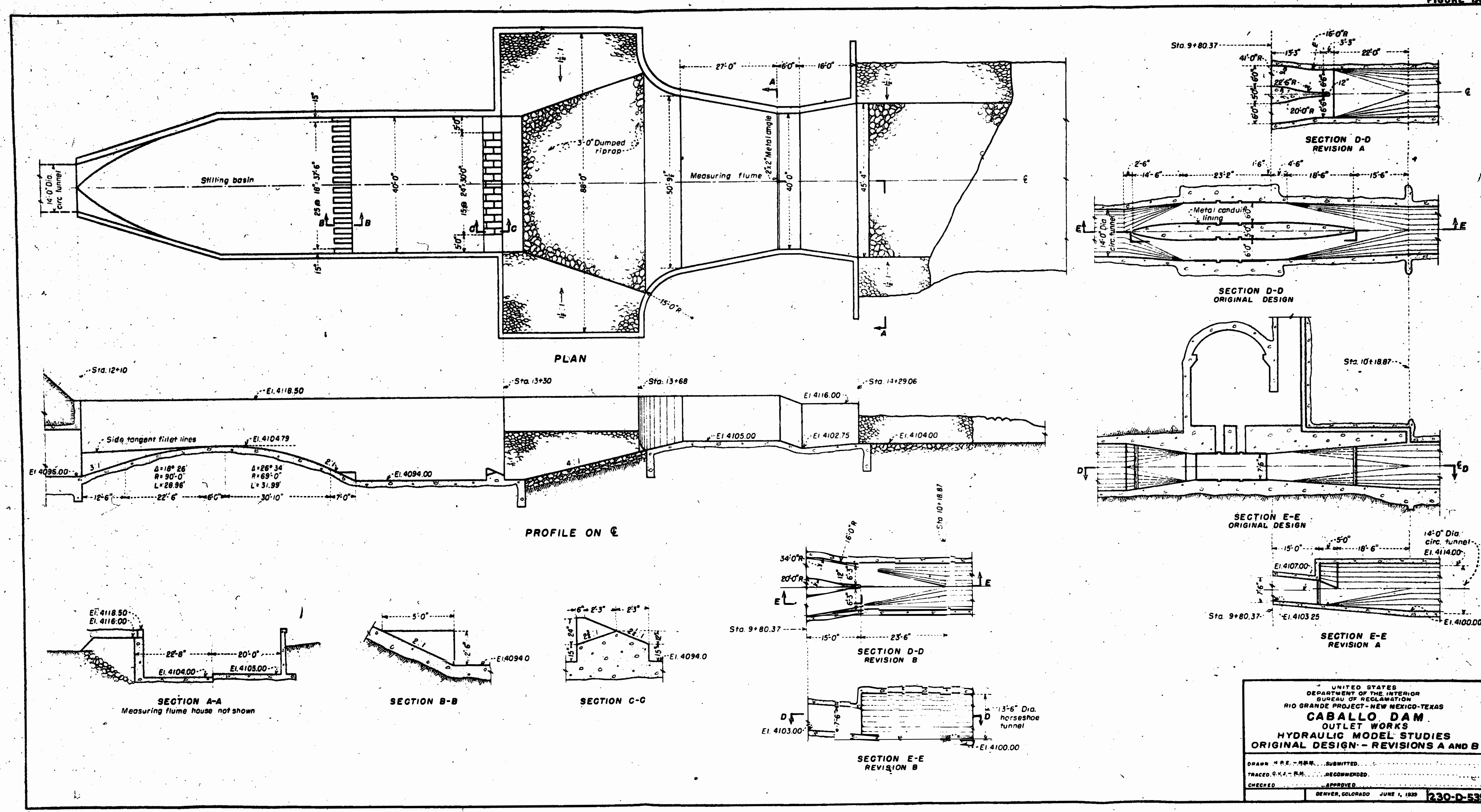


D. STILLING POOL
SHOWING HUMP

C. PARSHALL FLUME
LOOKING UPSTREAM

ORIGINAL DESIGN

FIGURE 1A


PLAN
Stilling basin
14'-0" Dia. circ. tunnel
3'-0" Dumped riprap
Measuring flume
2"x2" Metal angle
PROFILE ON ℄
Sta. 12+10
El. 4118.50
Side tangent fillet lines
El. 4104.79
El. 4096.00
El. 4094.00
Sta. 13+30
Sta. 13+68
El. 4105.00
El. 4116.00
El. 4102.75
Sta. 14+29.06
El. 4104.00
Δ=18° 26'
R=90'-0"
L=28.96'
Δ=26° 34'
R=69'-0"
L=31.99'
SECTION A-A
Measuring flume house not shown
El. 4118.50
El. 4116.00
El. 4104.00
El. 4105.00
SECTION B-B
El. 4094.0
SECTION C-C
El. 4094.0
SECTION D-D
REVISION A
Sta. 9+80.37
SECTION D-D
ORIGINAL DESIGN
Metal conduit lining
14'-0" Dia. circ. tunnel
Sta. 10+18.87
SECTION E-E
ORIGINAL DESIGN
SECTION D-D
REVISION B
Sta. 9+80.37
SECTION E-E
REVISION B
13'-6" Dia. horseshoe tunnel
El. 4103.00
El. 4100.00
SECTION E-E
REVISION A
14'-0" Dia. circ. tunnel
El. 4114.00
El. 4107.00
El. 4103.25
El. 4100.00
Sta. 9+80.37
UNITED STATES
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BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
ORIGINAL DESIGN - REVISIONS A AND B
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO JUNE 1, 1939
230-D-539

With the gates equally open at normal head, the flow through the gates joined at the end of the pier to form a series of standing waves in the tunnel and a high central fin on the stilling-pool hump.

At the lower rates of discharge, up to 900 cubic feet per second, the tailwater backed over the hump and caused a whirl on the upstream side. The jump was not complete and high surface velocities continued through the pool and Parshall flume, causing a source of error in discharge measurements.

At higher rates of discharge, the pool was very splashy although little erosion resulted downstream from the Parshall flume.

Plates II and III show the model of the original design in operation.

Revision of gate section and tunnel. To correct the poor performance in the gate section and tunnel, the transition and pier downstream from the gates were altered as shown on Revision A, Figure 1a. As a result, the fin off the end of the pier was reduced considerably and the flow down the tunnel and over the hump appeared to be slightly improved. To further reduce the spiral flow in the tunnel with one gate open under normal head, a horseshoe tunnel was tried. The water surface in the tunnel was smoothed out considerably and the velocity distribution in the stilling-pool was improved, the effluence of the tunnel being nearly level for all combinations of gate openings. This alteration is shown on Revision B, Figure 1a, and also on Plate IV.

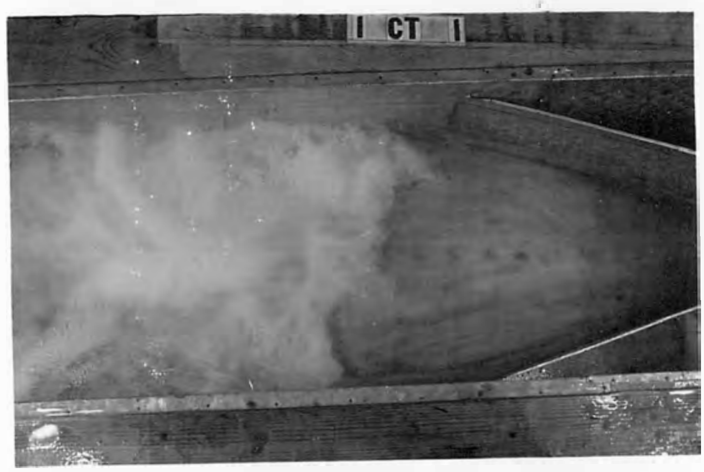
Depth of pool as controlled by Parshall flume. A series of quantitative tests were made to determine the relation between the discharge through the outlet works, depth of water in the stilling-pool, and the tailwater elevation in the river downstream from the Parshall flume. The tailwater was controlled in accordance with the rating curve of the Rio Grande River at the Caballo Damsite, Figure 2.

The control effect of the flume is shown in graphic form on Figure 3.

Revisions on stilling-pool and flume approach. With one gate partly or fully open, a high side fin occurred on the hump at the side walls, as originally designed. Although the characteristics of the flow in the gate section and tunnel were greatly improved by Revision B, a high central fin and sidewall fins remained on the upstream side of the hump with both gates open. It was found that vertical sidewalls curved to fit the spread of the tunnel discharge eliminated the sidewall fins (Revision H, Figure 4).

To spread the effluence of the tunnel over the full width of the pool, humps 5 feet and 2-1/2 feet higher than that of the original design were found to be of little improvement. The high central fin broke up on the hump and sprang clear of the hump on the downstream side causing a very rough and splashy pool. At the lower discharges, the jump occurred within the tunnel and the portal was flooded. This is illustrated on D, Plate V.

A. TUNNEL AND GATE SECTION
LOOKING UPSTREAM

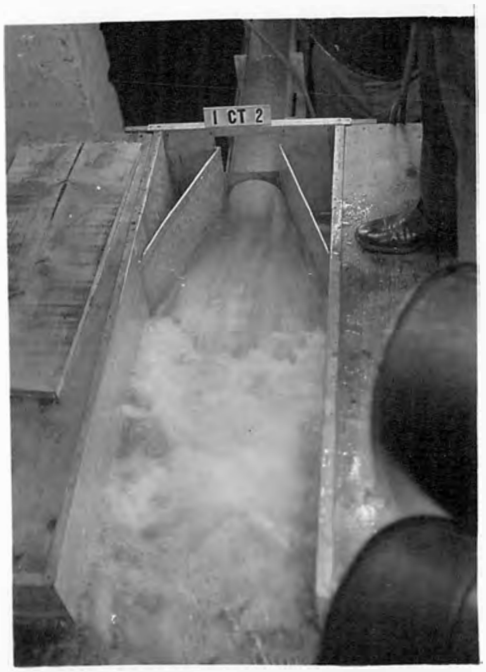


B. STILLING POOL

C. PARSHALL FLUME

ORIGINAL DESIGN
DISCHARGE 4930 SECOND-FEET

A. GATE SECTION

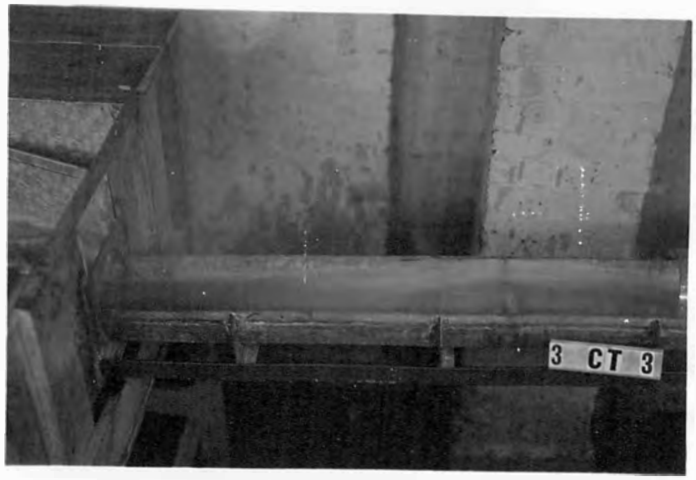


B. STILLING POOL

C. PARSHALL FLUME

ORIGINAL DESIGN

A. GATE SECTION AND HORSESHOE TUNNEL



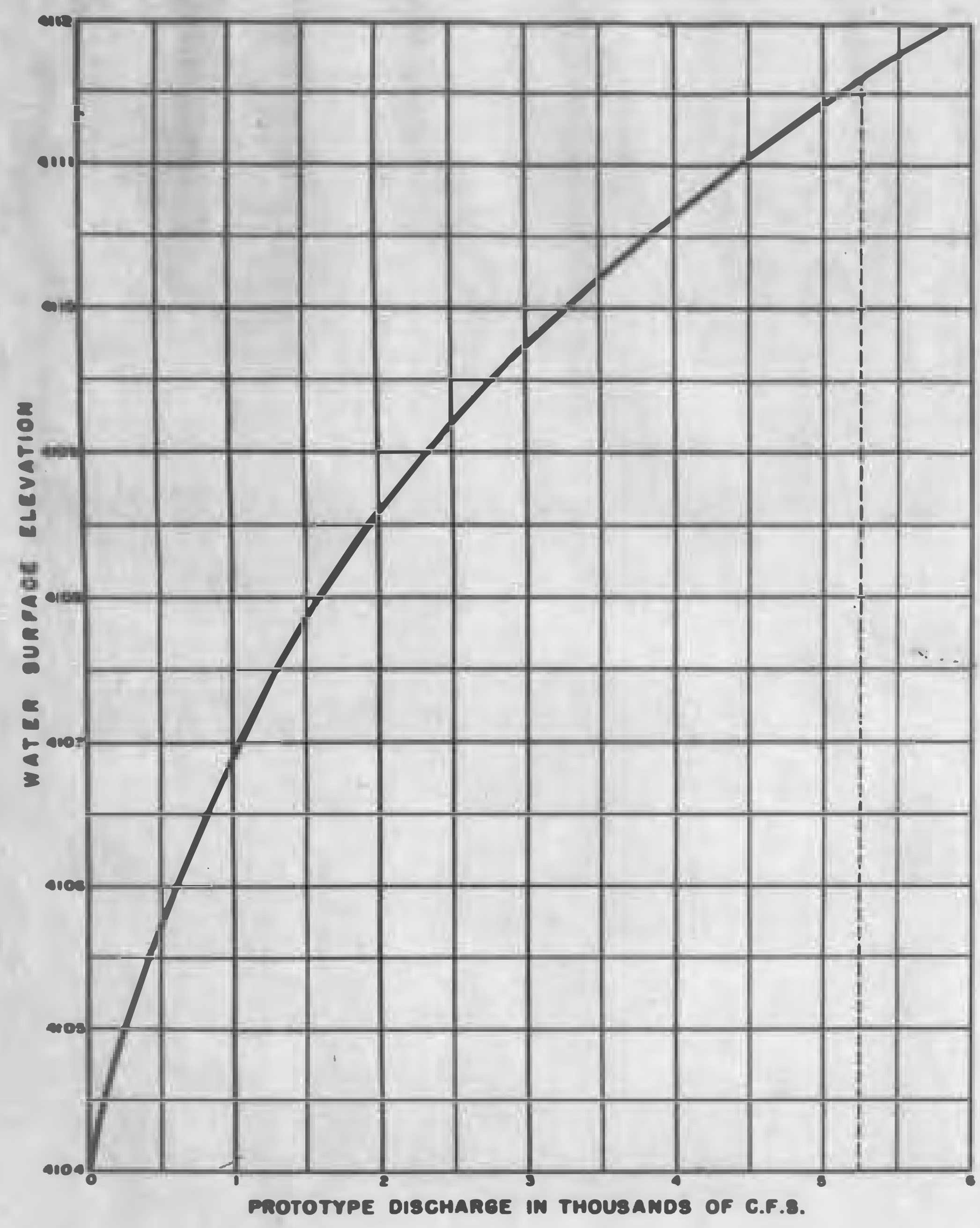
B. HORSESHOE TUNNEL NEAR STILLING POOL

C. STILLING POOL

D. PARSHALL FLUME

REVISION B
DISCHARGE 2578 SECOND-FEET

FIGURE 2



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RIO GRANDE PROJECT-NEW MEXICO-TEXAS

CABALLO DAM

OUTLET WORKS

RATING CURVE, RIO GRANDE RIVER, AT CABALLO DAM SITE

DRAWN R.E.K. - H.E.M. SUBMITTED

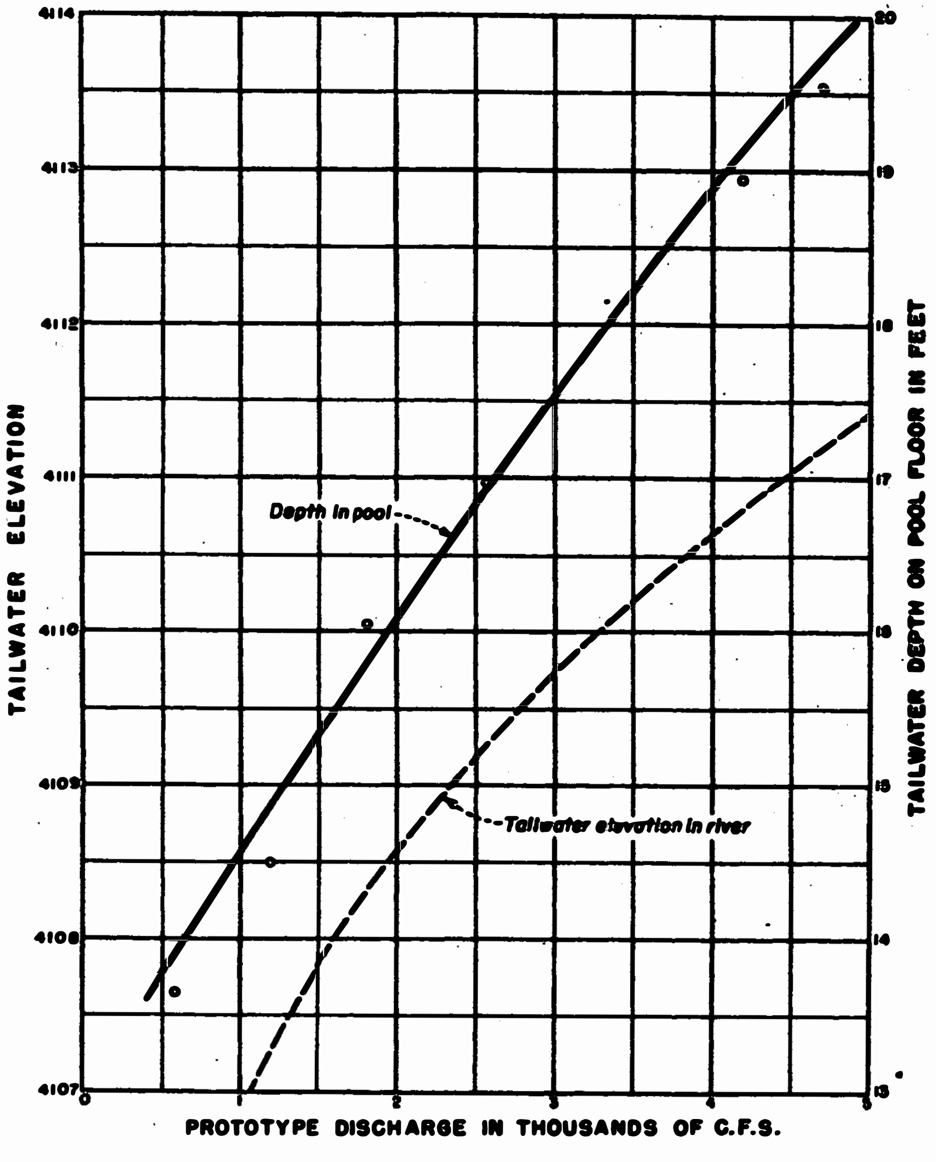
TRACED E.W.P. - H.S. RECOMMENDED

CHECKED APPROVED

DENVER, COLORADO - JULY 31, 1939

230-D-540

FIGURE 3



UNITED STATES
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RIO GRANDE PROJECT-NEW MEXICO-TEXAS

CABALLO DAM
OUTLET WORKS
POOL DEPTH AS CONTROLLED BY
PARSHALL FLUME

DRAWN. R.K.V.-H.M.B.	SUBMITTED.
TRACED. E.W.R.-H.S.	RECOMMENDED.
CHECKED.	APPROVED.
DENVER, COLORADO - JULY 31, 1939	230-D-541

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It was found that a tunnel with a flat invert improved the performance of the pool and that a ridge up the center of the hump spread the flow quite effectively over the entire width of the pool for all combinations of gate openings.

Summarizing, the best solution to the stilling-pool problem and the Parshall flume approach was found in the following features shown on Revisions H and I, Figure 4, and on Plate VII:

a. Curved sidewalls at the transition from the tunnel to the stilling-pool, to eliminate side fins for the entire range of discharge;

b. A 13-1/2-foot horseshoe tunnel with flat invert to reduce the banking of flow to a minimum, particularly for greatly unbalanced gate openings;

c. A "whaleback" hump beginning in the tunnel to distribute the flow over the full width of the pool;

d. Tapered sills, V-shaped in plan, to break up strong undercurrents along the sides of the pool;

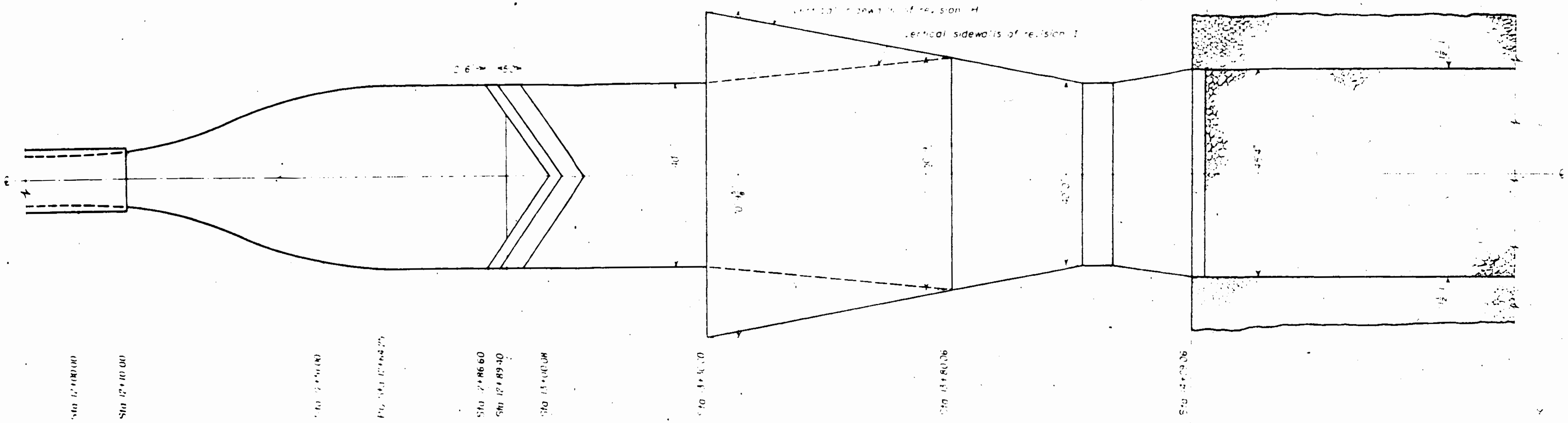
e. Vertical sidewalls in the approach to the Parshall flume from Station 13+30 to Station 13+80; (It was found that either of the sidewall locations shown in Figure 4 was an improvement over the original design. Revision H was preferable because it caused the least disturbance in the immediate approach to the Parshall flume.)

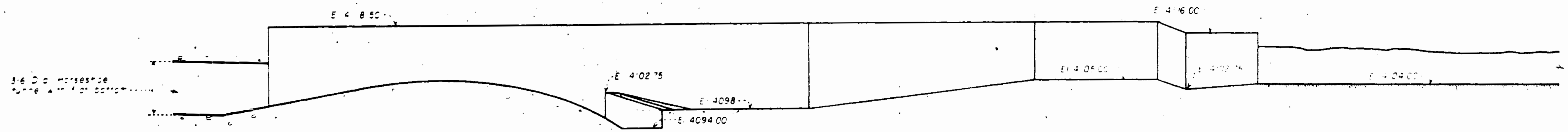
f. An addition of 5 feet of height to the sidewalls throughout the pool to provide for splash height (not shown on Figure 4).

Since the Parshall flume was only 50 feet downstream from the stilling-pool, an entirely satisfactory solution was not possible for all rates of discharge. It was decided to replace the Parshall flume with a venturi meter installed in the pressure tunnel upstream from the gate section.

Water surface profiles--Tentative design. Photographs of the tentative design model are shown in Plate VI. The plan and a longitudinal section are shown on Figure 4. Floor profiles and sections for various rates of discharge through the model are shown in Figures 5, 6, and 7.

Revision of the stilling-pool, Parshall flume removed. With the removal of the Parshall flume, the situation presented the problem of developing the stilling-pool that would cause the least erosion in the channel leading to the river and the least splash and disturbance in the pool itself. A series of short hasty investigations were conducted.





PROFILE ON ℄

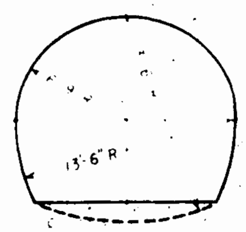
ELEVATIONS OF HUMP

STATION	℄	.88	3.75	SIDE
		DISTANCES TO RIGHT OR LEFT OF CENTERLINE		
[illegible]	4098.[illegible]	4098.[illegible]	4098.00	4098.00
[illegible]	4098.43	4098.[illegible]8	4098.00	4098.00
[illegible]	4098.98	4098.[illegible]	4098.83	4098.22
[illegible]	4099.39	4098.93	4098.45	4098.33
[illegible]	4[illegible].03	4099.38	4098.88	4098.6[illegible]

STATION	℄	2.50'	5.00'	6.25	6.88'	7.50	8.75'	10.00	[illegible]25	12.50'	15.00'
[illegible]	4[illegible]	4099.22	4098.55	4099.44							
[illegible]	4[illegible].69	4099.64	4098.95	4098.86							
[illegible]65	4[illegible].53	4[illegible].62	4099.94		4099.6						
[illegible]	4[illegible]8	4[illegible].82	4[illegible]7			4[illegible].80					
[illegible]	4[illegible]	4[illegible]2.58	4[illegible].97			4[illegible].62	4[illegible]05.55				
[illegible]78	4[illegible]4.2[illegible]	4[illegible]3.68	4[illegible]032			4[illegible]2.88		4102.66	4[illegible]02.98		
[illegible]95	4[illegible]	4[illegible]4.75	4[illegible]04.32			4[illegible]04[illegible]2		4[illegible]038		4103.77	
[illegible]95	4[illegible].82		4105.27					4104.94			4104.97
[illegible]95	4[illegible]6[illegible]		4105.99					4[illegible]058			4105.78
[illegible]	4106.36										
[illegible]95	4[illegible]6.33										
[illegible]	4[illegible]5.[illegible]										
[illegible]85	4[illegible]4.38										
[illegible]	4[illegible]2.67										
[illegible]80	4102.78										
[illegible]	4098.08										
[illegible]	4096.16										
[illegible]	4094.0[illegible]										

PLAN DIMENSIONS OF TRANSITION SYMMETRICAL ABOUT ℄

STATION	WIDTH FT.
2+0.00	[illegible]2.0
2.75	[illegible]3.60
7.65	14.45
22.65	16.40
25.95	18.66
30.78	22.50
35.85	27.20
40.95	30.15
45.95	33.35
51.00	35.60
55.90	37.85
60.90	39.40
64.85	40.00



CROSS SECTION
(ENLARGED)
STA. 9+95.37 TO STA. 12+00

Transition from Sta. 9+78.87 to 9+95.37 identical to that shown on Recommended Design Figure 15.

NOTE
Revisions H and I are identical except for location of vertical sidewalls from Sta. 13+30 to Sta. 13+80

UNITED STATES
DEPARTMENT OF THE INTERIOR
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RIO GRANDE PROJECT - NEW MEXICO - TEXAS

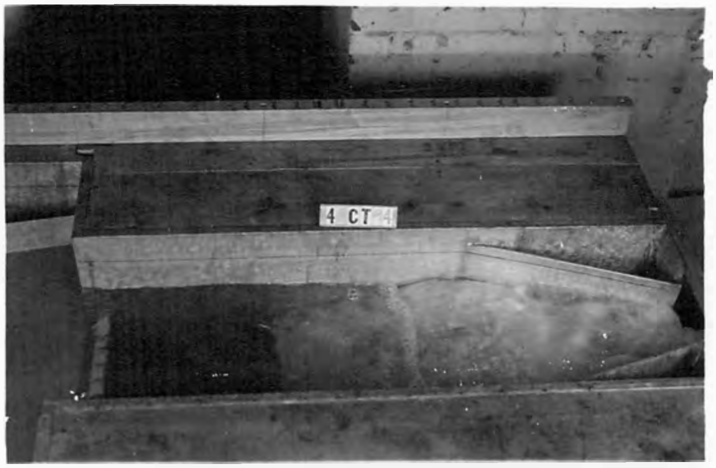
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
TENTATIVE DESIGN - REVISIONS H AND I

DRAWN H.M.M. SUBMITTED
TRACED F.A.J.-H.H. RECOMMENDED
CHECKED APPROVED

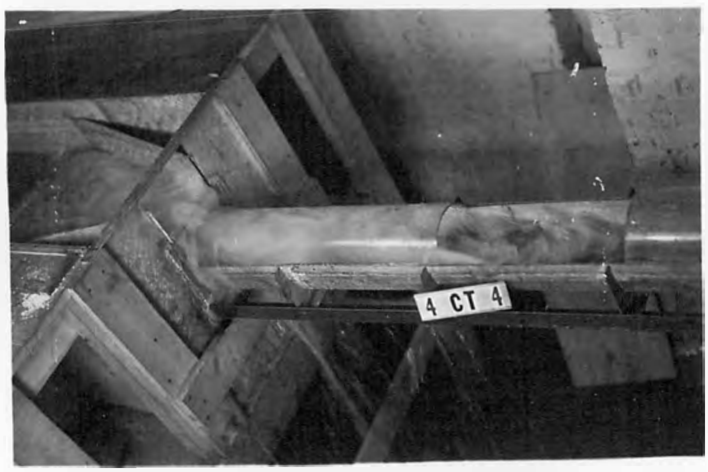
DENVER, COLORADO JUNE [illegible] 1939 230-D-542

A. SHOWING RAISED HUMP

STILLING POOL
DISCHARGE 4777 SECOND-FEET



C. STILLING POOL
DISCHARGE 878 SECOND-FEET



D. JUMP IN HORSESHOE TUNNEL
PORTAL FLOODED
DISCHARGE 878 SECOND-FEET

REVISION H

DISCHARGE 3120 SECOND-FEET

DISCHARGE 4670 SECOND-FEET

DISCHARGE 1810 SECOND-FEET

RECOMMENDED DESIGN

The requirements for this stilling-pool were somewhat different from those of the pool developed for the Parshall flume in that for the latter it was essential that there be a uniform velocity throughout the entire width of the flume. In the new situation, uniform velocity was not essential. Only a minimum of erosion or scour in the channel was necessary.

Figures 8 to 14, inclusive, outline the essential features of these tests. The layout shown on Figure 14 and on Plate VII is essentially the same as that recommended on Figure 15 and that of the final design, Figures 16 to 20, inclusive.

The horseshoe tunnel was found to be feasible as the pool developed dissipated energy to such a degree that the difference between the performance of the flat-bottom and round-bottom tunnel was not appreciable in the scour.

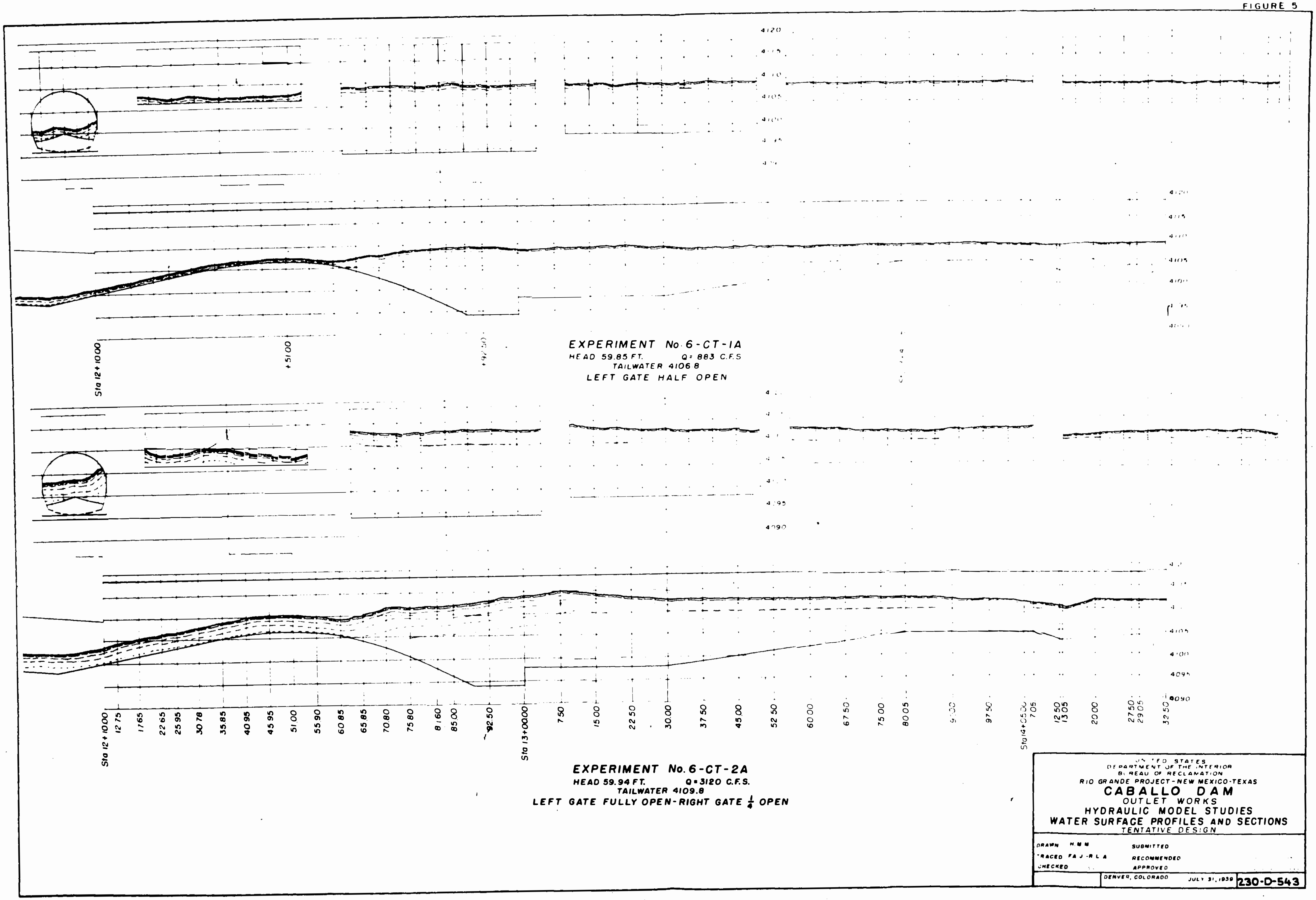
Water-surface and scour profiles and cross-sections for the recommended design. Figures 21 and 22 are plotted profiles and cross-sections of the water-surfaces and scour for various rates of discharge for the recommended design. Plates VIII and IX show the model in operation.

IV. THE SPILLWAY

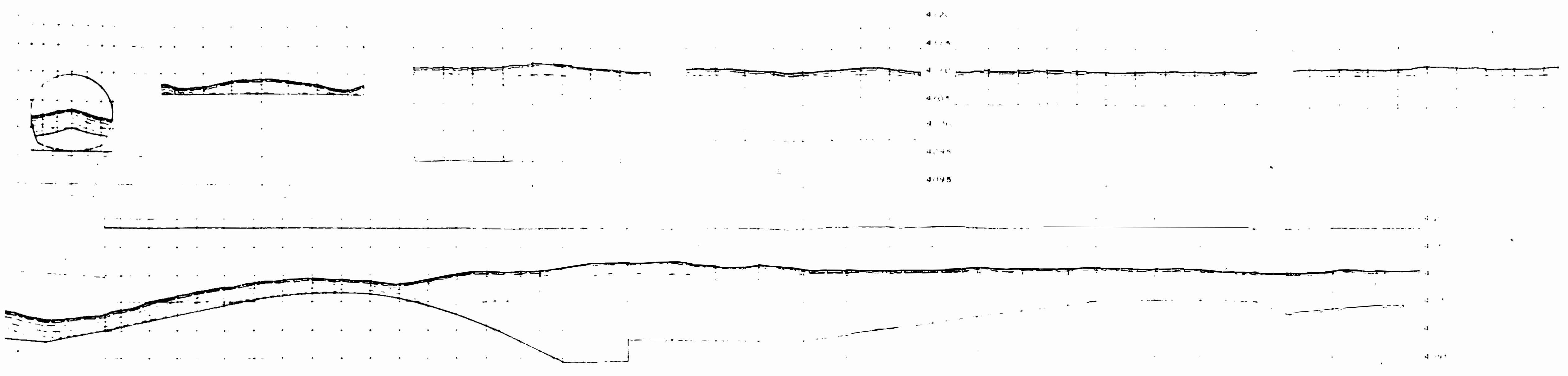
As previously described, three distinct plans for the construction of the dam and spillway were presented for investigation. Figures 26 and 33 are model drawings of Plans Nos. 1 and 2, respectively. Figure 23 illustrates the general arrangement of the structure for Plan No. 3. Details of the spillway are given in Figures 24 and 25.

Low dam--Plan No. 1. A scale of 1 to 60 was chosen for the spillway models. A framework of wood was covered with wood sheathing and lined with galvanized sheet steel (Figure 26). The topography above the spillway crest was also built of wood and lined with metal. The crest, to which all elevations were referenced, was constructed of heavy gage, galvanized metal templates, held rigid by steel angles and covered with heavy gage galvanized iron. Piezometers were placed at uniform intervals over the crest to indicate the pressure heads at various discharges. The stilling-pool floor and walls were constructed of wood, set on an adjustable base by means of which the floor could be raised or lowered. This adjustable base was enclosed by a watertight sandbox in which the downstream topography was duplicated with sand. The recommended stilling-pool design was obtained by visual inspection and by comparison of the scoured sandbeds. Views of the model are shown on Plate X.

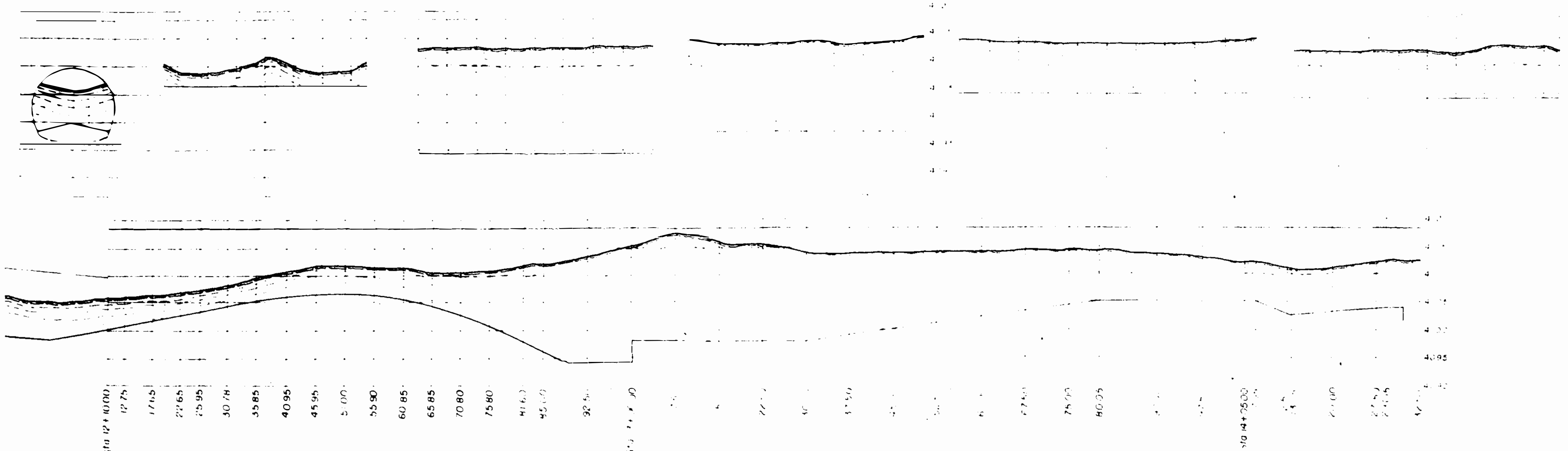
The results of quantitative studies of crest discharges are indicated in Figure 27. Water-surface elevations were measured with both point gage and piezometer.



EXPERIMENT No. 6-CT-1A
HEAD 59.85 FT. Q = 883 C.F.S.
TAILWATER 4106.8
LEFT GATE HALF OPEN
Sta 12+10.00
+51.00
4120
4110
4105
4100
4095
4090
EXPERIMENT No. 6-CT-2A
HEAD 59.94 FT. Q = 3120 C.F.S.
TAILWATER 4109.8
LEFT GATE FULLY OPEN - RIGHT GATE $\frac{1}{4}$ OPEN
Sta 12+10.00
12.75
17.65
22.65
25.95
30.78
35.85
40.95
45.95
51.00
55.90
60.85
65.85
70.80
75.80
81.60
85.00
92.50
Sta 13+00.00
7.50
15.00
22.50
30.00
37.50
45.00
52.50
60.00
67.50
75.00
80.05
97.50
Sta 14+05.00
7.05
12.50
13.05
20.00
27.50
29.05
32.50
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
WATER SURFACE PROFILES AND SECTIONS
TENTATIVE DESIGN
DRAWN H.M.M.
TRACED F.A.J.-R.L.A.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO
JULY 31, 1939
230-D-543



EXPERIMENT No. 6-CT-3A
HEAD 60.15 FT Q=1810 CFS
TAILWATER 4108.0
BOTH GATES HALF OPEN

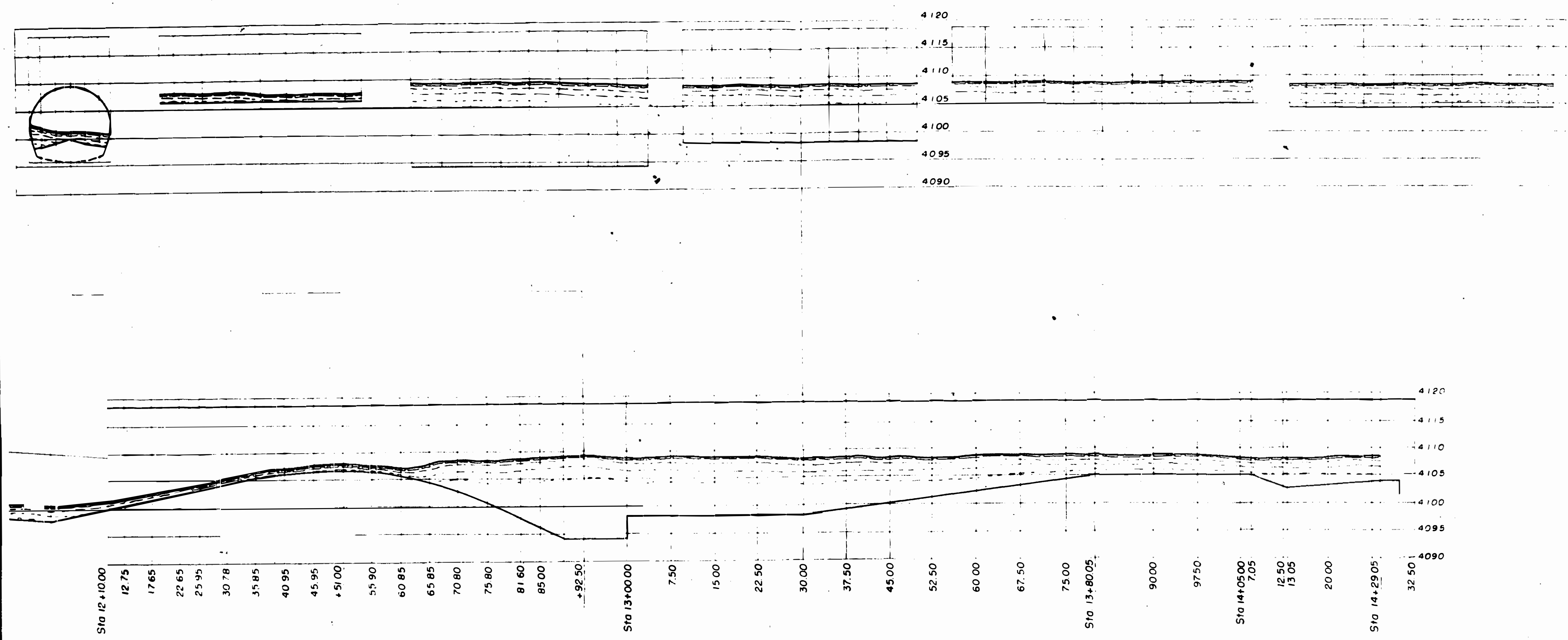


EXPERIMENT No. 6-CT-4A
HEAD 42.36 FT Q=4670 CFS
TAILWATER 4111.3
BOTH GATES FULLY OPEN

RIO GRANDE PROJECT-NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
WATER SURFACE PROFILES AND SECTIONS
TENTATIVE DESIGN

230-D-544

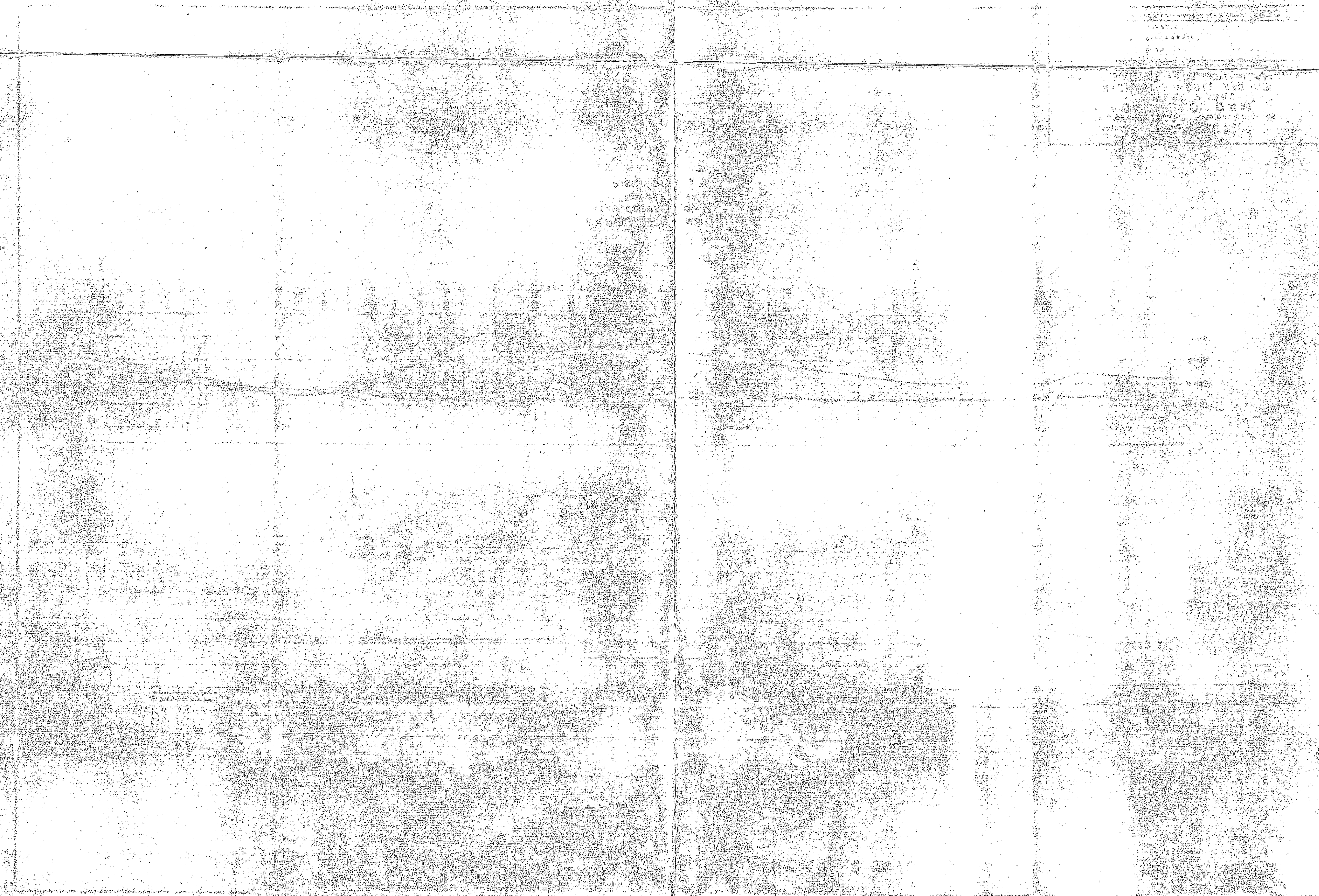
FIGURE 7



EXPERIMENT No. 7-CT-1
HEAD 60.09 FT. Q = 887 C.F.S.
TAILWATER 4106.8
RIGHT GATE ½ OPEN

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
WATER SURFACE PROFILES AND SECTIONS
TENTATIVE DESIGN

DRAWN H.M.M.		SUBMITTED
TRACED B.B.	D.W.B.	RECOMMENDED
CHECKED		APPROVED
	DENVER, COLORADO, JULY 31, 1939	230-D-545



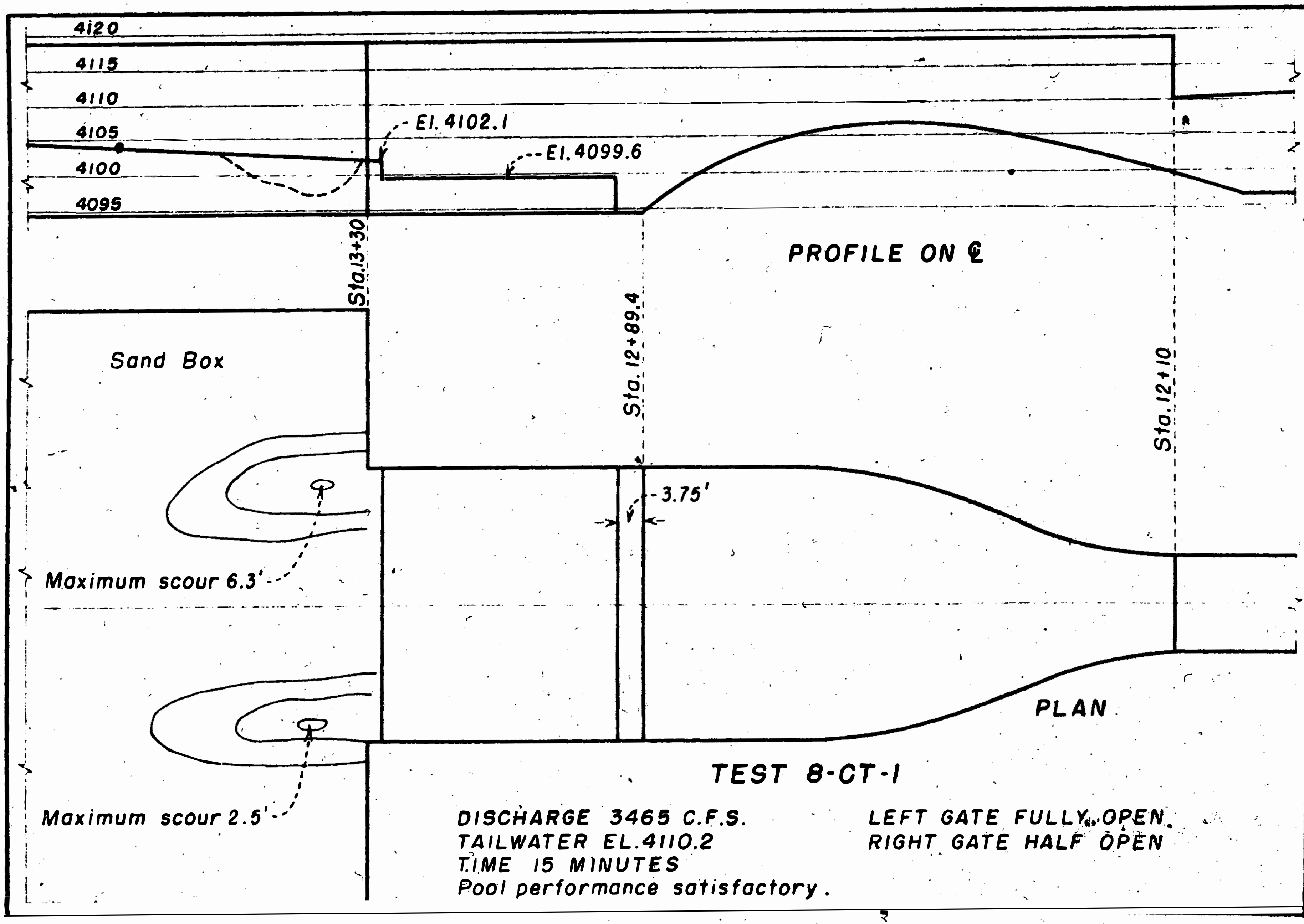
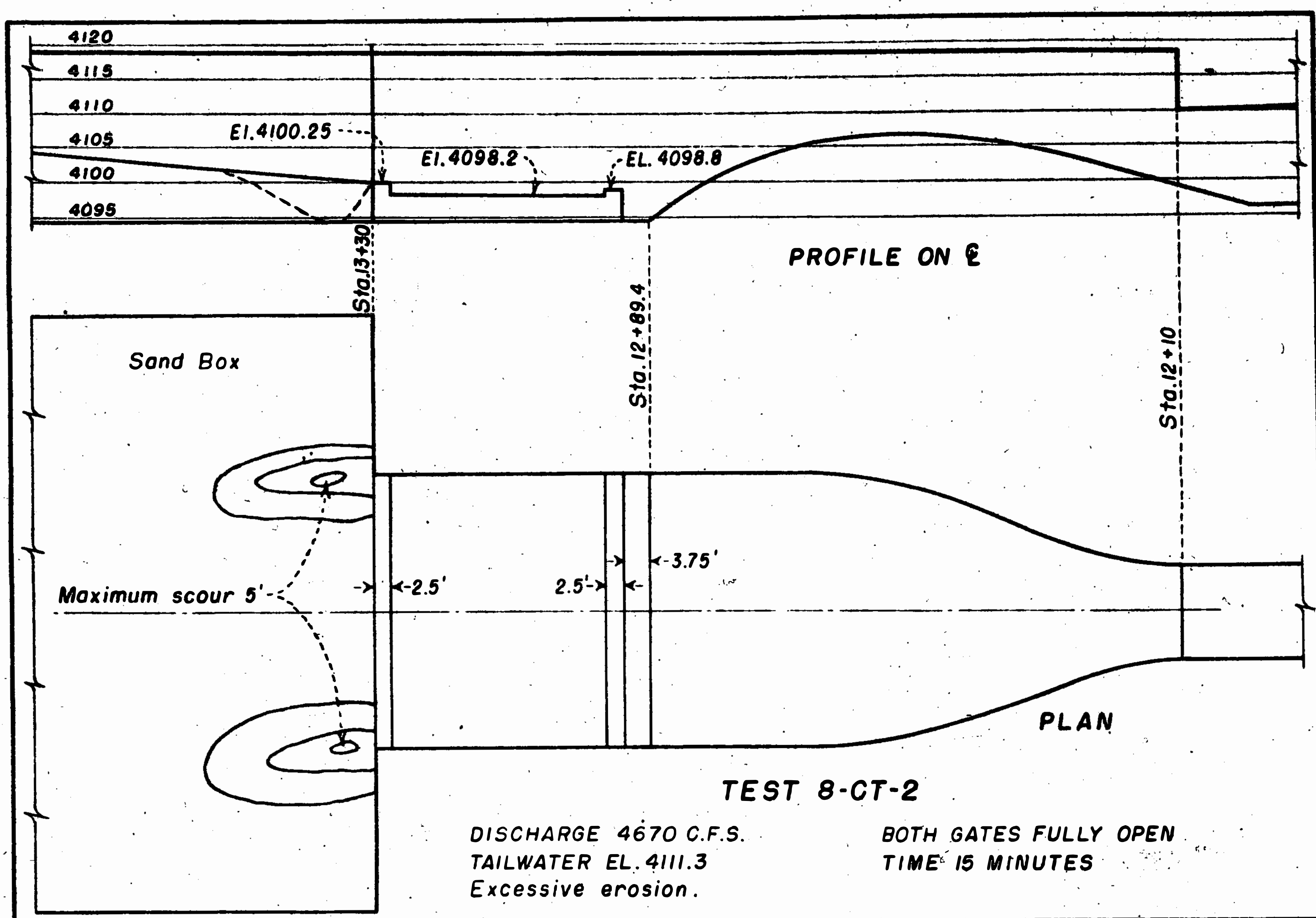

4120
4115
4110
4105
4100
4095
El. 4102.1
El. 4099.6
PROFILE ON ℄
Sta.13+30
Sta. 12+89.4
Sta. 12+10
Sand Box
3.75'
Maximum scour 6.3'
Maximum scour 2.5'
PLAN
TEST 8-CT-1
DISCHARGE 3465 C.F.S.
TAILWATER EL.4110.2
TIME 15 MINUTES
Pool performance satisfactory.
LEFT GATE FULLY OPEN.
RIGHT GATE HALF OPEN

FIGURE 8



4120
4115
4110
4105
4100
4095
El. 4100.25
El. 4098.2
EL. 4098.8
Sta. 13+30
Sta. 12+89.4
Sta. 12+10
PROFILE ON ℄
Sand Box
Maximum scour 5'
2.5'
2.5'
3.75'
PLAN
TEST 8-CT-2
DISCHARGE 4670 C.F.S.
TAILWATER EL. 4111.3
Excessive erosion.
BOTH GATES FULLY OPEN
TIME 15 MINUTES

FIGURE 9

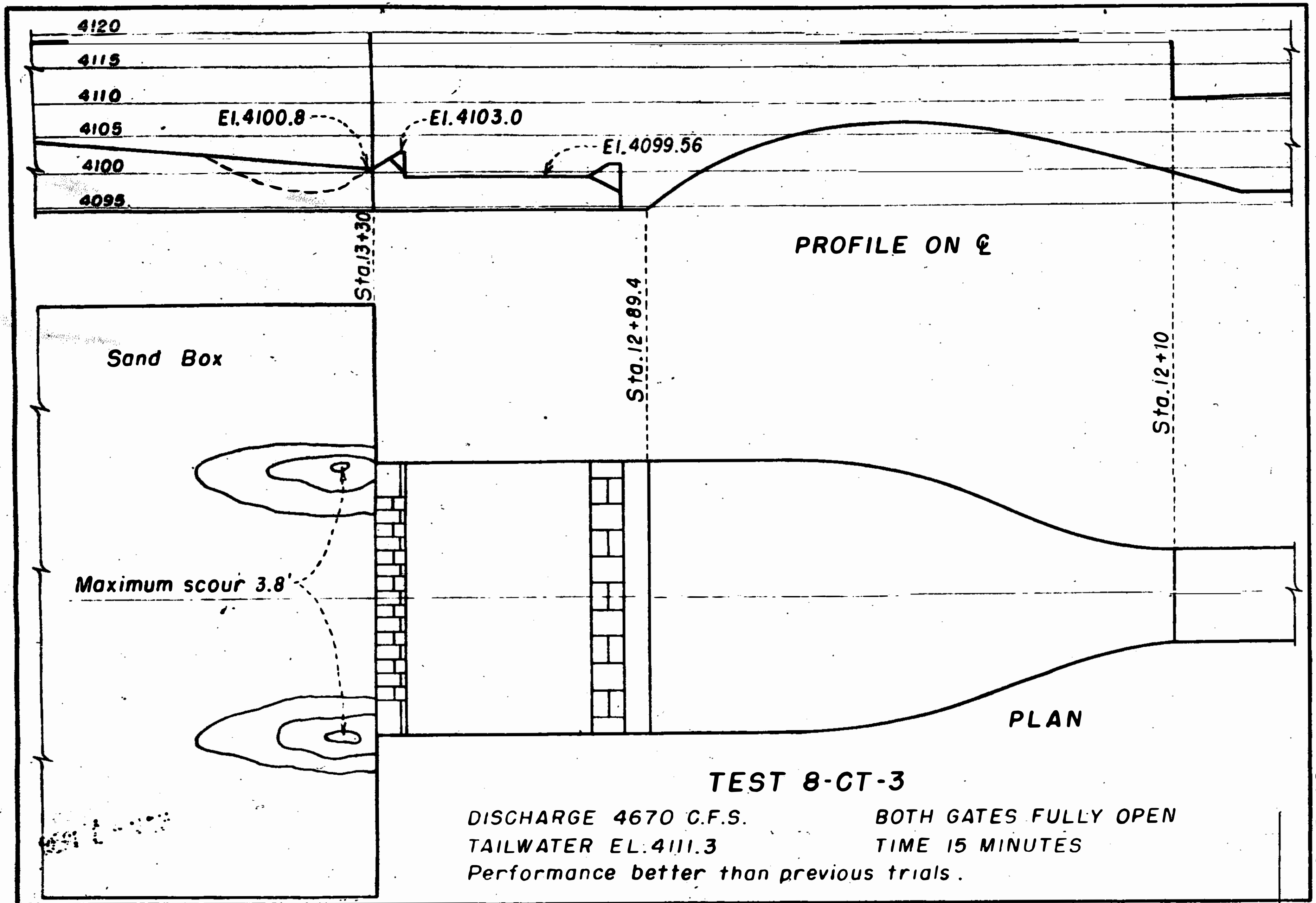

4120
4115
4110
4105
4100
4095
El. 4100.8
El. 4103.0
El. 4099.56
PROFILE ON ℄
Sta. 13+30
Sta. 12+89.4
Sta. 12+10
Sand Box
Maximum scour 3.8'
PLAN
TEST 8-CT-3
DISCHARGE 4670 C.F.S.
TAILWATER EL. 4111.3
BOTH GATES FULLY OPEN
TIME 15 MINUTES
Performance better than previous trials.

FIGURE 10

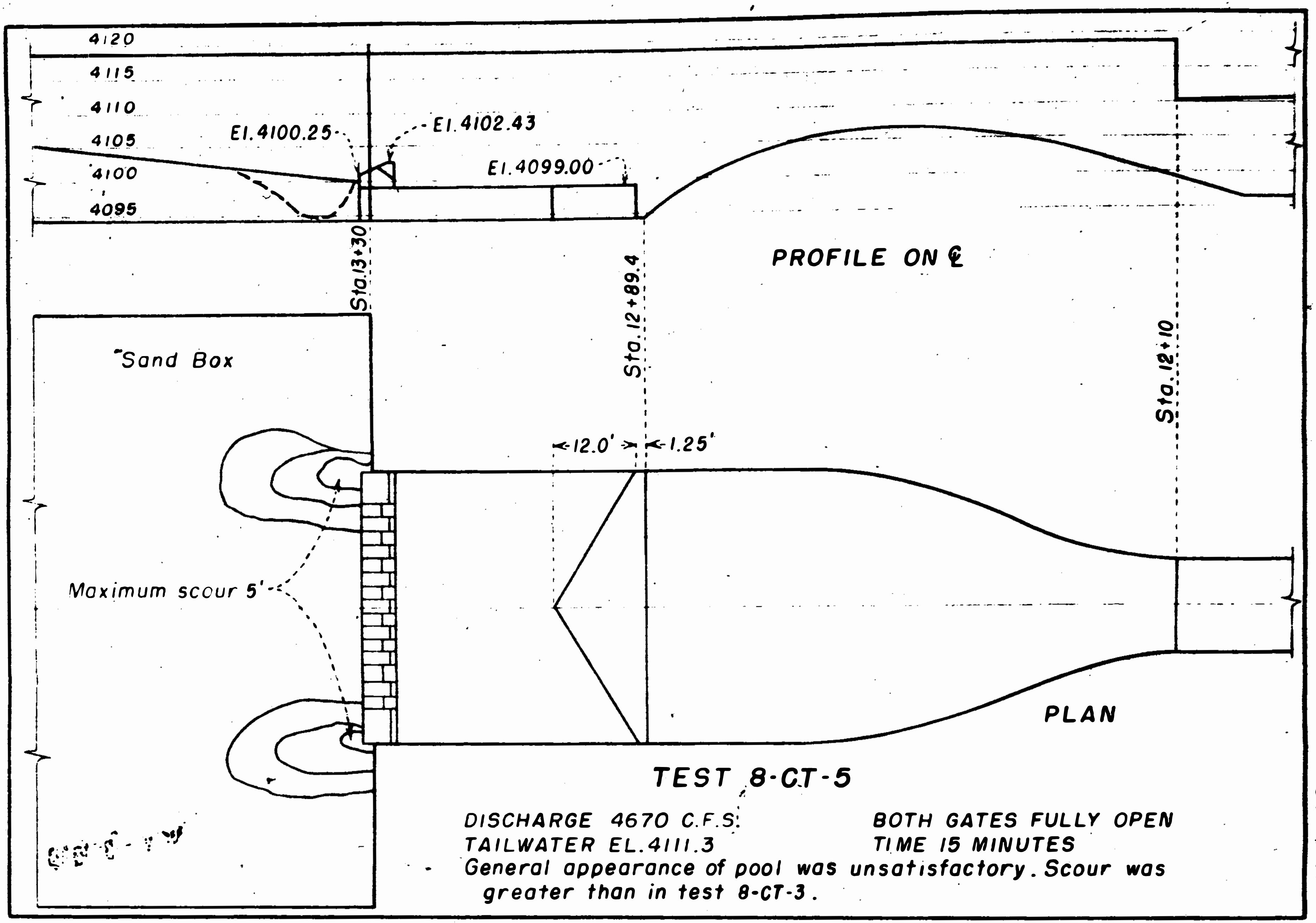

4120
4115
4110
4105
4100
4095
El. 4100.25
El. 4102.43
El. 4099.00
Sta. 13+30
Sta. 12+89.4
Sta. 12+10
PROFILE ON ℄
Sand Box
12.0'
1.25'
Maximum scour 5'
PLAN
TEST 8-CT-5
DISCHARGE 4670 C.F.S.
TAILWATER EL. 4111.3
BOTH GATES FULLY OPEN
TIME 15 MINUTES
General appearance of pool was unsatisfactory. Scour was greater than in test 8-CT-3.

FIGURE 11

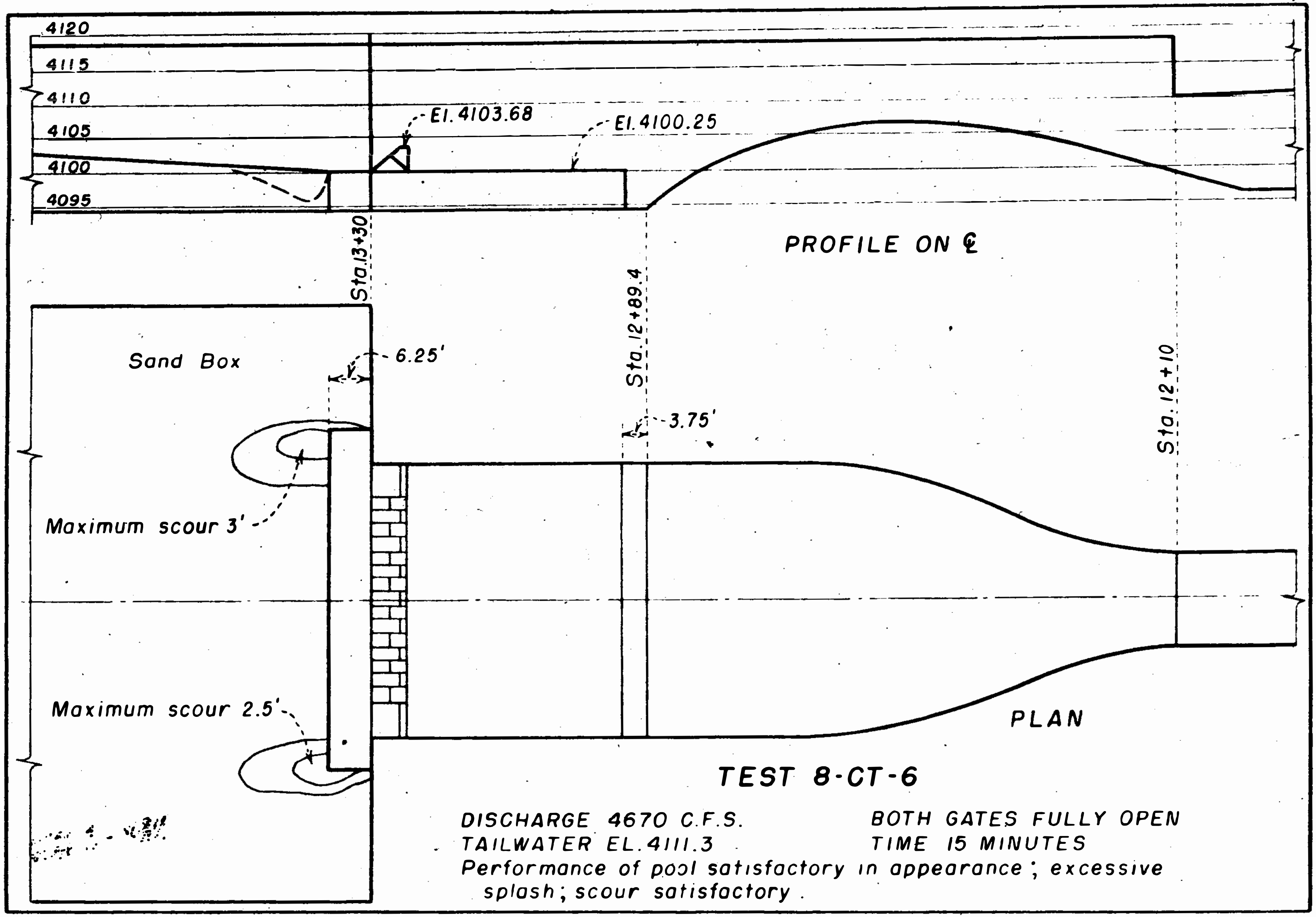

4120
4115
4110
4105
4100
4095
El. 4103.68
El. 4100.25
PROFILE ON ℄
Sta. 13+30
Sta. 12+89.4
Sta. 12+10
Sand Box
6.25'
3.75'
Maximum scour 3'
Maximum scour 2.5'
PLAN
TEST 8-CT-6
DISCHARGE 4670 C.F.S.
TAILWATER EL. 4111.3
BOTH GATES FULLY OPEN
TIME 15 MINUTES
Performance of pool satisfactory in appearance; excessive splash; scour satisfactory.

FIGURE 12

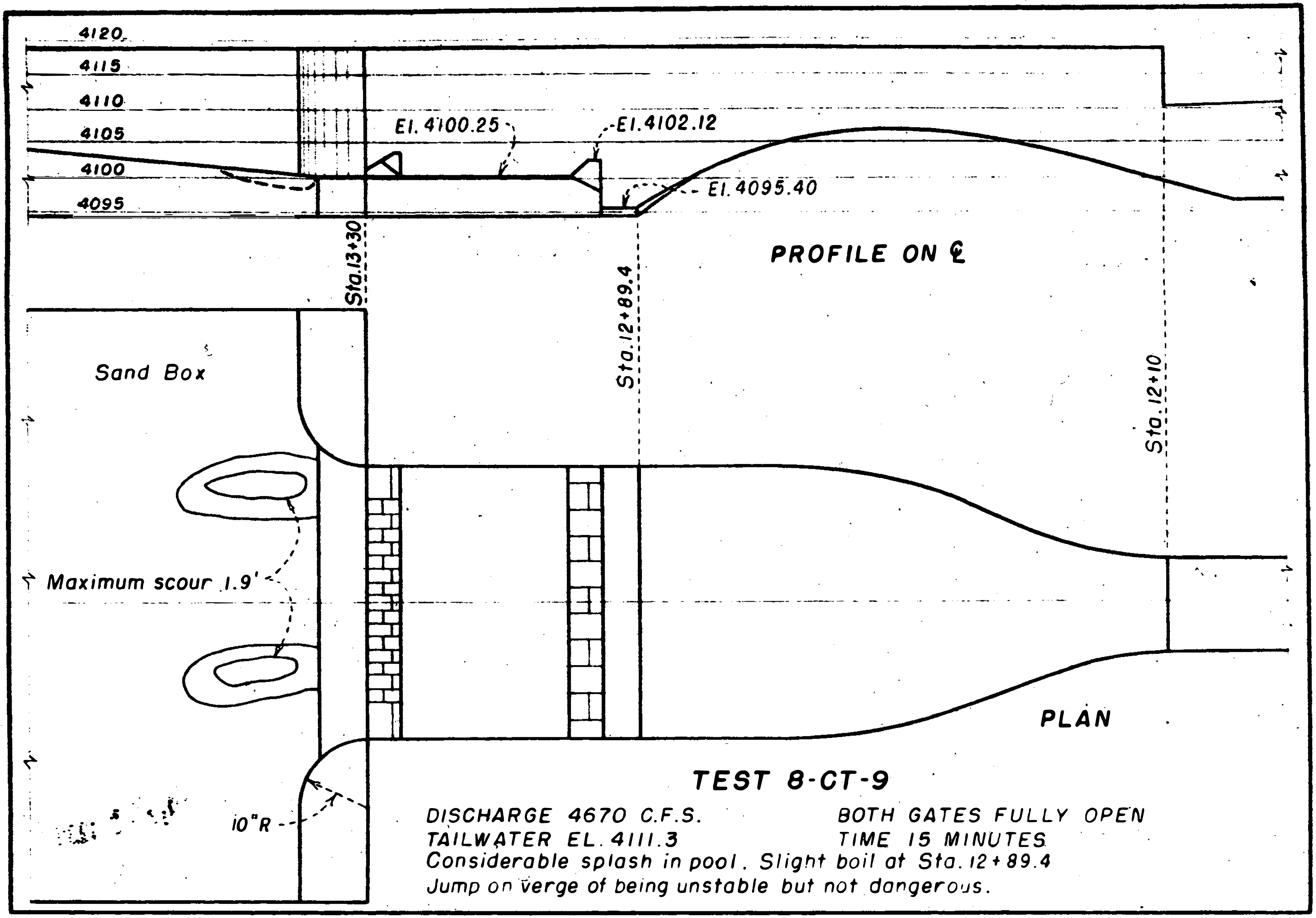
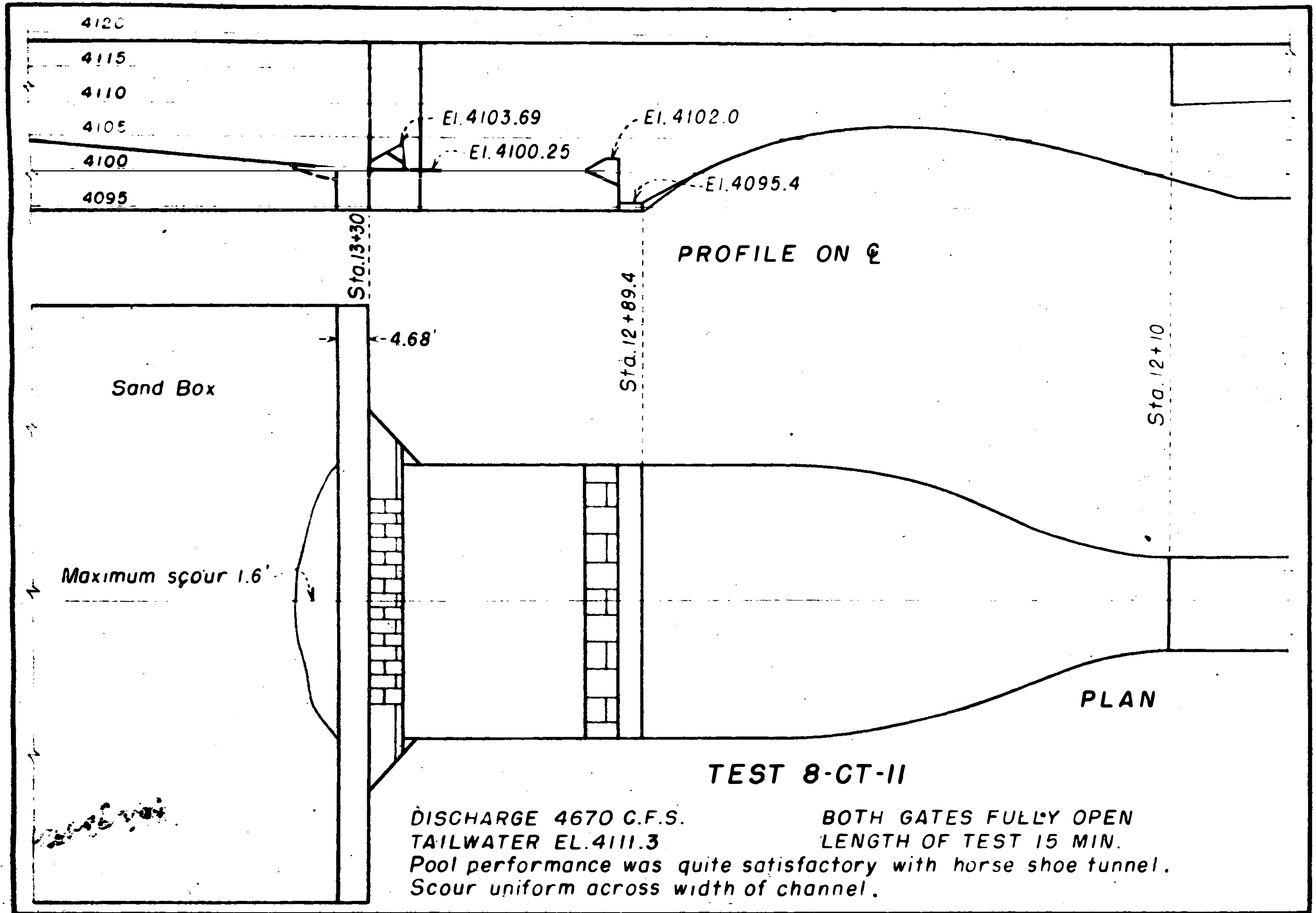

4120
4115
4110
4105
4100
4095
El. 4100.25
El. 4102.12
El. 4095.40
Sta. 13+30
Sta. 12+89.4
Sta. 12+10
PROFILE ON ℄
Sand Box
Maximum scour 1.9'
10"R
PLAN
TEST 8-CT-9
DISCHARGE 4670 C.F.S.
TAILWATER EL. 4111.3
BOTH GATES FULLY OPEN
TIME 15 MINUTES
Considerable splash in pool. Slight boil at Sta. 12+89.4
Jump on verge of being unstable but not dangerous.

FIGURE 13

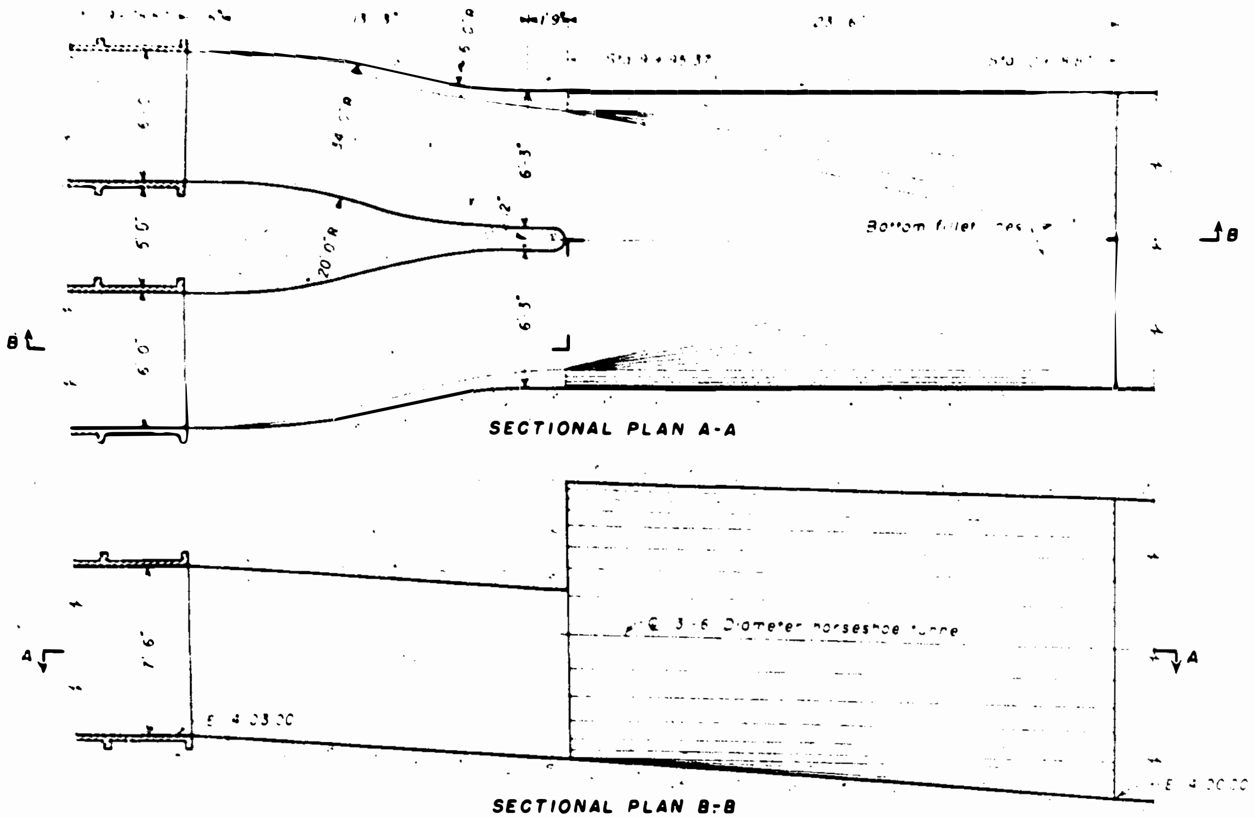


TEST 8-CT-11

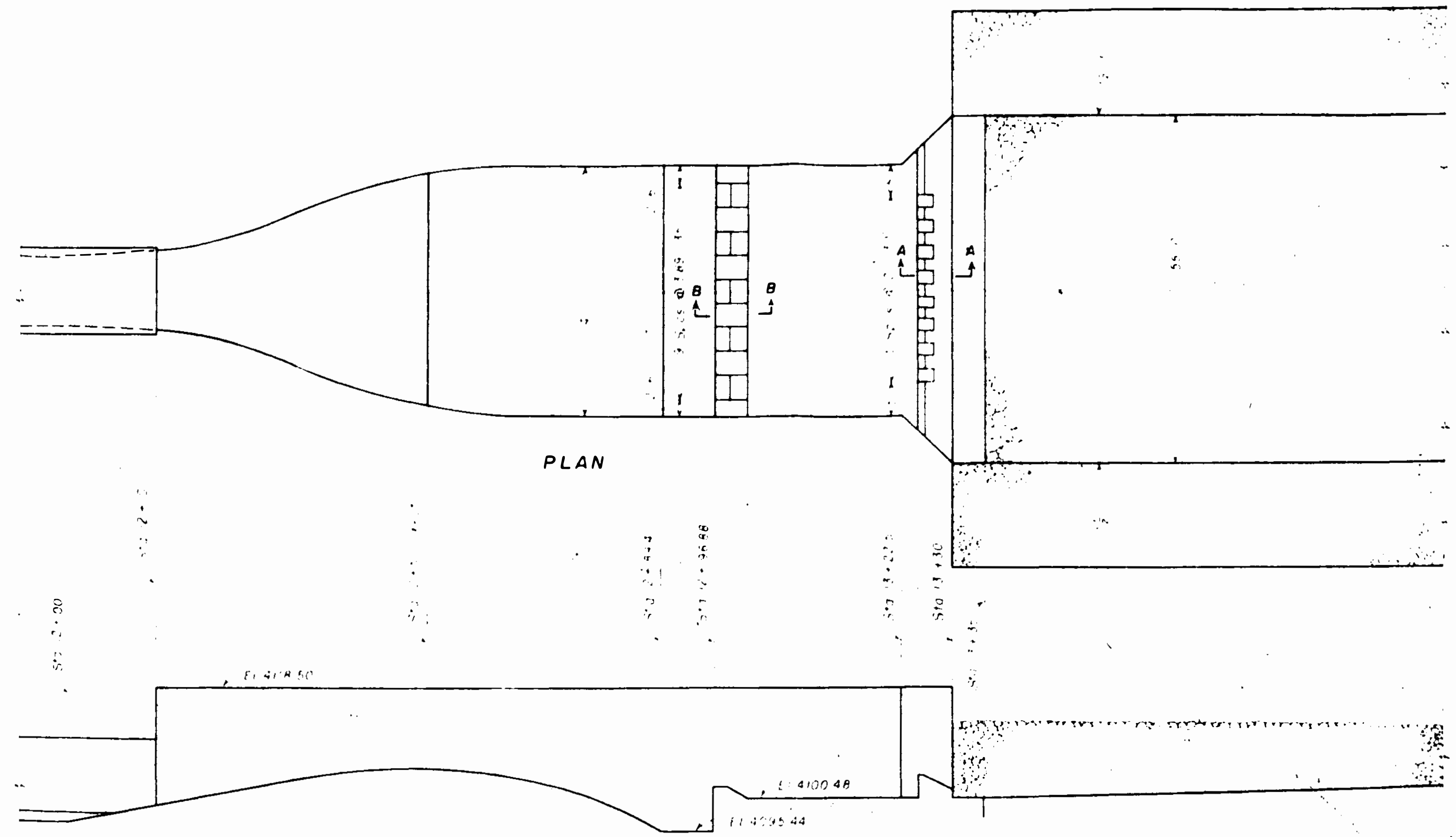
DISCHARGE 4670 C.F.S. BOTH GATES FULLY OPEN
TAILWATER EL. 4111.3 LENGTH OF TEST 15 MIN.
Pool performance was quite satisfactory with horse shoe tunnel.
Scour uniform across width of channel.

FIGURE 14

FIGURE 5



TRANSITION FROM GATES



ELEVATIONS OF HUMP

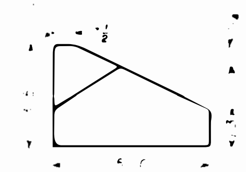
STATION	℄	1.88'	3.75'	SIDE
12+00.00	4098 00	4098 00	4098 00	4098 00
+ 2.50	4098 43	4098 [illegible]8	4098 00	4098 00
+ 5.00	4098 98	4098 50	4098 23	4098 22
+ 7.50	4099 38	4098 93	4098 45	4098 33
+10.00	4100 03	4099 38	4098 88	4098 60

DISTANCES TO RIGHT OR LEFT OF CENTERLINE

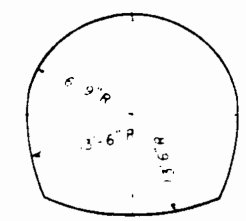
STATION	℄	2.5'	5.0'	6.25'	6.88'	7.50'	8.75'	10.0'	11.25'	12.50'	15.00'
12+10.00	4100 03	4099 22	4098 55	4099 44							
+12.75	4100 48	4099 64	4098 95	4098 86							
+ [illegible]65	4101 53	4100 52	4099 94		4099 6[illegible]						
+22.65	4102 58	4100 92	4[illegible]			4100 80					
+25.95	4103 33	4102 58	4101 97			4101 62	4 05 55				
+30.78	4104 29	4103 68	4103 2[illegible]			4102 82		4102 66	4102 58		
+35.85	4105 13	4104 70	4104 12			4104 02		4103 8[illegible]		4103 7[illegible]	
+40.95	4105 82		4105 27					4104 94			4[illegible]4 97
+45.95	4106 [illegible]8		4105 99					4105 8			4105 78
+51.00	4106 36										
+55.90	4106 33										
+60.90	4105 82										
+65.85	4104 50										
+70.80	4102 88										
+75.80	4101 99										
+81.60	4098 53										
+85.00	4097 [illegible]5										
+89.40	4095 44										

PLAN DIMENSIONS OF TRANSITION SYMMETRICAL ABOUT ℄

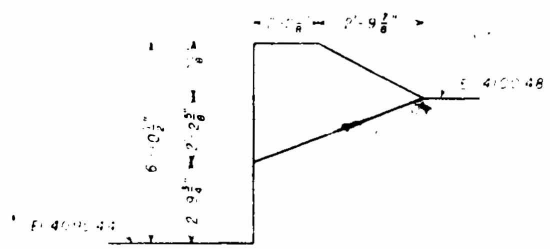
STATION	WIDTH FT
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	4 45
[illegible]	[illegible]
[illegible]	6 60
[illegible]	[illegible]
	[illegible]
	[illegible]
[illegible]	33 3[illegible]
[illegible]	35 60
[illegible]	37 85
[illegible]	39 40
+04 25	40 00



SECTION B-B
(ENLARGED)



CROSS SECTION
(ENLARGED)
TUNNEL STA. 10+18.87 TO 12+00



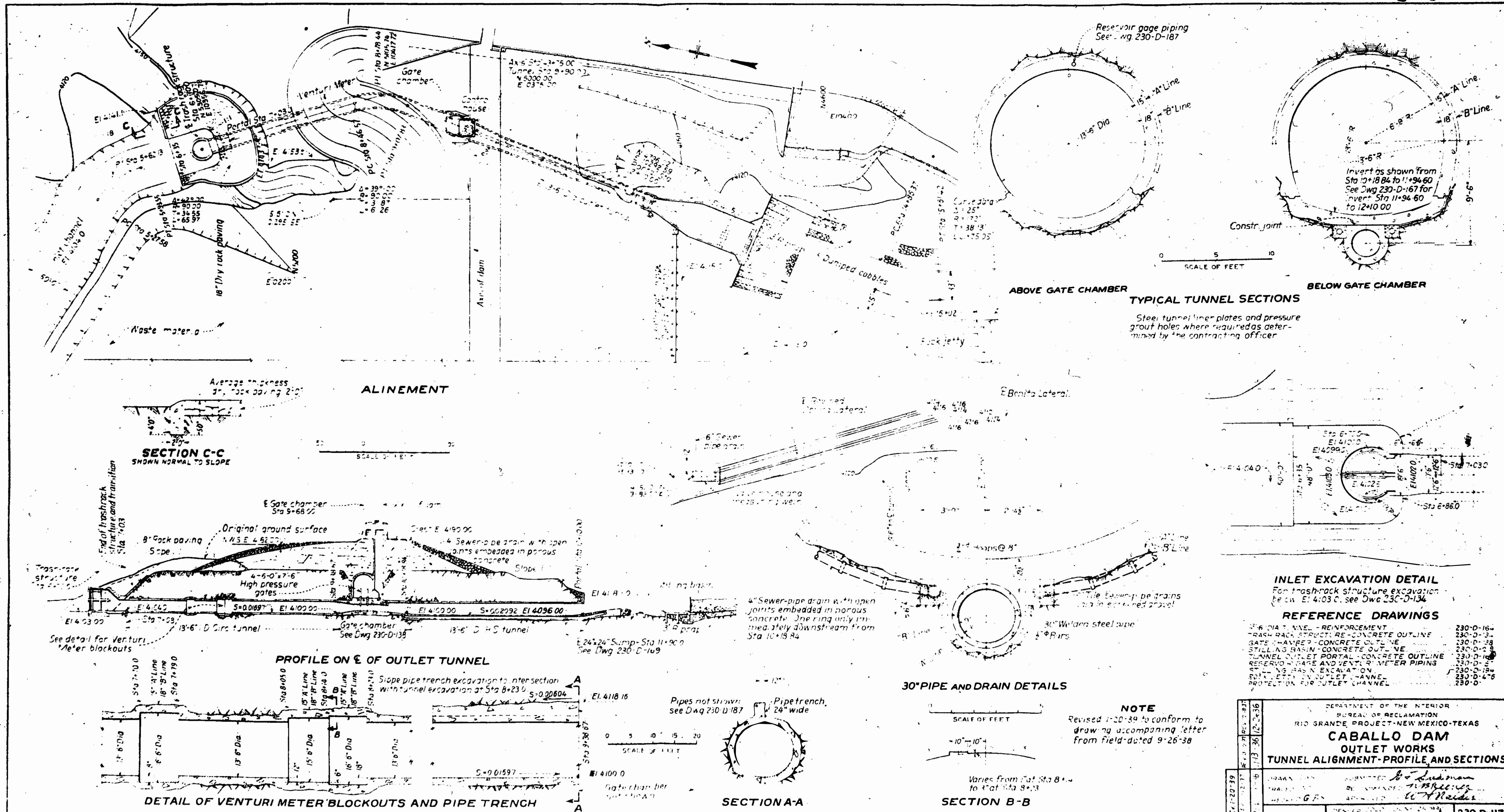
SECTION A-A
(ENLARGED)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
RECOMMENDED DESIGN

DRAWN	H W N	SUBMITTED	
TRACED	F A J - R L A	RECOMMENDED	
CHECKED		APPROVED	
	DENVER, COLORADO	JUNE 1939	230-D-546

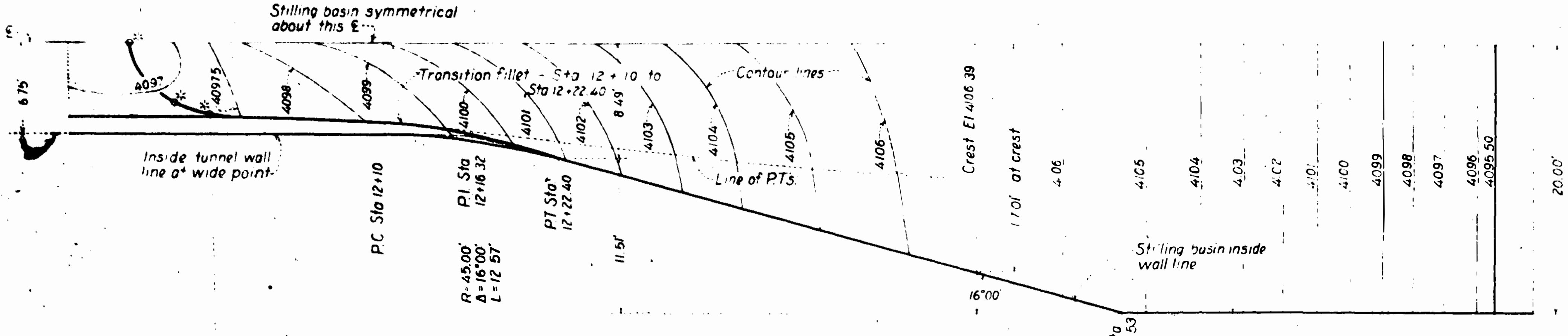
Figure 16


ALINEMENT
SECTION C-C
SHOWN NORMAL TO SLOPE
TYPICAL TUNNEL SECTIONS
ABOVE GATE CHAMBER
BELOW GATE CHAMBER
Steel tunnel liner plates and pressure grout holes where required as determined by the contracting officer
Invert as shown from Sta 10+18.84 to 11+94.60
See Dwg 230-D-167 for invert Sta 11+94.60 to 12+10.00
Constr. joint
SCALE OF FEET
Reservoir gage piping
See Dwg. 230-D-187
Gate chamber
Venturi Meter
Control house
Axis of dam
Waste material
18" Dry rack paving
Dumped cobbles
Rock jetty
Original ground surface
8" Rock paving
4-6'-0"x7'-6" High pressure gates
13'-6" D Circ. tunnel
13'-6" D H S tunnel
El 4100.00
El 4096.00
See detail for Venturi Meter blockouts
Gate chamber See Dwg 230-D-139
PROFILE ON ℄ OF OUTLET TUNNEL
4" Sewer-pipe drain with open joints embedded in porous concrete. One ring only immediately downstream from Sta 10+18.84
30" Welded steel pipe
30" PIPE AND DRAIN DETAILS
INLET EXCAVATION DETAIL
For trash-rack structure excavation below El 4103.0, see Dwg 230-D-134
REFERENCE DRAWINGS
Slope pipe trench excavation to intersection with tunnel excavation at Sta 8+23.0
Pipes not shown, see Dwg 230-D-187
Pipe trench, 24" wide
DETAIL OF VENTURI METER BLOCKOUTS AND PIPE TRENCH
SECTION A-A
SECTION B-B
NOTE
Revised 1-20-39 to conform to drawing accompanying letter from field dated 9-26-38
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT-NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
TUNNEL ALIGNMENT-PROFILE AND SECTIONS
230-D-117

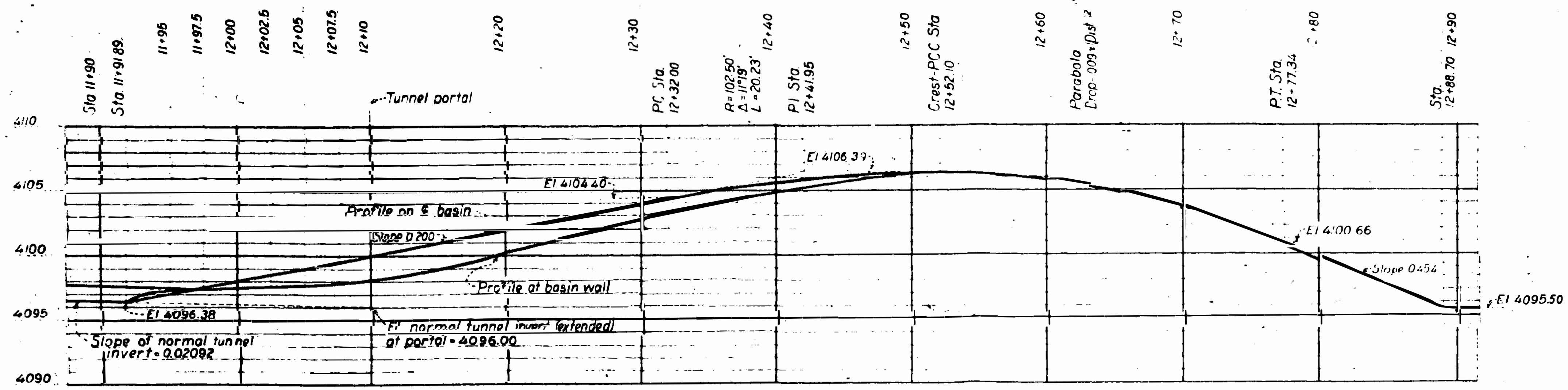
DIMENSION DATA - STILLING BASIN FLOOR

STATIONS 12+10 TO 12+52.10

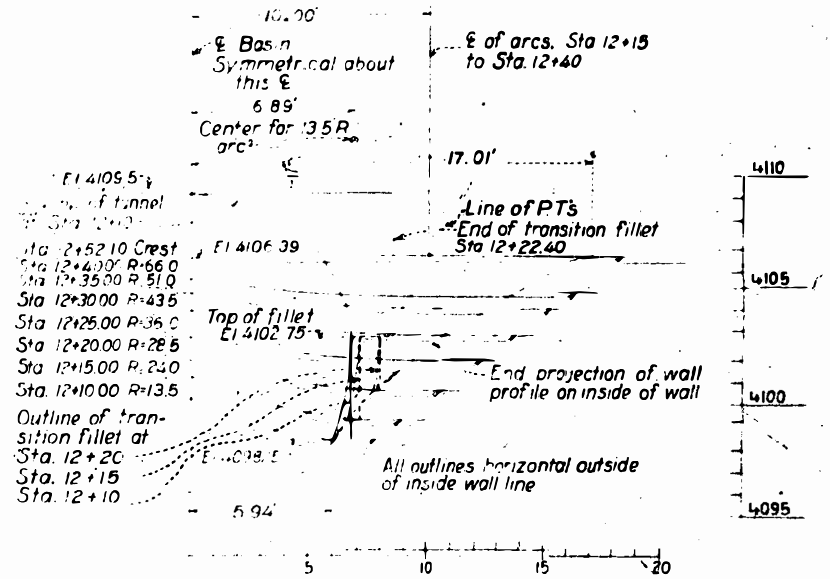
STATION	RADIUS OF ARC	LOCATION OF ARC CENTER		SURFACE ELEVATION AT ℄	LOCATION OF PT		SLOPE PT TO WALL LINE	LOCATION AT WALL LINE		REMARKS
		DISTANCE FROM ℄	ELEVATION		DISTANCE FROM ℄	ELEVATION		DISTANCE FROM ℄	ELEVATION	
12+10	13.5'	6.89	4111.61	4100.00	5.94'	4098.15	0.071	6.15'	4098.09	Figures at normal
12+15	24.0'	10.00'	4122.82	4101.00	6.40'	4099.09	0.152	7.03	4099.00	wall line, neglecting
12+20	28.5'	10.00'	4128.69	4102.00	7.02'	4100.35	0.105	7.88'	4100.25	transition fillet
12+25	36.0'	10.00'	4137.58	4103.00	7.68'	4101.65	0.065	9.24'	4101.55	Slab horizontal
12+30	43.5'	10.00'	4146.33	4104.00	8.27'	4102.86	0.040	10.68'	4102.75	from wall line
12+35	51.0'	10.00'	4154.96	4104.95	8.81'	4103.97	0.023	12.11'	4103.90	to edge
12+40	66.0'	10.00'	4170.91	4105.67	9.27'	4104.91	0.011	13.54'	4104.86	
12+52.10	Surface of floor level-El. 4106.39							17.01'	4106.39	



HALF PLAN

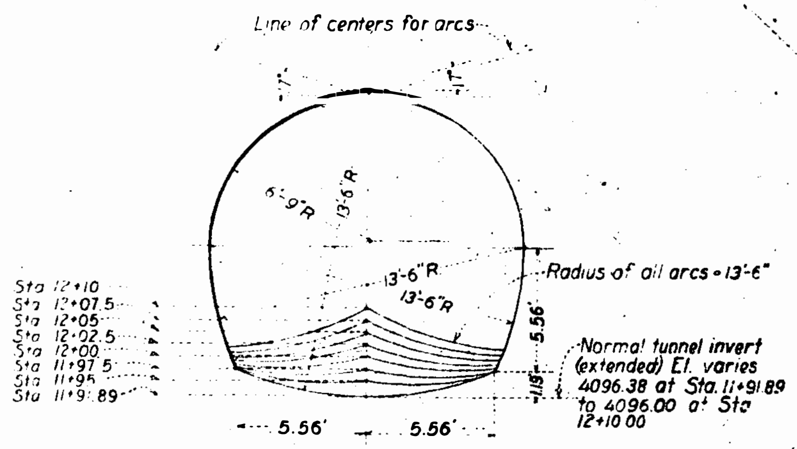


LONGITUDINAL PROFILE



TRANSVERSE PROFILES STILLING BASIN FLOOR

STATIONS 12+10 TO 12+52.10



TRANSVERSE PROFILES - TUNNEL INVERT

STATIONS 11+91.89 TO 12+10

DIMENSION DATA - TUNNEL INVERT

STATIONS 11+94.60 TO 12+10

STATION	RADIUS OF ARC	LOCATION OF ARC CENTER		SURFACE ELEVATION AT ℄	INTERSECTION OF ARC WITH SIDE WALL	
		DISTANCE FROM ℄	ELEVATION		DISTANCE FROM ℄	ELEVATION
11+91.89	13.5	0	4109.88	4096.38	0	4096.38*
11+95	13.5'	1.84'	4110.37	4097.00	4.84'	4097.21*
11+97.5	13.5'	2.98'	4110.67	4097.50	5.40'	4097.39*
12+00	13.5'	3.94'	4110.91	4098.00	5.60'	4097.51
12+02.5	13.5'	4.79'	4111.12	4098.50	5.68'	4097.65
12+05	13.5'	5.56'	4111.30	4099.00	5.77'	4097.80
12+07.5	13.5'	6.25'	4111.46	4099.50	5.86'	4097.97
12+10	13.5'	6.89'	4111.61	4100.00	5.94'	4098.15

* Intersection with normal tunnel invert

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT-NEW MEXICO-TEXAS

CABALLO DAM
OUTLET WORKS
TUNNEL PORTAL AND STILLING BASIN INVERT AND FLOOR SURFACE OUTLINE

DRAWN L.B. SUBMITTED S.E. Rockwell
TRACED J.L. RECOMMENDED J.H. Keener
CHECKED G.E.S. APPROVED W.H. Nalder

DENVER, COLO. NOV 13, 1936. 230-D-167

Figure 18

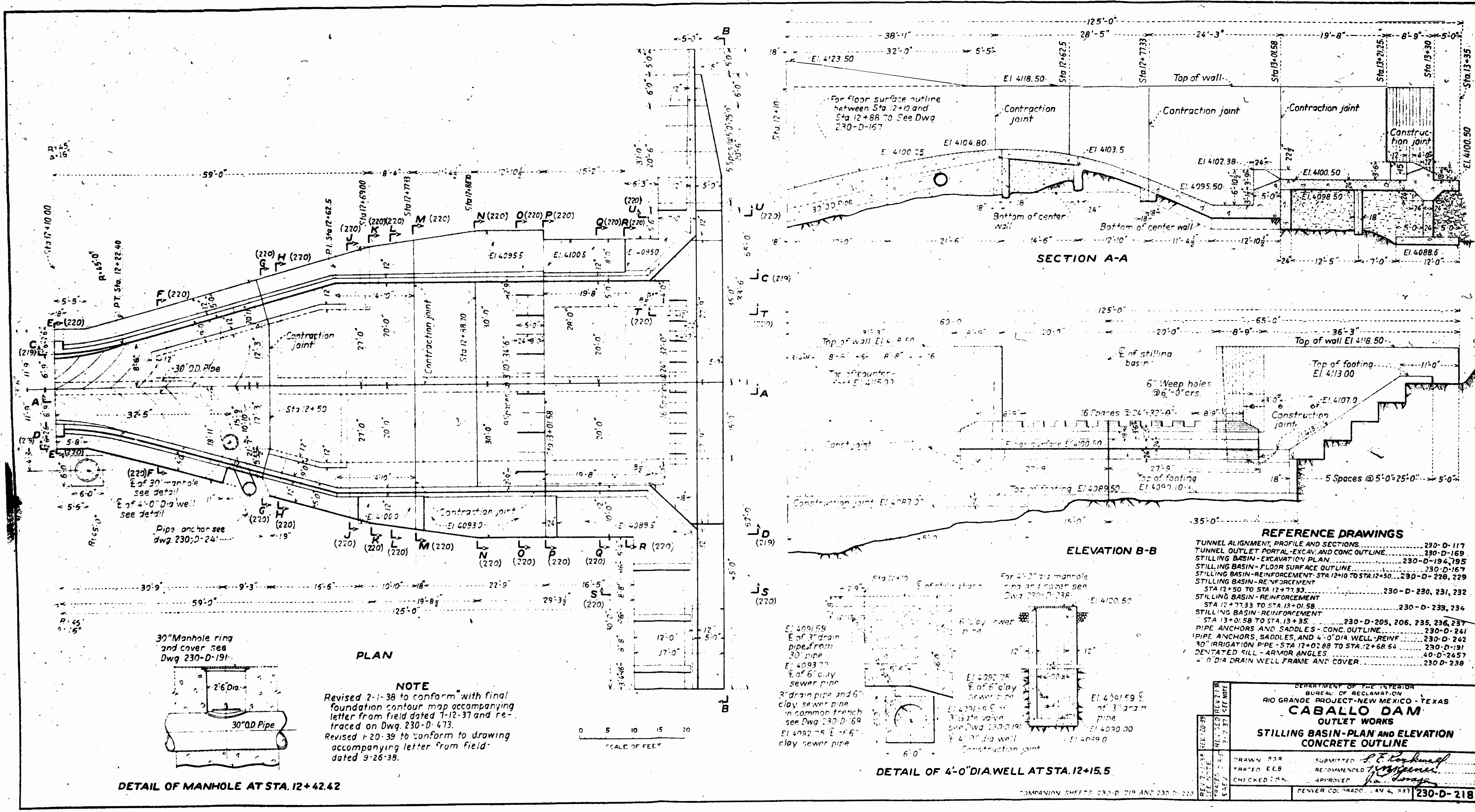
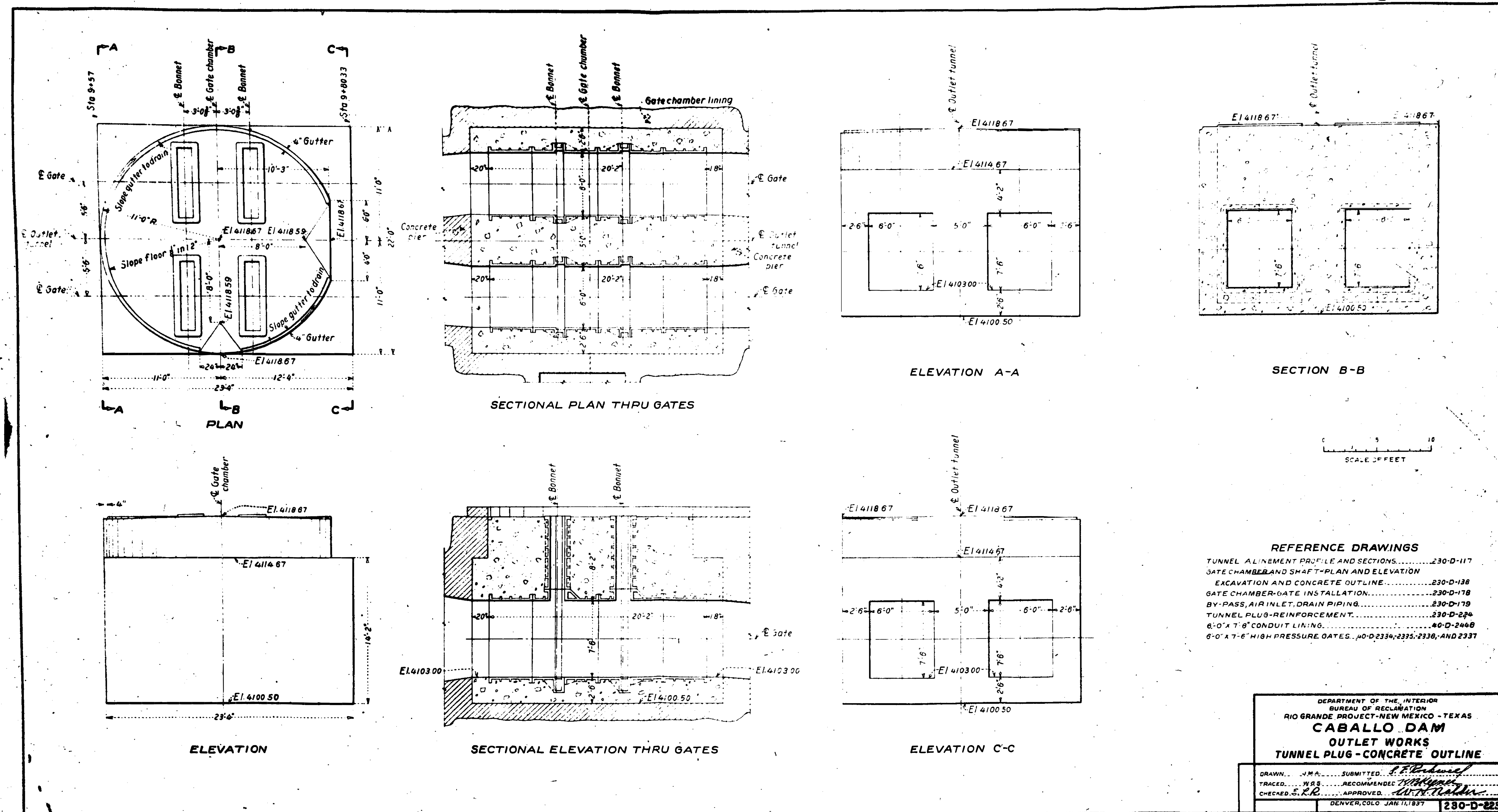
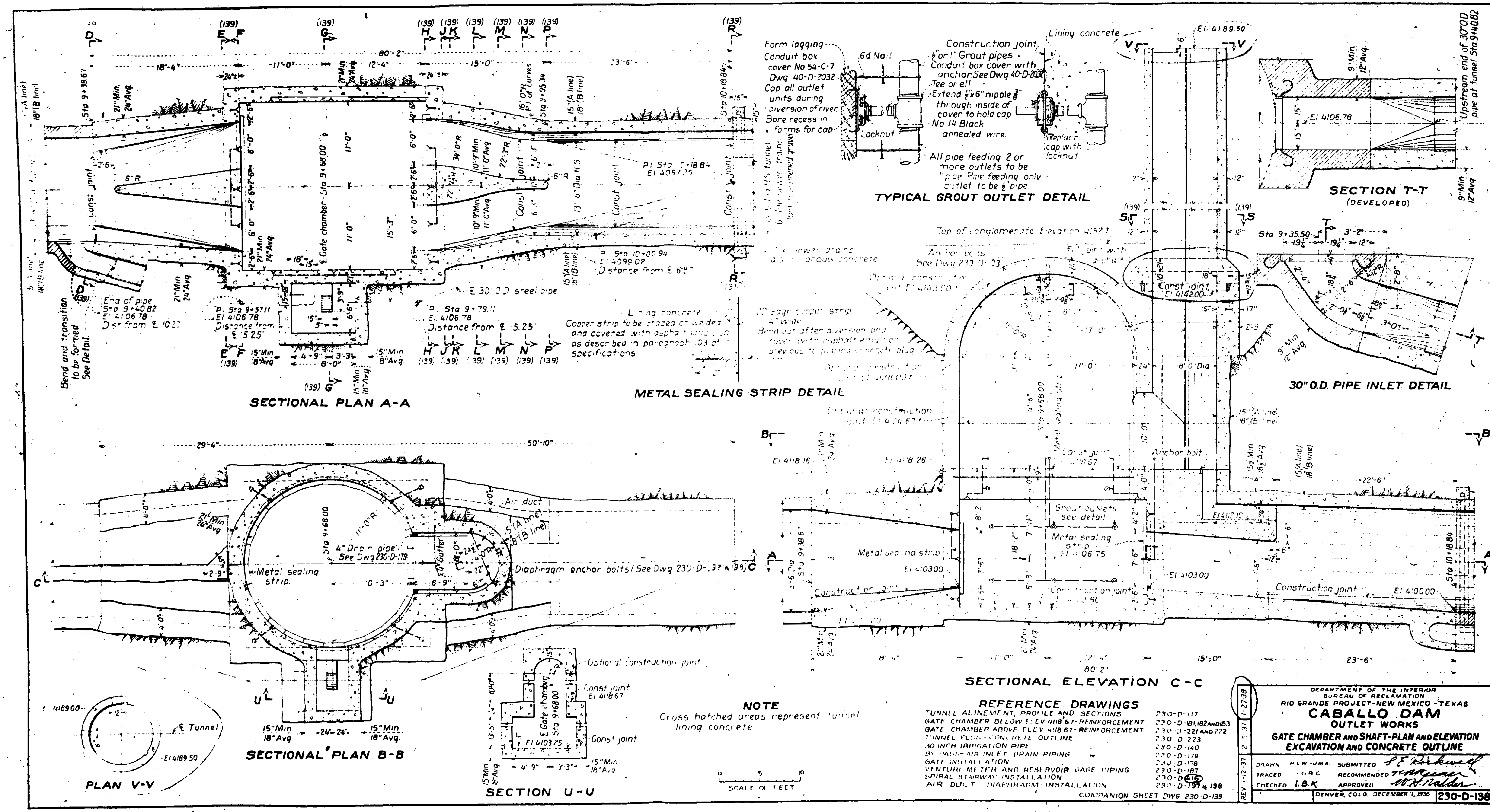

PLAN
SECTION A-A
ELEVATION B-B
DETAIL OF MANHOLE AT STA. 12+42.42
DETAIL OF 4'-0" DIA. WELL AT STA. 12+15.5
30" Manhole ring and cover see Dwg 230-D-191
30" O.D. Pipe
Pipe anchor see dwg. 230-D-241
Contraction joint
Construction joint
Top of wall
Bottom of center wall
6" Weep holes @ 6'-0" crs.
NOTE
Revised 2-1-38 to conform with final foundation contour map accompanying letter from field dated 1-12-37 and re-traced on Dwg. 230-D-473.
Revised 1-20-39 to conform to drawing accompanying letter from field dated 9-26-38.
SCALE OF FEET
REFERENCE DRAWINGS
TUNNEL ALIGNMENT, PROFILE AND SECTIONS 230-D-117
TUNNEL OUTLET PORTAL-EXCAV. AND CONC. OUTLINE 230-D-169
STILLING BASIN-EXCAVATION PLAN 230-D-194, 195
STILLING BASIN-FLOOR SURFACE OUTLINE 230-D-167
STILLING BASIN-REINFORCEMENT-STA 12+10 TO STA 12+50 230-D-228, 229
STILLING BASIN-REINFORCEMENT STA 12+50 TO STA 12+77.33 230-D-230, 231, 232
STILLING BASIN-REINFORCEMENT STA 12+77.33 TO STA 13+01.58 230-D-233, 234
STILLING BASIN-REINFORCEMENT STA 13+01.58 TO STA 13+35 230-D-205, 206, 235, 236, 237
PIPE ANCHORS AND SADDLES-CONC. OUTLINE 230-D-241
PIPE ANCHORS, SADDLES, AND 4'-0" DIA. WELL-REINF. 230-D-242
30" IRRIGATION PIPE-STA 12+02.88 TO STA 12+68.64 230-D-191
DENTATED SILL-ARMOR ANGLES 40-D-2457
4'-0" DIA DRAIN WELL FRAME AND COVER 230-D-238
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT-NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
STILLING BASIN-PLAN AND ELEVATION
CONCRETE OUTLINE
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLORADO
230-D-218

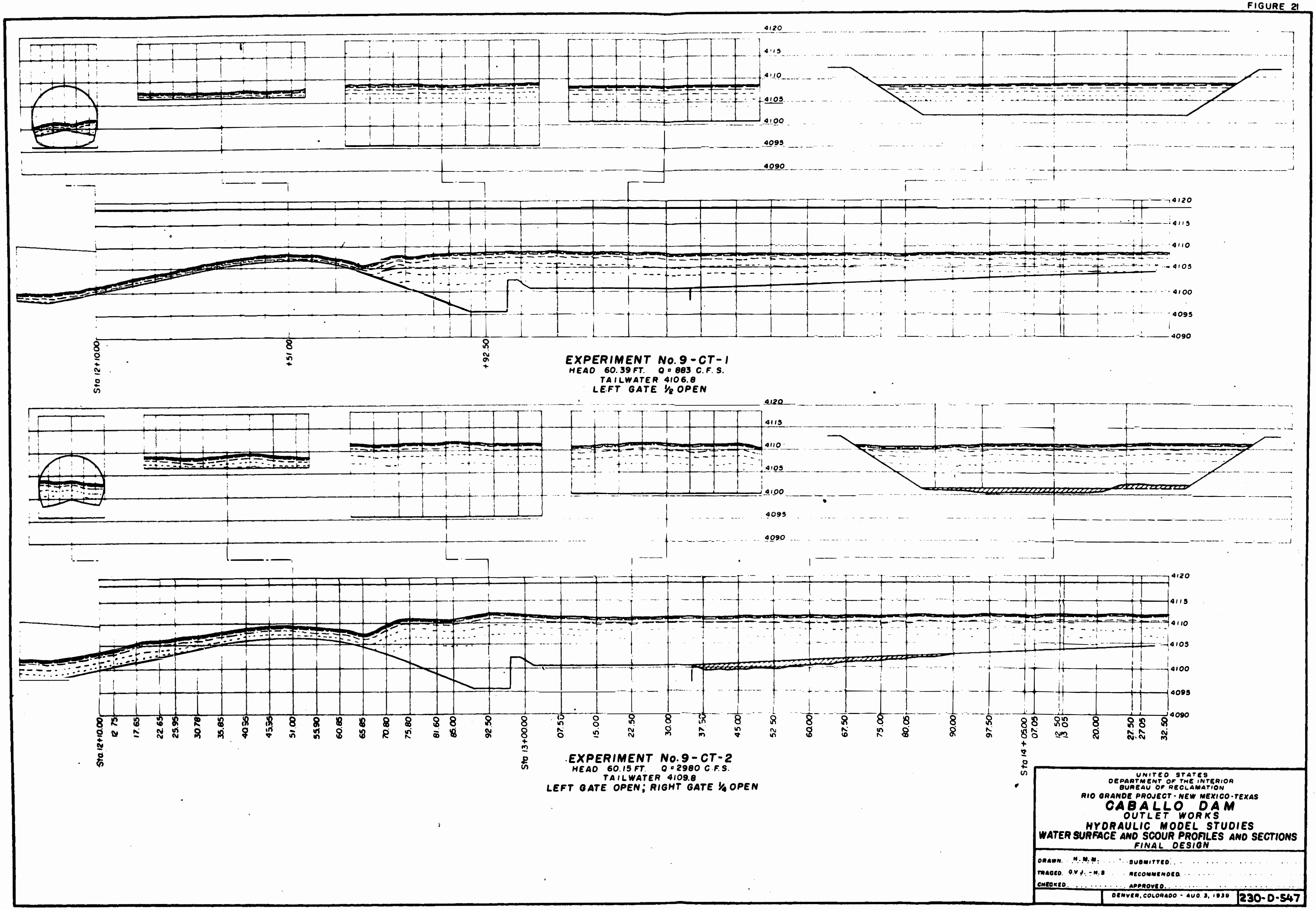
Figure 19



Job No. 11

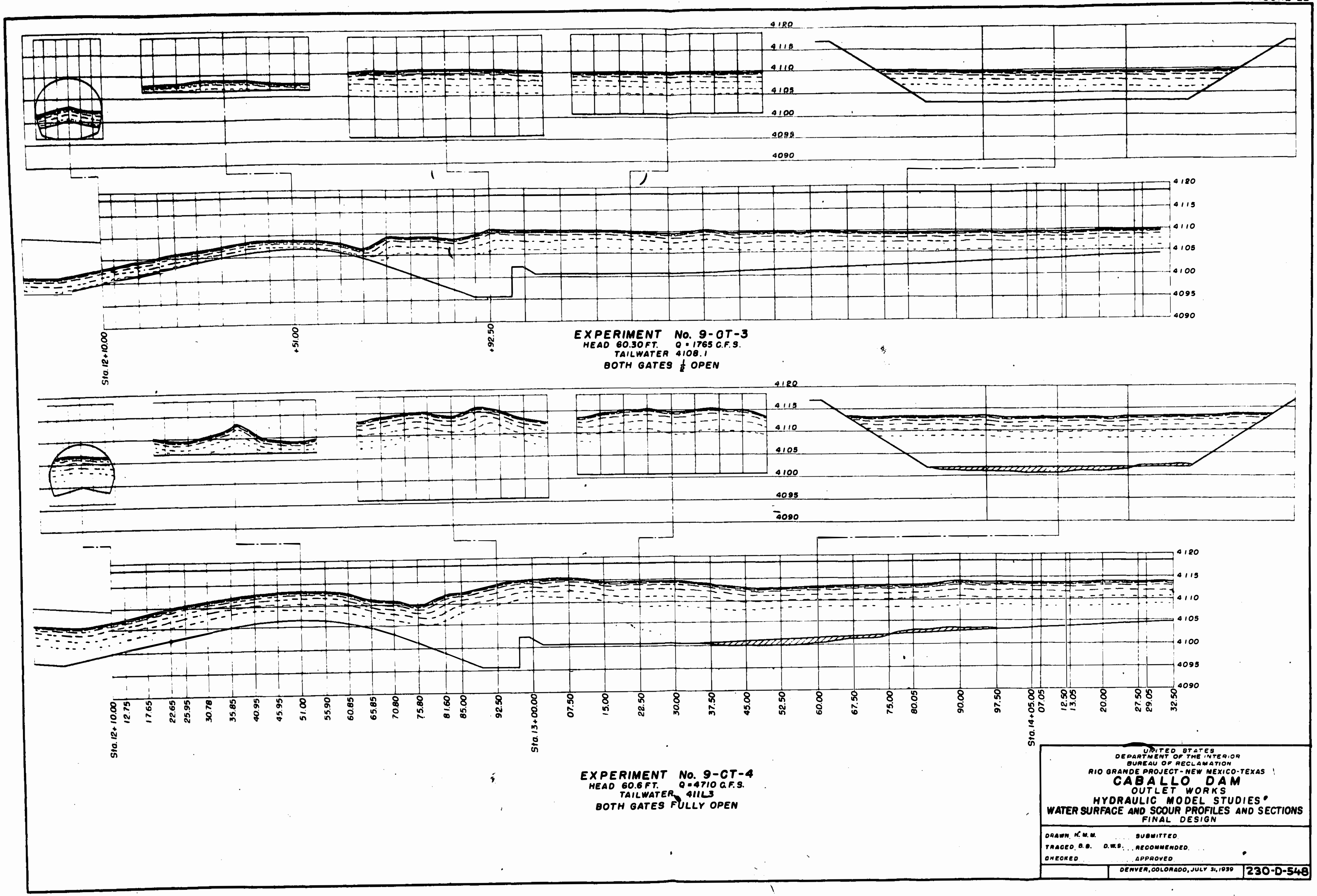


SECTIONAL PLAN A-A
METAL SEALING STRIP DETAIL
TYPICAL GROUT OUTLET DETAIL
SECTION T-T (DEVELOPED)
30" O.D. PIPE INLET DETAIL
SECTIONAL PLAN B-B
SECTION U-U
PLAN V-V
SECTIONAL ELEVATION C-C
Form lagging
Conduit box cover No 54-C-7 Dwg 40-D-2032
Cap all outlet units during diversion of river
Bore recess in forms for cap
6d Nail
Locknut
Construction joint
¾" or 1" Grout pipes
Conduit box cover with anchor See Dwg 40-D-2032
Tee or ell
No 14 Black annealed wire
Replace cap with locknut
All pipe feeding 2 or more outlets to be 1" pipe. Pipe feeding only 1 outlet to be ¾" pipe
Lining concrete
Copper strip to be brazed or welded and covered with asphalt emulsion as described in paragraph 103 of specifications
Upstream end of 30" O.D. pipe at tunnel Sta 9+40.82
Bend and transition to be formed See Detail
End of pipe Sta 9+40.82 El 4106.78 Dist from ℄ 10.27
Gate chamber Sta 9+68.00
℄ 30" O.D. steel pipe
Air duct
4" Drain pipe See Dwg 230-D-179
Metal sealing strip
Diaphragm anchor bolts (See Dwg 230-D-197 & 198)
Optional construction joint
Const joint El 4186.7
Grout outlets see detail
Metal sealing strip El 4106.75
Construction joint
Anchor bolt
Top of conglomerate Elevation 4152±
El 4189.50
El 4142.00
El 4103.00
El 4100.00
SCALE OF FEET
NOTE
Cross hatched areas represent tunnel lining concrete
REFERENCE DRAWINGS
TUNNEL ALINEMENT, PROFILE AND SECTIONS 230-D-117
GATE CHAMBER BELOW EL EV 4118.67 - REINFORCEMENT 230-D-181,182 AND 183
GATE CHAMBER ABOVE ELEV 4118.67 - REINFORCEMENT 230-D-221 AND 222
TUNNEL PLUG - CONCRETE OUTLINE 230-D-223
30 INCH IRRIGATION PIPE 230-D-140
BY PASS - AIR INLET - DRAIN PIPING 230-D-179
GATE INSTALLATION 230-D-178
VENTURI METER AND RESERVOIR GAGE PIPING 230-D-187
SPIRAL STAIRWAY INSTALLATION 230-D-216
AIR DUCT DIAPHRAGM INSTALLATION 230-D-197 & 198
COMPANION SHEET DWG 230-D-139
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
OUTLET WORKS
GATE CHAMBER AND SHAFT - PLAN AND ELEVATION
EXCAVATION AND CONCRETE OUTLINE
DRAWN H.L.W. - J.M.A. SUBMITTED
TRACED G.R.C. RECOMMENDED
CHECKED I.B.K. APPROVED
DENVER, COLO. DECEMBER 1, 1936
230-D-138

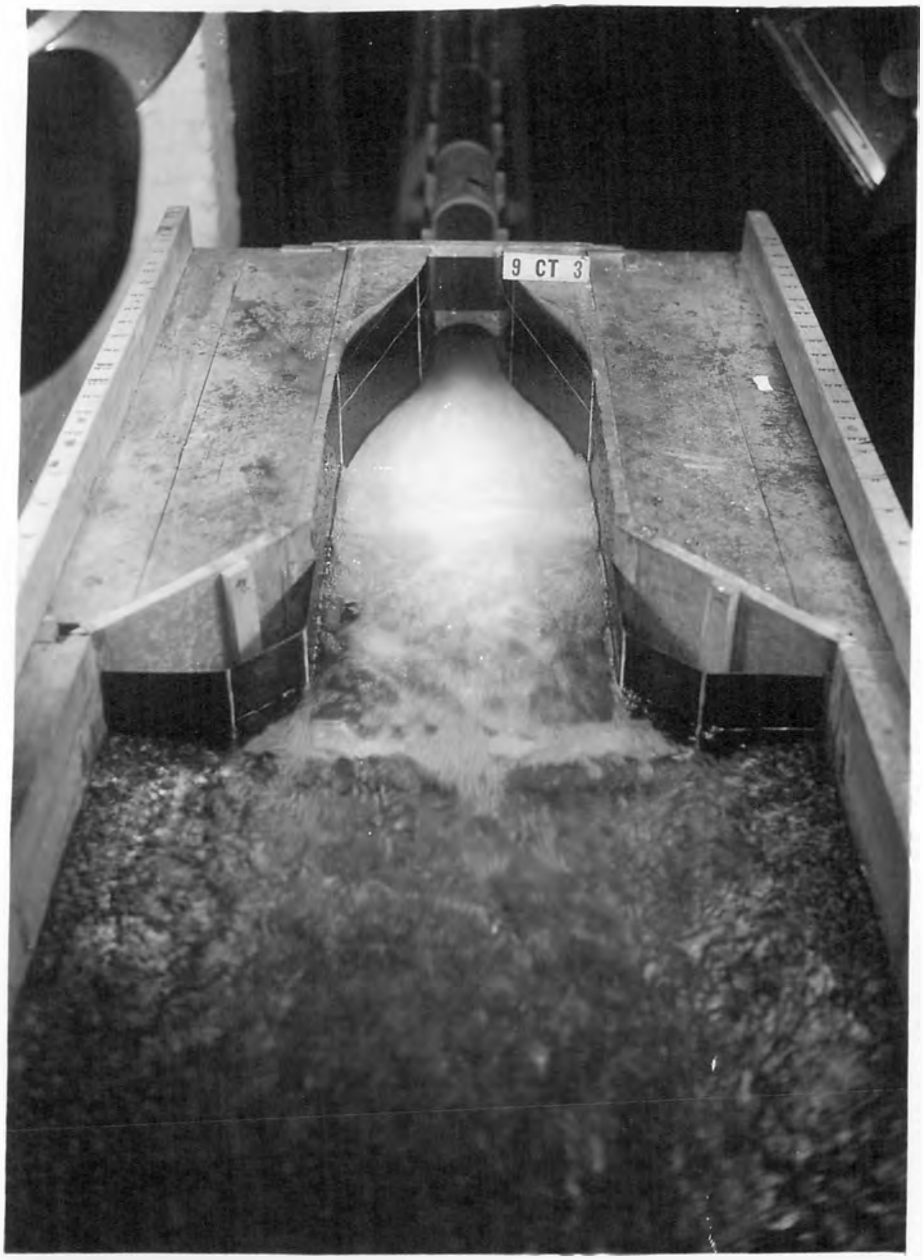


4120
4115
4110
4105
4100
4095
4090
Sta 12+10.00
+51.00
+92.50
EXPERIMENT No. 9-CT-1
HEAD 60.39 FT. Q = 883 C.F.S.
TAILWATER 4106.8
LEFT GATE ½ OPEN
Sta 12+10.00
12.75
17.65
22.65
25.95
30.78
35.85
40.55
45.36
51.00
55.90
60.85
65.85
70.80
75.80
81.60
85.00
92.50
Sta 13+00.00
07.50
15.00
22.50
30.00
37.50
45.00
52.50
60.00
67.50
75.00
80.05
90.00
97.50
Sta 14+05.00
07.05
12.50
13.05
20.00
27.50
27.05
32.50
EXPERIMENT No. 9-CT-2
HEAD 60.15 FT. Q = 2980 C.F.S.
TAILWATER 4109.8
LEFT GATE OPEN; RIGHT GATE ¼ OPEN
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
WATER SURFACE AND SCOUR PROFILES AND SECTIONS
FINAL DESIGN
DRAWN. H.N.M.
SUBMITTED
TRACED. O.V.J. - H.S
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO - AUG. 3, 1939
230-D-547

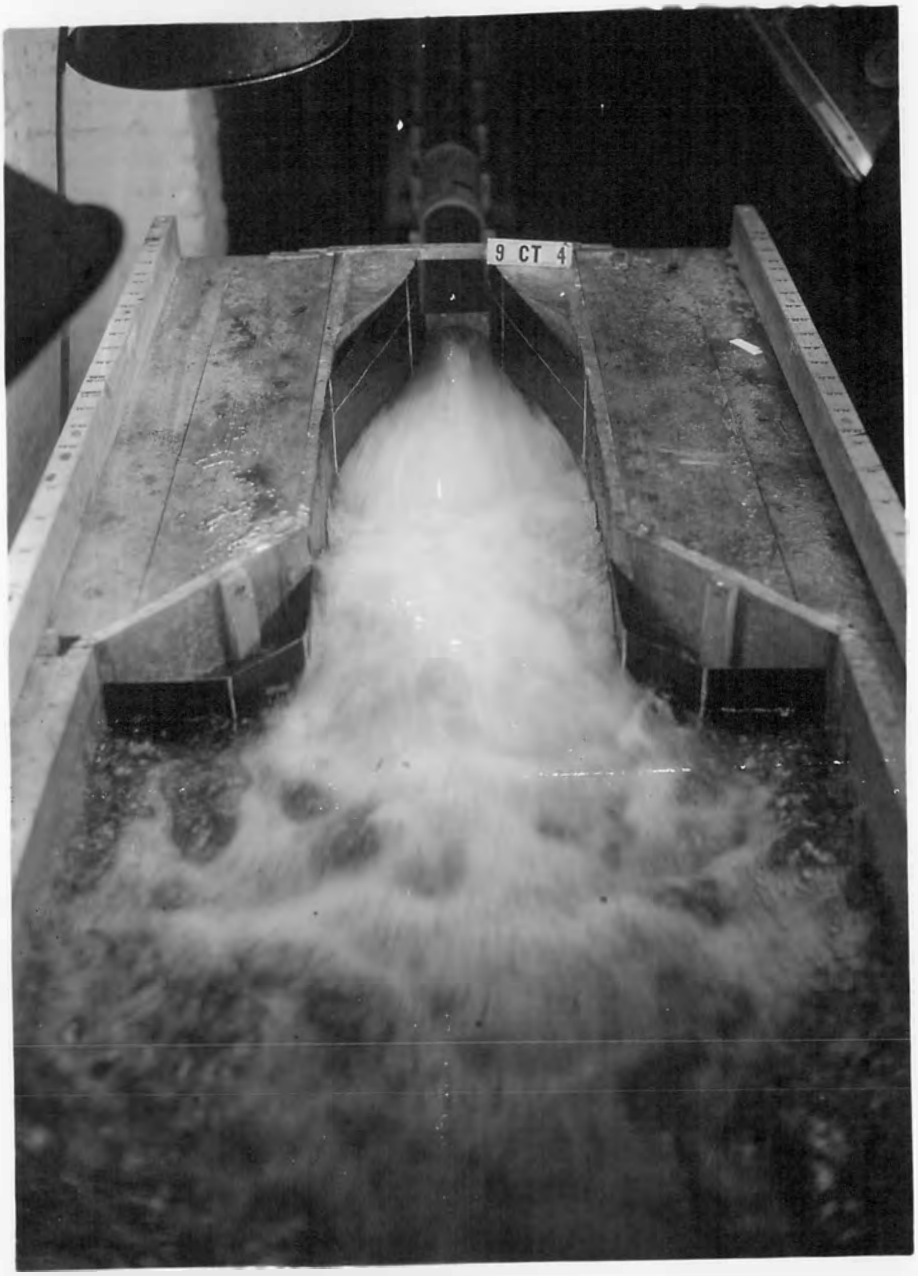
FIGURE 22



4120
4115
4110
4105
4100
4095
4090
Sta. 12+10.00
+51.00
+92.50
EXPERIMENT No. 9-CT-3
HEAD 60.30 FT. Q = 1765 C.F.S.
TAILWATER 4108.1
BOTH GATES ½ OPEN
Sta. 12+10.00
12.75
17.65
22.65
25.95
30.78
35.85
40.95
45.95
51.00
55.90
60.85
65.85
70.80
75.80
81.60
85.00
92.50
Sta. 13+00.00
07.50
15.00
22.50
30.00
37.50
45.00
52.50
60.00
67.50
75.00
80.05
90.00
97.50
Sta. 14+05.00
07.05
12.50
13.05
20.00
27.50
29.05
32.50
EXPERIMENT No. 9-CT-4
HEAD 60.6 FT. Q = 4710 C.F.S.
TAILWATER 4111.3
BOTH GATES FULLY OPEN
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS
CABALLO DAM
OUTLET WORKS
HYDRAULIC MODEL STUDIES
WATER SURFACE AND SCOUR PROFILES AND SECTIONS
FINAL DESIGN
DRAWN K.M.M.
SUBMITTED
TRACED B.B. D.W.S.
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO, JULY 31, 1939
230-D-548



RECOMMENDED DESIGN
DISCHARGE 1765 SECOND-FEET



RECOMMENDED DESIGN
DISCHARGE 4710 SECOND-FEET

The head discharge curves shown in Figure 27 were plotted from the model data on the assumption that,

$$Q \text{ prototype} = n^{5/2} \, Q \text{ model}$$

n being the scale ratio and Q the discharge. The assumption is an approximate one, but sufficient experimental data to provide a more accurate estimate of the true relations between models and prototype are lacking. Also shown in Figure 27 are the variations of the coefficient, C, in $Q = Clh^{3/2}$, with the head on the crest; and the variation of the dimensionless coefficient, C, in $Q = Clh\sqrt{2gh}$, with Froude's number $F = \frac{v^2}{gR}$, in which v has been treated as a nominal velocity equal to $\sqrt{2gh}$ and R is a nominal hydraulic radius equal to $\frac{hb}{2h+b}$, or $\frac{hb}{4h+b}$ with the pier in place. The dimensionless Froude's number curves are added primarily for their value in comparison with tests of other structures.

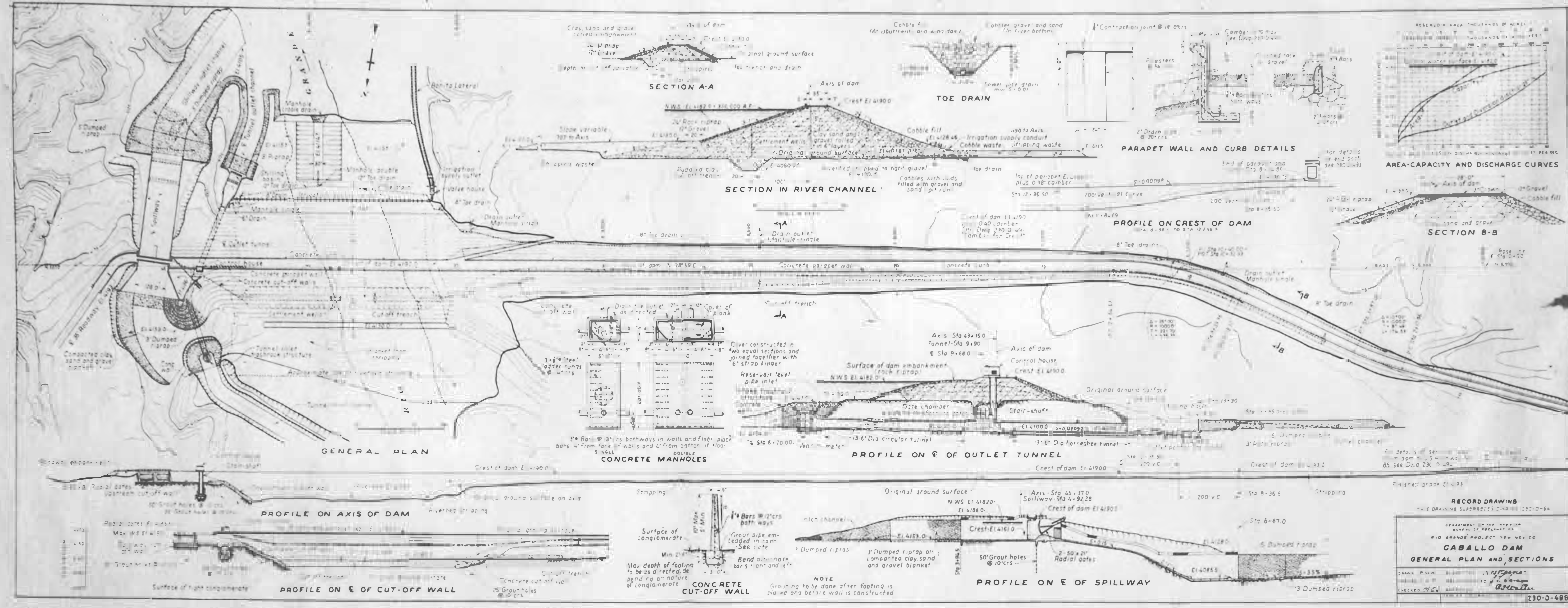
When the approach conditions were modified by introducing a sloping floor as shown in Figure 28-E, the head on the crest required to produce the specified discharge of 34,000 second-feet was found to be 5 percent greater than the designed head. At the designed head the discharge was reduced 7 percent. A gradual flat slope substituted for the curbed drop of the crest (Figure 28b) also decreased the discharge for maximum designed pond elevation.

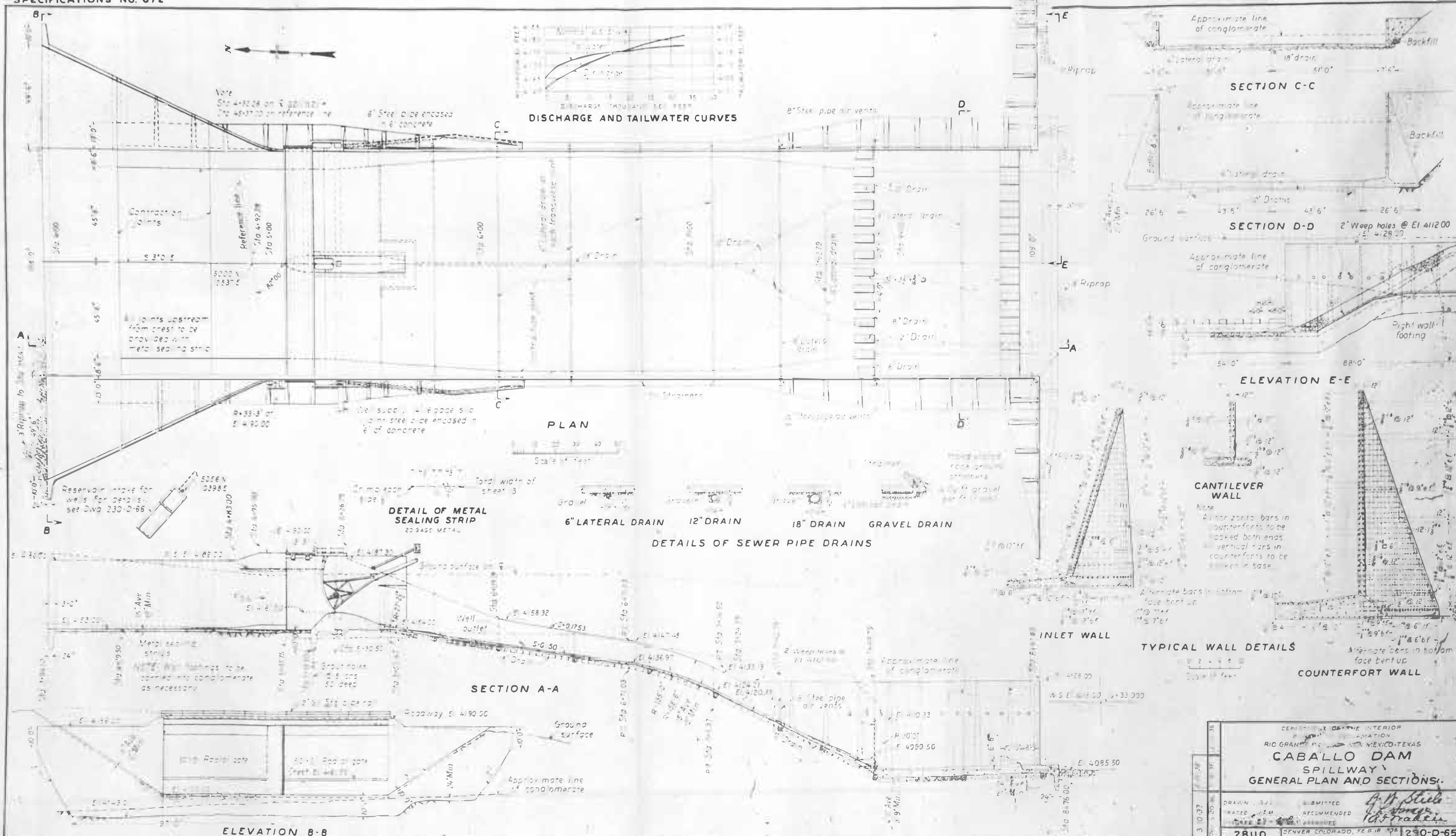
Pressure heads observed at uniform intervals along the crest are plotted in Figure 29. All pressures for the low-dam crest are positive. A comparison of pressure heads and surface profiles may be made from the data shown on Figure 28.

Flow in the chute was rough (Plate X). Attempts to reduce this roughness were unsuccessful. However, the introduction of a dentated step ~~and~~ a sill into the pool eliminated all detrimental effects from this source.

Since one pool was to be used for both Plans Nos. 1 and 2, and the crest of Plan No. 2 was 30 feet higher than that of Plans No. 1, the higher crest and higher velocities of Plan No. 2 determined the design of the pool. Hence the pool shown for test 13-CA-2 (Figure 30 and Plate XIa and b) applies to the low-dam plan. The low crest was used for Test 13-CA-6 (Plate XIc and d). Because of the reduction in the amount of energy to be dissipated, the less efficient, drowned roller was formed, and the scour below the pool increased. For normal tailwater, however, (elevation 4118) the scour was not excessive.

Figure 23


SECTION A-A
TOE DRAIN
PARAPET WALL AND CURB DETAILS
AREA-CAPACITY AND DISCHARGE CURVES
SECTION IN RIVER CHANNEL
PROFILE ON CREST OF DAM
SECTION B-B
GENERAL PLAN
CONCRETE MANHOLES
PROFILE ON ℄ OF OUTLET TUNNEL
PROFILE ON AXIS OF DAM
PROFILE ON ℄ OF CUT-OFF WALL
CONCRETE CUT-OFF WALL
PROFILE ON ℄ OF SPILLWAY
RECORD DRAWING
CABALLO DAM
GENERAL PLAN AND SECTIONS


DISCHARGE AND TAILWATER CURVES
PLAN
DETAIL OF METAL SEALING STRIP
6" LATERAL DRAIN
12" DRAIN
18" DRAIN
GRAVEL DRAIN
DETAILS OF SEWER PIPE DRAINS
SECTION A-A
ELEVATION B-B
SECTION C-C
SECTION D-D
ELEVATION E-E
CANTILEVER WALL
INLET WALL
TYPICAL WALL DETAILS
COUNTERFORT WALL
Riprap
Backfill
Approximate line of conglomerate
Roadway El. 4190.00
Ground surface
CABALLO DAM
SPILLWAY
GENERAL PLAN AND SECTIONS
28110
DENVER, COLORADO
230-D-65

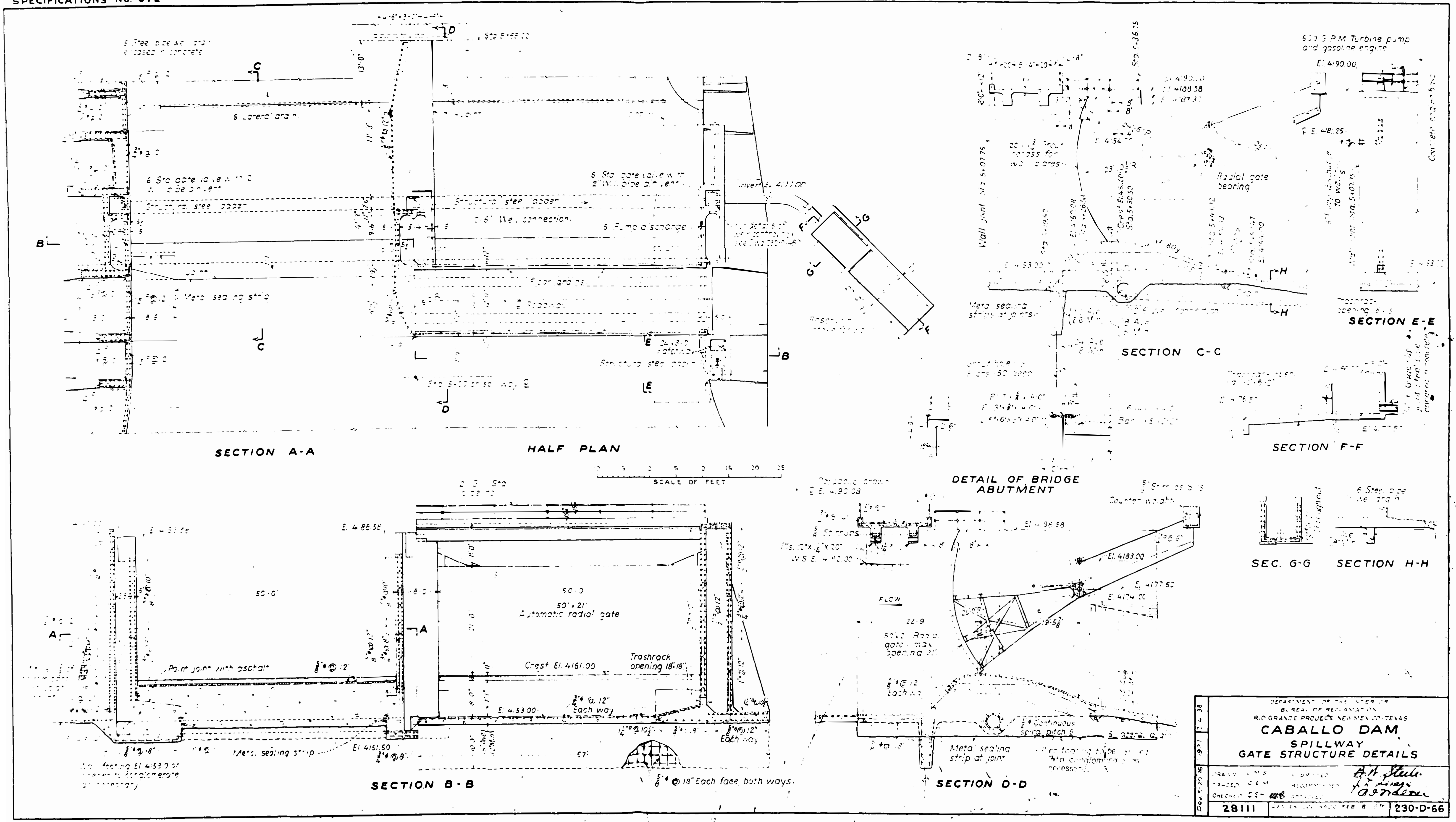
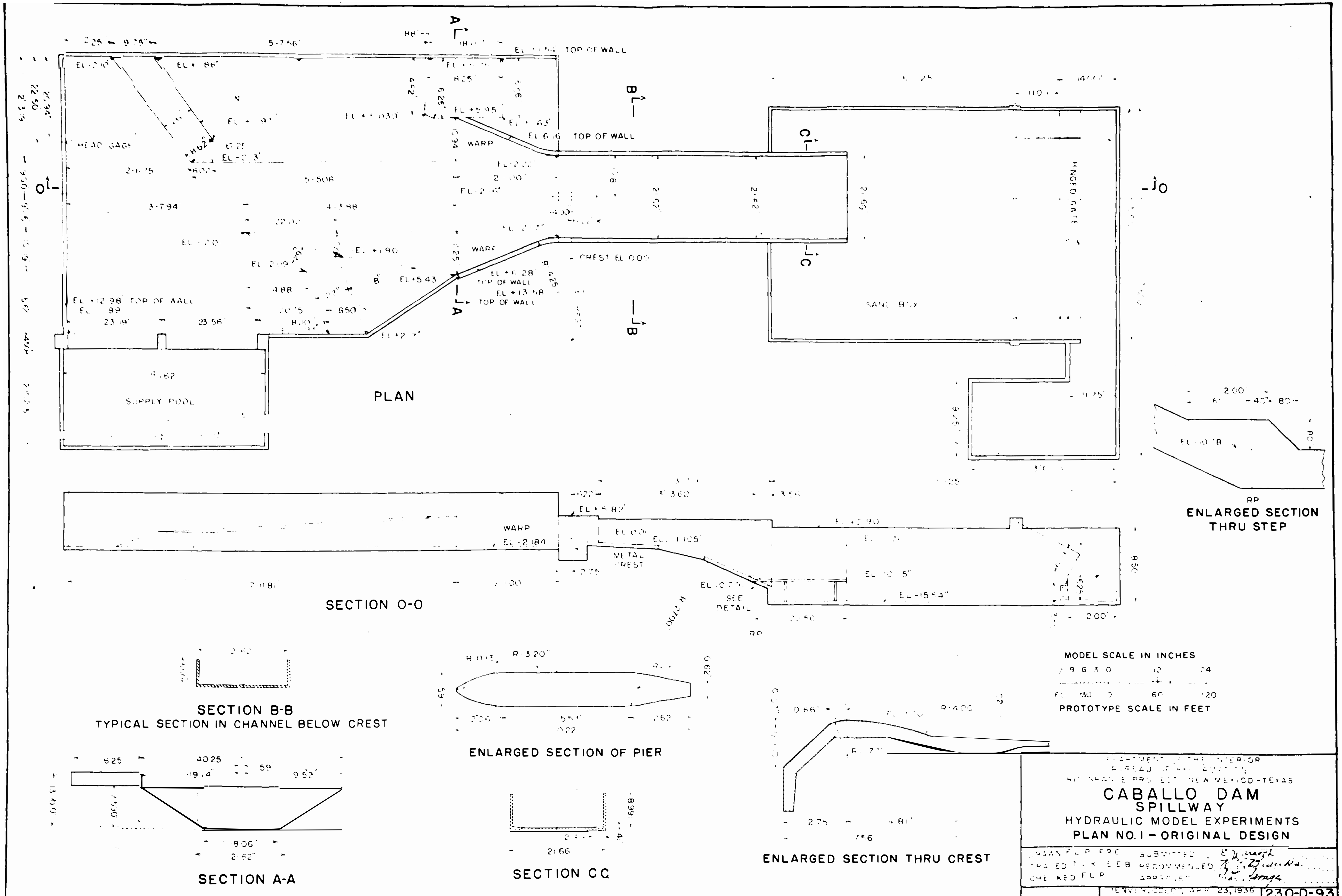
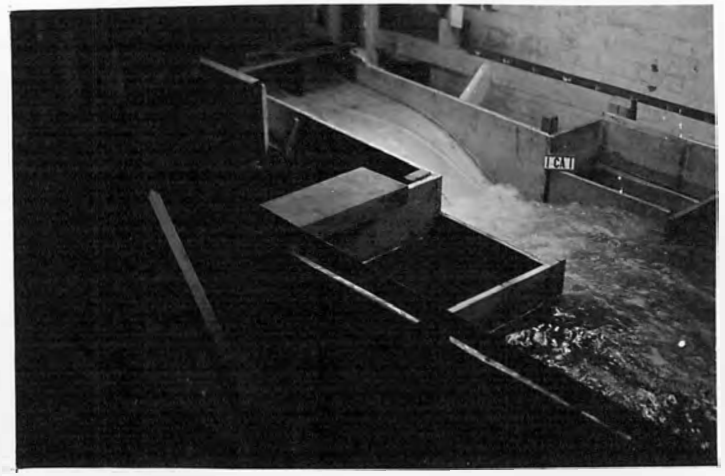

SECTION A-A
HALF PLAN
SCALE OF FEET
SECTION B-B
50'×21' Automatic radial gate
Crest El. 4161.00
Trashrack opening 18"×18"
Paint joint with asphalt
Metal sealing strip
$\frac{5}{8}$"ϕ @ 18" Each face, both ways.
SECTION C-C
Radial gate bearing
SECTION E-E
SECTION F-F
DETAIL OF BRIDGE ABUTMENT
SECTION D-D
FLOW
50'×21' Radial gate max. opening 21'
Metal sealing strip at joint
Counterweight
SEC. G-G
SECTION H-H
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT NEW MEXICO-TEXAS
CABALLO DAM
SPILLWAY
GATE STRUCTURE DETAILS
28111
230-D-66

Figure 26

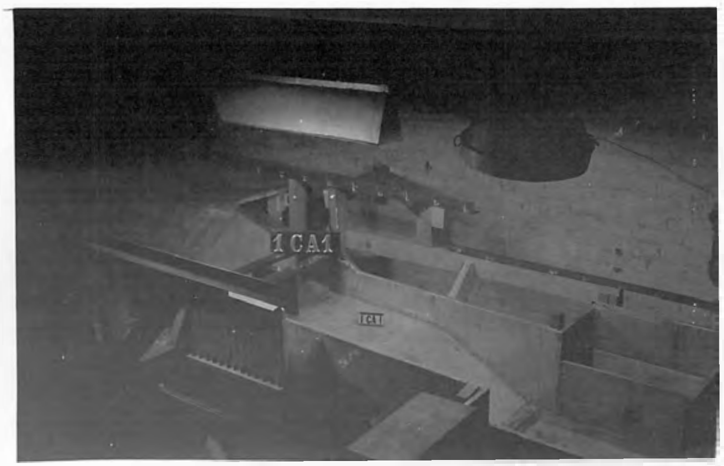

PLAN
HEAD GAGE
SUPPLY POOL
WARP
TOP OF WALL
CREST EL 0.00
SAND BOX
HINGED GATE
SECTION O-O
METAL CREST
SEE DETAIL
ENLARGED SECTION THRU STEP
SECTION B-B
TYPICAL SECTION IN CHANNEL BELOW CREST
ENLARGED SECTION OF PIER
SECTION A-A
SECTION CC
ENLARGED SECTION THRU CREST
MODEL SCALE IN INCHES
PROTOTYPE SCALE IN FEET
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
PLAN NO. 1 – ORIGINAL DESIGN
230-D-93

A. Discharge 34,000 c.f.s.



C. Discharge 34,000 c.f.s.

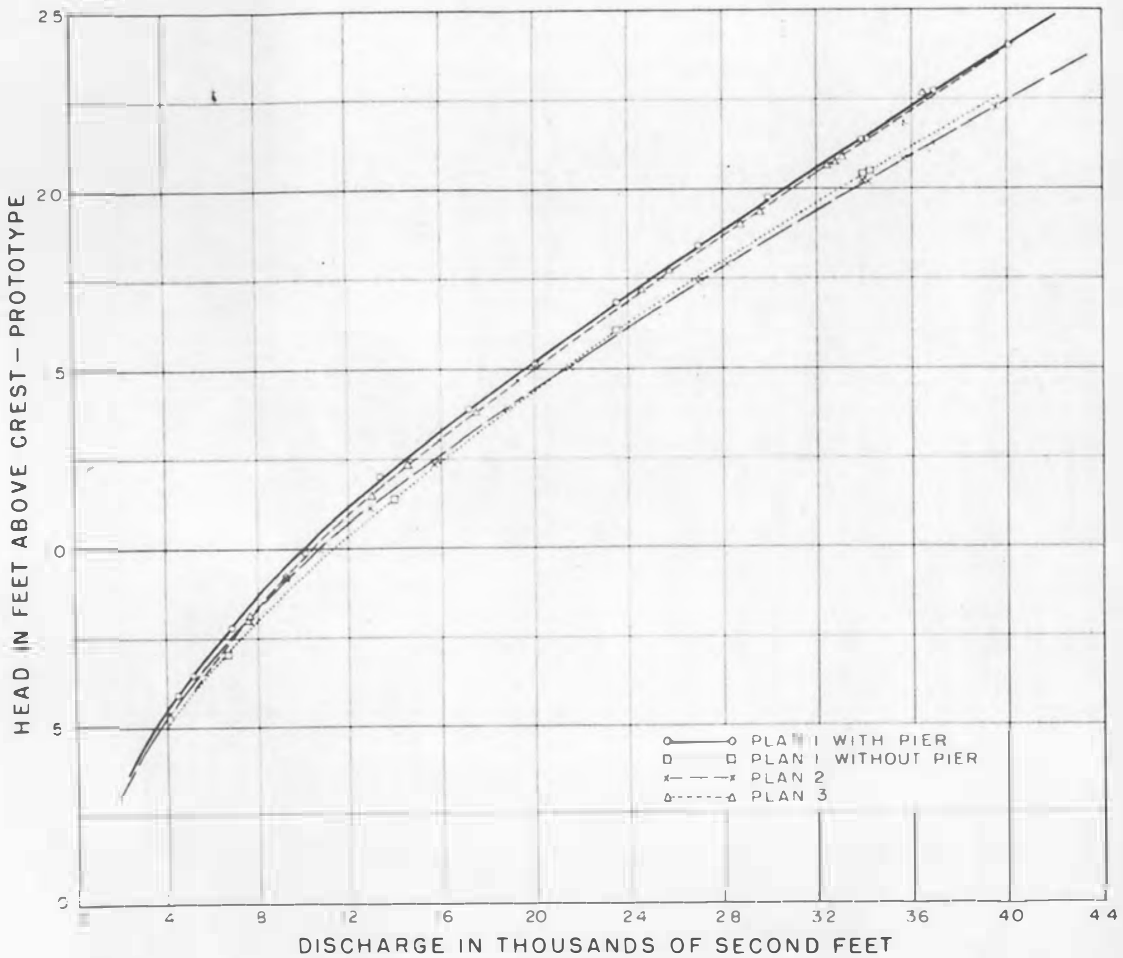
B. Crest Showing Piezometers.

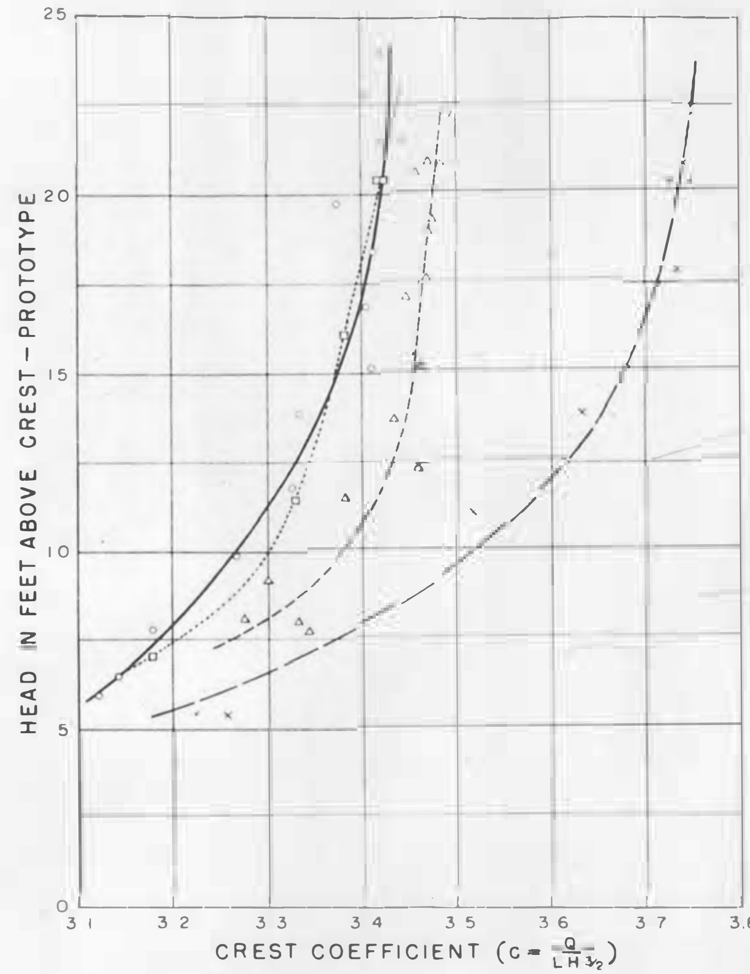


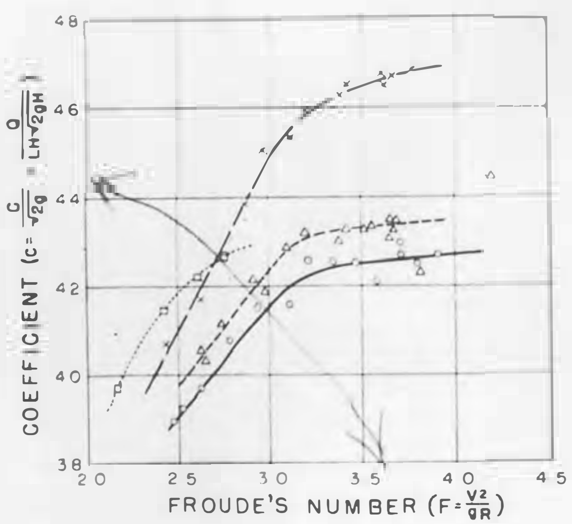
D. Original Spillway.

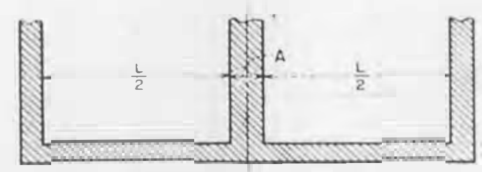
MODEL DESIGN - PLAN No. 1

PLATE X

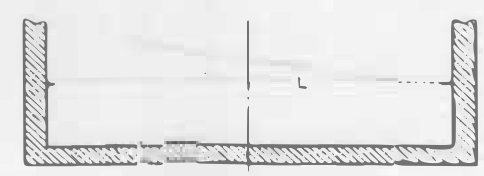








CROSS-SECTION AT CREST FOR ALL PLANS WITH PIER



CROSS-SECTION AT CREST FOR PLAN I WITHOUT PIER

PLAN	MODEL (INCHES)		PROTOTYPE (FEET)	
	L	A	L	A
1 (WITH PIER)	20.03	1.59	100.15	7.96
1 (WITHOUT PIER)	21.62	—	108.10	—
2 (WITH PIER)	20.05	1.54	100.25	7.70
3 (WITH PIER)	20.00	1.64	100.00	8.20

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
DISCHARGE AND CREST COEFFICIENT CURVES

DRAWN F.R.C. SUBMITTED
TRACED E.F.J. H.S. RECOMMENDED R. F. Blanks
CHECKED F.L.P. APPROVED

DENVER, COLO., APR. 4, 1936 230-D-100

Sill "R" (Figure 30) was designed from Sill "P" in an attempt to decrease the cost. The two governing dimensions, the total height and the slope of the notch inclines, were made approximately equal. Comparison of the performance of Sills "P" and "R" shows that Sill "R" was as good or better than Sill "P." Hence Sill "R" was recommended for the design (Figure 30, c and d, and Plates XId and XII).

In order to determine to what extent, if any, the effectiveness of sills would be impaired when the corners and edges became worn, tests were run on modifications of each type with all edges chamfered about 3-3/4 inches. No perceptible influence was noted.

Pressures were measured on the faces of both the dentated step and the dentated sill. Piezometer openings were located about three feet above the floor and on the centerline of the vertical face of each tooth of the step and along the centerline of the sloping downstream face of each tooth of the sill. In none of the tests made for Plan No. 1 were negative pressures observed. In subsequent tests for the other two plans, however, negative pressures were observed on the downstream faces of the dentated step (Figure 42). Dentated steps are discussed more fully on page 10 in conjunction with Plan No. 2. No improvement over Type "T" (Figure 32) was observed.

<u>High dam--Plan No. 2.</u> As was previously stated, the high dam was designed to increase the storage capacity from 100,000 to 350,000 acre-feet. The crest was 30 feet higher than that of the low dam, but no change in the chute or stilling-pool was to be involved.

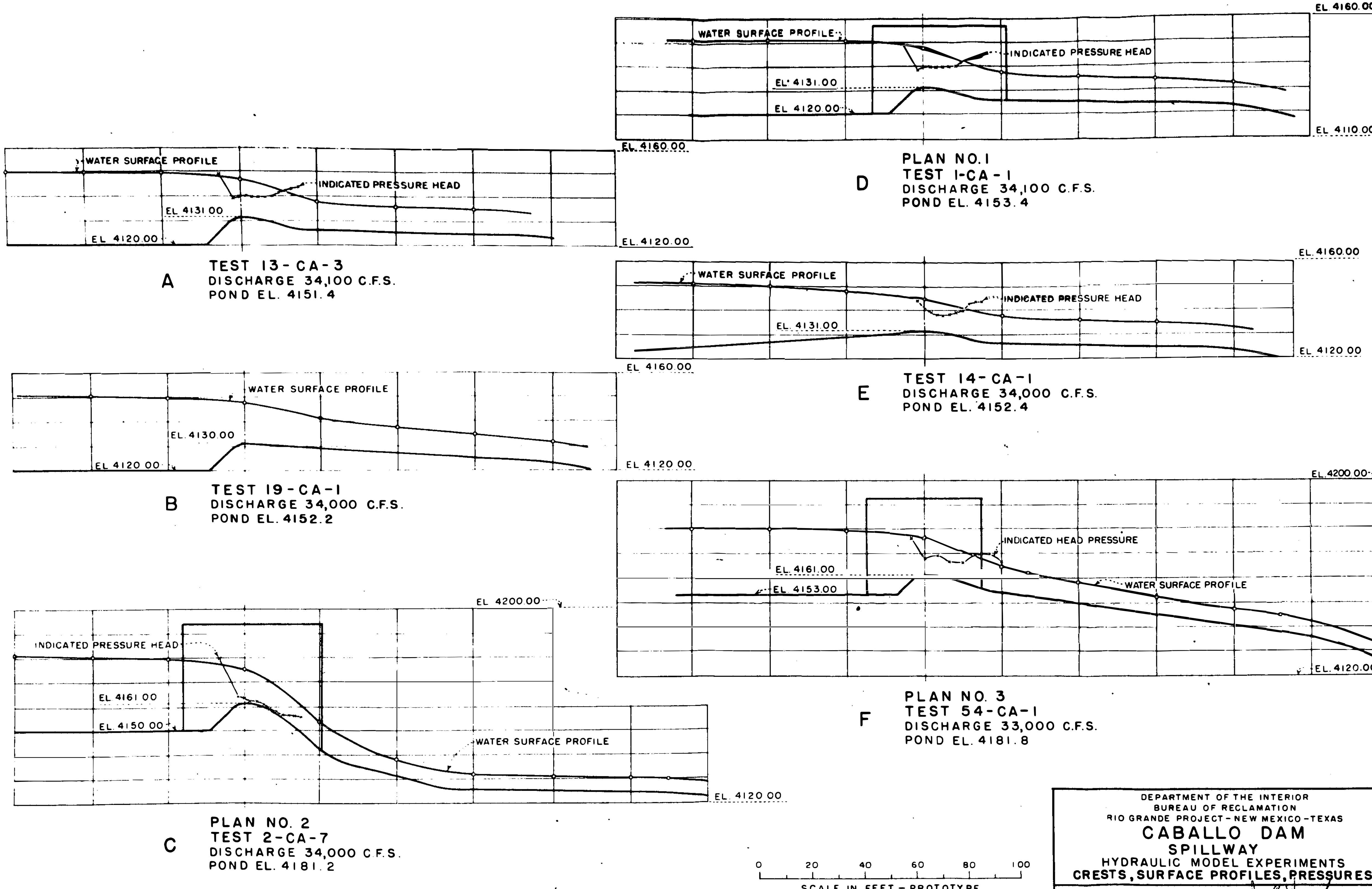
The reconstructed model crest, shaped and covered with sheet metal and stiffened with angles, is shown on Figure 33. For the upstream fill, required to raise the bed elevation from 4120 to 4150, compacted sand was used.

The results of discharge and coefficient studies are illustrated in Figure 27. The same basis was used for the calculations of coefficients. It will be noted that the coefficients for Plan No. 2 are about 10 percent higher than those of Plans Nos. 1 and 3 at high heads.

The pressures obtained over this crest are shown in Figure 29. At a discharge slightly above maximum, a definitely negative pressure was obtained. Both pressures and water surfaces are plotted in Figure 28c.

Because the fins which formed in the chute were not prohibitive in size and their effects were adequately dissipated in the pool, no further attempt was made to reduce them (Plate XIIIa and Plate XIIb).

Regarding the stilling-pool, preliminary runs demenstrated that the floor was lower and longer than necessary. The floor was therefore raised 4 feet and shortened from 112.5 feet to 78.75 feet. Additional

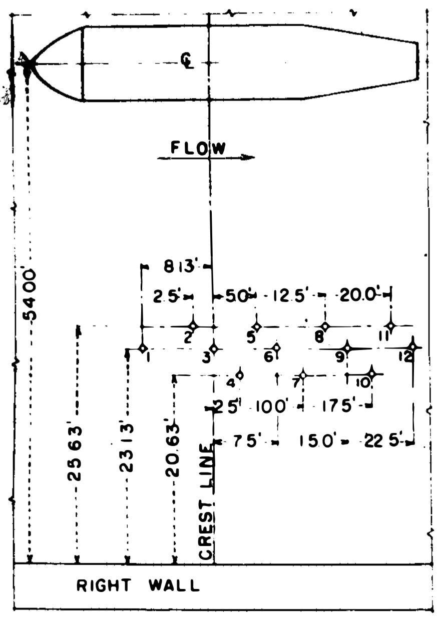


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

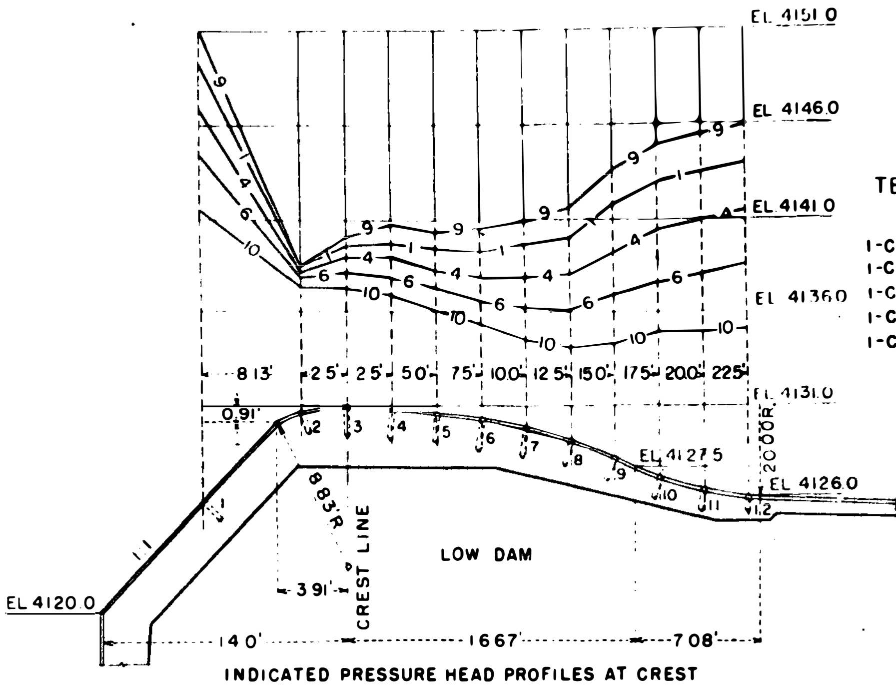
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
CRESTS, SURFACE PROFILES, PRESSURES

DRAWN F.R.C.	SUBMITTED C. Warnock		
TRACED E.F.J. H.S.	RECOMMENDED R. F. Blanks		
CHECKED F.L.P.	APPROVED J. L. Savage		
	DENVER, COLO., MAR. 14, 1936	230-D-94	

[redacted]



LOCATION OF PIEZOMETERS IN CREST



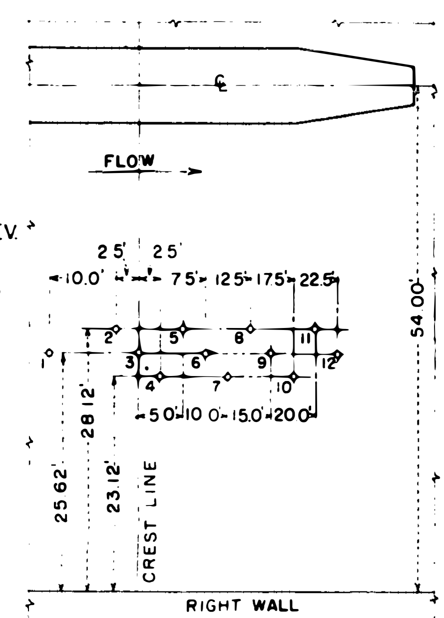
INDICATED PRESSURE HEAD PROFILES AT CREST

PLAN 1

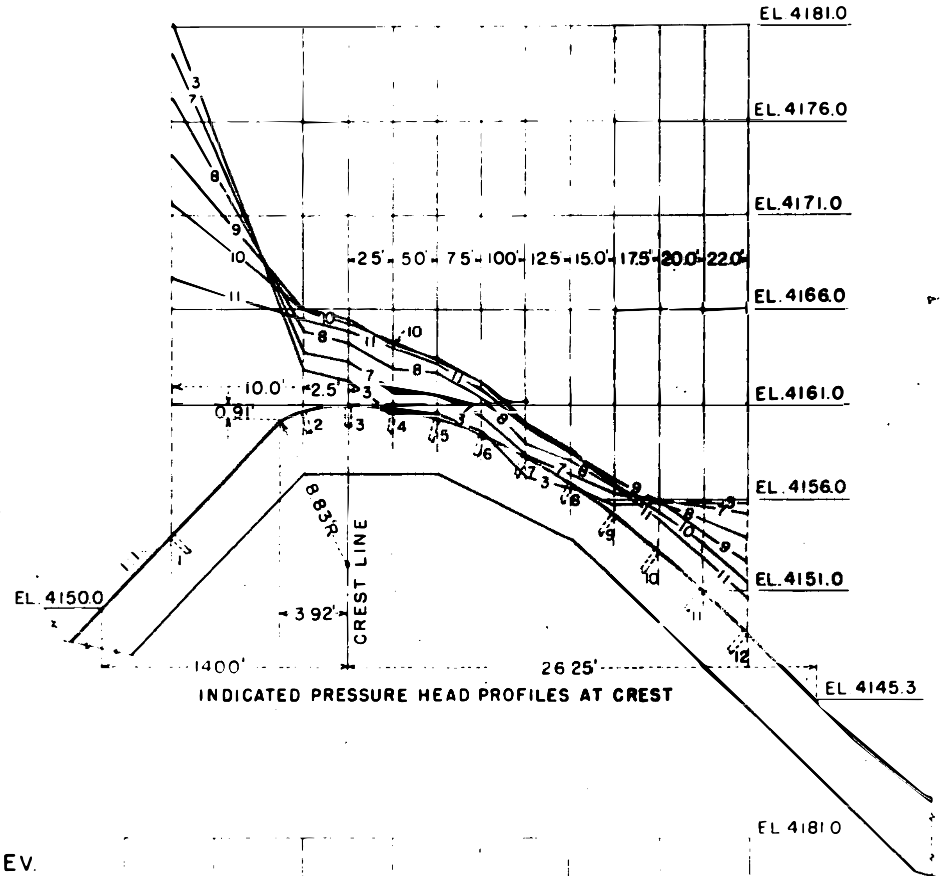
TEST	DISCHARGE	RES. ELEV.
1-CA-9	40,100 C.F.S.	4154.9
1-CA-1	34,200 C.F.S.	4152.4
1-CA-4	27,000 C.F.S.	4149.4
1-CA-6	20,100 C.F.S.	4146.1
1-CA-10	13,400 C.F.S.	4142.8

PLAN 2

TEST	DISCHARGE	RES. ELEV.
2-CA-3	39,500 C.F.S.	4183.3
2-CA-7	34,000 C.F.S.	4181.2
2-CA-8	27,000 C.F.S.	4178.4
2-CA-9	18,900 C.F.S.	4174.9
2-CA-10	13,000 C.F.S.	4172.1
2-CA-11	7,300 C.F.S.	4168.8



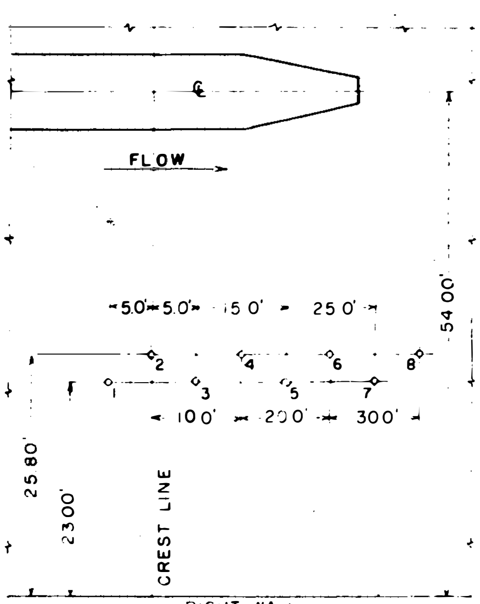
LOCATION OF PIEZOMETERS IN CREST



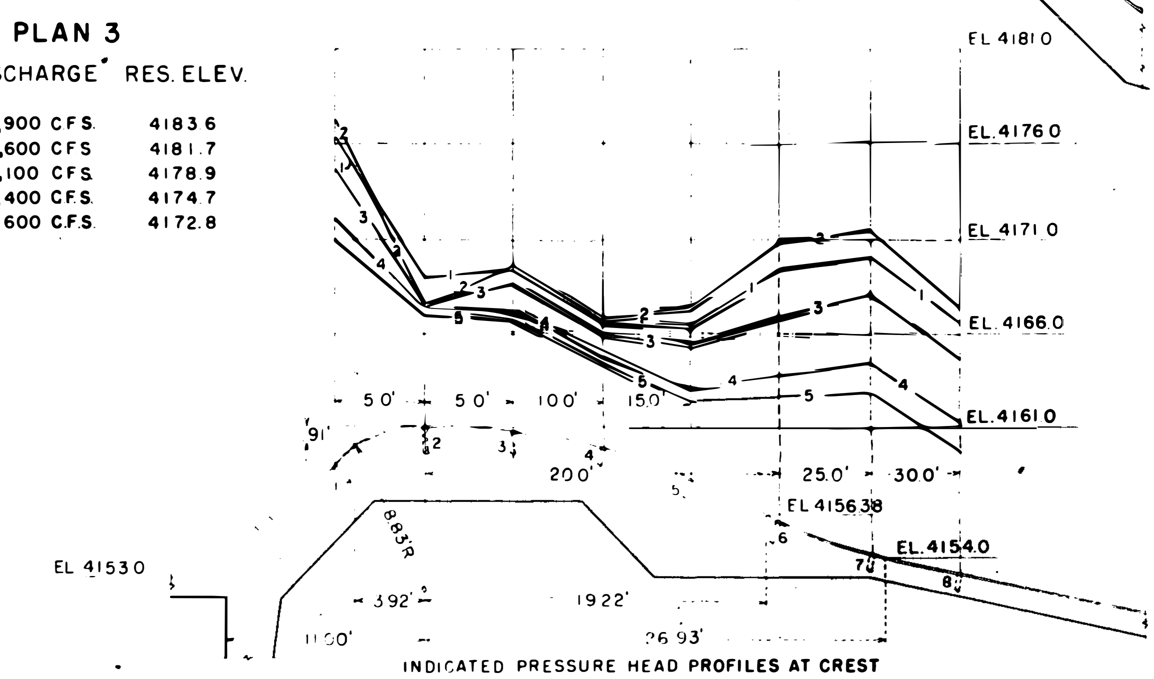
INDICATED PRESSURE HEAD PROFILES AT CREST

PLAN 3

TEST	DISCHARGE	RES. ELEV.
57-CA-2	37,900 C.F.S.	4183.6
53-CA-1	32,600 C.F.S.	4181.7
57-CA-3	27,100 C.F.S.	4178.9
57-CA-4	17,400 C.F.S.	4174.7
57-CA-5	13,600 C.F.S.	4172.8



LOCATION OF PIEZOMETERS IN CREST



INDICATED PRESSURE HEAD PROFILES AT CREST

0 5 10 15 20 25
SCALE OF FEET FOR PROFILES

0 10 20 30 40 50
SCALE OF FEET FOR PLANS

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM

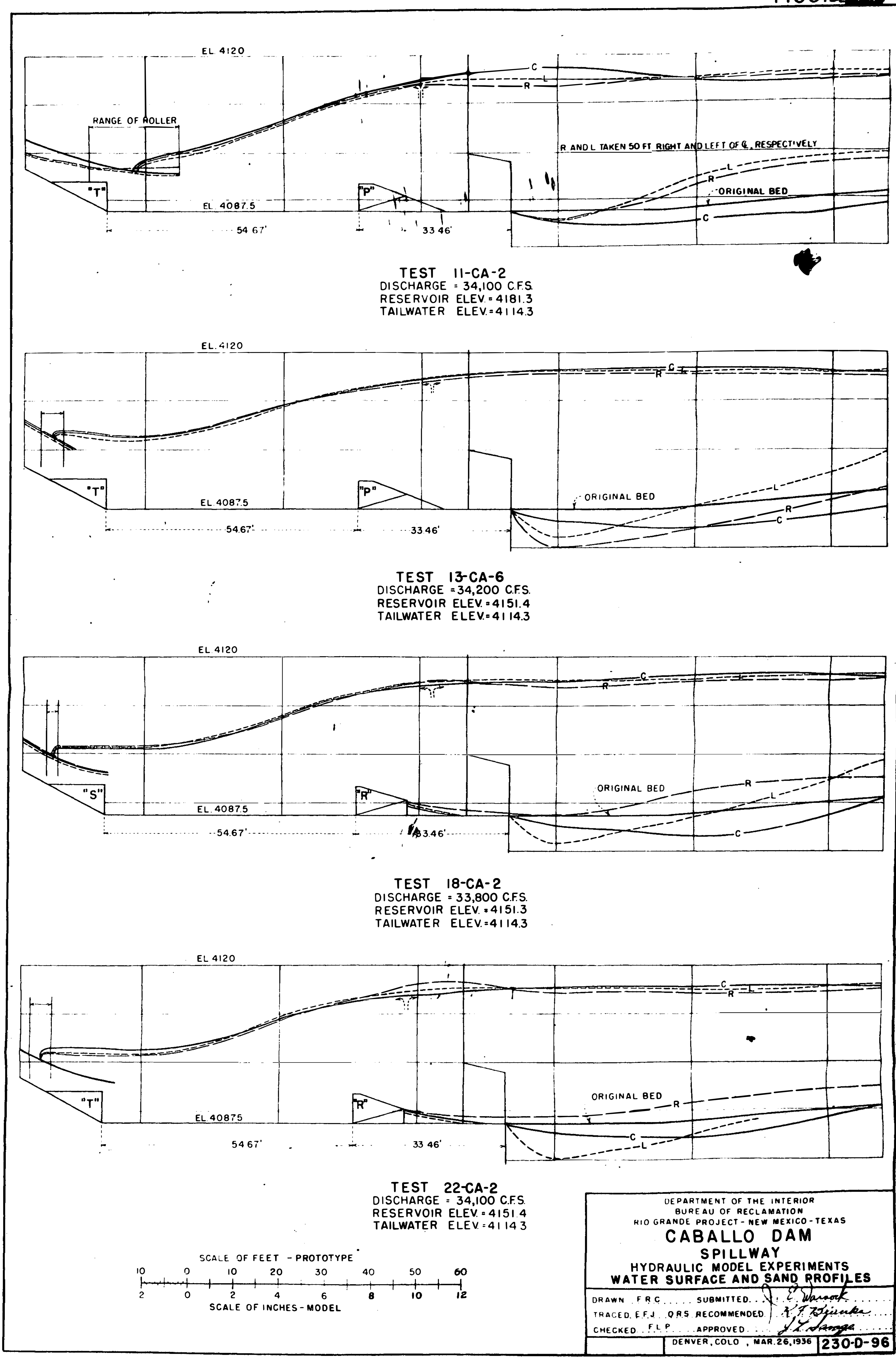
SPILLWAY

HYDRAULIC MODEL EXPERIMENTS
INDICATED PRESSURES AT THE CRESTS

DRAWN. F.R.C. H.G.D.,JR. SUBMITTED J. E. Warnock
TRACED. E.F.J. O.R.S. RECOMMENDED R. F. Blanks
CHECKED. F.L.P. APPROVED J. L. Savage

DENVER, COLO., MAR. 16, 1936 230-D-95

Figure 29



EL. 4120
RANGE OF ROLLER
R AND L TAKEN 50 FT. RIGHT AND LEFT OF ℄, RESPECTIVELY
"T"
"P"
EL. 4087.5
ORIGINAL BED
54.67'
33.46'
TEST 11-CA-2
DISCHARGE = 34,100 C.F.S.
RESERVOIR ELEV. = 4181.3
TAILWATER ELEV. = 4114.3
EL. 4120
"T"
"P"
EL. 4087.5
ORIGINAL BED
54.67'
33.46'
TEST 13-CA-6
DISCHARGE = 34,200 C.F.S.
RESERVOIR ELEV. = 4151.4
TAILWATER ELEV. = 4114.3
EL. 4120
"S"
"R"
EL. 4087.5
ORIGINAL BED
54.67'
33.46'
TEST 18-CA-2
DISCHARGE = 33,800 C.F.S.
RESERVOIR ELEV. = 4151.3
TAILWATER ELEV. = 4114.3
EL. 4120
"T"
"R"
EL. 4087.5
ORIGINAL BED
54.67'
33.46'
TEST 22-CA-2
DISCHARGE = 34,100 C.F.S.
RESERVOIR ELEV. = 4151.4
TAILWATER ELEV. = 4114.3
SCALE OF FEET - PROTOTYPE
10 0 10 20 30 40 50 60
2 0 2 4 6 8 10 12
SCALE OF INCHES - MODEL
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
WATER SURFACE AND SAND PROFILES
DRAWN F.R.C. SUBMITTED J. E. Warnock
TRACED E.F.J. Q.R.S. RECOMMENDED
CHECKED F.L.P. APPROVED
DENVER, COLO., MAR. 26, 1936 230-D-96

Figure 30

A. Discharge 34,100 c.f.s.
Tailwater 4114.3.

C. Low Crest - No Pier.

B. Discharge 34,100 c.f.s.
Tailwater 4111.5.

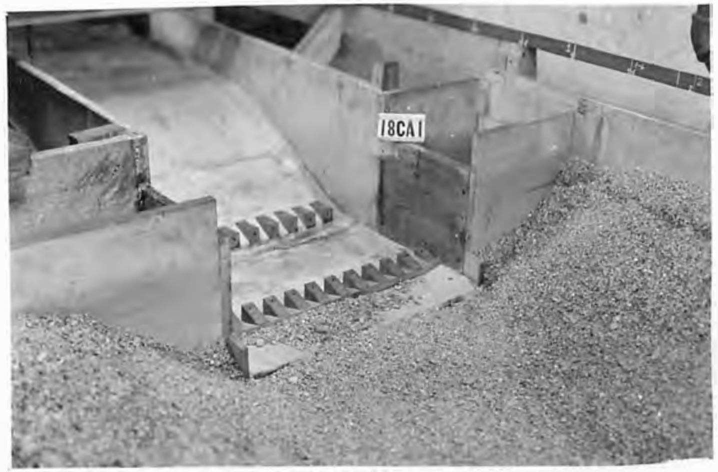
D. Sand Bed After Run, Tailwater 4114.3.

POOL DESIGN - PLAN No. 1 & 2

PLATE XI

A. Discharge 34,000 c.f.s.
Tailwater 4118.3.

B. Discharge 33,900 c.f.s.
Tailwater 4114.3.



C. Sand Bed After Run.

D. Sand Bed After Run.

FINAL POOL DESIGN - PLAN No. 1 & 2

PLATE XII

runs demonstrated that the floor should be lengthened. The remainder of the tests were made with a floor length of 88.13 feet and a side wall length of 78.75 feet.

Tests on dentated steps showed that "T" (Figure 32) was most effective. The steps "x" and "w" were not high enough to effectively break up the high-velocity jet. Other dentated steps were placed with the downstream edge at the intersection of the 2 to 1 slope and the horizontal pool floor, and varied little in effect from "R." The tops of the teeth were horizontal in all designs.

One series of tests was run with double dentated steps. The second row of teeth was located upstream and staggered with respect to the teeth in the first row. Additional energy was dissipated but not enough to justify the additional cost of construction.

Sills "A" to "P," inclusive, (Figure 31) were tested for Plan No. 2. Triangular sills were not effective. Square sills and square teeth were not satisfactory. Double rectangular sills (Test 5-CA-1) were very effective at normal tailwater (elevation 4118), but with a comparatively small drop in tailwater, the scour became excessive. Several Rehbock sills were tried. Sill "P" (Figure 31) was the most effective.

Because of the fillets installed at the sides of the pool, for structural reasons, and because of the distribution of the water in the pool, it was found that the two end teeth must be wider than the other teeth. Tests with the two end spaces filled or partially filled showed slightly less scour than with the spaces open. This improvement did not warrant a change in design.

After the high crest was taken out, the size of the sill was computed from theoretical considerations and found to be excessive. Sill "R" was designed from Sill "P" and comparative tests (Figure 30) were run for the low crest (Plan No. 1). Since Sill "R" exhibited less scour, it was recommended for the final design.

The recommended position of the sill (Figure 34 and Plate XIII) is 54.67 feet from the upstream edge of the pool. The recommended length of the pool was 78.75 feet; the recommended floor length was 88.13 feet. Greater scour occurred for either a shorter or a longer pool.

Side whirls which occurred at the ends of the pool walls washed the material away from the retaining wall, and scoured holes at the downstream corners of the floor. Wide end teeth decreased this action. In another attempt to eliminate the scour and wash, small wing-walls 10 feet to 12.5 feet high and 9.4 feet long were added as extensions to the sidewalls. With the coarse sand used in the model, the scour was reduced. The wing-walls were therefore recommended (Plate XIV).

<u>High dam--Plan No. 3.</u> The same scale (1 to 60) and general type of construction were used for Plan No. 3 as for the preceding models (Figures 35 and 36 and Plate XV).

Figure 31

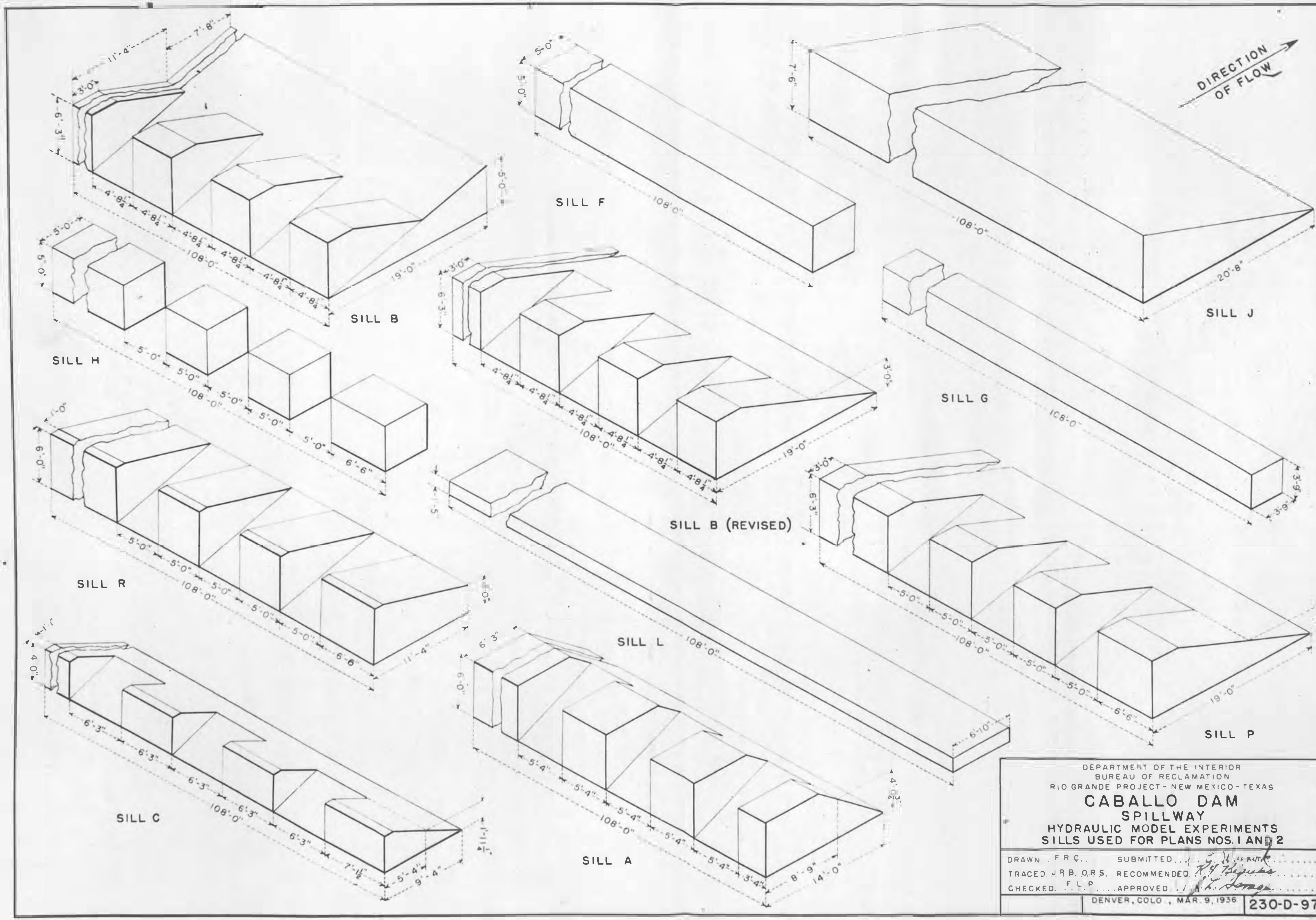
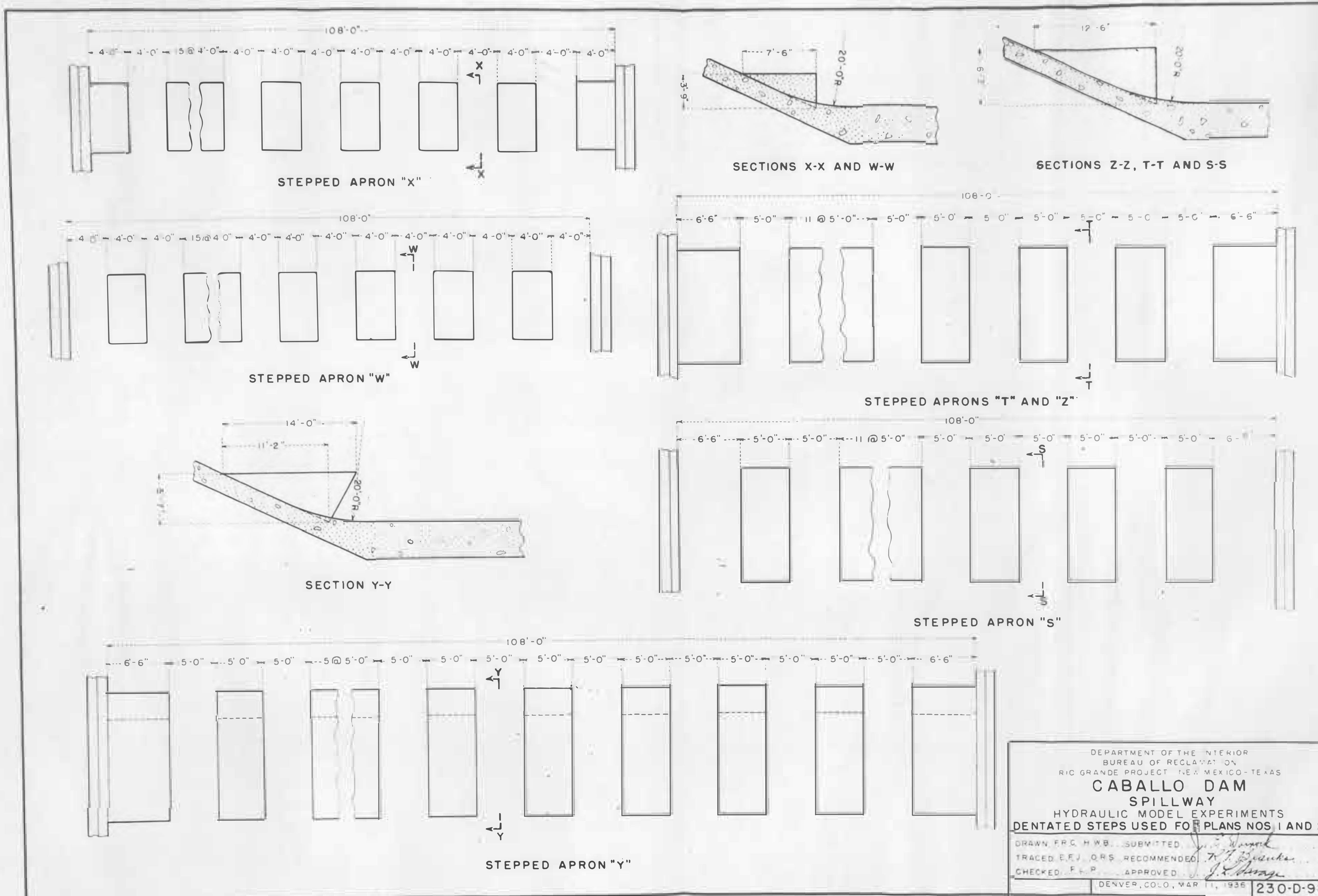
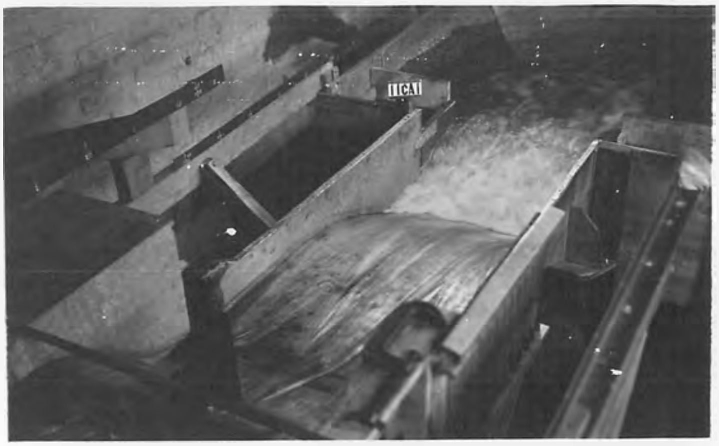

DIRECTION OF FLOW
SILL B
SILL F
SILL J
SILL H
SILL G
SILL B (REVISED)
SILL R
SILL L
SILL P
SILL C
SILL A
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
SILLS USED FOR PLANS NOS. 1 AND 2
DRAWN F.R.C. SUBMITTED
TRACED J.R.B. O.R.S. RECOMMENDED
CHECKED F.L.P. APPROVED
DENVER, COLO., MAR. 9, 1936
230-D-97
FIGURE

Figure 32



STEPPED APRON "X"
SECTIONS X-X AND W-W
SECTIONS Z-Z, T-T AND S-S
STEPPED APRON "W"
STEPPED APRONS "T" AND "Z"
SECTION Y-Y
STEPPED APRON "S"
STEPPED APRON "Y"
108'-0"
15@4'-0"
11@5'-0"
5@5'-0"
14'-0"
11'-2"
7'-6"
12'-6"
20'-0"R
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT NEW MEXICO-TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
DENTATED STEPS USED FOR PLANS NOS 1 AND 2
DRAWN F.R.C. H.W.B. SUBMITTED
TRACED E.F.J. O.R.S. RECOMMENDED
CHECKED F.L.P. APPROVED
DENVER, COLO., MAR 11, 1936
230-D-98



A. Final Design - Discharge 34,100 c.f.s.

C. Original Design from Upstream.

B. Original Design from Downstream.

D. Final Design - Discharge 34,100 c.f.s.

MODEL DESIGN - PLAN No. 2

The crest, however, was made of concrete, polished smooth with a carborundum stone. The stilling-pool was made a continuation of the chute and was connected to the sandbox with a watertight joint at the end of the pool floor. The topography upstream from the crest was made of wood and lined with metal, and the topography in the sandbox was formed of sand and riprap replaced before each run.

Crest coefficients (Figure 27) and pressures (Figure 29) were found to be generally similar to those observed for Plan No. 1. This was to have been expected from the similarity of the crests. Little change in the characteristics of the flow in the chute was observed. Surface profiles obtained for Plan No. 3 are shown in Figure 43.

Numerous modifications of the pool designed were tried. The dentated step, "D_3" (Figure 37) was not as effective as "D_1" (Figure 37), but the difference in cost offsets the difference in effectiveness. In general, for a given tooth height, the more effective energy dissipation is obtained with the narrower tooth.

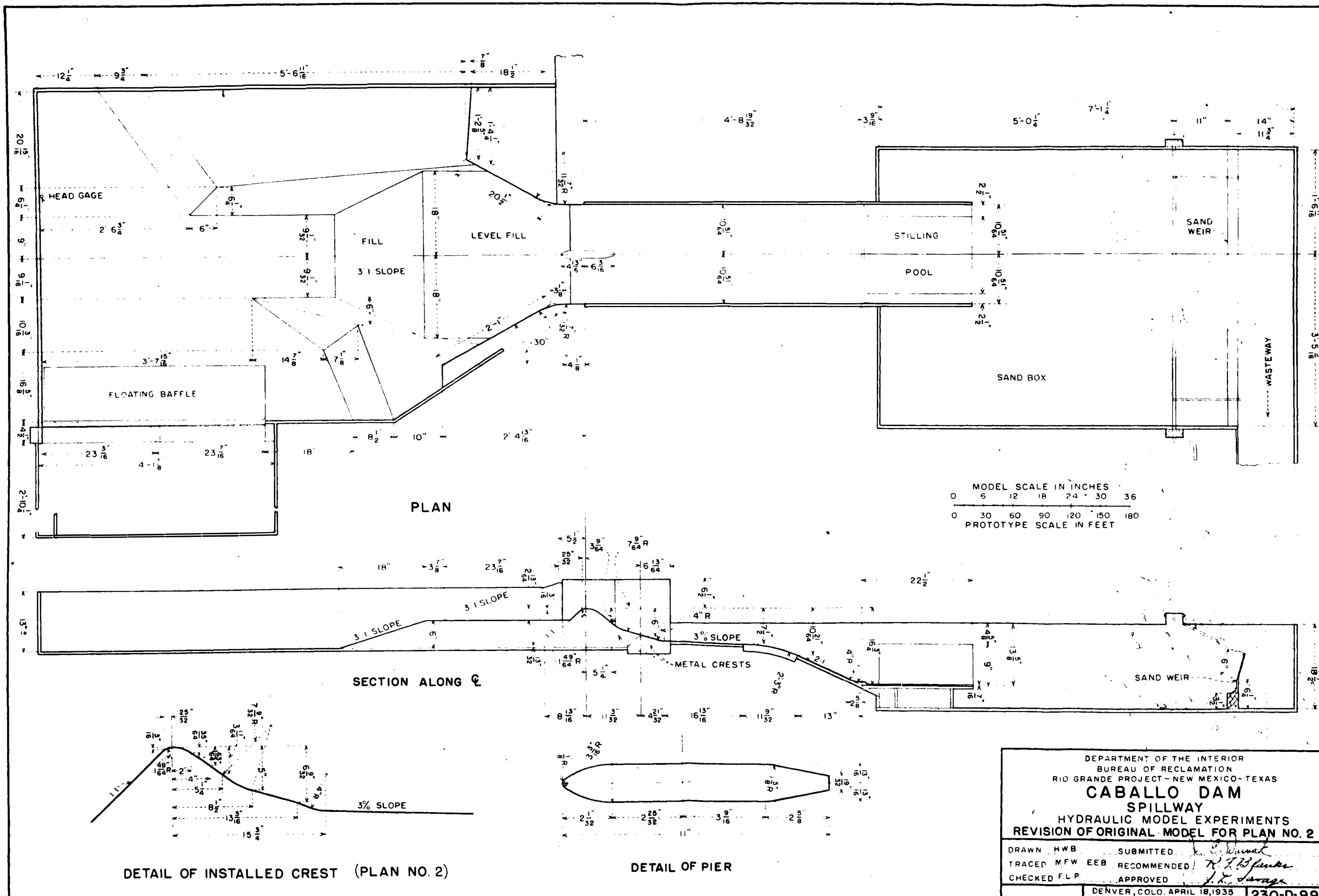
The design of a Rehbock or modified Rehbock sill consists in determining the height, the spacing of the teeth, and the slope of the base. In these tests two heights were tried. Sill "R_3" (Figure 37) although only 5 feet high served better than either of the 6-foot sills (Figure 38 and Plate XVI). The spacing and width of the teeth should be from 0.8 to 1.0 times their height.

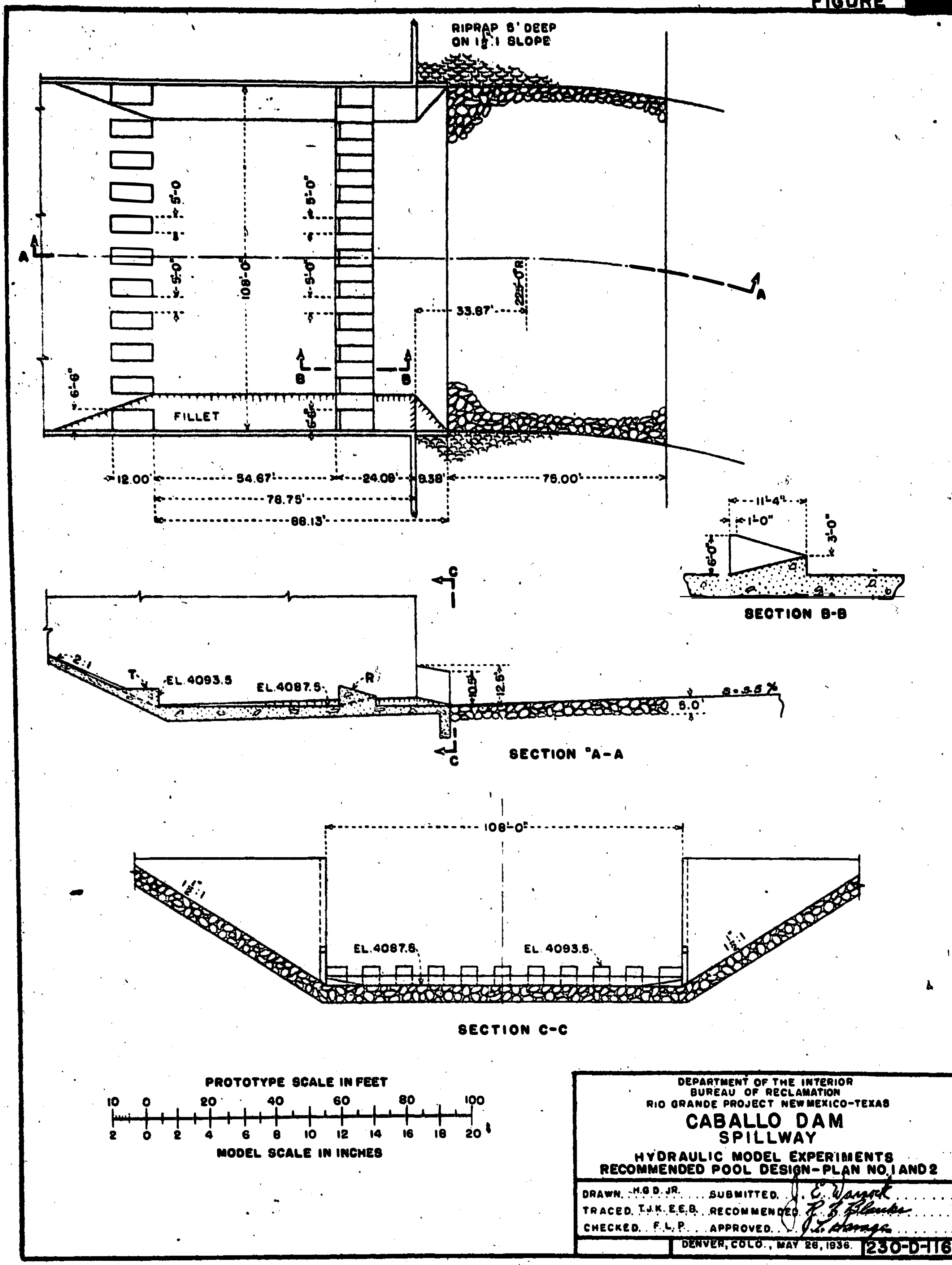
In practically all tests for Plan No. 3, greater scour occurred beyond the corners of the pool than beyond the center. In an attempt to correct this scour caused by fillets in the pool and by side whirls at the end of the pool, various widths of end teeth were used. With a space instead of a tooth adjacent to the sidewall, scour at the corners was very deep. With the end teeth equal in width to the other teeth, the scour was deep. But with the end teeth two to three times the width of the other teeth, the scour was greatly reduced (Figure 39 and Plate XVII). This is in accord with Rehbock's findings. However, with larger end teeth, greater scour occurred at the center. An end tooth with twice the width of the other teeth was recommended. An attempt to eliminate this scour by raising the end teeth was unsuccessful.

The slope of the base between the teeth influences the direction of the high-velocity flow. A steep slope directs the high-velocity water toward the surface while a mild slope permits a higher velocity nearer the bottom. The slopes varied from 15 degrees (R_3) to 25 degrees 42 minutes (R_6). The Sill R_6 drew material up near the sill better than Sill R_3 (Figure 38 and Plate XVIII), but was not satisfactory because scour at the left corner was increased.

A combination sill developed in experiments for the Moon Lake Project was next tried. The combination sill is a dentated sill superimposed on a plain rectangular sill (Figure 38, Sill R_{3c}). The combination sill appeared to accomplish a more complete dissipation of energy.

Figure 33


HEAD GAGE
FILL
3:1 SLOPE
LEVEL FILL
FLOATING BAFFLE
STILLING
POOL
SAND WEIR
SAND BOX
WASTEWAY
PLAN
MODEL SCALE IN INCHES
0 6 12 18 24 30 36
0 30 60 90 120 150 180
PROTOTYPE SCALE IN FEET
3:1 SLOPE
3:1 SLOPE
4" R
3% SLOPE
METAL CRESTS
SAND WEIR
SECTION ALONG ℄
3% SLOPE
DETAIL OF INSTALLED CREST (PLAN NO. 2)
DETAIL OF PIER
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
REVISION OF ORIGINAL MODEL FOR PLAN NO. 2
DRAWN HWB
TRACED MFW EEB
CHECKED FLP
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. APRIL 18, 1938
230-D-99


RIPRAP 8' DEEP ON 1½:1 SLOPE
FILLET
12.00'
54.67'
24.08'
9.38'
75.00'
78.75'
88.13'
108'-0"
5'-0"
6'-6"
33.87'
225'-0" R.
SECTION B-B
11'-4"
1'-0"
3'-0"
6'-0"
EL. 4093.5
EL. 4087.5
S = 3.5 %
6.0'
10.5'
12.5'
SECTION "A-A
SECTION C-C
PROTOTYPE SCALE IN FEET
MODEL SCALE IN INCHES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT NEW MEXICO-TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
RECOMMENDED POOL DESIGN-PLAN NO. 1 AND 2
DRAWN. H.G.D. JR. SUBMITTED.
TRACED. T.J.K. E.E.B. RECOMMENDED.
CHECKED. F.L.P. APPROVED.
DENVER, COLO., MAY 26, 1936.
230-D-116

Both sills R_3 and R_6 were tried in combination with a rectangular sill 2.34 feet wide and 1.50 feet high. Both combinations worked well, but the former caused a very pronounced secondary roller downstream. The latter combination called R_{3c} produced less scour and side wash than any other and was therefore chosen for the final recommendation (Figure 38 and Plate XVIII).

The results of tests on different lengths of pool are shown in Figure 41 and Plate XIX. As is readily apparent, an optimum length of pool exists from which changes in the direction either of lengthening or shortening result in an increase in the scour. A pool length of 55 feet (Figure 40) appeared to produce results as satisfactory as those obtained with the 60-foot pool, but because of its adaptability to a slightly greater range of tailwater elevations, the 60-foot pool was recommended.

Considerable attention was given to the elimination of effects destructive to the downstream embankments. As previously stated, wide end teeth and the combination sill (R_{3c}) partially reduced the sill whirl which washed material away from the sidewalls and the scour at the corner (Plate XVII). Longer sidewalls and supplementary walls failed to effect any improvement. The measures finally found necessary to prevent the erosion of the banks included a reduction of the stream-bed side slope to 3 to 1 and an increase in the depth of the riprap to 5 feet. It is possible that with prototype materials a steeper slope would be permissible (Figure 45 and Plates XX and XXI).

The small wing-walls recommended for Plan No. 2 proved objectionable for Plan No. 3. With riprap in place, the wing-walls appeared to increase the side wash slightly without materially changing the scour.

The pressure measurements made in the stilling-pool (Figure 42) yielded the following conclusions:

a. The piezometer in the downstream face of the dentated step tooth, at maximum discharge and normal tailwater, showed a slight negative pressure and an increasing negative pressure at maximum discharge as the tailwater was lowered. As the discharge was reduced, the piezometer showed an increasing positive pressure.

b. The piezometer in front of the sill indicated an increase in the pressure with a drop in tailwater, the discharge being held at maximum. When the discharge was lowered, the pressure also fell off.

c. The piezometers between the step and the sill show the effects of the change in direction of the flow and the superposition of the roller. These varied directly with the discharge and with the tailwater elevation.

Recapitulating, the following results of the studies for Plan No. 3 may be emphasized.

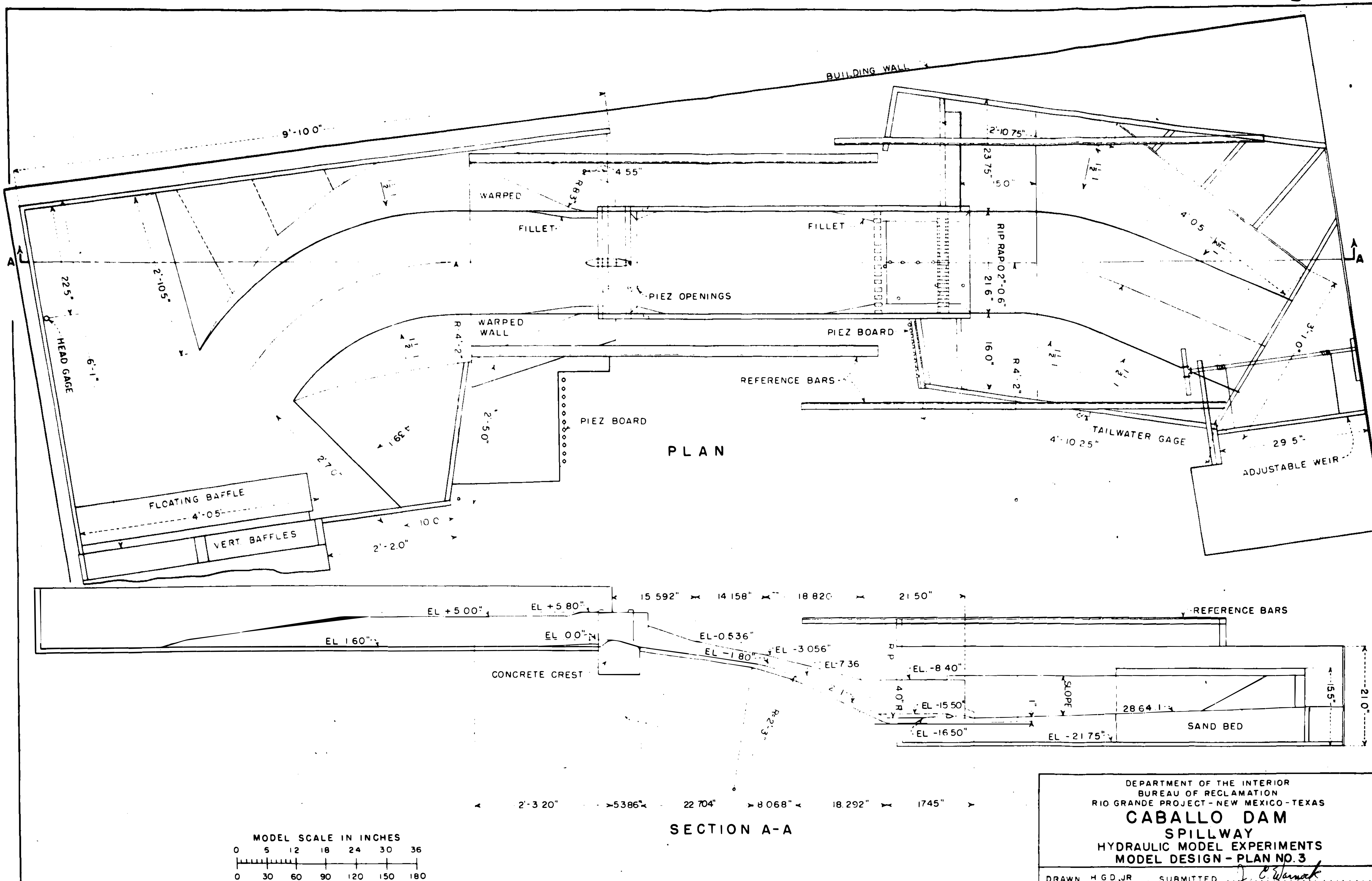
A. Sand Bed Before Run.

C. Sand Bed After Run, Tailwater
4118.3.

B. Sand Bed After Run, Tailwater
4114.3.

D. Sand Bed After Run, Tailwater
4114.3.

FINAL DESIGN - PLAN No. 2

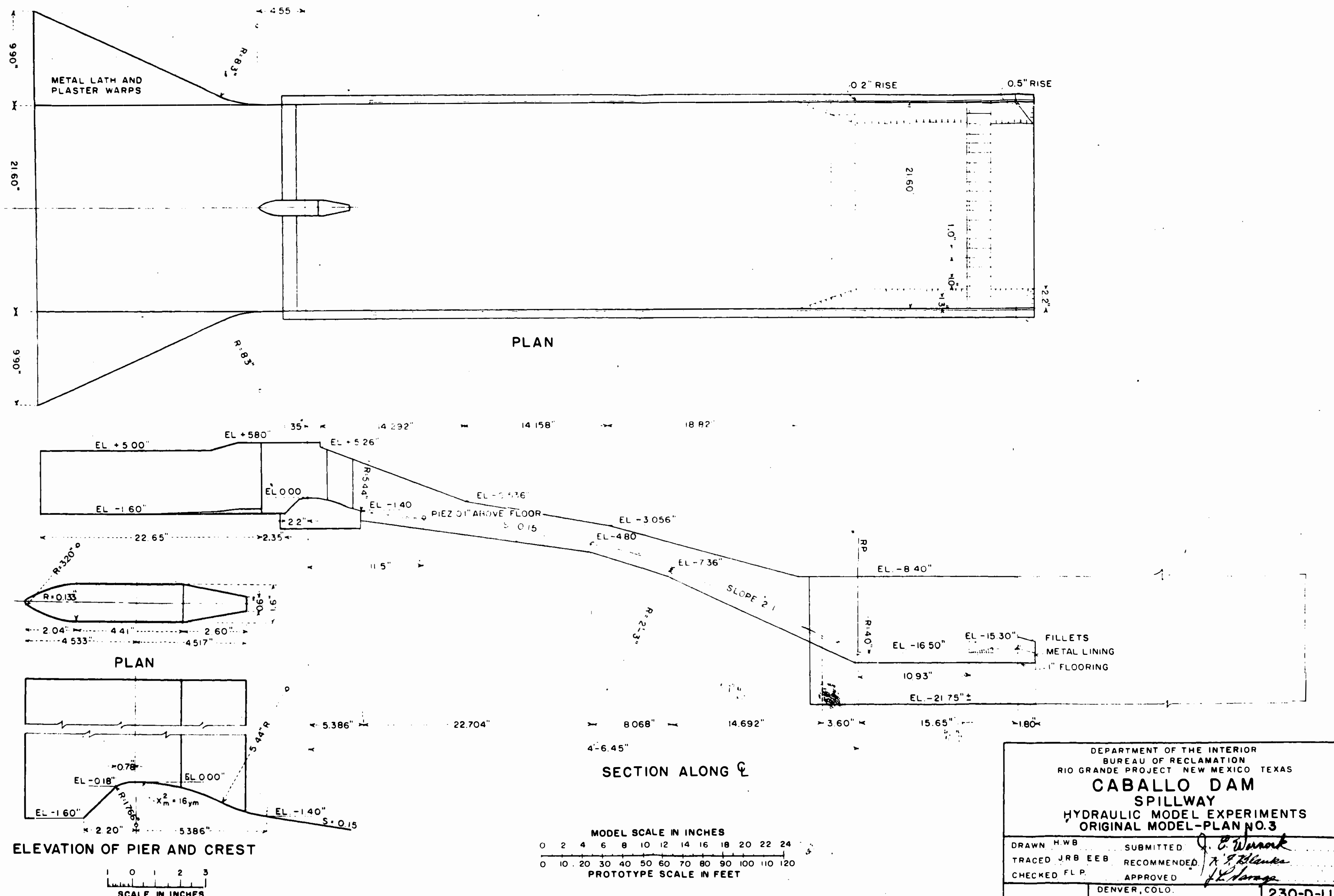


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
MODEL DESIGN - PLAN NO. 3

DRAWN H.G.D.,JR.	SUBMITTED C. Warnok
TRACED J.R.B. H.S.	RECOMMENDED R.F. Blanks
CHECKED	APPROVED J.L. Savage
	DENVER, COLO., FEB. 27, 1936 — 230-D-101

Figure 56

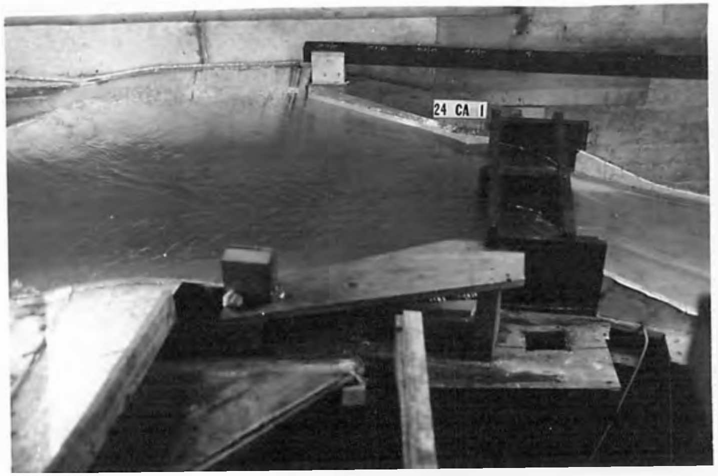


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT NEW MEXICO TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
ORIGINAL MODEL-PLAN NO.3

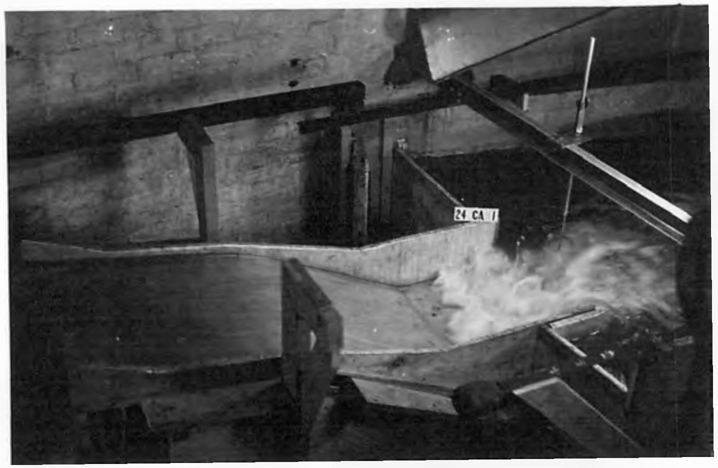
DRAWN H.W.B. SUBMITTED J. E. Warnock
TRACED J.R.B. E.E.B. RECOMMENDED J. F. Blanks
CHECKED F.L.P. APPROVED J. L. Savage
DENVER, COLO. 230-D-113

A. Discharge 33,100 c.f.s.. Approach.



C. Discharge 33,100 c.f.s. - Crest.

B. Discharge 33,100 c.f.s. - Chute.

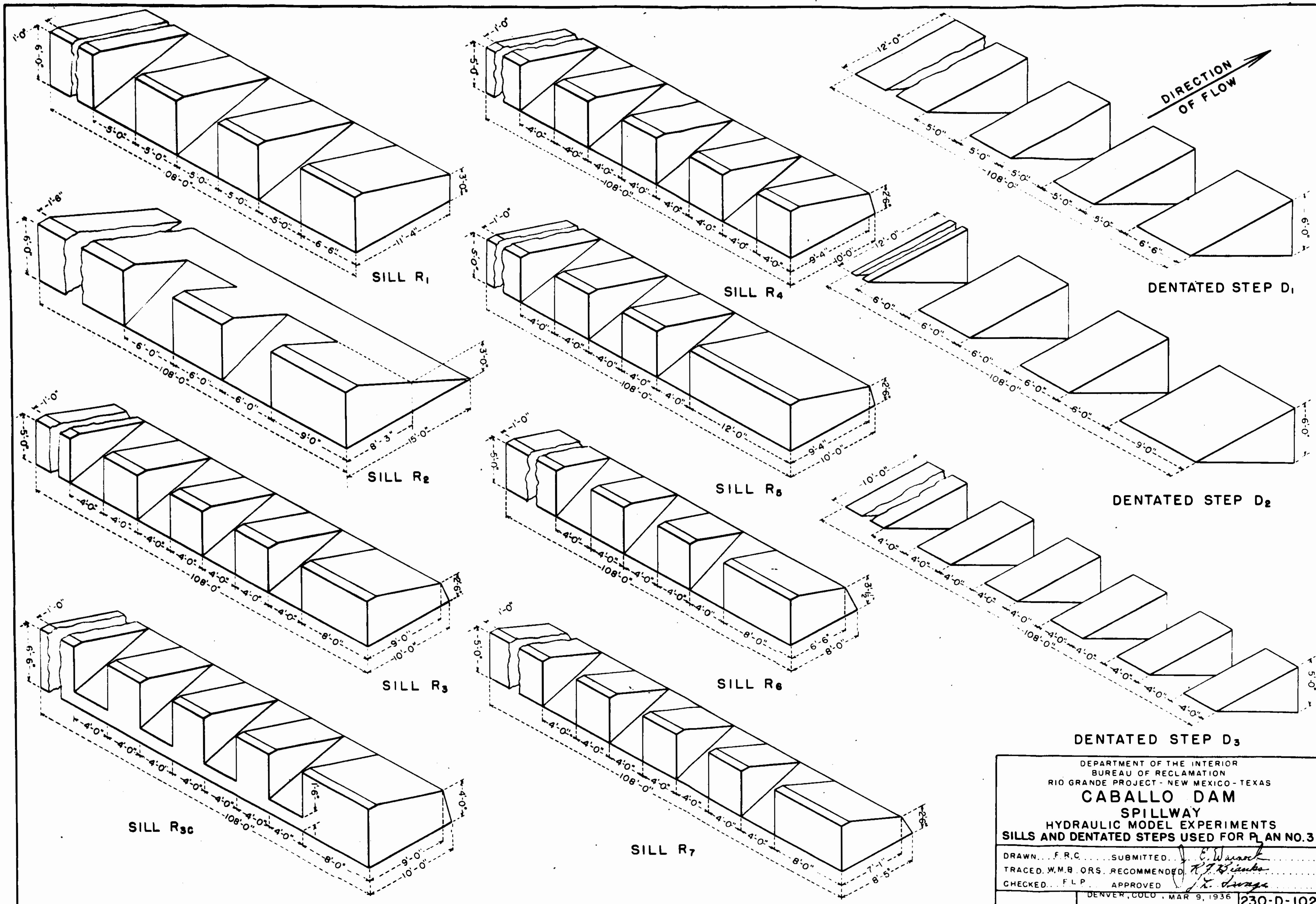


D. Discharge 33,100 c.f.s. Crest

ORIGINAL MODEL - PLAN No. 3

PLATE XV

Figure 31

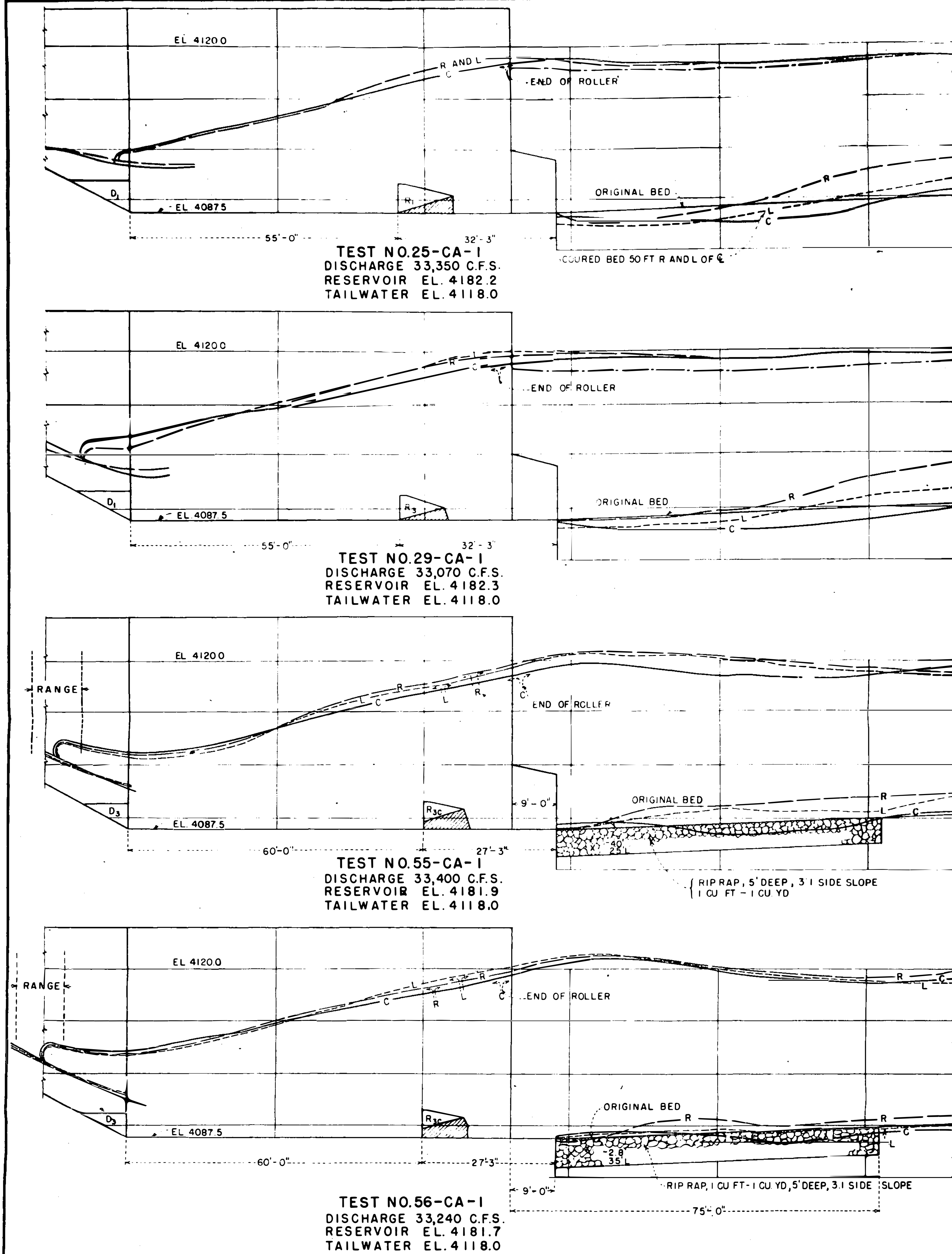


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
SILLS AND DENTATED STEPS USED FOR PLAN NO. 3

DRAWN F.R.C. SUBMITTED J. E. Warnock
TRACED W.M.B. ORS. RECOMMENDED R.F. Blanks
CHECKED F.L.P. APPROVED J.L. Savage
DENVER, COLO., MAR 9, 1936 230-D-102

FIGURE 28



SCALE OF FEET-PROTOTYPE

10 0 10 20 30 40 50 60

2 0 2 4 6 8 10 12

SCALE OF INCHES-MODEL

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

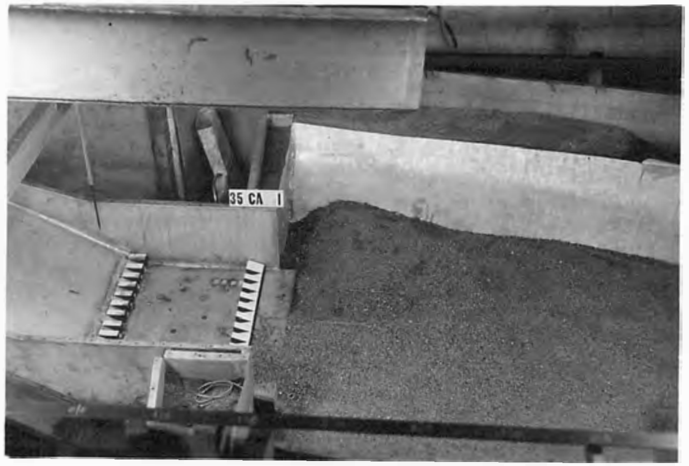
CABALLO DAM

SPILLWAY

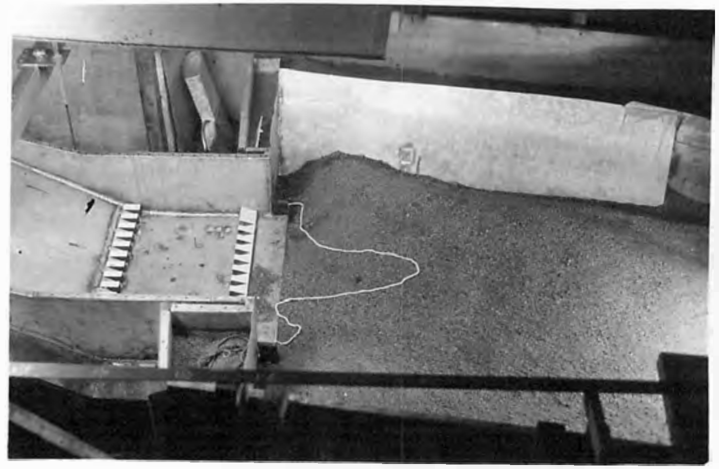
HYDRAULIC MODEL EXPERIMENTS
WATER SURFACE AND SAND PROFILES

DRAWN J.D.M. F.R.C. SUBMITTED J. E. Warnock
TRACED E.F.J. N.H. RECOMMENDED
CHECKED F.L.P. APPROVED
DENVER, COLO., MAR. 20, 1936 230-D-103

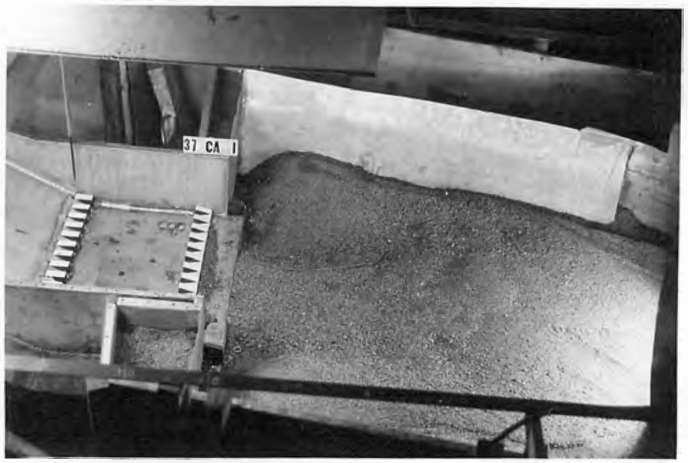
Figure



A. Sand Bed After Run - Double tooth.



C. Sand Bed After Run - Triple Tooth.



B. Sand Bed After Run - Single Tooth.

D. Riprap After Run - Triple Tooth.

COMPARISON OF END TEETH

PLATE XVII

A. Sand Bed After Run - Sill R_3.

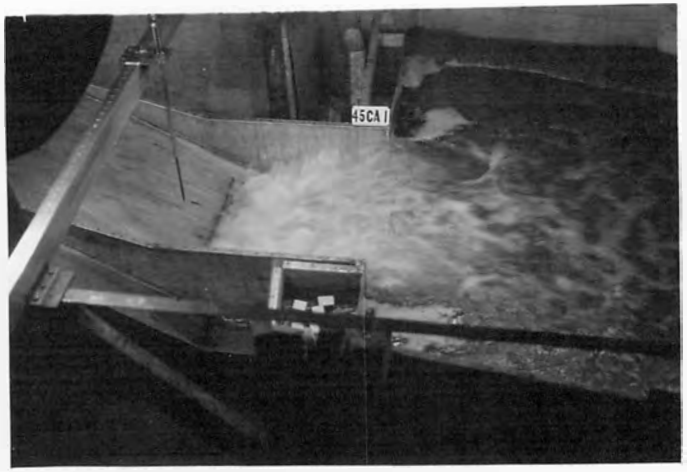
B. Sand Bed After Run - Sill R_6.

C. Sand Bed After Run - Sill R_{3c}.

D. Riprap After Run - Sill R_{3c}.

COMPARISON OF SILLS

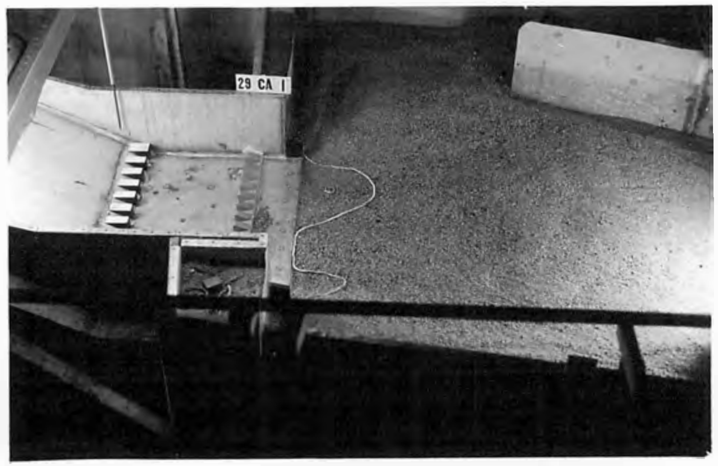
PLATE XVIII



A. Q=33,050 C.F.S. T.W.=4118.7
55 FT. - R.P. to Sill R_3.

B. Q=33,000 T.W. 4118
60 FT. - R.P. to Sill R_3.

C. Sand Bed After Run - Sill R_1.



D. Sand Bed After Run - Sill R_3.

COMPARISON OF TYPE & POSITION OF SILLS
PLAN No. 3

PLATE XVI

The side slopes of 1-1/2 to 1 as used in the model were too steep. The sand was washed out from under the riprap, permitting the riprap to subside and collect in the bed. As a result scour in the bed was completely obscured for considerably more than the normal duration of the run. Side slopes of 3 to 1 maintained their integrity very well. Sand from downstream was in some instances carried up and deposited on the riprap. A very small amount of scour appeared in the riprap floor, principally at the left corner near the pool floor.

The small wing-walls of Plans Nos. 1 and 2 were not necessary with the riprap in place. Although in sand the wing-walls were advantageous, their effect was detrimental with the riprap. Floor scour was diminished, but the sloughing of the side slopes was increased by the wing-walls.

Wide end teeth were advantageous because of the fillets installed for structural reasons and because of their effect in minimizing the side whirls at the end of the pool floor.

The combination sill proved most effective in decreasing scour and side whirls. Rehbock sills with mild slopes produced less sand movement in the tailwater channel but did not seem to prevent destructive side whirls. Rehbock sills with steep slopes drew material upon the apron floor through the agency of a larger ground roller. Double rectangular sills were good for the designed tailwater, but did not maintain a surface roller with a decrease of tailwater depth.

The dentated step should be as high or slightly less high than the thickness of the descending sheet of water. The narrower the teeth the more effective is the dissipation of energy.

In Figure 43 are shown water-surface profiles and sections for Plan No. 3. Figures 44 and 45 and Plates XX and XXI illustrate the final model design in detail.

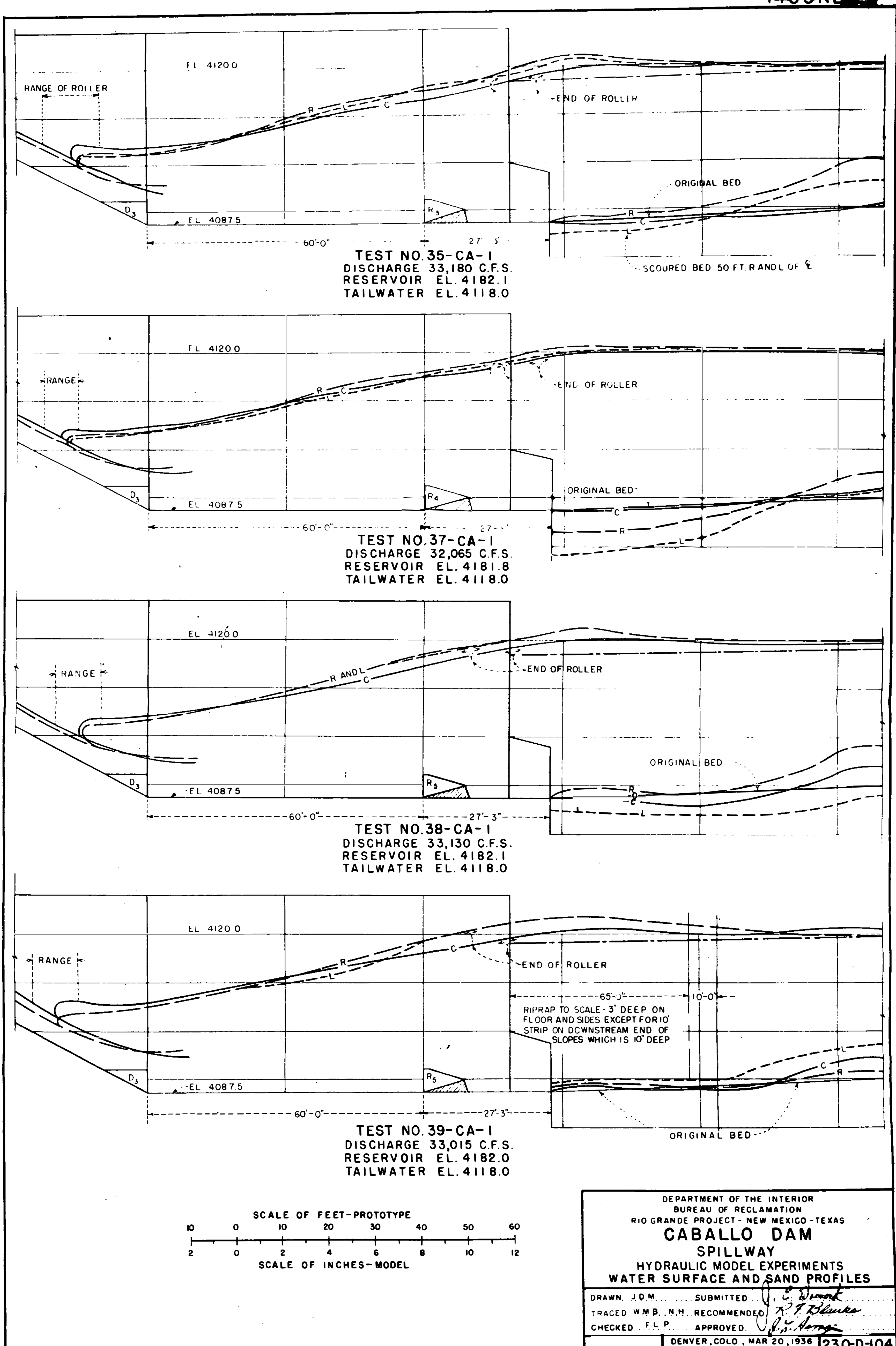

EL 4120.0
RANGE OF ROLLER
END OF ROLLER
R
L
C
ORIGINAL BED
D3
R3
EL 4087.5
60'-0"
27'-3"
SCOURED BED 50 FT. R AND L OF ℄
TEST NO. 35-CA-1
DISCHARGE 33,180 C.F.S.
RESERVOIR EL. 4182.1
TAILWATER EL. 4118.0
RANGE
R4
TEST NO. 37-CA-1
DISCHARGE 32,065 C.F.S.
RESERVOIR EL. 4181.8
TAILWATER EL. 4118.0
R AND L
R5
TEST NO. 38-CA-1
DISCHARGE 33,130 C.F.S.
RESERVOIR EL. 4182.1
TAILWATER EL. 4118.0
65'-0"
10'-0"
RIPRAP TO SCALE 3' DEEP ON FLOOR AND SIDES EXCEPT FOR 10' STRIP ON DOWNSTREAM END OF SLOPES WHICH IS 10' DEEP.
TEST NO. 39-CA-1
DISCHARGE 33,015 C.F.S.
RESERVOIR EL. 4182.0
TAILWATER EL. 4118.0
SCALE OF FEET-PROTOTYPE
10 0 10 20 30 40 50 60
2 0 2 4 6 8 10 12
SCALE OF INCHES-MODEL
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
WATER SURFACE AND SAND PROFILES
DRAWN J.D.M. SUBMITTED
TRACED W.M.B. N.H. RECOMMENDED
CHECKED F.L.P. APPROVED
DENVER, COLO., MAR 20, 1936
230-D-104

Figure 29

F[redacted]RE 30

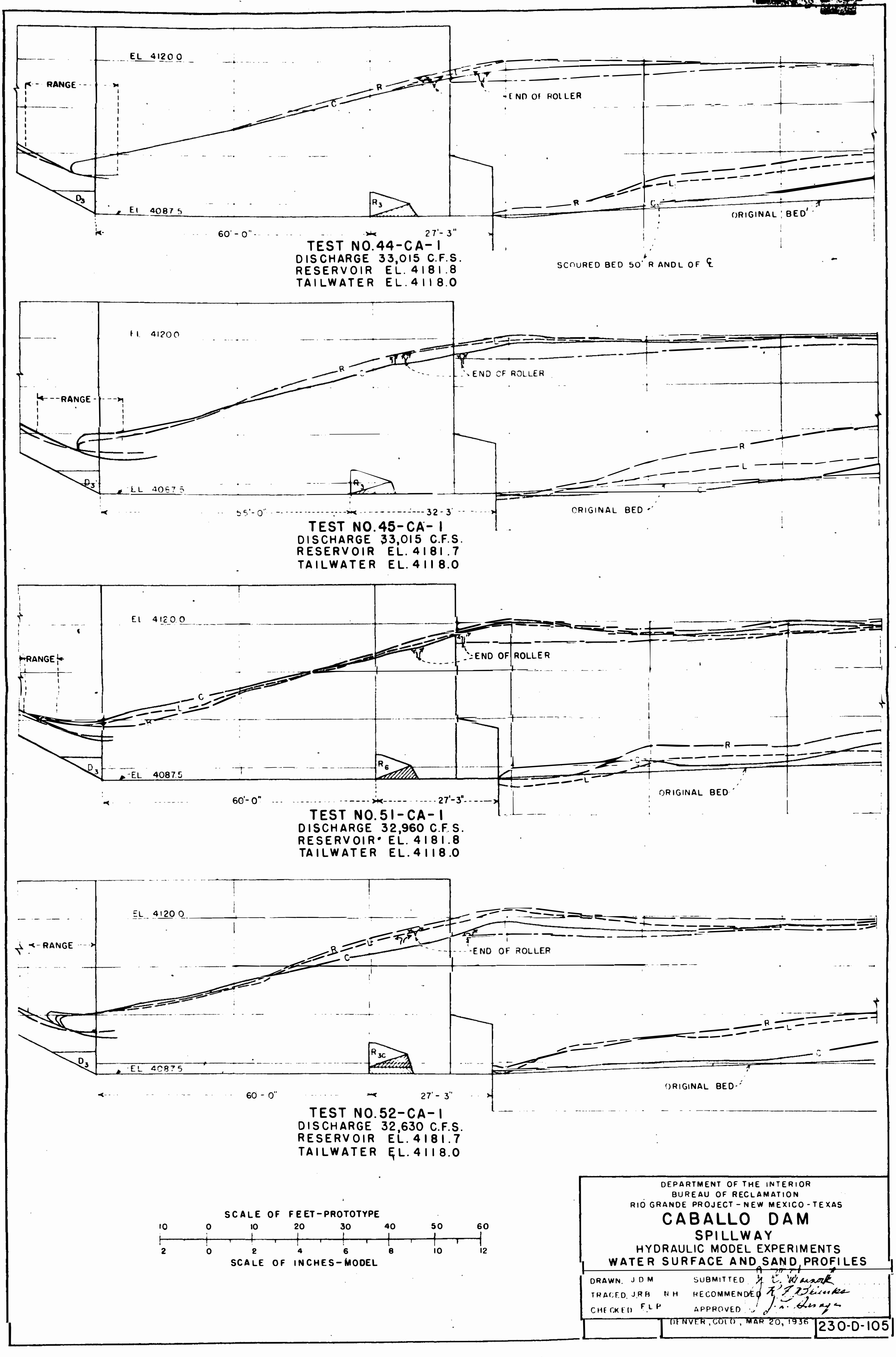
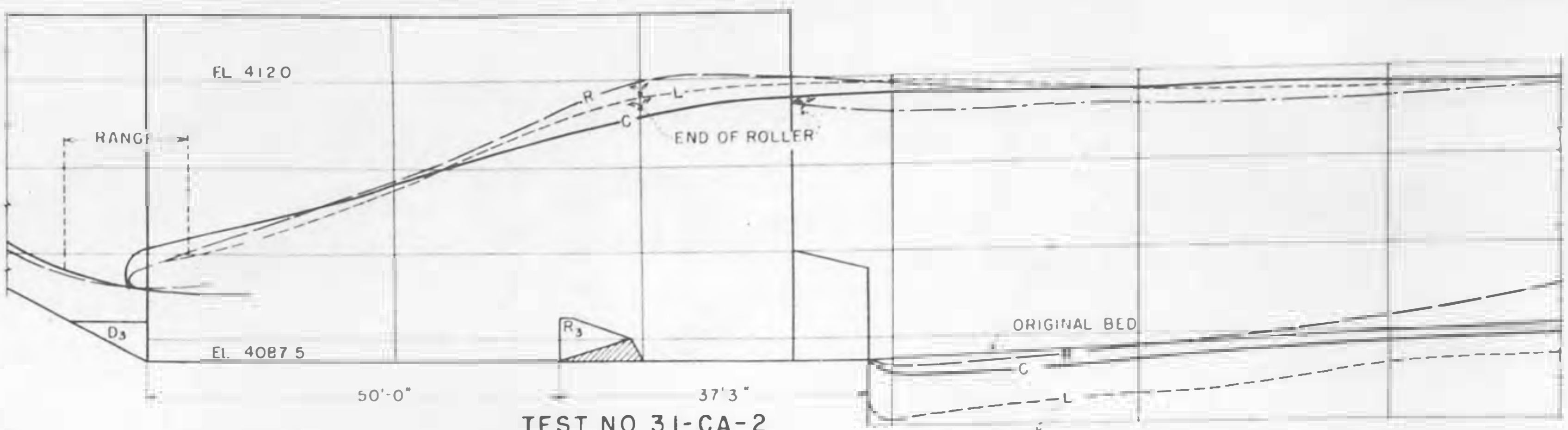


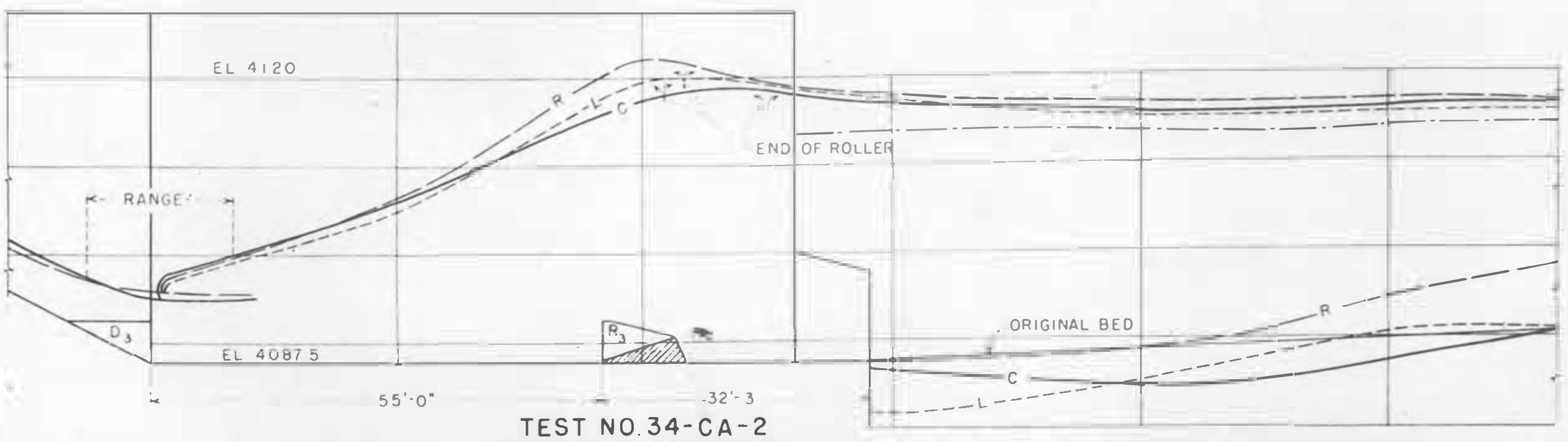
Figure 40

FIGURE 31

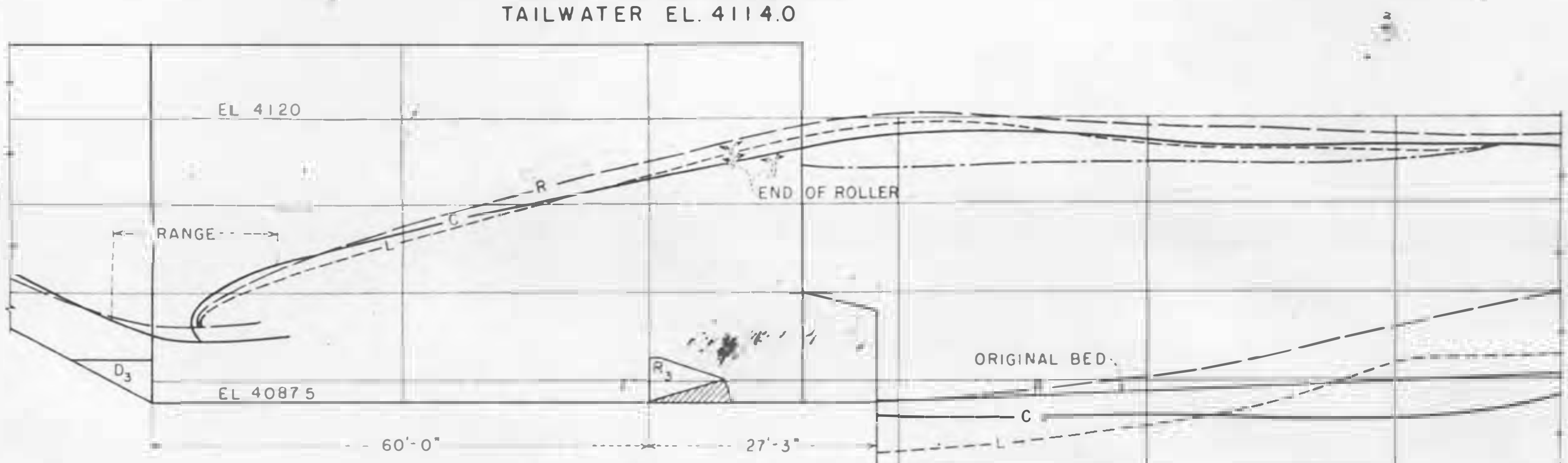


TEST NO. 31-CA-2
DISCHARGE 33,180 C.F.S.
RESERVOIR EL. 4182.0
TAILWATER EL. 4114.0

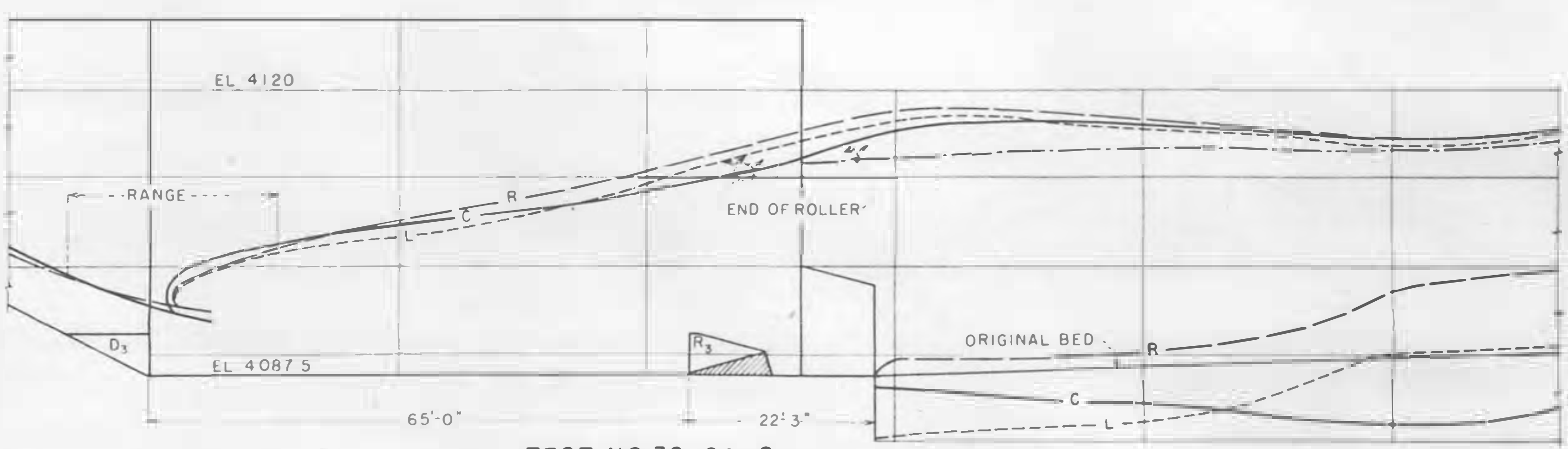
Note R and L taken 50' Right and Left of ℄



TEST NO. 34-CA-2
DISCHARGE 33,070 C.F.S.
RESERVOIR EL. 4182.1
TAILWATER EL. 4114.0



TEST NO. 35-CA-2
DISCHARGE 33,160 C.F.S.
RESERVOIR EL. 4182.1
TAILWATER EL. 4114.0



TEST NO. 36-CA-2
DISCHARGE 33,015 C.F.S.
RESERVOIR EL. 4182.0
TAILWATER EL. 4114.0

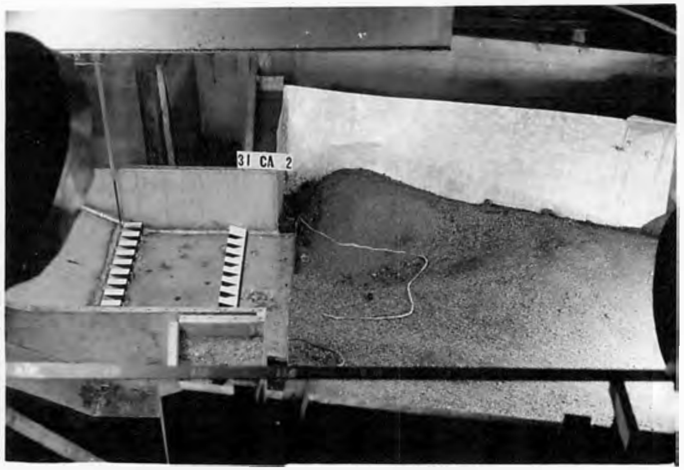
SCALE OF FEET-PROTOTYPE
10 0 10 20 30 40 50 60
2 0 2 4 6 8 10 12
SCALE OF INCHES-MODEL

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO - TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
WATER SURFACE AND SAND PROFILES

DRAWN J. D. M.	SUBMITTED J. E. Warnock
TRACED E.F.J., H.S.	RECOMMENDED R. F. Blanks
CHECKED F.L.P.	APPROVED J. L. Savage
DENVER, COLO., MAR. 20, 1936	230-D-106

Figure 41



A. Sand Bed After Run - 50-foot pool.

C. Sand Bed After Run - 55-foot pool

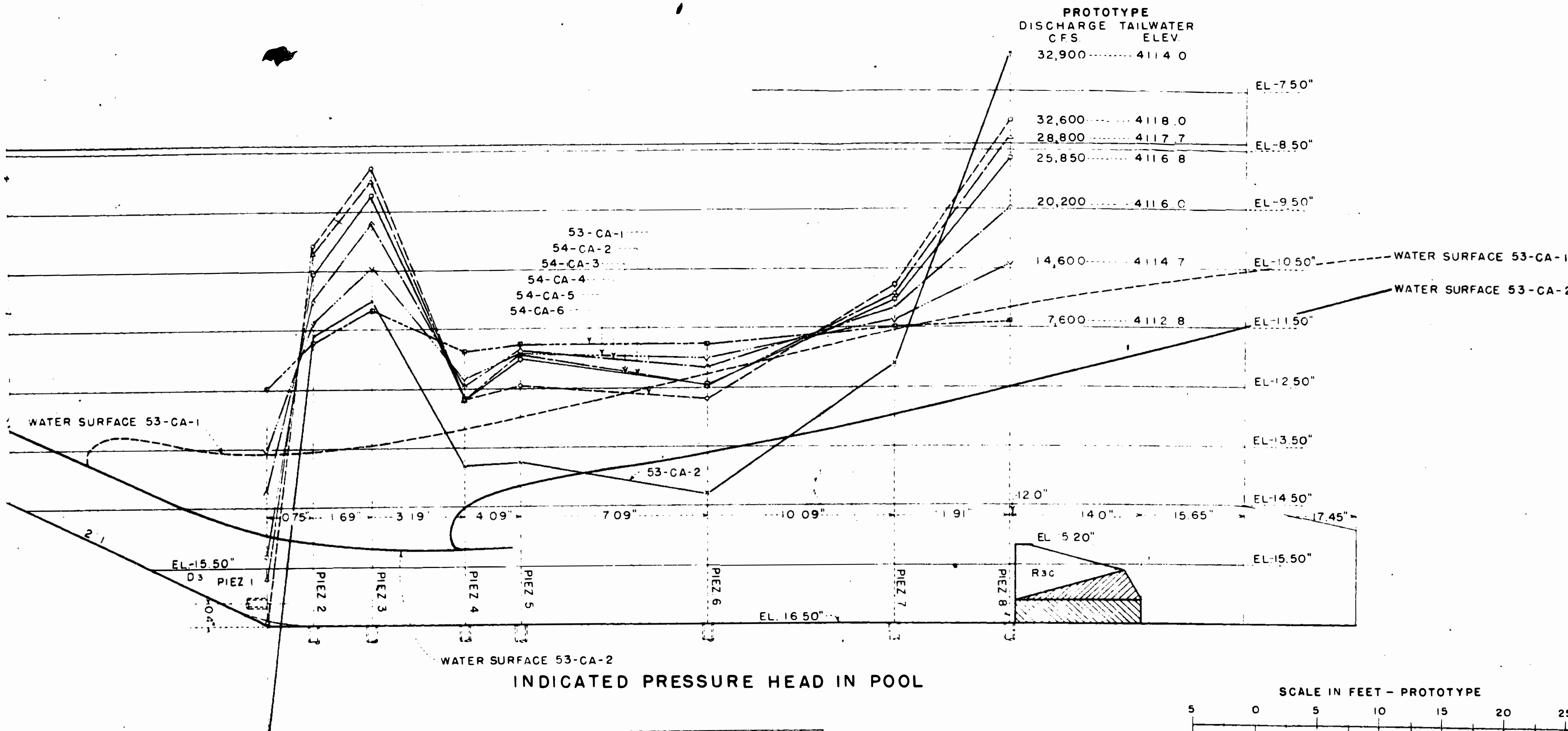
B. Sand Bed After Run - 45-foot pool.

D. Sand Bed After Run - 65-foot pool.

COMPARISON OF LENGTH OF POOL

PLATE XIX

Figure 82



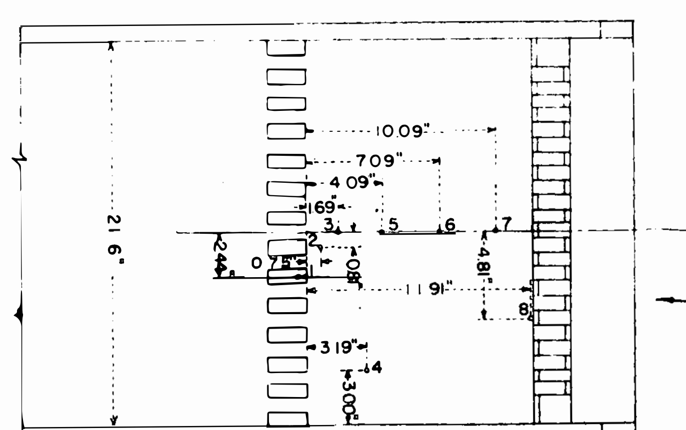
INDICATED PRESSURE HEAD IN POOL

SCALE IN FEET - PROTOTYPE

5 0 5 10 15 20 25 30

1 0 1 2 3 4 5 6

SCALE IN INCHES-MODEL



LOCATION OF PIEZOMETERS IN POOL

SCALE IN FEET - PROTOTYPE

30 15 0 30 60

6 3 0 6 12

SCALE IN INCHES-MODEL

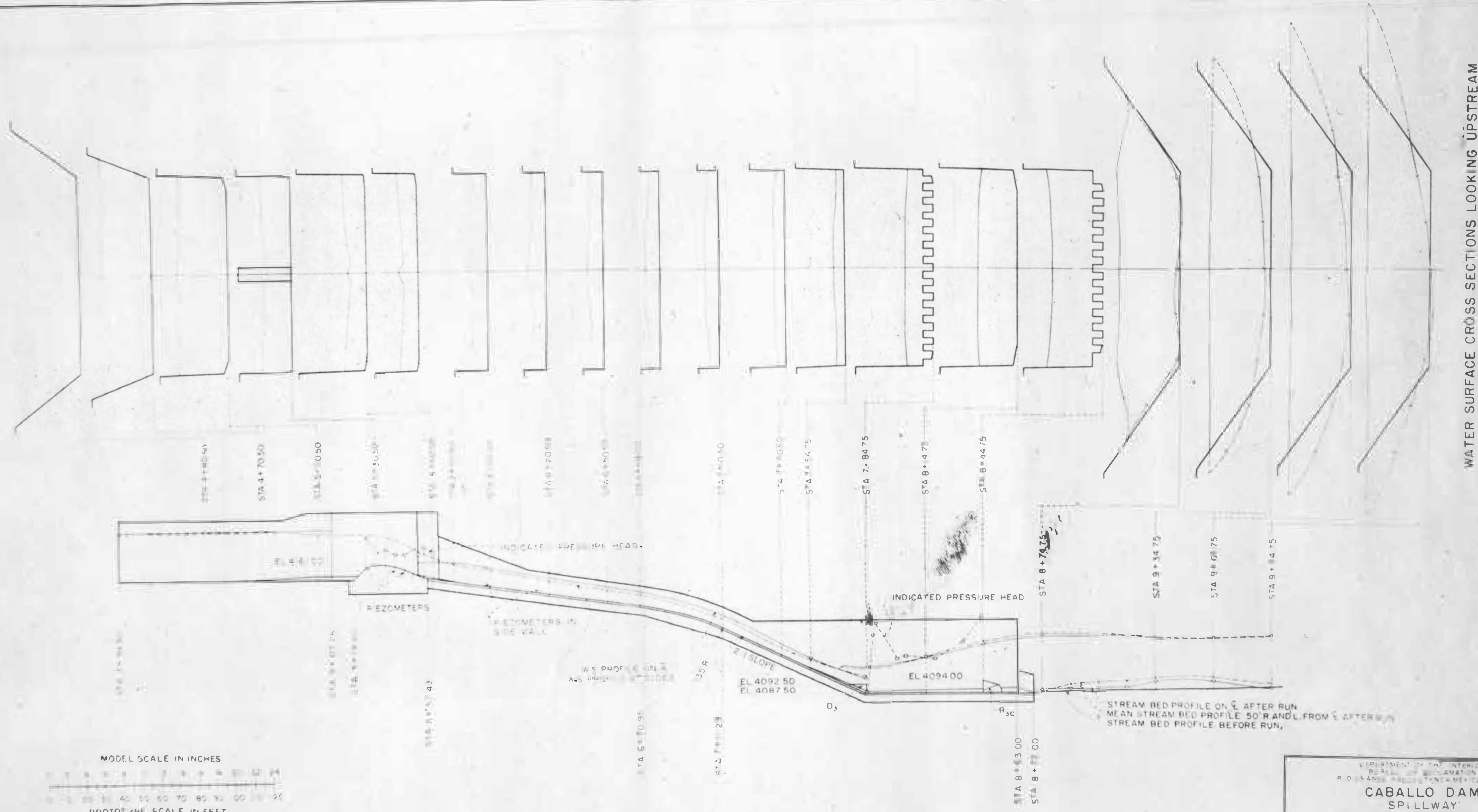
NOTE
Elevation 0.0" is at model crest

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
PRESSURES IN THE STILLING POOL

DRAWN H.G.D.JR. F.R.C. SUBMITTED J. E. Warnock
TRACED E.M.W. H.S. RECOMMENDED R. F. Blanks
CHECKED F.L.P. APPROVED J. L. Savage
DENVER, COLO., FEB. 29, 1936 230-D-107

FIGURE



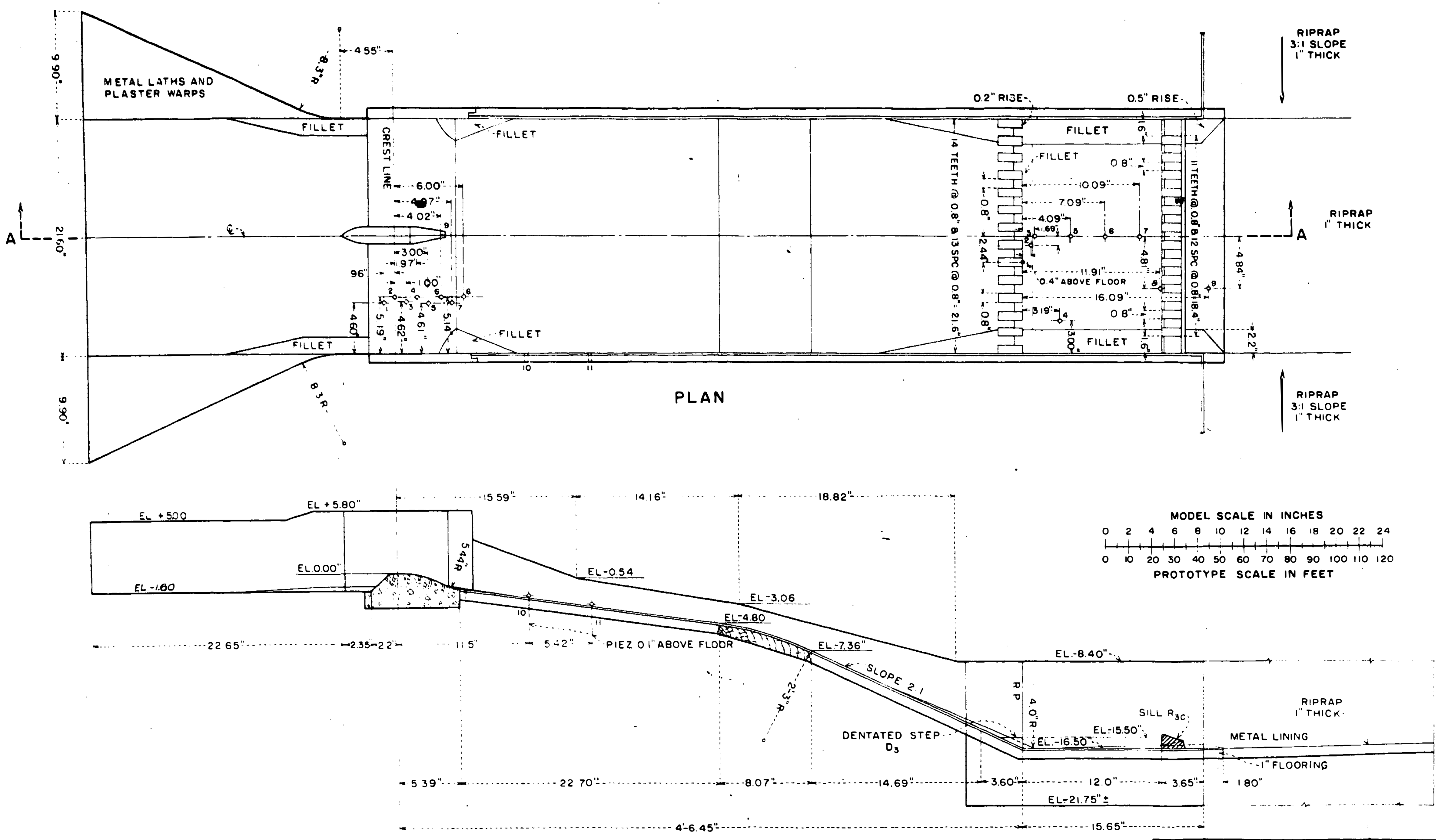
TESTS 53-CA-1 AND 54-CA-1
DISCHARGE 33,000 C.F.S.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT—NEW MEXICO—TEXAS
CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
SURFACE PROFILES - PLAN NO. 3

DRAWN F.S.C. SUBMITTED
TRACED EER RECOMMENDED
CHECKED FLP APPROVED

DENVER, COLO., MAR. 5, 1936 230-D-108

Figure 44



SECTION A-A

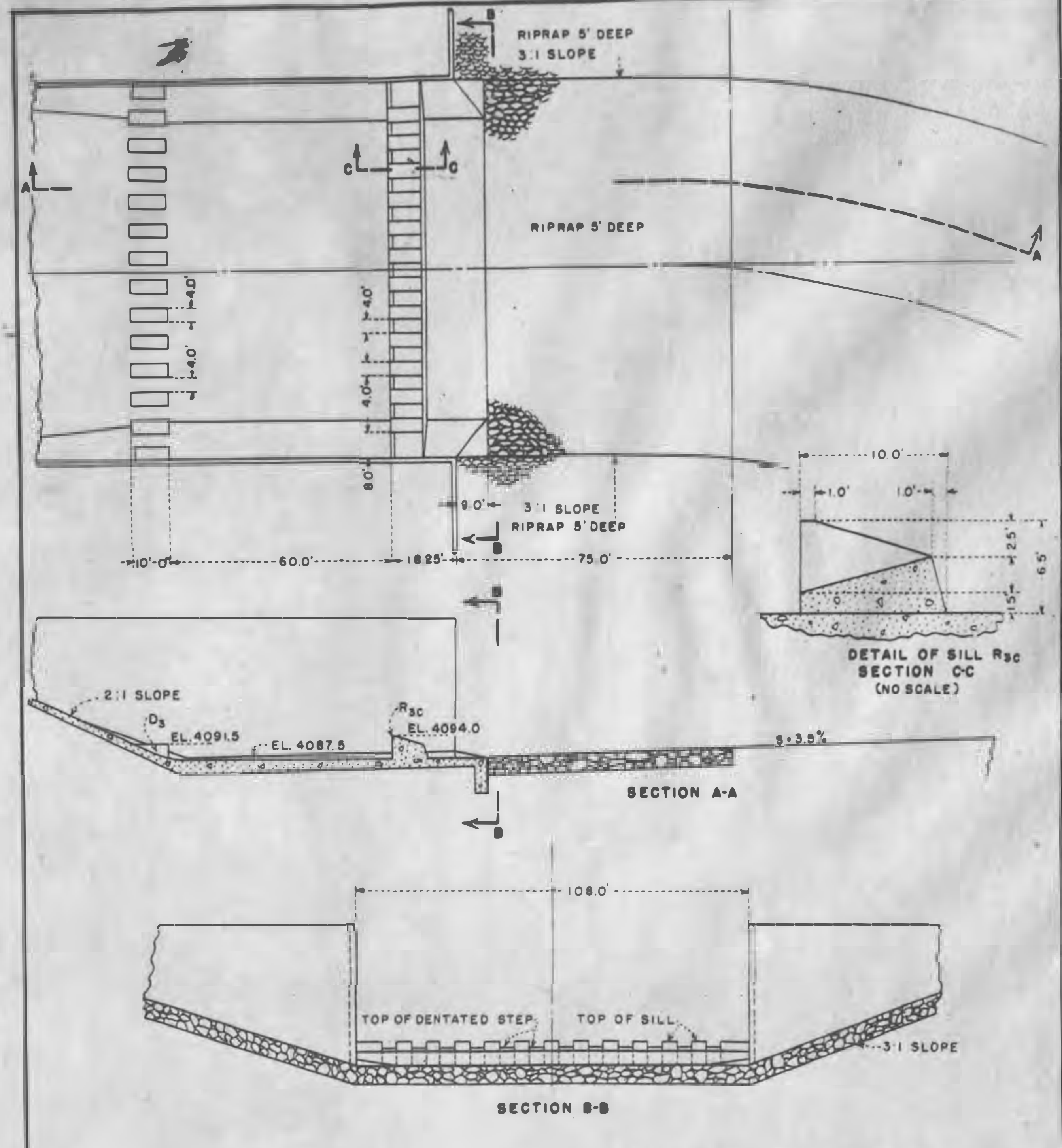
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT - NEW MEXICO-TEXAS

CABALLO DAM
SPILLWAY
HYDRAULIC MODEL EXPERIMENTS
FINAL MODEL DESIGN - PLAN NO. 3

DRAWN H.G.D., JR. SUBMITTED E. Warnock
TRACED E.F.J. E.E.B. RECOMMENDED R.F. Blanks
CHECKED F.L.P. APPROVED J.L. Savage

DENVER, COLO., FEB. 14, 1936 230-D-109

FIGURE 45



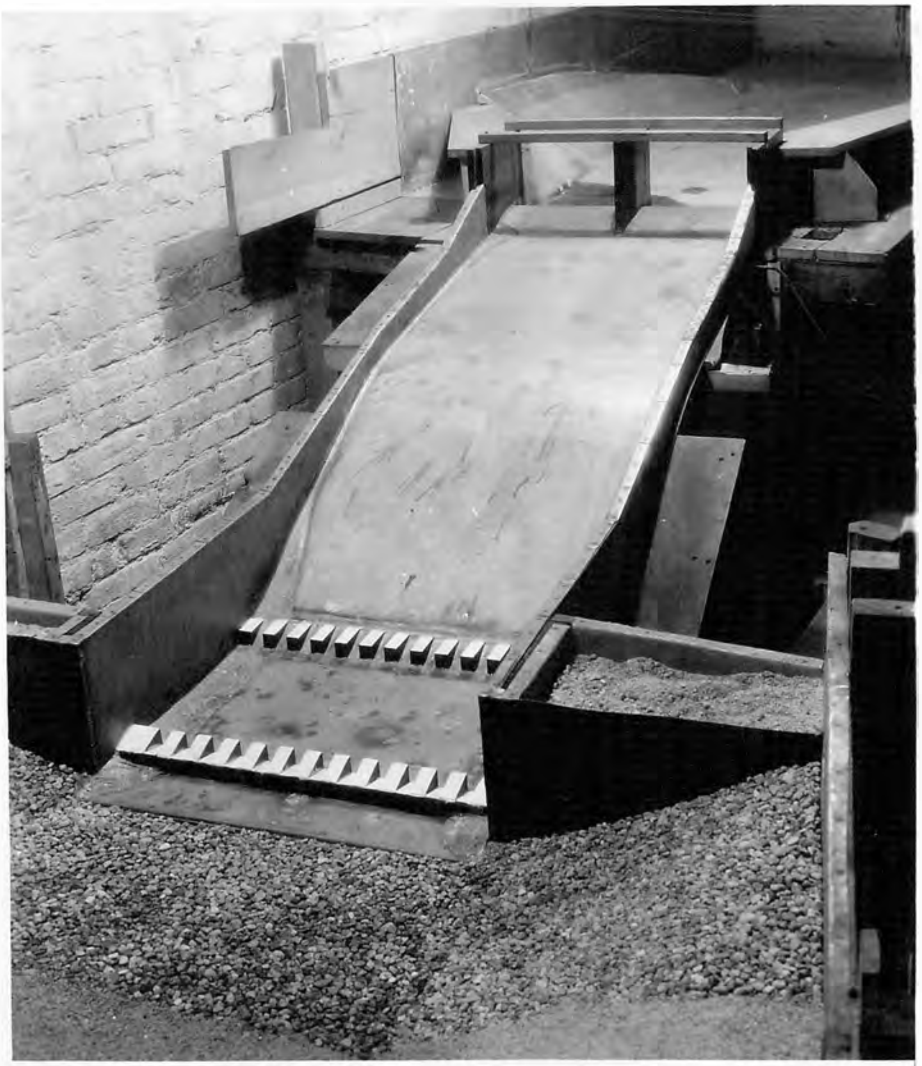
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RIO GRANDE PROJECT-NEW MEXICO-TEXAS

CABALLO DAM
SPILLWAY

HYDRAULIC MODEL EXPERIMENTS
RECOMMENDED POOL DESIGN — PLAN NO.3

DRAWN F.R.C. SUBMITTED J. E. Warnock
TRACED E.M.W. ORS RECOMMENDED R. F. Blanks
CHECKED F.L.P. APPROVED

DENVER, COLO., APR. 1, 1938 230-D-110



BEFORE RUN

SCOURED BED - 33,000 C.F.S.
2 HRS. @ 4114 T.W., $\frac{1}{2}$ HR. @ 4118 T.W.

FINAL MODEL - PLAN 3

POOL ACTION - 33,000 C.F.S.- T.W. 4114

SCOURED BED - 33,000 C.F.S.- T.W. 4114 & 4118

POOL ACTION - 33,000 C.F.S.- T.W. 4118

FINAL DESIGN - **PLAN 3**